Zion National Park



2003-2004 Invasive Non-Native Plant Inventory

Northern Colorado Plateau Inventory and Monitoring Network

Final Report

May 2005

Prepared by
Steven Dewey and Kimberly Andersen
Utah State University

Cover photo:

Bromus tectorum and *Bromus rigidus* found growing throughout Zion Canyon. Photo by K. A. Andersen.

Zion National Park

2003-2004 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

Report prepared for: Northern Colorado Inventory and Monitory Network, National Park Service, 2282 S. West Resource Blvd., Moab UT 84532 by Utah State University.

Suggested citation:

Dewey, S. A. and K. A. Andersen. 2005. An Inventory of Invasive Non-native Plants in Zion National Park (2003-2004) – Final Report. Prepared for the National Park Service, Northern Colorado Plateau Network, by Utah State University; Plants, Soils, and Biometeorology Department; Weed Science Research Project Report No. SD0521A, 33 pp. plus appendices.

FINAL REPORT

Inventory of Invasive Non-native Plants Conducted during 2003-2004 in portions of Zion National Park, Northern Colorado Plateau Network of the National Park Service.

TABLE of CONTENTS

INTRODUCTION 1

BACKGROUND and JUSTIFICATION 1

OBJECTIVES 2

METHODS 2
- Selection of Inventory Areas and Target Species 3
- Data Categories 4
- Field Procedures 8
- Points of Interest 11
- General Photographs 11
- Voucher Specimens 12
- Field Data Processing 12
- Post-Season Data Processing 13
- Quality Assurance 14

RESULTS and DISCUSSION 16
- Firepit Knoll 20
- Lee Valley 21
- Grapevine Wash 22
- Northgate Peaks and Pine Valley 23
- Little Creek Drainage 23
- West Rim Trial and Horse Pasture Plateau 23
- Zion Canyon 24

CONCLUSIONS and RECOMMENDATIONS 25

ACKNOWLEDGEMENTS 29

REFERENCES CITED 30

APPENDICES 33

Appendix A. Crew Qualifications and Project Quality Assurance for 2003-2004

Invasive Non-native Plant Inventory in Zion National Park.

Appendix B. Standard GPS Data Dictionary Used in the 2003-2004 Invasive Non- native Plant Inventory in Zion National Park

Appendix C. Relationship of NCPN Project Data Elements to IMR and NAWMA Weed Mapping Standards Used in 2003-2004 Invasive Non-native Plant Inventory in Zion National Park.

Appendix D. GPS Settings Used in 2003-2004 Invasive Non-native Plant Inventory in Zion National Park.

Appendix E. Photograph and List of Equipment Used in 2003-2004 Invasive Non-native Plant Inventory in Zion National Park.

Appendix F. Dominant Vegetation Types Key Used in 2003-2004 Invasive Non-native Plant Inventory, Zion National Park.

Appendix G. Project Photographs of Weed Species Detected, Inventoried Landscapes, and Crew Working in Zion National Park During the 2003-2004 Invasive Non-native Plant Inventory.

Appendix H. Maps of Overall Weed Distribution in Inventoried Areas of Zion National Park in the 2003-2004 Invasive Non-native Plant Inventory.

H-1 Overall Weed Distribution in Inventoried Areas – Zion Canyon (Inset A)
H-2 Overall Weed Distribution in Inventoried Areas- Firepit Knoll (Inset B)
H-3 Overall Weed Distribution in Inventoried Areas – Pine Valley (Inset C)
H-4 Overall Weed Distribution in Inventoried Areas – Lee Valley (Inset D)
H-5 Overall Weed Distribution in Inventoried Areas – Tabernacle Dome (Inset E)
H-6 Overall Weed Distribution in Inventoried Areas – Sawmill Spring (Inset F)
H-7 Overall Weed Distribution in Inventoried Areas – Corral Hollow (Inset G)
H-8 Overall Weed Distribution in Inventoried Areas – Telephone Canyon (Inset H)

Appendix I. Maps Showing Weed Species Detected in Inventoried Areas of Zion National Park During the 2003-2004 Invasive Non-native Plant Inventory.

I-1 Weed Species Detected in Inventoried Areas – Zion Canyon (Inset A)
I-2 Weed Species Detected in Inventoried Areas – Firepit Knoll (Inset B)
I-3 Weed Species Detected in Inventoried Areas – Pine Valley (Inset C)
I-4 Weed Species Detected in Inventoried Areas – Lee Valley (Inset D)
I-5 Weed Species Detected in Inventoried Areas – Tabernacle Dome (Inset E)
I-6 Weed Species Detected in Inventoried Areas – Sawmill Spring (Inset F)
I-7 Weed Species Detected in Inventoried Areas – Corral Hollow (Inset G)
I-8 Weed Species Detected in Inventoried Areas – Telephone Canyon (Inset H)

Appendix J. Weed Seed/Propagule Decontamination Standards and Procedures Used in 2004 EPMT Field Training Exercise in Arches National Park.

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 2003-2004 Inventory of Invasive Plants in Zion National Park.

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 Zion National Park. Results from other Parks are documented in separate Park-specific project reports. Also, please note that this report updates and replaces the 2003 Zion National Park 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. Zion National Park is a member of the Northern Colorado Plateau Inventory and Monitoring Network. A knowledge of current weed distribution, especially in or near previously disturbed areas and riparian areas, was identified as an extremely high priority need by the Northern Colorado Plateau Network.

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 Zion National Park. It was anticipated that information from this inventory will be useful in the Park'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 potential sources of weed introductions and significant vectors involved in weed spread in the Park.

3) Within the scope of this project, USU was to work with regional, network and Park 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 6-person crew in 2003 and a 4-person crew in 2004 to inventory designated areas within Zion National Park. Crew qualifications are documented in Appendix A.

SELECTION OF TARGET SPECIES AND INVENTORY AREAS

Twenty-eight species were identified as high-priority targets in the ZION inventory (Table 1), and searched for systematically by all inventory crew members. Any other non-native species recognized as relatively new to ZION 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 Zion National Park in the 2003-2004 Non-native Plant Inventory.

Invasive species	Common Name
Alhagi pseudalhagi	Camelthorn
Ailanthus altissima	Tree of heaven
Arundo donax	Giant reed
Brassica tournefortii	Asian mustard
Cardaria draba	Hoary cress
Carduus nutans	Musk thistle
Centaurea diffusa	Diffuse knapweed
Centaurea maculosa	Spotted knapweed
Centaurea repens	Russian knapweed
Centaurea solstitialis	Yellow starthistle
Centaurea virgata v. squarrosa	Squarrose knapweed
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle
Cynodon dactylon	Bermuda grass
Elaeagnus angustifolia	Russian olive
Euphorbia esula	Leafy spurge
Lepidium latifolium	Perennial pepperweed
Linaria dalmatica	Dalmatian toadflax
Linaria vulgare	Yellow toadflax
Lythrum salicaria	Purple loosestrife
Molluccella laevis	Bells of Ireland
Onopordum acanthium	Scotch thistle
Rubus discolor	Himalayan blackberry
Salsola kali	Russian thistle
Sorghum halepense	Johnsongrass
Tamarix ramosissima	Saltcedar
Tribulus terrestris	Puncturevine
Verbascum thapsus	Common mullein

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 Zion National Park in 2003 and 2004 included everything in the original Implementation Plan, plus additional areas added after

consultation with Denise Louie, Botanist for Zion National Park. Lands inventoried primarily consisted of plateaus, burned areas, riparian areas, roads, and hiking trails.

The focus of this inventory project was NPS lands. However, in some cases a limited number of additional lands immediately adjacent to the Zion National Park border were inventoried. This occurred if crew members found an infestation of a high-priority weed species straddling across the Park 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 Park boundary. This occurred in the Firepit Knoll inventory area.

Park 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 and 2004 field inventories, and in gathering and analyzing data. NCPN and ZION 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).

Table 2. Description of data fields used in 2003-2004 Inventory of Invasive Non-Native Plants in Zion National Park.

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	ZION	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

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, stage of growth, topography, and associated vegetative cover, in order to maintain the 90 percent minimum detection standard. 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 2003 inventory in Zion National Park was conducted from May 12 – May 22 and involved a six-person crew. In 2004 a four-person crew inventoried portions of Zion National Park from July 12-23 (Table 3). Sites inventoried included Zion Canyon, burned areas near Firepit Knoll, burned areas near Pine Valley, Lee Valley, the West Rim trail, Telephone Canyon, and Horse Pasture Plateau.

For purposes of planning and data analysis the inventoried lands were divided into 9 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 in Firepit Knoll, Lee Valley, and Pine Valley were generally open and visibility was good, allowing relatively broad EDSW's (typically 50 to 100 yards). In areas such as stream corridors or where vegetation cover was heavy such as in Corral Hollow, EDSW's were usually 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. In situations of extremely steep or otherwise inaccessible terrain where vegetation could be identified clearly from a distance, crew members sometimes used binoculars to visually scan the area for suspected target species. 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 Zion National Park was assigned a detection confidence value based on the crew's 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

Table 3: Invasive plant inventory areas, inventory dates, crew members, and acres inventoried during 2003-2004 in Zion National Park.

Area Number	Area Description	Dates Inventoried	Crew Members*	Acres Inventoried**	Corresponding Inset Map Names and Letter Codes ***
1	Firepit Knoll	May 12-13, 2003	KA, MB, JS, EL, RR	511	Firepit Knoll - B
2	PineValley	May 14-16, 2003	KA, MB, JS, EL, RR	1381	Pine Valley - C
3	Horse Pasture Plateau	May 16, 20-22, 2003	KA, MB, JS, EL, RR	1086	Sawmill Spring – F Corral Hollow – G
4	West Rim	May 19, 2003	KA, MB, JS, EL, RR	406	Telephone Canyon - H
5	Zion Canyon	May 17, 22, 2003	KA, MB, JS, EL, RR	376	Zion Canyon - A
6	Lee Valley	July 12, 17, 20, 23, 2004	KA, BA, RR	1954	Pine Valley – C Lee Valley - D Tabernacle Dome - G
7	Little Creek drainage	July 08, 2004	KA, BA	337	Pine Valley – C Lee Valley - D
8	Grapevine Wash	Jul 07, 09, 10, 2004	KA, BA	588	Lee Valley – D Tabernacle Dome - G
9	Potato Hollow, Telephone Canyon	Jul 13-15, 21-22, 2004	KA, BA, MP, RR	1704	Telephone Canyon - H
	TOTALS			8,343	

* Crew abbreviations: BA = Bridget Atkin, KA = Kim Andersen, MB = Melanie Ballard, EL = Eric Lamalfa, RR = Ruth Richards, JS = Janna Simonsen, MP = Monica Pokorny.

** An average of 74.6 acres inventoried per person per 10-hr day in 2003. An average 91.2 of acres inventoried per person per 10-hr day in 2004.

*** Indicates the key to mapped areas presented later in Figure 2.

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 were typically 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, essentially all infestations within this size range were recorded as point features in Zion National Park.

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 Park. 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 Zion National Park. A Voucher specimen of *Marrubium vulgare* was collected along the west side of the road, just north of Tabernacle Dome, near Lee Valley. Duplicate voucher specimens were processed for deposit in herbaria at USU and Zion National Park. The specimen deposited at USU is considered "on loan" from NPS and documented in a loan agreement. Specimens were curated and managed following NPS service-wide protocols. The specimens collected as part of this project are affixed with labels containing information on species, collector, collection date, collection site, and NPS record number. Specimen data also is provided in electronic format.

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 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 Park 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 2003-2004 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 2003-2004 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 policies, and to improve all skills related to the job. Each crew member was 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 inservice training in the form of weed I.D. quizzes or demonstrations, reviewing targeted and other invasive weed species at various stages of growth. Each time any new weed species was found, the identity was verified by the CS and/or PI. Throughout both seasons the PI and CS conducted random field inspections of areas already 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

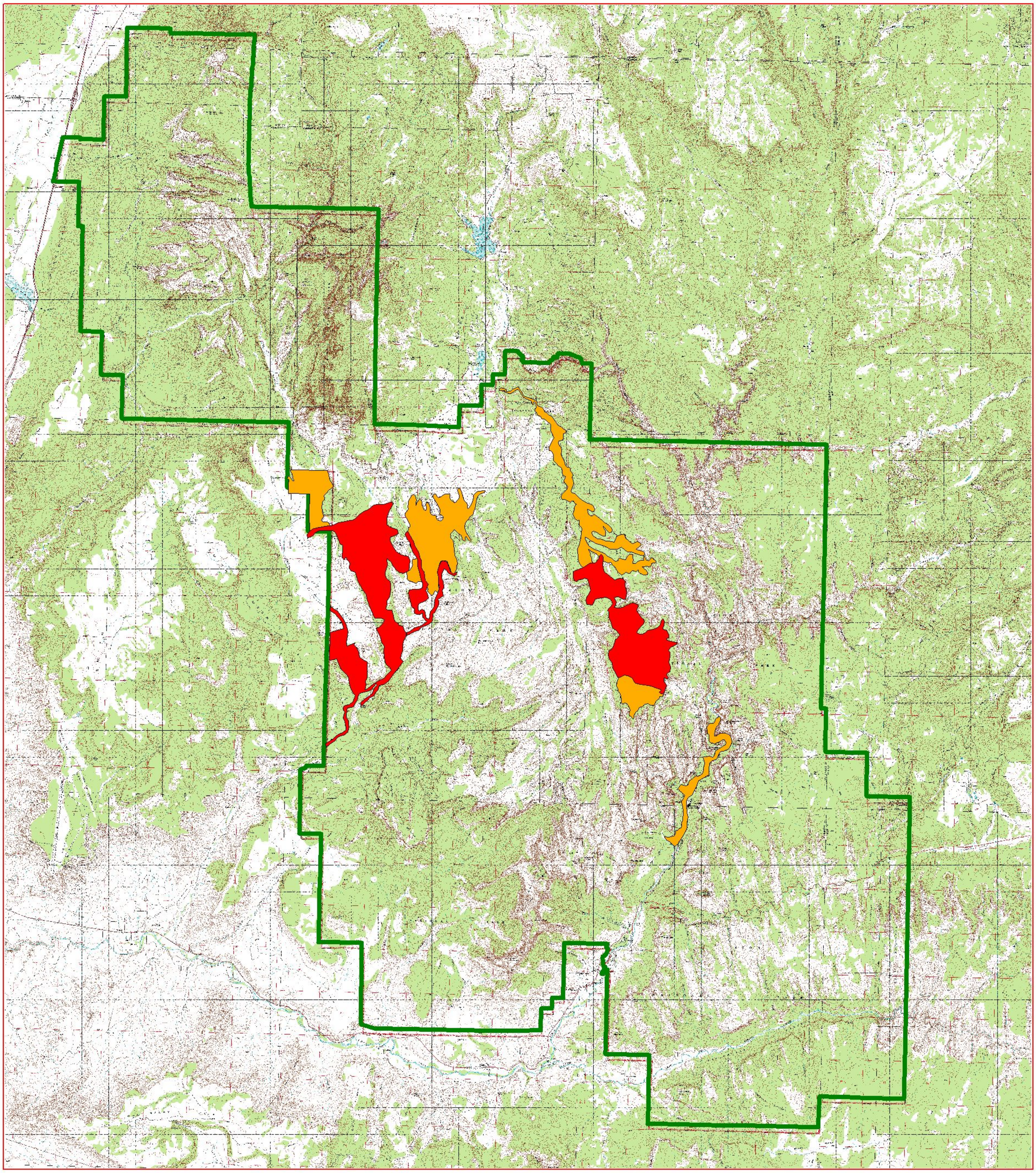
Field Crews inventoried 8,343 acres in Zion National Park during the summers of 2003 and 2004 (Table 3), an amount representing approximately 5.7 percent of the entire 146,598-acre Park. An average of 74.6 acres was inventoried per person per 10-hr day in 2003, and 91.2 acres per person were inventoried per 10-hr day in 2004.

The location and size of areas inventoried in 2003 and 2004 are represented in Figure 1. Lands inventoried in 2003 are shown in orange and those inventoried in 2004 are in red. Figure 2 shows the same lands divided into the nine individual areas referred to for planning and reporting purposes. The identification number, name, and acreage of each inventory area are listed in the legend. Each inventory area is also color-coded for ease in identification. Figure 3 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 - H, plus the name of a distinct geographic feature found within its boundaries. The corresponding inventory area numbers from Figure 2 are included in the legend in parentheses behind each inset map name. Eight inset maps are required to cover all nine inventory areas, and large inventory areas may span over several subunit maps. For example, different sections of Horse Pasture Plateau and the West Rim (Inventory Area 3) appear on Corral Hollow and Sawmill Spring inset maps F and G.

