United States Department of the Interior

NATIONAL PARK SERVICE
Grand Canyon National Park
P.O. Box 129
Grand Canyon, Arizona 86023-0129

F54 (GRCA 8213)

Ms. Evelyn Erlandsen
Arizona Water Protection Fund
3550 N. Central Avenue
Phoenix, AZ 85012

Dear Ms. Erlandsen:

Enclosed please find the revised and final October 31, 2008 deliverable for the project entitled "Management & Control of Tamarisk and Other Invasive Vegetation at Backcountry Seeps, Springs and Tributaries in Grand Canyon National Park (Second Year of Phase II of Comprehensive Project)", Arizona Water Protection Fund (AWPF) Grant Number 06-138WPF. The deliverable falls under Task # 5 in the contract and is the final report for all of the work completed during this contract period.

The funding that the Arizona Water Protection Fund has provided has allowed the park's Backcountry Vegetation Program staff to accomplish critical preservation and restoration work in the park's backcountry areas. With issues like invasive species, it is essential to disregard boundaries, and this project has provided the opportunity to work directly with the Hualapai Tribe and look at the greater Grand Canyon area as a whole, rather than segmented parts. I appreciate the support that you have provided as the project manager.

Please consider this the final version of the report, one professionally bound, and one copy of just the report body itself to merge with the appendices you already have. I mailed two copies of the poster-size map separately. If you have any questions about the revised and final report, please contact me at (928)226-0165.

Sincerely,

Lori J. Makarick
Vegetation Program Manager

Enclosures (2)

Grand Canyon National Park and Grand Canyon National Park Foundation

Final 2008 Management and Monitoring Report
Management & Control of Tamarisk and Other Invasive Vegetation
at Backcountry Seeps, Springs and Tributaries
in Grand Canyon National Park
(Phase II-B, First Year of Phase II of Comprehensive Project)

Arizona Water Protection Fund Contract Number 06-138WPF

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Revised and Re-Submitted December 9, 2008

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APPENDICES

Appendix A. Representative Project Photographs
Appendix B. Representative Project Photodocumentation
Appendix C. Habitat Assessment Forms
Appendix D. Hydrology Data
Appendix E. Monitoring Transect Data
Appendix F. Data Collection Forms
Appendix G. Project Press
Appendix H. Public Education Materials
Appendix I. Plant Lists from Project Areas
Appendix J. Plant Collections
Appendix K. Rare Plant Monitoring Data
Appendix L. Final Project Maps (also included as large-format poster)

I. Abstract

Grand Canyon National Park's backcountry seeps, springs and tributaries of the Colorado River are among the most pristine watersheds and desert riparian habitats remaining in the coterminous United States. These riparian systems deserve a high level of protection from invasive exotic plants. It is well documented that the encroachment of invasive plant species into natural areas is a serious ecological problem worldwide, second only to habitat fragmentation. The spread of invasive plants is one of the greatest threats to biodiversity and the preservation of intact, native ecosystems. Preventing their spread is considered one of the most important issues facing natural resource managers across the nation. The Arizona Statewide Invasive Species Advisory Council developed a Statewide Invasive Species Management Plan and without argument, the board agreed that tamarisk (*Tamarix ramosissima*) poses one of the greatest threats to Arizona's diverse landscapes. There is no doubt that these riparian systems deserve a high level of protection from invasive exotic plants. Grand Canyon National Park Foundation (GCNPF) received a grant from the Arizona Water Protection Fund (AWPF) to control invasive plants in selected riparian areas within Grand Canyon National Park (GRCA), allowing native plant communities to recover and persist. The grant supports a partnership between GCNPF, the National Park Service (NPS), and the Hualapai Tribe and funds this project through December 31, 2008, with work occurring in 30 areas within GRCA and surrounding lands. This report contains the details from the invasive plant control and monitoring efforts completed for the duration of the project.

This work is Phase II-B of a large-scale backcountry invasive plant management project. The primary objectives of this phase of the overall project are to remove tamarisk and other invasive exotic plants from 30 tributaries of the Colorado River in Grand Canyon National Park and on Hualapai tribal lands, and to monitor the success of the tamarisk removal through pre- and post-removal monitoring. This project will significantly reduce invasive plant distribution within the treated areas and allow native vegetation to reestablish without exotic plant competition. This work is a follow up of the very successful AWPF funded Phase I, in which crews removed 70,616 tamarisk trees from 70 project areas, and Phase II-A, in which crews removed 130,504 tamarisk trees from 35 project areas. The lessons learned during the implementation of those two phases have allowed the project manager to improve upon the management and monitoring portions of the project.

At the close of this project, crews removed 48,573 tamarisk trees including 38,555 seedlings, 6,877 saplings, and 3,141 mature trees from 108 hectares (267 acres) in Phase II-B project sites. The total tamarisk canopy removed from within the 30 project areas was 13,694 m^2, allowing native vegetation access to critical resources such as nutrients, sunlight and water. In addition, crews also removed 187,152 individual plants of other invasive exotic species from project areas and the Colorado River corridor. This report includes all of the data from the backcountry trips completed from spring 2006 through spring of 2008. The AWPF Commission has funded all or a portion of this report. The findings presented are the Grantee's and do not necessarily represent those of the Commission, the State, or the Arizona Department of Water Resources.

Please Note: The data and photographs for this report have all been entered into the project database, which is included on the enclosed DVD. To open the database, click on the grca.mdb file. Upon review and acceptance from AWPF, this report will be available on Grand Canyon National Park's website (http://www.nps.gov/grca/naturescience) in the .pdf format.

II. Introduction

a. Overview of project status

The Grand Canyon ecoregion's backcountry seeps, springs and tributaries of the Colorado River are among the most pristine watersheds and desert riparian habitats remaining in the coterminous United States. These riparian systems deserve a high level of protection, particularly from the invasion of exotic plant species. Grand Canyon National Park Foundation (GCNPF) received a grant from the Arizona Water Protection Fund (AWPF) to control invasive plants at 30 selected riparian areas within Grand Canyon National Park (GRCA) and on adjacent Hualapai lands, allowing native plant communities to recover and persist. The grant funds this project through December 31, 2008 and supports a partnership between GCNPF, the National Park Service (NPS) and the Hualapai Tribe. This report contains the details from the invasive plant control efforts completed to date.

This work is Phase II-B of a landscape-level backcountry invasive plant management project. The primary objectives of this phase of the overall project are to remove invasive vegetation (hereafter referred to as tamarisk, which is the dominant exotic species in these areas) from 30 tributaries of the Colorado River in GRCA and on adjacent Hualapai lands and to monitor the success of the management actions through pre- and post-removal monitoring. This project will significantly reduce invasive plant distribution within the treated areas, allowing native vegetation to reestablish without exotic plant competition. This work is a follow up of the very successful Phase I and II-A, also funded by the AWPF, in which crews removed 200,530 tamarisk trees from 105 project areas. The data from Phase I showed that only 7% of the initially treated trees required follow-up control and that nearly all project areas displayed nearly 100% reduction of tamarisk cover and frequency. The lessons learned during the implementation of Phase I and II-A have allowed project managers to improve upon the management and monitoring protocols for this project.

In February 2002, prior to the initiation of Phase I, the NPS released an Environmental Assessment / Assessment of Effect for this overall project. Staff received and analyzed public comments and prepared a Finding of No Significant Impact Statement (FONSI), signed by the regional office on June 18, 2002. These documents continue to guide the implementation of this project. The park received a written response to the informal consultation with the U.S. Fish and Wildlife Service (USFWS) on January 25, 2001. That letter, along with the incorporation of their recommended changes, completed the Section 7 consultation required for this project. On April 8, 2002, the State Historic Preservation Officer (SHPO) provided the park with written concurrence on the project moving forward.

With the initiation of each new phase of the project, project managers and coordinators re-examined the compliance documents to ensure all consultation, permits and determinations remain valid. Prior to the initiation of Phase II-B, Reuben Terán, AWPF Project Manager, and GRCA superintendent Joe Alston re-consulted with the SHPO. The SHPO again stated a determination of "no impact" for the grant work.

The GRCA superintendent also sent a letter to the USFWS as a follow-up on the preliminary consultation from 2001. On February 28, 2005, GRCA staff received a letter from the USFWS stating that Phase II tamarisk management actions "are not likely to adversely affect the Southwestern willow flycatcher" since they will occur in areas that are not proposed critical habitat. This letter updated the USFWS consultation and approval. During the May 2006 monitoring trip, field crews documented changed conditions in two of the tributaries (Spring and Three Springs Canyons) included under this grant. The park's Wildlife Biologist and Vegetation Program Manager documented the current conditions with Habitat Assessment forms, Tamarisk Mapping forms, and photographs. The changes were caused by flash floods, which removed the dense vegetation that at one time might have contained potential habitat to support Southwestern willow flycatchers. In May 2006, both of these areas contained ideal conditions for the removal of invasive vegetation. To this end, GRCA Superintendent Joe Alston sent a letter to USFWS on December 12, 2006 requesting an amendment to the Biological Assessment (BA) to include tamarisk removal in Spring and Three Springs Canyons. The Project Coordinator provided the Project Manager with the USFWS's response as part of the Task #1 deliverables for this project. The additional Habitat Assessment forms that were completed during the spring 2007 trips are included in Appendix C (Habitat Assessment Forms).

Prior to the initiation of Phase II-B, the Hualapai Tribe completed a document entitled "Environmental Assessment for Proposed Tamarisk Eradication and Riparian Restoration on the Hualapai Reservation." The document was signed on January 5, 2006 with a Finding of No Significant Impact. By April 2006, the Project Coordinator had acquired a signed partnership agreement with the Hualapai Tribe, as well as the required park and tribal permits for Phase II-B, completing the final requirements of Task #1 in the grant contract. In addition, following the May 2006 monitoring river trip, the Project Coordinator revised the Tamarisk Monitoring and Management Plans and re-submitted them to AWPF in order to finalize the deliverables listed in Task #2 of the grant contract. The Tamarisk Management Plan called for seven backpacking trips (five 7-day backpacking trips to tributaries and side canyons, and two 6-day backpacking trips to main corridor trails, which include areas accessed from the North Bass and Tonto Trails), two tamarisk removal river trips, and two monitoring river trips.

Under this contract (#06-138WPF), crews removed tamarisk from 30 areas within Grand Canyon National Park and on surrounding Hualapai Tribal lands. The numbers of tamarisk trees found during the preliminary surveys (i.e. feasibility of control at this time) and the extent of the seeps, springs, and riparian habitat found within the project areas were factors in project area selection.

b. Justification for recent work

Tamarisk (*Tamarix* spp.), commonly known as salt cedar, is an invasive exotic tree that grows in dense stands along rivers and streams in the western United States. Tamarisk, introduced to the U.S. in the 19th century as an erosion control agent, spread throughout the West and caused major changes to natural environments. Tamarisk (*Tamarix ramosissima*) reached the greater Grand Canyon area during the late 1920s and early 1930s, and became a dominant riparian zone species along the Colorado River following completion of Glen Canyon Dam in 1963. The impacts caused by tamarisk are well documented (refer to Reference Section of the EA/AEF and Stevens 2001). These prolific non-native trees displace native vegetation, create conditions that are inhospitable for the germination of native plant seeds, impact wildlife abundance, and increase fire frequency. Tamarisk is an aggressive competitor, often developing monoculture stands and lowering water tables, which can negatively affect wildlife and native vegetative communities (Duncan 1996). Adapted to a wide range of environmental conditions, tamarisk fills previously unoccupied niches. Once established in an area, it typically spreads and persists.

In the Southwest, riparian areas account for less than 2% of the land, yet over 65% of southwestern wildlife depend on these areas. Riparian habitats are the most productive, most biologically diverse, most valuable and most threatened habitats in the American Southwest (Johnson et al. 1985). Tributaries and side canyons of the Colorado River, and seeps and springs in the Grand Canyon ecoregion, are worthy of the highest level of protection from non-native plant invasion. The recent encroachment of tamarisk into these tributaries poses a significant threat to the integrity of the natural ecosystems. The removal of tamarisk from these tributaries protects valuable resources, increases native plant diversity, and provides an excellent opportunity for stewardship through an extensive volunteer program.

GRCA, GCNPF, and the Hualapai Tribe are committed to the preservation of native plant communities and native ecosystems. NPS management policies require park managers "to maintain all the components and processes of naturally evolving park ecosystems, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems" (NPS 2006). Park managers are directed to give high priority to the control and management of exotic species that can be easily managed and have substantial impacts on park resources (NPS 1985, NPS 2006). GCNPF's mission is to project and preserve Grand Canyon's irreplaceable natural, cultural and historic resources while enhancing the visitor experience. In addition, the Hualapai Tribe considers the removal of tamarisk to be a beneficial activity in terms of water quality and quantity improvements and the restoration of wildlife habitat. In April 2005 Governor Janet Napolitano issued an Executive Order to create a statewide Invasive Species Advisory Council and develop a statewide invasive species management plan. By doing this, the Arizona legislature acknowledged the importance of the invasive species issue and the need to address it at a statewide level, disregarding agency boundaries. Through the management of invasive plant species, this multi-year project implements a partnership among the State of Arizona, the NPS, the Hualapai tribe, and the GCNPF, while securing thousands of hours of volunteer labor from citizen stewards.

c. Management objectives

The overarching objective of this project is to continue the successful, large-scale tamarisk management work that biologists initiated in 2000 with support from the Arizona Water Protection Fund (AWPF). During this current project (Contract #06-138WPF), crews will remove tamarisk and other invasive exotic plant species from 30 backcountry seeps, springs and tributaries in the Grand Canyon area.

The goals of this project are to:

1. Decrease the colonization and spread of tamarisk and other invasive vegetation in the tributaries and side canyons of Grand Canyon National Park and adjacent Hualapai Tribal lands;
2. Allow the recovery of native plant communities;

3. Restore proper stream and riparian conditions by removing invasive plant components;
4. Restore and protect native wildlife habitat, including potential habitat for endangered species, such as the Southwestern willow flycatcher;
5. Utilize an extensive monitoring process to assess the success of management and control efforts; and,
6. Promote citizen stewardship by providing volunteer opportunities.

The specific objectives of this project are to:

1. Remove/control at least 30,000 tamarisk trees, at 30 separate project sites, on approximately 400 acres (162 hectares) within Grand Canyon National Park and on Hualapai Tribal lands;
2. Control all known, or newly-discovered, populations of date palm (*Phoenix dactylifera*), Ravenna grass (*Saccharum ravennae*), Russian olive (*Elaeagnus angustifolia*), Russian thistle (*Salsola tragus*), Sahara mustard (*Brassica tournefortii*), sowthistles (*Sonchus* spp.) and tree of heaven (*Ailanthus altissima*) within the 30 target project areas and also within the main Colorado River corridor in order to minimize invasion into the side canyons;
3. Install a long-term, integrated, inter-disciplinary monitoring system that includes vegetation transects, wildlife observations, hydrological samples, archeological inventories, photopoints, and GPS data collection;
4. Ensure effective training and utilization of volunteers (estimate of at least 10,000 volunteer hours); and,
5. Prepare public information/education material on this important environmental issue.

d. Monitoring objectives

Another project objective is to monitor the success of the tamarisk removal through pre- and post-project vegetation monitoring, which will help determine the level of success of the effort. The overall monitoring design will help answer the following questions in the long-term:

- How successful is removing tamarisk from seeps, springs and tributaries in reducing the colonization of tamarisk in these areas?
- How much and to what extent do native plant communities recover and benefit from this removal?
- Will wildlife and hydrological resources benefit from the removal of tamarisk?

An acceptable goal will be to decrease tamarisk cover to 5% or less of the pre-management tamarisk cover values in the project areas. Tamarisk trees sequester a large amount of water through their extensive root system, and project managers expect to observe long-term beneficial changes in the hydrology and soil chemistry, the monitoring of which is a secondary objective. With often extreme annual variation in hydrological measurements, it will be difficult to detect long-term change within the time frame of this project; therefore, the hydrological data included in the final project report will be preliminary and will be used as part of a long-term monitoring program. Interdisciplinary teams record wildlife observations throughout the project and collect wildlife inventory data in project areas.

III. Management Methods

a. General Vegetation Community Description

Under this contract (#06-138WPF), crews will remove tamarisk from 30 areas (plus two additional areas) within Grand Canyon National Park and on adjacent Hualapai Tribal lands. The numbers of tamarisk trees found during the preliminary surveys (i.e. feasibility of control at this time) and the extent of the seeps, springs, and riparian habitat found within the project areas were factors in project area selection.

All of the project areas in Phase II-B occur below Phantom Ranch, and the majority of them are located in the western reaches of the Grand Canyon, typified by Mohave Desert influences. High species diversity, high species density, and high productivity generally characterize riparian areas. Continuous interactions occur among riparian, aquatic, and upland terrestrial ecosystems through exchanges of energy, nutrients, and species. Warren et al. (1982) provided the following description of Grand Canyon riparian areas:

> "Riparian woodlands (or forests) characterized by cottonwood-willow associations are primarily restricted to the larger perennial streams and drainages of the Colorado Plateau region of northern Arizona. The great biological importance and floristic diversity of these cottonwood-willow riparian forests is disproportionate to their limited total area…. Riparian scrub usually occurs along ephemeral or intermittent watercourses (such as desert arroyos), or in narrow canyons which are periodically scoured by floods. Riparian scrub communities are characterized by a broad continuum of vegetative associations that range from mesic vegetation types to xeric growth along desert arroyos (Brown et al., 1980). These arroyos often contain water only one day or less each year and the resulting vegetation is commonly composed of a mixture of facultative riparian species and upland species. This is in contrast to mesic species, which are generally absent from the surrounding uplands…. Side canyons throughout the park with perennial water support riparian vegetation characterized by cottonwood (*Populus fremontii*) and willow (*Salix* spp.) which is generally very similar to that found in similar situations throughout northern Arizona (Phillips and Phillips, 1979)…."

Each stream, spring, seep, or dry wash has a different association of species, depending on environmental features including elevation, permanence of water, substrate, frequency of flooding, and colonization (Warren et al., 1982). Riparian vegetation typically occurs in small, discrete stands or patches. The floristic diversity in wetland and riparian composition is highly variable, but is extremely high when compared to the upland vegetation. Typical stands may consist of broad-leaved deciduous trees in the overstory, with a mixture of shrubs and grasses in the understory. Species typical of drainages with perennial water sources are:

- Fremont cottonwood (*Populus fremontii*)
- Long-leaf brickellbush (*Brickellia longifolia*)
- Catclaw acacia (*Acacia greggii*)
- Willow (*Salix exigua*, *S. goodingii*)
- Monkey flower (*Mimulus cardinalis*)
- Mesquite (*Prosopis glandulosa*)
- Seep willows (*Baccharis emoryii*, *B. salicifolia*)

Species typical of drainages with dry washes or intermittent water are:

- Catclaw acacia (*Acacia greggii*)
- Baccharis (*Baccharis sergiloides, B. sarathroides*)
- Snakeweed (*Gutierrezia sarothrae*)
- Apache plume (*Fallugia paradoxa*)
- Utah agave (*Agave utahensis*)
- Mormon tea (*Ephedra* spp.)
- Four-wing saltbush (*Atriplex canescens*)
- Fremont cottonwood (*Populus fremontii*)
- Skunkbush (*Rhus trilobata*)
- Red-bud (*Cercis occidentalis*)
- Alkali goldenbush (*Isocoma acradenia*)

Upland species, described below, are also present in these dry or intermittent washes. Trees and shrubs tend to be scattered, but may also form dense thickets. Species composition varies depending on moisture availability, elevation, and geographic location in the canyon. Within the park and on adjacent lands, tamarisk occurs in the many of the side canyon and tributaries; however, the distribution and density is highly variable.

Desert scrub communities, which are composed of plant species from three of the four North American desert floras, surround the tributaries. The Sonoran desert scrub has the highest plant species diversity. A two-season rainfall regime and lack of freezing temperatures characterizes the Sonoran desert. The Mojave desert scrub has higher local species diversity with shrubs as the dominant component. Winter rains and the absence of freezing temperatures characterize this desert. The Great Basin desert receives more winter rain than the Mojave and frequently has severe winter freezes and the lowest diversity of the three (Warren et al., 1982).

The three deserts within GRCA overlap significantly in distribution, with many species shared among them; however, certain species are characteristic of each community. Big sagebrush (*Artemisia tridentata*), rabbitbrush (*Ericameria* spp.), Mormon tea (*Ephedra* spp.) and a variety of perennial grasses dominate the Great Basin desert scrub. These associations are typically found in the eastern portion of the canyon and comprise the vegetation surrounding some of the upper and middle tributaries. Typical Mojave desert species include creosote bush (*Larrea tridentata* var. *tridentata*), white bursage (*Ambrosia dumosa*), Mormon tea (*Ephedra* spp.), blackbrush (*Coleogyne ramosissima*), turpentine broom (*Thamnosma montana*), and other species. They most often occur in the central and western portion of the canyon. The Sonoran desert species include brittlebush (*Encelia farinosa*), catclaw acacia (*Acacia greggii*), ocotillo (*Fouquieria splendens*) and desert willow (*Chilopsis linearis*). Sonoran associations occur in the lower portion of the canyons, and many of these species can grow directly in infrequently scoured drainages. The project areas for this grant occur from Colorado River Mile 90 (Horn Creek) to Colorado River Mile 224, covering portions of each of the major desert ecosystems.

b. Project Area Specifics and Descriptions

Each project area is highlighted in individual sections which include: the vegetation community name and characteristic species (Warren et al., 1982), the soil and geological information (USDA et al., 2003); and a general description of the physical characteristics of the tributary, including information on tamarisk distribution, various obstacles, and project area boundaries, which came from project mapping data and from field crew leaders' notes. Project areas were divided into 500 m sections and named in consecutive order, generally starting at the river with one, and moving upstream or up canyon from that point.

Project areas outside of the GRCA boundary, on Hualapai tribal land, do not have current vegetation, soil or geologic spatial data available at this time. These areas include Honga and 221 Mile Springs, and National, Mohawk, Prospect, 190 Mile, Granite Park, Three Springs, 217 Mile, Granite Spring, 221.5 Mile, 222 Mile, and 224 Mile Canyons. Vegetation, soil and geologic information for these areas was generated by comparing similar topographic features from canyons in close proximity and applying that information (i.e. vegetation, soils and geology) to the project locations.

Horn Creek

Vegetation community name: **153.11014**—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana - Guterrezia sarothrae - Lycium andersonii*)

The elevational range is 730 to 1,860 m (2,400 to 6,100 ft). This type is found on moderate to steep slopes of all aspects occasionally occurring on higher elevations of southerly aspects. Soils are thin and coarse with gravel and cobbles on limestones, sandstones and shales. This community type is microphyll desert scrub with cacti and annual grasses and herbs scattered throughout. Shrubs are 0.3 to 0.6 m (1 to 2 ft) tall. The type is found in Marble Canyon and in the eastern Grand Canyon from Nankoweap Creek to Red Canyon.

Characteristic Species:

Gutierrezia sarothrae	snakeweed
Ephedra viridis/torreyana	Mormon Tea
Lycium andersonii	wolf-berry
Acacia greggii	catclaw acacia
Eriogonum inflatum	desert trumpet
Bromus rubens	red brome

Secondary vegetation community: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*)

The elevational range is 730 to 1,520 m (2,400 to 5,000 ft). This community type is found on steep unstable talus slopes of all aspects. Soils are coarse with many cobbles and boulders, derived from

Redwall Limestone or geological formation of lower elevation. The type is found in the inner canyon from Marble Canyon to Shivwits Plateau.

Characteristic Species:

Gutierrezia sarothrae	snakeweed
Ephedra viridis	Mormon Tea
Agave utahensis	Utah Agave
Acacia greggii	catclaw acacia
Encelia frutescens	rayless encelia
Sphaeralcea ambigua	desert mallow

Tertiary vegetation community: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima* - *Ephedra nevadensis/viridis* - *Yucca baccata*)

The elevation range is 850 to 1,580 m (2,800 to 5,200 ft). This community type occurs on the level to rolling terrain of the Tonto Platform and Sanup Plateau (slopes up to 40 %). Soil is moderately deep sandy loam derived from Tapeats Sandstone and Bright Angel Shale. This type is found throughout the inner canyon from Marble Canyon to the Grand Wash Cliffs.

Characteristic Species:

Coleogyne ramosissima	blackbrush
Ephedra nevadensis/viridis	Mormon tea
Yucca baccata	banana yucca
Gutierrezia sarothrae	snakeweed
Agave utahensis	Utah agave
Encelia frutescens	rayless encelia
Acacia greggii	catclaw acacia

Soil and geology information: 110—Rock outcrop-Lithic Torriorthents complex, Vishnu Schist Formation, 15 to 60% slopes

Landform: plateau
Elevation: 488 to 610 m (1,600 to 2,000 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 14 to 17 °C (57 to 63 °F)
Mean annual soil temperature: 16 to 19 °C (59 to 65 °F)
Frost-free period: 200 to 240 days
Rock outcrop: 60%
Lithic Torriorthents and similar soils: 40%
Rock outcrop: Very steep to vertical canyon side walls composed of the Vishnu Schist and Zoroaster granite
Lithic Torriorthents soils
Geomorphic position: pockets and concavities in canyon side walls
Parent material: colluvium derived from mica schist and/or aeolian sands
Slope: 15 to 60%
Surface fragments: N/A
Depth to restrictive feature: 20.3 to 50.8 cm (8 to 20 in) to bedrock (lithic)

Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Secondary soil and geology information: 136—Typic Haplocalcids, 15 to 55% slopes

Landform: plateau
Elevation: 1,372 to 1,524 m (4,500 to 5,000 ft)
Mean annual precipitation: 6 to 10 in (15.2 to 25.4 cm)
Mean annual air temperature: 13 to 14 °C (55 to 57 °F)
Mean annual soil temperature: 15 to 16 °C (57 to 59 °F)
Frost-free period: 180 to 195 days
Typic Haplocalcids and similar soils: 100%
Typic Haplocalcids soils
Taxonomic classification: Typic Haplocalcids
Geomorphic position: summits and side slopes of fan terraces on canyon escarpments
Parent material: colluvium derived from limestone
Slope: 15 to 55%
Surface fragments: N/A
Depth to restrictive feature: N/A
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Tertiary soil and geology information: 16—Calcic Petrocalcids-Rock outcrop complex, 15 to 55% slopes

Landform: plateau
Elevation: 1,067 to 1,372 m (3,500 to 4,500 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 14 to 17 °C (57 to 63 °F)
Mean annual soil temperature: 16 to 19 °C (59 to 65 °F)
Frost-free period: 200 to 240 days
Rock outcrop: 20%
Calcic Petrocalcids and similar soils: 80%
Calcic Petrocalcids soils
Geomorphic position: summits of fan terraces and colluvial toeslopes on canyon side walls
Parent material: alluvium derived from limestone, sandstone, and shale and/or colluvium derived from limestone, sandstone, and shale
Slope: 15 to 55%
Surface fragments: N/A
Depth to restrictive feature: 25.4 cm to 50.8 cm (10 to 20 in) to petrocalcic
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (1.8 m (6 ft))

Quaternary soil and geology information: 63—Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes

Landform: plateau
Elevation: 1,067 to 1,372 m (3,500 to 4,500 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 14 to 17 °C (57 to 63 °F)
Mean annual soil temperature: 16 to 19 °C (59 to 65 °F)
Frost-free period: 200 to 240 days
Lithic Haplocambids and similar soils: 60%
Lithic Haplargids and similar soils: 40%
Lithic Haplocambids soils
Taxonomic classification: Lithic Haplocambids
Geomorphic position: pediments
Parent material: residuum weathered from calcareous shale
Slope: 2 to 15%
Surface fragments: N/A
Depth to restrictive feature: 30.4 to 50.8 cm (12 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: The Horn Creek project area includes roughly 2.5 k along the creek. The project area extends onto the Tonto platform with the Tonto trail running through it. Water is seasonally present in this drainage and may contain uranium from the Orphan Mine upstream. At this site, 172 tamarisk trees were treated; these trees were primarily located up the west fork of upper Horn Creek, outside of the initial project area boundary.

Salt Creek - Upper

Vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Secondary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Horn Creek for full description)

Soil and geology information: 136—Typic Haplocalcids, 15 to 55% slopes (refer to Horn Creek for full description)

Secondary soil and geology information: 63—Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes

Landform: plateau

Elevation: 1,372 to 1,829 m (4,500 to 6,000 ft)
Mean annual precipitation: 25.4 to 35.6 cm (10 to 14 in)
Mean annual air temperature: 11 to 13 °C (52 to 55 °F)
Mean annual soil temperature: 13 to 15 °C (54 to 57 °F)
Frost-free period: 145 to 160 days
Rock outcrop: 45%
Lithic Ustic Torriorthents and similar soils: 35%
Ustic Haplocalcids and similar soils: 20%
Rock outcrop: tall, vertical cliffs and escarpments
Lithic Ustic Torriorthents soils
Geomorphic position: colluvial slopes on ledges of canyon sidewalls
Parent material: colluvium and/or residuum weathered from limestone
Slope: 30 to 60%
Surface fragments: N/A
Depth to restrictive feature: 25.4 to 50.8 cm (10 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: The Salt Creek project area begins 1.5 k up canyon from the Colorado River and is approximately 1.3 k long. The Tonto trail runs through this project site as well. It sits at the eastern base of the geologic feature known as The Alligator. At this site, 85 tamarisk trees were treated.

Cedar Spring

Vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Secondary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima* - *Ephedra nevadensis/viridis* - *Yucca baccata*) (refer to Horn Creek for full description)

Tertiary vegetation community name: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana* - *Guterrezia sarothrae* - *Lycium andersonii*) (refer to Horn Creek for full description)

Soil and geology information: 58—Lithic Haplargids, Shinumo Formation, 8 to 15% slopes

Landform: plateau
Elevation: 1,067 to 1,372 m (3,500 to 4,500 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 14 to 17 °C (57 to 63 °F)
Mean annual soil temperature: 16 to 19 °C (59 to 65 °F)

Frost-free period: 200 to 240 days
Lithic Haplargids and similar soils: 100%
Geomorphic position: pediments
Parent material: residuum weathered from quartzite
Slope: 8 to 15%
Surface fragments: N/A
Depth to restrictive feature: 20.3 to 50.8 cm (8 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Secondary soil and geology information: 16—Calcic Petrocalcids-Rock outcrop complex, 15 to 55% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 63—Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Project area description: This project area is 800 m away from the river and is defined by the Bright Angel Shale rock layer but also includes the Tapeats sandstone. Although this is a relatively small project area with a length of about 500 m, 426 tamarisk trees were treated in the area. The majority of those were seedlings. The Tonto trail runs through this project area. This project area was identified as a priority as crews were accessing other areas in the vicinity. It provides a major source of water for backcountry users, thus removing the tamarisk was beneficial.

Topaz Creek

Vegetation community name: 223.2121—Cottonwood-Brickellia - Acacia - Apache Plume (*Populus fremontii - Brickellia longifolia - Acacia greggii - Fallugia paradoxa*)

The elevational range is 520 to 1,710 m (1,700 to 5,600 ft). The type is found on low slopes, up to 5 %, but may be steeper at mouths of springs on all aspects. Soils may be gravelly streambed alluvium, or silty floodplain soil, with cobbles and gravel depending upon location relative to the stream channel. The type is found in drainages and side canyons with perennial water flow throughout the inner canyon, commonly beginning below the Redwall Limestone on terrace situation.

Characteristic Species:

Populus fremontii	cottonwood
Brickellia longifolia	brickellia
Acacia greggii	catclaw acacia
Fallugia paradoxa	Apache plume

Secondary vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Tertiary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Horn Creek for full description)

Quaternary vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*)

The elevational range is 61 to 1,340 m (2,000 to 4,400 ft). This community type is found on moderate to steep slopes, predominantly on southerly aspects. The soil is rocky and shallow with frequent bedrock outcrops, derived from igneous rocks. The type is found throughout the inner gorge from lower Marble Canyon downstream almost to Toroweap Point. The community is characterized by xeromorphic desert scrub with cacti scattered throughout. All species are 30.4 to 91.4 cm (1 to 3 ft) tall.

Characteristic Species:

Encelia farinosa	brittlebush
Ephedra nevadensis/viridis	Mormon tea
Acacia greggii	catclaw acacia
Opuntia basilaris	beavertail cactus

Quinary vegetation community name: 122.41411—Juniper – Pinyon Pine – Mormon Tea - Greasebush (*Juniperus osteosperma – Pinus edulis – Ephedra viridis – Glossopetalon spinescens*)

The elevational range is 980 to 2,190 m (3,200 to 7,200 ft). This community type is found on moderate to steep slopes and talus, generally of northerly aspects. Soils are coarse and rocky, derived from sandstone or limestone. This type is generally found on the south side of the inner canyon from Desert View to Fossil Bay. It is characterized by evergreen needle- and scale-leaved woodland in open stands. The understory is composed of evergreen sclerophyllous shrubs and scattered deciduous shrubs and succulents. Trees are 3 to 6 m (10 to 20 ft) tall and shrubs are 0.3 to 1.8 m (1 to 6 ft) tall.

Characteristic Species:

Juniperus osteosperma	Utah juniper
Pinus edulis	pinyon pine
Ephedra viridis	Mormon tea
Glossopetalon spinescens	greasebush
Gutierrezia sarothrae	snakeweed
Yucca baccata	banana yucca
Agave utahensis	Utah agave
Artemisia tridentate	sagebrush
Ericameria nauseosus	rabbitbrush

Soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Salt Creek for full description)

Secondary soil and geology information: 63—Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 136—Typic Haplocalcids, 15 to 55% slopes (refer to Horn Creek for full description)

Project area description: Topaz project area is 3.5 k long and begins 1.2 k up from the river where it joins with Boucher Creek, a previously treated area. This drainage runs between Diana Temple and Vesta Temple. Near the river, the drainage is wide, but it narrows up creek. At the beginning of this project area, the Boucher and Tonto trails intersect. At this site, 579 tamarisk trees were treated. There is quite a bit of re-growth in this area and it will be a priority for a revisit in the spring of 2009.

