Land Retirement Demonstration Project

Five-Year Report

U.S. Department of the Interior
Interagency Land Retirement Team
1243 N Street
Fresno, California

September 2005

Cover photos: The imprinter used to plant native seed, restored native perennial shrub habitat, and an alkali scrub annual flower called *Monolopia stricta* or Crum's monolopia.

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Acronyms and Abbreviations

ac	Acres
AIWD	Atwell Island Water District
ANOVA	Analysis of variance
BLM	Bureau of Land Management
BO	Biological Opinion
CDFG	California Department of Fish and Game
CDWR	California Department of Water Resources
CIMIS	California Irrigation Management Information System
cm	Centimeters
CNDDB	California Natural Diversity Database
COC	Constituents of concern
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DOI	Department of the Interior
dS/m	DeciSiemens per meter
EA	Environmental Assessment
EC	Electrical conductivity
EPA	Environmental Protection Agency
ER	Ecological Reserve
ESRI	Environmental Systems Research Institute
ESRP	Endangered Species Recovery Program
EUP	Experimental Use Permit
ft	Foot or feet
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information System
GPS	Global Positioning System
ha	Hectares
HRS	Habitat Restoration Study
IPM	Integrated pest management
km	Kilometer
LRDP	Land Retirement Demonstration Project
LRP	Land Retirement Program
LRT	Land Retirement Team
m	Meter
mg/kg	Milligrams per kilogram
mi	Miles
µg/L	Micrograms per liter
µS/cm	MicroSiemens/centimeter
mg/L	Milligrams per liter
mm	Millimeter
MOU	Memorandum of Understanding
msl	Mean sea level
NRCS	Natural Resources Conservation Service

NWR	National Wildlife Refuge
PEMA	Deer mouse
pH	Symbol for logarithm of the reciprocal of hydrogen ion concentration in gram atoms per liter
ppb	Parts per billion
ppm	Parts per million
PVC	Polyvinyl Choride
QAPP	Quality Assurance Project Plan
REC	Recognized environmental condition
Reclamation	Bureau of Reclamation
SJVDP	San Joaquin Valley Drainage Program
TU	Tritium units
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior
USGS	U.S. Geological Survey
WWD	Westlands Water District

Executive Summary

Irrigated agriculture in areas with shallow groundwater tables and little or no drainage outlet, as practiced in the center and western side of the San Joaquin Valley, has resulted in high salt concentrations that inhibit plant growth. More than 708,200 hectares (ha) (1,750,000 acres) of agricultural land in the San Joaquin Valley are considered drainage-impaired. Adverse effects to plants, fish, and wildlife can occur from this saline drain water, especially with its high concentrations of the trace elements, selenium, and boron. Selenium is of a primary concern because it is widely distributed throughout the valley and has proven to be toxic to certain vertebrate species, especially in aquatic habitats. Decades of irrigation have transferred soluble selenium from the upper soils to the shallow groundwater.

The Central Valley Project (CVP) provides water deliveries to San Joaquin Valley farms on more than 404,700 ha (1,000,000 acres). As the majority of the watershed was urbanized or converted to agricultural production, less than 5 percent of the lands remained uncultivated. This change in land use resulted in the loss of native wetland, saltbush scrub, alkali sink, and California prairie habitats, which contributed to the listing of numerous endemic species of plants and wildlife (FWS 1998).

The selective retirement of irrigated lands characterized by low productivity, poor drainage and high selenium concentrations in the shallow groundwater was recommended. The Central Valley Project Improvement Act (CVPIA), enacted in 1992 as Public Law 102-575 Title 34, Section 3408(h), authorized the purchase of land, water and other property interests from willing sellers who received CVP water. The program goals were to reduce drainage, enhance fish and wildlife resources, and make water available for other CVPIA purposes. The Land Retirement Program (LRP) was developed cooperatively by an interagency Department of the Interior team with representatives from the Bureau of Reclamation (Reclamation), the U.S. Fish and Wildlife Service (FWS), and the Bureau of Land Management (BLM).

Because concerns were raised about the magnitude of the project and the lack of knowledge about its effects on listed species, the Land Retirement Demonstration Project (LRDP) was implemented to provide site-specific scientific data. The FWS Biological Opinion (BO) for the LRDP in 1999 raised specific concerns about the scope and degree of land retirement impacts on groundwater levels, groundwater and surface water quality, soil chemistry, and biota. There was a need to monitor selenium loads at different trophic levels for corresponding groundwater levels and quality.

The LRDP was designed as a 5-year project to provide site-specific scientific data to determine the effects of land retirement on drain water volume, groundwater depth and quality, soils, and biota. Contaminants analysis was regularly performed on surface and groundwater, soils, vegetation, invertebrates, and vertebrates. Techniques were tested to determine effective, safe, and economical upland habitat restoration. Various efforts were taken to educate stakeholders about the effects of land retirement and habitat restoration techniques. The need for continued use of acquired water on LRDP lands was evaluated.

A resource monitoring plan (Selmon et al. 1999) that outlined the focus of habitat restoration research and established wildlife monitoring protocols was prepared and implemented by the California State University, Stanislaus, Endangered Species Recovery Program (ESRP). The plan included a Habitat Restoration Study (HRS) to monitor four restoration treatments and the vegetative and wildlife response to those treatments. Twenty study plots were established and a wide-range of data were collected over the 5 years. Selenium levels in a variety of trophic levels were monitored. Results of the LRDP are reported in this document and represent the culmination of the 5-year research and monitoring efforts implemented in 1999 and concluded in 2004. Although habitat restoration research and active site restoration efforts were included in the plan, results of those tasks will be given in a later report.

The Land Retirement Demonstration Project has two study sites located in two drainage-impaired basins. The Tranquillity site is located in western Fresno County and the Atwell Island site is located in Kings and Tulare Counties. The lands purchased were previously in agricultural production—primarily cotton, tomatoes, grain, and sugar beets.

The full 5-year study was completed at the Tranquillity site. Accordingly, this report primarily focuses on data from that site, but does include information from Atwell Island on the physical impacts and on selenium. Only at the Tranquillity site were 5 years of data collected for the Habitat Restoration Study. Activities at Atwell Island included baseline sampling prior to installation of treatments in 2001 and 1 year of post-treatment sampling conducted in early 2002. Physical impacts monitoring is discussed for the Atwell Island site. Due to reductions in CVPIA funding, all responsibilities for restoration research, site management, and monitoring of biota and selenium levels were reassigned from ESRP to BLM in 2002. BLM reports accomplishments and survey results for Atwell Island annually. The 5 year report for the site activities and research will be produced in 2007.

Appropriate habitat restoration must accompany land retirement to maximize benefits for wildlife and endangered species. Land retirement without habitat restoration often leads to large fields infested with weeds and pests that impact neighboring agriculture and require extensive and continuous management. Although land retirement has the potential to enhance wildlife values and improve ecological systems in the San Joaquin Valley, it is recognized that land uses other than wildlife habitat may take precedence on some lands. Some land uses, particularly grazing and dryland farming can be compatible with and may even contribute to habitat values for wildlife.

Restoration activities were expanded to include the collection of more than 100 native upland plant species from Ecological Reserves and isolated, small remnants of native habitat within an 80 kilometer (km) or (50 mile [mi]) radius of the Tranquillity site. Native plant research continues at an on-site nursery and is yielding large quantities of seed for use in replicated restoration trials and other restoration efforts. The results of these efforts will be reported at a later date.

Tranquillity Site Physical Impacts Monitoring Results

Five years of groundwater monitoring at the Tranquillity site supports conceptual and numerical models that predicted a declining shallow water table in response to land retirement. The performance objective established by FWS regarding water table response to land retirement stated that the depth to groundwater shall not show a net increasing trend (i.e. not rise to the land surface) over the life of the project. The FWS performance objective at the Tranquillity site was clearly met. Groundwater levels in all the wells monitoring the shallow water table at the site showed a declining trend (increasing depth to groundwater from land surface) during the study. Percolation of applied irrigation water prior to land retirement was the primary source of groundwater recharge that sustained the high water table. In the absence of irrigation recharge, the shallow water table has steadily receded from the land surface over the 5-year study. Large downward hydraulic gradients measured at the site confirm the presence of perched water table conditions in the fine-grained Coast Range deposits at the site. Discharge of the shallow groundwater occurs primarily through slow downward percolation through the thick, low-permeability, surficial clay deposits at the site. Some shallow groundwater was also undoubtedly discharged by evaporation from the water table when it was in proximity to the land surface at the beginning of the study. The water table response observed at the Tranquillity site is representative of conditions that would be present at a high percentage of lands that are targeted for retirement on the lower alluvial fan and basin rim settings in the western San Joaquin Valley.

The declining shallow water table is a very important aspect of land retirement due to the poor quality of the shallow groundwater observed beneath the Tranquillity site. The high salinity and selenium concentrations in the shallow groundwater found in the Coast Range deposits at the site are a result of leaching from soils under irrigated conditions and evaporation from the shallow water table. Evaporation from the shallow water table has concentrated salts and trace elements in the shallow groundwater. The performance objective for selenium in groundwater at the Tranquillity site established by FWS stated that the selenium concentration in groundwater shall not show a net increasing trend over the life of the project. The FWS performance objective was clearly not met. Rising levels of selenium observed in the shallow groundwater in the Coast Range deposits are likely a result of oxidation and advective transport of mobile selenium species in the alkaline conditions near the falling shallow water table. As long as the water table continues to decline, as expected in response to land retirement, the high concentrations of selenium in the groundwater should have no consequences to biota at the site. In contrast, selenium is present at very low concentrations in the groundwater found in the coarse-textured Sierran deposits at the Tranquillity site. In the reducing geochemical environment observed in the Sierran groundwater, selenium is relatively insoluble and immobile.

The Tranquillity site is underlain by flood basin and basin rim deposits that consist primarily of moderately to densely compacted clays that range in thickness from 1.5 to 10.7 meters (m) (5 to 35 feet) thick. The clay soils have low-permeability and provide poor drainage conditions for irrigated agricultural production. The predominant soil type at the Tranquillity site is Tranquillity clay. This is the most extensive soil type mapped by the U.S. Department of Agriculture on the lower alluvial fans and basin rim landforms in the areas targeted for land retirement. Soils at the Tranquillity site contain moderately elevated concentrations of selenium (average 1.0 milligrams per kilogram [mg/kg]) when compared to the common range (0.1-1.4 mg/kg) for western U.S. and San Joaquin Valley soils; however, they are still well within the range commonly found in western soils.

Total selenium concentrations, soluble selenium concentrations, and salinity (EC_e) in the surface soil (depth 0- 30 cm—centimeters [1 foot]) showed a decreasing trend over the 5 years of monitoring at the Tranquillity site. The decreasing selenium and salinity trends in the surface soil indicate that upward flux of salt and selenium from capillary rise and evaporation of shallow groundwater at the soil surface is minimal, and that some leaching of soluble selenium and salt from surface soils occurred during the 5-year study despite dryer than average climatic conditions.

About 10-20 percent of the selenium present in the subsoils (depth 0.6 to 0.9 m and 1.2 to 1.5 m [2-3 and 4-5 feet]) is soluble and mobile in the alkaline, oxidizing chemical conditions found in the soil. Soluble selenium concentrations (average 4.6 parts per billion [ppb] in saturation extracts) and percentages are much lower in the surface soils (depth 0-1 foot). Even if surface water ponding should occur during very wet periods, it is probable that selenium concentrations in the ponded water would be below the aquatic life criteria of 5 ppb based on the soil selenium saturation extract data. No performance objectives were established for soil selenium levels for the demonstration project; however, the maximum surface soil concentration (1.7 mg/kg) observed during the 5 years of monitoring at the Tranquillity site was well below typical soil toxicity thresholds for selenium in sediment (4 mg/kg).

FWS established performance standards for selenium and mercury in ponded surface water that lasts for more than 30 days. Due to dry climatic and soil conditions during the study, no surface water ponding was observed at the site that lasted for more than 30 days. Monitoring of precipitation during the course of the study suggests that the precipitation threshold to cause ponding of surface water at the site is well in excess of 5 centimeters (cm) (2 inches) of rainfall per month. The extensive network of dessication cracks in the clay soils at the Tranquillity site greatly inhibits the formation of surface water ponds.

Atwell Island Site Physical Impacts Monitoring Results

The Atwell Island site lies on the southwestern margin of the Tulare Lake bed. The site is underlain by lakebed and marsh deposits consisting primarily of clay and silt with some sand. Soils in the Atwell Island study area consist of silt and sand loams that are formed from alluvium derived from igneous and sedimentary rocks. The U.S. Department of Agriculture soil mapping units found at the site in order of abundance include the Posochanet silt loam, Nahrumb silt loam, Westcamp silt loam, Excelsior fine sandy loam, and Lethent fine sandy loam. Baseline soil chemistry data from three research areas at the site were collected during 2002. The surface soils (0 to 30 cm [0-12 inch] depth) at the research sites are moderately to highly saline (mean EC_e 3.85-9.25 deciSiemens/meter [dS/m]) and contain low selenium concentrations (mean total selenium 0.097-0.114 milligrams per kilogram [mg/kg]). By comparison, the mean selenium concentration in western U.S. soil is about 0.34 mg/kg.

Soils at the Atwell Island site are relatively low in both soluble and total selenium. Boron concentrations were moderate in surface soils and are elevated in subsoils. Both boron and soil salinity are plant growth limiting factors at the Atwell Island sites. Study Area 1 appeared to be using moisture from the water table. While this has benefitted plant growth in the short term, it may indicate soil salinity problems in the future. The medium textured soils at the Study Area 1 site exhibited capillary fringe zones approaching 1.5 m (5 feet) thick. A declining shallow water table in response to land retirement will lessen the likelihood of salinization of surface soils.

Monitoring wells were installed at the site in the fall of 2001 to establish baseline groundwater conditions. Initial groundwater level measurements indicate the presence of a perched water table beneath much of the site. Groundwater levels observed to date in the shallow groundwater system range from approximately 1.2 to 4.6 m (4 – 15 feet) below land surface. The water table is generally shallowest (nearest to the land surface) in the northwest portion of the site and becomes deeper to the southeast. A declining shallow water table in response to land retirement has been observed on portions of the site where irrigation has ceased or been greatly reduced.

The shallow groundwater underlying the Atwell Island site is moderately saline in nature. Salinity in the shallow groundwater samples, expressed as electrical conductivity (EC), ranged from 575 to 52,925 microSiemens/centimeter (µS/cm), with a median value of 13,740 µS/cm. By comparison, drinking water typically is less than 750 µS/cm, irrigation water is less than 1,250 µS/cm, and seawater is about 50,000 µS/cm. The shallow groundwater at the site is best described as a sodium sulfate type of water. Sodium is the dominant major cation found in the shallow groundwater samples, with sodium concentrations ranging from 469 to 15,100 milligrams/liter (mg/L), and a median concentration of 4,500 mg/L. Sulfate is the dominant major anion found in the shallow groundwater, with sulfate concentrations ranging from 261 to 22,200 mg/L, and a median concentration of 5,700 mg/L. Selenium concentrations measured in the shallow groundwater wells at the site during the baseline year of monitoring range from less than the detection limit of 0.4 to 208 micrograms per liter (µg/L), with a median concentration of 8.56 µg/L. The Environmental Protection Agency (EPA) water-quality criterion for long-term exposure to selenium in aquatic environments is 5 µg/L (EPA 1988). Approximately 50 percent of the groundwater samples (35 of 72 samples) collected during the baseline year of sampling had selenium concentrations that were less than the EPA aquatic life criteria.

No ephemeral surface water pools resulting from rainfall were observed at the site to date. Selenium concentrations in three surface water samples taken from the artificial wetland at the site are below the EPA aquatic life criteria, and ranged from below the detection limit (less than 0.4 µg/L) to 0.6 µg/L.

Selenium Monitoring in Biota

As required by the LRDP Biological Opinion (FWS 1999), we monitored selenium levels in plants, invertebrates, and small mammals on retired agricultural lands over a 5-year period at the Tranquillity site and over a 3-year period at the Atwell Island site. Results are compared to performance standards established by FWS for the project (FWS 1999) and to selenium levels in biota from selenium-normal situations in the western United States (USDI 1998). We compare the concentrations of selenium in biota from our study sites to concentrations of selenium in biota found at Kesterson National Wildlife Refuge (NWR).

The mean concentration of selenium in plants, invertebrates, and small mammals at both the Atwell Island and Tranquillity sites was below the established performance standards, within the range for biota typically found in selenium-normal situations in the western United States, and usually about an order of magnitude less than selenium levels found at Kesterson NWR. Selenium levels in biota from Atwell Island tended to be lower than at Tranquillity. Generally, no clear differences in selenium levels were found between years. At the Tranquillity site, selenium levels in plants and small mammals tended to be greater on cultivated (irrigated) lands than on uncultivated (non-irrigated lands). Approximately 6 percent of all samples were considered unusually high in selenium (exceeding one standard deviation of the data set). The outliers suggest the need for selenium monitoring on newly acquired lands and continued monitoring on existing retired lands.

Results of the Habitat Restoration Study

The Biological Opinion for the Land Retirement Demonstration Project required that a 5-year Habitat Restoration Study be conducted to determine the responses of wildlife to land retirement and restoration efforts. We designed a study with four levels of restoration treatments (seeding with native plants, installing topographic contours, a combination of seeding and contouring, and control) and applied these treatments to twenty 4 ha (10-acre [ac]) study plots in a randomized block design. On the plots, we monitored vegetation, invertebrates, and amphibians and reptiles once each year, and we monitored birds and small mammals four times each year. Other monitoring at the site included track station surveys, spotlighting, winter raptor surveys, and monitoring of bird nesting success.

We successfully established plant cover to stabilize soils, established plant cover to provide wildlife habitat, and established native wildlife. Some of the restoration approaches used on the HRS plots showed promise. Microtopographic contouring appeared to have both positive effects in promoting establishment of native vegetation, and providing habitat heterogeneity for small mammals and other biota. Shrub establishment—particularly of *Atriplex polycarpa*—was very successful and approached densities that would be considered appropriate habitat for some species of concern. Nevertheless, restoration response was generally less than optimal. Factors contributing to the limited success of native plant restoration are thought to include inadequate seed delivery methods (imprinting may not be appropriate for use on the HRS soil types and for many of the species), competition from invasive species (primarily black mustard, London rocket, and tumbling saltweed), inappropriate seed source (most of the seed was purchased commercially and was not obtained from the proximity of the project site), and drought conditions experienced throughout the term of the project.

Because there were few notable differences among the restoration treatments, there were also few observable trends in wildlife diversity and abundance associated with the treatments. However, the information on wildlife diversity and abundance that was obtained shows that retired agricultural lands are valuable to wildlife. Over a 5-year period, we identified 101 families within 21 orders of invertebrates, 1 species of amphibian, 4 species of reptiles, 48 species of birds, and 8 species of small mammals, 1 species of canid (coyote), 2 species of mustelids (skunk and long-tailed weasel), and 2 domesticated species (cat and dog) that utilize the Tranquillity site. Nine species of birds utilized the study area as breeding habitat and 12 species of sensitive birds were using the study area. One factor that may have limited the abundance and diversity of native wildlife on the study plots is the lack of nearby lands that support wildlife which could disperse onto the study plots. Only small, remnant parcels of native habitat exist in the vicinity.

There were no indications the HRS lands supported greater agricultural pest densities than did surrounding retired and fallowed lands. Rather, agriculturally beneficial species were common and widespread on the site, especially in restored areas.

Although this pilot project did not necessarily emphasize the establishment of threatened and endangered wildlife on the study plots, we were successful in providing suitable habitat for a number of rare species of birds. With the incorporation of appropriate management actions, the habitat that has been established should be suitable for various other rare species.

The wildlife information generated by this project is immensely valuable as a description of baseline conditions that, if compared to data collected from retired lands that are restored to prime native habitats, would provide insight into the value of restoration to wildlife. There have been no other wildlife studies or monitoring efforts in the central San Joaquin Valley of this duration or scope, making this a unique data set that describes the wildlife community existing on lands dominated by non-native plant species. Within the San Joaquin Valley, similar conditions are common and widespread among scattered, remnant patches of land that are not intensively farmed.

Recommendations

A number of tasks remain to be accomplished to fulfill the intent of this pilot project and to ensure that land retirement and the restoration of retired lands can proceed. Some of these include:

- Publish findings of completed and ongoing research in open scientific literature.

- Develop a long-term management and monitoring plan for the Tranquillity site.

- Continue maintenance and expansion of the native plant nursery and seed collecting activities.

- Continue research on development of restoration technologies, including seed delivery techniques, weed control methods, harvesting techniques, and seed cleaning techniques, which are promising and have begun to bear fruit.

- Document and protect localities of known populations of native plants and animals in the project vicinity to ensure the survival and persistence of existing populations.

- Develop criteria and methods for the propagation and translocation of threatened and endangered species to restored lands.

- Provide public awareness of the positive effects and benefits of land retirement, such as increased depth to groundwater and establishment of native shrub species using various habitat restoration techniques.

Based upon the findings presented in this report and experiences gained during this 5-year project, the Land Retirement Team and the Endangered Species Recovery Program fully support land retirement. We believe that land retirement has the potential to solve a variety of drainage issues while concurrently providing habitat for wildlife. Restoration can improve the overall ecosystem function by improving air quality, reducing weed loads, creating wildlife habitat, and assisting with recovery of sensitive species. Land retirement is expected to be beneficial to adjacent farming operations by improving water quality, improving air quality through dust abatement, and increasing abundance and diversity of invertebrate pollinators and predators. These benefits are justification for continuation and expansion of retiring drainage impacted lands, continued research of restoration techniques, and restoration of selected parcels of retired lands in the San Joaquin Valley.

Chapter 1. Introduction

by Curtis E. Uptain and Beatrice A. Olsen

1.1. Background

“Land Retirement,” defined here as the removal of land from irrigated agricultural production, is a means by which drain water accumulation can be substantially reduced. Drain water reduction can be imperative because irrigated agriculture in areas with shallow groundwater and no drainage outlet can sustain drainage water with high salt concentrations that can, in turn, inhibit plant growth. These conditions are characteristic of large portions of the center and western side of the San Joaquin Valley, as evidenced by the more than 708,200 hectares (ha) or (1,750,000 acres [ac]) of agricultural land in the valley that are considered to be drainage-impaired (Figure 1-1).

The salt content of irrigation water increases as water evaporates, passes over saline soils, or occurs through plant uptake. Where drainage is adequate, salts can be flushed from the root zones by sufficient rainfall or irrigation. However, this seldom eliminates the long-term accumulation of salinity. Short-term flushing of salts from soils results in excess drain water with high salt concentrations. Adverse effects to plants, fish, and wildlife can occur from saline drain water when present at the surface or in downstream tributaries. In areas lacking good drainage, repeated irrigation may raise the water table. When the water table reaches the root zone of plants, capillary action often carries water close to the soil surface, where it evaporates and leaves a surface salt residue.

Additionally, high concentrations of trace elements that occur naturally in westside San Joaquin Valley soils, including selenium, boron, molybdenum, and arsenic, are problematic. Selenium is of a primary concern because it is widely distributed throughout the valley and has proven to be toxic to certain vertebrate species, especially in aquatic habitats. Decades of irrigation have transferred soluble selenium from the upper soils to the shallow groundwater.

The Central Valley Project (CVP), with its massive system of dams, reservoirs, canals, power plants and other facilities, began providing irrigation water for San Joaquin Valley agriculture in 1951. The San Luis Unit and the State Water Project of the CVP, which were authorized in 1960, expanded water deliveries to approximately 404,700 ha (1,000,000 acres) by1968. By 1979, fewer than 61,500 ha (151,750 acres), or about 2 percent, remained uncultivated. The majority of the watershed was converted to agricultural production or urbanized. Most of the remaining undeveloped land is located in the foothills of the Coast

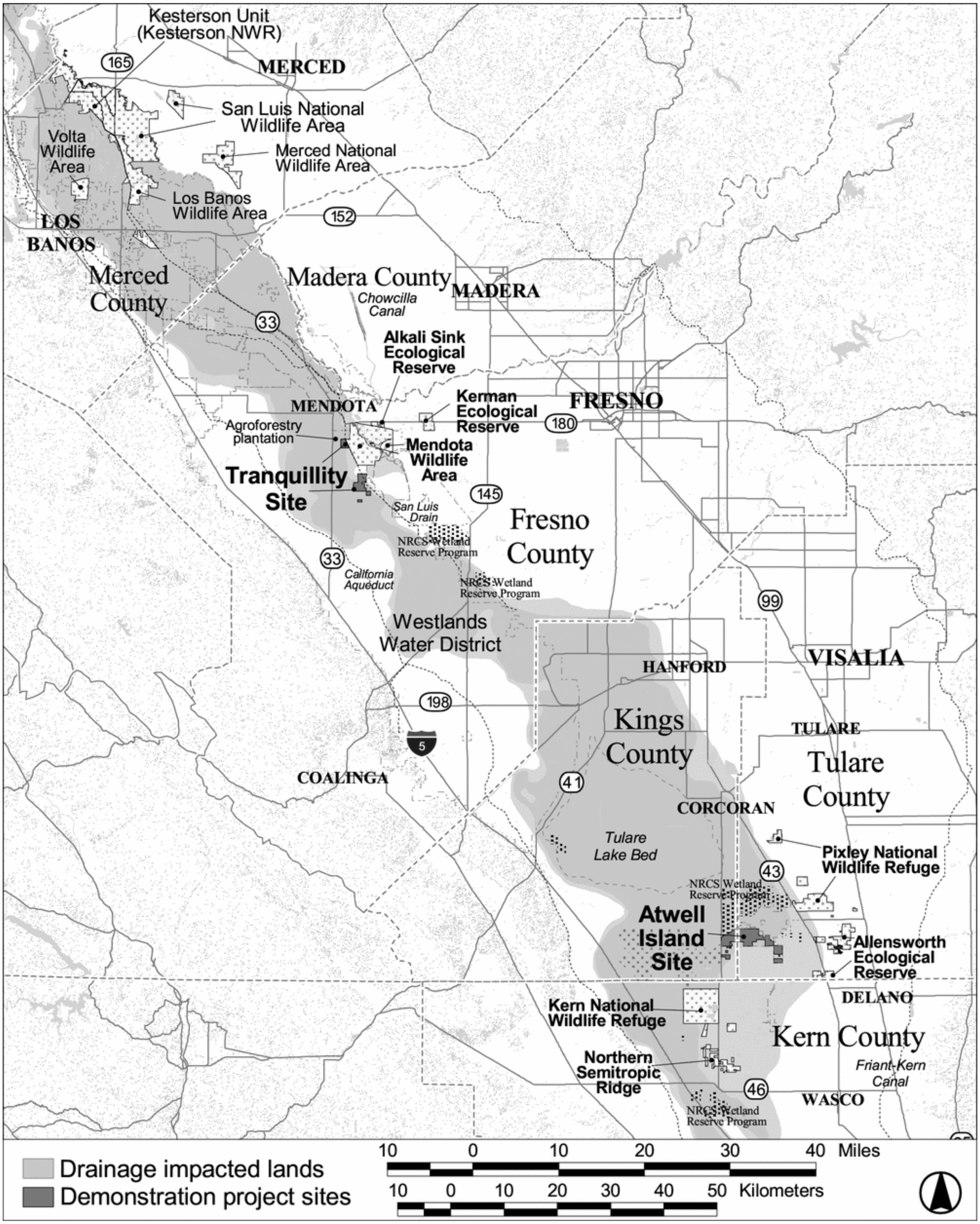

Figure 1-1. Drainage-impaired lands in the San Joaquin Valley.

Range and in the extreme southern portion of the valley. This change in land use resulted in the loss of native wetland, saltbush scrub, alkali sink, and California prairie habitats and contributed to the listing of numerous endemic species of plants and wildlife (FWS 1998).

The San Joaquin Valley Drainage Program (SJVDP), established in 1984, combined federal and state efforts to investigate drainage issues and identify possible solutions. The program estimated that 161,800 to 225,000 ha (400,000 to 554,000 acres) would become unsuitable for irrigated agriculture by 2040 if no actions were taken to remedy drainage problems. One recommended action to reduce drainage-related problems was the selective retirement of irrigated lands characterized by low productivity, poor drainage and high selenium concentrations in the shallow groundwater.

The Central Valley Project Improvement Act (CVPIA), enacted in 1992 as Public Law 102-575 Title 34, Section 3408(h), authorized the purchase of land, water, and other property interests from willing sellers who received CVP water. Such lands would achieve the program goals to reduce drainage, enhance fish and wildlife resources, and make water available for other CVPIA purposes. CVPIA did not authorize a recommended quantity of acres for permanent land retirement. The Land Retirement Program (LRP) was developed cooperatively by an interagency Department of the Interior team with representatives from the Bureau of Reclamation (Reclamation), the U.S. Fish and Wildlife Service (FWS), and the Bureau of Land Management (BLM) (See Appendix 1). Additional background information on the CVPIA Land Retirement Program can be found in a variety of reports (USDI 1997, USDI 1999, Selmon et al. 2000, Uptain et al. 2001, 2002, and 2004) and web sites (see http://usbr.gov/mp/cvpia).

1.2. Development, Implementation, and Scope of the Land Retirement Demonstration Project

During the comment period for the Land Retirement Program Draft Environmental Assessment (EA), concerns were raised about the magnitude of the project and the lack of knowledge about the positive and negative effects of retiring agricultural land on a large scale (USDI 1999). Although land retirement was featured in the FWS Recovery Plan for Upland Species of the San Joaquin Valley (FWS 1998), FWS had concerns that the high selenium levels would be unsafe for listed species. The Land Retirement Demonstration Project (LRDP) was implemented to provide site-specific scientific data to guide the implementation of the LRP and develop tools to predict potential benefits and impacts of retiring land from irrigated agriculture. The FWS Biological Opinion (BO) for the LRDP raised specific concerns about the scope and degree of land retirement impacts on groundwater levels, groundwater and surface water quality, soil chemistry, and biota. There was a need to monitor selenium loads at different trophic levels for corresponding groundwater levels and quality (FWS 1999).

The Land Retirement Demonstration Project was designed and implemented as a 5-year project to address the concerns expressed in the Biological Opinion by accomplishing five goals:

- Provide site-specific scientific data to determine the effects of land retirement on drain water volume, groundwater depth and quality, soils, and biota.

- Perform contaminants analysis regularly on surface and groundwater, soils, vegetation, invertebrates, and vertebrates.

- Evaluate techniques to determine effective, safe, and economical means for upland habitat restoration that contain self-sustaining native upland communities, using adaptive management principles (Holling 1978, Walters and Holling 1990) to maximize efficiency of the restoration research program.

- Educate stakeholders about the Land Retirement Program effects of land retirement and habitat restoration techniques.

- Evaluate the need for continued use of acquired water on Demonstration Project lands.

Other requirements of the Biological Opinion were met and are addressed in Appendix 2.

In this report, the physical setting for the LRDP sites, monitoring methods employed for physical parameters, and a conceptual model of the groundwater system are presented in Chapter 2. Reclamation implemented a monitoring plan that utilized approved sampling protocols and analysis of physical factors, including surface water, groundwater, and soils (CH2M Hill 1999). Groundwater monitoring data are compared against performance criteria set forth in the Biological Opinion (FWS 1999).

A resource monitoring plan (Selmon et al. 1999) that outlined the focus of habitat restoration research and established wildlife monitoring protocols was prepared by the California State University, Stanislaus, Endangered Species Recovery Program (ESRP). The plan included a Habitat Restoration Study (HRS) to monitor four restoration treatments and the vegetative and wildlife response to those treatments. Twenty study plots were established and a wide-range of data were collected over the 5 years (See Section 4.2.1 for experimental design description). Selenium levels in a variety of trophic levels were monitored. Results of the LRDP are reported here that represent the culmination of the 5-year research and monitoring efforts implemented in 1999 and concluded in 2003. Although habitat restoration research and active site restoration efforts were accomplished, the results of those tasks will be presented in other reports.

The Land Retirement Demonstration Project has two project sites, the Tranquillity and the Atwell Island sites (Figure 1-1, shown earlier). The full 5-year study was completed only at the Tranquillity site. Accordingly, this report primarily focuses on data obtained at the Tranquillity site, but does include information from Atwell Island on the physical impacts of land retirement (Chapter 2) and on selenium levels in biota (Chapter 3). Only at the Tranquillity site were 5 years of data collected for the Habitat Restoration Study (Chapter 4). Activities at Atwell Island included baseline sampling prior to installation of treatments in 2001 and 1 year of post-treatment sampling conducted in early 2002. Due to reductions in CVPIA funding, all responsibilities for restoration research, site management, and monitoring of biota and selenium levels were reassigned from ESRP to BLM in 2002. BLM will report Atwell Island site activities and research in 2007.

Appropriate habitat restoration must accompany land retirement to maximize benefits for wildlife and endangered species. Land retirement without habitat restoration often leads to large fields infested with weeds and pests that impact neighboring agriculture and require extensive and continuous management. Although land retirement has the potential to enhance wildlife values and improve ecological systems in the San Joaquin Valley, it is recognized that land uses other than wildlife habitat may take precedence on some lands. Some land uses, particularly grazing and dryland farming, can be compatible with and may even contribute to habitat values for wildlife.

Although the goals of the LRDP focus primarily on requirements described in the Biological Opinion, restoration activities were expanded to include the collection of more than 100 native upland plant species from Ecological Reserves and isolated, small remnants of native habitat within an 80 km (50 mile) radius of the Tranquillity site. Seed collected from local plant genotypes have been planted in an on-site nursery and are yielding large quantities of seed for use in restoration research and other restoration efforts. Seed is cleaned, processed, and stored in our mechanized seed-cleaning facility. Research continues to be conducted on planting, propagation, weed control, and harvesting techniques. The replicated research trials that we are conducting are directly applicable to large-scale restoration efforts. A list of current research activities are provided in Appendix 3. The results of these efforts will be reported at a later date.

1.3. Tranquillity Project Site Location and Description

The LRDP study sites are located in two geographically and physiographically different drainage-impaired basins. The Tranquillity site is located in western Fresno County (Figure 1-2) and the Atwell Island site is located in Kings and Tulare Counties (see Figure 1-1). In the fall of 1998, the Land Retirement Team (LRT) purchased 666 ha (1,646 acres) in western Fresno County. By late 2001, a total of 845 ha (2090 acres) had been acquired, of which 239 ha (591 acres) were purchased with water.

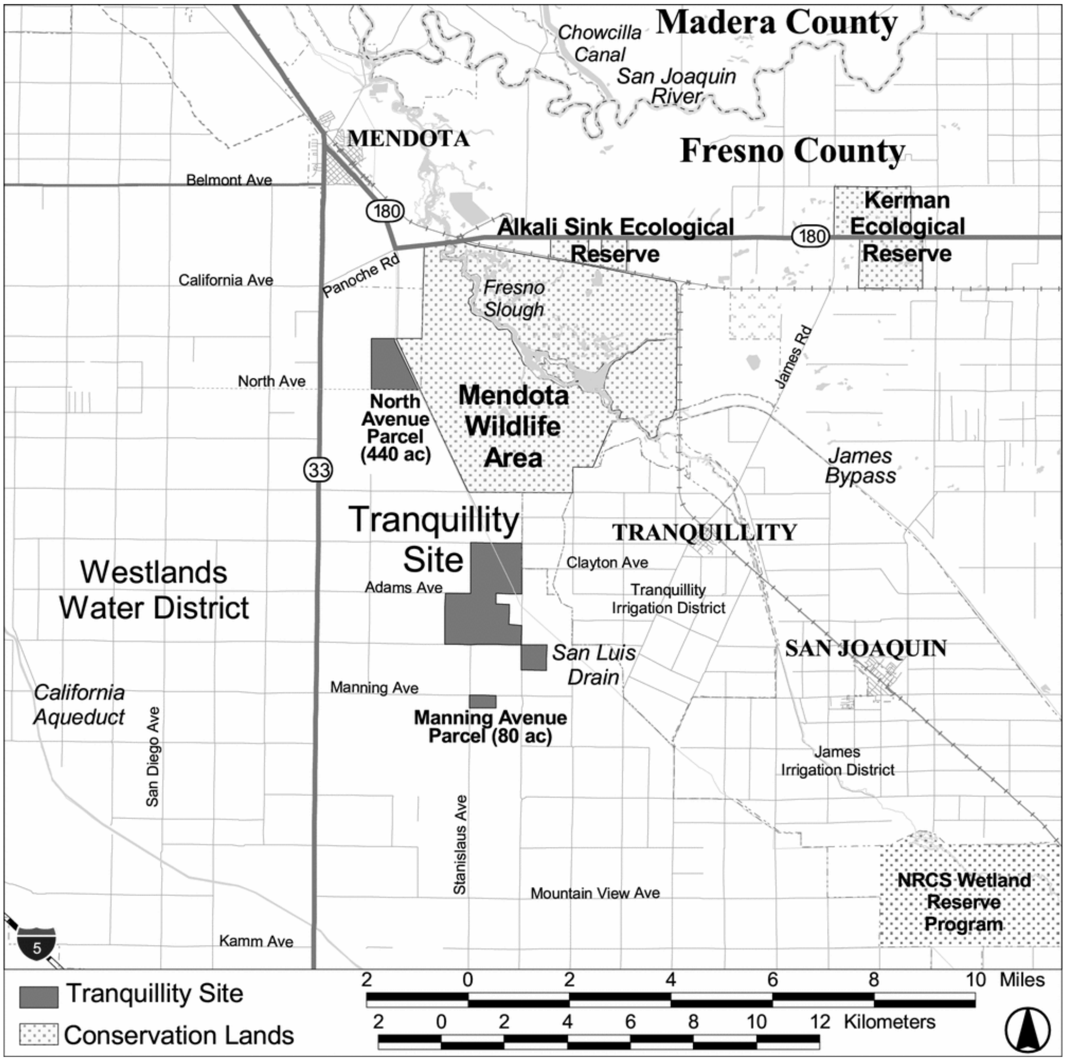

Figure 1-2. Location of the Tranquillity site including the 178 ha (440 ac) North Avenue parcel and the 16 ha (40 ac) Manning Avenue parcel.

The 178 ha (440 acre) North Avenue Parcel was obtained in late 2001 and was previously fallowed and grazed by sheep. The land initially purchased in 1998 had previously been in agricultural production, primarily cotton, tomatoes, grain, and sugar beets. The remaining acreage had been idled for longer than 5 years and contained sufficient plant cover. For weed and erosion control, and to provide as homogeneous a plant cover as possible for the research plots, barley was planted on approximately 486 ha (1,200 acres) in 1999.

The site is immediately surrounded by agricultural fields, although in the last few years more of these fields have been idled under the land retirement program initiated by Westlands Water District (WWD). The San Luis Canal, which previously transported drainage water to Kesterson National Wildlife Refuge (NWR), traverses the site.

The 3,468 ha (8,570 acre) Mendota Wildlife Area is located adjacent to the eastern boundary of the North Avenue Parcel and within 4.8 kilometers (km) (3 miles) north of the HRS site. The 377 ha (932 acre) Alkali Sink Ecological Reserve (ER) and the 718 ha (1,775 acre) Kerman ER are located within 16 km (10 mile [mi]) of the HRS site. These areas contain remnants of the once widespread alkali sink, saltbush scrub, and annual grassland habitats.

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Chapter 2. Physical Impacts of Agricultural Land Retirement in the San Joaquin Valley

by Stephen L. Lee, Joseph Brummer, and Jim Yahnke

2.1. Introduction

This chapter describes the physical setting at the Tranquillity and Atwell Island Project sites including soil, groundwater, and surface water conditions. The methods utilized for monitoring soil, groundwater, and surface water during the study are discussed. A conceptual model of the groundwater system at the Tranquillity site is presented with a discussion of soil and groundwater response to land retirement. Monitoring data from the Tranquillity Site are compared against performance criteria established by the U.S. Fish and Wildlife Service (FWS) and summarized in the table below.

FWS Performance Standard	Performance Standard Met?
Depth to groundwater will not show a net increasing trend (decreasing depth to soil surface) over 5 years of monitoring.	YES
Selenium concentration in groundwater will not show a net increasing trend over 5 years of monitoring.	NO
Standing water that persists more than 30 days in duration shall not exceed 2 µg/L (parts per billion) selenium and 2 ng/L (parts per trillion) mercury.	NOT MEASURED

2.2. Tranquillity Site

2.2.1. Geology

The Tranquillity Demonstration Project site is located in the western San Joaquin Valley, an asymmetrical basin bounded by the Coast Ranges on the west, the Tehachapi Mountains on the south, the Sierra Nevada on the east and the delta of the San Joaquin and Sacramento Rivers on the north. The axis of the valley trough is closer to the Coast Ranges than to the Sierra Nevada. The basin is filled with alluvium overlying older Mesozoic and Cenozoic marine and continental sediments. Alluvial deposits underlying the central San Joaquin Valley were shed from the adjacent Coastal and Sierra Nevada ranges and vary in thickness from 274 to 1,006 meters (m) (900 to 3,300 feet [ft]) (Miller et al. 1971). The Sierra Nevada consists mainly of granitic and metamorphic rocks of pre-Tertiary age. The Coast Ranges are composed primarily of folded and faulted beds of Cretaceous age marine shale and sandstone in the north and Cenozoic age sandstone and shale in the south (Prokopovich 1987). Bull (1964a and b) identified a series of alluvial fans derived from sediments from the coastal ranges that form the western margin of the San Joaquin Valley in the study area.

The Tranquillity demonstration project site is located in the trough of the San Joaquin valley in western Fresno County. The site is underlain directly by flood basin deposits derived from overbank deposition from the San Joaquin River and Fresno Slough. The flood basin deposits consist of fine textured, moderately to densely compacted clays that range in thickness from 1.5 to 10.7 m (5 to 35 feet) (Belitz and Heimes 1990). The flood basin clays have low-permeability and greatly impede the downward movement of water. On the northern part of the site (Section 10, Figure 2-1), the flood basin deposits rest upon well sorted micaceous sand derived from the Sierra Nevada. The Sierran sands are highly permeable, reduced in oxidation state, and vary in thickness between 122 and 152 m (400 and 500 feet) in the project vicinity. On the southern part of the site (Sections 15 and 16, Figure 2-1), the flood basin deposits overlie sediments derived from the coastal ranges. The coastal range sediments inter-finger with Sierran sands in the project vicinity, and are oxidized and primarily fine grained. The Corcoran clay is a regionally extensive fine grained lakebed deposit that underlies the site at a depth of approximately 152 m (500 feet).

2.2.2. Soils

Soils in the Tranquillity Demonstration Project area primarily consist of clays, silty clays, and silty clay loams, which formed in alluvium, derived from igneous and sedimentary rock. Individual soil mapping units at the project site include (in order of abundance) Tranquillity clay, Lillis clay, and Lethent silt loam. These soil series cover more than 56,658 hectares (ha) (140,000 acres) in western Fresno County, and are representative of soil conditions found in the drainage impacted lands in Western Fresno County. The Tranquillity mapping unit is the predominant soil type in the study area and covers approximately 80 percent of the site, while the Lillis and Lethent mapping units occur exclusively in Section 10 and cover the remainder of the site (Figure 2-1). The Tranquillity clay is a very deep, poorly to moderately drained saline-sodic soil found on low-lying alluvial fans and flood plains with slopes between 0 and 1 percent. The permeability of this soil is slow and the unit is suited to growing irrigated, salt-tolerant crops, or for wildlife habitat (USDA 1996). Runoff is low, and the hazard of water erosion is slight. The depth to the water table varies and is commonly highest during irrigation applications in the winter and early spring. These soils generally require intensive management to reduce salinity and maintain agricultural productivity.

The U.S. Department of Agriculture (USDA) took soil samples from the major soil horizons in a test pit located in the NW 1/4 of Section 16 (Figure 2-1) at the site in 1992. The samples were analyzed in the laboratory for particle size, chemistry, and mineralogy. These soils consist predominantly of clay-sized particles less than 0.002 millimeters (mm) in diameter. The USDA reported that the clay fraction from six samples taken from the test pit ranged from 48 to 52 percent of the total samples. Silt size particles (0.002-0.05 mm in diameter) ranged from 36-37 percent of the total samples, and sand-size particles made up from 11-16 percent of the total samples (USDA 1992). Total selenium concentrations ranged from 0.5 to 1.1 parts per million (ppm), and the

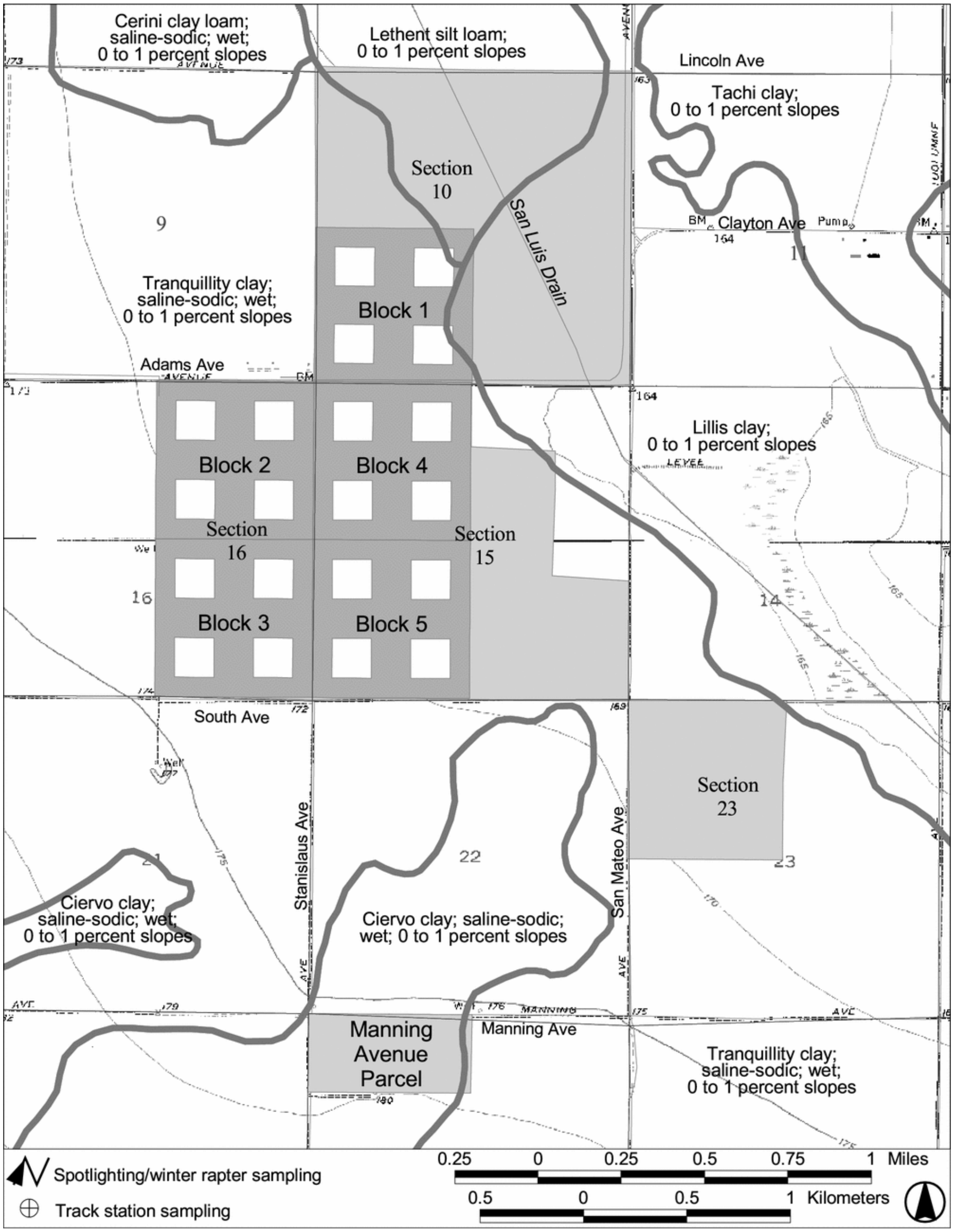

Figure 2-1. U.S. Department of Agriculture soil mapping units, Tranquillity site.

Electrical Conductivity (EC) of saturation extracts ranged from 3.7 to 10.9 deciSiemens/meter (dS/m). These soils are highly plastic with Plasticity Indices ranging from 23-52 percent. The predominant clay mineral is Montmorillonite, which can take on water in the crystal lattice, resulting in high shrink-swell potential and development of deep cracks at the soil surface upon drying.

The Lillis clay mapping unit covers about 10 percent of the study area in the eastern half of Section 10 (Figure 2-1). These soils are very deep, poorly drained, saline-sodic soils found typically on floodplains and basins. Permeability of the Lillis soil is extremely slow, water infiltration rate is high, and when the soil is dry, the surface cracks open. As the soil becomes wet and the cracks close, the infiltration rate greatly decreases. Surface water runoff is low and the hazard of water erosion is slight. The unit is used mainly for wildlife habitat and recreation.

The USDA took soil samples from the major soil horizons in a test pit located in the SW 1/4 of Section 10 at the site in 1992. The samples were analyzed in the laboratory for particle size, chemistry, and mineralogy. These soils consist predominantly of clay-sized particles less than 0.002 mm in diameter. The USDA reported that the clay fraction from nine samples taken from the test pit ranged from 59 to 66 percent of the total samples. Silt-size particles (0.002-0.05 mm in diameter) ranged from 29-36 percent of the total samples, and sand-sized particles made up from 2-7 percent of the total samples (USDA 1992). Total selenium concentrations ranged from 0.3 to 0.7 ppm, and the EC of saturation extracts ranged from 9.6 to 38.6 dS/m. These soils are highly plastic with Plasticity Indices ranging from 33-61 percent. The predominant clay mineral is Montmorillonite, which can take on water in the crystal lattice, resulting in high shrink, swell potential.

The Lethent silt loam mapping unit covers about 10 percent of the site in the north half of Section 10, Figure 2-1). These soils are deep, moderately well drained, saline-sodic soil found on low-lying alluvial fans and basin rims. Permeability of this soil is very slow; runoff is slow; and the hazard of water erosion is slight (USDA 1996).

2.2.3. Groundwater

A conceptual site model for current groundwater conditions at the Tranquillity site is shown in Figure 2-2. Prior to agricultural development, the site was a discharge point for groundwater. Recharge to the semi-confined aquifer occurred along the Coast Range and intermittent stream channels to the west of the site and groundwater generally flowed toward the axis of the valley, where it rose close to the land surface and was discharged by evapotranspiration and also contributed to streamflow along the valley trough (Belitz and Heimes 1990). Evaporation of groundwater from a shallow water table resulted in high concentrations of salt and trace elements in the soil near the land surface. Heavy groundwater pumping that occurred concurrently with agricultural development lowered the regional water table and created large downward hydraulic gradients in the semi-confined aquifer. Irrigation with imported surface water and pumped groundwater in the absence of artificial drains flushed the salts from the surface soils into the shallow

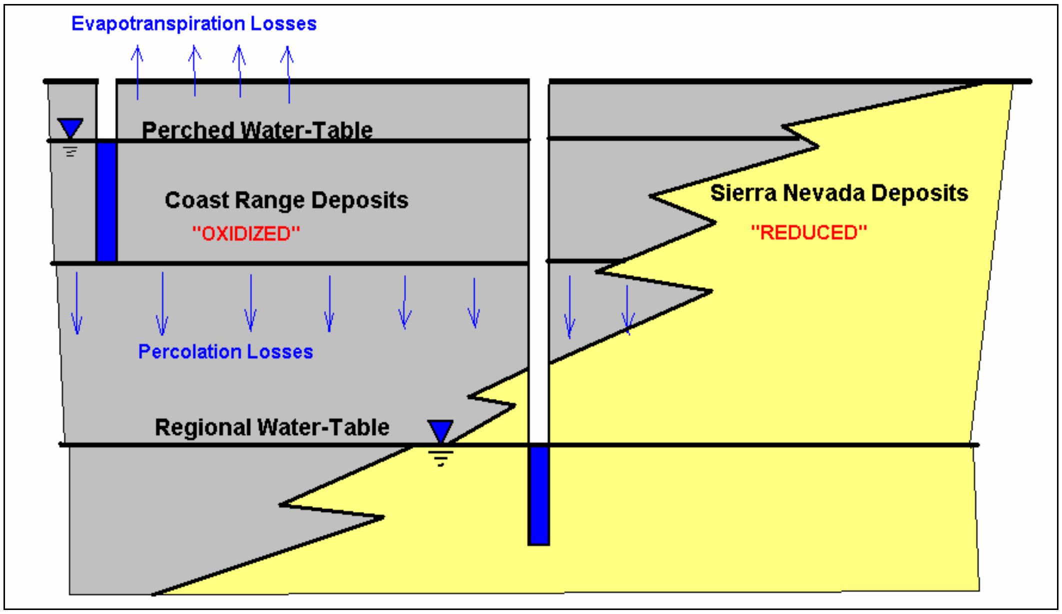

Figure 2-2. Conceptual site model for groundwater conditions at the Tranquillity site.

groundwater and created a perched water table condition in the heavy clay soils underlying the site. Evaporation from the shallow water table under irrigated conditions further concentrated high levels of salts and trace elements in the shallow groundwater. Retirement of the land from irrigated agriculture has resulted in a decline in the shallow water table as recharge has been essentially eliminated and perched groundwater is discharged by downward percolation from the bottom of the clay layer and evaporation from the near surface water table. Selenium is expected to be mobile in the oxidized geochemical conditions found in the Coast Range deposits at the site and immobile in the reduced conditions found in the Sierra Nevada deposits.

2.2.4. Climate and Weather

The Mediterranean climate in central California is characterized by cool, wet winters and hot, dry summers. The project site receives an average of about 7 inches of rainfall annually, with most of the rain occurring between the months of November through April. Hourly precipitation, temperature, wind, and relative humidity data are collected at the California Irrigation Management Information System (CIMIS) weather station No. 105, located 2.4 kilometers (km) (1.5 miles) west of the demonstration project site at the Westlands Water District (WWD) Tranquillity Field Office. The CIMIS station is operated and maintained by the California Department of Water Resources (CDWR), and is the best source of weather data for the Tranquillity site. As shown in Figure 2-3 and Figure 2-4, 4 of the 6 years (1993, 1995, 1996 and 1998) preceding the land retirement

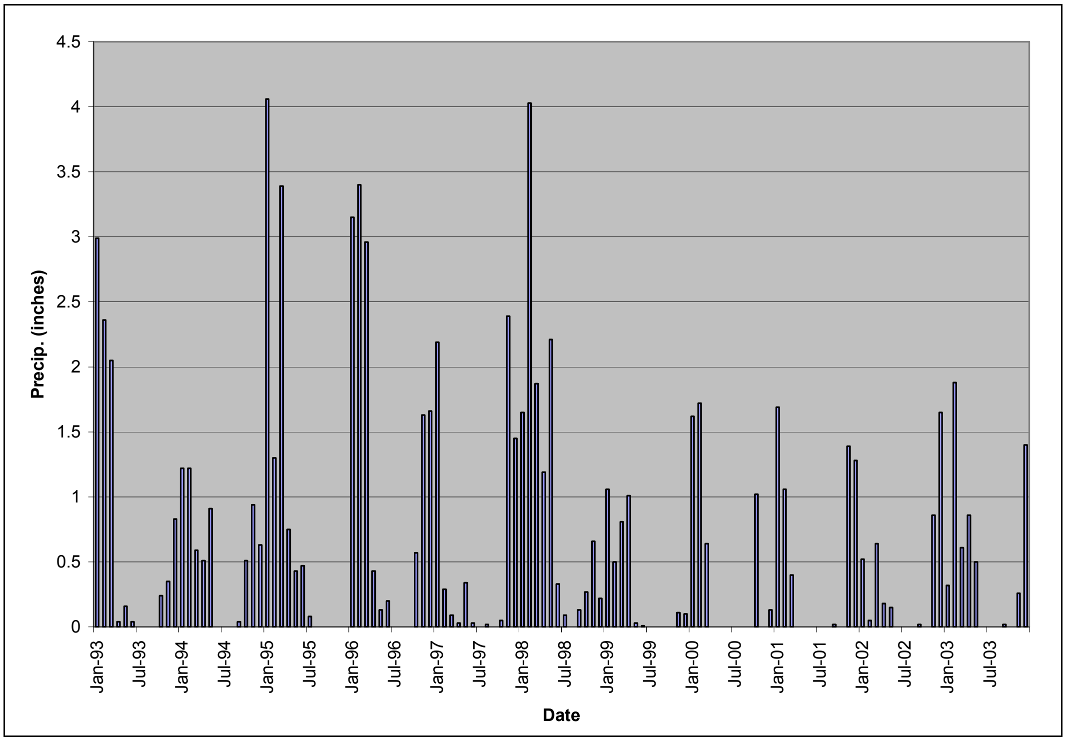

Figure 2-3. Monthly precipitation at CIMIS Station 105, Westlands Water District, near the Tranquillity site (1993-2003).

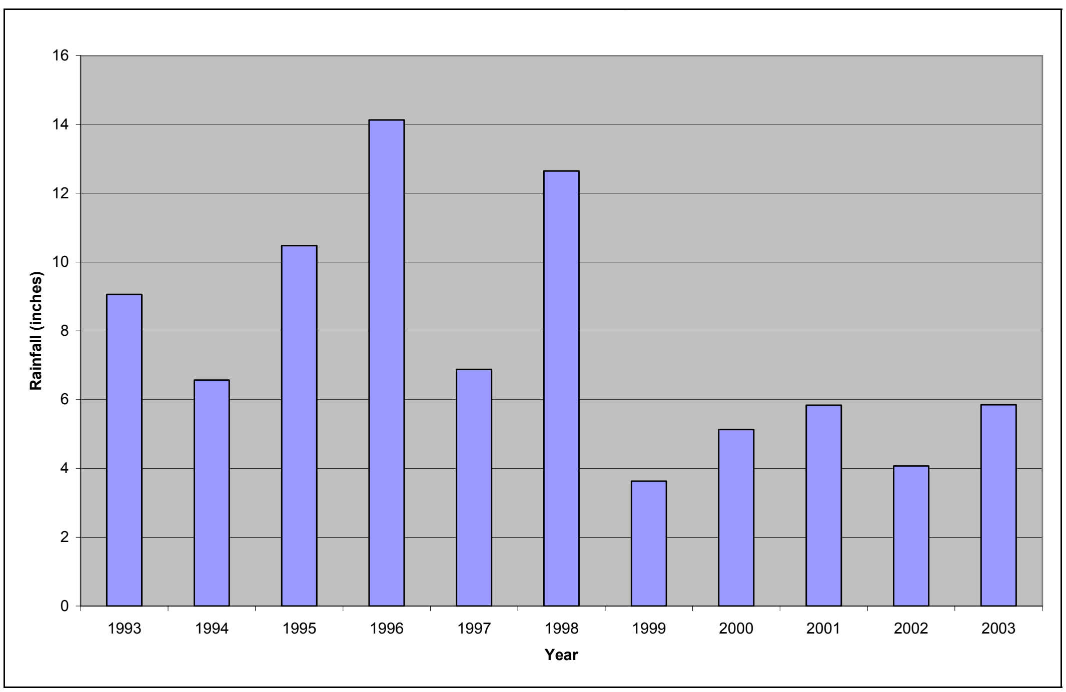

Figure 2-4. Annual precipitation at CIMIS Station 105, Westlands Water District, near the Tranquillity site (1993-2003).

demonstration project had above average rainfall, while the 5 years of monitoring during the demonstration project have been dry, with below average rainfall (1999-2003).

2.2.5. Irrigation

The demonstration project lands south of Adams Avenue were actively farmed and irrigated up to the time they were retired from irrigated agriculture in 1998 for the study. The crops consisted primarily of cotton, sugar beets, and alfalfa, which were irrigated by furrow or sprinkler irrigation systems. The land north of Adams Avenue has not been irrigated since 1989, except for a 24.3 ha (60 acre) field of safflower located in the northwest corner of section 10. Approximately 15.2 centimeters (cm) (6 inches) of water have been applied annually to the safflower field by the California Department of Fish and Game (CDFG). The safflower is left in the field to attract upland game birds for hunting. During the first 3 years of the demonstration project, a small quantity of irrigation water was applied to the barley crop planted in the habitat restoration study area. The barley covers an area of about 389 ha (960 acres) and serves as a cover crop to provide weed and dust control, as well as to isolate the experimental restoration plots from each other. Approximately 7.6, 12.4, and 11.7 cm (3.0, 4.9, and 4.6 inches) of water were applied to the barley during 1999, 2000 and 2001, respectively, using a hand moved sprinkler irrigation system. The barley buffer area has not been irrigated since 2001.

2.2.6. Monitoring of Selenium Levels

The monitoring of selenium levels in groundwater and biota followed a tiered sampling approach that was cooperatively developed with FWS specifically for this project (FWS 1999). The monitoring of selenium and salinity in soils was not a requirement in the FWS Biological Opinion for the project; however, the soil monitoring program was implemented to address concerns raised by the scientific community over potential impacts to soils that may result from land retirement

2.2.6.1. Surface Water Monitoring

In the Biological Opinion for the Land Retirement Demonstration Project, the FWS established performance standards for selenium and mercury concentrations in surface water. The performance standard specified that standing water that persists for more than 30 days shall not exceed 2 micrograms/liter (µg/L) selenium, and 2 nanograms/liter mercury (FWS 1999). Precipitation at the site was monitored by viewing the CIMIS website during the rainy season. The site was also visited during the wet season to document any standing water that persisted for more than 30 days in duration.

2.2.6.2. Soil Monitoring

The objective of the soil monitoring program for the demonstration project is to detect changes in levels of constituents of concern (COCs) including selenium, boron, and salinity that may result from land retirement over the 5-year life of the study. The soil sampling program was accomplished by members of the Interagency Land Retirement Team and Reclamation's Technical Service Center. Baseline soil samples were collected at the Tranquillity site during September and October 1999. The Tranquillity sites were re-sampled in November 2002 and August 2004 for the purpose of change detection. A rectangular sampling grid was chosen for monitoring soil chemistry at the demonstration project site (Figure 2-5). The sampling protocol used at the Tranquillity site is as follows.

Baseline soil samples were taken at the land surface at 124 locations. Surface soil samples were taken at the corners of the 4 ha (10 acre) study plots from a depth of 0-30 cm (0-1 foot) using a shovel. The samples were homogenized in the field at field moist conditions using a putty knife and stainless steel mixing bowls. The samples were collected at each site within a radius of about 1 meter of the staked locations. The coordinates of the sample locations were recorded in the field with a Global Positioning System (GPS) receiver. Discrete soil samples were taken at depths of 0-30 cm (0-1 foot), 60.9 - 91.4 cm (2-3 feet), and 121.9-152.4 cm (4-5 feet) at the centers of the 4 ha (10-acre) experimental plots to assess baseline soil chemistry with depth from the land surface (Figure 2-5). The baseline 60.9 to 91.4 cm and 121.9 to 152.4 cm (2-3 and 4-5 foot) depth samples were taken with a 10.1 cm (4-inch) inside diameter split barrel core sampler to a depth of 152.4 cm (5 feet). A continuous core was obtained at each site by pushing the core barrel with the hydraulic system of a Mobile Drill Model B-90 drill rig. Discrete depth samples were taken at a total of 26 locations at the site during the baseline sampling event. The discrete depth samples were homogenized in the field at field moist conditions using a putty knife and stainless steel mixing bowls. The coordinates of the sample locations were recorded in the field with a GPS receiver.

During the re-sampling events in 2002 and 2004, a slightly different sampling strategy was employed. Eight-increment composite soil samples were collected in a stratified random manner from the 0-30 cm (0-1 foot) depth within a 6.1 m (20-foot) radius of the original baseline sampling site. The 60.9 to 91.4 cm and 121.9 to 152.4 cm (2-3 and 4-5 foot) depth discrete soil samples were collected from a single core located approximately 152.4 cm (5 feet) south of the original site for the 2002 sampling event, and 152.4 cm (5 feet) west of the original site in the 2004 sampling event. The 152.4 cm (5 feet) offset was used to ensure that backfill from the original sampling site was not incorporated into the later sample. Identical sampling depths of 0-30, 60.9 to 91.4 and 121.9 to 152.4 cm (0-1, 2-3 and 4-5 feet) were used for all the surveys. The 0 to 30 cm (0-1 foot) depth samples were collected with a tile spade. A hand auger was used to collect all the 60.9 to 91.4 and 121.9 to 152.4 cm (2-3 and 4-5 feet) depth samples in the 2002 and 2004 sampling events. A total of 110 sites were re-sampled in 2004. A

Figure 2-5. Soil sample locations at the Tranquillity site.

subset of 57 sites, including nearly all of the 1.5 m (5 feet) deep (24 of 26) boring sites, were re-sampled in the 2002 sampling event.

2.2.6.3. Soil Chemical Analyses

The soil samples were tested for total selenium, soluble boron, soluble selenium, and soil salinity. Soil salinity analysis included the electrical conductivity of one part soil, five-part water extracts (EC_e), and the electrical conductivity of saturation extracts (EC_e). The EC_e test was used to be consistent with the baseline sampling event while the saturation extracts were run to evaluate soil salinity in relation to plant growth response.

The Quality Assurance Project Plan (QAPP) for the Land Retirement Demonstration Project describes in detail the analytical procedures and quality assurance measures taken to ensure soil and water data quality (CH2MHill 1999). Data quality analysis and data validation were conducted by Reclamation's Mid-Pacific Regional Office, Environmental Monitoring Branch. Soil samples were sent to Reclamation's Technical Service Center in Denver (D-8570), Soil and Sediment Laboratory to be dried, ground, mixed, and split for chemical analysis. The D-8570 laboratory determined pH5, pH paste, EC_e, percent field soil moisture by weight, and saturation percentage. The soil preparation lab also inserted about 15 percent certified reference materials and water samples in the sample batches that were sent to the analytical laboratory. These samples were double blind to the analytical laboratory. Samples were sent to the U.S. Geological Survey (USGS) Rock and Mineral Analysis Laboratory for selenium and boron analysis. Selenium was run by hydride generation (Method A011), while boron was determined by ICAP (Method E011) analysis. Total selenium was determined on a multi-acid digest. All USGS testing procedures used in this investigation are listed in their analytical methods manual (USGS 1996).

2.2.6.4. Groundwater Level Monitoring

One of the primary objectives of the Demonstration Project is to measure the response of the shallow water table to land retirement. Various conceptual and numerical models (SJVDP 1990a, Fio 1999, and Belitz and Phillips 1992) predicted a decline in the shallow water table in response to land retirement. FWS established a performance objective for the project that the depth to groundwater will not show a net increasing trend (decreasing depth to the soil surface) over a 5-year monitoring period (FWS 1999). There are approximately 50 monitor wells and 3 drain sumps in the project vicinity that are used to measure groundwater levels beneath the site on a quarterly basis. Water levels are measured to the nearest 3 millimeter (mm) (0.01 foot) using an electric well sounding device. The water level data are recorded in a field book and is on file at the Reclamation office in Fresno, California. The locations of the monitoring wells and sumps are shown on Figure 2-6. Existing wells constructed prior to the 1998 purchase of the demonstration project lands were installed by Westlands Water District and Reclamation for the primary purpose of measuring depths to

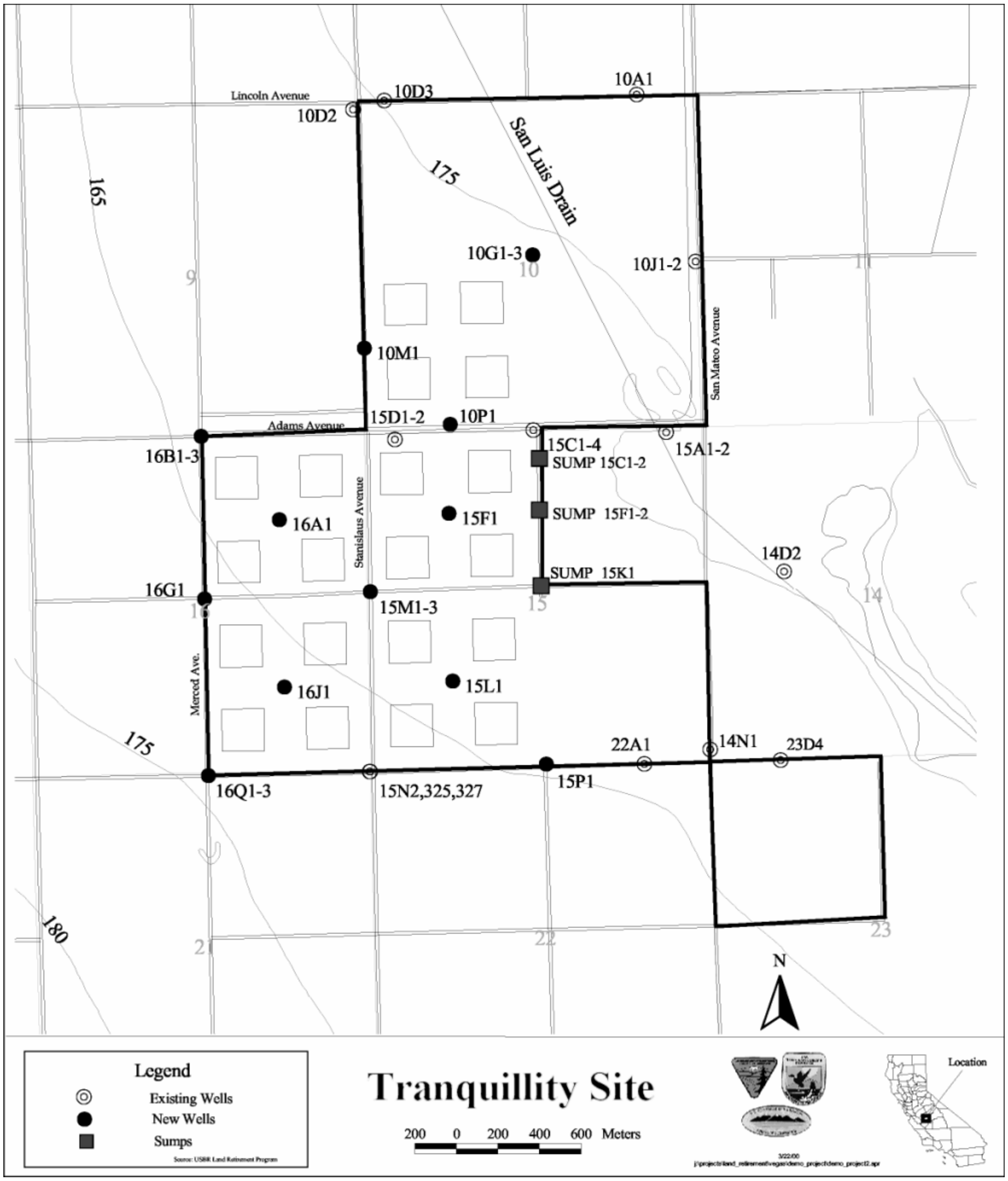

Figure 2-6. Monitor well and sump location map, Tranquillity site.

groundwater beneath drainage impacted lands in WWD. The previously existing wells are constructed of polyvinyl chloride (PVC) casing ranging in diameter from 1.9 to 10.1 cm (0.75 to 4 inches) and vary in depth from 0.9 to 26 m (3 to 86 feet) below the ground surface. These wells were installed using various construction techniques that range from jetting a short length of pipe into the ground to standard rotary drilling with hydraulic drill rigs. A complete set of water level data are available from 20 monitoring wells at the project site for the entire period of record from October 1999 to October 2004.

During summer 1999, Reclamation installed 15 additional wells to measure groundwater levels and to obtain representative groundwater samples for water quality analyses for this study. The new wells were installed using a hollow stem-auger drill rig and are constructed of 5 cm (2-inch) PVC casing and 3 m (10 feet) sections of 0.5 mm (0.020 inch) slotted PVC wellscreen. A commercial filter pack was placed around the wellscreen with a tremie pipe. Screened intervals were chosen after reviewing the soil cores during drilling. Typical screened intervals for the shallow wells are 4.3 to 7.3 m (14 to 24 feet) below land surface. The wellscreens for the deeper wells were placed in the more permeable materials encountered during drilling and range in depth (to bottom of wellscreen) from 15 to 24 m (50 to 78 feet) from land surface. Well construction diagrams for the new wells are on file at the Reclamation office in Fresno, California. Well construction diagrams for the previously existing wells are unavailable.

There are 18 subsurface drain water collection sumps located in a north-to-south alignment bisecting the northern half of Section 15 at the site. The sumps are part of an experimental drainage system that was installed at the site in 1966. Subsurface tile drains lines were installed beneath the northwest quarter of Section 15 at a depth of approximately 1.8 m (6 feet), with a drain spacing of approximately 46 m (150 feet) and a length of approximately 366 m (1,200 feet). The drain lines are 5 to 10 cm (2 to 4 inches) in diameter and discharge to 91.4 cm (3 feet) diameter concrete outlet stands that are open to the atmosphere. The outlet stands are connected to a master sump by a 39 cm (12 inch) collector pipe. Water levels have been measured quarterly using an electric sounding device in the three outlet stands shown in Figure 2-6. No drain water was discharged by pumping the master drain sump during this study.

2.2.6.5. Groundwater Quality Monitoring

A groundwater quality monitoring program was implemented to assess project performance against standards set by FWS (FWS 1999). The groundwater quality performance standard states that the selenium concentration in the groundwater will not show a net increasing trend over 5 years of monitoring. Groundwater samples were taken on a quarterly basis during year 1 and year 5 of monitoring at the Tranquillity site. The baseline year groundwater quality samples were taken in October 1999 and February, May, and July 2000. The 5-five groundwater samples were taken in October 2003 and February, May, and July 2004. Annual groundwater samples were taken in May 2001, 2002, and 2003. Unfiltered groundwater samples were taken from 12 wells and 2 drain sumps to assess baseline groundwater quality at the site. Shallow wells were sampled with a peristaltic pump or bailer while the deep wells were sampled with a submersible pump (Grundfos Redi Flo 2). Standard operating procedures for groundwater sampling used by the Mid-Pacific Region of Reclamation and those outlined in the Quality Assurance Project Plan for the Land Retirement Demonstration Project (CH2M Hill 1999) were employed to obtain, preserve, and analyze groundwater samples.

Unfiltered groundwater samples were analyzed for major ions (calcium, magnesium, potassium, sodium, chloride, sulfate, total alkalinity), trace elements (selenium, boron, iron, manganese), and isotopes (H^2, O^{18} and H^3). Specific conductance (electrical conductivity), pH, and temperature of groundwater samples were measured in the field at the time of sampling. Fluorometric analyses of groundwater samples for selenium were performed by Olsen Biochemistry Laboratories, South Dakota State University. Analyses for isotopes (H^2, O^{18}) were performed by the USGS Water Resources Division Laboratory in Reston, Virginia. Analyses for tritium (H^3) were performed by the USGS Water Resources Division laboratory in Menlo Park, California. All other analyses were performed by various contract laboratories with oversight from the environmental monitoring branch of Reclamation in Sacramento, California.

The selenium data in groundwater were evaluated for seasonal bias using the SYSTAT (SPSS 2000) nonparametric Kruskal-Wallis one way analysis of variance procedure. The selenium trends for individual monitor wells were analyzed with SYSTAT using both parametric and non-parametric regression techniques. The Wilcoxon sign rank test was used to analyze the selenium data for soil.

2.2.7. Groundwater Response to Land Retirement

Groundwater level data were analyzed by plotting hydrographs for individual monitoring wells—hydrographs are time series plots of groundwater levels measured in monitor wells. Synoptic groundwater maps depicting the depth to shallow water table on a site-wide basis on specific dates were also used to examine water table response over time. The synoptic maps were produced using the Spatial Analyst module of the Environmental Systems Research Institute (ESRI) ArcView software. A contour map showing net water table declines over the 5-year monitoring period was produced using version 8 of Surfer (Golden Software 2004) to show the spatial distribution of the water table response.

Groundwater level data from the demonstration site support the conceptual model of a declining shallow groundwater table in response to land retirement. All of the wells monitored at the Tranquillity site have shown a declining water level trend over the 5-year period of record. The hydrographs for the drain sumps and wells shown in Figure 2-7 are representative of the declining groundwater level trend observed at the site during the 5 years of monitoring. The hydrographs shown in Figure 2-7 represent water levels measured in three drain sumps (15C1, 15F2, 15K1) during the time period from July 1998 to July 2000. The drain sumps are connected to tile drain lines that underlie the northwest quarter of Section 15, and are useful for measuring shallow groundwater trends in that portion of the site. The drain sump locations are shown in Figure 2-6. No water was pumped from the sumps during the demonstration project. All three of these sumps show an overall declining trend in groundwater levels for the period of record. Total water-level declines observed in sumps 15C1, 15F2, and 15K1 are 1.4, 0.9, and

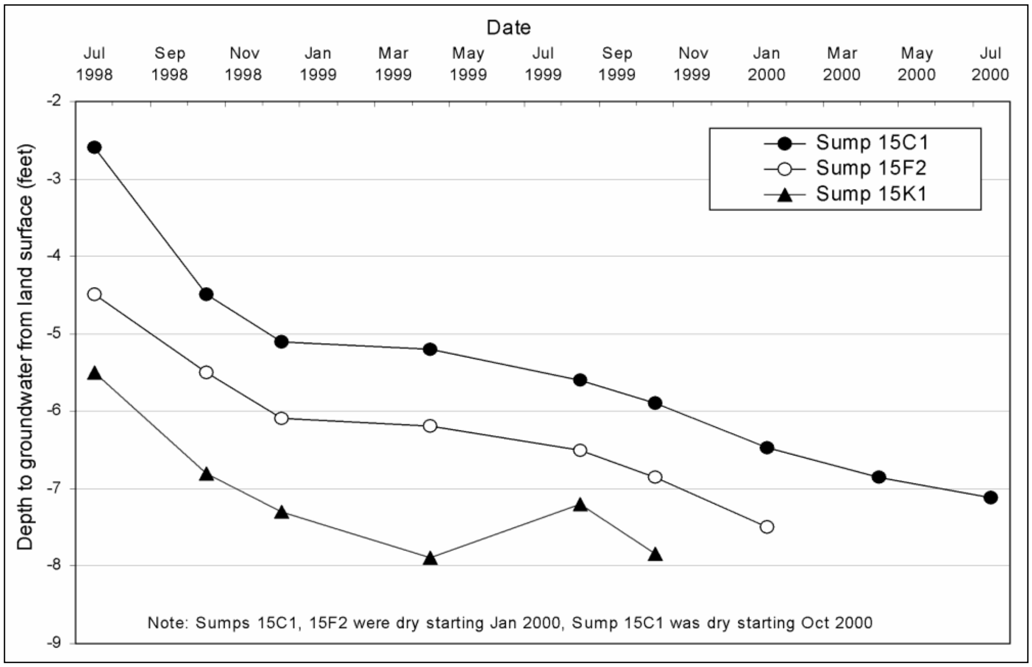

Figure 2-7. Hydrographs for three agricultural drain sumps at the Tranquillity site showing a declining shallow groundwater trend.

