Guadalupe Restoration Project

Pilot Impact Assessment Report

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
BA	Buffer Area
BACI	Before-After, Control-Impact
BBL	Blasland, Bouck & Lee
bgs	below ground surface
CAO	Cleanup or Abatement Order
CC	Community coefficient
CEQA	California Environmental Quality Act
DFR	daily field report
EMP	Ecological Monitoring Program
ESA	Environmental Screening Analysis
FDS	Field Data Sheet
GAC	granular activated carbon
GIS	geographical information system
GPS	global positioning satellite
GRP	Guadalupe Restoration Project (or Project)
HDPE	high density polypropylene
MRS	Marine Research and Environmental Sciences
NAPLs	non-aqueous phase liquids
PET	Pilot Ecological Team
PIA	Pilot Impact Analysis
Pilot Test	pilot testing of steam/hot water injection followed by biosparging
ppmv	parts per million, by volume
PTP	Pilot Test Panel
QA/QC	Quality Assurance/Quality Control
RA	Reference Area A
RB	Reference Area B
RWQCB	Calif. Regional Water Quality Control Board, Central Coast Region
SA	Study Area
SAIC	Science Applications International Corporation
SCADA	Supervisory Control and Data Acquisition
scfm	standard cubic feet per minute
TA	Test Area
Unocal	Union Oil Company of California
VOCs	Volatile Organic Compounds

EXECUTIVE SUMMARY

Introduction and Background

The objective of this report is to present the results of the Steam Flood Pilot Impact Analysis (PIA) conducted at the Guadalupe Restoration Project (GRP), an oil field operated by Union Oil of California (Unocal) from 1951 to 1994 in southern San Luis Obispo County and northern Santa Barbara County, California. The PIA was designed to assess a limited range of environmental impacts associated with the Pilot Test and was restricted to the construction, operation and abandonment of the Pilot Test project.

A Pilot Test Panel (PTP) was convened in early 1999 in accordance with Cleanup or Abatement Order (CAO) No. 98-38 and agreed to by Unocal. The CAO establishes requirements for Phase I remediation of the GRP. The PTP's mission was to evaluate a range of existing, new, or modified remediation technologies and then recommend up to three technologies to be pilot tested at the GRP for the removal of separate-phase diluent. The PTP was charged with recommending technologies that will remove separate-phase diluent as effectively as excavation. Consistent with the CAO, steam/hot water injection was included among the methods considered by the panel.

The recommendations made by the PTP were used by the Executive Officer of the Regional Water Quality Control Board (RWQCB) in making his recommendation of technologies to be pilot tested at the GRP. In doing so the PTP advised that a combination of remediation technologies, steam/hot water injection followed by biosparging (referred to in this report as the "Pilot Test"), be tested as part of the pilot test process. Additionally, the PTP is expected to make recommendations to the RWQCB and Unocal on the design, implementation, and evaluation of results of the pilot tests. The results of these tests will be included for consideration by the RWQCB in making decisions about future remediation strategies at the GRP.

One of the objectives outlined in the PTP Final Report for the Pilot Test (Concur, 2000) was to assess the potential adverse environmental impacts associated with the implementation of the steam/hot water injection technology. This document in concert with the Environmental Screening Analysis described below is intended to address this objective.

The PIA was designed to assess a limited range of environmental impacts associated with the Pilot Test and is restricted to the construction, operation and abandonment phases of the Pilot Test project. The impact of volatile petroleum hydrocarbon products that may affect biota was not directly analyzed; however, there were no observable indications to suspect impacts associated with gaseous fugitive hydrocarbons. The goal of the PIA was to draw upon the ability to design a monitoring program that allows for the measurement of impacts under pilot-scale conditions, thus minimizing speculative impact predictions in future assessments.

The PIA focuses on assessing the impact of the Pilot Test upon the biota at the study area. The main objectives of the PIA are to:

- Determine baseline levels and variability for a broad category of indicators.
- Monitor and measure selected variables that could help determine if impacts are realized.
- Quantify the effects of the Pilot Test on the variables.
- Identify statistically significant changes in measured variables.
- Prepare a final report for submittal to the PTP.

Building upon the results of the PIA, an Environmental Screening Analysis (ESA) was prepared to assess the potential environmental impacts/issues associated with the implementation of a hypothetical build-out, or full-scale steam flood program at the GRP. The ESA is a screening tool that can be used by stakeholders and decision-makers to ascertain the potentially significant environmental impacts and related issues likely to occur as a result of the hypothetical build-out. The ESA will provide all stakeholders with a better idea of the potential environmental impacts/issues associated with a full-scale steam flood program, but it is not intended to provide the details typically associated with a formal environmental review required by the California Environmental Quality Act (CEQA). Should the full-scale steam flood program be carried forward, formal environmental review would be required, which could require approximately two years to complete.

To better insure impartiality in the conduct of this analysis, a special team was formed referred to as the "Pilot Ecological Team" (PET). The PET consists of environmental specialists from both Unocal and its contractors, and the County of San Luis Obispo and its contractors (MRS and SAIC). All of the work products generated as part of this analysis were undertaken jointly by representatives from Unocal, the County and their respective contractors.

The Pilot Test consisted of three phases:

- Pre-Operations: baseline soil sampling, mobilization, and construction.
- Operations: hot water and steam injection and extraction of total fluids.
- Post-Operation: cooling phase, decommissioning and demobilization.

Certain deviations from the Pilot Test as originally envisioned affected the PIA including a longer Pre-Operations phase construction period, a longer Operations phase due to equipment failure, proponent changes, and a greater impact to the surface due to additions of larger support structures.

Pilot Impact Analysis Study Design and Methods

The PIA of the Pilot Test was organized in two issue areas: (1) an evaluation of the primary (i.e., physical) impacts associated with the construction, implementation and decommissioning of the Pilot Test, and (2) an evaluation of the secondary impacts associated with the functioning of the Pilot Test. The secondary impacts included potential thermal or other indirect types of stressors, such as, diluent vapors.

To meet the project objectives, both abiotic and biotic variables were measured before (Pre-Operations), during (Operations) and after the Pilot Test (Post-Operations).

Primary Impact Study Methods

Quantitative and qualitative survey methods were employed to assess vegetative parameters. A baseline survey of the habitat was conducted prior to initiating project activities to provide a measure to compare the habitat with following the implementation of the steam technology

Ground level photographs were taken before, during, and after the Project to record the vegetation condition over time. Standardized locations, targets, and methods were employed to facilitate the reproducibility of images over time. Aerial photographs were taken annually, covering the time period prior to equipment mobilization and continuing through the final stages of demobilization. The photographs were ortho-rectified, digitized and downloaded into the GRP Geographical Information System (GIS) database.

Secondary Impact Study Methods

To evaluate the potential for secondary impacts to the environment, a modified Before-After, Control-Impact (BACI) analysis was designed. In general, BACI designs allow investigators to use analysis of variance (ANOVA) as a statistical means of comparing the impact site to control site(s) over time (before and after impact). Following this type of design, the PIA included a comparison of a Study Area (SA) (assumed to be the impact area) to two Reference Areas (assumed to represent the range of natural variation encompassed by the SA), and an evaluation of the SA before, during and after the Pilot Test.

The SA was selected to represent locations where potential secondary impacts of the Pilot Test were most likely to occur and consisted of three ecological study plots located within the buffer zone surrounding the Pilot Test area

Secondary impact data were collected once every six weeks before Operations (Pre-Operations), monthly during Pilot Test Operations, and monthly following the completion of the Operations.

To evaluate the potential impacts of the Pilot Test on physical characteristics of the environment, a number of abiotic variables were measured, including:

- Near-surface soil temperature data,
- Sub-surface soil temperature data,
- Process emissions,
- Soil moisture data, and
- Soil gas.

To facilitate the assessment of secondary impacts to larger, more complex biological systems, the following indicator or surrogate parameters were selected for the PIA:

- Vegetation: Plants are expected to be sensitive to changes in soil temperature, soil moisture, increased volatile emissions and other potential secondary impacts from the Pilot Test due to the close contact of their root systems in the soil horizon. Thus changes to the plant community could have significant impacts on the ecosystem as a whole.
- Arthropods: Most arthropods live in close association with the soil and are likely to be exposed to changes in the Study Area due to the Pilot Test and they serve as a primary food source for many of the more complex and difficult to monitor organisms.
- Wildlife: Small mammals were chosen to represent potential impacts to vertebrate wildlife because they have relatively small home ranges, are present in large enough numbers to quantify change over time and many species burrow, putting them in closer contact with potential environmental changes caused by the Pilot Test.

For the purposes of this document, the term "significance" is being applied from a statistical perspective in order to avoid confusion with the CEQA term "significant impact". Statistical significance was defined as $P<0.05$, below which the null hypotheses were rejected.

Results

Primary Impacts

The application of the steam technology resulted in the disturbance of over half of the coastal dune scrub habitat within the 2.4-acre Project site. There was a total loss of native perennial plant species within the disturbed area. The amount and severity of surface disturbance resulting from the Pilot Test impacted the habitat to a degree consistent of a "major" disturbance. The ongoing activities at the site prevented any restoration before the demobilization phase and therefore the loss or disturbance of habitat represented a loss of habitat through the duration of all phases of operations and demobilization. Baseline mature coastal dune scrub habitat with shrubs and high diversity was reduced to no shrub vegetation and a dense mix of a few annual species following the Pilot Test.

Areas with little vehicle access were able to naturally restore with shrubs and diversity comparable to the baseline conditions. Areas with heavy vehicle access were more prone to weed invasion due to the highly disturbed and compacted soils. During construction, operation, and decommissioning of the equipment the top soil was severely churned and disturbed, possibly impacting the native seed bank and/or microorganisms. The continual churning of the top soil destroyed the native seed bank and native soil components, and created an ideal situation for invasive exotics.

Secondary Impacts

Near surface temperatures (i.e., eight-inch below the ground surface [bgs]) were more influenced by seasonal weather than operation of the Pilot Test (i.e., in the Operations phase near-surface temperatures decreased during the winter, when steam was being injected).

Sub-surface temperatures were highest at depth in the Treatment Zone, and approached ambient soil temperatures close to the surface. The most unexpected temporal variation occurred during the Post-Operations phase, when the extraction wells were turned-off. Without the extraction system, residual subsurface heat continued to rise to the surface for approximately six-months, elevating near-surface soil temperatures in the SA above reference conditions. The impacts of this increase in sub-surface temperatures is not known since the PIA was suspended/concluded before the subsurface temperatures equilibrated to ambient conditions. Since temperatures 15 feet bgs rose as high as 110 degrees Fahrenheit (i.e., approximately 50 degrees above ambient values), some impact would be expected. However, whether these impacts would be positive or negative is not known.

Process Emissions of volatile organic compounds (VOCs) emissions were within the air permit conditions of 95 percent removal efficiency, or less than 10 parts per million, by volume (ppmv) as hexane if the input concentration was less than 200 ppmv.

The mass of nitrogen oxides (NO_x) and carbon dioxide (CO) was determined based on the mass balance calculation of the propane burned in the boiler and steam generator. Also, during the construction of the

Pilot Test diesel and gasoline fuel usage was reported by all the project contractors and used to estimate construction equipment exhaust emissions:

Near-surface soil moisture measurements were consistently very low (approximately 3 percent water) throughout the study period due to the sandy soil and therefore, a quantitative analysis of soil moisture data was not considered useful for this study.

Vegetation plant species association and other vegetation indices in SA, RA and RB showed that Reference Areas span the natural variability found in area. The majority of plant indices measured in the PIA showed a strong seasonal component. Once seasonal variability was partitioned out, only subtle differences in plant indices were measured. For total cover, only a marginally statistically significant increase in the delta between the SA and Reference Areas was seen in the Operations phase. For species richness, a significant increase in the delta during the Post-Operations phase in the SA was found. The biological relevance of a significant increase in cover and richness is not known. Additionally, it is not clear whether they constitute a positive or negative impact. For leaf condition, there was a significant decrease in delta between SA and the reference locations in the Post-Operations time period for one of the two species measured. It is unknown whether the Pilot Test is responsible for the decrease in leaf condition, as field observations identified a beetle infestation as the probable cause and these beetles have also been found elsewhere in the Field.

Arthropods from twelve taxonomic groupings were observed at the sampling sites within established transects over the two year study period. The Reference Areas were very similar to SA, supporting between 10 and 12 of the known taxonomic groupings. Seasonal variation in abundance, frequency and arthropod diversity was slight. Any potential impacts of the Pilot Test on abundance, frequency and diversity of the arthropod community were also minimal. No statistically significant effects on the arthropod variables measured as a result of the Pilot test were identified.

Wildlife captures consisted almost entirely of two species, deer mouse and Heermann's kangaroo rat. Seasonal variation in captures, tracking activity and number of active burrows were slight. Only the number of captures was influenced by seasonality. Potential impacts of the Pilot Test on captures, tracking activity and number of active burrows were also slight. Although, there was a statistically significant difference between SA and the Reference Areas with respect to active burrows, the biological significance of this result is considered low because other related wildlife indices (track activity and the number of captures) were not similarly affected.

Conclusions

The Pilot Test resulted in substantial primary (i.e., physical) impacts to the habitat within the construction boundaries that will require extensive restoration efforts, consistent with those employed to restore areas disturbed by excavations.

The level of disturbance to vegetated habitat was assumed to correlate to the level of impacts to other biological resources including wildlife and sensitive plant and animal species. In terms of wildlife impacts, there was a loss of 0.55-acres of wildlife foraging, cover, and den sites.

The area of disturbance for implementing steam technology may be smaller compared to what would be required for a site excavation but the duration of time required to install and implement steam technology is anticipated to require more time than an excavation. This temporal loss of habitat could actually result in habitat for sensitive species, wildlife and plants being unavailable for a longer period of time.

Secondary impacts to abiotic and biotic parameters from the Pilot Test appeared to be minimal, with the exception to the impacts from sub-surface heat migration. Significant temperature increases within the rooting zone of coastal dune scrub species like silver lupine (*Lupinus chammisonis*) and in proximity to small mammal burrows are likely to have pronounced impacts upon the habitat and wildlife residents.

1.0 INTRODUCTION

The objective of this report is to present the results of the Steam Flood Pilot Impact Analysis (herein referred to as the PIA) conducted at the Guadalupe Restoration Project (GRP), an oil field operated by Union Oil of California (Unocal) from 1951 to 1994 in southern San Luis Obispo County and northern Santa Barbara County, California. The PIA was designed to assess a limited range of environmental impacts associated with the Pilot Test and was restricted to the construction, operation and abandonment of the Pilot Test project.

Key Elements

- Objective of report is to present the results of the Steam Flood Pilot Impact Analysis (PIA).
- Pilot Test evaluated steam/hot water injection as a possible technology for the remediation of separate-phase diluent.
- PIA was designed to assess a limited range of environmental impacts to biota associated with the Pilot Test and was restricted to the construction, operation and abandonment of the Pilot Test project.
- To insure impartiality, the Pilot Ecological Team (PET) was formed to conduct all aspects of the PIA. The PET consists of environmental specialists from both Unocal and its contractors, and the County of San Luis Obispo and its contractors.

1.1 Purpose and Scope of Steam Flood Pilot Test

A Pilot Test Panel (PTP) was convened in early 1999 in accordance with Cleanup or Abatement Order (CAO) No. 98-38 and agreed to by Unocal. The CAO establishes requirements for Phase I remediation of the GRP. The PTP's mission was to evaluate a range of existing, new, or modified technologies and then recommend up to three to be pilot tested at the GRP for the removal of separate-phase diluent. The PTP was charged with recommending technologies that will remove separate-phase diluent as effectively as excavation. Rather than try to find technologies that can meet certain numerical clean-up targets, the panel identified a range of potentially successful technologies, then estimated the degree of clean-up each technology could offer. Consistent with the CAO, steam/hot water injection was included among the methods considered by the panel.

The recommendations made by the PTP were used by the Executive Officer of the Regional Water Quality Control Board (RWQCB) in making his recommendation of technologies to be pilot tested at the GRP. In doing so the PTP advised that a combination of remediation technologies, steam/hot water injection followed by biosparging (referred to in this report as the "Pilot Test"), be tested as part of the pilot test process. Additionally, the PTP is expected to advise the RWQCB and Unocal on the design, implementation, and evaluation of results of the pilot tests. The results of these tests will be considered by the RWQCB in making decisions about future remediation strategies at the GRP.

Several goals and objectives were outlined in the PTP Final Report for the Pilot Test (Concur, 2000). The objectives most germane to this report include assessing the performance of the implemented technology, determining the economics of that process, and assessing potential adverse environmental impacts. This document is intended to address the latter of these objectives.

1.2 Purpose and Scope of Steam Flood Pilot Impact Analysis

In preparing the goals and objectives of the Pilot Test the PTP envisioned some level of environmental monitoring to allow for the assessment of environmental impacts. The following excerpt was taken from Section 4.3 *Considerations for Pilot Test Implementation and Monitoring* of the Concur 2000 report: "Field monitoring of impacts to the ground surface and the root zone should be conducted in the vicinity of the pilot test."

The Pilot Impact Assessment (PIA) was designed to assess a limited range of environmental impacts associated with the Pilot Test and is restricted to the construction, operation and abandonment of the Pilot Test project. The effects of volatile petroleum hydrocarbon products that may affect biota was not analyzed; however, no petroleum hydrocarbon vapors were detected in the root zone that could impact the biota. However, the scope of the PIA was flexible to accommodate unexpected issues, changes to the Pilot Test, etc. Again, the goal of the PIA was to draw upon the ability to design a monitoring program that allows for the measurement of impacts under pilot-scale conditions, thus minimizing speculative impact predictions in future assessments.

The PIA focused on assessing the impact of the Pilot Test upon the biota at the study area. The main objectives of the PIA were to:

- Determine baseline levels and variability for a broad category of indicators.
- Monitor and measure selected variables that could help determine if impacts are realized.
- Quantify the effects of the Pilot Test on the variables.
- Identify statistically significant changes in measured variables.
- Prepare a final report for submittal to the RWQCB.

The implementation of the Pilot Test provides an opportunity to investigate possible mechanisms for monitoring environmental impacts during the construction, operation, and decommissioning of the project. Thus, Unocal, the RWQCB and the other stakeholders agreed to conduct the PIA to explore the unknown effect that this technology may impart on the environment on a limited scale. Inherent to the PIA is the ability to analyze those potential impacts that, without pilot-scale monitoring, would be speculative in nature.

1.3 Purpose and Scope of Environmental Screening Analysis

Building upon the results of the PIA, an Environmental Screening Analysis (ESA) was prepared to assess the potential environmental impacts/issues associated with the implementation of a hypothetical build-out, or full-scale steam flood program. The ESA is a screening tool that can be used by stakeholders and decision-makers to ascertain the potentially significant environmental impacts and related issues likely to occur as a result of the full scale build-out of the technology. The ESA will provide all stakeholders with a better idea of the potential environmental impacts/issues associated with a full-scale steam flood program, but it is not intended to provide the details typically associated with a formal environmental review required by the California Environmental Quality Act (CEQA). Should the full-scale steam flood program be carried forward, formal environmental review would be required.

1.4 Pilot Ecological Team

To better insure impartiality in the conduct of this analysis, a special team was formed referred to as the “Pilot Ecological Team” (PET). The PET consists of environmental specialists from both Unocal and its contractors, and the County of San Luis Obispo and its contractors (MRS and SAIC). Appendix A provides a summary of PET participants. The conduct of all field work, data compilation and analysis, and report writing was undertaken cooperatively and collectively. All of the work products generated as part of this project are being undertaken jointly by representatives from Unocal, the County and their respective contractors.

1.5 Summary of PIA Contents

This PIA is organized in the following manner:

Section 1 – Introduction. An overview of the objectives of the PIA and the regulatory setting associated with the Steam Flood Pilot Test.

Section 2 – Steam Flood Pilot Test Project Description. This section provides an overview of the Steam Pilot Test as proposed. Additionally, it describes variances to the proposed plan that had the potential to affect the conduct or the results of the PIA.

Section 3 – Pilot Impact Analysis – Field Studies Design. This section summarizes the study design used to evaluate the two main types of impacts studied: (1) primary impacts, defined as physical in nature, and (2) secondary, non-invasive types of impacts.

Section 4 – Assessment of Primary Impacts. Physical impacts associated with the construction, operation and demobilization of the Pilot Test are discussed here.

Section 5 – Assessment of Secondary Impacts – Abiotic. The methods used to collect data, a summary of the results and an analysis of the potential impacts of the Pilot Test on abiotic variables are presented here.