Slate Creek

Vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*) (refer to Topaz for full description)

Secondary vegetation community name: 253.4221—Catclaw Acacia - Baccharis - Apache Plume (*Acacia greggii - Baccharis spp. - Fallugia paradoxa*)

The elevational range is 1,500 to 5,200 ft (460 to 1,580 m). This type occurs along drainages and washes and on adjacent floodplains. Soils are alluvial, commonly of gravelly, sandy, or cobbly texture, but occasionally of sandy loam. The type occurs throughout the canyon at or below the Redwall Limestone and extending to the Colorado River. This type includes all dry riparian washes and intermittent water courses found in the side canyons throughout the Park.

Characteristic Species:

Acacia greggii	catclaw acacia
Baccharis spp.	baccharis
Fallugia paradoxa	Apache plume
Ephedra spp.	Mormon tea
Gutierrezia sarothrae	snakeweed

Tertiary vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Quaternary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Horn Creek for full description)

Quinary vegetation community name: 122.41411—Juniper – Pinyon Pine – Mormon Tea - Greasebush (*Juniperus osteosperma – Pinus edulis – Ephedra viridis – Glossopetalon spinescens*) (refer to Topaz for full description)

Soil and geology information: 16—Calcic Petrocalcids-Rock outcrop complex, 15 to 55% slopes (refer to Horn Creek for full description)

Secondary soil and geology information: 110—Rock outcrop-Lithic Torriorthents complex, Vishnu Schist Formation, 15 to 60% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Topaz Creek for full description)

Quaternary soil and geology information: 63—Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Project area description: The Slate Creek project area begins 800 m up canyon from the river. It extends 4.2 k up a narrow drainage. Water is available at locations above the Tonto. Just below Slate Creek drainage is Crystal Rapid, one of the more well-known and challenging rapids in Grand Canyon. Access from the river is incredibly challenging, thus crews accessed this area via backpacking. About midway through this project area, the Tonto trail intersects it. A large number of tamarisk (1,935) trees were treated in this project area.

Agate Canyon

Vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*) (refer to Topaz Creek for full description)

Secondary vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Tertiary vegetation community name: 122.41411—Juniper – Pinyon Pine – Mormon Tea - Greasebush (*Juniperus osteosperma – Pinus edulis – Ephedra viridis – Glossopetalon spinescens*) (refer to Topaz for full description)

Quaternary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Horn Creek for full description)

Soil and geology information: 16—Calcic Petrocalcids-Rock outcrop complex, 15 to 55% slopes (refer to Horn Creek for full description)

Secondary soil and geology information: 110—Rock outcrop-Lithic Torriorthents complex, Vishnu Schist Formation, 15 to 60% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Topaz Creek for full description)

Quaternary soil and geology information: 63—Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Project area description: Agate Canyon project area is 3 k long and begins within a couple hundred meters of the river. It is the beginning of a series of side canyons and coinciding rapids named after gems. At this site, 154 tamarisk trees were treated.

Sapphire Canyon

Vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*) (refer to Topaz Creek for full description)

Secondary vegetation community name: 253.4221—Catclaw Acacia - Baccharis - Apache Plume (*Acacia greggii - Baccharis spp. - Fallugia paradoxa*)

The elevational range is 1,500 to 5,200 ft (460 to 1,580 m). This type occurs along drainages and washes and on adjacent floodplains. Soils are alluvial, commonly of gravelly, sandy, or cobbly texture, but occasionally of sandy loam. The type occurs throughout the canyon at or below the Redwall Limestone and extending to the Colorado River. This type includes all dry riparian washes and intermittent water courses found in the side canyons throughout the Park.

Characteristic Species:

Acacia greggii	catclaw acacia
Baccharis spp.	baccharis
Fallugia paradoxa	Apache plume
Ephedra spp.	Mormon tea
Gutierrezia sarothrae	snakeweed

Tertiary vegetation community name: 122.41411—Juniper – Pinyon Pine – Mormon Tea - Greasebush (Juniperus osteosperma – Pinus edulis – Ephedra viridis – Glossopetalon spinescens) (refer to Topaz for full description)

Quaternary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Horn Creek for full description)

Soil and geology information: 16—Calcic Petrocalcids-Rock outcrop complex, 15 to 55% slopes (refer to Horn Creek for full description)

Secondary soil and geology information: 110—Rock outcrop-Lithic Torriorthents complex, Vishnu Schist Formation, 15 to 60% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Topaz Creek for full description)

Project area description: The Sapphire project area is 3.2 k long and begins within a few hundred meters of the river. The Tonto trail intersects the beginning section of this project area. The upper end of this project area sits between two dominant geologic features, Pollux and Castor Temples. At this site, 733 tamarisk trees were treated.

Turquoise Canyon

Vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa* - *Ephedra nevadensis/viridis* - *Acacia greggii*) (refer to Topaz Creek for full description)

Secondary vegetation community name: 253.4221—Catclaw Acacia - Baccharis - Apache Plume (*Acacia greggii* - *Baccharis spp.* - *Fallugia paradoxa*) (refer to Sapphire Canyon for full description)

Tertiary vegetation community name: 122.41411—Juniper – Pinyon Pine – Mormon Tea - Greasebush (*Juniperus osteosperma – Pinus edulis – Ephedra viridis – Glossopetalon spinescens*) (refer to Topaz for full description)

Quaternary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata) (refer to Horn Creek for full description)

Quinary vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (Gutierrezia sarothrae-Ephedra viridis-Agave utahensis) (refer to Horn Creek for full description)

Soil and geology information: 16—Calcic Petrocalcids-Rock outcrop complex, 15 to 55% slopes (refer to Horn Creek for full description)

Secondary soil and geology information: 110—Rock outcrop-Lithic Torriorthents complex, Vishnu Schist Formation, 15 to 60% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Topaz Creek for full description)

Quaternary soil and geology information: 63— Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Project area description: This project area is about 4.5 k long and begins about 600 m up from the river. To the northwest of this area along the rim is Hualapai Point. The Tonto trail runs through this project area. For most of this project area, the main vegetation is catclaw acacia, baccharis, and Apache plum. At this site, 296 tamarisk trees were treated.

Ruby

Vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*) (refer to Topaz Creek for full description)

Secondary vegetation community name: 253.4221—Catclaw Acacia - Baccharis - Apache Plume (*Acacia greggii - Baccharis spp. - Fallugia paradoxa*) (refer to Sapphire Canyon for full description)

Tertiary vegetation community name: 122.41411—Juniper – Pinyon Pine – Mormon Tea - Greasebush (*Juniperus osteosperma – Pinus edulis – Ephedra viridis – Glossopetalon spinescens*) (refer to Topaz for full description)

Quaternary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Horn Creek for full description)

Quinary vegetation community name: 153.11011——Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Soil and geology information: 16—Calcic Petrocalcids-Rock outcrop complex, 15 to 55% slopes (refer to Horn Creek for full description)

Secondary soil and geology information: 110—Rock outcrop-Lithic Torriorthents complex, Vishnu Schist Formation, 15 to 60% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Topaz Creek for full description)

Quaternary soil and geology information: 63— Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Project area description: Ruby Canyon project area is about 3.6 k long and begins within about 360 m of the river. The Tonto trail runs through this area about midway and rain pools are present near the trail in wet seasons. At this site, 64 tamarisk trees were treated.

Above Serpentine

Vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*) (refer to Topaz Creek for full description)

Secondary vegetation community name: 153.11011——Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Tertiary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata) (refer to Horn Creek for full description)

Soil and geology information: 16—Calcic Petrocalcids-Rock outcrop complex, 15 to 55% slopes (refer to Horn Creek for full description)

Secondary soil and geology information: 110—Rock outcrop-Lithic Torriorthents complex, Vishnu Schist Formation, 15 to 60% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Topaz Creek for full description)

Project area description: Above Serpentine project area is about 2 k long and begins within a few hundred meters of the river. The Tonto trail runs through the upper portion of this area. Havasupai point is just above this area on the rim. At this site, 30 tamarisk trees were treated.

White Creek

Vegetation community name: 122.4146—Pinyon - Scrub Oak - Manzanita (*Pinus edulis - Quercus turbinella - Arctostaphylos pungens*)

The elevational range is 1,520 to 2,440 m (5,000 to 8,000 ft). This community type is found on steep slopes of canyon walls and terraces and on narrow ledges. Soils are rocky, derived from limestone or sandstone. This type is widespread north of the Colorado River from the Shivwits Plateau to Nankoweap Valley.

Characteristic Species:

Pinus edulis	pinyon pine
Quercus turbinella/undulata	scrub oak
Arctostaphylos pungens	manzanita
Juniperus osteosperma	Utah juniper
Garrya flavescens	silk-tassle
Ephedra viridis	Mormon tea
Yucca baccata	banana yucca

Secondary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Horn Creek for full description)

Tertiary vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Quaternary Vegetation Type: 122.4142—Juniper-Pinyon-Mormon Tea-Scrub Oak (*Juniperus osteosperma - Pinus edulis - Ephedra viridis - Quercus turbinella*)

The elevational range is 1,160 to 2,320 m (3,800 to 7,600 ft). This community type is found on steep canyon walls and talus slopes of all aspects. Soils are typically coarse with many cobbles, derived from sandstone or limestone. It occurs throughout the canyon north of the river from the Shivwits Plateau east to Nankoweap Valley. This type is evergreen needle- and scale-leaved woodland in open stands. The understory is composed of sclerophyllous evergreen shrubs with scattered deciduous shrubs and succulents. The trees are 3 to 6 m (10 to 20 ft) tall and the shrubs are 0.3 to 1.2 m (1 to 4 ft) tall.

Characteristic Species:

Juniperus osteosperma	Utah juniper
Pinus edulis	pinyon pine
Ephedra viridis	Mormon tea
Quercus turbinella/undualta	scrub oak
Gutierrezia sarothrae	snakeweed
Yucca baccata	banana yucca

Soil and geology information: 63—Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Secondary soil and geology information: 110—Rock outcrop-Lithic Torriorthents complex, Vishnu Schist Formation, 15 to 60% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 136—Typic Haplocalcids, 15 to 55% slopes (refer to Horn Creek for full description)

Quaternary soil and geology information: 6—Aridic Lithic Ustorthents-Rock outcrop complex, Supai Group, cool, 15 to 55 % slopes

Landform: plateau
Elevation: 2,134 to 2,436 m (7,000 to 7,990 ft)
Mean annual precipitation: 35.6 to 45.7 cm (14 to 18 in)
Mean annual air temperature: 9 to 11 °C (48 to 52 °F)
Mean annual soil temperature: 11 to 13 °C (50 to 54 °F)
Frost-free period: 120 to 160 days
Aridic Lithic Ustorthents and similar soils: 70%
Rock outcrop: 30%
Aridic Lithic Ustorthents soils
Geomorphic position: pockets and ledges of canyon sidewalls
Parent material: colluvium derived from sandstone
Slope: 15 to 55%
Surface fragments: N/A
Depth to restrictive feature: 20.3 to 50.8 cm (8 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Quinary soil and geology information: 158—Ustic Torriorthents-Lithic Ustic Torriorthents-Lithic Ustic Haplargids complex, Tonto Group and Redwall Formation, 8 to 60% slopes

Landform: plateau
Elevation: 1,524 to 1,829 m (5,000 to 6,000 ft)
Mean annual precipitation: 25.4 to 35.6 cm (10 to 14 in)
Mean annual air temperature: 11 to 13 °C (52 to 55 °F)
Mean annual soil temperature: 13 to 15 °C (54 to 57 °F)
Frost-free period: 145 to 160 days
Ustic Torriorthents and similar soils: 40%
Lithic Ustic Torriorthents and similar soils: 35%
Lithic Ustic Haplargids and similar soils: 25%
Ustic Torriorthents soils
Geomorphic position: colluvial slopes on canyon sidewalls
Parent material: colluvium derived from sandstone
Slope: 15 to 60%
Surface fragments: N/A
Depth to restrictive feature: 20.3 to 50.8 cm (8 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: White Creek project area runs along the North Bass trail and is about 8.2 k long. The North Bass trail is in Muav Canyon, which lies between Rainbow and Powell Plateaus on the North Rim. This project area begins about 3.1 k up from the river with Shinumo Creek running along part of it. The upper portions of this area are defined vegetatively by pinyon, scrub oak and Manzanita. Of the 1,484 tamarisk trees treated in this area, most were seedlings.

Flint Creek

Vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (Gutierrezia sarothrae-Ephedra viridis-Agave utahensis) (refer to Horn Creek for full description)

Secondary Vegetation Type: 122.4142—Juniper-Pinyon-Mormon Tea-Scrub Oak (Juniperus osteosperma - Pinus edulis - Ephedra viridis - Quercus turbinella) (refer to White Creek for full description)

Tertiary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata) (refer to Horn Creek for full description)

Quaternary community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii) (refer to Topaz Creek for full description)

Soil and geology information: 136—Typic Haplocalcids, 15 to 55% slopes (refer to Salt Creek for full description)

Secondary soil and geology information: 63—Lithic Haplocambids-Lithic Haplargids complex, Bright Angel and Tapeats Formations, 2 to 15% slopes (refer to Horn Creek for full description)

Tertiary soil and geology information: 68—Lithic Torriorthents-Rock outcrop complex, Dox Formation, 15 to 60% slopes
Landform: plateau
Elevation: 1,067 to 1,372 m (3,500 to 4,500 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 14 to 17 °C (57 to 63 °F)
Mean annual soil temperature: 16 to 19 °C (59 to 65 °F)
Frost-free period: 200 to 240 days
Lithic Torriorthents and similar soils: 55%
Rock outcrop: 45%
Lithic Torriorthents soils
Geomorphic position: pockets on ledges
Parent material: colluvium and/or residuum weathered from sandstone and shale
Slope: 15 to 60%
Surface fragments: N/A
Depth to restrictive feature: 15.2 to 50.8 cm (4 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Quaternary soil and geology information: 158—Ustic Torriorthents-Lithic Ustic Torriorthents-Lithic Ustic Haplargids complex, Tonto Group and Redwall Formation, 8 to 60% slopes (refer to White Creek for full description)

Quinary soil and geology information: 6—Aridic Lithic Ustorthents-Rock outcrop complex, Supai Group, cool, 15 to 55 % slopes

Project area description: Flint Creek project area is about 5 k long and in some areas almost 2 k wide. It is located off the west fork of the North Bass trail that leads up to Merlin and Mordred Abyss. This is a huge drainage, and will be a priority for re-treatment in the future. Access is difficult, as it is a very long hike. Of the 2,271 tamarisk trees that were treated, most were seedlings.

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122 Mile Canyon

Vegetation community name: 153.11015—Wolfberry - Snakeweed - Shadscale (*Lycium andersonii – Gutierrezia sarothrae – Atriplex confertifolia*)

The elevation range is 1,280 to 1,550 m (4,200 to 5,100 ft). This type is found on moderate to steep slopes with southerly aspects. Soils are thin and gravelly with numerous cobbles derived from basalt flows. This type is limited to Vulcan's Throne. This community is an evergreen xeromorphic desert scrub with cacti scattered throughout. All plants are 0.3 to 0.6 m (1 to 2 ft) tall. Estimated total cover ranges from 15 to 40% and is evenly distributed.

Characteristic species:

Lycium andersonii	wolfberry
Gutierrezia sarothrae	snakeweed
Atriplex confertifolia	shadscale
Ephedra viridis	Mormon tea
Yucca baccata	banana yucca

Soil and geology information: 128—Torriorthents-Lithic Haplargids-Rock outcrop complex, Tonto Group, 15 to 60% slope
Landform: plateau
Elevation: 488 to 762 m (1,600 to 2,500 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 17 to 20 °C (63 to 68 °F)
Mean annual soil temperature: 19 to 22 °C (65 to 70 °F)
Frost-free period: 210 to 280 days
Torriorthents and similar soils: 60%
Lithic Haplargids and similar soils: 25%
Rock outcrop: 15%
Torriorthents soils

Taxonomic classification: Torriorthents
Geomorphic position: fan terraces and alluvial fans
Parent material: colluvium derived from limestone, sandstone, and shale
Slope: 15 to 60%
Surface fragments: N/A
Depth to restrictive feature: 15.2 to 152.4 cm (6 to 60 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: 122 Mile Canyon project area is relatively small, and is located just upstream from Forester Canyon. It is about 740 m long and begins right at river level. This project area lies entirely within the Mormon tea, big galleta grass and acacia vegetative zone. Of the 2,878 tamarisk trees treated, 2,398 were seedlings.

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140 Mile

Vegetation community name: 153.11015—Wolfberry - Snakeweed - Shadscale (*Lycium andersonii – Gutierrezia sarothrae – Atriplex confertifolia*) (refer to 122 Mile Canyon for full description)

Soil and geology information: 59—Lithic Haplargids-Rock outcrop complex, Redwall Formation, 2 to 30% slope

Landform: plateau
Elevation: 1,067 to 1,372 m (3,500 to 4,500 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 14 to 17 °C (57 to 63 °F)
Mean annual soil temperature: 16 to 19 °C (59 to 65 °F)
Frost-free period: 200 to 240 days
Lithic Haplargids and similar soils: 80%
Rock outcrop: 20%
Lithic Haplargids soils
Taxonomic classification: Lithic Haplargids
Geomorphic position: summits and sideslopes of low hills
Parent material: residuum weathered from limestone
Slope: 2 to 30%
Surface fragments: N/A
Depth to restrictive feature: 25.4 to 50.8 cm (10 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Secondary soil and geology information: 128—Torriorthents-Lithic Haplargids-Rock outcrop complex, Tonto Group, 15 to 60% slope (refer to 122 Mile Canyon for full description)

Tertiary soil and geology information: 112—Rock outcrop-Lithic Ustic Torriorthents-Ustic Haplocalcids complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Topaz Creek for full description)

Project area description: 140 Mile project area is forked like a Y with the base beginning at river level. The branches are between 2.0 and 2.5 k long. In the mouth of the canyon is a small spring with running water and a few cottonwood trees. There are a few waterfalls about 400 meters up this drainage. At this site, 184 tamarisk trees were treated. In this project area, botanists collected *Mentzelia abyssa*, a newly named plant species and a new record for the park.

148.5 Mile Spring

Vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*) (refer to Topaz Creek for full description)

Soil and geology information: 128—Torriorthents-Lithic Haplargids-Rock outcrop complex, Tonto Group, 15 to 60% slope (refer to 122 Mile Canyon for full description)

Project area description: 148.5 Mile Spring is a small project area, about 130 x 200 m. It is on river right just above Upset rapids. This spring has lush native vegetation tucked amidst the steep limestone slopes. At this site, 67 tamarisks were treated.

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151 Mile Spring

Vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*) (refer to Topaz Creek for full description)

Soil and geology information: 128—Torriorthents-Lithic Haplargids-Rock outcrop complex, Tonto Group, 15 to 60% slope (refer to 122 Mile Canyon for full description)

Project area description: 151 Mile Spring project area is also small, covering only 380 m by 50 m. At this site, 27 tamarisk trees were treated. This spring was a priority due to the presence of the endemic MacDougall’s flaveria that grows on the site.

National Canyon

Vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Secondary vegetation community name: 153.1912—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa* - *Ephedra nevadensis/viridis* - *Acacia greggii*) (refer to Topaz Creek for full description)

Tertiary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima* - *Ephedra nevadensis/viridis* - *Yucca baccata*) (refer to Horn Creek for full description)

Soil and geology information: 128—Torriorthents-Lithic Haplargids-Rock outcrop complex, Tonto Group, 15 to 60% slope (refer to 122 Mile Canyon for full description)

Secondary soil and geology information: 59—Lithic Haplargids-Rock outcrop complex, Redwall Formation, 2 to 30% slope (refer to 140 Mile Canyon for full description)

Tertiary soil and geology information: 115—Rock outcrop-Torriorthents-Lithic Torriorthents complex, Supai Group and Redwall Formation, 2 to 60% slopes

Landform: plateau
Elevation: 762 to 1,371 m (2,500 to 4,500 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 14 to 20 °C (57 to 68 °F)
Mean annual soil temperature: 16 to 22 °C (59 to 70 °F)
Frost-free period: 200 to 320 days
Rock outcrop: 50%
Torriorthents and similar soils: 30%
Lithic Torriorthents and similar soils: 20%
Torriorthents soils
Taxonomic classification: Torriorthents
Geomorphic position: colluvial slopes
Parent material: colluvium derived from limestone and sandstone
Slope: 2 to 30%
Surface fragments: N/A
Depth to restrictive feature: 53.3 to 152.4 cm (21 to 60 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: National Canyon project area is 6.2 k long. This a large drainage beginning with a wide wash that quickly narrows into a deep limestone canyon. This drainage can be hiked 32 km all the way to the rim. Up canyon, after a series of difficult climbs and waterfalls, there are pools and patios. The lower climb requires ropes for safe access, and future crews should visit this area with extreme care. The Project Coordinator dislocated her shoulder near the upper transect areas in April 2008, and the down climb with one arm required a series of ropes and assistance from all of the trip's boatmen to accomplish. This canyon lies within the park and the Hualapai reservation. At this site, 1,143 tamarisk trees were treated.

Mohawk Canyon

Vegetation community name: **153.1912**—Brittlebush - Mormon Tea - Catclaw Acacia (*Encelia farinosa - Ephedra nevadensis/viridis - Acacia greggii*) (refer to Topaz Creek for full description)

Secondary vegetation community name: 153.11011—Snakeweed-Mormon Tea-Utah Agave (*Gutierrezia sarothrae-Ephedra viridis-Agave utahensis*) (refer to Horn Creek for full description)

Tertiary vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*)

The elevational range is 460 to 1,070 m (1,500 to 3,500 ft). This community type is found on moderate to steep slopes (up to 50%) with southerly aspects. Soils are thin and rocky or cobbly, derived from the Bright Angel Shale, Tapeats Sandstone, igneous rocks and volcanic sources. This type occurs on slopes above the river from Toroweap Point to Lake Mead. The community is characterized by mixed evergreen and deciduous xeromorphic desertscrub with sub-shrubs and cacti scattered throughout. All species are 0.3 to 0.9 m (1 to 3 ft) tall except ocotillo which may reach 2.4 to 3.0 m (8 to 10 ft).

Characteristic Species:

Encelia farinosa	brittlebush
Larrea tridentata	creosotebush
Ephedra nevadensis/viridis	Mormon tea
Ferocactus acanthodes	barrel cactus
Fouquieria splendens	ocotillo
Opuntia basilaris	beavertail cactus

Soil and geology information: 128—Torriorthents-Lithic Haplargids-Rock outcrop complex, Tonto Group, 15 to 60% slope (refer to 122 Mile Canyon for full description)

Secondary soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes

Landform: plateau
Elevation: 487 to 1,036 m (1,600 to 3,400 ft)
Mean annual precipitation: 15.2 to 229 cm (6 to 9 in)
Mean annual air temperature: 18 to 21 °C (64 to 70 °F)
Mean annual soil temperature: 20 to 23 °C (66 to 72 °F)
Frost-free period: 230 to 280 days

Lithic Torriorthents and similar soils: 70%
Rock outcrop: 30%
Lithic Torriorthents soils
Geomorphic position: colluvial slopes on ledges
Parent material: colluvium and/or residuum weathered from limestone
Slope: 15 to 70%
Surface fragments: N/A
Depth to restrictive feature: 20.3 to 35.6 cm (8 to 14 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Tertiary soil and geology information: 115—Rock outcrop-Torriorthents-Lithic Torriorthents complex, Supai Group and Redwall Formation, 2 to 60% slopes (refer to National Canyon for full description)

Project area description: Mohawk Canyon project area is 6.1 k long and begins at river level. It lies entirely on the Hualapai Reservation. In the fall, winter and spring, about 800 m up this drainage, there is running water and some small waterfalls. Further up, the water stops for most of the year, and there are large chockstone pourovers. Of the 12,602 tamarisks that were treated n this area, 12,077 were seedlings. This is one of the highest priority areas for re-treatment in the future due to the large number of seedlings.

Honga Spring

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Secondary soil and geology information: 115—Rock outcrop-Torriorthents-Lithic Torriorthents complex, Supai Group and Redwall Formation, 2 to 60% slopes (refer to National Canyon for full description)

Project area description: Honga Spring project area is 700 m long and lies within the Hualapai reservation. It is just across river from Vulcan’s Throne. At this site, 118 tamarisk trees were treated.

Prospect Canyon

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyons for full description)

Secondary vegetation community name: 153.11015—Wolfberry – Snakeweed – Shadscale (*Lycium andersonii – Gutierrezia sarothrae – Atriplex confertifolia*) (refer to 122 Mile Canyon for full description)

Soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Secondary soil and geology information: 115—Rock outcrop-Torriorthents-Lithic Torriorthents complex, Supai Group and Redwall Formation, 2 to 60% slopes (refer to National Canyon for full description)

Project area description: Prospect Canyon project area is 2.2 k long and begins within a few hundred meters of the river. It lies within the Hualapai reservation. This is the massive drainage from which tons of debris washed into the river to create one of the biggest rapids in Grand Canyon, Lava Falls. The drainage covers an area of over 160 square kilometers. After hiking up this steep drainage involving cinder hills, cliffs and pourovers, the full view of Prospect Canyon is visible. At this site, 32 tamarisk trees were treated.

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190 Mile Canyon

Vegetation community name: 153.1121—Creosotebush – White Bursage – Mormon Tea (*Larrea tridentata – Ambrosia dumosa – Ephedra nevadensis*)

The elevational range is 1,160 to 1,520 m (3,800 to 5,000 ft). This community type is found on gentle to moderate slopes (5 to 40%), generally with southerly aspects. Soil is shallow and gravelly with numerous rock fragments and may be derived form limestone, sandstone or metamorphic rock. This type occurs from Whitmore Wash to Lake Mead. This type is characterized by evergreen xeromorphic desertscrub with succulents and deciduous shrubs. The height of all species is less than 1.2 m (4 ft) except ocotillo, which may reach 3.0 to 3.6 m (10 to 12 ft). This type is the richest in cactus species of any type in the Park.

Characteristic Species:

Larrea tridentata	creosotebush
Ambrosia dumosa	white bursage
Ephedra nevadensis	Mormon tea
Opuntia basilaris	beavertail cactus
Fouquieria splendens	ocotillo
Krameria grayii	white ratany
Eriogonum inflatum	desert trumpet

Ferocactus acanthodes	barrel cactus

Secondary vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyons for full description)

Tertiary vegetation community name: 153.11017—Mormon Tea – Blackbrush – Creosotebush (*Ephedra nevadensis – Coleogyne ramosissima - Larrea tridentata*)

The elevational range is 1,100 to 1,250 m (3,600 to 4,100 ft). This community type is found on gentle to moderate slopes generally on southerly aspects. Soils are thin, coarse and rocky derived primarily from limestones. This type occurs in the inner canyon below the Shivwits Plateau. This community is characterized by evergreen microphyll desertscrub with deciduous shrubs and cacti scattered throughout. Shrubs and cacti are 0.3 to 0.9 m (1 to 3 ft) tall except for ocotille and catclaw acacia, which may reach 1.2 to 2.4 m (4 to 8 ft).

Characteristic Species:

Ephedra nevadensis	Mormon tea
Coleogyne ramosissima	blackbrush
Larrea tridentata	creosotebush
Yucca baccata	banana yucca
Opuntia echinocarpa	silver cholla
Ferocactus acanthodes	barrel cactus
Fouquieria splendens	ocotillo
Aloysia wrightii	oreganillo
Thamnosma montana	turpentine broom
Acacia greggii	catclaw acacia
Xylorhiza tortifolia	Mojave woodyaster

Soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Project area description: 190 Mile Canyon is 1.7 k long and begins within a few hundred meters of the river. It lies within the Hualapai reservation. At this site, 837 tamarisk trees were treated.

Spring Canyon

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Secondary soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes

Landform: plateau
Elevation: 488 to 762 m (1,600 to 2,500 ft)
Mean annual precipitation: 15.2 to 229 cm (6 to 9 in)
Mean annual air temperature: 18 to 21 °C (64 to 70 °F)
Mean annual soil temperature: 20 to 23 °C (66 to 72 °F)
Frost-free period: 230 to 280 days
Lithic Torriorthents and similar soils: 70%
Lithic Calciargids and similar soils: 30%
Lithic Torriorthents soils
Geomorphic position: flat to very steep pediments of the Bright Angel Shale
Parent material: residuum weathered from calcareous shale
Slope: 2 to 55%
Surface fragments: N/A
Depth to restrictive feature: 15.2 to 50.8 cm (6 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: Spring Canyon project area is about 1 k long and begins within a few hundred meters of the river. There is a trail, Spring Canyon route, that runs through the length of this area and water can be found about 90 m up this drainage in a thick stand of phragmites. The spring provides an oasis and is host to many lizards, toads, birds and snakes. During spring of 2007, it was a dry and open canyon due to flash flood events. At this site, 140 tamarisk trees were treated.

Granite Park Canyon

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Secondary vegetation community name: 153.11017—Mormon Tea – Blackbrush – Creosotebush (*Ephedra nevadensis – Coleogyne ramosissima - Larrea tridentata*) (refer to 190 Mile Canyon for full description)

Tertiary vegetation community name: 153.1811—Desert Mallow – Mormon Tea – Creosotebush (*Sphaeralcea ambigua – Ephedra nevadensis - Larrea tridentata*)

The elevational range is 460 to 980 m (1,500 to 3,200 ft). This community type is found on moderate to steep slopes (15 to 50%) of northerly aspect. The soil is shallow and cobbly and may be derived from limestone or metamorphic rock. This type occurs in the inner gorge downstream from Whitmore Wash to Lake Mead. It is characterized by mixed deciduous and evergreen xeromorphic desertscrub with cacti and half-shrubs. Height of all species is less than 0.9 m (3 ft), except catclaw acacia which may reach 1.2 m (4 ft) and *Fouquieria* which may reach 3 m (10 ft).

Characteristic Species:

Sphaeralcea ambigua	desert mallow
Ephedra nevadensis	Mormon tea
Larrea tridentata	creosotebush
Acacia greggii	catclaw acacia
Ferocactus acanthodes	barrel cactus
Fouquieria splendens	ocotillo
Yucca whipplei	whipple yucca

Soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes (refer to Spring Canyon for full description)

Secondary soil and geology information: 144—Typic Torrifluvents-Typic Torripsamments complex, 0 to 6% slopes

Landform: Stream terrace
Elevation: 488 to 762 m (1,600 to 2,500 ft)
Mean annual precipitation: 7.6 to 15.2 cm (3 to 6 in)
Mean annual air temperature: 21 to 25 °C (70 to 77 °F)
Mean annual soil temperature: 23 to 27 °C (72 to 79 °F)
Frost-free period: 300 to 330 days
Typic Torrifluvents and similar soils: 75%
Typic Torripsamments and similar soils: 15%
Minor components: 10%
Typic Torrifluvents soils
Geomorphic position: beaches of sandy terraces along the Colorado River
Parent material: alluvium derived from mixed sources
Slope: 0 to 2%
Surface fragments: N/A
Depth to restrictive feature: greater than 1.5 m (60 in) to bedrock
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Tertiary soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Project area description: The Granite Park project area is shaped like a Y with the base beginning within a few hundred meters of the river. The length of one arm, starting from the base is 2.5 k and the other is 3.5 k. This area lies within the Hualapai reservation. There are two hikes from this area, one going south to the top of the Redwall and the other going west to Dr. Tommy Mountain. Of the 15,142 tamarisk trees treated in this area, 14,338 were seedlings.

Three Springs Canyon

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Secondary vegetation community name: 153.11017—Mormon Tea – Blackbrush – Creosotebush (*Ephedra nevadensis – Coleogyne ramosissima - Larrea tridentata*) (refer to 190 Mile Canyon for full description)

Tertiary vegetation community name: 153.1811—Desert Mallow – Mormon Tea – Creosotebush (*Sphaeralcea ambigua – Ephedra nevadensis - Larrea tridentata*) (refer to Granite Park Canyon for full description)

Soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes (refer to Spring Canyon for full description)

Secondary soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Project area description: Three Springs Canyon project area is 2.3 k long and begins within a few hundred meters of the river. It lies within the Hualapai reservation. About 400 m along the Three Springs Canyon trail, which runs the length of the project area, there is a spring surrounded by heavy brush. After the spring, the canyon is open and dry. At this site, 6,482 tamarisk trees were treated, most of which were seedlings.

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217 Mile Canyon

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Secondary vegetation community name: 153.11017—Mormon Tea – Blackbrush – Creosotebush (*Ephedra nevadensis – Coleogyne ramosissima - Larrea tridentata*) (refer to 190 Mile Canyon for full description)

Tertiary vegetation community name: 153.1811—Desert Mallow – Mormon Tea – Creosotebush (*Sphaeralcea ambigua – Ephedra nevadensis - Larrea tridentata*) (refer to Granite Park Canyon for full description)

Quaternary vegetation community name: 153.1211—Blackbrush - Mormon tea - banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Horn Creek for full description)

Soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes (refer to Spring Canyon for full description)

Secondary soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Tertiary soil and geology information: 115—Rock outcrop-Torriorthents-Lithic Torriorthents complex, Supai Group and Redwall Formation, 2 to 60% slopes (refer to National Canyon for full description)

Project area description: 217 Mile Canyon project area is in the shape of a Y with the base beginning within a few hundred meters of the river. It lies within the Hualapai reservation. The length of one arm from the base is 3.2 k and the other is 3.0 k. At this site, 16 tamarisk trees were treated.

