Natural Bridges National Monument

2003 Invasive Non-Native Plant Inventory

Northern Colorado Plateau Inventory and Monitoring Network

Final Report

April 2005

Prepared by

Steven Dewey and Kimberly Andersen

Utah State University

Cover photo:
Owachomo Bridge in Armstrong Canyon. Photo by K. A. Andersen

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FINAL REPORT

Inventory of Invasive Non-native Plants Conducted during 2003 in portions of Natural Bridges National Monument, Northern Colorado Plateau Network of the National Park Service.

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INTRODUCTION

Utah State University conducted a two-year project to inventory and map invasive non-native plants for the National Park Service (NPS), Northern Colorado Plateau Network, in the summers of 2003 and 2004. The project included portions of Arches National Park (ARCH), Black Canyon of the Gunnison National Park (BLCA), Bryce Canyon National Park (BRCA), Canyonlands National Park (CANY), Capitol Reef National Park (CARE), Cedar Breaks National Monument (CEBR), Colorado National Monument (COLM), Dinosaur National Monument (DINO), Hovenweep National Monument (HOVE), Mesa Verde National Park (MEVE), Natural Bridges National Monument (NABR), and Zion National Park (ZION). This document contains the results of the portion of this inventory project that occurred within Natural Bridges National Monument. Results from other Parks are documented in separate Park-specific project reports. Also, please note that this report updates and replaces the 2003 Natural Bridges National Monument Inventory Annual Progress Report (Dewey et al. 2003).

BACKGROUND AND JUSTIFICATION

Numerous recent studies demonstrate that invasive non-native plant species pose one of the greatest threats to national ecosystems regionally and globally by altering native plant communities, wildlife populations, fire regimes, nutrient cycling, hydrology, and energy budgets of native ecosystems (D'Antonio and Jackson 2003, Duncan and Clark 2005, Mack et al. 2000, Sakai et al. 2001, Westbrooks 1998). A panel of scientists recently commissioned by the Council for Agricultural Science and Technology compiled an extensive list of those invasive plant species considered to be of greatest ecological and economic concern in the United States (Mullin et al. 2000). Most of those species are present in our region, and some have already invaded Parks of the Northern Colorado Plateau Network.

In a 1992 a nationwide survey of Nature Conservancy stewards, 59 percent ranked invasive plants among their top-ten conservation concerns, and 13 percent considered them the greatest challenge they faced (Randall 1995). In a similar survey of National Park Superintendents regarding the conditions in their Parks, 61 percent of the 246 respondents indicated that non-native plants were a moderate or major problem (Layden and Manfredo 1994). Currently, invasive non-native plants are estimated to infest in excess of 7 million acres of National Park System lands (USDI-NPS 1996). Scientists estimate that invasive exotic plants are spreading on federal lands at a rate in excess of 4600 new acres per day, and warn that without significantly increased prevention, detection, and control efforts, the situation is certain to worsen dramatically (Asher and Harmon, 1995).

The management and control of invasive non-native species has been identified as a high priority issue within the National Park Service and is specifically, under the Government Performance and Results Act (GPRA 1993), identified as an accountable goal for all National Park units. Executive Order 13112 signed on February 3, 1999 (Clinton 1999), further identifies and strengthens the obligations of federal agencies to address the significant economic and biological threats posed by non-native species.

Additionally, the NPS has emphasized the importance of invasive species issues and their associated impacts by identifying non-native species as one of three major areas of focus under

the Natural Resource Challenge initiative (USDI-NPS 1999). The Natural Resource Challenge specifically states, "Identifying, mapping and evaluating nonnative species are critical for effective management". Similarly, the development of the Exotic Plant Management Team (EPMT) initiative has further confirmed the dedication of the NPS to the management and control of invasive plant species. However, the EPMT program has a primary funding focus on the actual treatment and control of weed infestations and has not been established as a funding source for the actual inventory and mapping of invasive weed populations. Although the Natural Resources Challenge identifies the need for obtaining "accurate data about nonnative species distributions" as critical to meeting the goal of effective and efficient management, a specific funding source to accomplish this goal was not identified.

To meet this need, in 2001, the Intermountain Region Support Office in Denver prepared a successful Natural Resource Preservation Program (NRPP) proposal (USDI-NPS 2001) to conduct invasive plant mapping in high priority areas of Parks throughout the Intermountain Region, including six Parks within the Northern Colorado Plateau Inventory and Monitoring Network (NCPN). NCPN took the lead of coordinating this project and added network funding to increase the project scope to encompass work in 12 Park units. A cooperative agreement was negotiated between NCPN and Utah State University (USU) Extension to conduct inventory work during 2003 and 2004. Natural Bridges National Monument is a member of the Southeast Utah Group of Parks, which are part of the Northern Colorado Plateau Inventory and Monitoring Network as well as a member of a Prototype Park Cluster. The drafting of a plan for network vital signs monitoring is currently underway. A knowledge of current weed distribution, especially in riparian areas, was identified as an extremely high priority need by Natural Bridges National Monument and NCPN.

OBJECTIVES

1) The primary objective of this project was to document distribution and abundance of targeted invasive non-native plant species across the range of habitats and areas of management concern in Natural Bridges National Monument. It was anticipated that information from this inventory will be useful in the Monument’s ongoing efforts to improve strategic planning and to increase the effectiveness and efficiency of field operations associated with invasive plant management.

2) Based on the inventory results, efforts were to be made to identify significant sources of weed introductions and significant vectors involved in weed spread in the Monument.

3) Within the scope of this project, USU was to work with regional, network and Monument staff to test and refine data collection and field inventory techniques that might be used by NCPN in future invasive plant inventories.

METHODS

Utah State University supplied a 4-person crew to inventory targeted species in designated areas of Natural Bridges National Monument in 2003. Crew qualifications are documented in Appendix A.

SELECTION OF TARGET SPECIES AND INVENTORY AREAS

Ten species were identified as high-priority targets in the NABR inventory (Table 1), and searched for systematically by all inventory crew members. Any other non-native species recognized as relatively new to NABR and potentially invasive on wildlands in the West were documented if found. Forty-seven species were listed in the GPS data dictionary, representing all species targeted for inventory by the 12 Parks included in this project, plus some additional species of regional or national concern.

Table 1. List of invasive plant species targeted in Natural Bridges National Monument in the 2003 Non-native Plant Inventory.

Invasive species	Common Name
Centaurea diffusa	Diffuse knapweed
Centaurea maculosa	Spotted knapweed
Centaurea repens	Russian knapweed
Cirsium arvense	Canada thistle
Convolvulus arvensis	Field bindweed
Elaeagnus angustifolia	Russian olive
Marrubium vulgare	Horehound
Onopordum acanthium	Scotch thistle
Tamarix ramosissima	Saltcedar
Ulmus pumila	Siberian elm

General categories of areas to be inventoried had been identified previously in the Intermountain Support Office Project Proposal and Implementation Plan (USDI-NPS 2001) based on what was considered to be the most likely invasive plant habitat, with priority given to areas of present or anticipated Park development and high visitor use. Areas of likely weed seed introduction as well as sites identified as significant known or potential weed seed sources or "vector areas" were also given priority. Areas actually inventoried in NABR in 2003 included everything in the original Implementation Plan, plus additional areas added after consultation with Ian Torrence, Vegetation Manager for the NPS Southeast Utah Group. Lands inventoried in Natural Bridges National Monument primarily consisted of riparian areas in canyon bottoms, roads, and a campground.

The focus of this inventory project was NPS lands. However, in some cases a limited number of additional lands immediately adjacent to the NABR border were inventoried. This occurred if crew members found an infestation of a high-priority weed species straddling across the Monument boundary and wanted to determine its full size. In other cases searches were extended if crew members suspected a possible "contamination source" of one or more species immediately adjacent to the Monument boundary. Those areas outside the Monument boundary include portions of To-ko-chi Canyon, Armstrong Canyon, Deer Canyon, and White Canyon.

Monument natural resource staff and the NCPN Vegetation Ecologist worked closely with USU and NPS crews to provide pre-existing weed distribution information. They also provided information about weed control efforts currently underway, and the best access routes to targeted areas. All of this information was used in planning the 2003 field inventory, and in gathering

and analyzing data. NCPN and NABR staff also helped to ensure that data were assembled and provided to the network in a useable format

DATA CATEGORIES

The data categories included in this inventory were discussed at length and agreed upon by NCPN and USU project leaders prior to initiation of the project. A complete description of the data categories and value options appears in Table 2. The GPS data dictionary developed to electronically capture data elements while in the field is presented in Appendix B. Data collection categories and definitions comply with the minimum mapping data standards established by North American Weed Management Association (NAWMA 2003) and include most of the core elements contained in the NPS Intermountain Region Weed Mapping Guidelines (Benjamin 2001, USDI-NPS 1995). Appendix C indicates the relationship of NCPN data fields to NAWMA standards and IMR Weed Mapping recommendations. A rationale is presented for any deviations from the IMR-recommended data fields.

Data elements were collected by one of several methods: automatically recorded or manually entered into GPS units in the field (GPS-entered); transcribed from field notes; obtained from previously existing GIS data sets during post-processing (GIS-derived), or added manually in the office during post-processing (office). GIS-entered data included the location and size of each infestation, percent canopy cover, phenology of the weedy species, woody growth stage (if a woody species), presence of site disturbance, hydrology, dominant native species present, date, time, and any additional pertinent notes about the site. Data entered in the office during post-processing included ecological status, Park code, record numbers, detection confidence for inventory area polygons, scientific name, ITIS code, lifeform of species, county, state, and country. Additional data elements (e.g. datum, UTM zone, source of data) that pertain to the spatial data set as a whole are provided as metadata files (e.g., datum, UTM zone).

FIELD PROCEDURES

Some of the terms used in this and subsequent sections of the report have been created by the authors to describe new methods and standards developed by USU for conducting invasive weed inventories on wildlands. Terms unique to this report are defined as follows:

> **Search Target** (ST): Refers to invasive plants that are the object of a field search. ST descriptions must always include species, growth stage, and MDTS.
>
> **Minimum Detection Target Size** (MDTS): The smallest infestation size (single plant or patch) of the least-visible targeted invasive species that searchers are confident of detecting and identifying at a stated level of probability under actual field conditions using their stated protocols. In this project the MDTS was set at 0.01-acre.
>
> **Effective Detection Swath Width** (EDSW): The maximum width of a linear walking search pattern in which an on-the-ground searcher is confident of visually detecting at least 90 percent of all invasive plant infestations of the stated minimum target size. EDSW must be adjusted according to factors influencing target visibility, such as species,

Table 2. Description of data fields used in 2003 Inventory of Invasive Non-Native Plants in Natural Bridges National Monument.

Data Field	Description	Options / Values	Priority	Entry
Species Name	Latin name of species	Pick-list to be provided by Park staff	Required	GPS
Species Code	IT IS		Required	Office
Additional Names	Common name of the species			Office
Date	Date species observed		Required	GPS
Observer	Name of person observing population	First initial of person's last name used in data file name	Required	GPS
Location ID	Unique identifier for species population ("Record #")		Required	GPS
Park Code	Four-letter abbreviation of Park	NABR	Required	Office
Country	Name of country (e.g. USA)		Required	Office
State	Two-letter state abbreviation		Required	Office
County	County name		Required	Office
UTMN	UTM northing coordinate for population		Required	GPS
UTME	UTM easting coordinate for population		Required	GPS
Elevation	Elevation in meters (and feet)	Meters (or feet)	Required	GPS
Size of Infested Area	Size of population (if a point feature). Based on average diameter of weed infestation.	- 1 to few plants - 0.1 acre - 0.25 acre - 1 acre - 2.5 acres - 5 acres	Required only for points.	GPS
Gross Area		Gross estimate of land area occupied by a weed species	Required in specific situations.	GPS
Cover of infested area	Estimated percent of area infested with weed	trace (<1%) low (1 to 5%) moderate (6 to 25%) high (26 to 50%) majority (51-100%)	Required.	GPS
Distribution	Characterization of density	To be determined by PI		GPS
Phenology	Life stage of majority of population. Use most progressive life stage if population appears evenly split.	- vegetative - bud - flower - immature fruit - mature fruit - seed dispersing - dormant	Required	GPS

Table 2 continued.

Data Field	Description	Options / Values	Priority	Entry
Woody Growth	Predominant growth stage of species. Use for woody weed species only (elm, tamarisk, Russian olive, etc.) If stages are mixed, use most advanced stage. (valuable for planning control efforts)	- seedling - sapling - mature - old-growth	Optional	GPS
Lifeform	Lifeform of species.	-tree -shrub -graminoid -forb	Required	office
Ecological Status	Qualitative description of the level of infestation that identifies ability of site to recover to natural state once the weeds have been removed.	1. No weeds -The management emphasis is preventing weed encroachment. 2. New and/or small infestations - These infestations have good potential for eradication because they are small and there is a good understory of desirable plants. 3. Large scale infestation with 30% or greater understory of residual grasses and good potential productivity – Management of these sites in a way that selects for the recovery of the residual native grasses and shrubs has good potential for control but not eradication of the weeds. May be more that one noxious weed species, but the underlying biologic integrity of the unit is good. 4. Large-scale infestations with few or no (less than 30% cover) desirable grasses in the understory. Infestation often dense and/or multiple weed species. Control will require intense treatment and probably revegetation. Control may be possible but not eradication. In some areas, the infestation may have changed the character of the land so much that attempts for rehabilitation are cost prohibitive.	Required	Field and Office
Dominant Species	Species Latin name for dominant species at site (up to four species can be recorded)	Two to three dominant species need to be provided at each point (list of dominant species provided by Park). If single or few plants, use dominant species in 1/10 acre area.	Required	GPS
Buffer	Buffer needed to encompass population if GPS'ed as a line or polygon feature	Enter number in feet	Required for lines, optional for polygons	GPS

Table 2 continued.

Data Field	Description	Options / Values	Priority	Entry
Hydrology	General hydrologic setting of site. If further specificity is needed in Park, add items as subcategories to existing terms (e.g., wetland - seep).	- upland (above and away from floodplains) - riparian (along rivers or stream channels) - perennial: stream flows continuously in time. - intermittent: stream flows only at certain times of the year (typically on seasonal basis) when it receives water from springs or from melting snow. - ephemeral: stream flows only in direct response to precipitation. Ephemeral streams generally lack obligate riparian vegetation. - wetland (saturated soil for majority of growing season) - playa lakebed (poorly drained depressions)	Required	GPS
Disturbance	Evaluate disturbance at population site	1 - no disturbance apparent 2 - light to moderate disturbance 3 - site heavily disturbed	Required	GPS
Notes	Additional comments	Can include compass bearing for photos, description of non-weed features, etc.	Optional	GPS and field notes
Area ID	Unique identifier for inventory area		Required	GPS
Disturbance Comments	Comments on type and extent of disturbance noted in inventory area. If area is undisturbed, note as such.	-Agriculture/Livestock Grazing -Construction/Development -Fire -Fire Suppression -Flooding -Wind -Geothermal -Animal Disturbance (e.g. gopher mound, buffalo wallow -Irrigation/Ditches -Mining and Quarries -Oil and Gas Exploration/Production -Habitat Improvement Project -Recreation/Visitor Use -Right-of-Way -Construction/Maintenance -Utility -Construction/Maintenance -Trail/Outfitter/ORV use	Required	Field notes

stage of growth, topography, and associated vegetative cover, in order to maintain the 90 percent minimum detection standard. GPS data dictionary choices for effective detection swath widths in this project were 25, 50, 100, 150, 200, 250, and 300 yards.

Patch Separation Resolution (PSR): The minimum distance between single weeds or patches of weeds that are considered to be separate infestations. Plants separated by the PSR distance or more are mapped as separate infestations. Plants separated by less than the stated PSR are usually mapped as a single infestation. The PSR for this project was 50 yards.

