ECOLOGY

2000 Annual Vegetation Report for the Rocky Flats Environmental Technology Site

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Kaiser-Hill, LLC
Rocky Flats Environmental Technology Site
Golden, Colorado 80402-0464

May 2001

Doc. no. 8601454.004 0202 0501 0375

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Acronyms and Abbreviations

CNHP	Colorado Natural Heritage Program
DOE	U.S. Department of Energy
GPS	global positioning system
K-H	Kaiser Hill Company
QA/QC	quality assurance and quality control
Site	Rocky Flats Environmental Technology Site

Executive Summary

The Kaiser-Hill Company (K-H) Ecology Group conducts ecological monitoring of the Site's natural resources to ensure regulatory compliance and to preserve and protect those resources during cleanup and closure operations. Ecological monitoring is an integral aspect of determining whether the management objectives and goals for the plant communities at the Site are being achieved. One component of the ecological monitoring program is annual vegetation monitoring, the goal of which is to assess the status and quality of the plant communities on the Site, document any trends, and assess the effectiveness of various management techniques. This report summarizes the results of the vegetation monitoring that was conducted at the Rocky Flats Environmental Technology Site (the Site) during 2000.

At an elevation of approximately 6,000 ft, the Site contains a unique ecotonal mixture of mountain and prairie plant species resulting from the topography of the area and its proximity to the mountain front. The Buffer Zone, the area surrounding the Industrial Area, is one of the largest remaining undeveloped areas of its kind along the Colorado Piedmont. A number of plant communities present at the Site have been identified as increasingly rare and unique by the K-H Ecology Group and the Colorado Natural Heritage Program (CNHP). These communities include the xeric tallgrass prairie, tall upland shrubland, wetlands, and Great Plains riparian woodland communities. Small inclusions of a number of other increasingly rare plant communities are also found on the Site. Many of these communities support populations of increasingly rare animals as well, including the federally protected Preble's meadow jumping mouse, and other uncommon species such as the grasshopper sparrow, loggerhead shrike, Merriam's shrew, black crowned night heron, and hops blue and Arogos skipper butterflies.

Vegetation monitoring is conducted at the Site using several methods to meet the monitoring objectives. During 2000, these objectives included species richness inventories, noxious weed and rare plant species mapping, photographic documentation, qualitative habitat assessment surveys, quantitative monitoring of long-term plant community changes, quantitative assessments of the effectiveness of herbicide applications and potential associated impacts to the native plant communities, and an evaluation of the effects of a prescribed burn on the xeric tallgrass prairie.

As a result of the 2000 field work, a total of seven new records of vascular plant species are reported for the Site. This increase brings the total number of plant species known to occur on the Site to 592. None of the new species recorded on the Site in 2000 is a rare species or state-listed noxious weed. Four plant species of concern listed by the CNHP as rare or imperiled occur at the Site. During 2000, populations of mountain-loving sedge, forktip three-awn, carrionflower greenbriar, and dwarf wild indigo were visited and evaluated. All four species were observed in vegetative, flowering, and fruiting condition, and their populations appeared to be healthy.

Tall Upland Shrubland

During 2000, species richness and qualitative abundance were assessed in the tall upland shrubland management units at the Site. A total of 363 plant species were recorded, of which 82 percent were native species. This was an increase over past inventories of the tall upland shrubland, which documented 352 species in 1997 and 333 species in 1996. The tall upland shrubland continues to be the richest plant community at the Site, despite the fact that it represents less than one percent of the Site's total area. The most critical management issue in the tall upland shrubland, as well as the greatest threat, is from noxious weeds. Canada thistle is common throughout the tall upland shrubland patches, particularly on the downhill sides where more moisture is available. Diffuse knapweed is present on the grasslands surrounding most of the tall upland shrubland and is invading into the openings within the tall upland shrubland patches. Without effective control in these upper drainages of Rock Creek, diffuse knapweed will become increasingly problematic, and will be more difficult to control near the tall upland shrubland. One other weed species of particular concern in the tall upland shrubland is bouncing bet. Small patches were observed in four of the ten tall upland shrubland management units. Spot control planned for FY2001 should control and begin to eradicate this weed from these locations.