Granite Springs Canyon

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Secondary vegetation community name: 153.11017—Mormon Tea – Blackbrush – Creosotebush (*Ephedra nevadensis – Coleogyne ramosissima - Larrea tridentata*) (refer to 190 Mile Canyon for full description)

Tertiary vegetation community name: 153.1811—Desert Mallow – Mormon Tea – Creosotebush (*Sphaeralcea ambigua – Ephedra nevadensis - Larrea tridentata*) (refer to Granite Park Canyon for full description)

Soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes (refer to Spring Canyon for full description)

Secondary soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Tertiary soil and geology information: 103—Rock outcrop-Lithic Torriorthents complex, 15 to 60% slopes

Landform: plateau
Elevation: 366 to 488 m (1,200 to 1,600 ft)
Mean annual precipitation: 7.6 to 15.2 cm (3 to 6 in)
Mean annual air temperature: 21 to 24 °C (70 to 75 °F)
Mean annual soil temperature: 23 to 26 °C (72 to 77 °F)
Frost-free period: 300 to 360 days
Rock outcrop: 70%
Lithic Torriorthents and similar soils: 30%
Rock outcrop: very steep and slick sidewalls of Precambrian metamorphic rocks in entrenched canyons and gorges
Lithic Torriorthents soils
Geomorphic position: pockets, ledges, and crevices
Parent material: colluvium derived from schist and/or sandy aeolian deposits derived from mixed
Slope: 15 to 60%
Surface fragments: N/A
Depth to restrictive feature: 20.3 to 50.8 cm (8 to 20 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: Granite Springs Canyon project area is 3.0 k long and begins within a few hundred meters of the river. It lies within the Hualapai reservation. This was one of the most difficult project areas, because there is no camp in the river corridor, which meant that crews had to accomplish project work during one-day periods over a few trips. It is possible to backpack to this area, and re-treatment crews should further investigate this for future trips. The drainage extends beyond the project area, and there is additional tamarisk removal work to complete in the future. At this site, 525 tamarisk trees were treated.

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221 Mile Spring

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes (refer to Granite Park for full description)

Secondary soil and geology information: 103—Rock outcrop-Lithic Torriorthents complex, 15 to 60% slopes (refer to Granite Springs for full description)

Project area description: 221 Mile Spring project area is 250 x 150 m and begins right at the river's edge. This area lies within the Hualapai reservation. At this site, 4 tamarisk trees were treated. This was a priority area due to the limited number of tamarisk and the availability of water for local wildlife.

221.5 Mile Creek

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes (refer to Granite Park for full description)

Secondary soil and geology information: 103—Rock outcrop-Lithic Torriorthents complex, 15 to 60% slopes (refer to Granite Springs for full description)

Project area description: 221.5 Mile Creek project area is 300 x 170 m and begins right at the river's edge. This area lies within the Hualapai reservation. At this site, 7 tamarisk trees were treated.

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222 Mile Canyon

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Secondary vegetation community name: 153.1811—Desert Mallow – Mormon Tea – Creosotebush (*Sphaeralcea ambigua – Ephedra nevadensis - Larrea tridentata*) (refer to Granite Park Canyon for full description)

Soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes (refer to Spring Canyon for full description)

Secondary soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Tertiary soil and geology information: 103—Rock outcrop-Lithic Torriorthents complex, 15 to 60% slopes (refer to Granite Springs for full description)

Project area description: 222 Mile Canyon project area is 1.5 k long and begins within a hundred meters of the river. It lies within the Hualapai reservation. About 800 m up this drainage is a small seep in the schist and up about another 400 m is a drainage coming in from the northeast. At this site, 76 tamarisk trees were treated.

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224 Mile Canyon

Vegetation community name: 153.1911—Brittlebush - Creosotebush – Mormon Tea (*Encelia farinosa – Larrea tridentata – Ephedra nevadensis*) (refer to Mohawk Canyon for full description)

Secondary vegetation community name: 153.11017—Mormon Tea – Blackbrush – Creosotebush (*Ephedra nevadensis – Coleogyne ramosissima - Larrea tridentata*) (refer to 190 Mile Canyon for full description)

Soil and geology information: 67—Lithic Torriorthents-Lithic Calciargids complex, Bright Angel and Tapeats Formations, thermic, 2 to 55% slopes (refer to Spring Canyon for full description)

Secondary soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70 % slopes (refer to Mohawk Canyon for full description)

Tertiary soil and geology information: 103—Rock outcrop-Lithic Torriorthents complex, 15 to 60% slopes (refer to Granite Springs for full description)

Quaternary soil and geology information: 115—Rock outcrop-Torriorthents-Lithic Torriorthents complex, Supai Group and Redwall Formation, 2 to 60% slopes (refer to National Canyon for full description)

Project area description: 224 Mile Canyon project area is 2 k long and begins within a few hundred meters of the river. It lies within the Hualapai reservation. From this drainage there is a trail leading to Diamond Peak. At this site, 9 tamarisk trees were treated.

c. Project Logistics

Phase II-B of the invasive plant management work brought with it many new insights and subsequent improvements based on lessons learned from earlier experiences with the overall project. In May 2006, crews surveyed and mapped project areas for tamarisk distribution, completed Southwestern willow flycatcher (SWIFL) habitat assessments, and installed long-term photopoints in transect areas. During the surveys, crews established the protocol of using 500 m long mapping sections in drainages, in an effort to more consistently gather tamarisk distribution estimates. The consistent section length standardized data collection in the control phase of the project, and allowed for standard comparison units between areas. During the April and May 2006 survey work, crews took representative photographs in many of the project areas, which were included with the Habitat Assessments. Based on input from crew leaders, it was easier to install the additional permanent photopoints during the control trips. The protocol was for crews to take before and after pictures of project areas during work implementation.

Table 1. Phase II-B Project Areas List and Completion Status

River Mile	River Side	Project Area Name	SWIFL HA Complete	Transect Area	Work Complete	Area Access Via River	Area Accessed Via Backpacking
90	L	Horn Creek	X		X		X
92.5	L	Salt Creek - Upper	X		X		X
93	L	Cedar Spring	X		X		X
96.7	L	Topaz Creek	X	X	X	X	X
98.1	L	Slate Creek	X		X		X
100.6	L	Agate Canyon	X		X		X
101.2	L	Sapphire Canyon	X		X		X
102	L	Turquoise Canyon	X		X		X
104.5	L	Ruby Canyon – Upper	X		X		X
105.8	L	Above Serpentine	X		X		X
108	R	White Creek	X		X	X	
108	R	Flint Creek	X		X	X	
122.3	L	122 Mile Canyon L	X		X		X
140	L	140 Mile Canyon	X	X	X		X
148.5	R	148.5 Mile Spring *	X		X		X
151.2	R	151 Mile Spring *	X		X		X
166.3	L	National Canyon	X	X	X		X
171.6	L	Mohawk Canyon	X	X	X		X
177.2	L	Honga Spring	X		X		X
179	L	Prospect Canyon	X		X		X
190.3	L	190 Mile Canyon *	X		X		X
204.9	L	Spring Canyon	X		X		X
208.8	L	Granite Park Canyon	X	X	X		X
215.7	L	Three Springs Canyon	X	X	X		X
217.4	L	217 Mile Canyon	X		X		X
220.4	L	Granite Spring Canyon	X		X		X
221	L	221 Mile Spring*	X		X		X
221.5	L	221.5 Mile Creek*	X		X		X
222	L	222 Mile Canyon	X		X		X
224	L	224 Mile Canyon	X		X		X

***Areas with slight name changes to match topographic maps.**

Backpacking Logistics

Crews completed invasive plant management work from April 2006 through April 2008. The field crew supervisor prepared trip schedules and river trip itineraries, which were reviewed and approved by park management, prior to each trip (please refer to Table 1. Phase II-B Project Area List and Completion Status, Table 2. Phase II-B Backpacking Trips). The Phase II-B grant deliverables called for a total of five 7-day backpacking trips to tributaries and side canyons, and two 6-day backpacking trips within the main trail corridor of GRCA. In total, crews complete 12 backpacking trips, far exceeding what was required by the project contract. This was primarily due to having matching support from GCNPF in the form of two interns, and additional support from Grand Canyon Trust (GCT).

Six individuals served as crew leaders (Melissa McMaster, Loren Bell, Steve Till, Kelly McGrath, Kari Malen and Shannon Sellers), all of which were funded either fully or in some portion by this grant. Most of the crew leaders who worked on the project during Phase II-A, returned during this phase of the project for more fun-filled tamarisk killing days. These experienced leaders built upon on their expertise and project knowledge, and all are now very dedicated, knowledgeable, physically fit, and absolutely invaluable to the project.

Throughout the project, crew leaders have continually improved logistics in an effort to make the trips more smooth and productive. The backpacking trips remain the most logistically and physically challenging aspect of the project, both for the crew and the field crew supervisor. The greatest challenge with these trips was carrying the tools and herbicide needed to perform tamarisk management in remote locations in addition to hauling 18 kilograms (40 pounds) of gear needed for a standard backpacking trip. In a subset of the remote canyons that were accessed via remote trails, crews were able to stash gallons of herbicide from the river, or via packing operations, minimizing the need to carry jugs of herbicide for long distances. However, several canyons were so remote that tools and herbicide had to be accessed completely via backpacking, which was an incredible challenge. Despite efforts to cut down on tools and gear, the main struggle with the backpacking trips was the extremely heavy packs that crew leaders and volunteers must carry in order to make the project work. This was further complicated by the fact that the work was completed during the winter and spring, when weather is unpredictable and days are short. The backpacking trips were up to eight days long and consisted of a varying number of volunteers and one or two crew leaders. In most cases, this schedule allowed for four or five days of solid work with the other time spent hiking or driving. Days began early with breakfast at 6:30 and crews heading off to work by 7:30. The workdays ended about 4:30 or 5:00. The long workdays and extensive trail commutes did not hamper the spirits of the volunteer participants, who somehow remain to be a robust community of individuals committed to ridding the Grand Canyon region of tamarisk. Despite these obstacles, crews were able to complete work via backpacking in Horn Creek, Salt Creek, Cedar Spring, Topaz Creek, Slate Creek, Agate Canyon, Sapphire Canyon, Turquoise Canyon, Ruby Canyon, Above Serpentine, White and Flint Creeks.

The Phase II-B backpacking areas are all some of the most remote tributaries in the Grand Canyon and are accessed via long, steep, remote trails without any river access. Slate, Above Serpentine and Ruby Canyon all required at least 1 ½ days of hiking time just to reach the project site.

Table 2. Phase II-B Backpacking Trips

Trip Dates	Trip Leaders	Project Areas	Total Participants
April 21-28 2006	Steve Till, Kari Malen	Topaz Creek, Slate Creek, Agate Canyon, South Rim	2 volunteers, 2 crew leaders
September 16-23 2006	Kari Malen, Loren Bell	North Bass Trail, White Creek	2 volunteers, 2 crew leaders
November 8-15 2006	Kari Malen	Horn Creek, Salt Creek, Cedar Spring	5 volunteers, 1 crew leader
November 19-25 2006	Kari Malen, Steve Till	Slate Creek	12 volunteers, 2 crew leaders
January 4-12 2007	Melissa McMaster, Hillary Hudson	Slate Creek	7 volunteers, 2 crew leaders
March 21-28 2007	Melissa McMaster, Hillary Hudson	Slate Creek	6 volunteers, 2 crew leaders
March 21-28 2007	Loren Bell, Kelly McGrath	Ruby Canyon-Upper, Above Serpentine, Below Ruby	6 volunteers, 2 crew leaders
October 10-12 2007	Shannon Sellers	Horn Creek	1 volunteers, 1 crew leader
October 20-27 2007	Loren Bell	Agate Creek	5 volunteers, 1 crew leaders
November 3-10 2007	Loren Bell	Flint Creek, White Creek	5 volunteers, 1 crew leaders
November 14-21 2007	Kelly McGrath, Shannon Sellers	Turquoise Creek	3 volunteers, 2 crew leaders
March 23-April 1 2008	Shannon Sellers, Kelly McGrath	Turquoise Creek, Sapphire Creek	3 volunteers, 2 crew leaders

River Trip Logistics

Due to the remoteness of Grand Canyon's terrain, it is necessary to access the more than half of the project areas from the Colorado River. The field crew supervisor prepared the river trip itineraries, which were reviewed and approved by Park management, prior to each trip (please refer to Table 1. Phase II-B Project Area List and Completion Status, Table 3. Phase II-B River Trip Participant Lists, and Table 4. Phase II-B River Trip Itineraries). The Phase II-B grant deliverables called for two tamarisk management river trips. Crews worked in 19 out of the 30 canyons via two 18-day river trips from September 2006 through March 2007. Each of the river trips launched from Lees Ferry and took out 226 miles down river at Diamond Creek. The project areas on the river trip were all located in the lower portion of the canyon, below river mile 96.

Table 3. Phase II-B River Trip Participant Lists

Hualapai Partnership River Trip Participant List, Fall 2006

Role	Upper Half	Lower Half
Trip Coordinator / Project Leader	Do Not Fill	Kate Watters
Head Boatman / Trip Leader	Johnny Janssen	Johnny Janssen
Boatman	Tim Stephenson	Tim Stephenson
Boatman	Simone Langress	Simone Langress
Boatman	Jeri Riley	Jeri Riley
Boatman	Lisa Gelczis	Lisa Gelczis
NPS Crew Leader #1	Eric York (GRCA paid)	Loren Bell
NPS Crew Leader #2	Andy Shepard (GRCA paid)	Steve Till
NPS Crew Leader #3	Tim Laws (GRCA paid)	Kari Malen
Hualapai Leader #1	Do not fill	Childs Quarta
Hualapai Leader #2	Do not fill	Gary Gonzalez
Hualapai Leader #3	Do not fill	Cody Bravo
Hualapai Leader #4	Do not fill	Vacant
Hualapai Hydro Tech #1	Do not fill	Harry Sahneyah
Hualapai Hydro Tech #2	Do not fill	Alvin Crooke

Hualapai Partnership River Trip Participant List, Spring 2007

Role	Upper Half	Lower Half
Trip Coordinator / Project Leader	Loren Bell	Loren Bell
Head Boatman / Trip Leader	Johnny Janssen	Johnny Janssen
Boatman	Jeri Riley	Jeri Riley
Boatman	Jed Koller	Jed Koller
Boatman	Willow Griffith	Willow Griffith
Boatman	Wayne Ball	Wayne Ball
Boatman	Pat Phillips	Pat Phillips
NPS Crew Leader #1	Do not fill	Kelly McGrath
NPS Crew Leader #2	Do not fill	Steve Till
NPS Crew Leader #3	Do not fill	Kari Malen
Hualapai Leader #1	Do not fill	~~Gary Gonzalez~~
Hualapai Leader #2	Do not fill	~~Cody Bravo~~
Hualapai Leader #3	Do not fill	~~Harry Sahneyah~~
Hualapai Leader #4	Do not fill	Manuel Bravo Sr.
NPS Volunteer	GRCA staff-unfilled	Gisela Kluwin
NPS Volunteer	GRCA staff -unfilled	Bob Chessman
NPS Volunteer	Do not fill	Lou Lorber

Table 4. Phase II-B River Trip Itineraries

Fall Hualapai Partnership River Trip Itinerary, Fall 2006

Date	Day	Work Location	Camp
9/27	1	None	North Area, 20 R
9/28	2	None	Saddle Area, 47 R
9/29	3	None	Lava Area, 65.5 R
9/30	4	None	Cremation, 87 L
10/1	5	Leave 10 gallons of herbicide at Boucher	Crystal, 98 R
10/2	6	122 Mile Creek L	121.5 Mile L
10/3	7	122 Mile Creek L	Galloway, 131 R
10/4	8	140 Mile L	Kanab, 144 R
10/5	9	National hydrology	Mohawk, 171.5, L
10/6	10	Mohawk	Mohawk, 171.5, L
10/7	11	Mohawk, Honga Spring	Honga, 177, L
10/8	12	Prospect, Beecher Spring hydro	190 R
10/9	13	190 Mile L	196 Mile, L
10/10	14	Granite Park Canyon L	Below 209 on the R
10/11	15	217 Mile L, Pumpkin Spring hydro	220 R
10/12	16	Granite Springs, 220.5 L	221 R
10/13	17	221 L, 221.5L, 222L, 224L	Diamond Creek
10/14	18	225.5 R	Take out

Hualapai Partnership River Trip Itinerary, Spring 2007

Date	Day	Work Location	Camp
2/16	1	None	North, 20 R
2/17	2	None	Saddle, 47 R
2/18	3	Drop herbicide for backpacking work.	Hance Creek, 77 L
2/19	4	Clear Creek	Clear Creek
2/20	5	Clear Creek	Cremation
2/21	6	Crystal, Boucher, Topaz	Crystal, 98 R
2/22	7	Crystal Creek	Crystal, 98 R
2/23	8	S. Bass (Drop off herbicide)	118.5 R
2/24	9	148.5R, 151R	Upper Ledges, 151.5
2/25	10	National Canyon	National Canyon, 166.5 L
2/26	11	National Canyon	National Canyon, 166.5 L
2/27	12	National Canyon	National Canyon, 166.5 L
2/28	13	Transit	Parashant, 198.5 R
3/1	14	Spring Canyon	Spring Canyon, 204.5 R
3/2	15	Spring Canyon	Spring Canyon, 204.5 R
3/3	16	Three Springs	215.5, R
3/4	18	Three Springs	215.5, R
3/5	19	Three Springs	215.5, R
3/6	20	222 Mile Canyon, Trail Canyon	Diamond Creek
3/7	21	TAKE OUT!!!!!!! Everyone help with clean up	

d. Invasive plant management methods and conditions

After incorporation of public comments into the Environmental Assessment / Assessment of Effect (EA/AEF) document, which is required under the National Environmental Policy Act (NEPA) and the National Historic Preservation Act (NHPA), project managers selected the final control methods. For this project, staff used a combination of mechanical and chemical methods. The field crew leaders selected the methods for each project location based on site characteristics and weather conditions. A brief description of each method follows:

Manual Removal

Crews used this method to remove tamarisk seedlings (and sometimes saplings) in washes, streambeds, and non-sensitive areas, and to control other invasive species such as African mustard (*Malcomia africana*), camelthorn (*Alhagi maurorum*), common sandbur (*Cenchrus incertus*), perennial pepperweed *(Lepidium latifolium*), puncture vine (*Tribulus terrestris*), Ravenna grass (*Saccharum ravennae*), London rocket (*Sisymbrium irio*), Russian thistle (*Salsola tragus*), Sahara mustard (*Brassica tournefortii*), sowthistle (*Sonchus* spp.), and white clover (*Melilotus alba*). Workers used geology picks and shovels to loosen the soil surrounding the plants and then remove the entire root system, or at least to below the root crown.

Girdle Method

Crews used hand saws, bow saws or hatchets to cut several centimeters into the water-conducting tissue (xylem) of standing trees. The cut was within one meter of the ground surface (usually within 20 cm), forming a concentric circle at the ends. Using hand-pressurized sprayers, herbicide applicators then applied the chemical directly into the cut and onto the bark from the cut to the base of the tree.

Cut Stump Method

Crews cut the tree trunks near ground level with handsaws and then sprayed the cut surface with herbicide. The tree's tissues absorb the mixture and transport it to the roots, with quick application increasing the effectiveness. Pressurized hand sprayers allowed precision herbicide application with minimum overspray or drift risk. Crews used this method extensively alone, but also in combination with girdling.

Basal Bark Application

With this method, herbicide applicators sprayed the entire stem from near ground level up to about 40 cm. They applied the herbicide with hand held pressurized sprayers, which have small nozzles and coarse spray settings that allow for direct spraying with minimal drift or overspray. This method is much less labor intensive, but is less effective on mature trees so limited use on smaller saplings and seedlings occurred, often in combination with other methods.

Mitigation Measures

The following specific measures applied to all methods used for the project:

- Debris was disposed of to minimize visual impact.
- Cut stumps were hidden from view to the extent possible.

- Soil was tamped when manual removal was used to help minimize establishment of other invasive exotic species and to minimize visual impact.
- Tree cuts were made on tree sides least visible to backcountry users.
- When pruning, a minimal number of branches were cut to minimize visual impact.

Much of the debris remained on site to decompose and provide habitat for wildlife. Crews minimized the visual impacts of the project by employing a combination of control methods at each project site and being aware of the visibility of the cuts and girdles.

Herbicide Use

The herbicides used for control were triclopyr-based general use herbicides. Crews used Garlon® 4 or Tahoe 4E® in a mixture of 25% with 75% methylated soybean oil (MOC). They used Garlon® 3a mixed with 50% water when working close to water. The application tool is a 32-ounce stainless steel sprayer, hand-pressurized with bicycle pumps. These sprayers are well suited for the backcountry conditions the Grand Canyon offers as they are virtually indestructible, easy to repair in the field, and are fairly lightweight.

Pesticide certification is not required for the application of any of these non-restricted herbicides; however, Park vegetation staff adopted the policy of requiring trained and certified applicators on site during application. The project coordinator and all field crew leaders maintained Arizona state pesticide certification. All project participants received herbicide orientation and training from the project coordinator, and understood and abided by the established personal protective equipment (PPE) requirements and rules outlined in the safety plan for the project. Rubber gloves, long sleeve shirts, long pants, and eye protection were part of the PPE necessary for this project. All project participants reviewed the job hazard analyses (JHAs) for exotic plant removal and herbicide application.

Crew leaders followed all information and instructions on the herbicide label. All herbicide containers were leak and spill resistant. In 2006, the field crew supervisor purchased fluorinated high-density polyethylene plastic jugs in various sizes to minimize the possibility of leaks and spills, especially since the containers are hauled in backpacks, on boats and by mules. All application equipment and chemicals were stored in sealed ammunition cans or large silver boxes during transport on rafts and pack mules, and all storage containers had the product's specimen label and the Material Safety Data Sheet (MSDS) clearly displayed underneath a waterproof plastic sheet. The MSDS contains fire and explosive hazard data, environmental and disposal information, health hazard data, handling precautions, and first aid information. All trip participants reviewed the MSDS with the project leader and understood the first aid instructions described on the MSDS. On the river, one boat contained all herbicide and application equipment, herbicide containers, and PPE disposal containers, isolated from food and personal items. On backpacking trips, crew leaders carried herbicide containers in heavy-duty plastic dry bags which were strapped to the outside of backpacks.

e. Review of methods

Although current scientific literature documents successful control methods for tamarisk, refinement to the methods continue to occur in GRCA's remote backcountry areas. Please refer to Appendix A

(Representative Project Photographs) for visual examples of methods and field crews at work. Other Parks, agencies and non-profit organizations learn about these methods through outreach and education.

Throughout the life of the Phase II-B project, the field crew leaders continued to improve upon the South Rim storage area where all of the project equipment, herbicide and gear are stored in a locked trailer. A large part of the program success is managing gear and equipment so it is easier for crews to get the job done. Although the methods and tools are paramount to completing tamarisk removal, the quality of food eaten while working is also critical. With input from crew leaders, the crew supervisor continued to improve the packing lists, menus, and food purchase lists in order to streamline the trip preparation process. The trip evaluations from volunteers contain detailed reports about how much they enjoyed the food and the creative way it was prepared for them.

The biggest challenge with the control methods continued to be the lack of a lightweight, sturdy hand saw with good quality, inexpensive replacement blades. Despite experimentation with various qualities of hand saws, the best choice to date is a Bahco 7" folding saw. However, the replacement blades cost as much as the saw itself and they bend and break easily. The saws typically only last a few trips, and then they begin to break as well. The field crew supervisor has had some success at returning the saws for full refund due to their short lifespan. The productivity and morale of volunteer workers plummets in the face of dull blades, so the project leader tried to keep spares on hand for every trip. The project leaders continue the search for the best hand saw available for backcountry sawyers and welcome any suggestions.

IV. Management Results

a. Results of recent data collection

Tamarisk Control Results

During Phase II-B project, crews removed 48.573 tamarisk trees including 38,555 seedlings, 6,877 saplings, and 3,141 mature trees from 108 hectares (267 acres) in Phase II-B project sites. Crews removed 13,694 m^2 of total tamarisk canopy cover from within the 30 project areas (Table 5. Tamarisk Control Summary, Figure 1. Tamarisk Treatment by Size Class). On each trip and at each project site, crew leaders analyzed the site and determined which control methods to use (Figure 2. Tamarisk Treatment by Method).

During the life of the project, crews completed work in all 30 project areas (Table 1. Phase II-B Project Areas List and Completion Status). Regardless of the current level of completion listed, all of the sites will require follow-up work in the form of seedling control, which will be completed with supplemental funding sources. The one area in particular that needs additional work is Granite Spring Canyon. While crews completed work within the project area boundary, the drainage continues upstream and work remains in the watershed. This is a logistically challenging area because there is no camp in the river corridor. Future project managers should consider backpacking into the area from Diamond Creek. The three areas that crews should return to for the next few years to remove seedling are National, Mohawk and Three Springs canyons.

Table 5. Tamarisk Control Summary

	Size Class			Control Method					Area Treated	
Park Area	**Seedlings**	**Saplings**	**Mature**	**Pulled**	**Cut / Girdle Combo**	**Girdle**	**Basal Bark**	**Cut Stump**	**Cover (m2)**	**Area Infested (m2)**
122 Mile Canyon L	2398	380	100	2149	1	0	0	728	447	17500
140 Mile Canyon	98	48	38	96	0	0	0	88	231	10000
148.5 Mile Spring	5	26	36	8	6	1	6	46	167	18252
151 Mile Spring	2	11	14	2				25	49	5000
190 Mile Canyon	470	212	155	454	1	0	0	382	601	12500
217 Mile Canyon	12	4	0	12	0	0	0	4	2	5000
221 Mile Spring	0	1	3	0	0	0	0	4	10	5000
221.5 Mile Creek	2	3	2	2	0	0	0	5	30	5000
222 Mile Canyon	39	17	20	29	0	0	0	47	137	25000
224 Mile Canyon	0	3	6	0	0	0	0	9	68	10000
Above Serpentine	12	6	12	4				26	53	35000
Agate Canyon	13	37	104	3	4			147	333	10000
Cedar Spring	394	24	8	397	0	0	0	29	37	10000
Flint Creek	1861	236	174	1650		1		620	466	95200
Granite Park Canyon	14338	609	195	14353	0	0	0	789	1038	55000
Granite Spring Canyon	115	237	173	56	0	1	0	468	639	37000
Honga Spring	19	58	41	21	1	0	0	96	209	6000
Horn Creek	42	113	17	3	0	0	0	169	129	26000
Mohawk Canyon	12077	398	127	12202	1	0	0	399	625	81500
National Canyon	327	682	134	176	1			966	965	55000
Prospect Canyon	5	12	15	4	1	0	0	27	93	15000
Ruby Canyon	12	33	19	8				56	131	45000
Salt Creek	54	25	6	51	0	0	0	34	46	16000
Salt Creek Spring	20	0	0	20	0	0	0	0	5	500
Sapphire Canyon	132	382	219	108		3		622	296	10000
Slate Creek	210	960	765	191	0	0	51	1693	3250	143000
Spring Canyon	29	48	63					140	458	25000
Spring East of Cedar	31	4	0	16				19	5	10000
Three Springs Canyon	4368	1745	369	3767	6	5	0	2704	2204	72000
Topaz Canyon	262	285	32	124	0	0	0	455	113	35400

	Size Class			Control Method					Area Treated	
Park Area	**Seedlings**	**Saplings**	**Mature**	**Pulled**	**Cut / Girdle Combo**	**Girdle**	**Basal Bark**	**Cut Stump**	**Cover (m2)**	**Area Infested (m2)**
Turquoise Canyon	38	87	171	19	216	3	0	58	552	5000
White Creek	1170	191	123	1174	0	0	0	310	305	179500
TOTALS	**38,555**	**6,877**	**3,141**	**37,099**	**238**	**14**	**57**	**11,165**	**13,694**	**1,080,352**

Figure 1. Tamarisk Treatment by Size Class

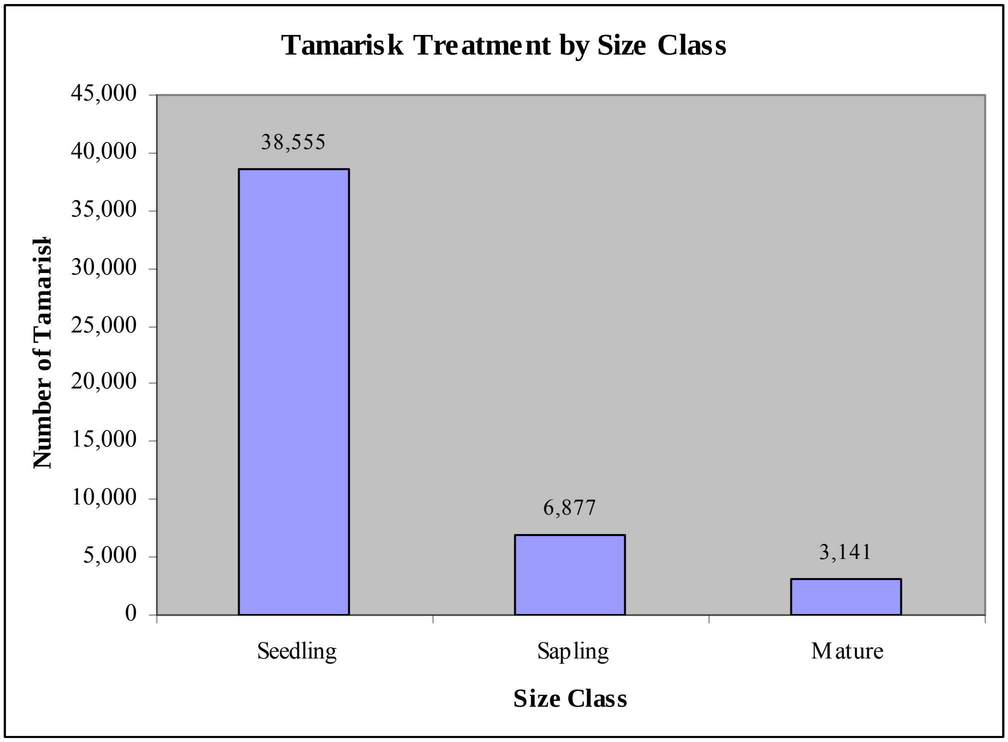
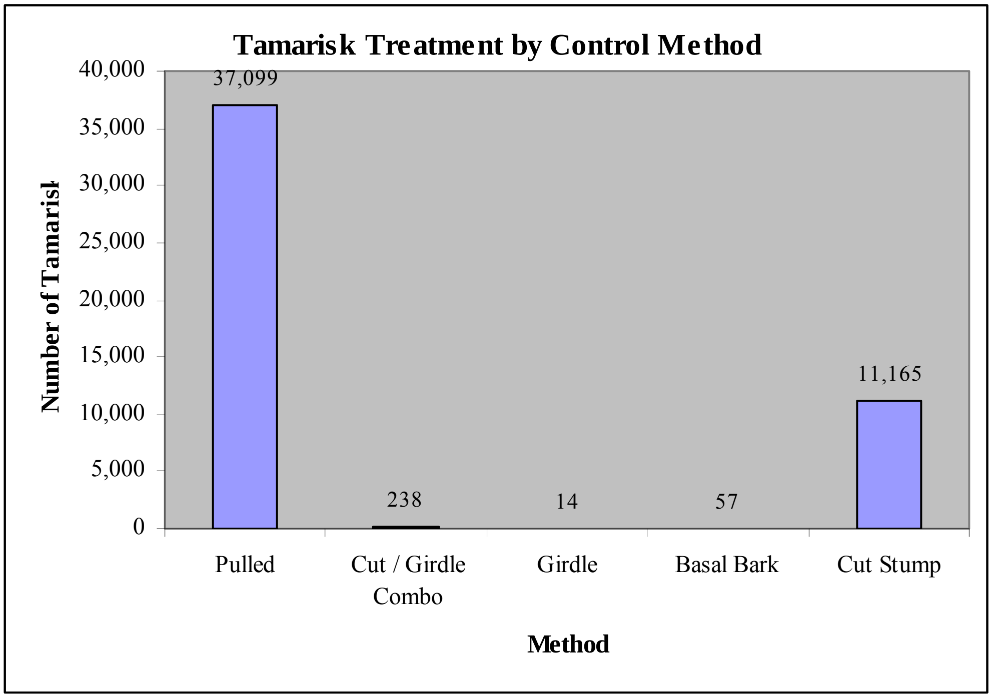


Figure 2. Tamarisk Treatment by Method



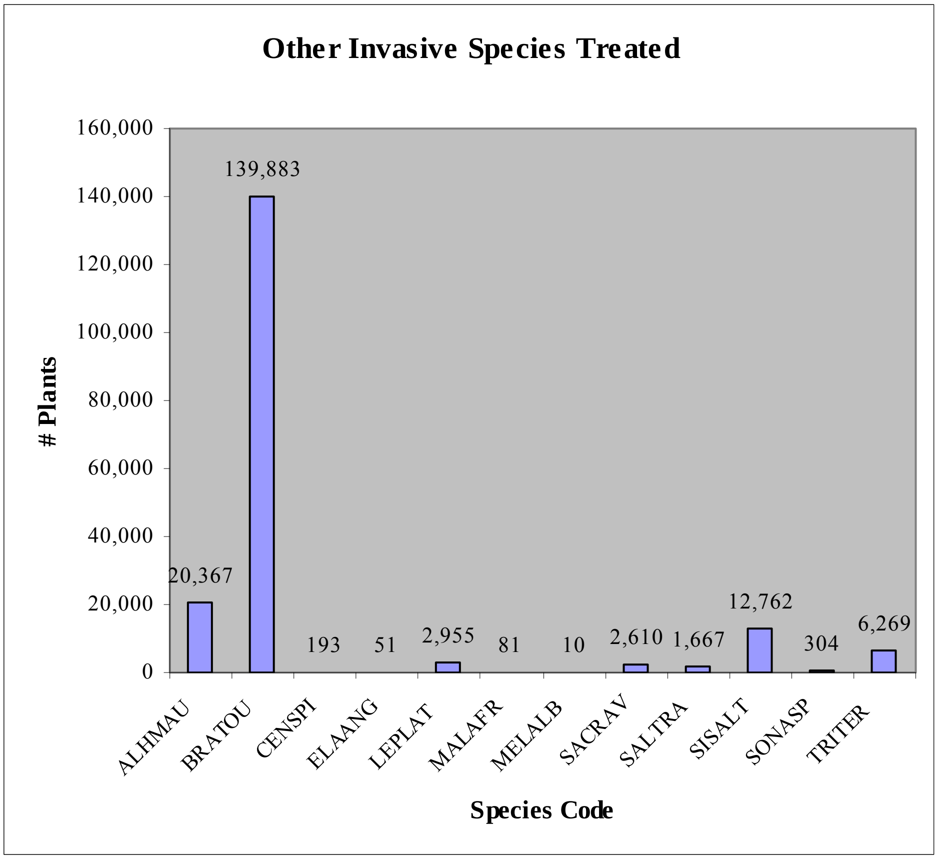
Other Invasive Species Control Results

In addition, crews also removed 187,152 individual plants of other invasive exotic species from project areas and the Colorado River Corridor on AWPF and matching river and backpacking trips (Table 6. Other Invasive Species Controlled, Figure 3. Other Invasive Species Treated). The majority of the plants were Sahara mustard, which were primarily controlled at Lees Ferry and in the upper portion of the river corridor. This work was done by individual volunteers and groups supervised by the AWPF project manager.