0.7 m (4.5, 3.0, and 2.4 feet), respectively. Sumps 15C1 and 15 F2 were observed to be completely dry starting in January 2000, while sump 15C1 was observed to be completely dry starting in October 2000. The drain sumps have remained dry as of October 2004.

The hydrographs for wells 325 and 326 are shown in Figure 2-8. These hydrographs are representative of the declining water level trends observed at the site during the 5 years of monitoring. The total water-level declines observed in wells 325 and 326 for the period of record are 3.08 and 3.14 m (10.1 and 10.3 feet), respectively. These wells constitute a nested pair of wells that were drilled in the same location but are completed at different depths. All of the nested well pairs at the site have significant vertical (downward) groundwater gradients, indicating perched water table conditions at the site. A declining groundwater level trend was observed in wells 15M1 and 16A1 (Figure 2-9). The total water-level declines observed in wells 15M1 and 16A1 were 2.7 and 3 m (8.8 and 9.8 feet), respectively.

Synoptic depth to groundwater maps are another way to portray the decline of the shallow water table at the Tranquillity site. Figure 2-10 through Figure 2-12 show the depth to groundwater from the land surface as measured in monitor wells at the site in October 1999, 2000, and 2001. The measured depth to groundwater data was contoured using ESRI ArcView Spatial Analyst software. During October 1999, approximately 30 percent 243 ha (600 acres) of the site was underlain by a water table within 2.1 m (7 feet) of the land surface. During

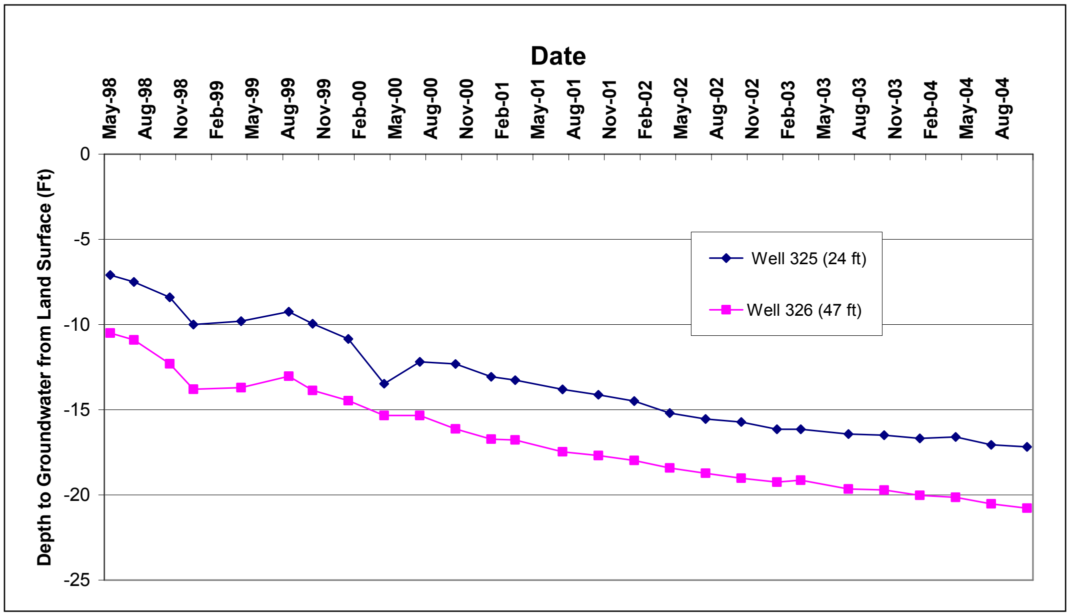

Figure 2-8. Hydrographs for the monitor well cluster site 325 and 326 at the Tranquillity site showing a declining shallow groundwater trend and vertical (downward) hydraulic gradient.

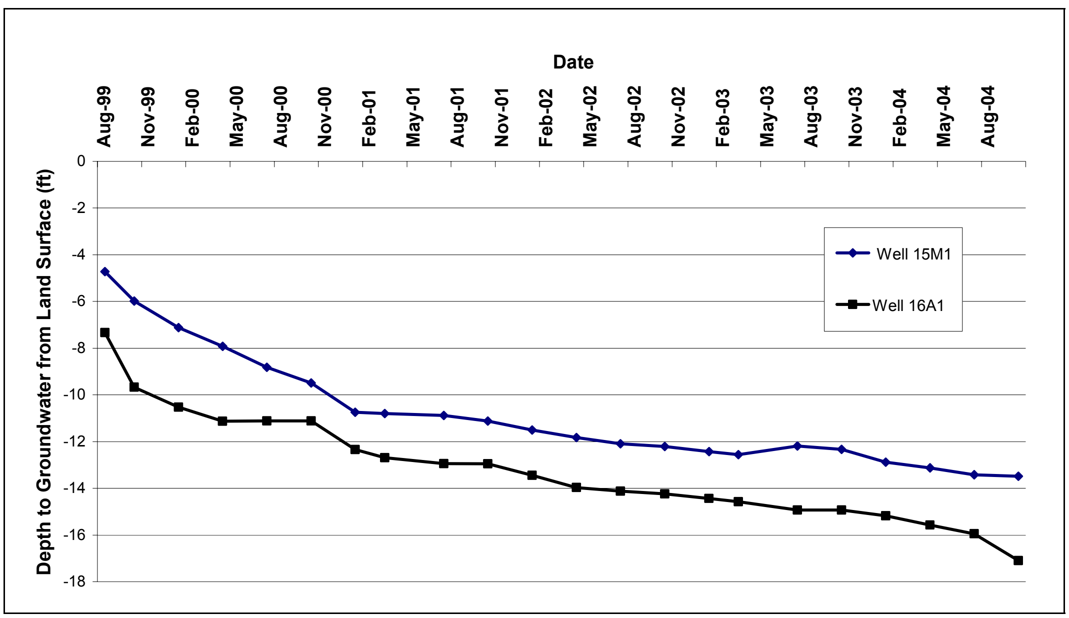

Figure 2-9. Hydrographs for monitor wells 15M1 and 16A1 at the Tranquillity site showing a declining shallow groundwater trend.

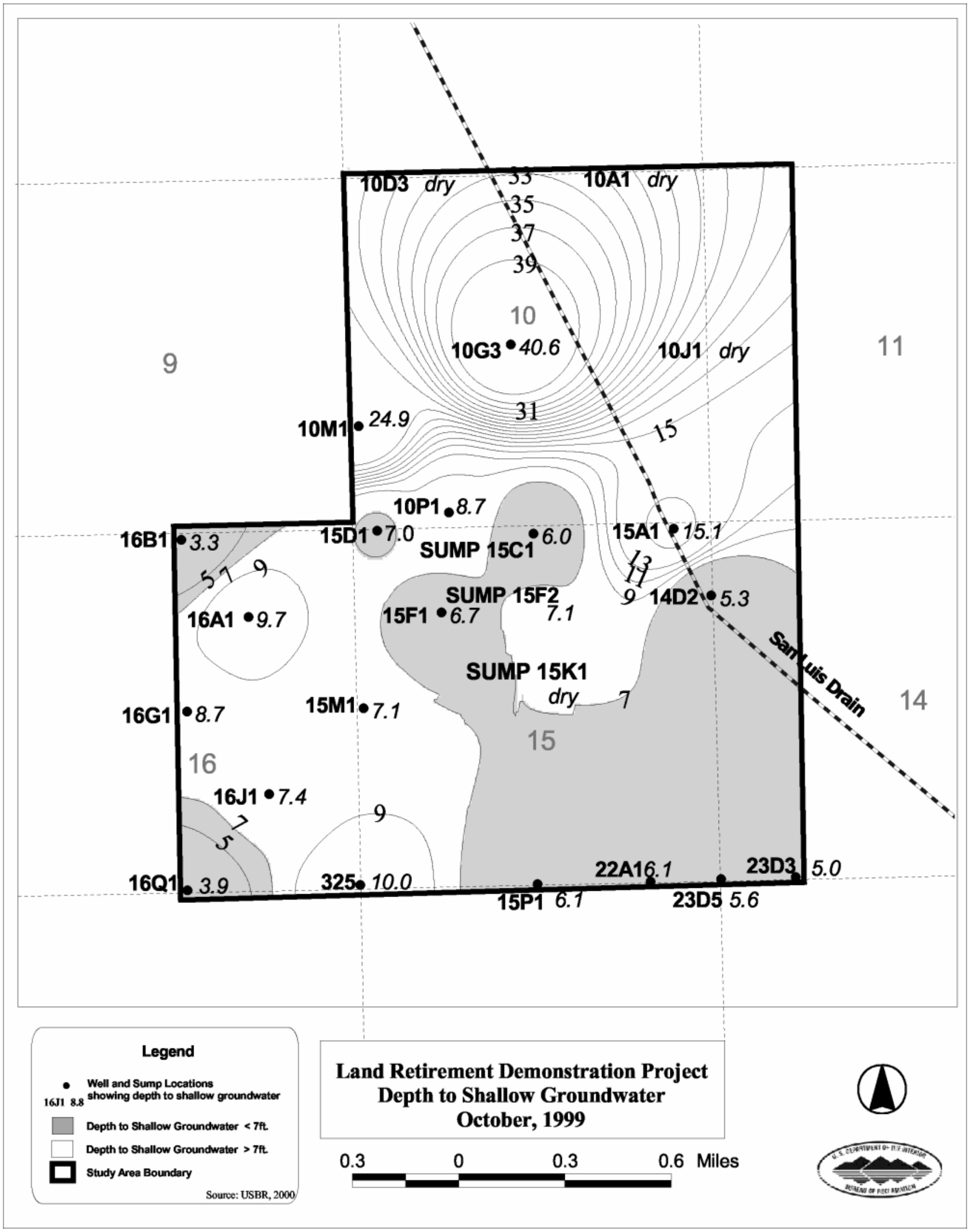

Figure 2-10. Depth to shallow groundwater, October 1999. The project area underlain by shallow groundwater within 2.1 m (7 feet) of the land surface is approximately 243 ha (600 acres).

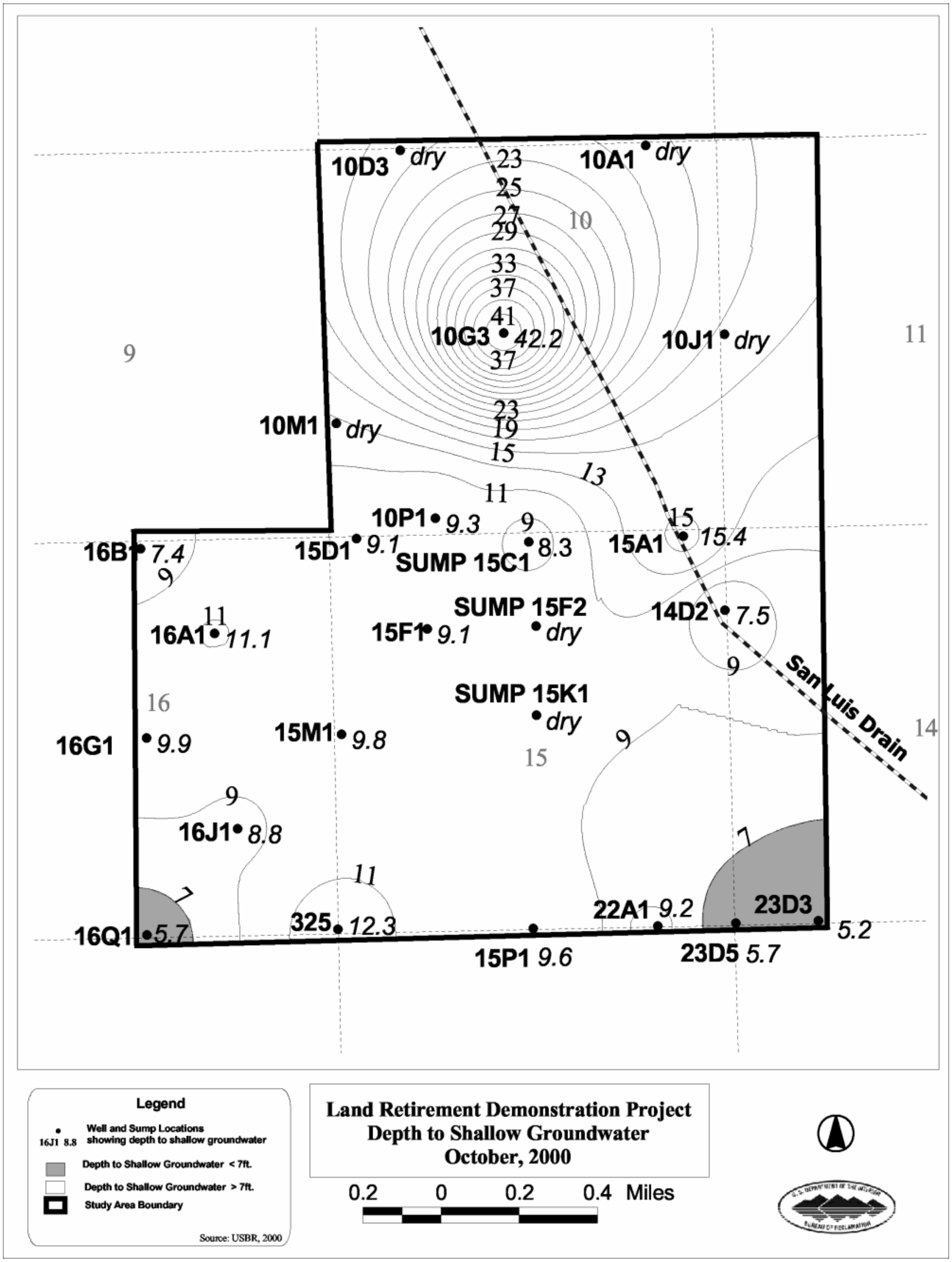

Figure 2-11. Depth to shallow groundwater, October 2000. The project area underlain by shallow groundwater within 2.1 m (7 feet) of the land surface is approximately 22 ha (55 acres).

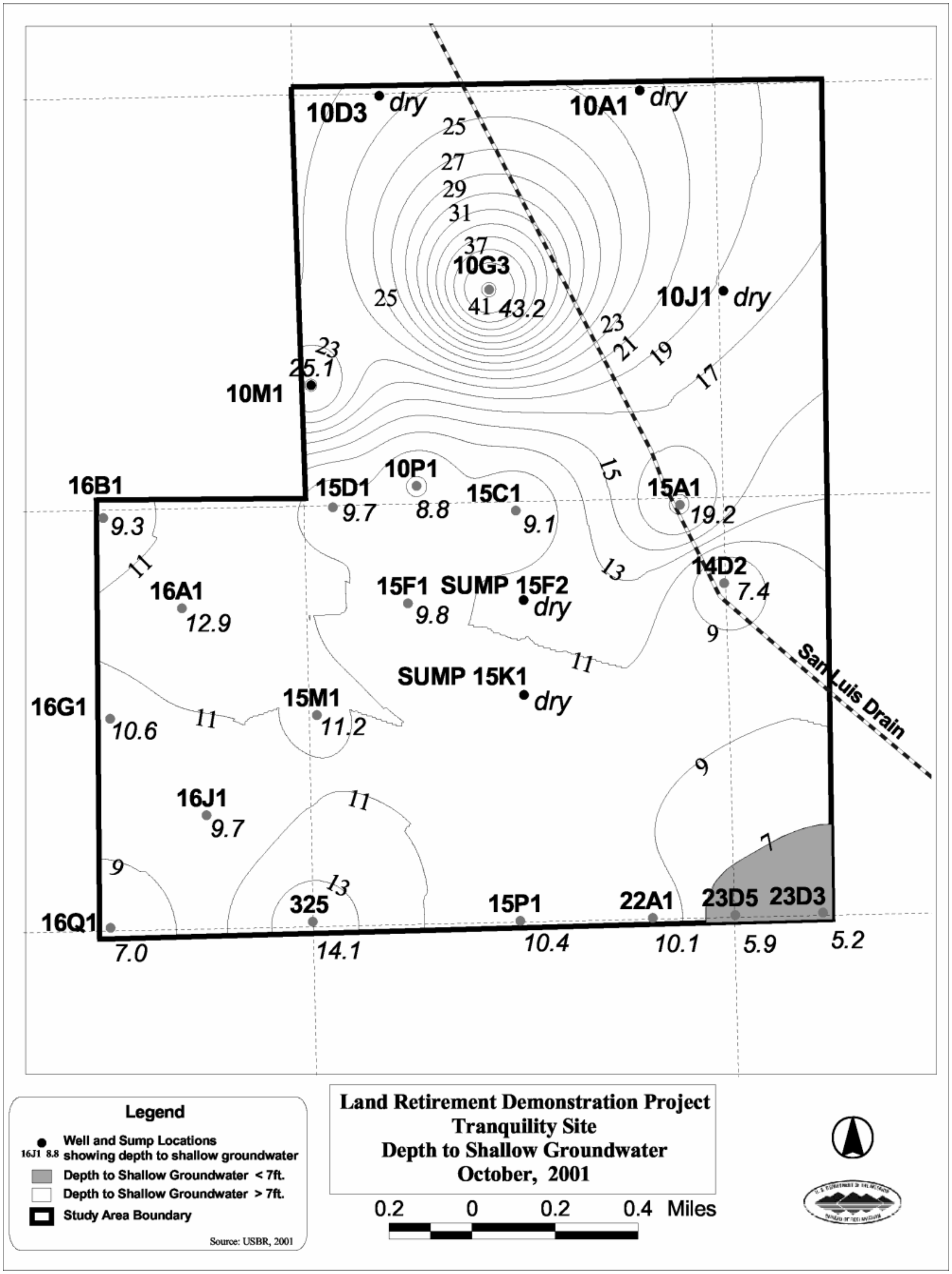

Figure 2-12. Depth to shallow groundwater, October 2001. The project area underlain by shallow groundwater within 2.1 m (7 feet) of the land surface is approximately 14 ha (34 acres).

October 2000, approximately 3 percent of the site (22 ha or 55 acres) was underlain by a water table within 2.1 m (7 feet) of the land surface. In October 2001 the area of the site underlain by a water table within 2.1 m (7 feet) of the land surface decreased to less than 2 percent of the site (14 ha or 34 acres). As of October 2002, no part of the site had a shallow water table within 2.1 m (7 feet) of the land surface.

The site can be divided into two distinct areas based on the depth to groundwater observations. The depth to the water table north of Adams Avenue (Section 10) was significantly greater than that observed south of Adams Avenue. The differences can be attributed to two factors. This northern part of the site (Section 10) has been retired from irrigated agriculture since 1994, and has not received significant application of irrigation water (groundwater recharge) since that time. Section 10 is also underlain by more permeable Sierran sand deposits, which allow more rapid percolation of applied irrigation water.

Analyses of the groundwater data at the Tranquillity site indicate a decreasing rate of water table decline over time. The slopes of the hydrographs shown in Figure 2-8 and Figure 2-9 show a flattening trend over time. Examination of individual wells suggests that the extinction depth for groundwater evaporative discharge may be about 3 m (10 feet). The volume and flow of upflux is so small between a depth of 2.1 and 3 m (7 and 10 feet) that evaporative discharge in the soil cracking system at the 60.9 to 121.9 cm (2-4 feet) depth may be sufficient to maintain a very small amount of unsaturated upward flow. Once the water table receded below 3 m (10 feet), all discharge is believed to be vertical deep percolation through the first barrier layer. Deep percolation rates are controlled by the permeability of the first barrier layer and the hydraulic head on the barrier. Examination of well logs, cone penetrometer data, and nested well water levels indicates the first barrier layer is present at depths ranging from 4.0 to 9.1 m (13-30 feet) below the ground surface (average 6.1 m or 20 feet) and that unsaturated conditions are present below the first barrier layer. The average annual rate of decline was about 44 cm (1.2 feet) per year which equates to a water volume of about 1.8 cm (.06 feet) per year. This rate is expected to decrease as less head is available to push water through the barrier layer.

2.2.7.1. Natural Drainage Rates

The Tranquillity site is currently isolated from actively irrigated lands; however, during the first few years of the study irrigation of lands near site 16Q1 may have contributed some lateral flows to that site. No commercial irrigation was conducted near well 15M1 and lateral gradients (.0008) have remained nearly flat in that area. The natural drainage at the demonstration site is controlled by the permeability of the first barrier layer, the depth of saturation above the barrier, and the thickness of the barrier layer. All nested wells in the area indicate unsaturated conditions below the first barrier layer and perched water table conditions.

Based on observations of soil substrata at drill sites, examination of 12 cone penetrometer logs, as well as hydraulic conductivity testing in the area, the specific yield of the substrata in the 1.8 to 3.7 m (6-12 feet) zone is estimated at about 5 percent and the average depth to barrier is about 6.1 m (20 feet). Substrata soil textures at site 16Q1 were somewhat coarser in the deep substrata and a specific yield of 10 percent was estimated for that boring. Hydraulic barriers were also noted in the two drill holes. The barrier was at 6.2 m (20.5 feet) in well 15M1 and about 4.2 m (13.8 feet) in well 16Q1. Based on the water table decline over the 5-year period, the depth of the head on the hydraulic barriers and the assumption that lateral water movement and evaporative discharge is negligible, a vertical permeability and natural drainage rate could be estimated. Vertical permeability and natural drainage estimates are shown in Table 2-1. Soil data for site 15 M1 was used to estimate the natural drainage rates for the min, max, and average water table declines.

Table 2-1. Estimates of Natural drainage rates and vertical permeability at the Tranquillity site.

Site	Water table decline (feet)	Natural drainage rate (feet/year)	Vertical permeability of barrier (feet/day)
15M1	6.01	0.060	5.48 x 10-5
15M1*	2.38	0.040	4.38 x 10-5
16Q1	6.38	0.128	2.06 x 10-4
Min	0.51	0.005	nd
Max	9.54	0.095	nd
Ave	5.79	0.058	nd

* last 3 years after water receded below 10 feet.
nd = not determined

The FWS performance objective regarding declining groundwater levels in response to land retirement was clearly met. The combination of dry climatic conditions and greatly reduced application of irrigation water associated with land retirement have resulted in significant declines of the shallow water table at the Tranquillity demonstration site. Every monitor well at the site showed a declining water level trend over time. The average decline in the water table measured in 15 wells at the site during the 5-year period of record is approximately 1.8 m (6 feet). The average rate of decline in the water table measured in these wells over the 5-year period of record was approximately 0.4 m (1.2 feet) per year. The maximum decline of the water table was 2.9 m (9.54 feet) (Well 16G1), while the minimum decline of the water table was 0.15 m (0.51 feet) (Well 10M1) (Table 2-2 and Figure 2-13) The largest drop in the water table occurred on the westernmost part of the site in section 16, while the smallest drop observed was in the northern part of the site in Section 10 (Figure 2-13).

Table 2-2. Groundwater level decline observed in fifteen wells at the Tranquillity site for the time period from October 1999 to October 2004.

Well	Water Level Decline (Feet)
10M1	0.51
15A1	5.94
15A2	5.99
15C2	5.65
15M1	6.38
15N2	6.90
325	7.23
15P1	6.78
15F1	4.44
16A1	7.69
16B1	8.10
16G1	9.54
16J1	4.44
16Q1	6.01
23D4	4.27
MAX	9.54
MIN	0.51
AVG	5.99
RATE	1.20

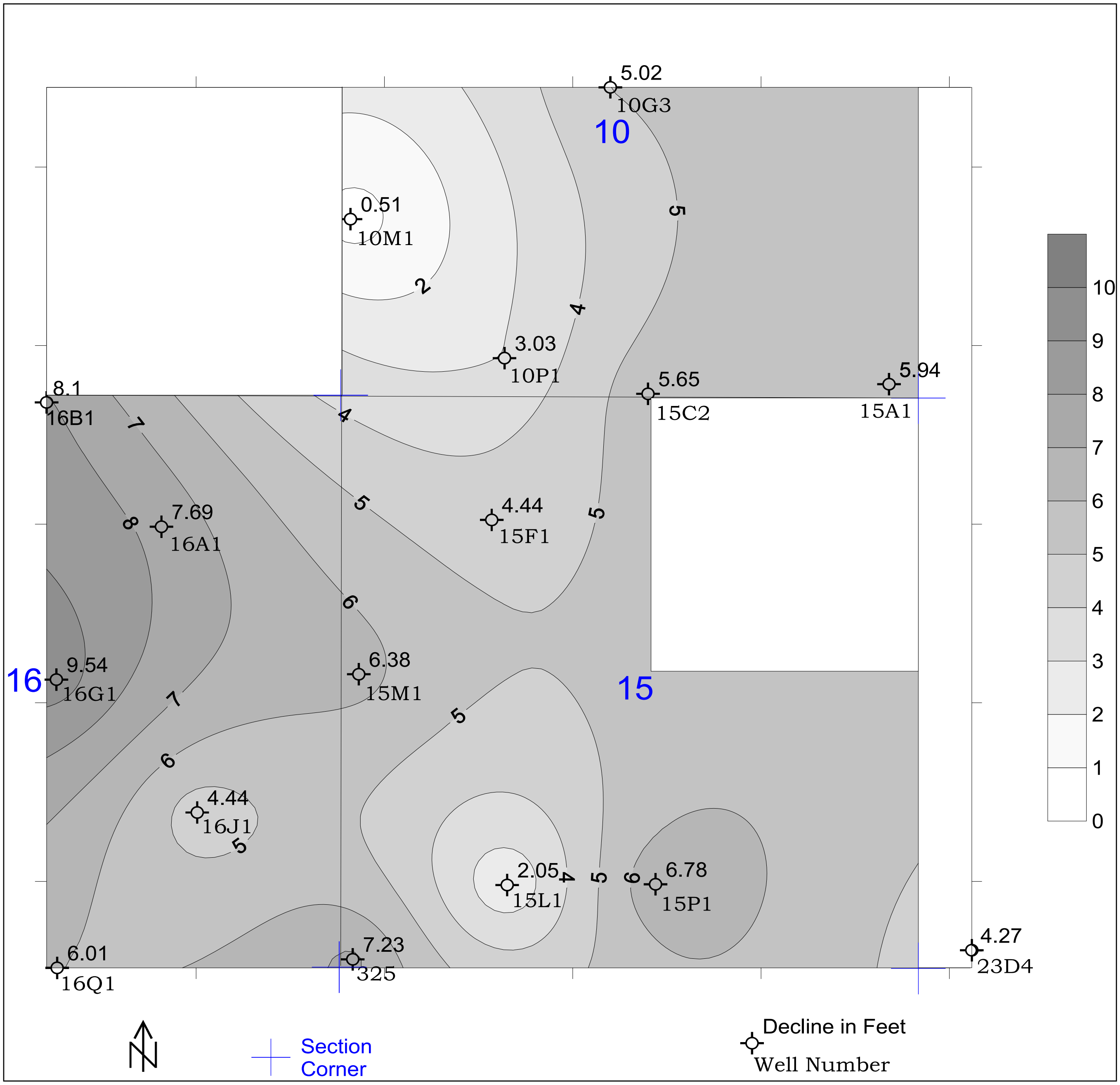

Figure 2-13. Contour map showing spatial distribution of net water table declines at the Tranquillity site from October 1999 to October 2004.

2.2.8. Groundwater Quality

2.2.8.1. Groundwater Salinity

A general indication of the total dissolved ionic constituents in the groundwater can be obtained by determining the capability of a groundwater sample to conduct an applied electrical current. This property is reported as specific conductance (also electrical conductivity, EC), and is expressed in terms of the conductivity of a cube of water 1 square centimeter on a side. EC is expressed in units of microSiemens/cm (µS/cm).

Baseline EC data for the groundwater samples collected during the first year of monitoring are presented in Table 2-3 and Table 2-4. The shallow, perched groundwater is extremely saline in nature. Salinity in the shallow groundwater and drain sump samples, expressed as EC, ranged from 11,500 to 76,980 µS/cm, with a median value of 43,925 µS/cm. By comparison, drinking water typically is less than 750 µS/cm, irrigation water is less than 1,250 µS/cm, and seawater is about 50,000 µS/cm. The groundwater samples obtained from the underlying semi-confined aquifer are much less saline. Salinity in the groundwater samples obtained from the deep wells (> 50 feet deep), expressed as EC, ranged from 5,630 to 18,580 µS/cm, with a median value of 7,675 µS/cm.

The extreme salinity of the shallow groundwater at the site is a result of the irrigation of saline soils. Naturally occurring salts have been leached from the soil profile under irrigated conditions. Salts also have been transported to the site in the applied irrigation water. Direct evaporation from the shallow water table and transpiration of applied water by crops has concentrated salts in the shallow groundwater, resulting in the high EC values observed in the shallow groundwater samples.

2.2.8.2. Groundwater Major Ion Chemistry

Baseline major ion chemistry for the groundwater samples collected during year 1 of monitoring at the Tranquillity site are presented in Table 2-5 and Table 2-6. The groundwater found in the perched zone and in the underlying semi-confined aquifer is best described as a sodium-sulfate type of water. Sodium is the dominant major cation found in the shallow groundwater samples, with sodium concentrations ranging from 2,300 to 25,000 milligrams per liter (mg/L), and a median concentration of 13,000 mg/L. Sodium is also the dominant major cation found in groundwater samples taken from the deep wells, with concentrations ranging from 760 to 3,800 mg/L, and a median concentration of 1,100 mg/L. Sulfate is the dominant major anion found in both the shallow, perched groundwater and in the underlying semi-confined groundwater at the site.

Table 2-3. Baseline year groundwater quality data for shallow wells at the Tranquillity site — major ions and field parameters.

Statistic	Min.	25th percentile	Median	75th percentile	Max.	Mean
Number of Samples	44	44	44	44	44	44
EC(field) (µS/cm)	11,500	32,620	43,260	52,350	76,980	41,987
pH (field)	6.74	7.54	7.78	7.9	8.37	7.73
Calcium (mg/L)	250	400	420	450	500	417
Magnesium (mg/L)	42	250	525	663	1300	515
Sodium (mg/L)	2,300	8,725	13,000	16,500	25,000	13,009
Potassium (mg/L)	7	20	30	42	94	32
Total Alkalinity (mg/L)	150	260	330	423	610	351
Chloride (mg/L)	380	1,150	2,700	3200	4,100	2,332
Sulfate (mg/L)	4,300		24,500	31,000	62,000	26,330

Table 2--4. Baseline year groundwater quality data for deep wells at the Tranquillity site — major ions and field parameters.

Statistic	Min.	25th percentile	Median	75th percentile	Max.	Mean
Number of Samples	12	12	12	12	12	12
EC(field) (µS/cm)	5,630	6,763	7,675	17,315	18,580	10,633
pH (field)	6.82	7.13	7.21	7.28	7.46	7.21
Calcium (mg/L)	280	300	320	360	390	327
Magnesium (mg/L)	280	300	310	328	350	315
Sodium (mg/L)	760	823	1,100	2,425	3,800	1,714
Potassium (mg/L)	6	9	13	14	20	12
Total Alkalinity (mg/L)	200	250	270	329	340	277
Chloride (mg/L)	300	410	540	1,700	1,900	924
Sulfate (mg/L)	2,100	2,750	3,100	5,525	7,300	4,067

Table 2--5. Baseline groundwater quality data for shallow wells at the Tranquillity site — trace elements and tritium.

Statistic	Min.	25th percentile	Median	75th percentile	Max.	Mean
Number of Samples	44	44	44	44	44	44
Boron (mg/L)	10	26	46	55	81	42
Iron (mg/L)	0.1	0.8	2.1	15	160	19.4
Manganese (mg/L)	0.008	0.11	0.23	1.1	3.9	0.757
Selenium (mg/L)	0.005	0.195	1.28	3.812	5.39	2.095
Tritium (TU)	0	0.9	2.4	3.7	6	2.3

Table 2-6. Baseline groundwater quality data for deep wells at the Tranquillity site— trace elements and tritium.

Statistic	Min.	25th percentile	Median	75th percentile	Max.	Mean
Number of Samples	12	12	12	12	12	12
Boron (mg/L)	2.5	2.8	3.2	6.6	8.3	4.4
Iron (mg/L)	0.3	0.6	1.2	1.3	1.6	1
Manganese (mg/L)	0.25	0.318	1.75	2.5	4.3	1.718
Selenium (mg/L)	< 0.0004	0.0005	1.84	1.91	1.95	1.0873
Tritium (TU)	0	0.4	10.1	11.6	14	7.5

TU = tritium units

Sulfate concentrations found in groundwater samples from the shallow wells (< 15 m or 50 feet deep) ranged from 4,300 to 62,000 mg/L, with a median concentration of 24,500 mg/L. Sulfate concentrations in groundwater samples from the deep wells (> 15 m or 50 feet deep) completed in the semi-confined aquifer ranged from 2,100 to 7,300 mg/L, with a median concentration of 3,100 mg/L (Figure 2-14).

High sodium and sulfate concentrations in the groundwater on the west side of the San Joaquin Valley result from weathering of sulfate rich rocks in the adjacent Coast Ranges. Davis (1961) hypothesized that the sulfate in groundwater in the study region originates from the oxidation of organic marine shales containing reduced iron sulfide minerals. Presser et al. (1990) reported oxidation of iron sulfide minerals for west-side streams in the study vicinity. Another probable source of sulfate in the shallow groundwater is from gypsum (calcium sulfate) that has historically been applied to soils by farmers in the region as a method of soil salinity (sodium) management.

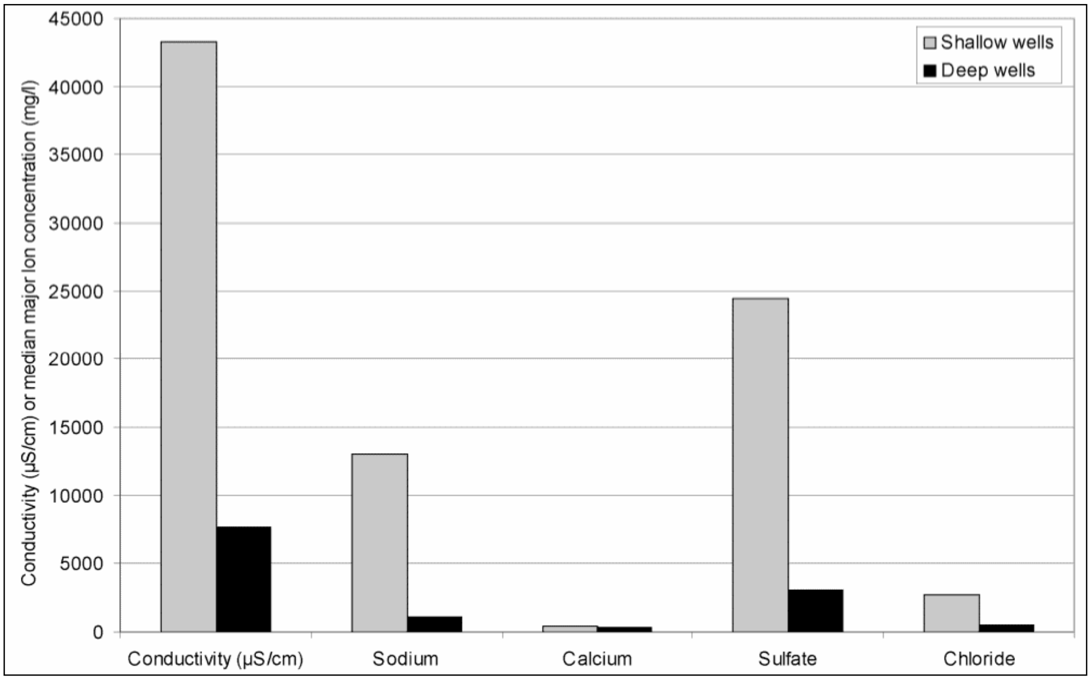

Figure 2-14. Comparison of dominant major ion concentrations and electrical conductivity for groundwater samples from shallow and deep wells.

2.2.8.3. Trace Elements in Groundwater

The trace elements of concern monitored for this study include selenium and boron. High concentrations of selenium and boron in the shallow groundwater are of concern due to potential toxicity to wildlife and plants. Iron and manganese concentrations were also monitored because they provide insight into geochemical conditions in the groundwater system. A summary of baseline trace element data for the first year of groundwater monitoring is presented earlier in Table 2-5 and Table 2-6.

Selenium concentrations measured in the shallow groundwater system (wells < 15 m or 50 feet deep) during the first year of monitoring were high, ranging from 5 to 5,390 µg/L (0.005 to 5.390 mg/L), with a median concentration of 1,280 µg/L (1.280 mg/L). By comparison, the Environmental Protection Agency (EPA) water-quality criterion for long-term exposure in aquatic environments is 5 µg/L (EPA 1988). It becomes clear why the conceptual model of a declining shallow water table is an essential element of land retirement in light of the extremely high concentrations of selenium observed in the shallow groundwater. Deverel and Millard (1988) concluded that the main factors affecting selenium concentrations in the shallow groundwater of the western San Joaquin Valley are the degree of groundwater salinity and the geologic source of the alluvial soils.

Selenium concentrations measured in the deep wells (> 15 m or 50 feet deep) at the site showed considerable spatial variation (Table 2-6). Selenium concentrations found in well 15M3 (21 m or 69 feet deep), ranged from 1,840 to 1,950 µg/L during the first year of monitoring, while selenium concentrations found in wells 15C3 and 10G3 (25 and 23 m or 83 and 75 feet deep, respectively) ranged from the analytical limit of detection (< 0.0004 mg/L) to 0.0005 mg/L. The large variation in selenium concentration seen in the deep wells may be explained due to differing geochemical conditions found in Coast Range deposits and the Sierran sands underlying the site. Well 15M3 is perforated in Coast Range sediments, while wells 15C3 and 10G3 are perforated in sediments derived from the Sierra Nevada Range.

Dubrovsky et al. (1993) noted high concentrations of selenium in shallow groundwater in Coast Range sediments and low concentrations in underlying Sierra Nevada sediments in previous groundwater quality investigations in the western San Joaquin Valley. The authors hypothesized that the absence of selenium in groundwater from wells screened in the Sierra Nevada deposits may be due to a redox (chemical reduction or oxidation) process. Selenium can exist in four valence states; -2, 0, +4, and +6. The +6 and +4 valences occur as the oxyanions selenate (SeO^{42}) and selenite (SeO^{32}) under alkaline, oxidizing conditions. Selenate is the most oxidized form of selenium, is relatively mobile in aqueous environments, and does not associate with solid phase materials (Leckie et al. 1980, Frost and Griffin 1977, and Hingston et al. 1974). Deverel and Fujii (1988) reported that the selenium in soil solutions and shallow groundwater in the western San Joaquin Valley is in the selenate form, and a very small percentage of soil selenium is in the absorbed phase. Although no attempt has been made to speciate selenium in groundwater samples from the Land Retirement Demonstration Project, the selenium found in the shallow groundwater at the site probably occurs predominantly as selenate.

Under more reduced conditions, such as those found in the underlying Sierra Nevada deposits in the northern part of the site, selenium can exist as elemental selenium (zero valence) and selenide (Se^{2}). The solubility of selenate minerals generally is high (Elrashadi et al. 1987), and there are no apparent solubility constraints on selenate in shallow groundwater in the western San Joaquin Valley, even in groundwater saturated with respect to sulfate minerals (Deverel and Gallanthine 1989). Consequently, selenate tends to behave conservatively in oxidizing groundwater. The mobility of selenite in groundwater is severely constrained by adsorption onto a variety of mineral surfaces (Balistrieri and Chao 1987, Neal et al.1987, Goldberg and Glanbig 1988). The solubilities of the reduced forms of selenium (elemental selenium and selenide) are extremely low (Elrashadi et al. 1987). Field and laboratory studies of selenium contamination at Kesterson Reservoir demonstrated selenium removal by reduction of selenate to less mobile forms (Lawrence Berkeley Laboratory 1987, White et al. 1988, Weres et al. 1989). Similar geochemical processes may be responsible for the extremely low selenium concentrations observed in Wells 15C3 and 10G3 at the Tranquillity site.

Dubrovsky et al. (1993) noted that selenium concentrations in groundwater decreased rapidly at the same depth at which manganese concentrations increase at a research site located in the vicinity of the Tranquillity site in the western San Joaquin Valley. The authors concluded that the decrease in selenium is due to a process that occurs under reducing conditions. High concentrations of dissolved iron and manganese in groundwater can indicate geochemically reducing conditions. A similar trend is observed at the land retirement study site when ratios of selenium to manganese concentrations are plotted verses well depth. The selenium/manganese ratios are generally high in the shallow wells and extremely low in the deep wells, especially those perforated in the Sierran deposits (Figure 2-15). This supports the conceptual model that oxidizing conditions are prevalent in the shallow groundwater, and that reducing conditions are prevalent in the deep groundwater found in the Sierran deposits. The presence of reducing geochemical conditions in the Sierran deposits probably play a significant role in the extremely low selenium concentrations observed in wells 15C3 and 10G3.

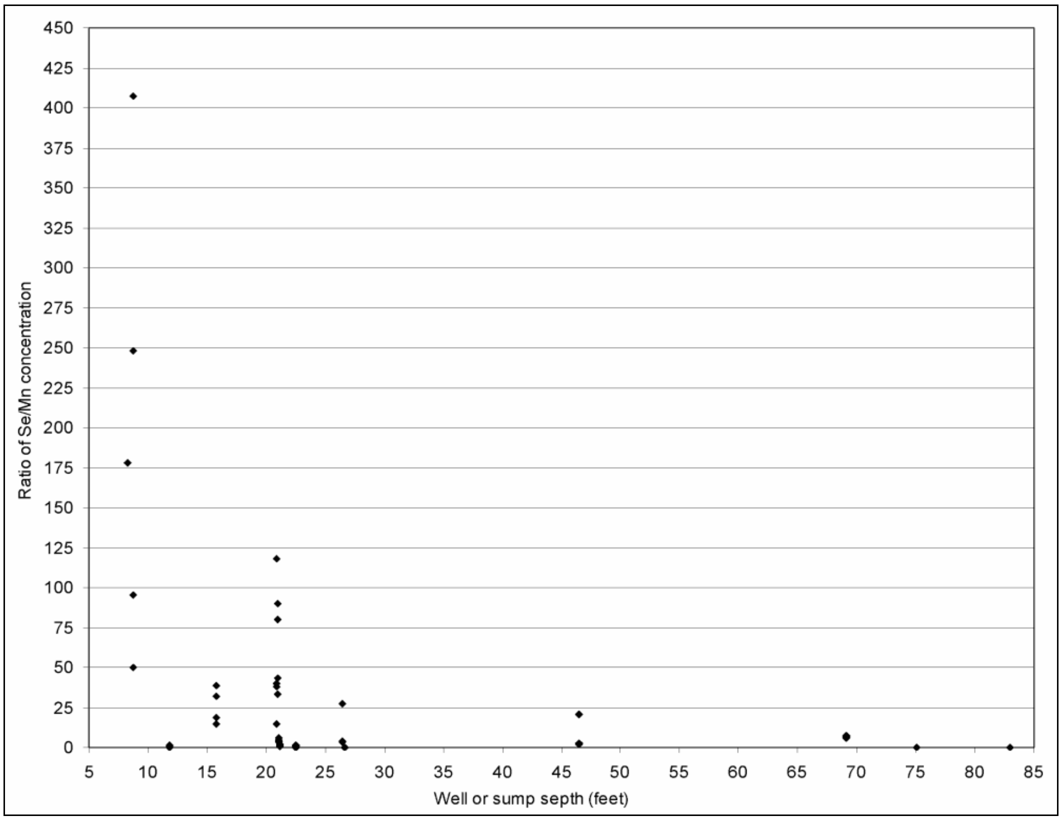

Figure 2-15. Ratio of selenium to manganese (Se/Mn) concentration in groundwater samples plotted verses well depth. The Se/Mn ratio shows a decreasing trend with depth indicating oxidizing geochemical conditions in the shallow wells and reducing conditions in the deep wells.

2.2.8.4. Selenium Trend in Groundwater

The Fish and Wildlife Service established performance standards for selenium in groundwater in the Biological Opinion for the Land Retirement Demonstration Project (FWS 1999). The performance standard for selenium in groundwater specifies that the selenium concentration in groundwater will not show a net increasing trend over the 5-year monitoring period. The summary statistics for the annual selenium data for the wells monitoring Coast Range deposits at the Tranquillity site are shown in Figure 2-16 and Table 2-7. The annual selenium data for the Coast Range wells show a relatively high degree of spatial variability. The coefficients of variation (standard deviation/mean) for the annual data ranged from 0.79-0.89 mg/L. The 95 percent confidence intervals calculated for the median annual selenium data were also large, indicating high spatial variability.

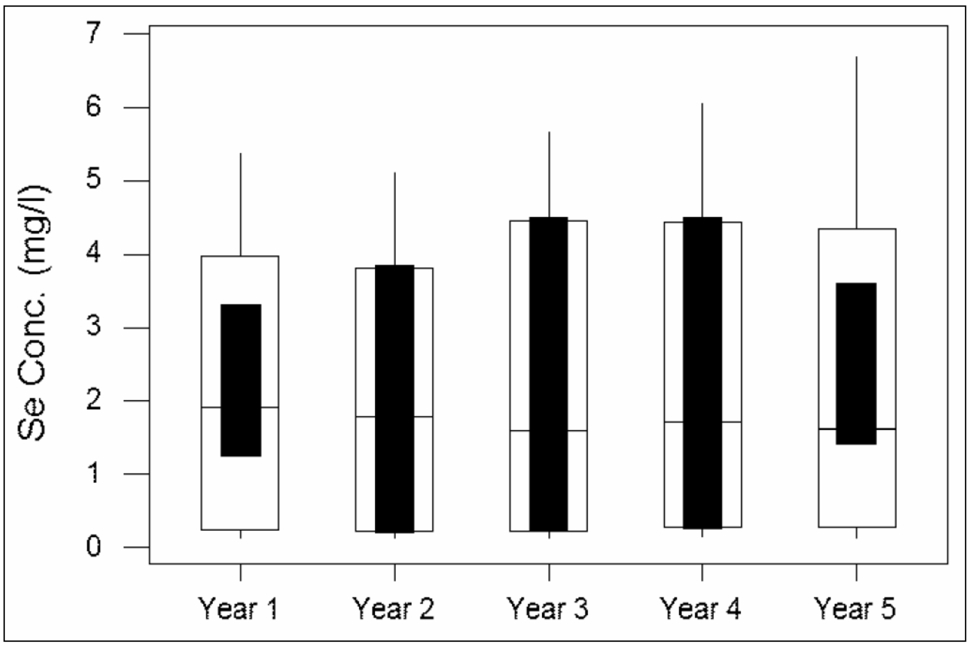

Figure 2-16. Boxplots of selenium concentrations in Coast Range deposits for the 5 years of groundwater sampling at the Tranquillity site. The inner black boxes represent the 95 percent confidence interval of the median concentration.

Table 2-7. Summary statistics for selenium concentrations measured in groundwater samples taken from Coast Range deposits for the 5 years of groundwater monitoring at the Tranquillity Site. All selenium concentrations are reported in milligrams/liter (mg/L).

Year	Number samples	Min	25th percentile	Median	Mean	75th percentile	Max	Std. Dev.	Coeff. of variation
1	45	0.095	0.237	1.910	2.237	3.975	5.39	1.782	0.79
2	10	0.104	0.212	1.785	2.111	3.820	5.14	1.795	0.85
3	10	0.110	0.222	1.595	2.367	4.468	5.70	2.107	0.89
4	11	0.119	0.262	1.710	2.403	4.450	6.08	2.125	0.88
5	44	0.110	0.272	1.610	2.441	4.345	6.72	2.089	0.85

Regression analyses of selenium concentrations over time for individual wells were performed as a way to evaluate observed trends against the FWS performance standard for selenium in groundwater.

A problem often encountered in time series analysis of groundwater quality data is the inherent seasonality sometimes present in the data. The seasonal variation in time series data may overwhelm any longer term trend. This is particularly true in a small data set. The Tranquillity well data consist of 11 samples collected from 10 wells and 8 samples from 1 other well between October 1999 and July 2004. The samples are not consistent within the years. Of the 11 samples, 5 were collected during May and the remainder were collected during February, July, and October (2 in each month). The data were evaluated for seasonal bias using the SYSTAT (SPSS 2000) nonparametric Kruskal-Wallis one way analysis of variance procedure. The results are shown in Table 2-8. The seasons were represented by the 4 months in which the samples were collected. None of the well data sets showed any significant degree of seasonality ($\alpha < 0.05$). It should be noted that there were only 8 samples from well 10M1 and that none of those samples were collected during October. The lack of seasonality helps to validate the use of linear regressions of selenium on time as a way to evaluate project performance.

Table 2-8. Analysis of seasonality of selenium data based on Kruskal-Wallis 1-way analysis of variance (ANOVA).

Well	K-W Stat.	Prob. > K-W Stat
10M1	1.409	0.4945
15F1	1.618	0.6553
15M1	0.955	0.8122
15M3	3.711	0.2944
15P1	4.950	0.1755
16A1	0.589	0.8989
16B1	1.372	0.7122
16B3	0.354	0.9496
16G1	0.275	0.9646
16J1	2.653	0.4483
16Q1	2.954	0.3988

Parametric and non-parametric regression analyses were performed to analyze the selenium trends in eleven of the wells at the Tranquillity site using the SYSTAT statistical software (SPSS 2000). All of the wells with the exception of well 10M1 monitor groundwater in the Coast Range deposits at the site. A way of eliminating the influence of large values early or late in the series is to run non-parametric (rank-order) correlations, rather than parametric correlation/ regressions. It should be noted that influence by large values also affects the distribution of residuals. Parametric correlation/regression analysis assumes that the residuals are normally distributed. The SYSTAT regression routine generates a number of statistics associated with the regression, including a list of outliers, identification of samples that exert undue influence on the result, and test statistics (F and t) for evaluating the significance of the relationship. None of the results showed observations that exerted undue influence on the results, but most included outliers. The effect of outliers is discussed later in this document.

Table 2-9 shows a comparison of the results of the nonparametric correlations with those of parametric correlation/regression analysis, including tests of significance based on the F-value of the regression. In addition to the r^2-value, the parametric regression generates an r-value (correlation coefficient), which is the same as if only a correlation was calculated. The nonparametric (Spearman) correlations generate a statistic known as ρ. The probability distribution associated with the significance of r and ρ is slightly different when the number of pairs is 10 or less, but is the same when the number of pairs is 11 or greater.

The parametric correlations show a significant increasing trend in selenium in 8 of the 11 wells (Table 2-9). The remaining three wells shown generated nonsignificant regressions and consequently showed no trend. There were also three wells that did not show a significant trend based on the nonparametric Spearman correlations. However, one of the nonsignificant parametric correlations shows a significant decreasing trend based on its Spearman correlation and one of the highly significant parametric trends (well 16J1 – r = 0.787, probability < 0.01) becomes non-significant based on the non-parametric correlation. The correlations for the remaining wells indicate the same trend based on either of the correlations, although the trend for well 16B3 is less definitive (compare r and ρ) based on the nonparametric correlation.

Table 2-9. Parametric and nonparametric correlations of selenium concentration in the Tranquillity wells on time

Well	r^2	Pearson r	Prob. > r[1]	Spearman ρ	Prob. > ρ[1]
10M1	0.4465	-0.6682	N.S.[2]	-0.8193	< 0.05
15F1	0.6931	0.8325	< 0.01	0.8091	< 0.01
15M1	0.5133	0.7164	< 0.05	0.8364	< 0.01
15M3	0.1099	0.3315	N.S.	0.5023	N.S.
15P1	0.0639	-0.2527	N.S.	0.1142	N.S.
16A1	0.8099	0.8999	< 0.01	0.8246	< 0.01
16B1	0.9049	0.9513	< 0.01	0.9589	< 0.01
16B3	0.7874	0.8874	< 0.01	0.7608	< 0.05
16G1	0.6621	0.8137	< 0.01	0.8585	< 0.01
16J1	0.6195	0.7871	< 0.01	0.5695	N.S.
16Q1	0.5291	0.7274	< 0.05	0.6865	< 0.05

[1] Prob.: probability of a Pearson's r or Spearman's ρ of the magnitude shown occurring by chance alone.
[2] N.S. - not significant, i.e. prob. > 0.05.

After a preliminary review of the regressions of the selenium data, it appeared that the outliers all occurred in the early part of the monitoring period. Because the data were not evenly distributed over time; i.e., four samples were collected during each of water years 2000 and 2004, with only one each in 2001, 2002, and 2003, there could be a biasing effect. Because of the possible bias, the regressions were recalculated after deleting the outliers. The review also indicated that rather than being outliers, the samples that appeared to be outliers were showing that a nonlinear, rather than a linear, regression might be more appropriate. To evaluate this, nonlinear regressions were calculated both with and without the outliers. The results are summarized in Table 2-10 and some of the regressions are shown in Figure 2-17, Figure 2-18, Figure 2-19, and Figure 2-20. Where Table 2-10 indicates that there is no trend, either there was no significant regression or the regression was significant, but no trend could be discerned. Significant regressions showing no trend were confined to nonlinear regressions.

Table 2-10. Summary of results of linear and nonlinear trends without and with adjustment for outliers.

Well	Outlier (Date)	Trend without adjustment		Trend with outliers deleted	
		Linear	Nonlinear	Linear	Nonlinear
15M1	May-01	Increase	Increase(?)	Increase	N/A[1]
15P1	Jul-00	None	None	None	None
15M3	May-02	None	None[2]	Increase	Increase
16B3	None	Increase	Increase	——	——
16J1	None	Increase	Decrease[3]	——	——
16A1	May-01	Increase	Increase	Increase	Increase
15F1	None	Increase	Increase	——	——
16Q1	Oct-99	Increase	Decrease[3]	Increase	Decrease[3]
16G1	Oct-99	Increase	Increase	Increase	Increase[4]
16B1	May-02	Increase	Increase	Increase	Increase
10M1	May-00	None	None[2]	Decrease	None[2]

[1] Linear trend is more significant
[2] Regression shows no current trend, but is statistically significant
[3] Following an initial increase, Se has been decreasing in more recent data
[4] Increase initially, but eventually forms an asymptote

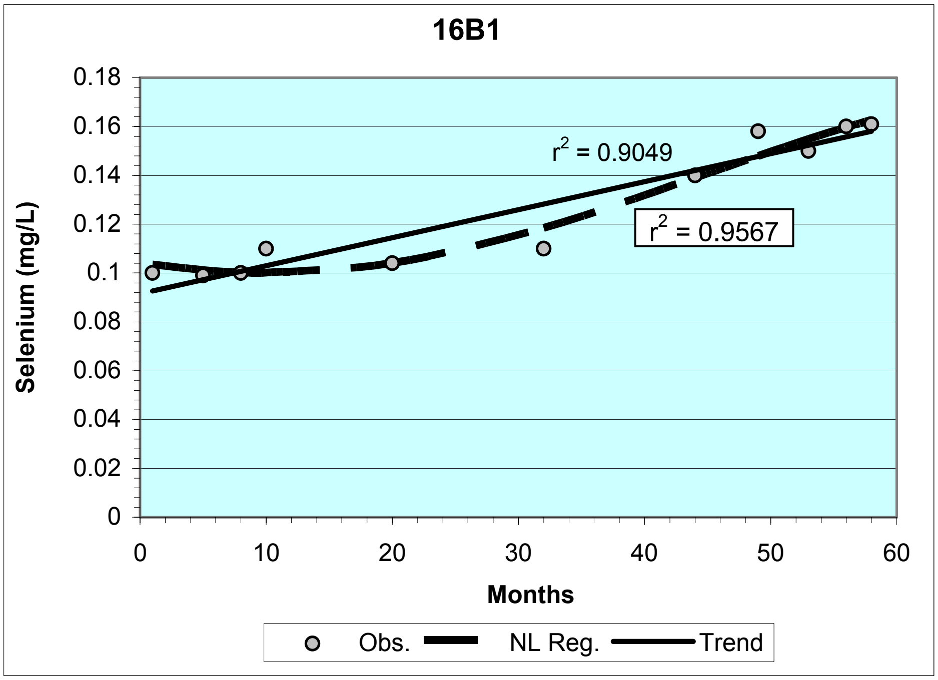

Figure 2-17. Selenium data and trend in well 16B1 along with "best fit" nonlinear regression [Sinusoidal Fit: y=a+b*cos(cx+d)].

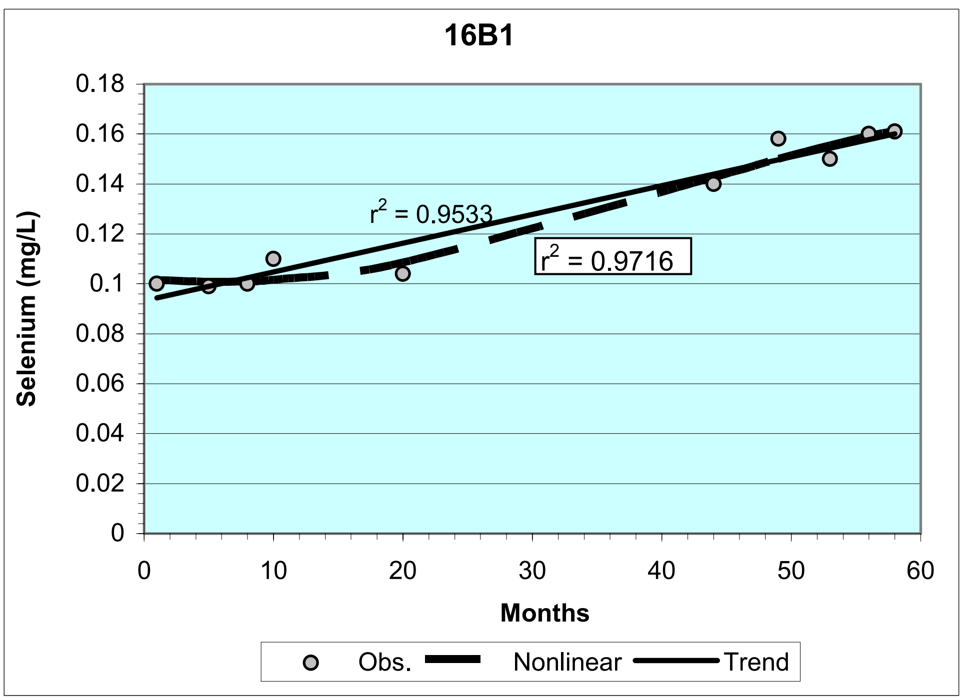

Figure 2-18. Selenium data and trend in well 16B1 without outlier datum along with "best fit" nonlinear regression - [Sinusoidal Fit: y=a+b*cos(cx+d)].

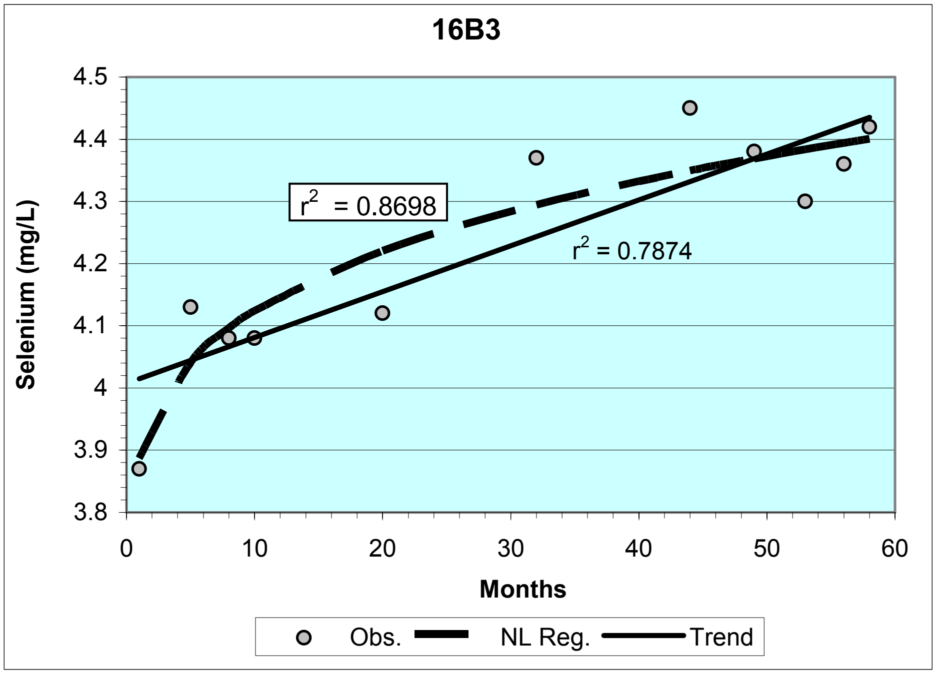

Figure 2-19. Selenium data and trend in well 16B1 along with "best fit" nonlinear regression - [Harris Model: $y=1/(a+bx^c)$].

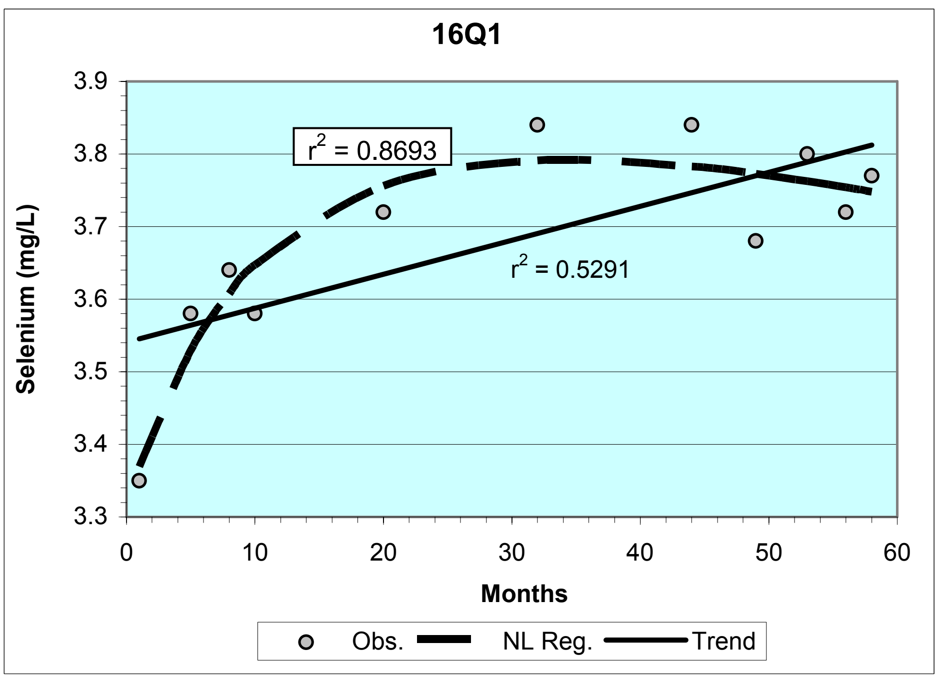

Figure 2-20. Selenium data and trend in well 16Q1 along with 'best fit" nonlinear regression - [Rational Function: $y=(a+bx)/(1+cx+dx^2)$].

The performance objective for selenium in groundwater at the Tranquillity site established by FWS stated that the selenium concentration in groundwater shall not show a net increasing trend over the life of the project. The FWS performance objective was clearly not met. Rising levels of selenium observed in the shallow groundwater in the Coast Range deposits are likely a result of oxidation and advective transport of mobile selenium species in the alkaline conditions near the falling shallow water table. As long as the water table continues to decline as expected in response to land retirement, the high concentrations of selenium in the groundwater should have no consequences to biota at the site. In contrast, selenium is present at very low concentrations in the groundwater found in the coarse-textured Sierran deposits at the Tranquillity site. In the reducing geochemical environment observed in the Sierran groundwater, selenium is relatively insoluble and immobile.

2.2.8.5. Boron in Groundwater

The presence of high concentrations of boron in the shallow groundwater is of concern due to potential toxicity to plants and wildlife. Boron concentrations in the shallow groundwater at the site are very high. The boron concentrations measured in the shallow wells during the first year range from 10 to 81 mg/L, with a median value of 45.5 mg/L (Table 2-5). No water-quality criteria for boron exist for aquatic life or human health. No more than 750 µg/L of boron should be applied to sensitive crops (EPA 1986). Perry et al. (1994) proposed a toxicity threshold in water for crops and aquatic plants of 10 mg/L. Deverel and Millard (1988) noted that boron is geochemically mobile and present as oxyanions in oxidized, alkaline environments such as the western San Joaquin Valley shallow groundwater.

The authors also reported high correlation between log transformed boron and specific conductance data for shallow groundwater in the western San Joaquin Valley. Boron concentrations observed in the deep wells at the site are an order of magnitude lower than those in the shallow wells. Boron concentrations measured in the deep wells during year 1 of monitoring range from 2.5 to 8.3 mg/L, with a median concentration of 3.2 mg/L (Table 2-6). The large difference in boron concentration between the shallow and deep groundwater at the site may be due to adsorption onto soil surfaces or differing geochemical conditions between the shallow and deep groundwater systems. Adsorption of boron on soil particles can affect and limit its solubility (Keren and Bingham 1985). Fujii and Swain (1995) concluded that the relatively conservative behavior of boron observed in shallow groundwater in the San Joaquin Valley probably reflects the presence of high concentrations of competing constituents for adsorption sites.

2.2.8.6. Origin and Isotopic Composition of Groundwater

Groundwater samples were analyzed for tritium and stable isotope ratios of oxygen and hydrogen during the first 3 years of monitoring. A summary of the tritium data are presented in Table 2-5 and Table 2-6. The oxygen and hydrogen isotope data shown in Figure 2-21 can provide insight into the evaporation history of the water, while the tritium data can be used to develop an understanding of the age and origin of the groundwater at the site.

2.2.8.7. Groundwater Age

The levels of tritium, a radioactive isotope of hydrogen with a half-life of 12.43 years, rose in the environment during the 1950s and 1960s because of atmospheric detonation of nuclear weapons. Tritium concentrations can be used to develop an understanding of the origin and history of water samples. Tritium concentrations in water samples are reported in tritium units (TU). Prior to 1952, precipitation contained < 5 TU. Due to radioactive decay, groundwater derived from precipitation before 1952 now has < 0.5 TU. Groundwater derived from precipitation recharged since 1952, including canal water used as irrigation since 1968, commonly has a tritium concentration exceeding 10 TU. Groundwater with

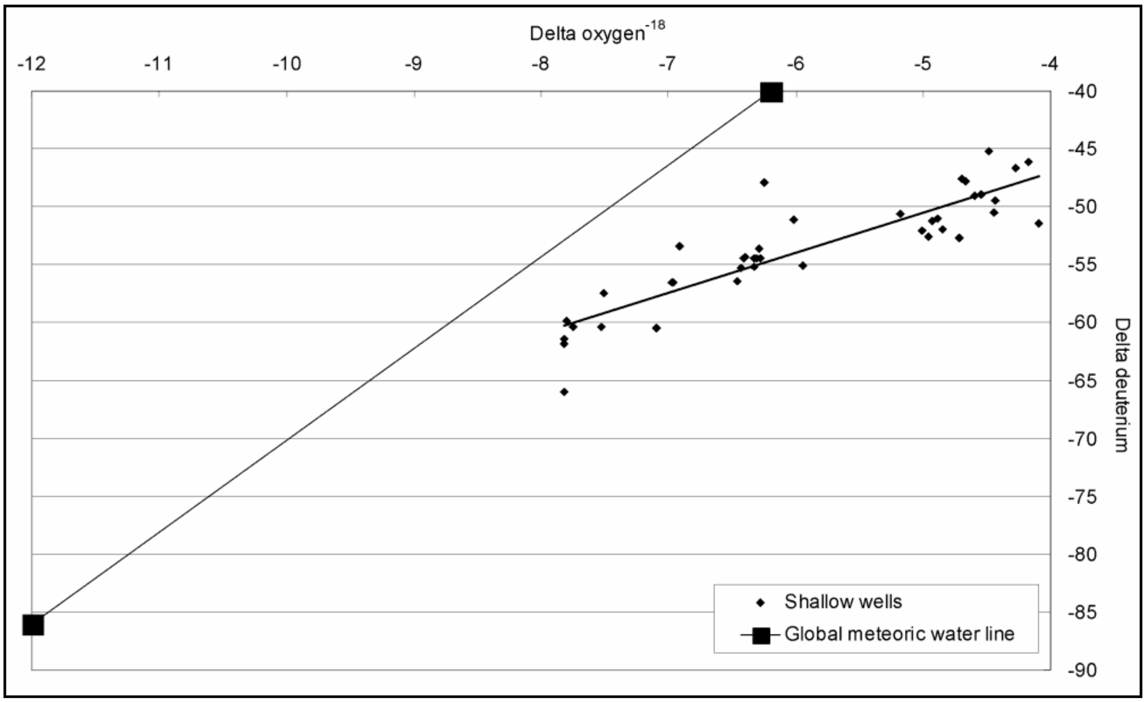

Figure 2-21. Plot of stable isotope data for groundwater samples from the Tranquillity site indicating the shallow groundwater has undergone significant evaporation.

a tritium concentration of < 1.6 TU either has recharged prior to 1952 or may have originated as post-1952 irrigation water from deep wells. This large contrast in tritium concentration allows comparison of older groundwater, much of which was recharged prior to agricultural development, to young water recharged since 1952 and derived from irrigation (Dubrovsky et al. 1993).

The tritium data from the shallow wells indicate that the shallow, perched groundwater consist of a mixture of water recharged before and after 1952. Tritium concentrations of the shallow groundwater samples range from 0 to 6 TU, with a median concentration of 2.4 TU. Low tritium concentrations (< 1 TU) observed in wells 16Q1 and 16F1 may indicate recharge from irrigation water that was pumped from deep production wells completed in the sub-Corcoran aquifer. The tritium data from the deep wells (well 15M3 and 16B3) completed in coastal range deposits indicate that the groundwater was recharged before 1952. Tritium concentrations observed in these two wells ranged from 0 to 0.5 TU, with a median concentration of 0.1 TU. The tritium data from the deep wells completed in Sierra Nevada sediments indicate that the groundwater has been recharged since 1952. Tritium concentrations found in wells 15C3 and 10G3 range from 9.6 to 14.0 TU, with a median concentration of 10.5 TU.

2.2.9. Evaporative Concentration of Shallow Groundwater

In areas where the water table is shallow in the western San Joaquin Valley, particularly at depths less than 1.5 m (5 feet) below land surface, evaporative concentration of dissolved solids in groundwater can increase salinity and selenium concentrations far above the levels resulting from leaching of soil salts by irrigation (Deverel and Fujii 1988). Under irrigated conditions, loss of water by evapotranspiration tends to concentrate salts in groundwater rather than soil because the salts are regularly flushed downward by percolating irrigation water and net groundwater movement is generally downward (Dubrovsky et al. 1993).

Hydrogen and oxygen isotope concentrations from shallow groundwater samples at the Tranquillity site show that groundwater salinity is primarily a result of evaporation and evapotranspiration of the shallow groundwater. The evaporation process adds kinetic separation to the hydrogen^{2} (deuterium) and oxygen^{18} species causing increased enrichment in the O^{18} species (Gat and Gonfiantini 1981). This results in a plot of the delta deuterium (D) verses delta O18 that has a smaller slope than the meteoric water line. The comparison of delta D and delta O^{18} shown in Figure 2-21 illustrates the evaporation that has taken place in the shallow groundwater at the site. Similar evaporative trend lines have been reported by Deverel and Fujii (1988) and Presser and Barnes (1984) for shallow groundwater in the western San Joaquin Valley.

2.2.9.1. Surface Water

In the Biological Opinion for the Land Retirement Demonstration Project, the FWS established performance standards for selenium and mercury concentrations in surface water. The performance standard specified that standing water that persists for more than 30 days shall not exceed 2 micrograms/liter (µg/L) selenium, and 2 nanograms/liter mercury (FWS 1999). Standing water at the site was monitored by examining precipitation data on the CIMIS website and periodically visiting the site during the wet season to document any standing water that persisted for more than 30 days in duration. Since groundwater levels beneath the site have steadily declined over the 5-year study, the only source of standing water would presumably come from precipitation that does not infiltrate, run off the site or evaporate within 30 days of a winter or spring storm event.

No vernal pools that persisted for more than 30 days were observed at the Tranquillity site during the 5-year study. Precipitation during the study has been below average (Figure 2-4), and the maximum monthly rainfall observed during the study was just below 5 cm (2 inches) (Figure 2-3). The precipitation threshold for formation of vernal pools at the site is unknown, but is certainly in excess of 5 cm (2 inches) per month. An important factor governing the formation of vernal pools at the site is the clay content of the soils. These basin rim clay soils have high plasticity indices (33-61 percent), and thus have a tendency to shrink upon drying and swell upon wetting as water enters and leaves the crystal lattice of the clay mineral structure. The shrink-swell behavior of the soil has resulted in a large network of surface cracks during the extended period of below-average rainfall (Figure 2-22). Before vernal pools can form on the surface, enough moisture must be absorbed by the clay soil to cause swelling sufficient to seal the surface cracks. Several unsuccessful attempts were made in 2004 to artificially simulate vernal pool formation by excavating small "ponds" and filling them with irrigation water. In all cases, the water seeped into the surface cracks after several days.

Figure 2-22. Photos of open surface cracks in Tranquillity clay soils at the Tranquillity site (Jan 2005).

The crack was open to a depth of approximately 42 inches on this date. Soil moisture from fall and winter storms had penetrated to a depth of about 12 inches. The extensive network of surface cracks in the soil at the site inhibits the formation of surface water ponds (vernal pools).

2.2.10. Trend Analysis for Soils

One of the objectives of the demonstration project was to evaluate the effect that land retirement would have on soils. Concerns were raised that upflux of shallow, saline groundwater with high selenium content on retired lands would salinize the surface soil and create potentially toxic conditions for wildlife. No performance objectives for soil salinity or soil selenium concentrations were established for the demonstration project. Constituents of concern for soil monitoring include soil salinity (EC_e), selenium and boron. Soil salinity and selenium data collected at 24 paired sites in 1999, 2002 and 2004 are presented in Figure 2-23 through Figure 2-31. This data are from the central sampling location in each 10-acre demonstration plot at the Tranquillity site as well as four sites located on retired lands east of the plots in sections 10 and 15. The bar graphs indicate that most of the changes in constituents of concern (COC) concentrations occurred during the first 3 years of the demonstration project.

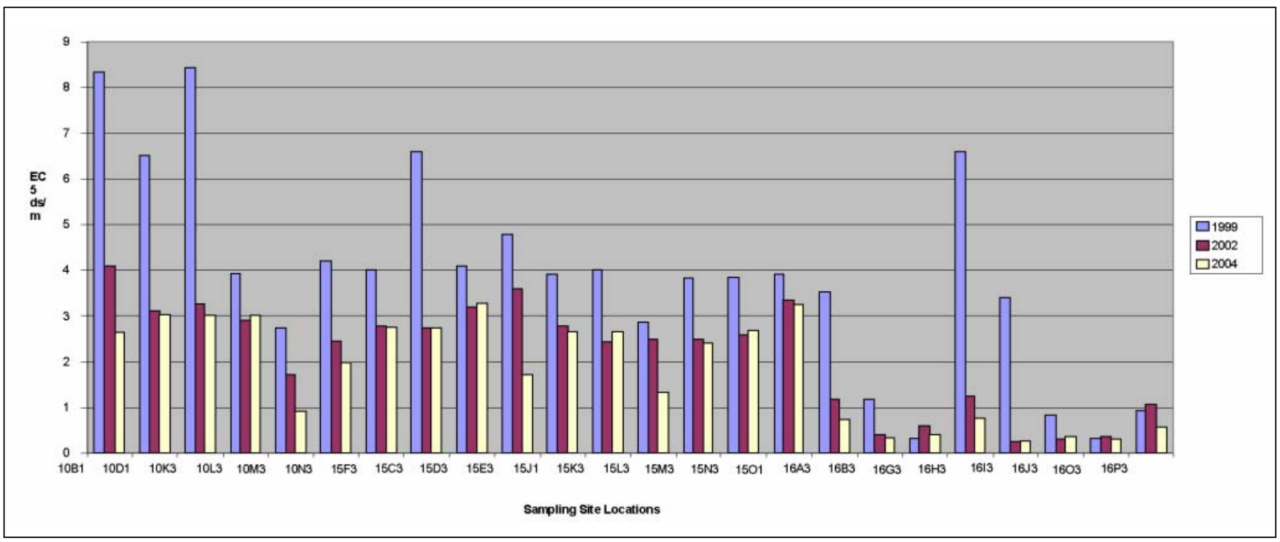

Figure 2-23. EC_e Trends in top foot of soil from 1999 to 2004.

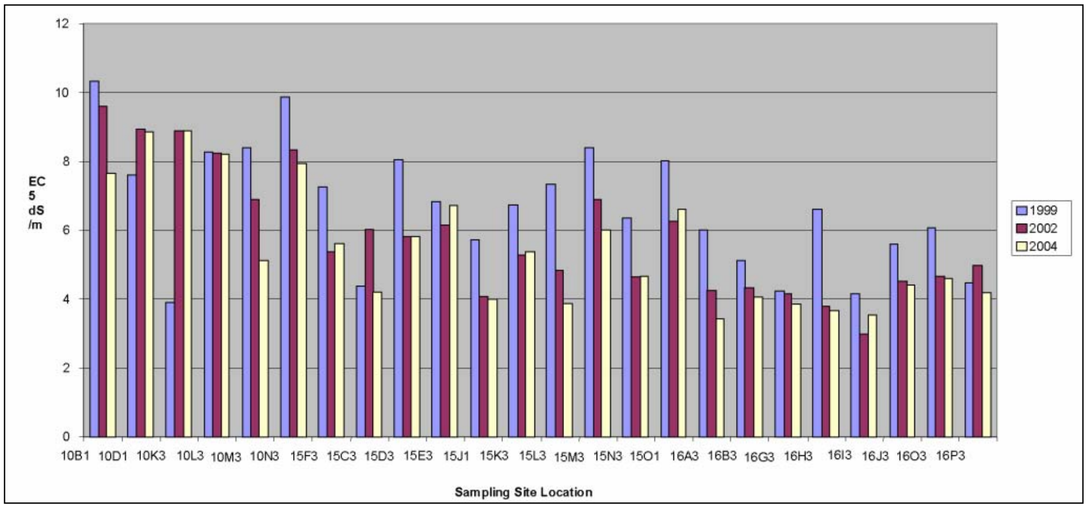

Figure 2-24. EC_e Trends in 2 to 3 foot depth of soil from 1999 to 2004.