Aside from these concerns, the tall upland shrubland appeared generally healthy. No substantial signs of disease, predation, injury, or die-off of any of the dominant tall upland shrubland species were observed. Most appeared to have flowered and produced fruit during 2000. In general, the tall upland shrubland continues to be a plant community of high importance, providing critical habitat for many plant species found nowhere else at the Site. In addition, the tall upland shrubland provides important forage and wildlife habitat for many birds, as well as the deer population on the Site.

Mesic Mixed Grassland

During 2000, three permanent monitoring sites (TR02, TR04, and TR11) in the mesic mixed grassland community were monitored to reassess conditions and determine whether changes observed in the 1999 data were simply an anomaly or part of a longer-term change. The 1999 data showed a large compositional shift from dominance by cool-season species to warm-season species since the sites were last monitored in 1995. Monitoring in 2000 was conducted to determine whether this shift could be documented for a second year. The results from 2000 continue to substantiate the overall increase in warm-season graminoid cover observed at all sites and in the community overall since 1995. The reduced cover of Japanese brome (a non-native species) and increased cover of native, perennial graminoids—blue grama and side-oats grama—has improved the quality of these grasslands and should reduce the potential for soil erosion and accidental wildfires. In addition, species richness has remained stable, and diversity and native foliar cover have increased.

Weed Monitoring and Control

Sitewide weed mapping continued for selected species, as a means of monitoring the distribution of specific noxious weed species on the Site, identifying high-priority treatment areas, and tracking the effectiveness of weed control efforts. The species with the greatest extent on the Site during 2000 were diffuse knapweed (2,223 acres), common mullein (1,010 acres), and musk thistle (792 acres). Since 1998, the total Site acreage infested by diffuse knapweed, musk thistle, and common mullein has decreased, largely due to the aerial herbicide applications conducted in May 1999 and May 2000. Diffuse knapweed acreage across the Site has decreased by almost 700 acres during this time, and musk thistle has decreased by almost 900 acres. Common mullein distribution has not been affected as much by the herbicide applications, however. Results of the 2000 mapping effort have been used to establish weed control plans for 2001. Several areas still needing control have been identified for larger-scale treatment, as well as spot control in 2001.

Physical and mechanical weed control measures at the Site in 2000 consisted of grading, mowing, and selective hand control. Mowing was done along the margins of the main east and west access roads, in addition to several miles of firebreak roads in the Buffer Zone, to prevent the roadside weeds from going to seed and spreading further. Grading was conducted along firebreak roads in the Buffer Zone, to maintain these firebreak roads, and timing was selected to have maximum impact on the roadside weeds. Hand control in 2000 was conducted at several locations to control localized infestations of scotch thistle, annual rye, bouncing bet, and dame's rocket. Hand control consisted of hand pulling, using sickles or sling blades, and spot herbicide spraying. The use of hand control has proven valuable in preventing these small infestations from becoming larger problems.

During 2000, a new biological control insect for Canada thistle (*Cirsium arvense*) was released at the Site. Approximately 200 adults of *Urophora carduii*, a gall-forming fly, were released at two locations in the Rock Creek drainage where other methods of controlling Canada thistle are impractical. The insects were obtained from the Colorado Department of Agriculture in an attempt to establish a reproducing population at the Site.

Herbicide applications of Tordon 22K and Transline were used to control several hundred acres of noxious weed–infested grasslands at the Site during 2000. Primary target species were diffuse knapweed, musk thistle, and mullein; however, other less aggressive exotic species such as goatsbeard, curly-top gumweed, alyssum, wild lettuce, small-seeded false flax, and some of the tansymustards were also controlled. Approximately 75 acres were treated on the ground, while almost 1,022 acres were treated with a helicopter during 2000.