Detection Confidence (DC): The percentage of the total number of infestations that crew members estimate they were able to find in a searched area, based on the probability of seeing patches of the established minimum detection target size of the least visible target species in that terrain. Detection confidence is essentially meaningless without also stating the search target associated with that DC. The minimum required DC set for this project was 90 percent based on a MDTS of 0.01 acre for plants of the least visible target species in a mature or flowering stage of growth.

Between-Feature Positions (BFP): A series of location points recorded automatically by Trimble GPS units indicating the daily search routes traveled by each crew member. The distance interval for collecting BFP's in this project was set to correspond to the average effective detection swath width for each area inventoried.

The inventory of invasive non-native plants in Natural Bridges National Monument was conducted by a four-person crew between July 17 and August 7, 2003. Sites inventoried included all riparian areas in the bottoms of Deer Canyon, White Canyon, To-ko-chi Canyon, Armstrong Canyon, and Tuwa Canyon; all Monument roads (20 linear miles), signed upland trails, some of the upland washes, and the campground.

For purposes of planning and data analysis the inventoried lands were divided into 5 areas (Table 3). The order in which areas were inventoried was determined by the USU crew leader. Potential invasive plant habitat within each targeted inventory area was considered prior to planning each day's travel route. Field crew members were expected to search along the planned inventory routes, spending more time in priority areas and areas of concentrated invasive plant habitat.

When arriving at a site, crews would determine the best search methods and GPS settings needed to achieve the required level of detection confidence for the established minimum target size. Terrain, vegetation cover, expected visibility of target weed species, and crew size were all factored into setting effective detection swath widths and other mapping techniques and standards used for each site.

Field searches were conducted at as fine of a scale as required to be confident that 90 to 100 percent of all invasive plant infestations 0.01 acre or larger within each inventory area were detected. Search swath widths were adjusted as needed based on variations in terrain, walking speed, associated vegetation, and target species. Areas north of the Visitor Center were open and

Table 3: Invasive plant inventory areas, inventory dates, crew members, and acres inventoried during 2003 in Natural Bridges National Monument.

Area Number	Area Description	Dates Inventoried	Crew Members*	Acres Inventoried **	Corresponding Inset Map Names and Letter Codes ***
1	Upper White Canyon	Jul 18, 2003	EL,RR	191.3	Sphinx Rock – A Horse Collar Ruin – B
2	Uplands north of headquarters & sewage ponds	Jul 21, Aug 7, 2003	KA,SD, EL, RR	496.7	Sphinx Rock – A
3	Tuwa Canyon	Jul 19, 21, 2003	KA, EL	185.7	Sphinx Rock – A Armstrong Canyon - C
4	Armstrong, Deer, To-ko-chi, and Lower White Canyons	Jul 18-19, 2003	KA, EL, RR	480.7	Armstrong Canyon – C Horse Collar Ruin – B
5	Main roads, trails, upland drainages	Jul 17-18, 21, 2003	KA, EL, RR	715.0	Sphinx Rock – A Horse Collar Ruin - B Armstrong Canyon - C
	TOTAL			2,070	

* Crew abbreviations: KA = Kim Andersen, SD = Steve Dewey, EL = Eric Lamalfa, RR = Ruth Richards
** An average of 161.7 acres inventoried per person per 10-hr day
*** Indicates the key to mapped areas presented later in Figure 2.

visibility was generally good, allowing relatively broad EDSW's (typically 50 to 75 yards). In areas such as canyon bottoms, or where vegetation cover was heavy, EDSW's were narrower, sometimes less than 25 yards. Whenever inventorying areas wider than a single swath width, multiple parallel passes of a lone crew member (or multiple crew members walking parallel transects or contours) were searched as contiguous or slightly overlapping strips to avoid coverage gaps. Daily inventory routes of each crew member were recorded and mapped using the BFP tracking function of the GeoExplorer GPS units. BFP tracking distance settings were adjusted as needed to correspond closely to the EDSW distance for each area.

Each inventoried area within Natural Bridges National Monument was assigned a detection confidence value based on the crews' estimated ability to see infestations of 0.01 acre in size of the least visible target species, taking into account terrain, vegetation cover, and the size and growth stage of the targeted plant species. Detection confidence was broken into three categories: Low (1 to 50 %), Medium (51 to 89 %), and High (90 to 100%).

As inventory units were traversed, locations of all target species were documented by the USU crew using Trimble GeoExplorer 3 global positioning system (GPS) units and GeoExplorer XM GPS units with 2- to 5-meter accuracy. Crews also recorded the location and documented the identity of any other non-target species they encountered if that species has a known history of invasiveness in other regions in the West. GPS configuration settings used in this project are

listed in Appendix D. Additional equipment used by crew members included laser rangefinders, compasses, binoculars, topographic maps, calculators, and radios. Appendix E contains a photograph and complete list of equipment used in this study. Field locations were recorded by GPS as UTM coordinates, and were later differentially corrected in the production of final digital products. The crews recorded invasive plant occurrence data on hard-copy (USGS 7.5-minute topographical maps) in any situation where GPS satellite reception was not possible (such as in narrow canyons) or in cases of GPS equipment malfunction. All data from field maps were converted to digital format.

Invasive plant infestations 1 acre or less in size typically were mapped as point features. The size of each infestation recorded as a point feature was estimated visually (using a laser rangefinder) and placed in the size category most closely matched to its actual area: 1) 1 to few plants (0.001 acre), 2) 0.01 acre, 3) 0.1 acre, 4) 0.25 acre, 5) 0.5 acre, 6) 1.0 acre, 7) 2.5 acres, or 8) 5 acres. Canopy cover of each infestation was estimated visually and placed in a category of either: 1) trace = less than 1 percent, 2) low = 1 to 5 percent, 3) moderate = 6 to 25 percent, 4) high = 26 to 50 percent or 6) majority = 51 to 100 percent. As a general rule, scattered plants with individuals or clusters separated by less than 50 yards were considered a single infestation and were mapped as a single feature (point, line, or polygon). Plants or groups of plants separated by more than 50 yards were mapped as separate infestations. (Refer to definition of PSR.)

Crew members were given the option to record infestations between 1 and 5 acres in size as points, polygons (either actual areas or gross areas), or line features, depending on which feature they felt would best represent the situation. However, there were no infestations within this size range found in Natural Bridges National Monument.

In deciding on the dominant vegetation cover, crews identified the two most prevalent or most dominant native species in the immediate vicinity of the weedy infestation. The full list was not a part of the data dictionary due to its size, but a paper copy (Appendix F) was carried and referred to by each crew member while working in the field. The vegetation list was compiled by Tamara Naumann, Botanist at Dinosaur National Monument, for an inventory conducted by USU in 2002-2003, and it was decided to use the same list for this project. Native species were coded with a 2-digit number and these codes were entered into the data dictionary. The list was not a complete list and crews had the option to add additional native species if they encountered them in the field.

POINTS OF INTEREST

The locations of some non-weed points of interest were recorded by field crews. These points include springs, seeps, Park boundaries, and sites of possible archeological interest. Points of interest were collected at the discretion of individual crew members. The information collected was delivered to NCPN, but not included within this report.

GENERAL PHOTOGRAPHS

Representative photos are included in this report showing some of the species and habitats inventoried, as well as a sampling of photographs of field crews doing inventory work.

Photographs were taken of each new weed species found in the Monument. Close-up photographs were intended to serve as a type of voucher specimen for weed species encountered, and landscape photos of weeds are expected to assist in relocating small isolated infestations for future control. The location of each weed infestation documentation photo was recorded as a GPS "photo point". In the case of landscape photographs of a weed and/or its surrounding habitat, the UTM coordinates represent the location of the photographer, and the direction that the camera was facing is noted as a compass bearing (magnetic north reference). The locations of photos taken to show general types of terrain and habitat, or crew activities usually were not documented with GPS points. Photographs were taken with 35-mm slide film and later digitized. Pertinent photographs are included with this report (see Appendix G). Digital copies of all photographs were submitted to NCPN as part of the final deliverables.

VOUCHER SPECIMENS

Specimens were to be collected to document new or otherwise unique occurrences of invasive species encountered within Natural Bridges National Monument. No plant voucher specimens were collected in 2003.

FIELD DATA PROCESSING

At the end of each day, field crews marked and dated all inventoried areas on USGS 7.5' topographic maps to assist in determining project progress and thoroughness of coverage. The GPS between-feature positions recorded automatically each day were used for reference when marking the topographic maps. Each crew member kept a daily log of where they searched, what species they encountered, disturbances noted, thoroughness of coverage, and any additional information that they felt might be of importance to the project. Data were downloaded from GPS units onto a laptop computer each day using Pathfinder Office GIS software. Edits (such as eliminating any duplicate features) were made to the data, and any additional information (such as infestations drawn by hand on field maps or other data not recorded with a GPS unit) were added at this time. Four sub-folders were created within the main project folder on the computer hard drive. These were for: 1) unedited raw GPS rover files, 2) edited GPS rover files, 3) differentially corrected edited GPS rover files, and 4) GIS shapefiles created from the differentially corrected rover files (for export and use in ArcView). Separate disks were used for raw and edited rover files.

Raw data consisted of rover files transferred directly from GPS units to the computer, and stored without any editing or modification. They were named using a 6-digit code (month-day-hour) preceded by a single letter (corresponding to the first letter in the crew member's last name), and ending in ".ssf." For example, "A051913.ssf" would be the file name for raw GPS data collected by Kim Andersen beginning in the thirteenth hour (24-hr local time) on May 19.

Edited data files were created from raw files that were viewed in Pathfinder Office and checked for accuracy. Features were added or deleted in the process of editing to eliminate any duplicate reporting (two crew members finding the same infestation), and to add locations drawn on field maps (as when satellite signals could not be obtained). Any locations added in the editing process were noted as "hand mapped" in the notes section and are denoted as "Non-GPS" under

the differential correction section. Notes were sometimes expanded during the editing process to include more detailed information about the surrounding habitat. Gross area features also were added during this process. File names were changed after editing to avoid confusion with the raw files. Edited files were named as a 3-letter month and 2-digit day abbreviation, followed by a dash and the first letter of the crew member's last name. If a crew member collected more than one file for that day, a number would follow the crew identification letter. For example, the edited version of the second file of GPS data collected by Kim Andersen on May 19 would be May19-A2.ssf.

The data from edited GPS rover files were then differentially corrected. Features that were added or deleted in the editing process were not differentially corrected; nor were points for which corresponding base station data were not available. Generally, the closest base station to the inventory area was used. However, if use of a slightly more distant base station resulted in a higher percentage of successfully corrected points, it was used in preference to a closer station. Corrected files retained the same name as their edited counterparts, but used the file extension "cor" rather than "ssf". Example: May19-A2.cor.

Shapefiles were created from exported data by exporting the differentially corrected files from Pathfinder Office into ArcView. The shapefiles were created from the various categories in the data dictionary such as point-weed shapefile, line-weed shapefile, area-weed shapefile, photo-point shapefile, and between-feature point shapefile. Three kinds of files were created from each ".cor" file. These are ".shp", ".shx", and ".dbf." Example: pt-weed.shp, pt-weed.shx, pt-weed.dbf.

POST-SEASON DATA PROCESSING

At the end of the field season, the project crew leader again reviewed the data in Pathfinder Office software to ensure all were present and complete. Data files were compared to entries in the field notebooks and maps served to ensure that all species were included in the data set and inventory areas were complete. Data were then exported from Pathfinder Office as shapefiles. Exported files were compiled into specific shapefiles for each type of data collected. The shapefiles created for this project were named according to the year of the data, the type of file, and the shape of the data collected. For example, points of weeds data collected in 2003 are compiled into one shapefile labeled as 03pt-weed.shp. Between-feature points from 2004 are labeled 04psnpnt.shp. Shapefiles were then imported into ArcView GIS 3.3 for map-making and data analysis. When shapefiles were imported into ArcView, additional data fields were added to comply with the task agreement. These fields include scientific name, ITIS code, life form of the species, county, state, country, and Park code. Individual record numbers, including the four-letter Park code, were assigned to each weed infestation location entry. It was decided to enter this information after the field season to minimize the amount of time spent collecting non-data in the field and maximize the acres inventoried. The data were checked again for any duplication of entries. Any gaps in the sequence of record numbers are due primarily to elimination of duplicated entries.

Polygons of areas inventoried within the various drainages of the Monument were created in ArcView 3.3 using the between-feature positions that tracked each crew member's daily route.

Individual areas represent the units used in planning and executing inventories. Each inventory unit is identified by a unique area number, and is described using names of associated canyons or other geographical features. Information provided for each inventory area includes area size (acres), dates of the inventory, the persons involved, Park code, county, state, and country. In addition, each area was assigned a detection confidence level indicating the crew's estimated ability to detect 0.01-acre patches of targeted weed species based on the vegetation types and the terrain. Each area also was given an ecological status rating which is a qualitative estimate of the ability of a site to recover to a natural state once the weeds have been removed. The levels of ecological status are defined in Table 2. The crew leader assigned this number based on crew field notes and/or personal on-site inspections of the areas.

The shapefiles were used to create maps using ArcView software. Large-scale maps were created to show the total area inventoried during the 2003 project and the location of smaller-scale (1:24,000) inset maps used to present weed distribution information. Each small-scale inset map is identified by a letter, as well as the name of prominent feature found on that section of map. The distribution maps also illustrate weed-free areas within inventoried units and may help managers prioritize areas for weed prevention efforts. Queries and summations of the weed acreages were conducted in ArcView and are included in the Results and Discussion portion of this report.

Individual maps were exported and saved as .jpeg files. Any data tables were exported and saved as Microsoft Excel spreadsheets. Metadata was compiled for the final 2003 dataset by Utah State University using ArcGIS ArcCatalog software. The metadata was provided to the Northern Colorado Plateau Network in an electronic format as part of the final project deliverables. All shapefiles, spreadsheets, raw, edited, and differentially corrected data files as well as digital photographs were also provided to NCPN as part of the final deliverables.

QUALITY ASSURANCE

Numerous measures were taken to ensure the quality of data collected by weed mapping crews. Quality assurance began by hiring only highly qualified individuals. In addition to in-person interviews, a written exam was administered to each applicant to evaluate their skills in weed recognition, taxonomic terminology, map reading and orienteering, GPS/GIS terms and applications, math, wilderness survival, and first aid. Crew members completed an intensive 1- to 2-week pre-season training course consisting of classroom presentations and field exercises to familiarize them with all inventory procedures and standards, and to improve all skills related to the job. Each NPS crew leader and all USU crew members were provided with a copy of the training manual.

During the first few weeks of the field season, and periodically thereafter, the Crew Supervisor (CS) and/or the Principal Investigator (PI) worked individually with each crew member to ensure that all skills had been mastered and that procedures were consistent among all crew members. The CS reviewed the crew's downloaded data and project log entries at the end of each day. Any gaps in search patterns that were significantly wider than the effective detection swath width were identified, revisited, and inventoried.

Periodically during the field season, the CS and/or PI conducted in-service training for the USU crew in the form of weed I.D. quizzes or demonstrations, reviewing the key identifying characteristics of targeted and other invasive weed species at various stages of growth. Each time any new weed species was found during an inventory, the identity was verified by the CS and/or PI. At the end of the season the PI and CS conducted random field inspections of areas previously inventoried by individual crew members. Data collected by the PL and CS were compared with data collected by individual crew members to evaluate detection thoroughness and data accuracy (species, location, size, canopy cover, stage of growth, associated vegetation, etc.). At the end of the season both the CS and PI reviewed the data again.

New field methods and standards such as effective detection swath widths, minimum detection target size, patch size resolution, MDTS-based between-feature position settings, and detection confidence guidelines (all described previously) that were developed for this project each contributed significantly to the overall quality and repeatability of the data, particularly with regard to collection of weed distribution and abundance data.

RESULTS and DISCUSSION

Field crews inventoried 2,070 acres in Natural Bridges National Monument during the summer of 2003 (Table 3), an amount representing approximately 27.1 percent of the entire 7,636-acre Monument. The general location and relative size of areas inventoried in 2003 are represented in Figure 1. An average of 161.7 acres was inventoried per person per10-hr day.

