Grand Canyon National Park and Grand Canyon National Park Foundation

Final 2007 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-A, First Year of Phase II of Comprehensive Project)

Arizona Water Protection Fund Contract Number 05-131WPF

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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 now considered to be 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 funds this project through December 31, 2007, with work occurring in 35 areas within GRCA. This report contains the details from the invasive plant control and monitoring efforts completed for the duration of the project. The AWPF Commission has funded all or a portion of this report.

This work is Phase II-A 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 35 tributaries of the Colorado River in Grand Canyon National Park 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 area and allow native vegetation to reestablish without exotic plant competition. This work is a follow up of the very successful Phase I, also funded by the AWPF, in which crews removed 70,616 tamarisk trees from 70 project areas. The lessons learned during the implementation of Phase I have allowed the project manager to improve upon the management and monitoring portions of the project.

At the close of this project, crews removed 130,504 tamarisk trees including 86,907 seedlings, 33,190 saplings, and 10,407 mature trees from 10,180 hectares (25,154 acres) in Phase II-A project sites. The total tamarisk canopy removed from within the 35 project areas where work was accomplished was 60,182 m^2, allowing native vegetation access to critical resources such as nutrients, sunlight and water. In addition, crews also removed 34,169 individual plants of other invasive exotic species from project areas. This report includes all of the data from the backcountry trips completed from spring 2005 through spring of 2007. 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/exotic-tamarisk.htm) 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 35 selected riparian areas (within Phase II-A) within Grand Canyon National Park (GRCA), allowing native plant communities to recover and persist. The grant funds this project through December 31, 2007 and supports a partnership between GCNPF and the National Park Service (NPS). This report contains the details from the invasive plant control and monitoring efforts completed throughout the duration of the project (from spring 2005 through fall of 2007).

This work is a follow up of the very successful Phase I (AWPF Contract #99-075WPF) also funded by the AWPF, in which crews removed 70,616 tamarisk trees from 70 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 an almost 100% reduction of tamarisk cover and frequency. The lessons learned during the implementation of Phase I allowed the project managers to improve upon the management and monitoring portions of the project. The work is continuing at this time with Phase II-B (AWPF Contract #06-138WPF) of a landscape-level backcountry invasive plant management project underway. The primary objectives of this Phase II-A 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 plant monitoring.

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 NPS 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.

Prior to initiation of Phase II-A, Reuben Terán, AWPF project manager, consulted with the State Historic Preservation Officer (SHPO) regarding this grant proposal. The response letter stated a determination of "no impact" for the grant but confirmed that the NPS should also consult with SHPO. GRCA superintendent Joe Alston submitted a letter to the SHPO to affirm continuing concurrence on the project, which SHPO confirmed through a letter. The 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" because they will occur in areas that are not proposed critical habitat.

By August 2005, project coordinators had acquired the necessary backcountry permits for Phase II-A, completing the final requirements of Task #1 in the grant contract. In addition, following the May 2005 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 two management and two monitoring river trips, nine Phantom Ranch area backpacking trips and twelve backcountry backpacking trips.

Under this contract (#05-131WPF), crews removed tamarisk from 35 areas within Grand Canyon National Park. 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 tamarisk, 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). As little as 100 years ago, Arizona's riparian areas comprised 10% of the state's land mass, today that number 0.5% (Arizona Riparian Council, 1994). 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 and GCNPF 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 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, and the GCNPF, while securing thousands of hours of volunteer labor from citizen stewards.

c. Management objectives

The overarching objective of this project was 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 (AWPF Contract #05-131WPF), crews removed tamarisk and other invasive exotic plant species from 35 backcountry seeps, springs and tributaries in the Grand Canyon area.

The goals of this project were to:

1. Decrease the colonization and spread of tamarisk and other invasive vegetation in the tributaries and side canyons of Grand Canyon National Park;
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 were to:

1. Remove tamarisk and other invasive exotic plant species from 35 tributaries backcountry seeps, springs and tributaries within Grand Canyon National Park. This effort significantly reduced the tamarisk within the management areas.
2. Initiate a long-term, integrated, inter-disciplinary monitoring system that includes vegetation transects, wildlife observations, hydrological samples, archeological inventories, photopoints, and GPS data collection;
3. Ensure effective training and utilization of volunteers; and,
4. Prepare public information/education material on this important environmental issue.

d. Monitoring objectives

A primary project objective was to monitor the success of the tamarisk removal through pre- and post-project vegetation monitoring, which helped determine the level of success of the effort. The overall monitoring design helped 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 was to decrease tamarisk cover to 5% or less of the pre-management tamarisk cover values in the project areas. Current scientific literature indicates tamarisk trees sequester a large amount of water through their extensive root system. Project managers expect to observe long-term beneficial changes in the hydrology and soil chemistry through monitoring, which was a secondary objective of the project. In addition, interdisciplinary teams monitored wildlife activity by recording wildlife observations throughout the project areas.

III. Management Methods

a. General Vegetation Community Description

The project areas in Phase II-A are well-distributed geographically throughout Grand Canyon National Park, and constitute most of the major tributaries, such as Nankoweap Bright Angel and Crystal Creeks, as well as some of the more remote drainages that needed to be reached via backpacking. 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, Salix goodingii*)
- Monkey flower (*Mimulus cardinalis*)
- Mesquite (*Prosopis glandulosa*)
- Seep willows (*Baccharis emoryii, Baccharis 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.

The vegetation surrounding the tributaries is generally very different from Park communities, which are composed of plant species from three of the four North American desert floras. The Sonoran Park has the highest plant species diversity. A two-season rainfall regime and lack of freezing temperatures characterizes the Sonoran desert. The Mojave Park 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 Park. 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 8 (Badger Creek) to Colorado River Mile 225.5, 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 notes from field crew leaders. Project areas were divided into 500 meter sections and named in consecutive order, generally starting at the river with one, and moving upstream or up canyon from that point.

Badger Canyon

Vegetation community name: 153.1741—Shadscale - Mormon Tea - Beavertail Cactus (*Atriplex confertifolia - Ephedra nevadensis - Opuntia basilaris*)

The elevational range is 950 to 1,460 m (3,100 to 4,800 ft). This community type is found on rolling terrain with gentle to moderate slopes of up to 40% and is derived from the friable silt- and mud-stones of the Grand Canyon Series and Hermit Shale. This type only occurs in the eastern part of the Park in the Chuar and Kwagunt Valleys and Marble Canyon. This community is an evergreen xeromorphic desert scrub with cacti and deciduous shrubs. The average height of all species is less than 0.6 m. In some places the substrate is so unstable and surface movement so great, that establishment of young perennial species is almost absent.

Characteristic species:

Atriplex confertifolia	shadscale
Ephedra nevadensis/torreyana	Mormon tea
Eriogonum inflatum	desert trumpet
Lycium andersonii	wolf-berry
Opuntia erinacea	grizzly-bear cactus
Opuntia basilaris	beavertail cactus

Soil and geology information: 116—Rock outcrop-Typic Torriorthents complex, Hermit Formation
Landform: plateau
Elevation: 976 to 1,829 m (3,200 to 6,000 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
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: 160 to 175 days
Rock outcrop: Very steep pediments of the Hermit Formation on canyon side walls
Typic Torriorthents soils
Geomorphic position*:* colluvial slopes on plateau escarpments and canyon sidewalls
Parent material: colluvium derived from limestone and sandstone

Slope: 15 to 60%
Surface fragments: N/A
Depth to restrictive feature: 53 cm to 152 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: Badger Canyon is a dry side canyon that gets scoured regularly. It contains sparse vegetation in the drainage bottom and is dominated by sand interspersed with large boulders and some gravel. After a wet winter there are typically a few pockets of water in the bedrock section. Toward the last section the canyon narrows and is strewn with large boulders that become a little more difficult to ascend. Badger has four sections that were treated for tamarisk to the Park boundary with the Bureau of Land Management (BLM). The Park will be working with the BLM and Grand Canyon Trust to survey and treat tamarisk in the upper portion of this drainage.

South Canyon – Lower and Upper

Vegetation community name: 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 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

Soil and geology information: 116—Rock outcrop - Typic Torriorthents complex, Hermit Formation (refer to Badger Canyon for full description)

Project area description: South Canyon is a tributary on the south side of Marble Canyon with seasonal water that flows in the Hermit Shale and Supai rock layers. It is a boulder-strewn canyon with a significant bedrock section with several small pourovers. It has sparse vegetation with warm desert scrub influences. South Canyon has seven sections that were treated for tamarisk reaching the upper section of the drainage where the South Canyon Trail drops down to the canyon floor. Upper South includes South 1-8 and Lower South includes South 9-14. Above that section the land ownership transfers to the Kaibab National Forest (USFS). At this time, the Park hopes to work with the USFS and Grand Canyon Trust to continue work in the upper portions of this tributary that are not on NPS lands.

36.5 Mile wash

Vegetation community name: 153.11014—Mormon Tea-Snakeweed-Wolf-berry (*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). 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

Soil and geology information: 116—Rock outcrop-Typic Torriorthents complex, Hermit Formation (refer to Badger Canyon for full description)

Project area description: 36.5 Mile Wash is a short drainage/alcove that ends less than 500 meters from the river in a large bowl with a pourover. There is surface water in bowls after seasonal rains or wet winters. Sowthistles (*Sonchus* spp.) and tamarisk seedlings were removed from the moist soil in the bowl. This project area gets regularly scoured, yet has an alcove area that harbors a collection of plants with warm desert scrub influences. There is a large, mature tamarisk on a small beach near the mouth of this alcove. The tree currently out of our project area boundary (it is in the new riparian zone below the canyon rim), but the boundaries should be redefined in order to allow for the removal of this tree, which supplies a constant supply of seedlings.

Saddle Canyon

Vegetation community name: 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

Soil and geology information: 116—Rock outcrop-Typic Torriorthents complex, Hermit Formation (refer to Badger Canyon for full description)

Project area description: Saddle Canyon is a narrow tributary with a dense stand of netleaf hackberry and a treasure of native plant diversity with warm desert scrub influences. Water is present year-round at the upper section of the canyon where a waterfall and seep trickle down moss-covered rocks and columbine flowers cling to the wet ledges. Crews removed a small patch of tamarisk in the first two sections, and removed sowthistles (*Sonchus* spp.) from the third section. There are three sections total that were treated for tamarisk and other invasives. Above the last section, access is blocked by a 9.1 meter (30 foot) waterfall.

Little Nankoweap Creek

Vegetation community name: 153.11014—Mormon Tea-Snakeweed-Wolf-berry (*Ephedra viridis/torreyana-Guterrezia sarothrae-Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

Soil and geology information: 117—Rock outcrop-Typic Torriorthents complex, Tonto Group and Redwall Formation, 30 to 60% slopes

Landform: plateau
Elevation: 762 to 1,067 m (2,500 to 3,500 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
Mean annual air temperature: 14 to17 °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%
Typic Torriorthents and similar soils: 40%
Rock outcrop: tall, vertical cliffs and escarpments
Typic Torriorthents soils
Geomorphic position: colluvial slopes on ledges and canyon sidewalls of plateau escarpments
Parent material: colluvium derived from limestone, sandstone, and shale and/or residuum weathered from limestone
Slope: 15 to 60%
Surface fragments: N/A
Depth to restrictive feature: 53.3 cm to 127 cm (21 to 50 in) to bedrock (lithic)

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

Secondary soil and geology information: **145**—Typic Torrifluvents-Typic Torripsamments complex, cool, 0 to 6% slopes

Landform: stream terrace
Elevation: 762 to 1,067 m (2,500 to 3,500 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: 210 to 280 days
Typic Torrifluvents and similar soils: 70%
Typic Torripsamments and similar soils: 30%
Typic Torrifluvents soils
Geomorphic position: beaches and stream terraces
Parent material: alluvium derived from mixed sources
Slope: 0 to 2%
Surface fragments: N/A
Depth to restrictive feature: 52 cm to 152 cm (20 to 60 in) to bedrock (lithic)
Drainage classification: N/A
Flooding hazard: rare
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: Little Nankoweap Creek is a narrow, boulder-strewn canyon with seasonal water flow after a wet winter. It is sparsely vegetated and gets regularly scoured by seasonal floods. There was no tamarisk in this drainage, yet crews removed sowthistles (*Sonchus* spp.) from the moist, sandy soils in the first 500 meters.

Nankoweap Creek – Lower and Middle

Vegetation community name: 153.11014—Mormon Tea-Snakeweed-Wolfberry (*Ephedra viridis/torreyana-Guterrezia sarothrae-Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

Soil and geology information: 117—Rock outcrop-Typic Torriorthents complex, Tonto Group and Redwall Formation, 30 to 60% slopes (refer to Little Nankoweap Creek for full description)

Project area description: The lower and middle sections of Nankoweap Creek are strewn with cobbles and stones and are very open. Several distinct channels occur in the flood zone. The lower portion of the tributary is lightly vegetated with plants of warm desert scrub influences, and appears to flood frequently in addition to the existence of a perennial stream. In the middle Nankoweap Creek section, the canyon narrows slightly, but is still dominated by boulders and

cobbles and contains multiple channels. There are great stands of healthy cottonwoods throughout the middle section, and large terraces of Apache plume (*Fallugia paradoxa*).

Nankoweap Creek – Upper

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

Soil and geology information: 146—Typic Torriorthents soils and Badlands, Chuar Group, 15 to 65% 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 to17 °C (57 to 63 °F)
Mean annual soil temperature: 16 to 19 °C (59 to 65 °F)
Frost-free period: 200 to 240 days
Typic Torriorthents and similar soils: 60%
Badlands: 40%
Typic Torriorthents soils
Geomorphic position: summits and side slopes of hills and ridges
Parent material: residuum weathered from mudstone
Slope: 15 to 65%
Surface fragments: N/A
Depth to restrictive feature: 25 cm to 152 cm (10 to 60 in) to bedrock (paralithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (1.8 m (6 ft))

Secondary soil and geology information: 2—Argic Petrocalcids, 8 to 15 % slopes
Landform: fan terrace
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: 57 to 63 °F (14 to17 °C)
Mean annual soil temperature: 59 to 65 °F (16to 19 °C)
Frost-free period: 200 to 240 days
Argic Petrocalcids and similar soils: 100%
Geomorphic position: summits of fan terraces
Parent material: alluvium derived from mixed sources
Slope: 8 to 15%
Surface fragments: N/A
Depth to restrictive feature: 22.9 to 50.8 cm (9 to 20 in) to petrocalcic
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: Middle and Upper Nankoweap include two major tributaries, Roosevelt and Woolsey Forks, which containing spring sources that provide permanent water and feed into the main Nankoweap Drainage. The middle portion of Nankoweap Creek includes Nankoweap 12-18 and the Woolsey Fork. The upper section includes Nankoweap 19-26 and the Roosevelt Fork ends at Nankoweap spring which emerges from a hole in the soil beneath a thicket of riparian vegetation. The entire Nankoweap drainage contains 24 sections treated for tamarisk, with the uppermost sections accessed via backpacking. All small forks and side drainages have been surveyed and treated for tamarisk.

Kwagunt Creek – Upper

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

Secondary vegetation community name: 122.4147—Blackbrush-Pinyon-Juniper (*Coleogyne ramosissima-Pinus edulis-Juniperus osteosperma*)

The elevational range is 1,160 to 1,890 m (3,800-6,200 ft). This type occurs on larger terraces with slightly rolling terrain of all aspects. Soils are relatively deep accumulations of sandy texture, derived from the Supai Group and occasionally the Redwall Limestone or Hermit Shale. It is an evergreen needle-leaved and scale-leaved woodland in open stands. The understory is composed of evergreen sclerophyllous shrubs, evenly spaced, and succulents. Trees are 3 to 6 m (10 to 20 ft) tall and shrubs are 0.3 to 1.2 m (1 to 4 ft) tall.

Characteristic Species:

Coleogyne ramosissima	blackbrush
Pinus edulis	pinyon pine
Juniperus osteosperma	Utah juniper
Ephedra viridis	Mormon tea
Yucca baccata	banana yucca
Gutierrezia sarothrae	snakeweed
Agave utahensis	Utah agave

Quercus turbinella/undualta scrub oak
Ericameria nauseosus rabbitbrush

Soil and geology information: 146—Typic Torriorthents soils and Badlands, Chuar Group, 15 to 65% slopes (refer to Upper and Middle Nankoweap Creek for full description)

Project area description: The upper portion of Kwagunt has perennial water for two sections, and above that point the wash is dry except for one small spring which is localized and does not flow downstream. The upper portion of this tributary includes a south fork, which drains the valley between Banta and Jeffords point. This fork ends in a small wet seep in an otherwise dry drainage channel. There are five sections (Kwagunt 9-14) in the Upper Kwagunt area, including the south fork tributary.

Carbon Creek – Upper

Vegetation community name: 153.1741—Shadscale - Mormon Tea - Beavertail Cactus (*Atriplex confertifolia - Ephedra nevadensis - Opuntia basilaris*) (refer to Badger Canyon for full description)

Soil and geology information: 146—Typic Torriorthents soils and Badlands, Chuar Group, 15 to 65% slopes (refer to Upper and Middle Nankoweap Creek for full description)

Project area description: Upper Carbon Creek includes the four sections in the main drainage of Carbon after exiting the narrows. At this point the canyon widens and becomes an open, sandy wash with ephemeral water in the Dox Formation. Upper Carbon also includes two sections in the east fork of the main drainage, as well as one lone seep that contained tamarisk in the very end of the East Fork of Carbon at the base of Carbon Butte. Crews removed tamarisk from Lower Carbon beginning at the mouth continuing upstream through the end of the narrows as part of Phase I.

Lava Chuar – Upper

Vegetation community: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana - Guterrezia sarothrae - Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

Secondary vegetation community: 152.1211—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: 154—Ustic Torriorthents soils and Badlands, Chuar Group, 15 to 65% slopes

Landform: hill
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
Ustic Torriorthents and similar soils: 60% Badlands: 40%
Ustic Torriorthents soils
Geomorphic position: summits and side slopes of hills and ridges
Parent material: residuum weathered from mudstone
Slope: 15 to 65%
Surface fragments: N/A
Depth to restrictive feature: 23 to 31 cm (9 to 15 in to bedrock) (paralithic)
Drainage classification: N/A
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Secondary soil and geology information: **2**—Argic Petrocalcids, 8 to 15% slopes (refer to Upper Nankoweap Creek for full description)

Project area description: The upper portion of Lava Chuar is a perennial creek with a rushing stream and densely-vegetated terraces with both cold and warm desert scrub influences. This project area also includes the Hubble Butte Fork of Lava Chuar Creek, which splits off to the east. Crews spike camped at this confluence on two different occasions to access the upper sections of this extensive drainage. The creekbed dries above the Lava spring source. There is a good stand of cottonwood trees and some flat ground which would be a good place to camp during subsequent visits. Upper Lava Chuar has eight sections, the last section begins 100m downstream of a perennial creek with dense riparian vegetation. This creek is from a drainage entering on creek right from Naji point. Crews removed tamarisk from this side drainage. Above this point, Lava Chuar has not been surveyed for tamarisk, the main drainage is dry, but likely has a seep or two that have tamarisk. Crews removed tamarisk from the lower portion of Lava Chuar as a part of Phase I.

Cardenas Hillside Spring

Vegetation community name: 153.11014—Mormon Tea-Snakeweed-Wolfberry (*Ephedra viridis/torreyana-Guterrezia sarothrae-Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

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)

Project area description: This is a spring/seep on the hillside upriver of Cardenas Creek drainage. There is great mosaic of riparian vegetation, including large stands of common reed (*Phragmites australis*).

70.8 Mile Drainage

Vegetation community name: 153.11014—Mormon Tea-Snakeweed-Wolfberry (*Ephedra viridis/torreyana-Guterrezia sarothrae-Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

Soil and geology information: 68—Lithic Torriorthents-Rock outcrop complex, Dox Formation, 15 to 60% slopes (refer to Cardenas Hillside Spring for full description)

Project area description: 70.8 Mile Drainage is a small, narrow, dry drainage at base of a hillside seep/spring, upriver from Cardenas Creek. The drainage is mostly dominated by catclaw acacia, with the tamarisk clustered around a small seep in the second and only section.

Unkar Creek – Lower

Vegetation community name: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana - Guterrezia sarothrae - Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

Soil and geology information: 68—Lithic Torriorthents-Rock outcrop complex, Dox Formation, 15 to 60% slopes (refer to Cardenas Hillside Spring for full description)

Project area description: The lower portion of Unkar Creek is a wide open wash in the Dox Formation, with intermittent, seasonal moisture coming from a small spring around Unkar 7. The lower sections of Unkar Creek include Unkar 1-9.

Unkar Creek – Upper

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

Secondary 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-leaved 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
Agave utahensis	Utah agave

Soil and geology information: 68—Lithic Torriorthents-Rock outcrop complex, Dox Formation, 15 to 60% slopes (refer to Cardenas Hillside Spring for full description)

Project area description: The first part of the upper portion of Unkar Creek is wide and open and flanked with cottonwoods, although the stream flow is intermittent. The last part of the uppermost section is in a narrow drainage of Tapeats Sandstone with hearty riparian vegetation and a perennial stream that flows from a spring source at the base of the Redwall Limestone. This portion is 10 kilometers from the river and required an overnight spike camp in order to

complete tamarisk control work. The upper section of Unkar Creek includes Unkar 10 and above.

Papago Creek

Vegetation community name: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana - Guterrezia sarothrae - Lycium andersonii*) (refer to 36.5 Mile Wash 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)

Project area description: Papago Creek is a narrow canyon with a series of polished, dry waterfalls in the Shinumo Formation. The canyon is fairly devoid of vegetation, as it gets regular scouring floods. There is no surface water, and crews removed tamarisk seedlings from the first section above the mouth and pulled sowthistles (*Sonchus* spp.) from section four, which ends in a large bowl with an impassable dry fall that is 22.8 m (75 ft) tall. In the future, crews should access the upper portions of Papago Creek via 75 Mile Canyon, which is the only way to bypass the large dry fall.

Red Canyon

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

Secondary vegetation community name: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana - Guterrezia sarothrae - Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

Soil and geology information: 105—Rock outcrop-Lithic Torriorthents complex, Hakatai 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
Rock outcrop: 80%
Lithic Torriorthents and similar soils: 20%
Lithic Torriorthents
Geomorphic position: pediments
Parent material: colluvium derived from shale
Slope: 15 to 60%
Surface fragments: N/A
Depth to restrictive feature: 4 to 12 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: Red Canyon begins at the river as a wide open dry wash, flanked by hearty thickets of catclaw acacia on steep slopes. Upstream of where the New Hance Trail drops into the drainage a stream flows over Hakatai bedrock with several small falls and seeps. Red Canyon contains four sections with tamarisk, ending at the base of the Redwall Limestone.

Hance Creek

Vegetation community name: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana - Guterrezia sarothrae - Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

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)

Project area description: Hance Creek is a narrow canyon in the Vishnu Schist with perennial water. There are several scrambly sections to access the lower sections close to the river that require route finding skills to get up and around. Crews treated tamarisk in ten sections of this canyon, all below where the Tonto Trail drops into the canyon from Horseshoe Mesa. The upper East fork of Hance Creek has about five mature tamarisk trees near a spring that will need to be treated on subsequent visits.