Monitoring results from recent herbicide applications continue to indicate that progress is being made in the control of noxious weeds at the Site. The 2000 aerial herbicide application reduced the total number of acres infested by diffuse knapweed (in the spray areas) by 409 acres, from 510 acres in 1999 to 101 acres in 2000. This represents an 80

percent reduction in the total number of diffuse knapweed–infested acres in the areas that were sprayed in 2000. In the areas sprayed by helicopter in spring 1999, many still contain little diffuse knapweed. However, at some locations, the effectiveness of the control has lessened, and diffuse knapweed has begun to increase. Although Tordon 22K is known to typically have a 3- to 4-year residual impact on diffuse knapweed, several factors might explain the shortened control period at some of the treated areas. Control at the Site has typically been best on the flat areas on top of the pediment, where the herbicide was applied most evenly. However, variations exist in the evenness of the herbicide application, even from the air, and missed flight lines and continued disturbances (largely from burrowing mammals) remain problematic. Control on the hillsides has been less consistent than on the flat areas, and this is where the diffuse knapweed has been returning most quickly. Without spot control to continually treat the missed or disturbed areas within the larger treated areas, diffuse knapweed can begin to return almost immediately. As a result, improvements in spot treatment of problem areas are planned for FY2001.

Quantitative monitoring of the impact of Tordon 22K on diffuse knapweed and native species on the xeric tallgrass prairie at the Site continues to provide valuable information for management decisions. Results have shown good control of diffuse knapweed, the primary target species, four years after herbicide treatment. In the treatment area, initial declines in species richness were transitory, and no changes in overall foliar cover were observed. Although species diversity, overall forb cover, native forb cover, and non-native forb cover declined initially in the treatment plot as a result of the herbicide application, these measures were reversed by 1999, and with the exception of non-native forb cover, they are no longer significantly different from the control area. Additionally, the reduced competition from forbs has improved the vigor and cover of the graminoid species. The results from the study at the Site are consistent with other studies that have examined the effect of Tordon 22K on grassland communities elsewhere. Continued monitoring in 2001 will provide additional information for management of the grassland communities at the Site.

Revegetation Monitoring

During 2000, one project disturbed a previously reclaimed area (approximately 0.5 acres) on a hillside in the Woman Creek drainage at the Site. It was revegetated using a site-specific native seed mix. Monitoring of several large revegetation projects that were done in 1999 was continued in 2000. Results were mixed, and as a result, current administrative and cultural controls were modified. At one revegetation effort, most of the grasses that initially came up in 2000 were non-native reclamation grasses that were not in the specified seed mix provided to the project. An investigation into the cause of this problem was inconclusive, and as a result, Site projects that conduct revegetation are now required to have the seed mix visually inspected by a qualified ecologist prior to planting. At other locations, the straw used for mulch contained viable seed heads. As a result, virtually none of the desired native seed species germinated, but instead, a wheat monoculture resulted. Straw used for projects on the Site now must be threshed (i.e., seed heads removed).

Prescribed Burn

In April 2000, a 48-acre prescribed burn was conducted by the U.S. Forest Service on the xeric tallgrass prairie in the south Buffer Zone at the Site. The objectives of the prescribed burn were to reduce litter, increase the vigor and health of the native species, benefit the warm-season graminoid species, and help recycle nutrients for plant growth. Monitoring results have shown several positive results from the fire. Species richness and diversity have not been affected. Plant litter was reduced by 77 percent (from 4,152 lbs/acre to 963 lbs/acre) in the burned area, lowering the potential for a catastrophic wildfire in this area of the Buffer Zone. One of the goals of the prescribed burn was to increase the dominance of the warm-season graminoid species, especially those that are the characteristic species of the xeric tallgrass prairie. This was accomplished by timing the fire so that it would have the greatest detrimental effect on the cool-season species.