Section 6 – Assessment of Secondary Impacts – Vegetation. This section presents the methods used to collect vegetation data, a summary of the results and an analysis of the potential impacts of the Pilot Test on the plant community.

Section 7 – Assessment of Secondary Impacts – Arthropods. This section presents the methods used to collect data, a summary of the results and an analysis of the potential impacts of the Pilot Test on the arthropod community.

Section 8 – Assessment of Secondary Impacts – Wildlife. This section presents the methods used to collect wildlife data, a summary of the results and an analysis of the potential impacts of the Pilot Test on the wildlife community.

Section 9 – Final Project Conclusions. This section integrates the results across all the data types evaluated and provides a summary of the overall PIA conclusions

Section 10 – References. All references cited in the report are listed in this section.

2.0 STEAM FLOOD PILOT TEST PROJECT DESCRIPTION

The Pilot Test design evolved prior to and during the conduct of the test. The following synopsis focuses upon those design elements that had the potential to or that did affect the conduct or results of the PIA.

2.1 Overview of Steam Flood Pilot Design

Key Elements

- The Pilot Test had 3 phases.
- Pre-Operations: baseline soil sampling, mobilization, construction.
- Operations: hot water and steam injected into the diluent smear zone. Extraction wells removed vapors, separate-phase diluent and groundwater.
- Post-Operation: : decommissioning and demobilization.
- Variances from the plan that impacted the PIA included:
- Longer Pre-operations Phase construction period.
- Longer Operations.
- Greater impact to the surface due to additions of larger support structures.

The Steam Flood Pilot Test is described in detail in the Project Description prepared by Cannon Associates (Cannon, 2002) and the revised final Work Plan prepared by SteamTech Environmental Services, Inc. (SteamTech, 2003). The final report for the Pilot Test operations was prepared by Haley & Aldrich (Haley & Aldrich, 2004). The following is a brief summary of the Pilot Test design.

The Pilot Test was designed to have three main phases: Pre-Operations (baseline soil sampling, mobilization, construction), Operations (hot water, steam, and cold water injection), and Post-Operation (cool-down, decommissioning and demobilization). .

The Pilot Test study area consisted of an approximate 140 feet by 140 feet square area demarcated by extraction wells. The well field layout included four injection wells, nine extraction wells, four vapor extraction wells, and three groundwater monitoring wells. The four injection wells were used to inject hot water and steam, and during cool-down ambient temperature water into an interval starting approximately 5 feet below the water table and extending 10 feet down. Eight extraction wells were located outside of the injection wells, with one additional extraction well located in the center of the treatment cell that pulled liquid and vapor from the subsurface. One vapor extraction well was installed near each of the four injection wells, for contingency should temperatures begin to rise above 40 feet below the ground surface (bgs) elevation. Three groundwater monitoring wells were installed in strategic locations within the test cell to monitor subsurface temperatures, and at regular distances from the central extraction well.

While not included in the original scope, air biosparge and monitoring wells were installed to evaluate the effectiveness of air sparging. The biosparge wells were installed at locations planned for soil boring; however, their installation required more surface support than soil borings and will require removal.

2.2 Pre-Operation or Construction Phase

Construction of the Pilot Test equipment was located primarily on existing roads and pads in order to minimize ground disturbances. Only the well field, pipeline runs, and some utility infrastructure extended beyond the existing roads and pads. Prior to well field piping installation, a revised, more efficient design was implemented. The initial design had a central trunk line directly from the process area diagonally through the test site with laterals running out to the perimeter wells. The new design connected from the process area and then branched to run around the perimeter of the test and extraction areas in a horse-shoe shape. (See Figure 2-1, Pilot Test Site Plan).

Pre-test subsurface characterization was established from drilling approximately 44 boreholes for collection of baseline soil samples, and installation of the injection, monitoring, and extraction wells. During the installation of the subsurface infrastructure, the soil gas sampling arrays, temperature monitoring arrays, and vertical electrode arrays were installed for monitoring the subsurface conditions.

Process equipment was assembled and hauled by truck from Bakersfield. The process equipment included a water softener/steam generation system, the injection and extraction equipment and an effluent treatment system. Some of the process equipment was mounted on skids, while the remainder were free-standing units.

Grated pathways were constructed to allow access to the well field with minimal ground disturbance. Interconnecting piping was laid out, fitted, and assembled on-site. An office trailer and portable restroom facilities was located on the ZH-5 pad. A tent was erected to house the storage and process water treating equipment and controls providing protection to equipment and personnel from rain and wind, and to shield lights during night operations.

The construction process was projected to require approximately four months for construction, mobilization, staging, connecting and testing of equipment and an additional two months for shake down and start-up for a total construction period of six months. The actual construction phase took one year.

2.3 Operation Phase

During Operations, hot water or steam from the steam generator was introduced via injection wells to the diluent smear zone. Extraction wells removed vapors, separate-phase diluent and groundwater. The fluids collected through the extraction wells were separated, the recovered diluent stored for transport off-site and the recovered water injected into the existing GRP process water recovery system. Vapors were recovered via the extraction wells and routed through a carbon absorption system.

The objective of the hot water injection phase was to elevate the temperature in the treatment cell between the screened intervals of the four injection wells and the central extraction well to a minimum of 180 degrees Fahrenheit. The hot water was directed evenly to the four injection wells. During hot water injection, the liquid and vapor extraction systems were continuously operated. To drawdown the water table approximately 3 to 5 feet at the extraction wells.

Hot water injection was planned to require approximately 30 days; however, due to unscheduled shut downs associated with the generation of hot water and steam from using hard water and other problems, the hot water injection phase lasted four months. The initial steam injection phase was anticipated to take five to ten days and designed to elevate the temperature in the test cell between the screened intervals of the four injection wells and central extraction well to a minimum of 212 degrees Fahrenheit. The second phase of steam injection was intended to optimize diluent extraction rates by performing cyclic steam injection; this phase was expected to last for three and one-half months.

There were two complete extraction and effluent treatment systems, one for the central extraction well and one for the remaining eight extraction wells and four vapor extraction wells. In order to do repairs on the extraction wells, a new access route had to be developed, which went a short distance through degraded native vegetation and did result in additional disturbance to native vegetation.

After the steam injection phase, the groundwater table was allowed to recover to near pre-test levels, and the Pilot Test site was cooled down by the injection of ambient temperature water into the four extraction wells, while vapor extraction continued. The Operation phase lasted approximately eight months and encompassed the time period over which hot water and steam were actively being injected in the subsurface soil and all the extraction wells were functional.

2.4 Post-Operation or Decommissioning/Demobilization Phase

Decommissioning of the Pilot Test site was planned to occur in stages, initially the wells were disconnected from the interconnecting pipelines and from other utilities. The pipelines were flushed with plant water prior to removal from the site. After the pipelines were removed a balloon-tired or track-mounted hollow-stem auger drill rig would be used to collect confirmation soil samples.

Once the well field was disconnected, the remainder of the process equipment was flushed with plant water, drained, and disconnected from the system. The equipment was prepared for shipping back to the equipment vendor. A crane was used to load the tanks, skids, and other equipment onto flat bed trucks. Once the equipment was removed, final decommissioning of the site occurred with the removal of electrical service, haul off of the office trailer and portable restrooms, and removal of the temporary water supply and process water HDPE lines connecting to the existing GRP systems.

3.0 PILOT IMPACT ANALYSIS – FIELD STUDIES DESIGN

As described in Section 1.2, the main objectives of the PIA include:

Determine baseline levels and variability for a broad category of indicators.

- Monitor and measure selected variables that could help determine if impacts are realized.
- Quantify the effects of the Pilot Test on the variables.
- Identify statistically significant changes in measured variables.

There were two main aspects of the impact assessment for the Pilot Test: (1) an evaluation of the primary physical impacts associated with the construction, implementation and decommissioning of the Pilot Test, and (2) an evaluation of the secondary impacts associated with the functioning of the Pilot Test. These secondary impacts could include potential thermal or other indirect types of stressors.

To meet the project objectives, both abiotic and biotic variables were measured before (Pre-Operations), during (Operations) and after the Pilot Test (Post-operations). The following sections provide an overview of the design of the field studies for the assessment of primary and secondary impacts of the PIA.

Key Elements

- Impact analysis has two main components
- Assessment of Primary Impacts
- Study design included pre-Project baseline surveys, monitoring during three phases of test, and post-Project habitat evaluation
- Used standard ecological monitoring protocols employed throughout GRP
- Overall evaluation of impacts to vegetation served as indicator to impacts to wildlife due to the close association of impacted fauna to vegetation habitat
- Assessment of Secondary Impacts
- Study area located in buffer zone directly adjacent to Test Area
- Reference Areas (RA and RB) located nearby but outside the zone of influence
- Data collection included abiotic and biotic variables (e.g., measures of vegetation and the arthropod and wildlife community)
- Analyses included descriptive analyses and statistics using a modified BACI design

3.1 Assessment of Primary Impacts

Primary impacts are those caused by the direct disturbance of the surface habitat from construction activities, equipment, personnel and related activities. These impacts could include physical damage to vegetation, compaction or alteration of the substrate, disturbance to wildlife foraging, cover and/or den sites, and the introduction and dispersal of invasive plant species.

The approach to assessing primary impacts to the Steam Pilot Project Site was similar to methods used for all previous construction activities on the Field. Using standard ecological monitoring protocols as prescribed in the Ecological Monitoring Program (EMP), impacts were assessed by:

- conducting a baseline survey to characterize the habitat on the project site prior to any construction disturbances;
- determining what physical disturbances could result to the habitat;
- developing work alternatives that would result in the least amount of surface disturbance; and
- Documenting the impacts to the vegetation, introduction of erosion or invasive exotic species, and harm to wildlife species.

Data collection relating to the quantity and severity of disturbances began during the project development stages when management walks were conducted, and continued through all three project stages and extended beyond the final decommissioning activities. The majority of monitoring activity occurred during the Pre- and Post-Operation phases when construction activities were the most active; relatively few disturbances occurred during the operations phase.

In general, primary impacts on biological resources based the analysis on effects to the existing vegetation on the project site. Impacts and disturbance to vegetation are more readily quantified and documented than disturbances to wildlife. Furthermore, disturbance to vegetation is a key indicator to impacts to the fauna of an area. The most abundant wildlife residents in this habitat are small mammals, reptiles, and invertebrates, which use the vegetation, duff, and vegetation structure for food, cover, and den sites. Therefore, the quantification and analysis of vegetation impacts, by corollary, also relates to impacts to wildlife species.

Assessment of primary impacts was quantified and evaluated through the implementation of several general methods. The following describes the method employed, the reason they were used in this assessment, and how they were implemented.

A baseline habitat characterization of the Pilot Test area was conducted during the Project development stages, prior to any construction or equipment mobilization. The baseline survey was used to characterize the type and quality of the habitat present; the data is typically used in the preparation of a site restoration plan. A baseline condition of the surface habitat prior to the Pilot Study provided a measure to compare the habitat to after the implementation of the steam technology. During a reconnaissance of the area, biologists noted the vegetation composition, including dominant species, species richness, presence of any sensitive vegetation, and presence and density of any invasive exotics. Likewise, a wildlife assessment was conducted to determine the likelihood of any special status species being present and the presence of any wildlife within the work area necessitating relocation. Any previously disturbed areas were mapped and described.

Ground level photographs were taken before, during, and after the Project. The first photographs were taken prior to equipment mobilization and photographs were taken continuously through the final stages of demobilization. The purpose of the photo-documentation was to record the vegetation condition at any particular time. Standardized locations, targets, and methods were employed to facilitate the reproducibility of images over time.

Aerial photographs, taken annually of the project site, covered the time period prior to equipment mobilization and continued through to the final stage of demobilization. The aerial photographs provided a method of assessing spatial disturbances to the site and documenting the expanse of project disturbances. These photographs are ortho-rectified (a process which assigns real-world geographic coordinates across the image field of vision) and the geo-rectified image was digitized which allowed it to be used in computer programs such as a Geographical Information System (GIS).

Ecological monitoring occurred on a daily basis which allowed for interaction of ecological monitors with Project and construction personnel to assess impacts due to Project activities. The routine monitoring allowed ecological monitors to evaluate and quantify impacts from individual Project activities, converse to the evaluation of aerial photographs which evaluates the cumulative disturbance from all activities. The determination of how activities impacted the habitat was a key element in the assessment of primary impacts. The evaluation of Daily Field Reports (DFRs) allowed for the assessment of the level of disturbance by activity and by the repetition of activities. Off-Road Authorization forms and Daily Field Reports were used to document the level of disturbance. Discussions with Project engineers and Proponent representatives provided the overall scope of how the pilot study would be constructed and operate. Familiarity with construction, operation, and decommissioning allowed biologists to anticipate the level of impact and to determine the study design to assess primary impacts to the habitat.

3.2 Assessment of Secondary Impacts

Both abiotic and biotic data were collected to assess secondary impacts of the Pilot Test. In its totality, data collection activities for the PIA were conducted over approximately a 2 year period from the late spring of 2002 to the summer of 2004. Data were collected during three time periods: Pre-Operations, Operations and Post-Operations. As discussed in Section 2.2, the Pre-Operations Phase was approximately a year in length. Although the infrastructure for the Pilot Test was constructed in the Pre-Operation Phase, this phase was assumed to be representative of baseline conditions as injection of hot water and steam had not yet begun.

The Operations phase was approximately eight months in length and encompassed the time period over which hot water and steam were actively being injected in the subsurface soil and all the extraction wells were functional. Data collected during this period represented the implementation phase of the project and is the time period when impacts would be expected to manifest themselves. The Post-Operation phase included the decommissioning of the Pilot Test and encompassed approximately 4 months of data after the injection of hot water, steam and cold water was terminated.

To evaluate the potential for secondary impacts to the environment, a modified Before-After, Control-Impact (BACI) analysis was designed. While there are a number of variations on the BACI theme, their general strength relies on the use of (1) comparison sites as covariates to reduce extraneous sources of variability, and (2) measurements before and after the impact (Underwood, 1994; Stewart-Oaten & Bence, 2001). Following this type of design, the PIA included a comparison of a Study Area (SA) (assumed to be the impact area) to two Reference Areas (assumed to represent the range of natural variation encompassed by the SA), and an evaluation of the SA before, during and after the Pilot Test.

Due to the magnitude of the primary physical impacts within the construction zone (refer to Section 4 for details), the SA was selected to represent locations where potential secondary impacts of the Pilot Test (e.g., thermal, or other non-physical types of stressors) were most likely to occur. The SA consisted of three ecological study plots located within the buffer zone surrounding the Pilot Test area (Figure 2-1, Pilot Test Site Plan). Each plot was approximately 2-meters wide by 20-meters long. The plots were protected with t-posts and nylon rope to exclude personnel and equipment from damaging the plots within the SA.

Two Reference Areas were also selected that were in proximity to the Pilot Test location. Reference Area A (RA) was located approximately 100 meters west from the closest extraction wells and overlaid the outermost boundary of the subsurface plume being treated (Figure 2-1, Pilot Test Site Plan). This distance was considered to be beyond any significant sub-surface influence of the Pilot Test operations (Dacre Bush, personal communication). Reference Area B (RB) was located approximately 100 meters south of the Pilot Test location (Figure 2-1, Pilot Test Site Plan).

Both Reference Areas had similar dune scrub habitat to that of the Pilot Test location. Each Reference Area included three staked off ecological study plots that were approximately 2-meter by 20-meters and were monitored in conjunction with the Pilot Test location monitoring.

3.2. 1 Overview of Data Collection Activities

The following sections provide an overview of the types of data collected, how the data were handled and what qualitative and quantitative comparisons were used to evaluate impacts. A detailed discussion of the sampling methodology for each data type can be found in later sections.

3.2.2 Abiotic Data

To evaluate the potential impacts of the Pilot Test on physical characteristics of the environment, a number of abiotic variables were measured. These variables included:

- Near-surface soil temperature data;
- Sub-surface soil temperature data;
- Process emissions;
- Soil moisture data.
- Soil Gas

3.2.3 Biotic Data

The PET investigated the use of surrogates (such as soil microbes and arthropods) as measures and indicators of ecological impact from changes in environmental conditions that may occur during the Pilot Test. The use of such surrogates allows for direct, straightforward measurements that can be used in the assessment of impacts to larger, more complex biological systems. Additionally, the use of surrogates reduces the number of dependent variables to be measured in the field before and during the Pilot Test.

A literature review and discussions with experts in wildlife biology (Lawrence Hunt, personal communication), plant physiology and ecology (Bruce Mahall, Shelly Cole, personal communication), soil microbes (Chris Kitts, personal communication) and soil mycorrhizae (Ted St. John, personal communication) were conducted to determine the potential for identifying indicator or surrogate parameters.

Criteria used to select indicator or surrogate parameters and their associated metrics included:

- Relatively easy to measure and sensitive enough to record an environmental change;
- Representative of a range of taxonomic and trophic groups found in the area of the Pilot Test Site;
- Can be extrapolated to predict the potential for impact to other biota, which may not have been measured in the study or impacted directly by the Pilot Test, but may indirectly experience long-term change due to the altered physical environment (e.g., soil temperature and soil moisture).

Based on this evaluation, the following indicator or surrogate parameters were selected for the PIA:

- Vegetation: Plants are expected to be sensitive to changes in soil temperature, soil moisture, increased volatile emissions and other potential secondary impacts from the Pilot Test due to the close contact of their root systems in the soil horizon. Additionally, plants provide structure, food and detritus, making them a critical component of the habitat. Thus changes to the plant community could have significant impacts on the ecosystem as a whole.
- Arthropods: Like plants, most arthropods live in close association with the soil and are likely to be exposed to changes in the Study Area due to the Pilot Test. Furthermore, many arthropod species are dependent on plants or plant detritus for food and shelter; thus, changes in the plant community structure due to the Pilot Test could also impact the arthropod community in the SA.
- Wildlife: Small mammals were chosen to represent potential impacts to vertebrate wildlife. Because they have relatively small home ranges, are present in large enough numbers to quantify change over time and many species burrow, they were expected to be conservative, representative surrogates for other wildlife species in the area.

Sections 6, 7 and 8 describe in detail the variables measured and the methodology used to collect data on vegetation, arthropods and wildlife, respectively.

3.2.4 PIA data handling QA/QC

Large quantities of data were collected over the two year period of the PIA. As such, the quality assurance/quality control (QA/QC) aspects of the project were important. Data QA/QC issues were handled as follows:

All Field Data Sheets (FDS) were checked in the field for completeness and accuracy. All cells or blocks in the FDS were completed (i.e., no fields on the data sheets were left blank). All FDS were checked and dated by an independent observer and verified to be complete. The checking observer and the field observer both initialed each FDS. Where an observation was made but there were no records or events the field observer recorded a ‘0’ (zero). If for any reason data were not recorded then the appropriate cell or block was filled with a ‘-‘(minus sign) and a note was provided to explain the data gap. All cells or blocks contained some information such as an alphanumeric code, a numeric value, zero, or a minus sign. No field data were recorded on micro-recorders. At least 5 percent of the transcribed data were checked at random by an independent observer to ensure accuracy. In the event that an error was found, the independent observer would check 15 percent of the transcribed data to ensure accuracy.

Data from the FDS were entered into an Excel spreadsheet. Some data (i.e., that from data loggers, etc.), was stored electronically and transferred to Excel spreadsheets. The data transcription process included a 10 percent randomized check to ensure that data were accurately and appropriately transcribed from the FDS to the Excel spreadsheet. In the event that transcription errors were noted, an additional 10 percent of the data were checked These data were reviewed and checked for potential errors during the transcription from the data sheets to Excel and between the data loggers and the Excel spreadsheets (exchange/conversion) Initially a 10 percent randomized check of transferred data was conducted. In the event that transcription errors were noted, an additional 10 percent of the dataset was checked. The checking of abiotic data is described in the Pilot Study Work Plan (SteamTech, 2003). All

Pilot Test data that was electronically transmitted was randomly checked for consistency, uniformity, error variation and data independence.

Following receipt of the electronic files, a preliminary data check was conducted to assess that all Excel cells contain information. The abiotic and biotic data sets were transferred from Excel into a statistical analysis program and combined for subsequent analysis. All subsequent data review and analysis were conducted in a statistical analysis program. An additional random check of data to ensure consistency with original Excel spreadsheets, and a QA/QC of all statistical tests within the statistical analysis program was also performed. Data review included an assessment of sample size. Data review verified that the method was sampling the population or variable thought to be sampled and to verify that the sample unit size was appropriate to the size, density and spatial distribution of the sampled population/variable. Data review also included data uniformity and/or heterogeneity, assessment of error variation, and data independence.