Cottonwood Creek

Vegetation community name: **153.11014**—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana* - *Guterrezia sarothrae* - *Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

Secondary vegetation community name: 223.2121—Cottonwood - Brickellia - Acacia - Apache Plume (*Populus fremontii* - *Brickellia longifolia* - *Acacia greggii* - *Fallugia paradoxa*) (refer to Lower and Middle Nankoweap Creek description)

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

Secondary 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: Cottonwood Creek is a short, narrow drainage that is accessed via the Tonto Trail from the west arm of Horseshoe Mesa. From here the canyon is in the upper Tapeats Sandstone and traverses through a narrow Tapeats gorge. There is a great deal of scrambling involved to reach the Vishnu Schist section that ends at Zoroaster granite pour-off, which is where the tamarisk control work ended. There were five sections in Cottonwood Creek treated for tamarisk including the west fork of the Creek. This would be a good candidate to return to with NPS rangers to attempt to rope access the section below the granite pour-off.

Grapevine Creek

Vegetation community name: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana* - *Guterrezia sarothrae* - *Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

Secondary vegetation community name: 223.2121—Cottonwood - Brickellia - Acacia - Apache Plume (*Populus fremontii* - *Brickellia longifolia* - *Acacia greggii* - *Fallugia paradoxa*) (refer to Lower and Middle Nankoweap Creek description)

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

Project area description: Grapevine Creek is a winding, narrow gorge in the Tapeats Sandstone and Vishnu Schist that is accessed via the Tonto Trail from Horseshoe Mesa. Access requires a bit

of scrambling over large pour-offs, especially closer to the river. There is seasonal water in pools interspersed throughout the canyon. There were nine sections in Grapevine Creek treated for tamarisk including an east and west fork and a spring that crosses the Tonto above Grapevine Canyon.

Boulder Creek

Vegetation community name: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana - Guterrezia sarothrae - Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

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

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

Project area description: Boulder Creek is a short drainage accessed from the Tonto Trail between Horseshoe Mesa and the South Kaibab Trail. It has some significant granite narrows and several pour-offs. Crews focused tamarisk treatment work in the western fork of Boulder Creek, as no tamarisk were in the eastern fork at the time of the survey. There were three sections in Boulder Creek treated for tamarisk. In the future, both forks should be resurveyed, including the spring to the east side of the west fork.

Clear Creek – Upper

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

Secondary vegetation community name: 223.2121—Cottonwood-Brickellia-Acacia-Apache Plume (*Populus fremontii-Brickellia longifolia-Acacia greggii-Fallugia paradoxa*) (refer to Lower and Middle Nankoweap Creek description)

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

Secondary soil and geology information: 68—Lithic Torriorthents-Rock outcrop complex, Dox Formation, 15 to 60% slopes (refer to Cardenas Hillside Spring for full description)

Project area description: The upper section of Clear Creek is a behemoth tributary with several distinct sections and includes the largest waterfall in the Grand Canyon, Cheyava Falls. This drainage has a perennial stream and wonderful stands of healthy riparian vegetation. There are several distinct geological sections, including a narrow Tapeats Sandstone gorge, narrow Schist gorge and yet another narrow Shinumo gorge, with 6 m (20 ft) tall walls. Upper Clear Creek was accessed via the Clear Creek Trail, which in itself is a 1 and ½ day venture. Clear Creek has 26 sections that were treated for tamarisk and Himalayan blackberry (*Rubus discolor*).

Bright Angel Creek / Phantom Creek

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

Secondary vegetation community name: 223.2121—Cottonwood - Brickellia - Acacia - Apache Plume (*Populus fremontii - Brickellia longifolia - Acacia greggii - Fallugia paradoxa*) (refer to Lower and Middle Nankoweap Creek description)

Soil and geology information: 101—Rock outcrop-Akela family complex, 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: 45%
Akela family and similar soils: 40%
Minor components: 15%
Rock outcrop: vertical cliffs of canyons in the Vishnu Schist and Zoroaster Granite
Akela family soils
Taxonomic classification: loamy-skeletal, mixed, super active, calcareous, thermic Lithic Torriorthents
Geomorphic position: pockets and ledges on vertical cliffs
Parent material: colluvium derived from schist and/or colluvium derived from granite and/or aeolian deposits derived from limestone and sandstone
Slope: 15 to 6%

Surface fragments: about 1 % gravel, about 10% cobbles, about 20% stones
Depth to restrictive feature: 20.3 to 50.8 cm (8 to 20 in) to bedrock (lithic)
Drainage classification: well drained
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)
Runoff class: very high

Secondary soil and geology information: **24**—Cliffdown, moderately steep-Cliffdown families complex, 15 to 40% slopes

Landform: plateau
Elevation: 3,500 to 4,500 ft (1,067 to 1,372 m)
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
Cliffdown family and similar soils: 45%
Cliffdown family and similar soils: 30%
Minor components: 25%
Cliffdown family, moderately steep, soils
Taxonomic classification: loamy-skeletal, mixed, super active, calcareous, mesic Typic *Torriorthents*
Geomorphic position: fan terraces on escarpments of plateaus
Parent material: colluvium derived from limestone, sandstone, and shale
Slope: 15 to 50%
Surface fragments: about 30% coarse gravel, about 5% stones, about 30% cobbles
Depth to restrictive feature: 101.6 to 152.4 cm (40 to 60 in) to bedrock (lithic)
Drainage classification: well drained
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)
Runoff class: very high

Project area description: Bright Angel Creek is one of the longest tributaries of the Colorado River, and contains a high-volume rushing perennial stream and thick stands of riparian vegetation as well as several major tributaries with permanent water. Many sections of this project area have extremely high public visibility as it flows right next to the North Kaibab trail, allowing visitors to witness the recovery of this area post-tamarisk removal. This project area also includes Phantom Canyon, Ribbon Falls, Wall Creek, Manzanita Creek, and Roaring Springs Canyon, all tributaries of Bright Angel Creek. Crews removed tamarisk from 14 sections in Phantom Canyon, including the Haunted Canyon tributary. Ribbon falls is 9.6 kilometers (6 miles) from Phantom Ranch and contains both an upper and lower falls, with perennial water and three sections total. Wall Creek is a steep and narrow drainage just south of Cottonwood Campground and crews removed tamarisk from 5 sections. Manzanita Creek is between Wall and Roaring Springs, with a stream and two sections of tamarisk removal before it cliffs-out in the Bright Angel Shale. Roaring Springs is a short canyon in the Redwall Limestone about 8.8 kilometers (5.5 miles) from the North Kaibab trailhead, with permanent water with two sections treated for tamarisk. Bright Angel Creek includes 26 sections in the lower section below

Cottonwood Creek (which is in between Roaring Springs and Phantom Ranch) and ten sections above the Cottonwood Campground. The lower portion of this tributary, including Phantom Canyon, was accessed from Phantom Ranch. Crews accessed the middle portion of Bright Angel Creek portion via Cottonwood Campground, and the uppermost sections via Roaring Springs. Crews removed date palm (*Phoenix dactylifera*) from the Phantom Canyon confluence and the Phantom Ranch vicinity and Pampus grass (*Cortaderia selloana*) from the Roaring Springs bunkhouse area.

Transept Canyon

Vegetation community name: 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-leaved 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
Agave utahensis	Utah agave

Secondary vegetation community type: 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

Soil and geology information: 21—Chilton-Teesto-Puertecito families complex, 15 to 55% slopes

Landform: plateau
Elevation: 1,372 to 1,524 m (4,500 to 5,000 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
Chilton family and similar soils: 40%
Teesto family and similar soils: 30%
Puertecito family and similar soils: 25%
Minor components: 5%
Chilton family soils
Taxonomic classification: loamy-skeletal, mixed, super active, calcareous, mesic Ustic Torriorthents
Geomorphic position: fan terraces on colluvial slopes of canyons and plateau escarpments
Parent material: alluvium and/or colluvium derived from limestone and sandstone
Slope: 15 to 55%
Surface fragments: about 10% boulders, about 35% gravel, about 15% cobbles, about 15% stones
Depth to restrictive feature: N/A
Drainage classification: well drained
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: Transept Canyon is a sizeable tributary of Bright Angel Creek that enters above Cottonwood Campground from the east. This is a narrow canyon in the Tapeats Sandstone and Redwall Limestone with a spring source about halfway up that creates perennial water flow all the way to the confluence of Bright Angel Creek. There are sizeable patches of riparian vegetation, including marshy vegetation patches with sawgrass (*Cladium califoricum*) and cattails (*Typha domingensis*) intermingled within cold temperate forest and woodland vegetation. Transept Canyon has nine sections treated for tamarisk, including and east and west fork at the uppermost section of the drainage.

Pipe Creek – Lower and Upper

Vegetation community name: 223.2121—Cottonwood - Brickellia - Acacia - Apache Plume (*Populus fremontii - Brickellia longifolia - Acacia greggii - Fallugia paradoxa*) (refer to Lower and Middle Nankoweap Creek description)

Soil and geology information: 101—Rock outcrop-Akela family complex, 15 to 60% slopes (refer to Hance Creek for full description)

Secondary soil and geology information: 34—Dera family, 15 to 55% slopes

Landform: plateau
Elevation: 1,372 to 1,524 m (4,500 to 5,000 ft)
Mean annual precipitation: 15.2 to 25.4 cm (6 to 10 in)
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
Dera family and similar soils: 75%
Minor components: 25%
Dera family soils
Taxonomic classification: loamy-skeletal, carbonatic, mesic Typic Haplocalcids
Geomorphic position: summits and side slopes of fan terraces on colluvial slopes of plateau escarpments and canyons
Parent material: alluvium and/or colluvium derived from limestone and sandstone
Slope: 15 to 55%
Surface fragments: about 10% boulders, about 35% gravel, about 15% cobbles, about 15% stones
Depth to restrictive feature: N/A
Drainage class: well drained
Flooding hazard: none
Seasonal water table minimum depth: greater than 1.8 m (6 ft)

Project area description: Pipe Creek is a narrow tributary with perennial water in several sections and many large waterfalls, seeps and pools. There are significant patches of riparian forests with healthy cottonwood stands and seep areas. Lower Pipe Creek has extremely high visibility as it flows right next to Bright Angel trail, allowing visitors to witness the recovery of this area post-tamarisk removal. Upper Pipe Creek is accessed via the Tonto Trail between Bright Angel and the South Kaibab Trail. Lower Pipe Creek is accessed via the Bright Angel Trail below the Devil's Corkscrew switchbacks. Crews removed tamarisk from eight sections in Lower Pipe Creek and four sections in Upper Pipe Creek, including one section in the west fork. Crews removed Sahara mustard (*Brassica tournefortii*) from two sections of lower Pipe Creek near the confluence of the Colorado River.

Garden Creek

Vegetation community name: 153.11014—Mormon Tea - Snakeweed - Wolfberry (*Ephedra viridis/torreyana* - *Guterrezia sarothrae* - *Lycium andersonii*) (refer to 36.5 Mile Wash for full description)

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

Project area description: Garden Creek is a short tributary in the Vishnu Schist that is accessed where the canyon intersects the Bright Angel Trail, above the Devil's Corkscrew. This project area has extremely high visibility due to its proximity to a major trail corridor and campsite,

Indian Gardens. Crews removed tamarisk from five sections in Garden Creek, as well as the following other invasives: Sahara mustard (*Brassica tournefortii*) common mullein, (*Verbascum thapsis*), horehound (*Marrubium vulgare*), Date palm (*Phoenix dactlyifera*) and Himalayan blackberry (*Rubus discolor*)**.**

Boucher Creek – Upper

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

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

Tertiary vegetation community name: 223.2121—Cottonwood - Brickellia - Acacia - Apache Plume (*Populus fremontii - Brickellia longifolia - Acacia greggii - Fallugia paradoxa*) (refer to Lower and Middle Nankoweap Creek description)

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

Secondary soil and geology information: 68—Lithic Torriorthents-Rock outcrop complex, Dox Formation, 15 to 60% slopes (refer to Cardenas Hillside Spring 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: Upper Boucher Creek is a tributary with perennial water that possesses several distinct geological sections reaching from the Vishnu Schist ending in the Redwall Limestone narrows. The area contains a variety of vegetation mosaics from large terraces to cobble bars covered in coyote willow (*Salix exigua*). This project area begins at Boucher Camp where the Boucher Trail meets the drainage. The canyon starts off quite wide with dense foliage, but turns into narrow gorge upstream with rocks and pools. The route through Redwall Limestone narrows to the Supai Sandstone is difficult but doable. There are several slick pour-offs (with some with exposure) to climb but are ascendable, or by-passable in the immediate area. The canyon bottom is quite rocky and littered with large boulders, loose pebbles and pools. There is record of a flash flood in July of 2005. Crews removed tamarisk from six sections in Upper Boucher Creek and two sections in Lower Boucher Creek, which was a Phase I project area. Three of the sections in upper Boucher Creek were outside of the initially proposed project area boundaries.

Crystal Creek

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

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

Project area description: Crystal Creek is one of the major north rim tributaries of the Colorado River, with a perennial creek that flows rapidly after wet winters. The mouth of the canyon and lower portion is wide with large terraces that were covered in dense thickets of tamarisk. Above that is a sizeable section of Vishnu Schist narrows with some seeps. The canyon continues through quartzite and narrows with big shrub live oak (*Quercus turbinella*) stands and lots of cottonwoods. In the upper sections there is beautiful intact riparian vegetation hardly any tamarisk. Dragon Creek is 2/3 of lower Crystal Creek's source flow that begins with short narrows and then opens with lovely pools. Towards the upper end of Crystal Creek there is an open section of canyon with large area of cliffside springs and seeps near the Tapeats Sandstone and Shinumo Quartzite contact. Crews removed tamarisk from the first three sections of Crystal Creek and mapped an additional 13 sections in Crystal and five sections in Dragon Creek. Due to the fact that Crystal Creek can only be access via the river, tamarisk treatment will have to continue with Park funding on future river trips.

Copper Canyon

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

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

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

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

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

Tertiary 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)

Project area description: Copper Canyon is a very narrow canyon in the Vishnu Schist. This canyon was accessed via the Tonto Trail from Bass Trail as access from the river involves route finding or ropes. Throughout the canyon there are small pools with diverse invertebrates and several small climbs. Crews removed tamarisk from nine sections of Copper Canyon.

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112 Mile Wash

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

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

Project area description: 112 Mile Wash is a steep narrow canyon in the Gneiss with a sketchy traverse around a chalk stone in the first section that requires the assistance of a throw rope. 112 Mile Wash is probably dry most of the year, although there was a trickle of water and small pools after our wet 2005 winter and small patches of warm desert scrub vegetation. There are two sections in 112 Mile Wash that were treated for tamarisk and work ended at the end of the second section with a large waterfall that was not possible to traverse.

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130 Mile Creek

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

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

Project area description: 130 Mile Creek is a 300 meter long canyon in the Vishnu Schist with a short waterfall with a slippery climb that ends in a bowl with a huge waterfall at the top end. The vegetation in the bowl is dominated by longleaf brickellia (*Brickellia longifolia*) and contains a suite of plants with warm desert scrub influences.

Trail Canyon

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

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)

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)

Project area description: Trail Canyon is a narrow drainage in the Vishnu Schist the lower stretch has a running creek during wet years and tall Schist walls and granite bedrock pools. Trail Canyon has thick riparian vegetation where there is running water. Above that, the water disappears below ground, resurfacing only for a tickle or small pool. The canyon reaches its narrowest spot in Tapeats Sandstone, after which it opens into lovely Bright Angel Shale patio. At that point, the water starts flowing again through that entire stretch, but vegetation is quite sparse. Above that area Trail Canyon is dry and becomes narrower and full of boulders and then finally cliffs out low in the Muav Limestone. Crews removed tamarisk from four sections in Trail Canyon.

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225 Mile Canyon

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

Secondary community name: 153.1211—Blackbrush - Mormon tea - Banana yucca (*Coleogyne ramosissima - Ephedra nevadensis/viridis - Yucca baccata*) (refer to Lava Canyon - Upper for full description)

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

Secondary soil and geology information: 70—Lithic Torriorthents-Rock outcrop complex, Muav and Redwall Formations, 15 to 70% slopes (see Trail 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: 225 Mile Canyon is a narrow (less than 10 m wide) drainage in the Vishnu Schist containing small patches of riparian vegetation and desert slopes covered in large stands of teddy bear cholla (*Cylindropuntia bigelovii*). Halfway through the first section there is a large waterfall that is either traversed from creek left or maneuvered with a throw rope. The majority of the work was above this waterfall and made for difficult access. The upper granite narrows open to a marshy section with cattails (*Typha domingensis*) and other riparian vegetation. Above that the canyon dries out and opens. Crews removed tamarisk from four sections in 225 Mile Canyon.

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c. Project Logistics

Phase II-A of the invasive plant management work brought with it many new insights and subsequent improvements from lessons learned from earlier experiences with the project. In May 2005, 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 500 meter-long mapping sections in drainages to more consistently estimate tamarisk distribution. The consistent section length standardized data collection in the control phase of the project, and allowed for standard comparison units between areas. During the May 2005 survey work, crews took representative photographs in all 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-A Project Areas List and Completion Status

River Mile	River Side	Project Area Name	SW WFL HA Complete	Transect Area	Work Complete	Area Accessed Via River	Area Accessed Via Back-packing
8	R	Badger Canyon	X		X	X	
31.6	R	South Canyon – Lower	X		X		X
31.6	R	South Canyon – Upper	X	X	X		X
36.5	R	36.5 Mile wash	X		X	X	
47.2	R	Saddle Canyon	X		X	X	
51.8	R	Little Nankoweap Creek	X		X	X	
52	R	Nankoweap Creek – Lower	X	X	X	X	
52	R	Nankoweap Creek – Middle	X	X	X		X
52	R	Nankoweap Creek – Upper	X		X		X
56.2	R	Kwagunt Creek – Upper	X		X		X
64.7	R	Carbon Creek – Upper	X	X	X	X	
65.5	R	Lava Chuar– Upper	X		X	X	
70.2	L	Cardenas Hillside Spring	X		X	X	
70.8	L	70.8 Mile Drainage	X		X	X	
72.3	R	Unkar Creek – Lower	X	X	X	X	
72.3	R	Unkar Creek – Upper	X		X	X	
76	L	Papago Creek	X		X		X
76.6	L	Red Canyon	X		X		X
78.6	L	Hance Creek	X				X
80.5	L	Cottonwood Creek	X		X		X
81.5	L	Grapevine Creek	X		X		X
82.8	L	Boulder Creek	X		X		X
84	R	Clear Creek – Upper	X		X		X
88	R	Bright Angel Creek	X	X	X		X
88	R	Transept Canyon	X		X		X
89	L	Pipe Creek – Lower	X		X		X
89	L	Pipe Creek – Upper	X		X		X
89	L	Garden Creek	X		X		X
96.7	L	Boucher - Upper	X		X		X
98	R	Crystal Creek	X	X		X	
110	L	Copper Canyon	X		X		X
112	L	112 Mile Wash	X		X	X	
130	R	130 Mile Creek	X		X	X	
219	R	Trail Canyon	X	X	X	X	
225.5	R	225 Mile Canyon	X		X	X	

Backpacking Logistics

Crews completed invasive plant management work from September 2005 through October 2007. The field crew supervisor prepared trip schedules and itineraries, which were reviewed and approved by Park management, prior to each trip (please refer to Table 1. Phase II-A Project Area List and Completion Status, Table 2. Phase II-A Backpacking Trips). The Phase II-A grant deliverables called for nine Phantom Ranch Area backpacking trips (i.e. Bright Angel Creek), and twelve backcountry backpacking trips. Crews completed a total of 29 backpacking trips during the

course of the project; eight more than the grant required, and 19 of the 35 areas were accessed via backpacking. Seven individuals served as crew leaders (Kate Watters, Melissa McMaster, Hillary Hudson, Loren Bell, Steve Till, Kelly McGrath and Kari Malen), all of which were funded either fully or in some portion by this grant. The majority of the crew leaders worked on the project throughout the duration of Phase II-A. These experienced leaders built upon their expertise and project knowledge, and have become very dedicated, knowledgeable, physically fit, and absolutely invaluable to the project.

Throughout the project, logistics have been improved to continually make the trips more smooth and productive. The backpacking trips were seven to eight days long and consisted of eight people (6 volunteers and 2 crew leaders). The greatest challenge of the backpacking trips was carrying the tools and herbicide needed to perform tamarisk management in remote locations in addition to the standard 18 kilograms (40 pounds) of gear needed for a standard backpacking trip. For project areas in the main trail corridor (i.e. Bright Angel, Pipe Creek and Garden Creeks), NPS mule strings carried tools, food, and herbicide, which cut down on the weight that individuals had to carry. 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, eliminating 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 is the extremely heavy packs that crew leaders and volunteers must carry in order to make the project work. Trips are generally seven to eight days long, which in most cases allowed for four to five solid days of work, including hiking and driving time. 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, as they somehow remain to be a robust community of individuals committed to ridding the Grand Canyon region of tamarisk.

All of the project areas were completed with the exception of Hance and Crystal Creeks. Crews accessed Hance Creek solely via backpacking, and had several challenging routes that needed to be determined in the field in order to get to the last large patches of tamarisk near the mouth of the canyon. In the fall of 2006, the entire staff of seasonal crew leaders conducted their pre-season training at Hance. Paul Austin, a GRCA Backcountry Ranger, joined the trip and provided critical training on search and rescue and evacuation protocols, as well as climbing safety. With Paul's help, crew members were able to access additional areas of the Hance Creek drainage with ropes and identify safe routes to access tamarisk populations. Hance is an excellent example of an area that was not completely mapped before management efforts began, thus making it difficult to plan treatment efforts accordingly. During the Spring of 2007, a crew returned to do follow-up work, and expected to finish the area in a couple days, but reached a large thicket of trees on the last afternoon. This area will be completed with funds from the National Park Service in the future.

Crystal Creek is a sizeable tributary on the north side that can only be accessed via a rafting trip on the Colorado River. Crews worked at Crystal Creek a total of seven days on three different river trips, including the Spring 2007 Phase II-B trip, and still were only able to treat the first two sections. This was due to the fact that the wide terrace at the mouth of the canyon was choked with dense thickets of mature tamarisk, and that alone kept workers occupied. In order to complete this canyon, a crew will need to spend about seven to ten days camped at the river, hiking up daily. This

will be a long-term project that will be completed on subsequent river trips funded by the National Park Service.