Figure 1 shows the 5 inventory areas used in planning and field operations. The identification number, drainage description, and acreage of each inventory area are listed in the legend. Each inventory area is also color-coded for ease in identification. Figure 2 serves as an orientation map for the smaller 1:24,000 scale weed-distribution "Inset" maps found in Appendices H and I. Inset maps are distinguished by letters A - C, plus the name of a distinct geographic feature found within its boundaries. The corresponding inventory area numbers from Figure 1 are included in the legend in parentheses behind each inset map name. Three inset maps are required to cover the five inventory areas, and large inventory areas may span over two or more inset maps. For example, different sections of Tuwa Canyon (Inventory Area 3) appear on Armstrong Canyon and Sphinx Rock inset maps (A and C).

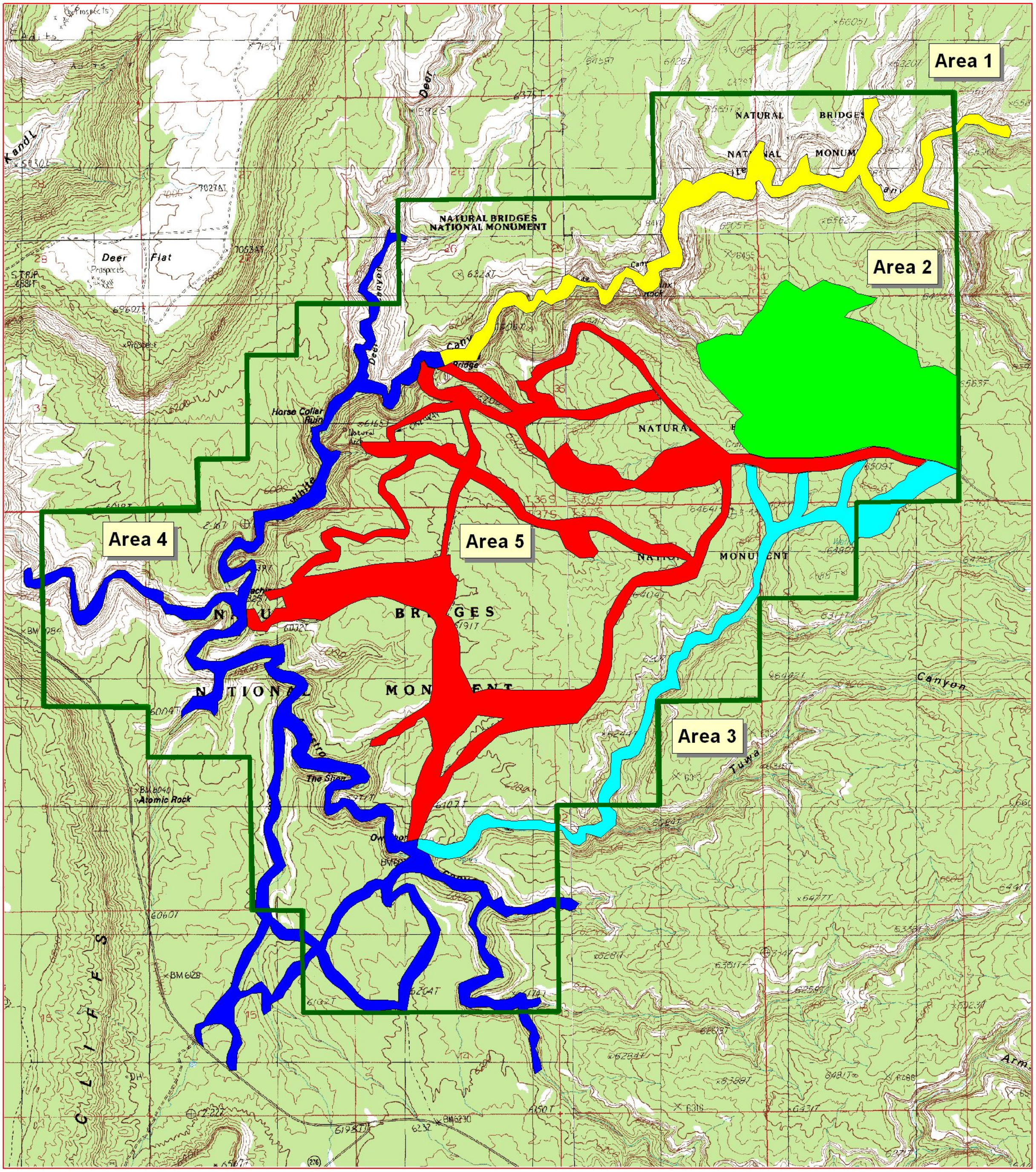
Invasive plants infested a total of 2.45 acres (Table 4), an amount equal to 0.12 percent of the land inventoried. Of the 10 initial targeted species, only *Cirsium arvense*, *Marrubium vulgare*, and *Tamarix ramosissima* were found in the Monument. No infestations of *Centaurea diffusa*, *Centaurea maculosa*, *Centaurea repens*, *Convolvulus arvensis*, *Elaeagnus angustifolia*, *Onopordum acanthium*, and *Ulmus pumila* were discovered. Non-target species found and mapped were *Linaria dalmatica*, *Solanum triflorum*, and *Sonchus oleraceus*.

Table 4: Acres infested by invasive plant species within inventoried areas of Natural Bridges National Monument and adjacent lands in 2003.

Species	Infested Acres (Inside Monument)	Infested Acres (Outside Monument)	Total Acres Infested
Cirsium arvense	0.01	---	0.01
Linaria dalmatica	0.04	0.01	0.05
Marrubium vulgare	0.05	---	0.05
Solanum triflorum	0.01	---	0.01
Sonchus oleraceus	0.01	---	0.01
Tamarix ramosissima	1.82	0.50	2.32
Totals	**1.94**	**0.51**	**2.45**

The most abundant target species found in the Monument was *Tamarix ramosissima*. The crew recorded 2.32 acres of this species during the project, 0.5 acres of which was located outside the Monument boundary. *Tamarix ramosissima* comprised more than 94 percent of the total infested acreage inventoried. However, infestations were generally small, often consisting of only one or two small trees. The remaining infestations (5.3 % of the total infested acreage) were comprised of the other two targeted species and the three additional non-native species that were mapped.

Figure 1. Identification number and acreage of individual areas inventoried for non-native invasive plant species in Natural Bridges National Monument in 2003.



Area 1 - Upper White Canyon (191 acres)

Area 2 - Upland plateau north of headquarters, sewage ponds (497 acres)

Area 3 - Tuwa Canyon (186 acres)

Area 4 - Armstrong, Deer, To-ko-chi, and Lower White Canyons (481 acres)

Area 5 - Main roads, trails, upland drainages (715 acres)

Park boundary

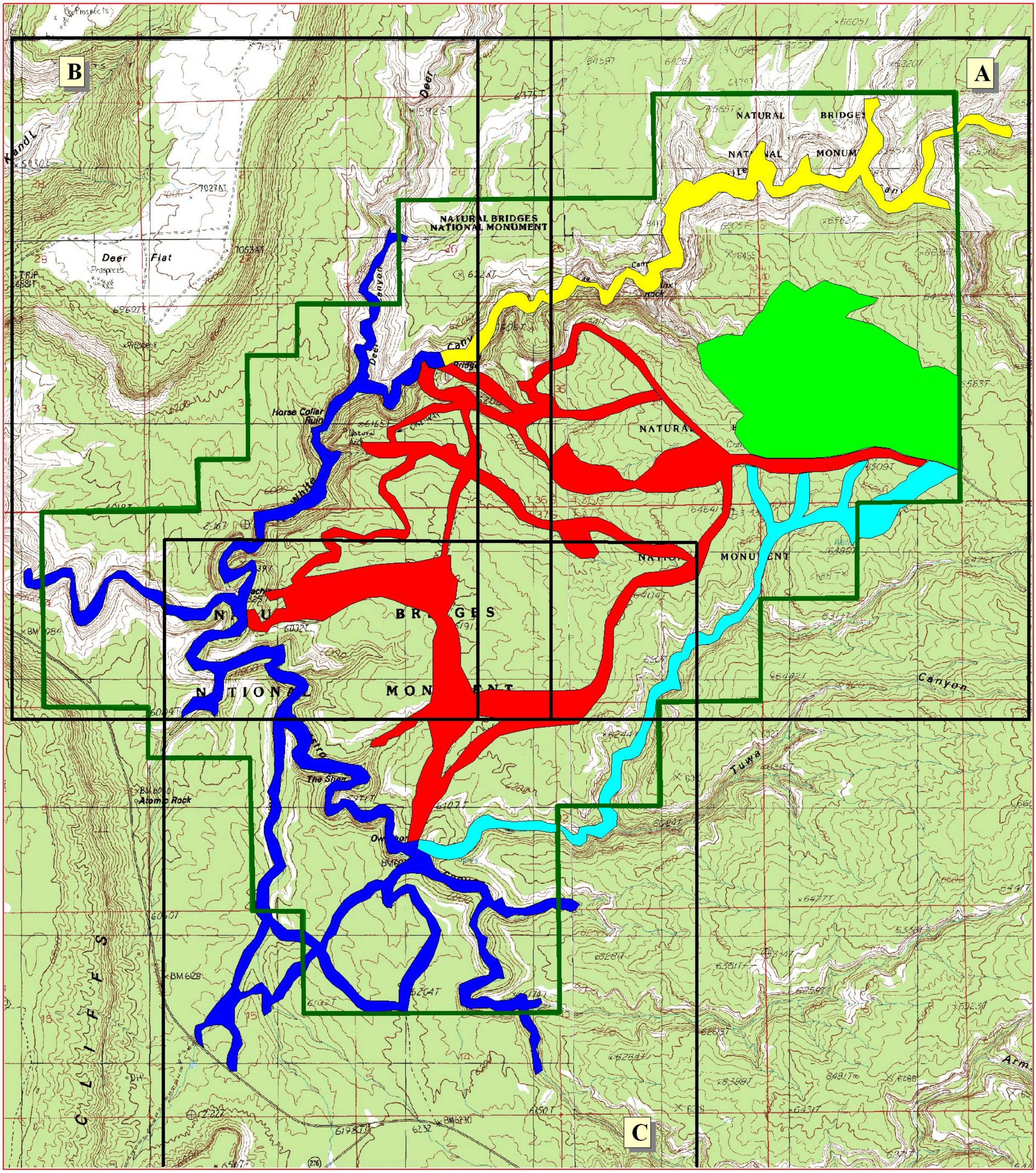
0 3000 6000 Feet

N

1:42,000 Scale

Utah State University
Natural Bridges National Monument
2003 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Figure 2. Insets indicating the location, letter code, and name of the three 1:24,000 scale maps used in Appendix tables to show weed distribution within inventories areas of Natural Bridges National Monument in 2003.



Inset A - Sphinx Rock (Areas 1, 2, 3, 5)

Inset B - Horse Collar Ruin (Areas 1, 4, 5)

Inset C - Armstrong Canyon (Areas 3, 4, 5)

Park boundary

Utah State University
Natural Bridges National Monument
2003 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Not all non-native species that were found were mapped. For example, species such as *Amaranthus albus, Bromus tectorum, Lactuca serriola, Melilotus officinalis,* and *Salsola kali* were present in inventoried areas but were ignored due to their previously recognized presence and/or abundance in the Monument. Deciding which non-target weeds to map was left to the discretion of individual crew members, based on their assessment of the potential threat and relative abundance of each species. Crew members were consistent in searching for and recording all infestations of *Linaria dalmatica*. However, not all crew members may have chosen to map all infestations of *Sonchus oleraceus* and *Solanum triflorum*. Therefore, the acreage values and corresponding distribution maps for these latter non-target species should be considered less than complete inventories.

Appendix H contains maps showing the overall distribution and relative abundance of all mapped weeds (no species distinction) within the boundaries of inventoried areas. Appendix I contains maps of individual species occurrences and weed-free areas within all inventoried portions of Natural Bridges National Monument. Following is a summary of the weed situation in individual drainages and other inventory units within Natural Bridges National Monument.

White Canyon (Area Numbers 1, 5; Inset Maps A, B)

White Canyon, one of two major canyons in Natural Bridges National Monument, was surveyed from Monument boundary to Monument boundary in this inventory.

The primary weedy species found in White Canyon was *Tamarix ramosissima.* Infestations were rarely larger than 0.1 acre in size and the *Tamarix ramosissima* infestations inventoried were mostly single saplings or small to large saplings in groups of 1-5 trees. It is possible that some single *T. ramosissima* saplings were missed during the inventory of White Canyon as they were often mixed in stands of willows of approximately the same size. A few *T. ramosissima* were found in White Canyon at or just beyond the Monument boundary and it is conceivable that additional infestations of this species would be found in White Canyon further outside of the Monument. These infestations are a possible seed source for future invasions into the Monument.

Linaria dalmatica was found near the Monument boundary west of Kachina Bridge. It was not included on the list of targeted species but was mapped due to its known aggressive nature in other regions of the West. Two separate infestations were recorded in this area and each was no larger than 0.01, but moderately dense in canopy cover. Both patches had already dropped their seeds at the time of the inventory. It is possible that during flash floods, seeds from infestations found in Deer Canyon were carried to this site, as Deer Canyon feeds into White Canyon above Horse Collar Ruin.

A single infestation of *Cirsium arvense* was also discovered in a corner pocket of White Canyon roughly between Sipapu Bridge and Sphinx Rock. It is possible that a few other small undetected infestations of *Cirsium arvense* could exist in White Canyon if growing inside larger patches of tall dense native vegetation. No other targeted species were found in White Canyon. Weedy species not mapped but noted were *Salsola kali, Bromus tectorum, Melilotus officinalis, Lactuca serriola,* and *Tragopogon dubius*. These non-targeted species were generally found as small patches or single plants.

Native vegetation, including willow, cottonwoods, and rabbitbrush, was abundant in much of the canyon. Visibility was generally good, and crews were confident of finding at least 90 percent of all targeted species infestations 0.01 acre or greater in size. No obvious disturbance was noted in the 191 acres inventoried in White Canyon, aside from the effects of periodic flash flooding in the canyon bottom. Due to the lack of significant human-related disturbances and the overall scarcity of non-native plant infestations, White Canyon was given an ecological status of two.

Deer Canyon (Area Number 4; Inset Map B)

Deer Canyon is a smaller canyon that feeds into White Canyon. A short portion of Deer Canyon is found inside the Monument boundary and was inventoried for this project.

Two small infestations of *Tamarix ramosissima* were found inside the Monument boundary, and both infestations consisted of a single sapling found within a stand of willows. An additional infestation was recorded outside the Monument boundary, and it is likely that even more infestations exist further up Deer Canyon.

A single infestation of *Linaria dalmatica* was found in Deer Canyon inside the Monument boundary, and two additional infestations of *L. dalmatica* were found just outside the boundary. The patches were small in size, no more than 3-5 plants in each. At the time of discovery, the plants had already flowered but had not dropped their seeds. Therefore, all plants were pulled, bagged, and removed from the canyon. It is likely that the seed origin for all *Linaria dalmatica* infestations currently in the Monument is further upstream in Deer Canyon. It is therefore recommended that significant effort be made to find and eliminate all additional infestations outside the boundary in Deer Canyon to prevent further introductions. Small patches of *Melilotus officinalis* and *Bromus tectorum* were noted in Deer Canyon but were not mapped.

Deer Canyon has a wide abundance of native plants including willows, cottonwoods, rabbitbrush, and oak. Visibility was generally good, and the crew was confident of finding at least 90 percent of all target-species infestations 0.01 acre or larger in size in its inventory of Deer Canyon. No obvious disturbances were noted, except for the expected effects of periodic flash flooding in the canyon bottom. An ecological status of two was assigned to Deer Canyon due to the presence of relatively few and small invasive weed infestations, and their high potential for eradication.