Table 6. Other Invasive Species Totals

Common Name	Scientific Name	Species Code	# Plants
Camelthorn	Alhagi maurorum	ALHMAU	20,367
Sahara mustard	Brassica tournefortii	BRATOU	139,883
Common sandbur	Cenchrus spiniflex	CENSPI	193
Russian olive	Elaeagnus angustifolia	ELAANG	51
Perennial peppergrass	Lepidium latifolium	LEPLAT	2,955
African mustard	Malcolmia africana	MALAFR	81
White clover	Melilotus alba	MELALB	10
Ravenna grass	Ravenna grass	SACRAV	2,610
Russian thistle	Salsola tragus	SALTRA	1,667
London rocket	Sisymbrium altissimum	SISALT	12,762
Sowthistle	Sonchus asper	SONASP	304
Puncture vine	Tribulus terrestris	TRITER	6,269
		TOTAL:	187,152

Figure 3. Other Invasive Species Treated



Tamarisk Retreatment Results

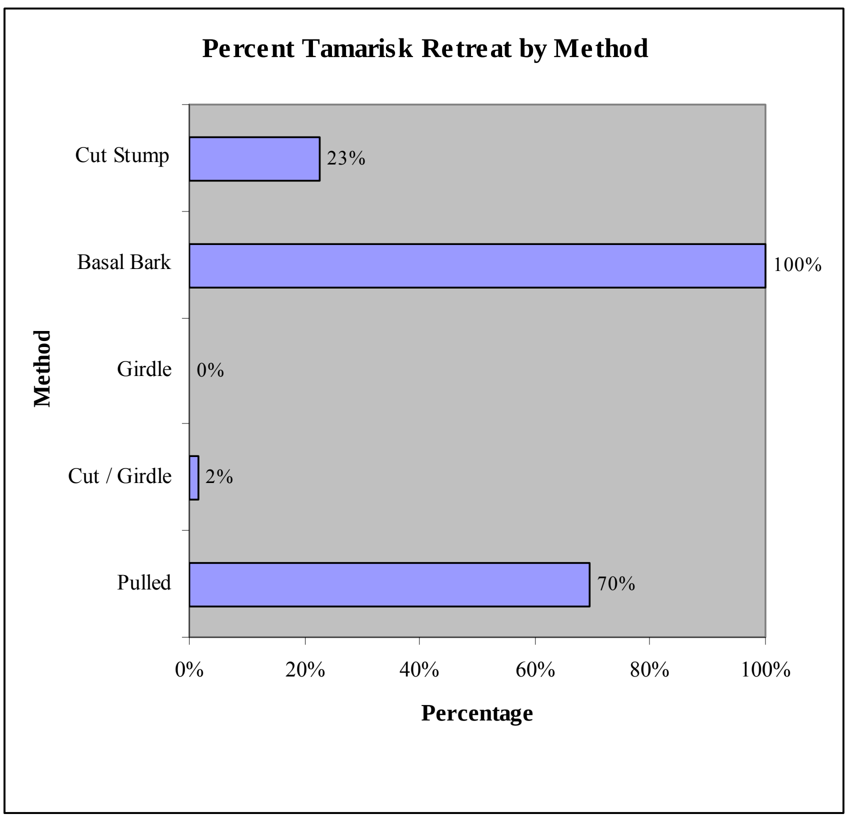
Retreatment rates are driven by how long it has been since the first treatment and how long since the last flash flooding event. Data from tamarisk retreatment results is higher than expected, with over 58% of the treatment occurring after the initial treatment (Table 7. Tamarisk Retreatment Results, Figure 4. Tamarisk Retreatment Results by Method). This almost entirely consists of seedlings in project areas that flash flooded following the preliminary treatment, likely from the seeds that were dormant in the soil. The largest amount of retreatment occurred in Mohawk and Granite Park Canyons, with 24,716 seedlings pulled following the initial visits to those areas. When seedlings are removed from retreatment data, the rate of retreatment for Phase II-B areas is 20%, which is slightly above the 7% retreatment rate from Phase I, and nearly double the 10% retreatment rate from Phase II-A. Of that 20%, crews retreated 15% of the saplings and 5% of mature plants, which is about average and some of this is likely due to new saplings emerging on the site between visits. With adult trees, the more time that passes between the initial cutting and the herbicide treatment, the less effective the herbicide is at penetrating plant cells. This time varies depending on how fast sawyers are working in ratio to how many sprayers are available, and how densely tamarisk infests an area. On a few dates, rain prevented the applicators from applying herbicide; thus, the sapling and mature trees were more likely to resprout.

A third factor is that GRCA vegetation crews are not currently using herbicide mixed with dye. This original decision was made in order to cut down on the visual impact of the tamarisk work to recreational backcountry users. However, when dye is added to the surfactant, both cutters and sprayers are certain when a stump or area has been sprayed. This cuts down on chances of missing stumps and makes it a safer environment for cutters, sprayers and recreational users, as they know when to stay away from an area that has been sprayed with herbicide. In the future, GRCA staff may want to reevaluate whether or not to use dye in herbicide mixtures, as many dyes fade within days of application and may prove to be helpful for both project effectiveness and safety.

Table 7. Tamarisk Retreatment Results

	# of Plants	Seedlings	Saplings	Mature	Pulled	Cut / Girdle	Girdle	Basal Bark	Cut Stump
# Initially Treated	20186	12198	5378	2610	11290	232	14	0	8650
# Retreated	28387	26357	1499	531	25811	4	0	57	2515
Tamarisk Totals	48573	38555	6877	3141	37101	236	14	57	11165
% Retreated	58%	68%	22%	17%	70%	2%	0%	100%	23%

Figure 4. Tamarisk Retreatment Results by Method



Herbicide Use

Throughout the Phase II-B project, crews used a total of 30.11 gallons of mixed herbicide and 9.06 gallons of actual herbicide product in the project sites (Table 8. Herbicide Use).

Table 8. Herbicide Use

Common Name	Scientific Name	Herbicide Type	Mixed Herbicide Used (gallons)	% Herbicide in Mixture	Actual Herbicide Used (gallons)
Tamarisk	*Tamarix ramosissima*	Garlon 3a	6.10	50	3.05
Tamarisk	*Tamarix ramosissima*	Garlon 4	23.66	25	5.92
Russian olive	*Elaeagnus angustifolia*	Garlon 4	0.35	25	0.09
		Herbicide Totals:	**30.11**		**9.06**

Volunteer Summary

Volunteers have been an absolutely critical component of the tamarisk management and tributary restoration project's success and accomplishments. The project has been extremely fortunate to attract an amazing crew of loyal and highly skilled volunteers. Literally, the project would be impossible without this contribution of time, expertise, and unmatched enthusiasm. From the spring of 2006 through the summer of 2008, volunteers donated a total of 11,207 hours to this project (Table 9. Volunteer Contribution to Project). These hours are valued at $18.77 per hour according to NPS guidelines, for a total matching contribution to the management portion of this project of $210,355.

The hours are broken down into different categories. The management portion of the project accrued 6,406 hours in tamarisk backpacking trips, 1,017 hours on tamarisk river trips, and 3,550 hours on river corridor invasive plant control on NPS matching trips. The monitoring portion of the project accumulated 234 hours, which is primarily from the valuable time spent collecting and identifying plants from our project areas by Desert Botanical Garden herbarium curator and senior research botanist, Wendy Hodgson. The volunteer hours for Phase II-B are fewer than those of Phase II-A, which is because on the tamarisk management river trips, the goal was to have even distribution between NPS and Hualapai crew leaders, leading to fewer spaces for volunteers on each trip. With overlap between Phase II-A and Phase II-B, some of the previously submitted Phase II-B reports contained volunteer hours that were included in the Final Phase II-A report (Schwantes, Miller, Wu, Thompson, McGrath, Hodgson 2006 and 2007, Williams, McMaster, Malen, Hahn, Boyter, Walls). Although folks worked on both phases during those periods, double listing of volunteer hours needed to be corrected, which it is in the table below.

Table 9. Volunteer Contribution to Project

Name	Start Date	End Date	Hours	Project
Aaron Devine	10/20/2007	10/27/2007	73	Tamarisk Backpacking
Akasha Faist	3/4/2007	3/10/2007	71	Tamarisk Backpacking
Akua Karen	10/20/2007	10/27/2007	73	Tamarisk Backpacking
Alan Neill	4/1/2008	4/15/2008	7	River Exotics
Alex Kimball	4/1/2008	4/15/2008	7	River Exotics
Alex Oettinger	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Alora Anderson	6/22/2006	6/28/2006	6	River Exotics
Amy Prince	5/2/2006	5/7/2006	51	Tamarisk River

Name	Start Date	End Date	Hours	Project
Amy Prince	5/8/2006	5/21/2006	129	Tamarisk River
Amy Prince	5/11/2007	5/22/2007	116	River Exotics
Amy Prince	4/29/2008	4/29/2008	4	Rare, Native and Exotic Inventory
Andrew Geppert	11/23/2007	11/29/2007	35	Tamarisk Backpacking
Anthony Ayers	3/28/2008	3/29/2008	13	Lees Ferry Exotics
Ben Dannelley	2/15/2008	2/18/2008	40	Lees Ferry Exotics
Betty June Kahrl	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Bill Crane	3/28/2008	3/28/2008	5	Lees Ferry Exotics
Bob Cheesman	11/4/2006	11/6/2006	32	Tamarisk Backpacking
Bob Cheesman	1/31/2007	2/7/2007	69	Tamarisk Backpacking
Bob Cheesman	2/20/2007	3/7/2007	144	Tamarisk River
Brian (Avery) McChristian	3/10/2007	3/16/2007	94	Tamarisk Backpacking
Caleb Belford	3/21/2007	3/28/2007	76	Tamarisk Backpacking
Caroline Williams	1/4/2008	1/11/2008	82	Tamarisk Backpacking
Casey DeCesari	3/28/2008	3/29/2008	8	Lees Ferry Exotics
Celia Southwick	3/30/2007	3/30/2007	3	Lees Ferry Exotics
Chad Morris	10/27/2007	10/29/2007	30	Tamarisk Backpacking
Chad Wanstrath	6/22/2006	6/28/2006	8	River Exotics
Chelsea Arndt	4/1/2008	4/15/2008	7	River Exotics
Claire Ramirez	3/28/2008	3/29/2008	8	Lees Ferry Exotics
Clifford Holtz	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Clifford Holtz	3/7/2008	3/10/2008	28	Lees Ferry Exotics
Clifford Holtz	3/28/2008	3/29/2008	15	Lees Ferry Exotics
Clinton Peters	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Conor Wakeman	1/4/2008	1/11/2008	80	Tamarisk Backpacking
Curt Howell	11/23/2007	11/29/2007	35	Tamarisk Backpacking
Curtis Moore	3/28/2008	3/29/2008	20	Lees Ferry Exotics
Dan Shein	3/21/2007	3/28/2007	85	Tamarisk Backpacking
Dan Shein	2/15/2008	2/18/2008	36	Lees Ferry Exotics
Dave Backcountry	9/20/2006	9/20/2006	6	Tamarisk Backpacking
David Bosquet	3/10/2007	3/11/2007	18	Lees Ferry Exotics
Dawn Goldman	9/27/2006	10/1/2006	49	Tamarisk Backpacking
Dawn Goldman	11/2/2007	11/4/2007	20	Tamarisk Backpacking
Dean Reese	9/20/2006	9/21/2006	12	Tamarisk Backpacking
Dean Wadsworth	9/17/2006	9/24/2006	78	Tamarisk Backpacking
Dean Wadsworth	11/4/2006	11/7/2006	42	Tamarisk River
Dean Wadsworth	12/5/2006	12/13/2006	82	Tamarisk Backpacking
Dean Wadsworth	3/21/2007	3/28/2007	85	Tamarisk Backpacking
Dean Wadsworth	11/2/2007	11/10/2007	86	Tamarisk Backpacking
Dean Wadsworth	3/23/2008	4/1/2008	95	Tamarisk Backpacking
Deanna Jones	4/1/2008	4/15/2008	7	River Exotics
Dewey Moffat	4/1/2008	4/15/2008	7	River Exotics
DH Nam	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Diane LaRue	11/2/2007	11/4/2007	28	Tamarisk Backpacking
Don Arkin	11/2/2007	11/4/2007	20	Tamarisk Backpacking
Donald Brubaker	1/3/2007	1/13/2007	103	Tamarisk Backpacking
Eleanor Curran	9/21/2007	9/25/2007	70	Tamarisk Backpacking
Eli Morgan	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Ellen Miller	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Emily Palmquist	3/9/2007	3/11/2007	17	Lees Ferry Exotics

Name	Start Date	End Date	Hours	Project
Erin Hoelting	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Ethan Hirsch-Taber	3/7/2008	3/10/2008	30	Lees Ferry Exotics
Forrest Allison	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Frank Hays	5/8/2006	5/22/2006	128	Tamarisk River
Gavin Boughner	6/22/2006	6/28/2006	8	River Exotics
Gavin Jeffers	11/23/2007	11/29/2007	35	Tamarisk Backpacking
Geoff Carpenter	4/1/2008	4/15/2008	7	River Exotics
Gisela Kluwin	11/8/2006	11/15/2006	62	Tamarisk Backpacking
Gisela Kluwin	2/20/2007	3/7/2007	144	Tamarisk River
Gisela Kluwin	10/10/2007	10/12/2007	22	Tamarisk Backpacking
Gisela Kluwin	2/15/2008	2/18/2008	30	Lees Ferry Exotics
Glenn Rink	3/30/2007	3/30/2007	3	Lees Ferry Exotics
Grand Canyon Youth	6/10/2007	6/21/2007	125	River Exotics
Grant Durham	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Greg Woodall	3/30/2007	3/30/2007	5	Lees Ferry Exotics
Greg Woodall	4/1/2008	4/15/2008	10	River Exotics
Gretchen Allison	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Guides Training Seminar	4/2/2006	4/2/2006	31	River Exotics
Guides Training Seminar	4/2/2007	4/20/2007	144	River Exotics
Helen Walker	9/22/2007	2/25/2007	16	River Exotics
Heidi Rockwood	9/22/2007	9/25/2007	16	River Exotics
Ian Torrence	3/21/2007	3/28/2007	87	Tamarisk Backpacking
Insok Hwang	3/7/2008	3/10/2008	70	Lees Ferry Exotics
James Holts	11/1/2007	11/10/2007	96	Tamarisk Backpacking
James Wyatt	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Jamie Braxton	3/7/2008	3/10/2008	28	Lees Ferry Exotics
Jamie Harding	11/23/2007	11/29/2007	35	Tamarisk Backpacking
Jan Kaplan	9/22/2007	9/25/2007	16	River Exotics
Jana Gunnell	9/22/2007	9/25/2007	16	River Exotics
Jared Hart	11/14/2007	11/14/2007	12	Tamarisk Backpacking
Jared Silverman	9/5/2006	9/22/2006	6	Tamarisk River
Jared Weaver	4/1/2008	4/15/2008	7	River Exotics
Jason Hogan	1/3/2008	1/12/2008	93	Tamarisk Backpacking
Jay Healy	4/1/2008	4/15/2008	7	River Exotics
Jeanny Bosack	6/22/2006	6/28/2006	7	River Exotics
Jeff Schulze	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Jenn Arkle	4/1/2008	4/15/2008	7	River Exotics
Jennifer Bilyard	9/22/2007	9/25/2007	16	River Exotics
Jennifer Whittam	1/4/2008	1/11/2008	80	Tamarisk Backpacking
Jess Page	3/29/2006	4/4/2006	45	Tamarisk Backpacking
Jess Page	11/4/2006	11/7/2006	39	Tamarisk River
Jesse Berube	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Jessica Schweiters	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Jessica Schwieters	11/23/2007	11/29/2007	35	Tamarisk Backpacking
Jessie Paulson	4/1/2008	4/15/2008	7	River Exotics
Jim McCarthy	3/28/2008	3/29/2008	9	Lees Ferry Exotics
Joanna Lett	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Joe Jonakin	11/5/2006	11/16/2006	102	Tamarisk Backpacking
Joe Longbotham	3/7/2008	3/10/2008	30	Lees Ferry Exotics
Joe Welke	2/18/2007	2/23/2007	62	Tamarisk Backpacking

Name	Start Date	End Date	Hours	Project
Joe Welke	3/4/2007	3/10/2007	71	Tamarisk Backpacking
John Clay	2/15/2008	2/18/2008	60	Lees Ferry Exotics
John Evans	3/28/2008	3/28/2008	5	Lees Ferry Exotics
John Gray	3/28/2008	3/28/2008	6	Lees Ferry Exotics
Johnny Sattigerald	4/1/2008	4/15/2008	7	River Exotics
Jonathan Balise	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Jordan Messerer	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Jose Perez	3/21/2007	3/28/2007	85	Tamarisk Backpacking
Joseph Jonakin	3/20/2007	3/29/2007	136	Tamarisk Backpacking
Josh Saritea	4/1/2008	4/15/2008	7	River Exotics
Joy Wolf	3/30/2007	3/30/2007	3	Lees Ferry Exotics
Justin Divine	3/23/2008	4/1/2008	90	Tamarisk Backpacking
Kalina Cox	11/7/2006	11/16/2006	72	Tamarisk Backpacking
Kate Thompson	1/4/2008	1/11/2008	80	Tamarisk Backpacking
Katie Proctor	4/1/2008	4/15/2008	7	River Exotics
Kelly McGettigan	4/1/2008	4/15/2008	7	River Exotics
Kelly Miller	3/7/2008	3/10/2008	28	Lees Ferry Exotics
Kelly Rowell	5/11/2007	5/21/2007	110	River Exotics
Kelly Williams	4/14/2006	4/17/2006	40	Tamarisk Backpacking
Kelsey Forrest	8/22/2006	8/31/2006	109	River Exotics
Kerry Miller	10/27/2007	10/29/2007	30	Tamarisk Backpacking
Klaus Bielke	3/28/2008	3/29/2008	18	Lees Ferry Exotics
Kristen Caldon	3/21/2007	3/28/2007	76	Tamarisk Backpacking
Kristin Huisinga	3/30/2007	3/30/2007	3	Lees Ferry Exotics
Kristin Huisinga	3/28/2008	3/28/2008	5	Lees Ferry Exotics
Kurt Caswell	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Larry Kahrl	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Laura Sparks	1/4/2008	1/11/2008	80	Tamarisk Backpacking
Laura Wade	6/22/2006	6/28/2006	8	River Exotics
Laurel Beth McLean	1/3/2008	1/12/2008	93	Tamarisk Backpacking
Laurel J. Herrmann	8/29/2006	9/8/2006	104	River Exotics
Laurel J. Herrmann	9/22/2007	9/25/2007	16	River Exotics
LeighAnn Meith	3/7/2008	3/10/2008	30	Lees Ferry Exotics
Leon Bassen	11/1/2006	11/16/2006	72	Tamarisk Backpacking
Lisa Hahn	5/2/2006	5/7/2006	55	Tamarisk River
Loie Evans	8/22/2006	8/31/2006	109	River Exotics
Loie Evans	3/28/2008	3/28/2008	5	Lees Ferry Exotics
Lou Lorber	2/20/2007	3/7/2007	144	Tamarisk River
Lou Lorber	3/20/2007	3/29/2007	92	Tamarisk Backpacking
Lou Lorber	10/19/2007	10/27/2007	78	Tamarisk Backpacking
Lynn Pratte	6/22/2006	6/28/2006	7	River Exotics
Lynne Silva	3/9/2007	3/11/2007	22	Lees Ferry Exotics
Macey Wilson	6/22/2006	6/28/2006	8	River Exotics
Margaret Corley	3/9/2007	3/11/2007	17	Lees Ferry Exotics
Maria Clementi	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Maria Clementi	3/21/2007	3/28/2007	76	Tamarisk Backpacking
Mark Lawler	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Mary Boyter	3/9/2007	3/11/2007	24	Lees Ferry Exotics
Mary Boyter	2/15/2008	2/18/2008	66	Lees Ferry Exotics
Matt Halter	4/1/2008	4/15/2008	7	River Exotics

Name	Start Date	End Date	Hours	Project
Matt Mason	11/13/2007	11/20/2007	74	Tamarisk Backpacking
Matt Mason	3/23/2008	4/1/2008	85	Tamarisk Backpacking
Matt Walsburger	4/1/2008	4/15/2008	7	River Exotics
Matthew Dunbar	3/28/2008	3/29/2008	8	Lees Ferry Exotics
Melissa McMaster	5/4/2007	5/11/2007	87	River Exotics
Mikaela Blake	4/1/2008	4/15/2008	7	River Exotics
Mike Boscarino	3/29/2006	4/5/2006	87	Tamarisk Backpacking
Mike Boscarino	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Mike Taylor	10/19/2007	10/27/2007	76	Tamarisk Backpacking
Mike Thiessen	3/7/2008	3/10/2008	42	Lees Ferry Exotics
Miles Bosquet	3/10/2007	3/11/2007	18	Lees Ferry Exotics
Nada Jawahery	11/23/2007	11/29/2007	35	Tamarisk Backpacking
Nate Jordon	4/1/2008	4/15/2008	7	River Exotics
Nate Reynolds	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Nick (Charles) Awalt	8/29/2006	9/8/2006	104	River Exotics
Nick (Charles) Awalt	9/22/2007	9/25/2007	16	River Exotics
Nikhil Deshpande	11/23/2007	11/29/2007	35	Tamarisk Backpacking
Olivia Rathbone	10/24/2006	10/31/2006	74	Tamarisk Backpacking
Omkar Mujumdar	11/23/2007	11/29/2017	35	Tamarisk Backpacking
Patricia Tertell	1/4/2008	1/11/2008	80	Tamarisk Backpacking
Patty Hubley	3/21/2007	3/28/2007	85	Tamarisk Backpacking
Paul Smolenyak	3/30/2007	3/30/2007	3	Lees Ferry Exotics
Peter Huntoon	4/1/2008	4/15/2008	7	River Exotics
Peter O'Brien	12/5/2006	12/13/2006	82	Tamarisk Backpacking
Peter Veals	6/22/2006	6/28/2006	8	River Exotics
Rachel Yang	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Rick Backcountry	9/16/2006	9/16/2006	4	Tamarisk Backpacking
Robert Southwick	3/30/2007	3/30/2007	3	Lees Ferry Exotics
Ronja Gibson	3/7/2008	3/10/2008	28	Lees Ferry Exotics
Ross Kantra	3/7/2008	3/10/2008	24	Lees Ferry Exotics
Ross Kantra	3/28/2008	3/29/2008	15	Lees Ferry Exotics
Ryan Bell	9/15/2006	9/24/2006	105	Tamarisk Backpacking
Sally Underwood	8/29/2006	9/8/2006	104	River Exotics
Sam Townsend	1/3/2008	1/12/2008	93	Tamarisk Backpacking
Sarah Carlson	6/22/2006	6/28/2006	6	River Exotics
Sarah Goss	3/7/2008	3/10/2008	30	Lees Ferry Exotics
Sarah Howell	1/3/2008	1/12/2008	93	Tamarisk Backpacking
Sarah Kuhn	3/28/2008	3/28/2008	5	Lees Ferry Exotics
Sarah Topp	5/3/2007	5/12/2007	107	River Exotics
Sari Nesbit	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Sari Nesbit	11/23/2007	11/29/2007	35	Tamarisk Backpacking
Savanna Reeves	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Shane Edwards	4/1/2008	4/15/2008	7	River Exotics
Shannon McCloskey	3/9/2007	3/11/2007	24	Lees Ferry Exotics
Sharon Massey	3/7/2008	3/10/2008	70	Lees Ferry Exotics
Stacey Hamburg	3/28/2008	3/29/2008	8	Lees Ferry Exotics
Stephen Polk	3/21/2007	3/28/2007	85	Tamarisk Backpacking
Steve Delaney	11/6/2006	11/16/2006	80	Tamarisk Backpacking
Steve Delaney	3/21/2007	3/28/2007	85	Tamarisk Backpacking
Steven Schooler	11/3/2007	11/9/2007	66	Tamarisk Backpacking

Name	Start Date	End Date	Hours	Project
Susan Melcher	3/7/2008	3/10/2008	44	Lees Ferry Exotics
Trevor Piersol	1/4/2008	1/11/2008	80	Tamarisk Backpacking
Trevor Williams	11/18/2006	11/25/2006	77	Tamarisk Backpacking
Tyler McElroy-Yeider	6/22/2006	6/28/2006	8	River Exotics
Tyler Zander	4/8/2006	4/8/2006	15	Lees Ferry Exotics
Tyler Zander	11/3/2007	11/9/2007	70	Tamarisk Backpacking
Val Malutin	3/29/2006	4/5/2006	85	Tamarisk Backpacking
Val Malutin	1/17/2007	1/23/2007	64	Tamarisk Backpacking
Val Malutin	3/9/2007	3/11/2007	24	Lees Ferry Exotics
Val Malutin	11/6/2007	11/9/2007	31	Tamarisk Backpacking
Wendy Hodgson	5/8/2006	5/22/2006	135	Tamarisk River
Wendy Hodgson	5/3/2007	5/22/2007	200	River Exotics
Wendy Hodgson	9/22/2007	2/26/2007	70	Rare, Native and Exotic Inventory
Wendy Hodgson	6/1/2008	10/10/2008	160	Rare, Native and Exotic Inventory
Wilhelmus Philipsen	11/13/2007	11/20/2007	74	Tamarisk Backpacking
William Sohveymah	4/1/2008	4/15/2008	7	River Exotics
Willie Hall	3/21/2007	3/28/2007	85	Tamarisk Backpacking
Zachary Kaylor	1/3/2008	1/12/2008	93	Tamarisk Backpacking
Zane de la Cruz	3/28/2008	3/29/2008	8	Lees Ferry Exotics
		Total Volunteer Hours Backpacking	**6406**	
		Total Volunteer Hours River	**1017**	
		Total Volunteer Hours Inventory & Monitoring	**234**	
		River Corridor Exotics	**3550**	
		TOTAL VOLUNTEER HOURS	**11207**	

During the course of this project there has been a great improvement in the essential task of volunteer recruitment, including the creation of a volunteer coordinator position. GCNPF and Grand Canyon Trust (GCT) initially shared the position, but in 2006, GCNPF created a separate position to recruit and manage the volunteer projects. In May of 2006, GCNPF hired Terra Crampton as the volunteer coordinator. Terra was very meticulous and made significant contributions to the development of the volunteer recruitment and paperwork process and improved communications with the park's part-time volunteer coordinator, Lisa Collins. Terra and the crew supervisor worked to refine and downsize the paperwork volunteers had to complete before each trip, based on input from volunteers and crew leaders. Terra moved into a fundraising position, and John Canfield, a former volunteer from the project, took over the time intensive duties of recruiting, contacting and preparing volunteers for backpacking trips in the spring of 2007. It was subsequently difficult for GCNPF to keep the volunteer coordinator position filled, which made consistency tricky. GRCA created a full-time volunteer coordinator position, and in 2007, GCT created a full time volunteer coordinator position. These positions became crucial for the success of this project. The project supervisor for GRCA, Kate Watters, moved to GCT in the volunteer coordinator position in December 2007. While this was a great loss for the park, it was beneficial for this project and future work in these project areas. The GCT website (http://www.gcvolunteers.org), which has information about each trip, was re-designed and continues to be the primary source for volunteer recruitment.

The grant provided funds to give uniquely designed tee shirts and bandanas to volunteers who donated their time on backpacking or river trips, as a small token of the many hours of hard labor they contributed. Project leaders sent thank you cards to every person who helped with the project.

The wonderful myriad of volunteers is the lifeblood of this project and the community of veteran "tammy wackers" continued to widen as this phase progressed. By involving volunteers in many aspects of tamarisk management and monitoring, the project has birthed many citizen scientists, which widens the significance of the project from restoration to education. GRCA staff and crew leaders are constantly amazed by the positive influence volunteers have on the Vegetation Program.

Many volunteers have life-changing experiences on tamarisk management trips and often return to do several trips a year or even serve as future crew leaders. For example, Kelly McGrath, a teacher who brought her Oregon high school students out for a backpacking tamarisk control trip in South Canyon, quit her job as a teacher and served the program in the fall of 2006 in an official capacity as the Polk Intern. She wrote an article about her experience, which will be published in an upcoming edition of Nature Notes.

Wildlife Observations

Crews began collecting information on wildlife distribution and activity at all of the project areas in 2006. They recorded observations of wildlife species (including mammals, birds, insects, reptiles and amphibians) by common name and a description of the activity. Table 10 (Wildlife Observations) includes observations from both the management and the monitoring trips for the Phase II-B project areas. This qualitative data on wildlife species presence in side canyons has proven valuable to update distribution information for Park wildlife biologists.