Invasive plants infested a total of 97.6 acres within the mapped areas (Table 4), an amount equal to 1.2 percent of the land inventoried. Of the 28 initial targeted species, crews found only *Carduus nutans*, *Cirsium vulgare*, *Convolvulus arvensis*, *Elaeagnus angustifolia*, *Onopordum acanthium*, *Salsola kali*, *Sorghum halepense*, *Tamarix ramosissima*, and *Verbascum thapsus.* No infestations of *Alhagi pseudalhagi*, *Ailanthus altissima*, *Arundo donax*, *Brassica tournefortii*, *Cardaria draba*, *Centaurea diffusa*, *Centaurea maculosa*, *Centaurea repens*, *Centaurea solstitialis*, *Centaurea virgata v. squarrosa*, *Cirsium arvense*, *Cynodon dactylon*, *Euphorbia esula*, *Lepidium latifolium*, *Linaria dalmatica*, *Linaria vulgare*, *Lythrum salicaria*, *Molluccella laevis*, *Rubus discolor*, or *Tribulus terrestris* were discovered within the 9 inventoried areas. (Note: *Ailanthus altissima*, *Arundo donax*, *Rubus discolor*, *Tribulus terrestris*, and other targeted species were observed in the Watchman and/or South campground, but these areas were not inventoried by the USU crew.) Non-target species found and mapped were *Marrubium vulgare*, *Rumex crispus*, *Ranunculus testiculatus*, *Sisymbrium altissimum*, and *Tragopogon dubius*.

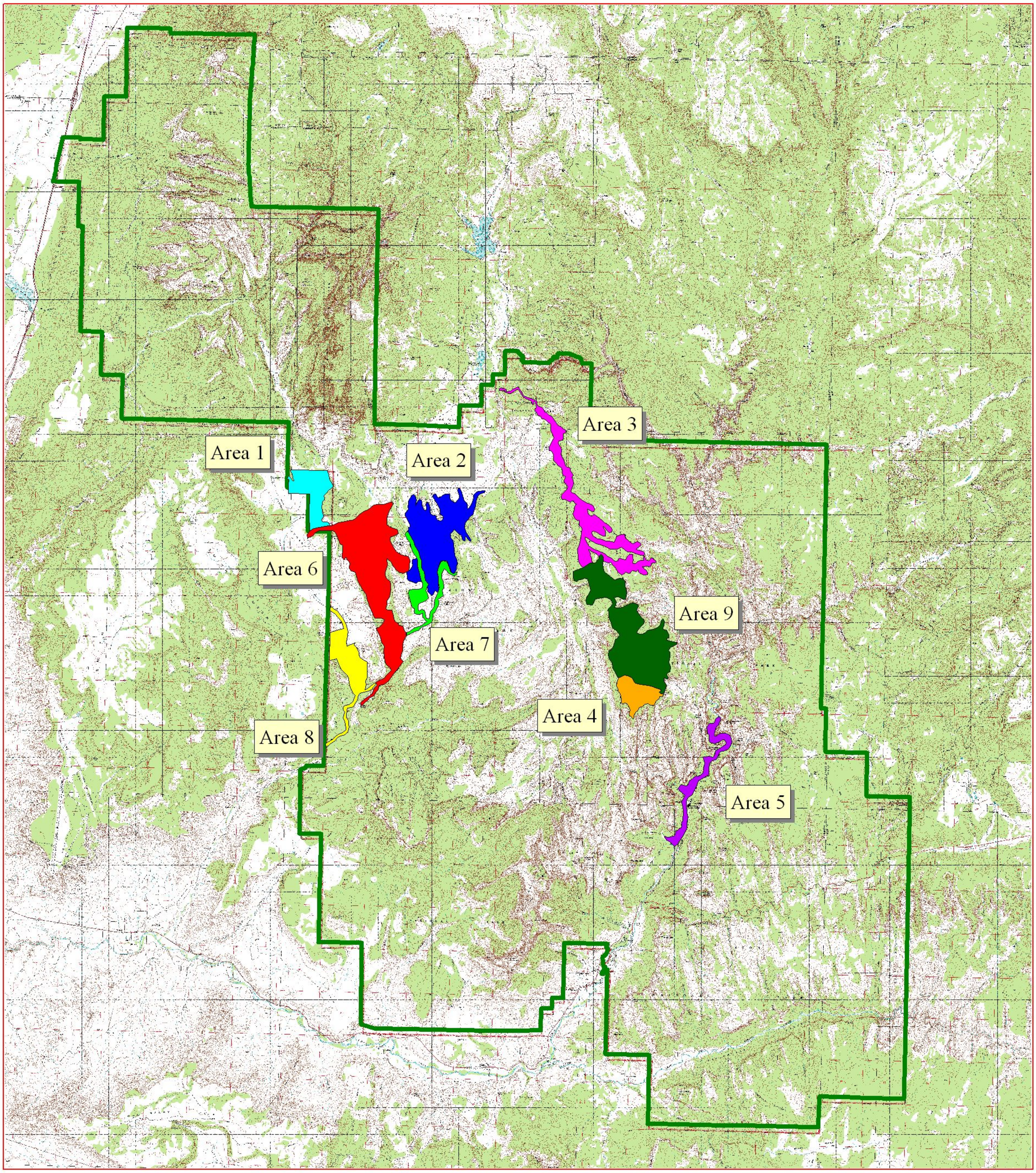
The most abundant target species found in the Park was *Verbascum thapsus*. The crew recorded 80.056 acres of this species during the project, 0.09 acres of which was located outside the Park boundary. *Verbascum thapsus* comprised 82 percent of the total infested acreage inventoried. However, infestations were generally small, often consisting of small patches of senesced stalks or rosettes. *Salsola kali* was the second most abundant species found in the Park and comprised approximately 7 percent of the total infested acreage. *Tamarix ramosissima* was the third most common species, making up 4 percent of the total infested acreage. The remaining infestations (7 percent of the total infested acreage) consisted of the other six targeted species and the five additional non-native species that were mapped.

Figure 1. Total area inventoried for non-native invasive plant species in Zion National Park during 2003 and 2004.



Utah State University
Zion National Park
2003-2004 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Figure 2. Identification number and acreage of individual areas inventoried for non-native invasive plant species in Zion National Park during 2003 and 2004.



Areas Inventoried (2003)

- Area 1 - Firepit Knoll (511 acres)
- Area 2 - Pine Valley (1381 acres)
- Area 3 - Horse Pasture Plateau (1086 acres)
- Area 4 - West Rim (406 acres)
- Area 5 - Zion Canyon (376 acres)

Areas Inventoried (2004)

- Area 6 - Lee Valley (1954 acres)
- Area 7 - Little Creek Drainage (337 acres)
- Area 8 - Grapevine Wash (588 acres)
- Area 9 - Potato Hollow, Telphone Canyon (1704 acres)
- Park boundary

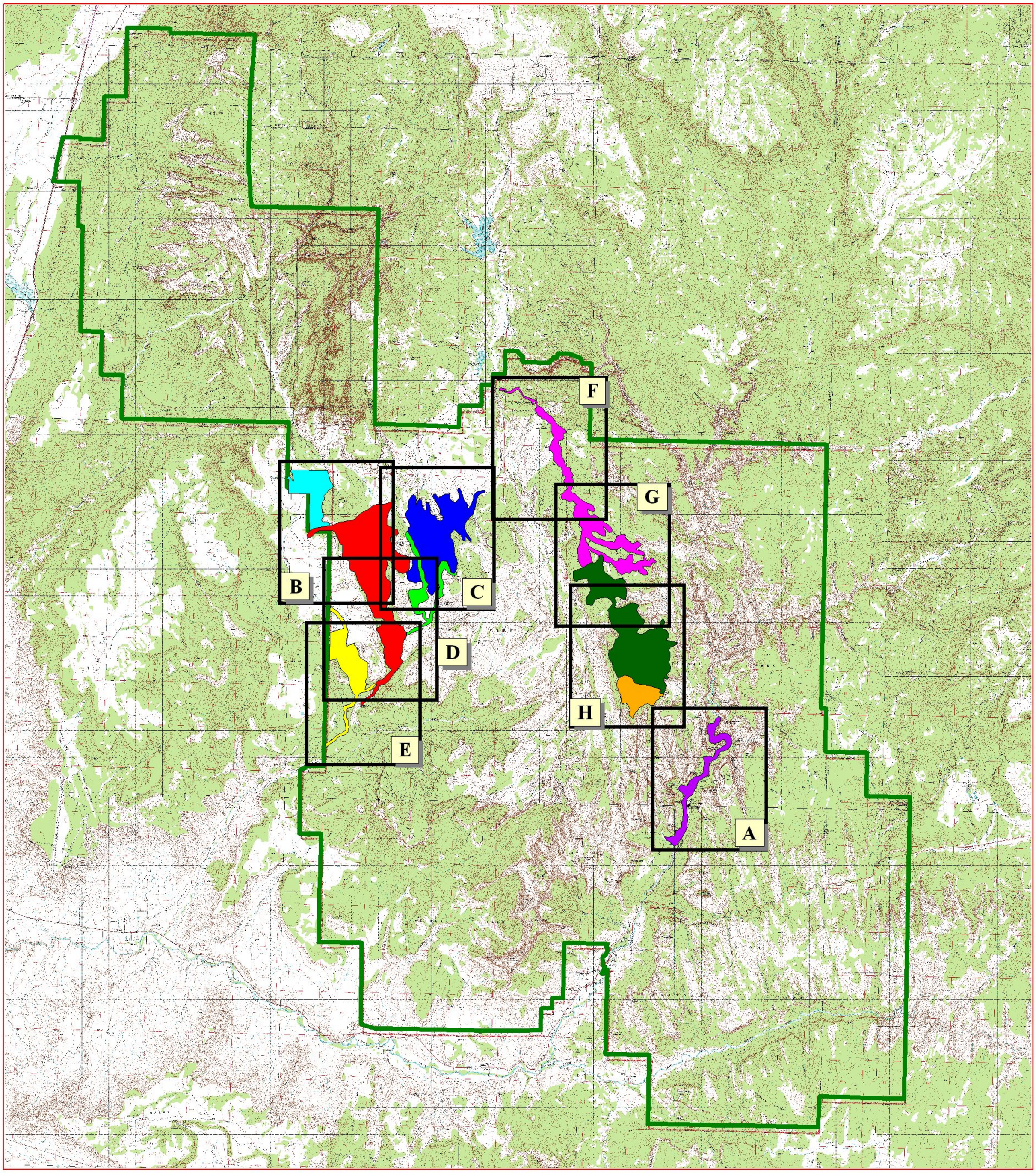
0 2 4 Miles

1:200,000 Scale

N

Utah State University
Zion National Park
2003-2004 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Figure 3. Insets indicating the location, letter code, and name of the eight 1:24,000 scale maps used in Appendix tables to show weed distribution within individual inventoried areas.



Inset A - Zion Canyon (Area 5)

Inset B - Firepit Knoll (Areas1, 6)

Inset C - Pine Valley (Areas 2, 6, 7)

Inset D - Lee Valley (Areas 6, 7, 8)

Inset E - Tabernacle Dome (Areas 6, 8)

Inset F - Sawmill Spring (Area 3)

Inset G - Corral Hollow (Areas 3, 9)

Inset H - Telephone Canyon (Areas 4, 9)

Park boundary

Utah State University
Zion National Park
2003-2004 Invasive Non-native Plant Inventory
Northern Colorado Plateau Network

Table 4: Acres infested by invasive plant species within inventoried areas of Zion National Park and adjacent lands in 2003-2004.

Species	2003	2004	2-Yr Total	Infested Acres (Inside Park)	Infested Acres (Outside Park)
Carduus nutans	0.100	---	0.100	0.100	---
Cirsium vulgare	0.870	0.036	0.906	0.906	---
Convolvulus arvensis	0.010	1.501	1.511	1.511	---
Elaeagnus angustifolia	0.040	0.002	0.042	0.042	---
Marrubium vulgare	0.210	0.103	0.313	0.313	---
Onopordum acanthium	0.370	1.713	2.083	1.563	0.520
Ranunculus testiculatus	---	0.110	0.110	0.110	---
Rumex crispus	1.310	---	1.310	1.310	---
Salsola kali	6.730	0.007	6.737	6.737	---
Sisymbrium altissimum	---	0.124	0.124	0.124	---
Sorghum halepense	0.010	---	0.010	0.010	---
Tamarix ramosissima	4.180	0.048	4.228	4.228	---
Tragopogon dubius	---	0.039	0.039	0.039	---
Verbascum thapsus	59.240	20.816	80.056	79.966	0.090
Totals	**73.07**	**24.499**	**97.569**	**96.959**	**0.610**

Not all non-native species that were found were mapped. For example, species such as *Bromus tectorum* and *Bromus inermis* were especially prevalent in many areas but were ignored due to their previously recognized abundance in the Park. Other species present but ignored included *Agropyron cristatum* and *Chenopodium album*.

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. Crews were consistent in searching for and recording all infestations of *Marrubium vulgare*. Because not all crew members may have chosen to map *Rumex crispus, Ranunculus testiculatus, Sisymbrium altissimum,* and *Tragopogon dubius*, the acreage values and corresponding distribution maps for these species should be considered to represent sample surveys rather 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 Zion National Park. Following is a summary of the weed situation within individual inventory units of Zion National Park.

Firepit Knoll (Area Number 1; Inset Map B)

The inventoried area near Firepit Knoll was fairly open and consisted of a mixture of grassland and oak woodlands. The primary weedy species found was *Verbascum thapsus*. Infestations were rarely larger than 0.01 acre in size and were mostly groups of senesced stalks from previous

years. The remaining infestations of *Verbascum thapsus* were generally composed of small rosettes. *Verbascum thapsus* was found in both open grasslands and under dense oakbrush.

Several infestations of *Onopordum acanthium* were found in fields northwest of Firepit Knoll. All were in the seedling to small rosette stage at the time of detection. Because several native thistle species are known to occur in the region, and because the rosettes of *Onopordum acanthium* can look very similar to some native thistles in early stages, it is possible that a few of these rosettes may have been misidentified. A follow-up visit to these sites later in the season is recommended for verification.

A few senesced *Salsola kali* were found west of the Knoll, and two infestations of *Rumex crispus* were recorded along the hiking trail. No other targeted species were found in the Firepit Knoll inventory area. Weedy species not mapped but observed included *Bromus tectorum*, *Chenopodium album*, and *Lactuca serriola*.

This Firepit Knoll area was inventoried in May of 2003 when many of the other target species would have been in very small rosette or vegetative stages of growth. Others may not yet have even emerged. It is therefore possible that some individual plants or very small infestations of one or more target species may have been missed. However, if any infestations of such species 0.01 acres in size or larger had been present, their standing dead vegetation from last year's growth almost certainly would have been observed and identified. Visibility was generally good and it is unlikely that any 0.01-acre infestations would have been missed in the open fields. Inventorying in the stands of oak and juniper was more difficult, but again is it unlikely that the crew would have missed patches of live or dead vegetation at least 0.01 acres in size. Fire was the most obvious recent disturbance but it was also evident that cattle had been in the area in the past couple of years. A stock pond at the northwest corner of the field was one of the weedier spots in this area. The Firepit Knoll inventory area was assigned an ecological status of two.

Lee Valley (Area Number 6; Inset Maps C, D, G)

Lee Valley was inventoried in 2004 and has a history of grazing and agricultural use which may have contributed to its weediness. The primary species present was *Verbascum thapsus*. Infestations ranged in size from 0.001 acre to 1 acre, but the vast majority of infestations were no larger than 0.01 acre. Infestations were more common in the northern half of the valley, where active grazing still occurs. A large number of infestations were also found in Wolf Spring Wash and the next wash east. Infestations of *Verbascum thapsus* were commonly comprised of large flowering stalks and it appeared that the species was actively reproducing and spreading in Lee Valley.

Onopordum acanthium was prevalent throughout Lee Valley, and most infestations included flowering plants at the time of inventory. Most infestations were less than 0.01 acre in size, and the majority were located in the southern half of the Valley in creek beds or dry stock ponds. *Onopordum acanthium* also occurred frequently in areas with past agricultural use. The southern tip of Lee Valley consists of fields of *Secale cereale*, and *Onopordum acanthium* could be found scattered throughout most of these fields. Infestations also were found near stock ponds along Pine Spring.

Tamarix ramosissima was found in Lee Valley almost exclusively in lower Wolf Springs Wash. A single *Tamarix ramosissima* also was found at a stock pond west of Pine Valley Peak. The majority of the infestations consisted of 1-2 saplings found mixed in with willows along the streambed. Some trees had evidence of previous control treatments. A single *Elaeagnus angustifolia* was found at a large spring feeding into Wolf Springs Wash, and had also been controlled prior to the inventory. Two infestations of *Cirsium vulgare* were also found in Wolf Spring Wash. A third infestation of Cirsium vulgare was found in the northeast corner of Lee Valley. *Convolvulus arvensis* was scattered throughout Lee Valley, often along roads or stock ponds with infestations ranging in size from 0.01 to 0.25 acres in size. *Salsola kali* was also found, often associated with roads or stock ponds.

Non-target species mapped include *Tragopogon dubius*, *Marrubium vulgar*e, and *Sisymbrium altissimum*. *Tragopogon dubius* was found in two separate areas in Lee Valley. One large group consisting of several infestations was found east of Spendlove Knoll at the head of Wolf Springs Wash amid the heavy oakbrush. The second group of infestations was found at the south end of Lee Valley mixed in the fields of *Secale cereale*. *Sisymbrium altissimum* was found in the southern half of the Valley associated with stock ponds. Two separate infestations of *Marrubium vulgare*, each consisting of a single plant were also found and recorded. Each occurred under heavy oakbrush. Species observed but not mapped include *Bromus tectorum*, *Bromus inermis*, *Secale cereale*, and *Chenopodium album.*

Lee Valley is a mixture of open fields with very good visibility, shrubland with good visibility, and oakbrush with limited or no visibility. It is likely the crew missed some smaller infestations of one or more target species in the oakbrush due to the limited visibility. However, inventoried oakbrush areas appeared to contain very few weedy species. Overall, the crew felt confident of finding 90 percent or more of all 0.01-acre infestations of the targeted species. The area showed signs of several disturbances including grazing, past cultivation of the fields, and fire. Most of the fields were either sagebrush or *Secale cereale*, while the edges of the Valley were comprised of oak woodlands. Due to the prominence of several weedy species as well as the lack of native species is several places, the overall ecological status of Lee Valley is given a rating of four.