Tuwa Canyon (Area 3; Inset Map A, C)

The main Tuwa Canyon, which lies mostly outside of the Monument, parallels the southeast border of the Monument and feeds into Armstrong Canyon at Owachomo Bridge. The north fork of Tuwa Canyon is mostly inside the Monument. The main Tuwa Canyon was inventoried from its mouth to the confluence with the north fork. The entire north fork within the Monument also was inventoried, including a small area near its northeast end which was outside of the Monument.

Tamarix ramosissima was the only targeted species recorded in the Tuwa Canyon complex. The majority of the inventoried area did not contain any targeted species. Five small infestations were recorded at the head of the north canyon, approximately south and near the solar panels.

Additional infestations were recorded between the mouth of the north fork and the junction of Tuwa Canyon with Armstrong Canyon. However, these infestations were small in size and typically consisted of a single sapling or seedling at each point recorded. Additional species noted but not mapped include *Melilotus officinalis* and *Bromus tectorum*. These species only occurred as small infestations and only occasionally throughout the inventoried area.

The north fork of Tuwa canyon was relatively narrow and contained little riparian vegetation. The lower portion of the main Tuwa canyon was comprised of mostly willows, cottonwood, and rabbitbrush. Visibility was generally very good in both canyons, and crews were highly confident of finding all target-species infestations 0.01 acre or larger in size. Little disturbance was noted aside from the effects of seasonal flash flooding. A level 2 was assigned for ecological status due to the small size and number of weed infestations recorded in Tuwa Canyon.

Armstrong Canyon (Area 4; Inset Map C)

Armstrong Canyon is the second of two major canyons in Natural Bridges National Monument included in this inventory. Armstrong Canyon runs along the southwest border of the Monument and feeds into White Canyon near Kachina Bridge.

Tamarix ramosissima was the primary targeted species found in Armstrong Canyon and infestations were typically 0.01 acre or less in size with trace to low canopy cover. Most of the scattered infestations throughout Armstrong Canyon were comprised of seedlings or saplings. The highest concentration of *Tamarix ramosissima* found in Armstrong Canyon was at or just outside the southern Monument boundary. These infestations consisted of mature trees suggesting that this area might be a seed source for infestations occurring lower in the canyon.

A single patch of *Solanum triflorum* was recorded at the junction of To-ko-chi Canyon and Armstrong Canyon. A single infestation of *Sonchus oleraceus* was found and mapped at the junction of a side canyon and Armstrong Canyon below Atomic Rock. Species noted but not mapped include *Bromus tectorum, Melilotus officinalis, Amaranthus albus,* and *Lactuca serriola*.

An old jeep trail that ran from Owachomo Bridge to the southern Monument boundary was also inventoried. A single *Tamarix ramosissima* was found in a small stream channel beside this jeep trail. It was evident that the tree had been controlled in the past, although it was alive and had begun to resprout at the time of this inventory.

Armstrong Canyon was similar to White Canyon in structure and composition of the native vegetation. There were several stands of willows and cottonwoods as well as rabbitbrush and native grasses along the canyon bottom. Visibility was generally good, and crews were confident of finding 90 percent or more all target-species infestations 0.01 acre or larger in size. The detection confidence for the two non-target species should be considered below 90 percent. Little disturbance was noted aside from seasonal flash flooding and a level two was assigned for ecological status.

To-ko-chi Canyon (Area 4, Inset Map C)

To-ko-chi Canyon was inventoried from highway 95 to its junction with Armstrong Canyon.

Tamarix ramosissima was the only species recorded in the canyon, and the five infestations recorded inside the Monument were relatively close to the boundary itself. Several additional infestations were found outside the boundary, and these sites are among the most likely seed sources for infestations occurring down canyon. Other species noted but not mapped in To-ko-chi Canyon were scattered patches of *Melilotus officinalis, Bromus tectorum,* and *Lactuca serriola*.

The composition of the native plant community found in To-ko-chi Canyon was similar to that of other canyons in Natural Bridges National Monument. Visibility was generally good, and crews were confident of finding 90 percent or more all target-species infestations 0.01 acre or larger in size. Little disturbance was noted aside from flash flood events and a level two ecological status was assigned to the canyon.

Roads, Trails, Campground, Southern Upland Drainages (Area Number 5; Insets Maps A, B, C)
All developed areas including the visitor center, roads, trails, and campground were inventoried in this project. Representative off-road areas above the canyon rim and south of the Visitor Center also were inventoried.

Of the targeted species, only *Tamarix ramosissima* and *Marrubium vulgare* were found. Most infestations of *Tamarix ramosissima* occurred in small patches away from the road in the bottoms of shallow draws. Typically infestations of *Tamarix* were single saplings or small groups of saplings less than 0.001 acres in size. Some of the trees inventoried had been controlled previously, but now had resprouted. Not all lands above the canyon rim were searched, and therefore it is likely that a few additional small infestations of *Tamarix* exist in these non-inventoried areas.

Five separate infestations of *Marrubium vulgare* were found and mapped. One small infestation consisting of two plants was recorded at a pullout at the east entrance of the Monument. A single plant also was recorded just east of the beginning of the one-way road along the scenic drive. An additional plant was found in the parking area above Owachomo Bridge. Two *Marrubium vulgare* plants were discovered in the disturbed area around the solar panels south of the Visitor Center.

No targeted species were found in the campground, around the Visitor Center, or along the hiking trails above the canyon rim. Species that were noted within the developed sites but not mapped were *Lactuca serriola, Salsola kali, Melilotus officinalis, Bromus tectorum,* and *Amaranthus albus*.

Vegetation was generally lacking along the road shoulders, and trails typically wound over slickrock and/or through stands of juniper having a bare-ground understory. Therefore, visibility was very good along roads and trails, and it is unlikely that any infestations of any target species 0.01 acre or larger in size were missed. Visibility also was good in off-road areas, although most were covered with scattered to moderately dense stands of juniper. Crew members estimated that they were able to find 90 percent or more of all target-species infestations 0.01 acre or larger in size in the off-road portions. A “level two” ecological status was assigned to these inventoried

areas overall. The upland drainages showed little sign of disturbance other than seasonal flash flooding. The roads, trails, and campground are continually disturbed through visitor use, and it is likely that new weed species will show up here first.

Sewage Ponds, Upland Drainages North of Visitor Center (Area Number 2; Inset Map A)
The sewage disposal ponds and adjoining area north of the Visitor Center were inventoried due to their high degree of continual disturbance likelihood of weed introduction. The area had moderate visibility as the native vegetation was juniper. A relatively large and representative juniper-dominated off-road area north of the Visitor Center also was inventoried. No target species were found around the sewage ponds. A single sapling of *Tamarix ramosissima* was found along one of the small off-road drainages at Sphinx Rock that could easily be eradicated. The sapling was found around cut stumps of what is presumed to be a previously treated *Tamarix* tree. The rest of the area was free of targeted weed species. *Melilotus officinalis* was noted in some of the small drainages but was not mapped. Overall the area was given an ecological status of 2 as it only contained 1 targeted invasive plant. The area around the sewge ponds likely receives continual disturbance but little disturbance was noted in the drainages.

CONCLUSIONS / RECOMMENDATIONS

The primary objective of this project was to document the distribution and relative abundance of targeted non-native invasive plant species across the range of habitats and areas of management concern within Natural Bridges National Monument. It is anticipated that the information obtained from this inventory will be useful in the Monument's ongoing efforts to improve strategic planning and to increase the efficiency and effectiveness of all field operations associated with invasive plant management.

It is acknowledged that Natural Bridges National Monument is already implementing many effective weed control strategies and practices, for which they are to be commended. Several inventoried sites of *Tamarix ramosissima* had been cut previously, and the infestations had simply resprouted. Discussion with Monument rangers also indicated that NPS employees had also been involved in removing *Tamarix ramosissima* over the past couple of years. This was evident by the absence of large mature *Tamarix* trees in the canyon bottoms and the absence of large infestations of *Tamarix* such as those found in infested areas outside the Monument.

If it does not already exist, the Monument is urged to develop a comprehensive written management plan for invasive plant species in NABR, similar to the plan currently being finalized by Utah State University for Dinosaur National Monument. If there currently is a written plan, the Monument is encouraged to review and improve it on a regular basis. An excellent reference that will aid the Monument in crafting specific control methods is the "Weed Control Methods Handbook: Tools and Techniques for Use in Natural Areas" developed by The Nature Conservancy (Tu et al. 2001).

Regularly scheduled weed inventories of all managed lands should be an ongoing part of any weed management plan aimed at early detection. Inspections of all high-visitation areas should be performed at least annually, whereas inventories of the most remote sites or habitats least suitable for weed establishment or spread might need to be performed only once every 3 to 5

years. A rotating schedule should be developed by Natural Bridges National Monument to inventory a portion of their land each year, so that within a reasonable number of years all of the Monument could be inspected. The key is to schedule inventories often enough to detect all new weed infestations before they exceed a size considered feasible for eradication. Early detection of invasive weeds through regular searches and mapping is just as essential to successful weed management as the early detection of wildfires is to effective fire management.

Tied to an ongoing inventory effort, Natural Bridges National Monument also should consider establishing permanent monitoring sites to evaluate the impact and spread of weeds, and to evaluate the effectiveness of its weed management approaches. Long-term studies provide valuable insight into the effectiveness of current management techniques and quantify whether management goals have been accomplished. Monitoring standards and protocols exist in the federal agencies and provide guidelines as to selecting appropriate sites and proper techniques for gathering information. Several excellent publications on monitoring methods and standards are currently available for reference (Coulloudon et al. 1999, Elzinga et al. 1998, Kuchler et al.1988, Silsbee et al. 1991, USDI-USGS 1994, Winward 2000).

If it has not already occurred, Natural Bridges National Monument is encouraged to become an active member of a local Cooperative Weed Management Area. Weed management goals can be achieved more effectively when managed in cooperation with partner organizations also trying to achieve the same goals. The following excerpt taken from the National Park Service's own 2002 publication "Inventory and Monitoring for Invasive Plants Guidelines" further emphasizes the importance of this concept, particularly as it relates to invasive weed inventories:

> "Although the Park's primary responsibility is to itself and to upholding the mission for which is was established, Parks have a role and responsibility in promoting and supporting collaborative information exchange among local weed and natural resource management professionals. It is in the self-interest of the Park (in fulfilling its mission) and the agency (as a cooperating federal land management agency) to do more than simply share data passively or opportunistically. To the extent a Park can place the distribution and abundance of its invasive plants in the context of a larger landscape, the Park's efforts to identify management objectives and allocate resources efficiently will be improved as the scale of that landscape grows in size."

Dinosaur National Monument is currently a member of a Cooperative Weed Management Area, as are some other NCPN Parks. If interested in more information and advice, we suggest contacting Tamara Naumann, Park Botanist at DINO.

Species prioritization is an important part of strategic weed management planning, especially when limited budgets don't allow all weed problems to be addressed equally. As a general rule when weed abundance exceeds weed control resources, the least abundant species should be given highest priority, with the ultimate objective being eradication whenever possible. Species that are somewhat more abundant but still highly manageable should be controlled as aggressively as possible, with containment being the initial goal, and followed by a significant reduction in acreage. Populations of invasive or otherwise undesirable non-native species presently beyond the hope of containment or reduction in acreage should not be ignored, but

should not be the object of significant expense until all higher-priority situations have been adequately addressed. Relatively inexpensive methods such as policy and procedural changes aimed at preventing or minimizing further spread (protecting non-infested areas), release of biological control agents, or use of cultural methods are generally recommended for weed species in this category.

Applying that strategy to NABR would mean that species such as *Linaria dalmatica, Cirsium arvense* and *Marrubium vulgare* should be given the highest control priority of the species mapped, and should be targeted for prompt Monument-wide eradication. At least initially, *Tamarix ramosissima* would likely fit into the second priority category of "contain and reduce" in the worst-infested portions of the Monument, with the long-term objective being eventual eradication. In other areas of the Monument where *Tamarix* was relatively rare and isolated, the species should be placed in the same control priority category as the *Linaria, Cirsium,* and *Marrubium* species, with prompt eradiation being the objective. All infestations of *Tamarix* were comprised of single seedlings, single saplings or small patches less than 0.01 acre in size; and the majority of the Monument is still free of *Tamarix*. If effective prevention, early detection, and rapid response strategies are implemented now, managers should be able to keep all remaining non-infested portions of the Monument free from the impacts of this species. Native vegetation is still abundant throughout the majority of the canyons inventoried. Thick patches of willows and several large cottonwoods are scattered throughout, and many of the side canyons contain no weedy species. However, it is likely that populations of willows, cottonwoods, and other native species will eventually be reduced significantly or even lost if control strategies are not maintained to stop the spread and continued to reduce the impact of *Tamarix*.

The Monument will likely need additional inventory information before deciding in which management category to place *Bromus tectorum, Melilotus officinalis, Salsola kali, Amaranthus albus, Sonchus oleraceus, Solanum triflorum* and *Lactuca serriola*. These non-native species appeared to be only lightly scattered in the Monument, but this assessment is based on an incomplete sample survey rather than a true inventory. If further study reveals that these species truly are relatively scarce in the Monument, we suggest that they be targeted for eradication, even though they were not originally considered high-priority species.

The second objective of this project was to identify potential sources of weed introduction and significant vectors involved in weed spread in the Monument. Humans are the most likely vectors for new introductions of invasive plant species into Natural Bridges National Monument and all other Parks of the Northern Colorado Plateau Network, and areas of highest human visitation are also the areas where new invaders might be expected to appear first. Millions of visitors come from all over the world to enjoy the unique beauty of the Northern Colorado Plateau region, and over 97,000 per year visit Natural Bridges National Monument. Every person potentially brings with them errant seeds of an exotic invasive plant lodged in the tread of a tire or hidden in the dried mud of a hiking boot. The ever-increasing number of visitors, combined with the distant and diverse geographical areas from which they come, all combine to make National Parks highly and uniquely vulnerable to exotic plant invasions. Frequent inspection of high-visitation sites within each Park is essential to the "early detection and rapid response" strategy of invasive plant management. Roadways, parking areas, visitor centers,

picnic sites, campgrounds, view points, trails, and all other high-visitation sites should be searched regularly (at least yearly) at a time when new plants would be visible. Monument visitors should be informed of the potential damage caused by invasive plants, and ways they can help minimize the chances of introduction and spread. This might be done in the form of written information distributed at the Monument's Visitor Center, through displays or a video program, and evening fireside presentations to visitors made by NPS personnel.

Routine Monument operations represent another significant source of potential weed invasions. Road maintenance, fire fighting, and even weed control operations can result in the unintentional introduction or spread of invasive weeds within Parks. Specific procedures should be developed and implemented to minimize the spread of weed seeds by Monument employees and/or the creation of unprotected disturbed sites that can be ideal for weed establishment. An excellent example of effective weed prevention methods can be seen in protocols developed for the recent multi-crew EPMT deployment exercise conducted at Arches National Park (USDI-NPS 2004) (Appendix J). Additional weed prevention protocols have been developed by the Forest Service (USDA-Forest Service 2001).

Natural vectors such as wind, water, and wildlife do play a role in weed seed dissemination within the National Parks, and cannot be overlooked as a significant source of introduction and spread. However, they probably play a much less significant role overall, compared to human-related vectors. Control of isolated new weed infestations at the heads of otherwise non-infested drainages could prevent rapid spread associated with flowing streams or flash flood events. Traditional annual migration routes of deer, elk, bighorn sheep, or other large animals should be considered a high-probability area for weed seed transport and introduction.

All NCPN Parks that were inventoried in 2003 and 2004 are in the enviable situation of still having the majority of their lands free of invasive weeds. In Natural Bridges National Monument 99.88 percent of the inventoried acres were free of all targeted species. And, because areas selected for this inventory were generally considered the sites most likely to be infested, it can be assumed that those NABR lands not inventoried have an even higher proportion of weed-free acres. Furthermore, 100 percent of all inventoried lands were completely free of at least 26 species of concern to the region (Appendix K).