Table 2. Phase II-A Backpacking Trips

Trip Dates	Trip Leaders	Project Areas	Total Participants
September 14-19, 2005	Melissa McMaster	Upper and Lower Pipe Creek, Garden Creek	5 Colorado Plateau EPMT, 2 crew leaders
September 28-October 4, 2005	Kate Watters and Hillary Hudson	Upper Bright Angel Creek, Transept Canyon	6 Colorado Plateau EPMT, 2 crew leaders
September 28-October 4, 2005	Kari Malen and Melissa McMaster	Lower Bright Angel Creek	9 volunteers, 2 crew leaders
October 13-15 2005	Loren Bell and Melissa McMaster	Cottonwood Creek	2 crew leaders
November 14-18 2005	Kari Malen and Melissa McMaster	Cottonwood Creek	4 volunteers, 2 crew leaders
November 13-20 2005	Kate Watters, Loren Bell and Steve Till	Nankoweap Creek	6 volunteers, 3 crew leaders
November 28-December 4 2005	Steve Till and Loren Bell	Upper Clear Creek	3 volunteers, 2 crew leaders
December 7-13 2005	Loren Bell and Steve Till	Upper Bright Angel Creek, Transept Canyon	6 volunteers, 3 crew leaders
January 4-10 2006	Melissa McMaster and Hillary Hudson	Bright Angel Creek	6 volunteers, 2 crew leaders
January 4-10 2006	Steve Till	Upper Boucher Creek	4 volunteers, 1 crew leader
February 4-11 2006	Loren Bell and Steve Till	Boulder and Grapevine Creeks	6 volunteers, 2 crew leaders
March 4-11 2006	Melissa McMaster	Cardenas Spring, 70.8 Mile Canyon, Red Canyon	3 volunteers, 1 crew leader
March 15-21 2006	Loren Bell and Kari Malen	South Canyon	7 volunteers, 2 crew leaders
March 29-April 5 2006	Loren Bell and Steve Till	Nankoweap Creek	5 volunteers, 2 crew leaders
March 29-April 5 2006	Kate Watters and Melissa McMaster	Red Canyon, Hance Creek	5 volunteers, 2 crew leaders
September 8-11 2006	All crew leaders	Hance Creek	0 volunteers, 6 crew leaders
September 27-October 1 2006	Melissa McMaster, Kelly McGrath	Grapevine Creek	3 volunteers
October 9-16 2006	Melissa McMaster	Upper Bright Angel Creek	6 Colorado Plateau EPMT, 1 crew leader
October 24-31 2006	Steve Till and Loren Bell	Upper Bright Angel Creek	6 Volunteers
October 30-November 6 2006	Melissa McMaster	Upper Bright Angel Creek	6 Colorado Plateau EPMT, 1 crew leader
November 8-14 2006	Steve Till and Loren Bell	Upper Clear Creek	4 volunteers
December 6-12 2006	Steve Till and Kelly McGrath	Bright Angel Creek / Phantom Canyon	6 volunteers

Trip Dates	Trip Leaders	Project Areas	Total Participants
January 17-23 2007	Steve Till and Kelly McGrath	Phantom Canyon	6 volunteers, 2 crew leaders
January 31-February 7 2007	Steve Till and Loren Bell	Bright Angel Creek	6 volunteers, 2 crew leaders
February 8-14 2007	Melissa McMaster	Grapevine Creek	4 volunteers, 1 crew leader
February 17-24 2007	Kate Watters and Melissa McMaster	Papago Canyon	6 volunteers, 2 crew leaders
March 6-12 2007	Melissa McMaster	Hance Creek	4 volunteers, 1 crew leader
March 11-17 2007	Loren Bell and Kelly McGrath	Copper Canyon	6 volunteers, 2 crew leaders
March 12-16 2007	Steve Till	Lower South Canyon	4 volunteers, 1 crew leader

River Trip Logistics

Due to the remoteness of Grand Canyon's terrain, it is necessary to access the majority 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-A Project Area List and Completion Status, Table 3. Phase II-A River Trip Participant List, and Table 4. Phase II-A River Trip Itineraries). The Phase II-A grant deliverables called for two tamarisk management river trips. Crews worked in 16 out of the 35 canyons via 20-day river trips from October 2005 through May 2007. The AWPF grant funded two trips, and an additional trip funded by the Colorado River Fund was completed with supplemental funding in November 2006 in order to complete follow-up work on Phase II-A project areas. 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 located throughout the length of the river.

Table 3. Phase II-A River Trip Participant List

Role	Upper Half	Lower Half
October 2005 Tamarisk Management River Trip		
Trip Coordinator / Project Leader	Kate Watters	Loren Bell
Head Boatman / Trip Leader	Bryan Edwards	Bryan Edwards
Boatman	Johnny Janssen	Johnny Janssen
Boatman	Dave Loeffler	Dave Loeffler
Boatman	Shana Watahomigie	Shana Watahomigie
Boatman	Jason Hughes	Jason Hughes
Crew Leader #1	Loren Bell	Melissa McMaster
Crew Leader #2	Melissa McMaster	Maria Clementi
Crew Leader #3 (upper) / Trail Worker (lower)	Kari Malen	Shannon McCloskey
Volunteer Crew Lead (upper) / Trail Worker (lower)	Hillary Hudson	Jocelyn Pawlicki
Volunteer Crew Lead / lower	Nate Emer	Bill Emig
Volunteer	Clayton Bliss	Regina Eason
Volunteer	Allen Cox	Steve Gaiser

Role	Upper Half	Lower Half
Volunteer	Sarah Reed	Donaig Gaiser
Volunteer	Dan Regan	Maria O'Sullivan
February 2006 Tamarisk Management River Trip		
Trip Coordinator / Project Leader	Kate Watters	Kate Watters
Head Boatman / Trip Leader	Johnny Janssen	Tim Stephenson
Boatman	Jason Hughes	Jason Hughes
Boatman	Tyler Williams	Tyler Williams
Boatman	Shana Watahomigie	Shana Watahomigie
Boatman	Matt Malone	Matt Malone
Baggage Boatman	Kevin Dowell	Kevin Dowell
Crew Leader #1	Loren Bell	Loren Bell
Crew Leader #2	Melissa McMaster	Steve Till
Volunteer Crew Lead	Mark Langdon	Emily Spencer
Volunteer	Tom Pringle	Kelly Williams
Volunteer	Val Malutin	Kelly Rowell
Volunteer	Chad Morris	Luke Moorehead
Volunteer	Carol Ogburn	Wyatt Sanders
Volunteer	Dawn Goldman	Ruth Richards

November 2006 Colorado River Fund River Trip		
ARR boatman	Mark Pillar	Mark Pillar
ARR boatman	David Sherman	David Sherman
ARR boatman	Lyndsay Hupp	Lyndsay Hupp
ARR boatman	Travis Vercammen	Travis Vercammen
ARR boatman	Christina Parker	Christina Parker
Cook	Ken Gouff	Ken Gouff
Project Leader	Kate Watters	Kate Watters
Crew Leader #1	Kelly McGrath	Kelly McGrath
Crew Leader #2	Rachel Stanton	Rachel Stanton
Veg. volunteer	Dean Wadsworth	Vacant
Veg. volunteer	Jess Page	Vacant
Arch. project leader	Jen Dierker	Vacant
ARR worker	Josh Macnaughton	Josh Macnaughton
ARR worker	Deanna Sanderson	Deanna Sanderson

Table 4. Phase II-A River Trip Itineraries

Date	Day	Work Location	River Mile	Camp (mile)
October 2004 Tamarisk Management CESU River Trip				
9/29/04	1	Badger Canyon	8 R	Soap, 11 R
9/30/04	2	Rider Canyon	17 R	South, 30 R
10/1/04	3	36.5 mile wash	36.5 R	Nankoweap Area, 52 R
10/2/04	4	Nankoweap	52 R	Nankoweap Area, 52 R
10/3/04	5	Nankoweap	52 R	Nankoweap Area, 52 R
10/4/04	6	Malgosa, Awatubi	57.5 R, 58.2 R	Awatubi, 58.2 R

Date	Day	Work Location	River Mile	Camp (mile)
10/5/04	7	Carbon Creek	64.7 R	Carbon, 64.7 R
10/6/04	8	Carbon Creek, Lava Chuar	64.7, 65.5 R	Carbon, 64.7 R
10/7/04	9	Unkar	72.3 R	Above Unkar, 72 R
10/8/04	10	Unkar	72.3 R	Above Unkar, 72 R
10/9/04	11	75 Mile and Papago	75 R, 75.8 R	Cremation, 87 R
October 2005 Tamarisk Management River Trip				
10/18/05	1	Transit – Ravenna as time allows		19 Mile L
10/19/05	2	36.5 Mile wash	36.5 R	Tatahatso, 37.5 L
10/20/05	3	Saddle Canyon	47.2 R	Nankoweap 52 R
10/21/05	4	Little Nankoweap-resurvey, Nankoweap Canyon	52 R	Nankoweap 52 R
10/22/05	5	Nankoweap Canyon	56.2 R	Kwagunt, 56.2 R
10/23/05	6	Kwagunt Creek – upper	56.2 R	Kwagunt, 56.2 R
10/24/05	7	Kwagunt Creek – upper	56.2 R	Kwagunt, 56.2 R
10/25/05	8	Carbon – work lower portion	59.8 R	Carbon, 64.7 R
10/26/05	9	Carbon Creek	64.7 R	Carbon, 64.7 R
10/27/05	10	Carbon Creek	64.7 R	Carbon, 64.7 R
10/28/05	11	Transit to Unkar – lower	71.9 R	Upper Unkar, 71.9 R
10/29/05	12	Unkar Creek – upper	71.9 R	Upper Unkar, 71.9 R
10/30/05	13	Transit – Exchange		Trinity, 91.6 R
10/31/05	14	112 Mile Wash	112 L	Garnet Area, 114 R
11/1/05	15	Transit		Randy's Rock, 126.5 R
11/2/05	16	127 Mile Creek, 130 Mile Creek	127 R, 130 R	Bedrock, 131 R
11/3/05	17	Transit – various		Tuckup, 164R
11/4/05	18	Transit – various		185 Mile, 185 R
11/5/05	19	Transit – Ravenna as time allows	219 R	Trail Canyon, 217 R
11/6/05	20	Trail Canyon	219 R	Trail Canyon, 217 R
11/7/05	21	Trail Canyon	224 R	Setup for takeout!
11/8/05	22	TAKE OUT!!!!!!! Everyone helps with clean up at South Rim boatshop.		

February 2006 Tamarisk Management River Trip				
2/18/06	1	Badger Canyon	8 R	Badger Canyon/Jackass area, 8 L
2/19/06	2	Transit		Tatahatso, 37 L
2/20/06	3	Transit–Drop herbicide at Nankoweap	52 R	Kwagunt, 56 R
2/21/06	4	Carbon Creek – Upper	64.7 R	Carbon, 64.7 R
2/22/06	5	Carbon Creek – Upper	64.7 R	Carbon, 64.7 R
2/23/06	6	Lava Chuar – Upper	65.5 R	Lava Chuar, 65 R
2/24/06	7	Lava Chuar – Upper/Spike Camp	65.5 R	Lava Chuar, 65 R
2/25/06	8	Transit		Cremation, 87 R
2/26/06	9	Transit - Boucher	97 L	Boucher, 97 L
2/27/06	10	Boucher	97 L	Boucher, 97 L
2/28/06	11	Crystal	98 R	Crystal, 98 R
3/1/06	12	Crystal	98 R	Crystal, 98 R
3/2/06	13	Crystal	98 R	Crystal, 98 R
3/3/06	14	127 Mile	127 R	Galloway, 131.2 R
3/4/06	15	TRANSIT		National, 166.5 L

Date	Day	Work Location	River Mile	Camp (mile)
3/5/06	16	TRANSIT		202 Mile, 202 R
3/6/06	17	Trail Canyon	219 R	Trail Canyon, 217 R
3/7/06	18	Trail Canyon	219 R	Trail Canyon, 217 R
3/8/06	19	225 Mile R	225.5 R	Diamond Creek
3/9/06	20	TAKE OUT!!!!!!! Everyone helps with clean up at South Rim boatshop.		

November 2006 Colorado River Fund River Trip				
11/1/06	1	Transit – Various arch monitoring		North Canyon, 20.5 R
11/2/06	2	Transit – Various arch monitoring		Eminence, 44 L
11/3/06	3	Transit – Various arch monitoring		Lava Chuar, 65 R
11/4/06	4	Upper Lava Chuar-Spike camp	65.5 R	Lava Chuar, 65 R
11/5/06	5	Upper Lava Chuar	65.5 R	Lava Chuar, 65 R
11/6/06	6	Upper Unkar – Spike camp	71.9 R	Upper Unkar, 71.9 R
11/7/06	7	Upper Unkar	71.9 R	Upper Unkar, 71.9 R
11/8/06	8	Transit – Investigate routes at Papago		Boucher, 97 L
11/9/06	9	Topaz Creek	97 L	Boucher, 97 L
11/10/06	10	Boucher Creek	97 L	Crystal, 98 R
11/11/06	11	Crystal Creek	98 R	Crystal, 98 R
11/12/06	12	Crystal Creek	98 R	Crystal, 98 R
11/13/06	13	Copper Canyon – Investigate routes	110 L	122 Mile, 122.8 R
11/14/06	14	Transit		Upper Ledges, 151 R
11/15/06	15	Transit		183 Mile, 183 R
11/16/06	16	Various		202 Mile, 202 R
11/17/06	17	Ravenna removal – Spring and 205 mile	209	209 Mile, 209 L
11/18/06	18	Granite Park	225	Diamond Creek
11/19/06	19	TAKE OUT!!!!!!! Everyone helps with clean up at ARR boatshop.		

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 methods including mechanical and chemical. 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 horehound (*Marrubium vulgare*), Himalaya blackberry (*Rubus discolor*), Pampas grass (*Cortaderia selloana*), Ravenna grass (*Saccharum ravennae*), Sahara mustard (*Brassica tournefortii*), puncture vine (*Tribulus terrestris*), silverleaf nightshade (*Solanum elaeagnifolium*), sowthistle (*Sonchus* spp.), and prickly lettuce (*Lactuca serriola*), London rocket (*Sisymbrium irio)*, Date palm *(Phoenix dactlyifera)*, African mustard (*Malcomia africana*), and perennial pepperweed *(Lepidium*

latifolium). 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 cm into the water-conducting tissue (xylem) of standing trees. The cut was within one meter of the ground surface (usually within 20 cm) and forms 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 and 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 where manual removal is 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 understand 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-A 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 created packing lists, menus, and food purchase lists in order to streamline the trip preparation process. The field crew supervisor also purchased bulk food for backpacking trips in order to supplement the backpacking trip menus. The Polk Intern in 2006, Kelly McGrath, vastly improved the backpacking trip menu and organization of the bulk food area during her tenure. 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 continues 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 tries to keep spares on hand on 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 and Other Invasive Species Control Results

During the entire Phase II-A project crews removed 130,504 tamarisk trees including 86,907 seedlings, 33,190 saplings, and 10,407 mature trees from 10,180 hectares (25,154 acres) in Phase II-A project sites. Crews removed 60,182 m^2 of total tamarisk canopy cover from within the 35 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).

In addition, crews also removed 34,169 individual plants of other invasive exotic species from project areas on AWPF funded river and backpacking trips (Table 6. Other Invasive Species Controlled, Figure 3. Other Invasive Species Treated).

During the life of the project, crews worked in all 35 project areas for Phase II-A at least once, and completed work in all but two areas (Table 1. Phase II-A Project Areas List and Completion Status). Regardless of the current level of completion, all of the sites will require follow-up work in the form of seedling control, which will be completed with supplemental funding sources. Eleven of the project areas required only one visit for treatment. Crews revisited 24 of the project areas two or more times in order to completely finish. Bright Angel Creek drainage, which had several major tributaries, required nine trips to finish.

Retreatment rates are driven by how long it has been since the first treatment and also how long since the last flash flooding event.

Table 5. Tamarisk Control Summary

	Size Class			Control Method					Area Treated	
Canyon Name	Seedling	Sapling	Mature	Pulled	Cut / Girdle Combo	Girdle	Basal Bark	Cut Stump	Cover (m^2)	Area Infested (m^2)
112 Mile Canyon	22	0	2	22	0	0	0	2	15	4000
130 Mile Creek	0	13	21	1	0	0	0	33	80	3000
225 Mile Canyon	3089	1178	114	3604	0	0	0	777	887	90400
36.5 Mile Wash	1705	1	5	1705	0	0	0	6	35	4000
70.8 Mile	15	17	5	0	0	0	0	37	49	400
Badger Canyon	0	10	28	0	0	0	0	38	164	17500
Boucher Creek	1023	1939	310	115	12	6	775	2364	2265	569199
Boulder Creek	66	280	162	80	0	0	0	428	993	24400

	Size Class			Control Method					Area Treated	
Canyon Name	**Seedling**	**Sapling**	**Mature**	**Pulled**	**Cut / Girdle Combo**	**Girdle**	**Basal Bark**	**Cut Stump**	**Cover (m^2)**	**Area Infested (m^2)**
Bright Angel Creek – (Phantom Creek & Ribbon Falls)	40268	14141	2519	34207	11	90	1390	21238	13026	2352085
Carbon Creek – Upper	510	273	206	510	19	15	0	445	1945	60400
Cardenas Hillside Spring	0	0	6	0	2	0	0	4	860	8800
Clear Creek – Upper	457	226	152	443	5	3	0	384	1150	225500
Copper Canyon	48	37	60	49	0	0	0	92	309	26000
Cottonwood Creek	829	69	49	831	0	0	0	116	91	30000
Crystal Canyon	310	3157	1383	244	2	0	0	4604	4202	115000
Garden Creek	18	21	15	20	3	0	0	31	64	167015
Grapevine Creek	463	246	281	378	1	0	5	606	1700	322300
Hance Creek	3682	1041	327	3332	2	6	0	1710	2030	176400
Kwagunt Creek	4089	739	393	3813	0	9	130	1269	3184	45051004
Lava Chuar – Upper	232	306	267	47	0	0	0	758	1801	21134771
Little Nankoweap Creek	0	0	0	0	0	0	0	0	0	0
Nankoweap Creek – Lower & Middle & Upper	12338	1853	1359	12181	36	17	0	3306	10113	10804580
Papago Lower	10	0	0	10	0	0	0	0	2	10000
Pipe Creek – Lower & Upper	943	779	663	989	0	0	42	1354	2265	495801
Red Canyon	146	203	109	87	0	1	0	370	764	80000
Saddle Canyon	165	101	8	50	0	0	0	224	464	761586
South Canyon – Lower & Upper	2230	288	200	2286	0	1	35	396	1642	131426
Trail Canyon	10542	2428	209	10268	3	0	0	2748	2473	250500
Transept Canyon	1305	2968	994	113	3	0	0	5161	4063	185000
Unkar Creek – Lower & Upper	2402	876	560	2041	4	0	1	1792	3546	18693436
TOTALS	**86,907**	**33,190**	**10,407**	**77,426**	**103**	**148**	**2,378**	**50,293**	**60,182**	**101,794,503**

**Note: Project areas in the same tributary have been combined (i.e. Pipe Creek-Upper, Pipe Creek-Lower) for ease in sorting data. Bright Angel Creek includes several tributaries (Roaring Springs, Manzanita, Wall, Ribbon Falls and Phantom Canyons).

Figure 1. Tamarisk Treatment by Size Class

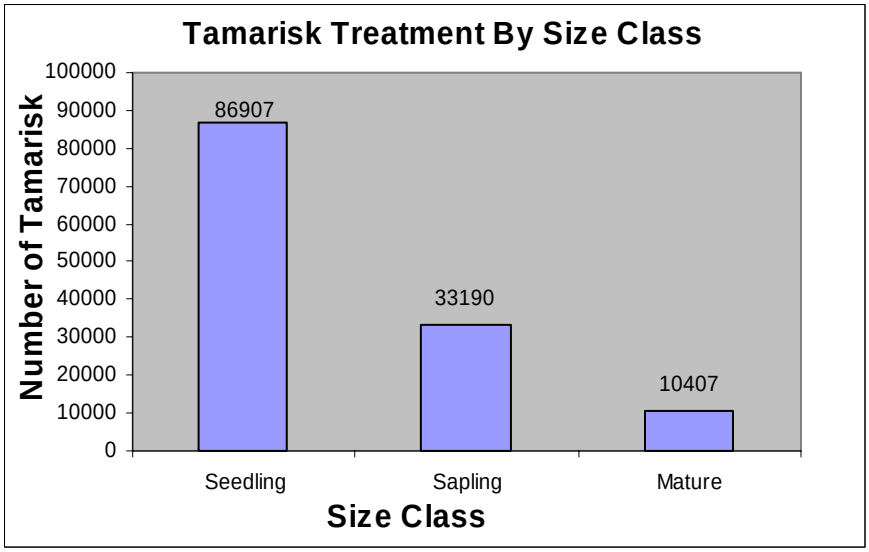


Figure 2. Tamarisk Treatment by Method

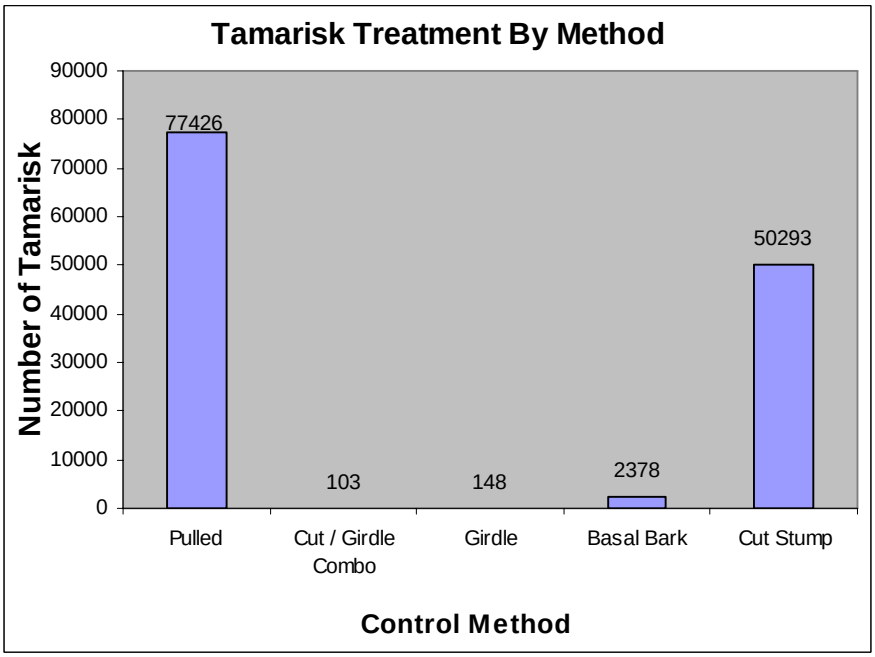
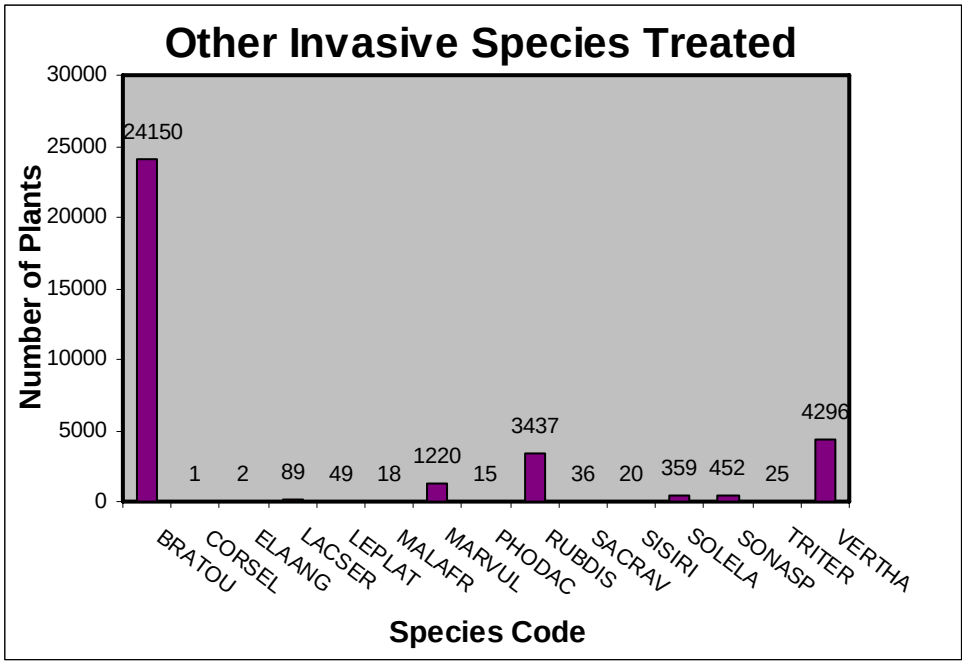