3.2.5 Data Analysis

As described above and detailed in subsequent sections, a large quantity of data was collected over a two year period for each data type. All data collected during the PIA were described qualitatively to provide an overview of the baseline conditions and observed trends or changes during and after the steam injection. Data analysis also included measures of similarity, diversity, richness and heterogeneity. Data output included statistical summary tables, graphs and frequency distributions. These results are presented in the Results Section for each taxonomic group. Additionally, variables hypothesized to be sensitive to potential impacts from the Pilot Test, and were robust metrics that lent themselves to quantitative evaluation, were compared statistically. The statistical evaluation is presented in the Section "Evaluation of Impacts due to the Steam Pilot Test" for each taxonomic group. For the purposes of this document, the term "significance" is being applied from a statistical perspective in order to avoid confusion with the CEQA term "significant impact". Statistical significance was defined as $P<0.05$, below which the null hypotheses were rejected.

Before the main statistical analyses, exploratory data analyses (descriptive statistics) were performed to measure patterns or trends of the central tendency. Analyses assessed the appropriateness of grouping data (e.g., by function or ranks). A preliminary data review assessed measures of dispersion (e.g., standard error) and frequency distributions. Where parametric assumptions of homogeneity of variance and audacity were constrained or violated, data were transformed so they became approximately normally distributed. For example, where data were in proportions or percentages, data may have been transformed according to the arcsine-square root transformation. Data were collated and summarized and the results made available for distribution to appropriate individuals.

The statistical evaluation for the impact analysis took the same form for each data group and will be described in detail here. As discussed in Section 3.2, a modified BACI design formed the basis for the study design. There is a large body of literature regarding BACI and its related forms (Stewart-Oaten & Bence, 2001). It is not the intent here to summarize this large body of literature. Instead a conceptual overview is provided as a foundation and then details of how this approach was modified for the PIA are discussed.

In general, BACI designs allow investigators to use analysis of variance (ANOVA) as a statistical means of comparing the impact site to control site(s) over time (before and after impact). BACI is especially powerful in those situations where the metric in question is affected by natural variability. Because of the natural noise in the system, it is very difficult to detect anthropogenic impacts. However, by comparing the variability of the impact site to one or more reference or control locations pre- and post-impact and evaluating statistical interactions, the natural variability in the system can be partitioned out. In this method, there is no need to select reference sites that are identical to the impact site. All that is required is that the reference sites represent the range of habitats and have similar variability to the impact site (Underwood, 1994)

Figure 3-1 (Conceptual Overview of the BACI design) provides a conceptual example of a generalized BACI analysis. In this example, there is one impact location and one reference (or control) location that is measured over time, both pre – and post-impact. The variable measured is seasonal and both the impact and reference locations show similar variability but there are differences between the two sites: the impact site consistently has higher numbers than the control site.

In the first example (refer to Figure 3-1a, Conceptual Overview of the BACI Design), there is no evidence of an impact since the lines between the Impact and Control Sites pre- and post-disturbance are parallel. Even though both sites are different, they experience the same temporal trends and there is no evidence of an impact. However, in Figures 3-1b and c, the Impact site shows evidence of an effect. This impact can either be a direct effect of the impact or a time-treatment interaction.

The study design for the PIA was more complicated than a simple BACI design because there were multiple reference sites (both RA and RB) and three treatment periods (Pre-Operations, Operations and Post-Operations) being evaluated. Because the ANOVA analysis for the PIA study design would be highly complex, a simple refinement of the analysis was developed. First, it was established (via qualitative means) that the two reference locations (RA and RB) encompassed the natural variability found in the area. Second, a factorial ANOVA was conducted on RA and RB to evaluate whether they were statistically similar when seasonality was apportioned out. If the means of RA and RB were similar then they were pooled together and a mean reference value for the variable of interest was developed. Finally, SA was compared to the mean reference value using a simple ANOVA.

Each step of the analysis is described in more detail below.

Step 1: Qualitative evaluation of intra- and inter-plot variability

Because all of the data collected within each area was collected from multiple transects or quadrants, it was important to ensure that the intra-plot variability encompassed the normal range of conditions within the SA, RA and RB. Additionally, it was important to ensure that the reference locations (RA and RB) were relevant and appropriate controls for SA. However, as described earlier, it is not critical that quadrants and transect within the SA, or the Reference Areas be identical; they only need to represent the range of variability observed within the habitat (Underwood, 1994). Therefore, statistical comparisons within and between plots were not required. Instead, qualitative evaluations were performed to ensure that variability within plots and between plots represented a reasonable range of natural variability. In general, transects were representative of conditions within each area. Detailed qualitative descriptions are presented in detail in Sections 5 through 8, for abiotic variables and for vegetation, arthropod and wildlife community parameters, respectively.

Step 2: Quantitative Analysis of Reference Locations

In order to group the data from the two reference locations together, it was important to determine first that they represented the same statistical population. Although it was not critical that the reference locations be identical to SA (as described above), it was critical to show statistically that the means of the two reference locations were similar so that the data from the two reference locations could be grouped together. This allowed for only one analysis between SA and reference to be conducted, simplifying the analysis.

To test that the two reference locations represented the same statistical population, a factorial ANOVA was conducted that compared RA to RB over the two year study period. Both seasons (as measured by quarter of the year) and area (RA vs. RB) were evaluated as well as the interaction between the two. In general, most variables did not differ between areas, but did have a statistically significant effect of seasonality. Therefore, data collected from RA and RB were grouped together and mean reference values were used to compare to SA.

Step 3: Quantitative valuation of the SA Over Time

The last step in the analysis was a comparison of SA over the three phases of the PIA. In this step, the difference between SA and the mean reference value (termed ΔSA-$\bar{x}$ Ref) was calculated for each data collection period. By calculating ΔSA-$\bar{x}$ Ref, seasonality and other sources of natural variability were minimized. Then a simple ANOVA comparing the means of ΔSA-$\bar{x}$ Ref across the three treatment periods could be conducted. The use of ΔSA-$\bar{x}$ Ref, allowed for a simple ANOVA to be conducted rather than a complicated multi-factorial ANOVA on the full dataset.

3.2.6 Statistical Case Study

The three step approach described above was conducted on each variable evaluated statistically. Because the same approach was used for each variable, the results of each test will be discussed in the appropriate section, but a detailed discussion of the methodology and analysis will not be presented as it is repetitive. Therefore, to provide some context for the results and a concrete example of the statistical approach used, a step-by-step case study is presented here using one of the variables discussed later in the PIA: number of active small mammal burrows (see Section 8.3.3).

Step 1: Qualitative evaluation of intra- and inter-plot variability

Based on a qualitative evaluation of the number of active burrows measured in transects within each area and between the SA and the Reference Areas, it was concluded that it was reasonable to use RA and RB as non-impacted reference locations when evaluating the impact of the Pilot Test on SA. This is because RA and RB represented similar vegetation communities and were expected to include a reasonable range of the natural variability in small mammal populations across the site.

Step 2: Quantitative Analysis of Reference Locations

To test the assumption that the two reference locations (RA and RB) are similar and can be grouped together, the mean number of active burrows in RA and RB were compared over the two-year time period. Because of the potential confounding influence of seasonal variability on abundance, a factorial analysis of variance (ANOVA) was conducted that evaluated the mean number of active burrows by evaluating the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms. There were no significant differences between the two Reference Areas or among the different seasons ($P>0.05$). Therefore, RA and RB were pooled in subsequent analyses.

Step 3: Evaluation of the SA Over Time

While seasonality did not significantly affect burrow activity, the statistical method of evaluating the delta of SA and the mean of the Reference Areas was still used, as it minimizes any other type of natural variability that could hide potential impacts associated with the Pilot Test. An ANOVA was therefore conducted on ΔSA-$\bar{x}$ Ref across all three periods. There was a significant difference among the three periods ($P=0.0001$). The delta between SA and the Reference Areas increased over the time period of the study with an increased negative ΔSA-$\bar{x}$ Ref in the Operations and Post-Operations phase. That is, there were fewer active burrows in the Operations and Post-Operations periods as compared to the reference as there were in the Pre-Operations phase.

Figure 3-2, Case Study Example of the Statistical Impact Analysis graphically illustrates this evaluation. In the Pre-Operations phase, burrow activity in the SA was greater than the Reference Areas. As shown in Figure 3-2, there was a positive Δ between SA and $\bar{x}$ Ref. However, after the Operations phase commenced, burrow activity in the SA decreased below that of the Reference Areas and Δ became negative. As the ANOVA compares the mean Δ across the three treatment periods, a statistically significant result was found. While this case study focuses on one variable, all the indices measured in the PIA could be evaluated with the same 3 step process.

4.0 ASSESSMENT OF PRIMARY IMPACTS

In this section, the methods used to collect data, a summary of the results, and an analysis of potential physical impacts of the Pilot Steam Test on the surface habitat are presented.

Key Elements for the Assessment of Primary Impacts

- Assessment of Primary Impacts Methods used quantitative survey methods to conduct pre-Project vegetation survey; qualitative methods were used for post-Project survey
- Both ground and aerial photographs were employed to evaluate habitat changes and disturbance amounts
- Ecological monitoring data sheets illustrated the level and type of impacts from construction activities
- Pilot Study was a scaled-down version of build out design; infrastructure and equipment was restricted to a compacted area
- Mature coastal dune scrub habitat with shrubs and much diversity prior to the test was reduced to no shrub vegetation and a dense mix of a few annual species following activities
- Areas with little vehicle access were able to naturally restore with shrubs and diversity; areas with multiple vehicle access resulted in much greater levels of disturbance
- Areas with heavy vehicle access were more prone to invasive weed invasion due to the highly disturbed and compacted soils
- Disturbance to vegetation could be used to infer impacts to wildlife due to the close relationship between impacted wildlife species to the native habitat
- Amount of disturbance from steam technology was comparable to excavation

4.1 Methods

4.1.1 Pre-and Post-Project Habitat Surveys

Prior to the onset of construction work, the general habitat within the project area was evaluated both qualitatively and quantitatively. Botanical surveys evaluated the type and general condition of the project area habitat and the presence of sensitive vegetation and invasive exotics species. Wildlife surveys were conducted to identify the presence, or likely presence of all wildlife species including sensitive species.

The Pre-Project Botanical Assessment provided the percent cover of all plant species with a five percent absolute cover or greater, and an inventory of all plant species in identifiable condition. Sampling was accomplished with an intercept survey method using the California Native Plant Society sampling protocol. Samples were collected every 0.5-meter along a 45 meter transect. Four, 45-meter transects were placed systematically throughout the Pilot Test area; transects were placed 12 meters apart in a north-south orientation. A total of 90 points were sampled along each transect, for a total of 320 sample points. Absolute vegetative cover was calculated by adding all the points with at least one vegetation record and dividing by the total number of points sampled. Relative vegetative cover was calculated by adding the absolute cover of all plant species and dividing by the absolute cover of all species.

A qualitative Vegetation Survey was conducted of the Project area after the steam project construction was completed. Qualitative field survey methods for recording observed species and estimating cover followed standard protocols prescribed in the EMP. In general, the disturbed area was walked and all species observed in identifiable condition were recorded. A visual estimate of cover was made. After the species composition was tabulated, a review of those listed was performed to evaluate whether they were natives/non-natives, invasive exotics, perennials/annuals, and the percent cover for each classification. While the post-project qualitative survey is not as detailed as the pre-project quantitative survey, the information is useful in assessing the general condition of the habitat and vegetation composition following disturbance. A quantitative survey was not conducted because of the uncertainty of future disturbances within the Project area; at the time of this report preparation sub-surface infrastructure remained in place and its outcome was undetermined.

4.1.2 Ground Photographs

Photographs taken from photo-point stations around the project area documented the changes to the habitat through all phases of the project beginning at pre-project conditions and continuing through post-operation activities. Photographs were taken prior to equipment mobilization (first photographs taken February 2002) through present (most recent photographs taken February 2005). The photographs were initially taken monthly until the late stages of decommissioning when photographs were taken bi-monthly. Established azimuth headings were used at each photo station to orient the photographer and correctly frame the photograph. Standardized methods were employed to ensure reproducibility and accuracy between the time sequenced photographs. Photograph data are stored in the general GRP database.

4.1.3 Aerial Photographs

Two aerial photographs of the Project area were obtained for the time period between the Project initiation and the last stages of demobilization. The aerial photos are geo-rectified and digitized. This format allows them to be used in GIS. The GIS allows a relational analysis between digitized Project drawings and aerial photos which provides additional information concerning locations of project disturbances. Additional layers in this analysis include DFR data where the disturbance area was surveyed with geographical positioning system (GPS) equipment. The aerial photographs provided a method of assessing spatial disturbances to the site and documenting the expanse of project disturbances (Figure 4-1, Pre-Operation Phase Pilot Test Aerial Photo, and Figure 4-2, Post-Operation Phase Pilot Test Aerial Photo).

4.1.4 Ecological Monitoring

Both botanical and wildlife monitors conducted ecological monitoring activities at the Site. Ecological monitoring activities consisted of: reviewing project activities with construction personnel, striving to find the construction alternatives that minimized disturbances; surveying and documenting sensitive resources within the project area; relocating wildlife from work areas; and documenting the resulting disturbance to the habitat. Work activities monitored during the course of the PIA included site walks with bidding contractors, trimming of vegetation, creating access corridors for drill rigs and other heavy equipment, installing and removing pipelines, installing and removing process equipment, and relocating wildlife from project areas. The disturbance evaluation of work activities follows definitions and criteria established in the EMP and were consistent with how criteria are employed at other GRP areas. The results of these monitoring activities were recorded on DFRs, the standard form used to record such data at the GRP. Following completion, the data from the DFRs was electronically entered into databases for future reporting; completed DFRs are placed in binders for repository.

Initially, work activities were closely monitored and evaluated. However, over time it became evident the same areas within the project boundary were being used repeatedly. Larger areas of the Project site were established as general work zones where contractors could access the well field to conduct work activities without repeated clearance by ecological monitors. The area designated as the general work zone had previously been denuded during subsurface infrastructure installations and was characterized as mostly bare sand with little vegetation remaining. A wildlife monitor continued to conduct daily surveys during the morning clearance activities prior to contractors working.

In determining the amount of surface disturbance, information from all of these sources were employed. The DFRs related the type of work activities, the resulting level of disturbance both spatially and in magnitude, and the impacts to any sensitive resources. Surveys conducted prior to project initiation provided a description of the original habitat quality and composition. Ground level photographs provided an account of changes to the area habitat over time. Aerial photographs were used to evaluate the spatial extent of disturbances.

4.2 Results

Facilities and equipment used for the Pilot Test project consisted of infrastructure and support equipment placed in a constricted, congested arrangement. There were a total of 56 subsurface borings and well developments which included injection wells, extraction wells, and groundwater monitoring wells, temperature monitoring arrays, vapor extraction wells, soil characterization sampling, confirmation soil sampling, and biosparge well installations. Support and process equipment for the pilot test were placed on a nearby pad surface. The pipe corridor between the equipment and the wells totaled 812 feet in length, with several pipes, wires, and conduit located along one pipe corridor. This entire infrastructure, including construction lay down, office space, parking, and staging areas, were located within a 2.4-acre project area, with half of the Project area (1.2-acres) consisting of pre-existing roads and pad surfaces. The portions of the Project area not on existing road or pad surface were considered the off-road portions of the project area. The off-road portions included the native coastal dune scrub habitat. This portion of the Project area (approximately 0.5 acres) was where all of the sub-surface wells, monitoring arrays, and borings were located.

During the pre-test soil sampling and sub-surface infrastructure installation, a balloon-tired, hollow-stem auger drill rig and front end loader were employed for the majority of the work. A mud-rotary drill rig was used to install the central extraction well, due to the larger well diameter required. This drill rig included two large semi-truck style vehicles to access the center of the well field area. A third vehicle type, a four-wheel drive pick-up truck, was used to develop all of the wells. Despite the heavy access to the well field area, efforts were made to minimize habitat disturbance. During the drilling activities, one additional drill rig access corridor was needed into the well field area. This initial work of installing the injection and extraction wells, numerous pre-test soil borings, installation of the sub-surface monitoring arrays and soil gas probes, and the subsurface equipment flattened or removed most of the above ground vegetation within the well field area. Some vegetation remained as individual branches of shrubs or as small clumps of vegetation. During the lengthy period between well installation and equipment construction and well connections (approximately 4 to 5 months), much of the flattened native shrubs were observed to re-sprout from their roots. Other native annual vegetation also sprouted within the denuded area, probably from a pre-existing seed bank within the soil.

The installation of the pipe, electrical controls, well pumps, and other equipment during the construction phase of the project resulted in the continued disturbance of vegetation. Pickup trucks, forklifts, and other small equipment routinely accessed the non-road/pad area of the Project area during the construction and operation phase. For the most part, access into the well field used areas previously disturbed by the drill rigs.

4.2.1 Pre- and Post-Disturbance Vegetation Report

The Pilot Study site consisted of 2.4 acres and included the well field area, equipment area, and lay-down areas (Figure 4-1; Pre-Operations phase Pilot Test Aerial Photo). Over three-quarters of the site consisted of roads and pads (about 1.2-acres) and thick oil sand and asphalt layers (about 0.7-acres). The remaining portion of the site consists of less degraded mature coastal dune scrub habitat (about 0.5-acre), which included the three ecological study plots.

Pre-Project surveys indicated the Pilot Test project area included mature coastal dune scrub habitat, roads, and former oil well pads. Although much of the project area's soil surface was covered with a layer of oil sand (approximately 32 percent), many of the native plants were able to grow through openings and cracks in the surface. The average total absolute plant cover on the site was approximately 43 percent, with native plants comprising 39 percent and exotic plants only four percent. The most dominant plant on the project site was mock heather (*Ericameria ericoides*) with coastal buckwheat (*Eriogonum parvifolium*) and coyote bush (*Baccharis pilularis*) as associates. Other shrubs present were Blochman's groundsel (*Senecio blochmaniae*), wooly blue star (*Eriastrum densifolium*) and poison oak (*Toxicodendron diversilobum*). Several arroyo willows (*Salix lasiolepis*) were also present at the northeast corner of the project area. Melic grass (*Melica imperfecta*) was a perennial herb found throughout the site, primarily in the shade of shrubs. Two other native herbs found throughout the site in the understory of shrubs were little stinging nettle (*Hesperocnide tenella*) and pygmy weed (*Crassula connata*). Several spring wildflowers were also found as seedlings: fiddleneck (*Amsinckia spectabilis*) and popcorn flower (*Cryptantha* sp.). There were almost 800 Blochman's groundsel individuals and 24 suffrutescent wallflowers, both sensitive species, within the non-road or pad portion of the Project area.

The most dominant exotic plants on site were annual grasses, which were most likely red brome (*Bromus madritensis*), but as seedlings it is hard to be certain. Other exotic plants seen on site but not observed along the transects were iceplant (*Carpobrotus edulis*) and slender leafed iceplant (*Conicosia pugioniformis*).

Several small mammal burrows and bird nests were observed throughout the Pilot Study area during pre-Project wildlife surveys.

The disturbed area of the Project area was surveyed following decommissioning activities to evaluate the overall condition of the habitat following the test. The area of surface disturbance was dominated by native annual species. The species included: fiddleneck, evening primrose (*Camissonia cheiranthifolia*, C. *strigulosa*), popcorn flower, and tansy mustard (*Descurainia pinnata*). Some native perennials were also present and included: deerweed (*Lotus scoparius*), California goosefoot (*Chenopodium californicum*), purple sand verbena (*Abronia umbellata*) and seedlings of coastal buckwheat. Also, non-native annual grasses (red brome and *Vulpia myuros*) and slender leafed iceplant were very common throughout the site. The total vegetative cover in the disturbed area was much higher than in the surrounding non-disturbed habitat. Total vegetative cover in the disturbed area was approximately 65 percent and was dominated by annuals, in comparison to the surrounding sites where vegetative cover was approximately 45 percent, consisting mostly of perennials. This may be a result of the heavy disturbance from the repeated vehicle traffic in the well field area which often promotes the growth of weedy annual species.

This area will require active restoration of outplantings, seeding, weed treatment, and other measures commensurate with restoration efforts following any construction activity on the Field.

4.2.2 Ecological Monitoring

Individual construction activities, when analyzed separately, resulted in a minimal amount of disturbance to the habitat. Typically, this level of disturbance would not require active restoration. Foot traffic within the project area and “one-time” access by drill rigs or other heavy equipment did not severely degrade the habitat. A few activities however, such as installation of additional equipment access corridors, resulted in a more serious level of disturbance; and would typically require active restoration measures (planting or seeding to aid habitat restoration).