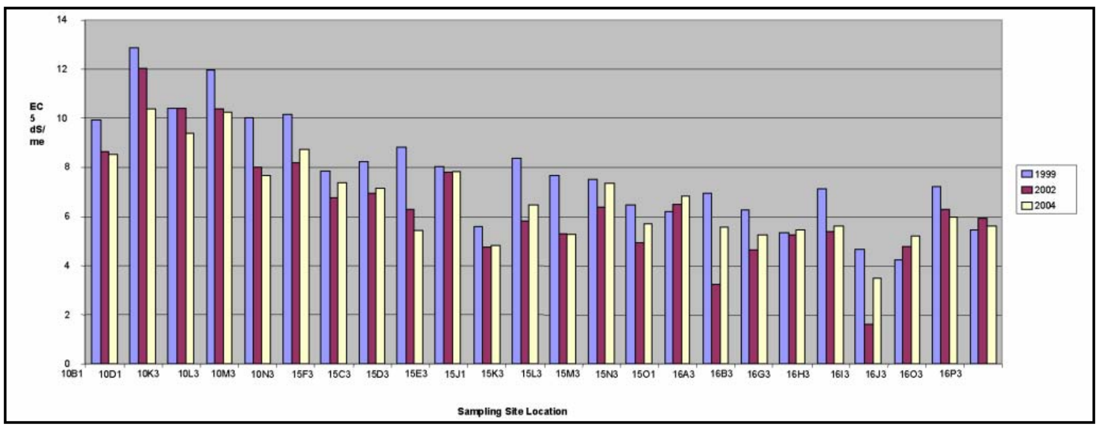

Figure 2-25. EC_e Trends in 4 to 5 foot depth of soil from 1999 to 2004.

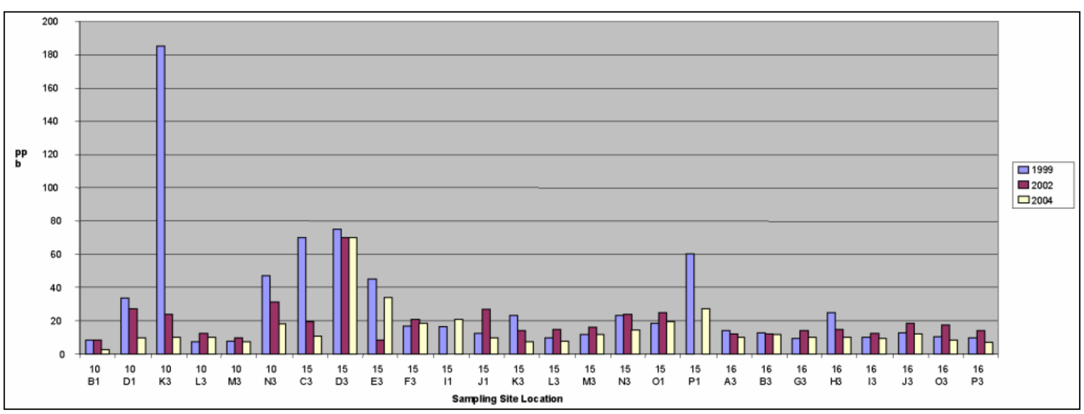

Figure 2-26. Soluble selenium trends in top foot of soil from 1999 to 2004.

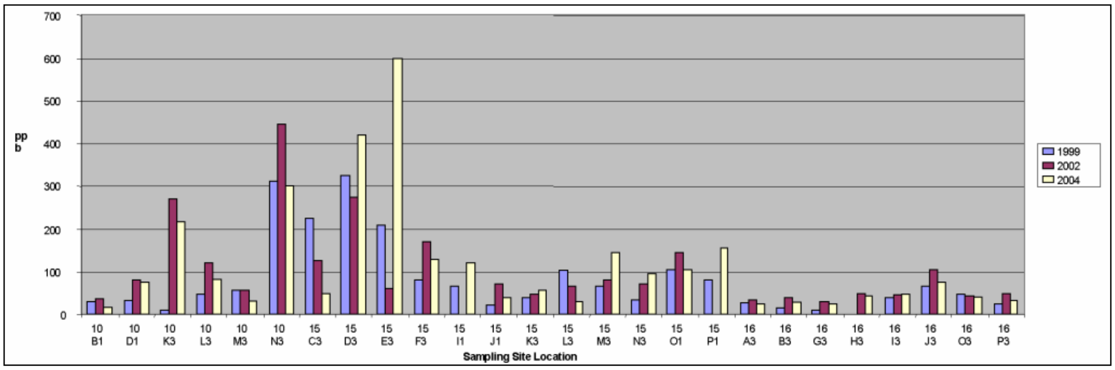

Figure 2-27. Soluble selenium trends in 2 to 3-foot depths of soil from 1999 to 2004.

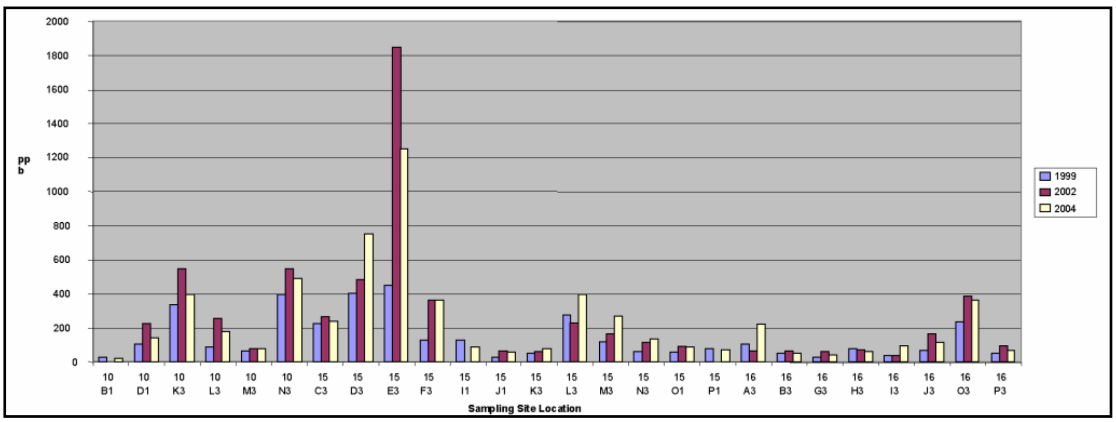

Figure 2-28. Soluble selenium trends in 4 to 5 foot depths of soil from 1999 to 2004.

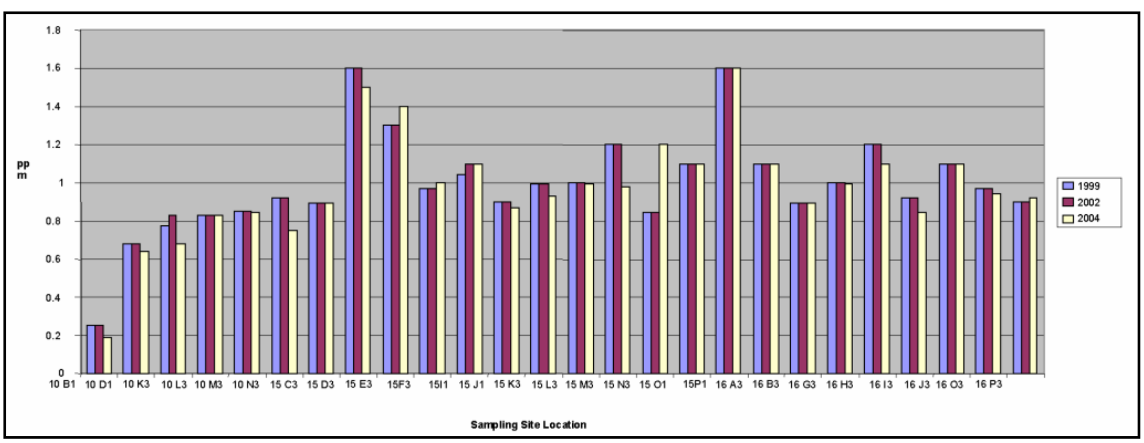

Figure 2-29. Total selenium trends in top foot of soil from 1999 to 2004.

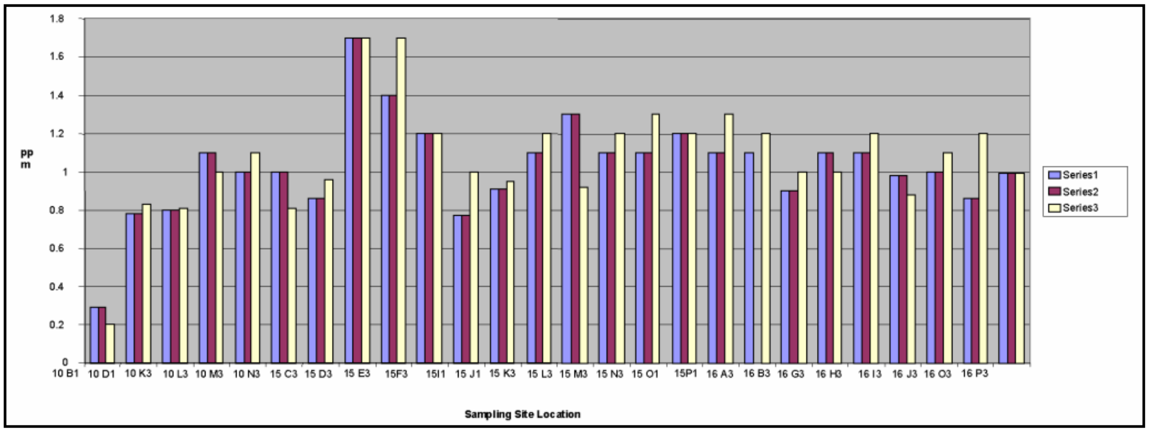

Figure 2-30. Total selenium trends in 2 to 3 foot depth from 1999 to 2004.

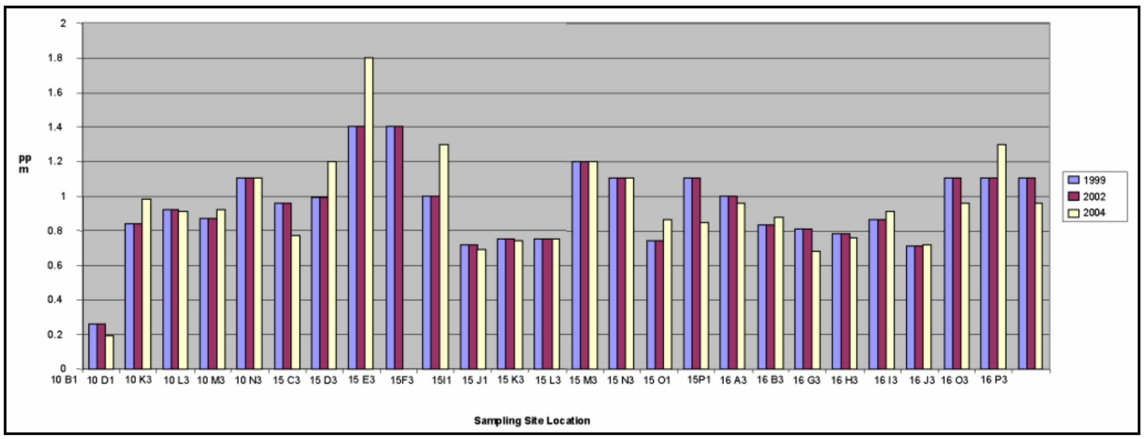

Figure 2-31. Total selenium trends in 4 to 5 foot depth from 1999 to 2004.

2.2.11. Change Detection Analyses

The Wilcoxon sign rank test was used to determine if the concentration changes at the paired soil sampling sites were statistically significant at the 95 percent confidence level. All data presented in the following statistical summaries are on a dry soil weight basis except for the soil salinity data, which are the concentration of the extract. Table 2-11 summarizes statistical analysis of the 1999 and 2004 data using the Wilcoxon sign-rank tests for each constituent of concern.

Table 2-11. Change detection analyses for COCs in soil at the Tranquillity site.

Constituents of Concern	Depth (feet)	Median 1999 ug/kg	Median 2004 ug/kg	Sites decreasing	Sites increasing	Z change direction	Prob>Z	Significant (95% CI)
Soluble Selenium	0-1	18	11	96	12	-8.03 down	<0.00001	Yes
Soluble Selenium	2-3	47	65	7	17	2.357 up	0.0184	Yes
Soluble Selenium	4-5	82.5	125	4	22	3.823 up	0.000132	Yes
Total Selenium	0-1	1000	990	66	19	-4.14 down	0.000035	Yes
Total Selenium	2-3	940	1075	7	17	2.959 up	0.0031	Yes
Total Selenium	4-5	920	910	11	10	0.400 up	0.6892	No
Salinity (ECe) dS/m	0-1	3.66	1.53	102	8	-8.74 down	<0.000001	Yes
Salinity (ECe) dS/m	2-3	6.67	4.99	24	2	-3.54 down	0.00396	Yes
Salinity (ECe) dS/m	4-5	7.35	5.88	22	4	-4.00 down	0.000063	Yes

2.2.12. Soil Interpretive Summary

Total selenium concentrations, soluble selenium concentrations, and salinity (ECe) in the surface soil (depth 0-30 cm or 0-1 foot) at the Tranquillity site showed a decreasing trend over the 5-year study. Soils at the Tranquillity site contain moderately elevated concentrations of selenium (mean selenium 1.0 milligrams per kilogram [mg/kg]) when compared to values reported for western U.S. and San Joaquin Valley soils (Table 2-12).

Table 2-12. Comparison of total selenium concentrations at the Tranquillity site to Western U.S. and San Joaquin Valley soils.

Mean selenium western states soils (Shacklette and Boerngen 1984)	0.34 mg/kg
Mean selenium San Joaquin Valley soils (Tidball et. al. 1986)	0.14 mg/kg
Mean selenium Tranquillity site (1999)	1.05 mg/kg
Max selenium Tranquillity site (2004)	1.7 mg/kg
Uncommonly high selenium western soils (Shacklette and Boerngen 1984)	1.4 mg/kg
Typical sediment toxicity threshold	4 mg/kg
Kesterson Reservoir sediment criteria (Benson et. al. 1993)	4 mg/kg

The spatial variability for total selenium in the Tranquillity soil series is low (Figure 2-23). The coefficient of variation for total selenium in the Tranquillity soils was about 18 percent during the baseline sampling event in 1999. Total selenium concentrations appear to be slowly decreasing in surface soils at the site.

This is an important trend because this represents the total inventory of selenium in the soil and is not subject to seasonal or temporary concentration changes due to climatic factors or soil reaction changes. Soluble selenium concentrations in surface soils (depth 0-30 cm or 0-1 foot) also decreased which is considered a positive change since most biologic activity takes place in surface soils. The soluble selenium concentrations in the substrata and the percent of soluble/ total selenium increased during the first 3 years but tended to decline during the 3-5-year demonstration period. A summary of soluble selenium percentages is presented in Table 2-13.

Table 2-13. Average soluble to total selenium percentages all sites at Tranquillity.

Depth zone	1999 (57 sites)	2002 (57 sites)	1999 (all sites)	2004 (all sites)
1 foot	3.2	2.5	2.9	1.5
2-3 feet	8.1	13.2	8.1	10.1
4-5 feet	15.3	28.7	15.2	19.1

* 2002 data are for about 50 percent of the shallow sites but include 22 of 26 substrata sites.

The surface soils appear to have been leached of selenium while the soluble selenium content of the substrata zones (60.9-91.4 cm and 121.9-152.4 cm or 2-3 and 4-5 foot depth) appears to have been enriched somewhat by leaching from surface layers. The principal reason for soluble selenium increases in substrata appears to be the slight increase in soil reaction (pH) and the increased oxidized conditions present as the water table elevation and associated capillary fringe zone declined during the study period.

Surface soil (0-30 cm or 0-1 foot depth) salinity (ECe) at the Tranquillity site decreased over the 5 years of monitoring for this study. Soil salinity decreased at 102 out of 110 sites sampled from the 0-30 cm (0-1 foot) depth from 1999 to 2004. Decreases in soil salinity based on 1-5 extract concentrations were statistically significant. Salinity declines were surprisingly large in soil surface samples. Decreases in soil salinity were also observed in the substrata (depths 60.9-91.4 and 121.9-152.4 cm or 2-3 and 4-5 feet). Some of the soil salinity reduction in surface layers may be due to the beneficial leaching effects of rainfall. The predominant salt at the site is sodium sulfate which is very soluble in water. The magnitude of the soil salinity reduction may also be related to the soils tendency to form deep and wide cracks upon drying. Before the land was retired from irrigation, bare soil surface evaporation may have formed a salt concentration in the upper few inches of soil. Upon extended drying, the soil cracked deeply while the saline surface layers developed a loose crumb structure. Much of the loose surface material dropped into the deep cracks and was deposited in the substrata. Some of the cracks observed at the Tranquillity Site were more than 1.5 m (5 feet) deep and 30 cm (1 foot) wide. These soils are commonly termed vertisols since they have the ability to invert over many wetting and drying cycles.

2.2.12.1. Saturation Extract Testing

Saturation extract testing was also conducted to determine plant adaptability, relative growth potential, and other agronomic factors. Soluble selenium concentrations are not limiting for plant growth at the site. The average concentration found in saturation extracts from samples collected in the top foot of soil was 4.6 µg/liter. The element most limiting plant growth and adaptability in the site surface soils probably is boron. Soil salinity was decreasing and average ECe values in the 2004 surveys were 3.3 dS/m in the top foot of soil. Soil salinity levels and boron levels sharply increased with depth in substrata. Boron and soil salinity are both elevated at the site and would limit plant selections as well as plant growth of many plants. Figures 2-32 through 2-35 show the ECe, SEe and the soluble boron concentration of surface soils 0-30 cm (0-1 foot) at the site during the 2004 soil surveys in September 2004. Soil boron phytotoxicity threshold levels are about 2 mg/L in a saturation extract and about 4 mg/kg on a soil dry weight basis. ECe thresholds are about 4 ds/m. About 40 percent of the survey area surface soils exceed soil salinity thresholds and about 95 percent exceed the boron threshold. Limited data collected during the survey indicate that soil salinity is lowest in the seedbed 0-10.1 cm (0-4 inch) inch zone. Seedbed soil salinity levels should permit germination, emergence, and growth of most climatically adapted native plants.

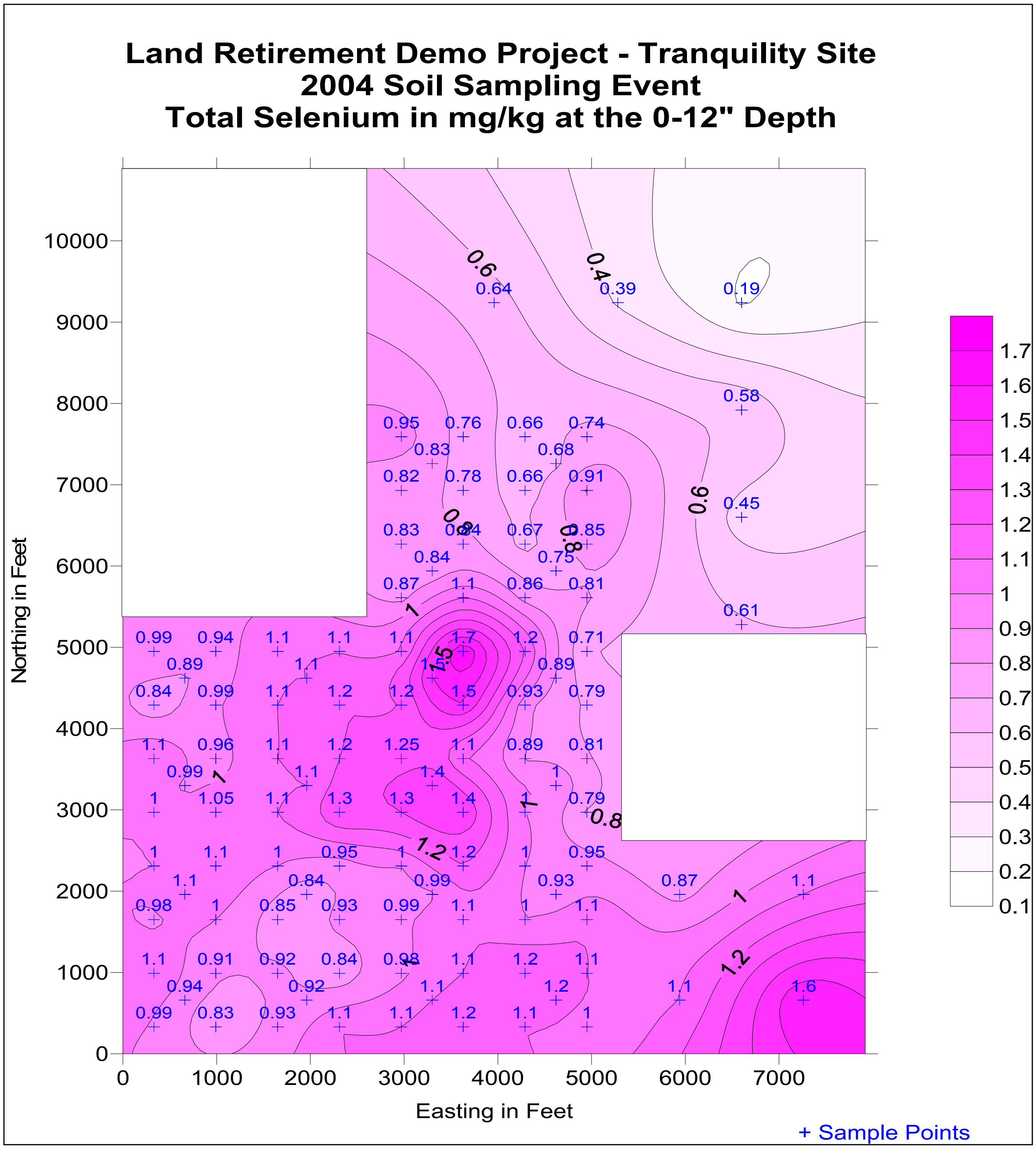

Figure 2-32. Total selenium concentrations in surface soils 0-30 cm (0-1 foot) at the Tranquillity site from the 2004 sampling event.

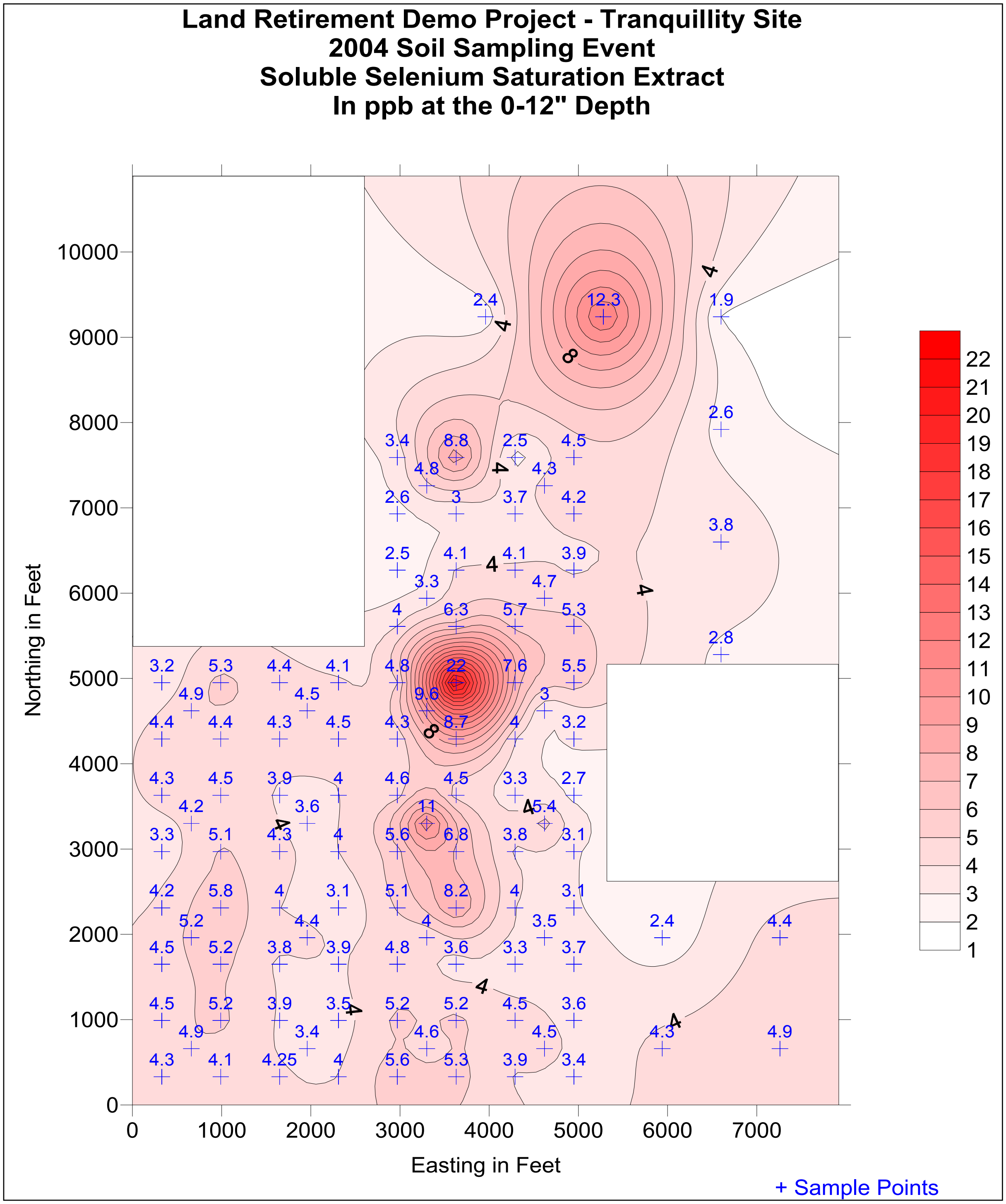

Figure 2-33. Soluble selenium in surface soils 0-30 cm (0-1 foot) at the Tranquillity site from the 2004 sampling event.

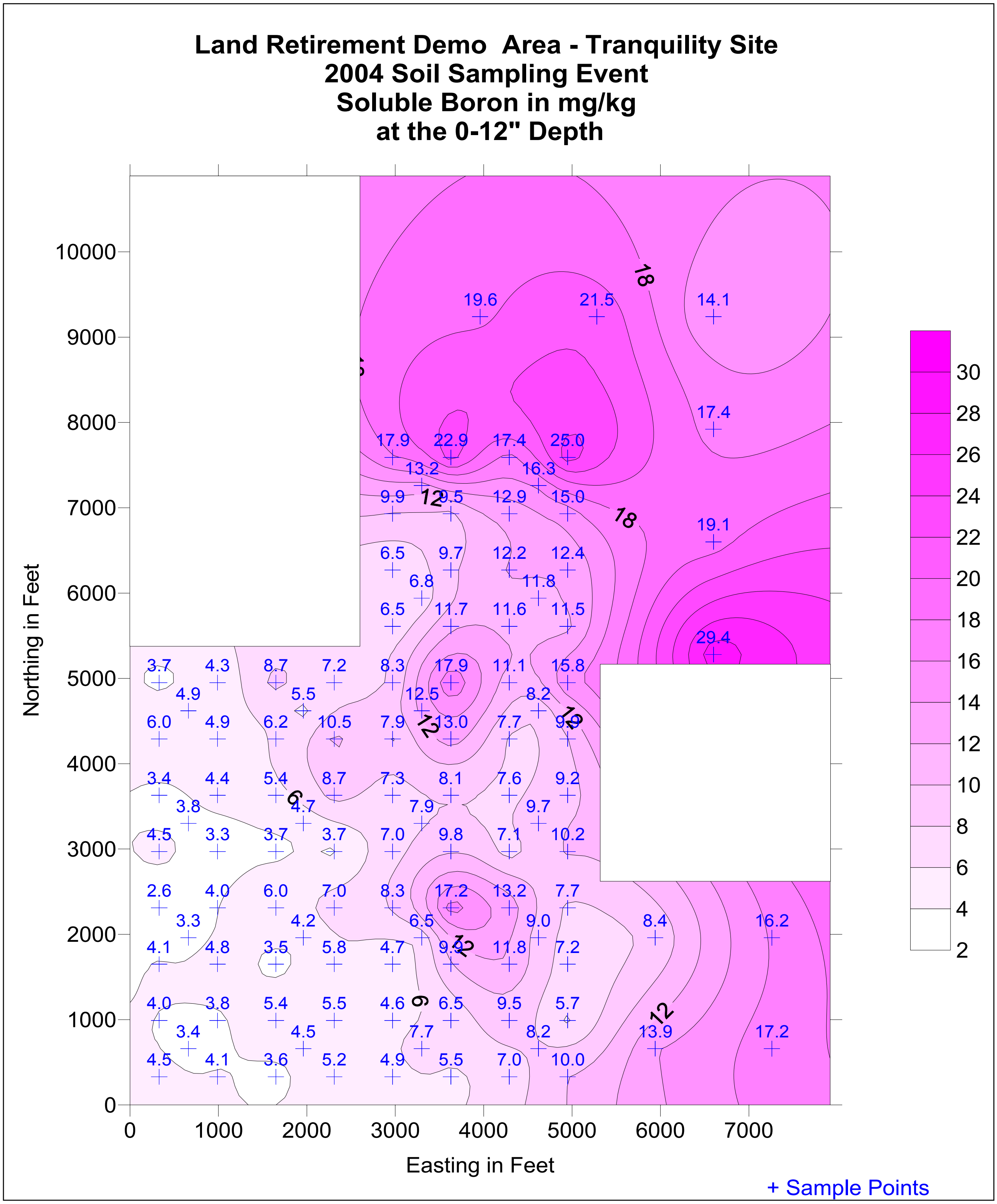

Figure 2-34. Soluble boron concentrations in the surface soils 0-30 cm (0-1 foot) at the Tranquillity site from the 2004 sampling event.

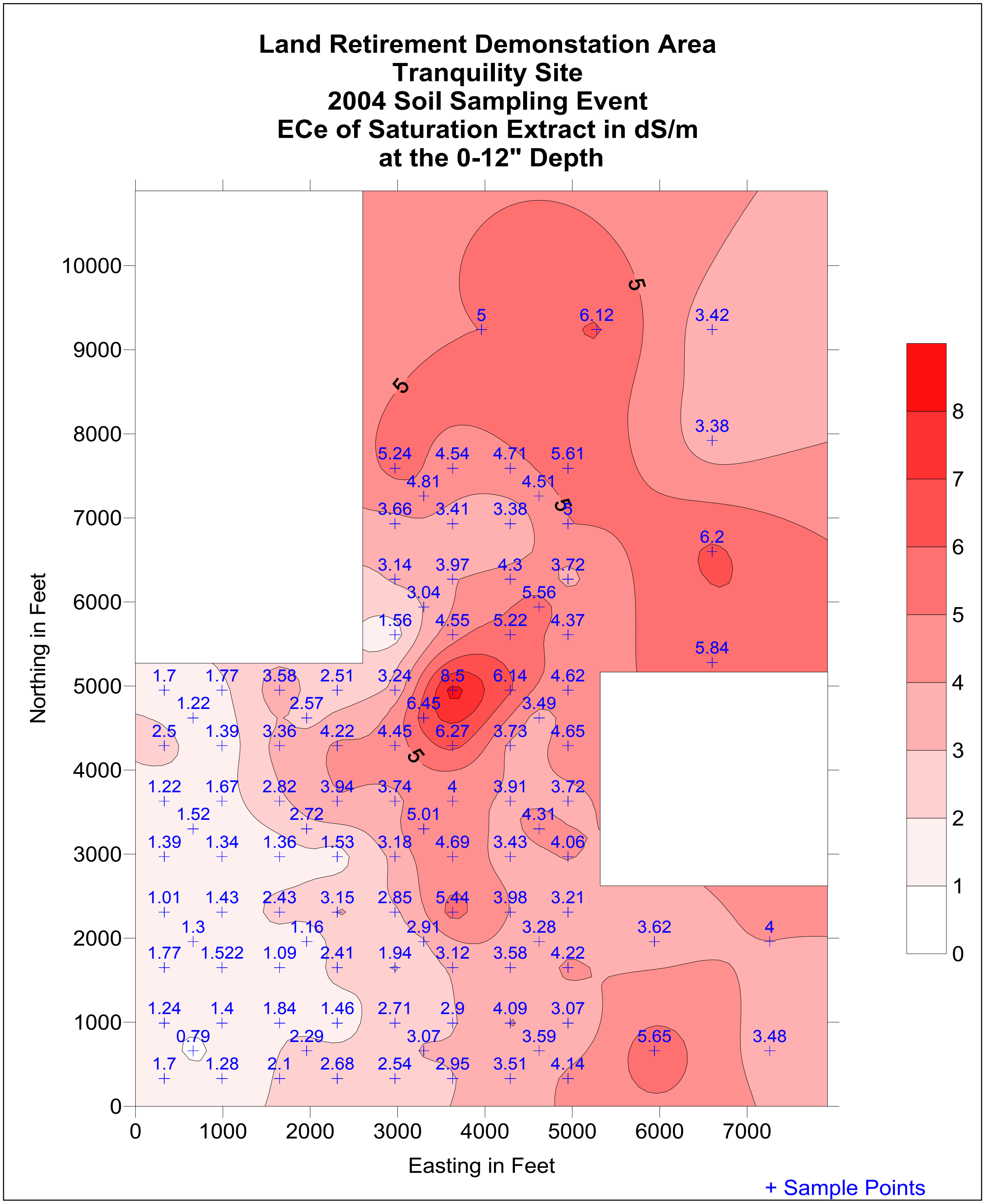

Figure 2-35. Soil salinity (ECe) concentrations (dS/m) in the surface soils 0-30 cm (0-1 foot) at the Tranquillity site from the 2004 sampling event.

2.2.13. Conclusions

Five years of groundwater monitoring at the Tranquillity site support conceptual and numerical models that predicted a declining shallow water table in response to land retirement. FWS performance objective regarding water table response to land retirement at the Tranquillity site was clearly met. Percolation of applied irrigation water prior to land retirement was the primary source of groundwater recharge that sustained the high water table. In the absence of irrigation recharge the shallow water table has steadily receded from the land surface over the 5-year study. Large downward hydraulic gradients measured at the site confirm the presence of perched water table conditions in the fine-grained Coast Range deposits. Discharge of the shallow groundwater occurs primarily through slow downward percolation through surficial clay deposits at the site. Some shallow groundwater was also discharged by evaporation from the water table when it was in close proximity to the land surface at the beginning of the study. The water table response observed at the Tranquillity site is representative of conditions that would be present at a high percentage of lands that are targeted for retirement on the lower alluvial fan and basin rim settings in the western San Joaquin Valley.

The declining shallow water table is an important aspect of land retirement due to poor quality of the shallow groundwater observed beneath the Tranquillity Site. The high salinity and selenium concentrations in the shallow groundwater found in the Coast Range deposits at the site are a result of leaching under irrigated conditions and evaporation from the shallow water table. Evaporation from the shallow water table has concentrated salts and trace elements in the shallow groundwater. The FWS performance objective for selenium in groundwater at the Tranquillity site was clearly not met. Rising levels of selenium observed in the shallow groundwater of the Coast Range deposits are likely a result of oxidation and advective transport of mobile selenium species in the groundwater near the falling shallow water table. **As long as the water table continues to decline as expected in response to land retirement, the high concentrations of selenium in groundwater should have no consequences to biota at the site.** In contrast, selenium is present at very low concentrations in the groundwater of the coarse textured Sierran deposits at the Tranquillity site. In the reducing geochemical environment observed in the Sierran groundwater, selenium is relatively insoluble and immobile.

The predominant soil type at the Tranquillity site is Tranquillity clay. This is the most extensive soil type mapped by the Natural Resources Conservation Service on the lower alluvial fans and basin rim landforms in the areas targeted for land retirement by district and federal programs. Soils at the Tranquillity site contain moderately elevated concentrations of selenium (average 1.0 mg/kg) when compared to the common range (0.1-1.4 mg/kg) for western U.S. and San Joaquin Valley soils; however, they are still well within the range commonly found in western soils. Total selenium concentrations, soluble selenium concentrations, and salinity in the surface soil (depth 0-1 foot) showed a decreasing trend over the 5 years of monitoring at the Tranquillity site. The decreasing selenium and salinity trends in the surface soil indicate that upflux of salt and selenium from capillary rise and evaporation of shallow groundwater at the soil surface is minimal, and that some leaching of soluble selenium and salt from surface soils occurred during the 5-year study despite dryer-than-average climatic conditions. About 10-20 per cent of the selenium present in the subsoils is soluble and mobile in the alkaline, oxidizing chemical conditions found in the soil. Soluble selenium concentrations and percentages are much lower in the surface soils (average 4.6 parts per billion [ppb] in saturation extracts). Even if surface water ponding should occur during very wet periods, it is probable that selenium concentrations in the ponded water would be below the aquatic life criteria of 5 ppb. No performance objectives were established for soil selenium levels for the demonstration project; however, the maximum surface soil concentration observed during the 5 years of monitoring at the Tranquillity site was well below typical soil toxicity thresholds for sediment (4 mg/kg).

FWS established performance standards for selenium and mercury in ponded surface water that lasts for more than 30 days. Due to dry climatic and soil conditions during the study, no surface water ponding was observed at the site that lasted for more than 30 days. Monitoring of precipitation during the course of the study suggests that the precipitation threshold to cause ponding of surface water at the site is well in excess of 5 cm (2 inches) of rainfall per month. The extensive network of desiccation cracks in the clay soils at the Tranquillity site greatly inhibits the formation of surface water ponds.

2.3. Atwell Island Site

2.3.1. Geology

The Atwell Island demonstration site lies on the southwestern margin of the Tulare Lake bed, which is the dominant geologic feature in the study area. The site is underlain by lakebed and marsh deposits consisting primarily of clay and silt with some sand with a thickness in excess of 1,097 m (3,600 feet) (Page 1986). The Corcoran Clay member of the Tulare Formation is a regionally extensive, fine-grained lake-bed deposit that underlies the Atwell Island site at a depth of approximately 274 m (900 feet) below the land surface. A relict sand dune deposit consisting of fine-grained wind-blown sand from the former shoreline of the Tulare Lake bed traverses the western boundary of the site from southwest to northeast.

2.3.2. Soils

Soils in the Atwell Island study area consist of silt loam and fine sandy loams that are formed in alluvium derived from igneous and sedimentary rocks. Silty clay loam soils are also present in the southeast portion of the site. Individual soil mapping units found in the study area, in the order of abundance, include the Posochanet silt loam, Nahrub silt loam, the Westcamp silt loam, Excelsior fine sandy loam, and Lethent fine sandy loam. The Posochanet soils occur primarily in the central portion of the site and cover about 30 percent of the total study area. These soils are saline, alkaline, very deep, and moderately well-drained with slow permeability. Subsoil and substrata textures are commonly silty clay loam and silty clay. Salinity ranges from 4 to 8 dS/m in the upper portion and 4 to 30 dS/m in the lower portion. Surface runoff is generally slow, with a low hazard of water erosion.

Nahrub silt loam occurs on basin rims and consists of mixed alluvium from granitic rocks. Nahrub soils cover about 30 percent of the total surface area in the southeast part of the site. These soils are very deep, somewhat poorly drained, with very slow permeability. Salinity ranges from 1-16 dS/m in the upper part to 8-30 dS/m in the lower part. Surface runoff is very slow with low surface erosion hazard.

Westcamp silt loam soils cover the northwest corner of the study area. The Westcamp soils are saline, alkaline soils that have a perched water table. These soils are very deep, somewhat poorly drained, with very slow permeability. A transient perched water table occurs at a depth of 1.2-1.8 m (4-6 foot). Salinity ranges from about 2-16 dS/m.

Excelsior fine sandy loam soils are found on the sand ridge that traverses the site from northeast to southwest. The sand ridge covers about 15 percent of the total study area. The Excelsior soils are very deep, somewhat excessively drained, alkaline soils. Permeability of the sand ridge soil is moderately rapid, runoff is very slow and hazard of water erosion is slight; however, the potential for wind erosion is high under sparsely vegetated conditions. Salinity ranges from 0-8 dS/m in the upper part and 2-16 dS/m in the lower part.

The Lethent fine sandy loam occurs in a small area in the southwest part of the study area. This soil is saline, alkaline, very deep, and moderately well drained. Permeability is very slow and the hazard of water erosion is slight.

2.3.2.1. Soil Monitoring

Soil Sampling Baseline soil sampling was conducted at the Atwell Island site during spring 2002. Sixteen sites were sampled within each experimental study area. Each site was located at the approximate center of the 0.8 ha (2-acre) research plots (Figure 2-36). Three soil samples were collected from each site. A 0-30 cm (0-12 inch), four increment composite soil sample was collected within 3 m (10 feet) of the central boring. A single soil sample was collected from the 30-76 cm (12-30-inch) depth interval. This sample represents the active root zone of irrigated soils. A single soil sample was also collected from the 76-152 cm (30-60-inch) substrata zone. This zone represents the lower root zone just above the vadose zone. All soil material was sampled in the 30-76 cm and 76-152 cm (12-30 and 30-60-inch) samples. Sampling in this manner resulted in 48 soil samples collected on each 65 ha (160-acre) study area (Figure 2-36). Two field replicate (QC) samples were collected from each quarter section. Field replicate

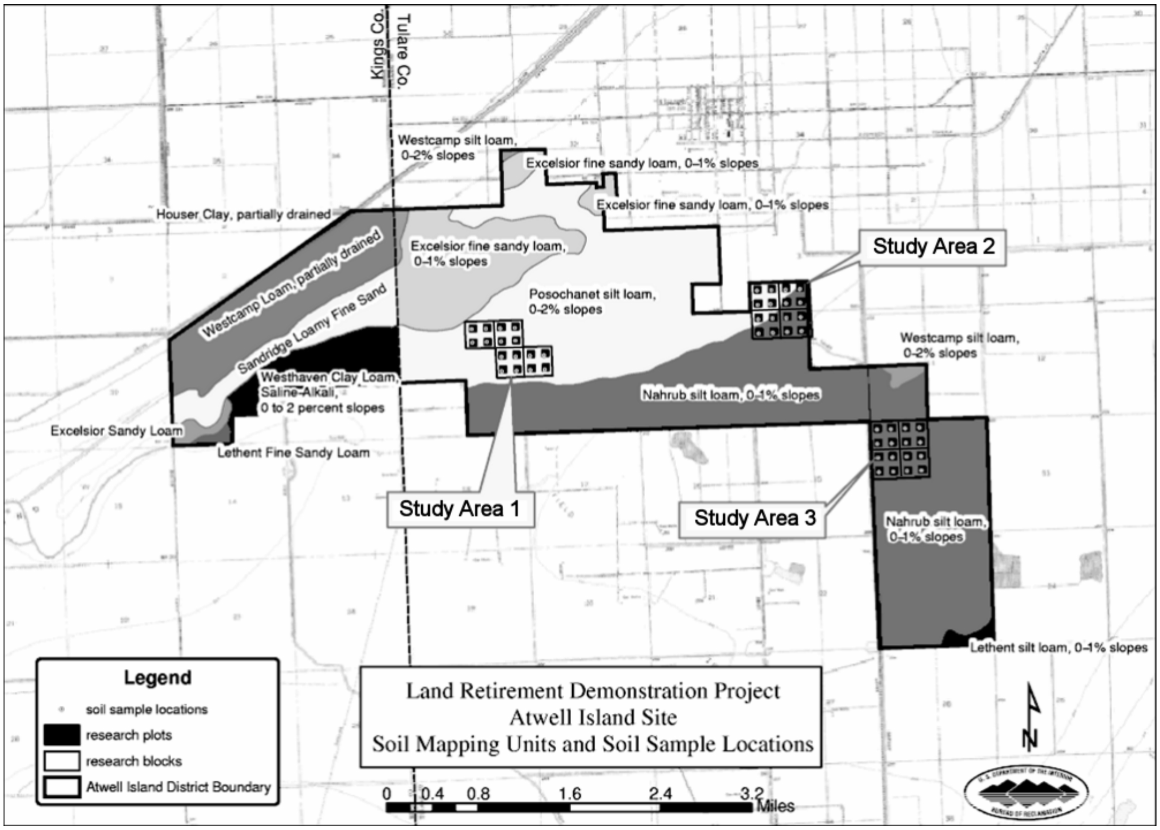

Figure 2-36. U.S. Department of Agriculture soil mapping units and soil sample locations at the Atwell Island site.

samples were obtained using the fractional shoveling method (Gerlach 2002). All sample sites were located and mapped using a global positioning system receiver.

Soil samples were analyzed for total and water-soluble selenium, sulfate, chloride, electrical conductivity, and moisture. All surface soil samples were analyzed for boron, magnesium, potassium, sodium, carbonate, and nitrate. The Quality Assurance Project Plan (QAPP) for the Land Retirement Demonstration Project described in detail the analytical procedures and quality assurance measures taken to ensure soil data quality (CH2M Hill 1999). The soils analyses were performed by the USGS and Reclamation analytical laboratories in Denver, Colorado.

The baseline soil-sampling event was completed during March of 2002. Surface 0-30 cm (0-12 inch) four increment soil samples where collected within 3 m (10 feet) of central deep boring sites. Deeper (30-76 cm and 76-152 cm or 12-30 inch and 30-60 inch) samples where collected from a single hand auger boring. All soil layers where included in the sampling. The soil samples have been analyzed and the data collected has been validated. A statistical summary of the baseline data are presented in the next section.

Statistical summary of the baseline data Statistical summaries of data collected during the 2002 baseline soil sampling event are presented in Table 2-14 through Table 2-18. All data are on a dry soil weight basis except for the soil salinity data, which are the concentration of the extract.

Table 2-14. Total selenium (mg/kg dry soil)

Study area	Depth (inches)	Median	Average	95 % CI
Study Area 1	0-12	0.100	0.097	0.076 - 0.118
	12-30	0.050	0.087	0.062 - 0.112
	30-60	0.050	0.076	0.061 - 0.091
	0-60 Weighted average	0.080	0.084	0.069 - 0.099
Study Area 2	0-12	0.115	0.144	0.092 - 0.196
	12-30	0.120	0.118	0.090 - 0.146
	30-60	0.120	0.139	0.100 - 0.178
	0-60 Weighted average	0.120	0.132	0.110 - 0.154
Study Area 3	0-12	0.100	0.104	0.083 - 0.125
	12-30	0.100	0.086	0.071 - 0.101
	30-60	0.145	0.141	0.110 - 0.172
	0-60 Weighted average	0.120	0.120	0.104 - 0.136

Total selenium A statistical summary of total selenium concentrations is presented in Table 2-15. In Study Area 1, there appears to be a slightly inverted selenium distribution, possibly from upflux and evaporative processes; however, this trend is not significant at the 95 percent confidence level. In Study Area 2, no trends with depth are apparent. In Study Area 3, the 76-152 cm (30-60 inch) substrata zone is significantly higher in total selenium than the 30-76 cm (12-30 inch) zone.

Table 2-15. Soluble selenium 1-5 extract (mg/kg dry soil)

Study area	Depth (inches)	Median	Geo Mean	Average	95% CI
Study Area 1	0-12	2.50	4.31	5.63	3.23 - 8.03
	12-30	2.50	3.46	4.5	2.23 - 6.73
	30-60	2.50	3.26	4.06	2.27 - 5.85
	0-60 Weighted average	3.35	3.92	4.53	3.22 - 5.84
Study Area 2	0-12	7.00	9.90	15.22	7.43 - 23.01
	12-30	12.00	16.48	24.22	11.89 – 36.54
	30-60	26.75	29.93	44.59	22.76 – 66.42
	0-60 Weighted average	19.55	24.52	32.63	18.44 – 46.82
Study Area 3	0-12	3.75	4.07	4.69	3.35 - 6.03
	12-30	13.75	16.64	18.03	13.97 – 22.09
	30-60	33.50	31.74	34.59	27.84 – 41.34
	0-60 Weighted average	21.10	22.18	23.67	19.45 – 27.89

Soluble selenium 1-5 extract A statistical summary of soluble selenium concentrations is presented in Table 2-15. The data are for 1 part soil to 5 parts DI water extracts. The concentrations found in the extracts were multiplied by a factor of 5 to determine the micrograms per kilogram (μg/kg) dry weight concentration in the soil.

In Study Area 1, no significant differences in soluble selenium occurred with depth. Study Area 2 showed no significant differences in soluble selenium concentrations due to the high selenium concentration variability. There appeared to be an increasing selenium concentration with depth in Study Area 2. However, the trend is not significant at the 95 percent confidence level. In Study Area 3, there was a significant increase in soluble selenium concentration with depth at this site (Table 2-15).

Soluble selenium commonly exhibits high, random spatial variability. The soils of the Atwell Island site were no exception, as coefficients of variation values were quite high (Table 2-15). The three study areas all had low total selenium values, yet it appears that a significant portion of the selenium at many of the sampled sites is in soluble form (Table 2-16). The alkaline soil reaction at the sites and the oxidized nature of the soils tend to favor the selenate selenium species, which is very soluble.

Table 2-16. A comparison of total selenium concentrations with soluble selenium concentrations

Study area	Weighted average of total selenium (mg/kg)	Weighted average of soluble selenium (mg/kg)	Percent soluble
1	0.084	0.0045	5.4
2	0.132	0.0326	24.7
3	0.120	0.0237	19.8

Study Area 1 was much lower in soluble selenium than the other two study areas. The distribution in the profile also was more uniform, probably indicative of upflux from shallow groundwater and the medium textured soils in Study Area 1 that are more conducive to capillary rise of water from the water table. Concentrations in surface soils were not elevated enough to warrant concern about terrestrial wildlife poisoning or accumulation in plants. The low total selenium concentrations at the site might cause selenium deficiencies for some organisms. However, a relatively large portion of the selenium probably is present in soluble and biologically available forms due to the oxidized, alkaline conditions prevailing in Atwell Island site soils.

The data summarized in Table 2-15 contains many values below the reporting limit. In all cases, the value used for statistical purposes was one-half of the lower reporting limit value.

Soil salinity A statistical summary of soil salinity concentrations is presented in Table 2-17. Although the variation in soil salinity with depth is not significant at the 95 percent confidence level in Study Area 1, the data indicate an inverted salinity profile. Study Area 1 contains medium textured soils that can conduct large amount of groundwater and salt into the root zone. Because of this soil texture, it will be important to lower the water table to at least 3.7 m (12 feet) on this study area in order to avoid salt accumulation in the active root zone. Winter rains should gradually leach out excess salts in the 0-76 cm (0-30-inch) active root zone if the water table is lowered to 3.7 m (12 feet) or greater.

Table 2-17. Soil salinity (EC_e dS/m) at the Atwell Island site

Study area	Depth (inches)	Median	Average	95% CI
Study Area 1	0-12	8.71	9.25	7.75 - 10.75
	12-30	7.53	7.59	6.42 - 8.75
	30-60	5.56	5.66	4.75 - 6.55
	0-60 Weighted average	6.85	6.92	5.95 - 7.89
Study Area 2	0-12	2.50	3.85	1.54 -6.16
	12-30	4.95	7.34	4.71 - 9.97
	30-60	12.13	12.61	9.98 - 15.24
	0-60 Weighted average	8.24	9.28	7.18 - 11.38
Study Area 3	0-12	4.85	4.29	3.46 - 5.12
	12-30	8.80	9.21	8.19 - 10.24
	30-60	13.66	13.52	11.62 - 15.44
	0-60 Weighted average	10.30	10.39	9.16 - 11.61

The 76-152 cm (30-60 inch) substrata zone in Study Area 2 was significantly higher in salinity than the 0-30 cm and 30-76 cm (0-12 and 12-30 inch) zone. The soil profile exhibited what is termed a regular soil salinity pattern with salinity increasing with depth. Variability was very high in this study area; it appears we should evaluate dividing the study area into two areas for the purpose of trend analysis.

The profile for Study Area 3 shows a favorable regular salinity distribution. The salinity increase with depth is significant at the 95 percent level. The clay soils at this site tend to discourage upflux from the groundwater table. As long as the water table remains below 2.7 m (9 feet), this site should be slowly leached of salts in the 0-76 cm (0-30 inch) active root zone. Variation of soil salinity was low on this study area.

The weighted average soil salinity is higher in Study Area 3 than in Study Area 1 but this is somewhat misleading. Surface soil salinity is significantly higher on

Study Area 1 than on the other two study areas. The elevated surface soil salinity could inhibit germination and emergence of seeds of salt sensitive plants; however, most weedy plants can germinate and emerge from moderately saline surface soils.

Soluble boron A statistical summary of the data is presented Table 2-18. The data are from 1 part soil to 5 parts DI water extracts prepared on a weight basis. The data were converted to mg/kg dry soil by multiplying the 1/5 extract concentration by a factor of 5.

Table 2-18. Soluble boron 1-5 extract (mg/kg dry soil) at the Atwell Island site.

Study area	Depth (inches)	Median	Average	95% CI
Study Area 1	0-12	4.05	4.10	3.72 - 4.48
	12-30	2.98	2.99	2.67 - 3.30
	30-60	8.50	8.45	7.1 - 9.8
	Weighted average	5.75	5.93	5.23 - 6.64
Study Area 2	0-12	1.95	2.32	1.81 - 2.83
	12-30	13.00	14.13	10.80 - 17.4
	30-60	22.75	22.5	21.05 - 23.95
	Weighted average	15.55	15.94	14.47 - 17.41
Study Area 3	0-12	3.10	2.99	2.47 - 3.51
	12-30	13.75	14.91	12.56 - 17.24
	30-60	22.00	20.56	18.32 - 22.80
	Weighted average	16.35	15.34	13.68 - 17.00

The concentrations at all depths in Study Area 1 were significantly different from one another. In Study Areas 2 and 3, boron concentrations increased sharply with depth with each depth increment significantly higher than the shallower sample zone. The surface 0-30 cm (0-12 inch) concentration is suited for all plants but deeper concentrations could be phytotoxic to most plants (Table 2-18).

Spatial trends between study areas Study Area 2 had the highest weighted-average total selenium values, while Study Area 3 is intermediate, and Study Area 1 has the lowest values (Table 2-14). At the 95 percent confidence level Study Areas 2 and 3 are significantly higher than Study Area 1 but are not significantly different from one another.

The 76-152 cm (30-60 inch) substrata zone in Study Areas 2 and 3 are significantly higher than the substrata zone in Study Area 1 (95 percent confidence level).

Soil selenium values are low at the Atwell Island site. USGS reports that the average total selenium value of a large random sample of western states soils is about 0.34 mg/kg. The geometric mean (median) value from the western states suite of soils was 0.23 mg/kg.

The selenium values at all three Atwell Island study areas are below toxic levels and may be deficient for some organisms. Soluble selenium data from the site will be examined to gain a better understanding of the selenium readily available for plant uptake and animal nutrition.

Boron concentrations in Study Area 1 were much lower than in the other two study areas. Study Area 2 and Study Area 3 had similar elevated concentrations of soluble boron in substrata. Only boron-tolerant plants are recommended for Study Areas 2 and 3. Shallow rooted annual grasses may also tolerate the high boron concentrations at these sites. Plants moderately tolerant to boron should be successful at Study Area 1.

Soil interpretive summary The Atwell Island site was relatively low in both soluble and total selenium. Boron concentrations were moderate in surface soils and are elevated in subsoils. Both boron and soil salinity are plant-growth-limiting factors at the Atwell Island sites. Study Area 1 appeared to be using moisture from the water table. While this has benefitted plant growth in the short term, it may indicate soil salinity problems in the future. The medium-textured soils at the Study Area 1 site exhibited capillary fringe zones approaching 1.5 m (5 feet) thick. A declining shallow water table in response to land retirement will lessen the likelihood of salinization of surface soils.

2.3.3. Weather

Precipitation, temperature, and wind data are collected at the National Weather Service weather station #42, which is located approximately 32 km (20 miles) southeast of the Atwell Island site in Wasco. The data from the Wasco station are available on the Western Region Climate Information website at http://www.wrcc.dri.edu. Precipitation has been below average during the first 3 years of hydrologic monitoring at the Atwell Island site. The average annual rainfall for the 51-year period of record at Wasco is approximately 17.5 cm (6.9 inches). Rainfall totals measured at the Wasco station for 2002, 2003, and 2004 were 10.8, 13.5, and 11.4 cm (4.27, 5.33 and 4.50 inches), respectively. Most of the rainfall has occurred from November through April.

2.3.4. Irrigation

The largest volume of irrigation water applied at the site during the baseline year of monitoring (2002) was from ongoing farming operations. Farming operations continued on approximately 951 ha (2,350 acres) of the Atwell Island site. Irrigation applications on these lands are currently scheduled based on a calendar or rotational approach. Metered pumping volumes for applied irrigation water are not available. Typical irrigation applications consist of gravity flow (flood irrigation) of about 15.2 cm (6 inches) per acre. An estimate of applied water and deep percolation (groundwater recharge) for irrigated lands within the demonstration project boundary at the Atwell Island site during 2002 is shown in Table 2-19. Estimated deep percolation losses in 2002 are about 15 percent less than those in 2001. Irrigation of high water use crops such as alfalfa will be phased out as restoration of the site to native upland progresses. Fifty seven hectares (140 acres) of barley were planted on the habitat restoration study blocks to provide weed and dust control and to isolate the individual study plots. The barley crop was not irrigated in 2002.

Table 2-19. Estimated 2002 net crop water requirement and deep percolation losses at the Atwell Island site.

Crop	Acreage	Total crop water requirement[1] CWR (acre-feet)	Irrigation water application requirement[2] IWAR (acre-feet)	Estimated deep percolation[3] DP (acre-feet)
Alfalfa	1,179	4,710	7,246	2,536
Oats	1,137	932	1,433	502
Safflower	37	96	148	52
Total	2,353	5,738	8,827	3,090

[1] CWR = Crop ET - Effective Precip. + Leaching Requirement (after Smith 2001)
[2] Assumes an Irrigation Efficiency of 65 percent
[3] IWAR - CWR = DP

2.3.5. Hydrology and Surface Water Monitoring

The natural drainage in the study area is to the north-northwest with ground surface elevations ranging from about 62.5 m (205 feet) above mean sea level (msl) in the southeast portion of the site to about 65.5 m (215 feet) above msl in the northeastern portion of the site. A pronounced sand ridge traverses the northern boundary of the site in a northeasterly direction. The sand ridge was formed from windblown sand deposited along the southern shore of the Tulare Lake bed. Surface water courses within the study area consist primarily of irrigation supply canals and irrigation return flow ditches. The site has an artificially constructed 8 ha (20 acres) wetland that is filled from surface irrigation water supplies. Shallow ephemeral surface water ponds may form on low-lying portions of the site due to localized sheet flow run-off during prolonged winter storm events. The surrounding areas near the Atwell Island site receive periodic unregulated winter storm flows from Deer Creek, Poso Creek, and the White River. The central portion of the Atwell Island site is generally not subject to long term flooding, due to its higher topographic position with respect to the adjacent lower lying lands. Although no flooding has been observed on the eastern portion of the Atwell Island site during this study to date, these lands are subject to periodic flooding due to topography and proximity to Poso and Deer Creeks.

The biological opinion for the demonstration project requires water quality monitoring for ephemeral surface water pools that form as a result of rainfall. No surface-water ponding that lasted more than 30 days was observed at the site during the first 3 years of monitoring due to dry climatic conditions. However, ponded water from the artificial wetland at the site was sampled and analyzed for selenium in January, July, and October 2002. Selenium concentrations were below detection limits (<0.4 µg/L) in the January and July samples. A selenium concentration of 0.6 µg/L was observed in the October sample, which is below the 5 µg/L EPA water-quality criteria for long term exposure in aquatic environments (EPA 1988).

2.3.6. Groundwater Level Monitoring

Approximately 20 monitor wells in the project vicinity are used to measure groundwater levels beneath the site on a quarterly basis. The well locations are shown on Figure 2-37. Existing wells constructed prior to the purchase of the demonstration project lands were installed by the USGS, the California Department of Water Resources (CDWR) and Reclamation to assess groundwater conditions in the Tulare basin.

These existing wells are constructed of PVC casing ranging in diameter from 1.9 to 7.6 cm (0.75 to 3 inches) and vary in depth from 6.1 to 58 m (20 to 190 feet) below the ground surface. The wells were installed using various construction techniques that range from jetting a short length of pipe into the ground to standard rotary drilling with hydraulic drill rigs. During fall 1999, Reclamation installed 17 new monitoring wells to measure groundwater levels and obtain representative groundwater samples for water quality analyses for the Land Retirement Demonstration Project. The new wells range in depth from 4.6 to 18.3 m (15 to 60 feet) below land surface and were installed using a hollow stem auger drill rig and are constructed of 5 cm (2-inch) PVC casing. Well construction diagrams for the new wells are on file in Reclamation offices in Fresno and Sacramento. Well construction information for the USGS wells are published by Beard et al. (1994), Fujii and Swain (1995) and Swain and Duell (1993).

2.3.7. Groundwater Quality Monitoring

The purposes of groundwater-quality monitoring at the site are to observe selenium concentrations over time and to evaluate selenium exposure risk to wildlife via the groundwater pathway. Baseline groundwater samples were taken on a quarterly basis during 2002 at the Atwell Island site. The baseline groundwater quality samples were taken in January, May, July, and October 2002. Annual groundwater sampling began at Atwell Island in May 2003, and will continue for 5 years. Sampling was conducted in spring to coincide with the seasonal high water table in the region. Annual and baseline groundwater quality data will be compared to evaluate changes in groundwater quality. Unfiltered groundwater samples were taken from 16 wells to assess baseline groundwater quality at the site. Standard operating procedures for groundwater sampling used by the Mid-Pacific Region of Reclamation and those outlined in the Quality Assurance Project Plan for the Land Retirement Demonstration Project (CH2M Hill 1999) were employed to obtain groundwater samples.

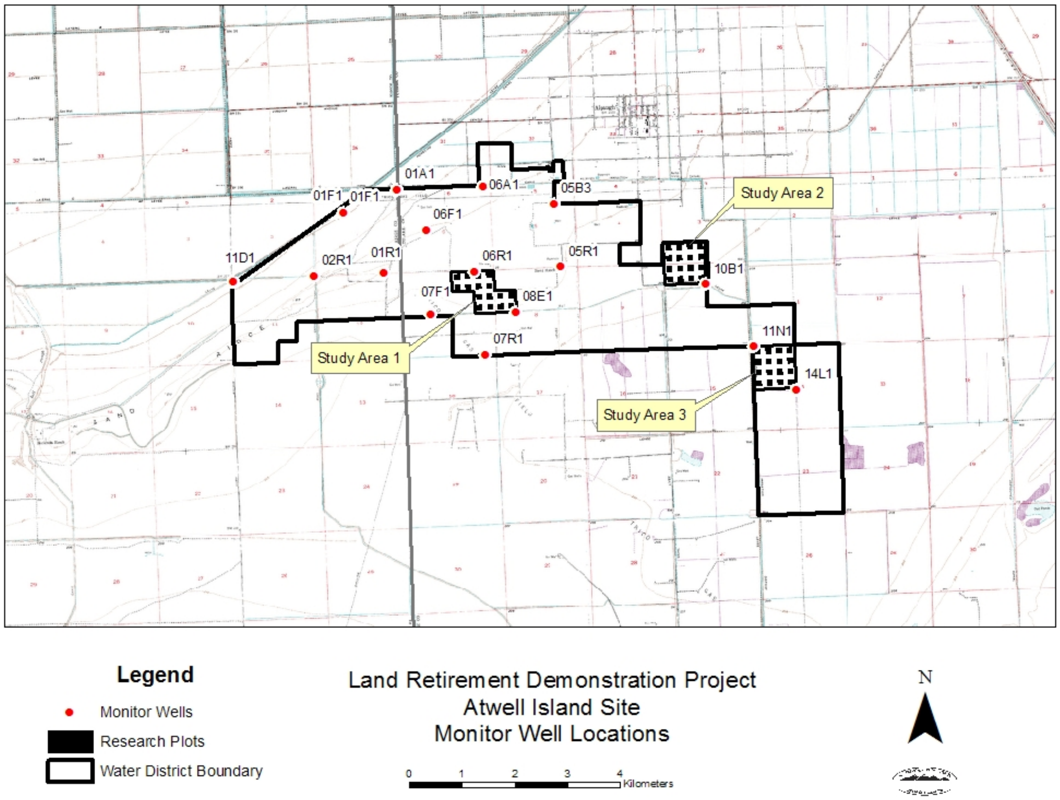

Figure 2-37. Monitor well locations at the Atwell Island site.

Unfiltered groundwater samples were analyzed for major ions (calcium, magnesium, potassium, sodium, chloride, sulfate, total alkalinity), trace elements (selenium, boron, iron, manganese) and isotopes (H^{-2}, O^{-18} and H^{-3}). Specific conductance (electrical conductivity [EC]), pH, and temperature of groundwater samples were measured in the field at the time of sampling. Fluorometric analyses of groundwater samples for selenium were performed by Olsen Biochemistry Laboratories, South Dakota State University. Analyses for isotopes (H^{-2}, O^{-18}) were performed by the USGS Water Resources Division laboratory in Reston, Virginia. Analyses for tritium (H^{-3}) were performed by the USGS Water Resources Division laboratory in Menlo Park, California. All other analyses were performed by commercial laboratories under contract to Reclamation. The Quality Assurance Project Plan for the Land Retirement Demonstration Project describes in detail the analytical procedures and quality assurance measures taken to ensure groundwater data quality (CH2M Hill 1999).

2.3.7.1. Groundwater Response to Land Retirement

Calendar year 2002 was the baseline year for monitoring groundwater levels and groundwater quality at the Atwell Island site. Groundwater levels measured in 20 wells confirm the presence of shallow, perched water table conditions at the Atwell Island site. Groundwater levels observed during the baseline year of monitoring (2002) in the shallow groundwater system range from 4.3 to 14.8 feet below land surface. In general, the water table is highest (nearest the land surface) in the northwest corner of the site and becomes deeper in the southeast portion of the site. These observations are consistent with those of Beard et al. (1994) and Reclamation (1982).

A declining shallow water table in response to land retirement has been observed on parts of the site where irrigation has ceased or been greatly reduced (Figure 2-38). Pre-project water level data reported by the USGS (Beard et al. 1994) show seasonal high groundwater levels around 5 feet below land surface. Post-project, seasonal high water levels measured in well 5B3 during 2002 have dropped to a depth ranging from approximately 7 to 8 feet below land surface (a decline of 2-3 feet). Groundwater level monitoring will continue at the site to evaluate shallow water table response to land retirement.

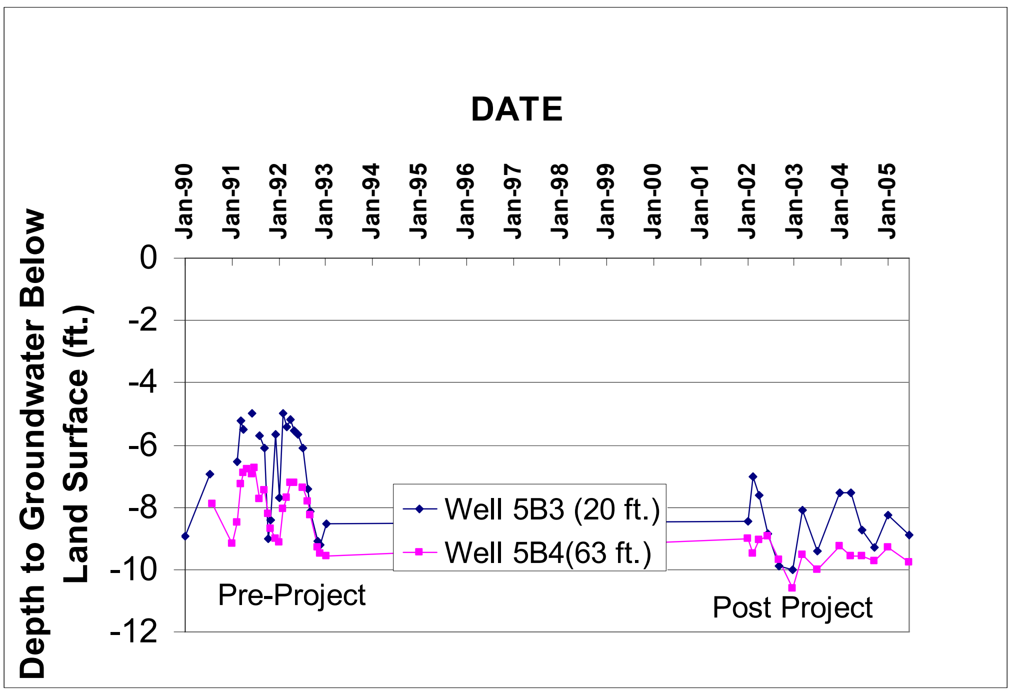

Figure 2-38. Hydrographs of groundwater levels observed in Wells 5B3 and 5B4 showing pre-project and post-project groundwater levels.

2.3.7.2. Groundwater Salinity

Baseline electrical conductivity data for the groundwater samples collected during the first year of monitoring are presented in Table 2-20. The shallow groundwater is moderately saline in nature. Salinity in the shallow groundwater samples, expressed as EC, ranged from 575 to 52,925 µS/cm, with a median value of 13,740 µS/cm. By comparison, drinking water typically is less than 750 µS/cm, irrigation water is less than 1,250 µS/cm, and seawater is about 50,000 µS/cm.

The elevated salinity of the shallow groundwater at the site is a result of the irrigation of saline soils. Naturally occurring salts have been leached from the soil profile under irrigated conditions. Salts also have been transported to the site in the applied irrigation water. Direct evaporation from the shallow water table and transpiration of applied water by crops has concentrated salts in the shallow groundwater, resulting in the high EC values observed in the shallow groundwater samples.

2.3.7.3. Groundwater Major Ion Chemistry

Baseline major ion chemistry data for the groundwater samples collected during 2002 at the Atwell Island site are presented in Table 2-20. The shallow groundwater at the site is best described as a sodium sulfate type of water. Sodium is the dominant major cation found in the shallow groundwater samples, with sodium concentrations ranging from 469 to 15,100 mg/L, and a median concentration of 4,500 mg/L. Sulfate is the dominant major anion found in the shallow groundwater with sulfate concentrations ranging from 261 to 22,200 mg/L, and a median concentration of 5,700 mg/L. By comparison, Fujii and Swain (1995) reported median shallow groundwater concentrations of 8,400 and 13,000 mg/L for sodium and sulfate, respectively, in nine samples taken from the southwestern margin of the Tulare Lake bed.

Table 2-20. Baseline groundwater quality data for shallow wells at the Atwell Island site - major ions, field parameters, and selenium. Note: selenium concentrations are expressed in micrograms/liter (µg/L). 72 samples were used to calculate the selenium statistics.

Statistic	Minimum	25th percentile	Median	75th percentile	Maximum	Mean
Number of Samples	64	64	64	64	64	64
EC(field) (µS/cm)	575	4,615	13,740	26,095	52,925	18,059
pH (field)	6.24	7.21	7.49	7.93	9.12	7.60
Calcium (mg/L)	3	40	320	438	850	282
Magnesium (mg/L)	1	21	148	590	1800	390
Sodium (mg/L)	469	1,290	4,500	11,350	15,100	6,180
Potassium (mg/L)	1	4	9	30	152	23
Total Alkalinity (mg/L)	366	429	580	881	2,050	736
Chloride (mg/L)	216	549	3,400	7,385	12,800	4,312
Sulfate (mg/L)	261	1,225	5,700	17,325	22,200	8,382
Selenium (mg/L)	<0.4	0.54	8.56	68.25	208	34.2

2.3.7.4. Selenium in Groundwater

Selenium concentrations measured in the shallow groundwater wells at the site during the baseline year of monitoring range from less than the detection limit of 0.4 to 208 micrograms per liter (µg/L), with a median concentration of 8.56 µg/L (Table 2-20). The EPA water-quality criteria for long-term exposure to selenium in aquatic environments are 5 µg/L (EPA 1988). Approximately 50 percent of the groundwater samples (35 of 72 samples) collected during the baseline year of sampling were less than the EPA aquatic life criteria. Selenium concentrations in the shallow groundwater show considerable spatial variation throughout the site. In general, the highest selenium concentrations in groundwater range from approximately 60 to more than 200 µg/L, and are found in the central portion of the site in sections 5, 6, 7, and 8 (Figure 2-37). These high selenium areas are associated with the Excelsior and Posochanet soil series (Figure 2-36). The Posochanet soils found within Study Area 1 also contained the highest selenium concentrations observed in the baseline soil investigation. The groundwater underlying the eastern and western portions of the site contain much lower levels of selenium (<0.4 to 17 µg/L). Fujii and Swain (1995) noted that the distribution of selenium in shallow groundwater in the Tulare basin is strongly influenced by sources of selenium, selenium concentrations in soil, evaporation of shallow groundwater, and redox conditions.

2.3.8. Conclusions

The soils at the Atwell Island site have relatively low concentrations of both soluble and total selenium. Boron concentrations were moderate in surface soils and are elevated in subsoils. Both boron and soil salinity are plant growth limiting factors at the Atwell Island sites. Study Area 1 appeared to be using moisture from the water table. While this has benefitted plant growth in the short term, it may indicate soil salinity problems in the future. The medium textured soils at the Study Area 1 site exhibited capillary fringe zones approaching 1.5 m (5 feet) thick. A declining shallow water table in response to land retirement will lessen the likelihood of salinization of surface soils.

No surface-water ponding that lasted more than 30 days was observed at the site during the first 3 years of monitoring due to dry climatic conditions. However, ponded water from the artificial wetland at the site was sampled and analyzed for selenium in January, July, and October 2002. Selenium concentrations were below detection limits (<0.4 µg/L) in the January and July samples. A selenium concentration of 0.6 µg/L was observed in the October sample, which is below the 5 µg/L EPA water-quality criterion for long term exposure in aquatic environments (EPA 1988).

A declining shallow water table in response to land retirement has been observed on parts of the Atwell Island site where irrigation has ceased or been greatly reduced. The seasonal pattern shown by some of the monitor well hydrographs is a result of periodic recharge to the shallow groundwater from irrigation that continues in the central portion of the project site. Sodium and sulfate are the dominant ions found in the shallow groundwater at the site. The elevated salinity and moderately high concentrations of selenium in the shallow groundwater are a result of leaching during irrigation and evaporation from the shallow water table. Selenium concentrations in groundwater at Atwell Island show considerable spatial variability, with the highest concentrations associated with Excelsior and Posochanet soils in the central part of the site. Groundwater, surface water and soils will continued to be monitored for five years as required in the FWS Biological Opinion for the Land Retirement Demonstration Project.

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Chapter 3. Selenium Levels of Biota from Retired Agricultural Lands in the San Joaquin Valley, California

by Curtis E. Uptain and Stuart H. Hurlbert

3.1. Introduction

The high concentrations of selenium in the groundwater and soils of the Land Retirement Demonstration Project (LRDP) study sites have the potential to be detrimental to wildlife. Alkaline soils and high selenium levels, conditions that are present on retired lands, are favorable to selenium bio-availability (USDI 1998). High concentrations of selenium are known to cause a variety of adverse effects to wildlife including embryonic malformation and death, reduced longevity, reduced reproductive success, reduced growth and survival rates, winter stress syndrome, food aversion, anemia and mass wasting, alopecia (loss of feathers) and loss of hair and nails, depressed immune system function, altered enzyme function, skin lesions, respiratory failure, and paralysis (Ghosh et al. 1993, Hedland 1993, Heinz and Fitzgerald 1993, Johnston 1987, Koller and Exon 1986, Lemly 1993a and b, Ohlendorf et al. 1993, Saiki and Ogle 1995). Although the groundwater and soils in the region contain high amounts of selenium, the degree that selenium is available to and accumulates in biota from agricultural lands and upland habitats is not well understood. The effects of land retirement and of habitat restoration of retired lands on the bio-availability of selenium are not known.

We monitored selenium levels in plants, invertebrates, and small mammals collected from retired agricultural lands over a 5-year period at the Tranquillity study site and over a 3-year period at the Atwell Island study site (see Figure 1-1 for site locations) following protocols established by the project's Biological Opinion (FWS 1999). Table 3-1 provides a list of the biotic groups monitored, the corresponding population-level performance standard established by FWS (1999) for each group, and an indication whether performance standards were met.

Results are compared to selenium levels found in similar biotic groups collected from selenium-normal situations in the western United States (USDI 1998). We also compare our results to the concentrations of selenium in corresponding biota that were previously collected from Kesterson National Wildlife Refuge (Kesterson NWR, see Figure 1-1), a site where high levels of selenium resulting from the deposition of agricultural drain water caused a variety of toxic effects to wildlife (USDI 1992). When comparative data are not available from Kesterson NWR, Reclamation relates its findings to other local and regional information.

Table 3-1. List of biotic groups monitored, corresponding performance standards (USFWS 1999), and an indication whether performance standards were met. ATWL = Atwell Island site, TRNQ = Tranquillity site. All selenium values are on a dry weight basis except rodent blood and coyote or kit fox blood, which is on a wet weight basis.

Biotic group	Performance standard	Met	Not met	Not monitored
Vegetation	Not to exceed 2ppm (2 mg/kg) Se	X		
Invertebrates	Not to exceed 2.5ppm (2.5 mg/kg) Se			
Crickets		X		
Beetles		X		
Spiders		X		
Isopods		X (ATWL)	X[1] (TRNQ)	
Reptiles				
Whole body	Not to exceed 3ppm (3mg/kg) Se			X[2]
Feces	Not to exceed 2ppm (2mg/kg) Se			X[2]
Eggs/ovaries	Not to exceed 5ppm (5 mg/kg) Se			X[2]
Blood	Not to exceed 1 ppm (1 mg/kg) Se			X[2]
Birds				
Blood	Not to exceed 1 ppm (1 mg/kg) Se			X[3]
Eggs	Not to exceed 5ppm (5 mg/kg) Se			X[3]
Feathers	Not to exceed 4ppm (4 mg/kg) Se			X[3]
Rodents				
Hair	Not to exceed 5ppm (5 mg/kg) Se	X[4]		
Blood	Not to exceed 0.5ppm (0.5 mg/kg) Se	X[4]		
Coyote or kit fox blood	Not to exceed 1 ppm (1 mg/kg) Se			X[5]

X[1] – Isopods from TRNQ slightly exceeded the performance standard for invertebrates. This is not unexpected since Isopods are known to be detritus feeders and accumulate Se in greater quantities than other invertebrate groups.
X[2] – Se levels in reptiles were not monitored because they were not available for sampling (see Chapter 4).
X[3] – Monitoring of birds was only required if standing water was present for more than 30 days. Standing water did not occur on either site.
X[4] – Although performance standards were set for rodent hair and blood, it was cooperatively determined that it would be preferable to sample rodent bodies and livers. No subsequent performance standards were established for rodent bodies and livers, but the Se values obtained for rodent bodies and livers appear to meet performance objectives.
X[5] – Se levels in coyote or kit fox were not monitored because they were not available for sampling.

3.2. Methods

The monitoring of selenium concentrations in groundwater (see Chapter 2) and biota followed a tiered sampling approach that was cooperatively developed with the FWS specifically for this project (FWS 1999). The monitoring of selenium in soils (see Chapter 2) was not included in those protocols. The intensity of sampling was based upon the depth to groundwater and concentration of selenium in groundwater. Although the depth to groundwater under the retired lands increased after irrigation ceased (see Chapter 2), the level of monitoring remained at the highest intensity (Tier IV) because of the high selenium concentration present in the groundwater.