Table 6. Other Invasive Species Controlled

Common Name	Scientific Name	Species Code	# of Plants
Sahara mustard	*Brassica tournefortii*	BRATOU	24150
Pampas grass	*Cortaderia selloana*	CORSEL	1
Russian olive	*Elaeagnus angustifolia*	ELAANG	2
Prickly lettuce	*Lactuca serriola*	LACSER	89
Perennial peppergrass	*Lepidium latifolium*	LEPLAT	49
African mustard	*Malcolmia africana*	MALAFR	18
Horehound	*Marrubium vulgare*	MARVUL	1220
Date palm	*Phoenix dactylifera*	PHODAC	15
Himalaya blackberry	*Rubus discolor*	RUBDIS	3437
Ravenna grass	*Saccharum ravennae*	SACRAV	36
London rocket	*Sisymbrium irio*	SISIRI	20
Silver leaf nightshade	*Solanum elaeagnifolium*	SOLELA	359
Sowthistle	*Sonchus asper*	SONASP	452
Puncture vine	*Tribulus terrestris*	TRITER	25
Common mullein	*Verbascum thapsus*	VERTHA	4296
		TOTAL:	**34169**

***Includes work completed on river trips funded through other sources to provide matching contribution to project, as well as work completed in Little Nankoweap, which did not have tamarisk.*

Figure 3. Other Invasive Species Treated



Tamarisk Retreatment Results

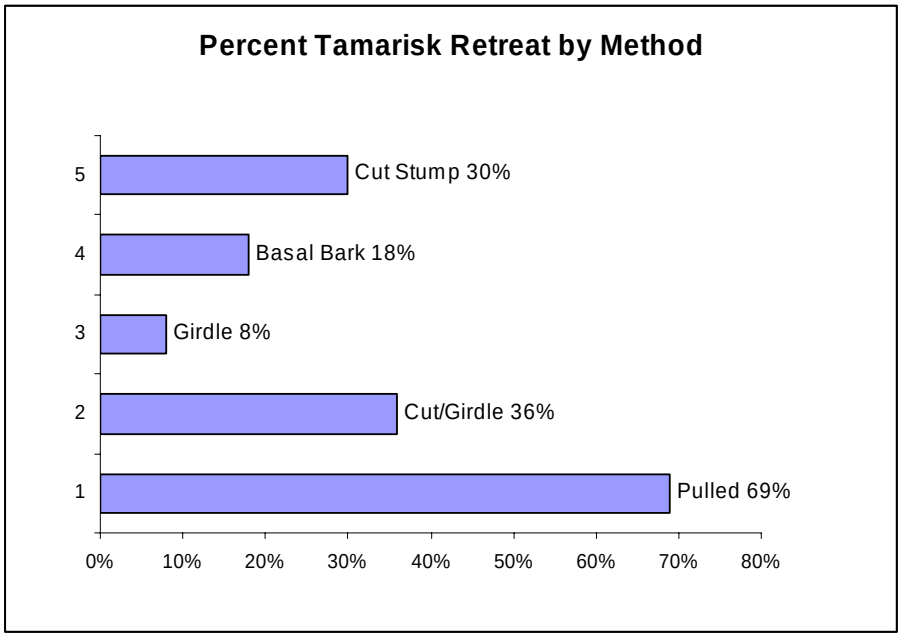
Data from tamarisk retreatment results is higher than expected (Refer to Table 7. Tamarisk Retreatment Results). The total number of plants retreated was 53%, which includes seedlings. During the initial treatment of a 500 meter section, seedlings are the last priority, with crews removing matures and saplings first. Often, when crews return to an area they encounter an increased number of seedlings, due to the tamarisk seeds that were dormant in the soil. When seedlings are removed from retreatment, the rate of retreatment for Phase II-A areas is 10%, which is slightly above the 7% retreatment rate from Phase I. Of that 10%, crews retreated 30% of the saplings and 34% of mature plants, which could be high for a few reasons. First, the data collection for retreats is somewhat skewed, as a result of the manner in which it was collected. Due to an oversight, crews sometimes coded a 500 meter section as a retreat, even when tamarisk trees were not removed from the entire section. In the future, field leaders will be careful to separate the plants that have been previously cut from those sections which were originally treated, but not completed. Another factor with initial treatment success is the amount of time between cutting of the tree and application of herbicide. The more time that passes 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.

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 and 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 the absence of 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	Cover (m^2)
# Initially Treated	60208	31104	23034	6840	23851	64	135	1934	34991	43603
# Retreated	69510	55803	10156	3567	53575	39	13	444	15302	16579
Tamarisk Totals	129718	86907	33190	10407	77426	103	148	2378	50293	60182
% Retreated	53%	64%	30%	34%	69%	36%	8%	18%	30%	27%

Figure 4. Tamarisk Retreatment Results by Method



Herbicide Use

Throughout the Phase II-A project, crews used a total of 121.3 gallons of mixed herbicide and 52.2 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	27.6	50.0	13.8
Tamarisk	*Tamarix ramosissima*	Garlon 4	64.6	25.0	16.1
Russian olive	*Elaeagnus angustifolia*	Garlon 4	1.1	25.0	0.3
Tamarisk	*Tamarix ramosissima*	Pathfinder	20.5	100.0	20.5
Himalayan blackberry	*Rubus discolor*	Rodeo	1.6	2.0	0.0
Tamarisk	*Tamarix ramosissima*	Tahoe 4e	5.9	25.0	1.5
		Herbicide Totals:	121.3		52.2

Volunteer Summary

Volunteers have been an absolutely critical element to 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 fall of 2005 through the spring of 2007, volunteers donated a total of 17,224 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 $323,295.00

The hours are broken down into different categories. The management portion of the project accrued 9,704 hours in tamarisk backpacking trips and 3,858 hours on tamarisk river trips for a total of 13,562 volunteer hours. The monitoring portion of the project accumulated 3,662 hours, including the valuable time spent collecting and identifying plants from our project areas by Desert Botanical Garden herbarium curator and senior research botanist, Wendy Hodgson.

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 initially shared by the GCNPF and the Grand Canyon Trust (GCT). In 2006, the GCNPF created a position to recruit and manage the volunteer projects. This alleviated the time GRCA staff spent recruiting, contacting and preparing paperwork for volunteers prior to trips. The volunteer coordinator updated the volunteer recruitment protocols and provided the public with additional information about the project via flyers and the new website. Additional paperwork gathers more complete background information from each volunteer so that crew leaders know about dietary restrictions and general health and medications. It has been difficult for the GCNPF to keep the volunteer coordinator position filled, which made consistency tricky. GRCA recently created a volunteer coordinator position, which will hopefully create an in Park person to recruit and manage paperwork. GCNPF and GCT created a website (http://www.gcvolunteers.org) that has information about each trip and continues to be the primary source for volunteer recruitment and allows volunteers to apply online.

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. The Polk Intern designed thank you cards, which project leaders sent 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" widens with every passing season. 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. Besides the fact that this daunting project would not be feasible without them, volunteers also provide endless support emotionally and sometimes financially to the success of our 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. Here are a few quotes from Backcountry Vegetation Program Volunteers from the fall 2006 season:

"Steve did a wonderful job with the tamarisk project this past week and I wanted to let you know how knowledgeable and energetic he was in providing the group with a well rounded and very rewarding experience. He is a great asset to the program. I finally made a tammy trip and it was well worth it." — Dan Shein

“The trip was GREAT! Even day one, which was a bit of a chore getting from the rim to the upper end of Grapevine, was enjoyable. First off, Melissa and Kelly were excellent. There were very competent, hardworking (our meals were very good), and a lot of fun to work with. I had not been in the GC for any length of time before this trip, and thoroughly enjoyed getting a bit 'off trail' during our work days in Grapevine Canyon. It was a beautiful canyon to work in.

We got a lot of tamarisk cleared, but one more day, I think, would have allowed us to completely clear Grapevine. Due to the location of the work, a lot of time was spent going to and from the work site. Still, we got down to the final pour-over above the river and worked back, so the lower, more difficult section to access, is cleared. I think it was a pretty successful trip, tammy-wise.

So... again, it was a great trip and I'd love to go back for another in the spring, if possible. Extend my sincere thanks to Melissa and Kelly for the work they did to make this such a fun experience.” — Lou Lorber

“When I start feeling totally overwhelmed here at my desk in SF, I look at the Grand Canyon map on my cube wall and think back to the great time I had in the Canyon with Kate Watters and the rest of the "Over the Edge Veg Team" in February '06 and feel much better! The NPS folk I work with up at Pt. Reyes where I've been a volunteer weed whacker since January '96 totally love my Over the Edge Veg Team t-shirt (as do I).”
— Mark Langdon

“Loren and Steve interacted very well, professionally and personally with our group of volunteers. They were polite, friendly, inclusive and fair with us in every way I observed. They are both bright and knowledgeable, and they taught and led us well in how and why we were doing what we did. As a plant/riparian biologist, I have performed tamarisk research resulting in my co-authoring several peer-reviewed scientific publications. I tried, but don’t believe I added any information of substance beyond what Loren and Steve presented to the group about the species, its biology and management. They explained the eradication activities well, and emphasized safety. Loren and Steve are upbeat people who really appear to enjoy their work. Their enthusiasm and ability to pass that to others helped make the time very enjoyable. The tamarisk eradication program in the Grand Canyon appears to me to be successful and in excellent hands.” — Scott Miles
“This donation of $250.00 is because my life has been touched by the inner canyon reveg team. I am proud of their dedication and commitment.” — Carol Ogburn

“You should know that the reason I volunteer is that you have such great people working for you. On the trips the atmosphere has been upbeat, we kept to the task at hand and they are all professional in their attitude. The thanks should be given to Kate, Melissa, Loren, Hillary, Steve, Maria and all of the others. You’ve also given me the opportunity to do what I always wanted to do: hike the Canyon and go down the Colorado. Thanks for everything you’ve done.” —Val Malutin

“I just wanted to say thank you for your professionalism and attention to the details. I felt that my experience with you all on the river was a very satisfying and rewarding one. I really enjoyed destroying tamarisk, and being a part of something that helps preserve the beauty of the Canyon. I was warm, well-fed and always secure in the wilderness environment, thanks to you and the great

bunch of boatman. Thanks so much for letting me be apart of your endeavor. I wish you much success!"—Dawn Goldman

Table 9. Volunteer Contribution to Project

Name	Work Project	Start Date	End Date	Hours
Adam Yeh	Tamarisk Backpacking	1/3/2006	1/11/2006	83
Adele Wiejaczka	Tamarisk River	9/5/2006	9/22/2006	9
Akasha Faist	Tamarisk Backpacking	3/4/2007	3/10/2007	71
Alexandra Suahara	Tamarisk River	9/5/2006	9/22/2006	9
Amanda Schwantes	Tamarisk Backpacking	1/3/2007	1/13/2007	103
Amber Schelot	Tamarisk Backpacking	3/18/2006	3/22/2006	40
Amy Prince	Tamarisk Monitoring	5/11/2007	5/22/2007	116
Anne Madsen	Tamarisk Backpacking	10/24/2006	11/1/2006	76
Avery McChristian	Tamarisk Backpacking	3/10/2007	3/16/2007	94
Ben Smith	Tamarisk Backpacking	3/18/2006	3/22/2006	40
Bill Emig	Tamarisk River	10/30/2005	11/8/2005	90
Bill Sheppard	Tamarisk Backpacking	11/13/2005	11/20/2005	80
Bob Cheesman	Tamarisk Backpacking	10/9/2006	10/13/2006	47
Carol Ogburn	Tamarisk River	2/17/2006	2/26/2006	91
Carolyn Ferlic	Tamarisk Backpacking	1/3/2006	1/11/2006	83
Cathleen Goff	Tamarisk Backpacking	11/12/2005	11/17/2005	46
Chad Morris	Tamarisk River	2/17/2006	2/26/2006	91
Charlie Kees	Tamarisk Backpacking	11/12/2005	11/18/2005	60
Chris Murphy	Tamarisk Monitoring	5/2/2005	5/21/2005	229
Clayton Bliss	Tamarisk River	10/16/2005	10/30/2005	158
Cody Spitzer	Tamarisk Backpacking	3/18/2006	3/22/2006	40
Courtney Dolezal	Tamarisk Backpacking	3/10/2007	3/16/2007	94
Crystal Winn	Tamarisk River	9/5/2006	9/22/2006	6
Dan Shein	Tamarisk Backpacking	11/8/2006	11/14/2006	69
Daniel Ragen	Tamarisk River	10/17/2005	10/30/2005	147
Danny Miller	Tamarisk Backpacking	9/27/2006	10/1/2006	54
Darryl Garcia	Tamarisk Backpacking	9/27/2005	10/4/2005	73
Dawn Goldman	Tamarisk River	2/17/2006	2/26/2006	91
Dean Wadsworth	Tamarisk Backpacking	1/30/2007	2/7/2007	85
Deborah Northcutt	Tamarisk Backpacking	11/13/2005	11/20/2005	80
Donaig Gaiser	Tamarisk River	10/30/2005	11/8/2005	88
Edmund Gray	Tamarisk Backpacking	3/12/2007	3/16/2007	47
Eleanor Curran	Tamarisk Backpacking	11/12/2005	11/18/2005	60
Elison W. Miles	Tamarisk Backpacking	3/29/2006	4/4/2006	66
Ellen Wyoming	Tamarisk River	2/21/2005	3/6/2005	140
Elliot Brinkman	Tamarisk Backpacking	3/11/2007	3/17/2007	67
Elysa Miller	Tamarisk Backpacking	1/3/2007	1/13/2007	103

Name	Work Project	Start Date	End Date	Hours
Emily Spencer	Tamarisk River	2/25/2006	3/9/2006	126
Eric Krouse	Tamarisk Backpacking	4/21/2006	4/24/2006	40
Erin Thurston	Tamarisk Backpacking	2/4/2006	2/11/2006	74
Frank Bruno	Tamarisk Backpacking	9/27/2005	10/6/2005	83
Frank Duringer	Tamarisk Backpacking	12/7/2005	12/13/2005	69
Frank Hays	Tamarisk Monitoring	5/3/2005	5/11/2005	126
Frankie Brandt	Tamarisk Backpacking	3/10/2007	3/16/2007	94
Gabi Barmettler	Tamarisk Backpacking	1/16/2007	1/24/2007	84
Gisela Kluwin	Tamarisk Backpacking	11/28/2005	12/4/2005	67
Hannah Marie Barrett	Tamarisk Backpacking	3/15/2006	3/23/2006	78
Heidi Kloeppel	Tamarisk Backpacking	4/21/2006	4/24/2006	40
Hernan Abreu	Tamarisk River	2/16/2005	3/6/2005	30
Hillary Hudson	Tamarisk Backpacking	3/19/2006	3/20/2006	18
Ian Smith	Tamarisk Backpacking	2/4/2006	2/11/2006	74
Iris Wu	Tamarisk Backpacking	1/3/2007	1/13/2007	103
Jaime Townsend	Tamarisk Backpacking	2/4/2006	2/11/2006	74
James Cox	Tamarisk River	10/17/2005	10/30/2005	147
Jared Silverman	Tamarisk River	9/5/2006	9/22/2006	6
Jasmine Hernandez	Tamarisk Backpacking	3/18/2006	3/22/2006	40
Jason Hogan	Tamarisk Backpacking	1/3/2007	1/13/2007	103
Jason Sather	Tamarisk River	9/5/2006	9/22/2006	6
Jeff Heikes	Tamarisk Backpacking	3/18/2006	3/22/2006	40
Jennifer Katcher	Tamarisk Monitoring	6/6/2005	6/8/2005	55
Jered Hanson	Tamarisk Backpacking	12/7/2005	12/13/2005	69
Jess Page	Tamarisk Backpacking	3/4/2006	3/10/2006	71
Jill Dassing	Tamarisk Backpacking	4/1/2006	4/4/2006	35
Jillian Edward	Tamarisk River	2/21/2005	3/6/2005	140
Joe Welke	Tamarisk Backpacking	2/18/2007	2/23/2007	62
Joel Barnes	Tamarisk River	9/5/2006	9/22/2006	9
John Cameron	Tamarisk Backpacking	3/10/2007	3/16/2007	94
John Canfield	Tamarisk Backpacking	2/4/2006	2/11/2006	74
John DeMarco	Tamarisk Backpacking	9/27/2005	10/5/2005	75
John Dietrich	Tamarisk River	9/5/2006	9/22/2006	6
John Donovan	Tamarisk Backpacking	1/3/2006	1/10/2006	75
Jordan Ford	Tamarisk River	9/5/2006	9/22/2006	6
Joshua Gaston	Tamarisk Backpacking	3/10/2007	3/6/2007	94
Kameron Matthews	Tamarisk Backpacking	3/15/2006	3/23/2006	78
Kari Malen	Tamarisk Monitoring	5/2/2006	5/6/2006	25
Kate Thompson	Tamarisk Backpacking	1/3/2007	1/13/2007	103
Kelly McGrath	Tamarisk Backpacking	1/3/2007	1/13/2007	101
Kelly Rowell	Tamarisk River	5/2/2006	5/6/2006	25
Kelly Watters	Tamarisk Backpacking	4/14/2006	4/17/2006	40

Name	Work Project	Start Date	End Date	Hours
Kelly Williams	Tamarisk Monitoring	4/21/2006	4/28/2006	78
Kelsey Forrest	Tamarisk Monitoring	4/14/2006	4/17/2006	40
Ken Gouff	Tamarisk Backpacking	12/5/2006	12/13/2006	82
Kirk Hoodenpye	Tamarisk Backpacking	3/15/2006	3/23/2006	78
Kristen Caldon	Tamarisk Backpacking	2/4/2006	2/11/2006	74
Kristine Klewin	Tamarisk Backpacking	12/5/2006	12/13/2006	72
Kyle Sheperd	Tamarisk Backpacking	3/15/2006	3/23/2006	78
Larry Dutch	Tamarisk Backpacking	3/11/2007	3/17/2007	67
Laura Prosseda	Tamarisk River	9/5/2006	9/22/2006	6
Linda Popp	Tamarisk Backpacking	3/29/2006	4/4/2006	66
Lisa Hahn	Tamarisk Monitoring	5/8/2006	5/22/2006	136
Lisa Neiro	Tamarisk Backpacking	10/23/2006	11/1/2006	76
Loren Bell	Tamarisk River	2/21/2005	3/6/2005	160
Lou Lorber	Tamarisk Backpacking	9/27/2006	10/1/2006	54
Luke Moorhead	Tamarisk River	2/25/2006	3/9/2006	136
Lynn Beuning	Tamarisk Backpacking	2/18/2007	2/22/2007	50
Maddie Tighe	Tamarisk River	2/25/2006	3/9/2006	124
Maria Clementi	Tamarisk River	10/30/2005	11/9/2005	99
Maria O'Sullivan	Tamarisk Monitoring	6/6/2005	6/8/2005	45
Mark Langdon	Tamarisk River	2/17/2006	2/26/2006	91
Martha Walker	Tamarisk Backpacking	9/27/2005	10/4/2005	40
Matt Mason	Tamarisk River	2/23/2006	2/24/2006	16
Matthew Haldorson	Tamarisk Backpacking	1/4/2006	1/10/2006	62
Matthew Klasek	Tamarisk Backpacking	11/28/2005	12/4/2005	70
McNeill Mann	Tamarisk River	9/5/2006	9/22/2006	6
Megan Wilder	Tamarisk Backpacking	9/27/2005	10/4/2005	71
Meghan Magennis	Tamarisk Backpacking	1/3/2006	1/11/2006	83
Melissa Guy	Tamarisk River	2/21/2005	3/6/2005	140
Melissa McMaster	Tamarisk Monitoring	5/4/2007	5/11/2007	87
Michael Smith	Tamarisk Backpacking	3/18/2006	3/22/2006	40
Mike Boscarino	Tamarisk Backpacking	3/3/2006	3/10/2006	79
Mike Fraser	Tamarisk Backpacking	11/13/2005	11/20/2005	80
Molly Boyter	Tamarisk Monitoring	5/2/2006	5/7/2006	55
Nash Caron	Tamarisk Backpacking	3/15/2006	3/23/2006	78
Nathan Emer	Tamarisk River	10/15/2005	10/30/2005	174
Olivia Rathbone	Tamarisk Backpacking	10/24/2006	10/31/2006	74
Pamela Walls	Tamarisk Monitoring	5/8/2006	5/21/2006	129
Quintin Brubaker	Tamarisk Backpacking	1/3/2007	1/13/2007	103
Randi Axtel	Tamarisk Backpacking	9/27/2005	10/4/2005	73
Regina Eason	Tamarisk River	10/30/2005	11/8/2005	88
Rian Ashford	Tamarisk River	9/5/2006	9/22/2006	9
Robert Koppe	Tamarisk Backpacking	12/6/2006	12/12/2006	82