An important new trend in weed management is the concept of identifying areas that are currently free of one or more species of invasive plants, and officially designating them as “Weed Prevention Areas” (WPA). Land units designated as WPA's are given a higher priority for prevention efforts, early detection, and rapid control (eradication) of any new invaders. In our opinion, all areas within Natural Bridges National Monument that are currently "clean" should be identified as WPAs, and Monument management should take all appropriate measures to keep invasives from spreading into them. Protecting and preserving lands in this weed-free condition is much more cost-effective than restoring extensive areas already badly infested by invasives, and therefore should be the highest weed management priority for the all Parks in the Northern Colorado Plateau Network. Programs based on prevention, early detection, and rapid response to eradicate all new invaders on presently weed-free lands will be needed to accomplish this objective.

The WPA concept is an excellent way to emphasize the fact that the majority of NPS lands are still clean and healthy with respect to the threat of invasive plants. The total number of acres in WPA's within a Monument or Park could help to justify increased budgets for prevention practices. Increasing the number of weed-free acres should be recognized as a highly significant accomplishment, and managers should be encouraged to make the necessary efforts to convert lightly infested lands to WPA's as quickly as possible (by aggressively controlling and eradicating those few plants keeping these areas from being declared "invasive weed free"). WPA's also present an opportunity for Parks to help the general public feel more involved as visitors see more clearly the value of preventive measures they are being asked to adopt.

The final objective of this project was to test and refine data collection and field inventory techniques that might be used by NCPN in future invasive plant inventories. As part of our effort to meet that objective, USU provided training in weed mapping techniques at several state weed conferences as well as at the regional Western Society of Weed Science Weed Management Short Course held in Montana annually. An overview of the USU weed mapping program was also presented to over 60 EPMT personnel from around the country during a week-long field training exercise held in Arches National Park in 2004. In addition, several documents were published containing detailed information about USU inventory procedures and techniques (Andersen et al. 2003, Andersen and Dewey 2005, Ballard et al. 2003, Dewey and Andersen 2004a, Dewey and Andersen 2004b, Dewey and Andersen 2005a; Dewey and Andersen 2005b, Dewey and Andersen 2005c).

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Appendix Tables and Figures

Appendix A. Crew Qualifications and Project Quality Assurance for 2003 Invasive Non-native Plant Inventory in Natural Bridges National Monument.

The Utah State University wildland weed mapping team has considerable experience conducting the type of survey required in this NPS project. Previous weed surveys conducted by USU include:

1997 Mt. Naomi Wilderness Area, Cache County, UT
1998 Wellsville Mountains Wilderness Area, Cache and Box Elder Counties, UT
1999 Franklin Basin Recreation Area, USFS Logan Ranger District, Cache County UT
2000 Rich County Public Lands (BLM, USFS), UT
2001 Hardware Ranch WMA, UDWR, Cache County, UT
2001 Bud Phelps WMA, UDWR, Cache County, UT
2002 Hawkins Fire, USFS, Bannock County, ID
2002 Canyon Fire, USFS, Franklin County, ID
2002 Cherry Creek Fire, USFS, Bannock County, ID
2002 West Fork Fire, BLM, Bannock County, ID
2002 Dinosaur National Monument, Green River District, UT

Kim Andersen (crew leader) and Melanie Ballard (assistant crew leader) have considerable experience working on the USU crew in past years. Kim has a Bachelor of Science degree in Fisheries and Wildlife from the College of Natural Resources and is currently working towards a Master's Degree in Weed Science. Melanie has a Bachelor of Science degree in Plant Science. Kim began work on the USU crew in 1999, and has been crew leader since 2000. Melanie started on the crew in 2002. Both Kim and Melanie have additional experience with invasive weed GPS mapping projects in National Parks (Grand Teton and Yellowstone). Ruth Richards has a Bachelor of Science degree in Crop Science and is currently working towards a Master's Degree in Weed Science. She has worked on the crew in 2003 and 2004. Janna Simonsen has worked as a biological technician for the Wasatch-Cache National Forest since 1999 conducting vegetation analyses and range monitoring studies using GPS/GIS technologies. Janna has a BS degree from USU in Environmental Studies. Hillary Hudson has a Bachelor's degree and has worked on an Exotic Plant Management Team in California from 2003 to 2004. She has also worked as a national park ranger in the Maze District of Canyonlands National Park. Eric Lamalfa is a student at USU in the Plant Science department. Liz Ballenger has a Bachelor's degree in Biology from the College of Wooster and a Master's Degree in Ecology from the University of Michigan. Heather Rickleff has a Bachelor's degree in Outdoor Recreation and Resource Management from Indiana University.

All USU weed survey crew members were required to pass a written exam in weed identification and mapping skills before being hired. Each also had passed an upper-division university course in weed identification, biology, and management, and/or has extensive practical experience in wildland plant identification. Once hired, USU and NPS crew members also attended a 3-week classroom and outdoor training course in late April and early May in wildland weed mapping

techniques taught by Dr. Dewey at Logan and Zion National Park during 2003. A similar training course was offered to the USU crew in 2004. Crew members were provided with weed identification field guide book, taxonomic keys, and pressed reference specimens of all targeted weeds. During the course of the summers USU crew members were quizzed periodically with fresh plant specimens provided by the crew leader and/or Dr. Dewey. Dr. Dewey also spent several days in the parks working with individual crew members under field conditions. To further authenticate findings, Dr. Dewey and/or the crew leader re-visited representative areas in each park that had been previously mapped by the USU crew, using the most recent crew-generated weed infestation maps to compare them against their own field observations.

Appendix B. Standard GPS Data Dictionary used in the 2003 Invasive Non-native Plant Inventory in Natural Bridges National Monument.

NPS-2004
Inventory of invasive weeds in NCPN

pt-weed Point Feature, Label 1 = Species Code 1 = IT IS code Code 2 = Plant Code

Species	Menu, Required, Normal	
Asparagus sp.	[42782]	[ASPAR]
Bells of Ireland	[32569]	[MOLA]
Bindweed, field	[30705]	[COAR4]
Blackberry, Himalayan	[24852]	[RUDI2]
Brome, downy	[40524]	[BRTE]
Brome, smooth	[40502]	[BRIN2]
Burdock	[36546]	[ARMI2]
Camelthorn	[508549]	[ALMA12]
Chamomile	[36330]	[ANTHE]
Cress, hoary	[23072]	[CADR]
Dock, curly	[20937]	[RUCR]
Elm, Siberian	[19057]	[ULPU]
Halogeton	[20692]	[HAGL]
Hemlock, poison	[29473]	[COMA2]
Henbane, black	[21454]	[HYNI]
Houndstongue	[31890]	[CYOF]
Horehound	[32561]	[MAVU]
Johnsongrass	[42111]	[SOHA]
Knapweed, diffuse	[36958]	[CEDI3]
Knapweed, Russian	[510530]	[CERE6]
Knapweed, spotted	[36964]	[CEMA]
Knapweed, Squarrose	[533280]	[CETR8]
Lambsquarter	[20592]	[CHAL7]
Loosestrife, purple	[27079]	[LYSA2]
Marshelder	[36041]	[IVA]
Mullein, common	[33394]	[VETH]
Mustard, Sahara	[23064]	[BRTO]
Olive, Russian	[27770]	[ELAN]
Orchardgrass	[193446]	[DAGL]
Pepperweed, perennial	[503379]	[LELA2]
Puncturevine	[29057]	[TRTE]
Reed, giant	[41450]	[ARDO4]
Saltcedar	[22310]	[TARA]
Salsify, western	[38564]	[TRDU]
Spurge, leafy	[28064]	[EUES]
Starthistle, yellow	[36972]	[CESO3]
Thistle, bull	[36428]	[CIVU]
Thistle, Canada	[36335]	[CIAR4]
Thistle, musk	[35787]	[CANU4]
Thistle, Russian	[20655]	[SAKA]
Thistle, Scotch	[38140]	[ONAC]
Timothy grass	[41062]	[PHPR3]
Toadflax, Dalmatian	[33219]	[LIDA]
Toadflax, yellow	[33216]	[LIVU2]
Tree of Heaven	[28827]	[AIAL]
Wheatgrass, crested	[40371]	[AGCR]
Woad, dyer's	[23151]	[ISTI]

OTHER	[XXXX] [XXXX]
% Cover Trace: < 1 % Low: 1 to 5 % Mod: 6 to 25 % High: 26 to 50 % Majority: 51 to 100 %	Menu, Required, Normal, weed canopy within infested area
Size 0.01 acres 0.1 acres 0.25 acres 0.5 acres 1.0 acres 2.5 acres 5.0 acres	Menu, Required, Normal, based on average perimeter diameter
Phenology Vegetative Bud Flower Fruit-immature Fruit-mature Seed dispersing Dormant/senesced	Menu, Required, Normal, weed growth stage
Woody Growth Seedling Sapling Mature Dormant/senesced	Menu, Normal, Normal, growth stage of woody species
Dominant Native Spp.	Text, Maximum Length = 30, 2-digit codes, 2 species, order of prevalence Normal, Normal
Disturbance None Low-Mod (default) High	Menu, Normal, Normal
Hydrology Upland (default) Rip-perennial Rip-intermittent Rip-ephemeral Wetland Playa-lakebed	Menu, Normal, Normal, site hydrology
Notes	Text, Maximum Length = 30 Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal

Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Ln-weed	Line Feature, Label 1 = Time
Species	Menu, Required, Normal

******See species list under pt-weed.

Line Width (ft)	Numeric, Decimal Places = 0, average width of linear area Minimum = 5, Maximum = 500, Default Value = 20 Required, Normal
Notes	Text, Maximum Length = 50 Normal, Normal
Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal
Ar-weed	Area Feature, Label 1 = Time GPS-generated polygon
Species	Menu, Required, Normal

******See species list under pt-weed.

Notes	Text, Maximum Length = 50 Normal, Normal
Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal
Gross-weed	Point Feature, Label 1 = Time, Office-generated polygon
Species	Menu, Required, Normal

******See species list under pt-weed.

Infested (% of Area Infested)	Numeric, Decimal Places = 0, (% of gross area actually infested) Minimum = 1, Maximum = 100, Default Value = 1 Required, Normal
% Cover (IA only) Trace: < 1 % Low: 1 to 5 % Mod: 6 to 25 % High: 26 to 50 % Majority: 51 to 100 %	Menu, Required, Normal, % weed cover in typical infestations

Area ID (# on map)	Numeric, Decimal Places = 0, From infestation ID # noted on field map
	Minimum = 1, Maximum = 100, Default Value = 1

	Required, Normal
Notes	Text, Maximum Length = 50 Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal
Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Point	Point Feature, Label 1 = Notes
Notes	Text, Maximum Length = 50 Normal, Normal
Line	Line Feature, Label 1 = Notes
Notes	Text, Maximum Length = 50 Normal, Normal
Area	Area Feature, Label 1 = Notes Text, Maximum Length = 50 Normal, Normal
Photo	Point Feature, Label 1 = Notes, Label 2 = Bearing (MN)
Species	Menu, Required, Normal

******See species list under pt-weed.

Bearing (MN)	Numeric, Decimal Places = 0 Minimum = 0, Maximum = 360, Default Value = 0 Normal, Normal
Notes	Text, Maximum Length = 50 Normal, Normal
Date	Date, Auto generate Create, Month-Day-Year Format Normal, Normal
Time	Time, Auto generate Create, 24 Hour Format Normal, Normal
Voucher	Point Feature, Label 1 = Notes
Species	Menu, Required, Normal

******See species list under pt-weed.

Notes	Text, Maximum Length = 50 Normal, Normal

Appendix C. Relationship of NCPN Project Data Elements to IMR and NAWMA Weed Mapping Standards used in 2003 Invasive Non-native Plant Inventory in Natural Bridges National Monument.

Relationship of NCPN Weed Mapping Project Database Elements to proposed IMR Weed Mapping Data Elements and NAWMA Standards. Column labeled 'NCPN Data Element Status' indicates whether or not data element were included in NCPN Weed Mapping Database. If data element was included (=YES) an indication is made whether or not the data was field collected or compiled in an office setting.

CATEGORY	*DATA ELEMENTS*	NPS Intermountain Region	NAWMA	NCPN Data Element Status	NCPN Data Source	Comments
AGENCY METADATA	1. Collection Date (yyyymmdd)	Required	Required	YES	Field	
	2. Source of Data (contact of individual who manages data)	Required	Required	YES	Office	Included in metadata only
	3. Scale of Data Source	Required (recommend 1:24000)	Required (recommend 1:24000)	YES	Office	Included in metadata only
	4. Datum of Original Data (N_{27}/N_{83})	Required	N/A	YES	Office	Included in metadata only
	5. Surveyor Name	Optional	Optional	YES	Field	
	6. Site ID (Name or Number)	Optional	Optional	YES	Field	
	7. Quality Control Assessment (Yes/No)	Optional	N/A	(yes)	Office	This will be done but not entered as a data field.
	8. Methodology Used For Inventory (casual observation/formal survey/remote)	Optional	Optional	YES	Office	Included in metadata only
INVASIVE SPECIES INFORMATION	1. Plant Scientific Name (Genus/species) a. Intraspecific Name b. Authority for Name	Required a. Optional b. Optional (Recommend Kartez)	Required a. Optional b. Required (Kartez)	YES	Field	Scientific Name only
	2. ITIS Code (allows for link to NPSpecies)	Required	N/A	YES	Office	ITIS code will allow linkage to authority, common name, state status etc.
	3. Common Name	Optional	Optional	YES	Office	
	4. Plant Code (Based on USDA "PLANTS" web Database)	Optional	Optional	NO		ITIS is cross-walked with PLANTS database.
	5. Species Status a. State listed noxious weed b. Species of concern to park	Optional	Optional	NO		
	6. Species On Priority List For Park (Yes/No)	Optional	Optional	NO		

LOCATION DATA (For Survey Unit and Each Weed Population	1. Country (USA/Canada/Mexico)	*Required*	Required	YES	Office	
	2. State (2-Letter Code)	Required	Required	YES	Office	
	3. County	Required	Required	YES	Office	
	4. Site Location (Lat/Long/ UTM/legal)	Required (UTM preferred)	Required	YES	Field	
	5. USGS 7.5 Quad Name	Optional	Optional	NO		This is readily available in GIS
	6. USGS 7.5 Quad Number	Optional	Optional	NO		This is readily available in GIS
	7. Hydrologic Unit Code (HUC#) for watershed	Required for aquatic invasives only	Required for aquatic invasives only	NO		This is readily available in GIS
	8. NPS LOCATION DATA a. Park Unit (4-letter code) b. Park Subunit c. Network Name d. Region e. Weed Management Area f. Other	a. Required b. Optional c. Required d. Required e. Optional f. Optional	N/A	a. YES b. NO c. YES d. NO e. NO f. NO	Office Office	
CHANGES IN SPECIES POPULATION OVER TIME	1. Infested Area a. Unit of Measure (Acre or Hectare)	Required a. Required	Required a. Required	YES	Field	
	2. Gross Area a. Unit of Measure (Acre or Hectare)	Optional a. Optional	Optional a. Optional	YES	Field	
	3. Canopy Cover (% Aerial) A. Type of Measurement (actual/estimated/mid-pt of cover class)	Required a. Required	Required a. not used	YES	Field	
	4. Distribution (light/moderate/heavy) (density)	Optional	N/A	YES	Field	Note: USU will experiment with defining a useful density characterization here – possibly by species
	5. Phenology (Vegetative/ flower/seed/senesced)	Optional	N/A	YES	Field	
	6. Distance to Water (horizontal & vertical	Optional	N/A	NO		
	7. Management Actions Taken (Manual/Chemical/BioControl/Domestic Livestock) a. Date of Action b. % of Population treated (1-25)(/26-50)(51-75)(76-100)	Optional a. Optional b. Optional	N/A	NO		
	8. Site Undergoing Active or Inactive Management	Optional	N/A	NO		

SITE ENVIRONMENTAL INFORMATION	ABIOTIC DATA	1. Elevation (Avg, max/min) - Unit of Measure (feet/meters)	Optional (highly recommended)	N/A	YES	Field	Also available in GIS
		2. Aspect	Optional (highly recommended)	N/A	NO		Can be derived in GIS
		3. Percent Slope - Actual or estimated	Optional (highly recommended)	N/A	NO		Can be derived in GIS
		4. Slope Position (top 1/3, mid 1/3, low, 1/3, toe)	Optional (highly recommended)	N/A	NO		Not a helpful data field – too variable, also can be derived in GIS
		5. Soil Type	Optional (highly recommended)	N/A	NO		Field crews not knowledgeable about soils. Can be derived from soil maps.
		6. Landform	Optional (highly recommended)	N/A	NO		We tried this last year, too much variation & difficult to interpret. Data quality not sufficient.
		7. Geologic Substrate	Optional (highly recommended)	N/A	NO		Can be derived in GIS from geologic maps.
		8. Climate (Develop Link to Separate Table with Avg. Temp & Precip.)	Optional (highly recommended)	N/A	NO		Tabular and spatial climate data are available for GIS analysis.
	BIOTIC DATA	1. Life Form (Grass/Forb/Shrub/Tree)	Required	N/A	YES	Office	
		2. Ecological Status	Required	N/A	YES	Field and Office	
		3. Values At Risk	Required	N/A	NO		Relationship of weed occurrences to resource values can be derived through GIS analysis as needed.
		4. Vegetation Classification	Optional (highly recommended)	N/A	NO		Vegetation classifications not available yet for NCPN parks
		5. Dominant Associated Species	Optional (highly recommended)	N/A	YES	Field	
		6. Cover Type	Optional (highly recommended)	N/A	NO		Standard cover type classifications not yet being applied in NCPN parks.
		7. Habitat Type	Optional (highly recommended)	N/A	NO		Not applicable to NCPN parks.
		8. Seral Stage	Optional (highly recommended)	N/A	NO		These relationships not described for NCPN parks.
		9. Disturbances *(See Below)	Optional (highly recommended)	N/A	(yes)	Field and office	Describe for broader survey areas, but only generally at polygon or point level

Appendix D. GPS Settings using in 2003 Invasive Non-native Plant Inventory in Natural Bridges National Monument.