The repeated usage of work areas for various activities lead to a level of disturbance where vegetation in particular portions of the project site was completely denuded and much of the subsurface structure of the plants was destroyed. Due to the small study site and the intensive density of subsurface borings, infrastructure, and pipelines, the well field area and access corridors were trampled repeatedly by drill rigs and construction equipment. Data recorded on botanical DFRs illustrated the numerous re-disturbances of areas. As an example, the following presents the progression where repeated access resulted in a greater disturbance to the habitat. One extraction well, E-9, required servicing during the Operation phase of the Project. Due to the configuration of the process pipelines, a new off-road access corridor was needed for the service truck to reach the well. While accessing the off-road corridor, the truck became stuck in the sand and required heavy equipment assistance for extraction. Although the truck became stuck, the resulting disturbance to the habitat was not severe enough to warrant active restoration measures. The resulting damage from the second access along the corridor was more extensive. The vegetation was denuded and the root structure was disrupted to such a degree that it would require active restoration efforts. The E-9 well was accessed for a third time to bring the well online. The service vehicle required to perform the work was not able to utilize the landing mats, nor was it able to negotiate the steep drop from the road surface to the off-road corridor. For this reason, road base material was brought in and placed on the corridor to facilitate the vehicle’s access to the well. This again, elevated the level of disturbance into the range requiring active restoration efforts of planting and seeding. Additionally, non-native material would require removal and surface grading would need to be performed to prepare the area for restoration.

A second representative example is the comparison between two areas with varying amounts of repeated vehicle access. An access corridor was necessary to install the E-6 extraction well and a Temperature Monitoring Array (TMA-16). This corridor was accessed by a drill rig and heavy support equipment. An assessment of the resulting disturbance was determined to require active restoration efforts due to the crushing of vegetation within the corridor. Once the wells were installed, repeated access to the wells by equipment and vehicles was not necessary. Although the above-ground vegetation required pruning or had been broken off, the coyote brush shrubs and other species sprouted from their roots and other herbaceous species sprouted from the existing seed bank. This area, at the time of this report preparation, is progressing toward restoration without active restoration measures being implemented;

the amount of natural revegetation is sufficient to satisfy habitat restoration goals. Comparing the E-6 well corridor to the well field area of the Pilot Study, vegetation was initially flattened by drill rigs and heavy equipment at both locations. However, the drill rigs, heavy equipment, and construction vehicles continuously and repeatedly accessed the well-field area (during the three separate drilling efforts throughout the duration of the Project). The continual and repeated vehicular access not only removed the above-surface vegetation, it also damaged the root structure and seed bank to the degree where native perennials and shrub species are no longer present.

Wildlife monitoring throughout the Project duration recorded any incidental observances within the work area (small mammal trapping, animal track stations, and arthropod survey results also reported several additional wildlife species). This includes those individuals relocated or found dead. Only one sensitive species was encountered; one silvery legless lizard was found dead during drilling activities, and a separate silvery legless lizard was relocated during decommissioning. Five deer mouse individuals were found dead, and four more were relocated beyond the work area. Two western rattlesnakes and one pacific tree frog were relocated from the work area. Two birds (white crowned sparrow and barn swallow) were relocated out of the work area. A dead northern flicker was recovered during decommissioning activities. Several more incidental observations of wildlife were made throughout the course of the project, however none were related to the death or relocation of the individuals.

4.2.3 Ground-Based Photographs

Ground photos recorded the change in habitat within the Project area from coastal dune scrub to a site that could be generally characterized as being denuded. The photographs illustrate that the habitat surrounding the project site has remained mature coastal dune scrub. Initially the photographs of the Project site illustrate the pre-Project conditions of mature coastal dune scrub dominated by native shrubs with some degraded areas. The progression of pictures then illustrates the mobilization of equipment and construction of infrastructure, final build-out conditions, and the demobilization process. Upon completion of the project, the Site no longer resembles coastal dune scrub habitat but rather a large denuded area with a carpet of low-growing annuals. The vertical structure and diversity of the coastal dune scrub habitat is no longer present.

4.2.4 Aerial Photograph

The use of geo-rectified, digitized aerial photography within GIS makes the calculation of spatial area more accurate and relatable to specific work areas. Cumulatively, the Pilot Test Pre-Operation, Operation, and Post-Operation phases resulted in a total disturbance of 0.55-acres of coastal dune scrub habitat. As is evident when comparing aerial photos from before and after the Pilot Test (Figure 4-1, Pre-Operation Phase Pilot Test Aerial Photo and Figure 4-2, Post-Operations Phase Pilot Test Aerial Photo), surface vegetation near and within the well field area has been totally removed. While the vegetation showed some level of recovery after the initial trampling, the re-growth was not as evident after the repeated disturbances during the decommissioning activities, post-operation soil sampling, and bio-sparge well installation. Furthermore, the disturbance area continued beyond the delineated work area to the northwest (4,350 square feet). This expansion of disturbance was the result of additional access into the site required to bring in equipment and utilities.

4.3 Conclusions

The implementation of the steam technology resulted in 0.55-acres of disturbance to coastal dune scrub habitat within the 2.4-acre Project site. Half of the Project site (1.2-acres) consisted of pre-existing roads or pad surfaces. Therefore, project-related disturbances resulted in disturbances to more than half (52 percent) of the available off-road portion of the Project. Most striking in assessing disturbance levels and quantities is the total loss of native perennial plant species within the disturbed area. In addition, the ongoing activities at the site prevented any efforts for active restoration before the demobilization phase. Therefore, the loss or disturbance of habitat represented an important temporal loss of habitat through the duration of all phases of operations and demobilization.

Although only one-half an acre of habitat was disturbed during the steam pilot project, 0.05-acres of the off-road area within the 2.4-acre Project site were excluded from work activities to act as study cells for assessing secondary impacts of the technology (see Section 5.0). The placement of the study cells effectively acted as barriers between the Treatment Area and the outlying vegetation areas, thus reducing the level of expected disturbance. Of the total disturbance area, 0.1-acre occurred beyond the Project limits (used for access corridors and utility corridors).

The level of disturbance to vegetated habitat was assumed to correlate to the level of impacts to other biological resources including wildlife and sensitive plant and animal species. In terms of wildlife impacts, the most populous species within the habitat (small mammals, reptiles, invertebrates) are closely dependant to the coastal dune scrub vegetation for foraging and housing. While exact numbers of individuals killed or impacted are not known, there was a loss of 0.55-acres of wildlife foraging, cover, and den sites.

Unlike an excavation where the top soil is removed, temporarily stored at a stockpile site, and returned to the site, the steam technology allowed the top soil to remain intact; however, the topsoil on the project site was subject to potential compaction and disturbance by equipment and vehicle tires. Typical excavations at GRP require the removal and replacement of the vegetated overburden (top soil), with an attempt on keeping the nutrients, seed bank, and mychorrizae intact.

The steam technology resulted in repeated disruptions of the surface soils and recovering vegetation. This type of disturbance and compaction of soil often leads to an increase in cover of non-native weedy species. This phenomenon may not yet have exhibited due to the earliness of the growing season when the survey was performed.

Although the area of disturbance resulting from implementing the steam technology may actually be smaller compared to what would be required for a site excavation, the duration of time required to install and implement steam technology is anticipated to require more time than an excavation. This temporal loss of habitat could actually result in habitat for sensitive species, wildlife and plants being unavailable for a longer period of time.

5.0 ASSESSMENT OF SECONDARY IMPACTS - ABIOTIC DATA

In this section, the methods used to collect data, a summary of the results, and an analysis of potential impacts of the Pilot Steam Test on abiotic variables are presented.

Key Elements

- Abiotic data included: near-surface and sub-surface temperature, process emissions and soil moisture.
- Pilot Study achieved desired project parameters for heating the Treatment Zone (60 to 70 feet bgs), and was contained within the Test Area.
- Near-surface temperatures appeared to be more influenced by ambient air temperatures (as defined by season) than operation of the Pilot Test.
- Near-surface soil temperatures rose during the Post-Operations phase when the extraction wells were discontinued.
- VOC emissions were within the air permit conditions.
- Soil moisture content was low throughout the PIA; this is a natural characteristic of the sandy soil found at GRP.
- Hydrocarbon vapors were limited to the Treatment Zone during operations, but migrated to within the root once the vapor recover wells were shut off

5.1 Methods

Abiotic data collected included near-surface and subsurface soil temperature, soil moisture and process emissions. These are described in more detail in the following subsections.

5.1.1 Near-Surface Soil Temperature Data

Near-surface (i.e., eight inches below the ground surface) soil temperature data was collected from fixed sampling locations. Two random sampling stations were established for each of the following areas: test area (TA), buffer area (BA), study area (SA), Reference Area-A (RA), and Reference Area-B (RB). Subsequently (as of March 12, 2004) four additional near-surface soil temperature sampling locations were collected midway between the center and each of the corners of the TA, and one additional sampling location was added to the SA so there would be one sampling location in each of the three SA sampling areas. There were a total of 55 near-surface soil temperature sampling events (16 Pre-Operations, 27 Operations, and 12 Post-Operations) during the two-year study period (June 28, 2002 and July 28, 2004).

Initially an Aquarter moisture/temperature meter (Model Temp 200) was used to measure soil temperature (in degrees Fahrenheit). However, early in the study gravel in the shallow soil damaged the temperature sensor (but not the moisture sensor) and it was replaced with a Spectrum Technologies temperature meter (Model TDR 300). At this same time it was decided to dig an approximately one-cubic foot hole at each sampling point and fill them in with nearby windblown sand. This provided a consistent media to standardize temperature (and moisture) measurements. Other parameters reported on the sampling log sheets included date, time of day, ambient air temperature, prevailing wind direction and speed, and general weather conditions.

5.1.2 Sub-Surface Soil Temperature Data

The Pilot Test included temperature monitoring arrays that were used to monitor the subsurface temperature. The subsurface temperature monitoring program incorporated hundreds of individual digital temperature sensors (digiTAMs). The primary focus of the Pilot Test was a smear zone of diluent-affected soil at the groundwater table, which was approximately 50 to 60 feet below the ground surface (bgs), referred to as the Treatment Zone.

Subsurface temperature data were collected from a network of temperature sensor arrays installed at 38 locations in the Pilot Test area (Figure 2-1, Pilot Test Site Plan). The number of digiTAMs at each location ranged from 3 to 32, which were installed between 0.5 to 85.5 feet bgs. The digiTAMs were wired to a central computer to electronically record data, which were collected every 2 to 24 hours depending on the location and phase of the Pilot Test. Once the Operations phase of the Pilot Test was completed and the control room decommissioned the subsurface soil temperature was manually collected every 3 to 6 weeks by connecting a laptop computer to each string of temperature sensors to download the temperature data.

5.1.3 Process Emissions

Vapors were extracted from the nine extraction wells and four vapor extraction wells using vacuum pumps. The extracted vapors were processed through a series of three knockout tanks, heat exchangers, and an air dryer to condense and separate liquids from non-condensable vapors. Vapor flow rates were continuously monitored and recorded by the Supervisory Control and Data Acquisition (SCADA) system. Before vapors (non-condensable gases) were discharged to the atmosphere they were treated using a two-stage granular activated carbon (GAC) system. The average flow rate from the GAC outlet was approximately 600 standard cubic feet per minute (scfm). Concentrations of organic compounds in the vapor system were measured approximately once every six hours when the vapor extraction system was operational.

All contractors were required to submit monthly fuel use reports for all the equipment they operated, including the propane fired boilers. Boiler emissions were calculated based on a mass-balance calculation. Each piece of construction equipment used at the Pilot Test has a SLO County Air Pollution District's approved emission factors. Emissions from construction equipment was then calculated by multiplying the fuel use by appropriate emission factor (refer to Appendix C, Calculated Pilot Test Air Emissions).

5.1.4 Soil Moisture Data

Near-surface soil moisture data were collected from the same fixed sampling locations as the near-surface soil temperature locations (see above). An Aquarter Soil Moisture Meter (Model Temp 200) was used to measure soil moisture (in percent, by volume).

5.1.5 Soil Gas

Four soil gas monitoring locations were established to document the gas composition before and after the Pilot Test operation. Two deep soil gas-sampling arrays were installed at locations with different flow paths and proximities from the central extraction well, and two shallow soil gas sampling arrays were installed in the ecological monitoring zones. All four soil gas monitoring locations had soil gas probes installed from 2 to 15 feet bgs, and the two deeper locations at the Test Site had additional soil gas probes from 2 to 32 feet above the water table. The analysis of the soil gas composition included carbon dioxide, methane, oxygen, and diluent vapors. Three soil gas samples events were taken prior to starting the Pilot Test (July 2002, September 2002, and June 2003). Three soil gas events were taken during the Pilot Test (September 2003, November 2003, and February 2004). And there was one sampling event taken post-operation (May 2004).

5.2 Results

The results of the abiotic data collection activities (near-surface and subsurface soil temperature, process emissions and soil moisture) are described in more detail in the following subsections.

5.2.1 Near-surface Temperature Results

All the recorded near-surface soil temperature data is presented in Appendix B, Pilot Test PIA Data. For illustrative purposes, data from each of the five sampling areas were averaged into a single value for each sampling event, then these values were combined into a representative Reference Area (i.e., average of the two Reference Areas) and the Pilot Test Area (i.e., average of the test areas [TA], buffer area [BA], and study area [SA]). The Reference Area and Pilot Test Area encompass approximately 0.5 acres each. These data are graphically summarized over the time period of the PIA in Figure 5-1, Pilot Test-Near Surface Temperature.

5.2.2 Sub-surface Temperature Results

The contractor McMillan-McGee provided interpreted color-coded temperature distribution contour plots of the Pilot Test on the project's website. Graphic interpretations were presented at multiple depth intervals and two vertical cross-sections through the Test Area. Data were evaluated both spatially and temporally.

Figures 5-2, Horizontal Cross-Section (29.25 ft. msl) Thermal Profile (March 19, 2003) and Figure 5-3, Horizontal Cross-Section (20.25 ft. msl) Thermal Profile (March 19, 2004) illustrate the temperature gradient in the Treatment Zone in the horizontal dimension at the beginning and the end of the steam treatment phase, respectively. These cross sections have color-coded temperatures ranging from 15 to 110 degrees Celsius (59 to 230 degrees Fahrenheit). The comparison of the lateral extent of heat in the treatment zone at the beginning of the steam injection phase (Figure 5-2) to end of the steam injection phase (Figure 5-3) indicates that the extraction wells on the perimeter of the Pilot Test Area (E-2 to E-9) successfully contained the lateral extent of subsurface heat to within the Pilot Test Area (i.e., an approximate radius of 70 feet from the middle of the Pilot Test Area). However, as all the extraction wells have been shut down after the Post-Operations phase, it is expected that without these perimeter controls heat expanded horizontally during the cooling down process.

In the vertical dimension, temperatures were highest at depth and approached ambient soil temperatures at the surface (Figure 5-4, Vertical Cross-Section (E8 to E4) Thermal Profile (March 19, 2004). Figure 5-5, PTMW-1 Temperature vs. Depth (ft. bgs) summarizes temperature at all subsurface soil depths across all three phases of the Pilot Test from a single monitoring location (PTMW-1). As expected, subsurface soil temperatures increased as soon as hot water, then steam was injected. Temperatures were highest at depth in the Treatment Zone, and approached ambient soil temperatures close to the surface. Temperatures began to fall when cold water was injected at the end of the Operations phase. However, while soil temperatures in the deeper soils continue to fall over the period measured after the Post-Operations phase, shallower soil temperatures rose during this same time period. This rise in temperature is due to the temperature of soils at different depths equilibrating when the extraction wells were shut down at the end of the Post-Operation phase. However, data collected after the PIA study indicated that temperatures at 15 feet bgs, which is considered the bottom of the root zone had increased up to 110 degrees Fahrenheit. This increasing trend did not peak until January 2005, when cold ambient temperatures and substantial rainfall finally reversed this near-surface

5.2.3 Process Emissions

Volatile organic compounds (VOCs) emissions were within the air permit conditions of 95 percent removal efficiency, or less than 10 parts per million, by volume (ppmv) as hexane if the input concentration was less than 200 ppmv. Based on using a VOC emission rate of 10 ppmv (as hexane) for the entire period of steam injection (3,511 hours) the mass of VOCs discharged to the atmosphere would be 267 pounds (refer to calculation sheet in Appendix C, Calculated Pilot Test Air Emissions.

There were no continuous measurements of flue gas emissions from the boiler and steam generator exhaust other than the compliance test for the air permit for emissions of NOx and CO, which were well below the permitted levels. Therefore, the mass of NOx and CO was determined based on the mass balance calculation of the propane burned in the boiler and steam generator. Based on this calculation approximately 1,200 pounds of NO_2 and 24 pounds of CO in the flue gas were discharged from the Test Pilot project (refer to calculation sheet in Appendix C).

During the construction of the Pilot Test (April 2002 to May 2003) 1,283 gallons of diesel fuel and 14 gallons of gasoline were reported to be used by project contractors. This fuel use is estimated to produce the following combustion air emissions: 643 pounds of nitrogen oxides, 109 pounds of carbon dioxide, 62 pounds of reactive organic gases, 48 pounds of particulate matter less than 10 microns, and 43 pounds of sulfur oxides in Appendix C, Calculated Pilot Test Air Emissions.

5.2.4 Soil Moisture

All the recorded near-surface soil moisture data are presented in Appendix B, Pilot Test PIA Data. Due to the sandy soil throughout the area, near-surface soil moisture measurements were consistently very low (approximately 3 percent water) throughout the study period; therefore, a quantitative analysis of soil moisture data was not considered useful for this study.

5.2.5 Soil Gas

No hydrocarbon vapors (as methane) were detected (i.e.,, less than 5 ppm) during the Pre-Operation phase (sampling dates September 2002 and June 2003). Methane was detected just above the diluent plume during the hot water injection of the Operation phase; however, the deepest sampling locations were too wet to collect vapor samples during the steam injection of the Operation phase. Methane was commonly detected in the Test Area during the Post-Operation phase (May 2004) with the concentrations decreasing towards the ground surface. Methane was detected in the root zone (maximum concentration at 15 feet bgs was 175 ppm); however, methane was very low or absent within 5 feet bgs Therefore, the operation of vapor recovery wells successfully limited hydrocarbon vapors to the deeper Treatment Zone; however, once the vapor recovery wells were shut off fugitive hydrocarbons could migrate to ecological root zone.

5.3 Evaluation of Impact to Abiotic Variables Due to Steam Plant Pilot Test

While a number of abiotic variables were measured (as described in Section 5.2), only near-surface soil temperatures were evaluated quantitatively as a relevant, potential secondary impact of the Pilot Test. Process emissions where *de minimis* and soil moisture in the sandy soil did not vary significantly during the study period. To evaluate potential temperature impacts in the near-surface soil horizon, near-surface soil temperatures were evaluated using the three step process outlined in Section 3.2.5.

<u>Step 1: Qualitative Evaluation of Intra and Inter-plot Variability:</u>

To simplify the impact analysis, pooling the data from transects within each area is preferred. To confirm that it is appropriate to pool the abiotic data within each location, SA, RA and RB were evaluated. SA was compared to reference rather than grouping SA, BA and TA, because temperature in the Study Area was deemed more relevant for comparison as the other biotic variables were only within the SA and not the BA or TA.

To confirm that near-surface soil temperatures in the Reference Areas were relevant as a control comparison to SA, near-surface soil temperatures in the three areas were statistically compared in the Pre-Operations phase to test the assumption that the reference locations had similar mean near-surface soil temperatures to the SA during baseline conditions. Near-surface soil temperature was the only variable evaluated statistically in Step 1 (the other biotic variables were evaluated qualitatively. An analysis of variance was conducted (ANOVA) and the mean temperature was found to be statistically similar across all 3 locations (SA, RA and RB). Thus, it was concluded that it is reasonable to use RA and RB as non-impacted reference locations when evaluating the impact of the Pilot Test on SA.

<u>Step 2: Quantitative Analysis of Reference Locations:</u>

To simplify the Impact Analysis, the assumption that the two reference locations (RA and RB) are similar and can be grouped together so that the SA can be compared to just one reference dataset was tested. To test this assumption, the mean, near-surface soil temperatures of RA and RB were compared over the two-year time period. Because of the potential confounding influence of seasonal variability in the ambient air temperature affecting near-surface soil temperatures, a factorial analysis of variance (ANOVA) was conducted that evaluated the mean soil temperatures during the Pre-Operations phase by evaluating the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms.