Table 10. Wildlife Observations

Date	Observer	Location	Wildlife Species	Activity
10/2/2006	Steve Till	122 Mile Canyon L	snake - 10" tan with dark brown ovals on back with dots	Hauling for the hills
10/3/2006	Kate Watters	122 Mile Canyon L	Pink rattler	Languidly rattling in the morning sun
5/10/2006	Kevin Dickerson	140 Mile Canyon	Blue Grey Gnatcatcher	Flying
5/10/2006	Kevin Dickerson	140 Mile Canyon	Red spotted toad tadpoles	Swimming
5/10/2006	Kevin Dickerson	140 Mile Canyon	Canyon Wren	Flying
5/10/2006	Kevin Dickerson	140 Mile Canyon	Canyon Tree Frog and Tadpoles	Hanging out in creek
5/10/2006	Kevin Dickerson	140 Mile Canyon	Turkey Vulture	Soaring
5/10/2006	Kevin Dickerson	140 Mile Canyon	Mourning Dove	Flying and nesting
5/10/2006	Kevin Dickerson	140 Mile Canyon	Black Throated Grey Warbler	Flying
5/10/2006	Kevin Dickerson	140 Mile Canyon	Side blotched lizard	Crawling on rock
5/10/2006	Kate Watters	140 Mile Canyon	Flame Skimmer Dragonfly	Flying over creek, landing on veg
5/10/2006	Kevin Dickerson	140 Mile Canyon	Says Phoebe	Flying
5/10/2006	Lori Makarick	140 Mile Canyon	White Moths	Flying and landing
5/10/2006	Kevin Dickerson	140 Mile Canyon	Tiger Swallowtail	Flying and landing
5/10/2006	Kevin Dickerson	140 Mile Canyon	Red Tailed Hawk	Soaring
5/10/2006	Kevin Dickerson	140 Mile Canyon	Western Whiptails	Crawling on rocks
5/10/2006	Kevin Dickerson	140 Mile Canyon	Ringtail	Scat under ledge

Date	Observer	Location	Wildlife Species	Activity
5/10/2006	Kevin Dickerson	140 Mile Canyon	2 Male Bighorns	Climbing up ledges
10/4/2006	Kate Watters	140 Mile Canyon	Red-spotted toad and Side-blotched lizard	Hopping and running
10/4/2006	Kate Watters	140 Mile Canyon	Bark scorpion	Fleeing and scurrying
5/14/2007	Lori Makarick	140 Mile Canyon	Swallowtail Butterfly	Soaring
5/14/2007	Kate Watters	140 Mile Canyon	Tadpoles	Swimming in pools
5/15/2006	Lori Makarick	190 Mile Canyon	Flame Skimmer Dragonfly- HUGE!	Flying over creek, landing on veg
5/20/2006	Lori Makarick	221.5 Mile Creek	Whiptail Lizard	Crawling on rocks
5/20/2006	Lori Makarick	222 Mile Canyon	Yellow Butterflies	Flying
5/20/2006	Lori Makarick	222 Mile Canyon	Blue Damsel Flies	Flying
5/20/2006	Lori Makarick	222 Mile Canyon	Gray fox	Climbing up ledges
5/20/2006	Lori Makarick	222 Mile Canyon	Red Dragonflies	Flying
5/20/2006	Lori Makarick	222 Mile Canyon	Mourning Dove	Flying
5/20/2006	Lori Makarick	222 Mile Canyon	Red Spotted Toad	Swimming
10/13/2006	Kate Watters	222 Mile Canyon	Tadpoles and red-spotted toads	Swimming, hopping and that awkward stage between the two
5/20/2006	Steve Till	224 Mile Canyon	2 female bighorn, 1 dead baby lamb bighorn, and 2 lambs	Walking up canyon
10/13/2006	Loren Bell	224 Mile Canyon	Grey fox	Walking up canyon - unhurried and unafraid
5/19/2006	Kate Watters	225.5 Mile Canyon	Juvenile Chuckwallas	Running away
5/16/2006	Lori Makarick	Granite Park Canyon	Bees	Lots of bees on the tamarisk and acacia
5/16/2006	Lori Makarick	Granite Park Canyon	Whiptail Lizards	Hanging out
5/16/2006	Lori Makarick	Granite Park Canyon	Red Spotted Toads	Hopping in creek
10/10/2006	Kari Malen	Granite Park Canyon	Scorpion	Running
5/20/2007	Kate Watters	Granite Park Canyon	Ash-throated flycatcher	Flying, singing from acacias
5/20/2007	Lisa Hahn	Granite Park Canyon	Peregrine falcon	Soaring over sidecanyon
5/20/2007	Kate Watters	Granite Park Canyon	Western tanager	Flying and calling from mesquite branches
5/20/2007	Wendy Hodgson	Granite Park Canyon	Gila monster	Seeking refuge under a creosote bush (Larrea tridentata)
5/20/2007	Lori Makarick	Granite Park Canyon	Red-spotted toad	Hopping
10/12/2006	Loren Bell	Granite Spring Canyon	Tarantula	Freaking out
10/12/2006	Kate Watters	Granite Spring Canyon	Red-spotted tadpoles	Swimming
10/12/2006	Kari Malen	Granite Spring Canyon	Centipede	Crawling
10/7/2006	Steve Till	Honga Spring	Many-tailed Swallowtail	Flying
10/6/2006	Kate Watters	Mohawk Canyon	Monarch butterfly	Flying
10/6/2006	Kari Malen	Mohawk Canyon	Tomato horn-worm	Eating
10/6/2006	Kate Watters	Mohawk Canyon	Millipede	Crawling on rock
10/6/2006	Kate Watters	Mohawk Canyon	Canyon wren	Chirping
10/6/2006	Loren Bell	Mohawk Canyon	Speckled rattlesnake	Traveling
10/7/2006	Steve Till	Mohawk Canyon	Grand Canyon pink rattle snake	Lounging in cool, wet ground near the stream
5/16/2007	Lori Makarick	Mohawk Canyon	Damselflies	Mating on scratchgrass
5/16/2007	Kate Watters	Mohawk Canyon	Canyon tree frog	Hopping along
5/16/2007	Kate Watters	Mohawk Canyon	Hummingbird	Drinking from the stream

Date	Observer	Location	Wildlife Species	Activity
5/16/2007	Kate Watters	Mohawk Canyon	Hummingbird	Drinking nectar from a cardinal monkeyflower (Mimulus cardinalis) flower
5/16/2007	Kate Watters	Mohawk Canyon	Water boatmen aquatic insects	Swimming in pools
5/16/2007	Lori Makarick	Mohawk Canyon	8 Red spotted toads	Hopping
5/16/2007	Kate Watters	Mohawk Canyon	Mexican amberwing dragonfly	Hovering above the creek
5/16/2007	Kate Watters	Mohawk Canyon	Black phoebe	Catching insects along the creek
5/16/2007	Kate Watters	Mohawk Canyon	Tadpoles	Swimming in pools
5/16/2007	Kate Watters	Mohawk Canyon	Grand Canyon Pink rattlesnake	Climbing on a rock and slithering in the grass
5/16/2007	Kate Watters	Mohawk Canyon	Grand Canyon Pink rattlesnake	Eating a songbird
5/16/2007	Kate Watters	Mohawk Canyon	Red-tailed hawk	Circling in the sky
5/17/2007	Lori Makarick	Mohawk Canyon	Cabbage white butterfly	Soaring along creek
5/17/2007	Kate Watters	Mohawk Canyon	Bewik's wren	Chirping
5/17/2007	Kate Watters	Mohawk Canyon	Canyon wren	Perched and calling
5/17/2007	Lori Makarick	Mohawk Canyon	Whiptail lizard	Journeying through tamarisk kill site
5/11/2006	Lori Makarick	National Canyon	Red Spotted Toads	Lounging near creek
5/11/2006	Lori Makarick	National Canyon	Whiptail Lizard	Crawling on rocks
5/12/2006	Kevin Dickerson	National Canyon	Blue Grey Gnatcatcher	Flying and landing
5/12/2006	Kevin Dickerson	National Canyon	Belted Kingfisher	Flying and landing
5/12/2006	Kevin Dickerson	National Canyon	Canyon Tree Frog	Hopping
5/12/2006	Kevin Dickerson	National Canyon	Red Spotted Toad	Hopping
5/12/2006	Kevin Dickerson	National Canyon	Western Whiptail	Lounging
5/12/2006	Kevin Dickerson	National Canyon	Canyon Wren	Flying
5/12/2006	Kevin Dickerson	National Canyon	Summer Tanager	Flying and landing
5/12/2006	Kevin Dickerson	National Canyon	Says Phoebe	Flying and landing
1/10/2007	Melissa McMaster	Slate Creek	bat (brown)	flying and eating bugs
3/22/2007	Hillary Hudson	Slate Creek	Canyon tree frog	Hanging out in the rocks
3/22/2007	Hillary Hudson	Slate Creek	Great Horned Owl	Flying down canyon
3/24/2007	Melissa McMaster	Slate Creek	Peregrine falcon (2)	Flying, screeching, and diving above.
3/25/2007	Melissa McMaster	Slate Creek	Red spotted toad	Mating in creek
11/17/2007		Slate Creek	Bighorn Sheep	Walking upslope
10/11/2006	Kari Malen	Three Springs Canyon	Squirrel	Running around
11/9/2006	Kate Watters	Topaz Canyon	Tarantulas	Walking
11/9/2006	Kelly McGrath	Topaz Canyon	Bighorn (2)	Walking
9/19/2006	Kari Malen	White Creek	Whip snake	Saw 3 separate snakes slithering in the Supai. The longest was 1.5 m.
9/19/2006	Kari Malen	White Creek	2 Tomato Worms	Big juicy bright green with white stripes caterpillars. Devoured an entire Datura metaloides plant. They were polishing off the last seed ball.

Date	Observer	Location	Wildlife Species	Activity
9/21/2006	Loren Bell	White Creek	Glow bugs	Several small 1" caterpillar looking bugs with glowing rear ends (like fireflies), walking and locomoting on their glowing posterior.

b. Project Matching Contribution

In addition to the volunteer contribution, GCNPF and NPS have also provided in-kind and financial support. From the spring of 2006 through the fall of 2008, a total matching of $212,541 was contributed to the Phase II-B portion of this project (refer to Table 11. Phase II-B Project Matching Contribution).

Grand Canyon National Park provided contributions to this project by paying for the base salaries of staff members, leaving only the overtime to be paid for by this grant. The GRCA ranger division provided two of the boatmen for the fall 2006 and spring 2007 river trips, in addition to matching food contributions. The Ranger Operations and Science and Resource Management divisions also provided joint support for completing the AWPF monitoring work on an already scheduled river trip, which saved valuable AWPF project funds. GRCA provided $50,000 of supplemental support for the Backcountry Vegetation Program's projects. Of that amount, $25,000 supported work in Phase II-A and $25,000 to support work in Phase II-B. These funds were used to support Kate Watters as the field supervisor, which, in combination with the AWPF funds, allowed Kate to have more non-field time to coordinate the project activities. The funds also partially supported Kim Fawcett, who entered the vast majority of the project data.

The GRCA Division of Science and Resource Management continued to provide critical support in the contribution staff time to support this project. Lori Makarick, the park's Vegetation Program Manager, continued to spend a significant amount of her time (valued at $43/hour) working on this project. She maintained overall responsibility for the project and her commitment never waned. Steve Mietz, the park's GIS Program Manager, provided mapping support and training to project staff, and provided Lori with many hours of GIS tutoring. Steve's time is valued at $53/hour. Chris Flaccus, the park's Database Manager, was a tremendous help with the data portion of this project. He ceaselessly worked on re-design of the database, and sought out ways to improve the ease of use and design of appendices for project reports. Chris worked a total of 600 hours on this database, valued at $51/hour. R.V. Ward, the park's Wildlife Program Manager, provided field assistance with the Southwestern willow flycatcher habitat assessments, and his time is valued at $46/hour. In addition, the Southern Colorado Plateau Network provided matching support during the data analysis phase of this project.

As stated earlier, GCNPF provided interns and a volunteer coordinator to assist with this project. Kelly McGrath worked with the project for 12 weeks each in the fall of 2006. Her contribution to the project was invaluable, with 90% of their time in the field leading crews, allowing project coordinators to add more trips than were funded through the AWPF grant. Shannon Sellers served as an intern through GCNPF in the fall of 2007, and she was a very hearty and stalwart volunteer with the program. Her time in the intern role also allowed additional backpacking trips to be completed, and she became a strong advocate for the park's invasive plant management efforts. GCNPF raised $10,000 to support Kelly and Shannon's positions. The volunteer coordinator provided the critical link to the successful implementation of this project. The GCNPF provided about $20,000 in funding to support that position. For detailed GCNPF matching funds information, contact GCNPF directly. In addition, the Grand Canyon Trust provided several interns to assist with some of the fieldwork and recruitment. The field hours are included in the volunteer hour contribution table, and a portion of their recruitment and supervision time is considered a matching contribution by GCT. The Hualapai Tribe provided funding for Sharon Wilder, the hydrologist on the May 2006 river trip.

Table 11. Phase II-B Project Matching Contribution

National Park Service Matching Contribution		
Name	**Role in Project**	**Matching Contribution**
Chris Flaccus	GRCA Database manager – 600 hours total	$30,600
Chris Lauver, Travis Belote	NPS – SCPN – I&M Program	$1,300
GRCA River Unit	Matching food for river trips	$2,000
Jeri Riley	GRCA River Unit, Fall 2006 GRCA River Unit, Spring 2007	$5,330 $10,196
Johnny Jannsen	GRCA River Unit, Fall 2006 GRCA River Unit, Spring 2007	$6,450 $5,305
Lori Makarick	GRCA Project Management, 2006, 400 hours GRCA Project Management, 2007, 440 hours GRCA Project Management, 2008, 440 hours	$17,200 $18,920 $18,920
NPS funding match	Kate Watters and Kim Fawcett's salaries for crew supervision and data entry	$25,000
NPS funding match	Support for April 2008 river trip	$15,000
R.V. Ward	GRCA Wildlife Program Manager – 120 hours	$5,520
Steve Mietz	GRCA GIS program manager – 100 hours	$5,300
	NPS Matching Funds Total:	**$166,771**
Grand Canyon National Park Foundation Matching Contribution		
Kelly McGrath	Intern and Field Crew Leader	$5,000
Shanon Sellers	Intern and Field Crew Leader	$5,000
Terra Crampton, John Canfield	Volunteer Recruitment	$20,000
	GCNPF Matching Funds Total:	**$30,000**
Grand Canyon Trust Matching Contribution		
Kate Watters	Volunteer Coordination and Recruitment	$8,000
Travis Wiggins	Volunteer Coordination and Recruitment	$3,000
Various interns	Volunteer Coordination and Recruitment	$3,000
	GCT Matching Total:	**$14,000**
Hualapai Matching Contribution		
Sharon Wilder	Hydrologist	$1,500
	Hualapai Matching Total:	**$1,500**

c. Project Press

This project continues to receive good press coverage. Many of the articles were completed during the overlap between Phase II-A and Phase II-B, but those that were primarily done during Phase II-B are included in this report as Appendix G (Project Press). GRCA's visitor guide continued to include information about this project, and the Grand Canyon – Williams News printed several short articles that helped with volunteer recruitment. GCNPF staff created a flyer to recruit volunteers, and also updated the volunteer recruitment website. Loren Bell, a crew leader for the project, wrote an article for South by Southwest titled "Killing the Creep." Wendy Hodgson, Research Botanist and Curator of the Desert Botanical Garden Herbarium, and a devoted volunteer, wrote an article for The Sonoran Quarterly titled "Grand Canyon: A case study for the importance of plant studies and plant documentation." Chris Murphy, a volunteer on the May 2006 monitoring river trip, published an article titled "Deserts, Stones, Plants, and Rivers – A Story of Change and Inspiration from a Grand Canyon Float Trip" in the Summer 2007 issue of Sage Notes, a publication of the Idaho Native Plant Society.

d. Public Education Materials

Task #4 of the AWPF contract was to produce public education materials that describe the issues with invasive vegetation within GRCA and how visitors can help. This task proved difficult to complete due to financial challenges faced by GCNPF. For Phase II-A, the Project Coordinator worked with Mary Beath to design and edit a leaflet entitled "Fight the Invasion" and an 8-panel training brochure that includes specific information about 13 of the highest priority invasive plant species in the park's backcountry areas. Both of those outreach items are currently being distributed to park visitors.

Under Task #4 of Phase II-B, the amount available was $3,150 for the printing costs of new material, but the design costs were to be covered by the grantee. GCNPF was unable to provide the funds for the design of new material. However, the project coordinator, Lori Makarick, received 3 boxes, totaling 1,500 brochures, of the very popular 8-panel training brochures directly from Starline Printing in 2008. They were excess printed during the Phase II-A project at a cost of $3,874 for 1,000 brochures. Thus, the shipment was valued at over $5,800 and is used to satisfy the task #4 deliverable for this phase of the project, at no cost to AWPF or the grantee. Additional outreach material will continue to be designed in partnership with Grand Canyon Association (GCA) after this contract is completed.

The Project Coordinator created a site bulletin, which is printed in park at no cost to AWPF. This bulletin is posted at inner canyon kiosks and distributed to park visitors and project volunteers. The Project Coordinator also prepared and presented a poster for the NPS Intermountain Regional conference, held in May 2008. The poster contained information about this project. The Project Coordinator gave many presentations about the park's vegetation program during the timeframe of this project, and every presentation included detailed information about this project. One presentation is included as an example of the type of information provided to the public and a wide diversity of user groups. Please note that during the conversion to the handout view with 6 slides per page, some of the formatting was altered; however, the full MS Powerpoint version of the presentation is included on the final report DVD.

All of these deliverables are included in Appendix H (Public Education Materials) as .pdf files.

V. Monitoring Methods

a. Vegetation Transects

The primary monitoring objective was to determine the change in vegetation and level of project success. Project managers expected to see an increase in native plant species' composition and cover in project areas as the native plants were released from competition with tamarisk for the available resources.

Table 12 (Phase II-B Monitoring Project Area List) contains the subset of project monitoring areas from the Project Monitoring Plan. Crews installed paired transects in each of the randomly selected areas. The number of transects in each area depended on the extent of tamarisk distribution, with one transect located within a tamarisk population and one in a nearby, non-invaded area to serve as a reference.

Table 12. Phase II-B Monitoring Project Area List

Canyon Name	River Mile	River Side	# of transect pairs	Pre-tamarisk monitoring date	Post-tamarisk monitoring date	5-Year monitoring date
Topaz Creek	96.7	L	1	April 2006	April 2008	April 2013
140 Mile Canyon	140	L	1	May 2006	May 2007	May 2012
National Canyon	166.5	L	3	May 2006	May 2008	May 2013
Mohawk Canyon	171.6	L	3	May 2006	May 2007	May 2012
Granite Park Canyon	209	L	2	May 2006	May 2007	May 2012
Three Springs	215.7	L	3	May 2006	May 2008	May 2013

Crews used 50 m line transects to measure vegetation cover, with one transect placed approximately in the middle of a treatment area and a second reference transect placed in a nearby area with similar substrate and aspect in which little or no tamarisk occurred. Both transect lines ran parallel to the drainage channel. The goal was to have 1-3 transect pairs per selected project area. Each transect was considered a sampling unit and was compared to themselves as well as the untreated pair to detect change in vegetation cover. Project leaders updated the detailed monitoring protocols each year and every crew member had a copy on hand in the field to refer to when questions arose. The protocols helped separate crews operate as one single mind to keep data collection as consistent as possible.

Along the 50 m transects crews recorded point intercept, cover within 3 m radius circles, and total vegetation volume measurements. The point intercept method characterized substrates and documented the major plant species present along the transect lines. Crews used a 0.75 cm diameter, 2 m tall measuring device and took a reading every 0.5 m along the 50 m transect, providing 100 points per transect. They noted the species identity of all live plants in contact with the pole, and characterized ground cover substrate in one of eleven categories (Table 13. Ground Cover Substrate Categories).

Table 13. Ground Cover Substrate Categories

Category	Description
Bare soil	<0.1 mm (smaller than sand)
Sand	0.1 – 2 mm
Gravel	2 mm – 6.4 cm
Cobble	6.4 cm – 19 cm
Stone	19 - 61 cm
Boulder	> 61 cm
Bedrock	Solid rock surface, non-boulder
Litter (duff)	Dead plant material < 3cm diameter
Coarse woody debris	Dead wood 3-10 cm diameter
Woody debris structure	Woody material > 10 cm in depth and width
Basal Vegetation	Visually clump all basal stems together. This should be between 1-10% for GRCA vegetation types.

In order to further describe the composition of plant species present along the transects, crews collected ground and vegetation cover data within a 3 m radius circle at five points along the transect (5 m, 15 m, 25 m, 35 m, and 45 m). Botanists recorded vegetative cover for all species present in a cylinder from the ground surface to the sky, including the categories of moss, lichen, and microbiotic soil crust. To minimize observer biases and increase the speed of the surveys, crews recorded cover in seven broad cover classes (Table 14. Cover Classes). Because points on the transect are not independent of each other, cover scale values were converted to the mid-point of the class ranges and averaged before being analyzed so that there was only a single value for each species recorded on the transect.

Table 14. Cover Classes

Class	Cover Range
0	0%
1	<1%
2	1-5%
3	5-10%
4	10-25%
5	25% - 50%
6	50% - 75%
7	> 75%

In order to understand how the vegetation recorded in the cover data is distributed vertically at each point, crews recorded the three-dimensional structure, measured as total vegetation volume (TVV) (Mills et al. 1991). At the center of each circle, crews held the survey rod vertically and recorded the number of 10 cm segments in each meter above the ground that had contact with live vegetation. If a given species was present more than once in a given 10 cm segment, crews only counted it once. The TVV measure for a particular point is the count of all 10 cm segments occupied over that point for each species. If two or more species occur at one point, crews recorded total number of 10 cm segments that were vacant. For analysis, the TVV measures at each point are summed to generate a transect measure, since individual points on the same transect cannot be considered independent for statistical purposes.

b. Hydrology Sampling

A secondary monitoring objective was to measure changes in hydrology, although it was very difficult to determine a trend during such a short time frame given the amount of annual variation. Using a small, compact Hanna probe, crews collected hydrological data including temperature, pH, electroconductivity (EC), total dissolved solids (TDS), and discharge. The items used for hydrology sampling were:

Hanna probe (HI 98129) and instructions
Thermometer
50 m tape
Metric ruler for depth measurements
Data sheets (blank ones and the printouts from the previous site visit)
Photopoint sheets (printouts from the previous site visit)
Maps
Watch with ability to clock seconds
Large bottle of DI water for rinsing
Small packets of ph7 buffer, ph4 buffer and EC calibration solution
Tech box with camera, compass and GPS unit

Before crews too the measurements, they calibrated the probe on a daily basis as follows:

For pH Calibration (*2 point calibration method):*

1. Get pH 7.01 solution ready.
2. From measurement mode, press and hold the ◎ / Mode button until CAL is displayed on lower LCD screen. Release the button. The LCD will display pH 7.01 USE and the CAL tag will blink on the LCD screen.
3. Rinse the meter 3 times with pH 7.01 solution and place the electrode directly into the pH 7.01 solution.
4. The meter will recognize the buffer and then it will display pH 4.01 USE on the LCD screen.
5. Rinse the meter 3 times with the pH 4.01 solution (*can also use pH10*) then place the electrode in pH 4.01 solution.
6. After the second buffer is recognized, the LCD screen will display OK for 1 second and the meter will return to normal measuring mode. The CAL symbol on the LCD screen means that the meter is calibrated.

For EC Calibration:

1. From the measurement mode, press and hold the ◎ / MODE button until CAL is displayed on the lower LCD screen.
2. Release the button and immerse the probe in the proper EC calibration solution.
3. Once the calibration has been automatically performed, the LCD screen will display OK for 1 second and the meter will return to normal measurement mode.

The hydrology sampling locations were located just below and above large tamarisk patches in project monitoring areas. To the extent possible, the locations coincided with transect locations. Once the point was located, the hydrology technician recorded basic site and environmental information (refer to Appendix F for sample data forms). Crews also installed and then retook photopoints at each hydrological sampling site in order to visually display the changes in the seep, spring or stream from year to year. To record discharge, crews used the float method. The technician recorded the wetted width of the channel and the measurement distance, with 5 m being the standard length. The channel dimensions were recorded by stretching a tape across the channel and recording the depth at 20 cm increments a total of 10 times. The hydrology technician the released the floating device at the beginning of the area 10 times and recorded the time it took to get to the end of the measurement area.

c. Soil Sampling

Another secondary monitoring objective was to measure changes in soil chemistry and structure. Crews collected soil pH and EC measurements at five locations (5 m, 15 m, 25 m, 35 m, and 45 m) along each vegetation transect. Crews used the same Hanna probe mentioned above to measure soil pH and EC. The protocol was to mix two parts de-ionized (DI) water with one part topsoil to make a slurry solution, and then dip the probe three different times, with rinsing between, to obtain readings at each point.

d. Photopoint Installation

Crews installed photopoints in project areas as part of the management activities, selecting areas that represented good examples of tamarisk-infested riparian areas. Project areas were divided into 500 m sections during tamarisk mapping, and ideally one photopoint was installed in each section. Photopoints were also installed in some sections with no tamarisk, which will still be valuable for long-term monitoring. At each photopoint location, the crew leaders recorded a compass bearing, UTM reading, camera height, and site description. Crews took photographs prior to tamarisk control, immediately following tamarisk removal, and again during final project monitoring as time allowed. As part of the tamarisk monitoring transects, photopoints were also installed at the transect start and end points to help locate transects, and to provide qualitative data on long-term vegetation change on the transects. Crews followed these standard operating procedures for photopoint installation:

- Write down the location and date on a dry erase photo-board and then take a photograph of the board. This helps with labeling and organizing the photographs following the trip.
- Make sure that the compass is declinated to 13 east.
- Make sure the GPS unit is set to NAD 83 (CONUS) and metric.
- Fill out the photo-log form as the photographs are taken. Write very neatly since someone else will be entering the data into the database.
- The photopoint name should be the name of the side canyon, followed by a number. If there is already a photopoint installed in the 500 m section, use a dash and the next consecutive number (e.g. Hance 1-1, 1-2 for two photopoints in Hance 1). Transect photopoint names should include the transect number and type in the name (e.g. Mohawk T1A Start).
- Keep in mind that there will usually be more than one view (i.e. different bearings) from the same photopoint. Those views should be labeled 1, 2, etc. in the view # column.
- Take at least one photograph of a person at the photopoint to help relocate it. This is the reference photo, denoted by an "A" in the view column. *Hance 2 View A* would be a photo of a person standing at Hance 2 photopoint.
- Please be as detailed and specific as possible in the photopoint description, keeping in mind to include key site characteristics that are of a permanent nature (e.g. rocks, large trees).
- For the view from photopoint, please include detail about the photograph displays (e.g. river in lower left corner, large mesquite on creek left bank).
- Keep in mind that this work will become part of the project archives, to be used by future resource specialists.

- For retaking photopoints take along a print out of the page. Write RETAKE and the date clearly right above the photopoint name and the camera # on top of the page. Take a photo of the page with the photopoint name (e.g. PP Carbon 1). Then retake the photos in the order that they are on the page. It is not necessary to retake View A, which is only a reference photo to help relocate the photopoint. Neatly cross out the time and write the new time the photo is taken. Cross out pre and write post-treatment. Check the bearings and descriptions and edit them as necessary.

e. Southwestern Willow Flycatcher Habitat Assessments and Wildlife Monitoring

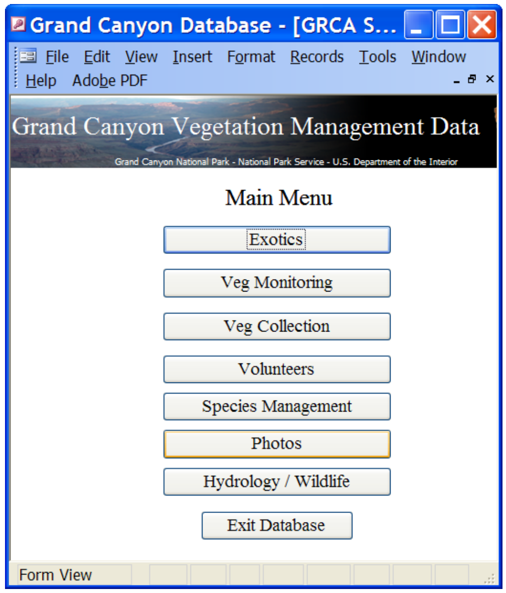
Prior to project implementation, project coordinators met the U.S. Fish and Wildlife Service's requirements from the informal and ongoing consultation. The obligation was to complete habitat assessments in order to ensure that the project areas do not include any currently or potentially suitable habitat for the Southwestern willow flycatcher (SWIFL). Crews also collected observational data on wildlife distribution and activity at all of the project areas during every visit. They identified, by common name, every wildlife species observed (including mammals, birds, insects, reptiles and amphibians) and a description of the activity.

f. Data Forms and Project Database

For this project, crew coordinators designed data forms and protocols for each of the project components. Over the course of the project, they revised and refined the forms based on input from crew leaders and project participants. Refer to Appendix F for a complete set of blank data forms.

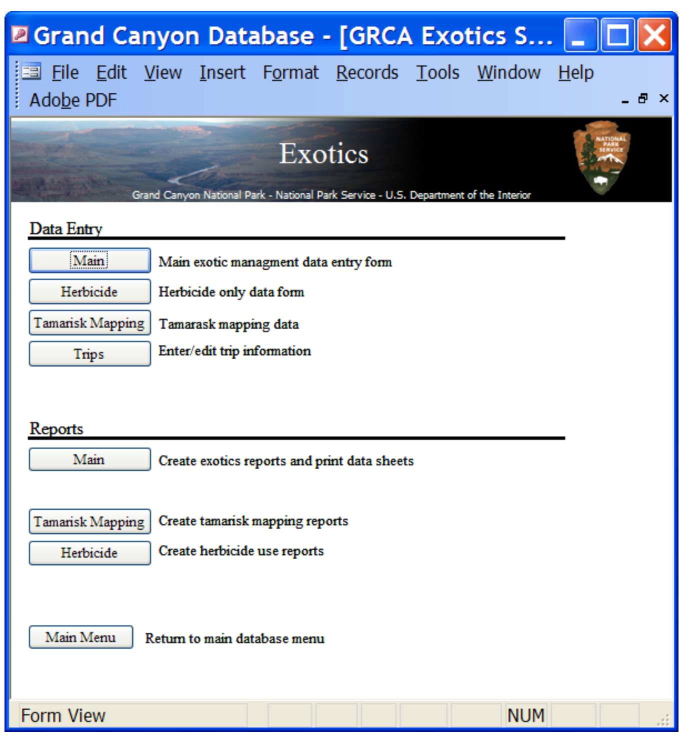
All of the data, including links to the photographs, are included in the project database, which is the primary storage repository for all of GRCA Vegetation Program's data. Because all of the data are entered into the database, the hardcopy data forms will be archived in the park's Museum Collection and are available upon request from the Project Coordinator. As a project matching contribution, NPS personnel and contract employees worked on the database design and development, with completion of the final version during 2008. NPS personnel are still working on a few minor issues with the database, but the vast majority of it is working. A few components that are not related to this project remain under development and will be completed by the GRCA Database Manager at cost to GRCA. The final version of the database and all project data, including the photographs for Phase II-B, are included on the report disk. To access the database, click on the grca.mdb file. A Security Warning will come up; just click the Open button, which will open the main menu.

Figure 5. Grand Canyon Database – Main Menu



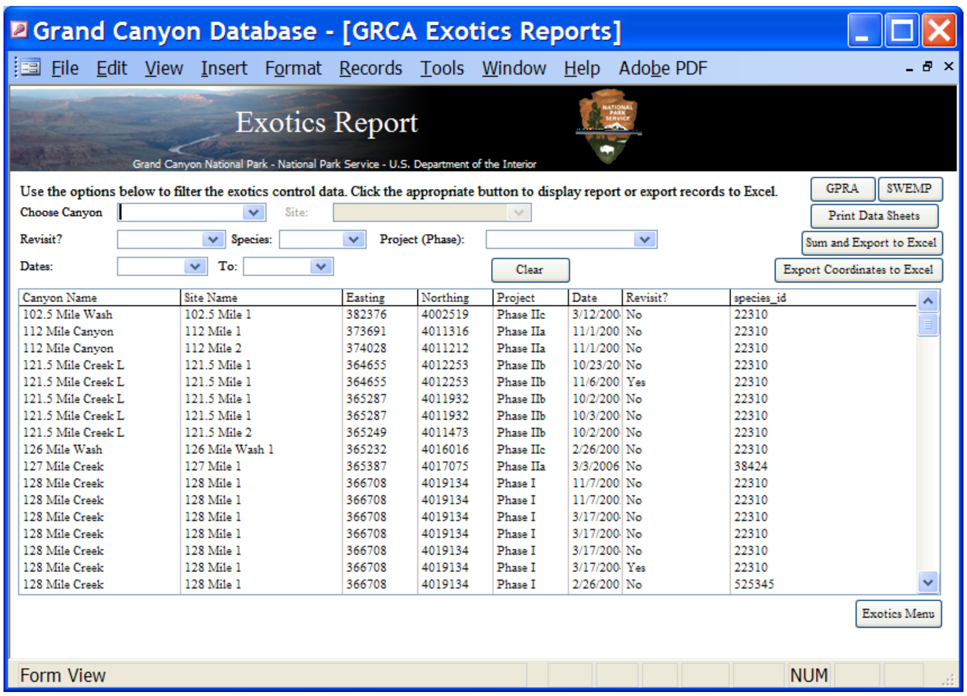
From the Main Menu, it is easy to access the project data related to each of the components. To view all of the tamarisk and other invasive species control information and generate reports, click on the Exotics button. Under data entry, by clicking on the various buttons, it is easy to view all of the information for the various project areas.

Figure 6. Grand Canyon Database – Exotics Menu



Use the buttons listed under Reports to obtain many useful views of the data. From that screen, you can filter the data by project area, phase, species, or date. The GPRA and SWEMP buttons are exports that provide specifically formatted data for National Park Service reporting, but as MSExcel exports, they can also be readily edited to provide the user with desired information. The Sum and Export to Excel button is very useful for summary information. For example, it is possible to filter for all the Phase II-B project areas, and then the database will produce an MSExcel spreadsheet that has the total number of plants controlled in each project area, and also the numbers of seedlings, saplings and mature trees, and the method of removal used. The Export Coordinates to Excel button is used to get the UTM information from the database into a format that is then imported into ArcGIS software and used to make the project maps.

Figure 7. Grand Canyon Database – Exotics Report Menu



VI. Monitoring Results

a. Trip summaries

The monitoring river trips associated with the project were extremely successful with a great deal of work accomplished by a small and productive group of people. Crews installed transects to collect vegetation, soils and hydrology data in selected project areas prior to tamarisk removal from April through May 2006. During May 2007 and April 2008, crews revisited the same project areas where tamarisk had been removed and recollected vegetation, soils and hydrology data (Table 12. Phase II-B Monitoring Project Area List, Table 15. Monitoring Trips - Participant Lists, and Table 16. Monitoring Trip Itineraries). Crews and volunteers also re-took long-term photopoints in Phase II-B project areas. Volunteers logged over 3,662 hours on the project (Table 9. Volunteer Contribution to Project).

It was a gratifying experience to see the positive results of tamarisk removal in the side canyons, as many participants have been involved with the monitoring and removal of tamarisk since the project began in 2002. Native plants are sprouting in places were once only tamarisk dominated. Volunteer Wendy Hodgson, research botanist for the Desert Botanical Garden, collected a large number of plants in project areas to further document lesser known plant species' distributions. See Appendix E (Monitoring Transect Data) for complete species lists in each of the transect areas.