System / Setup

Configurations

Data

Log between features:	Distance, 500 ft, (Set at surveyor's discretion)
Log PPRT data:	No
Log velocities:	No
Antenna height	4 ft
Allow GPS update	Yes
Warning distance:	Never
Filename prefix:	R

GPS

(Advanced mode window)

PDOP mask:	6.0 (Can be higher in areas where satellite reception is difficult, GPS will take best PDOP if set at a higher number)
SNR mask:	4.0
Elevation mask	15 deg
Minimum satellites	4
2D altitude	N/A

Real Time

Mode	Best available
Velocity filter	Off
RTCM age limit	50 s
Station ID	Any

Coordinates

System	UTM
Zone	12 North
Datum	NAD 1927 (Western U.S.)
Altitude reference	MSL
Geoid:	DMA 10x10 (Global)
Coordinate units	Meters
Altitude units	Feet

Units

Distance	Feet
Area	Acres
Velocity	Miles/Hour
Angle	Degrees
North reference	True
Declination	Auto

Formats

Language	English
Offset	Horz/Vert
Degrees	DD-MM-SS-ss
Date	YYYY/MM/DD
Time	12 Hour

Appendix . GPS Settings using in 2003 Invasive Non-native Plant Inventory in Natural Bridges National Monument. (cont)

Time Zone	-06.00 (daylight savings, Mtn Zone)
Coordinate order	North/East
COMMS	
Data transfer	Support module (must change to "Serial clip" when using clip)
RTCM input	Off
NMEA output	Off
Port settings	
Input baud rate	N/A
Output baud rate	N/A
Data bits	N/A
Stop bits	N/A
Parity	N/A
Other	
Beep volume	On
NMEA output interval	5s
NMEA messages	
GGA	Yes
VTG	Yes

Data Dictionaries

(Select NCPN-04)

Feature Settings

(Do not adjust. Interval and minimum positions are set in office upon creation of dictionary)

About

(Nothing to set here)

Reset (Do not adjust. It will reset everything to factory defaults)

Appendix E. Photograph and list of equipment used in 2003 Invasive Non-native Plant Inventory in Natural Bridges National Monument.

Equipment

- Trimble Geo3 Explorer GPS units
- Laser Range Finder
- Binoculars
- Clinometer
- Compass
- Calculator
- 2-way Radios
- Cellular Phone
- Field notebook
- Field Sheets
- Uinta Basin Flora and other plant taxonomic keys
- Plant dissection kits
- Hand lens
- Collection bags
- Topographic maps
- Geology maps
- 35-mm camera and slide film
- Surveyor marking ribbon

Appendix F. Dominant Vegetation Types Key used in 2003 Invasive Non-native Plant Inventory, Natural Bridges National Monument.

Key Code	Common Name	Scientific Name	Class Type
10	Rocky Mountain maple	Acer glabrum	T
11	boxelder	Acer negundo	T
12	Utah juniper, white cedar, bone-seed juniper	Juniperus osteosperma	T
13	Rocky Mountain juniper, R. Mtn. red cedar	Juniperus scopulorum	T
14	piñon, piñon pine, pinyon pine	Pinus edulis	T
15	ponderosa pine, Western yellow pine	Pinus ponderosa	T
16	Douglas fir	Pseudotsuga menziesii	T
17	narrow-leaf cottonwood, alamo sauco	Populus angustifolia	T
18	Fremont cottonwood, alamo	Populus fremontii	T
19	hackberry, net-leaf hackberry	Celtis reticulata	T
20	Gambel Oak	Quercus gembelii	T
21	Singleaf ash	Fraxinus anomala	T
22	*Add up to #29*		T
30	Basin big sagebrush, chamiso hediondo	Artemisia tridentata	S
31	spreading rabbitbrush	Chrysothamnus linifolius	S
32	rubber or gray rabbitbrush, chamiso blanco	Chrysothamnus nauseosus	S
33	gray horsebrush	Tetradymia canescens	S
34	mountain alder, thin-leaf alder	Alnus incana	S
35	red birch, river birch, water birch	Betula occidentalis	S
36	mountain snowberry	Symphoricarpos oreophilus	S
37	four-wing saltbush, chamiso	Atriplex canescens	S
38	hopsage, spiny hopsage, applebush	Grayia spinosa	S
39	greasewood, black greasewood	Sarcobatus vermiculatus	S
40	red osier dogwood	Cornus stolonifera	S
41	Torrey ephedra, Mormon tea, popotillo	Ephedra torreyana	S
42	green ephedra, Mormon tea, cañutillo	Ephedra viridis	S
43	serviceberry, Saskatoon serviceberry	Amelanchier alnifolia	S
44	Utah serviceberry	Amelanchier utahensis	S
45	dwarf or little-leaf mountain mahogany	Cercocarpus intricatus	S
46	curl-leaf mountain mahogany	Cercocarpus ledifolius	S
47	true or birch-leaf mountain mahogany	Cercocarpus montanus	S
48	chokecherry, capulin	Prunus virginiana	S
49	bitterbrush, antelope bitterbrush	Purshia tridentata	S
50	wild rose, Woods rose	Rosa woodsii	S
51	Salix sp.?	Willow	S
52	tamarisk, tamarix, salt cedar	Tamarix ramosissima	S
53	Mazanita sp.	Arctostaphylos sp	S
54	Three-leaf sumac	Rhus trilobata	S
55	Seep-willows	Baccharis sp	S
56	Apache plume	Fallugia paradoxa	S
57	Cliffrose	Cowania stansburiana	S
58	Shrub oaks	Quercus sp.	S
59	*Add up to #59*		S
60	Bigelow sagebrush	Artemisia bigelovii	DS
61	black sagebrush	Artemisia nova	DS
62	rough brickellbush	Brickellia microphylla	DS
63	mountain low rabbitbrush, green rabbitbrush	Chrysothamnus viscidiflorus	DS
64	broom snakeweed, matchbrush	Gutierrezia sarothrae	DS
65	hairy goldenaster	Heterotheca villosa	DS
66	mountain peppergrass	Lepidium montanum	DS
67	shadscale	Atriplex confertifolia	DS
68	mat saltbush, mat atriplex	Atriplex corrugata	DS
69	winterfat, white sage, winter sage	Ceratoides lanata	DS
70	*Add up to #79*		DS
80	prairie sage, Louisiana sage, estafiate	Artemisia ludoviciana	H

Appendix F. Dominant Vegetation Types Key used in 2003 Invasive Non-native Plant Inventory, Natural Bridges National Monument.

Key Code	Common Name	Scientific Name	Class Type
81	arrow-leaf balsamroot	Balsamorhiza sagittata	H
82	Russian thistle, tumbleweed, tumbling thistle	Salsola iberica	H
83	bluebunch wheatgrass	Agropyron spicatum	H
84	slender wheatgrass	Agropyron trachycaulum	H
85	cheatgrass, downy chess, cheat	Bromus tectorum	H
86	Idaho fescue	Festuca idahoensis	H
87	Indian ricegrass, ricegrass	Oryzopsis hymenoides	H
88	needle-and-thread grass	Stipa comata	H
89	Wyoming big sagebrush	Artemisia tridentata var. wyomingensis	S
90	Mountain big sagebrush	Artemisia tridentata var. vaseyana	S
91	Common reed	Phragmites australis	H
92	Horsetail	Equisetum laevigatum	H
93	Cattail	Typha latifolia	H
99	Other		
99	Needlegrass (accidentally used in COLM for short time)	Stipa comata	H

Appendix G. Project Photographs of Weed Species Detected, Inventoried Landscapes, and Crew working in Natural Bridges National Monument during the 2003 Invasive Non-native Plant Inventory.

Weeds Detected

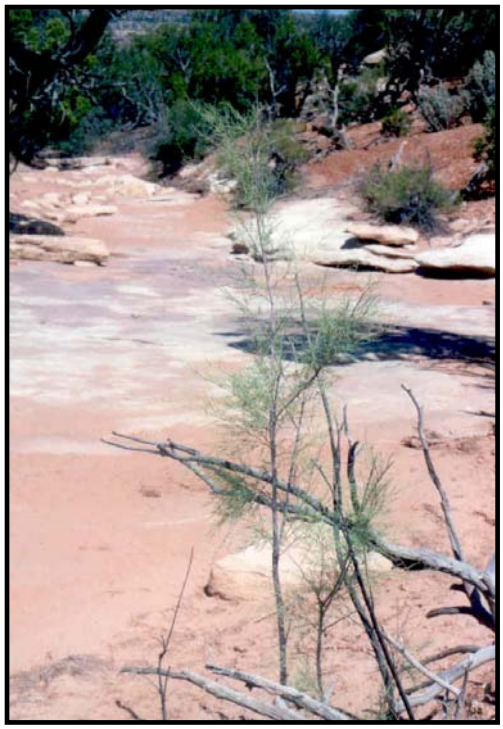


Figure 1. *Tamarix ramosissima* sapling. (NABR PR-7)

Figure 2. *Tamarix ramosissima* sapling in dry wash. (NABR PR-7)

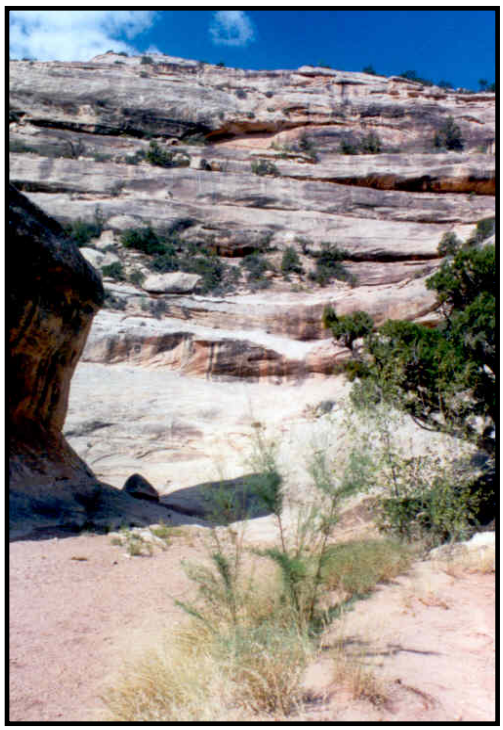


Figure 3. *Tamarix ramosissima* sapling in Deer Canyon. (NABR PR-8)

Figure 4. *Tamarix ramosissima* sapling in Deer Canyon. (NABR PR-8)

Weeds Detected

Figure 5. *Linaria dalmatica* plants in flower. (NABR PR-2)

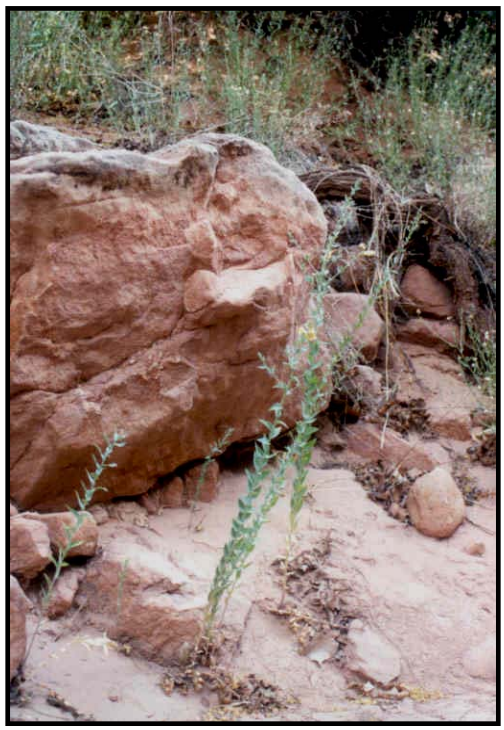


Figure 6. *Linaria dalmatica* in sandy wash of Deer Canyon. (NABR PR-2)

Figure 7. *Marrubium vulgare* found along fence line near park entrance. (NABR PR-9)

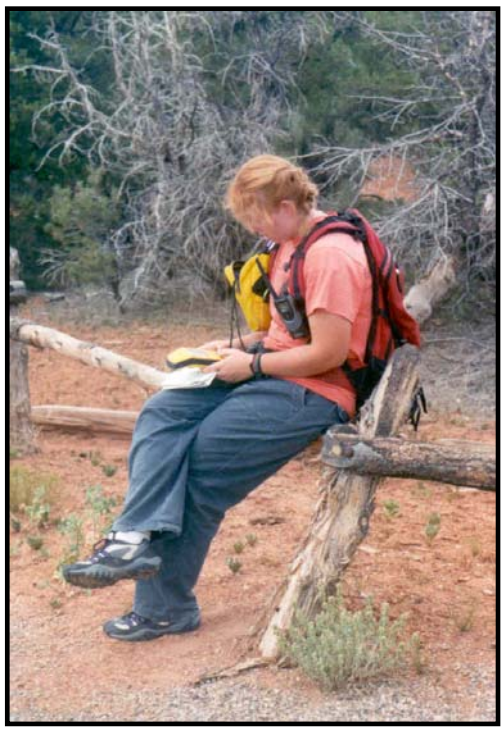


Figure 8. Ruth Richards mapping *Marrubium vulgare* near park entrance. (NABR PR-9)

Weeds Detected

Figure 9. *Cirsium arvense* in flower. *

Figure 10. *Cirsium arvense*. A thistle was found in White Canyon near Sipapu Bridge. *

Figure 11. *Sonchus oleraceus*. Plants were found in Armstrong Canyon near Atomic Rock. *

Figure 12. *Solanum triflorum*. Plants were found at the mouth of To-ko-chi Canyon. *

* Photographs not taken in Natural Bridges National Monument, but representative of the plants found and mapped.

Natural Bridges Landscape

Figure 13. View looking west of White Canyon and Sipapu Bridge.