At Tranquillity, samples of vegetative and reproductive parts of plants were collected in July and October 1999, June 2000, May 2001, April and May 2002, and in April, May, June, and August 2003. At Atwell Island, plant samples were collected in April and May 2000, May 2001, and April and May 2002. Samples were collected from areas that were widely scattered over the project sites and from a variety of cultivated, uncultivated, and experimental areas when possible. Cultivated areas are those where barley or some other irrigated crop was present; uncultivated areas are those that were fallowed or idled and have not recently received irrigation water. Experimental areas are those where restoration treatments (contouring, planting of native seed, or no treatment) were applied.

We collected samples of native and non-native vegetation that were dominant on the landscape. Hence, the number of species and number of samples collected varied from year to year depending upon the distribution and abundance of each species and the availability of funding (e.g., when sampling at both Atwell Island and Tranquillity concurrently, fewer samples were taken at Tranquillity because of the need to support work at Atwell Island). Despite the yearly changes in vegetation dominance and the variability in sampling, we attempted to collect a standardized set of samples that included a suite of species that were expected to occur in each of the collection areas throughout the study period. Some of these species are *Sisymbrium irio, Brassica nigra, Atriplex argentea, Hordeum murinum, Melilotus indica,* and *Hordeum vulgare*.

The plants were collected when green and not showing signs of advanced water stress. Samples were placed in plastic bags, labeled, and stored on ice. Upon returning to the lab, the samples were washed, dried, separated into “part” (e.g., fruits, vegetative structures, etc.), transferred to a whirl-pack bag, and frozen.

Invertebrate samples consisting of crickets, spiders, isopods, and beetles were collected from Tranquillity in July 1999, June 2000 and 2001, and May 2002 and 2003. At Atwell Island, samples were collected in July 2000, June 2001, and May 2002. Invertebrates were collected from pitfall traps located within the experimental areas of the project sites. At Tranquillity, invertebrates were collected from five pitfall arrays on each of 20, 4 ha (10 ac) study plots. Each pitfall array consisted of four, 13 liter (3 gal) pitfall buckets connected by a 6.1 m

(20 ft) long by 30 cm (1 ft) high galvanized steel flashing. One composite sample of each invertebrate type was collected from each study block (a set of four plots, one of each restoration treatment configured in a randomized block design). At Atwell Island, one composite sample of each invertebrate type was collected from each of three study areas. Each study area consisted of 16, 0.8 ha (2 ac) plots with each plot containing a single pitfall array. We attempted to collect a composite sample of at least 2 grams (g) of each invertebrate type from a pitfall bucket, pitfall array, multiple arrays on a plot, or sometimes multiple plots within a study block or study area. The spatial distribution of each sample depended upon the abundance and availability of the invertebrate type being collected. All samples were individually bagged and labeled, immediately stored on ice, then transferred to a freezer upon returning to the lab.

Small mammals were collected from the two project sites by a combination of live-trapping using Sherman traps and by collecting mammals from pitfall traps. We attempted to collect five deer mice *(Peromyscus maniculatus)* from each landform (cultivated, uncultivated, and experimental) and five shrews *(Sorex ornatus)* from experimental areas. Trapped animals were sacrificed by cervical dislocation, individually bagged and labeled, and placed on ice. Once the samples arrived at the lab, the livers were extracted from the animals and all samples were frozen. Small mammal liver tissues were analyzed for selenium concentration separately from the remaining body tissues. Small mammal body and liver tissues were collected and analyzed, instead of hair and blood, to ensure that an adequate amount of tissue for analysis could be collected.

All biotic samples were analyzed to determine selenium concentrations by Laboratory and Environmental Testing (L.E.T.), Inc., Columbia, Missouri. Data provided include selenium concentration by dry weight, selenium concentration by wet weight, sample dry weight, sample percent moisture, and sample detection limit. The laboratory also provided reports on duplicates, spikes, and reference samples for quality control. Selenium concentration by dry weight was used for analysis. The reported selenium concentrations of some samples were adjusted upwards: when the amount of selenium in a sample was less than the detection limit (e.g., selenium was at non-detectable levels), then the selenium value for that sample was increased to the detection limit. These increases are slight because the detection limits are at the lower range of the data sets. This allows each sample to be included in the analyses and it ensures that the mean selenium concentration for a sample group is not underestimated. The number of non-detects in each sample group is reported in figures and tables so that the bias introduced by this manipulation and the corresponding analysis can be appropriately interpreted.

Selenium data of the biotic samples were log transformed and statistically analyzed by performing single factor (e.g., years) or multifactor (e.g., years and landform types) analysis of variances (ANOVAs) using Statistica 6 (StatSoft, Inc. 2002). In most cases, post-hoc analyses were performed using the Fisher's PLSD test. Student's t-tests were used to compare mean selenium concentrations between the two study sites. SigmaPlot 8.0 (SPSS, Inc. 2002) was used for graphics generation. The geometric mean (hereinafter also referred to as mean) and standard deviation factor of each data group are presented in the data tables. The standard deviation factor is the standard deviation of the log-transformed data that has been back-transformed. The geometric mean and error bars (the geometric mean multiplied by and divided by one standard deviation factor) are shown in the figures. Data points that had selenium levels that exceeded the population-level performance standards are plotted on the figures to show the distribution of the highest and most problematic values within each data set. When a performance standard was not established (e.g., small mammal livers), then those values that exceeded the geometric mean multiplied by one standard deviation factor were plotted.

In addition to comparing mean selenium concentrations to the performance standards established for this project, the team also compared the values to typical population-level background concentrations of selenium in the western United States (USDI 1998) and to selenium concentrations reported in biota from Kesterson NWR (USDI 1992). Kesterson NWR is a site where drainage water was deposited, adverse affects to wildlife occurred, and remedial actions were implemented. Selenium values collected from 1988 to 1992 in the grassland habitat at Kesterson NWR were used because the grassland habitat type most closely resembles the conditions present at the project sites. Whenever comparative data from Kesterson NWR does not exist, Reclamation data are compared to other local and regional information when possible.

3.3. Results

3.3.1. Plants

The mean selenium concentration in 31 species of plants collected from Tranquillity varied from 0.11 to 1.10 mg/kg (Table 3-2). Many of these species are represented by only a single composite sample; hence, they have minor statistical value. Of the 14 species where 5 or more samples were obtained, the mean selenium concentrations were from 0.21 (*Bromus madritensis*) to 0.93 (*Suaeda moquinii*) mg/kg. The mean selenium concentration in 20 species collected from Atwell Island varied from less than 0.17 to 0.5 mg/kg. Ten species from Atwell Island were represented with five or more samples. These varied in selenium from less than 0.17 (*Hemizonia pungens*) to less than 0.25 (*Distichlis spicata*) mg/kg (Table 3-3). Seven species were common to both sites and were represented by five or more composite samples (*A. argentea, B. madritensis, B. nigra, H. murinum, H. vulgare, M. indica, and S. irio*). All of these species were lower in selenium levels at Atwell Island than at Tranquillity ($p < 0.01$ in all cases), except *B. madritensis* ($p = 0.71$).

Twelve species at Tranquillity and 8 species at Atwell Island were collected over multiple years (Tables 3-4 and 3-5). Only one species from Tranquillity, *B. nigra*, clearly showed a temporal increase in selenium; the mean selenium level was greater in 2003 (0.74 mg/kg) than in 2000 (0.47 mg/kg) and 2001 (0.30 mg/kg). There also is some evidence of a temporal increase in selenium in *Avena sp. and A. argentea* at Tranquillity. The mean concentration of selenium in plants from Atwell Island contained at least 32 to 49 percent less selenium than corresponding plant species from Tranquillity during the 3 years of concurrent sampling ($p < 0.01$ each year).

The mean selenium concentrations in plants at both sites were below the performance standards set for the project by the FWS (2.0 mg/kg). No plant samples of any species were collected from Atwell Island exceeded the performance standard; however, 11 samples (3.4%) of 5 species collected from Tranquillity exceeded the performance standard (Table 3-6). Although the mean selenium concentrations in vegetation collected from both Atwell Island and Tranquillity were approximately an order of magnitude less than the mean selenium concentration in plants collected from Kesterson NWR from 1988 to 1992 (2.3 to 6.7 mg/kg), 10 samples collected from Tranquillity were within this range (Table 3-6). The mean selenium concentrations in plants collected from both Tranquillity and Atwell Island are within the range typically found on non-seleniferous soils in the western United States.

Table 3-2. Geometric means (Mean), sample size (N), number of non-detects (ND), minimum (Min), maximum (Max), and standard deviation factor (SD factor) of selenium concentrations (mg/kg dry weight) in plant species collected from Tranquillity, 1999 to 2003.

Species	N (ND)	Mean	Min	Max	SD factor
Acroptilon repens	1 (0)	0.39	0.39	0.39	-
Allenrolfea occidentalis	1 (0)	0.11	0.11	0.11	-
Atriplex argentea	44 (13)	<0.37	<0.20	1.90	1.88
Atriplex polycarpa	13 (3)	<0.39	<0.20	2.10	2.13
Atriplex spinifera	2 (1)	<0.22	<0.10	0.50	3.12
Avena sp.	17 (1)	<0.27	<0.10	0.50	1.55
Bassia hyssopifolia	2 (0)	1.10	0.71	1.70	1.85
Beta vulgaris	6 (1)	<0.46	<0.20	0.73	1.61
Bromus madritensis	13 (11)	<0.21	<0.20	0.43	1.24
Brassica nigra	54 (9)	<0.49	<0.20	3.50	2.16
Capsella bursa-pastoris	1 (0)	0.77	0.77	0.77	-
Chenopodium album	1 (0)	0.78	0.78	0.78	-
Chenopodium murale	1 (0)	0.20	0.20	0.20	-
Grindelia camporum	1 (0)	0.71	0.71	0.71	-
Helianthus annuus	1 (0)	0.36	0.36	0.36	-
Heliotropium curassavicum	8 (3)	<0.68	<0.20	3.90	3.77
Hordeum murinum	12 (4)	<0.31	<0.10	0.83	1.86
Hordeum vulgare	74 (19)	<0.30	<0.10	1.30	1.66
Isocoma acradenia	1 (0)	0.40	0.40	0.40	-
Lasthenia californica	2 (0)	0.61	0.31	1.20	2.60
Lactuca serriola	1 (0)	0.50	0.50	0.50	-
Malvella leprosa	1 (0)	0.41	0.41	0.41	-
Malva parviflora	1 (0)	0.20	0.20	0.20	-
Melilotus indica	11 (5)	<0.28	<0.20	0.40	1.33
Phacelia distans	7 (4)	<0.25	<0.20	0.40	1.33
Phalaris minor	2 (0)	0.20	0.20	0.20	1.00
Sesuvium verrucosum	3 (0)	0.65	0.20	1.70	2.96
Senecio vulgaris	1 (0)	0.74	0.74	0.74	-
Sisymbrium irio	25 (3)	<0.61	<0.20	2.40	2.04
Sonchus sp.	5 (0)	0.55	0.31	1.00	1.70
Suaeda moquinii	12 (1)	<0.93	<0.20	5.00	3.09

Table 3-3. Geometric means (Mean), sample size (N), number of non-detects (ND), minimum (Min), maximum (Max), and standard deviation factor (SD factor) of selenium concentrations (mg/kg dry weight) in plant species collected from Atwell Island, 2000 to 2002.

Species	N (ND)	Mean	Min	Max	SD factor
Atriplex argentea	16 (14)	<0.21	<0.20	0.40	1.22
Atriplex polycarpa	2 (2)	<0.20	<0.20	0.20	1.00
Avena sp.	4 (4)	<0.20	<0.20	0.20	1.00
Bromus madritensis	7 (6)	<0.22	<0.20	0.40	1.30
Brassica nigra	10 (6)	<0.23	<0.20	0.50	1.41
Cressa truxillensis	12 (10)	<0.21	<0.20	0.30	1.17
Distichlis spicata	6 (4)	<0.25	<0.10	1.40	2.45
Heliotropium curassavicum	4 (4)	<0.20	<0.20	<0.20	1.00
Hemizonia pungens	13 (11)	<0.17	<0.10	0.20	1.36
Hordeum murinum	18 (17)	<0.20	<0.10	0.30	1.21
Hordeum vulgare	20 (19)	<0.20	<0.20	0.30	1.09
Isocoma acradenia	1 (1)	<0.20	<0.20	<0.20	-
Lasthenia californica	3 (2)	<0.20	<0.20	0.20	1.00
Lactuca serriola	1 (0)	0.50	0.50	0.50	-
Melilotus indica	14 (14)	<0.19	<0.10	<0.30	1.33
Medicago sativa	1 (1)	<0.20	<0.20	<0.20	-
Sesuvium verrucosum	2 (1)	<0.20	<0.20	0.20	1.00
Sisymbrium irio	12 (10)	<0.21	<0.10	0.73	1.55
Spergularia macrotheca	1 (1)	<0.20	<0.20	<0.20	-
Suaeda moquinii	2 (1)	<0.20	<0.20	0.20	1.00

Table 3-4. Results of analysis of variance tests of selenium concentrations (mg/kg dry weight) between sample years in plant species collected from Tranquillity, 1999 to 2003. GM = geometric mean, N = sample size, ND = number of non-detects. *p* values marked with an asterisk must be interpreted with caution because of the high number of non-detects in one or more data sets.

Species	GM by sample year(N:ND)					F	*p* value
	1999	2000	2001	2002	2003		
Atriplex argentea	<0.49 (12:3)	<0.31 (15:6)	<0.29 (9:4)	-	0.48 (8:0)	2.33	0.09
Atriplex polycarpa	-	-	<0.33 (4:1)	<0.29 (4:2)	0.57 (5:0)	1.05	0.38*
Avena sp.	-	<0.30 (10:1)	-	-	0.23 (7:0)	4.11	0.06
Beta vulgaris	-	<0.39 (4:1)	-	-	0.62 (2:0)	1.35	0.31
Bromus madritensis	-	<0.20 (5:4)	<0.20 (6:6)	-	-	No variance*	
Brassica nigra	-	<0.47 (26:5)	<0.30 (12:4)	-	0.74 (16:0)	5.55	0.01
Heliotropium curassavicum	-	<1.41 (3:1)	-	-	0.98 (2:0)	0.96	0.49
Hordeum murinum	-	<0.22 (4:3)	-	-	<0.41 (7:1)	1.72	0.23*
Hordeum vulgare	<0.25 (10:3)	<0.28 (20:8)	<0.40 (16:2)	<0.26 (12:6)	<0.33 (16:0)	1.44	0.23*
Melilotus indica	-	-	<0.25 (8:5)	-	0.34 (2:0)	2.22	0.17*
Sisymbrium irio	-	-	-	<0.51 (14:3)	0.77 (11:0)	2.01	0.17
Suaeda moquinii	-	-	0.51 (5:0)	<1.19 (4:1)	1.82 (3:0)	1.45	0.29

Table 3-5. Results of Analysis of Variance tests of selenium concentrations (mg/kg dry weight) between sample years in plant species collected from Atwell Island, 2000 to 2002. GM = geometric mean, N = sample size, ND = number of non-detects. *p* values marked with an asterisk must be interpreted with caution because of the high number of non-detects in one or more data sets.

	GM by sample year (N:ND)				
Species	2000	2001	2002	F	*p* value
Atriplex argentea	<0.21 (10:9)	<0.21 (6:5)	-	0.00	0.99*
Bromus madritensis	-	<0.20 (3:2)	<0.25 (3:3)	0.57	0.60*
Cressa truxillensis	<0.22 (9:7)	-	<0.20 (3:3)	0.71	0.42*
Hemizonia pungens	<0.15 (8:7)	<0.20 (3:2)	<0.20 (2:2)	1.15	0.35*
Hordeum murinum	<0.19 (10:10)	<0.21 (6:5)	<0.20 (2:2)	0.93	0.41*
Hordeum vulgare	-	<0.20 (6:6)	<0.21 (14:13)	0.42	0.53*
Melilotus indica	<0.18 (10:10)	<0.20 (4:4)	-	0.32	0.58*
Sisymbrium irio	<0.17 (4:4)	-	<0.24 (8:8)	1.64	0.23*

Table 3-6. List of plant samples from Tranquillity that exceeded the population-level performance standard (2.0 mg/kg). Those marked with an asterisk had selenium levels that fell within the range of geometric means of vegetation collected from Kesterson NWR between 1988 and 1992 (2.3 to 6.7 mg/kg).

Collection Year	Species	Se concentration (mg/kg)
2000	*Heliotropium curassavicum*	3.9*
2000	*Heliotropium curassavicum*	3.6*
2001	*Suaeda moquinii*	2.6*
2002	*Suaeda moquinii*	4.4*
2002	*Sisymbrium irio*	2.4*
2002	*Suaeda moquinii*	2.3*
2003	*Atriplex polycarpa*	2.1
2003	*Suaeda moquinii*	5.0*
2003	*Brassica nigra*	3.5*
2003	*Brassica nigra*	3.2*
2003	*Heliotropium curassavicum*	2.3*

Seven plant species from Tranquillity and five plant species from Atwell Island were collected in sufficient numbers on various landforms (cultivated, uncultivated, and experimental lands) to allow an analysis of the affects of landform type on selenium levels (Tables 3-7 and 3-8). There were no clear differences in selenium levels between landform types for any species at Atwell Island, but this could be because of the generally low selenium levels and the high percentage of non-detects in the data sets. At Tranquillity, mean selenium levels in *A. argentea* were at least 40 percent lower on uncultivated lands than on cultivated or experimental lands ($p < 0.01$ and $p = 0.02$, respectively) and mean selenium levels in *B. nigra* were at least 50 to 70 percent lower on uncultivated lands than on experimental or cultivated lands ($p < 0.01$ and $p < 0.01$, respectively).

Table 3-7. Results of analysis of variance tests of selenium concentrations (mg/kg dry weight) between landform types in plant species collected from Tranquillity, 1999 to 2003. GM = geometric mean, N = sample size, ND = number of non-detects, Uncult = uncultivated lands, Cult = cultivated lands, Exp = experimental lands. *p* values marked with an asterisk must be interpreted with caution because of the high number of non-detects in one or more data sets.

	GM by landform(N:ND)				
Species	Uncult	Cult	Exp	F	*p* value
Atriplex argentea	<0.24 (16:9)	<0.39 (10:1)	<0.41 (12:3)	10.02	< 0.01*
Avena sp.	-	0.26 (7:0)	<0.28 (10:1)	0.15	0.70
Brassica nigra	<0.28 (22:8)	0.87 (16:0)	<0.58 (16:1)	17.04	< 0.01
Hordeum murinum	<0.23 (3:2)	0.57 (1:0)	<0.33 (8:2)	0.85	0.46*
Hordeum vulgare	0.20 (2:0)	<0.32 (48:8)	<0.27 (22:3)	1.49	0.22
Melilotus indica	0.27 (6:3)	0.28 (4:2)	0.36 (1:0)	0.43	0.66*
Sisymbrium irio	0.78 (3:0)	<0.47 (10:2)	<0.71 (12:1)	1.08	0.36

Table 3-8. Results of Analysis of Variance tests of selenium concentrations (mg/kg) between landform types in plant species collected from Atwell Island, 2000 to 2002. GM = geometric mean, N = sample size, ND = number of non-detects, Uncult = uncultivated lands, Cult = cultivated lands, Exp = experimental lands. *p* values marked with an asterisk must be interpreted with caution because of the high number of non-detects in one or more data sets.

	GM by landform (N:ND)				
Species	Uncult	Cult	Exp	F	*p* value
Atriplex argentea	<0.22 (13:11)	<0.20 (3:3)	-	0.44	0.52*
Hordeum murinum	<0.20 (15:14)	<0.20 (3:3)	-	0.02	0.88*
Hordeum vulgare	-	<0.21 (14:13)	<0.20 (6:6)	0.41	0.53*
Melilotus indica	<0.18 (11:11)	<0.20 (3:3)	-	0.22	0.65*
Sisymbrium irio	<0.22 (8:6)	-	<0.20 (4:4)	0.07	0.79*

There were no discernable differences in the selenium concentration between plant parts (whole plant, vegetation, and fruits) from plants collected from Atwell Island, but there were clear differences in the selenium concentration between plants parts in two species collected from Tranquillity (Tables 3-7 and 3-9). In *H. murinum* the whole plant had 61 percent less selenium than the fruits ($p < 0.01$) yet in *H. vulgare* the fruits had 24 percent less selenium than the vegetative structures. There is some evidence that the fruits of *Phacelia distans* had about 40 percent less selenium than the vegetative structures and that the fruits of *Sonchus* sp. had about 60 percent less selenium than the vegetative structures. The small sample sizes (and high numbers of non-detects in the *P. distans* data) are reason to interpret the findings for these two species with caution. There also is some evidence that the fruits of *A. argentea* were higher in selenium than other parts of the plant and that the vegetative structures of *M. indica* were lower in selenium than the whole plant.

Table 3-9. Results of Analysis of Variance tests of selenium concentrations (mg/kg) between plant parts in plant species collected from Tranquillity, 1999 to 2003. GM = geometric mean, N = sample size, ND = number of non-detects, Whole = whole plant, Veg = vegetation. *p* values marked with an asterisk must be interpreted with caution because of the high number of non-detects in one or more data sets.

	GM by plant part (N:ND)				
Species	Whole	Veg	Fruits	F	*p* value
Atriplex argentea	<0.35 (19:5)	<0.35 (22:8)	0.84 (3:0)	2.87	0.07
Avena sp.	<0.30 (10:1)	0.22 (3:0)	0.24 (4:0)	0.86	0.44
Bromus madritensis	<0.20 (6:5)	-	<0.22 (7:6)	0.85	0.38*
Brassica nigra	-	<0.55 (27:4)	<0.43 (27:5)	1.26	0.27
Hordeum murinum	<0.22 (5:4)	0.26 (3:0)	0.57 (4:0)	4.73	0.04*
Hordeum vulgare	-	<0.34 (40:8)	<0.26 (34:11)	6.04	< 0.01
Melilotus indica	0.36 (3:0)	<0.25 (8:5)	-	4.62	0.06*
Phacelia distans	<0.20 (1:1)	<0.33 (3:2)	<0.20 (3:1)	15.62	< 0.01*
Sisymbrium irio	-	<0.79 (12:1)	<0.49 (13:2)	3.12	0.09
Sonchus sp.	-	0.71 (2:0)	0.31 (2:0)	806.35	< 0.01

Table 3-10. Results of Analysis of Variance tests of selenium concentrations (mg/kg) between plant parts in plant species collected from Atwell Island, 2000 to 2002. GM = geometric mean, N = sample size, ND = number of non-detects, Whole = whole plant, Veg = vegetation. *p* values marked with an asterisk must be interpreted with caution because of the high number of non-detects in one or more data sets.

	GM by plant part (N:ND)				
Species	Whole	Veg	Fruits	F	*p* value
Atriplex argentea	<0.21 (10:9)	<0.21 (6:5)	-	0.00	0.99*
Avena sp.	-	<0.20 (2:2)	<0.20 (2:2)	No variance*	
Bromus madritensis	<0.25 (3:3)	-	<0.20 (3:2)	0.57	0.60*
Brassica nigra		<0.28 (5:1)	<0.20 (5:5)	2.58	0.15*
Hemizonia pungens	<0.16 (10:9)	<0.20 (3:2)	-	1.09	0.32*
Hordeum murinum	<0.19 (12:12)	-	<0.21 (6:5)	1.74	0.21*
Hordeum vulgare	-	<0.18 (10:10)	<0.20 (10:7)	1.00	0.33*
Melilotus indica	<0.18 (10:10)	<0.20 (4:4)	-	0.32	0.58*
Sisymbrium irio	<0.17 (4:4)	<0.28 (4:4)	<0.20 (4:3)	1.42	0.29*

3.3.2. Invertebrates

The mean selenium concentrations in crickets (Figure 3-1) collected from Tranquillity (0.40 to 0.81 mg/kg) were higher than those collected from Atwell Island (0.13 to 0.49 mg/kg; $p < 0.01$). Selenium levels in crickets did not appear to vary between years at Atwell Island, but did at Tranquillity. The mean selenium concentration in crickets collected in 1999 was 44 percent lower than in those collected in 2000, 51 percent lower than in those collected in 2001, and 47 percent lower than in those collected in 2003 ($p = 0.2$, $p < 0.01$, and $p = 0.01$, respectively).

The mean selenium concentrations in beetles (Figure 3-2) collected from Tranquillity (0.65 to 1.35 mg/kg) were higher than those collected from Atwell Island (0.14 to 0.85 mg/kg, $p < 0.01$). The mean concentration of selenium in beetles varied between years at both sites. At the Tranquillity site, beetles were approximately 50 percent lower in selenium in 2002 than in 2000 and 2001 ($p = 0.02$ and $p = 0.01$, respectively) and at Atwell Island the selenium concentration in beetles was more than four times higher in 2000 than in 2001 and 2002 ($p < 0.01$ and $p = 0.02$). However, the high number of non-detects in the Atwell Island 2000 data set (8 of 10 samples) coupled with a high detection limit for some samples (4 samples had a detection limit of 2.0 mg/kg) makes this apparent relationship uncertain.

The mean selenium concentrations in spiders (Figure 3-3) were higher at Tranquillity (1.27 to 2.24 mg/kg) than at Atwell Island (0.25 to 1.04 mg/kg, $p < 0.01$). The mean concentration of selenium in spiders did not appear to vary between years at Tranquillity. At Atwell Island, selenium in spiders was almost twice as high in 2000 as in 2001 ($p = 0.03$) and more than four times higher than in 2002 ($p < 0.01$). These apparent relationships are uncertain because of the non-detects in the 2000 data set.

The mean selenium concentrations in isopods (Figure 3-4) were much higher at Tranquillity (1.04 to 3.47 mg/kg) than at Atwell Island (0.13 to 0.48 mg/kg, $p < 0.01$). The mean concentration of selenium in isopods appeared to vary between years at both sites. The mean concentration of selenium in isopods collected from Tranquillity in 2002 was approximately 70 percent less than those collected in 2000, 2001, and 2003 ($p < 0.01$ in all cases). At Atwell Island, the mean concentration of selenium in isopods was approximately 4 times greater in 2000 than in 2002 ($p < 0.01$), but this relationship is uncertain because of the number of non-detects in the 2000 and 2002 data sets.

The mean concentration of selenium in all invertebrate groups (crickets, beetles, spiders, and isopods) collected from Atwell Island remained below the performance standard of 2.0 mg/kg established for project lands (Figures 3-1, 3-2, 3-3, and 3-4; FWS 1999). Furthermore, only one spider sample and one isopod sample exceeded the performance standard. At Tranquillity, the mean concentration of selenium in invertebrates also remained below the performance standard, except for the spiders that were collected in 1999 and isopods that were collected in every year except 2002. Twelve isopod samples, 8 spider samples, 3 beetle samples and 0 cricket samples collected from Tranquillity exceeded the performance standard. It is not unexpected that spiders and isopods exceeded the performance standard. The performance standard established was for terrestrial invertebrates as a group. Spiders are predators and isopods are detritus feeders;

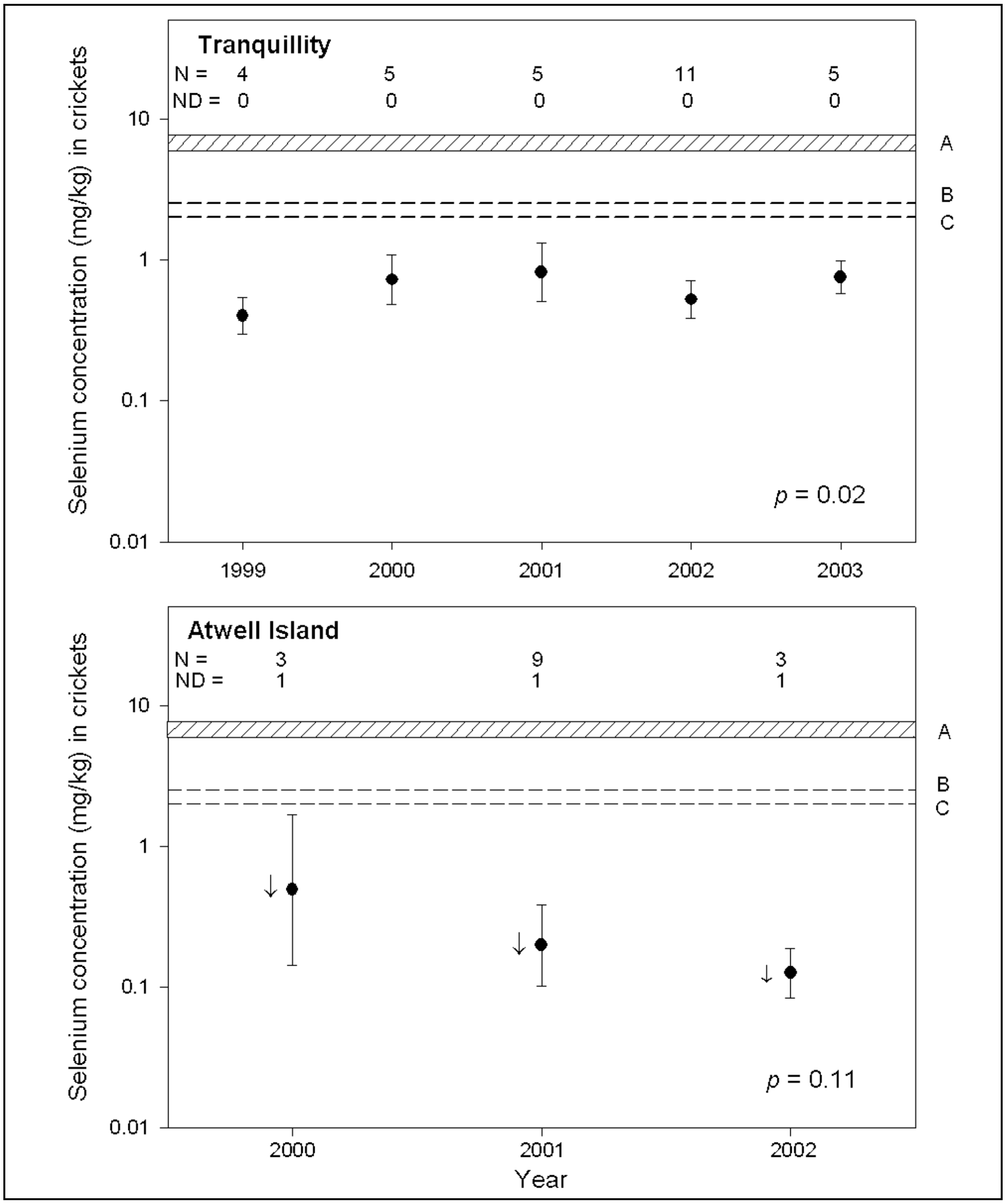

Figure 3-1. Geometric means (solid circles) and error bars (mean multiplied by and divided by one standard deviation factor) of selenium concentrations in crickets collected from the Tranquillity and Atwell Island study sites. Data points that exceed the performance standard are represented by open circles. The ↓ signifies a mean lower than that reported because of the occurrence of non-detects in the data set. A = the range of geometric means of selenium concentrations in crickets (5.9 to 7.6 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR (USDI 1992). B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). C = the performance standard set by the U.S. Fish and Wildlife Service for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for Land Retirement Demonstration Project lands (FWS 1999).

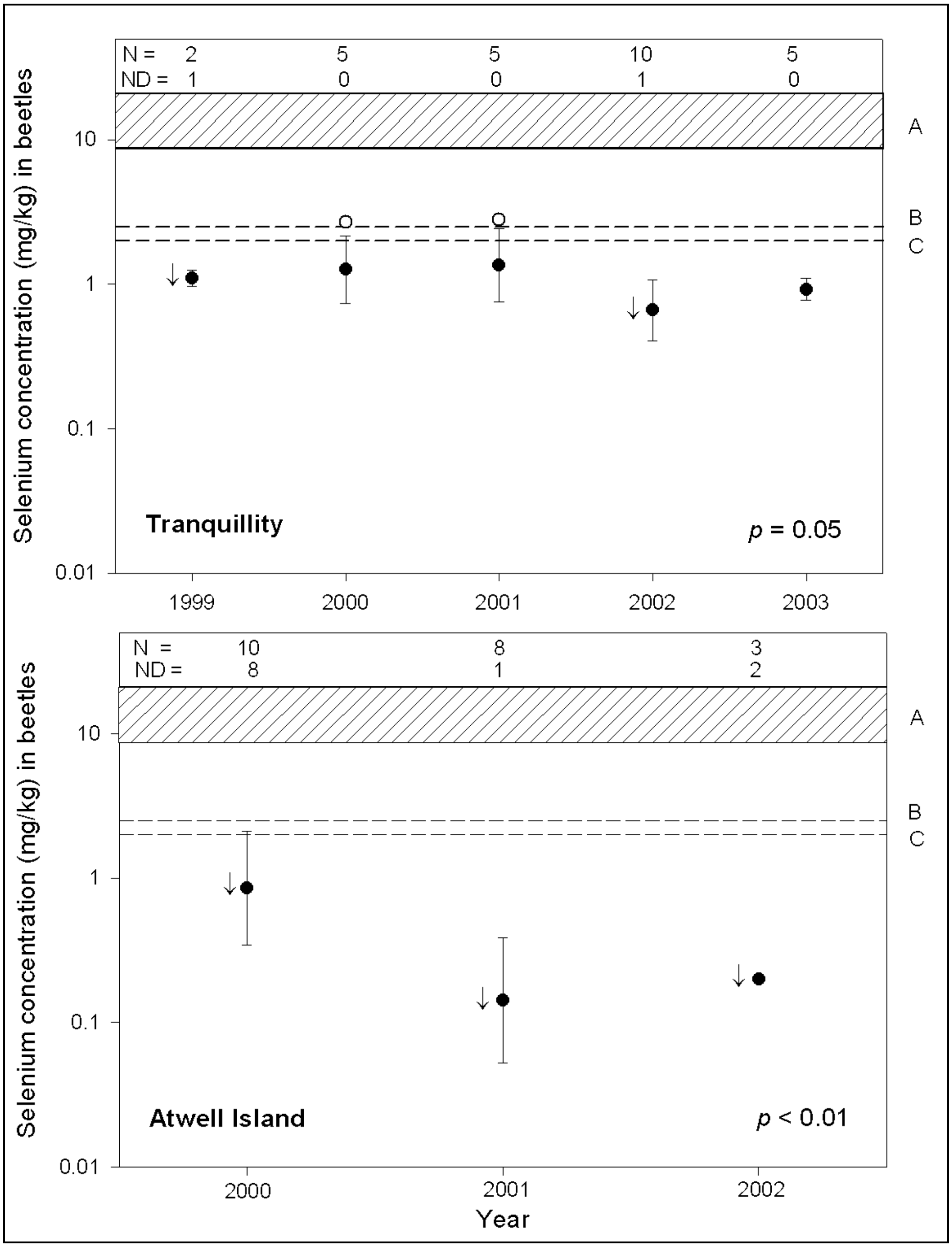

Figure 3-2. Geometric means (solid circles) and error bars (mean multiplied by and divided by one standard deviation factor) of selenium concentrations in beetles collected from the Tranquillity and Atwell Island study sites. Data points that exceed the performance standard are represented by open circles. The ↓ signifies a mean lower than that reported because of the occurrence of non-detects in the data set. A = the range of geometric means of selenium concentrations in beetles (8.7 to 21.0 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR (USDI 1992). B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). C = the performance standard set by the FWS for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for LRDP lands (FWS 1999).

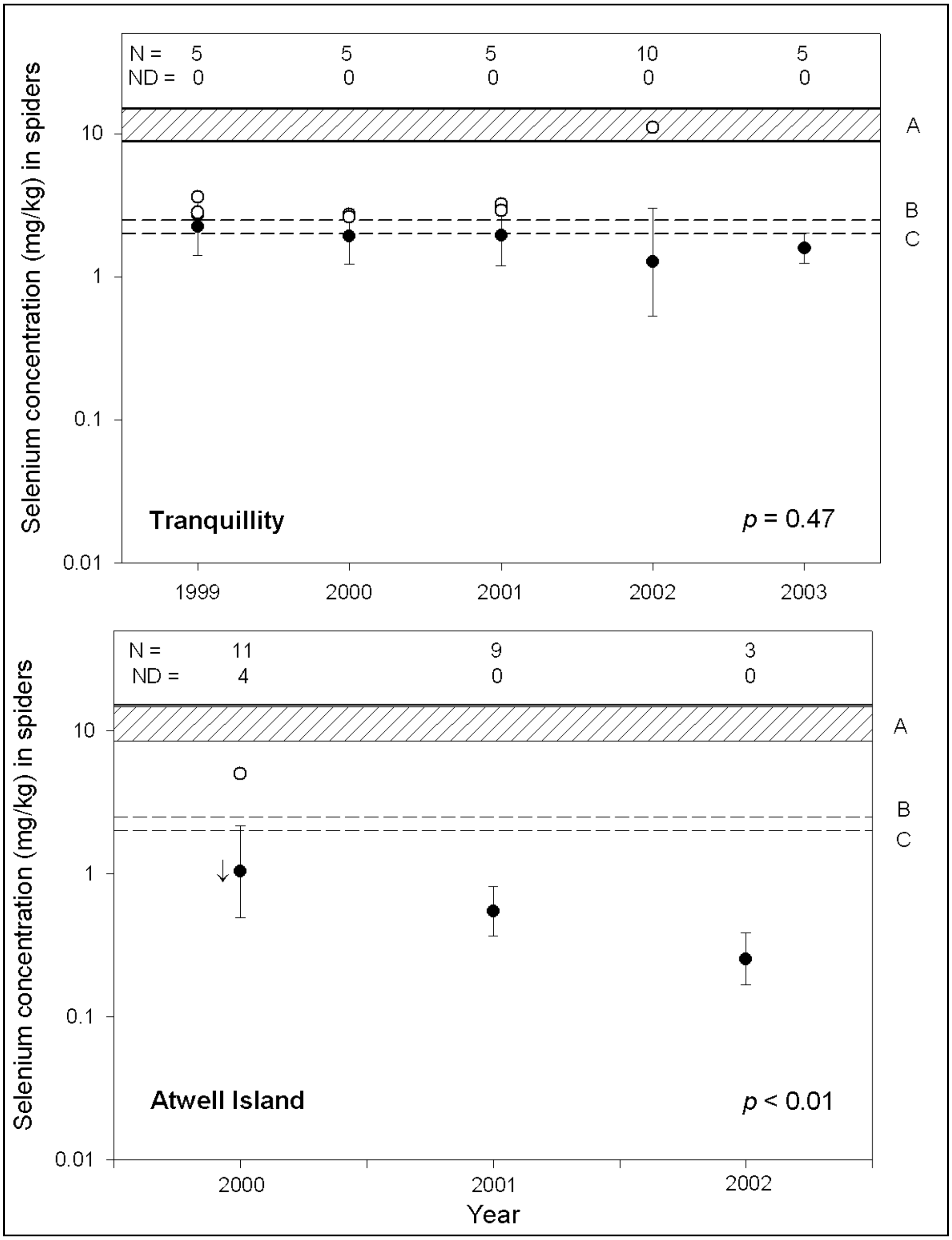

Figure 3-3. Geometric means (solid circles) and error bars (mean multiplied by and divided by one standard deviation factor) of selenium concentrations in spiders collected from the Tranquillity and Atwell Island study sites. Data points that exceed the performance standard are represented by open circles. The ↓ signifies a mean lower than that reported because of the occurrence of non-detects in the data set. A = the range of geometric means of selenium concentrations in spiders (8.8 to 15.0 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR (USDI 1992). B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). C = the performance standard set by FWS for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for LRDP lands (FWS 1999).

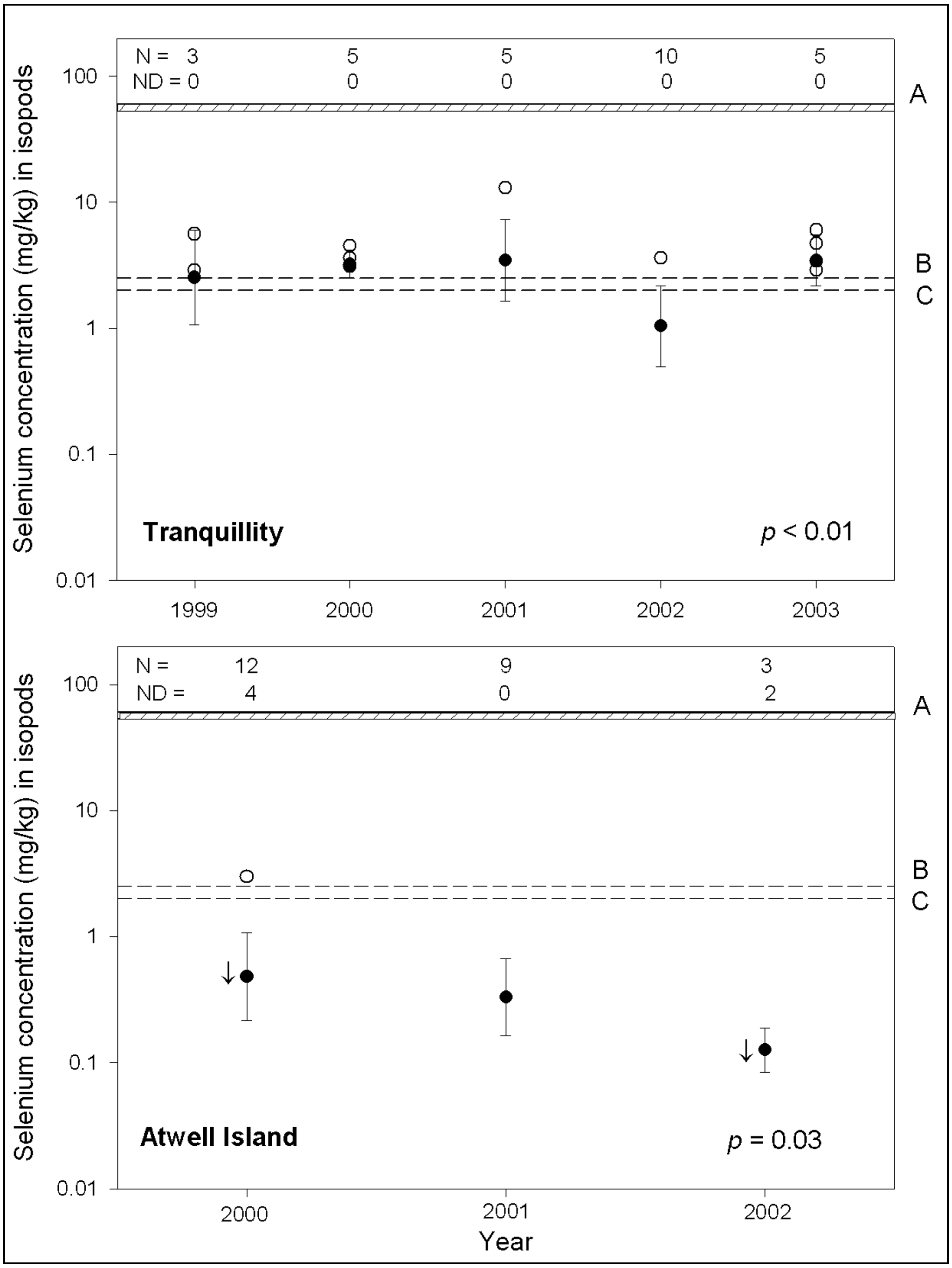

Figure 3-4. Geometric means (solid circles) and error bars (mean multiplied by and divided by one standard deviation factor) of selenium concentrations in isopods collected from the Tranquillity and Atwell Island study sites. Data points that exceed the performance standard are represented by open circles. The ↓ signifies a mean lower than that reported because of the occurrence of non-detects in the data set. A = the range of geometric means of selenium concentrations in isopods (53.0 to 60.0 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR (USDI 1992). B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). C = the performance standard set by FWS for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for LRDP lands (FWS 1999).

both would be expected to accumulate more selenium than herbivorous or granivorous terrestrial invertebrates and, indeed, isopods are known to accumulate high amounts of selenium (USDI 1992).

The mean selenium concentrations in terrestrial invertebrates collected from both sites generally remained within the range for terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). The only exception to this was at Tranquillity where isopods exceeded this range in all years but 2002. The selenium levels in all invertebrate groups collected from the Tranquillity and Atwell Island sites are approximately an order of magnitude less than corresponding invertebrate groups collected between 1988 and 1992 in grassland habitat at Kesterson NWR.

3.3.3. Small Mammals

The mean selenium concentrations in deer mouse (*Peromyscus maniculatus*) bodies (Figure 3-5) were higher at Tranquillity (0.89 to 1.34 mg/kg) than at Atwell Island (0.62 and 0.68 mg/kg, $p < 0.01$). The mean concentration of selenium in deer mouse bodies did not appear to vary between years at Atwell Island site, but at Tranquillity, deer mouse bodies had approximately 34 percent less selenium in 2001 than in 2003 ($p < 0.01$). Similarly, the mean selenium concentrations in deer mouse livers (Figure 3-6) were higher at Tranquillity (2.27 to 3.90 mg/kg) than at Atwell Island (2.21 to 2.37 mg/kg, $p < 0.01$). The concentration of selenium in deer mouse livers did not appear to vary between years at Atwell Island site, but at Tranquillity, deer mouse livers had approximately 30 to 42 percent less selenium in 2001 than in other years ($p \leq 0.01$ for all years). The concentrations of selenium in deer mice clearly differed between irrigated and nonirrigated landforms (Figure 3-7). The greatest difference was in 2001 when deer mouse body tissues from non-irrigated sites had 47 percent less selenium than those from irrigated sites and deer mouse liver tissues from nonirrigated sites had 50 percent less selenium than those from irrigated sites.

Selenium levels in deer mouse bodies collected from both Tranquillity and Atwell Island (Figure 3-7) were within the range that is typically found in small mammals occurring on non-seleniferous soils in the western United States (2.0 mg/kg, USDI 1998). Selenium levels in deer mouse bodies collected from both Tranquillity and Atwell Island were an order of magnitude less than selenium levels found in deer mouse bodies collected from grassland habitats at Kesterson NWR from 1988 to 1992. Selenium levels in deer mouse livers collected from Tranquillity and Atwell Island (Figure 3-7) were within the range of selenium levels found in small mammal livers collected near a selenium-normal wetland (between 1 and 10 mg/kg, USDI 1998) located in the San Joaquin Valley. Selenium levels in deer mouse livers from both sites also were within or slightly above the range of selenium concentrations in small mammal livers (< 3 mg/kg) collected from an agroforestry plantation located in the San Joaquin Valley (Clark 1987). No performance standards were set by FWS for small mammal body or

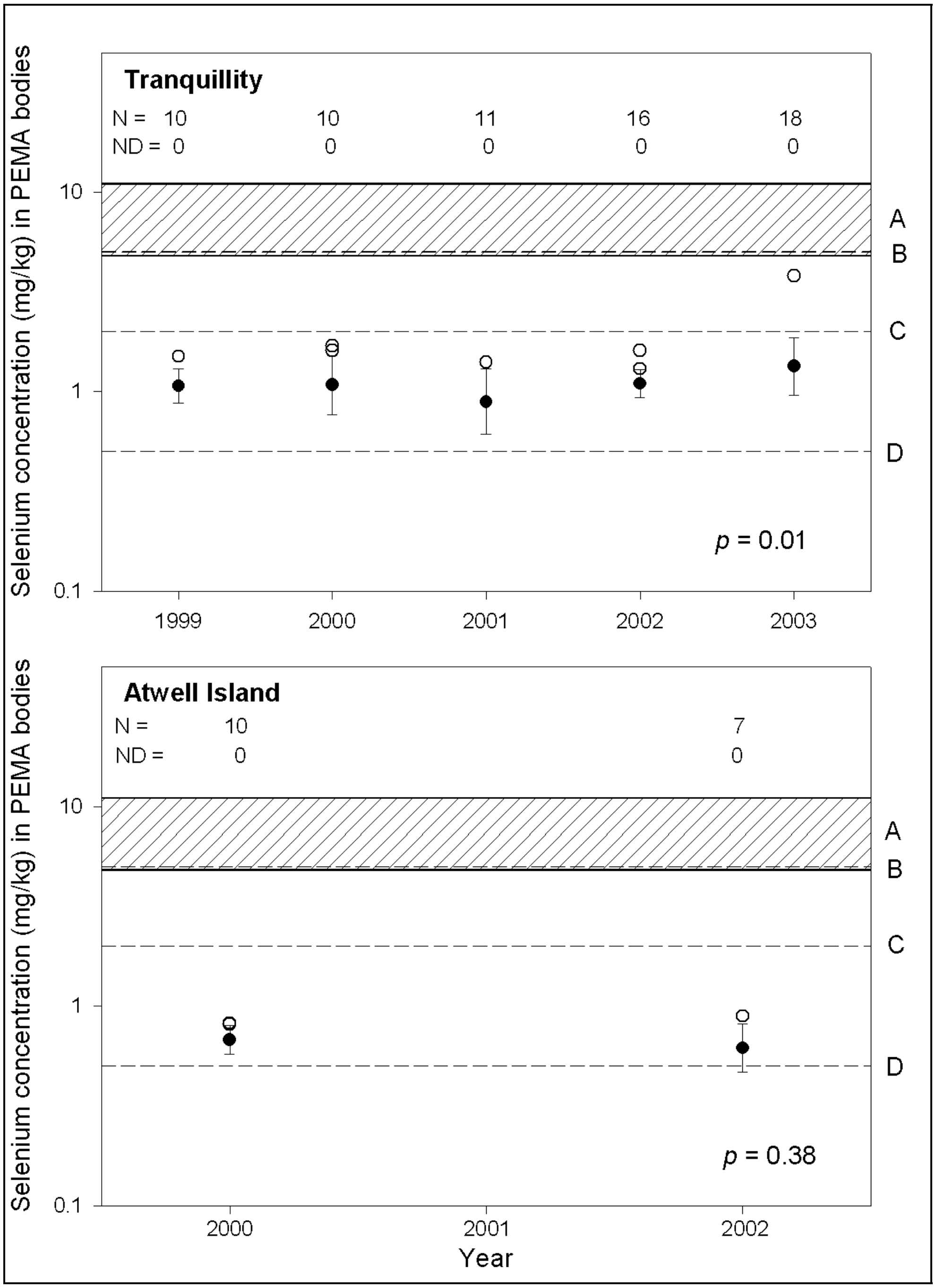

Figure 3-5. Geometric means (solid circles) and error bars (mean multiplied by and divided by one standard deviation factor) of selenium concentrations in deer mouse (PEMA) bodies collected from Tranquillity and Atwell Island. Data points that exceed the mean multiplied by one standard deviation factor are represented by open circles. A = the range of geometric means of selenium concentrations in deer mouse bodies (4.8 to 11.0 mg/kg) collected at Kesterson NWR from 1988 to 1992 (USDI 1992). B = the performance standard established for rodent hair for this project (5.0 mg/kg). C = background level of selenium in small mammal bodies (2.0 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). . D = the performance standard established for rodent blood for this project (0.5 mg/kg).

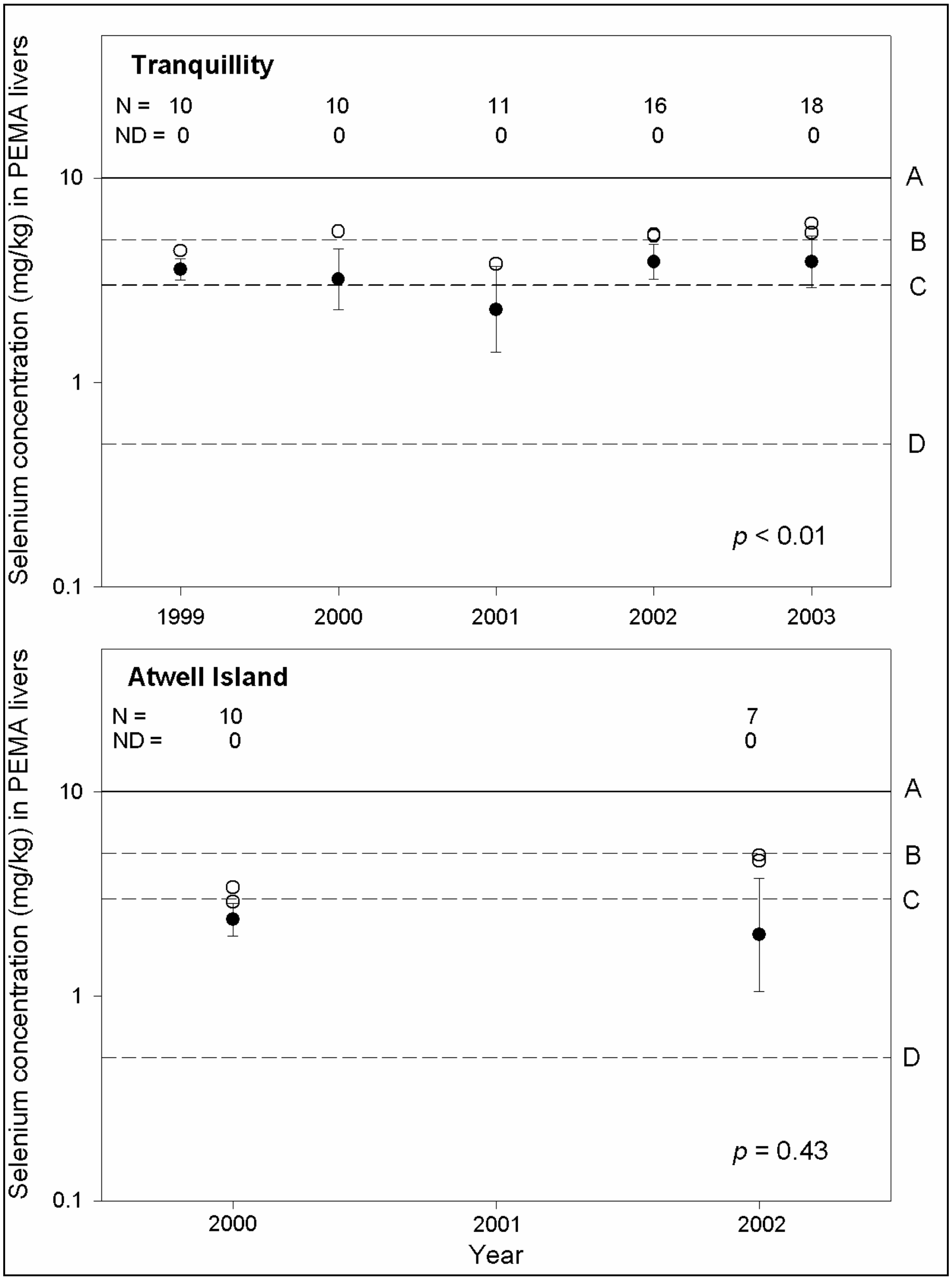

Figure 3-6. Geometric means (solid circles) and error bars (geometric mean multiplied by and divided by one standard deviation factor) of selenium concentrations in deer mouse (PEMA) livers collected from Tranquillity and Atwell Island. Data points that exceed the mean multiplied by one standard deviation factor are represented by open circles. A = the upper range of selenium in small mammal livers collected from near a selenium-normal wetland (between 1 and 10 mg/kg, Clark 1987). B = the performance standard established for rodent hair for this project (5.0 mg/kg). C = the upper range of selenium concentrations in small mammal livers collected from an agroforestry plantation (< 3 mg/kg, CDFG 1993). D = the performance standard established for rodent blood for this project (0.5 mg/kg).

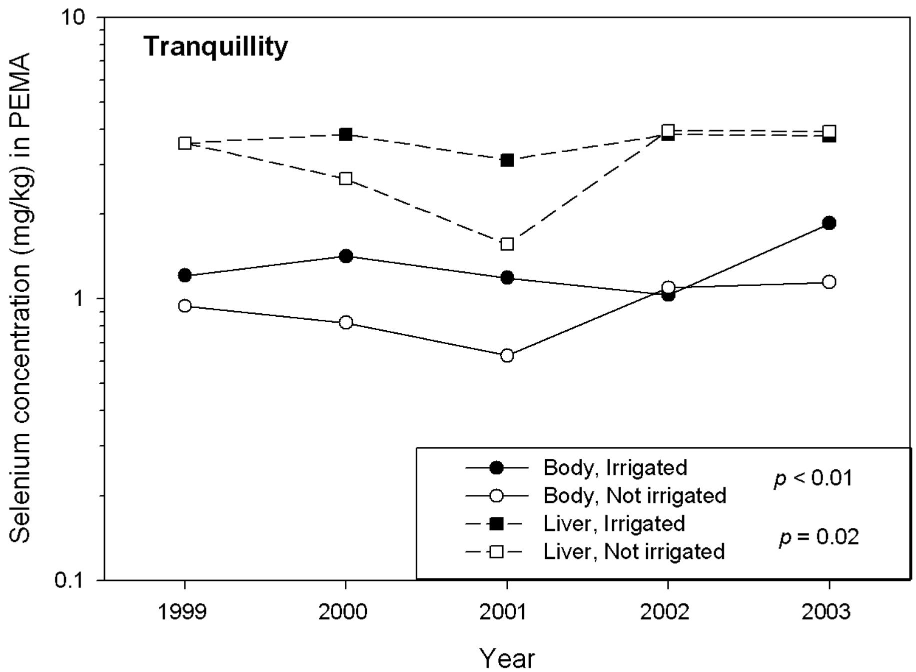

Figure 3-7. Geometric means of selenium concentrations in deer mouse (PEMA) bodies and livers collected from irrigated and non-irrigated lands at Tranquillity, 1999 to 2003.

liver tissues. Instead, performance standards were set for small mammal blood (0.5 mg/kg) and hair (5.0 mg/kg). The selenium values obtained from deer mouse bodies exceeded the values established for blood and the selenium levels obtained for livers were less than the performance standards set for hair. Nevertheless, the selenium levels present in the bodies and livers of deer mice appear to be within acceptable limits.

The mean selenium concentrations in shrew (*Sorex ornatus*) bodies collected from Tranquillity varied from 1.95 to 2.51 mg/kg (Figure 3-8). There were no discernable differences in selenium concentrations between years. Livers were not extracted from the bodies of shrews in 1999, so no data from that year are available for analysis. However, the mean selenium concentrations in shrew livers varied from 2.00 to 4.18 mg/kg (Figure 3-9) from 2000 to 2002 and there were clear differences between years. The selenium concentration in shrew liver tissue was 63 percent lower in 2002 than in 2000 ($p < 0.01$) and 45 percent lower than in 2001 ($p = 0.03$). This may be misleading, however, because of the small sample size (n = 1) of shrew livers analyzed in 2002.

The mean selenium concentrations in shrew bodies collected from Tranquillity (Figure 3-9) were near the upper level of the range of selenium in small mammal body tissues collected from non-seleniferous soils in the western United States (generally < 2.0 mg/kg, USDI 1998). This is not unexpected because shrews are

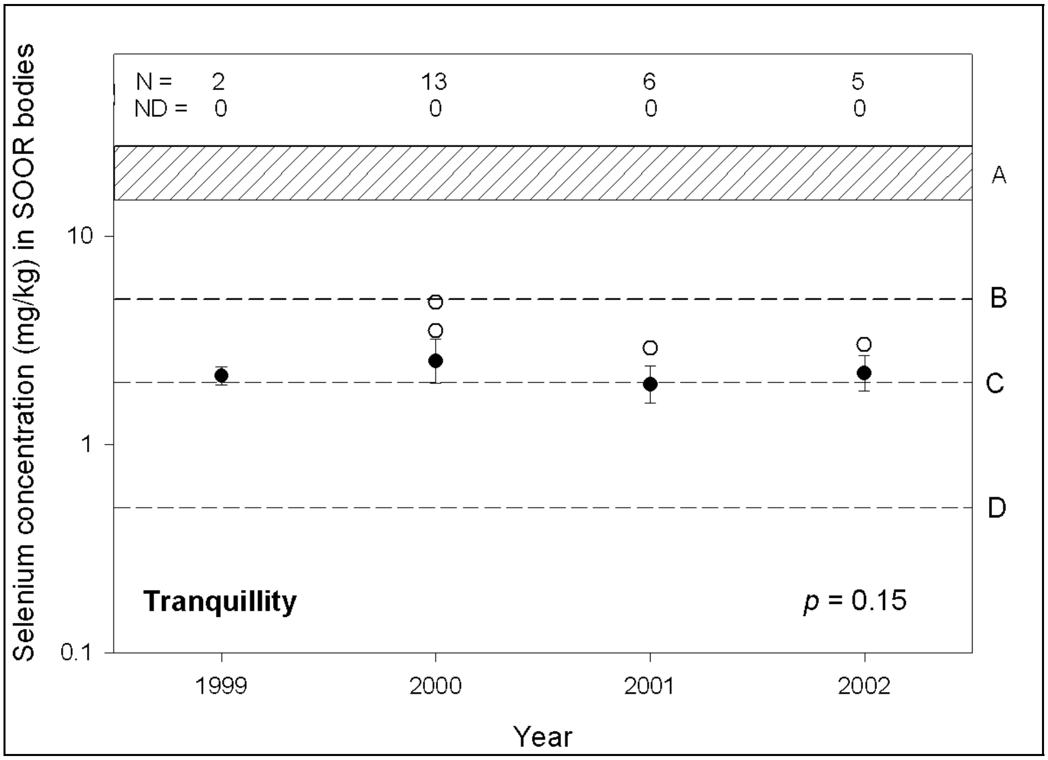

Figure 3-8. Geometric means (solid circles) and error bars (geometric mean multiplied by and divided by one standard deviation factor) of selenium concentrations in shrew (SOOR) bodies collected from Tranquillity. Data points that exceed the geometric mean multiplied by one standard deviation factor are represented by open circles. A = the range of geometric means of selenium concentrations in shrew bodies (15.0 to 27.0 mg/kg) collected at Kesterson NWR from 1988 to 1992 (USDI 1992). B = the performance standard established for rodent hair for this project (5.0 mg/kg). C = background level of selenium in small mammal bodies (2.0 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). D = the performance standard established for rodent blood for this project (0.5 mg/kg).

insectivores and bio-accumulation of selenium in shrews is expected to be greater than in most other small mammals. The mean selenium levels in shrews collected from Tranquillity were approximately an order of magnitude less than selenium levels found in shrews collected between 1988 and 1992 from grassland habitats at Kesterson NWR (15.0 to 27.0 mg/kg). No performance standards were set for small mammal body tissues by the FWS. Instead, performance standards were set for small mammal blood (0.5 mg/kg) and hair (5.0 mg/kg). The selenium in shrew bodies collected from the Tranquillity site exceeded those established for blood, but were lower than the standard established for hair. Selenium levels in the livers of shrews collected from Tranquillity (Figure 3-9) were within the range of selenium levels found in the livers of small mammals (between 1 and 10 mg/kg) collected from near a selenium-normal wetland located in the San Joaquin Valley. Selenium levels in the livers of shrews collected from Tranquillity were also near the upper range of selenium levels found in small mammal livers (< 3 mg/kg) collected from an agroforestry plantation in the San Joaquin Valley (Clark

1988). Accordingly, the selenium levels present in the bodies and livers of deer mice appear to be within acceptable limits.

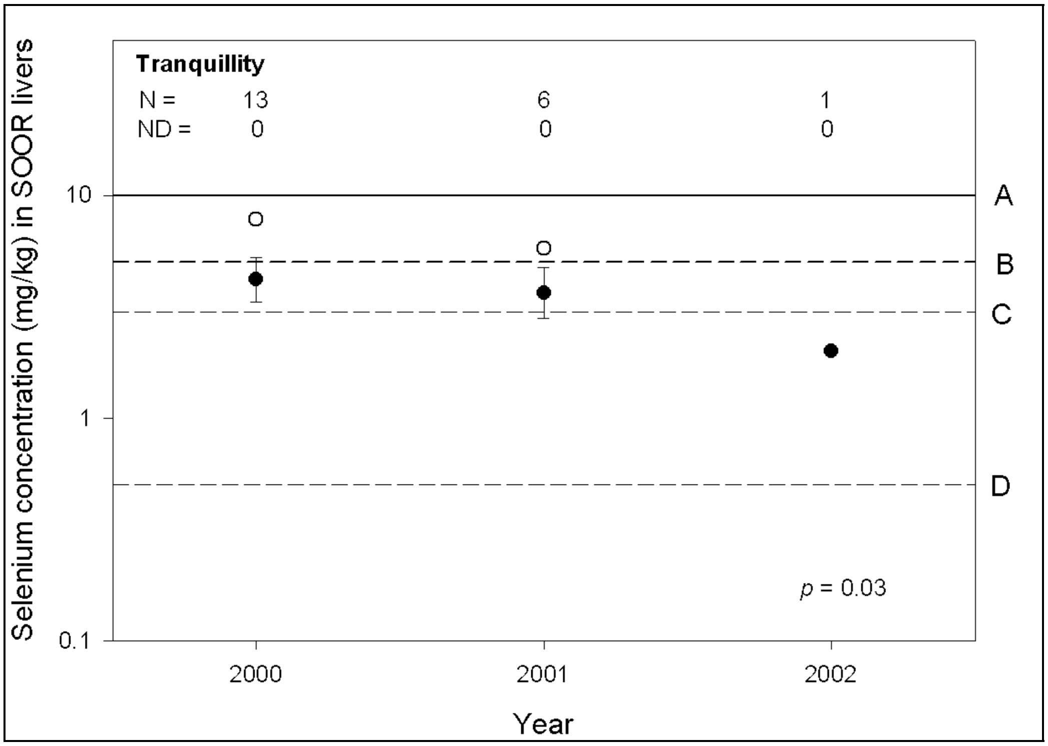

Figure 3-9. Geometric means (solid circles) and standard deviations of selenium concentrations in shrew (SOOR) livers collected from the Tranquillity study site. Data points that exceed the standard deviation are represented by open circles. A = the upper range of selenium in small mammal livers collected from near a selenium-normal wetland (between 1 and 10 mg/kg, Clark 1987). B = the performance standard established for rodent hair for this project (5.0 mg/kg). C = the upper range of selenium in small mammal livers collected from an agroforestry plantation (< 3 mg/kg, CDFG 1993). D = the performance standard established for rodent blood for this project (0.5 mg/kg).

3.4. Discussion and Conclusions

The concentrations of selenium observed in biota at both project sites are generally considered to be within acceptable limits and, although a risk assessment model was not generated, there is evidence of low risk to wildlife. Whereas high selenium levels in groundwater could result in a potential risk to biota, the exposure pathway is limited because the depth to groundwater has increased. Similarly, although selenium levels in the soils remain elevated (but show evidence of decline), the extremely dry conditions that prevail at both Atwell Island and Tranquillity may limit the exposure pathway. The physical conditions present on these sites are thought to be representative of other drainage impacted areas of the San Joaquin Valley and it is reasonable to assume that the bio-accumulation of selenium and risk to wildlife would be similar to that found on our study sites.

There is less risk of exposure to selenium at Atwell Island than at Tranquillity because of lower levels of selenium in the soils and groundwater. Mean selenium levels in biota on both project sites tend to be within the range typically found in biota occurring on non-seleniferous soils in the western United States and are generally below the population-level performance standards set for the project by the FWS (FWS 1999). Furthermore, selenium levels in biota from both sites are generally an order of magnitude less than found at Kesterson NWR.

The generally low levels of selenium in biota may be a result of very low water availability during the study period. Precipitation was below normal or near-normal; ephemeral pools (pools of water lasting 30 days or more) were never present, and the team suspects that soil moisture was too low to allow a high degree of selenium uptake. There were no wetlands on the Tranquillity site. Both project sites were primarily dry, upland environments rather than aquatic or wetland environments, which likely reduces the potential for the bio-availability and bio-accumulation of selenium.

The assumption that reduced water availability results in lowered selenium accumulation also is supported by the higher selenium levels observed in some biota from irrigated lands compared with selenium levels present in biota from non-irrigated lands. This trend was evident in some of the most common and widespread species present on the Tranquillity site: *A. argentea, B. nigra*, and in the bodies and livers of deer mice. These observations suggest that retiring lands from irrigated agriculture may reduce the potential for selenium bio-accumulation at the population level.

Although the mean selenium concentrations in biota were generally below the performance standards, some samples within specific groups exceeded those standards. Eleven of 325 (3.4 %) plant samples and 22 of 115 (19.1 %) invertebrate samples (mostly isopods and spiders) collected from Tranquillity exceeded performance standards and 2 of 83 (2.4%) invertebrate samples collected from Atwell Island exceeded performance standards (see Table 3-6 and Figures 3-1 through 3-4). Although performance standards were not set for small mammal bodies and livers, some samples collected from both Tranquillity and Atwell Island appeared to be somewhat high in selenium (see Figures 3-5, 3-6, 3-8, and 3-9). In many cases, these samples were collected from areas known to be rich in selenium (e.g., areas with high selenium levels in the soil or sediments within the San Luis Drain). These samples are reason for caution.

The Tranquillity site is reasonably representative of conditions found on other drainage impacted lands within the region (i.e., those lands that could potentially be retired from irrigated agriculture). Tranquillity clay—the predominant soil type at the site—is the most extensive soil type mapped by the Natural Resources

Conservation Service on the lower alluvial fan and basin rim landforms in the western San Joaquin Valley. Selenium levels in the soil and groundwater (prior to retirement) were similar to other drainage impacted lands in the region (see Chapter 2) and the vegetation and habitat characteristics that developed on the site (exclusive of successfully restored areas) appear to be similar to that occurring on fallowed lands within the region. We expect that our results are regionally applicable and would be indicative of conditions on other retired lands.

We contend that land retirement and the restoration of retired lands, if properly implemented, monitored, and managed, would be beneficial to wildlife, including threatened and endangered species, and would generally not pose a severe risk of selenium exposure. However, we urge that land retirement be integrated with a comprehensive selenium monitoring program to monitor exposure of wildlife to selenium on a site by site basis. Furthermore, a suite of remedial actions should be developed in the event that selenium exposure on a site is or becomes problematic.

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Chapter 4. Results of a Habitat Restoration Study on Retired Agricultural Lands in the San Joaquin Valley, California

by Curtis E. Uptain, Krista R. Garcia, Nur P. Ritter, Georgia Basso, Darren P. Newman, and Stuart H. Hurlbert

4.1. Introduction

Land retirement without habitat restoration would likely lead to large fields infested with weeds and pests which would affect neighboring agriculture and require extensive and continuous management. Appropriate habitat restoration must accompany land retirement to minimize weeds and pests and to maximize benefits for wildlife. Although land retirement has the potential to enhance wildlife values and improve ecological systems in the San Joaquin Valley, it is recognized that land uses other than wildlife habitat may take precedence on some lands. Some land uses, particularly grazing and, in some cases, dryland farming can be compatible with and may even contribute to habitat values for wildlife. Land retirement could provide wildlife habitat and contribute to the recovery of endangered and threatened plant and animal species (FWS 1998). Retired agricultural lands could provide connecting linkages and corridors between existing habitat areas or large areas of contiguous blocks of land that would provide habitat for new core populations of sensitive species.

The Biological Opinion for the Land Retirement Demonstration Project (LRDP) (FWS 1999) required that a 5-year Habitat Restoration Study (HRS) be conducted focusing on determining the responses of wildlife to land retirement and restoration efforts. Specific objectives of the HRS were to:

- Determine the efficacy of revegetation with native plants as a means to facilitate upland habitat restoration.
- Determine the efficacy of microtopographic contouring as a means to facilitate upland habitat restoration.
- Examine the responses of plants and wildlife to land retirement and restoration.

To accomplish these goals, a large-scale (323.75 ha; 800 ac) study was initiated at the Tranquillity site in 1999. Twenty long-term study plots were established and a broad range of data were collected over a 5-year period (see Section 4.2.1 for a description of the experimental design). At the plot-scale, vegetation, invertebrates, amphibians, reptiles, birds, and small mammals were all monitored throughout the duration of the project. Avian nesting success on the study plots also was studied in 2002 and 2003. Site-wide monitoring included track station surveys, windshield surveys, and spotlighting. The results of these monitoring efforts provide information on wildlife use of retired agricultural lands over a 5-year period. The results also allowed an evaluation of the effectiveness of the restoration efforts and the relative value of those restoration efforts to wildlife.

4.2. Methods

4.2.1. Study Design

A 323.75 ha (800 ac) Habitat Restoration Study (HRS) was established on retired agricultural lands in 1999 to examine the responses of wildlife to restoration efforts. The study incorporated a complete randomized block design and consisted of twenty, 4.05 ha (10 ac) study plots arrayed in 5 blocks (Figure 4-1). The size of the HRS was determined by that which could be reasonably manipulated and monitored with a high degree of experimental rigor, but which was sufficient to yield significant results in a relatively short amount of time (5 years or less). Two restoration factors were studied: (1) the introduction of native plants through seeding (imprinting) and transplanting; and (2) the re-establishment of surface contouring (i.e., microtography). Four combinations of these treatment factors were applied (Figure 4-1).

4.2.2. Restoration Methods

Plots were arranged in a randomized block design to control variation caused by the heterogeneous physical characteristics of the site. Four treatments were randomly assigned to plots within each block; plots were established in April of 1999. Plot corners were permanently marked with 0.91 m (3 ft) sections of reinforcing bar (rebar) and pin flags were added to help locate plot corners. Plot corners were located with a Global Positioning System (GPS) receiver, and data points were archived.

To minimize interactions between plots and to reduce weeds and soil erosion, each plot was surrounded by a 12.14 ha (30 ac) buffer that was maintained with a barley cover crop. During the first year of the Demonstration Project (1999), all HRS experimental plots and associated buffer regions were planted in barley. To grow a healthy cover crop the soil was disked and leveled and the soil was prepared until it was of uniform texture. Barley was drilled at approximately 77.11 kg per 0.40 ha (170 lbs per ac).

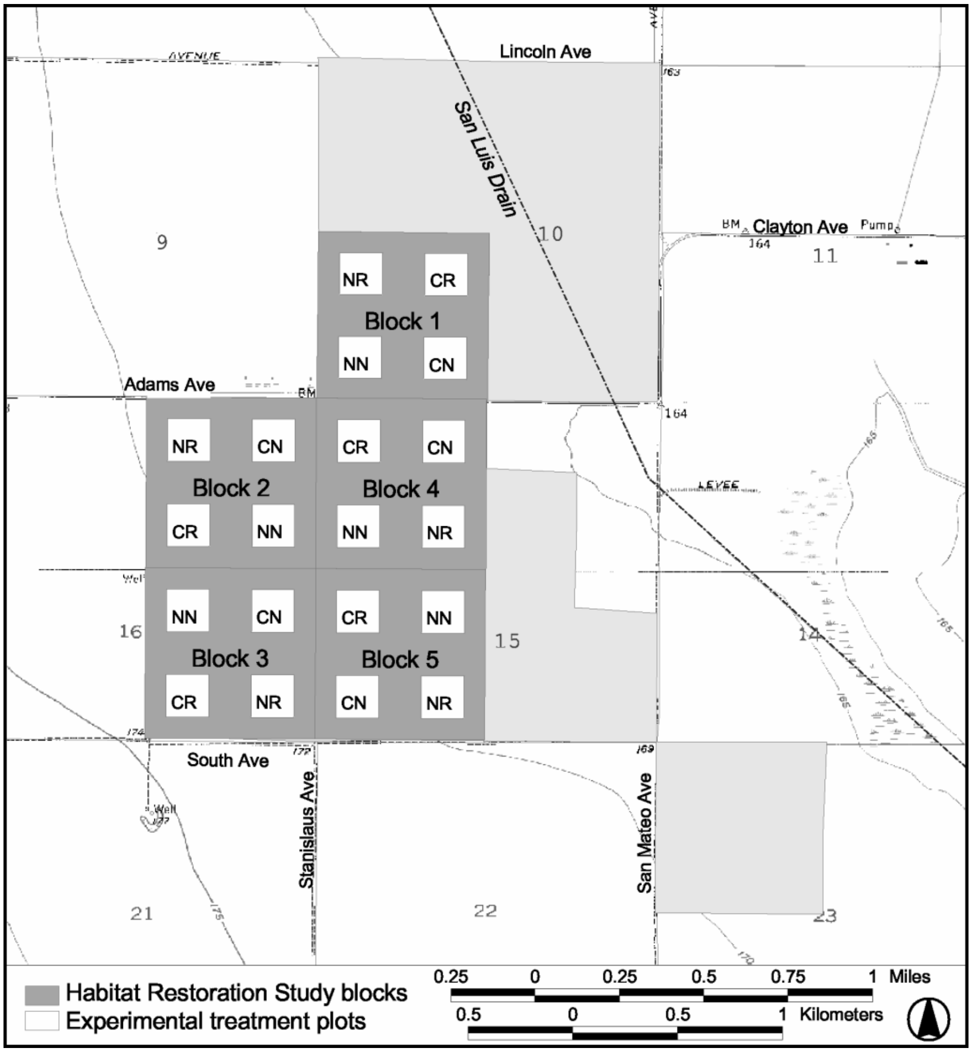


Figure 4-1. Map of the Tranquillity HRS plots showing treatments and blocks. Key to Treatments: CR = contouring and seeding; NR = seeding and no contouring; CN = contouring and no seeding, and NN = no contouring and no seeding.

Due to the effectiveness of the 1999 crop at controlling weeds and providing vegetative cover on retired lands, barley was used as the cover crop for all subsequent years. The seed was inexpensive ($0.10-$0.15 per .45 kilo) and was planted without extensive ground preparation. Irrigation was applied to give the barley a competitive advantage over weeds and with the hopes of obtaining a profitable crop. The barley was irrigated with approximately 7.6 cm (3 in) of water (an amount which would not contribute to deep percolation) in spring of 1999, 2000, and 2001. The barley was not irrigated in subsequent years to reduce costs and, although this precluded production of a harvestable crop, the barley was flailed and replanted to reduce the need to purchase seed.

Imprinting is an experimental seeding method that creates small impressions in the soil and deposits seed directly in the indentation (Dixon 1988). This method of seeding promotes seed-soil contact while protecting the seed from wind and predators. Native seed was imprinted evenly across the plots receiving the reintroduction prescription in March 2000. Plant species were selected based on representative species from nearby ecological reserves and known species composition of the desired plant communities. Further information on rates of applications, costs and mix preparation can be found in Selmon et al. (2000).

Microtopographic contours (berms) were created to reintroduce minor vertical variation across the landscape. Such heterogeneity may create microhabitat suitable for plant germination and animal burrows. Berms were established on experimental plots in January 2000 using a modified agricultural implement commonly used to create "checks" in flood-irrigated agricultural fields. The 240, 12 m (39.3 ft) long berms were installed on each plot. Prior to installation of the HRS plots, it was found that berms were compacted by imprinting. Accordingly, the berms in the seeded plots were initially installed at about twice standard height. The resulting berms on all plots after seeding were consistent in height.