Name	Work Project	Start Date	End Date	Hours
Robert McGillicuddy	Tamarisk River	9/5/2006	9/22/2006	9
Rosalee Sandy	Tamarisk Backpacking	3/18/2006	3/22/2006	40
Ruth Richards	Tamarisk River	5/8/2006	5/21/2006	129
Ryan Avery	Tamarisk Backpacking	3/15/2006	3/23/2006	78
Sam Carter	Tamarisk Backpacking	2/18/2007	2/23/2007	62
Sam Haverstock	Tamarisk River	9/5/2006	9/22/2006	6
Sam Tischler	Tamarisk River	9/5/2006	9/22/2006	6
Sara Barmettler	Tamarisk Backpacking	1/16/2007	1/24/2007	84
Sarah Reed	Tamarisk River	10/16/2005	10/30/2005	159
Sarah Topp	Tamarisk Monitoring	5/3/2007	5/12/2007	107
Satarae Cook	Tamarisk Backpacking	3/18/2006	3/22/2006	40
Scott Miles	Tamarisk Backpacking	10/23/2006	11/1/2006	82
Stacy McKnight	Tamarisk Backpacking	1/4/2006	1/10/2006	62
Stephanie Culbertson	Tamarisk Backpacking	1/3/2006	1/11/2006	83
Stephen Gaiser	Tamarisk River	10/30/2005	11/8/2005	88
Stephen Polk	Tamarisk Backpacking	1/30/2007	2/7/2007	89
Stephen Walker	Tamarisk Backpacking	9/27/2005	10/4/2005	41
Steve Anderson	Tamarisk Backpacking	1/16/2007	1/24/2007	74
Steve Delaney	Tamarisk Backpacking	1/16/2007	1/24/2007	74
Susan McIntyre	Tamarisk Backpacking	11/8/2006	11/14/2006	69
Talise Dow	Tamarisk Backpacking	11/8/2006	11/14/2006	69
Taylor Ebens	Tamarisk Backpacking	2/18/2007	2/23/2007	62
Tina Ayers	Tamarisk Monitoring	5/12/2005	5/20/2005	104
Tom Pringle	Tamarisk River	2/27/2006	3/9/2006	70
Travis Wiggins	Tamarisk Backpacking	12/6/2006	12/12/2006	62
Val Malutin	Tamarisk Backpacking	12/7/2005	12/13/2005	69
Val Malutin	Tamarisk Backpacking	11/8/2006	11/14/2006	69
Val Malutin	Tamarisk Backpacking	1/30/2007	2/7/2007	85
Wendy Hodgson	Tamarisk Monitoring	6/5/2007	8/30/2007	300
Will Nunez	Tamarisk River	9/5/2006	9/22/2006	6
Will Partin	Tamarisk Backpacking	3/4/2006	3/10/2006	71
William Fiscus	Tamarisk Backpacking	3/29/2006	4/4/2006	66
William Powers	Tamarisk Backpacking	3/11/2007	3/17/2007	67
William Wolverton	Tamarisk Backpacking	1/31/2007	2/8/2007	77
Wyatt Sanders	Tamarisk River	2/25/2006	3/9/2006	124
	Total Volunteer Hours Backpacking			**9,704**
	Total Volunteer Hours River			**3,858**
	Total Volunteer Hours Monitoring			**3,662**
	Total Volunteer Hours Combined Total			**17,224**
	Value of Donated Volunteer Hours			**$323,670.00**

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-A 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
1/6/2006	Melissa McMaster, Steve Till	Bright Angel Creek	Bald eagle	Soaring
1/6/2006	Steve Till	Boucher Creek	Mice, unknown species	Creeping
1/7/2006	Melissa McMaster	Bright Angel Creek	Mule deer	Foraging
1/17/2006	Melissa McMaster	Bright Angel Creek	Ringtail cat	Foraging
2/6/2006	Loren Bell	Boucher Creek	Owl, unknown species	Hooting at night
2/9/2006	Loren Bell	Boulder Creek	Owl, unknown species	Hooting at night
2/21/2006	Kate Watters	Carbon Canyon	Many lizards and spiders	Crawling on tamarisk stumps
2/21/2006	Kate Watters	Carbon Canyon	Two owls, unknown species	Hooting at night
2/23/2006	Kate Watters	Lava Canyon	Lizards, several species	Making their way across rocks
2/23/2006	Kate Watters	Lava Canyon	Butterflies, many species	Soaring about
2/24/2006	Kate Watters	Lava Canyon	Dead packrat	Lying by the creek
2/27/2006	Kate Watters	Boucher Creek	Spiders, unknown species	Crawling on rocks
2/27/2006	Kate Watters	Boucher Creek	Canyon tree frog	Hanging out in pools
2/28/2006	Kate Watters	Crystal Creek	Canyon tree frog	Hanging out in pools
2/28/2006	Kate Watters	Crystal Creek	Red spotted toads	Hopping over rocks on terrace
2/29/2006	Kate Watters	Crystal Creek	Two American dippers	Foraging for insects
2/29/2006	Kate Watters	Crystal Creek	Small hawk	Circling overhead
3/19/2006	Loren Bell	South Canyon	Packrat	Hanging out in midden under tamarisk tree
3/19/2006	Loren Bell	South Canyon	Peregrine falcon	Feeding young (saw and heard both)
4/1/2006	Kim Fawcett	Indian Garden	Two California condors	Flying overhead
4/3/2006	Loren Bell	Nankoweap Creek	Coyotes	Howling at 5:30 pm
4/3/2006	Kim Fawcett	Transept Canyon	Five red spotted toads	Resting
4/4/2006	Loren Bell	Nankoweap Creek	Great horned owl	Flying repeatedly in upper forks
4/4/2006	Kim Fawcett	S. Kaibab Trail	Several California condors	Flying overhead
4/4/2006	Loren Bell, Steve Till	Nankoweap Creek	Lots of frogs	Calling for mates

Date	Observer	Location	Wildlife Species	Activity
4/21/2006	Kate Watters	South Canyon	Collared lizards	Chasing each other
4/22/2006	Kate Watters	South Canyon	Collared lizards	Eating a butterfly
4/22/2006	Kate Watters	South Canyon	Canyon wrens	Singing madly
5/3/2006	Kari Malen, Steve Till	Badger Canyon	Peregrine falcon	Flying overhead
5/3/2006	Kate Watters	Badger Canyon	Desert spiny lizard	Doing pushups
5/4/2006	Kari Malen	Saddle Canyon	Red spotted toads	Mating
5/4/2006	Steve Till	Saddle Canyon	Tadpoles	Hanging out in pools shaded by dead tamarisk brush
5/4/2006	Kari Malen	Saddle Canyon	Rana species	Mating
5/6/2006	Kate Watters	Carbon Canyon	Desert spiny lizard	On an acacia tree
5/6/2006	Kevin Dickerson	Carbon Canyon	Black chinned hummingbird	Performing a mating flight
5/6/2006	Lori Makarick	Carbon Canyon	Red spotted toads- lots of them!	In the drainage
5/6/2006	Lori Makarick	Carbon Canyon	Whiptail lizard	In the drainage near tamarisk
5/19/2006	Kate Watters	Trail Canyon	Whiptail lizards	Scuttling on rocks
5/19/2006	Kate Watters	Trail Canyon	Canyon tree frog tadpoles	Waiting in pools to become frogs
5/19/2006	Dan Hall	225 Mile	Juvenile chuckwallas	Running away
5/19/2006	Dan Hall	225 Mile	Western whiptails	Resting on rocks
5/19/2006	Kate Watters	Trail Canyon	Sphinx moth larvae	Eating a primrose plant
9/9/2006	Kate Watters	Hance Creek	Scorpion	Under tamarisk duff
9/9/2006	Kate Watters	Hance Creek	Tarantula	Walking by the creek among the cobbles.
9/10/2006	Steve Till	Hance Creek	Red spotted toads	Everywhere and tadpoles too
9/10/2006	Kari Malen	Hance Creek	Centipede	Crawling under tamarisk
9/10/2006	Melissa McMaster	Hance Creek	Collared lizard	Crawling around in a Brickellia shrub
9/10/2006	Kate Watters	Hance Creek	Bats, unknown species	Flying low catching insects at dusk above the creek
9/28/2006	Melissa McMaster	Grapevine	Red spotted toads	Jumping across the creek
9/29/2006	Melissa McMaster	Grapevine	Water ouzel	Dipping for food in the creek
9/30/2006	Melissa McMaster	Tonto Trail	Raven	Stealing food and unzipping backpacks to search for food
10/10/2006	Melissa McMaster	Bright Angel Creek	Kingfisher	Flying up canyon
10/10/2006	Melissa McMaster	Roaring Springs Bunkhouse	Ringtail cat	Peeking in backpacks
10/12/2006	Melissa McMaster	Bright Angel Creek	Flickers (6-10)	Flitting about the creek in trees
10/12/2006	Melissa McMaster	Roaring Springs Bunkhouse	Flicker	In a tree
10/25/2006	Olivia Rathbone	Bright Angel Creek	Deer	Trotting down the hill
10/26/2006	Steve Till	Bright Angel Creek	American dipper	Bobbing and dipping

Date	Observer	Location	Wildlife Species	Activity
10/28/2006	Steve Till	Bright Angel Creek	Fish	About 12" long and swimming
10/31/2006	Melissa McMaster	Transept Canyon	Fish	Flopping around on a rock
11/1/2006	Brennan Hauk	Bright Angel Creek	Bighorn (2 females)	High on creek left across from the campground
11/1/2006	Melissa McMaster	Bright Angel Creek	Skunk	Hiding under a rock in camp
11/1/2006	Melissa McMaster	Bright Angel Creek	Ringtails	Jumping from bushes on to the hanging poles and unzipping packs
11/2/2006	Melissa McMaster	Transept Canyon	Mule deer (5-3 does, 2 bucks)	Feeding on hillside
11/2/2006	Melissa McMaster	Transept Canyon	Water ouzel	Dipping for food in the creek
11/2/2006	Melissa McMaster	Transept Canyon	Grasshopper	On a rock with little rhombuses on their backs
11/3/2006	Melissa McMaster	Transept Canyon	Rock wren	Calling from the creek bed
11/4/2006	Melissa McMaster	Transept Canyon	Flicker	In a tree, diving at folks who got too close
11/5/2006	Brennan Hauk	Transept Canyon	Beaver dams	In the creek
11/5/2006	Kate Watters	Lava Chuar	Spotted toads	Lounging in pools
11/6/2006	Kelly McGrath	Lava Chuar	Flickers	Flying and landing on cut stumps
11/6/2006	Kate Watters	Lava Chuar	American dippers	Bobbing and dipping, flying and calling
11/7/2006	Kate Watters	Unkar Creek	Great horned owl	Sitting on a ledge, watching
11/10/2006	Mark Pillar	Boucher Creek	Road runner, tarantula	Walking along the creek
11/11/2006	Kate Watters	Crystal Creek	Falcon, centipede	Flying and hanging out in tamarisk duff
2/1/2007	Melissa McMaster	Cottonwood Campground	Striped skunk	Actively pursing food hung in a tree and climbing on my head!
2/1/2007	Bill Wolverton	Tonto between Cottonwood and Hance	Mule deer	Grazing
2/1/2007	Steve Till	Bright Angel - Cottonwood Camp	Bald eagle	Flying above the stream looking for fish
2/2/2007	Melissa McMaster	Grapevine Camp	Mouse unknown species	Actively pursing food in the kitchen and climbing over my legs
2/3/2007	Steve Till	Bright Angel - Cottonwood Camp	Ring-tail	Stealing food and harassing camp
2/5/2007	Steve Till	Bright Angel Creek	Bald eagle	Circling to roost
2/6/2007	Melissa McMaster	Grapevine Canyon	Brown nosed bat	Dead, next to a pool
2/19/2007	Melissa McMaster	Papago Canyon	Peregrine falcon	Soaring
2/21/2007	Kate Watters	Red Canyon	Canyon wren	Singing
3/5/2007	Melissa McMaster	Hance Creek	Owl	An owl hooting at night
3/5/2007	Melissa McMaster	Hance Creek	Mouse	Crawling in Joe's bag

Date	Observer	Location	Wildlife Species	Activity
3/7/2007	Melissa McMaster	Hance Creek Camp	Striped skunk	Striped skunk in camp, he wanted cheese
3/8/2007	Melissa McMaster	Hance Creek	Canyon tree frog	Jumping from rock to rock
3/9/2007	Melissa McMaster	Hance Creek	Turkeys (2)	Walking about
3/12/2007	Kelly McGrath	Copper Canyon	Owl species	Hooting
3/12/2007	Loren Bell	Tonto Trail near Copper	Chuckwalla	Very large (12") on a rock
3/12/2007	Loren Bell	Tonto Trail near Bass	Brown rattlesnake (juvenile)	Slithering across trail
3/13/2007	Kelly McGrath	Copper Canyon	Brown rattlesnake (juvenile)	Hiding under rock - nowhere near water.
3/15/2007	Loren Bell	Tonto Trail between Copper and Bass	Redtail hawk	Soaring above Colorado
5/9/2007	Lori Makarick	Unkar Creek	2 red spotted-toads	Frolicking in creek
5/9/2007	Lori Makarick	Unkar Creek	Swallowtail butterfly	Pollinating/feeding on nectar
5/9/2007	Lori Makarick	Unkar Creek	Whiptail lizard	Scrambling around
5/9/2007	Lori Makarick	Unkar Creek	Whiptail lizard	Running down drainage
5/9/2007	Lori Makarick	Unkar Creek	5 mourning doves	Resting in mesquites, flying
5/9/2007	Lori Makarick	Unkar Creek	Cabbage white butterfly	Flittering
5/9/2007	Lori Makarick	Unkar Creek	Rose-breasted grosbeak	Flying across tamarisk transect
5/9/2007	Lisa Hahn	Unkar Creek	Canyon tree frog	Jumping into water
5/11/2007	Lori Makarick	Crystal Creek	whiptail lizard	Scurrying through brush
5/11/2007	Lori Makarick	Crystal Creek	Garter snake	Slithering on rocks
5/11/2007	Lisa Hahn	Crystal Creek	Giant hairy scorpion	Cruising around on rocks after dark
5/11/2007	Lori Makarick	Crystal Creek	Thousands of tadpoles and canyon tree frogs	Jumping and swimming
5/11/2007	Lori Makarick	Crystal Creek	Hooded oriole	Flying around and landing in mesquites
5/11/2007	Lori Makarick	Crystal Creek	Cabbage white butterfly	Fluttering
5/11/2007	Lori Makarick	Crystal Creek	3 speckled dace	Swimming upstream
5/11/2007	Lori Makarick	Crystal Creek	Minnows	Swimming
5/11/2007	Lori Makarick	Crystal Creek	Ladybugs	On tamarisk
5/11/2007	Lori Makarick	Crystal Creek	Damselfly	Flying low over water
5/12/2007	Kate Watters	112 Mile Wash	Lots of tadpoles	Huddling in a dwindling pool
5/13/2007	Kate Watters	130 Mile Creek	Tadpoles	Waiting in pools to become frogs

b. Project Matching Contribution

In addition to the volunteer contribution, GCNPF and NPS have also provided in-kind and financial support. From the fall of 2005 through the fall of 2007, a total matching of $165,353 was contributed to the Phase II-A portion of this project (refer to Table 11. Phase II-A Project Matching Contribution).

As stated earlier, GCNPF provided funding for an intern and a volunteer coordinator to assist with this project. Two GCNPF Polk interns, Melissa McMaster and Kelly McGrath worked with the

project for 12 weeks each in the fall of 2005 and 2006. Their contribution to the project was invaluable, with 90% of their time in the field leading crews, allowing the project to add more trips than were funded through the AWPF grant. GCNPF raised nearly $10,000 to support the internships. The volunteer coordinator provided the critical link to the flawless implementation of this project. The GCNPF provided about $30,000 in funding to support the hiring of that position. For detailed GCNPF matching funds information, contact GCNPF directly. In addition, the Grand Canyon Trust provided two interns, Maria Clementi and Hillary Hudson, to assist with some of the fieldwork. The hours worked by all of the interns are included in the volunteer 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 four of the boatmen for the October tamarisk management river trip and two of the boatmen for the February 2006 river trip and the Trails division provided one additional boatmen. In addition, the ranger division also provided about $1,000 of food for the river trip, which allowed project coordinators to conduct additional backpacking trips with the remaining funds. The GRCA ranger division provided Paul Austin for safety training and the Trails division provided supplemental packing support during their routine runs to Indian Gardens and Phantom Ranch. The Grand Canyon Science Center continues to provide critical support in the contribution of the project coordinator's time on this project as well as GIS and database support.

The National Park Service provided GRCA with four weeks of work from the Exotic Plant Management Team (EPMT) based at Petrified Forest. The costs included transportation, travel reimbursement, food, logistical coordination, project oversight and supplies. The EPMT labor allowed project coordinators to conduct four additional trips into project areas.

In addition, the NPS also provided a match for bulk food purchases for the spring 2006 backpacking trips. Project coordinators were able to conduct additional backpacking trips with the remaining funds. The NPS provided a funding match for three April transect and photomonitoring backpacking trips and data entry, totaling $5,998.

For the first year since the project's inception, GRCA provided $25,000 of supplemental support for the Backcountry Vegetation Program projects. A portion of these funds have been used to date 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 enters all of the project data.

The Colorado River Fund (CRF) supported the November 2006 river trip through Arizona River Runners, a river outfitter that provided all of the logistics, equipment, boatmen and food for the trip. The CRF is generated by outfitter's fees and is managed jointly by the Grand Canyon River Outfitters Association (GCROA) and the NPS. A portion of the fees go into the Cooperative Resource Conservation Program (CRCP), which provides river outfitters, guides and NPS personnel the opportunity to work closely together to implement priority projects within GRCA. The Backcountry Vegetation Program, along with the Park's Archeology Program, developed the itinerary and work schedule for a 19 day river trip, which allowed follow-up work to be completed in many Phase II-A project areas.

Table 11. Phase II-A GRCA Matching Contribution

Name	Role in Project	Matching Contribution
Bryan Edwards	GRCA boatman (Fall 2005)	$4,053
Chris Flaccus	GRCA Database manager	$3,548
Coconino Rural Environmental Corps (CREC)	Partner organization with EPMT - provided crew for tamarisk management	$19,200
Colorado River Fund (CRF)	Boatmen, food, equipment for 11/2006 river trip	$22,000
Dave Loeffler	GRCA boatman (Fall 2005)	$3,792
Exotic Plant Management Team (EPMT)	Provided crew for tamarisk management	$37,550
Ray Knight	GRCA Packer	$1,000
Johnny Janssen	GRCA boatman (Fall 2005, Spring 2006)	$8,000
Kevin Dowell	GRCA boatman (Spring 2006)	$4,200
Lori Makarick	GRCA Project management	$15,127
NPS EPMT Leaders	Crew leaders for CREC trips	$6,070
NPS funding match	April 2006 transect and photomonitoring backpacking trips and data entry	$5,998
NPS funding match	Kate Watters and Kim Fawcett's salaries for crew supervisor and data entry	$25,000
GRCA River Unit	Food for river trip	$1,000
Paul Austin	GRCA Backcountry Ranger – provided training	$1,800
Shana Watahomigie	GRCA boatman (Fall 2005, Spring 2006)	$6,115
Steve Mietz	GRCA GIS program manager	$900
	NPS Matching Funds Total:	**$165,353**

c. Project Press

This project continues to receive good press coverage. The GCNPF and GRCA created a flyer to recruit volunteers. A brief article appeared in the Grand Canyon/Williams News recruiting volunteers for backcountry vegetation projects. The fall and winter 2005 and 2006 issues of GRCA's visitor guide include an article about this project. GRCA Vegetation Program staff Lori Makarick and Kate Watters gave a talk on vegetation issues, including the tamarisk project for a Grand Canyon Association Lecture Series. The organization, Riverwire, circulated an article entitled "Tammies Targeted in Drought Mitigation Efforts." The Arizona Daily Sun published an article on a unique fossil found by tamarisk mapping crews in 2005. A Grand Canyon News Release highlighted the invasive plant management program at GRCA for invasive species awareness week. GRCA staff created a site bulletin about the Tamarisk Management and Tributary Restoration Project. This project was highlighted in an Invasive Weed Awareness Coalition (IWAC) publication. A volunteer, Joe Jonakin, wrote an article in The Blaze, about his experience working with the tamarisk project in Grand Canyon. National Public Radio (NPR) visited field crews at Nankoweap Creek and interviewed leaders and participants about the project. Tyler Williams, a boatman for the tamarisk river trips, wrote an article about the project in Canoe and Kayak Magazine titled "Botanical Warfare." 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". Refer to Appendix G (Project Press) for examples of recent press coverage.

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. The Project Coordinator designed a leaflet entitled "Fight the Invasion", which includes general information about invasive plants, descriptive information about six species, and then an overview of the tamarisk management project, including how people can help join the fight against invasives. This leaflet is distributed to backcountry users, volunteers, and park visitors.

The Project Coordinator created an 8-panel training brochure that includes specific information about 13 of the highest priority invasive plant species in the park's backcountry areas. The goals of the brochure are: 1) to train people in how to identify the species, 2) to provide information about why the species pose a threat to the park's ecosystems, and 3) to develop an easy mechanism through which people can report actions they take to remove species. This deliverable also included postcards that people could fill out and mail back to the park's Vegetation Program Manager. The brochure is provided to NPS staff, river / backcountry guides who work in GRCA's backcountry, and people who spend a lot of time hiking in GRCA.

The Project Coordinators created a full-size poster about this project. The poster contains background information and also details about how to lend a hand. The poster is displayed in public locations and is used for outreach events.

All of these deliverables are included in Appendix H (Public Education Materials) as .pdf files. The leaflet and brochure were formatted and edited by Mary Beath, a graphic designer and illustrator hired by GCNPF, who did a wonderful job making sure both products were very professionally prepared.

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-A 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-A 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
South Canyon – Upper	31.6	R	2	May 2005	Apr 2006	Apr 2011
Nankoweap Creek – Lower	52	R	1	Oct 2004	May 2007	May 2012
Nankoweap Creek – Upper	52	R	2	Oct 2004	May 2007	May 2012
Carbon Creek – Upper	64.7	L	2	May 2005	May 2006	May 2011
Unkar Creek – Lower	72.3	R	2	Oct 2004	May 2007	May 2012
Bright Angel Creek	88	R	2	Jun 2005	Apr 2006	May 2011
Crystal Creek	98	R	2	May 2005	May 2007	May 2012
Trail Canyon	219	R	2	May 2005	May 2006	May 2011

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 occurs. Both transect lines ran parallel to the drainage channel. The goal was to have 1-3 transect pairs per selected project area. Each transect is considered a sampling unit and will be 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.

On 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 also 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 cover and vegetation cover data on all plant species present in 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 is 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, a survey rod was held vertically and the number of 10cm segments in each meter above the ground with contacts with live vegetation was recorded. If a given species is present more than once in a given 10 cm segment, it is only counted 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 also record total number of 10 cm segments that are 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.

Crews sampled the vegetation structure slightly differently in 2005 due to a misunderstanding of the protocols, so we now read both an old and a new category. New being the correct way described above, and the old way includes a count of every plant part, dead or alive that hit a segment, many times more than 10 counts.

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 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 (10 m would work fine)
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 ⓪ / 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 then 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 ⓪ / 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 hydrology sampling site in order to visually display the changes in the seep, spring or stream from year to year. To record discharge, crews either used the container or float methods. For the container method, the container volume was recorded, 10 samples were taken with the fill time recorded for each sample. The more often used method was 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 water with one part topsoil to make a slurry solution, and then dip the probe three different times to record readings at each point. Soil sampling data for Nankoweap and Unkar Creeks is not available because the protocols were not developed at the time those transects were installed.