Figure 14. White Canyon and Kachina Bridge.

Figure 15. Owachomo Bridge and Armstrong Canyon.

Figure 16. Trail sign. All trails were surveyed for invasives.

Natural Bridges Landscape

Figure 17. View from Owachomo Bridge looking up Tuwa Canyon.

Figure 18. View looking NE of Tuwa Canyon (NABR PR-5)

Figure 19. Armstrong Canyon. (NABR PR-3)

Figure 20. Mouth of Deer Canyon. (NABR PR-1)

Natural Bridges Landscape

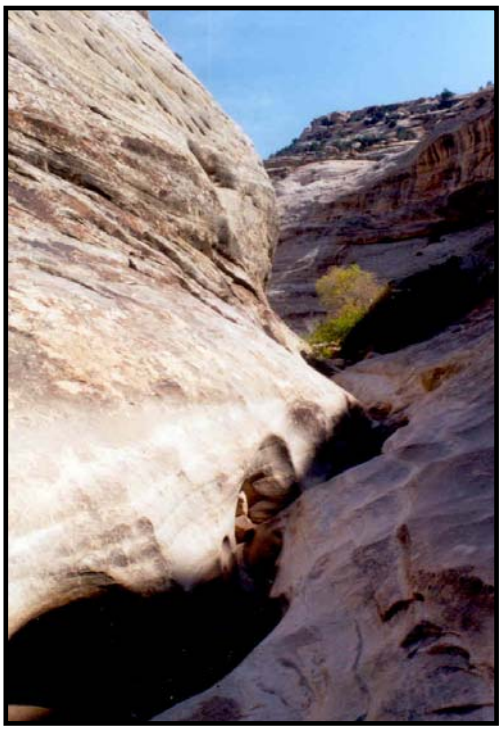


Figure 21. One of many slots in Deer Canyon.

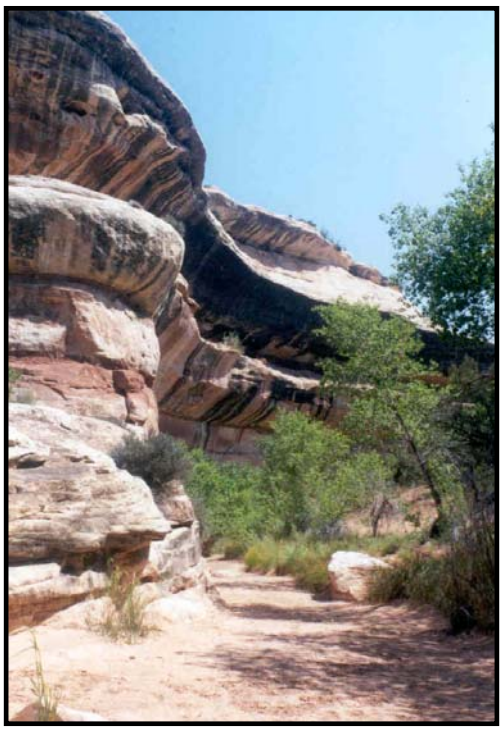


Figure 22. Armstrong Canyon. (NABR PR-4)

Natural Bridges Landscape

Figure 23. Steve Dewey at Owachomo Bridge

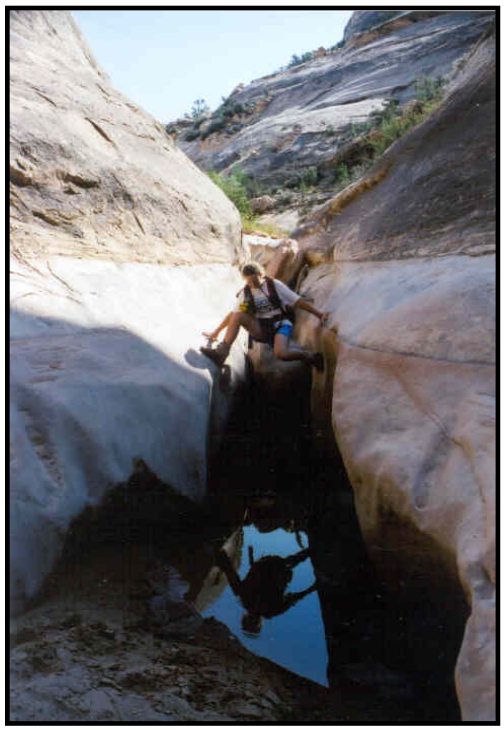
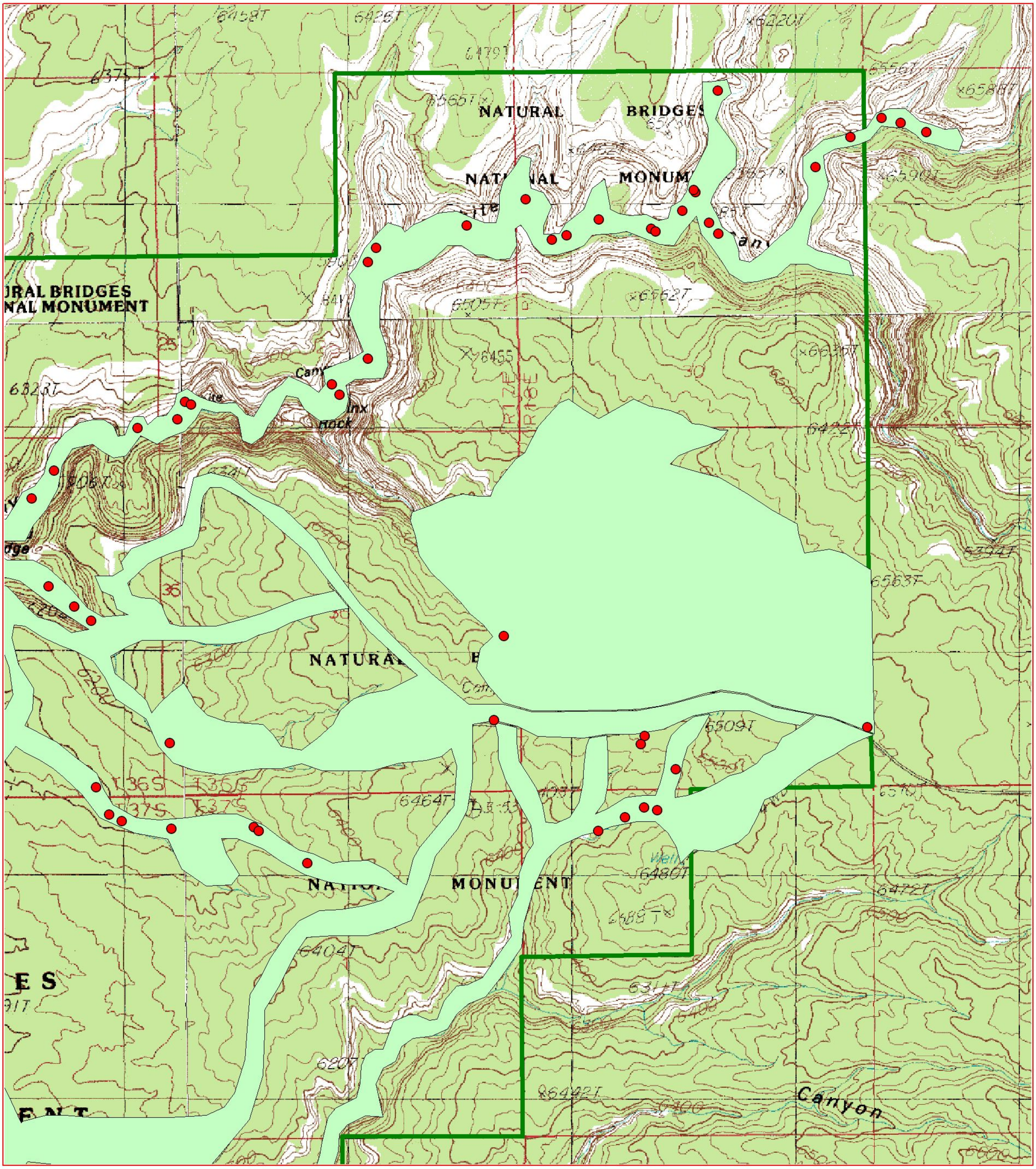
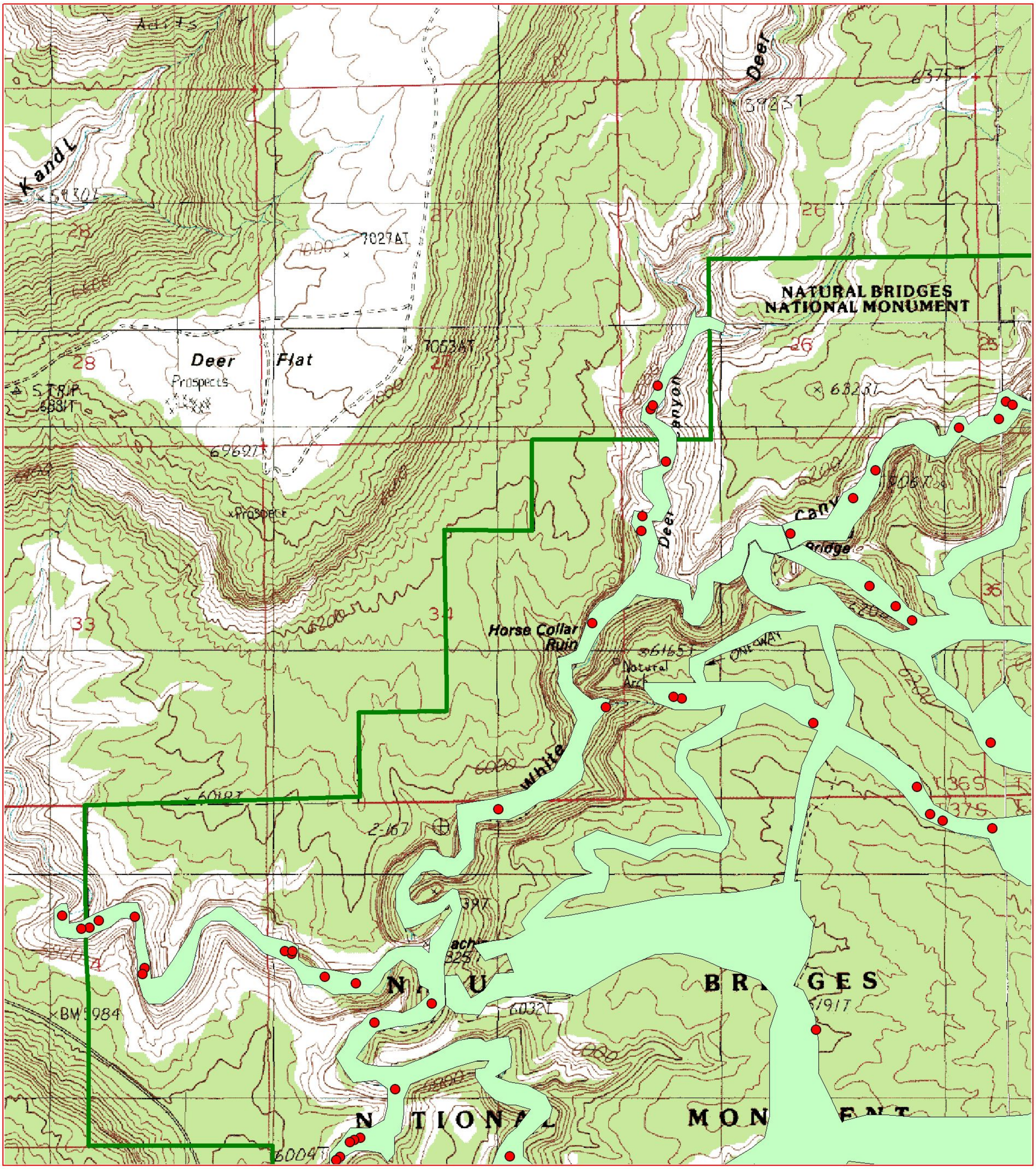


Figure 24. Kim Andersen climbing over a pool in Deer Canyon.

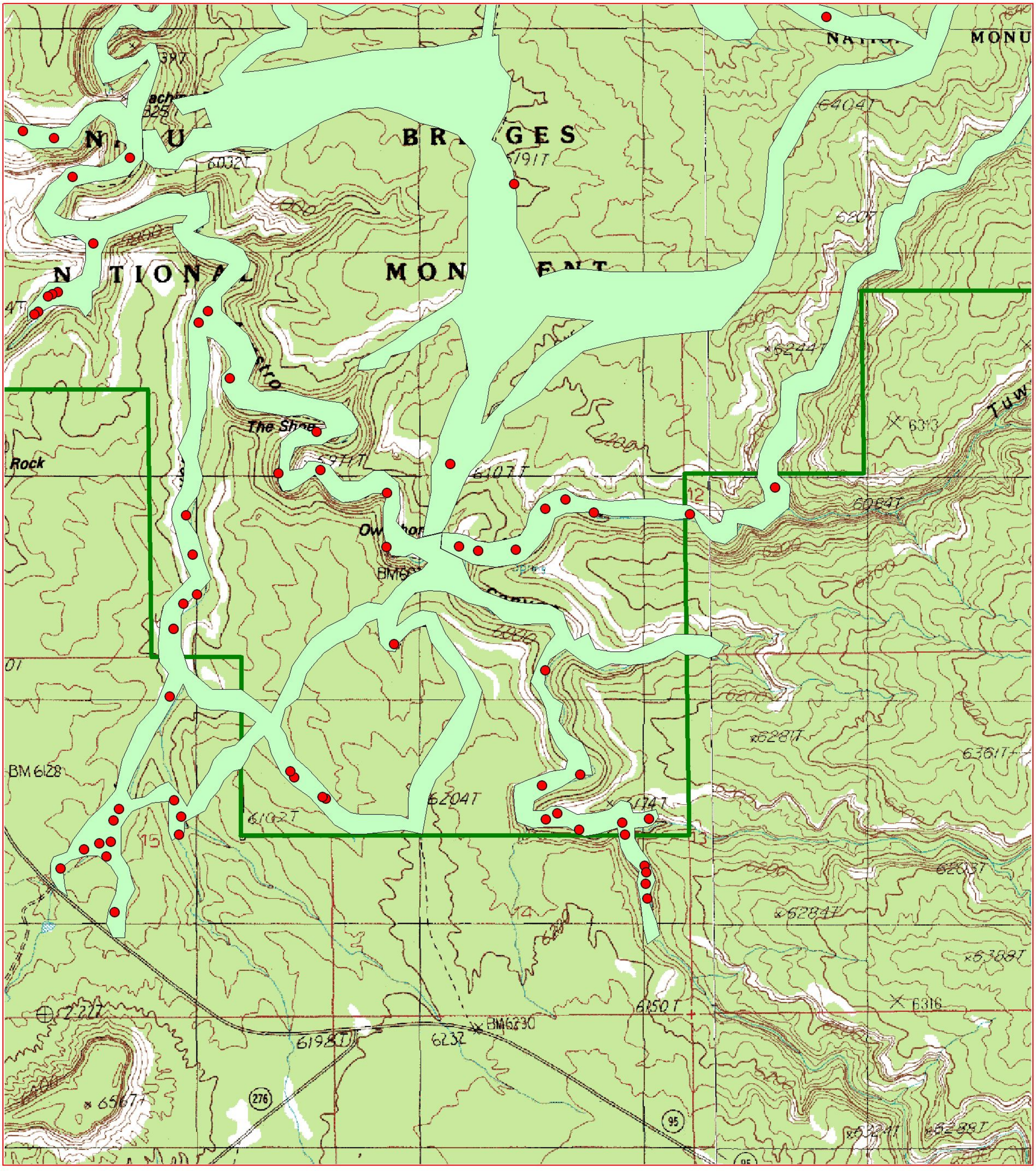
Appendix H. Overall Weed Distribution in Inventoried Areas - Sphinx Rock (Inset A)