Grapevine Wash (Area Number 8; Inset Maps D, G)

The area between the western Park boundary and Tabernacle Dome, including Grapevine Wash, was inventoried in 2004. Crews found only four targeted species in this inventory area, and the majority of infestations were near the main highway. Four infestations of *Verbascum thapsus* were recorded, of which three were directly on the road shoulder. A single infestation of *Convolvulus arvensis* also was found on the road shoulder. A single infestation of *Salsola kali* was located in Grapevine Wash.

One large patch of *Onopordum acanthium* was discovered outside the Park boundary north of Lamb's Knoll. This 0.5-acre infestation was less than 500 yards from the Park boundary and less than 200 yards from the main road. Although outside Zion National Park, it was documented due to its potential to spread and invade into the Park.

Non-target species found and recorded in or near Grapevine Wash include *Marrubium vulgare*, *Tragopogon dubius*, and *Ranunculus testiculatus.* The majority of these infestations were

located directly on the road shoulder. Species noted but not mapped include *Bromus tectorum*, *Bromus inermis*, *Chenopodium album*, and *Secale cereale*. The *Secale cereale* found in Grapevine Wash likely came from the agricultural fields above the head of the Wash.

Visibility was moderate in this inventory area due to the heavy canopy cover of native shrubs and trees. The native plant community is very healthy and no obvious disturbance was noted. Crews were confident of finding all 0.01-acre or greater infestations of the targeted species. Due to the lack of abundant invasive species and the healthy nature of the native community, an ecological status of two was assigned to this inventoried area.

Northgate Peaks, Pine Valley (Area Number 2; Inset Map C)

Pine Valley and the areas north of Northgate Peaks were inventoried in 2003. The unit consists of a mixture of grassy meadows and ponderosa pine. Only four target species were found in this area. The most abundant was *Verbascum thapsus*. Although the sizes of these infestations ranged from 0.01 acre to 5 acres in size, the majority were 0.01 acre in size and consisted of small groups of 1-5 rosettes. Infestations occurred most frequently in creek beds or in areas that were heavily disturbed by fire.

A single infestation of *Onopordum acanthium* was discovered near the Lava Point trail, and a single patch of *Cirsium vulgare* was found at the base of Northgate Peaks. These infestations were pulled at the time of their discovery. Although not a target species, *Rumex crispus* was also mapped in Pine Valley.

The inventory area was open, and visibility was generally very good. Crews were confident of finding at least 90 percent of all targeted species infestations 0.01 acre or greater in size. The native plant community appeared intact despite the disturbance caused by recent fire, and there was a good mix of native grasses, sagebrush, oak, ponderosa pine, and Douglas fir. The area inventoried was assigned an ecological status of two.

Little Creek Drainage (Area Number 7; Inset Map C, D)

The Little Creek drainage was inventoried from its head at Pine Valley Peak to its junction with Left Fork in Great West Canyon in 2004. The primary species found in Little Creek was *Verbascum thapsus*. The infestations were concentrated at either the head of Little Creek, or at the junction of Little Creek and Left Fork. Twenty-two of the twenty-six infestations of *Verbascum thapsus* in this unit were in the 0.001-acre size category, and often consisted of single plants or groups of 1-5 plants.

Tamarix ramosissima was the only other target species found in the unit, scattered intermittently along Little Creek. Seven infestations were recorded, with each infestation consisting of a single tree. Three of the seven trees were mature, while the remaining four were saplings. Non-native species observed but not mapped include *Melilotus officinalis, Lactuca serriola, Bromus inermis,* and *Bromus tectorum*.

Little Creek is a small drainage with a good stand of native vegetation. Willow, cottonwood, wild rose, oak, and rabbitbrush are all present in the drainage. The only disturbances noted were flooding and rock slides. Crews were very confident of finding all 0.01-acre or larger

infestations of targeted weed species. An ecological status of two was assigned to this inventory area.

West Rim and Horse Pasture Plateau (Area Numbers 3, 4, 9; Inset Map F, G, H)
Horse Pasture Plateau was inventoried in its entirety between 2003 and 2004. The majority of Horse Pasture Plateau is abundantly infested with *Verbascum thapsus*. *S*everal of the side canyons along Horse Pasture Plateau including Corral Hollow, Potato Hollow, Sleep Hollow, and several other unnamed draws and canyons also were heavily infested with *Verbascum thapsus*. It also was found heavily along the West Rim Trail and areas disturbed by recent fires.

Cirsium vulgare was discovered in a few places along Horse Pasture Plateau. One infestation was located at the base of a large tree that had burned in the recent fire in Corral Hollow. Several other infestations were found in a burned area within the southernmost drainage south of Telephone Canyon. *Cirsium vulgare* was also found at the spring in Potato Hollow and at the top of Potato Hollow.

Two infestations of *Onopordum acanthium* were noted along the West Rim Trail approximately 200-300 yards from the backcountry campsites. A single infestation of *Carduus nutans* was discovered in the southernmost drainage south of Telephone Canyon. The infestations of *Onopordum acanthium* and *Carduus nutans* were pulled by the mapping crew. An infestation of *Salsola kali* also was found in Corral Hollow.

Tragopogon dubius was a non-target species, but two infestations were recorded at the spring in Potato Hollow. Species noted but not mapped include *Bromus inermis, Bromus tectorum, Lactuca serriola,* and *Chenopodium album.*

Horse Pasture Plateau is a large area consisting of both upland ponderosa pine forests, canyons of oakbrush, and grassland meadows. There is a healthy amount of native vegetation over the majority of the Plateau. Some areas contained heavy amounts of oak, and visibility was often extremely limited, making progress slow. All areas were inventoried as thoroughly as possible. The crew did sample some areas rather than conduct a thorough inventory because it was nearly impossible to walk through the densest stands of oak. Those sampled areas contained few if any weedy species, and those species present usually occurred in small clearings. It is likely this situation could be extrapolated to all areas with heavy oak cover. Overall, the crew was confident of finding at least 90 percent of all 0.01-acre infestations in the areas they were able to inventory. The only obvious disturbance in this unit was due to recent fires. An ecological status of three was assigned to Horse Pasture Plateau due to the prevalence of *Verbascum thapsus.*

Zion Canyon (Area Number 5; Inset Map A)
The area between the main road and the Virgin River in Zion Canyon was inventoried in 2003. The inventory extended from Court of the Patriarchs to the area below Scout Lookout. Zion Canyon has been historically disturbed and continues to be disturbed by foot traffic, horse pack trails, roads, and natural flooding from the Virgin River. It was the weediest unit inventoried during 2003 and 2004. The most abundant target species recorded in Zion Canyon was *Verbascum thapsus*. Infestations ranged in size from 0.01 acre to 0.25 acres, and often consisted

mainly of rosettes. The second most abundant species was *Tamarix ramosissima*. Most of the *Tamarix* infestations were 0.01 acres in size, but infestations ranged from 0.01 acres to 1 acre. *Tamarix ramosissima* infestations were mostly small to large saplings occurring as singles or groups of 2-10 plants. It is possible that some single *T. ramosissima* saplings were missed during the inventory of Zion Canyon as they were often mixed in heavy stands of willow of approximately the same size.

Salsola kali was also a common species in Zion Canyon. Infestations were found in the open meadows near the riverbed, forming moderately dense stands intermixed with weedy grasses. Infestations ranged from 0.01 acres to 2.5 acres in size, and often were senesced at the time of mapping. Other species found and inventoried include four infestations of *Elaeagnus angustifolia*. Two of those infestations were located south of Mount Moroni, near the Court of the Patriarchs. The other two infestations were discovered north of the Organ. Additional target species found in trace amounts include *Cirsium vulgare, Onopordum acanthium, Sorghum halepense*, and *Convolvulus arvensis.*

Non-target species mapped in Zion Canyon include *Marrubium vulgare* and *Rumex crispus*. Species observed but not mapped include *Bromus inermis, Bromus tectorum, Melilotus officinalis*, and *Lactuca serriola*. *Bromus inermis* and *Bromus tectorum* were especially prevalent throughout Zion Canyon, often making it difficult to see other lower-growing weeds. Nevertheless, crews were still confident of finding at least 90 percent of all targeted species infestations 0.01 acre or greater in size. Despite the abundance of weeds, Zion Canyon still contained some native vegetation, and efforts should be made to protect these species. However, an ecological status of four was assigned to the area.

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 Zion National Park. It is anticipated that the information obtained from this inventory will be useful in the Park'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 Zion National Park is already implementing many effective weed control strategies and practices, for which they are to be commended. The USU crew frequently encountered evidence of control efforts on infestations they mapped. For example, the inventoried site of *Elaeagnus angustifolia* as well as several sites of *Tamarix ramosissima* along the Virgin River had been previously cut, and infestations had simply resprouted. Also, infestations of *Arundo donax, Rubus discolor*, and other invasive species observed by the USU crew in the Watchman campground showed evidence of active control efforts.

If it does not already exist, the Park is urged to develop a comprehensive written management plan for invasive plant species in ZION, similar to the plan currently being finalized by Utah State University for Dinosaur National Monument. If there currently is a written plan, the Park

is encouraged to review and improve it on a regular basis. An excellent reference that will aid the Park 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 emphasizing early detection and rapid response. 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 5 to 10 years. A rotating schedule should be developed by Zion National Park to inventory portions of their land each year, so that within a reasonable number of years all of the Park 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, Zion National Park also should consider establishing permanent monitoring sites (if it hasn't already done so) 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, Zion National Park 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 highly invasive species should be given highest priority, with the ultimate objective being their 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, 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 this strategy to Zion National Park would mean that species such as *Carduus nutans*, *Cirsium vulgare*, *Marrubium vulgare*, and *Elaeagnus angustifolia* should be given the highest control priority of the species mapped, and should be targeted for prompt Park-wide eradication. The small infestations of *Ailanthus altissima, Arundo donax, Rubus discolor, Tribulus terrestris,* and other targeted species located in the Watchman and South campgrounds should continue to be the objects of eradication efforts. *Tamarix ramosissima*, *Onopordum acanthium*, *Convolvulus arvensis*, and *Salsola kali* probably fit best into the second priority category of "contain and reduce" in some portions of the Park, but also could be candidates for eradication in other areas. For example, *Tamarix ramosissima* was prevalent in Zion Canyon and probably beyond feasibility of eradication there, at least in the near term. But it was relatively rare in Wolf Springs Wash, and could be eliminated from that drainage. Plants that we would place in the third management category (lowest priority) include *Verbascum thapsus*. We would also include *Bromus tectorum* and *Bromus inermis* in that category, both of which were widespread throughout the Park and too abundant for meaningful mapping.

The Park will likely need additional inventory information before deciding in which management category to place *Tragopogon dubius, Sisymbrium altissimum, Ranunculus testiculatus, Rumex crispus, Chenopodium album, Lactuca serriola,* and *Melilotus officinalis*. These non-native species appeared only scattered throughout the Park, but this assessment is based on an incomplete survey rather than a true inventory. If further study reveals that these species truly are relatively scarce in the Park, 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 Park. Humans are the most likely vectors for new introductions of invasive plant species into Zion National Park 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 2,600,000 per year visit Zion National Park alone. 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. Park 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 Park's Visitor Center, through displays or a video program, and evening fireside presentations to visitors made by NPS personnel.

Routine Park 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 Park 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 K). 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. 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, 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 Zion National Park, 98.8 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 ZION 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 25 invasive weed species of great concern to the region (Appendix L).

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 Zion National Park that are currently "clean" should be identified as WPAs, and Park management should take all appropriate measures to keep invasive weeds 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 invasive weeds 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 with a Park could help to justify increased budgets for prevention practices. Increasing the number of weed-free acres in a Park should be recognized as a highly significant accomplishment, and land 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 "weed free"). WPA's also present an opportunity for Parks to help the general public feel more involved as visitors see more clearly the focus of the 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).

ACKNOWLEDGEMENTS:

We express appreciation to Pam Benjamin at the NPS Intermountain Support Office in Denver, CO, and Angie Evenden and Margaret Beer at the Northern Colorado Plateau Network in Moab, UT, for their vision and efforts in initiating this inventory project. Thanks to Angie and Margaret for their thorough reviews of our data and reports, and to Aneth Wight for always being able to solve our GIS problems. We are grateful to Ian Torrence and Liz Ballenger for their help in logistical planning and coordination with individual Parks. Thanks to the contacts in each Park and Monument (Tamara Naumann, Denise Louie, Sean Haile, Kristen Legg, Tom Clark, Dave Worthington, and Danguole Bockus) who went out of their way to accommodate the requests of our crews. Above all, we thank the dedicated and hard-working USU and NPS crew members who frequently encountered potentially dangerous situations and conditions, and endured considerable physical hardship while hiking hundreds of miles in the intense summer heat and rugged backcountry of southern Utah to collect this information.

References Cited

Andersen, K., S. Dewey, and M. Ballard. 2003. Field Techniques for Improving Accuracy and Efficiency of GPS Wildland Weed Surveys. Proc., Western Society of Weed Science, 56:87.

Andersen, K. and S. Dewey. 2005. Do's and Don'ts of Wildland Weed Mapping - The USU Experience. Proc., Idaho Weed Control Association Conf., Nampa, ID.

Asher, J. E. and D. W. Harmon. 1995. Invasive exotic plants are destroying the naturalness of U.S. wilderness areas. International Journal of Wilderness, Vol 1, No.4, p. 35-37.

Ballard, M., S. Dewey, and K. Andersen. 2003. Using GPS Point Features to Describe Spot, Line, and Area Infestations in Wildland Weed Surveys. Proc., Western Society of Weed Science, 56:86.

Benjamin, Pamela K. 2001. Weed Mapping and Database Development Guidelines for the National Park Service Intermountain Region (IMR). Intermountain Support Office, Denver, CO. 22pp. plus appendices.

Clinton, William. 1999. "Invasive Species." Executive Order 13112 of February 3, 1999 (as amended by E.O. 13286 on February 28, 2003). (64 F.R. 6183, February 8, 1999).

Coulloudon, B, K. Eshelman, J. Gianola, N. Habich, L. Hughes, C. Johnson, M. Pellant, P. Podborny, A. Rasmussen, B. Robles, P. Shaver, J. Spehar, and J. Willoughby. 1999. Sampling Vegetation Attributes. Interagency Tech. Ref. 1734-4. p. 31-130.

D'Antionio, C. and N. Jackson. 2003. Invasive plants in natural and managed systems: linking science and policy. Abstr., 7th International Conference on the Ecology and Management of Alien Plant Invasions, Ft. Lauderdale, FL., 104 pp.

Dewey, S., K. Andersen, M. Ballard, J. Simonsen, R. Richards, and E. Lamalfa. 2003. Invasive non-native plant inventory conducted in portions of Arches, Canyonlands, Hovenweep, Natural Bridges, Black Canyon, and Zion National Parks. Ann Prog Report (8 volumes), submitted to the Intermountain Regional Office of the National Park Service, Denver, CO, and the Northern Colorado Plateau Network, Moab, UT.

Dewey, S.A. and K.A. Andersen. 2004a. Strategies for Early Detection - Using the Wildfire Model. Weed Technol. 18:1396-1399.

Dewey, S.A. and K.A. Andersen. 2004b. Distinct Roles of Surveys, Inventories, and Monitoring in Adaptive Weed Management. Weed Technol. 18:1449-1452.

Dewey, S.A. and K.A. Andersen. 2005a. Determining Effective Search Swath Widths for Wildland Weed Surveys. Proc., Western Society of Weed Science Conf., Vancouver, BC.

Dewey, S.A. and K.A. Andersen. 2005b. Quality Assurance Measures for Invasive Weed Surveys on Wildlands. Abstr., Weed Science Society of America Conf., No. 121, p. 37.

Dewey, S.A. and K.A. Andersen. 2005c. Strategies for Early Detection – Using the Wildfire Model. Weed Technology 18: 1396-1399.

Duncan, C. L., and J. K. Clark (eds.). 2005. Invasive Plants of Range and Wildlands and Their Environmental, Economic, and Societal Impacts. Weed Science Society of America, 222 pp.

Elzinga, C. L, D. W. Salzer, and J. W. Willoughby. 1998. Measuring and Monitoring Plant Populations. USDI-BLM Tech. Ref. 1730-1 BLM/RS/ST-98/005+1730. p. 1-10.

[GPRA] Government Performance and Results Act of 1993. P.L. 103-62 (2003).

Kuchler, A. W. and I. S. Zonneveld (eds.). 1988. Vegetation Mapping. Handbook of Vegetation Science, Vol. 10. Kluwer Academic Publishers, Boston, MA. p. 193-202.

Layden, P. C. and M. J. Manfredo. 1994. National Park conditions: a survey of Park superintendents. National Parks and Conservation Association, Washington, D.C.

[NAWMA] North America Weed Management Association. 2003. North American Invasive Plant Mapping Standards. (Web page: http://www.nawma.org).

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. Issues in Ecology, 5:1-20.