Native plants also were introduced onto the experimental plots via direct transplanting in March and April of 2000. Seedlings were grown from seed in local nurseries from commercial and local seed sources. Transplanted seedlings were closely grouped in "shrub islands" (i.e., closely-grouped planting) to maximize the potential for "nurse plant" effects. Two types of shrub islands were created (Table 4-1). Twenty-five islands (13 Type A and 12 Type B) were installed on each plot. In fall 2000, all shrub islands were inventoried. Wherever necessary, additional seedlings were transplanted into the existing shrub islands such that each island had the minimum number of species as shown in Table 4-1. Transplanting in the Type B islands was augmented by broadcast seed of *Isocoma acradenia*.

Table 4-1. Overview of shrub island planting, Tranquillity HRS. Figures in the Initial Planting columns indicate the number of individuals that were initially transplanted to each island. Figures in the Fall Replanting columns indicate the target number (i.e., minimum number of living individuals) for each species following replanting in fall 2000.

	"Type A"		"Type B"	
	Initial Planting	Fall Replanting	Initial Planting	Fall Replanting
Allenrolfea occidentalis	14	4	-	-
Atriplex polycarpa	-	-	12	8
Isocoma acradenia	-	-	2	seeding
Leymus triticoides	4	0	-	-
Sporobolus airoides	22	8	-	-

Nursery stock generally needs ample rain or irrigation after planting for establishment in native soils. The Tranquillity study site rarely receives sufficient rainfall to support transplanted nursery stock, so DriWater™, a time-release water product, was installed adjacent to seedlings when planting the shrub islands. To facilitate establishment, additional water was applied 2-3 times with a backpack sprayer within 2 weeks of planting.

4.2.3. Plot-Level Monitoring

4.2.3.1. Vegetation Survey Methods

Vegetation monitoring was timed (as much as possible) to coincide with the period when the majority of the annual species had begun to senesce. Monitoring dates for all years are presented in Table 4-2. Sampling methodologies were consistent throughout the 4 years of monitoring on the plots. Data were collected from 24 quadrats (35 x 70 cm) on each plot. A stratified random sampling approach was employed, with plots divided into sixth-sections and four sampling points randomly selected within each section. All species were noted and the percent cover for each species estimated using a modified Daubenmire cover scale (0-1 percent; 1-5 percent; 5-25 percent; 25-50 percent; 50-75 percent; 75-95 percent; 95-100 percent; Bonham 1989). The total percent cover of all species within the quadrat was also estimated using the same scale. Whenever possible, species were identified completely; failing this, species were assigned morpho-species names (e.g., “Unknown Compositae”).

In addition to cover data, qualitative data were entered for each quadrat (e.g., whether or not the percent cover of vegetation in the quadrat was representative of the general area), and for individual species (e.g., flowering condition). Qualitative assessments were also made at the plot-wide scale. To document that portion of the flora that was not represented in the quadrats, a running list was compiled of all species noted on the plot. However, estimates of species richness were based solely on the species that occurred in the quadrats.

In fall of 2002, a census of shrubs and shrub-like annuals was conducted on the HRS plots; however, this survey was not repeated in 2003. A complete account of the 2002 survey was presented in Uptain et al. (2004).

Photographic vouchers were taken on the HRS plots to document post-treatment conditions and to provide a permanent record of changes in vegetation structure and composition. Photographs (one 35 millimeter [mm] and one digital) were taken from each of two standard locations along the southern boundary of each plot (43 meters [m] from each of the corners), with the cameras oriented northwards. Copies of the photos are archived at Endangered Species Recovery Program (ESRP) and Reclamation offices in Fresno, with the 35 mm photos stored in binders and the digital photos archived on compact disk. Photographs were taken quarterly, except in 2003 when three photographic surveys were made (March 21; June 18, 24-25; September 16-18).

Table 4-2. Plot-level survey dates for the various biotic groups, 1999 to 2003. Monitoring in 1999 (baseline monitoring) preceded the installation of the HRS plots but was conducted on the 323.75 ha (800 ac) area on which the plots were subsequently cited.

Biotic group	Year	Survey Dates
Vegetation	1999	23, 26, 27, 29 Apr
	2000	25-27 Apr; 1 May
	2001	7-9 May
	2002	11, 12, 15, 20 Mar
	2003	8-11, 15-16, 21-22 Apr
Invertebrates	1999	8-10 June
	2000	6-7, 13-14 June
	2001	19-22 June
	2002	16-19 April
	2003	20-23 May
Amphibians and Reptiles	1999	8-10 June
	2000	6-7, 13-14 June
	2001	11-13 July
	2002	8-10 June, 29 April, 2-3 May, 9-11 July, 8-10 Jan(pitfall)
	2003	14-16 Jan, 7-9 May, 8-10 July, 21-23 Oct, 3-4 Dec (just amphib)
Birds	1999	12-14 May, 21-23 July, 20-22 Oct
	2000	12-14 Jan, 8-10 May, 26-28 July, 17-19 Oct
	2001	17-19 Jan, 18-20 April, 18-20 July, 2-4 Oct
	2002	16-18 Jan, 2-4 April, 22-24 July, 8-10 Oct
	2003	14-16 Jan, 7-9 May, 8-10 July, 21-23 Oct
Small Mammals	1999	11-14 Oct
	2000	15-18 May, 8-11Aug, 6-9 Nov
	2001	27 Feb-2 Mar, 30 April-3 May, 6-9 Aug, 5-8 Nov
	2002	29 Jan-1 Feb, 6-9 May, 15-18 July, 28-31 Oct
	2003	4-7March, 28-30 April-1 May, 21-24 July, 6-9 Oct

4.2.3.2. Invertebrates

Invertebrates were collected over a 5-year period (Table 4-2) from five pitfall arrays (Figure 4-2) that were established on each of the 20 study plots. Each array consisted of four, 11.36 liters (3 gal) buckets sunk into the ground to the rim. The buckets were connected by 6.1 m by 30 cm (20 ft by 1 ft) sections of galvanized steel flashing used to guide invertebrates into the buckets. During the four consecutive survey days, bucket lids were removed and supported approximately 2.5 cm (1 in) above the rim by wooden stakes. Buckets were opened for approximately 24 hours between each survey day.

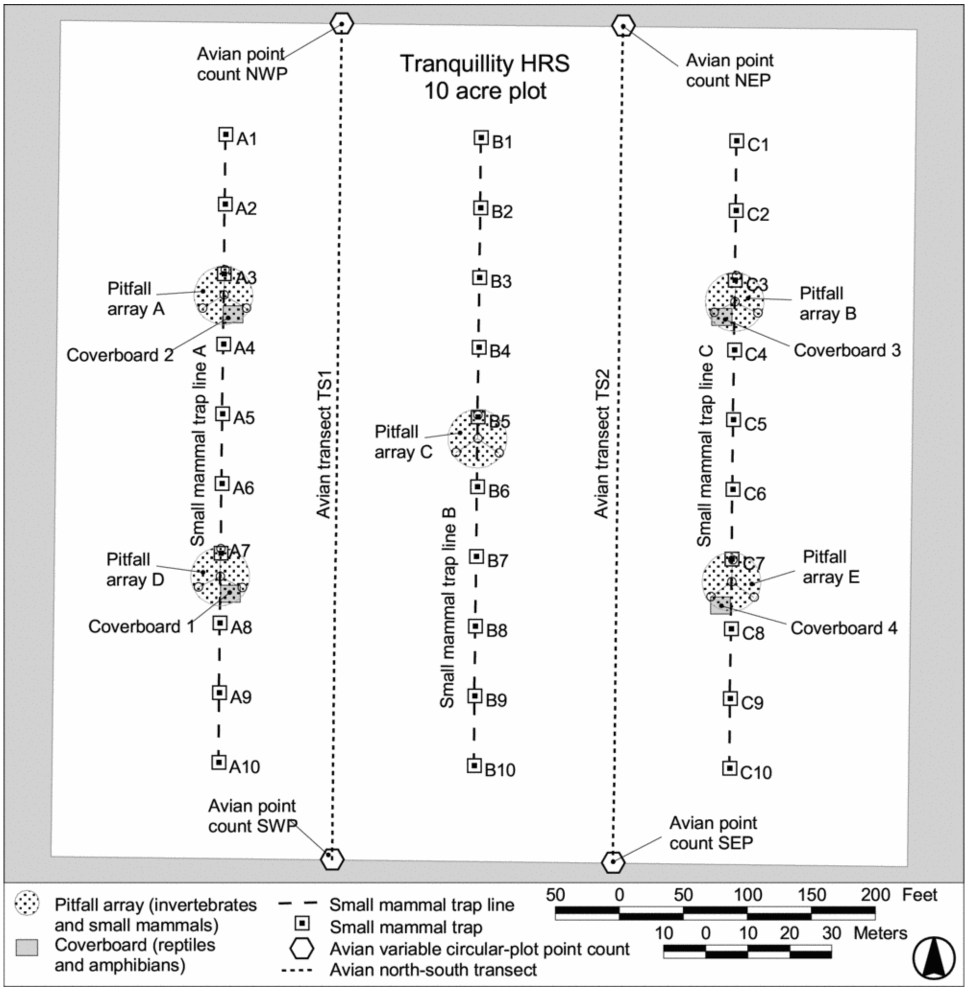


Figure 4-2. Locations of pitfall arrays, amphibian and reptile coverboards, avian transects and point-count locations, and small mammal trapping lines on a study plot at the Tranquillity site.

All invertebrates found within the pitfalls were identified to order and counted. A voucher specimen was collected of each invertebrate type that was present on each plot. These were later identified to the family level whenever possible. The numbers of orders found on each plot over the 4-day survey period were tallied to obtain richness. The abundance of invertebrates present on each plot was determined by tallying the numbers of invertebrates found in each bucket over the 4-day sampling period, then adding the tallies of all buckets on a plot, then dividing the total by four to obtain an average number per day. Richness and abundance values are based upon the ordinal level because consistent and accurate invertebrate field identification beyond that level was not possible.

Once the identification process was complete, invertebrate orders and families were classified into one of four functional groups; herbivores, predators, pollinators, and parasites. Although this process is not complete, the classification has enabled us to identify agriculturally beneficial and harmful invertebrates which occur on the study plots and assess the potential impacts of land retirement in promoting populations of these invertebrates.

4.2.3.3. Amphibians and Reptiles

Reptile and amphibian surveys were typically conducted concurrently with avian surveys (Table 4-2). On occasion, asynchronous surveys were conducted because of time constraints imposed by the avian surveys and the need to conduct amphibian surveys during periods of rain. Visual encounter surveys (Heyer et al. 1994) were conducted along the small mammal trapping transects, and four 0.37 m by 0.37 m (4 ft by 4 ft) coverboards per plot (Figure 4-2) were inspected for the presence and/or sign of amphibians and reptiles. Additionally, incidental sightings of amphibians and reptiles were recorded during other surveys and other site visits.

4.2.3.4. Birds

Bird diversity and abundance surveys Avian surveys were conducted quarterly over a 5-year period (Table 4-2) on the study plots. Four point counts on variable circular plots (Verner 1985) and two parallel north-south transects (Figure 4-2) were censused for four consecutive mornings. Surveys began within 30 minutes of sunrise (Ralph et al. 1993). All five blocks were concurrently sampled by 5 biologists synchronizing starting times between blocks to within 5 minutes of each other. Each circular-plot was censused for 5 minutes and each transect was censused for 5 minutes, resulting in 30 minutes of observations per plot. The direction of the survey route was alternated on each subsequent survey day. All species recorded on experimental plots were included in data analyses; fly-over and species not on experimental plots were incidentally noted but excluded from analyses. Avian species observed on experimental plots were identified to species and all detected birds were documented as either a visual or a vocal account. Location, activity, and distances from observer also were recorded.

Nest survey We searched for nests from the first week of March through the first week of April in 2002 and 2003 to identify nests, determine nesting success, and the causes of nest failure. Rope dragging, the standard method used to search for ground nesting birds and their nests (Labisky 1957), was conducted using a 60 m (200 ft) long, 0.95 cm (0.38 inch) thick nylon rope. Each plot was surveyed once each week for 4 consecutive weeks. Three sweeps of the rope were necessary to completely cover each plot. When a bird flushed, the surrounding area was searched for active nests. Nest locations were mapped on a site map, their positions were recorded using a hand-held global positioning system unit, and they were marked in the field using a pin-flag placed 5 m (16.5 ft) south of the nest. Active nests were checked at 3- to 4-day intervals until nesting ended. Precautions described by Ralph et al. (1993) were used to minimize nest disturbance and the risk of predation. Data recorded included nest height, nest dimensions, nest orientation, the presence or absence of adults, the number of eggs or nestlings present, and a brief description of nestlings (e.g., number, size, presence of pin feathers, etc.). Clutch initiation was estimated by backdating (Alisauskas and Ankney 1992) and mean clutch size and median fledge date were calculated for all monitored nests. Photographs of nests and nestlings were taken. Vegetation at each nest site was characterized once nests were vacated. Each site was characterized using four 35 cm by 70 cm (14 - 28 inch) sampling quadrats placed immediately adjacent to the nest in each cardinal direction. Within each quadrat, we estimated percent cover (total vegetative cover, cover of shrubs, grasses, forbs, litter, and bare ground), the total cover of each plant species present, and the average height of plants.

4.2.3.5. Small Mammals

Small mammal trapping was conducted quarterly over a 5-year period (Table 4-2). On each study plot, 30 Sherman live-traps were placed in three lines of 10 traps each with an inter-trap spacing of 15m (50 ft) (Jones 1996, Figure 4-2). Traps were baited with a small handful of millet, opened approximately an hour before sunset, and checked and closed starting 2 hours after dark. All five blocks were checked simultaneously by one biologist per block. Each night, the starting point was moved to the ending point of the previous night so that the traps were open for approximately the same amount of time over the survey period. Captured mammals were identified, sexed, weighed, and reproductive status and trap location noted. Kangaroo rats (*Dipodomys heermanni*) were marked with passive integrated transponders (PIT tags) and other species were marked by clipping a patch of fur from the rump or hindquarters.

Pitfall traps also were used to capture small mammals. Data from the pitfall traps were used to augment the assessment of species richness and some small mammals captured in the pitfalls were sacrificed for selenium analysis. The 4-day pitfall survey was conducted concurrently with the invertebrate surveys (Table 4-2). Pitfall traps were checked after sunrise for small mammals and closed, prior to processing invertebrates. The tip of the tail was removed from shrews (*Sorex ornatus*) and pocket mice (*Perognathus inornatus*) to be used in a genetics study.

4.2.4. Site-Wide Surveys

4.2.4.1. Spotlighting Surveys

Spotlight surveys were conducted quarterly from fall 1999 to fall 2003 (Table 4-3) to evaluate the site-wide richness and abundance of wildlife at the Tranquillity site. In spring 2001, heavy rains and flooding of the site precluded a survey. Two biologists illuminated the landscape along a 25.07 km (15.58 mi.) route (Figure 4-3) using 1,000,000 candlepower spotlights. Surveys were conducted for 3 consecutive days, except in spring of 2002 when flooding of the site required the survey to be conducted during two, 2-day periods. Each survey began at sunset and was completed in approximately 2 hours. The vehicle was driven at 15 to 25 kph (10 to 15 mph), and species observed were identified with the aid of 10 x 50 power binoculars. Data recorded included species, number of individuals, location (odometer reading and/or GPS waypoint) and additional notes. The start and end times, temperature, mileage, environmental conditions (wind speed and direction, cloud cover and moon phase), and additional notes (e.g., flooded areas, unusual activity etc.) were recorded. The richness and abundance of amphibians, reptiles, avian, and mammals were generated for each survey period.

Table 4-3. Dates of spotlighting surveys, track station surveys, and winter raptor surveys conducted from 1999 to 2003.

Survey	Year	Dates
Spotlighting	1999	14-16 Sep; 20-22 Dec
	2000	27-29 March; 19-21 June; 11-13 Sep; 27-29 Nov
	2001	29-31 May; 17-19 Sep; 17-19 Dec
	2002	4-5, 11-12 March; 24-26 June; 9-11 Sep; 9-11 Dec
	2003	24-26 March; 16-18 June; 15-17 Sep
Track stations	1999	15-17 Sep; 21-23 Dec
	2000	28-30 March; 20-22 June; 12-14 Sep; 28-30 Nov
	2001	14-16 March; 30-31May, 1 June; 11-13 Sep; 18-20 Dec
	2002	5, 12-13 March; 25-27 June; 11-13 Sep; 10-12 Dec
	2003	25-27 March; 17-19 June; 16-18 Sep
Winter raptor	1999	21-23 Dec
	2000	3-5 Jan (2001)
	2001	18-20 Dec
	2002	10-12 Dec
	2003	6-8 Jan (2004)

4.2.4.2. Track Station Surveys

Seventeen track stations (Figure 4-3) were checked for 3 consecutive days each quarter from 1999 to 2003 (Table 4-3). Surveys were not conducted in spring or summer 1999 because the project had not yet been initiated. Each station consisted of a 1 m (3.3 ft) square galvanized steel plate covered with a 5 to 8 cm (2 to 3 in) layer of equal parts of dolomite and fine sand. A can of wet cat food was set in the center of the plate as an attractant. The substrate and cat food were replaced as needed. Each track station was checked for tracks between 0600 and 1000 hours. We attempted to identify tracks to the species level, but sometimes only identifications to family or order were possible. Data are reported as richness and rate of visitation.

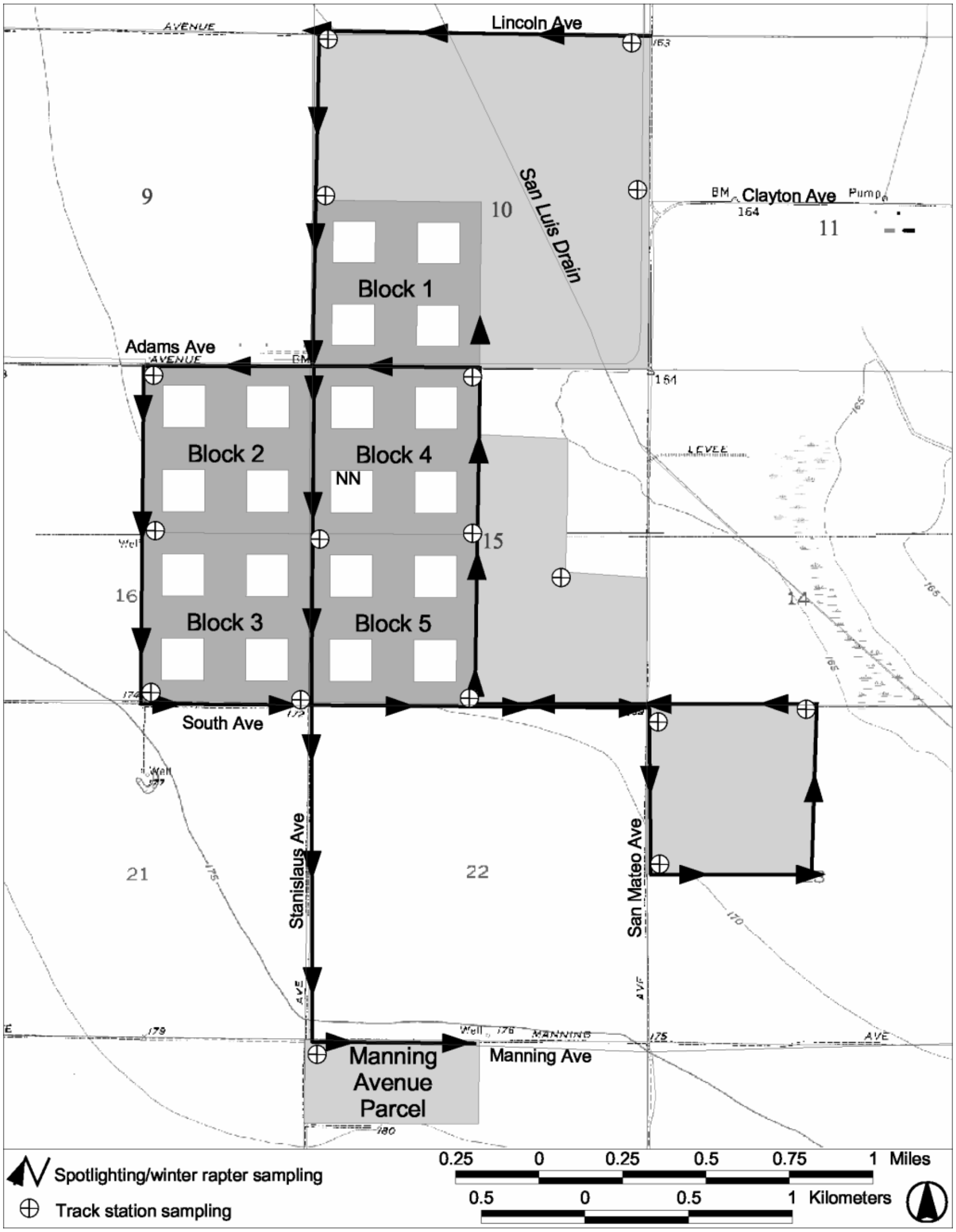


Figure 4-3. Locations of the spotlight survey route, track stations, and winter raptor survey route, 1999 to 2003.

4.2.4.3. Winter Raptor Surveys

Windshield surveys were conducted in December or January from 1999 to 2003 (Table 4-3) to determine raptor abundance and distribution. Surveys generally began 1 hour after sunrise, but start times were delayed if fog hindered visual observations. The 25.07 km (15 mi) survey route was located adjacent to the demonstration site (Figure 4-3). The route was surveyed for 3 consecutive days each survey period by driving the route slowly (approximately 5 to 10 miles per hour or 8 to16 kilometers per hour). Raptors were identified using binoculars and a spotting scope. Data recorded included species, sex, age (when possible), activity at time of first observation, and location. The start location, weather conditions (cloud cover, wind, moon phase, and temperature), start and end times, and start and end odometer readings were recorded. Loggerhead shrikes (*Lanius ludovicianus*), mountain plovers (*Charadrius montanus*), and other sensitive bird species also were recorded and reported to the California Natural Diversity Database (CNDDB). Raptor abundance was calculated as the average number observed per day over each 3-day census.

4.2.4.4. Statistical Analysis of Vegetation Data

Species were grouped by “origin” (e.g., introduced, native, etc.) for some analyses. One category, the “tumbling saltweeds” is a modification of what had been referred to in previous annual reports as the “Native–Undesirable” category. The tumbling saltweeds are composed of two species, *Atriplex argentea* (silverscale saltbush) an undesirable native species, and the non-native *Atriplex rosea* (tumbling oracle). These annual herbs, which possess a shrub-like form, have demonstrated the capacity to quickly become established and to dominate large areas of the study plots.

The remaining categories are self-explanatory (e.g., “Native”); however, the “Imprinted and Introduced” category merits a brief explanation. This category was created to integrate the contribution of species that could be ascribed to genera that were represented in both the “Native - Imprinted” and “Introduced” categories, but which were frequently not identifiable to the level of species. In the 2003-04 growing season, the “Imprinted and Introduced” category was represented at the Tranquillity HRS by a single pair of species: the grasses *Vulpia microstachys* (imprinted) and *V. myuros* (introduced). Fertile individuals of both species were frequently encountered; nevertheless, quadrats would often contain only infertile material, and it was not possible to confidently ascribe this material to a particular species. It was assumed that both species were present on any plot in which *Vulpia* was noted; hence, the Imprinted and Introduced category contributed two species to estimates of species richness. For analyses of abundance, one-half of the percent cover value from the Imprinted and Introduced species was applied to the Native – Imprinted category and one-half to the Introduced category.

Descriptive statistics, t-tests, and Analysis of Variance (ANOVA) procedures were conducted using the software package STATISTICA (StatSoft, Inc. 2002). To simultaneously express floristic relationships among the Tranquillity Study Plots and to examine the relationship between site vegetation and block effect, data were organized into a binary matrix of plots versus species (recorded as percent cover values) and were analyzed by Detrended Correspondence Analysis

(DCA, Hill and Gauch Jr. 1980). Ordinations were conducted using the software package PC-Ord (McCune and Mefford 1999).

4.2.4.5. Analysis of Data for the Other Biotic Groups

The effects of restoration treatments on the richness and abundance of invertebrates, amphibians and reptiles, birds, and small mammals were analyzed using Analysis of Variance applied to log-transformed data. If warranted, post-hoc analyses using Fisher LSD tests were performed. Statistical analyses were accomplished using Statistica 6 (Statsoft, Inc. 2002). The geometric means (hereafter referred to as means) of the data sets were graphed using Sigma Plot (SPSS Inc. 2002).

In addition to evaluating the affects of restoration on richness and abundance of invertebrates as a group, we separately evaluated the abundance of the beetles (*Coleoptera*) and spiders (*Araneae*). These two orders are commonly used as indicators of restoration effects because they are sensitive to environmental change, taxonomically well known, and biologically diverse (Perner and Malt 2003, Rykken et al. 1997). Additionally, we separated invertebrate orders into three groups—herbivores, pollinators, and predators—to evaluate the abundance of these groups in response to restoration treatments. Similarly, we grouped birds into one of three categories—obligate grassland species (those birds that require grassland habitats), facultative grassland species (those birds that benefit from grassland habitats), and other species—to evaluate the abundance of birds based upon ecological roles.

Nesting data were analyzed using the Mayfield method (Mayfield 1961, 1975) to calculate various parameters associated with nesting survival. The relationship between the presence of plants and nest success was statistically evaluated. Chi-square tests were used to determine if nest success or failure was influenced by the presence of individual plant species and student's *t*-tests were used to evaluate nest success relative to nest height and the mean number of plant species present. Spearman rank correlation was used to evaluate the correlation between the number of successful nests and the number of plant species present at the nest site. All statistical tests were performed in Statistica 6 (Statsoft, Inc. 2002).

Data from spotlight and track station surveys were log transformed and analyzed using single-factor or multifactor Analysis of Variance in Statistica 6 (StatSoft, Inc. 2002). Data from winter raptor surveys were log transformed and analyzed using repeated measures Analysis of Variance and Spearman rank correlation.

4.3. Results

4.3.1. Plot-Level Monitoring

4.3.1.1. Vegetation

Results are initially considered with reference to site-wide patterns. Subsequently, patterns among treatments and blocks (i.e., replicates) are considered.

Site-level At the site level, species richness initially increased after imprinting (i.e., from 1999 to 2000; Table 4-4). Nevertheless, site-level richness decreased during the following 2 years, reaching levels that were approximately equivalent to that of the baseline year (i.e., 1999).

Table 4-4. Overall vegetation species richness in the Tranquillity HRS study plots. Included data are solely those species which occurred within the quadrats.

Species Category	1999	2000	2001	2002	2003
Native - Imprinted	0	5	5	4	3
Native	3	5	2	2	2
'Tumbling Saltweeds'	1	1	1	1	1
Imprinted & Introduced	0	2	2	2	0
Barley	1	1	1	1	1
Introduced	15	16	15	12	17
Not Known	6	5	1	4	0
Total	26	35	27	26	24

Thirteen native species were imprinted into the plots in 2000 (Table 4-5); see Selmon 2000 for an overview of the experimental design and plot installation). Of these imprinted species, only six (46.2 percent) were noted during vegetation monitoring in 2000 and 2001, and only five (38.5 percent) in 2002. By 2003, only three of the imprinted species occurred in the spring monitoring quadrats (Table 4-5). Less than half of the species that were imprinted were observed during any particular year's monitoring; however, approximately two-thirds (9) of the imprinted species have been observed at some point during monitoring (i.e., during at least 1 year's monitoring).

Table 4-5. Species imprinted in the Tranquillity HRS Plots (1999), and an overview of those imprinted species noted in the quadrats during spring vegetation monitoring, 2000-2003.

Species	Family	Common Name	2000	2001	2002	2003
Allenrolfea occidentalis[A]	Chenopodiaceae	iodinebush	-	-	-	-
Atriplex polycarpa	Chenopodiaceae	allscale saltbush	-	-	+	+
Atriplex spinifera	Chenopodiaceae	spinescale saltbush	-	-	-	-
Bromus carinatus	Poaceae	California brome	+	+	+	-
Frankenia salina	Frankeniaceae	alkali heath	+	-	+[B]	-
Heliotropium curassavicum	Boraginaceae	seaside heliotrope	-	-	-	-
Hemizonia pungens	Asteraceae	common spikeweed	-	+	-	-
Isocoma acradenia	Asteraceae	goldenbush	+	-	-	-
Lasthenia californica	Asteraceae	California goldfields	+	+	+	+
Leymus triticoides	Poaceae	creeping wild-rye	-	+	-	-
Sporobolus airoides	Poaceae	alkali sacaton	-	-	-	-
Suaeda moquinii	Chenopodiaceae	bush seepweed	+	+	-	-
Vulpia microstachys	Poaceae	small fescue	+	+	+	+

A. A few, transplanted individuals are still alive on Block 1; however, none of these occurred within the quadrats.

B. Noted in a single, non-imprinted plot.

In addition to species that are actively introduced to restoration sites through imprinting and direct planting, it is hoped that native species would become established on retired lands without human intervention. It is expected that these species would become established either through existing seed banks or through colonization from other areas and, indeed, at the Tranquillity HRS, a number of non-imprinted natives have been noted on the plots (Table 4-6). As discussed in the Methods section, the native *Atriplex argentea* (the native component of the 'tumbling saltweeds') is considered to have an overall negative impact on restoration and, hence, is non-desirable. Therefore, that species is not included in the tally of "naturally established" native species. Discounting *A. argentea*, eight non-imprinted native species have been noted on the HRS plots (Table 4-6).

Non-imprinted native species were best represented during the first year of restoration (i.e., 2000), with five species noted during monitoring (Table 4-6). However, only two such species were noted during each of the subsequent year's monitoring. As will be discussed later, none of these species were well-represented on the HRS plots.

Table 4-6. Non-imprinted, native species (excluding Atriplex argentea) noted in the quadrats during spring vegetation monitoring in the Tranquillity HRS, 1999-2003.

Species	1999	2000	2001	2002	2003
Amsinckia menziesii	-	-	+	+	-
Eremalche parryi	+	-	-	-	-
Hordeum depressum	+	+	-	-	+
Malacothrix coulteri	-	-	-	+	-
Malvella leprosa	-	+	-	-	-
Monolepis nuttalliana	-	+	-	-	-
Phacelia ciliata	+	+	+	-	+
Solanum americanum	-	+	-	-	-
Total:	**3**	**5**	**2**	**2**	**2**

The dominance by non-native species that was suggested by the site-level richness patterns was even more evident when species' abundances were considered (Table 4-7). The eleven most abundant species were non-native, with three species (*Sisymbrium irio*, *Bromus madritensis*, and *Capsella bursa-pastoris*) providing more than three-quarters (77.0 percent) of the vegetative cover.

In general, vegetation on the HRS plots tended towards dominance by one or the other of two most abundant species: *Sisymbrium irio* (London rocket) and *Bromus madritensis* (red brome). To examine the spatial partitioning of these two species, we developed a spatial analysis in which the plots were divided into sixths and the mean abundances of selected species represented graphically (Figure 4-4 and Figure 4-5).

As was noted, vegetation monitoring employed stratified random sampling, with the plots divided into sixth-sections (sextants) and four quadrats situated within each section. For this analysis, the mean percent cover for each 'sextant' was calculated from the cover values from the four quadrats. Although this type of representation does not allow for statistical analyses, it is well-suited to show spatial variations in species abundances.

This approach was employed, because there was an evident partitioning of the two dominant weeds, with *Bromus madritensis* dominant on the northernmost plots (Block 1) and *Sisymbrium irio* the more abundant species on most areas of the remaining 16 plots (Blocks 2-4). This partitioning is clearly represented in the graphs (Figure 4-4 and Figure 4-5). Although not included here, a graph of the sextant abundance data for *Capsella bursa-pastoris* (the third most abundant species) showed a similar pattern to that of *S. irio*.

Table 4-7. All species noted in the quadrats during spring vegetation monitoring in the Tranquillity HRS, 2003, including species code, common name, life-form, origin, mean percent cover, and relative abundance. Species codes are used to identify species in subsequent figures. Relative abundance represents the percent contribution of a particular species to the total cover. Key to Origins: C = Cultivar; I = Introduced, N = Native (non-imprinted): N-I = Imprinted Native; T = Tumbling Saltweeds; U = Unknown.

Taxon	Code	Common Name	Life-form	'Origin'	% Cov.	Rel. Abd.
Sisymbrium irio	A	London rocket	annual herb	I	42.048	47.889
Bromus madritensis	B	red brome	annual herb	I	15.190	17.299
Capsella bursa-pastoris	C	shepherd's purse	annual herb	I	10.335	11.771
Melilotus indica	D	sourclover	annual herb	I	5.962	6.791
Brassica nigra	E	black mustard	annual herb	I	3.329	3.792
Senecio vulgaris	F	old-man-in-the-Spring	annual herb	I	3.184	3.627
Erodium cicutarium	G	redstem filaree	annual herb	I	2.775	3.160
Hordeum murinum	H	foxtail barley	annual herb	I	2.690	3.063
Sonchus sp.	I	prickly lettuce	annual herb	I	0.341	0.388
Vulpia myuros	J	rattail fescue	annual herb	I	0.311	0.355
Avena sp.	K	oats	annual herb	I	0.289	0.329
Atriplex polycarpa	L	allscale saltbush	shrub	N-I	0.286	0.326
Lactuca serriola	M	prickly lettuce	annual herb	I	0.272	0.310
Beta vulgaris	N	beet	annual herb	I	0.194	0.221
Hordeum vulgare	O	barley	annual herb	C	0.158	0.180
Vulpia microstachys	P	small fescue	annual herb	N-I	0.149	0.170
Atriplex argentea	Q	silverscale saltbush	annual herb	T	0.079	0.090
Hordeum depressum	R	alkali barley	annual herb	N	0.040	0.045
Bromus diandrus	S	ripgut brome	annual herb	I	0.031	0.036
Bromus sp.	T	brome	annual herb	I	0.031	0.036
Malacothrix coulteri	U	snake's head	annual herb	N	0.031	0.036
Lasthenia californica	V	California goldfields	annual herb	N-I	0.030	0.034
Malva parviflora	W	cheeseweed	annual herb	I	0.023	0.026
Phacelia ciliata	X	Great Valley phacelia	annual herb	N	0.009	0.011
Bromus carinatus	Y	California brome	perennial herb	N-I	0.006	0.007
Lolium perenne	Z	perennial ryegrass	perennial herb	I	0.006	0.007
Bromus hordeaceus	a	soft brome	annual herb	I	0.001	0.001
Chenopodium sp.	b	N.A.	not known	U	0.001	0.001
Phalaris minor	c	littleseed canarygrass	annual herb	I	0.001	0.001

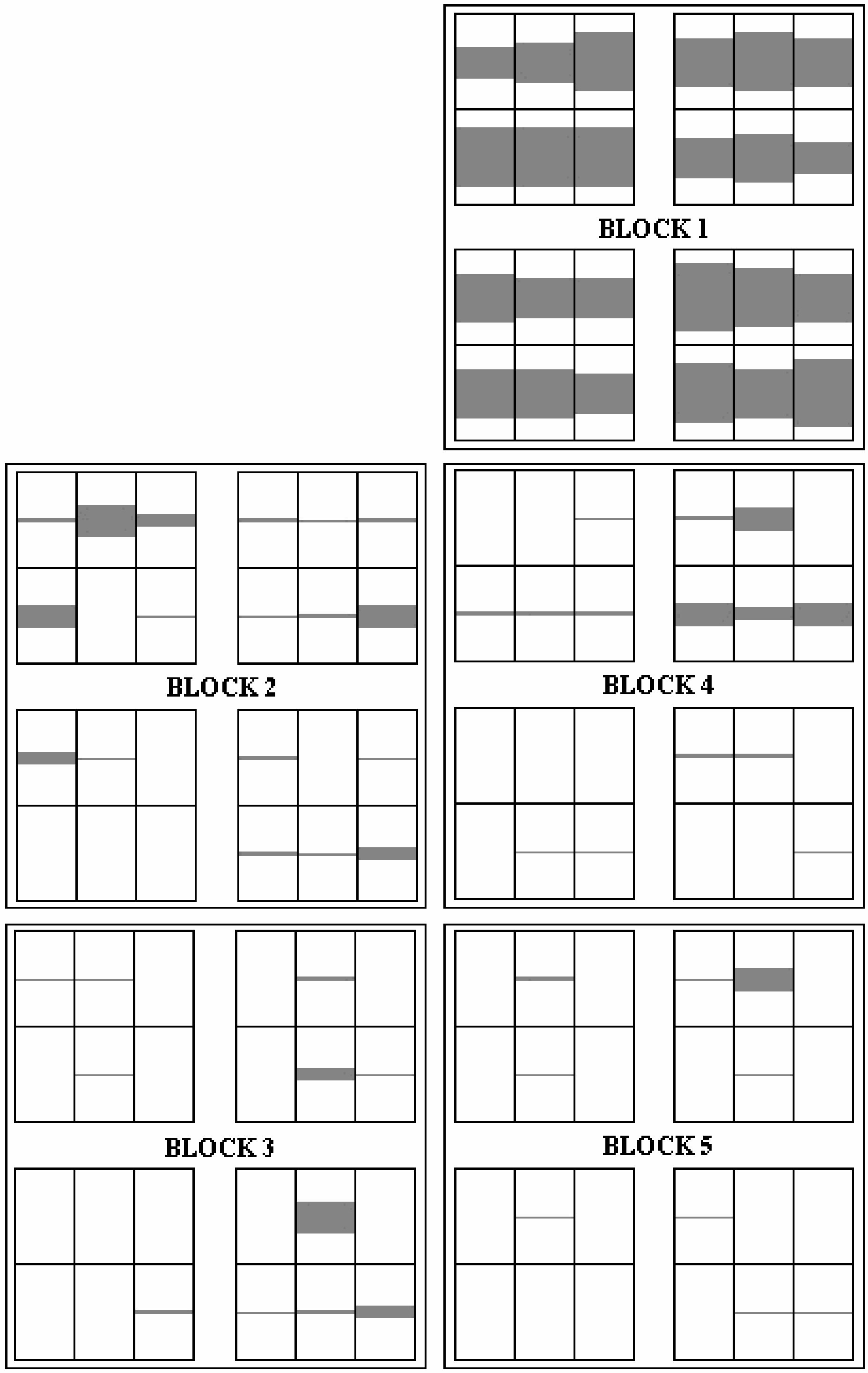


Figure 4-4. Distribution of Bromus madritensis (red brome) at the Tranquillity HRS, 2003. Each small rectangle represents a 'sextant'; i.e., the portion of the plot in which a particular group of four sampling quadrats was located. The shading represents the mean percent cover of red brome in that particular sextant.

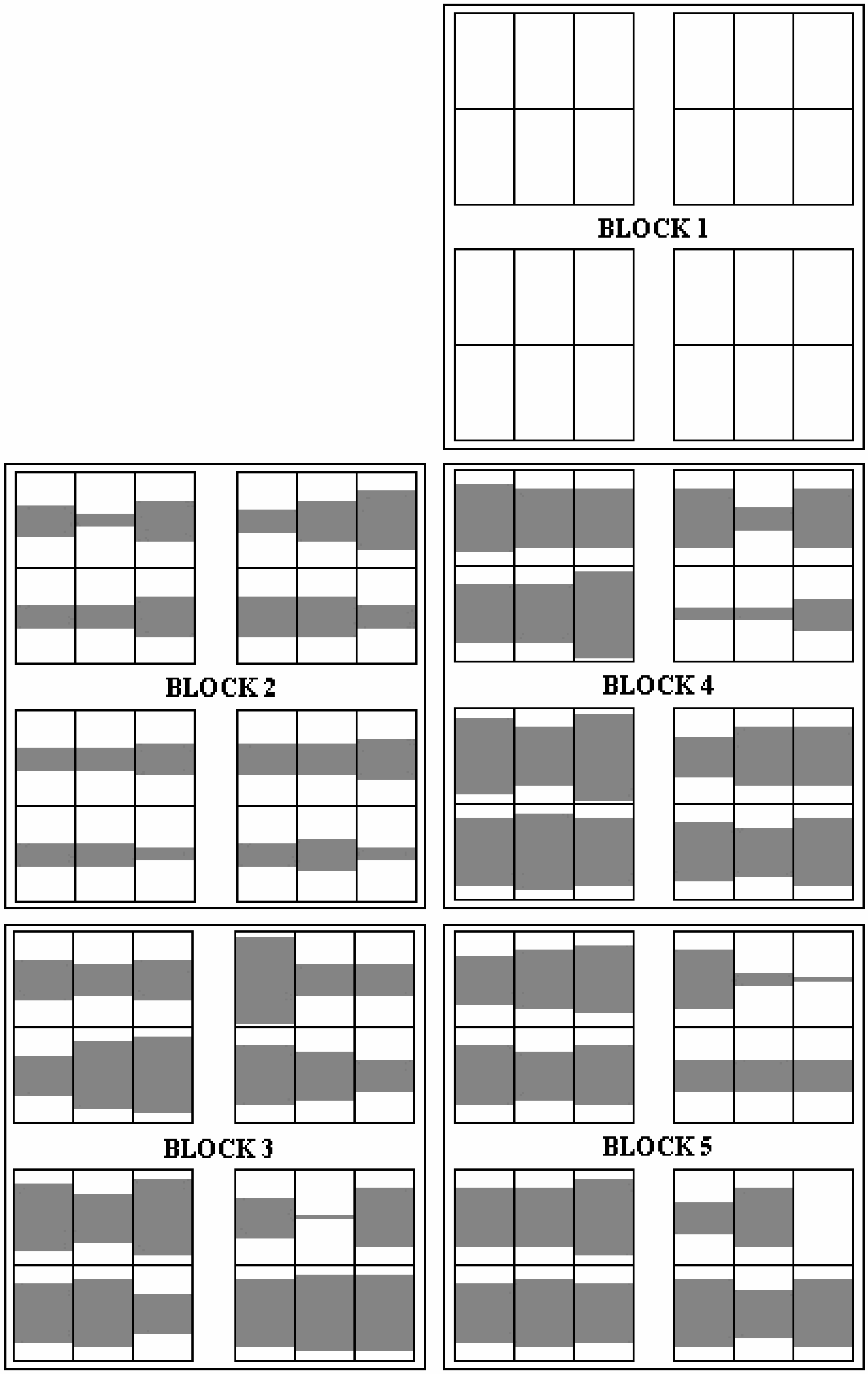


Figure 4-5. Distribution of Sisymbrium irio (London rocket) at the Tranquillity HRS. Each small rectangle represents a 'sextant', i.e., the portion of the plot in which a particular group of four sampling quadrats was located. The shading represents the mean percent cover of London Rocket in that particular sextant.

Generally, the areas dominated by *Bromus madritensis* were those with soils characterized by high electrical conductivity readings and high levels of soluble boron. These areas were the only part of the HRS in which the salt-tolerant *Allenrolfea occidentalis* survived. The buffers of the red brome-dominated plots also tended to have a large component of brome. This pattern was increasingly evident in the later years of the project, and was apparent throughout Block 1 and in the northern half of Block 4. Although *Sisymbrium irio* was an obvious component in buffers of the London rocket-dominated plots, it was not nearly as abundant as was red brome in the northernmost buffers.

A few additional, site-wide patterns should be noted. First, the relative absence of non-imprinted, native species was particularly troubling. With the exception of the tumbling saltweed *Atriplex argentea,* few non-imprinted native species have been observed on the study Plots. To date, only two 'desirable' native species, *Malacothrix coulteri* (snakes head) and *Phacelia ciliata* (valley Phacelia), have shown any sign of becoming established on the study site. Throughout the course of the project, abundances of both these species have been low (Table 4-7; Figure 4-6; Figure 4-7).

Also of note was the difference in appearance between the herbaceous vegetation on the plots and in the buffer areas (excluding those buffers dominated by red brome). Generally, species (both introduced and adventitious natives) in the buffer were more robust and showed less stress with the onset of the dry season than did the same species on the plots. In part, this pattern may be attributable to the barley ameliorating conditions to some degree (i.e., by functioning as a nurse crop). This difference in vegetation may also be a function of the different delivery techniques, as the plots were imprinted and the buffers drilled. Specifically, the depressions created by the imprinter appear to facilitate erosion of the clay soils at the Tranquillity site.

Treatments and blocks The predominance of non-native species that was evidenced in the site-wide abundance data (Table 4-7) was also clear when considering treatment-level vegetation patterns. To graphically represent the contribution of the various species and species classes to the site's vegetation, a series of rank-abundance curves were plotted (Figure 4-6; Figure 4-7).
Plots were ordered sequentially by Block number within each graph; hence, the leftmost curve represents the Plot from Block 1, the second to the left, Block 2, etc. Rank-abundance curves were plotted along the x-axis in such a way as to minimize overlap. Thus, no ordinal scale is presented along the x-axis; rather, the curves are interpreted such that the leftmost data point represents the highest (first) ranked species, with subsequent data points representing the second highest ranked species, etc.

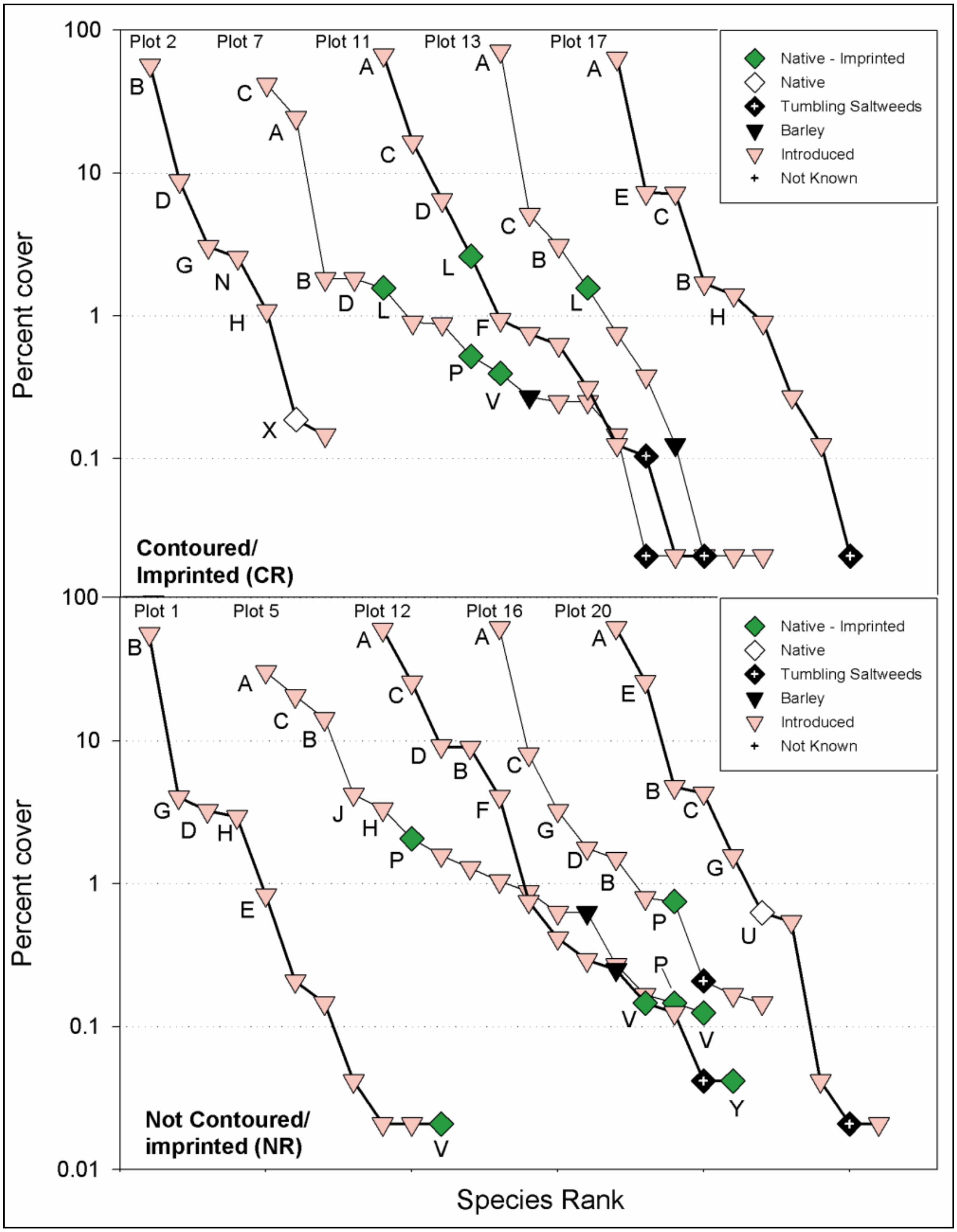


Figure 4-6. Species rank-abundance by treatment, Tranquillity HRS Plots 2003. Species letter codes correspond to those presented in Table 4-7. The five most abundant species in each plot and all native species are identified by letter code.

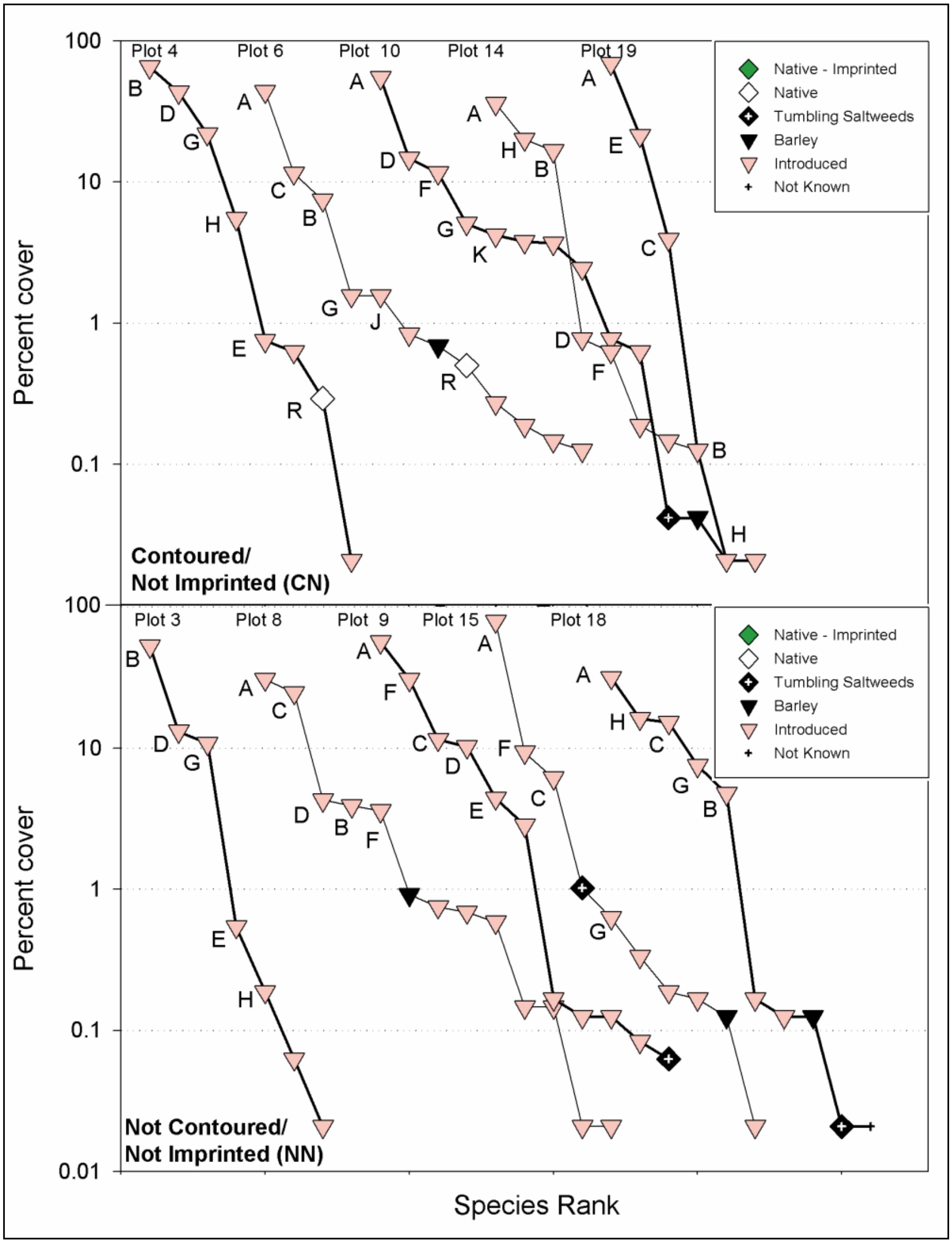


Figure 4-7. Species rank-abundance by treatment, Tranquillity HRS Plots 2003. Species letter codes correspond to those presented in Table 4-7. The five most abundant species in each plot and all native species are identified by letter code.

Regardless of treatment, the most abundant species on all plots were introduced. *Sisymbrium irio* (A) was the most abundant species on 15 plots. *Bromus madritensis* (B) was the most abundant species on 4 plots, and *Capsella bursa-pastoris* (C), the most abundant on a single plot. In no instances were imprinted native species highly ranked.

No strong differences were apparent in the slopes of the curves generated for the restored plots (Figure 4-6) versus those of the non-restored plots (Figure 4-7). This pattern differs from that observed in the preceding year (see Uptain et al. 2004), when the curves for the restored plots were noticeably less steep than those of the non-restored plots. This difference suggests that vegetation on the restored plots was becoming more homogenous, more dominated by a few species, over time.

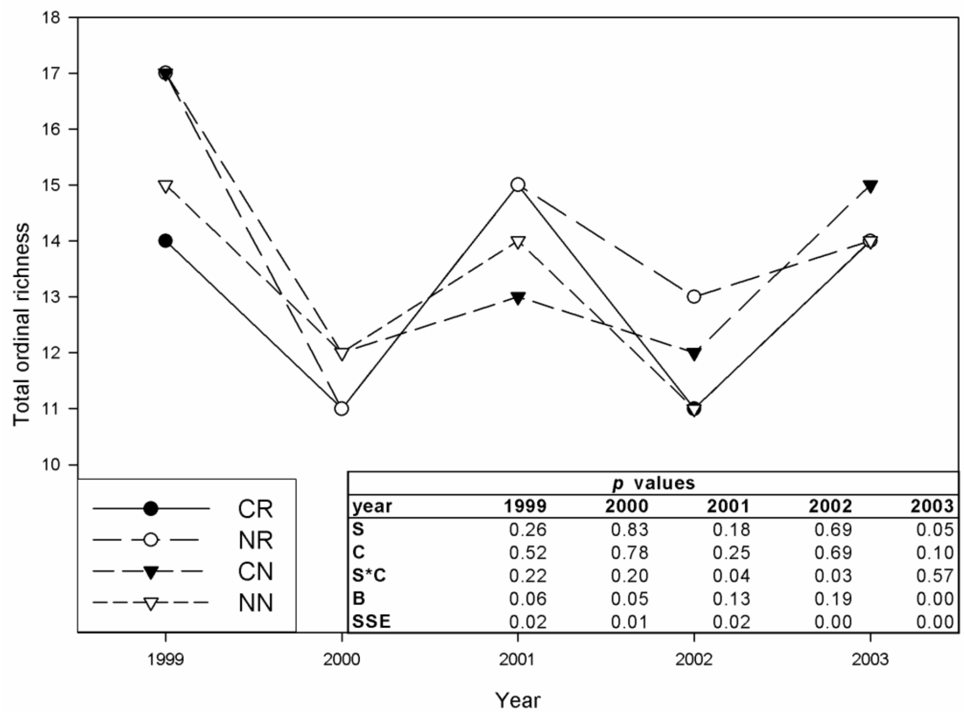
Atriplex polycarpa (L) is seen to have been more abundant on the imprinted and contoured plots (Figure 4-6) than on the imprinted but not contoured plots. This pattern was not surprising, as it was obvious during monitoring that *A. polycarpa*—as well as the other seeded perennial species—were most often located on the berms and associated trenches. In contrast, the most abundant imprinted annual species, *Vulpia microstachys* (P), was somewhat better represented on the non-contoured plots. Although the aforementioned patterns are noteworthy, the strongest pattern evidenced in the rank-abundance curves is the relatively low overall percent contribution of the native species.

The diminished presence of the cultivated barley (*Hordeum vulgare*) and of the tumbling saltweeds (*Atriplex rosea* and *A. argentea*) is of interest. In the first years following imprinting, there was concern that the barley that had persisted on the plots would out-compete the seeded species. While this may have occurred to some extent, the low abundance of barley relative to that of the dominant weed species suggests that this exclusion was not a major limiting factor in the establishment of native species. The low abundance of tumbling saltweeds is noteworthy because these species had dominated much of the site during the first summer after imprinting, and had facilitated the establishment of *Sisymbrium irio* (Uptain et al. 2004). Although *Atriplex rosea* and *A. argentea* were still abundant in re-seeded areas of the buffers in 2003, they had become scarce on the plots by this time. It seems likely that the diminished abundance of the tumbling saltweeds can be attributed to the low levels of soil disturbance on the plots. To elaborate, these species were readily able to colonize the plots in the summer following imprinting, as these areas had been recently disked.

4.3.1.2. Invertebrates

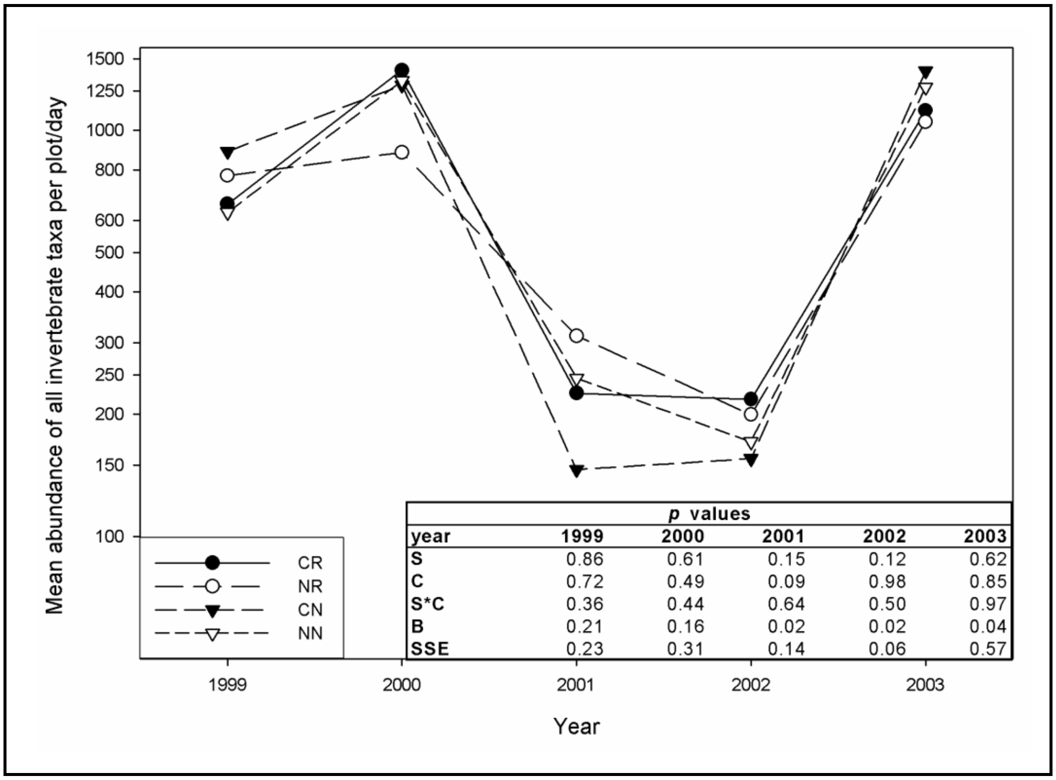
From 1999 to 2003 the richness (number of orders) of invertebrates on each treatment ranged from 11 to 17 (Figure 4-8). When data from all years are combined, the mean richness of invertebrates on each treatment varied only slightly (from 7.9 on contoured and unseeded plots to 8.5 on not contoured and seeded plots). Similarly, when data from all treatments are combined, the mean richness of invertebrates in each year varied only slightly (from 7.5 in 2002 to 8.6 in 2003). An analysis of the treatment factors (seeding and contouring) shows that there were differences between seeded and contoured plots versus not-seeded and not-contoured plots in both 2001 and 2002 (Figure 4-8). However, the mean richness of invertebrates is nearly identical (9.3 vs. 9.1 in 2001 and 7.1 vs. 7.1 in 2002) which indicates that there are no real differences.

There were large differences in invertebrate abundances between years ($p < 0.01$) with the fewest invertebrates present in 2002 (mean = 184.6 invertebrates per plot) and the most invertebrates present in 2000 and 2001 (mean = 1,207.7 invertebrates per plot; Figure 4-9). There were no clear effects of seeding (S) or contouring (C) in any year. There were clear differences in the abundance of invertebrates between the study blocks in 2001, 2002, and 2003.



p values					
year	1999	2000	2001	2002	2003
S	0.26	0.83	0.18	0.69	0.05
C	0.52	0.78	0.25	0.69	0.10
S*C	0.22	0.20	0.04	0.03	0.57
B	0.06	0.05	0.13	0.19	0.00
SSE	0.02	0.01	0.02	0.00	0.00

Figure 4-8. Ordinal richness of invertebrates for all treatments in 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

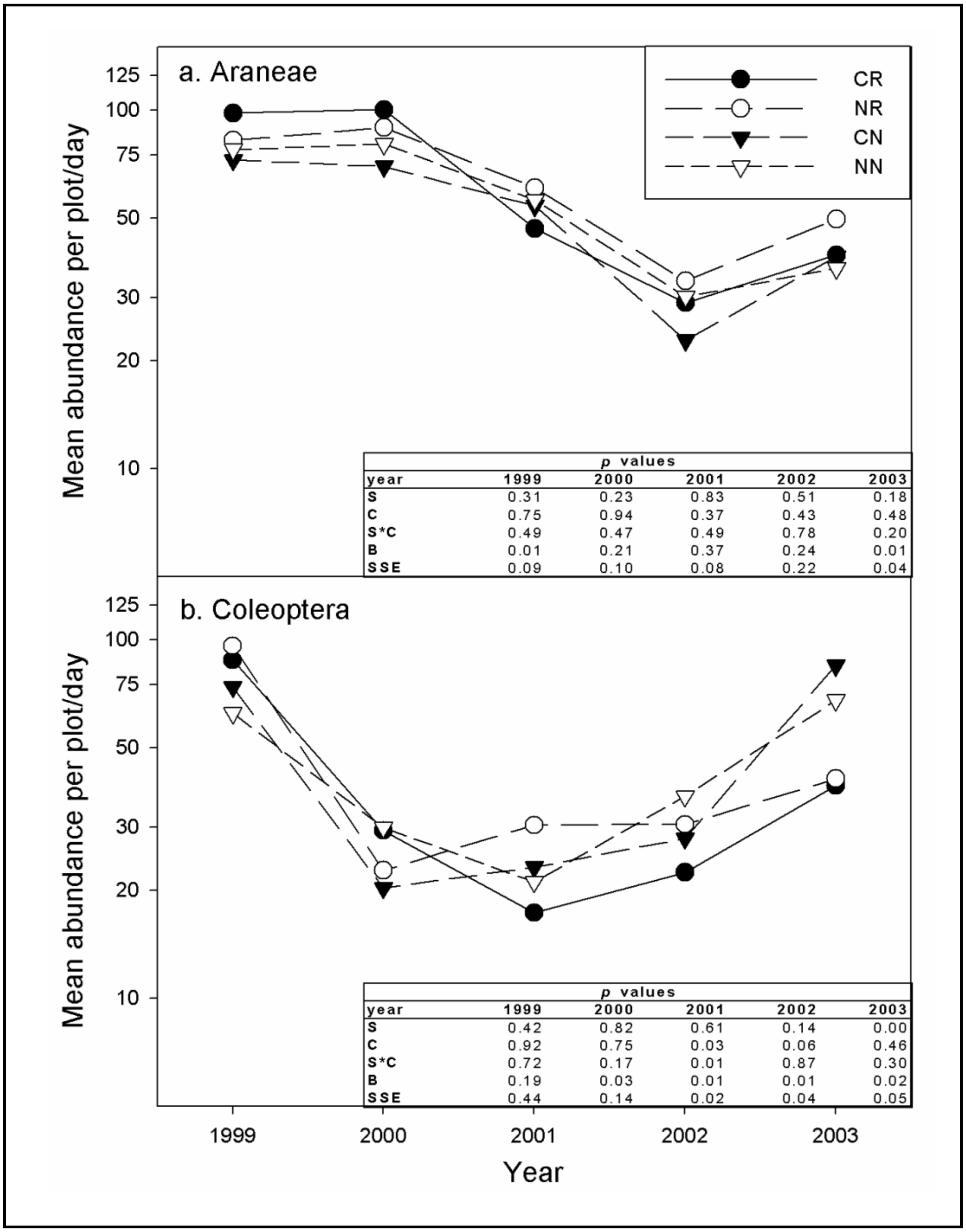


	p values				
year	**1999**	**2000**	**2001**	**2002**	**2003**
S	0.86	0.61	0.15	0.12	0.62
C	0.72	0.49	0.09	0.98	0.85
S*C	0.36	0.44	0.64	0.50	0.97
B	0.21	0.16	0.02	0.02	0.04
SSE	0.23	0.31	0.14	0.06	0.57

Figure 4-9. Mean invertebrate abundance for all treatments in 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

Neither beetles (Coleopteran) nor spiders (Araneae) showed a consistent response to contouring or seeding (Figure 4-10). However, in 2001 the abundance of beetles was greater on non-contoured plots (mean = 25.3) than on contoured plots (mean = 20.0) and in 2003 beetles were greater on non-seeded plots (mean = 75.7) than on seeded plots (mean = 40.0, Figure 4-10). In 2001 the plots that were seeded and contoured had a lower abundance of beetles (mean = 17.38) than plots that had no treatment applied (mean = 20.89; Figure 4-10), which is attributed to the influence of contouring.

Predators, pollinators, and parasites are beneficial to Central Valley agriculture and several herbivorous invertebrate families contain agricultural pests (N. Smith pers. comm. 2004). There were 12 orders containing at least 57 agriculturally-beneficial families identified on the HRS plots and 8 orders containing 17 families of agricultural pest species (Table 4-8 and Table 4-9Table 4-9).



year	1999	2000	2001	2002	2003
	p values				
S	0.31	0.23	0.83	0.51	0.18
C	0.75	0.94	0.37	0.43	0.48
S*C	0.49	0.47	0.49	0.78	0.20
B	0.01	0.21	0.37	0.24	0.01
SSE	0.09	0.10	0.08	0.22	0.04

year	1999	2000	2001	2002	2003
	p values				
S	0.42	0.82	0.61	0.14	0.00
C	0.92	0.75	0.03	0.06	0.46
S*C	0.72	0.17	0.01	0.87	0.30
B	0.19	0.03	0.01	0.01	0.02
SSE	0.44	0.14	0.02	0.04	0.05

Figure 4-10. Mean abundance of Coleoptera and Araneae for all treatments in 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

Table 4-8. Invertebrate families collected on the Tranquillity study plots that contain agriculturally beneficial species, 1999 to 2003.

Order	Family	Functional group(s)
Acarina	Anystidae	Predator
Araneae	Araneidae	Predator
	Clubionidae	Predator
	Gnaphosidae	Predator
	Lycosidae	Predator
	Oxyopidae	Predator
	Pholcidae	Predator
	Salticidae	Predator
	Theridiosomatidae	Predator
	Thomisidae	Predator
Coleoptera	Carabidae	Predator
	Cleridae	Predator
	Coccinellidae	Predator
	Histeridae	Predator
	Melyridae	Predator
	Staphylinidae	Predator
Diptera	Chironomidae	Pollinator
	Dolichopodidae	Predator
	Muscidae	Pollinator
	Sciomyzidae	Parasite/sitiod
	Stratiomyidae	Predator
	Syrphidae	Predator, Pollinator
	Tachinidae	Pollinator, Parasite/sitiod
Hemiptera	Anthocoridae	Predator
	Lygaeidae	Predator
	Nabidae	Predator
	Reduviidae	Predator
Hymenoptera	Andrenidae	Pollinator
	Apidae	Pollinator
	Bethylidae	Pollinator, Parasite/sitiod
	Braconidae	Pollinator, Parasite/sitiod
	Ceraphronidae	Pollinator, Parasite/sitiod
	Chalcididae	Pollinator, Parasite/sitiod
	Chalcidoidea	Pollinator, Parasite/sitiod
	Chrysididae	Pollinator, Parasite/sitiod
	Cynipidae	Pollinator, Herbivore
	Diapriidae	Pollinator
	Encyrtidae	Pollinator, Parasite/sitiod
	Eulophidae	Pollinator, Parasite/sitiod
	Formicidae	Predator, Pollinator
	Halictidae	Pollinator
	Ichneumonidae	Pollinator, Parasite/sitiod
	Megaspilidae	Pollinator
	Mutillidae	Pollinator, Parasite/sitiod
	Platygastridae	Pollinator, Parasite/sitiod
	Pompilidae	Predator, Pollinator
	Pteromalidae*	Parasite/sitiod
	Scelionidae	Pollinator, Parasite/sitiod
	Torymidae	Pollinator, Parasite/sitiod
Mantodea	Mantidae	Predator
Neuroptera	Chrysopidae	Predator
	Hemerobiidae	Predator
Odonata	Coenagrionidae	Predator
	Unknown Odonata	Predator
Opiliones	Unknown Opiliones	Predator
Scorpiones	Unknown Scorp.	Predator
Scolopendromorpha	Unknown Scolo.	Predator

Table 4-9. Invertebrate families collected on the Tranquillity study plots that contain agricultural pest species, 1999 to 2003.

Order	Family	Genus/Species	Common name	Functional group
Acarina	(Astigmata)	*Rhizoglyphus sp.*	Rhizoglyphid mites	Scavenger
Coleoptera	Chrysomelidae	*Chaetocnema repens*	Dichondra Flea Beetle	Herbivore
	Chrysomelidae	*Epitrix hirtipennis*	Tobacco Flea Beetle	Herbivore
	Curculionidae	*Hypera postica*	Alfalfa weevil	Herbivore
	Elateridae	*Aeolus sp.*	Click Beetle	Herbivore
	Elateridae	*Anchastus sp.*	Click Beetle	Herbivore
Diptera	Opomyzidae		Opomyzidae Fly	Herbivore
Hemiptera	Lygaeidae	*Nysius raphanus*	False Chinch Bug	Herbivore
	Miridae	*Lygus hesperus*	Lygus bug	Herbivore
	Pentatomidae	*Chlorochroa sp.*	Green Stink Bug	Herbivore
		Chlorochroa uhleri	Uhler's Stink Bug	Herbivore
		Chlorochroa sayi	Say Stink Bug	Herbivore
		Thyanta punctiventris	Stink Bug	Herbivore
Homoptera	Aphididae	*Macrosiphum euphorbiae*	Potato Aphid	Herbivore
	Cicadellidae	*Circulifer tenellus*	Beet Leafhopper	Herbivore
Lepidoptera	Noctuidae	*Peridroma saucia*	Variegated Cutworm	Herbivore
	Plutellidae	*Plutella maculipennis*	Diamondback Moth	Herbivore
Orthoptera	Acrididae		grasshopper	Herbivore
Thysanoptera	Thripidae	*Frankliniella occidentalis*	Western Flower Thrips	Herbivore
	Thripidae	*Caliothrips fasciatus*	bean Thrips	Herbivore

4.3.1.3. Amphibians and Reptiles

Diversity of amphibians and reptiles increased from a low of one species observed in 1999, to three species observed since 2001 (Table 4-10). Western toads (*Bufo boreas*) were the only amphibian observed and were seen during a variety of surveys and seasons. Two species of reptiles, the western whiptail (*Cnemidophorus tigris)* and the gopher snake (*Pituophis catenifer*), were seen in 1999 and 2000, but were not observed in the following years. They are likely still present in low numbers. California king snakes (*Lampropeltis getulus californiae*) and western fence lizards (*Sceloporus occidentalis*) were observed 3 of the 5 years.

Table 4-10. Diversity of amphibians and reptiles observed at Tranquillity 1999-2003.

Year	Species observed	Richness
1999	western whiptail	1
2000	western toad, gopher snake	2
2001	western toad, western fence lizard, California king snake	3
2002	western toad, western fence lizard, California king snake	3
2003	western toad, western fence lizard, California king snake	3

4.3.1.4. Birds

Bird diversity and abundance surveys Forty-four species of birds were observed using the study plots over the 5-year study period. In addition to these, numerous other species had been documented using neighboring areas including the buffer, roadsides, adjacent lands, and airways. Of the 44 species observed using the study plots, ten are of special status (Table 4-11).

Table 4-11. Special status bird species observed on the Tranquillity study plots, 1999 to 2003. CSC = California special concern species, FSC = federal special concern species, FP = fully protected in California.

Species	Status
western burrowing owl *(Athene cunicularia hypugaea)*	CSC, FSC
California horned lark *(Eremophila alpestris actica)*	CSC
loggerhead shrike *(Lanius ludovicianus)*	CSC, FSC
long-billed curlew *(Numenius americanus)*	CSC
mountain plover *(Charadrius montanus)*	CSC
northern harrier *(Circus cyaneus)*	CSC
prairie falcon *(Falco mexicanus)*	CSC
short-eared owl *(Asio flammeus)*	CSC
white-tailed kite *(Elanus leucurus)*	FP
Vaux's swift *(Chaetura vauxi)*	CSC

The richness (number of bird species present) per year on all plots combined ranged from 13 to 19 and richness per season ranged from 7 to 19. The lowest richness for a restoration treatment was in the summer of 1999 when there was a mean of 0.40 bird species per plot on the control plots (Figure 4-11). Surprisingly, the highest richness was also on control plots in the winter of 2001, when there was a mean of 6.40 bird species per plot. The greatest variation in mean richness among treatments was during the summer surveys, but summer also accounted for the lowest richness in all years. Neither seeding nor contouring, nor their interaction, had a detectable effect on avian richness, except in the summer of 1999 when seeding resulted in a 127 percent greater mean

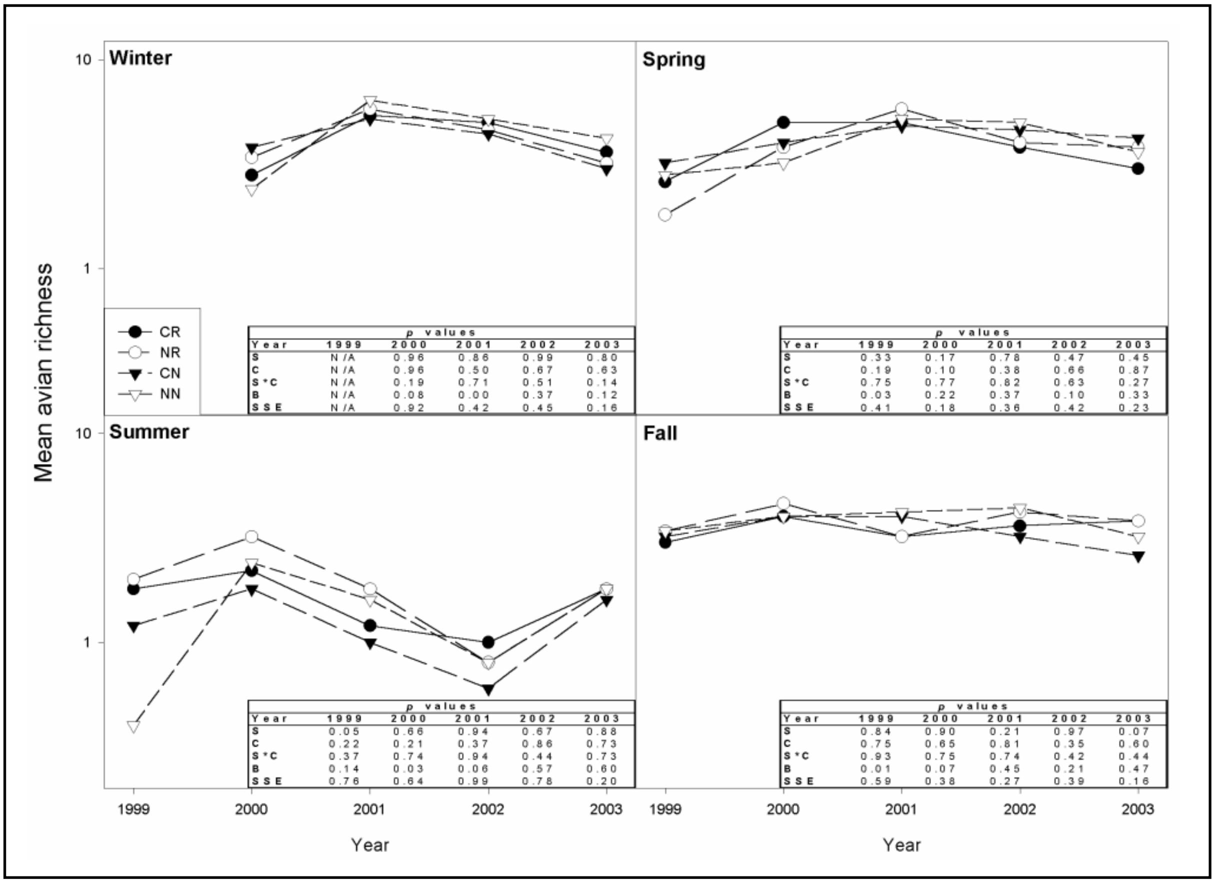


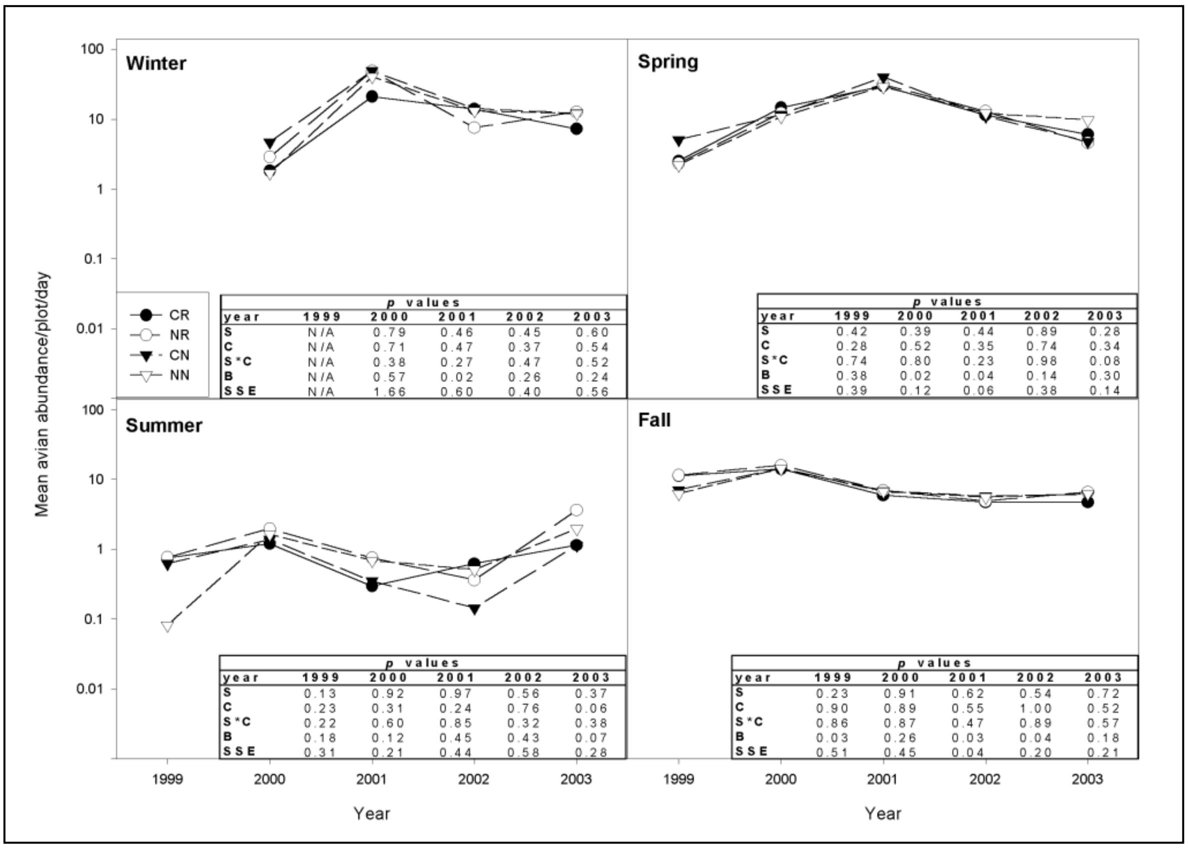
Figure 4-11. Mean richness of birds by treatment in winter, spring, summer, and fall 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

richness than other treatment factors. There were discernable differences in richness between study blocks in all seasons but not in all years. In those instances, blocks 1, 2, and 4 had richness values from 106 to 284 percent greater than on other blocks (Table 4-12).