Table 15. Monitoring Trips - Participant Lists

April 2006 Monitoring Backpacking Trip Participant List

Role	Participant
Trip Coordinator	Kari Malen
Trip Leader	Steve Till
Volunteer	Kelly Williams
Volunteer	Melissa McMaster

May 2006 Monitoring River Trip Participant List

Role	Upper Half	Lower Half
Trip Coordinator / Project Leader	Lori Makarick	Lori Makarick
Head Boatman / Trip Leader	Dan Hall	Dan Hall
Boatman	Mike Kearsley	Mike Kearsley
Boatman	Sam Jones	Sam Jones
Boatman	Tyler Williams	Tyler Williams
Boatman / Wildlife (NPS Boat)	R.V. Ward	R.V. Ward
Crew Leader #1	Kate Watters	Kate Watters
Crew Leader #2	Kari Malen	Frank Hays
Crew Leader #3	Steve Till	Steve Till
Crew Leader #4 (Hualapai on lower)	Vacant	Sharon Wilder
Botanist invited	Wendy Hodgson	Wendy Hodgson
Botanist invited	Amy Prince	Amy Prince
Botanist invited	Lisa Hahn	Lisa Hahn
Botanist invited	Molly Boyter	Pam Walls
Wildlife technician	Kevin Dickinson	Kevin Dickinson

May 2007 Monitoring River Trip Participant List

Role	Upper Half	Lower Half
Trip Coordinator / Project Leader	Lori Makarick	Lori Makarick
Head Boatman / Trip Leader	Dan Hall	Dan Hall
Boatman	Sam Jones	Sam Jones
Boatman	Dave Edwards	Dave Edwards
Boatman	Jeri Riley	Jeri Riley
Crew Leader #1	Kate Watters	Kate Watters
Crew Leader #2	Lisa Hahn	Lisa Hahn
Crew Leader #3	Steve Till	Steve Till
Botanist invited	Wendy Hodgson	Wendy Hodgson
Botanist invited	Melissa McMaster	Empty
Botanist / Hydrologist on lower	Sarah Topp	Kelly Rowell
Botanist invited	Do not fill this spot	Amy Prince

April 2008 Monitoring River Trip Participant List

Role	Upper Half	Lower Half
Boatman/TL	Paul Lauck	Paul Lauck
Boatman/Asst. Veg. Tech	Dan Hall	Dan Hall
Boatman/Asst. Arch Tech	Tim Stephensen	Tim Stephensen
Boatman/Asst. Veg. Tech	Sam Jones	Sam Jones
Boatman/Coordinator/Rec.	Mathieu Brown	Mathieu Brown
Avifauna Tech	Jeremy White	Hattie Oswald
Avifauna – Veg Tech	Anna Schrenk	Cheryl Decker
Archaeologist	Ian Hough	Amy Horn
Arch Tech	Jim Hasbargen	Jim Hasbargen
Arch Tech	Vacant	Stewart Robertson
Rec Tech	Shannon McCloskey	Vacant
Veg lead	Lori Makarick	Lori Makarick
Veg Tech	Jane Cipra	Jane Cipra
Veg Tech	Kassy Theobald	Amy Prince
Veg Tech	Akasha Faist	Akasha Faist

The itineraries for the trips were extremely full. Miraculously, the crews completed all the work planned for each trip (Table 16. Monitoring Trip Itineraries). Transects in Topaz were installed by a 4-person backpacking crew. The April backpacking trip gave crew leaders an idea of the logistics involved in this phase of the project. The crew hiked about 35 miles just to get to the project areas, but then covered another 15 miles within the project sites. The journey will be much more difficult when the participants are hauling tools and herbicide, but the remote project areas are beautiful and their restoration is worth the grueling trip. The remainder of the transects required access from the river.

The May 2006 transects were installed and read by crews on a joint trip in which they also visited Phase II-A project areas. Crews installed transects in all of the remaining monitoring areas for Phase II-B during this river trip. During May 2007, crews again visited both Phase II-A and Phase II-B project areas, which made for an extremely busy trip. The Phase II-B project areas included on that trip were 140 Mile, Mohawk and Granite Park Canyons. The post-restoration monitoring work was divided into two years, 2007 and 2008, but just one post-restoration monitoring boat trip was included in the contract for Phase II-B. However, because crews were able to complete the 2007 work jointly with the Phase II-A work, there was sufficient funding to contribute to the work that was required in 2008. In order to support this project, GRCA extended the length of the April 2008 Colorado River Management Plan monitoring river trip by 4 days, allowing the skilled crews to visit Topaz, National, and Three Springs Canyons as required by the contract. AWPF funded the trip extension, including the cost of the boatmen and crew leaders for those extra days, and the rest of the cost of the trip was covered by GRCA matching funds.

Table 16. Monitoring Trip Itineraries

April 2006, Backpacking Monitoring Trip Itinerary

Date	Day	Project	Camp
April 21	1	Hike in to Work Sites	Topaz Creek
April 22	2	Vegetation Inventory & Monitoring, Photodocumentation, Wildlife Surveys **Topaz Transects**	Topaz Creek
April 23	3	Vegetation Inventory & Monitoring, Photodocumentation, Wildlife Surveys	Slate Creek
April 24	4	Vegetation Inventory & Monitoring, Photodocumentation, Wildlife Surveys	Slate Creek
April 25	5	Vegetation Inventory & Monitoring, Photodocumentation, Wildlife Surveys	Agate Canyon
April 26	6	Vegetation Inventory & Monitoring, Photodocumentation, Wildlife Surveys	Sapphire Canyon
April 27	7	Vegetation Inventory & Monitoring, Photodocumentation, Wildlife Surveys	Topaz Canyon
April 28	8	Vegetation Inventory & Monitoring, Photodocumentation, Wildlife Surveys	South Rim

Monitoring River Trip, May 2006

Date	Day	Work Location	Camp
5/3	1	Badger	Lone Cedar, 23.5 L
5/4	2	36.5 Mile	Saddle, 47 R
5/5	3	Little Nankoweap, Nankoweap	Carbon, 64.7 R
5/6	4	Carbon	Carbon, 64.7 R
5/7	5	Transit	Cremation, 87 L
5/8	6	Transit, orientation	102 R
5/9	7	122 Mile L	Randy's Rock, 126.5 R
5/10	8	140 Mile L	Above Kanab, 143.3 L
5/11	9	143 Mile L, Sinyala, 164 L	National, 166 L
5/12	10	National	Mohawk, 171.6 L
5/13	11	Mohawk	Mohawk, 171.6 L
5/14	12	Honga, Prospect Canyon, Hell's Hollow	Hell's Hollow, 182.5 L
5/15	13	Below Hell's, Whitmore, 190 Mile, Basalt, 193 Mile, 194 Mile, 196 Mile	Parashant, 198 R
5/16	14	205 Mile	Granite Park, 208.8 L
5/17	15	Three Springs	215, R
5/18	16	217 Mile	217 L
5/19	17	Trail Canyon	220, R
5/20	18	220.5 L, 221 L, 221.5 L, 222 L, 224 Mile L, 225.5 Mile R	Diamond Creek

Monitoring River Trip, May 2007

Date	Day	Work Location	Camp
5/4	1	Badger Canyon	Hot Na Na, 16.4 L
5/5	2	36.5 Mile, Saddle Canyon	Lower Anasazi, 43.3 L
5/6	3	Little Nankoweap, Nankoweap Creek	Little Nankoweap, 52 R
5/7	4	Nankoweap Creek, Kwagunt Creek, Kwagunt Camp	Kwagunt, 56 R

Date	Day	Work Location	Camp
5/8	5	70.2 Mile, 70.8 Mile	Upper Unkar, 72 R
5/9	6	Unkar Creek-Transects	Upper Unkar, 72 R
5/10	7	Transit	Cremation, 87 L
5/11	8	Upper Boucher, Crystal Creeks	Crystal, 98 R
5/12	9	Crystal Creek-Transects 112 Mile Wash	Waltenberg, 112 R
5/13	10	Transit, various	Talking Heads, 133 L
5/14	11	130 Mile, 140 Mile Canyon	Above Olo, 145 L
5/15	12	Transit, various	Below Tuckup,164.8 R
5/16	13	Mohawk Canyon-Transects	Mohawk, 171.5 L
5/17	14	Mohawk Canyon-Transects	Mohawk, 171.5 L
5/18	15	Transit, various	Whitmore Wash, 188 R
5/19	16	Transit, various	Granite Park, 209 L
5/20	17	Granite Park-Transects	214 R
5/21	18	Trail Canyon and 225 Mile Canyon	Take Out!!!!

Monitoring River Trip, April 2008

Date	Day	Work Location	Camp
4/5	1	Various CRMP and Tamarisk	Six Mile, 5.9R
4/6	2	Various CRMP and Tamarisk	20 Mile, 20.2L
4/7	3	Various CRMP and Tamarisk	30 Mile, 30.4L
4/8	4	Various CRMP and Tamarisk	Duck 'n' Quack, 47.2L
4/9	5	Various CRMP and Tamarisk	Opposite Malgosa
4/10	6	Various CRMP and Tamarisk	Palisades, 66L
4/11	7	Various CRMP and Tamarisk	Upper Nevills, 75.7L
4/12	8	Various CRMP and Tamarisk	Cremation, 87.7L
4/13	9	Salt Creek	Boucher, 97.2L
4/14	10	Topaz Creek	Crystal, 87.7R
4/15	11	Various CRMP and Tamarisk	110 Mile, 110.0R
4/16	12	122 Mile	Below Bedrock, 131.7R
4/17	13	Various CRMP and Tamarisk	Across Deer Creek, 136.8L
4/18	14	Various CRMP and Tamarisk	Above Olo, 148.5L
4/19	15	Various CRMP and Tamarisk	161 Mile, 171.3R
4/20	16	National Canyon	National, 166.5L
4/21	17	National Canyon	National, 166.5L
4/22	18	Various CRMP and Tamarisk	UPR 185, 185.8R
4/23	19	Fat City	Froggy Fault, 196.9L
4/24	20	Three Springs Canyon	214 Mile, 214.9R
4/25	21	Three Springs Canyon	Opp. Three Springs, 216.1R
4/26	22	217 Mile Canyon	Diamond Creek, 226L
4/27	23	Take-Out 5am De-Rig	

b. Vegetation transects

Vegetation crews installed 13 transects pairs (26 individual transects) in six project areas. Initial transect installation took a three person team three hours. With the ancillary data already recorded on the 2006 trips when transects were installed, each transect took 2-3 person teams about two hours to read and record during the revisits. This stepped up the pace of the trips and allowed crews to use the extra time to revisit long-term photopoints in all of the areas.

The transect data have been entered into the project database and are included as Appendix E (Monitoring Transect Data). Travis Belote, Ecologist for USGS, and Chris Lauver, Quantitative Ecologist for the NPS SCPN I&M network, conducted the data analyses. Additional analyses will be conducted in the future when the final Phase II-B transect data have been collected, providing a greater sample size.

Statistical Methods

To test for differences in plant species composition and diversity between control and tamarisk transects, two sets of species abundance data were analyzed: cover data from 3 m radius plots, and count data from point intercept measures along the transects. Cover class data were converted to cover values by using the midpoint of the cover class value, and mean cover of all species was obtained by averaging across the five sample points on the transect. Point intercept counts were summed across transects to calculate percent cover for all species. To test for differences in vertical vegetation structure between control and tamarisk transects, transect data on total vegetation volume (TVV; Mills et al. 1991) were also analyzed. All species were classified as native, exotic, or unknown using the USDA PLANTS database (http://plants.usda.gov/) and these designations were confirmed using GRCA species lists. Exotic species included those not native to the southwestern U.S. 'Unknown' species included those that were only identified to genera and where nativity could not be determined.

Four plant community responses were investigated for several species groupings. Total cover of native, exotic, and all species was calculated by summing cover across plots and point intercept counts. Richness of native, exotic, and all species was calculated as those species present within plots or occurring as point intercept counts. Shannon's diversity index (*H*') was calculated for native, exotic, and all species as $-\sum P_i \log (P_i)$, where P is the proportion of total cover for each species *i* (Clarke and Gorley 2006). A single TVV value for each transect was derived by summing contacts for all species across all five transect points. TVV values were produced for two species groupings: all species, and all species without tamarisk.

Mixed model analysis of variance (ANOVA) was used to test for main effects of treatment (control vs. tamarisk), canyon (or site), and year (or pre vs. post treatment) on the response variables (total cover, richness, diversity, and TVV). Transects were nested within canyons and were considered random effects because their placement was meant to sample site or canyon variability. Treatment, canyon, and year were considered fixed effects in all mixed models. The effects of treatment x year interactions on response variables were also tested. A critical alpha value of 0.10 was employed for significance. All statistical analyses were conducted using SAS and PRIMER software.

Species composition from control and tamarisk transects were also analyzed using analysis of similarity (ANOSIM; Clarke 1993) to determine if there were significant treatment and year effects, and to evaluate the influence of tamarisk in pre- and post-treatment vegetation composition. These tests were conducted using the plot data because of greater species richness compared to the point intercept data (Figure 8). To further evaluate the effect of individual species contributing to observed dissimilarities in species composition between control and tamarisk transects, a similarity of percentages (SIMPER; Clarke and Gorley 2006) routine was also conducted.

Results

Significant differences in total cover of all species were found in both the plot and point intercept data, but these depended on a treatment x year interaction (Tables 17 and 18). Specifically, total cover decreased on tamarisk transects while decreasing slightly on control transects (Figure 8). Cover of native species, using the plot data, differed between control and tamarisk transects (Table 17, Figure 8), but this result was likely due to initial pre-treatment conditions and not because of changes following tamarisk treatments. No differences were observed in native species cover using the point intercept data (Table 18, Figure 8). As expected, cover of exotic species (from both the plot and point intercept data) decreased dramatically on tamarisk transects but not on control transects (Figure 8), leading to significant treatment x year interactions (Tables 17 and 18).

Table 17. ANOVA results (p values) of using plot cover data to investigate main effects of treatment, canyon, year, and treatment x year interaction for total cover, species richness, and Shannon's diversity index for native, exotic, and all species. Values ≤ 0.10 are bolded to highlight patterns.

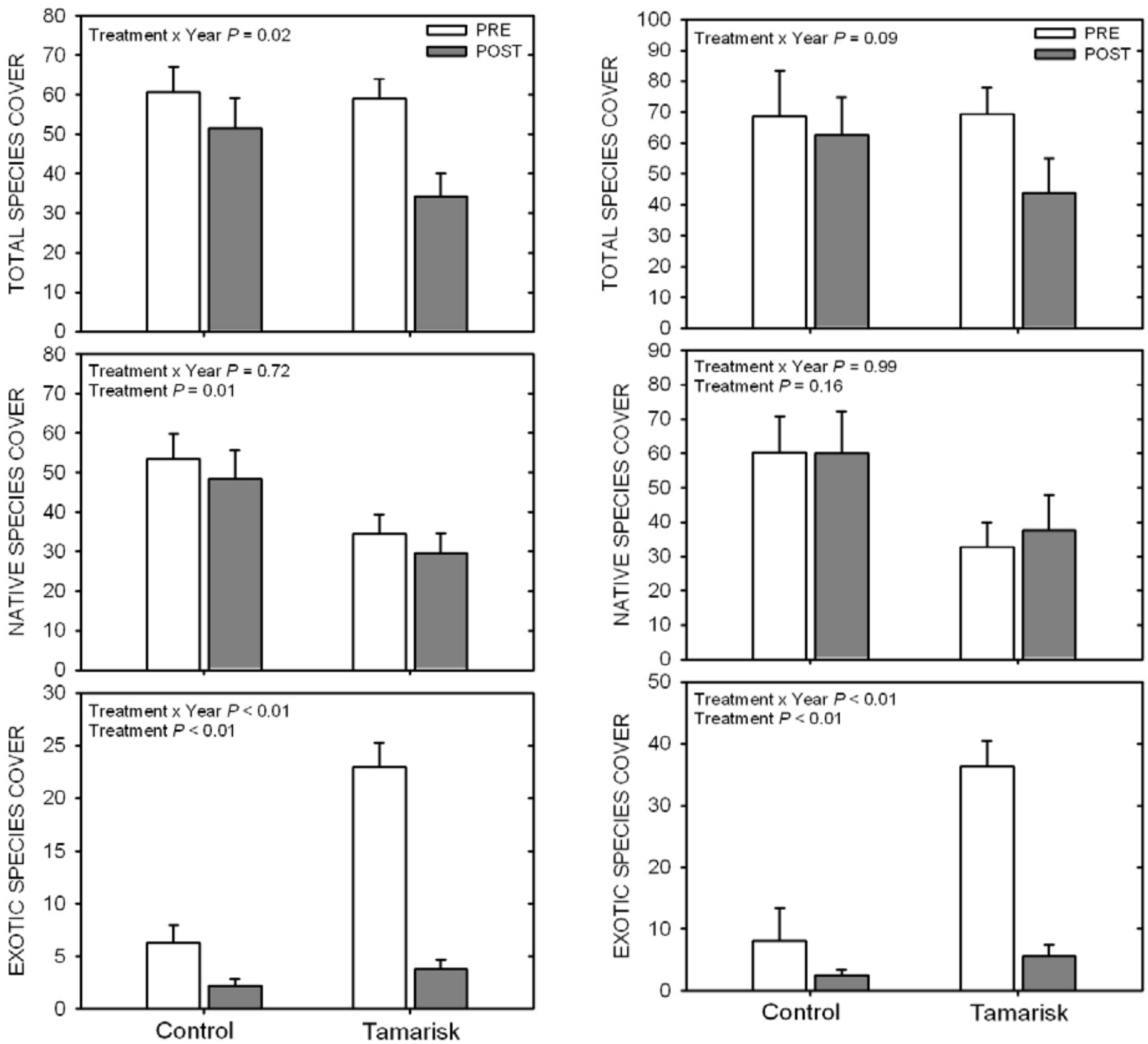
Response Variable		All Species	Native	Exotic
Total Cover	Treatment	0.15	**0.01**	**<0.01**
	Canyon	**0.02**	**0.03**	0.94
	Year	**<0.01**	0.13	**<0.01**
	Treatment × Year	**0.02**	0.72	**<0.01**
Species Richness	Treatment	0.57	0.40	0.11
	Canyon	0.61	0.48	0.39
	Year	0.26	0.20	0.21
	Treatment × Year	0.74	0.54	0.97
Shannon's diversity index	Treatment	0.87	0.96	0.41
	Canyon	0.11	**0.05**	0.43
	Year	0.52	0.76	0.19
	Treatment × Year	0.13	0.88	**0.08**

Table 18. ANOVA results (p values) of using point intercept data to investigate main effects of treatment, canyon, year, and treatment x year interaction for total cover, species richness, and Shannon's diversity index for native, exotic, and all species. Values ≤ 0.10 are bolded to highlight patterns.

Response Variable		All Species	Native	Exotic
Total Cover	Treatment	0.71	0.16	**<0.01**
	Canyon	0.26	0.26	0.62
	Year	**0.03**	0.96	**<0.01**
	Treatment × Year	**0.09**	0.99	**<0.01**
Species Richness	Treatment	0.93	0.50	0.20
	Canyon	**0.09**	**0.10**	0.26
	Year	0.41	0.84	**0.10**
	Treatment × Year	0.56	0.57	0.70
Shannon's diversity index	Treatment	0.92	0.89	0.74
	Canyon	0.22	0.20	0.15
	Year	0.88	0.89	0.27
	Treatment × Year	0.53	0.67	0.39

Figure 8. Mean cover of all species, natives, and exotics for control and tamarisk transects comparing pre and post-treatments (year). Figures on the left are from plot data, and figures on the right are from point intercept data.

PLOT DATA ***POINT INTERCEPT DATA***



In analyzing species richness, no significant treatment effect or treatment x year interaction was found (Tables 17 and 18, Figure 9). No differences were found in any groupings of species richness when using the plot data (Table 17, Figure 9), but richness of all species and native species varied by canyon when using the point intercept data (Table 18, Figures 10 and 11). As expected, exotic species richness on tamarisk transects decreased following treatment, but this decrease also occurred on control transects (Figure 9).

Figure 9. Species richness of all species, natives, and exotics for control and tamarisk transects comparing pre- and post-treatments (year). Figures on the left are from plot data, and figures on the right are from point intercept data.

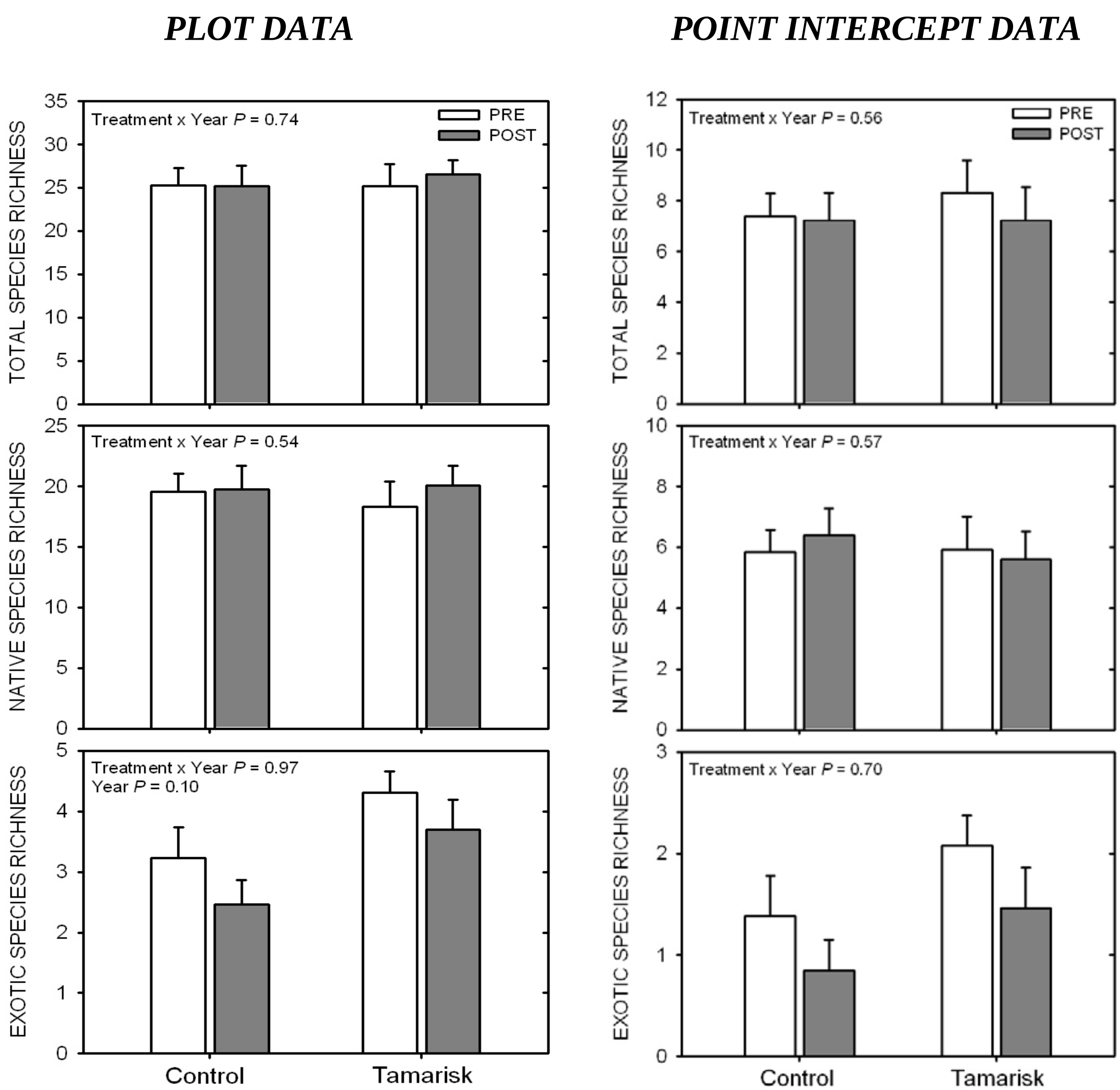


Figure 10. Total species richness (from point intercept data) by canyon for control and tamarisk transects comparing pre- and post-treatments (year).

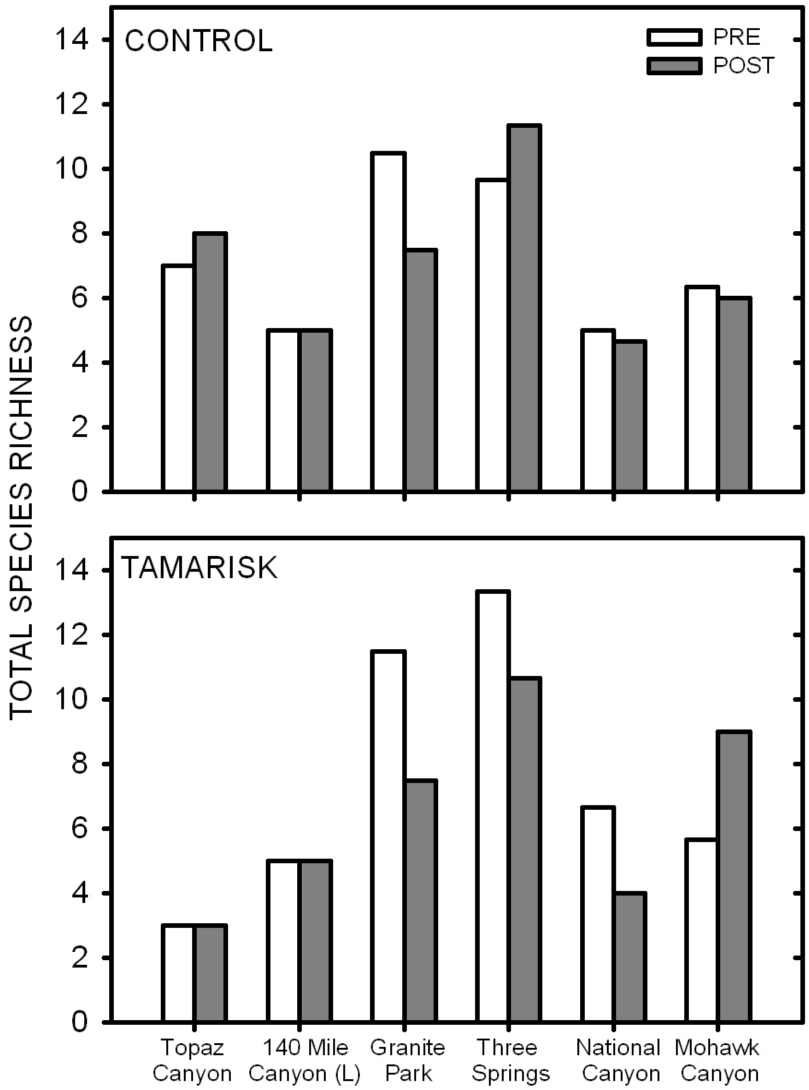
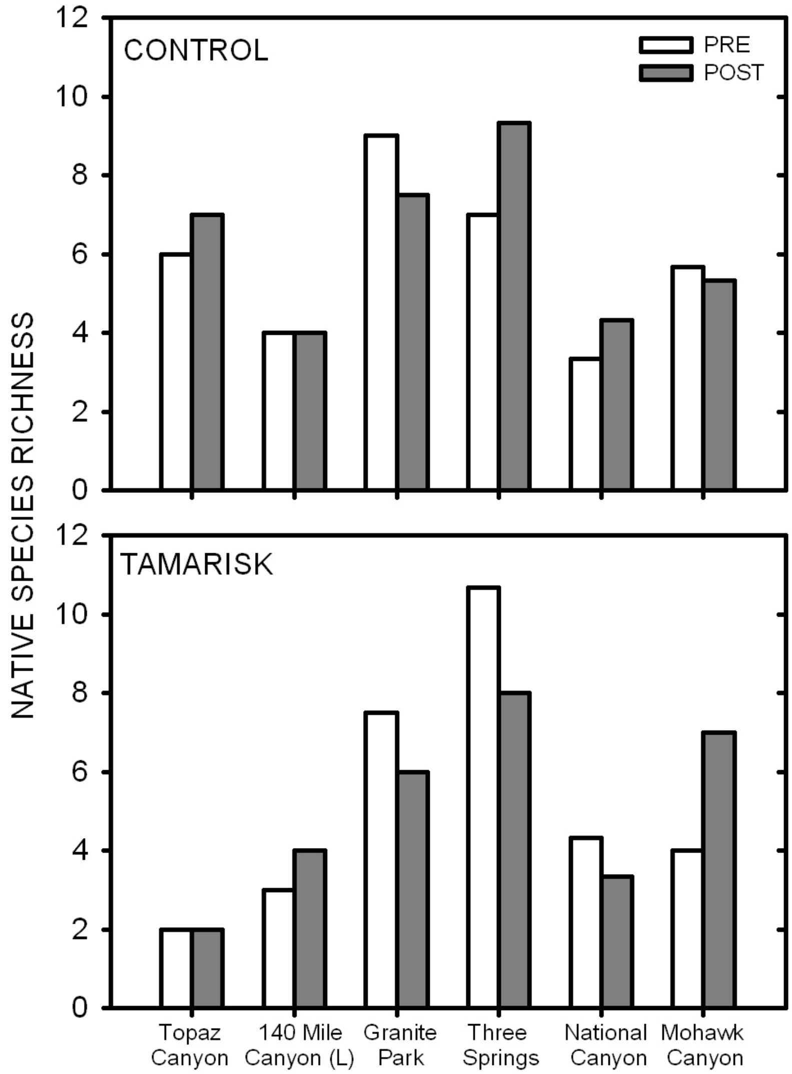
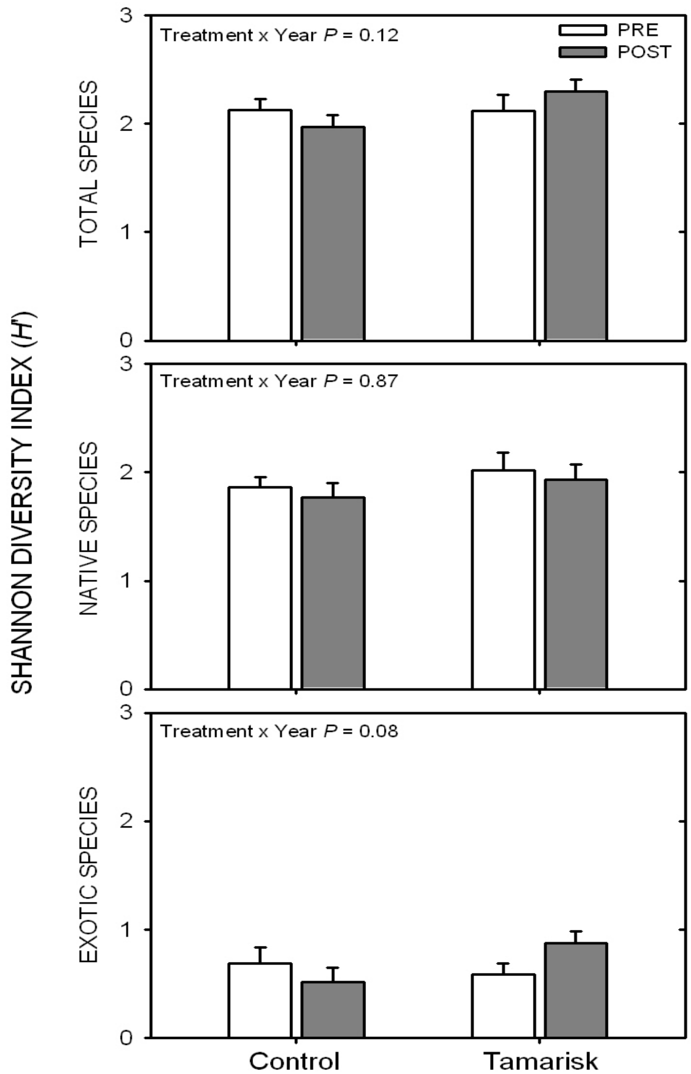


Figure 11. Native species richness (from point intercept data) by canyon for control and tamarisk transects comparing pre and post-treatments (year).



Native species diversity (using Shannon's index, *H*', calculated from plot data) varied by canyon, but diversity of all species and native species did not vary by treatment or year (Table 17, Figure 12). Interestingly, there was a significant treatment x year interaction for exotic species diversity (Table 17). While diversity of exotic species tended to decrease on control transects, it increased following tamarisk removal (Figure 12).

Figure 12. Shannon's diversity index (from plot data) for control and tamarisk transects comparing pre and post-treatments (year).

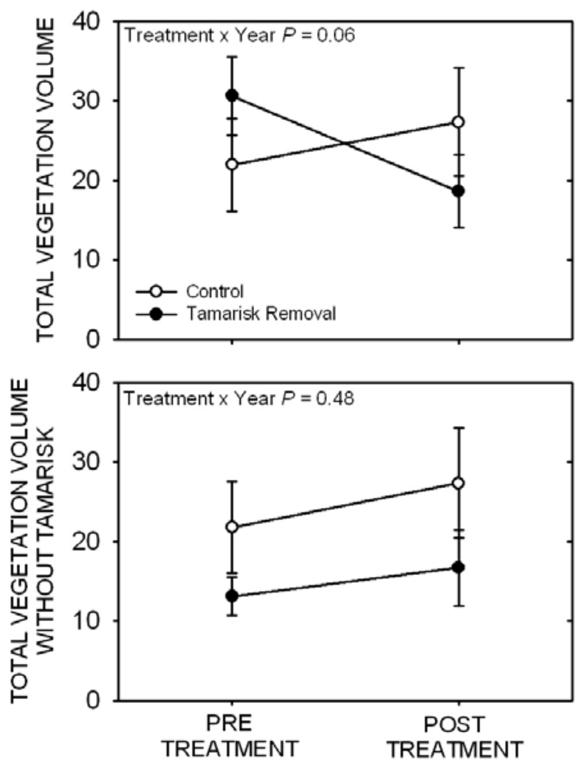


As expected, total vegetation volume decreased more so on tamarisk treated transects than on control transects (Figure 13), with a significant treatment x year interaction (Table 19). This finding is likely a result of the treatments to remove tamarisk; TVV without tamarisk tended to increase regardless of treatment (Figure 13; year main effect $P = 0.09$, Table 19).

Table 19. ANOVA results (F statistics and p values) of using total vegetation volume (TVV) to investigate main effects of treatment, canyon, year, and treatment x year interaction for TVV of all species, and TVV without tamarisk. Values ≤ 0.10 are bolded to highlight marginally significant patterns.