Mullin, B. H., L. W. J. Anderson, J. M. DiTomoso, R. E. Eplee, and K. D. Getsinger. 2000. Invasive plant species. Council for Agricultural Science and Technology, Issue Paper No. 13, 17 pp.

Randall, J. M. 1995. Assessment of the invasive weed problem on preserves across the Unites States. Endangered Species Update 12 (4&5): 4-6

Sakai, A. K., F. W. Allendorf, J. S. Holt, D. M. Lodge, J Molofsky, K. A. With, S. Baughman, R. J. Cabin, J. E. Cohen, N. C. Ellstrand, D. E. McCauley, P. O'Neil, I. M. Parker, J. N. Thompson, and S. G. Weller. 2001. The Population Biology of Invasive Species. Ann. Rev. Ecol. Syst., 32:305332.

Silsbee, D.G. and D.L. Peterson. 1991. Designing and implementing comprehensive long-term inventory and monitoring programs in the National Parks. NPS Natural Resources Rept. NPS/NRUW/NRR-95/16.

Tu, M., Hurd, C., & J.M. Randall, 2001. Weed Control Methods Handbook, The Nature Conservancy. Web page: http://tncweeds.ucdavis.edu/handbook.html, Version: April 2001.

[USDA-FS] United States Department of Agriculture, Forest Service. 2001. Guide to Noxious Weed Preventive Practices. Version 1, July 5, 2001. 25 pp. (Web page: http://www.fs.fed.us/rangeland/ecology/invasives)

[USDI-NPS] United States Department of Interior, National Park Service. 1995. Natural resource inventory and monitoring guidelines. NPS-75.

[USDI-NPS] United States Department of Interior, National Park Service. 1996. Preserving Our National Heritage - a Strategic Plan for Managing Invasive Nonnative Plants on National Park System Lands. Natural Resources Stewardship and Science, National Park Service, Washington, D.C. 16 pp.

[USDI-NPS] United States Department of Interior, National Park Service. 1999. Natural Resource Challenge: The National Park Service's Action Plan for Preserving Natural Resources. U.S.D.I. National Park Service, Washington, D.C. 21 pp. (Web page: http://nature.nps.gov/challengedoc)

[USDI-NPS] United States Department of Interior, National Park Service. 2001. Initiate an Intermountain Region Noxious Weed Inventory and Mapping Program. Implementation Plan prepared by Intermountain Support Office PMIS #72973. January 2001. 77 pp. plus appendices.

[USDI-NPS] United States Department of Interior, National Park Service. 2002. Inventory and Monitoring for Invasive Plant Guidelines. Workshop report held in Fort Collins, CO, June 4-6, 2002. 60 pp.

[USDI-NPS] United States Department of Interior, National Park Service. 2004. Weed Seed/Propagule Decontaimination Procedures. Arches National Park EPMT Strike Team Incident Action Plan, Courthouse Wash Project, March 9-14, 2004.

[USDI-USGS] United States Department of Interior, U. S. Geological Survey. 1994. USGS-NPS Vegetation Mapping Program Documents and Standards. Web page: http://biology.usgs.gov/npsveg/standards.html.

Westbrooks, R. 1998. Invasive plants, changing the landscape of America: Fact book. Federal Interagency Committee for the Management of Noxious and Exotic Weeds, Washington, D. C. 109 pp.

Winward, A. 2000. Monitoring the Vegetation Resources in Riparian Areas. USDA Forest Service General Technical Report RMRS-GTR-47. p. 10-32.

Appendix Tables and Figures

Appendix A. Crew Qualifications and Project Quality Assurance for the 2003-2004 Invasive Non-native Plant Inventory in Zion National Park.

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 2003-2004 Invasive Non-native Plant Inventory in Zion National Park.

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 -2004 Invasive Non-native Plant Inventory in Zion National Park.

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 2003-2004 Invasive Non-native Plant Inventory in Zion National Park.

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 D . GPS Settings using in 2003-2004 Invasive Non-native Plant Inventory in Zion National Park. (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 2003-2004 Invasive Non-Native Plant Inventory in Zion National Park.

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 2003-2004 Invasive Non-native Plant Inventory, Zion National Park.

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 2003-2004 Invasive Non-native Plant Inventory, Zion National Park.

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 Zion National Park During the 2003-2004 Invasive Non-Native Plant Inventory.

Weeds Detected



Figure 1. *Verbascum thapsus* rosette growing in a burned area in Corral Hollow, 2003.

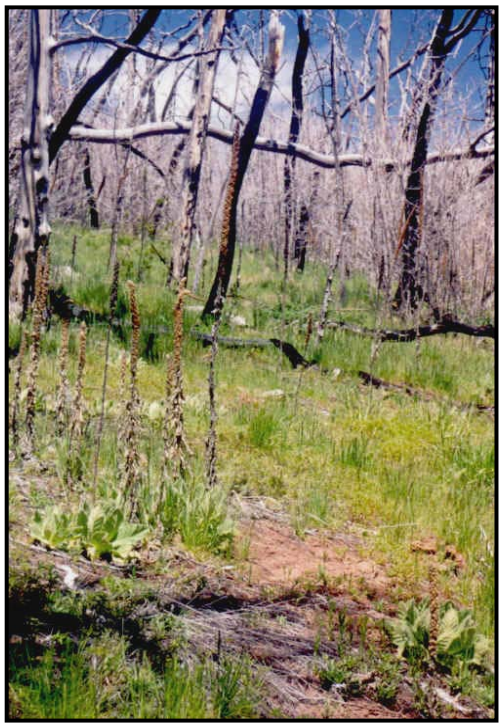


Figure 2. *Verbascum thapsus* stalks and rosettes in burned area on west facing slope in Corral Hollow, ZION PR-4, 2003.



Figure 3. *Verbascum thapsus* senesced stalks in burned oak stand in Corral Hollow, near ZION PR-4, 2003.



Figure 4. *Verbascum thapsus* senesced under burned juniper in Pine Valley near Northgate Peaks, ZION PR-1, 2003.

Weeds Detected



Figure 5. *Verbascum thapsus* rosette near stock pond at Firepit Knoll, ZION PR-12, 2003.



Figure 6. *Verbascum thapsus* rosettes near stock pond at Firepit Knoll, ZION PR-12, 2003.



Figure 7. *Verbascum thapsus*, north of campground, Potato Hollow area, ZION PR-22, 2004.



Figure 8. *Verbascum thapsus*, north of campground, Potato Hollow area, ZION PR-22, 2004.

Weeds Detected



Figure 9. *Verbascum thapsus* in Pine Valley inventory area, ZION PR-39, 2004.



Figure 10. *Verbascum thapsus* in Pine Valley, ZION PR-39, 2004.



Figure 11. *Cirsium vulgare* rosette found near downed logs by fire line in Corral Hollow, ZION PR-6, 2003.



Figure 12. Several *Cirsium vulgare* rosettes found near downed logs in Corral Hollow, ZION PR-6, 2003.

Weeds Detected



Figure 13. *Cirsium vulgare* at spring in Potato Hollow, ZION PR-44, 2004.



Figure 14. *Cirsium vulgare* at spring site in Potato Hollow, ZION PR-44, 2004.



Figure 15. *Convolvulus arvensis* on the road shoulder below Firepit Knoll, ZION PR-46, 2004.



Figure 16. *Convolvulus arvensis* on the road shoulder below Firepit Knoll, ZION PR-46, 2004.

Weeds Detected



Figure 17. *Tamarix ramosissima* sapling along the Virgin River, ZION PR-9, 2003.



Figure 18. *Tamarix ramosissima* sapling in willows along the Virgin River in Zion Canyon, ZION PR- 9, 2003.

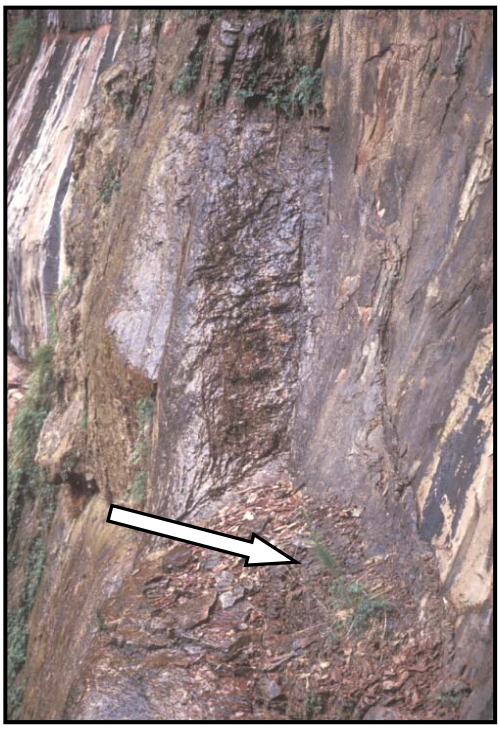


Figure 19. *Tamarix ramosissima* seedling found growing in seep at Weeping Rock, 2003.



Figure 20. *Tamarix ramosissima* seedling found growing in seep at Weeping Rock, 2003.

Weeds Detected



Figure 21. *Marrubium vulgare* found on road shoulder amid *Bromus tectorum* near Lamb's Knoll, ZION PR-42, 2004.



Figure 22. *Marrubium vulgare* on road shoulder growing in *Bromus tectorum* near Lamb's Knoll, ZION PR-42, 2004.



Figure 23. *Marrubium vulgare* found on the road shoulder near Lamb's Knoll, ZION PR-42, 2004.



Figure 24. *Bromus tectorum* (left) and *Bromus rigidus* (right). Although not mapped, these two species were prevalent in Zion Canyon, 2003.

Weeds Detected



Figure 25. *Bromus rigidus* underneath cottonwoods near Zion Lodge in Zion Canyon, 2003.



Figure 26. *Bromus rigidus* along inventory area in Zion Canyon, ZION PR-8, 2003.



Figure 27. *Bromus rigidus* and *Bromus tectorum* in Zion Canyon, ZION PR-8, 2003.



Figure 28. *Bromus rigidus* and *Bromus tectorum* along the bottom of Zion Canyon, 2003.

Weeds Detected



Figure 29. *Rumex crispus* was found in the areas of Firepit Knoll and Northgate Peaks, 2003.*



Figure 30. *Salsola kali* was found in Zion Canyon, Firepit Knoll, Horse Pasture Plateau, and Northgate Peaks, 2003.*



Figure 31. *Elaeagnus angustifolia* was found along the Virgin River in Zion Canyon, 2003. *



Figure 32. *Carduus nutans*. Rosettes were found on Horse Pasture Plateau south of Telephone Canyon, 2003.*

Photographs not taken in Zion National Park, but are representative of weed species inventoried during this project.

Weeds Detected



Figure 33. *Sorghum halepense*. *Sorghum halepense* was found in Zion Canyon along the Virgin River as well as in the Watchman Campground, 2003.*



Figure 34. *Onopordum acanthium*. Rosettes were found near Firepit Knoll, Northgate Peaks, Lee Valley, Telephone Canyon, and in Zion Canyon, 2003. *

Photographs not taken in Zion National Park, but are representative of weed species inventoried during this project.

Zion Landscapes



Figure 35. View of surveyed area looking east-southeast to Firepit Knoll, ZION PR-13, 2003.



Figure 36. View of surveyed area looking south to Firepit Knoll, ZION PR-14, 2003.



Figure 37. Firepit Knoll inventoried area, ZION PR-27, 2004.



Figure 38. Inventory area west of Firepit Knoll, 2004.

Zion Landscapes



Figure 39. Inventoried area in Lee Valley, looking south, ZION PR-30, 2004.



Figure 40. Lee Valley with Spendlove Knoll in the distance, ZION PR-31, 2004.



Figure 41. Inventoried fields in Lee Valley, ZION PR-40, 2004.



Figure 42. Inventoried fields at the base of Spendlove Knoll in Lee Valley, ZION PR-32, 2004.

Zion Landscapes



Figure 43. Inventoried fields in Lee Valley, ZION PR-41, 2004.



Figure 44. Inventoried area below the North Guardian Angel, ZION PR-18, 2004.



Figure 45. View of inventoried area looking towards Pine Valley Peak, ZION PR-2, 2003.



Figure 46. View looking south at inventoried area in Pine Valley near Northgate Peaks, ZION PR-3, 2003.

Zion Landscapes



Figure 47. Inventoried fields along the trail in Pine Valley, ZION PR-38, 2004.



Figure 48. Inventoried section of stream along the Left Fork, ZION PR-15, 2004.



Figure 49. Inventoried areas on Horse Pasture Plateau, along the West Rim Trail, ZION PR-3, 2004.



Figure 50. Inventoried fields along Horse Pasture Plateau, ZION PR-34, 2004.

Zion Landscapes



Figure 51. View south of Corral Hollow, ZION PR-5, 2003.



Figure 52. Corral Hollow along the West Rim Trail, ZION PR-7, 2003.



Figure 53. Inventoried area in Potato Hollow (looking east), ZION PR-20, 2003.



Figure 54. Potato Hollow, along the West Rim Trail, ZION PR-21, 2003.

Zion Landscapes



Figure 55. View into inventoried hollow west of Potato Hollow, 2004.



Figure 56. View of inventoried area above Imlay Canyon, along the West Rim Trail, ZION PR-19, 2004.



Figure 57. Inventoried area within Sleepy Hollow, ZION PR-45, 2004.



Figure 58. Inventoried area along the West Rim Trail above Sleepy Hollow, 2004.

Zion Landscapes



Figure 59. Inventoried area along West Rim Trail. The two Guardian Angels are in the background, ZION PR-23, 2004.



Figure 60. Janna Simonsen and Eric Lamalfa at a West Rim Trail viewpoint looking towards the Guardian Angels, 2003.



Figure 61. Inventoried area in Telephone Canyon, ZION PR-25, 2004.



Figure 62. Inventoried area in Telephone Canyon, near ZION PR-25, 2004.

Zion Landscapes



Figure 63. Telephone Canyon, inventoried in 2004, ZION PR-26.



Figure 64. Telephone Canyon, inventoried in 2004, near ZION PR-26.



Figure 65. Ruth Richards searching in burned area on Horse Pasture Plateau, south of Telephone Canyon, ZION PR-07, 2003.



Figure 66. Ruth Richards searching in burned area on Horse Pasture Plateau, south of Telephone Canyon, ZION PR-07, in 2003.

Zion Landscapes



Figure 67. West Rim Trail inventoried below Horse Pasture Plateau, 2004.



Figure 68. Inventoried area along West Rim Trail below Horse Pasture Plateau, 2004.



Figure 69. Looking up Zion Canyon from Angel's Landing, 2003.



Figure 70. View looking down Zion Canyon from the top of Angel's Landing, 2003.

Zion Landscapes



Figure 71. *Bromus tectorum* along inventoried fields in Zion Canyon, 2003.



Figure 72. Inventory area below Angel's Landing in Zion Canyon, 2003.



Figure 73. Weedy grasses that have been mowed around the South campground in Zion Canyon, 2004.



Figure 74. Mowed *Bromus rigidus* and *Bromus tectorum* around the South campground in Zion Canyon, 2004.

Zion Landscapes

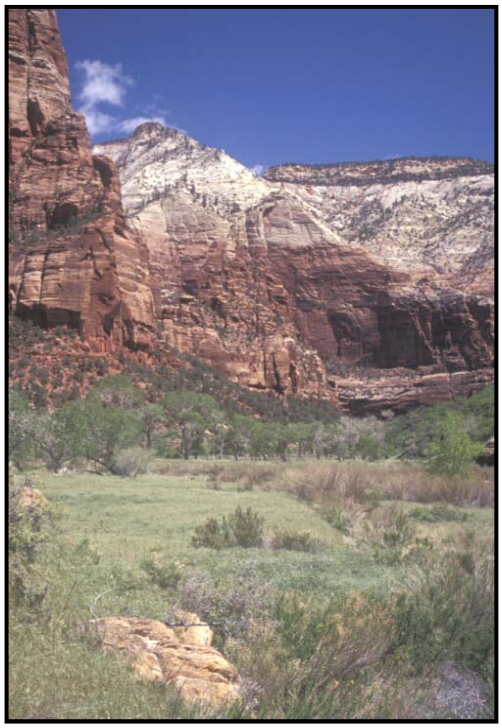


Figure 75. View looking up Zion Canyon to Weeping Rock, 2003.



Figure 76. View near the Virgin River, looking into Zion Canyon, 2004.

Crew



Figure 77. NPS crews during training in Zion National Park during May, 2003. (Left to right: Gary Lenhart, Steve Dewey, Christine Craig, Liz Ballenger, Stephanie Shoemaker, Heather Rickleff, Ruth Richards, Emily Spencer).



Figure 78. NPS crew training in Zion National Park during May, 2003.



Figure 79. NPS crew weed ID training in May, 2003.



Figure 80. Melanie Ballard above Corral Hollow on Horse Pasture Plateau, 2003.

Crew



Figure 81. Melanie Ballard and Ruth Richards on the West Rim Trail along Horse Pasture Plateau.



Figure 82. Kim Andersen and Ruth Richards on the West Rim Trail above Corral Hollow.



Figure 83. Ruth Richards along the West Rim Trail, on the ridge between Potato Hollow and Corral Hollow, ZION PR-11, 2003.



Figure 84. Bridget Atkin in Wolf Springs Wash below Lee Valley, ZION PR-16, 2004.

Crew



Figure 85. Kim Andersen in Wolf Springs Wash below Lee Valley, 2004.