There was no significant difference in the mean, near-surface soil temperatures between RA and RB ($p>0.05$). However, when data were grouped by the quarter of the year that they were collected (e.g., January, February and March were defined as the first quarter, April, May and June as the second quarter and so on), there was a statistically significant difference in near-surface soil temperature based on the time of year collected ($P=0.0001$). Based on this evaluation, it was concluded that soil temperatures did not vary among the reference locations, but did vary seasonally over the year. Thus, it is reasonable to group RA and RB together to compare to SA when evaluating the impact of the Pilot Test on SA. However, due to the significant seasonality component, the time of year that data are collected must be factored into any impact analysis of temperature.

Step 3: Quantitative Evaluation of SA Over Time:

To address the seasonality issue, the difference (ΔSA- $\bar{x}$ Ref) between SA and the mean of RA and RB was calculated for each data point. By evaluating ΔSA- $\bar{x}$ Ref, seasonal impacts were minimized and an evaluation of the impact due to the Pilot Test was conducted. An ANOVA was then conducted on ΔSA- $\bar{x}$ Ref across all three periods. There was a significant difference among the three periods (P=0.0004). A post-hoc analysis using a Bonferroni Test found that the mean delta was similar between the Pre-Operations and Operations phase, but was statistically higher in the Post-Operations phase. This is consistent with the qualitative evaluation of temperature discussed in Section 5.2.2 and Figure 5-5, in that the shallower soil temperatures rose in the Post-Operations phase after the injection wells were shut off. However, during the actual Operation phase, when extraction wells were controlling the heat to the Treatment Zone, near-surface soil temperatures were unimpacted.

5.4 Conclusion

The subsurface temperature sensors confirmed that the Pilot Study achieved the desired project parameters for heating the Treatment Zone (60 to 70 feet bgs), and was contained within the Test Area (bounded by extraction wells E2 to E9). Temporal variations by depth over time demonstrated the effects of injecting hot water, steam and cold water in Test Area. However, near-surface temperatures were more influenced by seasonal weather than operation of the Pilot Test (i.e., in the Operations phase near-surface temperatures decreased during the winter, which was when steam was being injected). The most unexpected temporal variation occurred during the Post-Operations phase, when with the end of parameter controls (i.e., the extraction wells), the residual subsurface heat began to rise to the surface, statistically elevating near-surface soil temperatures in the SA above reference conditions. The impacts of this increase in sub-surface temperatures is not known since the PIA study was suspended/concluded before the subsurface temperatures equilibrated to ambient conditions. Since temperatures 15 feet bgs rose as high as 110 degrees Fahrenheit above ambient values, some impact would be expected. However, whether these impacts would be positive or negative is not known.

Volatile organic compounds (VOCs) emissions were within the air permit conditions of less than 10 parts per million, by volume (ppmv) as hexane, or less than 90 percent removal efficiency if the input concentration was less than 200 ppmv as hexane. Fuel emissions from the construction equipment during the almost one year prior to operation of the Pilot Test were *de minimis*. Finally, there was inadequate differentiation of the very low soil moisture content to evaluate the effect of the operation of the Pilot Test project.

6.0 ASSESSMENT OF SECONDARY IMPACTS – VEGETATION

Vegetation monitoring was chosen as a relevant indicator of the potential ecological impact of the Pilot Test on the environment Plants are expected to be exposed to changes in soil temperature, soil moisture and any other secondary impacts of the Pilot Test through their roots. Furthermore, they are a critical element of the habitat and changes in the plant community could have significant impact on other components of the ecosystem.

Key Elements

- Vegetation data collected and analyzed included: number of individuals per species, cover, richness, leaf abundance and condition, and community coefficients.
- SA, RA and RB established in same plant species association and had other similar vegetation indices supporting conclusion that Reference Areas span the natural variability found in area.
- Majority of plant indices showed a strong seasonal component.
- Once seasonal variability was partitioned out, only subtle impacts from the Pilot Test were measured.
  - o Total cover: only a marginally statistically significant increase in the SA was seen in the Operations phase.
  - o Species richness: a significant increase in the SA in the Post-Operations phase.
  - o Leaf condition: a significant decrease in delta in the Post-Operations phase for one of the two species measured.
- The biological relevance of a significant increase in cover and richness is not known. Additionally is not clear whether this constitutes a positive or negative impact.
- It is unclear if the Pilot Test is responsible for the decrease in leaf condition, as field observations identified a beetle infestation as the probable cause.

In this section, the methods used to collect and analyze vegetation data, a summary of the results, and an analysis of potential impacts of the Pilot Test on the plant community are presented.

6.1 Methods

The purpose of the vegetation monitoring was to determine if there were any changes in vegetation characteristics in the Study Area as compared to changes in the Reference Areas. Data collection was designed to compare samples between three time periods: Pre-Operation, Operation and Post-Operation.

The design of the data collection required the establishment of permanent sampling units so data could be collected consistently and thereby facilitate time-series analysis both within- and between-sampling areas. Two methods of sampling were utilized for this project, quadrat (or plot method) and point-intercept. Both methods have advantages and disadvantages. By using both methods, the disadvantages were minimized.

The quadrat method can be used to provide information on plant cover, density, frequency and species richness. However, using the quadrat method for determining cover can be problematic. Observer bias can be as high as 25 percent of the mean (Greig-Smith, 1983). To verify the cover measurements from the quadrat method, the point-intercept method was also used. The point-intercept method is considered the least biased and most objective method of measuring cover (Bonham, 1989). However, a key disadvantage of the point-intercept is that species with low cover values are often not sampled adequately. By using both methods, cover measurements from quadrat data were verified and species with lower cover were represented by use of the quadrat method.

Qualitative data were also collected at the same time as the quantitative vegetation surveys. The qualitative data were collected to assist in determining the health and vigor of plants by making a number of observations, such as leaf condition and life cycle. In addition, photo-documentation was used to qualitatively monitor disturbances to and the recovery of native vegetation. The key value of the photo-documentation is to provide a visual permanent record of the past, allowing factors and changes to be evaluated that might not have been considered when the monitoring was initiated. Photo-documentation is also useful to evaluate invasion by weedy species, successional changes, soil disturbance and trampling.

The methodology used in studying and analyzing potential effects of the project on vegetation is described more thoroughly below.

6.1.1 Quadrat Method

Data Collection

Three transects, 20-meters in length were permanently established at the Study Area and within each of the two Reference Areas. Four, 2-meter square quadrats were placed at 3-meter intervals along each transect (at the 1-meter, 6-meter, 11-meter, and 16-meter marks on the tape), so there were a total of 12 quadrats established in each sampling area. The quadrats were centered on the transect line.

To permanently mark the locations of the transects and quadrats, both ends of the transect were securely marked with rebar and PVC pipe, ensuring minimal break down during the monitoring period. Each quadrat was marked with flags in each corner of the quadrat and one in the center.

For each quadrat, the following were recorded:

- Number of individuals per species, if perennial
- Visual estimate of cover per species using the Daubenmire Cover Class scale. The Daubenmire cover class scale uses 6 classes for visual estimation of cover within a quadrat as follows:

  1 – 0 to 5 percent

  2 – 6 to 25 percent

  3 – 26 to 50 percent

  4 – 51 to 75 percent

  5 – 76 to 95 percent

  6 – 96 to 100 percent
- Tallest and average height of each perennial species
- Life cycle (seedling, non-reproductive, reproductive, senescent)
- Leaf abundance was rated on a scale from one to four as follows:

  1 - 0-25 percent

  2 - 26-50 percent

  3 - 51-75 percent

  4 - 76-100 percent
- Leaf condition was described as follows:

  Normal

  Yellowing

  Desiccated
- Annual or perennial
- Native or non-native

Vegetation data from the Study Area and the Reference Areas were collected concurrently. Quadrat data were collected once every six weeks before Operations (Pre-Operations), monthly during Pilot Test Operations, and monthly following the completion of the Operations. Vegetation sampling began in the end of May 2002 and continued to August 2004. The data were collected 9 times prior to operation, eight times during operation and four times after completion of operations (Post-Operations).

Data Reduction and Analysis

Individual plant species cover data were collected from each quadrat. Measures of species richness and cover for each Reference Area and the Study Area were derived from this data. Individual species data were also aggregated to obtain the total and proportional cover of native perennials, native annuals and non-native species. To evaluate the potential impact of the Pilot Test, cover and species richness were then evaluated statistically using the modified BACI design discussed in Section 3.2.5

Leaf abundance and leaf condition were also examined. However, leaf abundance remained steady throughout the study period. This is typical of plants in the coastal dune scrub, was measured during the study since it was theorized that if the Pilot Test was having an effect on plants, leaf abundance may be affected. No statistical analysis of leaf abundance was conducted as there was no change in this variable over time.

Conversely, leaf condition did change during the study period. Two perennial plants that are common to all three areas were studied in terms of leaf condition: mock heather (*Ericameria ericoides*) and coastal buckwheat (*Eriogonum parvifolium*). Mock heather is a larger native perennial shrub with a relatively deep root structure. Coastal buckwheat is a small native sub-shrub with relatively shallower roots. Leaf condition was given a numerical score, where plants with normal leaves received a score of 10, plants with yellowing leaves a score of 5 and plants with desiccated leaves a score of 1. During each cycle the leaf condition for all life cycles of mock heather and coastal buckwheat were averaged. To evaluate the potential impact of the Pilot Test on leaf condition the modified BACI analysis was conducted to determine if there were any statistical differences between the Study and Reference Areas.

For each sampling cycle, a community coefficient (CC) based on presence and cover was also calculated. The CC is a method to express the similarity between any two stands in a single number. Basically the formulae indicate the relative number of species shared by two stands or sample areas. A CC of 100 represents complete similarity, while a CC of 0 represents complete difference. If two areas have a CC based on presence of greater than 50 they are assumed to be in the same plant species association (Barbour and Pitts 1987). Using the Jacard CC based on cover, the values are lower. Thus if two stands have a CC greater than 25 they are considered to be in the same plant species association.

6.1.2 Point Intercept Method

Data Collection

Point-intercept data were collected from each 20-meter transect at 0.5-meter intervals. Therefore, 40 points were collected along each transect and a total of 120 points were sampled in the Study Area and each Reference Area.

For each point along the transect, the following were recorded:

- Plant species
- Annual or perennial
- Native or non-native
- Substrate (Bare Ground, Litter, Cryptogramic soil, Dead Vegetation)

Point-intercept data were collected during every other sampling event (10 times) for the duration of the PIA study.

Data Analysis

Since the transects were short in length (20-meters with only 40 points), all transects within a sampling area were aggregated to increase the sample size. Therefore, 120 points were studied for each sampling area and measures of species richness and cover for the Study Area and each of the Reference Areas were derived from this data. Cover was measured as the number of "hits" on the target species out of the total number of points measured.

The point-intercept data were used to confirm the output of the quadrat method. In general, the same trends as those seen with the quadrat data were observed; however, much fewer species were represented. The transect data represented approximately 35 percent of the species observed in the quadrat data in the SA during the Pre-Operation phase. Similarly, at RA and RB only 45 and 42 percent respectively of the species from the quadrat data were represented in the transect data during the Pre-Operation phase. Since the quadrat method included more species than the transect method, the rest of the botanical data analysis and quantitative statistics were based on the quadrat dataset.

6.1.3 Qualitative Data

Data Collection

Photographs were taken of each transect, during each study cycle. Photographs were taken from opposite ends of each transect with a digital camera. Care was taken to use the same focal length for each photograph to allow for better repeatability. A representative sample of the photos is presented in Appendix D, Representative Photos of Vegetation Transects.

6.2 Results

The results of all vegetation indices measured during the PIA can be found in Appendix B, Pilot Test PIA Data. A qualitative description of the abundance (cover), composition (richness), and leaf condition of plant species in the Study and Reference Areas follows.

6.2.1 Cover

To describe species abundance at the different sites, the average total absolute cover of each area throughout the study was determined. Cover is measured as the percentage of quadrat area covered by the canopy of a given species. The total absolute cover of each area was determined for each cycle. To determine the average total absolute cover, each of the 21 sampling cycle's total absolute cover was averaged with the other cycles. The summary results for species composition are provided in Table 6.1, Summary of Species Composition and Frequency Data by Sampling Area. The following provides discussion of these results for each area.

Study Area

The total absolute cover at the SA during the entire study period was 86 percent. Native perennial plants comprised 76 percent cover, native annual plants comprised 6 percent, and non-native perennial plants comprised 2 percent as well as non-native annual plants (Figure 6-1, Absolute Cover of Total Vegetation).

The two most dominant plants in terms of cover were the native perennial shrubs mock heather and coastal buckwheat, which comprise 63 percent of the average total cover. Mock heather had an absolute cover of 34 percent and coastal buckwheat an average absolute cover of 20 percent. Other common native perennial species at the SA were California aster *(Lessingia californica)* and Blochman's groundsel *(Senecio californica)* , with 7 percent and 6 percent absolute cover, respectively (Figure 6-2, Absolute Cover of Native Perennials).

The native annual plants, though common in spring, comprised only 6 percent of the total absolute cover. The most dominant native annual plants, in terms of absolute cover, were primrose (*Camissonia* spp.) and popcorn flower (*Cryptantha* spp.) (Figure 6-3, Absolute Cover of Native Annuals).

Non-native species only comprised 3.8 percent of the average total cover. This was contributed primarily by three species: slender-leaved iceplant (*Conicosia pugioniformis*), annual grasses (*Avena* spp. and *Bromus* spp.) and veldt grass (*Ehrharta calycina*) all with approximately 1 percent absolute cover (Figure 6.4, Absolute Cover of Non-Native Perennials; and Figure 6-5, Absolute Cover of Non-Native Annuals).

Reference Area A

The average total cover at RA during the entire study period was 75 percent. Native perennial plants comprised 58 percent cover, native annual plants comprised 9 percent, non-native perennial plants comprised 1 percent and non-native annual plants comprised 7 percent (Figure 6-1, Absolute Cover of Total Vegetation).

The most dominant plant in terms of cover at RA was mock heather with an absolute cover of 32 percent. Three other common species in terms of absolute cover were coastal buckwheat with 8 percent, coyote brush (*Baccharis pilularis*) with 6 percent and California croton (*Croton californica*) with 5 percent (Figure 6-2, Absolute Cover of Native Perennials).

The native annual plants comprised only 9 percent of the total absolute cover, with five species at approximately 1 percent absolute cover each. These plants are fiddleneck (*Amsinckia spectabilis),* primrose, popcorn flower, Pterostegia (*Pterostegia drymarioides*) and starwort (*Stellaria* sp.) (Figure 6-3, Absolute Cover of Native Annuals).

The cover of non-native perennial is low and represented by slender-leaved iceplant with approximately 1 percent average total absolute cover. The non-native annual cover was significantly higher at 7 percent and was dominantly represented by annual grasses and tocalote (*Centaurea melitensis*)(Figure 6.4, Absolute Cover of Non-Native Perennials; Figure 6-5, Absolute Cover of Non-Native Annuals).

Reference Area B

The total average cover at RB was approximately 69 percent. Native perennial plants comprised 47 percent cover, native annual plants comprised 8 percent, non-native perennial plants comprised 12 percent and non-native annual plants comprised 2 percent (Figure 6-1, Absolute Cover of Total Vegetation).

The most dominant plant in terms of cover was mock heather. Mock heather had an absolute cover of 28 percent. Another common species was coastal buckwheat with an absolute cover of 11 percent (Figure 6-2, Absolute Cover of Native Perennials).

The native annual plants comprised 8 percent of the total absolute cover but only two species with approximately 1 percent or greater average absolute cover. These plants were primrose and popcorn flower (Figure 6-3, Absolute Cover of Native Annuals).

Non-native species comprised 14 percent of the average total cover. This was contributed by primarily three species: slender-leaved iceplant, annual grasses and veldt grass. Slender-leaved iceplant provided the dominant non-native absolute cover with 9 percent. Veldt grass comprised approximately 3 percent average absolute cover and annual grass approximately 2 percent. An additional six non-native annual species provided only trace amounts of cover at RB (Figure 6-4, Absolute Cover of Non-Native Perennials; and Figure 6-5, Absolute Cover of Non-Native Annuals).

6.2.2 Measures of Species Composition

To describe species composition at the different sites, frequency and species richness was examined. Frequency is the percentage of total quadrats that contain a given species. Species richness is simply the number of different species that occur at a site. The summary results for species composition are provided in Table 6.1, Summary of Species Composition and Frequency Data by Sampling Area. The following provides discussion of these results for each area.

Study Area

Forty plant species were observed at SA during the quadrat sampling. Thirteen are native perennials, seventeen are native annuals, two are non-native perennials and eight are non-native annuals (Figure 6-6, Total Richness).

The native perennial species most common in terms of frequency at the SA are mock heather, and coastal buckwheat, with frequencies of 98 percent and 91 percent respectively. Blochman's groundsel and California aster are also common species (Figure 6-7, Richness Native Perennials).

Most of the other species that occurred at the SA were more seasonal, with the most species seen during the spring of each year. These species include the native annual species such as fiddleneck, evening primrose, popcorn flower wild carrot (*Daucus pusillus*), California everlasting (*Gnaphalium californicum*), and Pterostegia (Figure 6-8, Richness Native Annuals).

Veldt grass and slender-leaved iceplant two non-native perennial species common to the SA were found in approximately 20 percent of the quadrats. The non-native annual species were common to the SA in the spring of each year and included: annual grasses, cut-leaved filaree (*Erodium cicutarium*) and cudweed (*Gnaphalium luteo-album*) (Figure 6-9, Richness Non-Natives).

Reference Area A

Forty-five plant species were observed at RA during the quadrat sampling. Twelve are native perennials, twenty-two are native annuals, two are non-native perennials and nine are non-native annuals (Figure 6-6, Total Richness).

Mock heather is the most common species in terms of frequency, occurring in every quadrat at RA. Coastal buckwheat was also common with a frequency of approximately 70 percent. Other common species include: Blochman's groundsel, California aster, California croton and coyote brush (Figure 6-7, Richness Native Perennials).

Native annual species which were abundant in the spring of each year included: fiddleneck, evening primrose, wild carrot, California everlasting, cobwebby thistle (*Cirsium occidentale* ssp. *occidentale*), popcorn flower, and Pterostegia (Figure 6-8, Richness Native Annuals).

Slender-leaved iceplant is a non-native perennial species common to RA and had a frequency of 51 percent. Veldt grass only occurred in trace amounts. The non-native annual species common to RA in the spring of each year include: annual grasses and cut-leaved filaree. Tocalote is another common, non-native annual species in RA. This species is invasive and has a frequency of 23 percent. Tocalote is not common to the SA or Reference Area B (Figure 6-9, Richness Non-Native Species.

Reference Area B

Forty-seven plant species were observed at RB during the quadrat sampling. Twelve are native perennials, twenty-five are native annuals, two are non-native perennials and eight are non-native annuals (Figure 6-6 , Total Richness).

Three native perennial plants were common at RB; mock heather, coastal buckwheat, and California aster. Mock heather had 98 percent frequency, coastal buckwheat had 77 percent frequency and California aster had 55 percent frequency (Figure 6-7, Richness Native Perennials).

Native annual species play an important role at RB, with six species having a frequency 20 percent or greater. These species include: fiddleneck, popcorn flower, primrose, pygmy weed (*Crassula connata*), California everlasting, and Blochman's groundsel (Figure 6-8, Richness Native Annuals).

Slender-leaved iceplant is a non-native perennial species dominant in RB with 95 percent frequency. Veldt grass is also present in RB with a frequency of 20 percent. The non-native annual species were less common to RB but in the spring of each year annual grasses were common (Figure 6-9 – Richness Non-Natives).

6.2.3 Leaf Condition

Leaf condition was analyzed for two native perennial plant species, mock heather and coastal buckwheat, both of which are a dominant component of the vegetation at the Study Area and both Reference Areas. The purpose of this analysis was to determine if there was a difference in leaf condition between the phases of the Pilot Test project. Generally, only slight variability was seen over time in leaf condition in these two species in all the sampling areas (Figure 6-10 - Mock Heather Leaf Condition, and Figure 6-11, Coastal Buckwheat Leaf Condition). The exception to this was in the Post-Operations phase when field observations showed that a beetle had infested this area and was impacting the native perennial vegetation. The beetle appeared to be focused on one transect within the SA, but other shrubs within the SA were affected to a lesser extent. The beetle infestation was not restricted to the Pilot Test area. Other locations around the Field had been infested resulting in a similar defoliation of the perennial vegetation, so this infestation was not attributable to the Pilot Study.