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, as well as providing 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 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 a 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

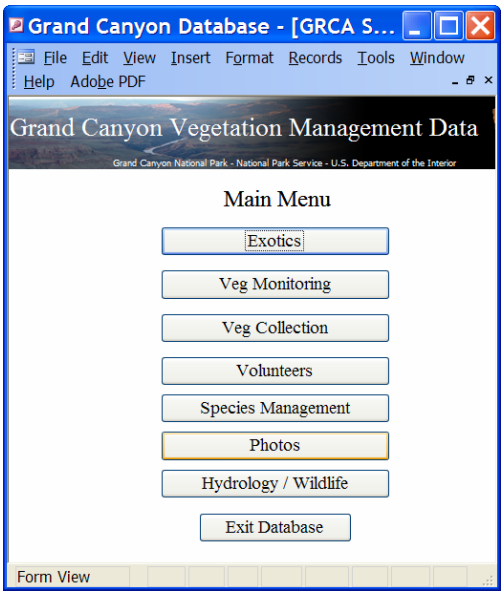
Prior to project implementation, project coordinators met the U.S. Fish and Wildlife Service's requirements from the informal and ongoing consultation. The obligation was to complete habitat assessments in order to ensure that the project areas do not include any currently or potentially suitable habitat 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.

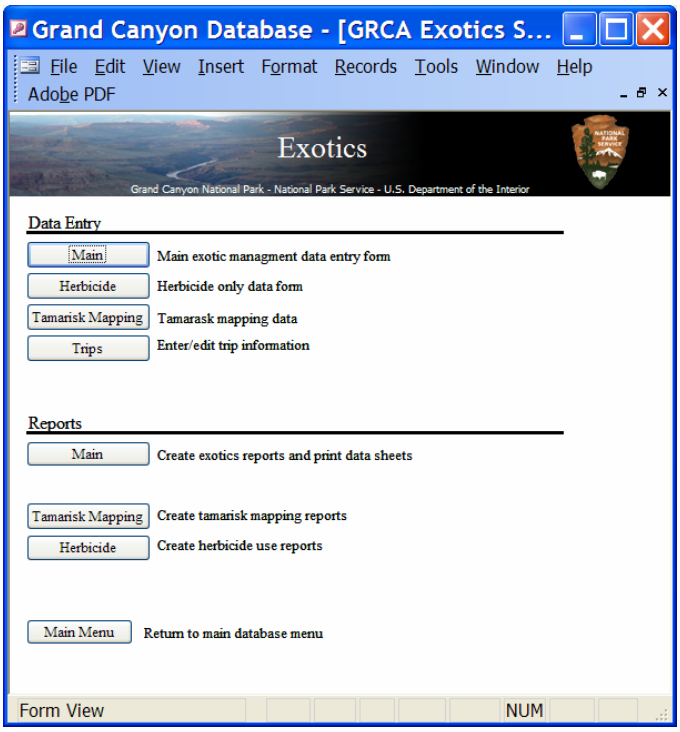
All of the data, including links to the photographs, are included in the project database, which has been under development for the past three years and is now the primary storage repository for all of GRCA Vegetation Program's data. Because all of the data are entered into the database, the hardcopy 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 draft version during the spring of 2007. 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 in the next few months. The final version of the database and all project data, including the photographs for Phase II-A, 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



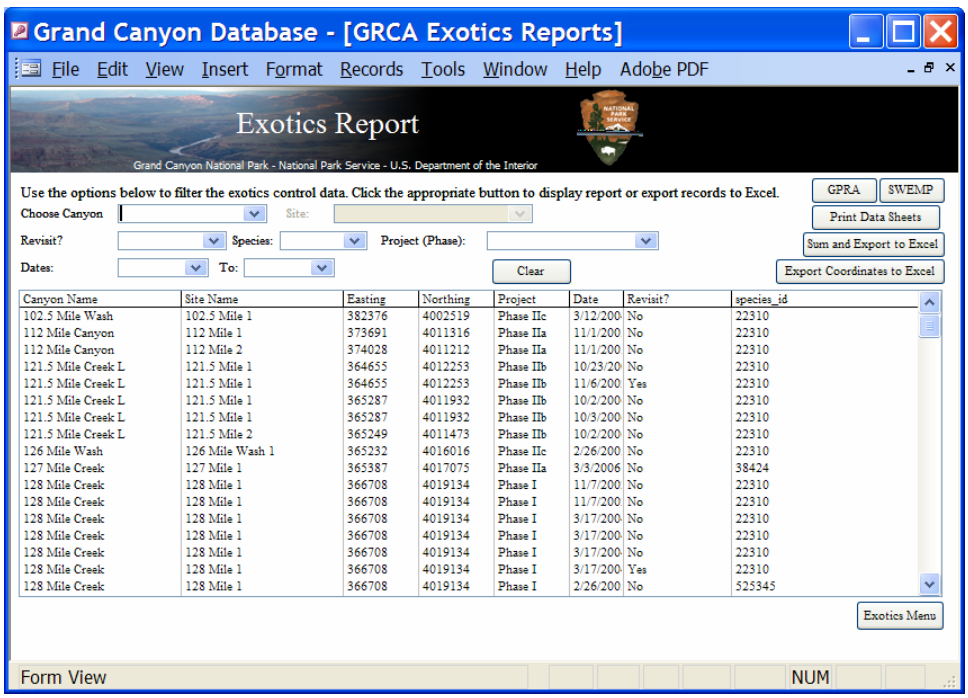
From the Main Menu, it is easy to access the project data related to each of the components. To view all of the tamarisk and other invasive species control information and generate reports, click on the Exotics button. Under data entry, by clicking on the various buttons, it is easy to view all of the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

Figure 6. Grand Canyon Database – Exotics Menu



The more useful section to view the data is by using the buttons listed under Reports. From that screen, you can filter the data by project area, phase, species, or dates. 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 the 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-A 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



Canyon Name	Site Name	Easting	Northing	Project	Date	Revisit?	species_id
102.5 Mile Wash	102.5 Mile 1	382376	4002519	Phase IIc	3/12/200	No	22310
112 Mile Canyon	112 Mile 1	373691	4011316	Phase IIa	11/1/200	No	22310
112 Mile Canyon	112 Mile 2	374028	4011212	Phase IIa	11/1/200	No	22310
121.5 Mile Creek L	121.5 Mile 1	364655	4012253	Phase IIb	10/23/20	No	22310
121.5 Mile Creek L	121.5 Mile 1	364655	4012253	Phase IIb	11/6/200	Yes	22310
121.5 Mile Creek L	121.5 Mile 1	365287	4011932	Phase IIb	10/2/200	No	22310
121.5 Mile Creek L	121.5 Mile 1	365287	4011932	Phase IIb	10/3/200	No	22310
121.5 Mile Creek L	121.5 Mile 2	365249	4011473	Phase IIb	10/2/200	No	22310
126 Mile Wash	126 Mile Wash 1	365232	4016016	Phase IIc	2/26/200	No	22310
127 Mile Creek	127 Mile 1	365387	4017075	Phase IIa	3/3/2006	No	38424
128 Mile Creek	128 Mile 1	366708	4019134	Phase I	11/7/200	No	22310
128 Mile Creek	128 Mile 1	366708	4019134	Phase I	11/7/200	No	22310
128 Mile Creek	128 Mile 1	366708	4019134	Phase I	3/17/200	No	22310
128 Mile Creek	128 Mile 1	366708	4019134	Phase I	3/17/200	No	22310
128 Mile Creek	128 Mile 1	366708	4019134	Phase I	3/17/200	No	22310
128 Mile Creek	128 Mile 1	366708	4019134	Phase I	3/17/200	Yes	22310
128 Mile Creek	128 Mile 1	366708	4019134	Phase I	2/26/200	No	525345

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 October of 2004 through May of 2007 crews revisited the same project areas where tamarisk has been removed and recollected vegetation, soils and hydrology data (Table 12. Phase II-A Monitoring Project Area List, Table 15. Monitoring River Trip Participant List, and Table 16. Monitoring River Trip Itineraries). Crews and volunteers also re-took long-term photopoints in Phase II-A 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 vast number of plants in project areas to further document lesser known plant species' distributions. See Appendix E (Monitoring Transect Data) for complete species lists for project areas.

Table 15. Monitoring River Trip Participant List

Role	Upper Half	Lower Half
May 2005 Tamarisk Monitoring River Trip		
Trip Coordinator / Project Leader	Lori Makarick	Lori Makarick
Head Boatman / Trip Leader	Dan Hall	Dan Hall
Boatman	Dave Edwards	Dave Edwards
Boatman	Nicole Corbo	Nicole Corbo
Boatman	R.V. Ward	Tyler Williams
Crew Leader #1	Kari Malen	Kate Watters
Crew Leader #2	Maggie Drechsler	Maggie Drechsler
Crew Leader #3	Steve Till	Steve Till
Volunteer Botanist	Wendy Hodgson	Wendy Hodgson
Volunteer Botanist	Amy Prince	Amy Prince
Volunteer Botanist	Lisa Hahn	Lisa Hahn
Wildlife Technician	Carmen Sipe	Jason Lovelady
Volunteer Botanist	Frank Hays	Tina Ayers
Volunteer Hydrologist	Chris Murphy	Chris Murphy
May 2006 Tamarisk Monitoring River Trip		
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
Volunteer Botanist	Wendy Hodgson	Wendy Hodgson
Volunteer Botanist	Amy Prince	Amy Prince
Volunteer Botanist	Lisa Hahn	Lisa Hahn
Volunteer Botanist	Molly Boyter	Pam Walls
Wildlife technician	Kevin Dickinson	Kevin Dickinson
May 2007 Tamarisk Monitoring River Trip*		
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
Volunteer Botanist	Wendy Hodgson	Wendy Hodgson

Role	Upper Half	Lower Half
Volunteer Botanist	Melissa McMaster	Empty
Botanist / Hydrologist on lower	Sarah Topp	Kelly Rowell
Volunteer Botanist	Do not fill this spot	Amy Prince

* This trip was funded through AWPF Phase II-B, with mostly Phase II-B areas.

The itineraries for the trips were extremely full. Miraculously, the crews completed all the work that was set out for each trip (Table 16. Monitoring River Trip Itineraries). Transects in Unkar Creek and Nankoweap Creek were completed during a cooperative agreement trip with Northern Arizona University in October 2004. Bright Angel Creek transects were completed via backpacking in June 2005 and revisited in April 2006. South Canyon transects were initially completed on the river in May 2005 and revisited via backpacking in April 2006. Carbon Creek and Trail Canyon were revisited in May 2006 during the Phase II-B monitoring river trip.

Table 16. Monitoring River Trip Itineraries

Date	Day	Work Location	River Mile	Camp (mile)
May 2005 Tamarisk Monitoring River Trip				
5/4/05	1	Badger Canyon	8 R	Badger Canyon, 8 R
5/5/05	2	Transit	31.6 R	South Canyon, 31.6 R
5/6/05	3	South Canyon - Transects 36.5 Mile Wash	31.6 R, 36.5 R	South Canyon, 31.6 R
5/7/05	4	Saddle Canyon	47.2 R	Upper Saddle, 47 R
5/8/05	5	Little Nankoweap Canyon, 60 Mile Creek	52 R, 56.2 R, 64.7 R	Carbon, 64.7 R
5/9/05	6	Carbon Creek - Transects	59.8 R	Carbon, 64.7 R
5/10/05	7	Cardenas Creek and nearby springs	71.2 L	Cardenas Creek, 71 L
5/11/05	8	Transit		Cremation, 87.2 L
5/12/05	9	Exchange – Transit, work at Crystal Creek		Crystal Creek, 98 R
5/13/05	10	Crystal Creek - Transects	98 R	Ross Wheeler, 107.8 L
5/14/05	11	Copper Canyon, 112 Mile, 130 Mile Creek	110 L, 112 L, 130 R	Below Bedrock, 131.1 R
5/15/05	12	Transit		Tuckup, 164.5 R
5/16/05	13	Transit	198 R	Upper Fat City, 191 R
5/17/05	14	Trail Canyon - Transects	219 R	Trail Canyon, 219.4 R
5/18/05	15	Trail Canyon - Transects	219 R	Trail Canyon, 219.4 R
5/19/05	16	225 Mile Canyon	225.5 R	225 Mile, RM 225.5 R
5/20/05	17	TAKE OUT and de-rig! Everyone helps with cleanup!		
May 2006 Tamarisk Monitoring River Trip				
5/3/06	1	Badger Canyon	8 R	Lone Cedar, 23.5 L
5/4/06	2	36.5 Mile Wash	36.5 R	Saddle, 47 R
5/5/06	3	Little Nankoweap, Nankoweap	52 R	Carbon, 64.7 R
5/6/06	4	Carbon-Transects	64.7 R	Carbon, 64.7 R
5/7/06	5	Transit		Cremation, 87 L
5/8/06	6	Transit, Exchange		102 R
5/9/06	7	122 Mile L	122 L	Randy's Rock, 126.5 R

Date	Day	Work Location	River Mile	Camp (mile)
5/10/06	8	140 Mile L	140 L	Above Kanab, 143.3 L
5/11/06	9	143 Mile L, Sinyala, 164 L	143 L, 164 L	National, 166 L
5/12/06	10	National-Transects	166 L	Mohawk, 171.6 L
5/13/06	11	Mohawk-Transects	171.6 L	Mohawk, 171.6 L
5/14/06	12	Honga, Prospect Canyon, Hell's Hollow	177.5 L	Hell's Hollow, 182.5 L
5/15/06	13	Below Hell's, Whitmore, 190 Mile, Basalt, 193 Mile, 194 Mile, 196 Mile	Various	Parashant, 198 R
5/16/06	14	205 Mile	Various	Granite Park, 208.8 L
5/17/06	15	Three Springs-Transects	215 L	215 R
5/18/06	16	217 Mile	217 L	217 L
5/19/06	17	Trail Canyon-Transects	219 L	220 R
5/20/06	18	220.5 L, 221 L, 221.5 L, 222 L, 224 Mile L, 225 Mile R	Various	Diamond Creek
May 2007 Tamarisk Monitoring River Trip*				
5/4/07	1	Badger Canyon	8 R	Hot Na Na, 16.4 L
5/5/07	2	36.5 Mile, Saddle Canyon	36.5 R, 47 R	Lower Anasazi, 43.3 L
5/6/07	3	Little Nankoweap, Nankoweap Creek	52 R	Little Nankoweap, 52 R
5/7/07	4	Nankoweap Creek, Kwagunt Creek, Kwagunt Camp	52 R, 56.2 R	Kwagunt, 56 R
5/8/07	5	70.2 Mile, 70.8 Mile	70.2 R, 70.8 R	Upper Unkar, 72 R
5/9/07	6	Unkar Creek-Transects	72.3 R	Upper Unkar, 72 R
5/10/07	7	Transit		Cremation, 87 L
5/11/07	8	Upper Boucher, Crystal Creeks	96.7 L, 98 R	Crystal, 98 R
5/12/07	9	Crystal Creek-Transects 112 Mile Wash	98 R, 112 L	Waltenberg, 112 R
5/13/07	10	Transit, various		Talking Heads, 133 L
5/14/07	11	130 Mile, 140 Mile Canyon	130 R, 140 L	Above Olo, 145 L
5/15/07	12	Transit, various		Below Tuckup,164.8 R
5/16/07	13	Mohawk Canyon-Transects	171.6 L	Mohawk
5/17/07	14	Mohawk Canyon-Transects	171.6 L	Mohawk
5/18/07	15	Transit, various		Whitmore Wash, 188 R
5/19/07	16	Transit, various		Granite Park, 209 L
5/20/07	17	Granite Park-Transects	209 L	214 R
5/21/07	18	Trail Canyon and 225 Mile Canyon	119 R, 225.5 R	Take Out!!!!

* This trip was funded through AWPF Phase II-B, with the primary focus on Phase II-B project areas.

b. Vegetation transects

Vegetation crews installed 15 transects pairs (30 individual transects) in eight project areas. Initial transect installation took a three person team three hours to read and record. With the ancillary data already recorded on 2004 and 2005 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 trip, 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). Mike Kearsley, former biology professor at Northern Arizona University and current GRCA Vegetation Mapping Coordinator, assisted with the final 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 Analyses

To test for differences between control and tamarisk transects, and to look for changes over time in total vegetative cover and species richness, data from the 3 m radius plots were analyzed with a split-plot analysis of variance analogous to a repeated measures design. Cover class data were converted to cover values by substituting the midpoint of the range for each cover class value (e.g. class 2 = 5 – 10% cover became 7.5% cover), and values for each species were averaged across all five sample points on the transect (5 m, 15 m, 25 m, 35 m, and 45 m). Species richness data were taken from the averaged cover data (i.e. species were not counted only once from all five sample points).

For the analysis, transects were nested within canyons and treated as a random effect. Canyon, year and transect type were fixed effects, and a transect type x year interaction term was added to the model. Because the interaction term was statistically significant in the analysis of cover data ($F(3,33) = 3.58$, $p < 0.05$), the trends in the two transect types were analyzed separately for the effects of the canyon and year terms in a similar design with only canyon, year, and transect nested within canyon as factors. For the species richness analysis, the interaction term was not statistically significant ($F(3,33) = 0.14$, n.s.), so only the overall analysis was performed.

Data from only the initial point intercept surveys (either 2005 or 2006) along each transect were analyzed with a 2-way analysis of variance to compare cover estimates from the two transect types as a check on patterns detected in the cover data from the 3 m radius circular plots. For each species encountered along the transect, the number of the 100 points at which it was detected was used as a % cover along that transect. For each transect, the sum of the individual species cover estimates was used as the transect total cover estimate. These numbers were analyzed in the same way as the 3 m radius plots, with using canyon, year and transect type as fixed effects, and a transect type x year interaction term.

To compare the species composition of the two transect types, an analysis of similarity (ANOSIM; Clarke 1993) was performed on the point-intercept data. This method begins by converting the species-in-plots data to a list of all pairwise compositional dissimilarities between all transects, measured as the Bray-Curtis dissimilarity. The dissimilarities are ranked, smallest to largest, and the average of the within-group dissimilarities is subtracted from the average of the between-group dissimilarities. This number is normalized so that the test statistic, R, can vary between +1 (all between-group > all within group) and -1 (all within-group > all between group), although for all practical purposes, it varies from 0 to 1 and strong patterns show up as values above 0.15. The statistical significance of patterns are assessed by 1000 Monte Carlo simulations in which R is calculated from random assignments of samples to groups, and the likelihood of the result with real data is the proportion of these random runs with greater values of R than that calculated from field data.

In order to better understand patterns in composition shifts, two ANOSIM analyses were performed on the data. First, an analysis was performed with the contacts from tamarisk included to create an overall picture of actual change. Second, an ANOSIM was performed with the tamarisk contacts removed to test for changes beyond those caused directly by the tamarisk removal crews.

To determine if control and tamarisk transects had similar vertical vegetation structure, data from the total vegetation volume (TVV; Mills et al 1991) surveys along transects were combined after converting initial survey results to numbers in line with the original TVV method. They were then analyzed with a 3-way analysis of variance with interaction. Contacts by all species at all five points were summed within each transect to generate a single TVV measure per transect. These data were analyzed in an unbalanced 3-way ANOVA with canyon, transect type, and number of years since treatment as factors, and an interaction term for transect type * years since treatment effects.

Results

The overall analysis of cover data from the 3 m radius circular plots showed no difference between transect types (Table 17), but the interaction between transect type and year was significant (i.e. the two transect types behaved differently pre- and post-tamarisk removal). When the tamarisk transects were analyzed separately, total cover in canyons was significantly different from one another, and cover in post-treatment years (2006 and 2007) was approximately 25% lower than in pre-treatment years (2004 and 2005) (Table 18, Figure 8). This reduction shows the results of tamarisk removal effort. Cover in 3 m radius plots in control transects did not change significantly between 2004 and 2007 (Table 19, Figure 8), and total cover did not differ between canyons. Species richness in the 3 m radius plots did not differ by transect type, nor was there a statistically significant interaction between transect types and year, but there were large differences between canyons (Bright Angel and Trail Canyons had approximately 30 species, Crystal and Unkar had approximately 13) and between years (Table 20, Figure 9). The lack of difference between transect types is because only one species was removed through this effort; therefore a significant increase in species richness would not be expected in the first few years following removal. In the more diverse canyons, the removal of one species does not immediately open the door for a large influx of additional species. It is more likely that over time, the canyons with fewer species may show a greater increase in species richness and the dominant force of tamarisk is removed.

The point intercept data confirmed that control and tamarisk transects had equivalent amounts of cover at establishment (Table 21, Figure 10). The two types of transects did not behave differently over time (Transect type * Years since treatment interaction: $F(1,26) = 4.031$, n.s.). However canyons differed significantly. The number of years since treatment had a significant effect: post-treatment cover was reduced in the first year (removal of tamarisk and drier years in 2005 and 2006) with recovery after that. The results were the same whether or not contacts with tamarisk were removed from the data.

The ANOSIM analyses showed different patterns depending on whether the tamarisk contacts were included. When they were included in the ANOSIM, both transect type and pre- vs. post categories had significant effects on composition of the plant species (Transect Type: $R = 0.164$, $p = 0.001$; Pre- vs. Post: $R = 0.141$, $p = 0.002$). In the absence of tamarisk contacts, neither of these were significant (Transect Type: $R = -0.007$, $p > 0.55$; Pre- vs. Post: $R = -0.022$, $p > 0.70$). Therefore, the tamarisk constituted a large part of the pre-treatment vegetation in the treatment transects and their

removal caused a significant shift in species composition, but the transects were very similar once the tamarisk were removed.

Total vegetation volume in the pre-treatment surveys did not differ between transect types (20.6 + 5.9 vs. 19.6 + 6.6; Figure 12), indicating that the structure of the two types were similar at the start. Although there was no significant difference in the behavior of the two transect types across time (Transect type * Years since treatment interaction: F (1,28)= 0.296, n.s.), there was a significant difference among years (Table 22, Figure 12). On average, transects' TVV measures increased by approximately 6.2 contacts per year after the initial treatment.

The pre-treatment tamarisk was 30.7% across all transects based on the point-intercept readings. Following tamarisk removal, the tamarisk cover was 0.6% across all transects. One of the monitoring objectives was to decrease tamarisk cover to 5% or less of the pre-management tamarisk cover values in the project areas. This goal was exceeded during the timeframe of this project (Table 23, Figure 13). Areas with high tamarisk density pre-treatment tend to be those areas with higher re-treatment densities ($F(1,13) = 5.082$, $p < 0.05$) during post-treatment sampling (Figure 14). After the post-treatment data from Phase II-B are available, Park staff will complete more detailed analyses of the full suite of data which will provide a much larger sample size.

Table 17. ANOVA table for analysis of all cover data from 3 m radius plots

Source	DF	F	Probability
Transect Type	1, 20	0.486	n.s.
Canyon	6, 20	3.835	$p < 0.05$
Pre- vs. Post	1,26	19.22	$p < 0.001$
Transect Type x Year	1, 26	6.01	$p < 0.05$

**Because denominator df are synthesized in the mixed effects model, values presented are approximate.*

Table 18. ANOVA table for analysis of cover data from 3 m radius plots in tamarisk transects

Source	DF	SS	F	Probability
Canyon	6	13400	2.928	$p < 0.05$
Year	3	7386	10.41	$p < 0.01$

Table 19. ANOVA table for analysis of cover data from 3m radius plots in control transects

Source	DF	SS	F	Probability
Canyon	6	1846	1.11	n.s.
Year	3	407	.489	n.s.