Table 4-12. Blocks with the highest mean richness of birds, season and year of occurrence, and the magnitude of difference from other blocks (percent greater than the lowest and highest values from other blocks).

Block	Season	Year	Magnitude of difference	p-value
2 and 4	winter	2001	107 to 242%	< 0.01
1	spring	1999	147 to 284%	0.03
2	summer	2000	156 to 280%	0.03
4	fall	1999	106 to 284%	0.01

The seasonal abundances of birds on all plots combined ranged from a low of 35 birds in summer of 2002 to a high of 3,283 birds in winter 2001. The greatest variation in the mean abundance of birds between the various restoration treatments was during the summer survey periods (Figure 4-12). Neither seeding or contouring, or their interaction affected the abundance of birds. However, there were clear differences in avian abundance among blocks in some seasons and years. In those instances, blocks 2, 4, and 5 had from 102 to 835 percent greater abundance of birds than other blocks (Table 4-13). Obligate grassland birds and facultative grassland birds were more numerous than other birds ($p < 0.01$ and $p < 0.01$) by approximately 394 and 325 percent, respectively (Figure 4-13). Obligate grassland birds were more numerous than facultative grassland birds, except in 2001, but these differences were not statistically supported ($p = 0.56$). Neither seeding nor contouring, or the interaction of these factors, influenced the abundance of obligate grassland birds or facultative grassland birds (Figure 4-14). The only exception to this was in 2003 when obligate grassland birds were less common the contoured plots than on the seeded, seeded and contoured, or control plots.



Winter

p values					
year	1999	2000	2001	2002	2003
S	N/A	0.79	0.46	0.45	0.60
C	N/A	0.71	0.47	0.37	0.54
S*C	N/A	0.38	0.27	0.47	0.52
B	N/A	0.57	0.02	0.26	0.24
SSE	N/A	1.66	0.60	0.40	0.56

Spring

p values					
year	1999	2000	2001	2002	2003
S	0.42	0.39	0.44	0.89	0.28
C	0.28	0.52	0.35	0.74	0.34
S*C	0.74	0.80	0.23	0.98	0.08
B	0.38	0.02	0.04	0.14	0.30
SSE	0.39	0.12	0.06	0.38	0.14

Summer

p values					
year	1999	2000	2001	2002	2003
S	0.13	0.92	0.97	0.56	0.37
C	0.23	0.31	0.24	0.76	0.06
S*C	0.22	0.60	0.85	0.32	0.38
B	0.18	0.12	0.45	0.43	0.07
SSE	0.31	0.21	0.44	0.58	0.28

Fall

p values					
year	1999	2000	2001	2002	2003
S	0.23	0.91	0.62	0.54	0.72
C	0.90	0.89	0.55	1.00	0.52
S*C	0.86	0.87	0.47	0.89	0.57
B	0.03	0.26	0.03	0.04	0.18
SSE	0.51	0.45	0.04	0.20	0.21

Figure 4-12. Mean abundance of birds by treatment in winter, spring, summer, and fall 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

Table 4-13. Blocks with the highest mean abundance of birds, season and year of occurrence, and the magnitude of difference from other blocks (percent greater than the lowest and highest values from other blocks).

Block	Season	Year	Magnitude of difference	*p*-value
2	Winter	2001	116 to 440%	0.02
5	Spring	2000	104 to 214%	0.02
5	Spring	2001	102 to 136%	0.04
2	Fall	1999	135 to 835%	0.03
4	Fall	2001	112 to 167%	0.03
4	Fall	2002	105 to 277%	0.04

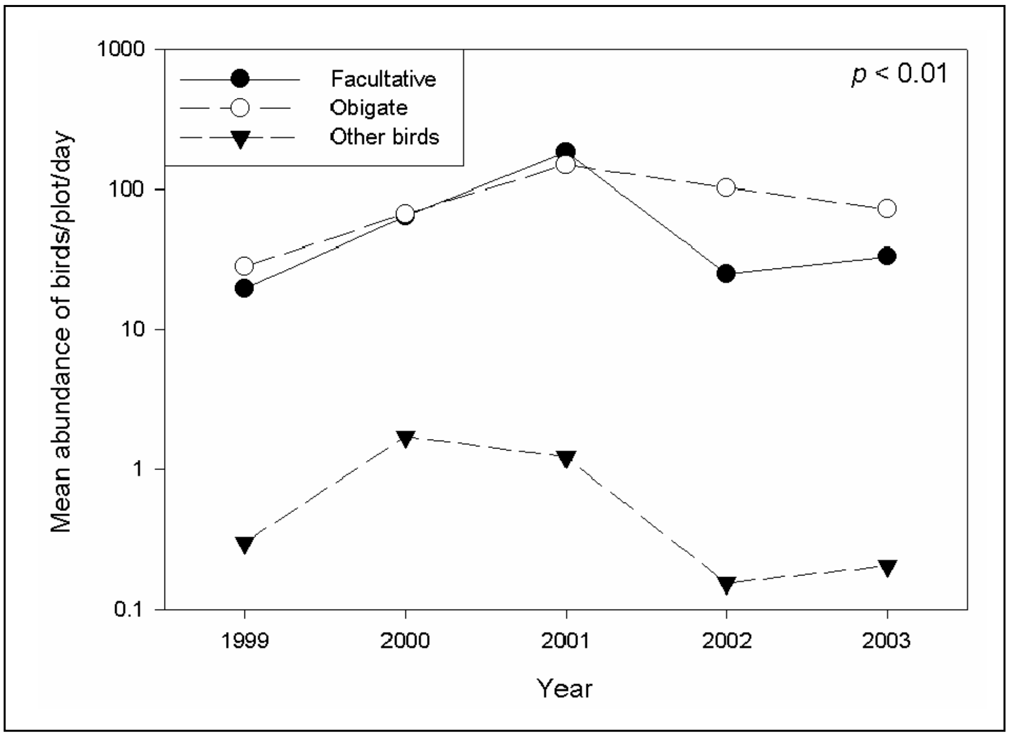


Figure 4-13. Mean abundance (mean number of birds observed per plot per day, all seasons combined) of obligate grassland birds, facultative grassland birds, and other birds, 1999 to 2003.

There were clear differences in the abundance of obligate and facultative grassland birds and other birds between study blocks. When differences occurred, blocks 2 and 4 had a greater abundance of obligate grassland species, Block 2 had a greater abundance of facultative species and Block 1 had a greater abundance of other birds (Table 4-14).

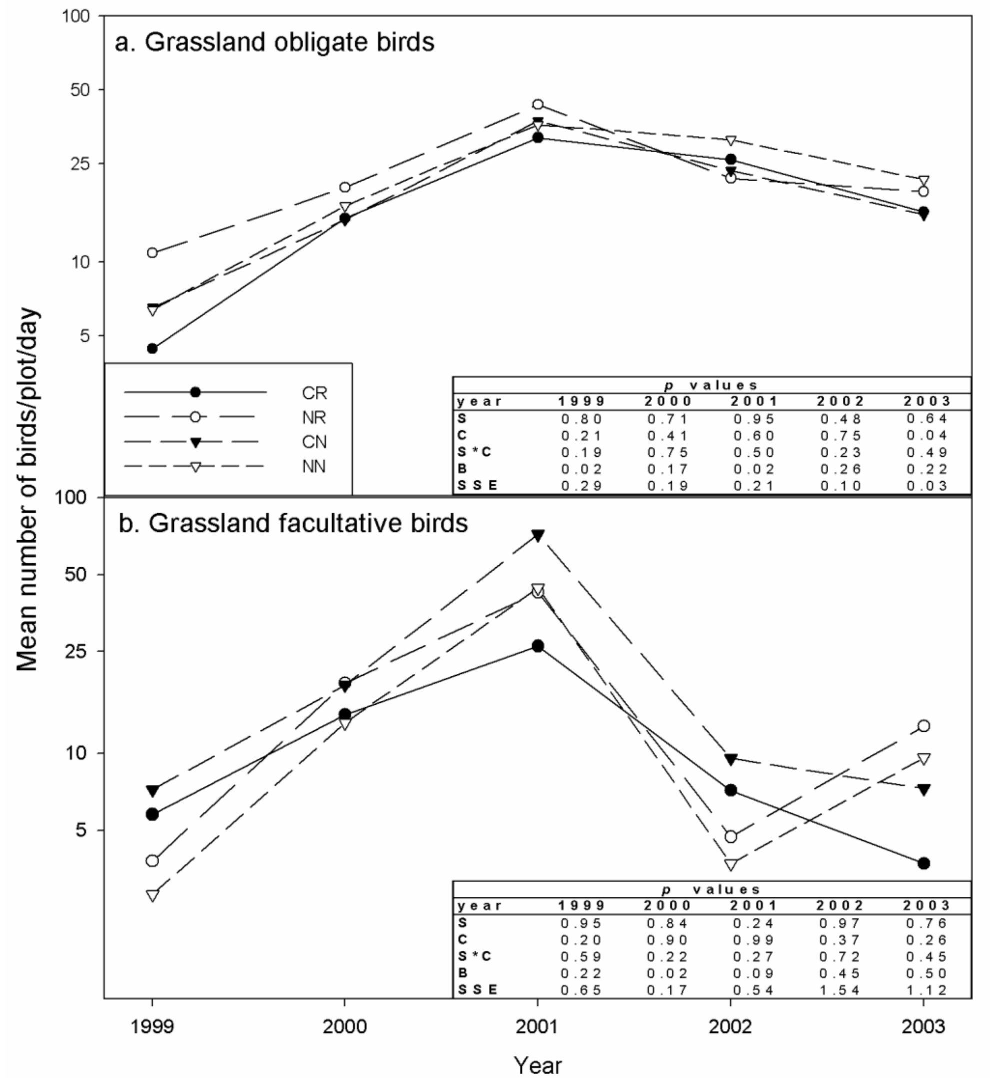


Figure 4-14. Mean abundance of grassland obligates and facultative birds by treatment, 1999 to 2003.

Table 4-14. Blocks with the highest mean abundance of grassland obligate birds, grassland facultative birds, and other birds, season and year of occurrence, and the magnitude of difference from other blocks (percent greater than the lowest and highest values from other blocks).

Grassland niche	Block	Year	Magnitude of difference	*p*-value
Obligate	2	1999	160 to 623%	0.02
	4	2001	110 to 204%	0.02
Facultative	2	2000	113 to 245%	0.02
Other	1	2000	91 to 292%	0.01

Bird nesting on the Habitat Restoration Study plots Seventeen nests of three species were located on the study plots in 2002 (Table 4-15). Six nests of two additional species were found outside of the study plots, five of which were monitored. In 2003, 21 nests of three species were located on the study plots. A single western meadowlark (*Sturnella neglecta*) nest was located in a buffer and it was not monitored. A northern harrier (*Circus cyaneus*) nest that was found on Plot 13 also was not monitored because of the sensitive status of this species and the potential for monitoring to interrupt nesting success. Mallard (*Anas platyrhynchos*) nests declined from 14 in 2002 to 4 in 2003 while red-winged blackbirds (*Agelaius phoeniceus*) did not nest on the site in 2002 but were the most common nesting bird with 16 nests present in 2003.

Table 4-15. Nest abundance and species richness, 2002 and 2003. Parentheses indicate nest numbers off study plot areas and asterisks indicate nests not monitored.

Species	Numbers of nests located	
	2002	2003
horned lark (Eremophila alpestris)	(1)*	0
loggerhead shrike (Lanius ludovicianus)	(2)	0
mallard (Anas platyrhynchos)	14	4
northern harrier (Circus cyaneus)	0	1*
red-winged blackbird (Agelaius phoeniceus)	0	16
short-eared owl (Asio flammeus)	2 (1)	0
western meadowlark (Sturnella neglecta)	1 (2)	(1)*
Total nests	17 (6)	21 (1)
Species richness	5	4

Approximately equal numbers of nests were found on plots with contours and on plots without contours in both 2002 and 2003 (Figure 4-15 and Figure 4-16). In 2002 nests were approximately 352 percent more abundant on non-seeded plots (13) than on seeded plots (4), but in 2003 nests were approximately equal in number on non-seeded (11) and seeded plots (10). The greatest concentration of nests found in 2002 (41 percent) was on plot 6; a plot that was contoured, but not seeded. In contrast, the greatest concentration of nests found in 2003 (33 percent) was on plot 20; a plot that was seeded, but not contoured. In 2002 the distribution of nests was concentrated in Block 2 (48 percent) and in 2003 nests were concentrated in Block 5 (59 percent).

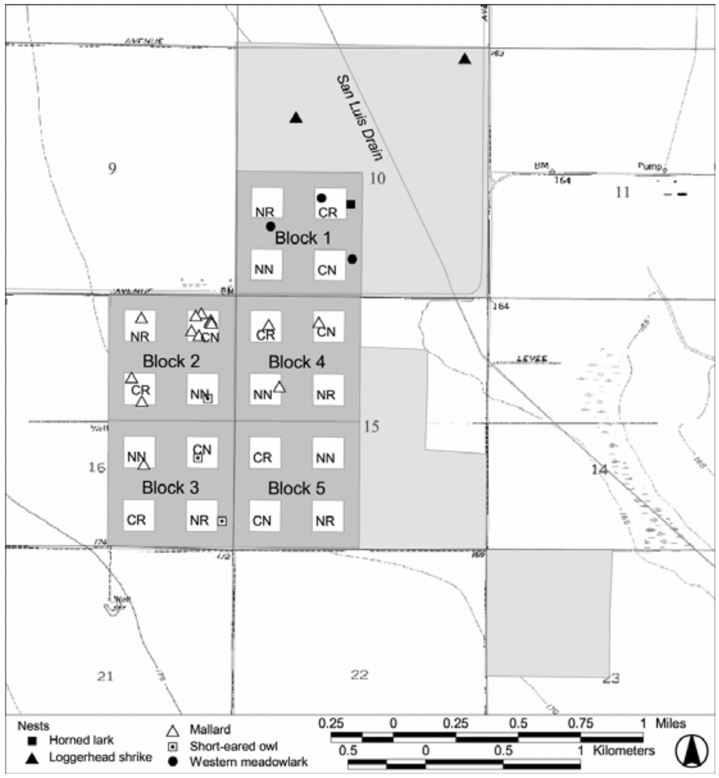


Figure 4-15. Locations of bird nests found in 2002 at the Tranquillity study site.

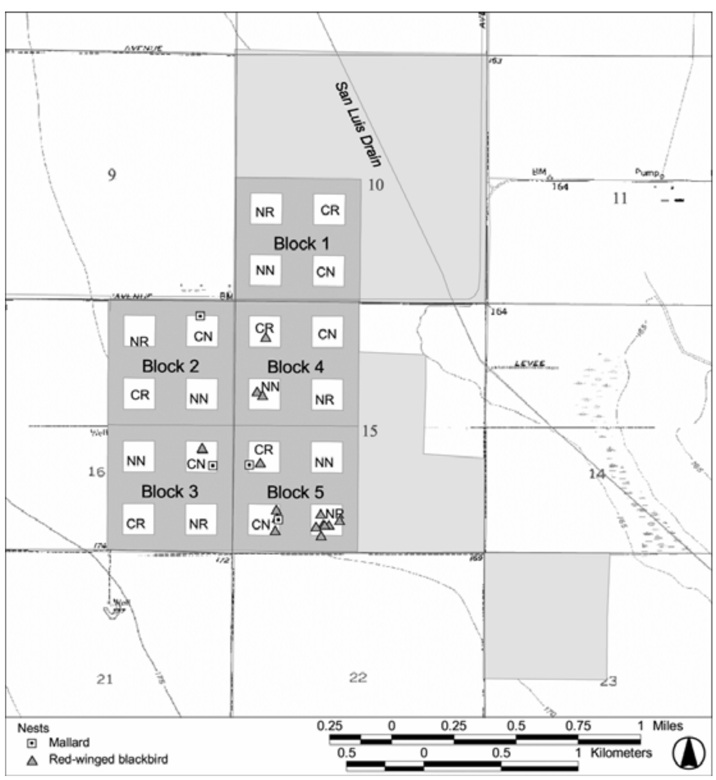


Figure 4-16. Locations of bird nests found in 2003 at the Tranquillity study site.

All nesting bird species initiated clutches in mid-March, except loggerhead shrikes, which initiated clutching in late February (Table 4-16). Mean fledging dates for all species occurred in April. Mean clutch size varied by species from 3.7 to 10.2 eggs. These clutch sizes are within the expected range for each species (Baicich and Harrison 1997). Nesting success rates varied by species from 33 percent in western meadowlarks to 100 percent in loggerhead shrikes (*Lanius ludovicianus*). The clutch size and nest success rate of mallards declined from 2002 to 2003.

Table 4-16. Mean nest initiation dates, mean fledging dates, mean clutch size, and nesting success rates of bird species nesting on the Tranquillity study site, 2002 and 2003.

Year	Species	Initiation date	Fledge date	Clutch size	Success rate	Sample size (n)
2002	mallard (Anas platyrhynchos)	16-Mar	17-Apr	10.2	0.57	14
	short-eared owl (Asio flammeus)	18-Mar	25-Apr	7.7	0.67	3
	western meadowlark (Sturnella neglecta)	19-Mar	09-Apr	3.7	0.33	3
	loggerhead shrike (Lanius ludovicianus)	28-Feb	06-Apr	5.5	1.00	2
2003	mallard (Anas platyrhynchos)	15-Mar	21.5-Apr	8.7	0.50	4
	red-winged blackbird (Agelaius phoeniceus)	11.5-Mar	26.5-Apr	3.4	0.62	16

Two of the three short-eared owl nests found in 2002 were successful, producing five and six fledglings, respectively. Both nests were oriented toward the north and they were approximately 50 cm (20 inches) in diameter. Nests consisted of a ground scrape sparsely lined with dead barley stems. The nests of western meadowlarks were domed structures concealed by a canopy of fine grass with a small tunnel at the entrance of each nest. One loggerhead shrike nest was located in a quailbush (*Atriplex lentiformis*)-hedgerow in the northern section of the project site, approximately 0.4 km (0.25 mi) north of the study plots. Another was located in an *A. polycarpa* shrub growing in the bottom of the Lateral 7 Inlet Canal. Both nests were approximately 1.5 m (5 ft) above the ground. One nest was a cup of small twigs lined with fine grass and no information was obtained on the second nest due to a fire, which occurred post-fledging. One nest produced six fledglings and the other produced five.

The 14 mallard nests present on the site in 2002 and the 16 red-winged blackbird nest present on the site in 2003 were sufficient to calculate various parameters associated with nesting survival. The Mayfield method (Mayfield 1961, 1975) was only applied to these two data sets.

Nesting parameters of mallards Eight of the 14 mallard nests successfully yielded fledglings. The survival rate of nests (nests surviving per day during incubation) was 0.98 resulting in a 55 percent probability of a nest surviving through the 27.5 day incubation period. There was a 95 percent probability that eggs would survive the incubation period within a surviving nest. However, since the success rate of nests is only 55 percent, the actual rate of egg survival is 52 percent. Some surviving eggs did not hatch and produce surviving young. When this is taken into account, there was a 51 percent probability that an egg would produce a hatchling. Due to the precocial behavior of mallard ducklings, determining the exact survival of nestlings and fledglings is difficult without constant nest monitoring following hatching. We have assumed that those eggs that successfully produced a hatchling also produced a successful fledgling (unless there was compelling evidence to the contrary obtained during nest inspections). Accordingly, the fledgling survival rate of 51 percent may be somewhat elevated.

Mallard nests typically were constructed of dead barley (*Hordeum vulgare*) and silver scale (*Atriplex argentea*) stems, contained down lining, and were constructed flush with the ground level. Approximately 80 percent of the nests were partially or completely concealed by shrubs, primarily dead *A. argentea*. One nest was found underneath a live *Atriplex polycarpa*. The vegetative composition surrounding the nest sites was approximately 27 percent forbs, 26 percent shrubs, and 9 percent grasses (Table 4-17). There was an average 3.14 plant species associated with mallard nests and there were no differences between the number of plant species associated with successful nests and unsuccessful nests ($p = 0.95$). There was no positive correlation between nest success and the number of plant species present at the nest sites ($p = 0.48$) and the presence of individual plant species did not affect nest success ($p > 0.34$ for all 6 species tested).

Table 4-17. Vegetative composition and ground cover at mallard and red-winged blackbird nests.

Average estimated percentages for ground cover categories	2002 mallard n = 14	2003 red-winged blackbird = 16
Litter	25%	47%
Bare ground	11%	18%
Grass	9%	35%
Shrub	26%	0
Forb	27%	0
Total green	62%	35%

Nesting parameters of red-winged blackbirds Ten of the 16 red-winged blackbird nests yielded at least one fledgling. The survival rate of nests was 0.96 resulting in a 50 percent probability of a nest surviving through the 14-day incubation period. There was a 96 percent probability that eggs would survive the incubation period within a surviving nest. However, since the success rate of nests was only 50 percent, the actual rate of egg survival was 48 percent. Because some surviving eggs did not produce surviving young, there was a 56 percent probability that a surviving egg would produce a hatchling.

Red-winged blackbird nests were constructed at an average height of 28.57 cm (11.2 inches) on a stand of London rocket (*Sisymbrium irio*). Dead grasses and forbs, primarily barley stems and black mustard (*Brassica nigra*), were woven into a deep cup to form each nest. There was no difference in the height of successful and unsuccessful nests ($p = 0.63$) and there was an average of 3.75 plant species associated with the nest sites. There were no differences in the number of plant species present at successful and unsuccessful nest sites ($p = 0.09$), but there was a positive correlation between nest success and the number of plant species present at the nest sites (R = 0.02). The presence of individual plant species did not affect nest success ($p > 0.25$ for all 11 species tested).

4.3.1.5. Small Mammals

Seven species of small mammals were captured (Table 4-18): deer mice (*Peromyscus maniculatus*), Heermann's kangaroo rats (*Dipodomys heermanni*), house mouse (*Mus musculus*), California vole (*Microtus californicus*), western harvest mouse (*Reithrodontomys megalotis*), ornate shrew (*Sorex ornatus*), and Botta's pocket gopher (*Thomomys botta*). The majority of captures (97 percent) were deer mice. Ornate shrews, California voles, deer mice, and Botta's pocket gophers were captured in pitfalls. Shrews were primarily captured from contoured plots in 1999 and from seeded plots in 2000, 2001, and 2002 (Table 4-19). In 2003 shrews were captured in equal numbers on treated plots but were captured in greater numbers on the control plots.

Table 4-18. The number of small mammals captured in live traps and pitfall traps on the Habitat Restoration Study plots, Tranquillity site, 1999 to 2003.

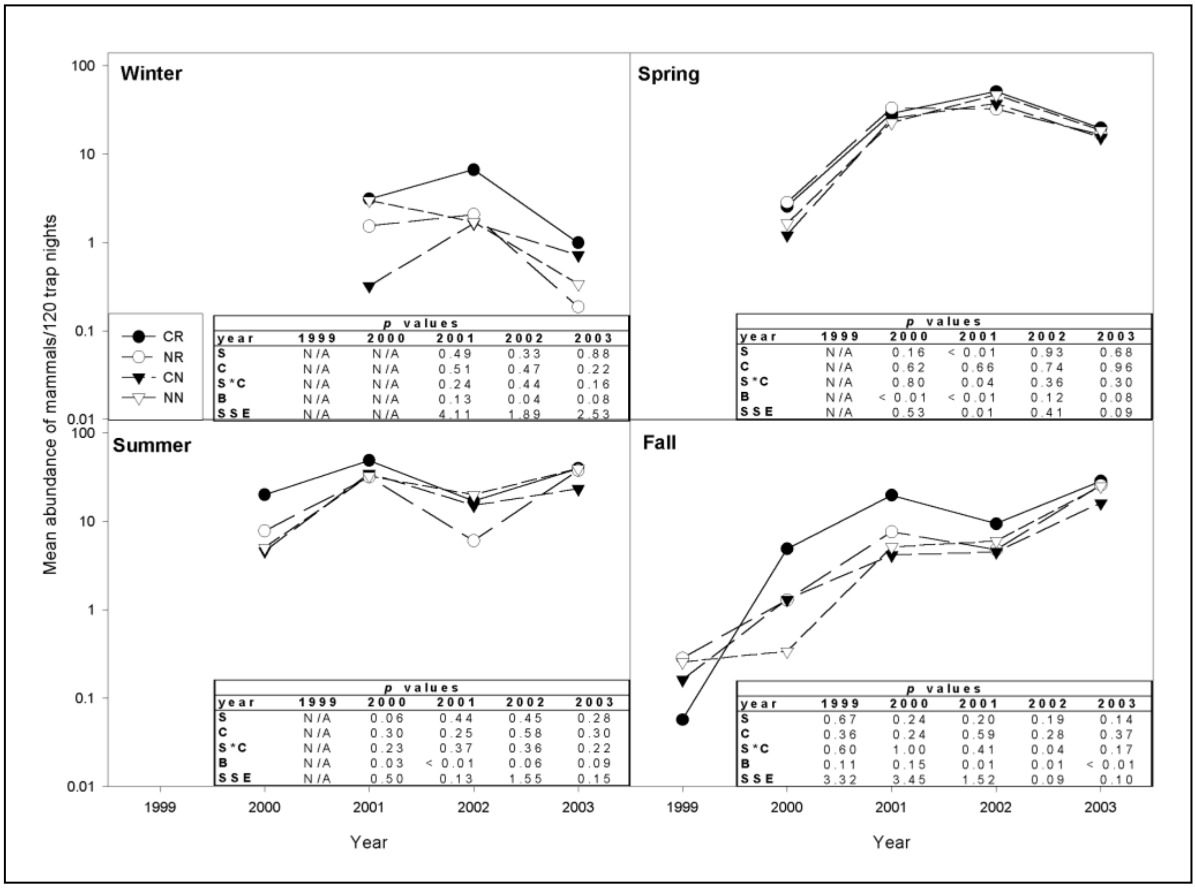
	Species	1999	2000	2001	2002	2003
Live-traps	*Dipodomys heermanni*	0	0	0	12	5
	Microtus californicus	0	0	1	0	0
	Mus musculus	2	14	47	1	0
	Peromyscus maniculatus	24	592	2,310	1,830	1,849
	Reithrodontomys megalotis	0	0	0	1	0
Pitfall traps	*Microtus californicus*	3	0	37	2	1
	Peromyscus maniculatus	0	0	0	40	14
	Sorex ornatus	14	18	25	20	26
	Thomomys botta	0	0	0	2	0
	species richness	4	3	4	7	4

Table 4-19. The number of ornate shrews (*Sorex ornatus*), California voles (*Microtus californicus*), and Botta's pocket gophers captured in the pitfall traps at the Tranquillity study site, 1999 to 2003.

Year	Species	Treatment code[1]				Total
		CR	CN	NR	NN	
1999	*Sorex ornatus*	1	10	2	1	14
	Microtus californicus	1	1	1	0	3
2000	*Sorex ornatus*	7	3	5	3	18
	Microtus californicus	0	0	0	0	0
2001	*Sorex ornatus*	11	0	11	3	25
	Microtus californicus	4	19	10	4	37
2002	*Sorex ornatus*	6	2	8	4	20
	Microtus californicus	1	0	1	0	2
	Thomomys botta	0	1	0	1	2
2003	*Sorex ornatus*	6	6	6	8	26
	Microtus californicus	0	1	0	0	1

[1] Treatment codes: CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded.

There was no clear evidence that restoration treatment ($p = 0.28$) or treatment factor ($p = 0.18$ for the seeded factor and $p = 0.56$ for the contoured factor) consistently affected the abundance of small mammals. However, in some years and seasons, treatment factor did seem to affect the abundance of small mammals (Figure 4-17). In spring 2001, seeding appeared to result in a 108 percent greater abundance of small mammals than non-seeding, and in fall 2002, the combination of seeding and contouring appeared to result in a 125 percent greater abundance of small mammals than not seeding and not contouring. The abundance of small mammals fluctuated yearly ($p < 0.01$), seasonally ($p < 0.01$), and by block ($p < 0.01$). The lowest total abundance was in fall 1999 when there were 27 captures and the greatest abundances were in summer 2001 and spring 2002 when we captured 996 and 995 animals, respectively.



Winter

p values					
year	1999	2000	2001	2002	2003
S	N/A	N/A	0.49	0.33	0.88
C	N/A	N/A	0.51	0.47	0.22
S*C	N/A	N/A	0.24	0.44	0.16
B	N/A	N/A	0.13	0.04	0.08
SSE	N/A	N/A	4.11	1.89	2.53

Spring

p values					
year	1999	2000	2001	2002	2003
S	N/A	0.16	< 0.01	0.93	0.68
C	N/A	0.62	0.66	0.74	0.96
S*C	N/A	0.80	0.04	0.36	0.30
B	N/A	< 0.01	< 0.01	0.12	0.08
SSE	N/A	0.53	0.01	0.41	0.09

Summer

p values					
year	1999	2000	2001	2002	2003
S	N/A	0.06	0.44	0.45	0.28
C	N/A	0.30	0.25	0.58	0.30
S*C	N/A	0.23	0.37	0.36	0.22
B	N/A	0.03	< 0.01	0.06	0.09
SSE	N/A	0.50	0.13	1.55	0.15

Fall

p values					
year	1999	2000	2001	2002	2003
S	0.67	0.24	0.20	0.19	0.14
C	0.36	0.24	0.59	0.28	0.37
S*C	0.60	1.00	0.41	0.04	0.17
B	0.11	0.15	0.01	0.01	< 0.01
SSE	3.32	3.45	1.52	0.09	0.10

Figure 4-17. Mean abundance of small mammals per 120 trap nights in winter, spring, summer, and fall at the Tranquillity study site, 1999 to 2003. Treatment codes: CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

4.3.2. Site-Wide Surveys

4.3.2.1. Spotlighting Surveys

The only amphibians and reptiles that were observed during the spotlight surveys were western toads (*Bufo boreas*) and California king snakes (*Lampropeltis getulus californiae*). These species were observed infrequently, with the greatest rate of observation occurring in 2000 when 0.13 western toads per km (0.6 mi) were observed (Figure 4-18). During the entire survey period, only two California king snakes were observed, one in summer of 2000 and one in fall of 2001 (Table 4-20). Birds and mammals were more common, but the rate of observations of these species never exceeded 0.6 observations per km (0.6 mi).

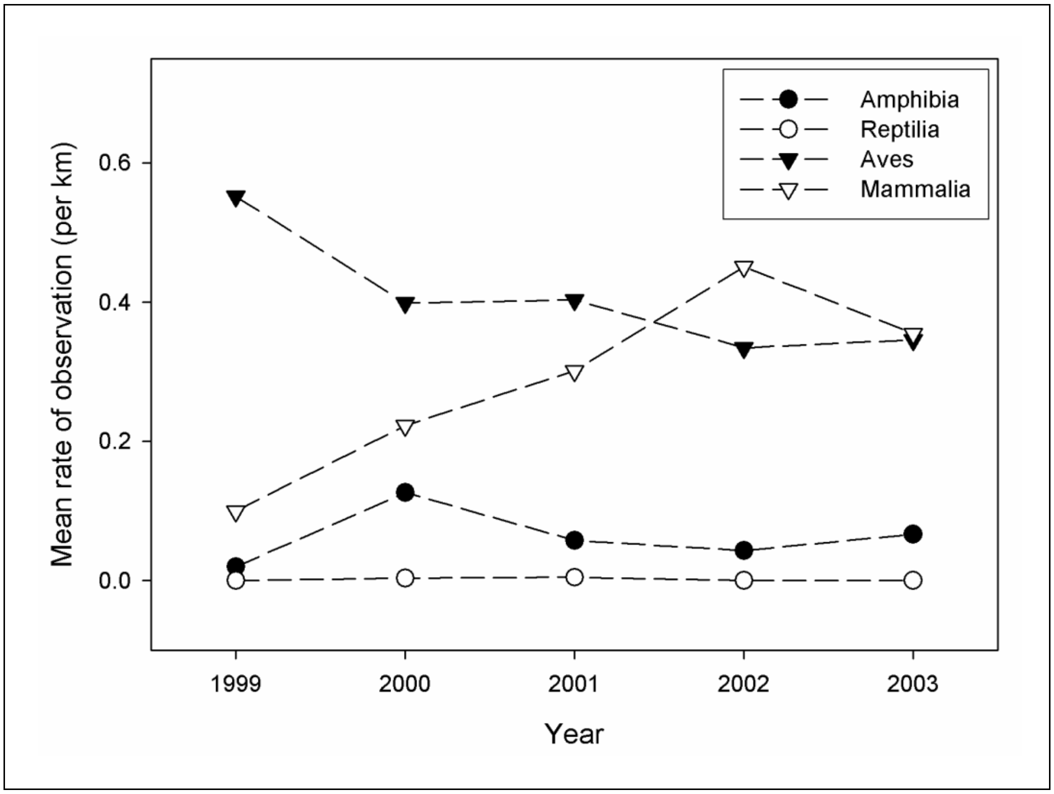


Figure 4-18. Annual wildlife abundance observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003.

The abundance of western toads did not vary between years, but did vary between seasons ($p < 0.01$, Figure 4-18 and Figure 4-19). They were more common in the summer than in any other season ($p < 0.01$ in all cases) and they were more common in the spring than in the winter or fall ($p < 0.01$ in both cases). The greatest abundance of western toads occurred in summer of 2000 (0.4 per km or 0.6 mile), but they declined by approximately 97 percent by the fall of 2000 ($p < 0.01$).

Table 4-20. Rates of observation (mean number per kilometer) of wildlife species observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003. Asterisks denote zero observations.

Taxa	Code	1999		2000				2001			2002				2003			Mean rate
		FA	WI	SP	SU	FA	WI	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	
Amphibians and Reptiles	BUBO	0.04	*	0.09	0.40	0.01	*	0.09	0.08	*	0.07	0.03	0.05	0.01	0.03	0.15	0.03	0.07
	LAGE	*	*	*	0.01	*	*	*	0.01	*	*	*	*	*	*	*	*	< 0.01
	Sub-totals	0.04	*	0.09	0.41	0.01	*	0.09	0.09	*	0.07	0.03	0.05	0.01	0.03	0.15	0.03	
	Yearly mean	0.02		0.13				0.06			0.04				0.07			0.06
Birds	BCNH	*	*	*	*	*	*	0.30	*	*	*	0.04	*	0.01	*	*	0.01	0.02
	KILL	*	*	0.04	0.01	0.03	0.19	*	*	0.03	0.08	*	*	*	*	*	*	0.02
	NOHA	*	*	*	*	*	*	*	*	*	*	*	*	0.01	*	*	*	< .01
	RTHA	*	0.27	*	*	0.12	0.19	0.01	0.13	0.15	0.01	*	*	0.24	0.04	0.03	0.08	0.08
	AMKE	*	*	*	*	*	*	*	*	*	0.01	*	*	*	*	*	*	< .01
	BAOW	0.56	0.19	*	0.39	0.21	0.11	0.05	0.31	0.15	0.04	0.40	0.23	0.11	0.01	0.23	0.28	0.20
	SEOW	0.01	*	0.05	0.01	0.01	0.01	0.01	0.01	*	*	*	*	0.01	*	*	*	0.01
	BUOW	0.04	0.04	0.16	0.07	*	*	*	*	*	*	0.12	0.03	0.03	0.17	0.09	0.09	0.05
	LENI	*	*	*	*	*	*	*	0.01	*	*	*	*	*	*	*	*	<0.01
	WEME	*	*	*	*	*	*	*	0.04	*	*	*	*	*	*	*	*	<0.01
	SAVS	*	*	*	*	*	*	*	*	*	0.03	*	*	*	*	*	*	<0.01
	Sub-totals	0.61	0.50	0.25	0.48	0.37	0.50	0.37	0.50	0.33	0.17	0.56	0.26	0.41	0.22	0.35	0.46	
	Yearly mean	0.56		0.40				0.40			0.35				0.34			0.41
	Unid avian	0.08	0.07	0.15	0.05	0.09	0.04	0.07	0.09	*	0.02	*	*	*	*	*	*	0.04
	Unid duck	*	*	*	*	*	*	0.01	*	*	*	*	*	*	*	*	*	<0.01
	Unid egret	*	*	*	*	*	*	0.01	*	*	*	*	*	*	*	*	*	< 0.01
	Unid raptor	*	*	*	*	*	*	*	*	*	*	*	*	0.01	*	*	*	< 0.01
	Unid owl	*	*	*	*	*	*	0.01	*	*	0.01	*	*	*	*	*	*	<0.01
Mammals	SYAU	0.04	*	0.17	0.11	0.03	0.04	0.05	0.16	0.11	0.17	0.52	0.35	0.17	0.15	0.05	0.12	0.14
	LECA	0.05	0.09	0.11	0.15	0.05	0.01	0.08	0.12	*	0.01	0.13	0.09	0.07	0.08	0.05	0.23	0.08
	SPBE	*	*	*	*	*	0.01	*	*	*	*	*	*	*	*	*	*	<0.01
	THBO	*	*	*	*	*	*	*	*	*	0.01	*	*	*	*	*	*	<0.01
	DIHE	*	*	0.01	0.11	*	*	*	0.08	*	0.03	0.04	0.04	*	0.12	*	0.20	0.04
	PEMA	*	*	*	*	0.01	*	0.13	0.09	*	0.01	0.07	0.01	*	*	*	0.04	0.02
	MICA	0.01	*	*	*	*	*	0.03	0.03	*	*	0.01	*	*	*	*	*	<0.01
	CAFA	*	*	*	*	*	0.01	*	*	*	*	*	0.04	0.01	*	*	*	<0.01
	CALA	*	*	0.03	*	*	0.04	0.03	*	*	*	*	*	0.01	*	*	*	0.01
	FESY	*	*	*	*	*	*	*	*	*	0.01	*	*	*	*	*	0.03	<0.01
	Sub-totals	0.10	0.09	0.32	0.37	0.09	0.11	0.32	0.48	0.11	0.24	0.77	0.53	0.26	0.35	0.10	0.62	
	Yearly mean	0.10		0.22				0.30			0.45				0.36			0.29
	Unid bat	0.01	*	*	*	*	*	*	0.01	*	0.09	*	*	*	*	*	*	0.01
	Unid leporid	0.01	0.03	*	*	*	0.01	*	*	*	*	*	*	0.01	*	*	*	<0.01
	Unid rodent	*	0.01	0.01	0.01	*	*	0.03	0.01	*	0.01	*	0.01	*	*	*	0.01	0.01
	Unid canid	*	0.01	*	*	*	*	0.01	*	*	0.01	*	*	*	*	*	0.01	<0.01
Totals		0.75	0.59	0.66	1.26	0.47	0.61	0.78	1.07	0.44	0.48	1.36	0.84	0.68	0.60	0.60	1.11	0.77
Species richness		7	4	7	8	8	9	10	11	4	11	8	7	11	6	6	9	7.88

Species codes: BUBO = western toad, LAGE = California king snake, BCNH = black-crowned night heron, KILL = killdeer, NOHA = northern harrier, RTHA = red-tailed hawk, AMKE = American kestrel, BAOW = barn owl, SEOW = short-eared owl, BUOW = burrowing owl, LENI = lesser nighthawk, WEME = western meadowlark, SAVS = savannah sparrow, SYAU = desert cottontail, LECA = black-tailed hare, SPBE = California ground squirrel, THBO = valley pocket gopher, DIHE = Heermann's kangaroo rat, PEMA = deer mouse, MICA = California vole, CAFA = domestic dog, CALA = coyote, FESY = domestic cat

The abundance of birds was approximately 40 percent higher in 1999 than in 2002 ($p = 0.01$) and 2003 ($p = 0.04$, Figure 4-18). The greatest decline in abundance (63 percent) occurred between fall 1999 and spring 2002 ($p < 0.01$, Figure 4-19). The abundance of birds also varied between seasons ($p < 0.01$); spring abundances were up to 72 percent lower than all other seasons ($p < 0.01$ in all cases). Barn owls (*Tyto alba*) or western burrowing owls (*Athene cunicularia hypugea*), a California species of special concern, were the most common birds observed in most years and in most seasons (Table 4-20). Although there was a decline in barn owls of approximately 36 percent between 1999 and 2000, this decline is not statistically meaningful. Barn owls remained more abundant than burrowing owls during all survey years (Figure 4-20). Short-eared owls (*Asio flammeus*), also a California species of special concern, were observed in fall 1999, winter 2002, and during each survey period from spring 2000 to fall 2001 (Table 4-20).

The abundance of mammals increased nearly five-fold from 1999 to 2002 ($p < 0.01$, Figure 4-18). There was an 87 percent decline in mammals from summer 2002 to summer 2003 ($p < 0.01$, Figure 4-19). The high numbers of mammals observed in 2002 was primarily due to an irruption of desert cottontails (*Sylvilagus auduboni*) during the summer and fall (Figure 4-21, Table 4-20).

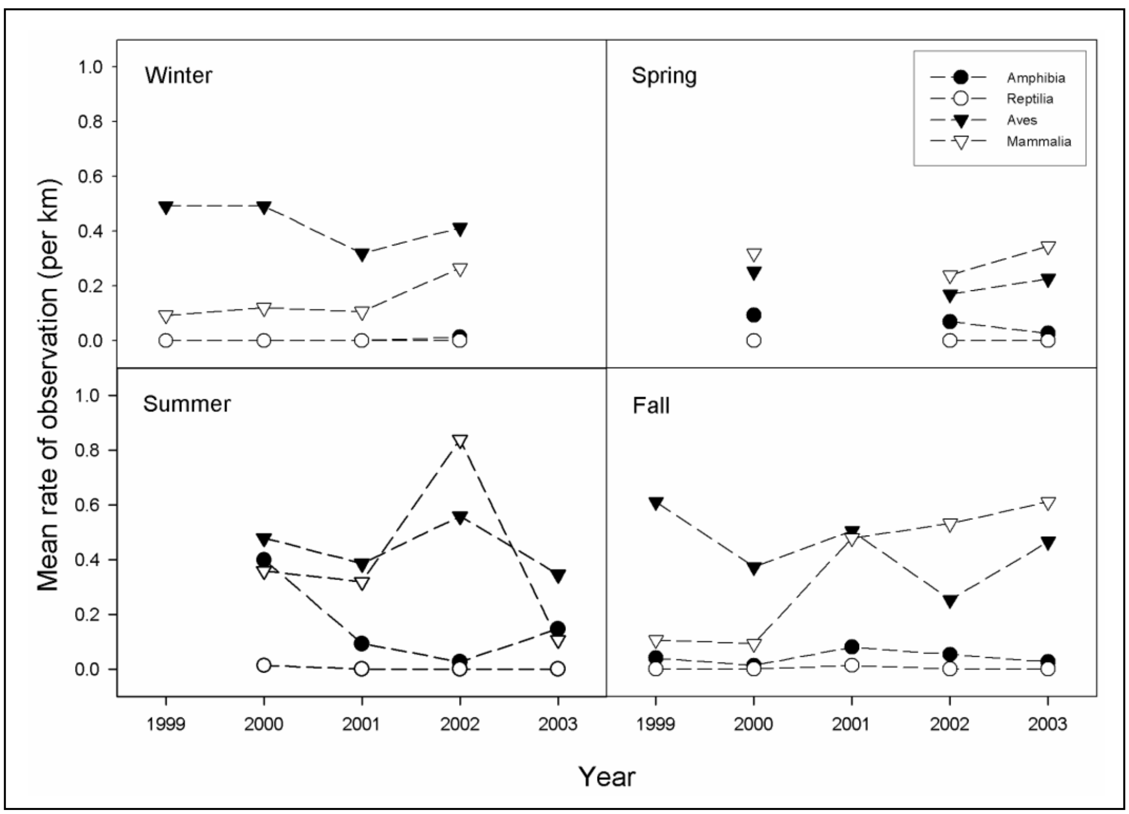


Figure 4-19. Seasonal abundance of wildlife observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003.

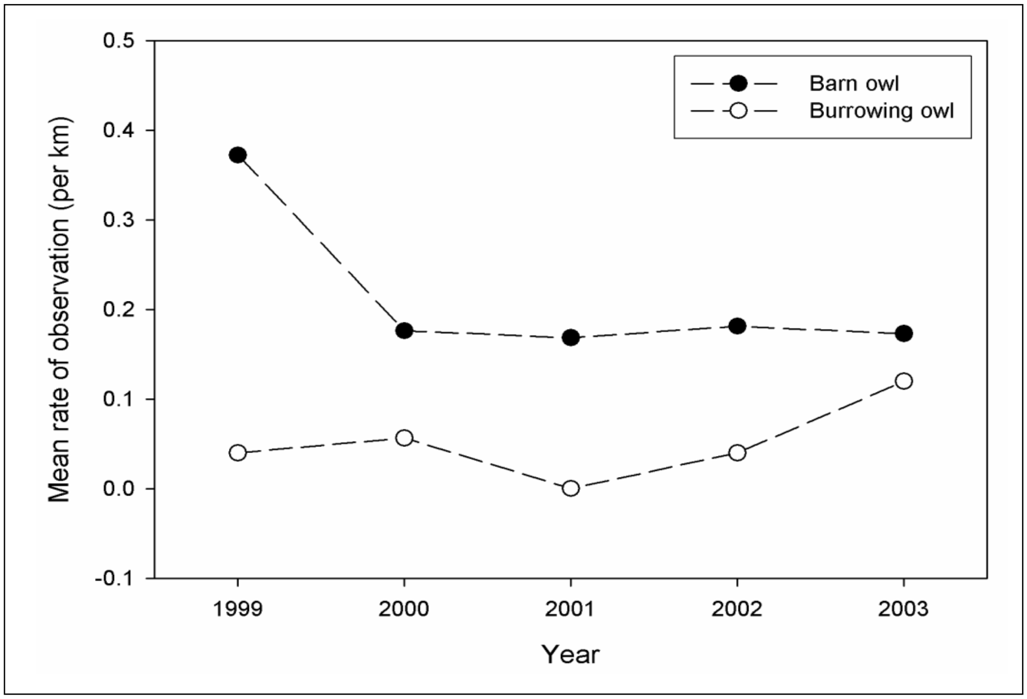


Figure 4-20. Abundance of barn owls (Tyto alba) and western burrowing owls (Athene cunicularia hypugea) observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003.

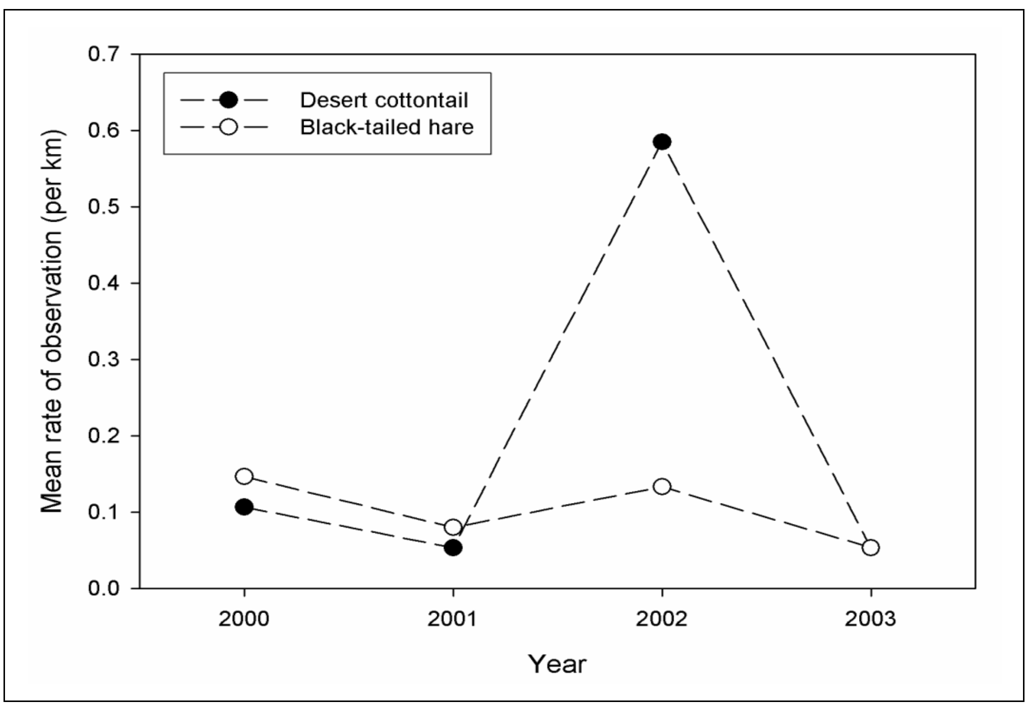


Figure 4-21. Abundance of desert cottontails (Sylvilagus auduboni) and black-tailed hares (Lepus californicus) observed during summer spotlight surveys conducted near Tranquillity, California, 1999 to 2003.

The mean abundance of mammals varied between seasons ($p = 0.01$). The mean abundance of mammals in winter was 80 percent lower than in summer, 78 percent lower than in fall, and 73 percent lower than in spring ($p < 0.01$, $p = 0.01$, and $p = 0.04$, respectively). The abundance of mammals increased more than six-fold from fall of 2000 to fall of 2003 (Figure 4-19, $p < 0.01$) due primarily to increases in desert cottontails, black-tailed hares (*Lepus californicus*), and Heermann's kangaroo rats (*Dipodomys heermanni*, Table 4-20). Domestic dogs and coyotes (*Canis latrans*) were the only species of canids observed and were infrequently encountered (Table 4-20). Both species were observed in the winter, only coyotes were seen in the spring and summer, and only domestic dogs were observed in the fall (Figure 4-22).

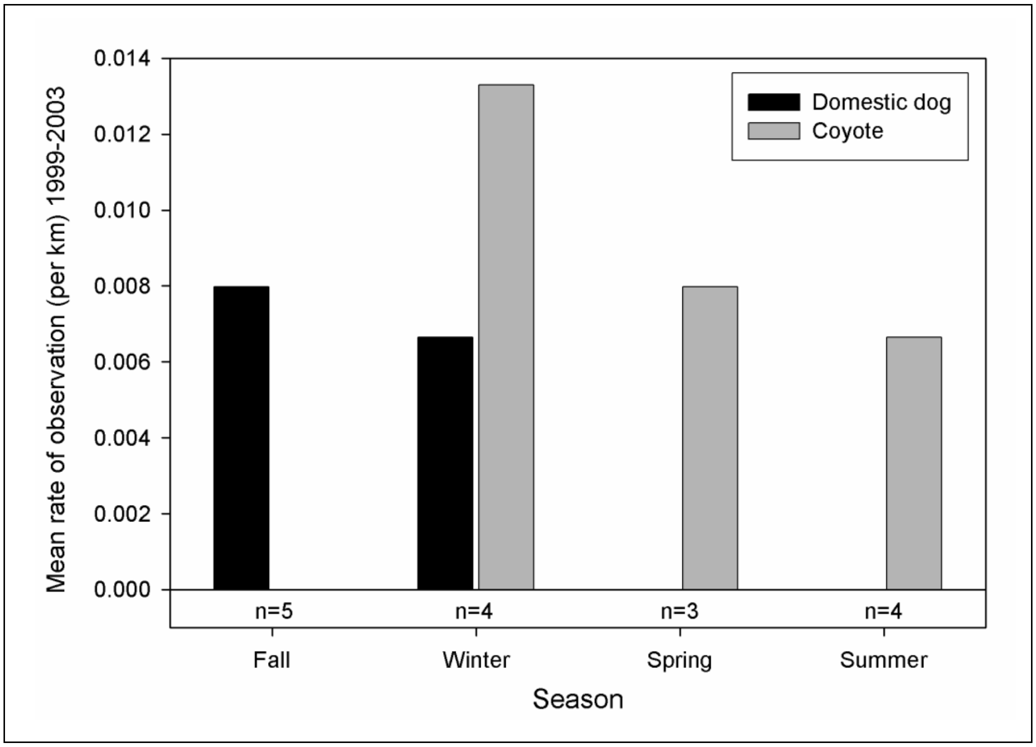


Figure 4-22. Seasonal abundance of coyotes (*Canis latrans*) and domestic dogs (*Canis familiaris*) observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003. n = number of spotlight surveys conducted for each season over the five-year study period.

4.3.2.2. Track Station Surveys

Nine orders of invertebrates, including seven families within six orders, visited track plates. The most frequent visitors were beetles (25 percent) and isopods (7 percent, Table 4-21). The number of track stations visited by invertebrates varied from 0 to 35 per three-day survey period. The highest rate of visitation was in 2000 (0.41), which was approximately 1.5 to 4.5 times the rate of visitation during other years (Table 4-21). The abundance (mean number of track stations visited) of invertebrates did not vary statistically between years or seasons (Table 4-21, Table 4-22, Figure 4-23, Figure 4-24).

Table 4-21. Annual numbers and mean rates of visitation of wildlife at track stations established at the Tranquillity site, 1999 to 2003. Asterisks denote zero observations.

Taxon	Code	1999	2000	2001	2002	2003	Total	Mean rate
Invertebrate	LYCOSIDAE	*		1	*	*	1	<0.01
	ISOPODA	*	10	5	*	*	15	0.02
	LITHOBIIDAE	*	1	1	*	*	2	<0.01
	ACRIDIDAE	1	*	*	*	*	1	<0.01
	GRYLLIDAE	*	2	*	1	1	4	<0.01
	PHLAEOTHRIPIDAE	*	4	*	*	*	4	<0.01
	CHRYSOPIDAE	1		*	*	*	1	<0.01
	COLEOPTERA	2	31	10	*	11	54	0.06
	DIPTERA	*	*	*	*	14	14	0.02
	APIDAE	1	1	*	*	*	2	<0.01
	UNKNOWN	4	33	7	52	22	118	0.14
Invertebrate total		9	83	24	53	48	217	0.25
Invertebrate mean rate		0.09	0.41	0.12	0.26	0.31	0.25	
Amphibia	BUBO	*	15	5	7	5	32	
Amphibia total		0	15	5	7	5	32	0.04
Amphibia mean rate		0.00	0.07	0.02	0.03	0.03	0.04	
Reptilia	OPHIDIA	*	*	1	*	*	1	<0.01
	SAURIA	*	*	2	*	*	2	<0.01
Reptilia total		0	0	3	0	0	3	<0.01
Reptilia mean rate		0.00	0.00	0.01	0.00	0.00		<0.01
Aves	BUOW	*	1	*	*	*	1	<0.01
	CORA	*	2	2	*	*	4	<0.01
	AMCR	*	1	2	1	3	7	0.01
	RWBL	*	7	7	*	*	14	0.02
	UNKNOWN	*	12	7	14	30	63	0.07
Aves total		0	23	18	15	33	89	0.10
Aves mean rate		0.00	0.11	0.09	0.07	0.22	0.10	
Mammalia	SYAU	2	*	*	1	21	24	0.03
	LECA	1	*	*	*	1	2	<0.01
	LEPORIDAE	3	2	8	14	3	30	0.03
	SPBE	*	5	4	14	22	45	0.05
	DIHE	1	3	*	5	19	28	0.03
	PEMA	*	*	*	6	*	6	0.01
	MICA	1	2	2	*	*	5	0.01
	RODENTIA	10	57	143	88	83	381	0.44
	CAFA	2	1	7	5	9	24	0.03
	CALA	1	*	*	*	*	1	<0.01
	CANIDAE	*	*	*	1	*	1	<0.01
	MEME	*	*	2	*	*	2	<0.01
	MUFR	*	*	*	*	1	1	<0.01
	MUSTELIDAE	*	*	*	4	*	4	<0.01
	FESY	*	1	*	1	*	2	<0.01
	UNKNOWN	*	*	3	*	1	4	<0.01
Mammalia total		21	71	169	139	160	560	0.65
Mammalia mean rate		0.21	0.35	0.83	0.68	1.05	0.65	
Unknown		*	*	6	5	3	14	
Unknown total		*	*	6	5	3	14	0.02
Unknown mean rate		0.00	0.00	0.03	0.02	0.02	0.02	
Year Total		**30**	**192**	**225**	**219**	**249**	**915**	**1.06**
Year Mean Rate		**0.29**	**0.94**	**1.10**	**1.07**	**1.63**	**1.06**	

Key to codes: LYCOSIDAE = wolf spider, ISOPODA = isopod, LITHOBIIDAE = centipede, ACRIDIDAE = grasshopper, GRYLLIDAE = cricket, PHLAEOTHRIPIDAE = thrips, CHRYSOPIDAE = lacewing, COLEOPTERA = beetles, DIPTERA = flies, APIDAE = bees, BUBO = western toad, OPHIDIA = unidentified snake, SAURIA = unidentified lizard, BUOW = burrowing owl, CORA = common raven, AMCR = American crow, RWBL = red-winged blackbird, SYAU = desert cottontail, LECA = black-tailed hare, LEPORIDAE = unidentified leporid, SPBE = California ground squirrel, DIHE = Heermann's kangaroo rat, PEMA = deer mouse, MICA = California vole, RODENTIA = unidentified rodent, CAFA = domestic dog, CALA = coyote, CANIDAE = unidentified canid, MEME = striped skunk, MUFR = long-tailed weasel, MUSTELIDAE = unidentified mustelid, FESY = domestic cat.

Table 4-22. Seasonal mean rates of visitation of wildlife at track stations established at the Tranquillity site, 1999 to 2003. Asterisks denote zero observations.

Taxon/Code	1999		2000				2001				2002				2003			Mean
	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	
Invert rate	0.18	*	0.08	0.98	0.29	0.27	0.16	0.08	0.22	0.02	0.37	0.67	*	*	0.47	0.20	0.27	0.25
Amphib rate	*	*	*	0.18	0.10	0.02	0.04	0.02	0.04	*	*	0.10	0.04	*	0.04	0.06	*	0.04
Reptilia rate	*	*	*	*	*	*	*	0.02	0.04	*	*	*	*	*	*	*	*	<0.01
Aves																		
BUOW	*	*	*	0.02	*	*	*	*	*	*	*	*	*	*	*	*	*	<0.01
AMCR	*	*	*	0.02	*	*	*	*	0.04	*	0.02	*	*	*	*	0.06	*	0.01
CORA	*	*	*	0.02	0.02	*	0.04	*	*	*	*	*	*	*	*	*	*	<0.01
RWBL	*	*	*	*	*	0.14	0.14	*	*	*	*	*	*	*	*	*	*	0.02
Unid avian	*	*	0.06	0.10	0.02	0.06	0.06	0.04	0.02	0.02	0.04	0.16	0.06	0.02	0.18	0.12	0.29	0.07
Aves rate	*	*	0.06	0.16	0.04	0.20	0.24	0.04	0.06	0.02	0.06	0.16	0.06	0.02	0.18	0.18	0.29	
Mammals																		
SYAU	*	*	*	*	*	*	0.02	*	0.04	*	*	*	*	*	*	*	0.02	<0.01
LECA	*	0.02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.02	<0.01
SPBE	*	0.04	*	*	*	*	*	*	*	*	0.02	*	*	*	0.06	*	0.35	0.03
DIHE	0.02	*	*	0.02	0.04	*	*	*	*	*	*	*	0.10	*	0.12	0.18	0.08	0.03
PEMA	0.08	0.12	0.25	0.37	0.25	0.24	0.75	0.80	0.76	0.49	0.71	0.27	0.59	0.16	0.43	0.69	0.51	0.44
MICA	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.02	<0.01
Rodentia	*	*	*	0.02	0.06	0.02	0.02	*	*	0.06	0.04	0.20	0.02	0.02	0.10	0.08	0.25	0.05
CAFA	0.02	0.02	*	*	*	0.02	*	0.02	0.10	0.02	0.02	*	0.02	0.06	0.02	0.12	0.04	0.03
CALA	0.02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	<0.01
MEME	0.02	*	*	0.04	*	*	*	0.02	0.02	*	*	*	*	*	*	*	*	0.01
MUFR	*	*	*	*	*	*	*	*	*	*	*	0.02	0.06	*	*	*	*	<0.01
Mustelidae	*	*	*	*	*	*	*	*	*	*	*	0.12	*	*	*	*	*	0.01
FESY	*	*	*	*	*	0.02	*	*	*	*	0.02	*	*	*	*	*	*	<0.01
Unid leporid	*	*	*	*	*	*	*	*	0.04	*	*	*	*	*	*	*	*	0.00
Unid canid	*	*	*	*	*	*	*	*	*	*	*	*	0.02	*	*	*	*	0.00
Unid mammal	0.06	*	*	*	0.02	0.02	*	0.10	0.06	*	*	0.24	0.04	*	*	0.06	*	0.04
Mammal rate	0.22	0.20	0.25	0.45	0.37	0.32	0.79	0.94	1.02	0.57	0.81	0.85	0.85	0.24	0.73	1.13	1.29	
Totals	0.40	0.20	0.39	1.77	0.80	0.81	1.23	1.10	1.38	0.61	1.24	1.78	0.95	0.26	1.42	1.57	1.85	1.04

Rate of visitation = number track stations visited / number of survey nights

Species codes: BUOW = burrowing owl, AMCR = American crow, CORA = common raven, RWBL = red-winged blackbird, SYAU = desert cottontail, LECA = black-tailed hare, SPBE = California ground squirrel, DIHE = Heermann's kangaroo rat, PEMA = deer mouse, MICA = California vole, Rodentia = unidentified rodents, CAFA = domestic dog, CALA = coyote, MEME = striped skunk, MUFR = long-tailed weasel, FESY = domestic cat

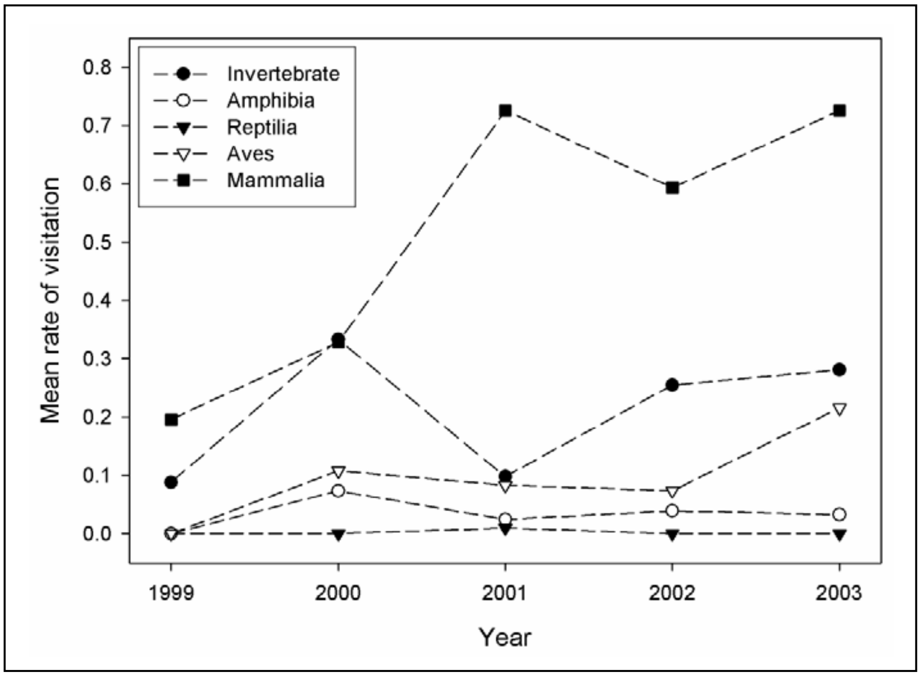


Figure 4-23. The yearly abundance (mean rate of visitation) of wildlife during track station surveys conducted at the Tranquillity site, 1999 to 2003.

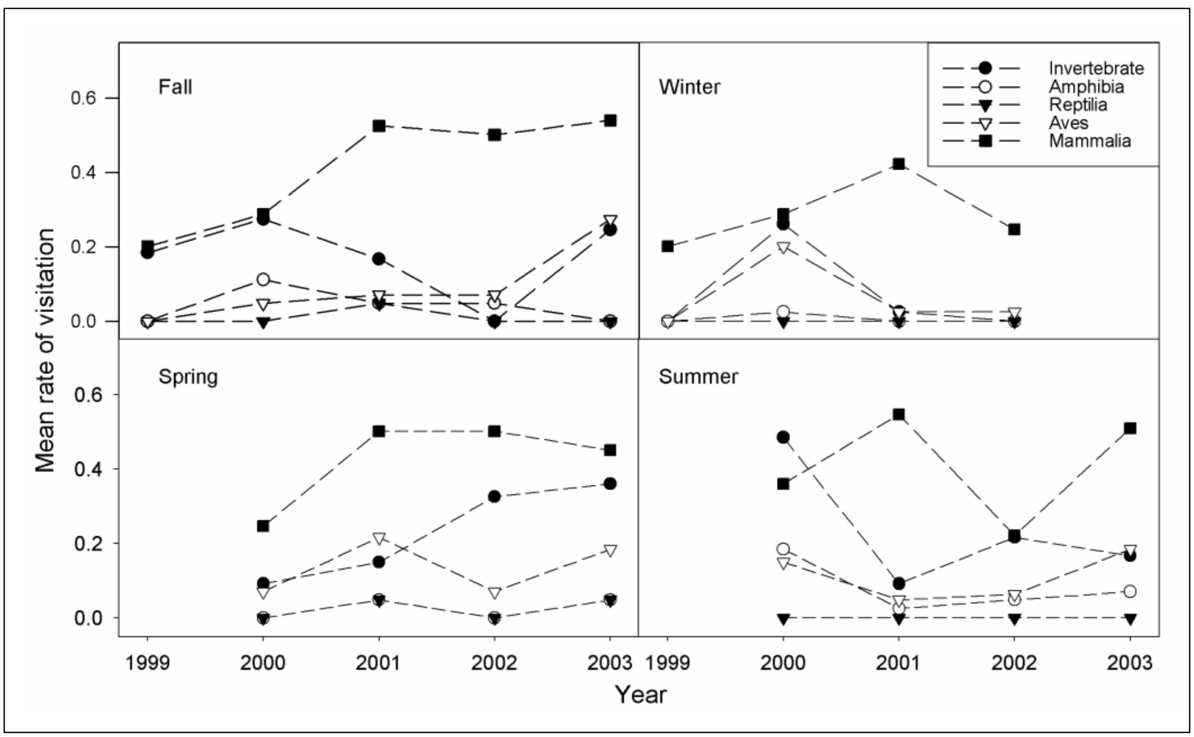


Figure 4-24. The seasonal abundance (mean rate of visitation) of wildlife at track stations established at the Tranquillity site, 1999 to 2003.

Western toads were the only amphibian that visited the track plates. Their abundance varied between years and seasons, but these variances were not statistically meaningful (Figure 4-23 and Figure 4-24). Western toads did not visit the track plates in 1999 but did in all other years (Table 4-21). The highest rate of visitation was 0.18 in summer of 2000 (Table 4-22).

Both lizard and snake tracks were observed. It is likely that these tracks were from western fence lizards and either gopher snakes or California king snakes because these were the only reptiles observed at the site. Reptiles were detected only in the summer and fall of 2001 (Table 4-22); the annual mean rate of visitation was 0.01 (Table 4-21).

At least four species of birds visited the track plates (Table 4-21 and Table 4-22). Approximately 11 percent of all tracks noted were from birds. Tracks of a western burrowing owl (a California species of special concern) were seen on a single track plate in 2000 (Table 4-21). The abundance of birds varied between years ($p < 0.02$, Figure 4-23) but did not vary between seasons (Figure 4-24). No avian tracks were noted in 1999 (Table 4-21). The rate of visitation of birds increased from 0.00 in 1999 to 0.22 in 2003 ($p < 0.01$, Figure 4-23). The greatest increases in the abundance of bird visits were from 1999 to 2000, and from 2002 to 2003. The rate of visitation increased from 0.00 in 1999 to 0.11 in 2000, and from 0.07 in 2002 to 0.22 in 2003.

At least 11 species of mammals visited the track plates over the five-year study period (Table 4-21 and Table 4-22). Mammals were less common in 1999 than 2001, 2002, and 2003 ($p < 0.01$, $p = 0.05$ and $p < 0.01$ respectively; Figure 4-23, Table 4-21). The rate of visitation of mammals increased nearly five-fold from 1999 to 2003. This increase was predominantly due to California ground squirrels (*Spermophilus beechyi*), desert cottontails (*Sylvilagus auduboni*) and Heermann's kangaroo rats (*Dipodomys heermanni*, Figure 4-23, Table 4-21). The yearly rates of visitation of unidentified rodents were and order of magnitude higher than any other taxonomic group and accounted for nearly 42 percent of all observations (Table 4-21).

4.3.2.3. Winter Raptor Surveys

American kestrels (*Falco sparverius*), northern harriers (*Circus cyaneus*), and red-tailed hawks (*Buteo jamaicensis*) were the most frequently observed raptors during the winter raptor surveys (Table 4-23). Although these species were observed during every day of every survey; their abundance was variable. Species richness increased annually (except in 2002) and reached a maximum of seven species in 2001 and 2003. Total raptor abundance ranged from 94 to 144 per survey. The abundance of raptors and additional wintering species increased each year except in 2003, but these increases were not statistically supported ($p = 0.99$). Approximate increases varied between years and differed by 20 percent from 1999 to 2000, 12 percent from 2000 to 2001, 14 percent from 2001 to 2002 and decreased approximately 35 percent from 2002 to 2003.

Table 4-23. Frequency and rate of bird species encountered at the Tranquillity site, 1999 to 2003 during winter raptor surveys.

	Species code[1]	1999			2000			2001			2002			2003		
		Total	Freq[2]	Rate[3]	Total	Freq[2]	Rate[3]	Total	Freq[2]	Rate[3]	Total	Freq[2]	Rate[3]	Total	Freq[2]	Rate[3]
Raptors	AMKE	34	100%	1.02	31	100%	0.93	33	100%	0.99	36	100%	1.08	23	100%	0.69
	BAOW	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00	1	33%	0.03
	FEHA	0	0%	0.00	0	0%	0.00	3	100%	0.09	0	0%	0.00	5	67%	0.15
	NOHA	24	100%	0.72	32	100%	0.96	37	100%	1.11	13	100%	0.39	12	100%	0.36
	PEFA	0	0%	0.00	0	0%	0.00	1	33%	0.03	2	67%	0.06	0	0%	0.00
	PRFA	1	33%	0.03	2	67%	0.06	0	0%	0.00	0	0%	0.00	3	67%	0.09
	RLHA	3	100%	0.09	1	33%	0.03	1	33%	0.03	0	0%	0.00	0	0%	0.00
	RTHA	21	100%	0.63	22	100%	0.66	24	100%	0.72	30	100%	0.90	28	100%	0.84
	WTKI	6	67%	0.18	14	100%	0.42	7	100%	0.21	1	33%	0.03	1	33%	0.03
Total raptor richness		6			6			7			5			7		
Additional wintering species	LOSH	0	0%	0.00	11	100%	0.33	14	100%	0.42	22	100%	0.66	14	100	0.42
	MOPL	0	0%	0.00	0	0%	0.00	6	33%	0.18	40	33%	1.20	0	0	0.00
	Buteo sp.	4	67%	0.12	0	0%	0.00	1	33%	0.03	0	0%	0.00	0	0	0.00
	unidentified	1	33%	0.03	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0	0.00
Total abundance		94			113			127			144			87		

[1] Species codes: AMKE = American kestrel, BAOW = barn owl, FEHA = ferruginous hawk, LOSH = loggerhead shrike, MOPL = mountain plover, NOHA = northern harrier, PEFA = peregrine falcon, PRFA = Prairie falcon, RLHA = rough-legged hawk, RTHA = red-tailed hawk, and WTKI = white-tailed kite.

[2] Frequency: Percent of survey with positive observations.[3] Rate: Mean number observed per mile of survey.

4.4. Discussion

4.4.1. Vegetation

Although it may appear that restoration efforts on the study plots were not as successful as initially hoped, a number of restoration goals were met. We successfully established plant cover to stabilize soils, established plant cover to provide wildlife habitat, and established native wildlife. Native shrub species were successfully established on many plots and in various research trials and hedgerows, but the long-term establishment of most native annual plant species has proven to be more problematic. Soil conditions that historically existed on the site were seasonally dynamic, with successive periods of flooding and drying. Decades of intensive agricultural use greatly affected soil characteristics, depleted the native plant seed bank, and promoted the dominance of introduced weeds. These historic conditions greatly increased the challenge in establishing native upland plant communities on the study site.

Although slightly more than two-thirds of the 13 imprinted species have been encountered during vegetation monitoring, establishment of the majority of these species has been quite limited. Additionally, the number of imprinted species encountered during each of the final 2 years of monitoring was less than the number encountered during the initial two post-imprinting surveys.

Some imprinted annual species persisted on the plots, but these species were characterized by low abundances and patchy distributions. Likewise, few additional native annual species were able to become established on the plots. And, although it had been hoped that the vegetation on the plots would be augmented by native seed from the existing seed bank and from adjacent lands, few additional native annual species were able to become established. As with the imprinted annuals, these adventitious natives were patchily distributed and of low abundance.

Generally, the establishment of perennial species was much more successful than that of annual species. Nevertheless, the perennial vegetation declined after attacks by agricultural pests (particularly, false chinch bugs; *Nysius* sp.). Additional decline in the perennial vegetation appeared to be linked to soil motility and extensive soil cracking.

While numerous fertile individuals of *Atriplex polycarpa, Suaeda moquinii* and *Isocoma acradenia* became established on the plots, we saw little evidence of successful second generation from these (potential) progenitors. This lack of successful establishment appears to be primarily attributable to competition from the annual invasive species on the plots. Seedling establishment from the parent native perennials was generally limited to the areas beneath and directly around the parent plants (i.e., areas where there was sufficient open soil). However, these seedlings rarely survived beyond seedling stage—probably due to competition with the parent plants. As noted, precipitation during the course of the Demonstration Project was substantially lower than the 30-year average. This scarcity of rainfall undoubtedly limited these species "expansion."

Non-native species dominated large portions of the HRS plots. By the final year of monitoring, three non-native species, *Sisymbrium irio*, *Bromus madritensis*, and *Capsella bursa-pastoris,* accounted for more than three-fourths of the vegetative cover. The "tumbling saltweeds," *Atriplex rosea* and *A. argentea* were readily established on the disturbed (i.e., tilled) soils of the HRS plots. By the end of the first growing season following imprinting, these species were dominant on many of the plots. Although the abundance of these species was greatly diminished in subsequent years, many of their "skeletons" (i.e., senescent stems and leaves) remained onsite for the following growing season and served to facilitate the establishment of other weeds, as only a few, invasive species were able to become established beneath the skeletons. The mustards, *Sisymbrium irio* and *Brassica nigra*, in particular, benefited in this way.

Bromus madritensis appeared to be particularly effective in limiting the establishment of imprinted species. This pattern is readily seen in the rank-abundance curves (previously shown in Figure 4-6 and Figure 4-7). All plots on Block 1 (represented by the leftmost curves in these figures) were steeper, and were generally poorer in species than plots in the other blocks. As noted, *Bromus madritensis* tended to dominate the northern HRS plots; the buffers of the red brome-dominated plots also tended to have a large component of brome. The northern portion of the HRS area had soils characterized by high electrical conductivity readings and high levels of soluble boron (Figure 2-34; Figure 2-35). However, it should also be noted that Section 10 (i.e., the area with the densest brome component) had a different land-use history than the areas on which the other four blocks were sited. Section 10 had been fallowed for a number of years prior to restoration, and it may be that vegetation on this portion of the site represented a later stage of post-agricultural succession.

Clearly, weed management is essential to ensure the long-term persistence of native species on restored lands. To date, only intensive and repeated weed suppression has successfully reduced weed loads and allowed natives to persist, but this has been costly and labor intensive. Numerous experimental techniques—including herbicide use, establishing cover crops, flaming, mowing, discing, pre-irrigating, solarization, and manual weeding—have been explored for weed-eradication techniques; however, none have yet provided effective long-term results. We are continuing research in an attempt to develop cost-effective and efficient techniques for weed control that would be applicable for large-scale land retirement (see Appendix 1).

The microtopographic contours (berms) persisted throughout the study period, although their height decreased over the course of the study due to compaction and disturbance, and as the shallow furrows along the edges of the berms became partially filled with soil and litter. Still, these contours successfully provided structural and vegetative heterogeneity to what had previously been a homogenous landscape. Topographic contouring clearly facilitated establishment of the perennial vegetation. The majority of the imprinted perennials became established either on the berms, or in the furrows. No clear pattern between establishment of imprinted annual species and contouring was discernable.

No strong statistical support was found for a positive correlation between the diversity and abundance of small mammals and contouring. Nevertheless, we suspect that contours would ultimately enhance the landscape for burrowing animals, and would become an increasingly important component of restored habitats as the wildlife community continues to diversify. The design of the contours could be improved to increase their benefit to wildlife. In restoration efforts that are not strictly controlled by a statistically rigorous study design and other limiting factors, heterogeneity could be greatly increased by fashioning meandering contours of variable height and width.

4.4.2. Invertebrates

The invertebrate community showed little notable response to the treatments, which was expected because of the similarity among the treatments. The overall richness of invertebrates and the abundance of coleopterans showed some limited responses to the treatments, but there were no prevailing trends. The richness and abundance of invertebrates tended to be more influenced by location (study block) than by the application of any particular treatment.