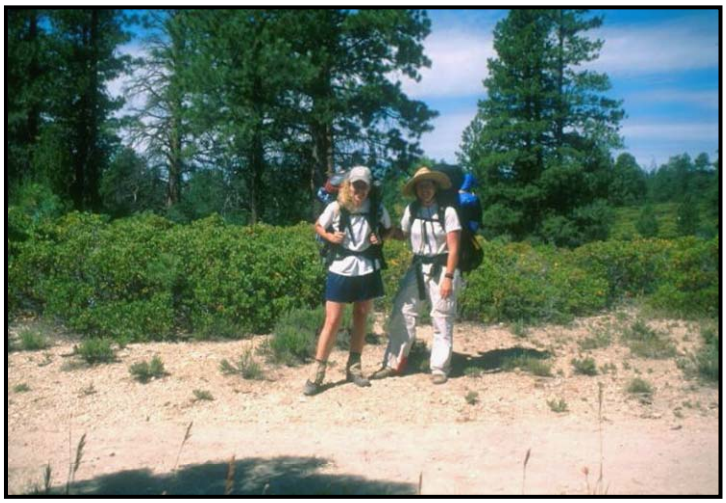


Figure 86. Kim Andersen and Ruth Richards along the West Rim Trail inventorying Horse Pasture Plateau, 2004.

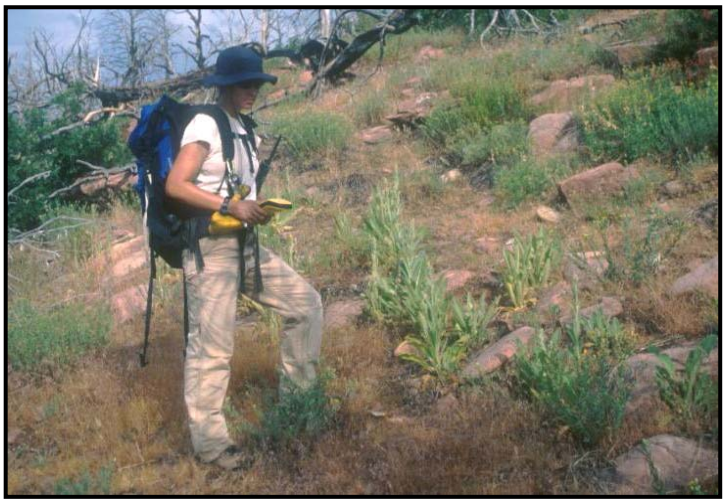


Figure 87. Bridget Atkin inventorying *Verbascum thapsus* in Potato Hollow, ZION PR-16, 2004.



Figure 88. Bridget Atkin and Ruth Richards during a planning session, above Potato Hollow, 2004.

Crew



Figure 89. Kim Andersen inventorying the canyon edge along the West Rim Trail, ZION PR-24, 2004.



Figure 90. Ruth Richards filtering water from a spring in Potato Hollow during the inventory along the West Rim Trail, 2004.



Figure 91. Bridget Atkin and Ruth Richards during a planning session in Telephone Canyon, 2004.



Figure 92. Ruth Richards along the West Rim Trail during the inventory of Horse Pasture Plateau, 2004.

Crew



Figure 93. Kim Andersen searching for weeds on Horse Pasture Plateau, 2004.



Figure 94. USU crew resting on West Rim Trail on their way to Telephone Canyon, 2003.



Figure 95. Kim Andersen inventorying weeds in Lee Valley, 2004.



Figure 96. Steve Dewey verifying previously inventoried weed points in Lee Valley, 2004.

Crew



Figure 97. Kim Andersen verifying previously inventoried weed points along the West Rim Trail, ZION PR-33, 2004.



Figure 98. Steve Dewey verifying previously inventoried weed points along the West Rim Trail above Corral Hollow, ZION PR-36, 2004.

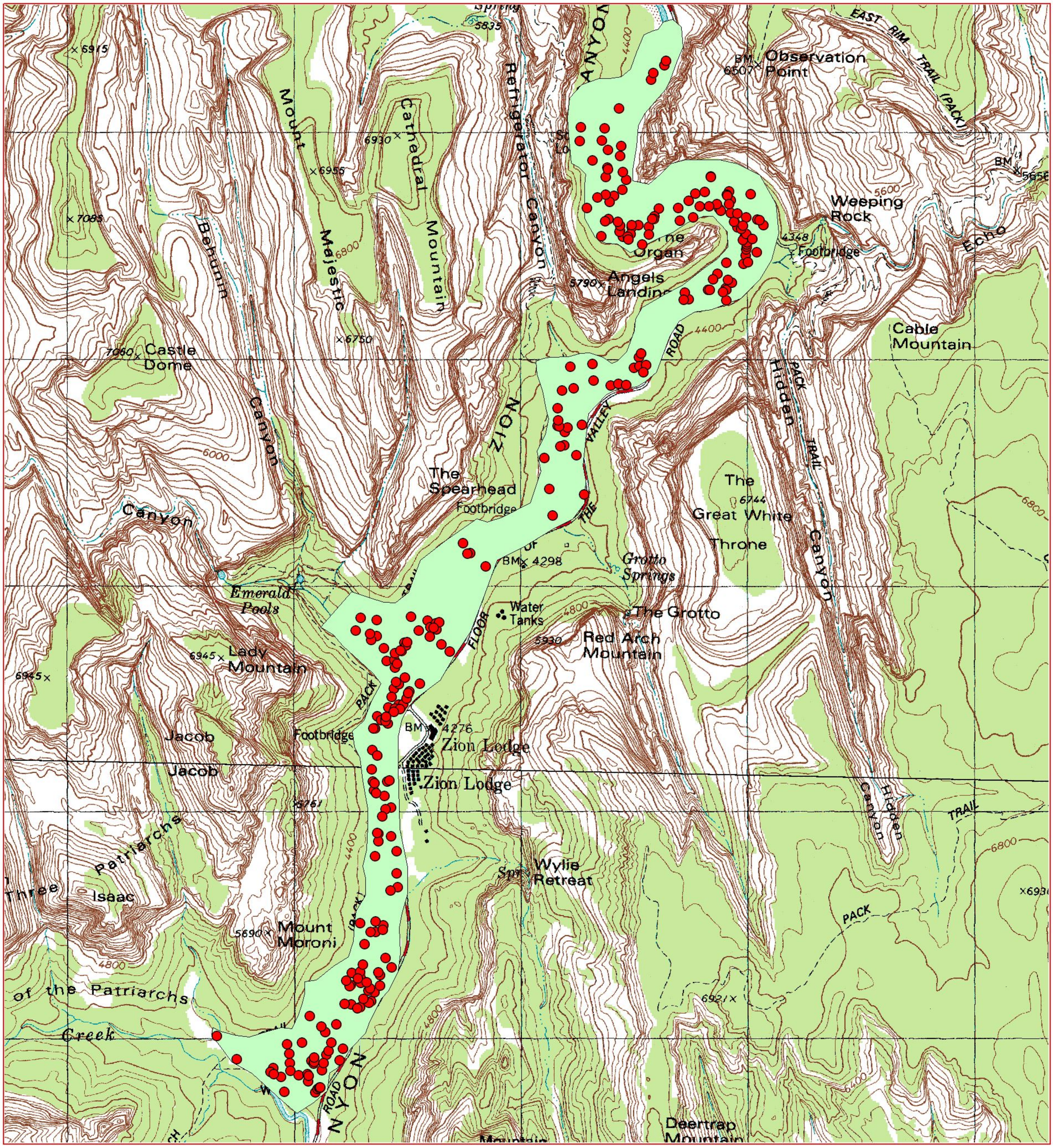


Figure 99. Steve Dewey verifying previously inventoried weed points in Pine Valley, ZION PR-38, 2004.



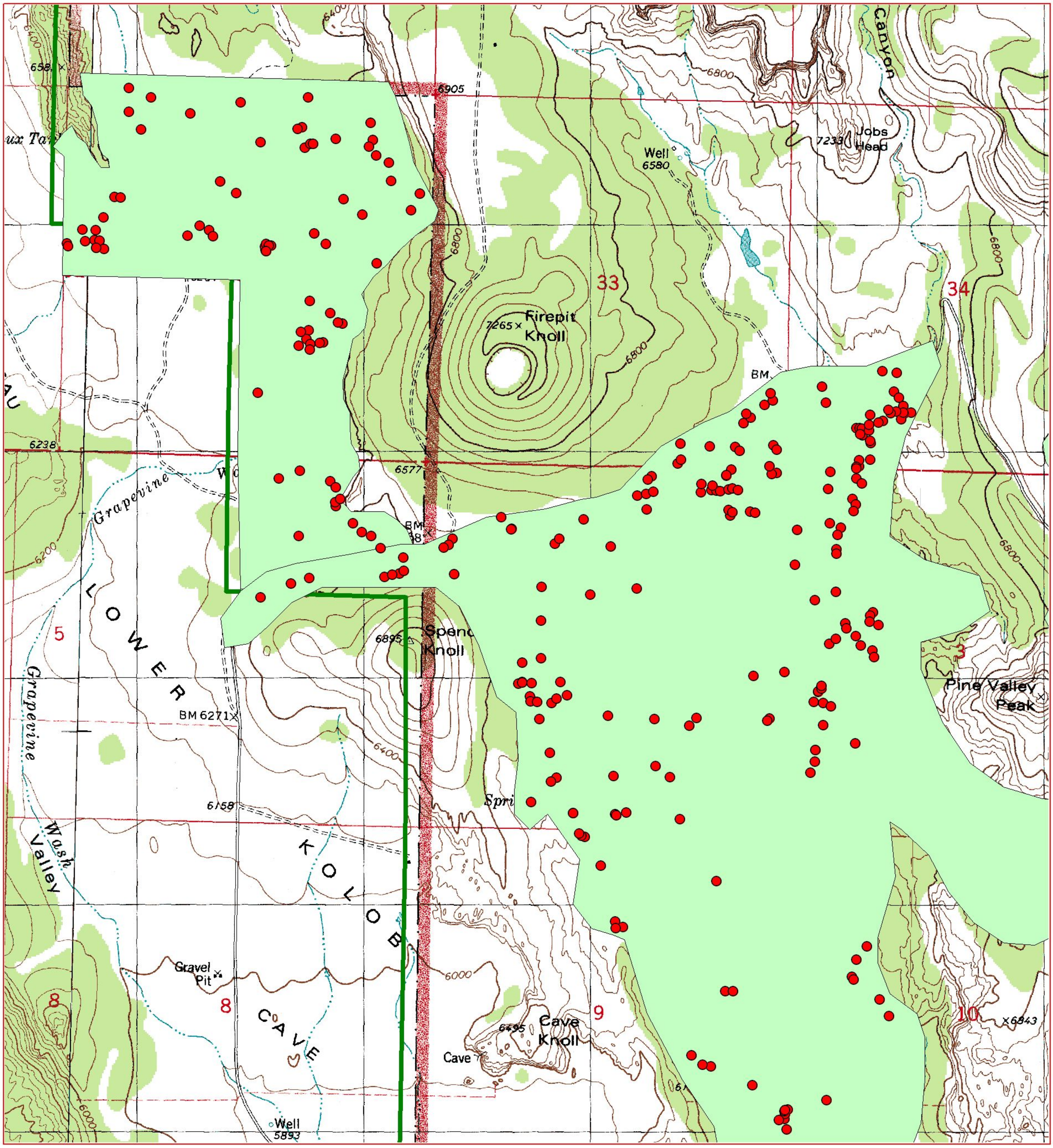
Figure 100. Trailer/office in campground for USU crew during stay in Zion National Park, 2003.

Appendix H. Overall Weed Distribution in Inventoried Areas - Zion Canyon (Inset A)



Inset A
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix H. Overall Weed Distribution in Inventoried Areas - Firepit Knoll (Inset B)



Weed Points

Area Inventoried

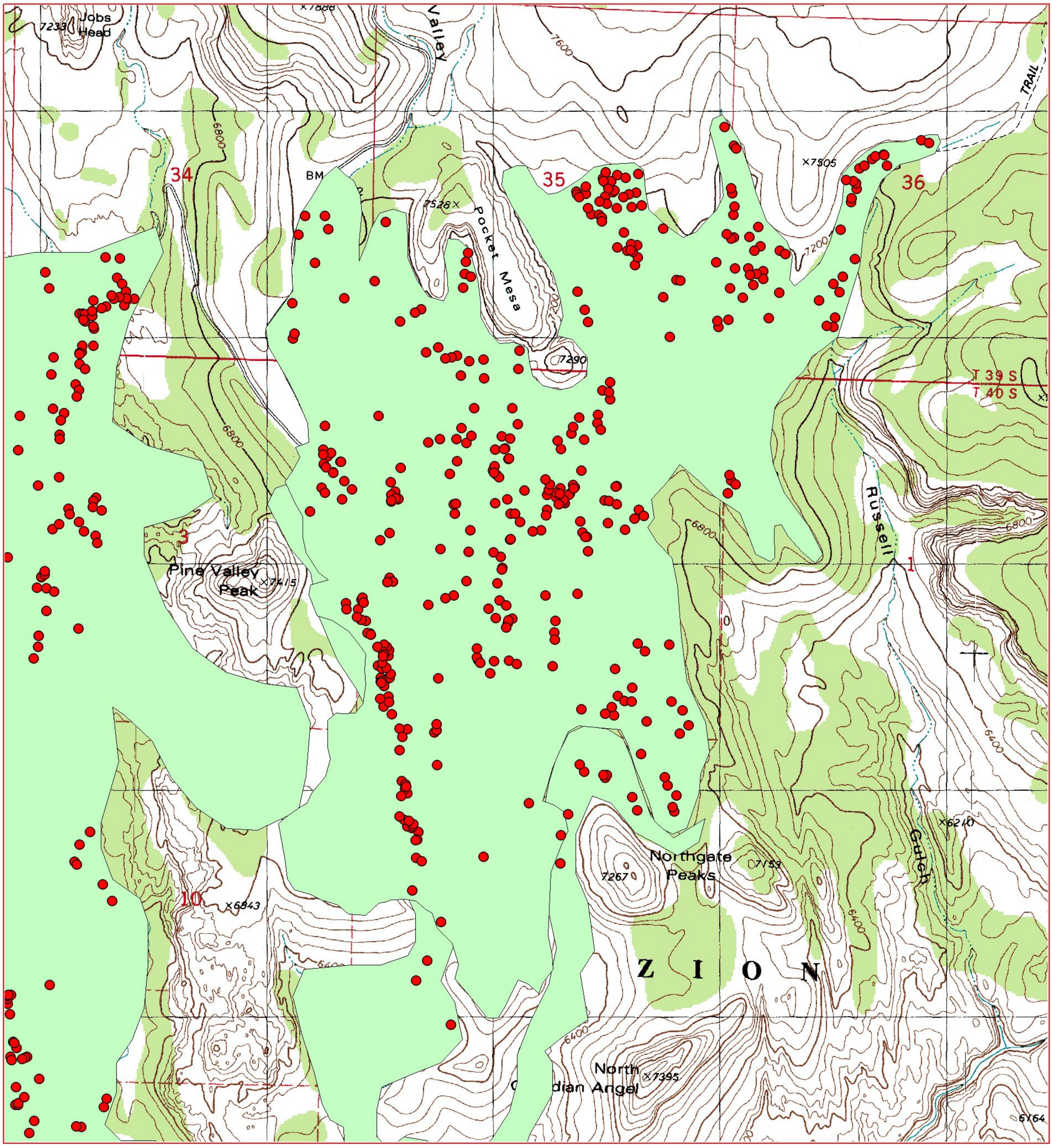
Park boundary

1:24,000 Scale

N

Inset B
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix H. Overall Weed Distribution in Inventoried Areas - Pine Valley (Inset C)