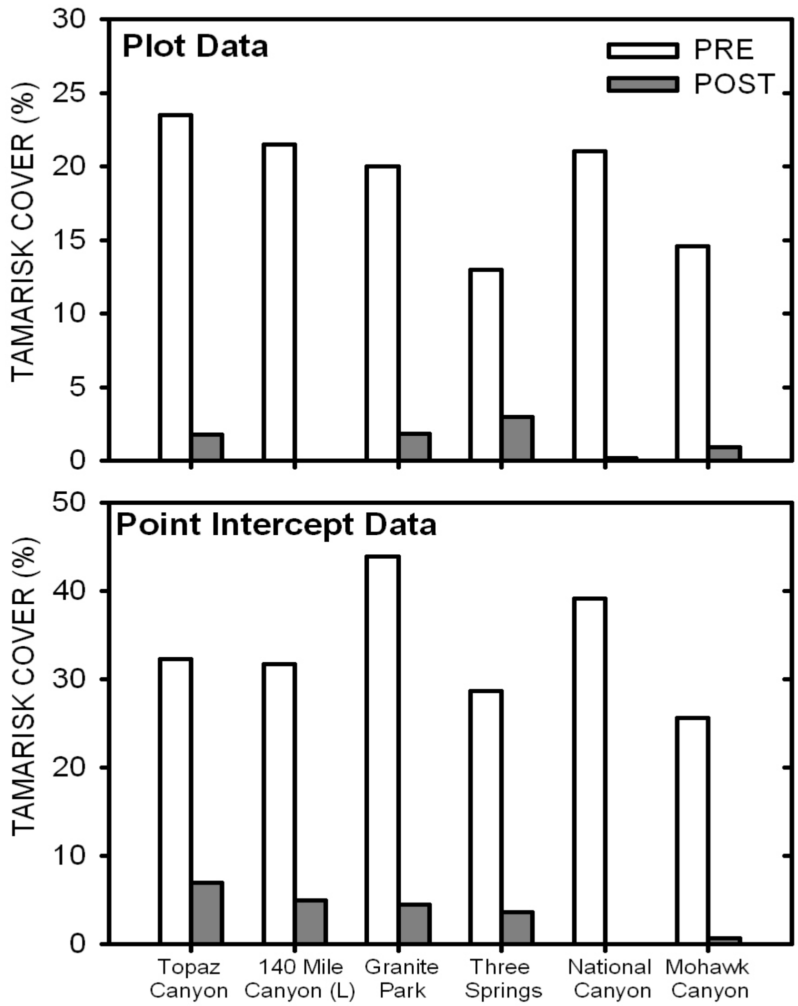
Response Variable		*F*	*P* value
TVV (all species)	Treatment	0.03	0.87
	Canyon	1.70	0.19
	Year	0.12	0.74
	Treatment × Year	4.30	**0.06**
TVV without Tamarisk	Treatment	1.84	0.20
	Canyon	1.88	0.16
	Year	3.25	**0.09**
	Treatment × Year	0.53	0.50

Figure 13. Mean total vegetation volume (TVV) of all species, and TVV without tamarisk for control and tamarisk transects comparing pre and post-treatments.



One of the monitoring objectives for the treated areas, to decrease tamarisk cover to 5% or less, was met and exceeded during this project. According to the plot and point intercept data, respectively, the average pre-treatment tamarisk cover was 18.9% and 33.6%, and was reduced to 1.3% and 3.5% following tamarisk removal (Figure 14). Only one canyon site (Topaz Canyon) had tamarisk cover exceeding 5% following treatment (according to the point intercept data; Figure 14).

Figure 14. Tamarisk cover (%) for both plot and point intercept data on tamarisk treated transects comparing pre- and post-treatments.

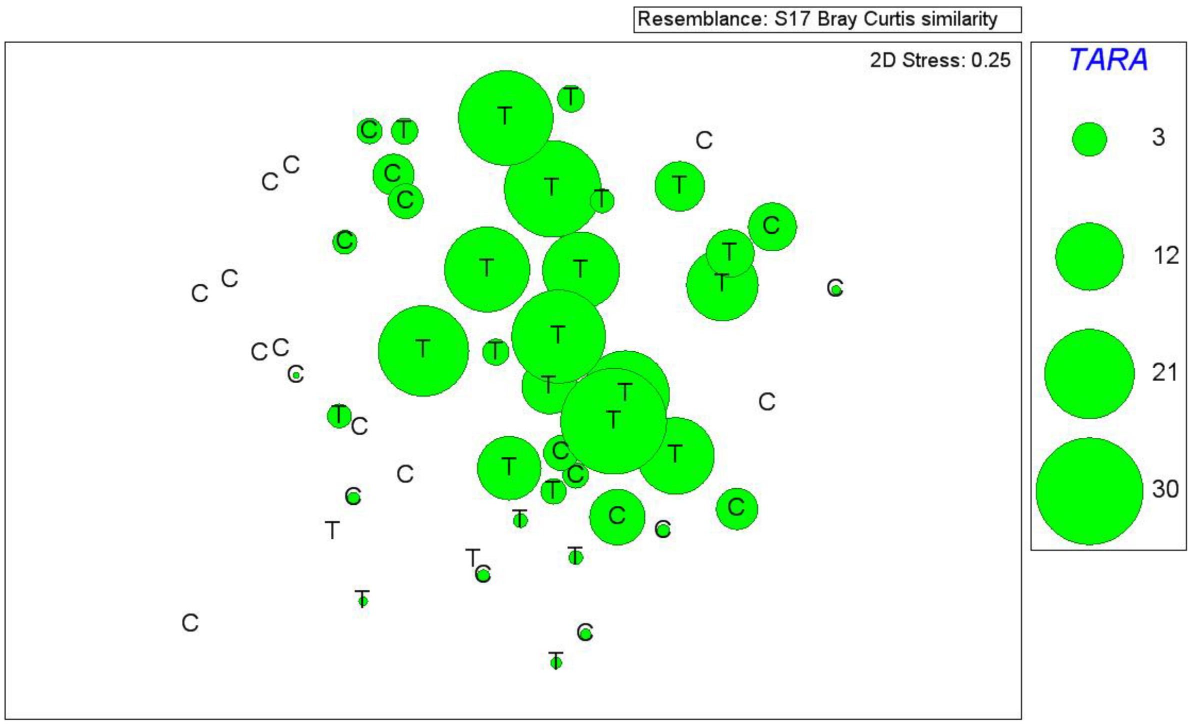


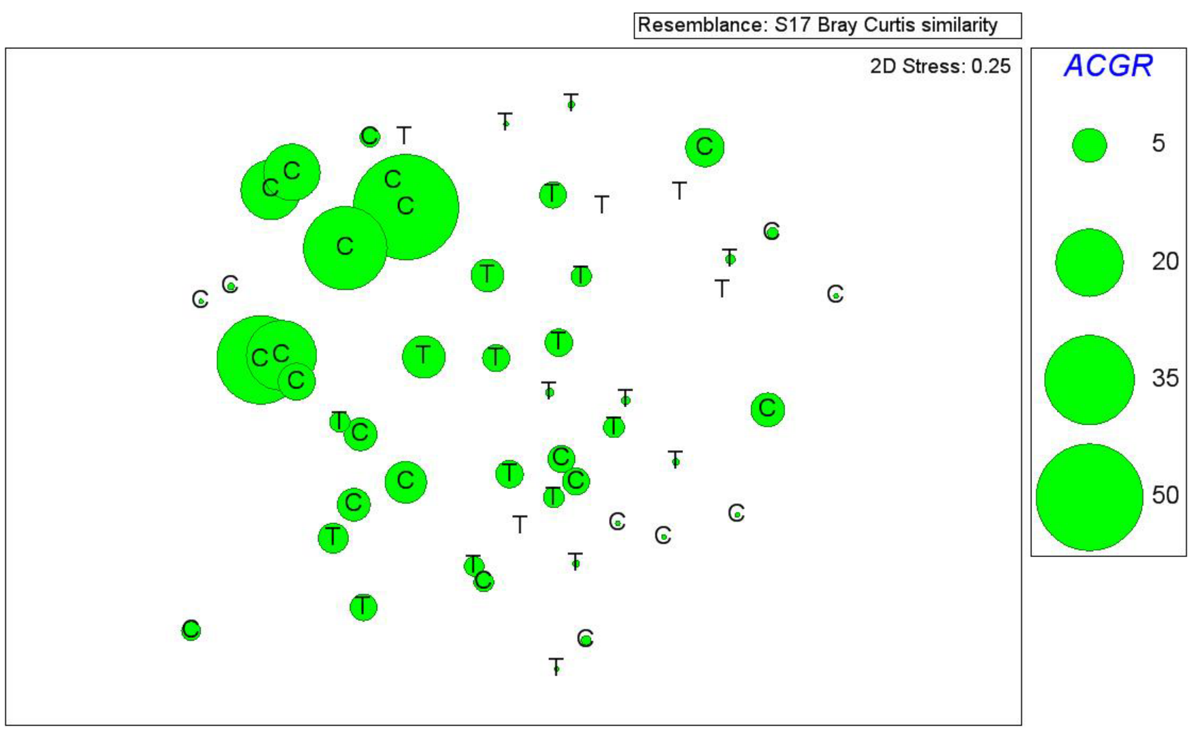
The analysis of similarity (ANOSIM) of the plot data showed different results depending on whether or not tamarisk was included. When all species were included, both treatment and year had significant effects on plant species composition (treatment: R = 0.133, p = 0.001; year: R = 0.139, p = 0.001). This finding is similar to the significant treatment x year interaction shown in Table 1. When tamarisk was removed from these data, no ANOSIM differences were detected (treatment: R = 0.036, p > 0.08; year: R = 0.005, p > 0.35). Thus, as expected, tamarisk cover played a significant role in the pre-treatment vegetation composition of transects slated for tamarisk control, and its removal resulted in a shift in species composition. After its removal, the species composition of transects were similar. The significance of tamarisk was further analyzed using a "similarity percentages" (or SIMPER) routine in PRIMER. The species contributing the most to dissimilar patterns between treatments and year was tamarisk (TARA or *Tamarix ramosissima*; Table 20), followed closely by catclaw acacia (ACGR or *Acacia greggii*). A bubble plot analysis (also conducted in PRIMER) confirmed that these two species had dissimilar cover patterns when comparing their relative abundances among control and tamarisk transects (Figure 15).

Table 20. Analysis of similarity percentages (SIMPER) showing the four most important species contributing to dissimilarities among treatment (across all years) and year (across all treatments) groups.

Group	Species code	Average Dissimilarity	% Contribution
Treatment	TARA	7.84	9.57
	ACGR	7.70	9.40
	BASA4	6.70	8.18
	ISAC2	4.52	5.51
Year	TARA	10.68	13.19
	ACGR	6.45	7.97
	BASA4	6.07	7.50
	ISAC2	4.32	5.34

Figure 15. Bubble plot analysis of tamarisk (top: TARA or *Tamarix ramosissima*) and catclaw acacia (bottom: ACGR or *Acacia greggii*) from non-metric multi-dimensional scaling (NMDS) ordination of species composition from all control (C) and tamarisk (T) transects. Maximum cover (from plot data) is indicated by the largest bubble and other bubble sizes indicate relative abundance at other transects.





Results Summary in Non-Technical Terms

Overall, when crew leaders returned to the re-visit the 26 transects, there were obvious differences in the tamarisk transect areas, which can be seen in the data and also in the transect photographs, but the reference transects remained similar to what was seen during the previous visits. During the initial installation of transects, it was very difficult to stretch the 50 meter transect tape through the dense tamarisk thickets. When crews re-visited the transects after treatment, the areas were more open, with cut stumps still present and debris on the ground, but the removal of tamarisk was evident, as show below in the pre- and post-view from the start of Granite Park Canyon Transect 1A. In the 2006 photograph, note the dense thicket of tamarisk. In the 2007 photograph, that thicket has been removed. In that photograph, the small green plants are tamarisk seedlings, which were subsequently pulled by Grand Canyon Youth volunteers.

In a few project areas, crews noticed some tamarisk seedlings and a limited number of cut stumps that had re-sprouted. They noted the locations for future removal teams. In general, the post-treatment areas had more arrowweed, seep willow, and coyote willow, along with more grass seedlings than in previous years. They also tended to have more seedlings of acacia and mesquite, primarily in the more mesic sites.

Because the transects were read only 1-2 years after treatment, much more time will be required to fully determine what new species will become dominant in the project areas. These results reflect the preliminary surge of species, and with 2007 being such a dry year, the data may not present a very full picture of what is to come. All of these data are entered into the database, and additional queries and analyses can be performed in the future. It would be interesting to see what life forms (i.e. grasses, forbs, and trees) will dominate the areas, after a few years of recovery, and also which species are the most successful in the post-tamarisk removal environment. At this time, the data are all entered into the database, and if anyone would like to do a more detailed or different analysis, they can access those data.

c. Plant Species Inventories

In addition to the vegetation cover and structure data, botanists compiled complete species lists for each of the transect areas, which are included in Appendix J (Plant Observations). Wendy Hodgson, senior research botanist and herbarium curator at the Desert Botanical Garden in Phoenix, annotated 257 specimens collected during the surveys under her Grand Canyon and Hualapai plant collection permits. The botanical survey work has already revealed range expansions for many under collected and rare species, and the collections have increased our knowledge about several plants for which little is known of their distribution and taxonomy. This botanical inventory work also yielded an exciting list of plants that are new records for Grand Canyon National Park, or the Grand Canyon area, and revealed at least one species that is new to science, *Mentzelia abyssa*, which was first found up 140 Mile Canyon (Table 21. New or Notable Species to Grand Canyon).

From this work, botanists will probably begin to see an interesting pattern, which will inform future collection and inventory work for the Park and help uncover the enduring mystery of Grand Canyon's amazing flora. The documentation by Ms. Hodgson and the project participants helps to verify the vast diversity of Grand Canyon's flora, found in the side canyons and tributaries of the Colorado River on both park and Hualapai lands, further determining their need for a high level of protection from invasive plants such as tamarisk.

Table 21. New or Notable Species to Grand Canyon

Scientific Name	Status
Alicellia subnuda	Three Springs Canyon, new record for Grand Canyon area
Cylindropuntia abyssii	Three Springs and Granite Park Canyons, previously known only from Peach Springs
Encelia resinifera var. *tenuifolia*	National and Prospect Canyons, endemic to Grand Canyon area, rare, under collected or misidentified
Flaveria macdougalii	National and Mohawk Canyons, endemic to Grand Canyon area
Fouquieria splendens	National Canyon, rarely collected in Canyon, not included in Vascular Plants of AZ
Galium proliferum	National Canyon, rare in Grand Canyon area, under collected
Gilia clokeyi	Mohawk Canyon, new record for Grand Canyon area if identified correctly
Heliomeris annua	Granite Park Canyon, third collection in Grand Canyon area
Hesperodoria salicina	140 Mile transects, endemic to Grand Canyon
Hesperoyucca newberryi	Mohawk Canyon, endemic to Grand Canyon area
Imperata brevifolia	Mohawk Canyon, remnant populations in Canyon from otherwise wider distribution
Lepidium eastwoodiae	140 Mile, close to L. montana, new to Grand Canyon
Mentzelia abyssa	140 Mile and National, new species, endemic to Grand Canyon
Mortonia scabrella var. *utahensis*	National Canyon, near endemic variety, otherwise known from sw Utah
Nolina cf. *microcarpa*	National Canyon, perhaps a new taxon
Opuntia cf. *phaeacantha* var. *laevis*	Mohawk Canyon, taxonomic questions, possibly new record for Grand Canyon area
Phacelia filiformis	National and Mohawk Canyons, endemic to Grand Canyon area
Piptatherum miliaceum	Three Springs Canyon, new record for Grand Canyon area, exotic
Rafinesquia californica	Granite Park Canyon, only second collection in Grand Canyon area
Rumex obtusifolius	National Canyon, only second collection in Grand Canyon area

In addition to the plant collection information, crew leaders recorded the dominant and associated species in the tamarisk control areas. These data were recorded on the tamarisk mapping and habitat assessment forms as the initial surveys were done. Crew leaders also recorded additional associated species that occurred in the areas when the invasive plant removal work was completed. Those lists are included as Appendix I (Plant Lists from Project Areas). Those lists, when combined with Ms. Hodgson's collections included as Appendix J (Plant Collections), present a full picture of the pre-removal species composition within each project area.

From the database, there are two ways to view the species lists that were generated by the field crew's data collection efforts. From the Main Menu, select Vegetation Monitoring (Figure 16). From there, either select the Plant Listings – Excel or the Plant Listings – Summary button. These reports do not allow you to do initial filtering for Phase II-B project areas, but you can view the information for specific project areas as needed by deleting the unneeded project areas from the exports. This section of the database will be further refined by the GRCA Database Manager in the future to make it more user-friendly.

When crews return to the project areas in the future to re-take photographs or complete follow-up maintenance and treatment activities, they will have the list of pre-treatment plant species with them. From that list, they will record new species found in the areas, which will enable project managers to keep track of how species composition changes in each project area over time. In the subset of the project areas in which crews installed transects, those transects were read pre- and post-treatment and they display the more detailed analysis of how species cover and composition have changed during the course of this grant, as described in detail on the previous pages.

Figure 16. Grand Canyon Database - Vegetation Monitoring Switchboard

d. Rare Plant Monitoring Data

Project leaders documented rare plants in project areas during implementation of the tamarisk management and monitoring actions. For species on GRCA lands, they gathered site information, specific information about the population of the rare plant, and also vegetation cover class data in the local area for the three rare plant locations identified during project implementation. One plant is ringstem, which was located in the Colorado River corridor near a tamarisk treatment area and was a newly identified site within the park. At one of the tamarisk project areas, 151 Mile Spring, the project coordinator completed monitoring documentation for MacDougall's flaveria, a species that is endemic to GRCA. During the first visit to 140 Mile Canyon, project botanists collected a mentzelia specimen, and it turned out to be a new species called *Mentzelia abyssa* (photo below on right). Very little is known about its distribution, and project leaders will fill out full monitoring data sheets for this new species on future trips.

Project leaders located additional rare species within project areas on Hualapai tribal lands; however, monitoring data sheets were only filled out for Mojave thistle (CIRMOH - *Cirsium mohavense*), which is found in Three Springs Canyon. The project leader will provide Hualapai partners with the location information for these species and they can determine whether or not to monitor the site. Crews recorded these four observations of a rare plant species within project areas, included as Appendix K – Rare Plant Monitoring Data.

Ringstem (ANULEI - *Anulocaulis leiosolenus* var. *leiosolenus*) is in the Nyctaginaceae family. It has a basal rosette of broad, leathery leaves, and purple tubular flowers, which are easy to recognize. It grows on alkaline clay and gypsum soils from 1700 to 4000 feet in elevation and is endemic to GRCA. The population found through this project has increased the park's knowledge of this plant's distribution (photo below on left)

McDougall's flaveria (FLAMAC – *Flaveria mcdougallii*) is in the Asteraceae family. It has opposite, narrowly linear leaves, with woody stems and flat-topped inflorescences. This plant grows at seeps and springs, primarily in the Muav limestone and Bright Angel shale layers, from 1800 to 1670 feet in elevation. The site documented during this project is new for the canyon (photo below in center).



The data collected will be used for long-term monitoring in an effort to determine trends over time. The removal of tamarisk is likely to benefit these species, but only long-term trends and monitoring will show the full picture.

e. Hydrology Sampling

The trip hydrologists gathered water quality and flow data at 32 total sites within the following 12 project areas: 140 Mile Canyon, Agate Canyon, Granite Park Canyon, Honga Spring, Mohawk Canyon, National Canyon, Prospect Canyon, Sapphire Canyon, Slate Creek, Spring Canyon, Three Springs Canyon, and Topaz Canyon. These data will be provided to Park and Hualapai hydrologists as a contribution to long-term water sampling and monitoring. For some project areas, the hydrologists have baseline information that can be used as additional pre-invasive plant removal data and compared following future data collection. The hydrology component of the project database was completed in 2006 and all of the data have been entered. For this report, the hydrology data for the 12 project areas as well as a sample photos are included as Appendix D (Hydrology Data). These data can be viewed under the Hydrology portion of the database, either as a report or in data entry mode. Post-tamarisk removal data were only collected at the project areas selected for monitoring (140 Mile Canyon, Granite Park Canyon, Mohawk Canyon, National Canyon, Three Springs Canyon and Topaz Canyon).

As stated in the project Monitoring Plan, one goal was to take a GPS reading the beginning and end of surface water flow in the project areas. Because of the lack of time during the May monitoring river trips and poor satellite coverage in project areas, this was not done consistently enough throughout the project areas to be included in the report or database.

Several preliminary findings are interesting to note at this time (see Table 22. Hydrology Sampling Results). Average water temperature decreased post-tamarisk removal, from 23.6 to 22.0° Celsius, which could be due to the fact that the readings in 2008 were taken one month early, or it could merely be normal annual variation. The average pH rose slightly, with pre-tamarisk pH levels of 8.07 and post-tamarisk removal levels decreasing to 8.10. There is not a large enough sample size or sufficient time between treatments to determine whether this is normal variation or a trend that will continue as the native vegetation re-enters the area.

Average electroconductivity (EC) levels rose from 1224.69 mS/cm pre-tamarisk to 1266.71 mS/cm post-tamarisk removal. Nutrient rich solutions have higher EC values than those with less ionic content. The short term rise in EC could reveal an increase in the nutrients in the water, which could have been released following the removal of tamarisk and not yet captured by vegetation encroaching into the project areas. However, EC is sensitive to temperature, so the decrease in water temperature likely affected those readings. The Hanna probe used for this project does not appear to standardize for temperature, which many other probes automatically due.

The total dissolved solids (TDS) went from 612.38 ppm pre-tamarisk and 632.87 ppm post-tamarisk removal. TDS, a measure of all organic and inorganic substances in water, relates to the electroconductivity of the water. Most of the content in natural water systems is inorganic compounds in the form of four negative ions (bicarbonate, carbonate, chloride, and sulfate) and four positive ions (calcium, magnesium, sodium and potassium) (Duluth Streams, 2007). The increase in TDS could be related to weather events preceding data collection events. It will be interesting to notice if those levels continue to increase over time as native vegetation recovers in the project areas.

With often extreme annual variation in hydrological measurements, it is not possible to detect or discuss long-term change within the time frame of this project; therefore, the hydrological data are preliminary and no solid conclusions can be made at this time. These measurements will be part of a long-term monitoring program and more data will help reveal long term trends.

Table 22. Hydrology Sampling Results

Site	Easting	Northing	Surface Water Type	Date	Avg Temp	Avg pH	Avg EC (mS/cm)	Avg TDS (ppm)	Discharge (m3/sec)
Pre- Tamarisk Removal									
140 L Hydro 1	359410	4029266	Stream	5/10/06	26.1	8.2	849.3	422.3	148.71
Agate Hydro 1	384673	4000306	Stream	4/26/06	23.2	7.6	2468	1223.3	N/A
Agate Hydro 2	384811	4000563	Stream	4/26/06	19.3	8.3	2853	1433	N/A
Agate Hydro 5	384039	3999003	Pothole	4/26/06	N/A	8.7	915.7	N/A	N/A
Granite Park Hydro 1	291484	3982798	Pothole	5/16/06	25.8	7.2	1070.3	528	N/A
Granite Park Hydro 2	291578	3982597	Stream	5/16/06	25.5	7.6	848.3	423.7	2019.06
Honga Hydro 1	315942	4009196	Seep	5/14/06	18.6	8.3	1459.3	728	N/A
Mohawk Hydro 1	323157	4010593	Stream	5/13/06	21.2	8.2	1735.7	867.3	1483.69
Mohawk Hydro 2	323127	4010686	Stream	5/13/06	22.4	8.2	1726	863	17.31
Mohawk Hydro 3	323055	4010622	Seep	5/13/06	29.7	8.5	1708.3	854	7003.12
Mohawk Hydro 4	323023	4010317	Seep	5/13/06	25.9	8.3	1668	833.3	2126.74
Mohawk Hydro 5	323032	4010269	Seep	5/13/06	28	8.1	1879.3	941.3	2952
Mohawk Hydro 6	322856	4009921	Seep	5/13/06	24.1	8	1872.7	934.3	2099.96
National Hydro 1	330364	4013868	Stream	5/12/06	19.9	8.1	1942.7	971	5998.63
National Hydro 2	330441	4013819	Stream	5/12/06	25.1	8.3	1911.7	956.3	4218.05
National Hydro 3	330759	4013779	Stream	5/12/06	22.1	8	1902.3	951.3	56.19
Prospect Hydro 1	313041	4007180	Seep	5/14/06	18.6	8.2	1435.3	690	N/A
Sapphire Hydro 1	383040	3999787	Stream	4/26/06	24	8.2	1139.3	539	305.87
Sapphire Hydro 2	382951	3999753	Pothole	4/26/06	25.5	7.9	1323.3	651.3	N/A
Slate Hydro 1	387667	3999308	Stream	4/25/06	N/A	7.9	3999	2000	1240.5
Slate Hydro 2	385620	3998424	Pothole	4/23/06	20	8.3	1575.3	785	N/A
Slate Hydro 3	386387	3998841	Spring	4/23/06	21	8.2	1738.7	882.7	443.18
Spring Canyon Hydro 1	287746	3988551	Spring	5/16/06	27.4	7.5	677.3	320.7	N/A
Three Springs Hydro 1	291702	3973711	Stream	5/17/06	24.6	8	475.7	237.7	488.53
Three Springs Hydro 2	291765	3973703	Stream	5/17/06	24.4	7.6	464.7	232.7	228.59
Three Springs Hydro 3	292649	3973654	Stream	5/17/06	26.9	8.1	436	218.7	17178.95
Three Springs Hydro 4	292737	3973616	Stream	5/17/06	26.1	7.7	434	217.3	7437.5
Topaz Hydro 1	387730	3996874	Stream	4/23/06	18	7.1	3215.3	1623.7	N/A
Topaz Hydro 6	386442	3996233	Pothole	4/24/06	N/A	8	625.7	323.7	N/A
Topaz Hydro 7	385888	3996052	Stream	4/24/06	N/A	8.2	838	419.3	N/A

Site	Easting	Northing	Surface Water Type	Date	Avg Temp	Avg pH	Avg EC (mS/cm)	Avg TDS (ppm)	Discharge (m3/sec)
Topaz Hydro 8	385511	3995868	Stream	4/24/06	N/A	8.1	726	355.7	N/A
Topaz Hydro 9	385082	3995387	Stream	4/24/06	N/A	8.1	341.7	175	N/A
Post- Tamarisk Removal									
140 L Hydro 1	359410	4029266	Stream	5/14/07	22.7	8.1	962	481	N/A
Agate Hydro 1	384673	4000306	Not Revisited Post-Tamarisk Removal						
Agate Hydro 2	384811	4000563	Not Revisited Post-Tamarisk Removal						
Agate Hydro 5	384039	3999003	Not Revisited Post-Tamarisk Removal						
Granite Park Hydro 1	291484	3982798	Pothole	5/20/07					
Granite Park Hydro 2	291578	3982597	Stream	5/20/07	19.4	7.5	724.3	367.3	N/A
Honga Hydro 1	315942	4009196	Not Revisited Post-Tamarisk Removal						
Mohawk Hydro 1	323157	4010593	Stream	5/16/07	23.5	8.6	1863.3	910.3	4666.67
Mohawk Hydro 2	323127	4010686	Stream	5/16/07	26.1	7.7	1773.7	905.7	4126.98
Mohawk Hydro 3	323055	4010622	Stream	5/16/07	33.2	8	1858.3	911.7	N/A
Mohawk Hydro 4	323023	4010317	Seep	5/16/07	19.1	7.7	1737	869.3	1523.81
Mohawk Hydro 5	323032	4010269	Seep	5/17/07	22	7.5	1976	985.7	4307.69
Mohawk Hydro 6	322856	4009921	Seep	5/17/07	27.6	8.2	1953.3	976.3	7196.26
National Hydro 1	330364	4013868	Stream	4/20/08	15.2	8.1	1664.3	833.3	52109.38
National Hydro 2	330441	4013819	Stream	4/20/08	19.5	8.1	1672.3	836.7	107.76
National Hydro 3	330759	4013779	Stream	4/20/08	13.7	7.6	1683.3	844.3	N/A
Prospect Hydro 1	313041	4007180	Not Revisited Post-Tamarisk Removal						
Sapphire Hydro 1	383040	3999787	Not Revisited Post-Tamarisk Removal						
Sapphire Hydro 2	382951	3999753	Not Revisited Post-Tamarisk Removal						
Slate Hydro 1	387667	3999308	Not Revisited Post-Tamarisk Removal						
Slate Hydro 2	385620	3998424	Not Revisited Post-Tamarisk Removal						
Slate Hydro 3	386387	3998841	Not Revisited Post-Tamarisk Removal						
Spring Canyon Hydro 1	287746	3988551	Not Revisited Post-Tamarisk Removal						
Three Springs Hydro 1	291702	3973711	Stream	4/25/08	19.4	7.6	631.3	316	9231.18
Three Springs Hydro 2	291765	3973703	Stream	4/25/06	21.5	7.1	629.3	314.3	N/A
Three Springs Hydro 3	292649	3973654	Stream	4/25/08	21.3	7.6	575.7	290	13975.69
Three Springs Hydro 4	292737	3973616	Stream	4/25/08	22.9	7.7	591.3	295.7	N/A
Topaz Hydro 1	387730	3996874	Not Revisited Post-Tamarisk Removal						
Topaz Hydro 6	386442	3996233	Pothole	4/14/08	16	7.7	660.7	330.7	N/A
Topaz Hydro 7	385888	3996052	Stream	4/14/08	24.8	8.4	1067	532.7	2941.18
Topaz Hydro 8	385511	3995868	Stream	4/14/08	27.4	8.1	777.7	390.7	N/A
Topaz Hydro 9	385082	3995387	Not Revisited Post-Tamarisk Removal						

f. Soil Sampling Results

The complete results of the soil sampling are included in Appendix E (Monitoring Transect Data) and can be viewed under the transect portion of the Vegetation Monitoring component of the database. The improvement in methodology since 2005 yielded more accurate readings. Mixing soil with de-ionized water and the investment in a new probe greatly improved results. Project leaders compared soil points below areas with dense tamarisk structure and cover to those with native vegetation, and monitored post-treatment trends in soil recovery.

It was expected that average pH and EC would drop following tamarisk removal. Across all transects, the average pH dropped from 8.64 to 8.40 and the average EC dropped from 1255.12 to 1175.39 (Refer to Table 23. Pre-Tamarisk Removal Soil Data and Table 24. Post-Tamarisk Removal Soil Data). When analyzing just the tamarisk removal transects, the average pH dropped from 8.68 to 8.34 (Figure 17) and the average EC dropped from 1443.37 to 1316.90 (Figure 18). Over the next few years, both readings are likely to continue to drop until they stabilize to those related to the native vegetation.