Because of the limited long-term success of our restoration treatments, all of the HRS study plots more closely resemble fallowed lands than restored habitat. Gelt (1993) noted that homogenous plant communities dominated by invasive species often characterize fallowed lands. Reduced grassland plant species richness, characteristic of fallowed lands and monocultures, results in altered invertebrate community structure (Knopps 1999). Because there is a positive correlation between increased habitat diversity and increased invertebrate richness and/or abundance (Dodero 2003, Kremen et al. 2002, Knopps 1999, Speight et al.1999, Erhardt 1985), we would expect that the successful restoration of retired agricultural lands would lead to a more stable and complex invertebrate community.

On the Habitat Restoration Study site, the diversity of agriculturally beneficial invertebrates was greater than the diversity of agricultural pests. Beneficial invertebrates, including predators, parasitoids, and pollinators, provide valuable pest regulation and pollination services to agricultural land (Samu 2003, Kremen et al. 2002, Schowaltzer 2000, Allen-Wardell et al. 1988). In structurally diverse agro-ecosystems, agriculturally beneficial insects tend to be more abundant (Kremen et al. 2002, Thomas et al.1992), and pest populations are typically reduced (Samu 2003, Schowalter 1996). Kremen et al.'s (2002, 2004) work in the Central Valley of California demonstrates the economic and production benefits of incorporating natural habitat into the agricultural landscape. Several studies have demonstrated that monocultures, typical of agricultural expanses, invite sudden, dramatic, and widespread outbreaks of invertebrate pests (Turchin 1988, Root 1973, Irving 1970). Reducing landscape homogeneity through the reestablishment of a diverse native plant community could provide a barrier to the movement of agricultural pests and reduce the severity of outbreak (Schowalter 1996, Piemeisel and Lawson 1937). These benefits could be achieved through the successful restoration of retired lands.

The native plant nursery that has been established on the Tranquillity site houses the greatest diversity of native plant species in the San Joaquin Valley. We have observed heightened invertebrate diversity, particularly with agriculturally beneficial species, in the nursery as compared to the study plots and other surrounding lands. This observation is supported by the competitive exclusion principle (Hardin 1960) and by Speight et al. (1999) who asserted that habitats having greater plant species richness should support greater insect species richness. The HRS study was designed to test for a correlation between the level of native plant diversity and the richness of invertebrates. However, the relatively low success of the restoration treatments precludes a meaningful analysis.

An analysis of invertebrate richness and abundance at the ordinal level, as was conducted in this study, is limiting. We have found that the data are too coarse to provide meaningful information on invertebrate community structure and dynamics. Furthermore, an analysis at the ordinal level is primarily relevant to short-term abiotic factors (Hemerik and Brussaard 2002) rather than long-term biotic factors. There is an opportunity to evaluate the invertebrate community structure, dynamics, and the correlation of invertebrate richness to native plant diversity at the family or species level. These studies could be implemented on lands where research trials or restoration have proven successful. An analysis of specific sensitive indicator orders (Coleoptera, Lepidoptera, and Araneae) has been used to measure restoration success at the ecosystem level (Waltz and Covington 2004, Perner and Malt 2003, Hemerik and Brussaard 2002) and could be incorporated into the design of future monitoring and evaluation efforts.

4.4.3. Amphibians and Reptiles

Amphibian diversity and abundance was low throughout the 5-year survey period. Fisher and Schaffer (1996) note a large-scale decline in native amphibian species in the San Joaquin Valley and suggest lack of suitable habitat as a major factor. The only amphibian species observed at the Tranquillity site, the western toad, is typically associated with lakes, rivers, and streams, but is also found in grassland habitats (Stebbins 1985). Western toads likely emigrated to the study area from canals and ditches that occur on surrounding farmland. These water sources are needed for breeding. Western toad abundance was especially high in the summer of 2001. The potential for the study site to provide a diverse assemblage of amphibians is fairly low in the near term. However, if suitable breeding sites become available, other species of amphibians could become established on the site. Species that could become established include: pacific treefrog (*Pseudacris regilla*), western spadefoot toad (*Spea* (=*Scaphiopus*) *hammondi;* a California species of special concern), and California tiger salamander (*Ambystoma californiense*, federally listed threatened species, USFWS 2004).

California king snake was the only species of reptile observed during spotlighting surveys although a gopher snake and western whiptail have also been observed on the site. A northern pacific rattlesnake (*Crotulus viridus oreganus*) was observed within 8 km (5 mi) of the site. In addition, a local farmer (Robert Jones, pers. comm.) reported seeing coast horned lizards (*Phrynosoma coronatum;* a California species of special concern, CDFG 2003) in the area until approximately 1990. There is one 2002 record of a coast horned lizard from Alkali Sink Ecological Reserve approximately 11 km (7 mi) to the north-northeast of the site (CDFG 2003).

Lack of suitable habitat likely precludes a greater diversity and abundance of reptiles. As native vegetation becomes established and microtopographic features are created due to rain and wind, it is expected that reptiles will colonize the site to a greater degree. Reptile species that may inhabit the site in the future include those listed above that have been seen in proximity to the site and the side-blotched lizard (*Uta stansburiana*), western skink (*Eumeces skiltonianus*), Gilbert skink (*E. gilberti*), southern alligator lizard (*Gerrhonotus multicarinautus*), western yellow-bellied racer (*Coluber constrictor*), San Joaquin Coachwhip (*Masticophis flagellum*), California glossy snake (*Arizona elegans occidentalis*), Valley garter snake (*Thamnophis sirtalis fitchii*), California black-headed snake (*Tantilla planiceps*), and southwestern black-headed snake (*Tantilla hobartsmithi*). Currently, the prey base appears adequate for most colubrid snakes (see Section 4.3.5). In addition, invertebrate abundance and diversity appears to be satisfactory to sustain species that prey upon insects.

4.4.4. Birds

There were no substantial differences in the richness or abundance of birds between treatments or treatment factors, but there were differences between blocks in all seasons. These results are not unexpected because of the similarity of the vegetation on all plots and inherent spatial differences between blocks. The abundance, richness, and composition of birds varied annually and seasonally, but this is expected because of the typical cyclic patterns of birds (circadian rhythms and circannual cycles, Gill 1999). Although the study plots were primarily composed of non-native weedy species, the landscape characteristics closely resembles a grassland and it is not surprising that the greatest abundance of birds were obligate grassland species, followed by facultative grassland species.

Eleven short-eared owlets (*Asio flammeus*) were successfully reared in plots 8 and 10 in 2002. During various surveys conducted in 2003 we observed 14 short-eared owls communally roosting on Block 1, and 10 roosting on Block 5. The only other known short-eared owl nesting locations in the San Joaquin Valley are Mendota Wildlife Area approximately 5 mi (8 km) from the Tranquillity site where one nest was documented in 1987 (CDFG 1987), and Kern NWR, approximately 72 mi (115 km) south of the Tranquillity site (Cooper 2004). There are also numerous western burrowing owls nesting under sections of the displaced concrete lining of the San Luis Drain, which traverses a portion of the Tranquillity site. They have been observed roosting, foraging, and burrowing on the site. The short-eared owl and the western burrowing owl are species of special concern in California (CDFG 1999) and the short-eared owl is a rare species in Fresno and Madera Counties according to Fresno Audubon Society (2001). The widespread use of the Tranquillity site by these species demonstrates the potential of retired agricultural lands to contribute to the recovery of a variety of sensitive species. The reproductive success and population dynamics of the short-eared owl are closely tied to the abundance of its prey (Holt and Leasure 1993), and the high density of deer mice and California voles on the study plots likely contributes to the success of these species at the Tranquillity site.

All of the successful mallard nests were associated with relatively high shrub cover, primarily dead *A. argentea* skeletons. The placement of nests in vegetation has been found to be beneficial (Gloutney and Clark 1997) and it is likely that shrubs contributed to nest success by providing nest cover and concealment. Approximately 57 percent of the nests on Plot 6 were successful, which may have led to high nest-site fidelity. It is not clear why mallards preferentially selected

Plot 6 for nesting when other plots had structural heterogeneity similar to Plot 6. Mallards typically nest within 1.6 km (1 mile) of a water source (Kaufman 1996, Baichich and Harrison 1997) but this was not observed on the Tranquillity site. There are a number of agricultural canals, ditches, and drains on and near the site, but they are dry during the breeding and nesting season and did not provide a source of water.

The most abundant nests in 2003 were of red-winged blackbirds. Male red-winged blackbirds were often observed actively defending nesting territories by mobbing and vocalizing to deter predators. Brown-headed cowbirds (*Molothrus ater*) were observed in the vicinity of blackbird nests, but we did not observe nest parasitism. It is well known that red-winged blackbirds are often parasitized by brown-headed cowbirds (Freeman et al. 1990), but the high degree of territory defense that we observed may have effectively eliminated parasitism. Past studies have shown that group defense against cowbirds may be an important deterrent to nest parasitism (Freeman et al. 1990). Berger (1951), Payne (1973), and Norman and Robertson (1975) found that female cowbirds would use perches to locate and monitor potential nests for subsequent parasitism. Adequate perch sites are extremely limited at the Tranquillity site, which may have contributed to a lack of parasitism. Parasite pressure on red-winged blackbirds may be reduced by an increased availability of other, more preferred hosts (Friedman 1963, Friedman et al. 1977). This is not likely to be the case at the Tranquillity site because there are few alternate hosts nesting on the site. The degree of cowbird parasitism also has been found to be lower in localities where cowbirds are recent arrivals (Friedman 1963, Friedman et al. 1977). It is likely that the lack of parasitism by cowbirds at the Tranquillity site is partially due to the recent conversion of agricultural crops to habitat, the recent nesting efforts by red-winged blackbirds, and the recent arrival of brown-headed cowbirds at the site.

The number of nests and the species of birds that successfully nested on the Tranquillity site changed dramatically from 2002 to 2003. The primary difference was that mallards were the most successful nesting bird in 2002 while red-winged blackbirds were the most successful nesting bird in 2003. We suspect that the principal reason for this shift was a change in vegetative structure and subsequent loss of potential cover. *Atriplex argentea,* which had been associated with all mallard nests, is an annual sub-shrub that was present on the study plots in large numbers in 2002, but was much less common in 2003. London rocket was a dominant component of the landscape in 2003. London rocket was used as nesting supports and nesting material for red-winged blackbird nests. Although both of these plant species have contributed to the nesting success of these two bird species, they are considered weedy, invasive plants and are undesirable. For habitat restoration to be beneficial to nesting birds, these plant species must be replaced by native species that would provide the same or better quality conditions for nesting birds. Furthermore, an increase in the abundance and diversity of native plants would likely provide nesting opportunities for a wider variety of bird species.

4.4.5. Small Mammals

In 1999, when the study plots were planted in barley, deer mice and ornate shrews were the most abundant small mammal species, but they were present in low numbers. Once the barley was replaced by restoration treatments and discing was halted, there was an increase in the abundance and diversity of small mammals. The abundance of deer mice and the diversity of small mammals in general did not differ between treatment or treatment factor. It is not surprising that seeding did not influence small mammal abundance or diversity because of the similarity between seeded and non-seeded plots. However, we are somewhat surprised that contouring did not enhance the small mammal community. Contours are thought to provide a suitable site in which to construct burrow systems and provide topographical relief to act as refugia during periods of high rainfall. The soils on the Tranquillity site exhibit a tremendous potential for shrinking and swelling. Large cracks in the soil are widespread, especially during the dry summer months. We suspect that these soil characteristics provide adequate opportunities for burrow construction and relief from the effects of flooding, and lessen the potential benefits of contouring to small mammals. Currently, the Tranquillity site supports a viable, self-sustaining small mammal community that contributes to the success of predatory birds and mammals. However, this small mammal community is not typical of native habitats in the San Joaquin Valley. Rather, the community is typical of disturbed, ruderal habitats. We would expect that effective restoration would ultimately enhance and naturalize the small mammal community.

4.4.6. Site-Wide Surveys

4.4.6.1. Spotlighting Surveys

Most of the 11 species of birds observed during spotlighting surveys were owls and grassland associated raptors. Barn owls and short-eared owls are associated with open grassland habitats and agricultural fields and small mammals constitute a majority of their diet (Marti 1992, Holt 1993). Because abundance of deer mice was typically very high during the study, we would expect that barn owls preyed significantly upon this species. While barn owls made up a majority of the observations, red-tailed hawks were also well represented throughout the survey period. Black-crowned night herons (*Nycticorax nycticorax*) were observed during four of the 16 survey periods but abundance was especially high in the summer of 2001. Black-crowned night herons are known to feed on fish and frogs (Kaufman 1996) and the relatively high abundance of herons during summer of 2001 may have been related to the high abundance of western toads seen during that same survey period.

There was a dramatic increase in abundance of mammals at the Tranquillity site over the 5-year study period. This increase is likely tied to the continued maturation of the vegetative community and reduced farming disturbance at the site. Leporid abundance fluctuated but was always the dominant mammalian taxa observed throughout the survey although Heermann's kangaroo rats were also highly abundant during the summer of 2000 and fall of 2003. Kangaroo rats are especially adapted to arid conditions (Jameson and Peeters 1988) in the valley grassland and foothill woodland communities of California to southwestern Oregon (Ingles 1965). As fossorial animals, kangaroo rats will provide aestivation and hibernation habitat for a variety of species, including invertebrates and small reptiles. Although coyotes have been observed infrequently during spotlighting surveys, they are known to den on the plots and forage in the area. Because coyotes feed extensively on leporids and small mammals (Jameson and Peeters 1988), we expect that abundance of coyotes will increase in the future. It is interesting that dogs and coyotes appeared to coexist in winter, yet seemed to exclude each other in spring, summer, and fall.

4.4.6.2. Track Station Surveys

Twenty-eight taxa were recorded visiting the trackplates over the 5-year study period. Approximately 75 percent of tracks observed were invertebrates (mostly beetles) or mammals (mostly rodents). Felids and mustelids were recorded in extremely low numbers suggesting that abundance of these taxa are especially low. While coyote and/or dog tracks were recorded during 12 of the 17 surveys, they were recorded infrequently during each survey period, which also suggests that these animals were relatively low in abundance. This is particularly evident given that the target species for track station surveys are typically meso-carnivores including canids, felids and mustelids.

4.4.6.3. Winter Raptor Surveys

There was an increase in the diversity and abundance of raptors on the Tranquillity site over the 5-year study period. The highest diversity was in 2001 and 2003 and the highest abundance was in 2002. The diversity and abundance of raptors present on the Tranquillity site is very similar to the abundance and diversity of raptors at Kern National Wildlife Refuge, (Cooper 2004). California special concern species (CDFG 1999) that were present at the Tranquillity site included ferruginous hawks (*Buteo regalis*), northern harriers, prairie falcons (*Falco mexicanus*), mountain plovers, and loggerhead shrikes. The abundance of northern harrier and the loggerhead shrikes remained relatively constant, but the abundance of the other sensitive species fluctuated. Red-tailed hawks at the Tranquillity site exhibited both light and dark morphologies (in 2003 approximately 25 percent of all red-tailed hawks observed exhibited a dark-morphology). However, the majority of the ground roosting red-tailed hawks were of the dark morphology. Ground roosting is relatively uncommon in this species, especially in light-morphed birds (Preston 1980).

Red-tailed hawks, white-tailed kites, northern harriers, kestrels, loggerhead shrikes, barn owls, western burrowing owls, and short-eared owls have all been observed nesting on and near the Tranquillity site. The presence of a viable, self-sustaining small mammal population likely contributes to the abundance, diversity, and successful breeding of these raptors. Although the Tranquillity site represents relatively high quality raptor habitat, it could be improved by successful restoration. Land retirement and the implementation of effective habitat restoration have the potential to greatly benefit raptors within the San Joaquin Valley.

4.5. Conclusions and Recommendations

4.5.1. Conclusions

The Land Retirement Demonstration Project proved to be a valuable learning experience regarding restoration of retired lands. This pilot project emphasized standard restoration techniques, which we have shown to be generally ineffective and not well suited to retired farmlands on heavy clay soils. By testing these standard methods on a small scale, we avoided the expense and inefficiency that likely would have occurred had these techniques been implemented on a larger scale. Based upon those initial results, we have implemented a wide array of research trials (see Appendix 3) that focus on the limiting factors that we identified. Some of those limiting factors have been overcome, but a number of issues remain to be resolved before restoration can be effectively conducted.

Some of the restoration approaches used on the HRS plots showed promise. Microtopographic contouring appeared to have positive effects in promoting establishment of native vegetation, and potentially providing habitat heterogeneity for small mammals and other biota. Shrub establishment—particularly of *Atriplex polycarpa*—approached densities that would be considered appropriate habitat for some species of concern. Nevertheless, in general, restoration response was less than optimal.

Factors contributing to the limited success of native plant restoration are thought to include inadequate seed delivery methods (imprinting may not be appropriate for use on the HRS soil types and for many of the species), competition from invasive species, inappropriate seed source (most of the seed was purchased commercially and was not obtained from the proximity of the project site), and drought conditions experienced throughout the term of the project.

The Habitat Restoration Study represents a significant expenditure of resources, and has required a concentrated effort by all involved parties. Given the immense challenges associated with the Tranquillity site (e.g., substantial weed loads, difficult soils, deficient rainfall, site history, etc.), it was not surprising that the restoration response was not as pronounced as was originally envisioned. Nevertheless, the HRS can be considered a valuable foundation in developing practical restoration strategies.

We are currently involved in an extensive research program that is advancing the state of knowledge of appropriate restoration technologies and recommendations for large-scale restoration efforts in the San Joaquin Valley (see Appendix 1).

The greatest obstacle to date has been weed control, so current research is primarily focused on that topic, but considerable time and expense is also being spent researching other restoration issues. Among these are: collecting seed from remnant populations of native plants, propagating and increasing the seed supply of locally collected plants, determining germination and propagation requirements of various plant species, and developing appropriate mechanical seed harvesting, planting, and ground preparation procedures. Continuation of this research is essential if land retirement and the restoration of retired lands are expected to proceed.

Because there were few notable differences among the restoration treatments, there were also few observable trends in wildlife diversity and abundance associated with the treatments. However, the information on wildlife diversity and abundance obtained shows that retired agricultural lands are valuable to wildlife. Even in the absence of widespread and successful restoration, retired agricultural lands are important to wildlife. Unquestionably, removing active agriculture and associated recurring disking and irrigating removes threats to wildlife. Over a 5-year period, the following were identified—101 families within 21 orders of invertebrates, 1 species of amphibian, 4 species of reptiles, 48 species of birds, 8 species of small mammals, 1 species of canid (coyote), 2 species of mustelids (skunk and long-tailed weasel), and 2 domesticated species (cat and dog) that utilize the Tranquillity study site. Nine species of birds utilized the study area as breeding habitat and 12 species of sensitive birds were using the study area.

Although there have been some instances of agricultural pest outbreaks and weeds which required control measures, there were no indications that the HRS lands supported greater pest densities than did surrounding retired and fallowed lands. Rather, agriculturally beneficial species were common and widespread on the site, especially in restored areas.

One factor that may have limited the abundance and diversity of native wildlife on the study plots is the lack of nearby lands that support wildlife which could disperse onto the study plots. Only small, remnant parcels of native habitat exist in the vicinity. Within 80 km (50 mi) of the site, fewer than 100 locations containing native plants have been located. The largest and most ecologically diverse areas are the Alkali Sink Ecological Reserve, the Kerman Ecological Reserve, and the Mendota Wildlife Area, all located within 16 km (10 mi) of the project site (see Chapter 1). A few sites in the immediate vicinity of the project site do provide opportunities for some wildlife dispersal. These are primarily limited to the San Luis Drain right-of-way, the Lateral 7 Inlet Canal right-of-way, various dirt roads that cross the site, and land directly north of the site which has been fallowed. The diversity of wildlife on these lands is not great and dispersal of wildlife onto the plots from these areas is expected to be minimal. The barley buffers, which are approximately 101 m (330 ft) wide, may also have contributed to lower abundance and diversity of some taxonomic groups than might otherwise be expected. The width of the buffers, however, was a compromise between the need to allow wildlife to invade the plots, yet at the same time isolate the plots to minimize interactions between restoration treatments.

Although this project did not necessarily emphasize the establishment of threatened and endangered wildlife on the study plots, that is one long-term goal of the land retirement program. We increased the suitability of habitat for a number of rare species of birds and, as restoration techniques are designed and applied, the benefits to wildlife including sensitive species would be expected to increase. With the incorporation of appropriate management actions, the habitat that has been established could become increasingly suitable for various other rare species (e.g., San Joaquin kit fox, blunt-nosed leopard lizard, and San Joaquin kangaroo rats). Many rare upland species seem to be dependent upon an open vegetative structure, independent of native plant diversity or the presence of a fully functional native plant community. Accordingly, habitat for rare species may be more easily established and managed than a diverse, native upland plant community.

The data presented in this report are immensely valuable as a description of baseline conditions that, if compared to data collected from retired lands that are successfully restored to native habitats, would provide insight into the value of restoration to wildlife. There have been no other wildlife studies or monitoring efforts in the central San Joaquin Valley of this duration or scope, making this a unique data set that describes the wildlife community existing on lands dominated by non-native species. Within the San Joaquin Valley, similar conditions are common and widespread among scattered, remnant patches of land that are not intensively farmed.

The three primary objectives of the Habitat Restoration Study have been accomplished. Below is a summary of findings related to each objective.

1. Determine the efficacy of revegetation with native plants as a means to facilitate upland habitat restoration.

Standard native plant revegetation techniques as applied to the study plots (planting commercially purchased seed of an appropriate species mix on prepared ground using a seed imprinter) facilitated upland habitat restoration, but to a degree that was less than optimal. Some species persisted for a short time, some species became established but diminished over time, and others (e.g., *Atriplex polycarpa* and *Suaeda moquinii*) became established on some plots. Competition with weeds appeared to be the primary factor limiting restoration success, although other factors (e.g., low seed viability, seed delivery methods, and insect damage) were problematic. Revegetation research, which became an increasingly important component of the project, led to the development of promising and innovative techniques to combat these issues. A combination of selective herbicide use, application of activated charcoal (to protect native seed from herbicide exposure), and planting seed using a modified seed drill seems particularly promising. These techniques will be applied and tested under field conditions in 2005 and 2006.

2. Determine the efficacy of microtopographic contouring as a means to facilitate upland habitat restoration.

Microtopographic contouring as applied to the study plots (i.e., straight, uniform size, uniform orientation), showed some value in facilitating the establishment of native plant species (particularly shrubs) but appeared to be of limited value to wildlife, at least in the short term. We suspect that with time, their importance to wildlife would increase (as burrowing species such as kangaroo rats become residents). A more complex system of microtopographic contouring would add additional heterogeneity and likely result in increased benefits to plants and wildlife.

3. Examine the responses of plants and wildlife to land retirement and restoration.

A multitude of plants and wildlife responded well to land retirement. The cessation of active agriculture and associated irrigation and disking allowed for the incursion and establishment of many native and non-native species on retired lands. The implementation of improved revegetation techniques and appropriate land management actions would be expected to enhance benefits for desirable species.

4.5.2 Recommendations

A number of tasks remain to fulfill the intent of this project and to ensure that land retirement and the restoration of retired lands can proceed. Continuation of current restoration research, the implementation of new restoration research topics, and other high priority tasks are needed. Specific tasks that should be accomplished include:

- Publish findings of completed and on-going research in the open scientific literature, which is subjected to world-wide scientific scrutiny. It is important to have this information widely available, especially to those attempting restoration in the San Joaquin Valley. Unfortunately, information contained in unpublished, gray literature is often overlooked or unavailable to scientists and managers. Government agencies should always provide their personnel and consultants with strong incentives and the time and resources to publish their work.

- Develop a long-term management and monitoring plan for the Tranquillity site. This management plan should include long-term wildlife monitoring on the HRS plots (or a subset) every 3 to 5 years to document changes in biota over time, monitoring of selenium levels to ensure safe conditions for wildlife, and developing and implementing a restoration strategy for Tranquillity site lands.

- Continue maintenance and expansion of the native plant nursery and seed collecting activities. The native plant nursery has proven to be an essential component of restoration. It facilitates research on seed delivery methods, propagation techniques, and harvesting techniques, and it also functions to increase the stock of locally collected native plant seed. The nursery has proved itself invaluable in outreach activities by providing a visually appealing representation of native landscapes. The continuation of seed collecting activities is necessary to increase the number of species of native plants and to improve the genetic diversity of local genotypes of plants that would be available for restoration.

- Continue research on development of restoration technologies, including seed delivery techniques, weed control methods, harvesting techniques, and seed cleaning techniques. Currently, there is an insufficient seed source and a severe lack of restoration technologies that are appropriate for the implementation of large-scale restoration in the San Joaquin Valley. Continuation of these activities is vital to a successful large-scale land retirement project and other large-scale restoration efforts in the region.

- Document and protect localities of known populations of native plants and animals in the project vicinity to ensure the survival and persistence of existing populations. Native populations of plants and wildlife in the San Joaquin Valley are exceedingly small in size and rare in occurrence. These fragmented populations are vital stockpiles of resources that would be needed for restoration.

- Develop criteria and methods for the propagation and translocation of threatened and endangered species to restored lands. Because there is a paucity of existing native lands (and those that do exist are isolated by large expanses of agricultural lands that act as barriers to the movement of wildlife) occurring in the western San Joaquin Valley, it is not likely that many threatened and endangered wildlife species would emigrate to retired lands. Accordingly, to ensure maximum benefits to threatened and endangered wildlife, techniques must be developed for the safe and successful translocation of these species.

- Provide public awareness of the positive effects and benefits of land retirement. An ongoing outreach program is essential to generate public interest and acceptance of land retirement and native lands restoration. Appropriate outreach can also be instrumental in developing and securing additional funding.

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Chapter 5. Overview of the Implications and Concerns of Agricultural Land Retirement in the San Joaquin Valley, California

by Beatrice A. Olsen and Curtis E. Uptain

This chapter is a synopsis of the results acquired from work at the Land Retirement Demonstration Project (LRDP) study sites over a 5-year period. The key points of the results of the various studies are summarized. The knowledge acquired will be used to address concerns associated with land retirement that were not a focus of the studies.

The LRDP Tranquillity site is representative of conditions encountered on most drainage impacted areas of the San Joaquin Valley, including a high percentage of those lands targeted for retirement by district and federal programs. The predominant soil type at the site is Tranquillity clay which is the most extensive soil type mapped by the Natural Resources Conservation Service (NRCS) on the lower alluvial fan and basin rim landforms in the western San Joaquin Valley. Accordingly, the information presented in this report is applicable to the entire region.

The 5-year studies clearly show that retiring land from irrigated agriculture results in numerous physical and biological benefits. Some of these include declining groundwater and a declining salinity and selenium in surface soils. Land retirement provides important habitat for a wide variety of wildlife and has the potential to contribute to the recovery of sensitive species. Selenium levels in biota from retired lands indicate that there is a low risk of contamination in this terrestrial environment, despite the relatively high (but declining) level of selenium in the system. Surface ponding of water did not occur and would not likely contribute to the bio-accumulation of selenium. A high number of agriculturally beneficial insects were found on retired lands, whereas the predicted increase in the abundance and diversity of agricultural pests has not occurred. Land retirement did not result in a decrease of selenium concentrations in groundwater.

Standard restoration techniques applied to the study plots were somewhat successful in establishing native shrubs and a limited variety of native annual plants. However, in general those techniques were relatively ineffective at establishing a diverse community of native flora. Appropriate restoration techniques are currently being developed and recommendations will be made in the near future.

The data set obtained from these studies is unique in that it describes the wildlife community existing on lands dominated by non-native species. No other wildlife studies or monitoring efforts in the central San Joaquin Valley of this duration or scope exist. The data provide insights into the value of land retirement and of habitat restoration to wildlife. The results obtained and the restoration techniques being developed can be applied to meet a variety of management objectives on large blocks of retired lands, including the recovery of threatened and endangered species.

5.1. Declining Groundwater

The water table response observed during groundwater monitoring supports the conceptual and numerical models that predicted a declining shallow water table in response to land retirement. Prior to land retirement, percolation of applied irrigation water was the primary source of groundwater recharge that sustained the high water table. Without irrigation, groundwater recharge has been greatly reduced and the shallow water table has steadily receded from the land surface.

5.2. Selenium in Groundwater

The high concentrations of salinity and selenium in the shallow groundwater found in Coast Range deposits at the site are a result of leaching under irrigated conditions and evaporation from the shallow water. Land retirement resulted in an increase in depth to groundwater, but did not substantially change the selenium concentrations in groundwater. Critical to the well being of biota is that the access to this contaminated groundwater is very limited because of the declining water table after cessation of irrigation.

5.3. Selenium in Soil

Soils of the predominant type at the site contain moderately elevated concentrations of selenium (average 1.0 mg/kg) when compared to the common range (0.1-1.4 mg/kg) for Western U.S. and San Joaquin Valley soils. Total selenium concentrations, soluble selenium concentrations, and salinity in the top 30 cm (1 foot) of surface soil showed a decreasing trend over the 5 years of monitoring. The decreasing selenium and salinity trends in the surface soil indicate that an upflux of salt and selenium from capillary rise and evaporation of shallow groundwater at the soil surface is minimal.

5.4. Selenium Concentrations in Biota

A risk assessment for the biota in this terrestrial system was not an objective of the LRDP. However, the levels of selenium concentrations observed in extensive monitoring of soil, groundwater, and biota indicate a low risk to wildlife. Whereas high selenium levels in groundwater could present a potential risk to biota, the exposure pathway is limited because the depth to groundwater increased to greater than 2.1 m (7 feet). Mean selenium levels in biota are within the range typically found in biota occurring on non-seleniferous soils in the western United States and are generally below performance standards set for the project by the U.S. Fish and Wildlife Service (FWS 1999). Furthermore, selenium levels in biota are generally an order of magnitude less than found at Kesterson National Wildlife Refuge. Although the risk to wildlife from selenium exposure is limited, a few samples contained relatively high levels of selenium and we recommend that land retirement be integrated with a comprehensive selenium monitoring program.

The generally low levels of selenium in biota may be a result of very little available water during the study period. The potential bio-availability and bio-accumulation of selenium is reduced because dry, upland environments, rather than aquatic or wetland environments, dominate the system. This is supported by the higher selenium levels that were found in common and widespread species collected from irrigated lands compared to those collected from non-irrigated lands.

5.5. Surface Water Ponding

Due to dry climatic and soil conditions during the study, surface water ponding did not last for more than 30 days at the site. Monitoring of precipitation during the study period suggests that the precipitation threshold to cause ponding of surface water is in excess of 5 cm (2 inches) of rainfall per month. The extensive network of dessication cracks in the Tranquillity clay soils greatly inhibits the formation of surface water ponds. Should surface water ponding occur during very wet periods, it is likely that selenium concentrations in the ponded water would remain below 5 parts per billion (ppb) (the aquatic life criteria) given the surface soil selenium concentrations.

5.6. Wildlife Abundance, Diversity, and Recovery of Sensitive Species

Results of the Habitat Restoration Study (HRS) demonstrate that retired lands provide habitat for a wide variety of wildlife, even in the absence of highly successful restoration. Over a 5-year period, we identified 101 families within 21 orders of invertebrates, 1 species of amphibian, 4 species of reptiles, 48 species of birds, and 8 species of small mammals, 1 species of canid (coyote), 2 species of mustelids (skunk and long-tailed weasel), and 2 domesticated species (cat and dog) that utilize the Tranquillity study site. Nine species of birds used the study area as breeding habitat and 12 species of sensitive birds were using the study area. Although this is an impressive list of species, we would have expected a greater diversity of wildlife and a greater degree of emigration had there been suitable wildlife habitat in the immediate vicinity.

The successful restoration of retired lands would provide increased vegetative diversity and result in an even greater diversity and abundance of wildlife. To maximize benefits for wildlife and to preclude retired lands from becoming infested with weeds and pests, appropriate habitat restoration must be conducted. Land uses, such as grazing and dryland farming, can be compatible with this effort. Creating topography, or berms, in the retired agricultural, laser-leveled landscape has benefits for plants and animals.

Land retirement and restoration, if properly implemented, monitored, and managed, would contribute to listed plant and animal species recovery. These lands could provide connecting linkages and corridors between existing habitat areas or large areas of contiguous blocks of land that would provide habitat for new core populations. The recovery of threatened and endangered animal species does not necessarily require a fully restored San Joaquin Valley ecosystem. Many rare upland species seem to be dependent upon an appropriate vegetative structure, rather than a highly diverse, fully functional native plant community. Habitat for rare species may be simplified and more easily established and managed than a diverse, native upland plant community. A diverse, native ecosystem, however, will provide the numerous benefits inherent in a totally functional ecosystem.

Providing the appropriate habitat for these species will require phases of implementation and successive management. Open spaces with low vegetation densities and heights are required for many listed species, while others require dense shrub cover. Phased restoration may or may not be immediately compatible with some sensitive species. Similarly, neither a single restoration prescription nor a single plant community would meet all species needs. Accordingly, a matrix of land uses, restoration strategies, plant communities, and management techniques is preferred. The LRDP data collected and the ongoing trials provide the basis for an implementation plan for the listed species recovery on retired agricultural lands.

5.7. Restoration Challenges and Techniques

Appropriate restoration must accompany land retirement or lands will largely become weed- and pest-infested fields. Without restoration, retired lands would require extensive and continuous management to reduce negative impacts to active agricultural practices on neighboring lands. Soil conditions that historically existed on the site were seasonally dynamic, with successive periods of flooding and drying. Decades of intensive agricultural use greatly affected soil characteristics, depleted the native plant seed bank, reduced topographic relief, and promoted the dominance of introduced weeds. These historic conditions greatly increased the challenges associated with establishing native upland plant communities on the study site.

Specific challenges to successful restoration include competition from invasive species, lack of sufficient quantities and varieties of local native plant seed, inadequate seed delivery methods, and insufficient knowledge of germination, propagation, harvesting, and seed cleaning techniques. Inconsistent and inadequate precipitation affected plant survivorship and decreased restoration success.

Despite the immense challenges associated with restoration of retired farmlands, we successfully established plant cover to stabilize soils, to provide for wildlife habitat, and to establish native wildlife. The establishment of native plant species on the site was more difficult than originally envisioned. As a result of the significant expenditure of effort and resources for this demonstration project, the information obtained provides a valuable foundation to develop practical restoration strategies.

Weed suppression is the primary challenge in the restoration of these lands. Initially, a barley crop was planted on many portions of the demonstration project to control weeds and prevent soil erosion. Barley persisted for several years without the need to replant, but insufficient rainfall and seed production required some reseeding in subsequent years. Barley was excellent at controlling weeds and is an excellent cover crop or nurse crop, but it must be maintained. Despite the use of barley to help control weeds, only intensive and repeated weed suppression has successfully reduced weed loads and allowed natives to persist. These efforts have been costly and labor intensive. Numerous experimental techniques including herbicide use, establishing cover crops, flaming, mowing, discing, pre-irrigating, solarization, and manual weeding have been explored for weed eradication techniques. None have provided effective long-term results. The team is continuing research in an attempt to develop efficient techniques for weed control that would be applicable for large-scale land retirement.

The observed succession of weed species as seen on the HRS plots, fallowed lands and reserves is tumbling saltweed (*Atriplex argentea)*, mustards, and finally non-native Mediterranean grasses. The general weed succession after fallowing appears to start with nearly 100 percent cover of *A. argentea* that begins to decline after 4-5 years. Each year, *A. argentea* dies and forms a skeleton that can carry for miles in a stiff wind. The skeleton eventually begins to break down but the process can takes years and in the meantime it makes a dense cover layer of dead and dry vegetation. The mustards begin to grow underneath these skeletons in the second year; *A. argentea* itself does not reproduce under them. These continue as co-dominant plants through the third and fourth years. After four or five years, Mediterranean grasses begin to establish, ultimately becoming the climax community. This pattern of succession must be overcome for native plant restoration to be effective.

No source of native plant seed is available in sufficient amounts to perform significant restoration in the San Joaquin Valley. The majority of plant species occurring in the targeted upland habitats are no longer found in the vicinity of the project site (within 80 km or 50 miles). Consequently, local ecotypes of native plants are largely absent or exceedingly rare and seed is extremely limited. The prime sources for seed have been Ecological Reserves and small, isolated remnants of habitat existing along roadsides. Seed from 100 species of native plants collected from the project vicinity were planted in the on-site native plant nursery. The nursery provides the seed used in the research trials and restoration activities.

Information on appropriate seed delivery techniques, germination, propagation, harvesting, and seed cleaning techniques is non-existent or insufficient for a majority of the targeted native species. The seed imprinter that was used in the initial restoration effort proved to be less effective on heavy clay soils than other seed delivery techniques. Valuable information on seed production is being generated through research in the native plant nursery and through partnership with the NRCS Plant Materials Center in Lockeford, California. Numerous research trials have been implemented and are ongoing (Appendix 3). Through these trials, we are exploring a variety of techniques to address the challenges encountered and to expand their applications to large-scale restoration.

Of the native species used in the work to date, the shrubs have proven to be easier to establish and maintain than winter and summer annuals. Shrubs survive better long-term against weeds, seem to be less susceptible to competition from weeds, and set seed better than annuals. The deep root system of established shrubs allows them to persist through drought conditions. Winter annuals cease to grow when overtopped by weeds and, without weed control, they quickly expire. Soil moisture is reduced by weeds causing a lack of germination in summer annuals. Drought exacerbates the competition between natives and weeds. Weed suppression will alleviate this competition for soil moisture and enhance success of annuals.

The restoration of a fully functioning ecosystem is much more involved than the successful planting of a few native species. A simplified ecosystem will tend to degrade to a weedy landscape. Even in many of the Ecological Reserves where the ecosystem has been degraded, intensive management is required to maintain the native floral diversity. Successful restoration must include a high diversity of sustainable populations of plants and animals.

5.8. Agricultural Pests

Although there have been some instances of agricultural pest outbreaks and weeds which required control measures, there were no indications that the HRS lands supported greater pest densities than did surrounding retired and fallowed lands or agricultural lands. Predatory insects were common on the site, which has likely kept the potential for pest infestation to a minimum. Agriculturally beneficial species were much more common and widespread on the site, especially in restored areas.

A few weed and insect pests are worthy of mention. Russian thistle is an invasive weed that has a high potential to become established on retired farmlands and adjacent agricultural fields. It is fairly widespread on the site, but has been present only in small patches and in low abundance. Both its distribution and abundance on the site decreased over the five-year study period. London rocket and black mustard are not generally considered agricultural pests, but they provide prime habitat for false chinch bugs and lygus bugs. There were two serious infestations of false chinch bugs. These infestations were regionally widespread, not restricted to the study site, and not influenced by land retirement or restoration activities. Lygus bugs were widespread on the study site, but they were not encountered in any great abundance. Few beet leafhoppers were observed. Predatory insects likely controlled their numbers.

5.9. Recommendation

Based upon the findings presented in this report and experiences gained during this 5-year project, the Land Retirement Team and the Endangered Species Recovery Program fully support land retirement. We believe that land retirement has the potential to solve a variety of drainage issues, including drainage reduction, and improved reliability of water supply. Restoration can improve the overall ecosystem function by improving air quality, reducing weed loads, creating wildlife habitat, and assisting with recovery of sensitive species. Land retirement is compatible with a variety of land uses including grazing, dryland farming, and enhanced recreational opportunities. Land retirement is expected to benefit adjacent farming operations by improving water quality, improving air quality through dust abatement, increasing abundance and diversity of invertebrate pollinators and predators.

These benefits are justification for the continuation and expansion of retiring drainage impacted lands, continued research of restoration techniques, and restoration of selected parcels of retired lands in the San Joaquin Valley.

The project objectives and associated performance criteria established by the USFWS have been met. Many of these criteria were based upon the premise that if met, retired lands could qualify for consideration of inclusion in the federal National Wildlife Refuge system. The retired lands at Tranquillity and Atwell

Island clearly meet the established criteria. The BLM recognized the potential value of the Atwell Island site and manages and restores the retired agricultural lands to meet wildlife values, including those of sensitive species. The Land Retirement Team and the Endangered Species Recovery program encourage the FWS to consider acquiring and managing the Tranquilllity site in a similar manner.

Appendix 1. CVPIA Land Retirement Program Chronology

by Beatrice A. Olsen

Introduction

This appendix provides an overview of the activities undertaken by the CVPIA Land Retirement Team (LRT) and the Endangered Species Recovery Program (ESRP) during the course of the Land Retirement Demonstration Project (LRDP) 1996-2005. Topics are presented in the calendar year they occurred. Some activities were repeated annually and are only briefly noted in Appendix 1. Appendix 3 contains more details of research and site activities that may only be mentioned in Appendix 1.

For each year included in this chronology, five sub-sections are described (except for 1996). Program Administration deals with personnel, key meetings, laws, planning, and documentation. Land Acquisition lists actions involved in retiring drainage impacted lands. Research and Monitoring lists actions related to the measurements of physical and biological impacts due to land retirement. The Restoration and Site Management sub-section describes and lists actions debated, planned, or taken on the Tranquillity and Atwell Island Demonstration site lands. Throughout the course of the project, members of the Land Retirement Team and Endangered Species Recovery Program staff have participated in, or taken the lead on, a variety of outreach activities. The final subsection for each year is a listing of these activities.

Year 1996 Accomplishments

Program Administration

In this year, the Bureau of Reclamation (Reclamation), Fish and Wildlife Service (FWS) and Bureau of Land Management (BLM) agreed to cooperatively accomplish the Land Retirement Program (LRP) authorized by the Central Valley Project Improvement Act (CVPIA) enacted by Congress in 1992 as Public Law 102-575. The LRP Office was established in Reclamation's South-Central California Area Office in Fresno. Robert May was hired as the Program Manager. The Fish and Wildlife Service (FWS) Land Retirement Team representative John Castellanos started working for James McKevitt in Sacramento. The Bureau of Land Management (BLM) team member Tracy Rowland reported for duty. A CVPIA Land Retirement Reclamation/FWS Monthly Coordination Meeting was established to discuss the program status and coordination between Reclamation and FWS. The Interim Program Guidelines drafted with Reclamation, BLM, FWS and DWR and state agencies, water districts, environmental groups, farmers, and academic representatives.

Outreach

Public information meetings were held in January 1996 to explain the program. The Draft Interim Program Guidelines released to public. Co-written with Department of Water Resources, they were mailed to water districts, farmers, federal and state agencies, county governments, and other interested parties.

Year 1997 Accomplishments

Program Administration

The Reclamation team member hydrologist Stephen Lee reported for duty, as did the FWS team member Bea Olsen, who replaced the representative from the Sacramento FWS office.

The Interim Guidelines and Selection Criteria were revised to add selenium ppm in soil criteria. A Memorandum of Understanding (MOU) between Westlands Water District (WWD) and Department of the Interior (DOI) was drafted regarding LRP partnership for program implementation. A DOI MOU was drafted that defined roles, responsibilities and implementation procedures for LRP. Regional and State Directors for Reclamation, FWS, and BLM signed the MOU for three agencies to implement and manage CVPIA Land Retirement Program. A third MOU between federal, state, and local agencies was drafted that outlined the shared vision and solidified support for the land retirement program.

The National Environmental Policy Act (NEPA) strategy defined the Prepared Scope of Work for a NEPA contract bid request. A Scope of Work was prepared and the contracting process was begun to acquire the services of a consulting firm to prepare an environmental assessment (EA) for the acquisition of selected parcels. Applications for parcels by Sumner-Peck were dropped due to the Settlement Agreement for the Sumner-Peck lawsuit.

A CALFED grant proposal was submitted for the Panoche Creek Riparian Habitat and Flood Control corridor project, which seeks to retire farmlands along a creek channel and to reestablish a meander zone for the stream. This widening and restructuring of the stream channel should reduce flooding and lessen the transport of contaminants, such as selenium, to the San Joaquin River.

Land Acquisition

The generalized criteria to address drainage, fish and wildlife enhancement, and acquisition of water for other purposes of CVPIA and select parcels for acquisition was developed by an interagency, multi-disciplinary team of both state and federal representatives. DOI began to solicit offers for voluntary land retirement from willing sellers within the eligible area. The LRT received 80 applications starting in 1997 and by September 2002 had approximately 22,258 hectares [ha] (55,000 acres). Applications were accepted on a continuous basis. Selections for first round of program totaled 5,108 ha (12,623 acres). Landowner applicants were notified of their status within 60 days, in conformance with the Interim Guidelines.

A coordinated appraisal process was performed by Reclamation and title and escrow services obtained. Preliminary title reports were requested for selected parcels. A coordinated assignment of one regional DOI solicitor to review title reports, deeds, etc. for all three agencies' acquisitions was obtained. A series of meetings with applicants was held to explain process and timelines. The first appraisal scheduled.

Bids for hazmat surveys were taken and a contract awarded to BSK. The contractor also provided recommendations for cleanup of any such materials. A pre-work meeting with hazmat contractor was held and progress monitored. The Hazmat Environmental Site Assessment reports were completed for selected properties. Pre-work meetings with hazmat contractor were held and progress was monitored. Hazmat Environmental Site Assessment reports were completed for selected properties.

Research and Monitoring

UC Davis was contracted to perform a groundwater model study on Panoche Fan area. The Hydrologic Model of Land Retirement: Panoche Water District (UC Davis and D. Perkey Model) was completed.

A 5-year Demonstration Project at Tranquillity and Atwell Island Water District was initiated to determine LRP Selection Criteria effectiveness, evaluate physical effects of retiring land, and develop effective and economic methods to rehabilitate retired lands to suitable upland wildlife habitat. The demonstration program would track progress, assess actual results and provide a means to determine future land retirement needs and identify actions needed to accomplish long-term land retirement objectives.

Restoration and Site Management

Parcels submitted in drainage impacted areas were field reviewed for best matches to the Interim Guidelines Criteria.

Outreach

Public information meetings were held to present Interim Guidelines. Advertisements were published in major newspapers, water and drainage district newsletters, and agricultural publications throughout the project area, which led to receipt of 31 applications, covering approximately 10,927 ha (27,000 acres).

LRP presentations were given to Westside Resource Conservation District, Fresno Co. Public Works and Development Services Director and staff, and separately to County Supervisors in Fresno, Tulare, and Kings Counties. Additional LRP presentations were given to LR subcommittee for San Joaquin Valley Drainage Implementation Plan, at an Open Houses for FWS Draft Recovery Plan for Upland Species in San Joaquin Valley and to the Region IV Director, California Department of Fish and Game.

Year 1998 Accomplishments

Program Administration

The Environmental Assessment for 526 ha (1,300 acres) of a Land Retirement Demonstration Project and a Draft Demonstration Study Plan were completed.

A scope of work was prepared and the contracting process begun to acquire the services of a consulting firm to prepare a programmatic environmental assessment for the land retirement program. The focus was the federal CVP service area on the western side of the San Joaquin Valley from the Sacramento-San Joaquin Delta on the north to the Tehachapi Mountains south of Bakersfield. A contractor was selected to prepare a Programmatic Environmental Assessment of the CVPIA Land Retirement Program. The Federal Register Notice of Intent (NOI) to prepare a Programmatic Environmental Assessment of the CVPIA Land Retirement Program, Vol. 63, No. 25/ Friday, February 6, 1998 was listed. A Internal Draft Programmatic Environmental Assessment was completed.

A Finding of No Significant Impact was signed for the Demonstration Project which included an agreement DOI made with WWD for the District to participate in the LRP. Terms of the cooperative agreement allowed the first 6,070 ha (15,000 acres) in WWD to be retired under the agreement. The amount paid would be fair market value, absent any appreciation due to the availability of Project water; WWD would pay the difference between that value and the full fair market value of the land up to $1,150 per acre. WWD would be permitted to reallocate the CVP water to which the retired lands are entitled to other lands in the District, provided that they do not lie within the designated drainage-impacted region of the District. Finally, DOI would apply for an allocation from the District supplemental water supply to use in establishing vegetation on retired lands for upland habitat.

A Feasibility Study for Panoche-Silver Creek Corridor Project was begun. The Panoche- Silver Creek Corridor Project had the contractor analyze the feasibility and cost of developing a riparian habitat and flood control corridor using retired agricultural lands in the vicinity of Panoche Creek. At an option to the government, all NEPA scoping activities could be performed and an environmental assessment prepared.

Land Acquisition

Preliminary Title Reports were requested for 5,084 ha (12,563 acres) of drainage-impaired irrigated agricultural land for potential acquisition under the Land Retirement Program as outlined in the Interim Guidelines. From work that was accomplished during 1997, appraisals on these acres were conducted for potential acquisition. Appraisals would determine the fair market value of these properties and establish the basis of negotiation and/or acquisition of the properties. Lands for acquisition under the Land Retirement Program were identified. More lands were available to be purchased and retired than funds would allow. A contractor conducted HAZMAT site-specific environmental compliance assessments on all properties prior to close of escrow.

Research and Monitoring

For the Westside San Joaquin Valley Groundwater Flow Model, a selected contractor utilized the groundwater flow model developed by Belitz and others to evaluate changes in groundwater flow due to land retirement in the central part of the western San Joaquin Valley, California.

At the University of California, Davis, researchers developed for a Water and Land Management Economic Study integrated hydrologic, soils, agricultural, and economic models for the area surrounding Firebaugh, California. The models quantified the economic, environmental, and social impacts of reductions in permanent surface water supply, reductions in lands irrigated, and reductions in selenium discharged from agricultural drainage in the study area.

A Groundwater Model (WESTSIM) developed by Reclamation modelers in Sacramento provided valuable information about the benefits and measurements of success of the program. This model provided a monitoring tool for sub-surface drainage reduction effects and potential groundwater table reduction.

The research design for monitoring biota on twenty 16 ha (40 acre) plots in the Demonstration Project in Fresno County was discussed with the Endangered Species Recovery Program Office, who will perform the research with CVPIA funds. ESRP performed Baseline Biological Survey on Demonstration Project lands in Fresno County. A Report of the Baseline Biological Survey was submitted to the LRT (See Appendix 2, 1999 Baseline Survey).

Groundwater monitoring was instituted in 1998 to detect the subsurface level of water and test the hypothesis that the water level would decline in the absence of surface watering (i.e., the irrigation of crops). Monitoring entailed collecting samples from 27 wells and sumps on the Tranquillity site.

Restoration and Site Management

Restoration funds were requested to start the conversion of the retired irrigated lands to suitable wildlife habitat. Lands were worked up and uniformly planted to a barley cover crop on approximately 493 ha (1,220 ac) at the Tranquillity site. This planting was done in the hopes of establishing relatively homogenous conditions for the Habitat Restoration Study (HRS) plots and to control weeds. ESRP contacted Ted St. John to discuss and demonstrate an imprinter and use of mychorriza.

Outreach

Public meetings were held to scope concerns regarding the Programmatic EA of the CVPIA Land Retirement Program. The LRT attended San Joaquin Valley Drainage Program Committee Meetings on Land Retirement.

Year 1999 Accomplishments

Program Accomplishments

A contractor was selected for preparation of a Programmatic EA of the CVPIA Land Retirement Program. The Expanded Demonstration Project Environmental Assessment for the 6,070 ha (15,000 acres) Expanded Demonstration Project area was completed. A Finding of No Significant Impact (FONSI) was signed by Reclamation, FWS, and BLM. A Biological Opinion as part of Formal Section 7 Consultation for the CVPIA Land Retirement Program Demonstration Project was received.

A notice was received from Fresno Agricultural Commissioner that sugar beets had to be controlled on 97 ha (240 acres) of LRDP lands.

Land Acquisition

The first appraisal was completed and the first parcel for the Demonstration Project (148 ha or 366 acres) acquired. A total of 666 ha (1,646 acres) in Fresno County was completed in FY 1999. Two appraisals in WWD were updated. About 24 ha (60 acres) of land were purchased from the WWD within the existing demonstration project area. Completed appraisals for purchase of 3,238 ha (8,000 acres) in Atwell Island WD (Tulare Lake Basin sub-area) were done. Phase 1 Environmental Site Assessments for approximately 2,428 ha (6,000 acres) of agricultural properties were done. The Assessments were completed in conformance with ASTM Standard E 1527-97 and Departmental Policy. Incoming applications continued to be evaluated and land acquired from a pool of applicants previously received.

Research and Monitoring

The Feasibility Study for the Panoche-Silver Creek Corridor Project was completed. The project proved to be too costly to provide significant flood control benefits without partnerships from other federal, state, or local partners. The U.S. Army Corps of Engineers (Corps) was identified as appropriate lead agency, but LRP may be a partner if project is ever implemented.

ESRP implemented the HRS on 324 ha (800 acres) of the 846 ha (2,090 acres) acquired in Fresno County (See Appendix 3.). The imprinter was built in Dos Palos. Surface manipulations were done to form berms. ESRP used seed collections and plant propagation on established plots and planted sterile barley to control weeds. A reference site was identified near the railroad in Firebaugh that is owned by Contra Costa Irrigation District has lots of iodine bush on it. Stuart

Hurlbert, statistician from San Diego State, reviewed the research design for the HRS. Soil scientists from UC Davis (Dr. Victor Claassen and David Kelley) and the Natural Resources Conservation Service (NRCS) (Kerry Arroues) visited the site to discuss soils and reference sites.

Weather data was collected by the California Irrigation Management System (CIMIS) weather station #105 located approximately 2.5 km (1.5 mi) west of the Tranquillity site and summarized in the final reports for each year. Data collected and summarized included precipitation, temperature, wind, and relative humidity.

The completed Quality Assurance Plan was implemented to monitor soil, groundwater, and surface water at the demonstration project site. A well network was installed to monitor groundwater levels and groundwater quality. Groundwater quality testing occurred on a quarterly basis during the first year of monitoring and annually thereafter. The initial surveys conducted in September and October of 1999 established baseline values for soil chemistry including salinity, selenium, boron, nitrate, pH, and major anions, cations, and nutrients. Unfiltered groundwater samples were analyzed for major ions, trace elements, isotopes, electrical conductivity, pH, temperature, and turbidity. Soil samples to establish baseline soil chemistry for demonstration project lands were collected.

The completed groundwater modeling study of various land retirement scenarios within the WWD will aid future land retirement planning within WWD.

Restoration and Site Management

Plugs of native species were grown and transplanted into “shrub islands.” The tillage question about not disturbing mycorrhizal development in buffers was discussed. Approximately 24 ha (60 ac) of the Tranquillity site was planted in safflower by the California Department of Fish and Game provided for an annual dove hunt. 22 hunters harvested 91 mourning doves (*Zenaida macroura*).

Outreach

1999 Partnerships were explored between the California State University system, local school districts, local tribal groups, and the proposed Central Valley Regional Historical Museum in Fresno, California, for the Tulare Lake artifacts and historical farm equipment held by sellers.

Year 2000 Accomplishments

Program Administration

The first Annual Monitoring Report on the Demonstration Project measuring physical and biological impacts from land retirement was published and distributed, as requested in the 1999 Biological Opinion.

An Interagency Agreement between Reclamation and BLM was developed that would allow BLM to directly acquire approximately 3,238 ha (8,000 acres) in the

Atwell Island study area that they manage. This 5-year agreement was for approximately $12 million, most of which was for land acquisition.

Land Acquisition

1,071 ha (2,646 acres) were acquired in the Atwell Island project area: 639 ha (1,578.48 acres) in Tulare County and 432 ha (1,067.5 acres) in Kings County, of which 184 ha (455 acres) were paid for by Central Valley Project Conservation Program.

Phase 1 Environmental Site Assessments were completed for approximately 2,428 ha (6,000 acres) of agricultural properties. The Assessments were completed in conformance with ASTM Standard E 1527-97 and Departmental Policy. Environmental Site assessments will be conducted on all properties purchased for land retirement prior to closure of escrow.

Appraisals for parcels in WWD were conducted by DOI-qualified appraisers to determine the fair market value of additional properties to be acquired and to establish the basis of negotiation and/or acquisition of the properties. Land acquisitions required the services of a title company and escrow to be opened prior to county recording of deeds and title processing.

Processing case files of acquired lands in accordance with federal land acquisition standards included locating properties utilizing all available survey records and markers and creating Geographic Information System (GIS) databases and maps.

Research and Monitoring

Some 32 biotic surveys were conducted each year on the Tranquillity site. The majority of surveys were specific to the HRS plots; however, a number of site-wide surveys were also conducted (See Appendix 3). Trials installed included imprinting vs. Drilling of Native Seeds Trial in the fall of 2000 (See Appendix 3). ESRP was to set up data management of the photo points and other photos and provide LRT copies.

Monitoring wells were installed at the Atwell Island Demonstration Site to measure groundwater response as part of the Land Retirement Demonstration Project. Groundwater, surface water, and soil samples were collected and analyzed for constituents of concern as part of the Land Retirement Demonstration Project. The results were shown and discussed in the annual monitoring report. As with the monitoring of physical impacts at the Tranquillity site, data collected at the Atwell Island site were used to determine the effects, if any, of selenium on biota. The groundwater modeling study of various land retirement scenarios continued.

Restoration and Site Management

The small-scale imprinting and berm trial was installed at Tranquillity. Applying adaptive management, those techniques which appeared to be best suited for conditions at the Tranquillity site were adopted for the HRS. Additional trials established tested Native Species, Cover Crops, and Mycorrhiza (See Appendix 3). Additionally, seed collecting at sites having remnant populations of native plants was initiated on a small scale (See Appendix 3). HRS plots at the Atwell Island site were established. Initial restoration efforts on more than 200 acres began.

The discussion of mowing techniques for HRS plots suggested that a strip down the center should be utilized instead of a circular pattern that would drive fauna to the center of the field. 8 ha (20 acres) of clover from the buffer area were offered to be harvested by neighbor to be used on idle land nearby. Discussions were held on the effects this could have on the buffers. Mowing would not impact much because the buffers were dried up already and mowing would act to remove another weed seed producer from the buffer. A field meeting with LRT, Karen, and Michelle resulted in agreement to mow Atriplex in buffer only (not plots) so that it does not spread tremendous numbers of seed over site. Consensus was that buffer areas need to be as weed free as possible to maintain the separation of experimental units and for aesthetic reasons—weedy areas look terrible to neighbors right now.

A meeting to discuss the serious weed problem at Tranquillity was held with Mike Williams of UCSB, Patrick Kelly, Michelle Selmon, and Woody Moise about serious weed problem. Sterile barley was found to reproduce and displayed recruitment of 50-75 percent cover in the plots. Weeds, such as *Sisymbrium irio* and *Senecio vulgare,* grew fast and threatened to swamp sprouting native seed. Native seed that sprouted 2.5-5 cm (1-2 inches) under the barley and London rocket did not do well unless the barley and weeds were controlled. All possible solutions, weed-eater, sheep, fire, aerial herbicide, or mowers, have problems.

Discussion of watering plots at Tranquillity and further plug planting of *Atriplex* and *Isocoma.* The thick cover of weeds, including sugar beets, was a problem. The suggestion was to disk areas slotted for a grass nursery where London rocket was seeding. Repeated disking was recommended to eliminate the weed seed base prior to restoration. The native grasses would be imprinted in the fall and a broadleaf herbicide used the next spring.

An unauthorized spraying at the Tranquillity site was experienced, most likely from the mosquito abatement district spraying. What the county's abatement program schedules are for the area needs to be known, as it affects personnel and experiments. This leads to talk of having research signs for the project site.

The Baseline Biological Surveys were scheduled for Atwell Island site. A field meeting with Michelle and Karen of ESRP, Bea and Larry Saslaw of BLM located HRS plots at Atwell Island.

First observation of false chinch bugs at site. "Brown stuff" noted that is sticky and appears shiny. Robust native plants were significantly affected. The "Low-till" situation may or may not have contributed to insect troubles, since false chinch bugs are drawn to those areas in addition to being attracted to stressed, thin stands of barley and mustard species.

To maintain the integrity and consistency of the buffer, mowing of the annual Atriplex on about 101 ha (250 acres) was warranted. It was agreed to disk weeds prior to the fall planting. The barley in the 243 ha (600 acres) of buffers surrounding the HRS plots was thrashed and surface disked. Barley was reseeded where necessary. A hedgerow with low berms constructed along the edges of the seeded area to allow for flood irrigation was installed and planted with 11 native species. A previous marsh area was seeded at Tranquillity on 3.2 ha (8 ac) of LRDP land where a seasonal wetland had been created by agricultural runoff (See Appendix 3). Some native seed was collected. Despite rain delays, 65 ha (160 acres) were planted in Tranquillity with berms constructed in a more or less random configuration (See Appendix 3).

Outreach

Partnerships were explored between the California State University system, local school districts, local tribal groups, and the proposed Central Valley Regional Historical Museum in Fresno, California.

Plant ID handout for tours and others working in restoration was discussed.
A Juvenile Dove Hunt had 45 hunters (quota was 50) on 24 ha (60 ac) of the Tranquillity site planted in safflower by the California Department of Fish and Game.

The LRT, in cooperation with FWS, staffed a booth at the Tulare County Farm Show which promoted the LRP and agricultural water incentive programs and SJV National Wildlife Refuges. Presentations were given by LRT, ESRP, and BLM to The Wildlife Society Western Section Conference in Visalia, California. A spring tour of the Fresno County site was given for a variety of stakeholders. Presentations were given at Kings County Farm Bureau and Westside Resource Conservation District Board of Directors.

Year 2001 Accomplishments

Program Administration

The 5-year Interagency Agreement between Reclamation and BLM began implementation to allow BLM to directly acquire approximately 3,238 ha (8,000 acres) in the Atwell Island study area.

John DiGregoria from Bitterroot Restoration worked on a CalFed project that would use Tranquillity to out-plant targeted species at sites in the SJV. Need to decide if want to let them use LRDP lands for some 9.1 m X 9.1 m (30 feet X 30 feet) plots. The grant did not go forward.

A request was received from Sacramento FWS Environmental Contaminants Division too late to look for bird eggs (blackbirds) for sampling for selenium. Perhaps a sample earlier in season can be done the next year by FWS, as ESRP does not have collecting permits for migratory bird eggs. The possibility was discussed of taking aerial photos to help define risks associated with water standing 30 days or greater, as identified in the Biological Opinion.

The second annual Land Retirement Demonstration Project Report documenting results of physical and biological monitoring programs, and adaptive management of retired lands was published and posted on the Reclamation website.

Land Acquisition

In Atwell Island Water District, 559.4 ha (1,382.22 acres) of land and associated water were acquired from willing sellers. A total of 1,630 ha (4,028.20 acres) was acquired to date. 862 ha (2,129.88 acres) were in escrow. In Fresno County, 180 ha (444 acres) (the North Avenue Parcel) was acquired.

For 160 parcels of land totaling 1,421 ha (3,512 acres) in the Atwell Island Water District, Phase II Environmental Site Assessments were completed. The Site Assessments directed sellers to address all recognized environmental conditions (RECs) prior to transfer of property. The LRT coordinated with appropriate regulatory agencies to confirm satisfactory mitigation of RECs prior to property transfer. The properties were thus transferred in a clean, safe, and satisfactory condition.

Research and Monitoring

Ancillary restoration studies at Tranquillity were initiated. Pitfall traps resulted in the first shrews and first herp, a western toad. The Imprinting vs. Drilling of Native Seeds trial, designed to investigate planting methods that require a minimal amount of ground preparation, had the vegetation sampled. Vegetation monitoring of the 100 "shrub islands" planted on the western and northern edges of the restoration area. Various habitat rehabilitation techniques were tested and monitored for adapting management actions on all retired lands. A reference site on vacant fields on a willing private landowner's property was found that may provide answers to many of the management and scientific questions raised at the Demonstration Project sites. These activities are discussed in more detail in Appendix 3.

Continued monitoring occurred of groundwater levels and groundwater quality in accordance with the Quality Assurance Project Plan at the Fresno site. Conceptual plans for monitoring groundwater and soils at the Atwell Island site were developed. Nitrate and carbonate testing were done at the Atwell Island site as had been done for the Fresno site. The irrigation system at the Atwell Island site was evaluated for its existing infrastructure; that evaluation provided a basis for future management decisions regarding supplemental irrigation applications for habitat restoration and land management activities.

Restoration and Site Management

At Atwell Island, harvesting of barley buffers was discussed and discouraged due to harvest conflicts with birds fledging. Meetings were held to discuss restoration activities, HRS plots, baseline surveys, and water purchase and delivery from Alpaugh ID. BLM planted 81 ha (200 acres) with a native mix purchased from S&S Seed. Atwell Island HRS plots initiated. Additionally, BLM planted 136 ha (335 acres) of safflower and hedgerow borders. BLM and LRT worked with the California Department of Corrections to mitigate prison fences with habitat work at Atwell Island. California Conservation Corps were contracted to set up pitfall arrays at Atwell Island in the HRS plots.

Water use from WWD and the Environmental Water Account (EWA) discussed. It is unclear what happens to water turned back that is put in the EWA.

ESRP got approval from landowners to do seed collection. Sites include railroad right-of-ways, golf course along Hwy 180 and CDFG Natural Areas at Alkali Sink and Kerman Flats Ecological Reserves. Sugar beets were hand weeded from HRS plots after the Agriculture Commissioner sent a second-year notification.

The Second Annual Report was published and sent to various divisions within the FWS per the Biological Opinion reporting requirement.

Outreach

ESRP gave a paper on the results to date of the Demonstration Project at the Western Section Conference on Restoration Ecology sponsored by the Wildlife Society in Sacramento, California. A lecture was given to biology students and faculty at California State University, Stanislaus, as part of a symposium series. Two presentations were given at the Society for Ecological Restoration, California Chapter, at a conference held in San Diego, California.

The Land Retirement Team gave an annual site tour to interested agency personnel and private parties in spring. The LRT gave a poster session on the Demonstration Project at the DOI Conference on the Environment in Albuquerque, New Mexico. The LRT spoke with the Kings County Farm Bureau and Westside Resource Conservation District Board of Directors about the program and the Demonstration Project. The LRT helped exhibit displays of SJV native plants and land retirement at the Tulare County Farm Show. The LRT gave a PowerPoint presentation of the LRDP to the Westlands Resource Conservation District. LRT attended a one-day workshop on restoration techniques sponsored by the BLM given by Craig Dremann of The Reveg Edge™ at the Kern National Wildlife Refuge. A LRT staff member attended the Central Valley Birding Symposium. A presentation was given by LRT, ESRP and BLM to The Wildlife Society Western Section Conference in Visalia, California. A LRT staff member attended the Central Valley Birding Symposium. Land Retirement Team staff attended the national conference of The Wildlife Society held in Reno, Nevada. A LRT staff member attended the Point Reyes Bird Observatory Landbird Monitoring Training Workshop.

During the summer, BLM cooperated with the California Department of Fish and Game (CDFG) and planted 24 ha (60 acres) of safflower and 4 ha (10 acres) of barley at the Atwell Island site. A lack of spring rain resulted in poor seed production such that only 13 dove were harvested by 27 hunters. At the Tranquillity site, the annual dove hunt had 35 hunters who harvested 213 mourning doves on the 24 ha (60 acres) of safflower planted by the CDFG.

Year 2002 Accomplishments

Program Administration

ESRP obtains permission from California Fish and Game to move a storage container and any other equipment or supplies to the Mendota Wildlife Area. This should help with controlling vandalism.

The third annual Land Retirement Demonstration Project Report documenting results of physical and biological monitoring programs and adaptive management of retired lands is published and posted on Reclamation's website.

Land Acquisition

At Atwell Island 559 ha (1,382.22 acres) of land and associated water from willing sellers is acquired. Late in the year 862 ha (2,130 acres) were acquired. The total acreage acquired to date in Atwell Island: 2,492 ha (6,158 acres).

In Fresno County 180 ha (444 acres) (North Avenue Parcel) was acquired.

Research and Monitoring

More ancillary trials to learn about alternate planting methods, native seed mixes, and cover crops were established. An *Atriplex spinifera* Planting Trial was installed and monitored in April, July, and December 2002, May 2003, and January 2004. A Berm and Mycorrhiza Trial was developed to investigate methods of enhancing topography and of facilitating recovery of the soil's mycorrhizal communities.

Annual monitoring activities at both sites occurred on the HRS plots and various habitat rehabilitation techniques were tested, results monitored and management actions adapted on all retired lands. All data collected for the study from 1999 to 2002 has been entered into databases, proofed and edited, and have been statistically analyzed.

As with the monitoring of physical impacts at the Tranquillity site, data were collected at the Atwell Island site to determine the potential negative effects of selenium, and other naturally occurring elements, on the site's biota. Baseline soil monitoring was initiated in 2002 at Atwell Island and comprised 432 samples. The groundwater levels and groundwater quality in Fresno continued to be monitored in accordance with the Quality Assurance Project Plan at the Westlands Demonstration Project site. Soil monitoring included re-sampling of all deep borings and a partial sampling of shallow sites where selenium concentrations were found to be highest in 1999. Results to date indicate a declining shallow water table in response to land retirement.

An annual bird count was conducted at Atwell Island on December 16, 2002. Participants helping with this effort included personnel from BLM, ESRP, and volunteers. Data compiled during this survey was intended for the National Audubon Society Christmas Bird Count (CBC), which is an annual survey conducted simultaneously in the Western Hemisphere during December (early winter). A total of 96 species were observed and 11,381 individuals were recorded. Thirteen participants equaling 29 party hours were dedicated to this survey.

ESRP conducted a baseline survey of the "North Avenue Property" (formerly, the Bell Property), an approximately 162 ha (400 acre) parcel that was added to the LRDP property in 2001.

Restoration and Site Management

BLM planted 136 (335 acres) safflower and hedgerow borders.

A fire occurred at Tranquillity site. Seed collecting was amplified in 2002-2003 Growing Season (See Appendix 3).

Outreach

The annual dove hunt, in which 43 hunters harvested 128 mourning doves, was held on the 24 ha (60 acres) of the Tranquillity site planted in safflower by the California Department of Fish and Game.

ESRP staff member attended the Partners in Flight Conference in March 2002 and presented information on avian responses to restoration in a poster. ESRP personnel and senior staff attended The Wildlife Society's Western Sections annual conference held in Visalia, California. Senior staff presented information and progress regarding the LRDP project. Another report also was presented at this conference on ornate shrews that included information derived from the LRDP project. Two articles were featured in the Central Valley Bird Club Bulletin submitted by an ESRP staff member. Two ESRP senior staff members presented papers on restoration of retired farmlands at a joint Ecological Society of America and Society for Ecological Restoration conference held in Tucson, Arizona.

The LRT and BLM gave a presentation on Atwell Island project accomplishments for BLM State Office Staff. BLM gave a talk on Atwell Island project for the

Tulare County Audubon Society. A tour of the Atwell Island project was given to a group from The Wildlife Society Western Section.

Year 2003 Accomplishments

Program Administration

Requests for restoration costs from San Luis Drainage Feature Re-evaluation coordinator Mike Delamore were developed.

Sign design for Research Site Land Retirement Demonstration Project was suggested. A Fire Plan for Tranquillity site was submitted to California Department of Forestry. Due to increased costs and logistical complications, BLM took over from ESRP all monitoring and management at Atwell Island site.

Harry McQuillen from FWS meets with WWD, BLM, Reclamation, and the I-5 Corridor Committee.

The third Land Retirement Demonstration Project Report was published documenting results of physical and biological monitoring programs, and adaptive management of retired lands. An electronic copy of this report was posted to Reclamation's website.

Land Acquisition

In Atwell Island, 862 ha (2,130 acres) of land and associated water were acquired. Total BLM acres acquired now totals 2,492 ha (6,158 acres).

Research and Monitoring

LRT and ESRP gave a presentation to the FWS Environmental Contaminants Division regarding the potential biological effects of land retirement and selenium. The reaction from Dr. Joe Skorupa was that land retirement "is not the loaded gun" FWS envisioned, but that the high concentrations in the groundwater warranted further monitoring (Joe Skorupa).

At Tranquillity site, the Pre-irrigation Trial was imprinted, as were the Herbicide and Growth Form Trials, and Burn Plots to examine the effectiveness of mowing as a pre-treatment and of imprinting induced disturbance following burning for restoration in *Bromus madritensis* dominated habitats (See Appendix 3).

Three soil samples were taken from near the center of each of the 48 0.8 ha (2 acre) research plots and groundwater monitored at Atwell Island. The Christmas count at Atwell Island had 79 censured bird species. Hedgerows were responsible for increases in species (20 to 27) and from 956 to 1,709 individuals from previous year. A major population of Horned Lizards and San Joaquin Valley Coachwip was discovered at Atwell Island.

Restoration and Site Management

Improvements were finalized by ESRP to the imprinter so that smaller amounts of seed could be run in the hopper. Study plots for burn, mowing, and herbicide/growth form trials (16 0.2 ha [½ acre] plots) were installed (See Appendix 3).

Quail Unlimited installed a guzzler at Tranquillity in area used for dove hunt. A trespass in the North Avenue Parcel occurred due to mismanagement of neighbor's irrigation pond that overflowed and wetted about 0.49 ha (1.2 acres) of LRT land. They also rutted up the road with heavy equipment. Hedgerows were hand-seeded. Fencing was installed at the nursery to prevent annual Atriplex from blowing in and to discourage trespass sheep. On the south side of the nursery, donated 3.8 liter (1 gallon) pots of alkali sacaton grass were planted. Barley had to be re-bagged at Mendota to be put in mouse-proof container. Large-scale restoration of 32 ha (80 acres) Manning Avenue Restoration was attempted.

The Tranquillity Native Seed Nursery (1.6 ha [4 acres], with an additional 0.8 ha [2 acres] being managed for future planting) was moved to a site on better soil and nearer a more convenient water supply. Research on seed delivery, plant propagation, and seed production methods was conducted on 34 different San Joaquin Valley locally collected native plant species. Five species show a high potential for mechanized production and harvest. Historical records for particular species were investigated from primarily herbarium specimens and site-searches initiated. Historical records for particular species were investigated from primarily herbarium specimens and site-searches initiated (See Appendix 3).

BLM established 48 km (30 miles) of hedgerows (about 20 ha [50 acres]), seeded 32 ha (80 acres) of range land after treatment with propane flamer, planted 150 trees in riparian-canal areas using hydro-planter, planted 50 potted trees and shrub in riparian-canal areas and developed a native seed source by increasing seed collection activities through seed collecting contracts and a seed grow-out contract. Restoration activities were coordinated with cooperating farmers who performed the work. Additionally, BLM developed 4 ha (10 acre) wetland for breeding season.

Outreach

BLM and LRT helped to establish and work with the newly established Tulare Lake Basin Working Group. They worked on developing partnerships with Sequoia Riverlands Trust; USDA NRCS; and USDI Fish and Wildlife Service. Tours given by BLM of Atwell Island project included The Wildlife Society Western Section, representatives of the California Department of Corrections and EDAW, the CVPIA Restoration Group from FWS, Patagonia's Sustainable Cotton Tour and to the BLM Bakersfield Field Office management team and interagency LRT. Workshops and conferences attended by BLM staff include: Seed for Success workshop in Sacramento (Instruction workshop on seed collecting), daylong workshop and open house at ConservaSeed in Courtland, tour of Union Slough restoration project in Yolo Co., and the Ecological Farming conference and Wildfarm Alliance Workshop at Asilomar.

BLM provided a day in the field for 25 school kids from Sierra Elementary Schools to tour Atwell Island and trap k-rats and horny toad lizards with BLM biologists. ESRP gave a presentation on the LRDP and SJV plant communities to the advanced science classes at Kerman High School in Kerman, California. A presentation on wildlife population monitoring in the Central Valley was given to biology classes at Kerman High School. Interested, biology career-driven students were offered the opportunity to accompany ESRP staff biologists on the spring blunt-nosed leopard lizard *(Gambelia sila)* survey at Pixley National Wildlife Refuge. ESRP staff members hosted an educational volunteer day for Kerman High School advanced placement biology students at the Tranquillity Native Plant Nursery. Students worked to remove weeds and transplant native species, do birding, and have lessons on local plant communities and habitat restoration. ESRP sponsors a student from the Center for Advanced Research and Technology who analyzed some of the small mammal data for her class project.

The LRT provided a Field Tour for the Sacramento Fish and Wildlife Restoration Program Implementation Division of CVPIA Land Retirement Demonstration Project and SJR Riparian Habitat. LRT member attended the Lemoore NAS Revegetation Workshop by John Crane and Craig Dremman and the UC Extension Conservation Tillage Workshop at Five Points. The LRT gave a second presentation to the Kings County Board of Supervisors. LRT gave a special Land Retirement Presentation to Wayne White, FWS.

LRT site tours were given to 50 members of the Fresno County Economic Opportunity Council and I-5 Business Corridor and to Dr. Ken Lair, Research Ecologist and Botanist from Reclamation's Denver Technical Services Center. The latter contact resulted in a cooperative effort being established for 2004 with the USDA-NRCS Plant Materials Center in Lockeford, California to augment seed supply.

The 2003 an annual dove hunt had 42 hunters who harvested 255 mourning doves at the Tranquillity site planted in safflower by the California Department of Fish and Game.

A science education program at Alpaugh School was initiated, with possible coordination with the California Institute of Biodiversity using CAL-Alive CD-ROM, their educators, and the Atwell Island Land Retirement Restoration Project.

Year 2004 Accomplishments

Program Administration

At Tranquillity, work was accomplished with a revised contract with ESRP.

Research, restoration, and continued acquisition at and Atwell Island continued with the Interagency Agreement with the Bureau of Land Management.

The Land Retirement Demonstration Project Fourth Annual Report was published in January 2004. An electronic copy of this report was posted to Endangered Species Recovery Program's website at http://esrpweb.csustan.edu/publications/pdf/lrdp/2002ar

A draft of the 5-year analysis and report was started in October 2004.

Development of an Implementation Plan for recovery of upland species on restored retired agricultural lands began. Discussions with listed species experts were held. Discussions of how to best utilize the techniques and native plant species of the CVPIA Land Retirement Program for upland habitat restoration on retired agricultural lands used this information.

Land Acquisition

Acquisitions for the Land Retirement Demonstration Site at Atwell Island continue to target completing transactions to reach the goal of 3,238 ha (8,000 acres). During FY 2004, 12 ha (30 acres) were purchased and an additional 62 ha (154 acres) closed by the end of FY 2004 (total 74 ha [184 acres]). Other acquisition actions began with the acceptance of a DOI offer for a 253 ha (625 acre) parcel and for an appraisal currently underway on a 65 ha (160 acre) parcel.

Research and Monitoring

ESRP met with Dr. Hurlbert about statistical questions and procedures, transformations of the data, and how to implement that.

Potential trials and restoration activities at Tranquillity: showplace, nursery, hedgerows, large scale restoration, herbicides vs. growth-forms, pre-irrigation trial, imprinting vs. broadcasting trial, seed augmentation, planting method trial and water use trial (See Appendix 3). Research for the program continued in field trials focused on determining ways to reduce competition between native plants and weedy species. Management activities continued in addition to monitoring, data gathering and analysis for the habitat Restoration Study at both the Tranquillity (ESRP) and Atwell Island (BLM) study sites.

Data gathering for the 5-year Habitat Restoration Study, designed to determine the effects of habitat restoration on wildlife on 20, 4 ha (10 acre) plots at the Tranquillity site, was completed. All data were entered into databases, proofed, edited and a suite of exploratory data analysis and graphing accomplished for selected data sets covering the 5 consecutive years of the study (1999 to 2004).