0 2000 4000 Feet

1:24,000 Scale

N

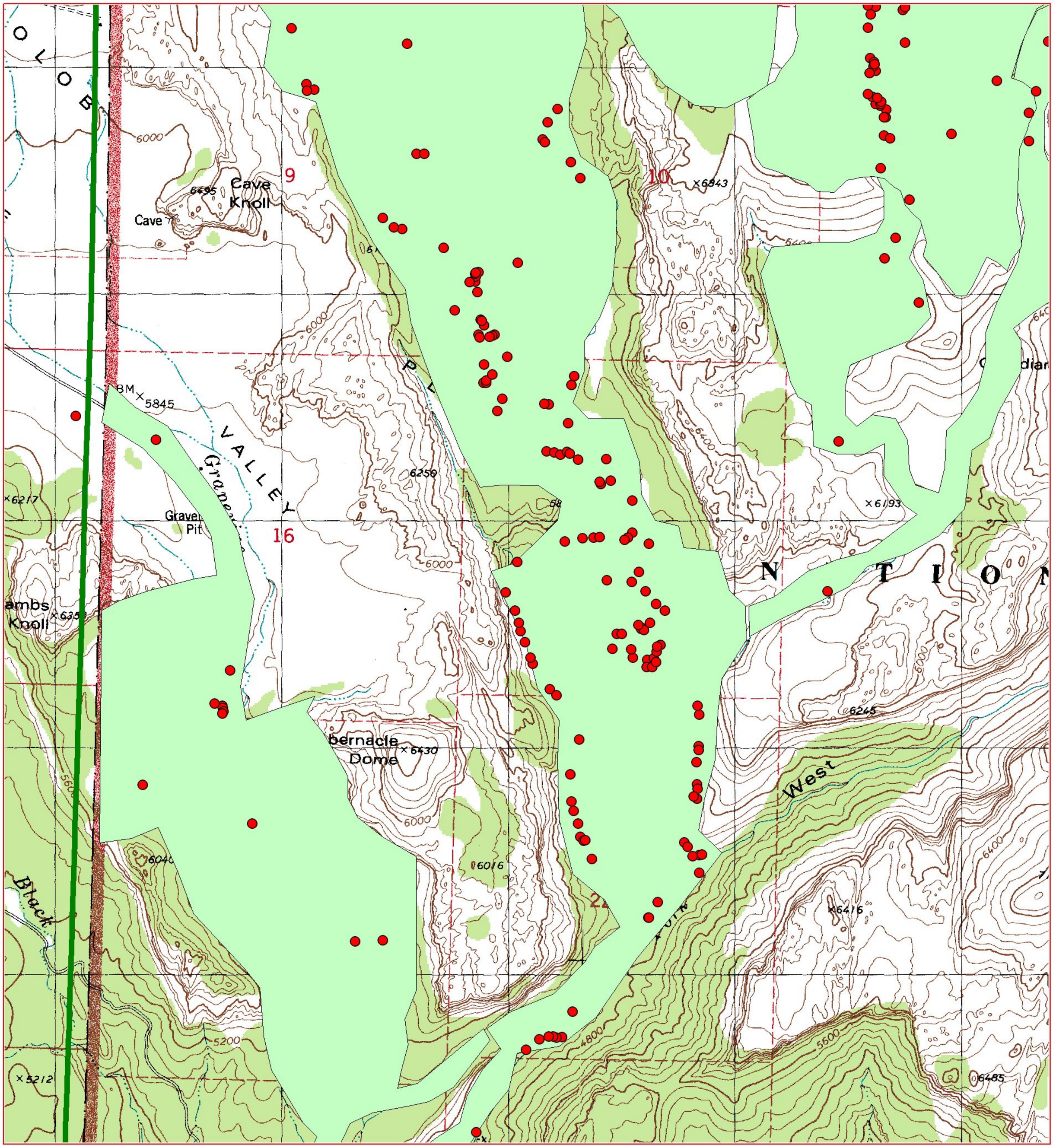
Weed Points

Area Inventoried

Park boundary

Inset C
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix H. Overall Weed Distribution in Inventoried Areas - Lee Valley (Inset D)



Weed Points

Area Inventoried

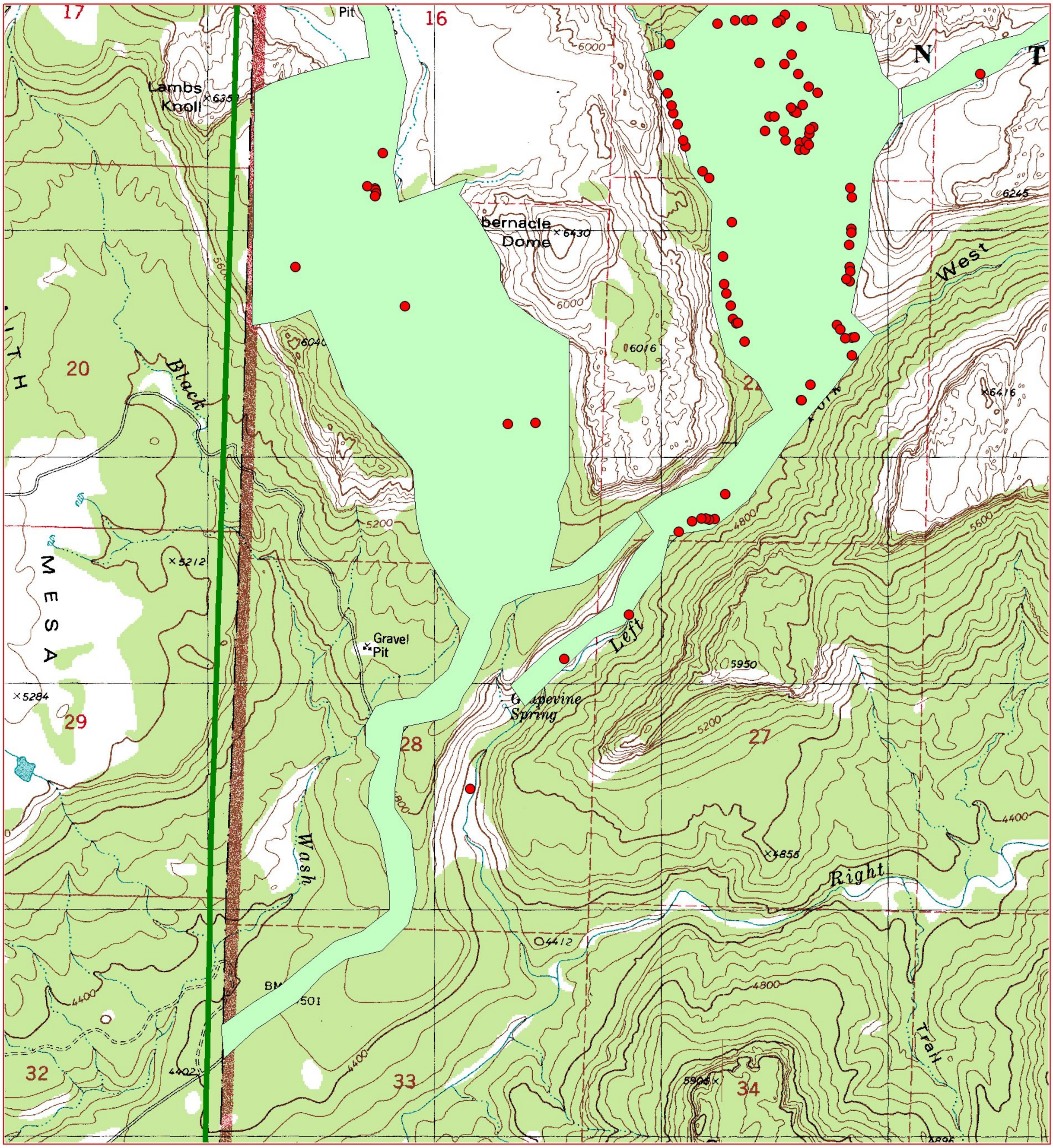
Park boundary

1:24,000 Scale

N

Inset D
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix H. Overall Weed Distribution in Surveyed Area - Tabernacle Dome (Inset E)



0 2000 4000 Feet

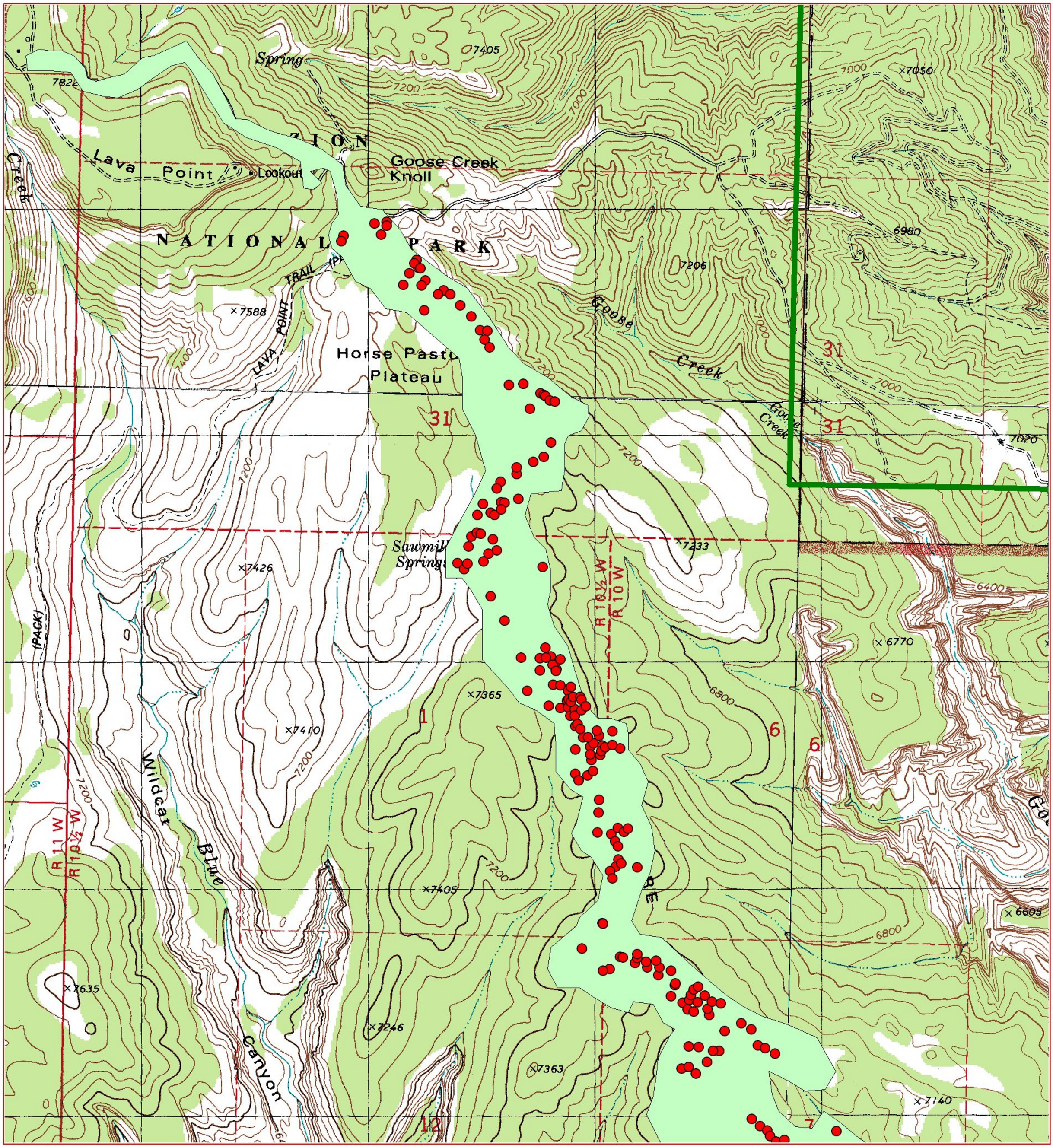
1:24,000 Scale

- Weed Points
- Area Inventoried
- Park boundary

N

Inset E
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix H. Overall Weed Distribution in Inventoried Areas - Sawmill Spring (Inset F)



0 2000 4000 Feet

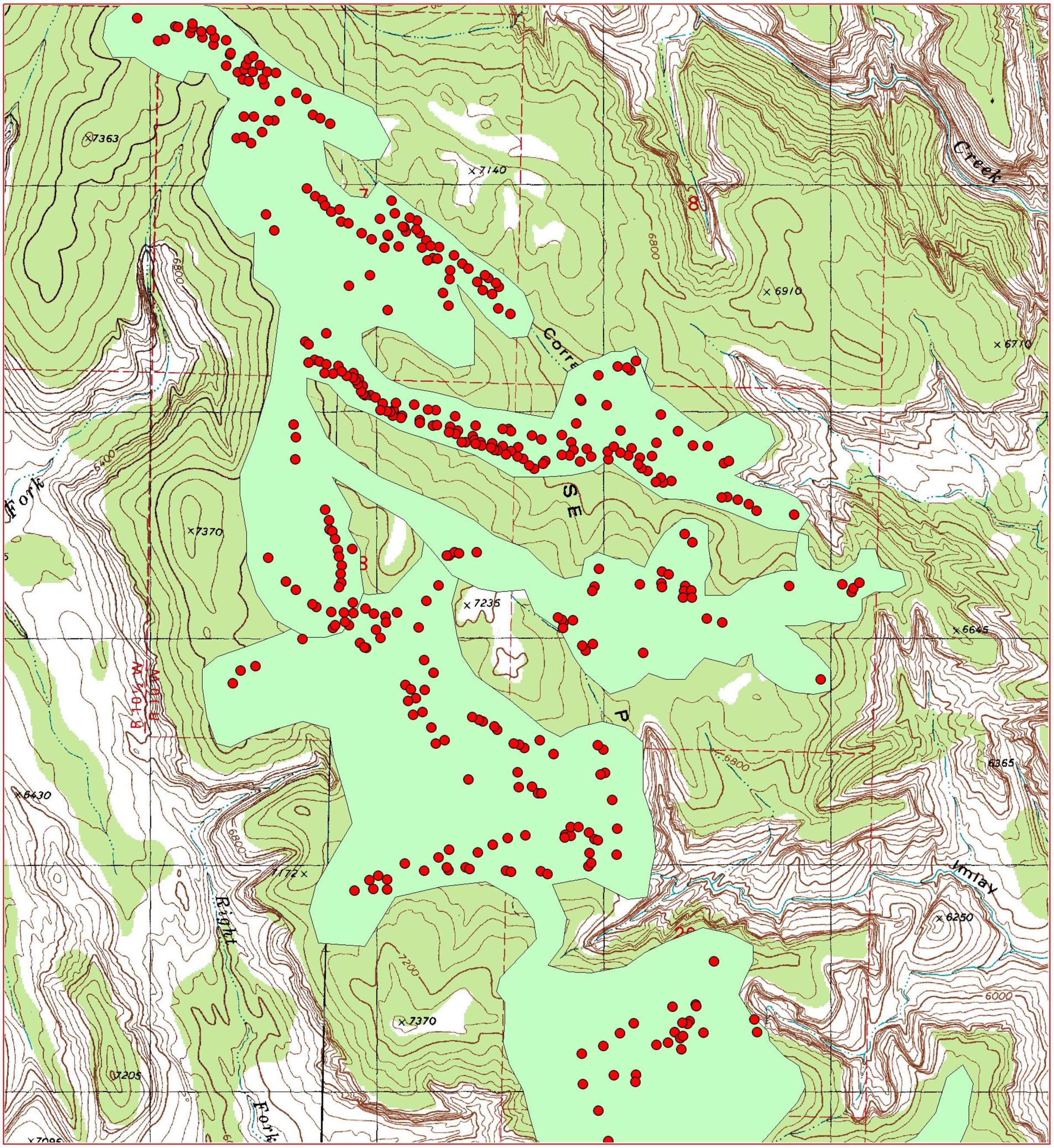
1:24,000 Scale

- Weed Points
- Area Inventoried
- Park boundary

N

Inset F
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix H. Overall Weed Distribution in Inventoried Area - Corral Hollow (Inset G)