Table 23. Pre-Tamarisk Removal Soil Data

Transect	Survey Date	Average pH	Average EC (mS/cm)
Pre- Tamarisk Removal			
140 Mile L 1 A	5/10/2006	8.73	850.67
140 Mile L 1 B	5/10/2006	8.82	118.27
Granite Park 1 A	5/16/2006	8.85	1217.53
Granite Park 1 B	5/16/2006	8.37	1344.47
Granite Park 2 A	5/16/2006	8.88	1158.80
Granite Park 2 B	5/16/2006	8.19	197.20
Mohawk Canyon 1 A	5/13/2006	8.98	2902.73
Mohawk Canyon 1 B	5/13/2006	8.47	301.80
Mohawk Canyon 2 A	5/13/2006	8.18	1895.20
Mohawk Canyon 2 B	5/13/2006	8.74	2666.67
Mohawk Canyon 3 A	5/13/2006	8.79	1002.53
Mohawk Canyon 3 B	5/13/2006	8.78	2801.80
National Canyon 1 A	5/11/2006	8.70	2276.60
National Canyon 1 B	5/11/2006	8.16	1518.27
National Canyon 2 A	5/12/2006	8.57	1247.87
National Canyon 2 B	5/12/2006	8.56	2035.40
National Canyon 3 A	5/12/2006	8.73	660.27
National Canyon 3 B	5/12/2006	8.64	742.33
Three Springs 1 A	5/17/2006	8.25	2650.07
Three Springs 1 B	5/17/2006	8.86	90.53
Three Springs 2 A	5/17/2006	8.81	398.47
Three Springs 2 B	5/17/2006	8.67	190.67
Three Springs 3 A	5/17/2006	8.82	754.73
Three Springs 3 B	5/17/2006	9.11	1655.13
Topaz Canyon 1 A	4/23/2006	8.54	1748.33
Topaz Canyon 1 B	4/23/2006	8.48	206.67
	Average	**8.64**	**1255.12**

Table 24. Post-Tamarisk Removal Soil Data

Transect	Survey Date	Average pH	Average EC (mS/cm)
Post- Tamarisk Removal			
140 Mile L 1 A	5/14/2007	8.11	318.00
140 Mile L 1 B	5/14/2007	8.92	79.33
Granite Park 1 A	5/20/2007	8.47	2910.67
Granite Park 1 B	5/20/2007	8.36	723.67
Granite Park 2 A	5/20/2007	8.12	1964.53
Granite Park 2 B	5/20/2007	8.18	196.93
Mohawk Canyon 1 A	5/17/2007	8.53	2893.67
Mohawk Canyon 1 B	5/17/2007	8.26	2153.47
Mohawk Canyon 2 A	5/17/2007	8.31	1298.73
Mohawk Canyon 2 B	5/17/2007	8.69	3732.80
Mohawk Canyon 3 A	5/16/2007	7.69	1425.40
Mohawk Canyon 3 B	5/16/2007	8.33	2975.93
National Canyon 1 A	4/20/2008	8.41	663.93
National Canyon 1 B	4/20/2008	8.72	746.80
National Canyon 2 A	4/20/2008	8.49	1498.13
National Canyon 2 B	4/20/2008	8.39	977.53
National Canyon 3 A	4/20/2008	8.31	1373.80
National Canyon 3 B	4/20/2008	8.08	828.80
Three Springs 1 A	4/25/2008	8.09	1386.80
Three Springs 1 B	4/25/2008	7.68	371.73
Three Springs 2 A	4/25/2008	8.22	144.13
Three Springs 2 B	4/25/2008	7.80	137.20
Three Springs 3 A	4/25/2008	8.32	499.73
Three Springs 3 B	4/25/2008	8.12	320.73
Topaz Canyon 1 A	4/14/2008	9.30	742.20
Topaz Canyon 1 B	4/14/2008	10.45	195.47
	Average	**8.40**	**1175.39**

Figure 17. Soil pH Across All Tamarisk Transects

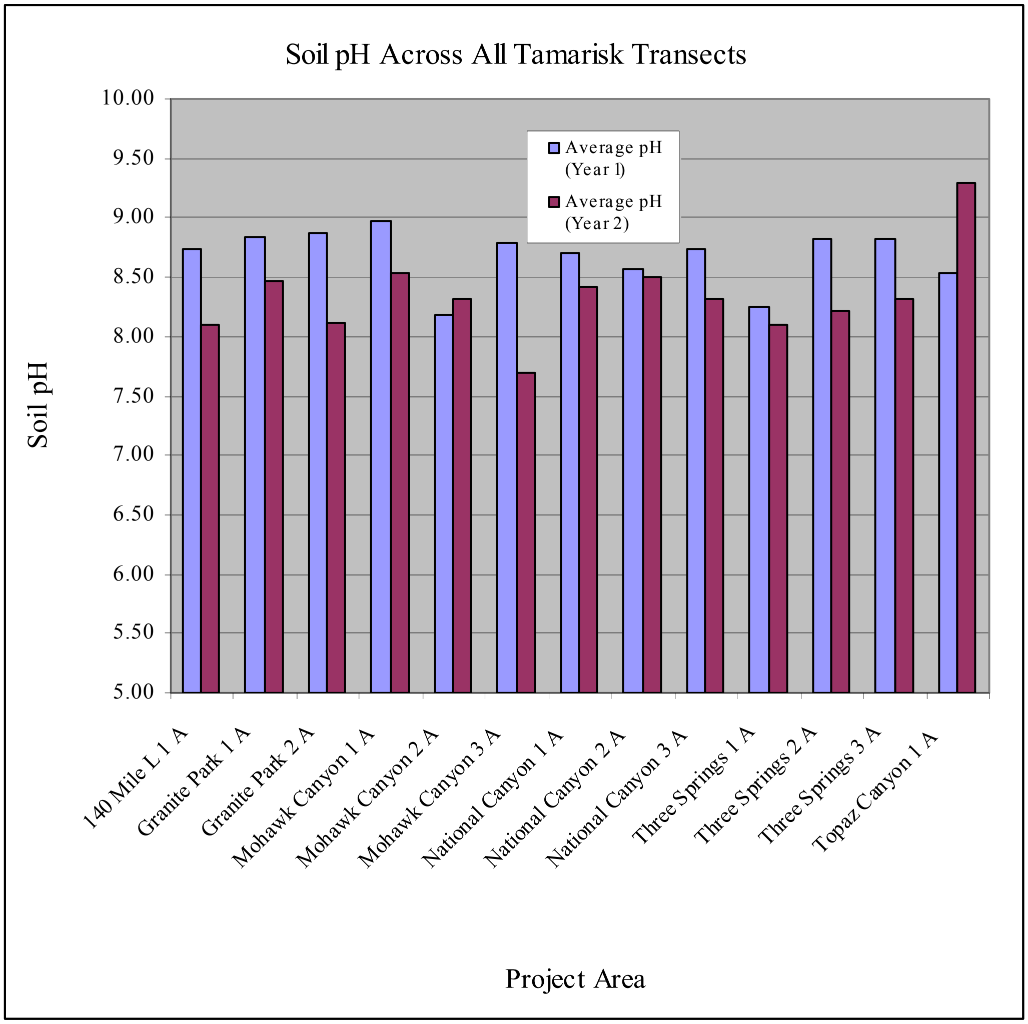
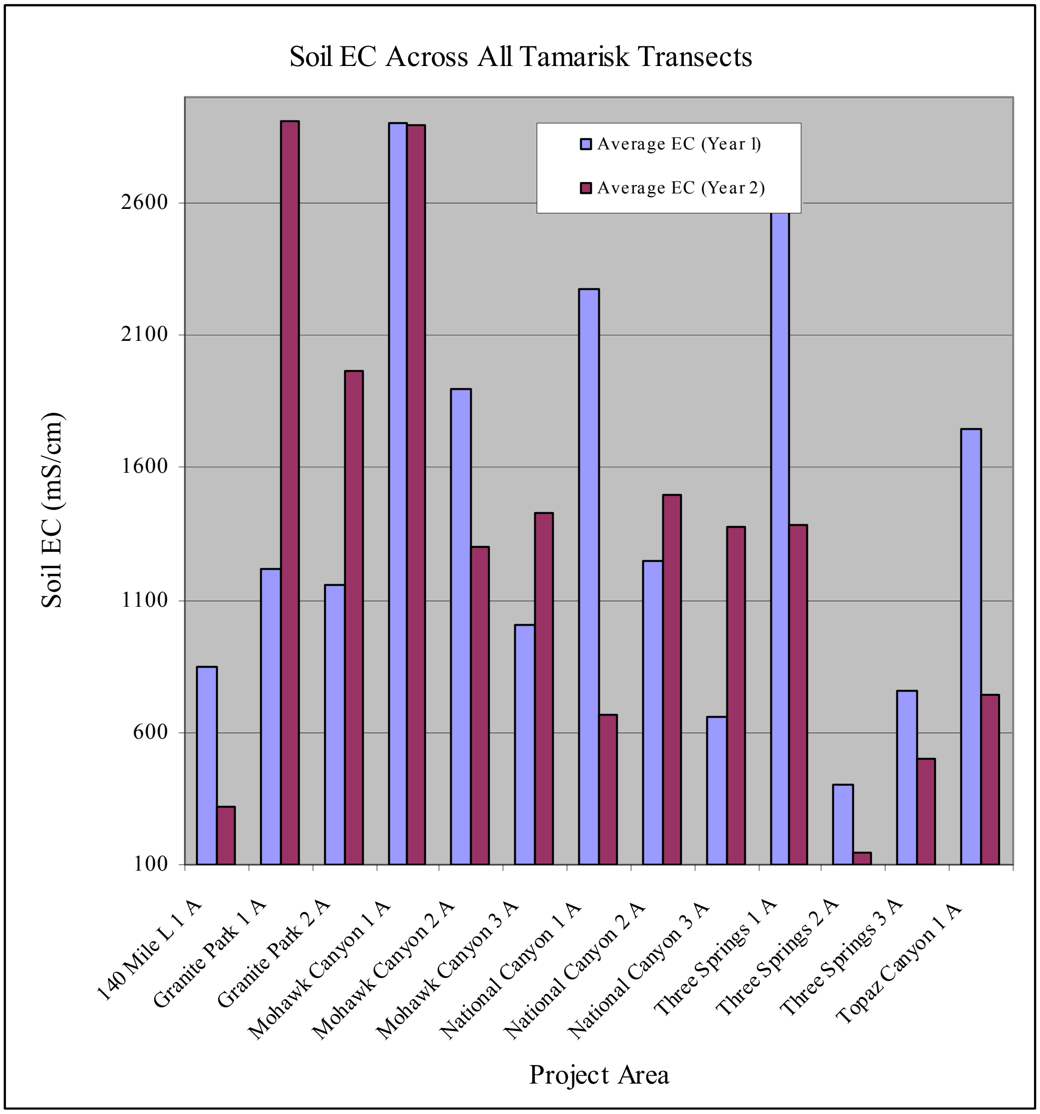


Figure 18. Soil EC Across All Tamarisk Transects



g. Photopoint Installation and Long-Term Monitoring

During the river and backpacking trips, crews installed 200 permanent photopoints in many of the project areas. More than one photograph was taken from each photopoint, resulting in over 1,094 photographs taken in the project areas. Appendix B (Representative Project Photodocumentation) contains a full summary of photopoint location data, along with representative printouts from each project areas. All of the Phase II-B project photographs are included on the Final Report DVD.

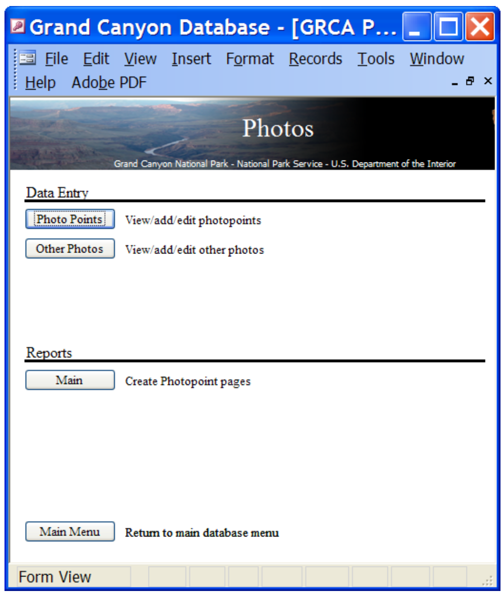
To view the photographs as .jpg images, open the following folders on the Final Report DVD:

- Database Version to Use
- Photos
- Park Areas

Folders for each project area are located within the Park Areas folder. The pre-work photos are located within sub-folders called Tamarisk Mapping, the post-work photographs are located within a sub-folder called Exotic Plant Control, the hydrology photographs are located within a sub-folder called Hydrology, the habitat assessments are located in a sub-folder called Habitat Assessments, and the transect photographs are located in a sub-folder called Vegetation Transect. Each photograph has a file name depicting its photopoint name and the date taken.

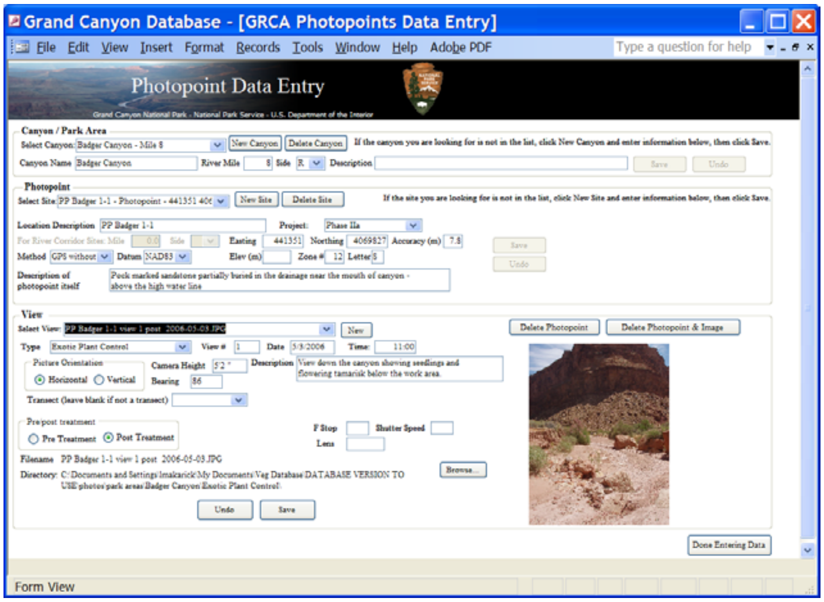
The database allows people to view the photographs in the database or print them in a format that is field ready so that crews can easily retake the photographs, or simply view the photographs in the database. To view the photographs, click on the Photos button from the Main Menu of the database. To view the photos within the database, click on the Photopoints button under Data Entry.

Figure 19. Grand Canyon Database – Main Switchboard Menu



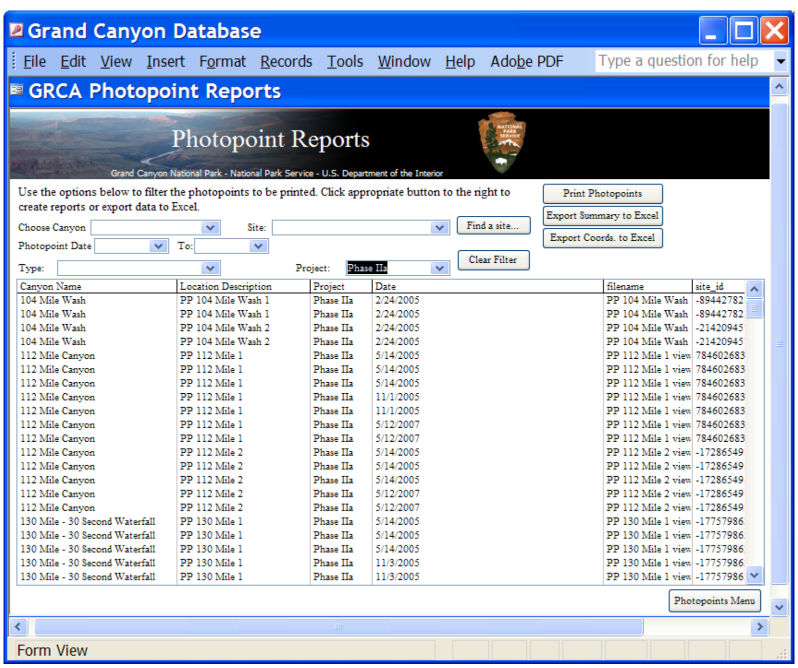
The next step is to select the Canyon or Park Area, which corresponds to the list of Phase II-B project area names under this grant. Then under the Photopoint section, where it says Select Site, click on the drop box arrow and the list of photopoints within that project area will come up on the screen. That section contains the UTM information and a description of the photopoint itself, which is helpful when returning to the site to re-take the photographs. On the bottom of the screen, under View, you can select which photograph you would like to view. That list contains the pre- and post-treatment photographs. In that section, the information about the photograph itself is stored (e.g. bearing, camera height, date and time taken, and a description of the view). These are the screens used during data entry.

Figure 20. Grand Canyon Database – Photopoint Data Entry Menu



To print the photographs in a field ready format, from the Photo main menu, select the button Main – Create Photopoint Pages under reports, and the Photopoint Reports screen will appear. On that screen, you can filter by canyon, site, date, type of photograph, or project by using the drop down boxes. Due to limitations in MSAccess, the easiest way to print the photographs is to select the canyon, and then the site within that canyon, and then hit the Print Photopoints button. Appendix B (Representative Photopoints) contains the printout of at least one photopoint from each project area, displayed in the format used by field crews.

Figure 21. Grand Canyon Database – Photopoint Reports Menu



Project leaders have taken post-treatment photographs in the majority of the tamarisk removal project areas. The majority of those photographs were taken immediately following the removal, and in most areas, the removal of tamarisk dramatically changes the landscape in view. In other cases, the tamarisk debris is still visible because trees were girdled or the debris was left directly on site to decompose. In all cases, these photographs provide an invaluable qualitative examination of project success and are also very useful for transect relocation. The primary goal is to see how vegetation enters the tamarisk-free areas and to monitor the natural progression over time. The project coordinator has established schedule for the re-visitation of all Phase II-B project areas, and as crews re-treat invasive plants within the areas, they will also re-take the photographs as part of the long-term monitoring process.

f. Southwestern Willow Flycatcher Habitat Assessments and Wildlife Observations

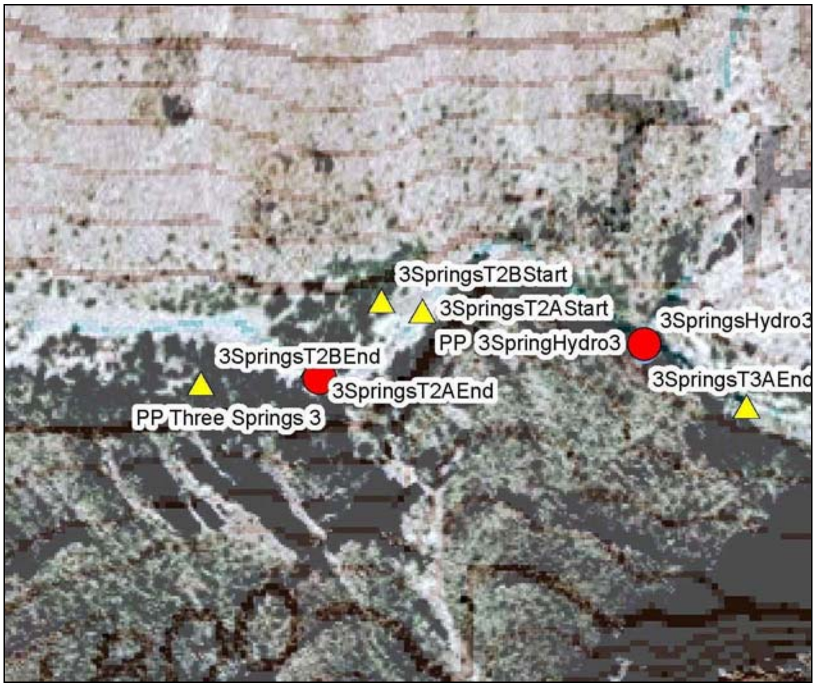
Crews completed SWIFL habitat assessment forms for all project areas. These data have all been entered into the project database and are included as Appendix C (Habitat Assessment Data). The Park's Wildlife Biologist has recorded all areas surveyed to date as "Not Suitable or Potential Southwestern Willow Flycatcher Habitat." During the monitoring portion of this project, participants documented many wildlife observations including bighorn sheep, Grand Canyon pink rattlesnakes, many lizards, and a variety of prospering frogs and toads (Table 10. Wildlife Observations).

g. Project Maps

For all of the data that have been collected, crew leaders have gathered corresponding spatial data (UTMs in NAD83) so that displaying the information in ArcGIS software is possible. In the project database, under the reports section of the various categories (e.g. exotics, vegetation monitoring, habitat assessments, tamarisk mapping, hydrology, photos), there is a button that is used to create a MSExcel export containing the Site Name, Northing and Easting. From that format, the table can be converted to a .cvs format and then imported into ArcGIS, where it is displayed as a spatial layer.

During the timeframe of this grant, project leaders have printed maps at various scales for the crew leaders to use as they are working in the project areas. The maps display the photopoint locations, the beginning of the various work sections within the drainage, and other pertinent information. Project leaders also loaded all of those data into Garmin GPS units, which enabled crew leaders to track their location and direct them to the site they are trying to find.

Figure 22. Mapping Example



For the final report, the Project Coordinator produced a poster-sized map to show the overall project area within Grand Canyon National Park, in addition to 8 ½ X 11" maps in the .pdf format for each of the project areas. The maps are included as Appendix L and two copies of the poster-sized map were submitted with the final report. The poster-size map was also submitted as a .pdf file. All maps include the following information:

- Project area boundaries
- Project names
- Tamarisk treatment locations (the beginning of each 500 m section)
- Vegetation transect locations
- SWIFL habitat assessment locations
- Photopoint locations
- Other invasive species locations
- Plant Collection Locations
- Hydrology sampling locations

Additional copies of the maps are available upon request.

VII. Discussion and Conclusions

a. Discussions and conclusions about results comparing current and past control results

Many of the project areas within Phase II-B represent some of the most significant tributaries of the Colorado River in Grand Canyon. Thanks to the support of the AWPF, GCNPF, the Hualapai Tribe, Grand Canyon Association (GCA) and the dedication of hundreds of individuals, they are effectively tamarisk-free ecosystems. Long drainages with permanent water such as National and

Granite Springs Canyon were very difficult to access due to some steep climbs and lack of suitable camping areas, but it was very beneficial to remove tamarisk from those areas. The project made great strides over the past two years. Despite the challenges that the Grand Canyon's remote wilderness poses, in a short time period crews were able to remove an incredible number of invasive plants from project areas. Based on the 2006 through 2008 work, crews have removed 48,573 tamarisk trees and 187,152 other invasive plants during the implementation of this grant, and in many of the areas, native plant species have returned and are even growing right on or out of the cut tamarisk stumps.

While there are fewer project sites in Phase II-B as compared to Phase I or Phase II-A, the sites were much more extensive, and often posed new logistical challenges as far as access. Completing management work in 30 project areas in two years was incredibly difficult. Given the remoteness of the majority of these canyons, and the great logistical effort it takes to access them, the schedule did not always allow the crews to revisit the project areas one year later in order to complete the necessary follow-up control work that helps to make this project successful. This leaves much of the essential maintenance work unfunded but committed to by the NPS. Fortunately, the NPS has provided funding to continue this valuable work, and will have small crews return to these project areas and continue this project. The former field crew supervisor created a maintenance schedule for all Phase I, Phase II-A and Phase II-B project areas, and a new position will be hired in the next month to initiate the follow-up treatment and monitoring actions that are called for in the project contracts.

b. Discussion and conclusions about results with relation to related literature.

Stromberg et al. (2007) demonstrated that in arid regions low-flow and high-flow characteristics of surface and ground water regimes influenced riparian vegetation. A combination of perennial stream flows, shallow groundwater in the aquifer and regular flooding resulted in high species diversity. More intermittent stream flows allow for lower herbaceous species diversity and cover. The data from Phase II-B transects supports this research. The highest pre-treatment diversity was found in Mohawk and Three Springs Canyons, which are both larger drainages with perennial water. National Canyon, another large drainage with perennial water in some stretches, had a lower diversity in the tamarisk transect areas than in the control areas. In 140 Mile Canyon, an area with more intermittent water flow, species richness was initially greater in the tamarisk transect areas, and then leveled out with the control areas in post-treatment years. Following removal, there may still not be sufficient resources for native species to survive in those areas (Graf, 1987). In order to really look at post-tamarisk recover trends in GRCA, these transects must be visited every 2-3 years over a longer period of time.

Harms and Hiebert (2006) found that both cutting and burning tamarisk reduced mean tamarisk foliar cover by 82-95%, and that over time tamarisk reduction was sustained. Phase II-B data support this observation. The average pre-treatment tamarisk cover was 18.9% and 33.6% within the two plot types, and was reduced to 1.3% and 3.5% following tamarisk removal. However, these data are only two years post-treatment, and only long-term monitoring will reveal what happens over time.

A greenhouse study by a graduate student at New Mexico University demonstrated that tamarisk duff can considerably increase the surface soil salinity if at least one rainfall event followed by soil desiccation occurs (Rosel, 2006). Rosel's research showed that the 0-1 cm soil depth was more susceptible to increases in salinity and sodicity that the 1-5 cm soil depth because of the affects of ion redistribution and accumulation at the soil surface due to water evaporation. Excessive quantities of soluble salts can be harmful to plants by interfering with water uptake, thus setting back the reestablishment of native species such as cottonwood and willow. Longer term soil data collection across Phase II-A and Phase II-B sites should show soil salinity difference between tamarisk treatment and control areas. At this point, the sample size is too small and the time frame of data collection is too short to make any conclusions.

Tamarisk grows well in moist, sandy, sandy loam, loamy, and clayey soil textures. It has a wide range of tolerance to saline and alkaline soil and water. It grows in Death Valley, California, where the ground water contains as much as 5% (50,000 ppm) dissolved solids. It tolerates high concentrations of dissolved solids by absorbing them through its roots and excreting the excess salts through glands in its stems and leaves. Eventually these salts end up on the ground beneath the plant, forming a saline crust (USDA, APHIS, 2005). In tamarisk removal and restoration efforts, soil salinity (along with texture and depth to groundwater) is one of the most important site characteristics used to determine the suitability of a site for revegetation (Taylor and McDaniel, 1998). Learning more about the effect of tamarisk on soil salinity may aid in restoration efforts if there is also a way to minimize the saline effects.

Tamarisk is capable of utilizing saline groundwater by excreting excess salts through leaf glands (Hem, 1967). The salts drip to the soil surface or fall with leaves in autumn, forming a layer of salt. Cottonwoods and willows can tolerate salinity levels of only 1,500-2,000 ppm but tamarisk can grow at levels up to 36,000 ppm (Jackson et al., 1995) or more. Weeks et al. (1987) reviewed studies that investigated water use by tamarisk in New Mexico and Arizona and determined that the estimates of water use were variable. While tamarisk trees are thought to consume more water than native riparian species, conclusive studies have yet to confirm that assumption. The estimates of water use were quite variable, presumably reflecting variations in weather and environment, as well as difficulties in estimating evapotranspiration precisely. Sala et al. (1996) and Davenport et al. (1982) found that water use may have more to do with stem density and leaf area rather than species composition. However, tamarisk has been shown to lower water tables, reduce stream flow, dry up desert springs, and reduce availability of water for agriculture, municipalities, native plants, and wildlife. The cost of water lost to tamarisk is estimated at $133 to $285 million annually (Zavaleta, 2000). This long-term project aims to recover water that had been previously lost to tamarisk.

Stromberg et al. (2007) suggest that that riparian species diversity and recovery can be maximized in the presence of natural flooding. In many southwestern areas, development, agriculture and industry have increased the demands on water sources over the past century. While directly affecting the water resource, the indirect effects of altered hydrological cycles are also apparent. Grand Canyon National Park's side canyons and tributaries harbor vast expanses of undammed waterways, areas which can continue to serve as refuges for native plant and animal species for the long-term. Tamarisk removal enhances land managers' ability to protect native resources.

This long-term project also aims to recover native vegetation in areas following tamarisk removal. Many of the baccharis and seep willow (*Baccharis* spp.) and coyote willow (*Salix exiqua*) shrubs are common along both low-flow and high-flow channels. Cottonwood trees (*Populus fremontti*) are obligate phraetophytes and will likely only survive in areas with perennial water and higher ground water tables. The natural post-treatment succession in the different project areas will help Park managers and other agencies plan active restoration activities for future work in some of the remaining project areas. GRCA project managers intend to publish the full suite of data following Phase II-B data collection in 2008, which will demonstrate the overall success rate of this invasive plant management effort.

VIII. Management Recommendations

a. Overview of management options

The monitoring results from Phase I and Phase II-A helped to refine the control methods and management options used for this project. The National Park Service (NPS) has an affirmative responsibility to protect and preserve the resources located within its units. NPS Management Policies require Park managers "to maintain all the components and processes of naturally evolving Park ecosystems, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems" (NPS 2006). Park managers are directed to give high priority to the control and management of exotic species that can be easily managed and have substantial impacts on the Park's resources (NPS 1985, NPS 2006).

This project further verified that the control of tamarisk and other invasive plant species in the Park's side canyons and tributaries is feasible. A vast body of literature documents the impacts that tamarisk has on southwestern ecosystems. Stevens (2001) summarizes the impacts and ecology of tamarisk. Since the control is feasible and tamarisk poses a substantial impact on the resources located within GRCA and on surrounding tribal lands, the continuation and expansion of this project should occur. Park management has been supportive of this project, and with continued documentation and successful implementation, the support should remain strong. Prior to future grants, the project coordinator must critically examine what is physically possible during one field season. Project leaders recommend that future phases span three or more years in order to allow for two preliminary visits to each project areas and one final visit.

b. Management recommendations and justification

The EA/AEF for this overall project included three phases of tamarisk management and tributary restoration. The work completed under this grant contract is Phase II-B of the overall project. The control trips completed between 2006 and 2008 were very successful and project leaders anticipate that the methods used will lead to successful management of tamarisk populations in the project areas. At this time, GRCA decided not to apply for a third grant to move into Phase III, as the Project Coordinator would like to focus treatment efforts cyclic maintenance on all 130 of the project areas from Phase I, II-A and II-B.

At this time, the fundraising tasks completed by GCNPF have been absorbed by the Grand Canyon Association (GCA). GRCA staff will be working closely with GCA to develop funding proposals that will allow the expansion of this project into new areas in the future. A few priorities would be to expand the partnership with the Hualapai to include more drainages on tribal lands, seek out a partnership with the Navajo Nation to work in the drainages the flow into the Colorado River, and implement actions along the Colorado River below Diamond Creek.

Crews should continue to systematically retake all of the photographs and re-read all of the vegetation transects according to the schedule developed. GRCA staff and volunteers are currently retaking photographs and completing follow-up control, and this will expand during 2009 under NPS funding. Project leaders will continue to recommend integration of this project into the overall resource and vegetation management plans.

Surrounding states and agencies are utilizing a biological control agent known as the tamarisk leaf beetle (*Diorhabda elongate deserticola*) which has the potential to reduce the cover and concentration of tamarisk infestations in the southwest (USDA, APHIS. 2005). There is currently a program for biological control in thirteen states and it is very likely the beetle will arrive in GRCA whether it is intentionally imported or not. At this time, GRCA Managers have no intention of removing tamarisk from the Colorado River Corridor, but in the future, the leaf beetle may make that effort more feasible to consider.

After completion of the final monitoring trip, project leaders should prepare articles for both internal NPS publications and peer-reviewed journals. The AWPF funding and support for this project has been essential to getting this project off the ground and protecting and restoring the Park's valuable riparian ecosystems. The partnership between GRCA and the GCNPF has also been integral to the success of the project, and GRCA staff is excited about the new partnership with GCA and the potential future successes that will allow. The primary recommendation at this point is to continue the work, and to expand the project to include all of the tamarisk populations in the side canyons and tributaries of the Park and surrounding lands.

IV. Literature Cited

Arizona Riparian Council. 1994. Arizona Riparian Council Fact Sheet. No. 1. Published by Arizona State University.

Brown, B.T., K.A. Butterfield, R.R. Johnson, and M.S. Moran. 1980. Pp. 422-432 in Proceedings of the Second Conference on Scientific Research in the National Parks, Volume 7: Ecosystem Studies. An Inventory and Classification of Surface Water Resources in Grand Canyon National Park, Arizona. USDI, National Park Service, Washington, D.C.

Clarke, K.R. and R.N. Gorley. 2006. PRIMER v6: user manual / tutorial. Primer-E Ltd, Plymouth.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology. 18:117-143.

Davenport, D.C., P.E. Martin, and R.M. Hagan. 1982. Evapotranspiration from riparian vegetation: Water relations and irrecoverable losses for saltcedar. Journal of Soil Water Conservation. 37:233-236.

Duluth Streams. Water Quality Primer. Accessed on October 22, 2007. http://www.duluthstreams.org/understanding/param_ec.html.

Duncan, K.W. 1996. Saltcedar and Native Species in New Mexico. Presentation at Saltcedar Management and Riparian Restoration Workshop, Las Vegas, NV. September 1996.

Graf, W.L. 1978. Fluvial adjustments to the spread of tamarisk in the Colorado Plateau region. Geological Society of America Bulletin. 89:1491-1501.

Hardy, R. L. 2005. Thirsty trees get the heave-ho. Deseret Morning News. Accessed on March 22, 2005. http://deseretnews.com/dn/print/1,1442,600120064,00.html.

Harms, R.S. and R.D. Hiebert. 2006. Vegetation response following invasive tamarisk (*Tamarix spp*.) removal and implications for riparian restoration. Restoration Ecology. 14 (3):461-472.

Hem, J.D. 1967. Composition of saline residues on leaves and stems of saltcedar. Geological Survey Professional Paper 491-C.

Jackson, J., J.T. Ball, M.R. Rose. 1990. Assessment of the salinity tolerance of eight Sonoran Desert riparian trees and shrubs. Final report for the Bureau of Reclamation, Yuma Projects Office, Yuma, Arizona, USA.

Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Fottiott and R.H. Hamre (eds). 1985. Riparian ecosystems and their management: reconciling conflicting uses. USDA For. Serv. Gen . Tech. Rept. RM-120.

Mills, G.S., J.B. Dunning, Jr., and J.M. Bates. 1991. The relation between breeding bird density and vegetation volume. Wilson Bull. 103:468-479.

National Park Service. 1995a. General Management Plan, Grand Canyon National Park. Grand Canyon, AZ: United States Department of the Interior, National Park Service, Denver Service Center.

National Park Service. 1995b. Grand Canyon National Park Strategic Plan. Grand Canyon National Park. Grand Canyon, AZ: United States Department of the Interior, National Park Service.

National Park Service. 1985. Guide for pesticide use in the national Park system. Washington, DC: United States Department of the Interior, Biological Resources Division, National Park Service.

Phillips, B.G., R.R. Johnson, A.M. Phillips, and J.E. Bowers. 1979. Pp. 141-155 in Proceedings of the Second Conference on Scientific Research in the National Parks, Volume 4: Resource

Analysis and Mapping. Resource Values of the Aquatic and Riparian Vegetation of Roaring Springs, Grand Canyon. USCA National Park Service, Washington, D.C.

Rosel, Cheryl E. 2006. Saltcedar (*Tamarix* spp.) leaf litter impacts on surface soil chemistry: electroconductivity and sodium adsorption ratio. Master of Science in Agronomy, New Mexico State University.

Sala, A., S. D. Smith and D. A. Devitt. 1996. Water use by Tamarix ramosissima and associated phraetophytes in a Mojave Desert floodplain. Ecological Applications 6:888-898.

Stevens, L.E. 2001. A synthesis of information on the ecology and management of saltcedar (Tamaricaceae: *Tamarix ramosissima*), with emphasis on the Grand Canyon Region: Final Progress Report. Report Prepared for the Arizona Water Protection Fund.

Stromberg, J.C., V.B. Beauchamp, M.D. Dixon, S.J. Lite, and C. Paradzick. 2007. Importance of low-flow and high-flow characteristics to restoration of riparian vegetation along rivers in arid southwestern United States. Freshwater Biology. 52:651-679.

Taylor, J.P. and K.C. McDaniel. 1998. Restoration of saltcedar (*Tamarix* spp.)-infested floodplains on the Bosque del Apache National Wildlife Refuge. Weed Technology. 12:345-352.

USDA, APHIS. 2005. Program for biological control of saltcedar (*Tamarix* spp.) in thirteen states. Environmental Assessment.

USDA, NRCS, NPS. 2003. In cooperation with Arizona Agricultural Experiment Station. Soil Survey of Grand Canyon Area, Arizona: Parts of Coconino and Mohave Counties.

Warren, P.L., K.L. Reichhardt, D.A. Mouat, B.T. Brown, and R.R. Johnson. 1982. Technical Report Number 9 - Vegetation of Grand Canyon National Park. Prepared for National Park Service, Grand Canyon National Park. Contracts No. CX8210-7-0028 and CX8000-9-0033 Contribution No. 017/06. Cooperative National Park Resources Studies Unit, University of AZ.

Weeks, E. P., H. L. Weaver, G. S. Campbell and B. N. Tanner. 1987. Water use by saltcedar and by replacement vegetation in the Pecos River floodplain between Acme and Artesia, New Mexico. Geological Survey Professional Paper 491-G. U. S. Geological Survey, Reston, VA.

Zavaleta, E. 2000. Valuing ecosystem service lost to Tamarix invasion in the United States. Pages 261-200 in H.A. Mooney, and R.J. Hobbs, eds. Invasive species in a changing world. Island Press, Washington, D.C.