The Land Retirement Team, ESRP, and BLM staff assisted Dr. Ken Lair, Reclamation Restoration Botanist, to design, establish, and sample plots containing 8 native plant species planted with a variety of techniques. Habitat rehabilitation techniques in replicated trials were conducted on 64 plots on 6 ha

(15 acres) at the Tranquillity site and inter-planted on 8 ha (20 acres) of alfalfa at Atwell Island.

Awarded grant from Reclamation's Science and Technology Program enabled research to be conducted on the effects of land retirement on project groundwater and soil. Continued monitoring of soil and groundwater conditions at both sites. Monitoring equipment to gather weather data at Atwell Island site to be integrated into California Irrigation Management Information System (CIMIS) was purchased.

The conceptual model of groundwater flow at Tranquillity site was developed in preparation for numerical model simulating groundwater response to land retirement.

Restoration and Site Management

ESRP and BLM noticed Atriplex lentiformes die-off in Mendota area and throughout the SJV.

At the Atwell Island site, hedgerows with native plant species have been established. A San Joaquin kit fox was observed using the hedgerows established in January 2003. 80 km (50 miles) of hedgerows were established on the Atwell Island project site and restoration work initiated on more than 40 ha (100 acres), including planting out flamed grasslands, canal banks, tree poles and upland shrub planting in formerly alfalfa fields (approximately 8 ha [20 acres]), and 4 ha (10 acres) of shorebird habitat and planting. Cooperation with an organic farmer to grow-out Alkali Sacaton and Indian Rice grass was initiated.

The SJV native plant nursery at Tranquillity expanded to 2 ha (5 acres) and increased from 34 to 64 species (13 shrubs, 30 annual herbs, 19 perennial herbs, 2 perennial grasses). Collections of 91 species from 78 locations were made on 314 collecting trips. Additionally, 8 species were established in 0.2 ha (0.5 acre) plots using mechanized production and harvesting methods. Mechanized seed cleaning equipment was purchased and operations established. Large quantities of seed were collected under contracts.

Research on seed delivery, plant propagation, and seed production methods continued with the USDA Plant Material Center in Lockeford, California. Seed augmentation of three targeted species will be done in FY 2005.

Restoration and site management activities at both sites were accomplished with cooperating farmers. Barley was planted at Tranquillity on 243 ha (600 acres) in buffers that isolate the study plots from one another, inhibit the establishment of weeds, and reduce erosion and dust. Additionally, barley was planted on 49 ha (120 acres) that was previously used as research trials so that new trials can be installed in FY 2005. On 32 ha (80 acres), a new cultivar of barley (UC937) was planted that UC Davis developed for use on high saline soils.

At Atwell Island, a wildlife farming demonstration area was established with 6 ha (15 acres) of native shrub plantings interspersed with 8 ha (20 acres) of crops, 2 ha (5 acres) each of vetch, milo maize, wheat, and safflower. The results of this wildlife habitat planting laid the groundwork for a Cooperative Agreement with the Westside Resource Conservation District to implement five units in Fresno County in FY 2005.

The existing 8 ha (20 acres) wetland at Atwell Island was managed for wintering waterfowl.

Outreach

Presentations and posters were given at a number of forums in FY2004. These included the Annual Statewide Department of Water Resources Workshop, Drainage and Salinity Annual Conference, American Society of Mammalogists, California Native Plant Society, Society of Ecological Restoration, and the Raptor Research Foundation.

Outreach to the local high school science classes and science clubs introduced a workshop on land retirement. A volunteer day at the native plant nursery was held in observance of Earth Day. Two CSU Fresno graduate students are conducting research at the Tranquillity site to investigate native plant pollinators' populations and seed delivery methods for seven native plant species. At Atwell Island, a CSU Fresno graduate student is studying of post-harvest flooding effects.

Participation in the Tulare Lake Basin Working Group fostered working partnerships with Sequoia Riverlands Trust; Tulare County Audubon Society; USDA-NRCS; and FWS Refuges and Joint Venture Program.

A presentation of the CVPIA Land Retirement Program was given to researchers Dr. Werner 'Erik' Klohn and Dr. Hans-Wilhelm Windhorst of the University of Vechta, Germany. These visitors studied and traveled the California water and agricultural regions for the past 15 years. Their work is sponsored by the Institute of Spatial Analysis and Planning (ISPA) in areas of intensive agriculture at the University of Vechta.

ESRP gave a presentation to two environmental science classes at the Center for Advanced Research and Technology (CART) in Clovis, California. ESRP biologists, CART students and teachers, and Clovis Botanical Garden personnel transplanted more than 150 native plants and installed a drip irrigation system along the Clovis Community Trail. Plants were donated from the LRDP nursery. ESRP biologists held an interview and volunteer day at the ERSP warehouse. The event was open to CART students interested in a part-time seeding experiment position with ERSP. The position was offered to and accepted by an environmental science student in his junior year of studies at CART.

Various LRT members and ESRP biologists attended the Hedgerows in Agriculture workshop sponsored by the Community Alliance with Family Farmers at the UC Center in Fresno, California.

Two presentations were given at the American Society of Mammalogists meeting at Humboldt State University, Arcata, California. A presentation was given at the Raptor Research Foundation conference in Bakersfield, California.

The California Department of Fish and Game annual dove hunt at the Tranquillity site had 38 hunters who harvested 183 mourning doves.

Year 2005 Accomplishments

Program Administration

The LRT received Reclamation's Science and Technology Program was awarded funds to conduct research on the effects of Land Retirement on project groundwater and soil.

A Cooperative Agreement with the Westside Resource Conservation District in Tranquillity, California was developed to establish upland habitat restoration units on retired lands in the SJV.

Participation in the Tulare Lake Basin Working Group fostered further working partnerships with Sequoia Riverlands Trust; Tulare County Audubon Society; USDA-NRCS; and FWS Refuges and Joint Venture Program for the Atwell Island site.

A California State University Fresno-Agriculture Research Initiative grant proposal was submitted with Dr. John Constable of CSUF by Dr. Nur Ritter of ESRP.

The Five-Year Land Retirement Demonstration Project Report (1999-2004) will be produced, pursuant to the FWS BO September 1999 for the CVPIA Land Retirement Program Demonstration and put on the Reclamation website.

Land Acquisition

The acquisition process for two parcels totaling 318 ha (785 acres) of land and associated water within the Atwell Island Water District was completed.

Research and Monitoring

The fourth year of the 5-year study at the Atwell Island Project Site continued. Monitoring soil and groundwater conditions at both sites continued. Numerical simulation of groundwater flow and salt transport in the shallow groundwater at the Tranquillity Site will be performed. The Hydrosphere groundwater model will be utilized to simulate groundwater flow and advective transport of solutes at the demonstration project site.

Research on seed delivery, plant propagation, and seed production methods continued with the USDA Plant Material Center in Lockeford, California. Seed augmentation of three targeted species will be done in FY 2005.

Data gathering for the 5-year Habitat Restoration Study, designed to determine the effects of habitat restoration on wildlife on 20, 4 ha (10-acre) plots at the Tranquillity site, was completed. The fourth year of the 5-year study at the Atwell Island Project Site will be done and the restoration activities continue, emphasizing previously successful techniques, while developing and testing new methods.

The Reclamation Denver Technical Services Center Restoration Ecologist Dr. Ken Lair will help with trials to expedite refinement and continuance of research on species adaptation, planting methods, weed control, plant selection, propagation, seed increase, plant materials supply for landscape-scale application, and interagency development for commercial retail supply

Joe Brummer, soil scientist at the Technical Service Center will collect and analyze soil chemistry data from the Land Retirement Demonstration Project, especially salinity, selenium, and boron and findings will be reported in the FY2005 report. Numerical simulation of groundwater flow and salt transport in the shallow groundwater at the Tranquillity Site will be performed in FY 05. The Hydrosphere groundwater model will be utilized to simulate groundwater flow and advective transport of solutes at the demonstration project site.

Restoration and Site Management

Restoration and site management activities at both sites were accomplished with cooperating farmers. Barley was planted at Tranquillity on 243 ha (600 acres) in buffers that isolate the study plots from one another, inhibit the establishment of weeds, and reduce erosion and dust. Additionally, barley was planted on 49 ha (120 acres) that was previously used as research trials, so that new trials can be installed in FY 2005. On 32 ha (80 acres), a new cultivar of barley (UC937) was planted that UC Davis developed for use on high saline soils.

Restoration activities at the Atwell Island Project Site will continue, emphasizing previously successful techniques, while developing and testing new methods. Restoration acreage will expand from the current 61 ha (150 acres) per year to more than 101 ha (250 acres). The existing 8 ha (20 acres) wetland at Atwell Island, established with the cooperation of the USDA-NRCS, was managed for wintering waterfowl. 51 km (32 miles) (32 ha [80 acres]) of hedgerows were established with native shrubs. On 8 ha (20 acres) of range land, seeding occurred after treatment with propane flamer. Iodine bush was seeded on 2.8 ha (7 acres) of a sump (former evaporation pond). A mix of native annuals and perennials was planted on 160 acres. A hydro-planter installed 200 tree cuttings in riparian-canal areas along with 150 potted trees and shrubs. BLM developed a native seed source by increasing seed collection activities (approx. 8000 pounds) utilizing seed collecting contracts and established a 1.5 acre grow-out area for native grass seed under contract Two acres of perennial grass seed were planted along ditch banks. Two more diversified upland habitat units were established on 80 acres. BLM coordinated with cooperating farmers to carry out restoration activities.

Outreach

Presentations given this year included one by a Reclamation hydrologist and soil scientist on research findings regarding soil and groundwater response to land retirement in the Western San Joaquin Valley at the International Salinity Conference held at Riverside, Ca in April, 2005. At the Society for Ecological Restoration, California Chapter annual meeting at Bass Lake, California, ESRP had one poster abstract and three oral presentations accepted and BLM and FWS another one.

BLM held a workshop on recreation and tourism potential for Atwell Island and the Tulare Basin. BLM established a partnership with AmeriCorp NCCC which provided a crew of 10 to work on numerous projects including construction of 0.5 miles of nature trail, reforestation of 3 miles of ditch and pond banks, and general cleanup and maintenance of the administrative site. The crew also worked on a greenhouse at the Alpaugh School as a first step to get students involved in the restoration project. The crew also conducted a major cleanup event and removed over 45 tons of garbage from the community, much of which might otherwise have been dumped on the project area. BLM continued to work with the Tulare Lake Basin Working Group and to help establish Tulare Basin Wildlife Partners, an NGO which will be a cooperator on the project. BLM expanded its work via partnerships developed with Tulare County Audubon Society; Alpaugh School District; Citizens for a Better Alpaugh; State Park Service – Allensworth SHM; USDA NRCS; USDA Forest Service (Trails Unlimited); and USDI Fish and Wildlife Service (FWS).

ESRP gave a day-long tour to the coordinators and nursery staff from the five native plant nurseries of the Golden Gate National Recreation Area. ESRP sponsored a booth and gave presentations to 100 underprivileged school children at the USDA Forest Service Central California Consortium event held at Grizzlies Stadium, Fresno, California.

ESRP developed a web-site that makes information on the Land Retirement Demonstration Project and research results available to the public and to cooperating agencies. Links are provided to the various annual reports and the 5-year report. The ESRP web site can be accessed at: http://esrp.csustan.edu/projects/lrdp/.

Appendix 2. Compliance with Biological Opinion

by Beatrice A. Olsen

The Fish and Wildlife Service (FWS) stated support for land retirement as one of several means to manage subsurface agricultural drainage as was recommended in the SJVDP 1990. Their belief was that the Land Retirement Demonstration Project could benefit the reduction of contaminated subsurface drainage water, increase available fresh water for fish and wildlife and provide large blocks of land that could potentially be restored to productive upland wildlife habitat, with potentially important endangered species benefits. The LRDP was thought likely to adversely affect SJ kit fox, Fresno kangaroo rat, blunt-nosed leopard lizard, giant garter snake, Aleutian Canada goose, delta smelt, and Sacramento splittail. A not-likely-to-adversely-affect determination was found for American peregrine falcon, bald eagle, mountain plover, California red-legged frog, vernal pool fairy shrimp, valley elderberry longhorn beetle, palmate-bracted birds-beak, San Joaquin woolly-threads, Hoover's eriastrum, and California jewelflower.

Conservation Measures

CONSERVATION MEASURES OF CVPIA LAND RETIREMENT DEMONSTRATION PROJECT

Task	Action Required	Results
Listed Species Recovery	Prioritize lands for acquisition	1997 Multi-agency LRP Guidelines used
Evaporative Pond Closure	Close pond to State Standards	Required & done prior to federal acquisition
Habitat Revegetation	Study options & implement habitat rehabilitation	In-depth study @ both sites. Mgt plans ongoing.
Enhancement Survival Program	Service to work w. LRP to develop a plan	Workload of Service personnel too great.
Monitoring Program	Tiered Contaminant Monitoring Se and GW	GW drops ave. 1-2 ft/yr. Se conc > 50ug/L See Chptr 2.
Performance Standards	Compare monitoring data to Se standards.	Met Perfc Stds except GW quality. See Chptrs 2 & 3.
Adapt Mgt/Contingency Plan	Minimize risk of Se exposure w. adaptive mgt.	Restoration uses adaptive mgt. Contingency plans not needed.

FWS Conservation Measures were determined to be critical to the conclusion that survival and recovery of the listed species in the action area would not be reduced appreciably by the LRDP. As noted by FWS, the information gained from the LRDP would be used to guide future implementation and future land acquisitions of the CVPIA Land Retirement Program. The 1997 Multi-agency Interim Land Retirement Guidelines were employed to determine lands for acquisition for the Demonstration Project.

Evaporation pond closures for any federal acquisitions had to be done to the State Regional Water Quality Standards. The evaporation pond at Atwell Island was closed to these standards prior to the LRT acquisition of the property.

The purpose of Habitat Re-vegetation was described by FWS as the re-establishment of native vegetation to foster the return of native species, which will enhance wildflower and wildlife viewing opportunities. Some retired lands could be managed for gamebird hunting programs. The extent to which recreational activities will be promoted will depend upon the type and success of the land management treatments employed. The restoration trials and study have been conducted to determine methods to recreate San Joaquin Valley ecosystems. For several years a small section has been planted to safflower for a California Department of Fish and Game dove hunt. Wildflower viewing, as envisioned by the FWS, would be limited to the spring and dependent upon access. It has not been a major recreational activity. As noted by the FWS, separate management plans will be developed for the lands in WWD and the Atwell Island area. The management plans will address contaminant issues for listed species and utilize the results described and analyzed in this five-year report. Some level of selenium and groundwater depth monitoring will be part of these plans. They will have separate section 7 consultation.

The Enhancement for Survival Program for neighboring landowners, after several interagency meetings, was left in the development stage due to the large workload of FWS employees.

The tiered contaminant monitoring program of selenium levels in groundwater and biota was cooperatively developed with the FWS specifically for this project (FWS 1999). The monitoring of selenium and salinity in soils was not a requirement in the FWS Biological Opinion for the LRDP; however, the soil monitoring program was implemented to address concerns raised by the scientific community over potential impacts to soils that may result from land retirement.

The hydrologic techniques, results and discussion are thoroughly described in Chapter 2. Groundwater level data from the demonstration site support the conceptual model of a declining shallow groundwater table in response to land retirement. All of the wells monitored at the Tranquillity site have shown a declining water level trend over the five year period of record. The hydrographs for the drain sumps and wells are representative of the declining groundwater level trend observed at the site during the five years of monitoring. Water levels measured in three drain sumps during the time period from July 1998 to July 2000 similarly show an overall declining trend in groundwater levels for the period of record. All sumps being monitored were completely dry starting in October 2000. The drain sumps have remained dry as of October 2004.

As discussed in Chapter 2, the slopes of the hydrographs for groundwater show a flattening trend over time. Examination of individual wells suggests that the extinction depth for groundwater evaporative discharge may be about 10 feet. The volume and flow of upflux is so small between a depth of 7 and 10 feet that evaporative discharge in the soil cracking system at the 2-4 foot depth may be sufficient to maintain a very small amount of unsaturated upward flow. Once the water table receded below 10 feet, all discharge is believed to be vertical deep percolation through the first barrier layer. The average annual rate of decline was about 1.2 feet per year. This rate is expected to decrease as less head is available to push water through the barrier layer.

The shallow, perched groundwater is extremely saline in nature. Salinity in the shallow groundwater and drain sump samples, expressed as EC, ranged from 11,500 to 76,980 µS/cm, with a median value of 43,925 µS/cm. The groundwater samples obtained from the underlying semi-confined aquifer are much less saline. Salinity in the groundwater samples obtained from the deep wells (> 50 ft deep), expressed as EC ranged from 5,630 to 18,580 µS/cm, with a median value of 7,675 µS/cm. The groundwater found in the perched zone and in the underlying semi-confined aquifer is best described as a sodium- sulfate type of water. Selenium concentrations measured in the shallow groundwater system (wells < 50 feet deep) during the first year of monitoring were high, ranging from 5 to 5,390 µg/l (0.005 to 5.390 mg/l), with a median concentration of 1,280 µg/l (1.280 mg/l).

Due to drought conditions, the FWS performance standards for selenium and mercury concentrations in surface water that persisted for more than 30 days were not observed at the project site. Precipitation at the site was monitored by viewing the CIMIS website during the rainy season. The site was also visited during the wet season to document any standing water that persisted for more than 30 days in duration.

In Chapter 3 the methods and results of Se monitoring in biota are discussed. The FWS Performance Standards required that Se contaminant levels be monitored in biota when high physical parameters results were obtained. The potential for adverse effects to sensitive species was measured each year in a number of non-listed species collected and analyzed. Not all Performance Standards were strictly utilized, as small sample sizes would have precluded adequate measurement and analysis. Samples of items at the base of the food chain were collected and analyzed for selenium but not birds or canids.

The mean selenium concentration in plants varied from 0.31 to 0.51 mg/kg at the Tranquillity site and from 0.21 to 0.26 mg/kg at the Atwell Island site. The mean selenium concentrations in plants at both sites were below the performance standards set for the project by the U.S. Fish and Wildlife Service (2.0 mg/kg) and were approximately an order of magnitude less than the selenium concentration in plants collected from Kesterson NWR. The mean selenium concentrations for all biota measured were higher at the Tranquillity site than at the Atwell Island site. At the Tranquillity site the mean concentration of selenium in invertebrates remained below the performance standard, except for spiders in 1999 and isopods. Mean selenium concentrations generally remained within the range for terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). At the Atwell Island site the mean concentration of selenium in all invertebrate groups remained below the performance standard of 2.0 mg/kg established for project lands. The selenium levels in all invertebrate groups (crickets, beetles, spiders, and isopods) collected from the Tranquillity and Atwell Island sites are approximately an order of magnitude less than corresponding invertebrate groups collected between 1988 and 1992 in grassland habitat at Kesterson NWR.

All biotic samples were analyzed to determine selenium concentrations by Laboratory and Environmental Testing (L.E.T.), Inc., Columbia, MO. Data provided include selenium concentration by dry weight, selenium concentration by wet weight, sample dry weight, sample percent moisture, and sample detection limit. The laboratory also provided reports on duplicates, spikes, and reference samples for quality control. Selenium concentration by dry weight was used for analysis.

An adaptive management approach has been the one used by the LRT for the project. Measurements of the various monitoring of physical and biotic parameters had to be made before management techniques to minimize the risk of wildlife exposure to contaminants were exercised. As the LRDP proceeded, the results that were reviewed indicated that contingency plans, as outlined in the Biological Opinion, would not be necessary. Continued vigilance of especially the groundwater depths and selenium levels in biota will be exercised and reported so that changes can be made if needed. To establish upland vegetation quickly and efficiently, a variety of re-vegetation techniques will continue to be tested and monitored and future efforts will be adapted accordingly.

Incidental Take Statement

The effect of anticipated take for the Land Retirement Demonstration Project was not likely to result in jeopardy to listed species or destruction or adverse modification of critical habitat of Fresno k-rat and delta smelt. The rest of the species have no designated critical habitat, so no critical habitat for these species could be destroyed or modified.

INCIDENTAL TAKE STATEMENT FOR THE CVPIA LAND RETIREMENT DEMONSTRATION PROJECT

Task	Action Required	Results
Reasonable & Prudent Measures	Protect/conserve species w. monitoring & toxic remediation	Monitored species not need toxic remediation.
	Future acquisitions will not result in take.	Data indicated measure met by LRDP.
	No converting of existing native species habitat.	DOI-WWD Agreement ensured water not go to convert habitat. Sent Hill Valley & AI info.
Terms & Conditions	Fund 5 years of tiered monitoring.	LRP funded ESRP contract and BLM biota monitoring & USBR for physical monitoring.
	Implement FWS remediation measures for bio-available toxic levels of Se.	No remediation bec. GW levels declined even w. bad quality. Se biota levels generally below Performance Standards.
	Close evap pond at Atwell Is per CRWQ Standards	Seller required to do prior to federal ownership.
Reporting Requirements	Provide annual reports to EC & ES Divisions of data collected from tiered monitoring.	Annual reports provided 2000, 2001, 2002 & 2004. 5-yr report available Aug. 2005.
	Notify SFWO w/in 3 work days of dead listed wildlife species.	April 26, 2002 ESRP captured 5 shrews (BVL). Notice sent to SFWO. Roadkill kit fox reported by BLM.
	Provide info of recent drainage mgt on acquired lands	1 piece of acquired land had drains, but no longer intact or functional.
	Notify SFWO of species take not authorized.	None taken so none reported.
	Report dead or sick listed wildlife species in/adjacent pesticide-treated areas.	None found during restoration activities.

The Reasonable and Prudent Measures necessary and appropriate to minimize the impact of the LRDP to listed species were each complied with. The LRDP's requirement to protect and conserve listed species on lands acquired under the project by monitoring and remediation of toxic conditions was done and results demonstrated that no remediation of toxic conditions was required. Data collected indicated that land retirement would insure that future acquisitions for the LRDP would not result in increased or unauthorized take of listed species. The Agreement with WWD ensured the Land Retirement Team that water would not be used to convert existing native species habitat.

The Land Retirement Demonstration Project met the nondiscretionary Terms and Conditions described in the 1999 Biological Opinion (BO). Funding of the tiered monitoring program was provided for at least 5 years. CVPIA funding for the LRP Demonstration Project met the project costs for the monitoring and restoration on the retired agricultural lands. Having a Fish and Wildlife Service Land Retirement Team Representative (co-lead) ensured that funds for proper monitoring and reporting occurred each year. The FWS Representative prepared and helped finalize all annual work plans and their implementation.

No remediation measures were necessary due to bio-available toxic levels of selenium. The groundwater levels showed a declining shallow watertable. This is an important aspect of land retirement due to the high salinity and selenium concentrations in the shallow groundwater. The high concentrations in the shallow groundwater found in the coast range deposits at the site are a result of leaching under irrigated conditions and evaporation from the shallow water. The access to this contaminated groundwater is very limited because of the increased depth after irrigation is removed and the selenium levels in biota tended to be within the range typically found in biota occurring on non-seleniferous soils in the western United States. Additionally, the mean selenium levels in biota were generally below the population-level performance standards set in the BO.

The evaporation pond in the Atwell Island Water District had to be closed in accordance with State of California standards. Adherence to these standards had to occur before federal ownership could be obtained of the lands containing the evaporation pond. The landowner had to close the evaporation pond to meet the California Regional Water Quality (CRWQ) Control Board, Central Valley Region Orders and Resolutions. The 16 March 2001 letter from Gary M. Carlton, Executive Officer California Regional Water Quality Control Board Central Valley Region certified that the discharge to the basin had ceased and that basin sediments remaining in the basin were at or near background levels of soils in the area. The evaporation pond was closed in accordance with CRWQ requirements. Vegetation cover is slowly taking hold and the pond continues to be monitored.

Reporting Requirements were all met. The first report was of the transactions between Atwell Island Water District (AIWD) and Hill Valley Irrigation District for the AIWD CVP allotment. These transactions occurred prior to the project dealings with AIWD. What historic information was available was forwarded to SWFO within 30 days of receipt of the BO in 1999. The lands acquired by the LRDP came with associated CVP contract allocations, except for those lands in Fresno County. The land purchase agreement with WWD was executed when the lands were purchased in the district and followed the language the FWS recommended for incorporation in the Agreement. Cover letter and Agreement language were agreed upon by the FWS prior to inclusion in the Environmental Assessment and the FONSI. Water was not used to convert habitat or where it would adversely affect listed species or their habitats and remained within the permitted place of use. The Agreement was an Appendix in the CVPIA Land Retirement Demonstration Project Environmental Assessment.

Reporting Requirements for the Biological Opinion centered primarily on an annual report that was to be provided to the various divisions for their review of the data collected from the Tiered Monitoring Program. These annual reports were provided beginning in May 2000 for 1999 data. Subsequent years' reports were produced in July 2001, September 2002, and January 2004 and copies sent to each of the interested departments/parties within the Sacramento Fish and Wildlife Office (SFWO). The Five Year Report will be available in September 2005.

Notification of the SFWO within 3 working days of the finding of any dead listed wildlife species occurred only when five Buena Vista Lake shrew (BVLS) were captured on April 26, 2002 at Atwell Island. A notice was sent to the SFWO about the captures. Since BVLS had just been listed the previous months, the FWS had not yet issued recovery permits to anybody. ESRP applied for and received a recovery permit later in 2002, with a take authorization of 20 animals as they had requested. Baseline trapping with pitfall traps in 2000, and more extensive trapping with Sherman live traps, did not result in the capture of any more shrews. The two living shrews were released after taking tail tissue samples. The three dead shrews were preserved for genetic analyses. From historical map information and air photos, the land where these shrews were captured appears to have been in row crops for many years until the restoration project in 2001. The LRDP lands were all planted in barley in the winter of 2000/2001. The nearest water way is a canal about 0.5 miles to the east of the plots where it was trapped. The plots are about 11 miles northeast from the center of the Kern NWR.

Information regarding the recent drainage management of the lands acquired in WWD was involved only one piece of land where drains were installed as part of a WWD experiment. No parcels had subterranean drainage infrastructure. The drains which had been installed were no longer intact or functional. This information was supplied to the SFWO early in the project.

The Reporting Requirement to provide the FWS with annual reports describing the progress of implementation of all commitments in the Conservation Measures were included in detail in the Annual Reports noted above. No take of any listed wildlife species not authorized in this opinion occurred. See the note above related to the BVLS. Additionally a road kill kit fox was found at the Atwell Island site. BLM reported this road kill at the time of its discovery. No dead or sick listed wildlife species found in or adjacent to pesticide-treated areas were found.

Conservation Recommendations

Implementation of any conservation recommendations or applications of the data have been included in the Annual Reports. Special presentations to the FWS at various times over the past six years have also served to inform them of results from the monitoring of land retirement impacts. Each Conservation Recommendation is described below with the compliance action.

CONSERVATION RECOMMENDATIONS OF CVPIA LAND RETIREMENT DEMONSTRATION PROJECT

Task	Action Required	Results
Future Acquisitions	Future acquisitions should contribute to listed species water supply	CVPIA not likely to have large-scale LRP in Fresno Co. due to WWD's 70,000 retired acres
Implementation of Recovery actions	LRT should assist FWS in implementation of various recovery plans	All plans w. SJV upland habitats benefit from CVPIA data & monitoring in Annual Reports
SJVDP Recommended Plan	LRT should assist FWS in implementation of this plan	SJVDP provided basis of CVPIA authorized LRP, but differences exist. LR currently considered in SLDFR EIS.
Educated Reclamation staff	Provide education to USBR staff at all levels on ESA & 7 (a)(1) responsibilities.	USBR staff training done by Sacto & Area Offices.
Outreach	Provide outreach to public & schools on protecting listed species	Tours, presentations, panel discussions, student projects & AmeriCorps integral part of LRP from its inception.
Fund USGS studies	Fund GW & contaminant levels studies thru USGS.	Physical monitoring done by USBR specialists under LRT Hydrologist. USGS specialists consulted as well.
Ecosystem protection components	Follow ecosystem protection components for Central Valley & Bay Delta of the FWS's Ecoregion Program.	The LRT Restoration Trials & Habitat Restoration Study provides background data for implementing protection measures on remnant populations or their habitat. Required & done prior to federal acquisition.

1. The CVPIA Land Retirement Program is not likely to embark on a large scale effort to retire more lands in Fresno County beyond those purchased under the current project. This is due to the initiation of WWD's own land retirement program which has now retired, either through lawsuit settlements or district purchase, approximately 70,000 acres.

2. All those recovery plans that involve San Joaquin Valley upland habitats can benefit from review of the Five Year Report or previous Annual Reports. The information from these has also been available on the Endangered Species Recovery Program website or the Bureau of Reclamation website. Data on physical parameters in retired drainage-impaired agricultural lands and on biota presence and habitat restoration techniques could be helpful to those agencies and entities responsible for management of the existing listed species habitat remnants. Specific funding to implement these recommendations will have to come through other means than the CVPIA Land Retirement Program.

3. The SJVDP provided a basis for the CVPIA. Some differences exist in the objectives of each, although many are similar, but the CVPIA Land Retirement Program is authorized by the CVPIA, which is not required to implement the SJVDP. Land retirement is currently being considered in the San Luis Drainage Re-Evaluation EIS.

4. The education of the ESA and 7(a) (1) responsibilities of Reclamation staff at all levels are handled by the appropriate division in Sacramento and the Area Offices.

5. Outreach in the form of tours, presentations, panel discussions, student projects and professional organization presentations have been an integral part of the CVPIA Land Retirement Program since its inception.

6. The FWS suggested that CVPIA fund studies of groundwater percolation and contaminant levels through USGS. Data collection for LRP groundwater monitoring and contaminants was accomplished by Bureau of Reclamation specialists and their contractors and USGS specialists consulted as well.

7. The last item recommended that the LRT follow ecosystem protection components for the Central Valley and Bay Delta of the FWS's Ecoregion Program. Restoration Trials and the Habitat Restoration Study can provide these entities background data for implementing protection measures on remnant populations or their habitat.

Appendix 3. Research and Restoration

by Nor P. Ritter

Introduction

In the appendix, an overview is presented of the activities undertaken by the Land Retirement Team and Endangered Species Recovery Program (ESRP) during the course of the Land Retirement Demonstration Project 1998-2004. Topics are presented as follows.

Baseline Surveys of the Tranquillity and Atwell Island Property were conducted prior installing the Habitat Restoration Studies (HRS) plots.

An established monitoring regime was carried out each year on both the Tranquillity and Atwell Island Habitat Restoration Studies.

ESRP undertook restoration of portions of the Tranquillity property, and conducted a large number of restoration trials.

A native plant nursery was established on the Tranquillity property. Seed collecting sites were located throughout the westside of the San Joaquin Valley, and seed was collected for use in the nursery and in restoration efforts. These activities, as well as a brief overview of the seed processing facility are presented in this appendix.

Biotic monitoring at Atwell Island was conducted by ESRP from 1998 until October 2002. Since that time, Bureau of Land Management (BLM) has taken over responsibility for all management and research activities at Atwell Island. Activities specific to BLM will be presented by that agency in a separate report.

Baseline Surveys

Tranquillity Site

Biotic Survey   A baseline biotic survey of the Tranquillity property was conducted on December 2, 1998. The survey protocol entailed driving the perimeter roads around each quarter section, with periodic foot surveys onto the first 15-30 m (50-100 feet) of each field. A preliminary species list was compiled, and areas that merited additional surveys were identified. A follow-up field survey was conducted on December 7 and 14, 1998, during which time, the previously identified high-priority areas were more intensively surveyed.

Outcomes from the baseline survey included (1) a preliminary catalog of all noted plant species and animals (identified visually or by sign) was compiled; and (2) areas which potentially might support species of interest were identified. Subsequent site work (e.g., tilling and contouring) was structured to avoid these areas. A report of the baseline survey was submitted to the Land Retirement Team (see Selmon 1999).

In 2002, ESRP conducted a baseline survey of the "North Avenue Property" (formerly, the Bell Property), an approximately 162 ha (400 ac) parcel that was purchased by the Land Retirement Team in May of that year. The property was surveyed in its entirety (May-June 2002). Monitoring was conducted for vegetation, invertebrates, birds, mammals, amphibians, and reptiles. Outcomes from this survey included a catalog of species noted on the site, and a survey report (included in Uptain et al. 2004).

Physical Impacts Monitoring Monitoring of physical conditions at the Tranquillity site was designed to address the potential for selenium contamination of the local biota. Soil monitoring was aimed at detecting changes in levels of soil selenium, boron, and salinity that might result from land retirement over the 5-year life of the Demonstration Project. The initial surveys conducted in September and October of 1999 established baseline values for soil chemistry including salinity, selenium, boron, nitrate, ph and major anions, cations, and nutrients.

Soil sampling methodologies were as follows. A rectangular sampling grid was established and land surface soil sampling was conducted at 124 locations. Soils were collected from a depth of 0 to 30.5 cm (0 to 1 foot) at each corner of the HRS plot using a shovel. In addition, sampling of soils from 0 to 30.5 cm (0 to 1 foot), 60.9 to 91.4 cm (2 to 3 feet), and 121.9 to 152.4 cm (4 to 5 feet) was performed in the center of each plot, and from an additional six locations per plot, using a 10.1 cm (4 in) inside diameter split barrel core sampler driven to a depth of 152.4 cm (5 feet).

Groundwater monitoring was instituted in July of 1998 to detect the subsurface level of water and test the hypothesis that the water level would decline in the absence of surface watering (i.e. the irrigation of crops). Monitoring entailed collecting samples from 27 wells and sumps on the Tranquillity site.

Atwell Island Site

Biotic Survey An initial baseline survey of the Atwell Island property was conducted in April and May 2000 (see Uptain et al. 2001 for a complete report of this survey). The property was divided into three large areas; the delineations were based primarily on land-use history. Surveys were conducted for vegetation, birds, small mammals, invertebrates, contaminants (selenium), and, peripherally, herptiles. Vegetation monitoring methodology consisted of a series of walkover surveys, in which all observed species were identified and recorded. Avian monitoring methodology utilized visual encounter surveys. In these surveys, researchers walked transects across designated field. Recorded data included all avian species that were heard or observed, as well as any observed mammals or reptiles. Small mammals were surveyed by nighttime trapping (Sherman traps). Invertebrates were surveyed using pitfall traps. Selenium monitoring followed the same general methodologies as were used at the Tranquillity project site.

Physical Impacts Monitoring   As with the monitoring of physical impacts at the Tranquillity site, data were collected at the Atwell Island site to determine the potential negative effects of selenium and other naturally occurring elements on the site's biota. Baseline soil monitoring was initiated in 2002 and comprised 432 samples. Three soil samples were taken from near the center of each of the 48 approximately 0.8 ha (2 ac) research plots. One composite sample consisting of four sub-samples was collected from a depth of 0.0 to 30.5 cm (0 to 12 in); three of the four sub-samples were taken from within a two-meter radius of the center; while the remaining sub-sample was taken from the center. Additionally, one sample each from 30.5 to 76 cm (12 to 30 in) and 76 to 152 cm (30 to 60 in) was taken. Two field replicate samples were taken from each quarter section. Samples were analyzed for selenium, sulfate, chloride, electrical conductivity, and moisture. Surface samples were analyzed for boron, magnesium, potassium, sodium, carbonate and nitrate. Protocols and procedures taken to ensure quality of data in soil collection and analysis are outlined in the Quality Assurance Project Plan (QAPP) for the LRDP (CH2M Hill 1999).

In the fall of 1999, Reclamation installed 17 monitoring wells to measure groundwater levels and sample for water quality. Baseline surface and groundwater monitoring was conducted in January 2002.

Annual Monitoring Activities

Tranquillity HRS

Biotic Surveys

Each year, 32 surveys were conducted of the biota on the Tranquillity site. The majority of surveys were specific to the HRS plots (Table A3-1); however, a number of site-wide surveys were also conducted (Table A3-2). The effort required to conduct these surveys was quite variable, with some (e.g., the vegetation contaminants monitoring) generally requiring only a couple of person-days to complete. Others, such as the small mammal trapping, required up to 20 person-days (e.g., five biologists for 4 days).

Table A3-1. Annual monitoring activities on the Habitat Restoration Study plots (Tranquillity site), 1999-2003, with the number of times each survey was conducted per year.

Survey	Repetitions
Avian Nesting Survey	1
Avian Survey	4[A]
Fall Shrub Monitoring	1[B]
Invertebrate Pitfall Survey	1
Invertebrate Sweep Survey	1
Photographic Stations Survey	4
Reptile and Amphibian Coverboard Survey	1
Reptile and Amphibian Transect Survey	1
Small Mammal Pitfall surveys	1
Small Mammal Trapping	4[C]
Spring Vegetation Monitoring	1

A. Only conducted 3 times in 1999.

B. Only conducted in 2002.

C. Only conducted once in 1999 and 3 times in 2000.

It should be noted that all monitoring activities outlined here were accompanied by a significant body of data-related activities. Examples are data entry, data proofing, voucher preparation and cataloging, photo archiving, etc.

Table A3-2. Annual site-wide monitoring activities at the Tranquillity site, 1999-2003, with the number of times each survey was conducted per year.

Survey	Repetitions
Invertebrate Contaminants Monitoring	1
Small mammal Contaminants Monitoring	1
Spotlighting Survey	4
Track Station Survey	4
Vegetation Contaminants Monitoring	1
Winter Raptor Survey	1

Physical Impacts Monitoring

Soil monitoring followed the methodologies outlined, re-sampling of all deep borings and a partial sampling of shallow sites where selenium concentrations were found to be highest in 1999 were conducted in November 2002. The Quality Assurance Project Plan for the LRDP describes the protocols and procedures taken to ensure quality of data in soil collection and analysis (CH2M Hill 1999).

Weather data have been collected by the California Irrigation Management System (CIMIS) weather station #105 located approximately 2.5 km (1.5 mi) west of the Tranquillity site and are summarized in the final reports for each year. Data collected and summarized included precipitation, temperature, wind, and relative humidity.

Irrigation regimes were reported on an annual basis beginning in 1999. Amount of water (in acre-feet) and methods and dates of application are reported. In addition to groundwater level monitoring, groundwater quality testing occurred on a quarterly basis during the first year of monitoring (October 1999; February, May, and July 2000), and annually thereafter. Unfiltered groundwater samples were analyzed for major ions, trace elements, isotopes, electrical conductivity, pH, temperature, and turbidity.

Atwell Island HRS

Biotic Monitoring

The same suite of surveys that were conducted on the Tranquillity site served as the model for the surveys undertaken at the Atwell Island HRS (Table A3-3). As with monitoring at the Tranquillity HRS, the effort required to conduct these surveys was quite variable, and spanned approximately the same range of person-days as did the surveys at Tranquillity. Likewise, monitoring at Atwell Island was accompanied by the same body of associated tasks (e.g., data entry and proofing).

Table A3-3. Annual monitoring activities on the Habitat Restoration Study plots (Atwell Island site) 2001-02, with the number of times each survey was conducted per year.

Survey	Repetitions
Avian Nesting Survey	1
Avian Survey	4[A]
Fall Shrub Monitoring	1[B]
Invertebrate Pitfall Survey	1
Invertebrate Sweep Survey	1
Photographic Stations Survey	4
Reptile and Amphibian Coverboard Survey	1
Reptile and Amphibian Transect Survey	1
Small Mammal Pitfall surveys	1
Small Mammal Trapping	4[C]
Spring Vegetation Monitoring	1

A. Only conducted 3 times in 2001.

B. Only conducted in 2002.

C. Only conducted once in 1999 and 3 times in 2000.

Physical Impacts Monitoring

Soil monitoring followed the methodologies outlined. All deep borings and the shallow sites with the highest selenium concentrations (in 1999) were re-sampled in November 2002.

Weather data were collected from the CIMIS station #21 located approximately 29 km (18 mi) west of the project site. Data collected included hourly precipitation, wind, and relative humidity.

In the fall of 1999, Reclamation installed 17 monitoring wells to measure groundwater levels and sample for water quality. Baseline surface and groundwater monitoring was conducted in January 2002; subsequent monitoring was conducted on a quarterly basis. To evaluate the influence of irrigation on groundwater levels, the amount (in acre-feet) of irrigation water applied, application method, and date were recorded throughout the course of the project

Restoration and Site Management — Tranquillity

During the course of the Demonstration Project, ESRP has conducted a variety of restoration trials and has undertaken restoration of portions of the Tranquillity property. Additionally, various management strategies have been utilized on portions of the property. These activities are briefly summarized in this section, and are presented in the following order: (1) restoration research (includes both the HRS and ancillary trials); (2) restoration; and (3) site management.

In contrast to the other sections of this Appendix, which are organized by calendar year, activities in this section are organized by growing season. This approach was taken because it better represents the order in which activities were undertaken. For example, trial installation would typically be scheduled for the latter portions of a particular calendar year (e.g., October to December); however, due to various limitations, some of the same year's trials might not be installed until January or February of the following calendar year. Nevertheless, treatment applications (e.g., herbicide applications) and monitoring for all the aforementioned trials would occur during the same period (generally, spring). By presenting the trials in this manner, it allows the reader to distinguish between those trials that were installed in the latter part of one growing season (e.g., January in the 2001-02 growing season) from those trials that were installed in the following fall (e.g., November of the 2002-03 growing season).

1998-99 Growing Season

In the fall of 1998, a cover crop of barley was planted on approximately 493 ha (1,220 ac) of the Tranquillity property. This planting was done in the hopes of establishing relatively homogenous conditions on the areas on which the HRS plots were to be sited.

1999-00 Growing Season

HRS Plot Installation

Treatments were applied to the HRS plots. Seed of 13 native species was imprinted across the 10 “seeded” plots in March 2000. Native seedlings were also transplanted onto these experimental plots in March and April 2000. Transplanted seedlings were closely grouped in “shrub islands.” Microtopographic contours (berms) were created on the ten “bermed” plots. The 240, approximately 12 m (39.4 foot) long berms were installed on each plot.

Imprinting Trial

To investigate the restoration techniques proposed for the HRS, a small-scale imprinting and berming trial was undertaken. Berms were constructed using various approaches, and the imprinter was pulled over the plot. Those techniques which appeared to be best suited for conditions at the Tranquillity site were adopted for the HRS.

Native Species, Cover Crop, and Mycorrhiza Trial

Another, small-scale trial was installed in which a variety of native species were interplanted with potential cover crop species. A second component of this trial involved the use of mycorrhizal inoculum, which was incorporated into a portion of the test plots.

Site Management

The barley in the buffers surrounding the HRS plots (~ 243 ha; 600 ac) was thrashed, and the area was surface disked. Barley was reseeded where necessary.

2000-01 Growing Season

Imprinting vs. Drilling of Native Species Trial

The Imprinting vs. Drilling of Native Seeds trial was designed to investigate planting methods that require a minimal amount of ground preparation. Tillage breaks down the soil structure and can bring weed seeds to the soil surface. It was hoped that less soil disturbance would decrease weed density and promote the establishment of mycorrhizal networks in the soil, both of which tend to favor native plants (cf. St. John 1995). Comparisons were made between two seeding methods, imprinting and drilling.

Plots were ca. 0.6 ha (1.5 ac) in size; treatments were replicated three times. A mixture containing seed of nine native species was imprinted. Data (percent cover and species composition) were collected from eight quadrats (35 x 70 cm) per plot. Installation of the experiment was undertaken in the fall of 2000; vegetation sampling was conducted the following spring (14-15 May 2001).

Imprinting vs. Drilling of Cover Crops Trial

This trial was designed to (1) investigate appropriate techniques for establishing cover crops, and (2) to examine the utility of planting native species in combination with a cover crop (i.e., a “nurse species”). The impetus for this trial came from the understanding that it will no doubt be necessary to undertake large-scale restoration in phases. Cover crops will most likely be an important tool in the implementation of restoration, particularly if the cover crops can be planted with minimal soil preparation.

Plots were ca. 0.6 ha (1.5 ac) in size; each treatment was replicated three times. Two seed "mixtures" were used: (1) barley and (2) barley in combination with three native grasses. Data (percent cover and species composition) were collected from eight quadrats (35 x 70 cm) per plot. Installation of the experiment was undertaken in the fall of 2000; vegetation sampling was conducted the following spring (14-15 May 2001).

Section 23 Restoration

Restoration of approximately 64.8 ha (160 ac) was undertaken in December 2000. Berms were constructed in a more or less random configuration. Both linear and curved berms were constructed; berms were oriented in either a north/south or an east/west direction. A mixture containing seed of 17 native species was imprinted at a rate of 9 pounds per acre of native seed and 14 pounds per acre of wheat bran used to keep variably sized native seeds in suspension).

One hundred "shrub islands" were planted on the western and northern edges of the restoration area. Forty-three seedlings were transplanted at each island: 20 of *Allenrolfea occidentalis*, 11 of *Atriplex polycarpa*, and 12 of *Sporobolus airoides*. For each island, an additional 5 seedlings of *A. occidentalis* and 2 seedlings of *S. airoides* were planted on an adjacent berm. In total, 2,500 seedlings of *A. occidentalis*, 1,100 seedlings of *A. polycarpa*, and 1,400 seedlings of *S. airoides* were transplanted. Vegetation monitoring was conducted in the May 2001 and again in February 2002.

Site Management

HRS Buffer Maintenance The barley in the buffers surrounding the HRS plots (~ 243 ha; 600 ac) was thrashed, and the area was surface disked. Barley was reseeded where necessary.

Hedgerow Seeding Vegetation on field borders may harbor pests; therefore, these areas are usually disked or sprayed with herbicide. Hedgerows planted with native species are a positive alternative to these management practices. Hedgerows can be maintained with minimal management, can provide important habitat for birds and other wildlife, and may tend to favor beneficial insects.

In December 2000, an approximately 3 m (10 foot) wide hedgerow was imprinted with seed of 11 native species. Low berms were constructed along the edges of the seeded area to allow for flood irrigation. In January 2001, seedlings of *Atriplex lentiformis, Leymus triticoides, Nassella pulchra* and *Sporobolus airoides* were planted along one berm at approximately 0.6 m (2 feet) on center.

Marsh Area Seeding During the initial years of the Demonstration Project, a seasonal wetland would form annually on lands adjacent to the Tranquillity project site. The wetland was created by agricultural runoff, and occasionally this water also inundated approximately 3.2 ha (8 ac) of LRDP land. During periods of inundation, these areas supported large numbers of herons and other water birds. To enrich this habitat, a mixture containing seed of 14 native species was imprinted onto the LRDP portion. Species were selected that were typical for both mesic and upland habitats.

Ditch Bank Seeding

Ditches are a common feature of the agricultural landscape and are often managed with herbicides and blading to prevent the accumulation of weedy species. Native plants can potentially prevent weedy species from overtaking ditches while providing excellent cover for wildlife. In December 2000, a ditch was created on the northern and western boundary of the Section 23 Restoration area. Seedlings of *Leymus triticoides* and *Nassella pulchra* were planted along the ditch banks. In January 2001, a mixture of 13 native species has hand-seeded along the ditch.

2001-02 Growing Season

Atriplex spinifer*a Planting*

In this trial, an evaluation was made of the success of *Atriplex spinifera* (spiny saltbush) when planted in various groupings. *Atriplex spinifera* is an important component of the Central Valley's native habitats. This species was also of interest because of its ability to become established in habitats dominated by red brome (*Bromus madritensis*).

Atriplex spinifera transplants were grown-out from cuttings taken from shrubs on Section 10. A local nursery with extensive experience working with California native plants (Intermountain Nursery, Auberry, California; Ray LeClerge, owner) was contracted to undertake the propagation and grow-out. Plants were maintained in approximately gallon-sized peat pots until transplanting, and were watered as deemed appropriate (approximately bi-weekly) while in the nursery. Two treatment effects were investigated: (1) planting density and (2) plant spacing. Shrubs were transplanted in groups (shrub islands) of four different configurations. All plants were watered at the time of transplanting. Additional watering occurred weekly until the site received soil-soaking rains (late December 2001). The condition of each plant was monitored in April, July, and December 2002, May 2003, and January 2004.

Berm and Mycorrhiza Trial

The Berm and Mycorrhiza Trial was developed to investigate methods of enhancing topography and of facilitating recovery of the soil's mycorrhizal communities. Two factors were considered: (1) berm "architecture" (i.e., the manner by which berms were constructed); and (2) mycorrhizal inoculation. Two methods of berm construction were compared. The first method ("dressed" berms) approximated that used to construct berms in the HRS trial; in the second method ("rough" berms), berms were constructed using just the border maker and were not compacted. Commercially purchased mycorrhizal was applied to half the plots.

Plot size was approximately 0.2 ha (0.5 ac); each treatment was replicated five times. Each plot contained seven berms; berms were evenly-spaced on approximately 9.1 m (30 feet) centers and were oriented east to west. A seed mixture of thirteen native species was imprinted. Installation of the trial began in mid-February 2002. Because of the late seeding date and the low rainfall, the plots were irrigated twice during the course of the experiment (March 21 and April 20, 2002). Data (percent cover and species composition) were collected from 15 quadrats (35 x 70 cm) per plot. Vegetation monitoring was conducted in mid-May 2002 (May 6, 11-12, 14, 17-20).

Succession Trial

The Succession Trial was developed to examine differences in the dispersal and establishment of three different seed mixtures: (1) barley: (2) barley with native grasses; and, (3) the native seed mixture that had been used on the HRS plots. Two factors were examined — the ability of native grasses to become established when imprinted over an existing barley crop; and, the relative abilities of barley and imprinted native grasses to spread beyond the confines of the area in which they had been seeded.

The trial was installed on an approximately 32.4 ha (80 ac) area of the Tranquillity property. Fifteen plots (five replicates of three treatments) were delineated. Plot width for the barley monoculture was approximately 36.6 m (120 feet); plot width for the other two treatments was ca. 18.3 m (60 feet). Barley had previously been planted as a cover crop in this area in the fall of 2000, and had been thrashed and harrowed in 2001. This planting had provided sufficient seed such that the plots assigned to the barley monoculture did not require replanting. Plots assigned to the other two treatments were disked and imprinted with the appropriate seed mixture. Trial installation took place during February 13-15, 2002.

Because of the low rainfall that year and the relatively late seeding date, vegetation establishment was not sufficient to warrant monitoring of this trial. Although systematic sampling of the Succession Trial was never conducted, the trial area received periodic visits during the following growing season, during which time general observations were recorded.

Suitability Trial

The Suitability Trial was developed to evaluate the performance (i.e., establishment and growth) of various native species under field conditions at the Tranquillity Demonstration Site. Forty-three species were initially considered for inclusion in the trial. These species represented species that had previously been used in restoration activities in California. The species were ranked based on

18 criteria (see, Uptain et al. 2004, p. 136). Six species (five perennial grasses and one sub-woody perennial), were selected for inclusion in the trial.

Each species was planted (imprinted) in a single, approximately 0.13 ha (0.33 ac) plot (12' x 1200'). This approach was adopted because of difficulties associated with seeding small plots with an imprinter. Although this experimental design promoted a more equitable seeding of the plots, this approach limited the analysis options as there were no true replicates (i.e., pseudoreplication, sensu Hurlbert 1984). Hence, rather than being treated as a rigorous experiment, this trial should be interpreted more as a structured step in identifying suitable species for inclusion in restoration efforts in the study area.

Imprinting was undertaken on March 15, 2002. The plots were sprinkler irrigated twice during the course of the experiment (March and April 2002). Vegetation sampling was conducted during June 16-18, 2002. Plots were divided into 40 equal-length (ca. 9.2 m; 30 feet) segments; vegetation data were collected from one randomly located quadrat (35 x 70 cm) within each segment.

Suaeda moquinii *Salvage Trial*

The *Suaeda moquinii* Salvage was an attempt to relocate a number of native perennials from an area that was undergoing development. The source population was located alongside State Route 180 in adjacent to the Kerman Ecological Reserve. This portion of the highway was being widened, and numerous native plants were threatened with removal.

Salvage activities were limited to a single species, *Suaeda moquinii* (bush seepweed). This species was selected because there were hundreds of individuals available and many were small enough (15 cm to 30.5 cm; 6-12 inches in height) to be transplanted with relative ease. Although many individuals of *Atriplex polycarpa* were also present, most were large and would have been problematic to transplant.

A portion of the Native Plant Nursery was prepared for transplanting by removing all weeds and working the soil. Transplanting took place on April 18, 2002. The soils at the donor site were hard clay and very dry. These conditions proved problematic, as the soil would crack when a shovel was put into the ground and fall away from the plant, leaving broken bare roots. Care was taken to dig around the plants in an attempt to remove them with an intact root ball, but this was generally not possible. The root ball was wrapped in a burlap sheet cut to size and then kept moist until transplanted. A few plants were also taken bare root.

One hundred forty individuals were transplanted. Plants were moved by truck to the nursery and were planted, with each individual given approximately 3.8 liters (1 gallon) of water. The following day, the transplants were flood irrigated to provide deep moisture to the plants.

Manning Avenue Restoration

Restoration (i.e., contouring and imprinting) of an approximately 32.4 ha (80 ac) parcel located south of Manning Avenue was undertaken late January and early February 2002. Seeding of this area was also used to refine calibration of the imprinter. Imprinting was undertaken when the ground was wet. The soils on the property are heavy clay, and imprinting under these conditions had pronounced negative effects. The soil was compacted to where it was not possible to push a shovel into the ground. As would be expected under these conditions, germination of both native and introduced species was very limited.

Site Management

HRS Buffer Maintenance The barley in the buffers surrounding the HRS plots (~ 243 ha; 600 ac) was thrashed, and the area was surface disked. Barley was reseeded where necessary.

Marsh Mix Planting Following the initial seeding of the "Marsh Mix Area," the area was mistakenly disked by the farmer that had been contracted to conduct site maintenance. The area (~ 3.9 ha; 9.6 ac) was re-seeded in January 2002 with a mixture of 14 native species.

2002-03 Growing Season

Section 23 Restoration Trial

As noted, rainfall during the first three years of the project was below average. In contrast, winter rainfall for the 2002-03 growing season was predicted to be fairly high (i.e., mild El Niño conditions were predicted). In anticipation of these wetter conditions, an experiment—the Section 23 Restoration Trial—was developed in which various species could be evaluated during an above-average rainfall year. In this experiment, two species mixtures were compared. The first mixture, the "traditional mix" was composed of a subset (9 of 13) of the species that were imprinted on the HRS Plots. The second mixture, the "experimental mix" incorporated various species that had been used to some success in other restoration trials at Tranquillity, augmented by a few species that had demonstrated restoration potential elsewhere in California.

The Section 23 restoration trial occupied an area of approximately 28.3 ha (70 ac). This area had received some weed control and was the largest contiguous block of "unassigned" land remaining on the Tranquillity site. Plots were ca.3.0 ha (7.5 ac) in size; a complete randomized block design was applied, with treatments replicated four times. Micro-topographic contours (berms) were installed in all plots. Berms were aligned east to west and were the full length of the plot. Berm spacing was 9.2 m (30 feet), such that part of a flat and half of a berm would be imprinted in a single pass and with a final pass through the middle of a flat, there would be no overlap in seeding. In this manner, the berms were also compacted slightly. Berms were constructed on December 11, 2002. Imprinting was scheduled to follow immediately thereafter; however, rainfall during this period precluded the use of heavy equipment throughout December and imprinting was postponed until January 28-31, 2003.

Pre-Irrigation Trial

In this trial, the utility of pre-irrigating lands prior to imprinting was investigated. Pre-irrigation is a common weed-control practice in agriculture (Lanini et al. 2003), and is a recommended approach in hedgerow installation (Earnshaw 2004). Hence, it appeared that this technique might also have some utility in the ecological restoration of retired agricultural lands.

Pre-irrigation entails irrigating the land before the start of the growing season (i.e., the initiation of winter rainfall in late fall-early winter) to promote germination of the 'winter weeds.' The weeds are then removed, either chemically, by tillage, or by burning, and the crop is seeded. In this manner, the seeded species hopefully have a competitive advantage over any additional weeds that germinate later in the growing season.

The area designated for the trial had been dominated by a variety of weeds during the preceding year, and the area had been disked for weed control during the winter of 2001-02. Plots were ca. 0.2 ha (0.5 ac) in size; a complete random block design was applied with treatments replicated four times. A single treatment factor (pre-irrigation) was evaluated.

Site preparation was initiated on September 3, 2002. The soil was disked and trenches were installed for flood irrigation. To account for the effects of site preparation on vegetation establishment, the control plots received the same preparation as the treatment plots (i.e., trenches were also dug in the control plots but these were not flooded). The pre-irrigated plots were sprinkler-irrigated (cf. Lee & Dyer 1997) from September 7-9. After the winter weeds had germinated, all plots (treatment and control) were disked (October 14, 2002).

Following disking, a mixture containing seed of eight native species was imprinted in all plots (19 November 2004). Data were collected from 12 quadrats (35 x 70 cm) per plot. Vegetation monitoring was conducted on April 29, 2003.

Growth Form and Herbicide Trial

The Growth-form and Herbicide trial was developed to examine how specific seed mixtures, in combination with specific herbicides could produce good ground cover, lower competition from weeds, and ultimately affect long-term planting success. Three seed and herbicide "treatments" were applied: (1) the "Grasses Treatment," a mixture of native grasses with an application of broadleaf herbicide (Weedar 64); (2) the "Forb Treatment," a mixture of native forbs with an application of a grass-specific herbicide (Sethoxydim); and (3) the "Late-Season Treatment," a mixture of late-germinating perennial species with an early application of a broad-scale herbicide (Glyphosate).

Plots were ca. 0.2 ha (0.5 ac) in size; a complete randomized block design was applied, with each treatment and a control (i.e., no treatment) replicated four times. The plots were seeded on November 20, 2002. The Forb and Late-Season Treatments were imprinted. Originally, it was intended that the Grass treatment would also be imprinted; however, the long awns on some of the seeds did not feed properly through the imprinter hopper. Therefore, for this treatment the seed was first broadcast over the plot, and was then worked into the soil by a pass with an empty imprinter. Herbicide for the Grass Treatment was applied on the last week of February; herbicides for the other two treatments were applied in the middle of March.

Vegetation monitoring of the Grass and Forb treatments and the control plots was conducted during May 2003. Monitoring of the Late-Season plots was timed to coincide with the plants having attained their maximum growth for the season. Monitoring of these plots occurred on November 8, 2003. Data were collected from twelve quadrats (35 x 70 cm) per plot, for the Grass, Forb and Control plots. The Late-Season plots received a higher-density of sampling, with 24 quadrats (100 cm x 150 cm) per plot.

Section 10 Burn and Mowing Trial

Section 10 on the Tranquillity site is an area dominated by *Bromus madritensis* (red brome), with a characteristically heavy layer of thatch. Prescribed fire is a common management tool that also possesses utility in restoration strategies, and has been demonstrated to be effective in grass-dominated habitats (Pollak and Kan 1998; Wilson and Stubbendieck 2000).

The Section 10 Burn and Mowing Trial was developed to take advantage an accidental fire that burned a large portion of Section 10 in June 2002. The timing of the accidental burn was not optimal in terms of controlling the winter-germinating grasses. Nevertheless, it was a good opportunity to evaluate the restoration potential of some seemingly fire-adapted native species. Mowing, another common management tool was incorporated in the trial as a second treatment factor.

Shortly after the fire, the burned area was mapped using a global positioning system receiver in June. Four “blocks” were designated within the burned area; these blocks were delineated in such a manner as to “standardize” the burn intensity of the areas selected for the study plots. Plots were ca. 0.2 ha (0.5 ac) in size; a complete randomized block design was applied, with treatments replicated four times. A mixture containing seed of seven native species was imprinted. In order to subject the control plots to the same level of disturbance as the treated plots, an empty imprinter was run over the control plots.

Data were collected from 12 quadrats (35 x 70 cm) per plot. Imprinting occurred on November 22, 2002. The “mowing” plots were mown a single time (March 28, 2003). Although it was anticipated that the plots might need to be mowed multiple times, weed growth under that year’s extremely dry conditions was not sufficient to warrant additional mowing. Vegetation monitoring was conducted on May 5, 2003.

Mowing Trial

The Mowing Trial was developed to test whether various mowing regimes could facilitate the establishment of native species by reducing weed competition. The trial was originally intended to be situated on the North Avenue Property; however, repeated incidences of trespass grazing on that property necessitated that the trial be relocated on Section 23.

Two treatment factors, seeding and mowing, were incorporated into the design. Restoration (imprinting, berming, and transplanting) had been attempted on Section 23 in 2000; however, the entire area had been trespass grazed in the summer following restoration, and few plants survived the grazing. Hence, unseeded plots were incorporated into the study design as it was hoped that mowing might help "release" the seed in the seed bank that remained from these restoration activities.

Plots were ca. 0.2 ha (0.5 ac) in size; a complete randomized block design was applied, with treatments replicated four times. A mixture containing seed of five native species was imprinted. To subject the non-seeded plots to the same level of disturbance as the seeded plots, an empty imprinter was run over the non-seeded plots. The plots were imprinted on November 13, 2002. The "mowing" plots were mown a single time (March 28, 2003); as with the Section 10 Burn Trial, weed growth was not sufficient to warrant additional mowing. Vegetation monitoring was conducted on 1 May and 6 May 2003. Data (percent cover and species composition) were collected from 12 quadrats (35 x 70 cm) per plot.

North Avenue Property Restoration

Restoration efforts were undertaken on an approximately 32.4 ha (80 ac) area at the northern end of the North Avenue Property. Restoration included micro-topographic contouring (berming) and imprinting of native seed (13 species). Berm installation took place from December 5-7, 2002; imprinted was conducted from December 8-10, 2002.

Prior to creating the berms, any large tumbling saltbushes (*Atriplex argentea* and *A. rosea*) were shredded to ground level. Berms were spaced on 6.1 m (20 feet) centers and were oriented east to west. The berms were installed in a serpentine manner to produce a more natural look and to maximize micro-habitat heterogeneity. The areas between the berms (the "flats") were not disked, as the soils were generally slightly moist and friable, allowing a good imprint without soil preparation. In some areas, the thatch of Mediterranean grasses was so thick that it prevented a solid imprint from forming; however, we felt that the benefits of imprinting into undisturbed soil outweighed the negatives associated with establishing vegetation in the thatched areas.

Manning Avenue Restoration

As described previously, the attempted restoration of the Manning Avenue Property during the 2001-02 growing season met with little success due to the soil compaction that resulted from imprinting on wet soils. Another attempt was made to restore (berming and seeding) this area during the 2002-03 growing season. At this time, the soil was still sufficiently hard-packed and required the area to be disked. Following disking, a series of low, serpentine berms were installed on approximately 9.1 m (30 feet) centers. Disking and berming took place during October 12-14, 2002.

A mixture of 12 native species was imprinted. Imprinting was originally scheduled for the first week of November; however rainfall at that time precluded imprinting until late in the month (November 24-30, 2002).

Site Management

HRS Buffer Maintenance The barley in the buffers surrounding the HRS plots (~ 243 ha; 600 ac) was thrashed, and the area was surface disked. Barley was reseeded where necessary.

Hedgerows Approximately 3 miles of hedgerow were installed during the 2002-03 growing season. Hedgerows were situated along the roads that parallel the HRS study blocks. A number of different mixtures of native seed were used (see Uptain et al. 2004), to investigate the potential of various species for their applicability in restoration. Seed was both imprinted and spread by hand. The hedgerows were watered (flood irrigation) at selected times during the growing season.

2003-04 Growing Season

Seed Augmentation and Planting Method Trial

The Seed Augmentation and Planting Method Trial, and the Herbicide and Charcoal Treatment Trial represent a collaborative effort involving Reclamation (Reclamation; Technical Service Center, Denver; and Land Retirement Program, Fresno), the Endangered Species Recovery Program, Dr. Joe DiTomaso (University of California, Davis; UCD), and the Lockeford Plant Materials Center (USDA-NRCS; Lockeford).

The Seed Augmentation and Planting Method Trial (5.6 ha; installed November 19-25, 2003) is a replicated, [3x4x4] factorial study evaluating effects of three factors on establishment success of eight native grass, forb and shrub species. Treatment factors were (a) mechanical soil surface (seedbed) manipulation, (b) cover crop use, and (c) chemical rhizosphere augmentation. Mechanical surface treatments addressed drilled seeding across variable depths and row spacing of deep-furrow seed placement (furrow depth: 1 cm [control standard], 10 cm, and 20 cm; row spacing: 30 cm [control standard] and 45 cm). Deep-furrow seed placement is designed to increase precipitation capture and retention, creating seed germination micro-sites exhibiting lower salinity and increased protection from environmental extremes. Second-level treatment involved use of a dryland barley "nurse crop" seeded at typical agronomic rates (68 kg ha^{-1}) in alternate rows (60 cm and 90 cm spacing) with seeded natives to evaluate effects on weed suppression and further buffering of climatic extremes. Third-level rhizosphere augmentation involved combinations of treatments for sodium reduction using banded application of HydraHume™ at 112 kg ha^{-1}; banded phosphorous fertilizer (0-45-0 super treble PO_4 at 45 kg ha^{-1}); and polymerized, clay-based seed coating (2:1 seed weight ratio). Influence of pre-treatment soil parameters will also be analyzed, including surface and subsurface texture, pH, sodium adsorption ratio (SAR), electrical conductivity (EC_e), and major nutrients.

Plant counts for native and weed species, utilizing ten 1,500 cm^2 (30 cm row spacing) or 2,300 cm^2 (45 cm row spacing) within-row quadrats per row, were conducted during the first growing season (April 26-30, 2004) for cool-season species to provide estimates of species germination, emergence, and survival (stand success). Because of extreme drought conditions after this date, emergence of warm-season species was insufficient to warrant data collection in 2004.

Planting Techniques Trial and Water Use Trial

These two trials were carried out by CSU, Fresno, Masters Student Emily Magill. The Planting Techniques Trial is a field-based experiment that was developed to investigate the relative performance of three planting techniques (drilling, imprinting, and broadcasting). Four species of native plants—*Atriplex polycarpa, Hemizonia pungens*¸ *Phacelia ciliata*, and *Suaeda moquinii*—were planted as monocultures. The study required 60 plots; plot size was approximately 3.7 m by 7.6 m (12 feet by 25 feet). Each treatment (i.e., species-planting combination) was replicated 5 times. Monitoring included measurements of soil moisture, soil electrical conductivity, percent cover, photosynthetic rates, and plant height.

The second trial, the Water Use Trial, was a greenhouse-based experiment that investigated how different watering regimes affected the germination and growth of native versus invasive species. Native species were represented by a subset of the species used in the Planting Techniques Trial (*Atriplex polycarpa* and *Phacelia ciliata*). Invasive species were represented by a single species, *Bromus madritensis* (red brome). Data collected in this trial included percent cover, photosynthetic rate, biomass (above- and below-ground), and water stress. This trial was initiated in the 2003-04 growing season and was continued into the 2004-05 growing season.

2004-05 Growing Season

Herbicide and Charcoal Treatment Trial

Weed control remains the overriding limitation of restoration efforts on LRDP—retired (dewatered) lands. Chemical methods of weed control can be particularly problematic because most potential herbicide choices exhibit activity on non-target species (i.e., seeded species). Other integrated pest management (IPM) strategies such as grazing, fire, and mechanical control are being evaluated, but have limited utility or windows of opportunity during seeded species establishment periods. Selective, pre-emerge herbicides with longer residual activity in conjunction with native seed / seedling safeners are needed to maximize this establishment window. The herbicide and Charcoal Treatment Trial was developed to determine if significant levels of control can be achieved using only natural precipitation to activate and move the herbicides into the root zone of the dominant weeds, with the activated charcoal serving as a protectant for the seeded natives. If one of the Experimental Use Permit (EUP) herbicides should prove more effective than other herbicide options, a special local need permit may be pursued for its broader-scale use within the CVPIA-Land Retirement project, since 28,329-40,470 ha (70,000-100,000 acres) within the project may eventually be targeted for revegetation.

The experimental design incorporates a [6x3] factorial study (0.9 ha; installed December 13-16, 2004), in which four seeded native forb and shrub species were drilled without protectant safener (control) or precisely within an incorporated powder band or beneath an over-sprayed slurry band of activated charcoal (Gro-Safe®; Norit Americas; applied at 336 kg ha^{-1}) to protect them from pre-emerge herbicides applied broadcast by ground rig. This weed management approach is commonly and successfully practiced in ryegrass and turfgrass industries, with possibilities for extension to drilled applications of native species. Six pre-emerge herbicide treatments (no herbicide [control], Landmark MP™, Telar DF™, Goal 2XL™, Broadrange™, and Cerano 5MEG™ [the latter two of which are evaluated under an EUP), compare potential control of a mixed composition of black mustard (*Brassica nigra*), London rocket (*Sisymbrium irio*), and the "tumbling saltbushes" (*Atriplex rosea* and *A. argentea*). Initial monitoring for seeded species emergence and survival will commence April 25, 2005.

It is anticipated that a similar study will be undertaken on the North Avenue Property in the 2005-06 growing season. This study will be situated in an area dominated by cool-season introduced grasses (*Hordeum murinum, Bromus madritensis, Avena* spp.), and will receive similar herbicide and activated charcoal treatments.

Planting Techniques Trial – Year II

This trial represents Emily Magill's second year of Masters research. The same three planting methods that were compared in the initial Planting Techniques Trial were used here; however, two additional species—*Grindelia camporum* and *Lessingia glandulifera*—were incorporated. The study required 90 plots; plot size was approximately 3.7 m by 7.6 m (12 feet by 25 feet). Each treatment was replicated 5 times. Data collection will include those parameters as were described for the preceding year.

Seed Delivery and Competition Trial

This trial was situated on the northernmost portion of the North Avenue Property (ca. 16.2 ha; 40 ac). Restoration efforts had previously been applied to this area;

however, almost all of the native vegetation that was established from these efforts was situated on the berms (and adjacent trenches).

The Seed Delivery and Competition Trial was developed to compare two seed delivery methods (imprinting and broadcasting). An additional treatment factor, seed mixture, was incorporated into the trial. Two seed mixtures, the “Phacelia mixture” and the “Late-season Mixture” were compared. Seeding took place only on the “flats” (i.e., the portion between berms), as establishment of the previously seeded species was deemed sufficient on the berms to preclude re-seeding. Each flat was treated as an experimental plot. Treatments (i.e., the four seed delivery-seed mixture combinations) were assigned randomly in a complete randomized block design; each treatment was replicated eight times (32 plots total).

The “Phacelia mixture” (eight species) had a substantial component of *Phacelia ciliata* (great valley Phacelia), an early-germinating native forb that has shown promise in the Native Plant Nursery and in various restoration trials. It was hoped that *P. ciliata* would be able to successfully compete with the annual winter grasses that dominate much of the North Avenue Property. *Phacelia ciliata* possesses a spreading habit; as the species dies back during the summer months, the stems disarticulate creating open habitat. A number of the remaining species in this seed mixture were late-germinating perennials. It was hoped that these species would be able to become established in the (theoretical) open spaces formerly occupied by *P. ciliata*.

The “Late-Season Mixture” (seven species) was composed entirely of late-season species. The areas seeded with this mixture will be treated with herbicide in the early spring (i.e., before any of the seeded species are expected to germinate), to create suitable conditions for the establishment of the seeded species.

Originally, it was intended that seeding would occur shortly after the first rains. In this way, it was hoped that seeding would precede germination of the winter weeds. However, in the fall of 2004, the initial rains were followed by periodic rainy periods, such that during an approximately 6-week long period, the soil never dried sufficiently to allowed seeding. Therefore, when conditions finally allowed seeding, the winter weeds (specifically, the non-native grasses) had developed sufficiently to allow them a distinct advantage over the seeded species. To control the weeds, seeding was proceeded by worked the soil with a hook-chisel. Seeding took place on November 22, 2004 (imprinting) and December 2-3 (broadcasting).

Native Release Trial

The Native Release Trial was developed to examine the possibility of promoting germination of native seed in the seed bank by reducing competition from weeds. The trial was situated on a portion of the Tranquillity site that possessed a good-sized population of the native annual forb, *Malacothrix coulteri* (snakes head). This area served as a seed collecting site for snakes head during the 2002-03 growing season. However, during the next two growing seasons, the abundance of the invasive grass *Bromus madritensis* increased dramatically. Concomitantly, *M. coulteri* decreased in abundance to the point that insufficient individuals did not allow harvesting.

It was hoped that by reducing *B. madritensis* through various weed-control methods, *M. coulteri* might once again proliferate in the area. Four treatments were applied: (1) flaming (i.e., burning existing vegetation with an agricultural flamer), (2) mowing, (3) spraying with Poast™, a grass-only herbicide, and (4) spraying with Roundup™, a broad-spectrum herbicide.

Plots dimensions were approximately 2 m by 3 m (6.7 feet by 9.8 feet). A complete randomized block design was applied, with treatments replicated eight times (40 plots total). Monitoring will be conducted during the spring of 2005.

Native Mowing Trial

The Native Mowing Trial, another small-plot trial, is situated in the same area as the Native Release Trial. This trial was developed to better evaluate the potential of mowing as a management strategy for promoting the continuance of native species in landscapes threatened by invasive species.

Treatments consisted of four mowing regimes (one to four mowings) and a control (no mowing). A complete randomized block design was applied, with treatments replicated eight times (40 plots total). Plots dimensions were approximately 2 m by 3 m (6.7 feet by 9.8 feet). Treatments will be applied during the 2004-05 growing season. Monitoring will be conducted during the spring of the following year (2006).

Restoration Release Trial

The Restoration Release Trial was another experiment that was developed to examine the possibility of promoting germination of native seed in the seed bank by reducing competition from weeds. This trial is situated on the Manning Avenue Property—an area that had previously undergone restoration efforts. It was hoped that by controlling the invasive species, some of the remaining imprinted seed might more readily germinate.

Four treatments were applied; with one exception, the treatments were the same as were used in the Native Release Trial. Treatments were (1) flaming (i.e., burning existing vegetation with an agricultural flamer), (2) mowing, (3) spraying with Roundup™, a broad-spectrum herbicide, and (4) spraying with BurnOut II™, a broad-spectrum herbicide.

Plots dimensions were approximately 2 m by 3 m 6.7 feet by 9.8 feet). A complete randomized block design was applied, with treatments replicated eight times (40 plots total). Monitoring will be conducted during the spring of 2005.

Restoration and Site Management – Atwell Island

2000-01 Growing Season

Site Management

Barley was planted on the areas where the Habitat Restoration Study would be sited (ca. 243 ha; 600 ac), to provide a homogenous setting for the HRS plots. The barley was flood irrigated in Study Area 1, and was sprinkler irrigated in the other two Study Areas.

2001-02 Growing Season

HRS Plot Installation

Treatments were applied to the 48 HRS plots. Seed of the same 13 native species as was used for the Tranquillity HRS plots was imprinted across the 24 "seeded" plots in December 2001. In contrast to the Tranquillity HRS plots, no transplanting occurred on the Atwell Island plots. Microtopographic contours (berms) were created on the 24 "bermed" plots. Forty-nine approximately 12 m (39.4 foot) long berms were installed on each plot.

Evaporation Basin Restoration

The Evaporation Basin—an approximately 13.3 ha (33-acre) former evaporation basin located along the western edge of the Atwell Island LRDP property—was targeted for a partial restoration in late 2001. The evaporation basin was characterized by a flat expanse of highly alkaline, salt-encrusted soil, nearly devoid of vegetation; however, adjacent lands, which are managed by the BLM, support fair-sized populations of native alkali sink vegetation.

Restoration efforts occurred during November and December 2001. Only the outer edges of the evaporation basin were accessible, as rainfall at that time had created extremely wet and muddy conditions. Vegetation was introduced to the site by both seeding and transplanting. Areas to be seeded were prepared by loosening the soil with rakes. Native seed from adjacent properties was collected and then broadcast onto the raked seedbeds. Species planted in this manner were: *Allenrolfea occidentalis*, *Distichlis spicata*, *Frankenia salina*, *Heliotropium curassavicum*, and *Suaeda moquinii*. Two of these, *Distichlis spicata* and *Allenrolfea occidentalis*, also were introduced to the site through transplanting. Rhizomes of *D. spicata* that were growing along the perimeter and encroaching onto the salt flat were transplanted onto the restoration area. Plugs of *Allenrolfea occidentalis* were grown by the Southern California Edison Nursery (Auberry) from native seed collected from the Tranquillity area, and were transplanted directly onto the site.

Site Management

The barley in the buffers around the HRS plots (ca. 155.4 ha; 384 ac) was thrashed and worked into the soil by surface disking. Barley was reseeded in areas where the yield was poor.

Native Plant Nursery and Seed Collecting

The LRDP Native Plant Nursery was established in the 2001-02 growing season to serve a variety of essential functions: (1) to augment available commercial sources of native seed; (2) to significantly amplify the number of San Joaquin Valley species that were available for use in local restoration activities; (3) to serve as a "laboratory", where the various species could be screened for their potential applicability in restoration settings; and (4) to provide a setting that was suited for outreach and volunteer-centered activities.

The nursery—and associated seed collecting and processing activities—have grown significantly throughout the course of the project. The original nursery occupied ca. 0.8 ha (2 ac), of which approximately 0.6 ha (1.5 ac) was planted. In the second year (2002-03 growing season), the nursery was relocated to a better site, and was expanded to approximately 1.6 ha (4 ac), with weed control measures applied to an additional 0.8 ha (2 ac) to prepare that area for future nursery expansion. During the third year (2003-04 growing season), the nursery expanded again. During this time ca. 0.2 ha (0.5 ac) of the area that was prepared during the previous year was put into production. Also, an additional 1.6 ha (4 ac) to the east of the nursery were established as a “mechanized nursery,” in which eight species were grown in single-species blocks (0. 2 ha; 0.5 ac). In contrast to the “main” portion of the nursery, which was reliant on extensive hand labor, cultivation and harvesting in the mechanized nursery emphasized machine-based technologies (e.g., the tractor, sprayer, and mechanical seed harvester). For the current year (2004-05 growing season), the nursery has been slightly reduced in area. The main nursery has been reduced to ca. 1.6 ha (4 ac) and the mechanized nursery has been reduced by ca. 0.2 ha (0.5 ac).

Despite the slight reduction in nursery area for the current growing season, the number of species in cultivation has grown steadily. Eighteen species were cultivated during the first year. The number of species in cultivation rose steadily since that time, with 31 species in 2002-03, and 64 species in 2003-04. Planting of the 2004-05 nursery was ongoing at the time of this writing, but it is anticipated that about 80 species will be in cultivation.

Seed collecting activities have also grown dramatically during this period. In the first year of seed collection (2000-01) seeds were collected from just seven locations. In subsequent years, a significant amount of effort was expended on locating additional seed collecting sites. As a result, 45 local collecting sites (i.e., within 40 miles of the nursery) are now known. To accommodate the seed (i.e., dry, clean, and store) from the nursery and from additional seed collecting, an approximately 1,500 square foot facility was leased in 2003. Since that time, a variety of seed processing equipment has been purchased and/or constructed, and the building has been “outfitted” (e.g., dust-collecting equipment has been installed, shelving has been built, etc.).

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