0 2000 4000 Feet

1:24,000 Scale

N

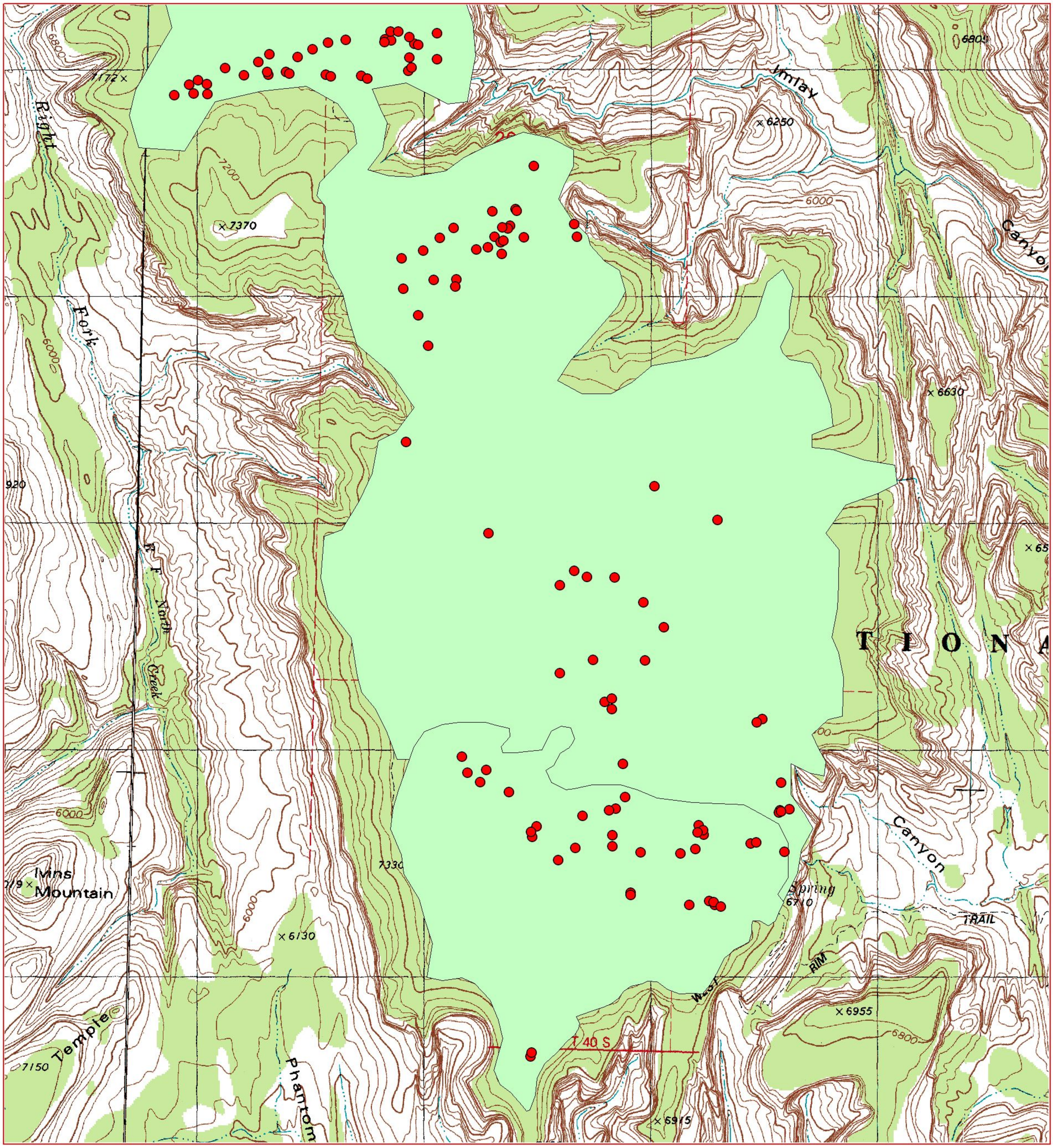
Weed Points

Area Inventoried

Park boundary

Inset G
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

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



0 2000 4000 Feet

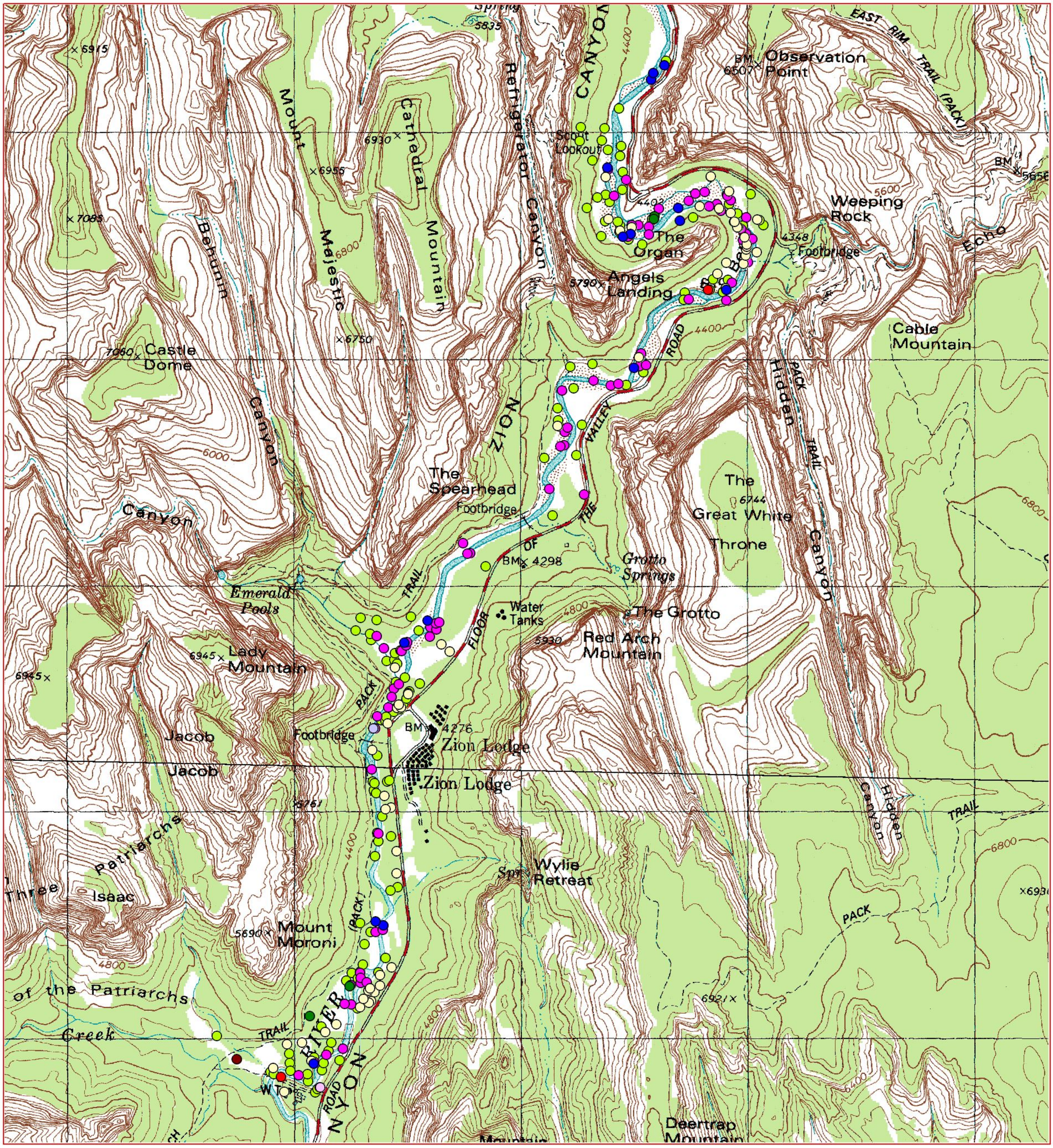
1:24,000 Scale

N

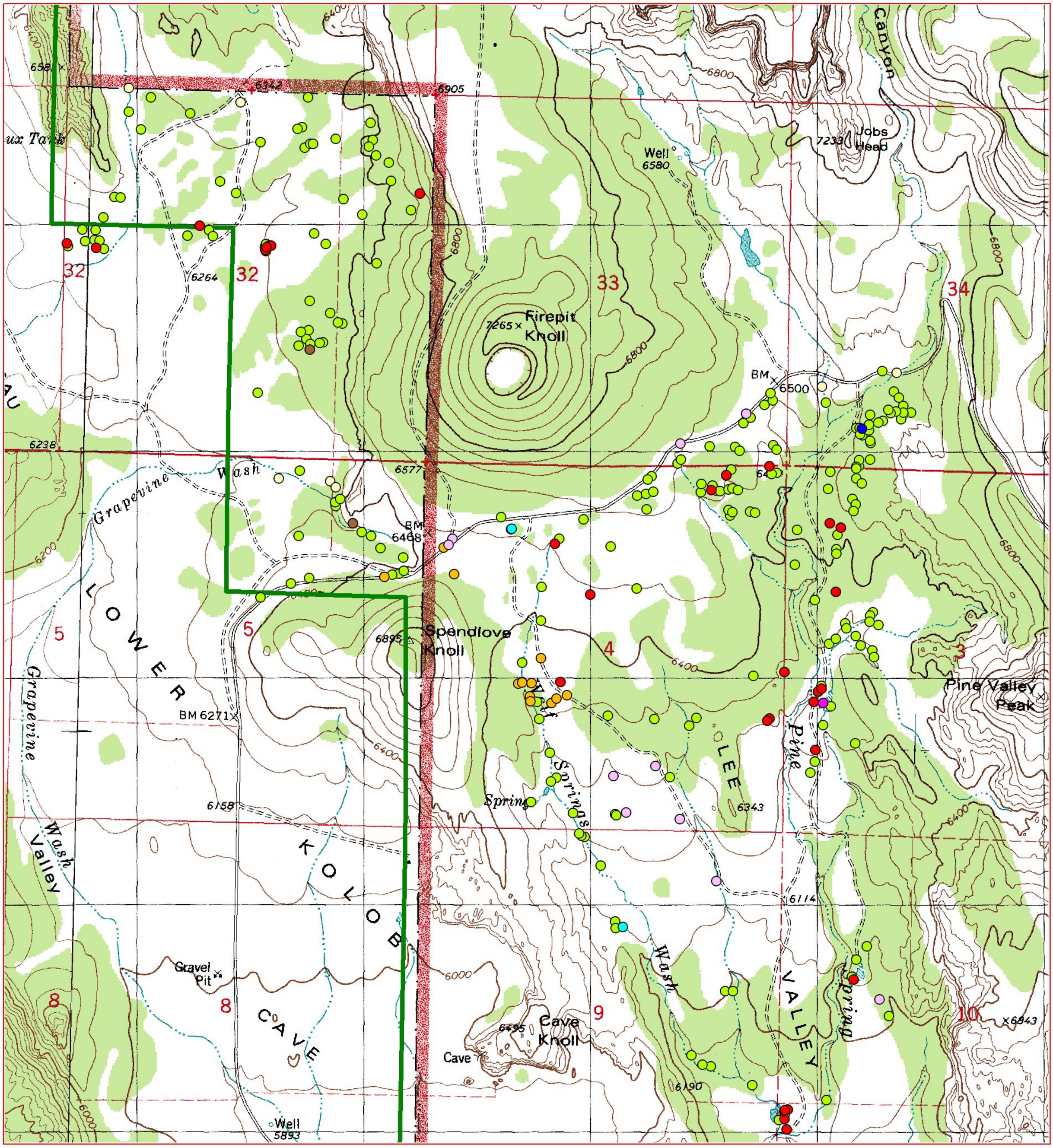
- Weed Points
- Area Inventoried
- Park boundary

Inset H
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Zion Canyon (Inset A)



Appendix I. Weed Species Detected in Inventoried Areas - Firepit Knoll (Inset B)



- *Cirsium vulgare*
- *Convolvulus arvensis*
- *Elaeagnus angustifolia*
- *Marrubium vulgare*
- *Onopordum acanthium*
- *Rumex crispus*
- *Salsola kali*
- *Tamarix ramosissima*
- *Tragopogon dubius*
- *Verbascum thapsus*
- Park boundary

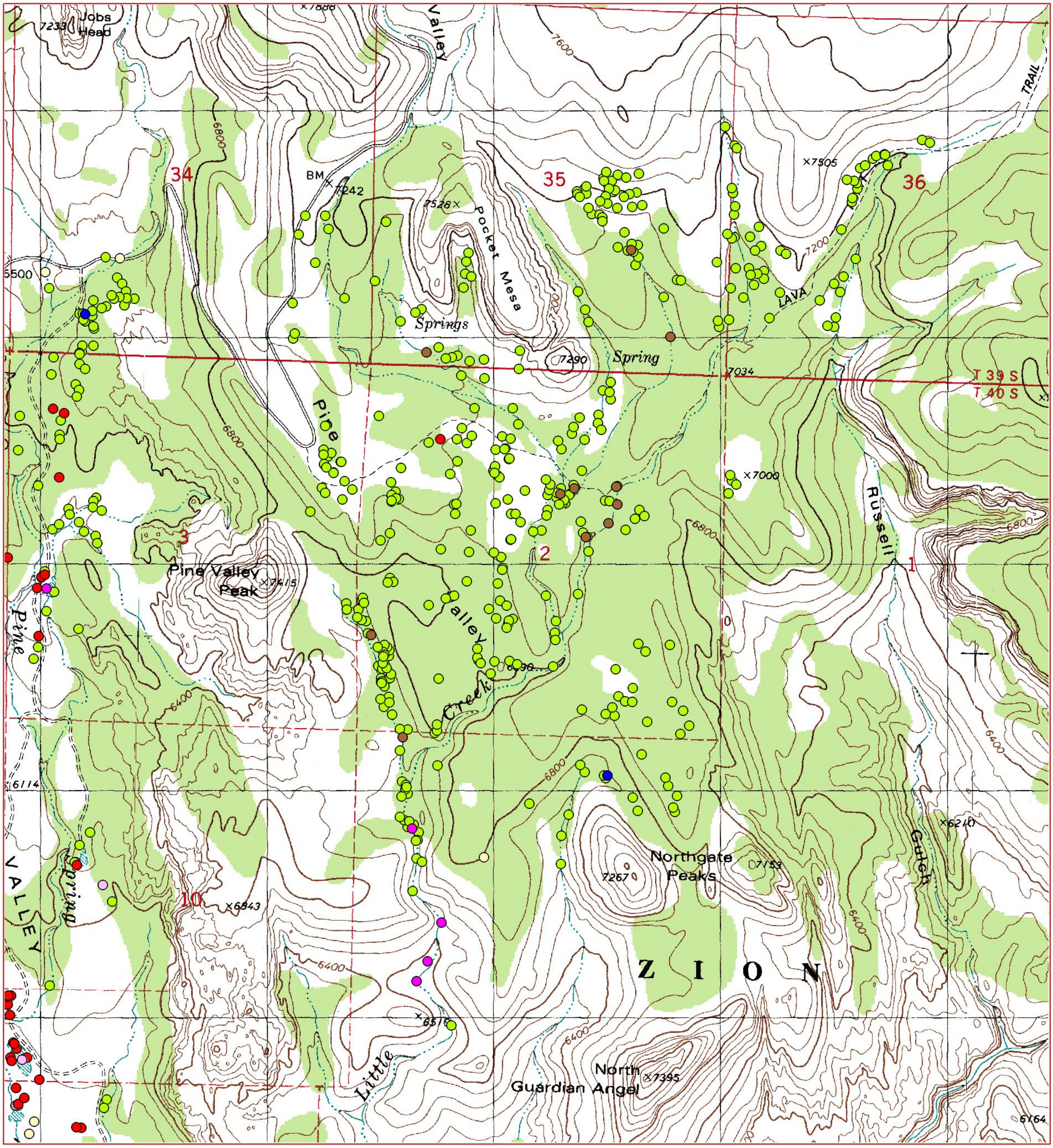
0 2000 4000 Feet

1:24,000 Scale

N

Inset B
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Pine Valley (Inset C)



- *Cirsium vulgare*
- *Convolvulus arvensis*
- *Onopordum acanthium*
- *Rumex crispus*
- *Salsola kali*
- *Sisymbrium altissimum*
- *Tamarix ramosissima*
- *Tragopogon dubius*
- *Verbascum thapsus*
- Park boundary

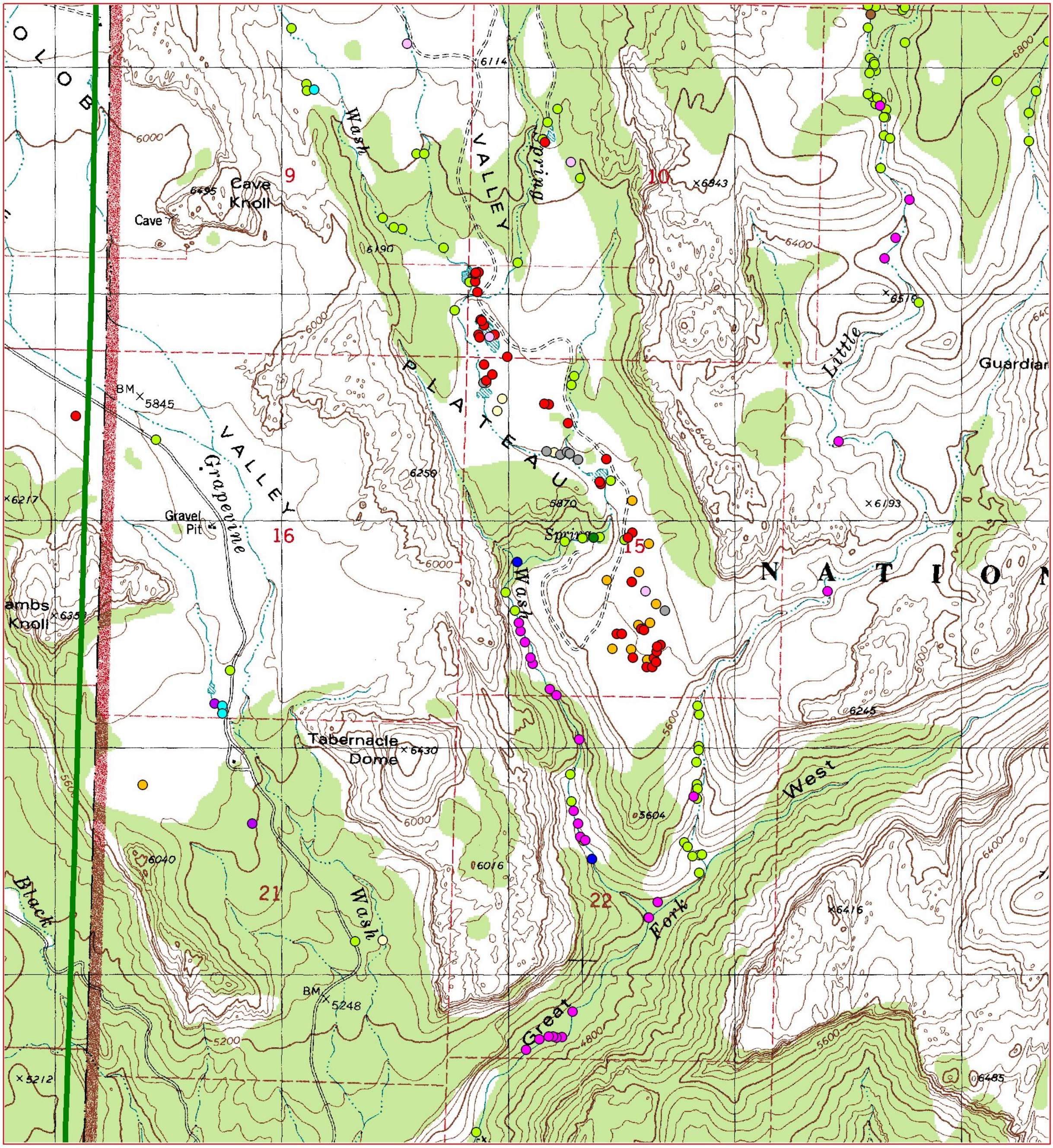
0 2000 4000 Feet

1:24,000 Scale

N

Inset C
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Lee Valley (Inset D)