6.2.4 Evaluation of Seasonality

The PIA captured two years of seasonal botanical variation in the dune scrub habitat, beginning in May 2002 and ending in August 2004. During this time period, a decrease was noted in total plant species richness and species cover throughout the late spring and summer months (June to August) when drought conditions occur, and increase over the winter and spring months (October through May), the rainy season (Figure 6-1, Absolute Cover of Total Vegetation. and Figure 6-6, Total Richness). The changes in plant cover and species richness are attributed largely to the natural dying off of annuals over the summer months, and the accumulation of the annuals over the winter months, peaking in the spring. This conclusion is supported by the data, which indicate plant species richness and cover for annual native species and annual non-native species drops to nearly zero in all sampling areas for the months of

July through November (Figure 6-3, Absolute Cover of Native Annuals; Figure 6-5, Absolute Cover of Non-Native Annuals; Figure 6-8, Richness Native Annuals; Figure 6-9, Richness Non-Natives,).

In addition, the plant species richness and vegetation cover drops slightly in the summer months for native and non-native perennial species (Figure 6-2, Absolute Cover of Native Perennials; Figure 6-4, Absolute Cover of Non-Native Perennials; Figure 6-7, Richness Native Perennials; Figure 6-9 Richness Non-Natives). This is due to several perennial plant species that die back completely (senesce) during the drought months including the native suffrutescent wallflower (*Erysimum insulare* ssp. *suffrutescens*), giant wool stars (*Eriastrum densifolium*), melic grass (*Melica californica*), and non-native veldt grass. Other native perennial species, such as California aster and Blochman's groundsel, often loose a portion of their leaves in the summer. One other factor that contributes to the reduction of native and non-native perennial species cover during the summer is the low survival rate of seedlings. Seedlings germinate in the spring months but not all seedlings survive through the summer months. This was most evident in the field observations with the non-native slender-leaved iceplant, which would have prolific seedling germination in the winter with very few surviving in the summer.

6.4 Evaluation of Impact to Vegetation Due to Steam Plant Pilot Test

While a number of vegetation indices were measured (as described in Section 6.2), only total cover, richness and leaf condition were evaluated statistically to assess whether there were any measurable secondary impacts from the Pilot Test. As described in Section 3.2.5, a three-step approach was used. The results of these analyses are described in more detail for each index in the following subsections.

6.4.1 Total Cover

Step 1: Qualitative Evaluation of Intra- and Inter-plot Variability:

To simplify the impact analysis, pooling the data from transects within each area is preferred. To confirm that it is appropriate to pool the data within each location (SA, RA and RB), transects were evaluated qualitatively. A similar approach was used to confirm that RA and RB adequately encompass the range of natural variability associated with the habitat in the Pilot Test Area and thus function as reasonable reference/control areas for SA. Quantitative, statistical analyses were not deemed necessary for this evaluation as the purpose was to confirm that the multiple transects and the two Reference Areas encompass the natural variability in the plant community in the area of the Pilot Test.

Intra-plot Variability: Study Area

The quadrat data from all three transects within the SA were very similar and showed similar trends in terms of cover and species richness (Table 6.2, Intra-Study Plot Variation – Comparison of Study Area Data). The quadrats within transect 1 had 33 species and consistently had the greatest amount of cover – an average absolute cover of 94.4 percent. The quadrats within transect 2 had 35 species but slightly less cover than those quadrats within transect 1 – an average absolute cover of 93.5 percent. Non-native annual species accounted for the two species associated with transect 2 that were not associated with transect 1. The quadrats associated with transect 3 were the most different from the quadrats of the other transects. Transect 3 quadrats had fewer species and consistently less cover than the other two transects. The quadrats within transect 3 had 29 species and an average absolute cover of 81 percent.

The quadrats within transect 1 and transect 2 shared 29 species; this is 88 percent of the total species found in transect 1's quadrats and 85 percent of those found in transect 2 quadrats. The quadrats in transect 1 and transect 3 shared 24 species; or, 83 percent of the species found in transect 3's quadrats and 71 percent of the total species found in transect 1's quadrats. The quadrats associated with transects 2 and 3 shared 26 species; this is approximately 76 percent of the species found in transect 2 quadrats and 90 percent of the species found in transect 3 quadrats.

Intra-plot Variability: Reference Area A

The quadrat data from the RA were very similar and showed similar trends in terms of cover and species richness (Table 6.3. Intra-Study Plot Variation – Comparison of Reference Area A Data). The quadrats within transect 1 had 37 species and consistently had the least amount of cover - an average absolute cover of approximately 60 percent. The quadrats within transect 2 also had 37 species but greater average absolute cover - 87 percent. The quadrats within transect 3 had similar results to those of transect 2. The quadrats within transect 2 had 37 species and 88 percent average absolute cover. The primary reason that the cover in transect 1 was lower than in transect 2 or 3 is that coastal buckwheat and coyote brush, which are common species in the quadrats of transects 2 and 3, were not abundant in transect 1.

The quadrats within transect 1 and transect 2 shared 34 species or 91 percent of the total species found in quadrats in both transect 1 and transect 2. The quadrats in transect 1 and transect 3 shared 32 species; or 84 percent of the species found in transect 3 quadrats and 86 percent of the total species found in transect 1 quadrats. The quadrats associated with transects 2 and 3 shared 33 species; this is approximately 89 percent of the species found in transect 2 quadrats and 87 percent of the species found in transect 3 quadrats.

Intra-plot Variability: Reference Area B

The quadrat data from all three transects within RB were very similar and showed similar trends in terms of cover and species richness. (Table 6.4, Intra-Study Plot Variation – Comparison of Reference Area B Data) The quadrats within transect 1 had 35 species and consistently had the greatest amount of cover – an average absolute cover of 80 percent. The quadrats within transect 2 had the most species but less cover than those quadrats within transects 1 and 3 – 39 species with an average absolute cover of 57 percent. The quadrats associated with Transect 3 had 37 species with an average absolute cover of 77 percent.

The quadrats within transect 1 and transect 2 shared 31 species; this is 88 percent of the total species found in transect 1 quadrats and 80 percent of those found in transect 2 quadrats. The quadrats in transect 1 and transect 3 shared 28 species; or, 76 percent of the species found in transect 3 quadrats and 81 percent of the total species found in transect 1 quadrats. The quadrats associated with transects 2 and 3 shared 33 species; this is approximately 85 percent of the species found in transect 2 quadrats and 89 percent of the species found in transect 3 quadrats.

The primary difference of the quadrats associated with Transect 1 is the high cover of mock heather as compared with the other quadrats. Though the quadrats associated with transect 2 had the highest number of species, the quadrats had relatively low cover. This is because these quadrats had a higher number of native annual species, only present in spring with typically low absolute cover. The quadrats associated with transect 3 are noticeably different from the other quadrats in terms of cover of non-native perennial cover.

Intra-plot Variability: Conclusion

Based on the qualitative evaluation presented above, the transects measured within each area were deemed to be adequately representative of the natural variability found in each plot.

Inter-study Plot Variation

To evaluate the appropriateness of the two Reference Areas (RA and RB) functioning as reasonable controls for SA, the Reference Areas and SA were evaluated qualitatively. The SA and Reference Areas are very similar in terms of species composition. The sites share 35 species, but have differences in terms of cover and frequency. Mock heather is the dominant plant in terms of cover whereas coastal buckwheat is an associate species at all sites. Other native perennials that are shared by all sites include: melic grass, Blochman's groundsel, California aster, deerweed (*Lotus scoparius*), bedstraw (*Galium* sp.), California goosefoot (*Chenopodium californica*) and evening primrose (*Camissonia cheiranthifolia).* The sites also share 17 native annual species, such as fiddleneck, pussy paws (*Calyptridium monandrum*), evening primrose, popcorn flower, cobwebby thistle, wild carrot, and tansy mustard. All sites have the non-native, perennial and invasive species, Veldt grass and slender-leaved iceplant. The SA and Reference Areas share non-native annual species: such as annual grasses and red-stemmed filaree.

Using the community coefficient (CC) based on presence data, the sites all had a score of 70 or greater (on a scale from 0 – 100) indicating great similarity between the sites. Typically any two plots with a CC of more than 50 represent the same plant association. However, in terms of cover there are slightly greater differences.

The SA consistently had greater cover and RB consistently had the least. Using the CC (Jacard) weighted by cover data, any two plots with a CC of more than 25 represent the same plant association. All sites had a CC of 30 or above again showing similarity between the sites and indicating all sites were located in the sample plant species association based on cover. This supported the assumption that RA and RB were relevant reference/controls for SA.

Step 2: Quantitative Analysis of Reference Locations:

To simplify the Impact Analysis, the assumption that the two reference locations (RA and RB) are similar and can be grouped together so that the SA can be compared to just one reference dataset was tested. To test this assumption, the mean cover of RA and RB were compared over the two-year time period. Because of the potential confounding influence of seasonal variability on plant growth, a factorial analysis of variance (ANOVA) was conducted that evaluated mean cover by evaluating the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms. There was no significant difference in the mean cover between RA and RB ($P>0.05$). However, when data were grouped by the quarter of the year that they were collected (e.g., January, February and March were defined as the first quarter, April, May and June as the second quarter and so on), there was a statistically significant difference in cover between RA and RB based on the time of year collected ($P=0.0019$). The finding that there is a significant affect of season on vegetation cover corroborates the qualitative observations discussed in Section 6.2.4.

Based on this evaluation, it was concluded that cover did not vary among the reference locations, but did vary seasonally over the year. Thus, it is reasonable to group RA and RB together to compare to SA when evaluating the impact of the Pilot Test on SA. However, due to the significant seasonality component, the time of year that data are collected must be factored into any impact analysis of cover.

Step 3: Quantitative Evaluation of SA Over Time:

To address the seasonality issue, the difference (ΔSA-$\bar{x}$ Ref) between SA and the mean of RA and RB was calculated for each data point. By evaluating ΔSA-$\bar{x}$ Ref, seasonal impacts were minimized and an evaluation of the impact due to the Pilot Test was conducted. An ANOVA was then conducted on ΔSA-$\bar{x}$ Ref across all three operational phases; a marginally significant difference among the three periods ($P=0.058$) was observed. A qualitative evaluation of the mean difference of ΔSA-$\bar{x}$ Ref in each time period identified the Operations Phase as the time period where ΔSA-$\bar{x}$ Ref had a marginal increase in cover. This difference decreased toward Pre-Operation levels in the Post-Operations phase. The biological relevance of this marginal increase in ΔSA-$\bar{x}$ Ref for cover during the Operations phase in the SA is not clear. However, the impact is short-lived, as ΔSA-$\bar{x}$ Ref cover is reduced in the Post-Operations period.

A qualitative evaluation of the total cover of the SA during the Pilot Study, in comparison with the Reference Areas indicates that excluding mock heather, the SA and RB had a very similar increase in plant cover from the Pre-Op phase through the Post-Op phase. However, mock heather decreased significantly in cover in the SA during the Post-Op phase because of the beetle infestation which resulted in the impact being "short-lived, as ΔSA-$\bar{x}$ Ref cover is reduced in the Post-Operations phase". The RA seemed to react the most different in terms of cover, staying almost static in terms of cover during the three periods.

6.4.2 Richness

Step 1: Qualitative Evaluation of Intra and Inter-plot Variability:

As described in Section 6.4.1, it was concluded that RA and RB are reasonable, non-impacted reference locations for the evaluation of impacts to SA.

Step 2: Quantitative Analysis of Reference Locations:

The potential impact of the Pilot Test on total plant species richness was evaluated in a similar fashion to vegetation cover. To test the assumption that the mean richness between RA and RB are similar so the two reference locations can be pooled, a factorial ANOVA was conducted that evaluated mean richness by evaluating the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms. There was no significant difference in the mean richness between RA and RB (P>0.05). However, when data were grouped by the quarter of the year that they were collected, there was a highly statistically significant difference in richness based on the time of year collected (P=0.0001). Based on this evaluation, it was concluded that richness did not vary among the reference locations, but did vary seasonally over the year. Thus, it is reasonable to group RA and RB together to compare to SA when evaluating the impact of the Pilot Test on SA. However, due to the significant seasonality component, the time of year that data are collected must be factored into the impact analysis.

Step 3: Quantitative Evaluation of SA Over Time:

To address the seasonality issue, ΔSA- $\bar{x}$ Ref was calculated for each data point and an ANOVA was conducted on the delta of SA and the two reference locations across all three periods. There was a significant difference in ΔSA- $\bar{x}$ Ref among the three periods (P=0.035). The Post-Operations phase had a significantly higher ΔSA- $\bar{x}$ Ref than either the Pre-Operations or Operations phases. Neither the mean ΔSA- $\bar{x}$ Ref of the Pre-Operations or the Operations phase was significantly different from each other.

The biological relevance of this significant increase in richness during the Post-Operations phase in the SA is not clear. As seen in Figure 6.6, Total Richness, the difference between SA and the Reference Areas varies from positive to negative (or in other words, the richness at SA is greater or less than the reference areas) over the course of a year. It may be that the time period measure in the Post-Operations phase only captured a positive delta and was too short (being only 4 months long) to measure the positive and negative differences observed over a longer time period.

A qualitative evaluation of the species richness of the SA during the Pilot Study, in comparison with the Reference Areas indicates that the SA differs from the Reference Areas by consistently having a greater number of native perennial plants and less native annuals. Because of this difference, the SA has less species richness than the other areas in the winter and spring, when annuals are more predominant in the Reference Areas. During the summer and fall months, when annuals are less prevalent, the SA has greater species richness than the reference areas.

The Post-Operations phase occurred in spring and summer, when annual species are on the decline and when the SA typically has a greater number of perennial species than the Reference Areas. The Post-Operations phase, in contrast to the other phases of the Pilot Study, did not include a winter-spring cycle when the number of annual species in the Reference Area would exceed those in the Study Area. This seems to have resulted in the Post-Operations phase having a significantly higher ΔSA- $\bar{x}$ Ref than either the Pre-operations or Operations Phases.

6.4.3 Leaf Condition

Step 1: Qualitative Evaluation of Intra and Inter-plot Variability:

Leaf condition was evaluated statistically for both mock heather and coastal buckwheat. As described in Section 6.4.1, it was concluded that RA and RB are reasonable, non-impacted reference locations for the evaluation of impacts for SA.

Step 2: Quantitative Analysis of Reference Locations:

A factorial ANOVA was conducted that evaluated mean leaf condition by studying the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms for mean leaf condition across time for both species. There was no significant difference (P>0.05) for both species between RA and RB so it was concluded that data from the Reference Areas could be grouped together.

Step 3: Quantitative Evaluation of SA Over Time:

To see if the leaf condition within the SA was impacted by the Pilot Test, the ΔSA- $\bar{x}$ Ref was calculated for each data point and an ANOVA was conducted on ΔSA- $\bar{x}$ Ref across all three phases of the Pilot Study. For the mock heather, there was a significant difference (P=0.0001) among time periods, with the Post-Operations phase having a significant decrease in ΔSA- $\bar{x}$ Ref. For coastal buckwheat, there was no statistically significant difference in the mean ΔSA- $\bar{x}$ Ref among time periods (P>0.05).

While there was a strong, significant effect measured in mock heather leaf condition, it is unclear what impact the Pilot Test may have had on leaf condition. As described earlier, field observations showed that a beetle had infested the SA and was impacting the native perennial vegetation. The beetle appeared to be focused on one transect within the SA, but other shrubs within the Study Area were also affected to a lesser extent. Additionally, other locations around the Field had been infested resulting in a similar defoliation of the perennial vegetation. Because the beetle infestation was not restricted to the Pilot Test area, it is unlikely that the decrease in leaf condition at SA is due to the Pilot Test Study.

6.5 Conclusions

The transect and quadrats established to study the SA, RA and RB were all established in the same plant species association and had other similar vegetation indices that support the conclusion that the Reference Areas span the natural variability likely to be found in the area and provide a good comparison to the SA.

The majority of plant indices measured in the PIA showed a strong seasonal component. This is consistent with field observations and expectation that cover of plant species and species richness fluctuates seasonally, with annual species (both native and non-native) completely dying out in the summer months and certain perennial species (both native and non-native) dying back or completely senescing.

Because of the strong seasonality component, the statistical comparisons to evaluate the potential impacts of the Pilot Test on vegetation in the SA required that the seasonal variability be partitioned out of the evaluation. Once seasonal variability was partitioned out, only subtle differences in plant indices were measured. For total cover, only a marginally statistically significant increase in the delta between the SA and Reference Areas was seen in the Operations phase. For species richness, a significant increase in the delta during the Post-Operations phase in the SA was found. The biological relevance of a significant increase in cover and richness is not known. Additionally, it is not clear whether they constitute a positive or negative impact. For leaf condition, there was a significant decrease in delta between SA and the Reference Area locations in the Post-Operations time period for one of the two species measured. It is not believed that the Pilot Test is responsible for the decrease in leaf condition, as field observations identified a beetle infestation as the probable cause and these beetles have also been found elsewhere at the GRP.

7.0 ASSESSMENT OF SECONDARY IMPACTS – ARTHROPODS

The purpose of the arthropod sampling was to identify the effects of the Pilot Test project on arthropods in terms of arthropod grouping diversity and abundance over time.

Arthropods are members of the phylum Arthropoda, which includes cold-blooded invertebrate animals with exoskeletons, segmented bodies, and jointed legs. Common members of the arthropod phylum include insects, spiders, crabs, and many others. As part of this study, arthropods identified on site were limited to members of the classes Insecta and Arachnida (insects and spiders).

To study and characterize arthropods on site, three permanent transects were used: a Study Area (SA), and two Reference Areas (RA and RB) (refer to Figure 2-1).

Key Elements

- Arthropod data collected and analyzed included: number of individuals per taxonomic group, frequency of encountering at least one individual in a quadrat, and Simpson's Diversity Index.
- Twelve taxonomic groupings of arthropods were observed over the two year study period.
- SA, RA and RB had similar taxonomic groupings and frequencies of encounter and were established in same plant species associations supporting conclusion that the reference areas span the natural variability found in Pilot test Area.
- Seasonal variation in abundance, frequency and arthropod diversity was slight. Only the frequency of encountering at least one individual in a quadrat was found to be statistically affected by seasonality.
- No statistically significant affects of the Pilot Test on arthropod indices were found. Thus potential impacts of the Pilot Test on abundance, frequency and diversity of the arthropod community were considered minimal.

7.1 Methods

Data for the project were collected approximately every 6 weeks for a total of 23 sampling events (cycles) from May 2002 through August 2004 (a total of 23 cycles were included as part of the PIA study, however, arthropod data were not collected during the first cycle of sampling). This time frame encompassed the Pre-Operation, Operation, and Post-Operation phases of the Pilot Test.

At each of the 22 cycles, soil samples were collected at three randomly selected points along each 20 meter vegetation transect line at SA, RA, and RB. Sample points along the transect line were identified using a random numbers generator, and the same quadrat was not sampled twice during the entire monitoring period. In order to increase the likelihood of encountering arthropods, at least two of the three samples collected during each sampling event were from beneath live shrubs and from the north side of the live shrubs to the extent feasible. If more than one random point on each transect fell on bare sand or beneath a dead shrub, an adjustment to the next nearest live shrub was made, in order to achieve at least 2 samples from beneath live shrubs.

Over the course of the sampling period, the number of live shrubs present within one of the SA sampling transects substantially decreased due to unknown reasons, although it has been suggested it was the result of a beetle, known to be present at the GRP. The effects of the beetle appeared to be focused on one transect within the SA, but other shrubs within the Study Area were also affected to a lesser extent. Other locations around the GRP had also been infested, but this was the only area located within the project area. As a result, a deviation from the standard method occurred and sampling from beneath dead shrubs increased.

Samples were collected by shoveling the upper 1-2 inches of soil and leaf litter from a 0.25 meter square quadrat area. The sand and leaf litter was transferred to a white cloth sheet and the material spread out to easily observe arthropods. The sample was allowed to settle for three minutes to allow the arthropods to start moving again before counting began (arthropods that emerged during this time were collected and counted). Once the three minute settling period elapsed, the sample was thoroughly searched and arthropods were collected for an additional seven minutes. Following the complete 10-minute interval, all individuals in each taxonomic grouping were counted and tallied on the data sheet. After counting individuals each data collection event, soils, leaf litter, and arthropods were returned to the quadrat area. Individual members of the class Insecta were identified down to the order; and arachnids (orders Araneae and Acari) were identified as a class.

In addition to the methods described above, notes on weather, general biological observations, and other sampling characteristics were recorded during each sampling event.

7.2 Results

All arthropod indices measured during the PIA can be found in Appendix B. A qualitative description of species composition and community diversity, and abundance and frequency of arthropod species identified at the Study and Reference Areas follows.