Appendix H. Overall Weed Distribution in Inventoried Areas -Horse Collar Ruin (Inset B)

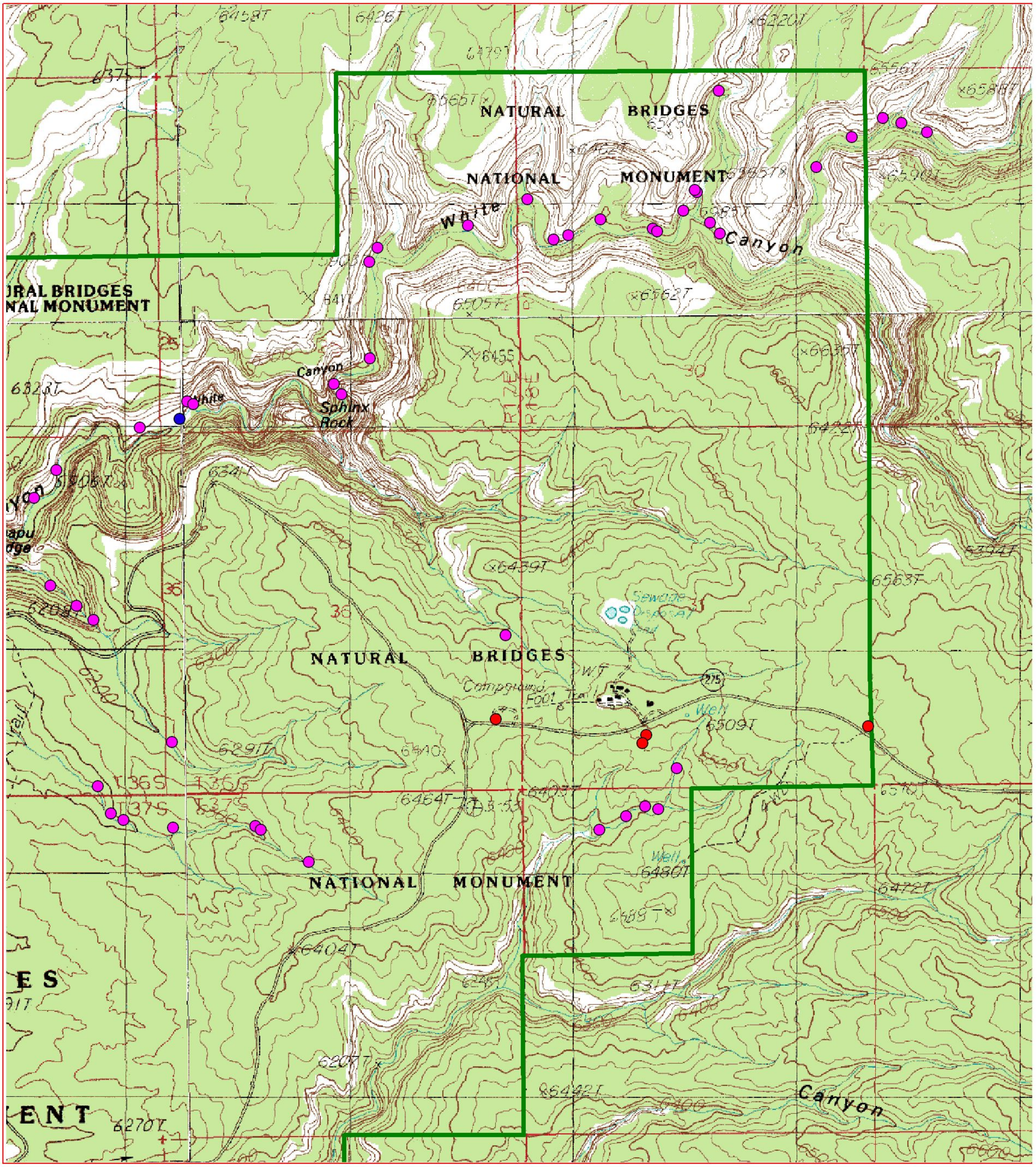


Appendix H. Overall Weed Distribution in Inventoried Areas -Armstrong Canyon (Inset C)



Inset C
Utah State University
Natural Bridges National Monument
2003 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Sphinx Rock (Inset A)



Cirsium arvense

Marrubium vulgare

Tamarix ramosissima

Park boundary

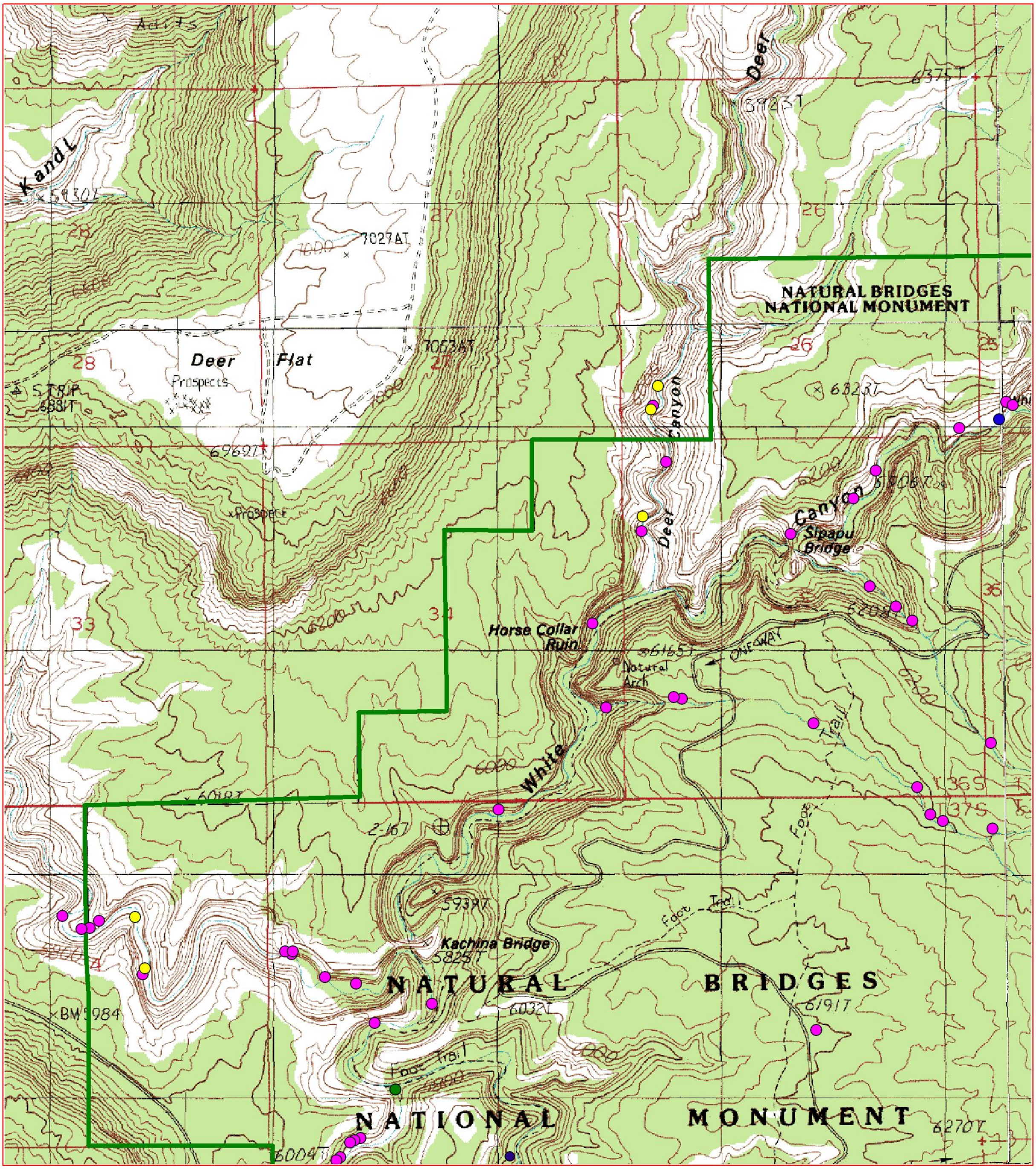
0 2000 4000 Feet

1:24,000 Scale

N

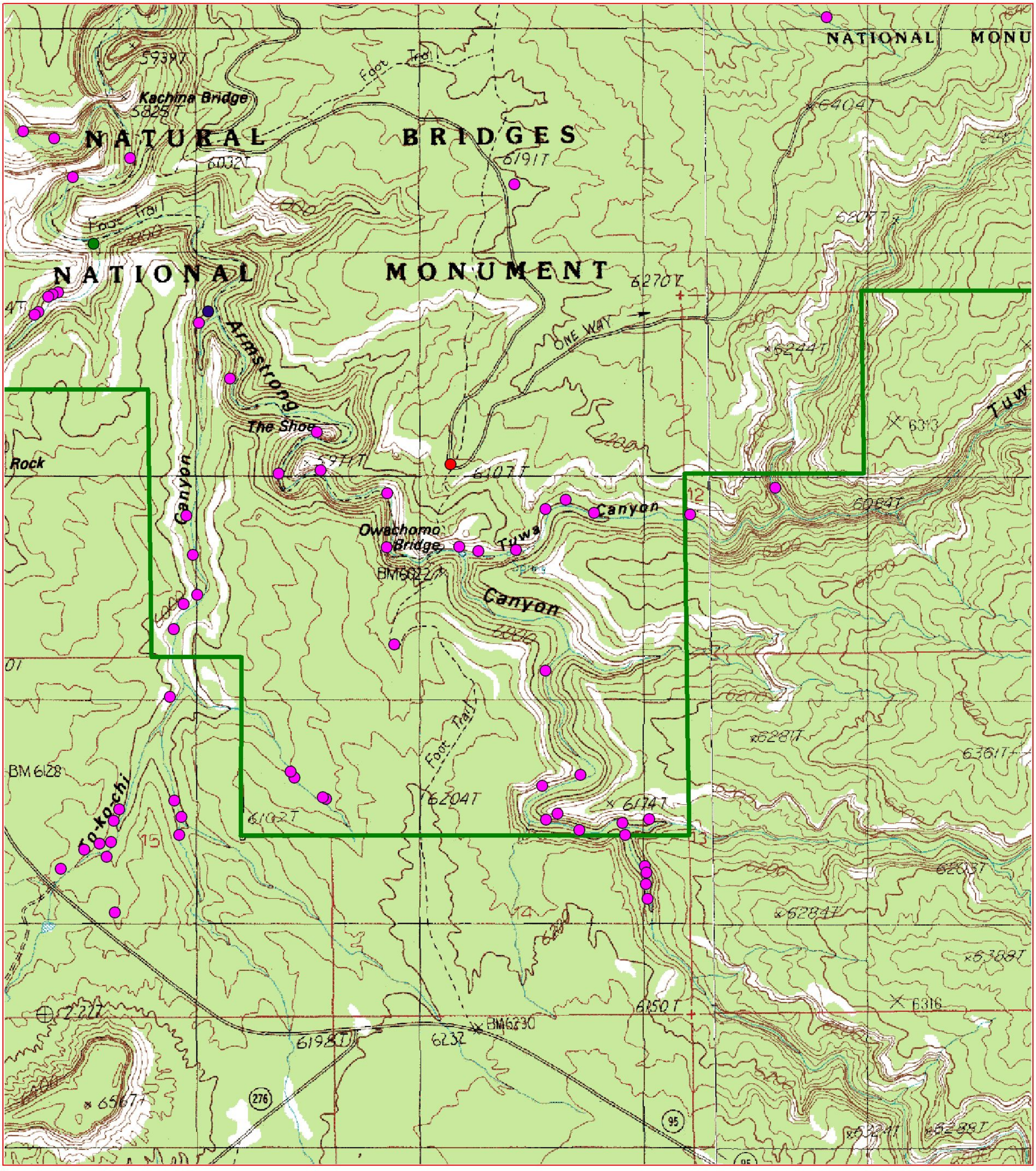
Inset A
Utah State University
Natural Bridges National Monument
2003 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Horse Collar Ruin (Inset B)



Inset B
Utah State University
Natural Bridges National Monument
2003 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Armstrong Canyon (Inset C)



- *Marrubium vulgare*
- *Solanum triflorum*
- *Sonchus oleraceus*
- *Tamarix ramosissima*
- Park boundary

0 2000 4000 Feet

1:24,000 Scale

N

Inset C
Utah State University
Natural Bridges National Monument
2003 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Appendix J. Weed Seed/Propagule Decontamination Procedures, 2004 EPMT Field Training Exercise, Arches National Park

EPMT COURTHOUSE WASH PROJECT

Arches National Park
March 9 – 14, 2004

EPMT Deployment to Arches NP:
The risk of this type of mobilization is that we will bring all types of nasty weeds from all over the country to Courthouse Wash. A recent exotic plant inventory has been conducted within the project area and the only high priority weeds detected were tamarisk and Russian olive. So we will know who to blame if nasty stuff like leafy spurge, miconia, malelueca, kudzu, and spotted knapweed show up (each team has its own signature).

Weed Seed/Propagule Decontamination Procedures:

If you are flying or driving:
Make sure that everything you bring has been cleaned/washed/decontaminated.
Especially be vigilant with gear and clothing you wear in the field at your home units:

- Backpacks
- Boots and shoes
- Socks
- Pants
- PPE

If you are driving be sure to clean/wash/decontaminate:

- Make sure your entire vehicle is power washed before you leave your home unit or go to a local car wash.
- Be extra vigilant while cleaning the undercarriage of the vehicle
- All your equipment
- Chainsaws
- Backpack sprayers
- Saw chaps
- Hard hats
- Gloves
- PPE

Demobilization Decontamination Process:
Same thing in reverse, because I know you don't want tamarisk, Russian olive or cheatgrass in your area!

- Visit a car wash in town
- Lake Mead EPMT will be bringing our steam cleaner power washer to share
- Clean boots in the hotel bath
- Wash clothes in the hotel laundry facilities

Appendix K. Summary of occurrence and inventory status of the 47 non-native species listed in the GPS data dictionary, plus any additional species noted in the 2003 inventory of invasive plants in Natural Bridges National Monument.

GPS Species	A	B	C	D	E	GPS Species	A	B	C	D	E
Agropyron cristatum					X	*Lepidium latifolium*				X	
Ailanthus altissima				X		*Linaria dalmatica*	X				
Alhagi pseudalhagi				X		*Linaria vulgaris*				X	
Anthemis L.					X	*Lythrum salicaria*				X	
Arctium minus				X		*Marrubium vulgare*	X				
Arundo donax				X		*Moluccella laevis*					X
Asparagus sp.					X	*Onopordum acanthium*				X	
Brassica tournefortii					X	*Phleum pratense*					X
Bromus inermis					X	*Rubus discolor*				X	
Bromus tectorum			X			*Rumex crispus*			X		
Cardaria draba				X		*Salsola kali*			X		
Carduus nutans				X		*Sorghum halepense*				X	
Centaurea diffusa				X		*Tamarix ramosissima*	X				
Centaurea maculosa				X		*Tragopogon dubius*			X		
Centaurea repens				X		*Tribulus terrestris*					X
Centaurea solstitialis				X		*Verbascum thapsus*				X	
Centaurea virgata				X		*Ulmus pumila*				X	
Chenopodium album					X						
Cirsium arvense	X					**Other:**					
Cirsium vulgare				X		*Amaranthus albus*			X		
Conium maculatum				X		*Lactuca serriola*			X		
Convolvulus arvensis					X	*Melilotus officinalis*			X		
Cynoglossum officinale				X		*Solanum triflorum*		X			
Dactylis glomerata					X	*Sonchus oleraceus*		X			
Elaeagnus angustifolia				X							
Euphorbia esula				X							
Halogeton glomeratus			X								
Hyoscyamus niger				X							
Isatis tinctoria				X							
Iva xanthifolia					X						

A = Present - Full inventory
B = Present – Partial inventory
C = Present – Not Mapped
D = Searched For - Absent
E = No Information