- *Cirsium vulgare*
- *Convolvulus arvensis*
- *Elaeagnus angustifolia*
- *Marrubium vulgare*
- *Onopordum acanthium*
- *Ranunculus testiculatus*
- *Rumex crispus*
- *Salsola kali*
- *Sisymbrium altissimum*
- *Tamarix ramosissima*
- *Tragopogon dubius*
- *Verbascum thapsus*
- Park boundary

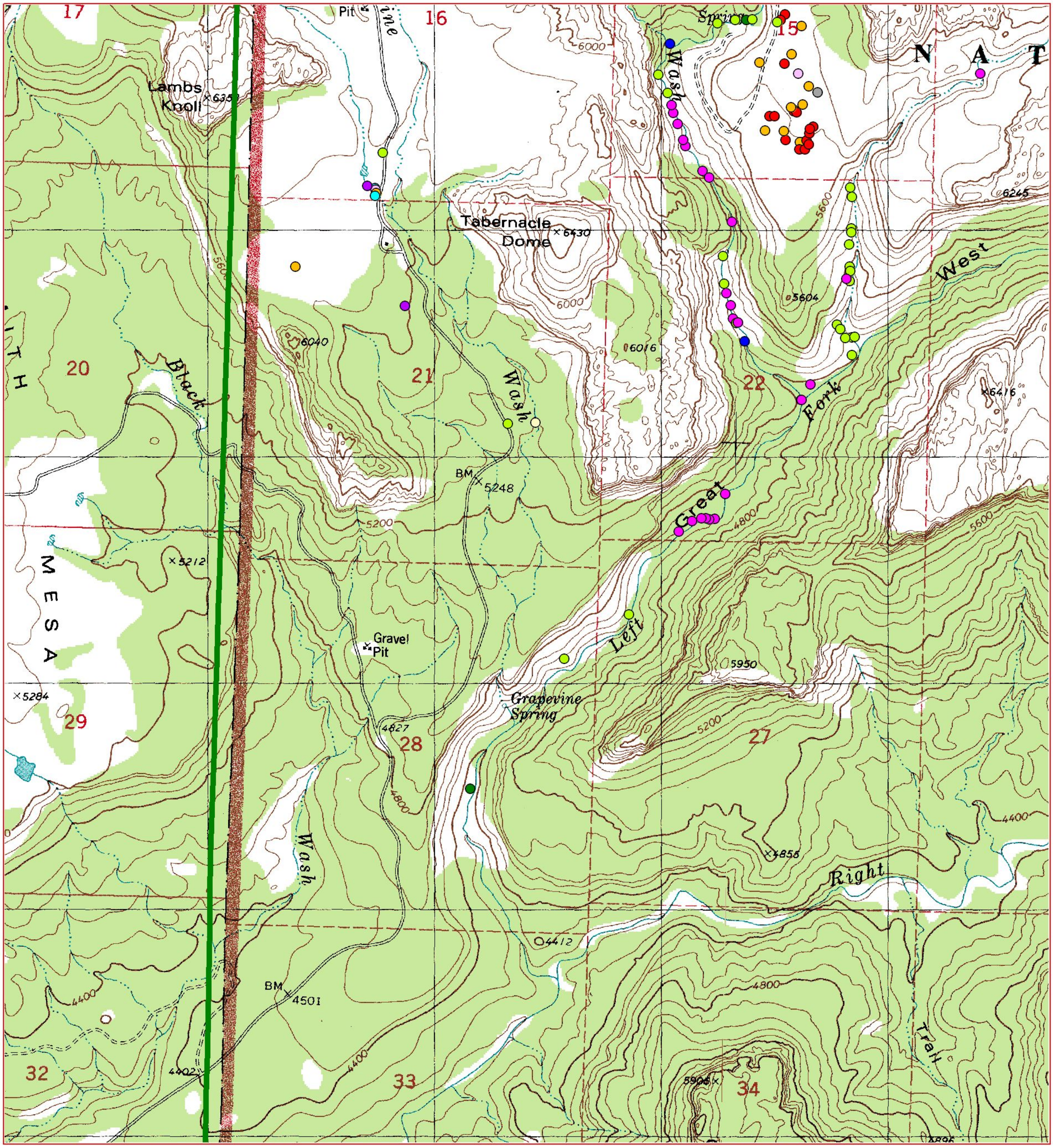
0 2000 4000 Feet

1:24,000 Scale

N

Inset D
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Tabernacle Dome (Inset E)



- *Cirsium vulgare*
- *Convolvulus arvensis*
- *Elaeagnus angustifolia*
- *Marrubium vulgare*
- *Onopordum acanthium*
- *Ranunculus testiculatis*
- *Salsola kali*
- *Sisymbrium altissimum*
- *Tamarix ramosissima*
- *Tragopogon dubius*
- *Verbascum thapsus*
- Park boundary

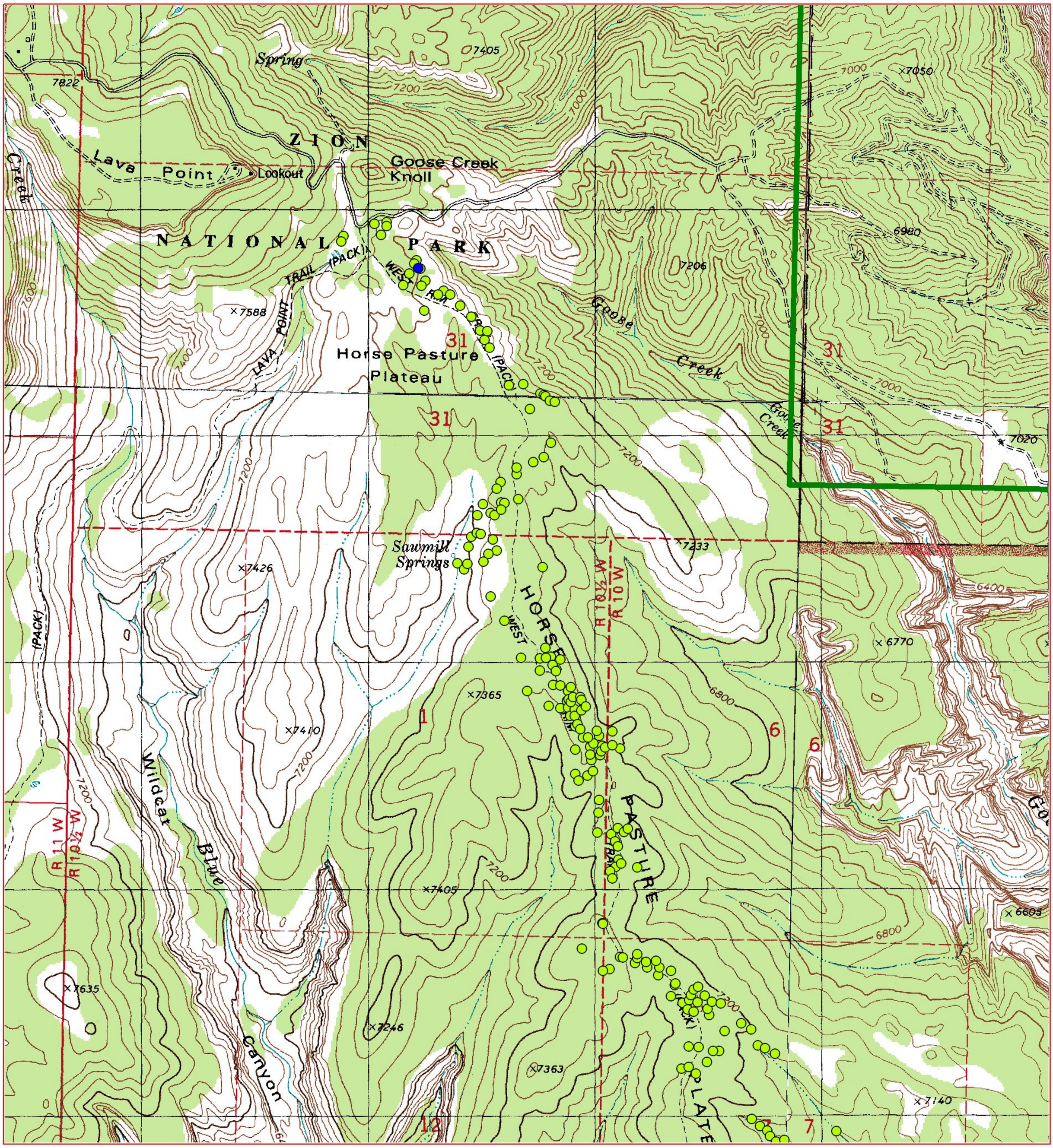
0 2000 4000 Feet

1:24,000 Scale

N

Inset E
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Sawmill Spring (Inset F)



0 2000 4000 Feet

1:24,000 Scale

N

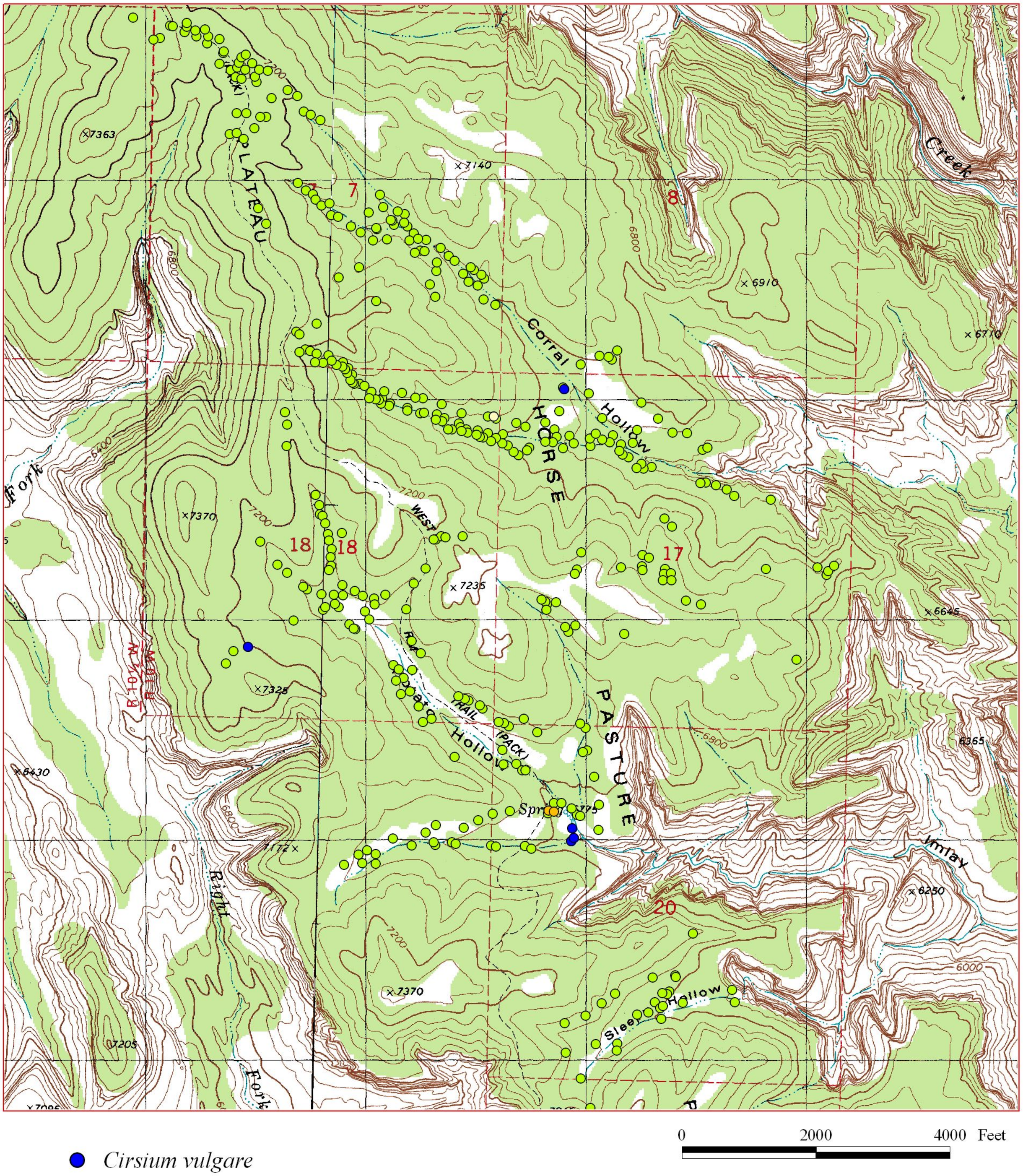
● *Cirsium vulgare*

● *Verbascum thapsus*

▭ Park boundary

Inset F
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Corral Hollow (Inset G)



- *Cirsium vulgare*
- *Salsola kali*
- *Tragopogon dubius*
- *Verbascum thapsus*
- Park boundary

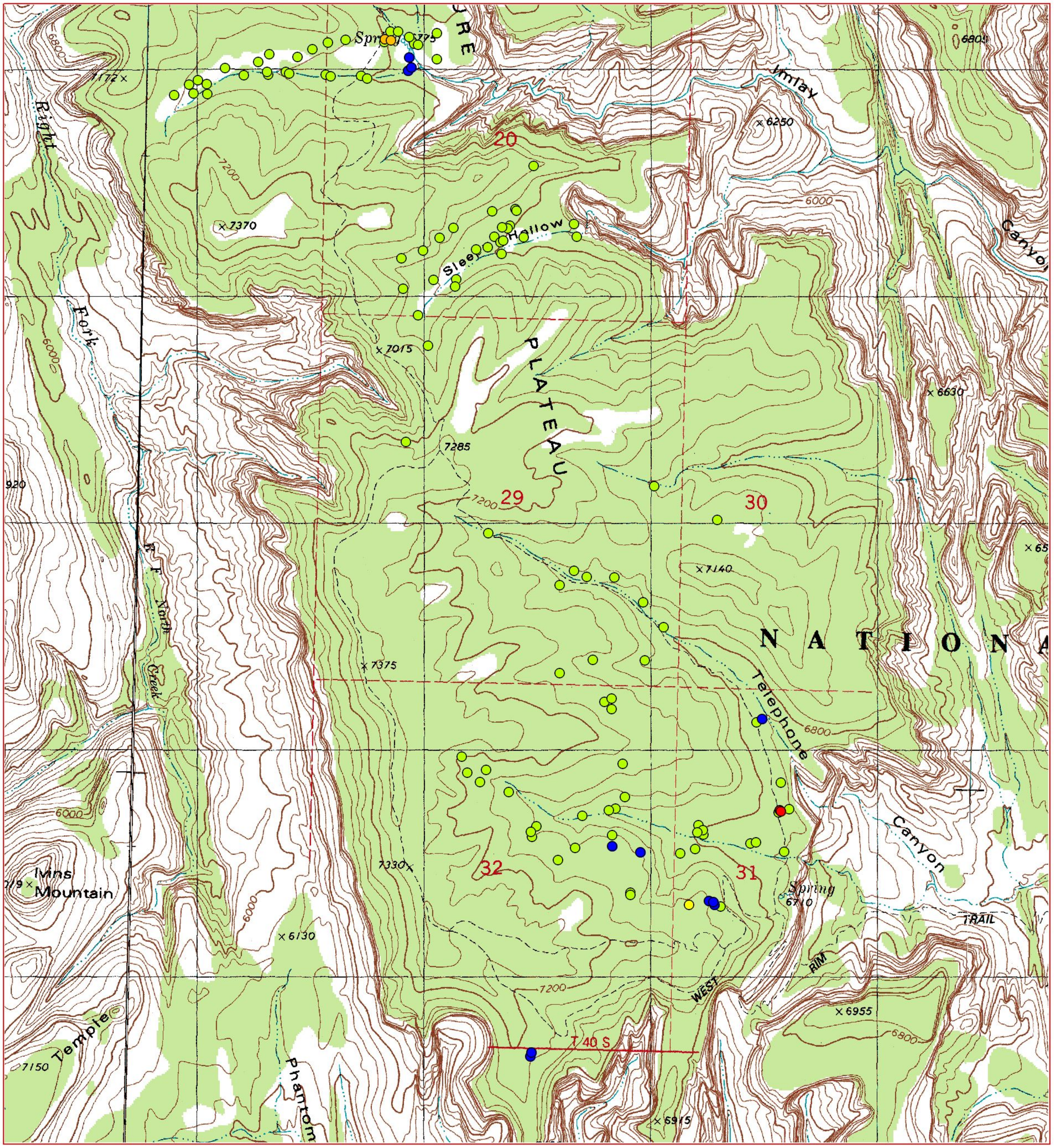
0 2000 4000 Feet

1:24,000 Scale

N

Inset G
Zion National Park
Utah State University
2003-2004 Invasive Non-Native Plant Inventory
Northern Colorado Plateau Network

Appendix I. Weed Species Detected in Inventoried Areas - Telephone Canyon (Inset H)



- *Carduus nutans*
- *Cirsium vulgare*
- *Onopordum acanthium*
- *Tragopogon dubius*
- *Verbascum thapsus*
- Park boundary

0 2000 4000 Feet

1:24,000 Scale

N

Inset H
Zion National Park
Utah State University
2003-2004 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 2003-2004 inventory of invasive plants in Zion National Park.

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					*Lactuca serriola*			X		
Conium maculatum				X		*Melilotus officinalis*			X		
Convolvulus arvensis	X					*Sisymbrium altissimum*		X			
Cynoglossum officinale				X		*Ranunculus testiculatus*		X			
Dactylis glomerata					X	*Secale cereale*			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