7.2.1 Species Composition

Table 7-1, Total Abundance and Frequency of Arthropods by Taxonomic Grouping characterizes the taxonomic groupings represented during the project sampling. The "Total" columns represent all arthropod individuals sampled during the PIA study. "Frequency" represents the occurrence potential of each grouping to occur in a quadrat, or the likelihood of encountering at least one individual within a sampling quadrat. This measure does not consider the number of individuals encountered, but is limited to presence/absence.

Twelve taxonomic groupings (11 orders of the class Insecta, and the class Arachnida) of arthropods were observed at the sampling sites within established transects: Arachnida, Coleoptera, Collembola, Dermaptera, Diptera, Hemiptera, Homoptera, Hymenoptera, Isoptera, Lepidoptera, Orthoptera, and Thysanura. As noted in Table 7-1, the most common taxonomic groupings in terms of abundance are Hymenoptera (1,231 individuals) and Arachnida (408 individuals). The order Hymenoptera was dominated by ants, generally Argentine carpenter ants. The class Arachnida consisted predominately of mites and unidentified spiders.

The order Hymenoptera was also the most frequently observed grouping. Overall, approximately 56 percent of all quadrats sampled contained members of this Order. Following Hymenoptera, the most frequently observed groupings were Arachnida, Thysanura, and Isoptera.

Eleven of the 12 groupings were encountered in SA (Dermaptera not represented). The most common groupings observed included Hymenoptera, Arachnida, Thysanura, Isoptera, Coleoptera, and Collembola. These groupings represent approximately 95 percent of the total individuals encountered. Hymenoptera was also the most frequently observed grouping (approximately 50 percent), followed by Arachnida (30 percent), Thysanura (20 percent), and Isoptera (8 percent).

The Reference Areas were very similar to SA, supporting between 10 and 12 of the known taxonomic groupings. Frequencies were also very similar to SA. The most common groupings observed included Hymenoptera, Arachnida, Thysanura, Isoptera, Coleoptera, and Collembola, which represented approximately 97 percent of the total individuals encountered.

Figure 7-1, Simpson's Diversity Index for Arthropods illustrates how Simpson's Diversity Index compares among locations and over the time period of the PIA. Simpson's diversity index is a commonly used ecological measure that takes into account species richness and evenness together and is the probability of picking two organisms at random that are of different taxonomic groupings. Simpson's Diversity Index was very variable both within and between areas.

7.2.2 Abundance

Twenty-two sampling events (cycles) occurred as part of the PIA project (Arthropods were not sampled during cycle 1). During that time, approximately 2,276 individuals were counted and identified (Table 7-1). On average, approximately 103 individuals were counted per cycle (which includes the sum of total individuals for SA, RA, and RB). The median number of individuals observed was approximately 90 per cycle. Figure 7-2, Total Arthropods by Sampling Area illustrates the total number of individuals counted in each Reference Area and in the SA over the entire time period of the PIA.

The frequency of hits (frequency of encountering at least one individual in a quadrat, independent of taxonomic grouping or abundance) was very consistent in all the sampling areas and between transects within each sampling area (Figure 7-3, Frequency of Arthropods). Approximately 75 percent of quadrats sampled had at least one individual. The frequencies at each individual sampling area (SA, RA, and RB) were also relatively consistent at approximately 75 percent.

Approximately 700 individuals were encountered within SA. In terms of abundance, the order Hymenoptera was the most dominant, more than doubling the next most abundant grouping, Arachnids. Thysanura and Isoptera were the next most dominant taxonomic groupings. RA had the highest abundance of occurrences at approximately 913 individuals. Approximately 670 individuals were encountered in RB. At all sites, Hymenoptera was the most dominant grouping of individuals encountered, followed by Arachnida, and Thysanura.

7.2.3 Seasonal Variation

A qualitative evaluation of abundance, frequency and diversity over time showed a great deal of variability between sampling events. There was no clearly observable seasonal component as seen with the vegetation indices. Therefore, statistical evaluations were performed to assess whether seasonal impacts on arthropod indices occurred. The results of the statistical analyses are discussed in Section 7.3.

7.3 Evaluation of Impact on Arthropods due to Steam Plant Pilot Test

To evaluate the potential for secondary impacts of the Pilot Test on arthropods, changes in arthropod abundance, frequency and changes in the Simpson's diversity index over time were evaluated statistically as described in the following sections. The following sections include a discussion of the results (Step 1); consideration of the appropriateness of evaluating the Reference Areas as a single data pool (Step 2); and a quantitative statistical analysis of SA with respect to abundance, frequency, and diversity.

7.3.1 Abundance

A discussion of arthropod abundance results is presented in this section both qualitatively (Step 1) and quantitatively (Step 2).

Step 1: Qualitative Evaluation of Intra- and Inter-plot Variability:

To simplify the impact analysis, pooling the data from transects within each area is preferred. To confirm that it is appropriate to pool the data within each location (SA, RA and RB), transects were evaluated qualitatively. A similar approach was used to confirm that RA and RB adequately encompass the range of natural variability associated with the habitat in the Pilot Test Area and thus function as reasonable reference/control areas for SA. Quantitative, statistical analyses were not deemed necessary for this evaluation as the purpose was to confirm that the multiple transects and the two Reference Areas encompass the natural variability in the area of the Pilot Test.

Intra-plot Variability:

Within each sampling area, three transects were sampled for arthropod presence. Each transect included three quadrats. The quadrat information collected within each sampling area was generally biologically similar. Transects were very close to each other and occurred within the same plant community. In addition, topography, geology, and surface conditions were very similar not only between individual transects but also between sampling areas. It was not uncommon to encounter a colony during surveys, generally Hymenoptera, which had the potential to skew abundance higher. In addition, not all groupings were identified within each quadrat or transect

Within SA, Transect 1 generally supported increased numbers of arthropods over the life of the PIA study. Transects 2 and 3 were nearly identical in total abundance. Frequencies ranged from 68 percent to 86 percent in SA. The physical characteristics and the plant communities of the three transects were nearly identical. Although abundances varied between transects, the differences do not appear to be biologically significant (within the natural variability expected to occur in the vicinity of the Pilot Test Project).

Within RA, Transect 1 again generally supported the highest total abundance of arthropods, with Transects 2 and 3 being very similar. Frequencies within RA were nearly identical within the three transects at approximately 75 percent. The three transects were located within the same plant community very close to each other, with nearly identical physical characteristics. Although abundances varied between transects, the differences do not appear to be biologically significant.

There was slightly more variation between transects within RB. Frequencies within RB ranged from 71 percent to 80 percent. Similar to above, transects within RB were within the same plant community which have very similar physical and biological characteristics. Differences in abundance and frequency within RA do not appear to be biologically significant.

Based on the qualitative evaluation presented above, the quadrats measured within each area were deemed to be adequately representative of the natural variability found in each plot.

Inter-study Plot Variation:

To evaluate the appropriateness of the two Reference Areas (RA and RB) functioning as reasonable controls for SA, the Reference Areas and SA were evaluated both qualitatively. The objective was to have the reference locations be representative of the natural environment occurring at the GRP as well as encompass the natural variability found in the area. Therefore, a qualitative evaluation of SA, RA and RB was conducted.

Based on the inter-study plot evaluation conducted for the vegetation indices, SA, RA and RB were found to share similar plant species and were found to represent the same plant species association based on cover and presence. Additionally, similar geology, topography and soils of the three locations also support the assertion that, independently, the reference locations would function as reasonable controls for SA. As major structural elements of the site, similarities between the three locations with regard to plant assemblages, geology, topography, and soils provide strong evidence that the two Reference Areas function as reasonable controls for SA for the arthropod indices.

Step 2: Quantitative Analysis of Reference Locations:

To simplify the impact analysis, the assumption that the two reference locations (RA and RB) are similar and can be grouped together so that the SA can be compared to just one reference dataset was tested. To test this assumption, the mean abundance of RA and RB were compared over the two-year time period. A factorial analysis of variance (ANOVA) was conducted that evaluated mean abundance by evaluating the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms. There was no significant difference in the mean abundance between RA and RB ($P>0.05$). Additionally, there was no statistically significant difference in abundance based on the time of year collected ($P>0.05$). Based on this evaluation, it was concluded that abundance of arthropods did not vary among the reference locations, nor did it vary seasonally over the year. Thus, it is reasonable to group RA and RB together to compare to SA when evaluating the impact of the Pilot Test on SA.

Step 3: Quantitative Evaluation of SA Over Time:

While seasonality was not a significant issue for the abundance metric, the statistical method of evaluating the ΔSA-$\bar{x}$ Ref was still used, as it minimizes any natural variability that could hide potential impacts associated with Pilot Test. An ANOVA was conducted on ΔSA-$\bar{x}$ Ref across all three periods. There was no significant difference among the three periods ($P>0.05$). Thus there was no statistically significant effect on arthropod abundance as a result of the Pilot Test.

7.3.2 Frequency

Step 1: Qualitative Evaluation of Intra and Inter-plot Variability:

As described in Section 7.3.1, it was concluded that RA and RB are reasonable, non-impacted reference locations for the evaluation of impacts to arthropods for SA.

Step 2: Quantitative Analysis of Reference Locations:

The potential effect of the Pilot Test on arthropod frequency was evaluated in a similar fashion to abundance. To test the assumption that the mean frequency between RA and RB are similar so the two reference locations can be pooled, a factorial ANOVA was conducted that evaluated mean frequency of encounter by evaluating the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms. There was no statistical difference in the mean frequency between RA and RB ($P>0.05$). However, when data were grouped by the quarter of the year that they were collected, there was a statistically significant difference in frequency ($P=0.04$). Based on this evaluation, it was concluded that frequency did not vary among the reference locations, but did vary seasonally over the year. Thus, it is reasonable to group RA and RB together to compare to SA when evaluating the impact of the Pilot Test on SA. However, due to the statistically significant seasonality component, the time of year that data are collected must be factored into the impact analysis.

Step 3: Quantitative Evaluation of SA Over Time:

To address the seasonality issue, the difference (ΔSA-$\bar{x}$ Ref) between SA and the mean of RA and RB was calculated for each data point. By evaluating ΔSA-$\bar{x}$ Ref, seasonal impacts were minimized and an evaluation of the impact due to the Pilot Test was conducted. An ANOVA was then conducted on ΔSA-$\bar{x}$ Ref across all three periods; there was no statistically significant difference among the three operational phases ($P>0.05$). Thus, there is no effect on the frequency of arthropods encounters as a result of the Pilot Test.

7.3.3 Simpson's Diversity Index

Step 1: Qualitative Evaluation of Intra and Inter-plot Variability:

As described in Section 7.3.1, it was concluded that RA and RB are reasonable, non-impacted reference locations for the evaluation of impacts to arthropods for SA.

Step 2: Quantitative Analysis of Reference Locations:

The mean of Simpson's Index of Diversity across time was compared between the reference locations to test if they could be grouped together in the subsequent analyses. There were no statistically significant differences between the two Reference Areas or among the different seasons ($P>0.05$). Therefore, RA and RB were pooled in subsequent analyses.

Step 3: Quantitative Evaluation of SA Over Time:

While seasonality was not a statistically significant issue for the diversity metric, the statistical method of evaluating the ΔSA-$\bar{x}$ Ref was still used, as it minimizes any natural variability that could hide potential impacts associated with Pilot Test. An ANOVA was therefore conducted on ΔSA-$\bar{x}$ Ref across all three periods. There was no statistical significant difference among the three periods ($P>0.05$). Thus there was no statistically significant impact on arthropod diversity as a result of the Pilot Test.

7.4 Conclusions

Twelve taxonomic groupings (11 orders of the class Insecta, and the class Arachnida) of arthropods were observed at the sampling sites within established transects over the two year study period. The Reference Areas were very similar to SA, supporting between 10 and 12 of the known taxonomic groupings. The frequency of encountering at least one individual in a quadrat, independent of taxonomic grouping or abundance was very consistent in all the sampling areas and between transects within each sampling area; approximately 75 percent of quadrats sampled had at least one individual. Based on a qualitative evaluation, the quadrats measured within each area were deemed to be adequately representative of the natural variability found in each plot. Additionally, because plants are a major structural element in the environment, similarities between plant assemblages among the three locations provide strong evidence that the two Reference Areas function as reasonable controls for SA for the arthropod indices.

Seasonal variation in abundance, frequency and arthropod diversity was slight. Only the frequency of encountering at least one individual in a quadrat was found to be statistically affected by seasonality. Any potential impacts of the Pilot Test on abundance, frequency and diversity of the arthropod community were also minimal. No statistically significant effects on the arthropod variables measured as a result of the Pilot test were identified.

8.0 ASSESSMENT OF SECONDARY IMPACTS – WILDLIFE

The purpose of the wildlife sampling was to identify the effects of the Steam Pilot Test project, if any, on wildlife species inhabiting the natural areas in the vicinity of the Pilot Test Project. Three measures (or indices) of wildlife activity were recorded within the project sampling areas: (1) the number of active small mammal burrows, (2) the abundance of tracks observed in sample areas, and (3) the number of trapped small mammals.

Key Elements

- Wildlife data collected and analyzed included: number of active small mammal burrows, track activity, and number of small mammals trapped.
- Wildlife species observed in the Pilot Test area included one reptile and one bird species and 10 species of mammals.
- Quadrats within each area and the two reference areas were deemed to be adequately representative of the natural variability found.
- Seasonal variation in captures, tracking activity and number of active burrows were slight. Only number of captures was influenced by seasonality.
- Potential impacts of the Pilot Test on captures, tracking activity and number of active burrows were slight. Only the number of active burrows showed a statistically significant impact from the Pilot Test. The two other indices showed no statistical differences among treatments periods

A list of the wildlife species that have been observed within the SA, RA, and RB sampling areas is provided in Table 8-1, List of Wildlife Species Observed in Sampling Areas. All project sampling sites are located within coastal dune scrub vegetation, which is important habitat for numerous wildlife species. This community provides forage for browsers, herbivores, and granivores. Both Heermann's kangaroo rat (*Dipodomys heermanni*) and deer mouse (*Peromyscus maniculatus*) are important prey species within coastal dune habitat. They are a primary prey of owls, gray fox (*Urocyon cinereoargenteus*), long-tailed weasel (*Mustela frenata*), and snakes, and are also hunted by coyotes (*Canis latrans*) and bobcats (*Lynx rufus*). Other common mammalian prey species of coastal dune scrub habitat include black-tailed deer (*Odocoileus hemionus columbianus*), black-tailed jackrabbit (*Lepus californicus*), and brush rabbits (*Sylvilagus* spp.).

Coastal dune scrub habitat is known to support several species of reptiles including western fence lizard (*Sceloporus occidentalis*), side-blotched lizard (*Uta stansburiana*), western rattlesnake (*Crotalus viridis*), gopher snake (*Pituophis melanoleucus*), and striped racer (*Masticophis lateralis*). Avian species typical of the coastal dune scrub habitat include wrentit (*Chamaea fasciata*), California thrasher (*Toxostoma redivivum*), white-crowned sparrow (*Zonotrichia leucophrys*), and Bewick's wren (*Thryomanes bewickii*). Shrubs provide nesting habitat for songbirds and cover for predators, small mammals, and reptiles, as well as shelter for larger mammals such as black-tailed deer.

No federally listed or state-listed wildlife species are present or are likely to occur within the SA, RA, or RB sampling areas. Three wildlife species that are classified as California Species of Concern are known to occur within coastal dune scrub habitat and may be present in the sampling areas include the California legless lizard (*Anniella pulchra*), coast horned lizard (*Phrynosoma coronatum*), and the loggerhead shrike (*Lanius ludovicianus*).

8.1 Methods

Most wildlife species have large ranges and many species are expected to be present in varying abundances in different seasons and years. Therefore, most wildlife species would be unsuitable to measure potential effects resulting from the project within a small defined area. However, small mammals have smaller home ranges relative to avian or large mammal species are present in large enough numbers to quantify change over time and would be suitable to represent similar potential effects on other wildlife in the area.

8.1.1 Survey Schedule

Wildlife surveys were performed during a five-day period every six weeks from May 2002 through July 2004. Monthly surveys were conducted from March 2004 until the end of the monitoring period in July 2004, for a total of 21 sampling events (cycles).

The wildlife survey schedule was broken down into Day 1 through Day 5, corresponding to the weekly calendar of Monday through Friday (Table 8-2, Wildlife Survey Schedule). Burrow survey activities occurred on Day 1 and 2. Small mammal trapping activities began on the Friday proceeding the survey week and then picked up again on Day 1 and continued through to Day 5. The tracking station activities occurred on Day 1 through 4. The wildlife surveys occurred in the week prior to the botanical and invertebrate surveys in order to minimize disturbance to wildlife prior to conducting the surveys.

8.1.2 Burrow Surveys

Survey areas were searched for burrows by walking transects spaced no greater than 15-feet apart. A pin flag was placed next to each burrow identified. Each burrow was examined for any sign of recent use, such as prints/tracks, fresh scat, fresh digging, etc. Burrows were identified as being either active or inactive; collapsed burrows were also counted and identified as inactive.

8.1.3 Track Stations

Each track station consisted of a 1-meter square area of open ground covered with a thin dusting of red rock silt. Three track stations were placed within each of the three sampling transects, for a total of nine track stations per sampling area. These track stations were placed outside of the vegetation transects and remained in the same location throughout the duration of the monitoring effort.

The track stations were established on the afternoon of Day 1 and checked on Days 2, 3, and 4. A track was counted each time an animal entered the station. For example if an animal walked through the corner of a station, thus entering and exiting the station that was counted as one track. If that same animal turned around after exiting the station and then re-entered the station that track was counted as a second track, even though the tracks came from the same animal. Each track was identified to the most specific taxonomic level possible, but was summarized in the data tables as belonging to one of the following categories: mammal, bird, reptile, amphibian, invertebrate, or other.

8.1.4 Small Mammal Trapping

Eighteen evenly spaced Sherman live traps (3 x 3.5 x 9 in.) were placed in each of the three sample areas (six per transect). The traps were placed on the Friday of the week preceding the trapping effort. They were kept closed and pre-baited in order to familiarize resident wildlife with their presence. Cotton stuffing or similar material was placed in each trap to serve as bedding and thermal protection. Birdseed, oatmeal, and peanut powder were used as bait and to provide food for captured animals.

The traps were opened and baited in the late afternoon on Days 2, 3, and 4. The traps were checked in the morning on Days 3, 4, and 5 and then closed during the daytime hours. Each small mammal trapping effort included a total of 162 trap nights per area.

All captures were weighed, measured, aged, sexed, and identified to species to the extent possible. Captured animals had their tails marked with a non-toxic color marker. A different color was used for each night of trapping. Captured animals were released unharmed.

8.1.5 Data Collection and Analysis

All data was recorded on data sheets in the field and then entered into an Excel database. The purpose of the wildlife sampling is to determine differences between sampling areas as a result of activities associated with the Pilot Test. As part of this assessment, all three indices of wildlife abundance and activity (number of active burrows, number of tracks, and capture trends/small mammal population estimates) were analyzed for seasonal variation, intra- and inter-area variation, and finally variation associated with varying phases of the Pilot Test Project.

8.2 Results

All small mammal data collected during the PIA can be found in Appendix B. A qualitative description of the species composition and abundance, track station activity, and burrow activity identified at the Study and Reference Areas follows.

8.2.1 Species Composition and Abundance – Small Mammal Captures

Table 8-1, List of Wildlife Species Observed in Sampling Areas summarizes wildlife observed in the vicinity of the Pilot Test Area. Species observed included one reptile and one bird species and 10 species of mammals.

Nearly 100 percent of the small mammals captures consisted of two species, deer mouse and Heermann's kangaroo rat. Total raw captures were nearly evenly divided between those two species; however, there was a single capture each of California vole (*Microtus californicus*) and long-tailed weasel *(Mustela frenata*). Small mammals were captured during every sampling event in all three locations (Figure 8-1, Total Small Mammal Captures for all Sampling Areas).

Approximately 1,800 total captures were counted over the life of the project at all sites (captures from SA, RA, and RB were 602, 620, and 561, respectively). Based on these values, small mammal population estimates were calculated following each cycle using both the Lincoln-Peterson and Schnabel methods (these methods incorporate total captures and recaptures at each event; (Brower *et al* 1998). Lincoln-Peterson and Schnabel small mammal population estimates ranged from 3 to 29 individuals per cycle and 8 to 45 individuals per cycle, respectively, over the life of the project. Additionally, Lincoln-Peterson and Schnabel small mammal population estimates averaged 14 and 24, respectively, over the life of the project.

Table 8-3, Months that Individual Heermann's Kangaroo Rats or Deer Mice were captured with a Biological Status Indicative of Breeding Season Period presents the breeding condition and status of individuals captured. Pregnant females were captured in every month except January, February, and October, and juvenile deer mice were captured in November and December.