** Because Transect are the error for the Canyon term, the effects are shrunk and not included in this table.*

Table 20. ANOVA table for analysis of all richness data from 3 m radius plots

Source	DF	F	Probability

Transect Type	1,20	0.237	n.s.
Canyon	6,20	7.563	$p < 0.001$
Pre vs. Post	1.20	5.920	$p < 0.05$
Transect Type x Year	1.20	1.189	n.s.

** Because Transect are the error for the Canyon term, the effects are shrunk and not included in this table.*

Table 21. ANOVA table for analysis of all cover data from point-intercept transects

Source	DF	F	Probability
Transect Type	1, 20	0.162	n.s.
Canyon	6, 20	1.997	n.s.
Pre vs. Post	1, 26	32.023	$p < 0.001$
Transect Type x Year	1, 26	4.031	n.s.

**Because denominator df are synthesized in the mixed effects model, values presented are approximate.*

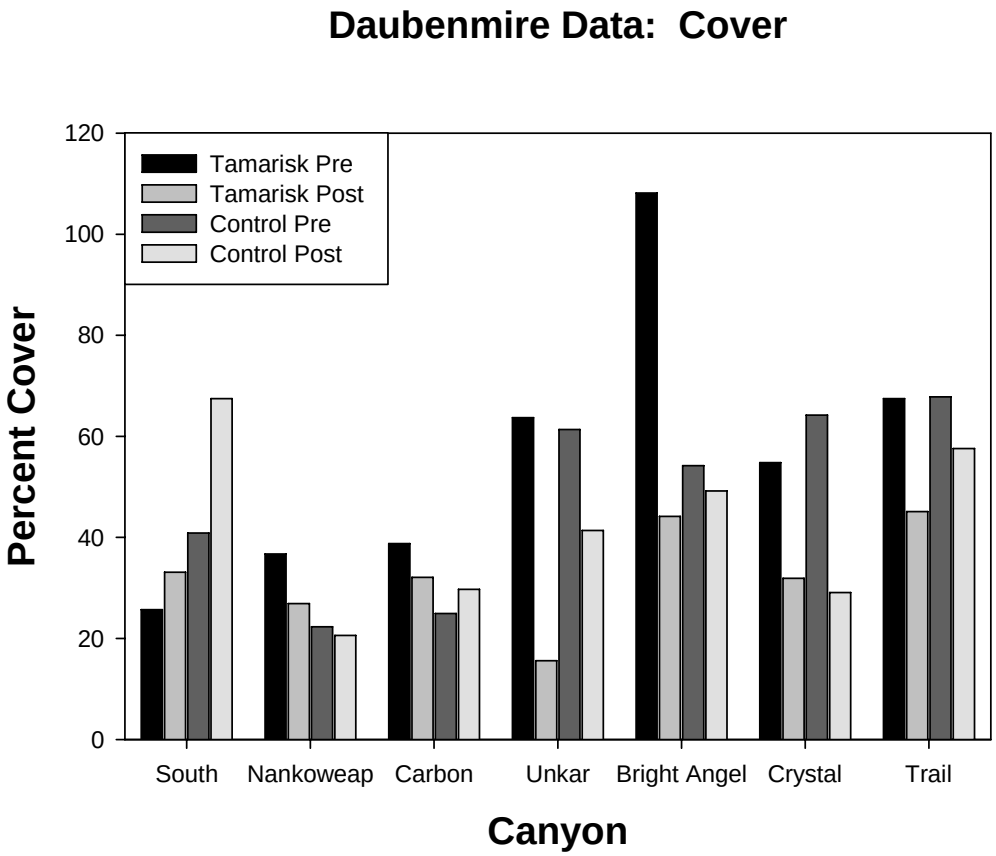
Table 22. ANOVA table for analysis of all TVV data from point-intercept transects

Source	DF	F	Probability
Transect Type	1, 19	0.229	n.s.
Canyon	6, 19	0.641	n.s.
Years since treatment	1, 25	7.248	$p < 0.005$
Transect Type x Years	1, 28	0.296	n.s.

Table 23. Change in the Tamarisk Cover Following Treatment

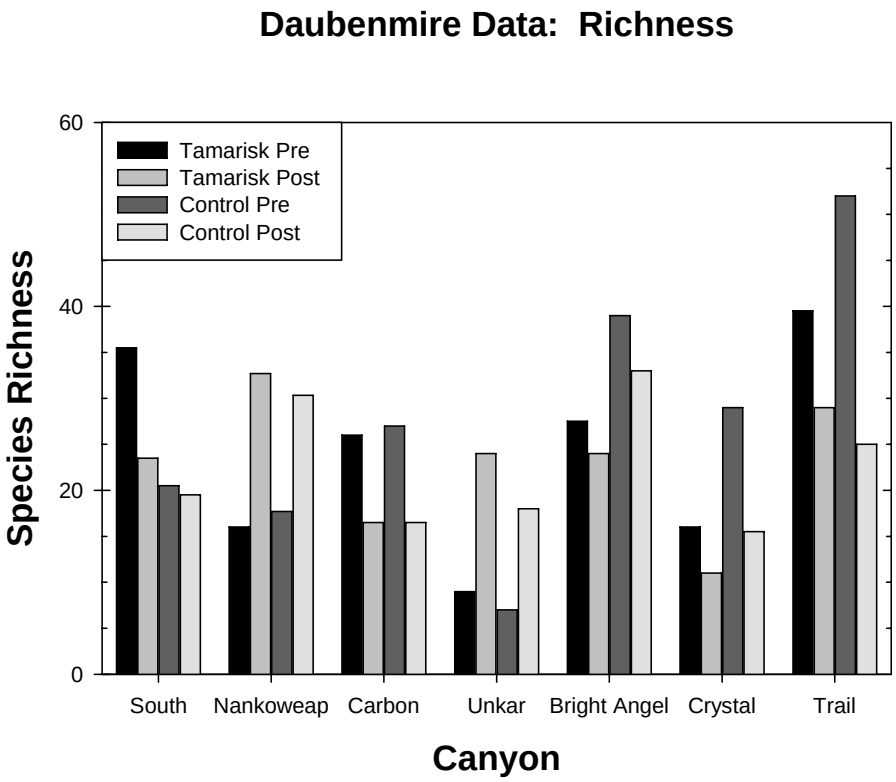
	Pre-Treatment Tamarisk Cover %	Post-Treatment Tamarisk Cover %
Bright Angel 1A	32	0
Bright Angel 2A	27	0
Carbon 4A	37	0
Carbon 5A	58	0
Crystal 1A	32	0
Crystal 2A	51	1
Nankoweap 1A	19	0
Nankoweap 2A	16	0
Nankoweap 3A	15	0
South 1A	18	1
South 2A	40	2
Trail 1A	56	4
Trail 2A	32	1
Unkar 1A	8	0
Unkar 2A	20	0
Average:	**30.7**	**0.6**

Figure 8. Change in vegetative cover in the 3 m radius circular plots in control and treatment transects.



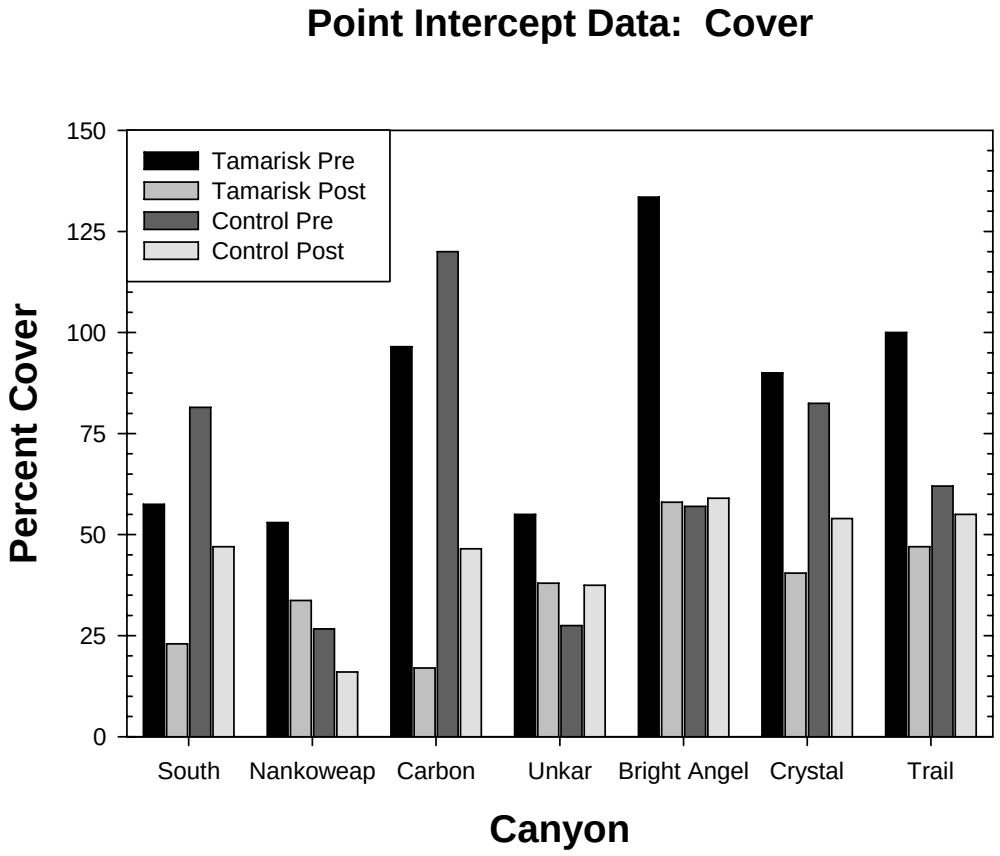
*Vertical bars represent ± standard error.

Figure 9. Change in richness in the 3 m radius plots



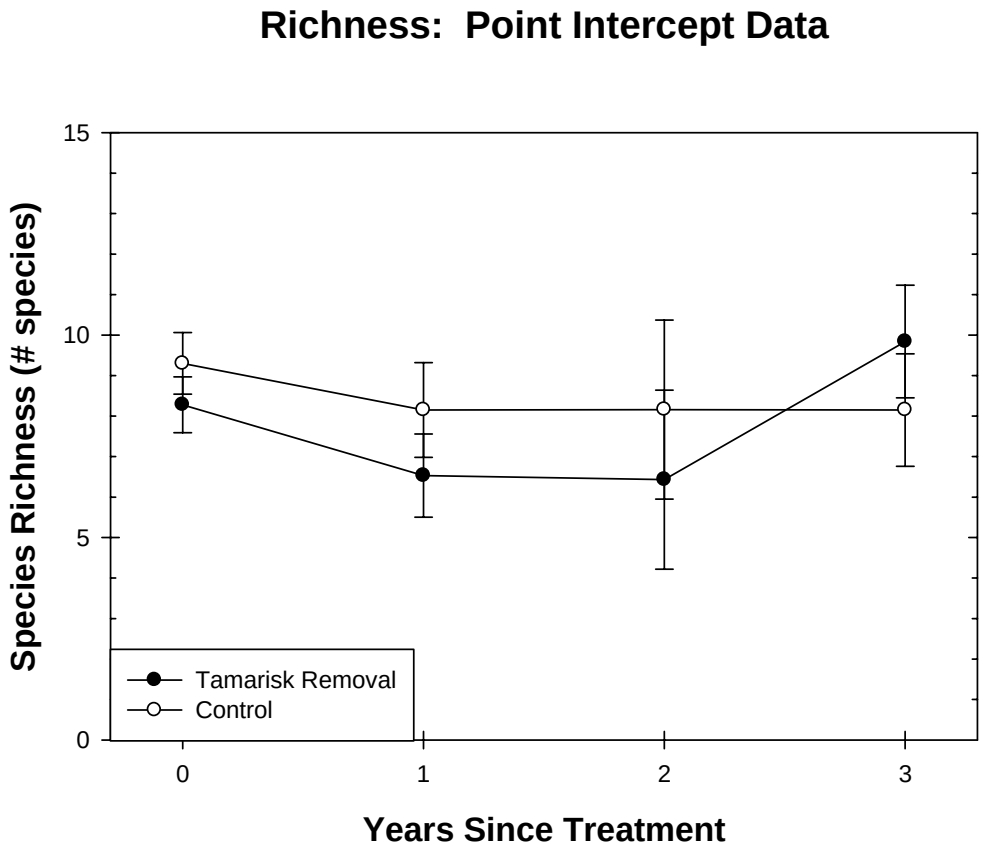
*Vertical bars represent ± standard error.

Figure 10. Cover estimates from the point-intercept transect data



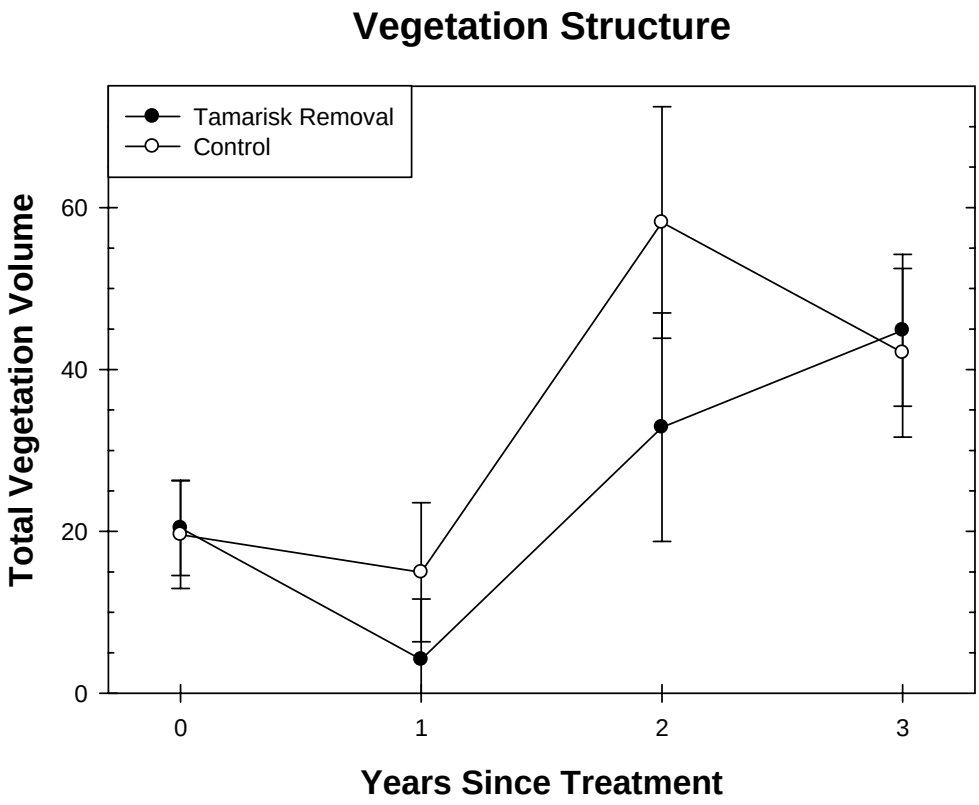
*Vertical bars represent ± standard error.

Figure 11. Species richness estimates from the point-intercept transects



*Vertical bars represent ± standard error.

Figure 12. Change in the Total Vegetation Volume of control and tamarisk removal transects



*Vertical bars represent ± standard error.

Figure 13. Change in the Tamarisk Cover Following Treatment

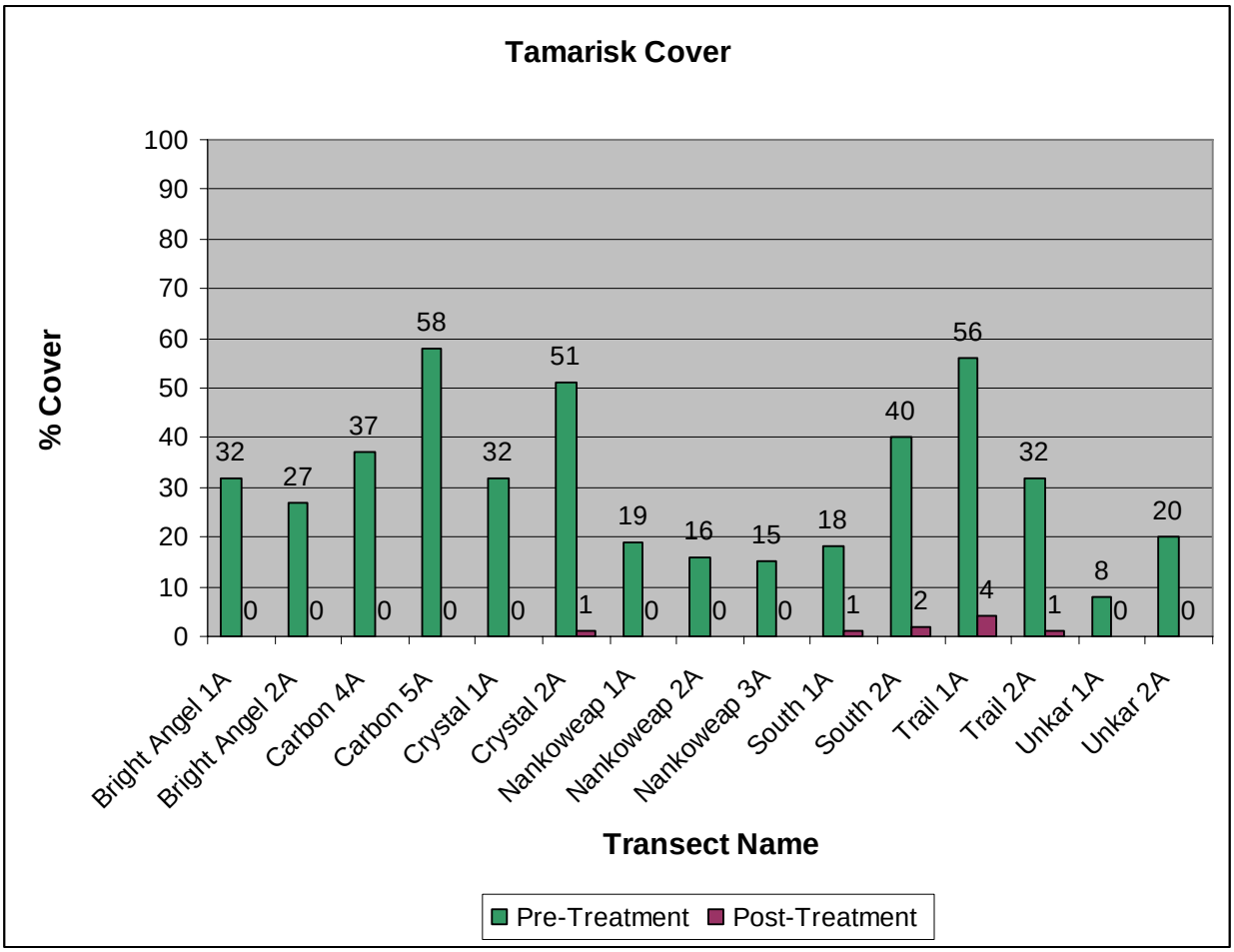
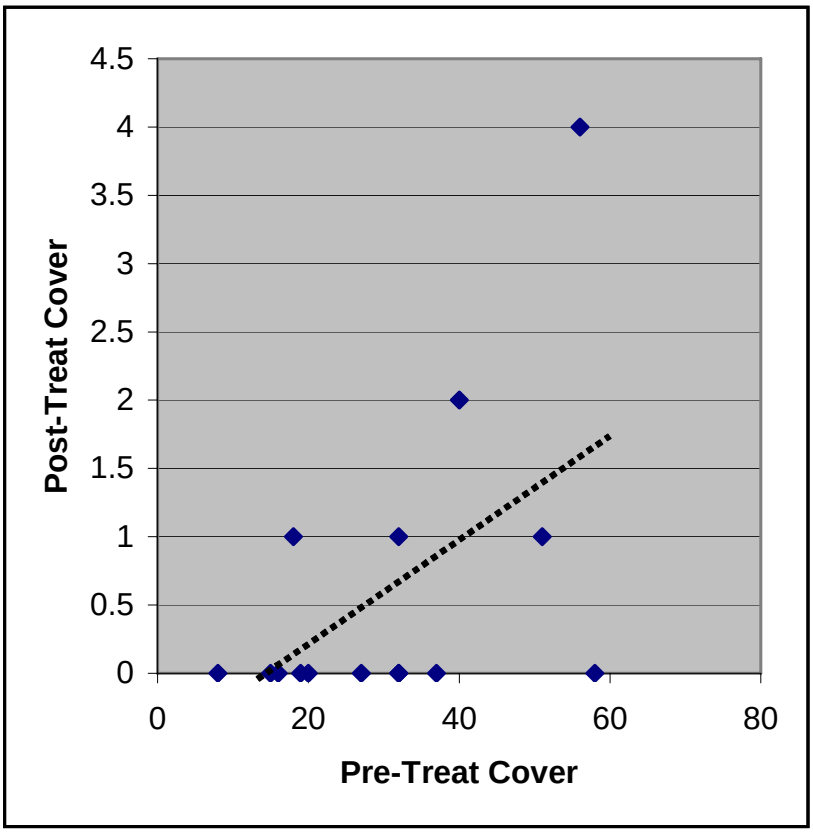


Figure 14. Change in the Tamarisk Cover Following Treatment Regression Analysis



Results Summary in Non-Technical Terms

Overall, when crew leaders returned to the re-visit the 30 transects, there were obvious differences in the tamarisk transects, which can be seen in the data and also in the transect photographs, and 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 end of Trail Transect 1A.

In a few 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 are becoming 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, trees) dominate the areas in the future, after a few years of recovery and also look at which species are the most successful in the post-tamarisk control 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 I (Plant Observations). Wendy Hodgson, senior research botanist and herbarium curator at the Desert Botanical Garden in Phoenix, annotated 800 specimens collected during the surveys. The data were entered into the project database and detailed plant species lists for the various project areas are now available for future trips to the project areas. The botanical survey work has already revealed range expansions for many under-collected and rare species, with roughly 50 species known from ten or fewer sites in the Grand Canyon. These collections have increased knowledge of several plants for which little is known of their distribution and taxonomy. This botanical inventory work also yielded an exciting list of 11 plants that are new records for Grand Canyon National Park, and some species potentially even new to science (Table 24. New or Notable Species to Grand Canyon National Park). Plant collections from this trip revealed specimens that previously were thought of as hybrid and now may be recognized as a taxon. Ms. Hodgson also compiled a list of canyon plants, based on current known collections that are known from two or fewer sites. From this work botanists will probably begin to see an interesting pattern, which will inform future collection and inventory work for the Park, and hopefully 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, further determining their need for a high level of protection from invasive plants such as tamarisk. This project funding has allowed GRCA staff and volunteers to make great stride in preserving these precious ecosystems.