8.2.2 Track Stations

Wildlife tracks encountered were composed of small mammal (84 percent), bird (10 percent), invertebrate (5 percent), and reptile (1 percent) species. Tracks were measured in every sampling event except when it was too wet from rain or fog to use the talc power for tracking (Figure 8-2, Total Tracks for All Sampling Areas).

8.2.3 Burrow Activity

Active and total burrows (both active and inactive) were identified within the sampling areas (as described in Section 8.1.2). Within SA, active burrows ranged from 0 to 19 burrows per cycle over the life of the project. Within RA and RB, active burrow counts ranged from 1 to 35 and from 0 to 20 per cycle respectively (Figure 8-3, Active Burrows for all Sampling Areas). Burrows are generally created by small mammal species such as Heermann's kangaroo rat; however, indicators of burrow activity, such as scat, fresh digging, and/or tracks are not specific to species and could be a result of several species using existing burrows including small mammals, lizards, and/or snakes.

8.2.4 Seasonal Variation

Seasonal variability in the small mammal indices measured was evaluated. Physical and biological factors may vary as a result of changes in season, including temperature, hours of sunlight, foraging habits, and breeding periods. Total small mammal captures fluctuated greatly over the life of the project where values ranged from 12 to 44 captures per study site per cycle. All sampling areas showed fluctuations over time. In addition, population estimates ranged from 8 to 45 individuals per site per cycle, with site averages over the life of the project ranging from 22 to 26 individuals. As expected, population estimates fluctuated over time similar to total captures.

Tracking activity was also variable over time, but tended to show an upward trend over the 2 year period of the PIA. The number of active burrows counted in each cycle also varied. Active burrows counted ranged from 2 to 35 burrows. Although the number of active burrows fluctuated at each sampling site, there does not appear to be a distinct seasonal variation in the number of active burrows observed. Since there were no clearly observable seasonal components as seen with the vegetation indices, statistical evaluations were performed to assess whether seasonal impacts on small mammals indices occurred. The results of the statistical analyses are discussed in Section 8.3.

8.3 Evaluation of Impact to Wildlife Due to Steam Plant Pilot Test

To evaluate the potential for secondary impacts from the Pilot Test on small mammals, changes in small mammals captures, track activity and burrow activity over time were evaluated statistically as described in the following sections. The following sections include a discussion of the results and variability within and between project locations (Step 1); consideration of the appropriateness of evaluating the Reference Areas as a single data pool (Step 2); and a quantitative statistical analysis of SA with respect to captures, burrowing activity, and tracks.

8.3.1 Small Mammal Captures

Step 1: Qualitative Evaluation of Intra and Inter-plot Variability:

To simplify the impact analysis, pooling the data from transects within each area is preferred. To confirm that it is appropriate to pool the data within each location (SA, RA and RB), transects were evaluated qualitatively. A similar approach was used to confirm that RA and RB adequately encompass the range of natural variability associated with the habitat in the Pilot Test area and thus function as reasonable reference/control areas for SA. Quantitative, statistical analyses were not deemed necessary for this evaluation as the purpose was to confirm that the multiple transects and the two Reference Areas encompass the natural variability in the small mammal community in the area of the Pilot Test.

Within each sampling area, three transects were sampled for burrow activity and tracks, as well as for trapped small mammals. Three track stations and six traps were placed in each transect. Burrows were counted within the entire transect. Within each transect, wildlife information collected was generally, very biologically similar. Transects were close to each other and occurred within the same plant community. In addition, topography, geology, and surface conditions were very similar.

Intra-plot Variability:

All three transects within plots are in the same plant community and within the same biological and physical environment. No artificial or natural barriers occur between transects within plots and there is no substantial change in vegetation cover, type, or abundance. Both trapping and tracking data were relatively consistent between transects of each of the sampling areas. Counts of active burrows were more variable. However, as with the other sampling methods, there does not appear to be physical or biological differences between transects within each sampling area.

Inter-plot Variability:

The sampling areas (SA, RA, and RB) associated with the project are very similar in biological and physical characteristics. Area SA is separated from area RA by the Project site, as well as a man-made berm and a road; however, there is an undeveloped corridor between the two sites. Area RB is located approximately one-quarter mile to the west, and separated by at least one road and other man-made barriers. Area SA is immediately adjacent to the project site.

Figure 8-1, Total Small Mammal Captures by Sampling Area, present small mammal trap data by sampling area. Total trapped small mammals for the individual sampling areas ranged from 12 to 44 captures per cycle. Area SA showed the largest variation between cycles; however, all three areas were very similar in trend and amplitude. Although the number of captures remained relatively consistent over the life of the project, all three sampling areas showed a dip in total captures at cycle 12 and a subsequent relative peak at cycle 16. The total number of captures in each area has steadily declined since cycle 16.

Figure 8-2, Total Tracks for All Sampling Areas, presents the total number of tracks over time by sampling area. Track activity varied greatly from cycle to cycle and ranged from 10 tracks counted per cycle to more than 50 tracks per cycle. All of the sampling areas showed some variation, and the number of tracks increased modestly over the life of the project.

Burrow activity by sampling area is presented in Figure 8-3, Active Burrows by Sampling Area. Active burrows within the SA ranged from 0 to 19 burrows per cycle. The large single cycle variation was from 0 to 9 active burrows between cycles 17 and 18 in SA. The variation in burrow counts was generally modest over the life of the project at this location. There is a greater variation in active burrow counts within RA and RB than SA. The largest variation was observed at RA (which also generally supported the most overall active burrows per cycle). All three sites showed distinct peaks during cycles 14 to 15, and cycle 21. Although the amplitude of these peaks varied, the rates of increase and decrease associated with the peak appear to be very similar.

The biological and physical characteristics of the sampling areas within the project area were very similar and close to each other in location. All areas were located within coastal dune scrub with very similar topography, plant composition, density, and cover. Wildlife activity in the vicinity of the sampling areas is expected to be similar in composition, abundance, and habit.

Step 2: Quantitative Analysis of Reference Locations:

To simplify the Impact Analysis, the assumption that the two reference locations (RA and RB) are similar and can be grouped together so that SA is just compared to one reference dataset was tested. To test this assumption, the mean number of small mammal captures in RA and RB were compared over the two-year time period. A factorial analysis of variance ANOVA was conducted that evaluated mean abundance by evaluating the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms. There was no statistically significant difference in the mean number of captures between RA and RB ($P>0.05$). However, when data were grouped by the quarter of the year that they were collected, there was a statistically significant difference in captures ($P=0.01$). Based on this evaluation, it was concluded that the number of small mammal captures did not vary among the reference locations, but it did it vary seasonally over the year. Thus, it is reasonable to group RA and RB together to compare to SA when evaluating the impact of the Pilot Test on SA. However, due to the significant seasonality component, the time of year that data are collected must be factored into the impact analysis.

Step 3: Quantitative Evaluation of SA Over Time:

To address the seasonality issue, the difference (ΔSA-$\bar{x}$ Ref) between SA and the mean of RA and RB was calculated for each data point. By evaluating ΔSA-$\bar{x}$ Ref, seasonal impacts were minimized and an evaluation of the impact due to the Pilot Test was conducted. An ANOVA was then conducted on ΔSA-$\bar{x}$ Ref across all three periods. There was no statistically significant difference among the three periods ($P>0.05$). Thus, there is no impact of the Pilot Test on the number of small mammals captured.

8.3.2 Track Stations

Step 1: Qualitative Evaluation of Intra and Inter-plot Variability:

As described in Section 8.3.1, it was concluded that RA and RB are reasonable, non-impacted reference locations for the evaluation of impacts to small mammals for SA.

Step 2: Quantitative Analysis of Reference Locations:

The potential impact of the Pilot Test on track activity was evaluated in a similar fashion to number of small mammal captures. To test the assumption that the mean track activity between RA and RB are similar so the two reference locations can be pooled, a factorial ANOVA was conducted that evaluated mean track activity by evaluating the potential impact of (1) the time of year, (2) the location and (3) any interaction between these two terms. There was no statistically significant difference in the mean track activity between RA and RB or seasonality ($P>0.05$). Thus, it is reasonable to group RA and RB together to compare to SA when evaluating the impact of the Pilot Test on SA.

Step 3: Quantitative Evaluation of SA Over Time:

While seasonality was not a statistically significant issue for the track activity, the statistical method of evaluating the delta of SA and the mean of the Reference Areas was still used, as it minimizes any natural variability that could hide potential impacts associated with the Pilot Test. An ANOVA was therefore conducted on the delta of SA and the two reference locations across all three periods. There was no significant difference among the three periods (P>0.05).

8.3.3 Burrow Surveys

This evaluation was presented as the case study for the statistical approach in Section 3.2.6.

Step 1: Qualitative Evaluation of Intra and Inter-plot Variability:

As described in Section 8.3.1, it was concluded that RA and RB are reasonable, non-impacted reference locations for the evaluation of impacts to small mammals for SA.

Step 2: Quantitative Analysis of Reference Locations:

Potential impacts on burrow activity were evaluated statistically. Following the method outlined above, mean burrow activity across time was compared between the reference locations to test if they could be pooled together in the subsequent analyses. There were no significant differences between the two Reference Areas or among the different seasons (P>0.05). Therefore, RA and RB were pooled in subsequent analyses.

Step 3: Quantitative Evaluation of SA Over Time:

While seasonality was not a statistically significant issue for burrow activity, the statistical method of evaluating the delta of SA and the mean of the reference areas was still used, as it minimizes any natural variability that could hide potential impacts associated with the Pilot Test. An ANOVA was conducted on the delta of SA and the two Reference Areas across all three operational phases. There was a significant difference among the three periods (P=0.0001). The delta between SA and the Reference Areas increased over the time period of the study with an increased negative difference in the Post-Operations phase (refer to Figure 3.2). That is, there were fewer active burrows in the Operations and Post-Operations phases as compared to reference as there were in the Pre-Operations phase. While there was a statistically significant difference between SA and the Reference Areas with respect to number of active burrows measured, it is unclear what the biological relevance of this is. Considering statistically significant differences between SA and the Reference Areas were not observed for other wildlife indices (tracking activity and number of captures), it is not known whether the decrease in active burrows is indicative of a negative impact on the small mammals in the SA as a result of the Pilot Test or other factors.

8.4 Conclusions

Wildlife species observed in the Pilot Test area included one reptile and one bird species and 10 species of mammals. Because of their small home range and other aspects of their natural history, small mammals were considered representative surrogates for wildlife in general. Variables measured included captures, track activity and burrow activity.

Nearly 100 percent of the small mammal captures consisted of two species, deer mouse and Heermann's kangaroo rat. Small mammals were captured during every sampling event in all three locations. Wildlife tracks encountered were composed of small mammal (84 percent), bird (10 percent), invertebrate (5 percent), and reptile (1 percent) species. Tracks were measured in every sampling event. Additionally active and total burrows (both active and inactive) were identified within all the sampling areas.

Based on a qualitative evaluation, the quadrats measured within each area were deemed to be adequately representative of the natural variability found in each plot. Additionally, because plants are a major structural element in the environment, the fact that the plant assemblages were similar among the three locations provides strong evidence that the two Reference Areas function as reasonable controls for SA for the small mammal indices.

Seasonal variation in captures, tracking activity and number of active burrows were slight. Only the number of captures was influenced by seasonality. Potential impacts of the Pilot Test on captures, tracking activity and number of active burrows were also slight. Although, there was a statistically significant difference between SA and the Reference Areas with respect to active burrows, the biological significance of this result is considered low because other related wildlife indices (track activity and the number of captures) were not similarly affected.

9.0 CONCLUSIONS

The objective of this report is to present the results of the Steam Flood Pilot Impact Analysis (PIA) conducted at the Guadalupe Restoration Project. The PIA was designed to assess a limited range of environmental impacts associated with the Pilot Test and was restricted to the construction, operation and abandonment of the Pilot Test project.

A Pilot Test Panel (PTP) was convened in accordance with Cleanup or Abatement Order (CAO) No. 98-38. The PTP's mission was to evaluate a range of existing, new, or modified technologies and then recommend up to three to be pilot tested at the GRP for the removal of separate-phase diluent. The PTP was charged with recommending technologies that will remove separate-phase diluent as effectively as excavation. Rather than try to find technologies that can meet certain numerical clean-up targets, the panel identified a range of potentially successful technologies, then estimated the degree of clean-up each technology could offer. Consistent with the CAO, steam/hot water injection was included among the methods considered by the panel. A combination of remediation technologies, steam/hot water injection followed by biosparging (referred to in this report as the "Pilot Test"), be tested as part of the pilot test process.

One of the objectives outlined in the PTP Final Report for the Pilot Test was to assess the potential adverse environmental impacts associated with the implementation of the steam/hot water injection technology. The PIA was designed to assess a limited range of environmental impacts associated with the Pilot Test and is restricted to the construction, operation and abandonment of the Pilot Test project. The impact of volatile petroleum hydrocarbon products that may affect biota was not analyzed. The goal of the PIA was to draw upon the ability to design a monitoring program that allows for the measurement of impacts under pilot-scale conditions, thus minimizing speculative impact predictions in future assessments.

The PIA focuses on assessing the impact of the Pilot Test upon the biota at the study area. The main objectives of the PIA are to:

- Determine baseline levels and variability for a broad category of indicators.
- Monitor and measure selected variables that could help determine if impacts are realized.
- Quantify the effects of the Pilot Test on the variables.
- Identify statistically significant changes in measured variables.
- Prepare a final report for submittal to the PTP.

Primary Impacts (Surface Disturbance)

The implementation of the steam technology resulted in 0.55-acres of disturbance to coastal dune scrub habitat; more than half (52 percent) of the available off-road portion of the Project. Of the total disturbance area, 0.1-acre occurred beyond the Project limits (used for access corridors and utility corridors). Most striking in assessing disturbance levels and quantities is the total loss of native perennial plant species within the disturbed area. In addition, the ongoing activities at the site prevented any efforts for active restoration before the demobilization phase. Therefore, the loss or disturbance of habitat represented an important temporal loss of habitat through the duration of all phases of operations and demobilization.

The level of disturbance to vegetated habitat was assumed to correlate to the level of impacts to other biological resources including wildlife and sensitive plant and animal species. In terms of wildlife impacts, the most populous species within the habitat (small mammals, reptiles, invertebrates) are closely dependant to the coastal dune scrub vegetation for foraging and housing. While exact numbers of individuals killed or impacted are not known, there was a loss of 0.55-acres of wildlife foraging, cover, and den sites.

Unlike an excavation where the top soil is removed, temporarily stored at a stockpile site, and returned to the site, the steam technology allowed the top soil to remain intact; however, the topsoil on the project site was subject to potential compaction and disturbance by equipment and vehicle tires. Typical excavations at GRP require the removal and replacement of the vegetated overburden (top soil), with an attempt on keeping the nutrients, seed bank, and mychorrizae intact. The steam technology does not require the removal of the top soil. The steam technology resulted in repeated disruptions of the surface soils and recovering vegetation. This type of disturbance and compaction of soil often leads to an increase in cover of non-native weedy species. This phenomenon may not yet have exhibited due to the earliness of the growing season when the post-project survey was performed.

Although the area of disturbance resulting for implementing steam technology may actually be smaller compared to what would be required for a site excavation, the duration of time required to install and implement steam technology is anticipated to require more time than an excavation. This temporal loss of habitat could actually result in habitat for sensitive species, wildlife and plants being unavailable for a longer period of time.

Secondary Impacts – Abiotic

The subsurface temperature sensors confirmed that the Pilot Study achieved the desired project parameters for heating the Treatment Zone, and was contained within the Test Area. Temporal variations by depth over time demonstrated the effects of injecting hot water, steam and cold water in Test Area. However, near-surface temperatures were more influenced by seasonal weather than operation of the Pilot Test (i.e., in the Operations phase near-surface temperatures decreased during the winter, which was when steam was being injected). The most unexpected temporal variation occurred during the Post-Operations phase, when with the end of parameter controls (i.e., the extraction wells), the residual subsurface heat began to rise to the surface, statistically elevating near-surface soil temperatures in the SA above reference conditions. The impacts of this increase in sub-surface temperatures is not known since the test was suspended/concluded before the subsurface temperatures equilibrated to ambient conditions. Since temperatures 15 feet bgs rose as high as 110 degrees Fahrenheit above ambient values, some impact would be expected. However, whether these impacts would be positive or negative is not known.

Secondary Impacts - Vegetation

The majority of plant indices measured in the PIA showed a strong seasonal component. This is consistent with field observations and expectation that cover of plant species and species richness fluctuates seasonally, with annual species (both native and non-native) completely dying out in the summer months and certain perennial species (both native and non-native) dying back or completely senescing.

Because of the strong seasonality component, the statistical comparisons to evaluate the potential impacts of the Pilot Test on vegetation in the SA required that the seasonal variability be partitioned out of the evaluation. Once seasonal variability was partitioned out, only subtle differences in plant indices were measured. For total cover, only a marginally statistically significant increase in the delta between the SA and reference was seen in the Operations phase. For species richness, a significant increase in the delta during the Post-Operations phase in the SA was found. The biological relevance of a significant increase in cover and richness is not known. Additionally, it is not clear whether they constitute a positive or negative impact. For leaf condition, there was a significant decrease in delta between SA and the reference locations in the Post-operations time period for one of the two species measured. It is unknown whether the Pilot Test is responsible for the decrease in leaf condition, as field observations identified a beetle infestation as the probable cause and these beetles have also been found elsewhere at GRP.

Secondary Impacts - Arthropods

Twelve taxonomic groupings (11 orders of the class Insecta, and the class Arachnida) of arthropods were observed at the sampling sites within established transects over the two year study period. The Reference Areas were very similar to SA. Based on a qualitative evaluation, the quadrats measured within each area were deemed to be adequately representative of the natural variability found in each plot. Additionally, because plants are a major structural element in the environment, similarities between plant assemblages among the three locations provide strong evidence that the two Reference Areas function as reasonable controls for SA for the arthropod indices.

Seasonal variation in abundance, frequency and arthropod diversity was slight. Only the frequency of encountering at least one individual in a quadrat was found to be statistically affected by seasonality. Any potential impacts of the Pilot Test on abundance, frequency and diversity of the arthropod community were also minimal. No statistically significant effects on the arthropod variables measured as a result of the Pilot test were identified.

Secondary Impacts - Wildlife

Wildlife species observed in the Pilot Test area included one reptile and one bird species and 10 species of mammals. Because of their small home range and other aspects of their natural history, small mammals were considered representative surrogates for wildlife in general. Variables measured included captures, track activity and burrow activity.

Nearly 100 percent of the small mammals captures consisted of two species, deer mouse and Heermann's kangaroo rat. Small mammals were captured during every sampling event in all three locations. Wildlife tracks encountered were composed of small mammal (84 percent), bird (10 percent), invertebrate (5 percent), and reptile (1 percent) species. Tracks were measured in every sampling event. Additionally active and total burrows (both active and inactive) were identified within all the sampling areas.

Based on a qualitative evaluation, the quadrats measured within each area were deemed to be adequately representative of the natural variability found in each plot. Additionally, because plants are a major structural element in the environment, the fact that the plant assemblages were similar among the three locations provides strong evidence that the two Reference Areas function as reasonable controls for SA for the small mammal indices.

Seasonal variation in captures, tracking activity and number of active burrows were slight. Only the number of captures was influenced by seasonality. Potential impacts of the Pilot Test on captures, tracking activity and number of active burrows were also slight. Although, there was a statistically significant difference between SA and the Reference Areas with respect to active burrows, the biological significance of this result is considered low because other related wildlife indices (track activity and the number of captures) were not similarly affected.

Summary

The Pilot Test resulted in substantial primary (i.e., physical) impacts to the habitat within the construction boundaries that will require extensive restoration efforts, consistent with those employed to restore areas disturbed by excavations.

The level of disturbance to vegetated habitat was assumed to correlate to the level of impacts to other biological resources including wildlife and sensitive plant and animal species. In terms of wildlife impacts, there was a loss of 0.55-acres of wildlife foraging, cover, and den sites.

The area of disturbance for implementing steam technology may be smaller compared to what would be required for a site excavation but the duration of time required to install and implement steam technology is anticipated to require more time than an excavation. This temporal loss of habitat could actually result in habitat for sensitive species, wildlife and plants being unavailable for a longer period of time.

Secondary impacts to abiotic and biotic parameters from the Pilot Test appeared to be minimal, with the exception to the impacts from sub-surface heat migration. Significant temperature increases within the rooting zone of coastal dune scrub species like Lupine and in proximity to small mammal burrows are likely to have pronounced impacts upon the habitat and wildlife residents.

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