Table 24. New or Notable Species to Grand Canyon National Park

Scientific Name	Common Name	Status
Sphaeralcea coccinea	scarlet globemallow	Only collection from within Park
Cheilanthes fendleri	Fendler's lipfern	New to Park, documented at 2 sites in Grand Canyon
Lathyrus brachycalyx ssp. *zionis*	bush pea	Sw UT, extreme nw NM, n AZ; "AZ plants may be new species" (Kearney & Peebles 1964)
Astragalus newberryi var. *blyae*	Newberry's milkvetch	If identification stands, new to Park
Chamaesyce albomarginata	whitemargin sandmat	Documented from 0 sites in Grand Canyon
Streptanthus carinatus ssp. *arizonicus*	lyreleaf	Rare in AZ; only collection from within Park
Nolina cf. *microcarpa*	chaparral beargrass	May represent a new variety or species
Eriogonum nidularium	birdnest	Pending identification, new to Park
Oenothera caespitosa var. *navajoensis*	Navajo evening-primrose	New to Park
Ericameria nauseosa ssp. *consimilis* var. *mohavense*	Mohave rabbitbrush	Otherwise known only from s NV and s CA; needs verification
Muhlenbergia appressa	Devils Canyon muhly	AZ endemic, rare in San Bernardino Co, CA, new to Park with only 3 collections

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 combined with Ms. Hodgson's collections present a full picture of the pre-removal species composition within each project area and are included as Appendix I (Plant Collections and Observations).

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. From there, either select the Plant Listings – Excel or the Plant Listings – Summary buttons. These reports do not allow you to do initial filtering for Phase II-A 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 during 2008 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 15. Grand Canyon Database - Vegetation Monitoring Switchboard

d. Rare Plant Monitoring Data

Crew leaders and project participants documented rare plants in project areas during implementation of the tamarisk management and monitoring actions. They gathered preliminary site information, specific information about the population of the rare plant, and also vegetation cover class data in the local area. Crews recorded 22 observations of ten rare plant species within project areas, which are included as Appedix J – 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 populations found through this project have increased the park's knowledge of this plant's distribution.

Canyonland's sedge (CARCUR – *Carex curatorum*) is in the Cyperaceae family. It is very similar in appearance to other sedges, but it is unisexual. The female scales are shorter and narrower than those of many other sedges. It grows at seeps and hanging gardens from 3770 to 4400 feet in elevation.

Fragrant ash (FRACUS – *Fraxinus cuspidata*) is in the Oleaceae family. It is a perennial tree or small shrub, with very fragrant flowers. It often grows in limestone from 4000 to 7500 feet in elevation.

Knowlton hop hornbeam (OSTKNO – *Ostrya knowltonii*) is in the Betulaceae family. It is a perennial tree that grows in shaded areas from 4900 to 8900 feet. Only a limited number of occurrences had been documented in GRCA, so these new observations have greatly increased the park's information regarding this tree.

Rock springparsley (PTEPET – *Pteryxia petraea*) is in the Apiaceae family. It is a perennial herb found in pinyon pine communities from 4600 to 7000 feet in elevation. The observations in Clear Creek extended the known range of this species in GRCA.

Satintail grass (IMPBRE – *Imperata brevifolia*) is in the Poaceae family. It is a perennial grass found in moist areas from 1200 to 4500 feet in elevation. It grows from Texas west to California, but its current distribution is unclear because this species has been affected by the development and alteration of southwestern riparian areas. It is rather widely distributed in GRCA side canyons, therefore crews did not always record this species on rare plant monitoring forms, but it does show up as an associated species in other project areas.

Catchfly (SILREC – *Silene rectiramea*) is in the Caryophyllaceae family. It is a perennial herb found in pinyon-juniper woodlands from 5600 to 6800 feet. This plant is endemic to GRCA, and the locations in Grapevine Creek expanded the known distribution of this species in the park.

Heermann wild buckwheat (ERIHER – *Eriogonum heermannii* var. *subracemosum)* is in the Polygonaceae family. It is a densely-branched perennial shrub that grows from 2000 to 8400 feet in elevation. This species was previously only recorded from a limited number of locations in GRCA, so the information gathered during this project has expanded the known range of this species.

Grand Canyon century plant (AGAPHI – *Agave phillipsiana*) is in the Agavaceae family. It is known to occur in a very limited number of sites in GRCA, and just a few areas outside of the park. This plant is a cultivar that was likely to have been introduced by pre-Columbian canyon residents. The documentation in the Phantom Canyon area is not new, but the information gathered about the site characteristics add to the database and the collection of cover class estimates and numbers will allow for future monitoring of the site.

Roaring Springs prickly poppy (ARGARI – *Argemone arizonica*) is endemic to GRCA and only occurs along the North Kaibab trail in Roaring Springs Canyon. It is a perennial herb that grows in talus slopes in the Supai Formation. The documentation crew leaders collected will help initiate long-term monitoring of the population.

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 hydrologist was able to gather water quality and flow data at 14 total sites within the following project areas: South Canyon, Carbon Canyon, Cardenas Hillside Seep, Crystal Creek, 112 Mile Canyon, Trail Canyon and 225 Mile Canyon. These data will be provided to the Park's

hydrologist as a contribution to long-term water sampling and monitoring. For some project areas, the Park's hydrologist has 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 was entered. For this report, the hydrology data for the four 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.

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 2005 and May 2006 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.

Due to several factors, only four hydrology points could be compared for analysis at this stage. The hydrology component of the monitoring was not introduced until May of 2005, and crews installed pre-tamarisk removal transects at both Nankoweap and Unkar Creeks in October of 2004. Cardenas Hillside Spring, 112 Mile and 225 Mile project areas were not revisited in 2006 or 2007 due to the amount of Phase II-B work on the trip itineraries, which was the primary focus of the trips. Several preliminary findings are interesting to note at this time (see Table 25. Hydrology Sampling Results). Average water temperature went up post-tamarisk removal, from 21.6 to 25.3 °Celsius, which could be due to the tamarisk removal or could merely be normal annual variations. The average pH dropped slightly, with pre-tamarisk pH levels of 8.17 and post-tamarisk removal levels decreasing slightly to 8.13. 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 2331 mS/cm pre-tamarisk to 2650 mS/cm post-tamarisk. In some areas, the EC readings exceeded the capacity of the Hanna probe (i.e. read 3999 on the LCD screen). 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 vegetation encroaching into the project areas. However, EC is sensitive to temperature, so the increase 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 1425 ppm pre-tamarisk and 1326 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 decrease in TDS could be related to weather events preceding data collection events. It will be interesting to notice if those levels decrease 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; however, these measurements will be part of a long-term monitoring program.

Table 25. Hydrology Sampling Results

Location Description	Surface Water Type	Measurement Date	Avg Temp	Avg pH	Avg EC (mS/cm)	Avg TDS (ppm)
Pre-Tamarisk Removal						
Carbon Hydro 1	stream	5/9/2005	22.3	7.84	3405	1708
Carbon Hydro 2	stream	5/9/2005	24.5	8.20	3300	1634
Crystal Hydro T1A	seep	5/13/2005	24.9	8.22	3999	3999
Crystal Hydro T2A	stream	5/13/2005	14.3	8.41	415	208
South Canyon Hydro 2	stream	5/6/2005	19.4	8.39	2540	N/A
South Canyon Hydro 4	pothole	5/6/2005	18.0	8.22	2989	N/A
Trail Creek - Hydro 1	stream	5/19/2005	24.9	8.38	1157	580
Trail Creek - Hydro 2	stream	5/19/2005	24.7	7.67	846	422
		Average	**21.6**	**8.17**	**2331**	**1425**
Post-Tamarisk Removal						
Carbon Hydro 1	stream	5/6/2006	23.2	8.02	3581	1792
Carbon Hydro 2	seep	5/6/2006	18.9	7.91	3198	1607
Crystal Hydro T1A	seep	5/11/2007	33.2	7.67	3999	2000
Crystal Hydro T2A	stream	5/11/2007	30.7	8.70	1891	945
South Canyon Hydro 2	stream	4/23/2006	22.2	8.28	3999	2000
South Canyon Hydro 4	pothole	4/23/2006	18.4	8.82	3137	1566
Trail Creek - Hydro 1	stream	5/21/2007	28.1	7.57	752	376
Trail Creek - Hydro 2	stream	5/21/2007	27.7	8.05	648	324
		Average	**25.3**	**8.13**	**2650**	**1326**

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 transects portion of the Vegetation Monitoring component of the database. The improvement in methodology from 2005 to 2006 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 is expected that average pH and EC drop in post-tamarisk removal areas. Unfortunately, due to the change in data collection methodology, there is no ability to compare between data collected in 2005 to data in 2006 and 2007. Refer to Table 26 (Post-Tamarisk Removal Soil Data) for the results from 2006 and 2007. Final analysis of soils will be included in the Phase II-B report. In the future, project coordinators can compare soil chemistry changes over time by collecting soil samples in subsequent years at Phase II-A areas.

Table 26. Post-Tamarisk Removal Soil Data

Transect Number	Survey Date	Meter Point	Average PH	Average EC (mS/cm)
Carbon Canyon T4B	5/6/2006	5	10.03	8
Carbon Canyon T4B	5/6/2006	15	8.74	52
Carbon Canyon T4B	5/6/2006	25	7.63	14
Carbon Canyon T4B	5/6/2006	35	8.32	135
Carbon Canyon T4B	5/6/2006	45	8.04	100
Carbon Canyon T5A	5/6/2006	5	8.70	619
Carbon Canyon T5A	5/6/2006	5	8.88	113
Carbon Canyon T5A	5/6/2006	15	8.37	1444
Carbon Canyon T5A	5/6/2006	25	9.03	3999
Carbon Canyon T5A	5/6/2006	35	8.41	1221
Carbon Canyon T5A	5/6/2006	45	8.65	787
Carbon Canyon T5B	5/6/2006	15	8.81	240
Carbon Canyon T5B	5/6/2006	25	8.60	306
Carbon Canyon T5B	5/6/2006	35	8.18	292
Carbon Canyon T5B	5/6/2006	45	8.46	150
Crystal Creek T1A	5/11/2007	5	8.92	3999
Crystal Creek T1A	5/11/2007	15	9.23	3999
Crystal Creek T1A	5/11/2007	25	8.95	3412
Crystal Creek T1A	5/11/2007	35	8.84	1816
Crystal Creek T1A	5/11/2007	45	8.76	3999
Crystal Creek T1B	5/11/2007	5	8.80	252
Crystal Creek T1B	5/11/2007	15	8.75	3999
Crystal Creek T1B	5/11/2007	25	9.19	3999
Crystal Creek T1B	5/11/2007	35	9.46	3999
Crystal Creek T1B	5/11/2007	45	8.76	2825
Crystal Creek T1B	5/12/2007	5	8.47	630
Crystal Creek T1B	5/12/2007	15	8.85	488
Crystal Creek T1B	5/12/2007	25	8.98	155
Crystal Creek T1B	5/12/2007	35	8.87	170
Crystal Creek T1B	5/12/2007	45	8.63	282
Crystal Creek T2A	5/12/2007	5	7.97	741
Crystal Creek T2A	5/12/2007	15	8.52	3999
Crystal Creek T2A	5/12/2007	25	8.54	3999
Crystal Creek T2A	5/12/2007	35	8.13	3463
Crystal Creek T2A	5/12/2007	45	8.44	1463
Trail Canyon T1A	5/19/2006	5	8.40	125
Trail Canyon T1A	5/19/2006	5	7.90	962
Trail Canyon T1A	5/19/2006	15	8.65	179
Trail Canyon T1A	5/19/2006	15	9.33	506
Trail Canyon T1A	5/19/2006	25	8.81	269
Trail Canyon T1A	5/19/2006	25	9.01	2937

Transect Number	Survey Date	Meter Point	Average PH	Average EC (mS/cm)
Trail Canyon T1A	5/19/2006	35	7.86	418
Trail Canyon T1A	5/19/2006	35	8.88	808
Trail Canyon T1A	5/19/2006	45	8.26	247
Trail Canyon T1A	5/19/2006	45	8.72	3999
Trail Canyon T1B	5/19/2006	5	8.28	450
Trail Canyon T1B	5/19/2006	15	9.10	508
Trail Canyon T1B	5/19/2006	25	9.40	195
Trail Canyon T1B	5/19/2006	35	9.24	1014
Trail Canyon T1B	5/19/2006	45	8.79	3999
	Average		**8.69**	**1476**

g. Photopoint Installation and Long-Term Monitoring

During the river and backpacking trips, crews installed 430 permanent photopoints in many of the project areas. More than one photograph was taken from each photopoint, providing over 1,304 separate views of project areas. Crews did not install photopoints in Garden Creek because photopoints are already installed for another project and can be used for long-term monitoring. Crews did not install photopoints in Lower Nankoweap due to a lack of time. All of the 1,304 photographs were entered in the project database and are available for viewing. Due to space limitations, only the Phase II-A project photographs are included on the Final Report DVD. Appendix B (Representative Project Photodocumentation) contains a full summary of photopoint location data, along with representative printouts from each project areas of one transect (when applicable), one tamarisk control area, and one hydrology area (when applicable).

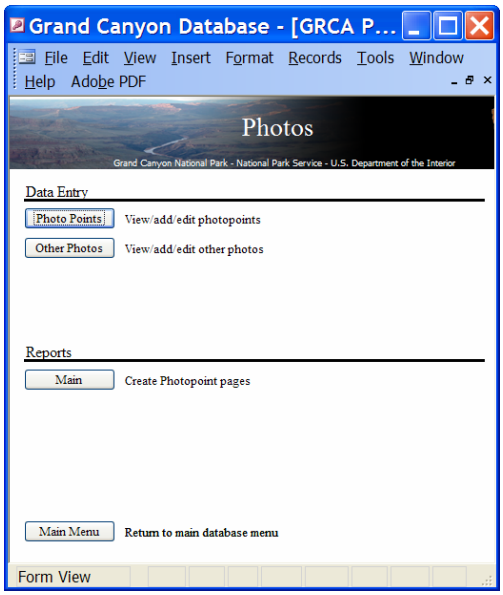
To view the photographs as .jpg images, open the following folders on the Final Report DVD:

- 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, and the post-work photographs are located within a sub-folder called Exotic Plant Control. Each photograph has a file name depicting its photopoint name and the date the photo was taken.

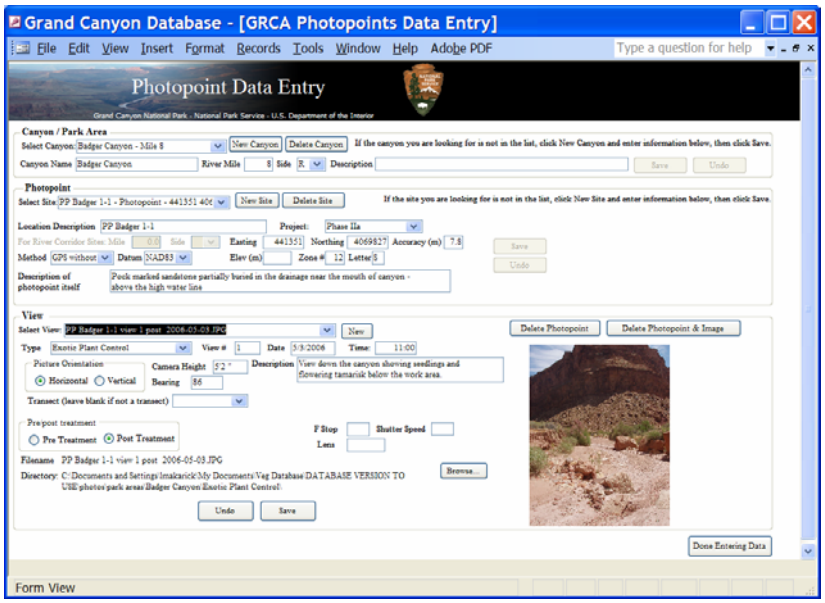
The database allows people to view the photographs in the database or print them in a format that is field ready so that crews can easily retake the photographs, or simply view the photographs in the database. To view the photographs, click on the Photos button from the Main Menu of the database. To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

Figure 16. Grand Canyon Database – Main Switchboard Menu



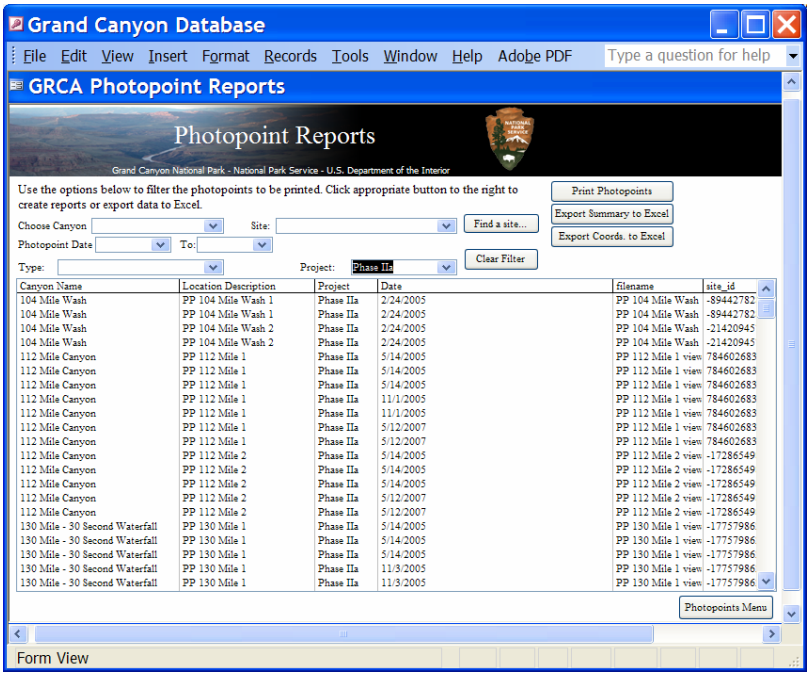
The next step is to select the Canyon or Park Area, which corresponds to the list of Phase II-A project area names under this grant. Then under the Photopoint section, where it says Select Site, click on the drop box arrow and the list of photopoints within that project area will come up on the screen. 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 which are used when the data are entered into the database.

Figure 17. 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, dates, type of photographs, 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 one photopoint from each project area, displayed in the format that is provided to field crews.

Figure 18. Grand Canyon Database – Photopoint Reports Menu



Project leaders have taken post-treatment photographs in all project areas from which tamarisk was removed. 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-A 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 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,

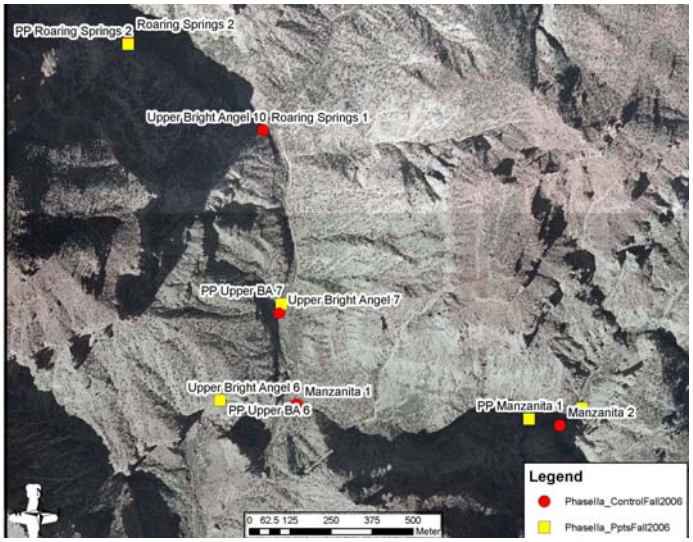
participants documented many wildlife observations including abundant bighorn along the river, Grand Canyon pink rattlesnakes, a variety of prospering frogs, and thanks to the tutelage of wildlife technician Jeremy White, and the crew observed many bird species, including a rare rose-breasted grosbeak in Unkar Creek (Table 11. Wildlife Observations).

g. Project Maps

For all of the data that have been collected, crew leaders have gathered 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 an MSExcel export containing the Site Name, Northing and Easting. From that format, the table is converted to a .cvs format and then imported into ArcGIS, where it is displayed as a spatial layer.

During the time frame 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 19. 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. The map is considered Appendix K and two copies will be submitted with the final report. The map was also saved and submitted as a .pdf file. The map includes the following information:

- Project area boundaries
- Project names
- Tamarisk treatment locations (the beginning of each 500 m sections)
- Vegetation transect locations
- SWIFL habitat assessment locations

- Photopoint locations
- Other invasive species locations
- Hydrology sampling locations

Additional copies of the map 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-A represent some of the most significant tributaries of the Colorado River in Grand Canyon. Thanks to the support of the AWPF and GCNPF and the dedication of hundreds of individuals, they are effectively tamarisk-free ecosystems. Long drainages with permanent water such as Nankoweap, Bright Angel and Crystal Creeks have been more difficult to complete than those that were in Phase I or II-B because they contained continuous dense patches of tamarisk trees. The project made great strides over the past two years, with now 33 of the 35 original project areas deemed complete. Despite the challenges that the Grand Canyon's remote wilderness poses, in a short period of time crews were able to remove an incredible number of invasive plants from project areas. Based on the work that was completed in 2005 through 2007, crews have removed 129,410 tamarisk trees and 34,169 other invasive plants during the implementation of this grant, and the tributaries are thriving.

While there are fewer project sites in Phase II-A as compared to Phase I, the sites were much more extensive, and often posed new logistical challenges. Completing management work in 35 project areas in two years was a major challenge, but not unfathomable. Given the remoteness of the majority of these canyons, and the great logistical effort it takes to access them, the schedule does 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. With the current state of the NPS budget, it will be challenging to get back to these project areas in the next two years, but both GCNPF and GRCA staff are committed to doing their best to ensure that this project continues. The field crew supervisor will be creating a maintenance schedule for all of the Phase I, Phase II-A and Phase II-B project areas. The Project Coordinator prepared and submitted a funding proposal to GRCA management that includes five years of continuing work in these areas.

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 make for lower herbaceous species diversity and cover. The data from Phase II-A transects supports this research. The highest pre-treatment diversity was found in Bright Angel and Trail Canyon, which are both larger drainages with perennial water. Crystal Creek, another large drainage with perennial water, had a much lower diversity in the tamarisk transect areas than in the control areas. In South Canyon, an area with 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. In South Canyon, tamarisk was growing in relatively bare

areas with little native plant cover. 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-A data support this, with a cover reduction from 30.7% pre-treatment to 0.6% post-treatment. However, these 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, but 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 has been found growing 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 parts per million (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 and, 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 or 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 Park manager's 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 willows (*Baccharis* spp.) shrubs and coyote willows (*Salix exiqua*) 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 will 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 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, 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-A of the overall project. The control trips completed between 2005 and 2007 were very successful and project leaders anticipate that the methods used will lead to successful management of tamarisk populations in the project areas. GCNPF and 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. GCNPF and GRCA staff should work together to secure another grant that would allow crews to revisit all of the previously treated project areas. Crews should systematically retake all of the photographs and re-read all of the vegetation transects during a two-to three-year period. GRCA is currently retaking photographs and completing follow-up control, but in the form of volunteer groups (e.g. Grand Canyon Youth) due to continued budget cuts within the NPS. Project leaders 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. 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.

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