Data from within the prescribed burn area showed that cool-season cover was reduced significantly after the fire, and warm-season graminoid cover increased significantly. In fact, results indicated that the species composition of the burn area was shifted from a cool-season-dominated community to a warm-season-dominated community. Qualitative observations of the burn area also showed that flowering of most of the native graminoid species increased as a result of the fire, in comparison to areas that were not burned, even with the dry summer conditions experienced during 2000. In general, the results of the 2000 spring prescribed burn on the xeric tallgrass prairie have demonstrated the utility of fire as a tool for effective management and restoration of the prairie ecosystems at the Site. With clearly stated objectives, the use of prescribed fire, integrated with other resource management techniques, can help maintain the viability and sustainability of the prairie ecosystems at the Site. Continued monitoring of these transects will provide a better understanding of the longer-term implications for fire on the xeric tallgrass prairie at the Site.

Summary

The ecological resources at the Site continue to provide an important island of biodiversity in a region where much of the native diversity is rapidly being lost to urbanization. However, the results also continue to underscore the serious issues that threaten the quality and long-term sustainability of the Site's ecological resources. These threats come primarily from noxious weeds, human disturbances, and plant litter build-up, the latter of which has resulted from an absence of wildfires and/or grazing over the past several decades. However, the data indicate that, beneath the sometimes visually dominant weedy appearance, the native plant communities are still present and viable. The management actions taken in recent years, such as weed control and prescribed burns, have improved the condition of the grasslands at many locations across the Site. Continued active management of these native communities is necessary if they are to survive over the long term and maintain their ecological value. Through good stewardship and use of best management practices, the Site's current ecological resource

management plan and vegetation management program provide direction for managing the resources in a sustainable manner. As stewards of the ecological resources at the Site, Kaiser-Hill and the Department of Energy continue to strive to preserve and maintain these unique resources into the future.

1. Introduction

Rocky Flats Environmental Technology Site (Site) is a U.S. Department of Energy (DOE) facility located on the Colorado Piedmont east of the Front Range between Boulder and Golden, Colorado. The Site is located in Jefferson County, approximately 16 miles northwest of downtown Denver (Figure 1). In production from 1951 through 1989, the Site manufactured nuclear weapons components for the Cold War. Since shutdown, it has been classified as a Superfund site and is currently undergoing cleanup and closure. One of the DOE's goals for natural resource management has been to preserve the unique ecological resources found at the Site (K-H 1997a).

At an elevation of approximately 6,000 feet, the Site contains a unique ecotonal mixture of mountain and prairie plant species, resulting from the topography and proximity to the mountain front. The Buffer Zone, the area surrounding the Industrial Area, is one of the largest remaining undeveloped areas of its kind along the Colorado Piedmont (approx. 5,600 acres; K-H 1997b). A number of plant communities at the Site have been identified as increasingly rare and unique by the Kaiser-Hill Company (K-H) Ecology Group and the Colorado Natural Heritage Program (CNHP). The largest communities include the xeric tallgrass prairie, tall upland shrubland, wetlands, and Great Plains riparian woodland communities (CNHP 1994, 1995). Small inclusions of a number of other increasingly rare plant communities are also found on the Site. Many of these communities support populations of increasingly rare animals as well, including the federally protected Preble's meadow jumping mouse, and other uncommon species such as the grasshopper sparrow, loggerhead shrike, Merriam's shrew, black crowned night heron, and hops blue and Arogos skipper butterflies (CNHP 1994, 1995).

The K-H Ecology Group conducts ecological monitoring of the Site's natural resources to ensure regulatory compliance and to preserve and protect those resources during cleanup and closure operations. The goal of vegetation monitoring is to assess the status and quality of the plant communities on the Site, document any trends, and assess the effectiveness of various management techniques. Ecological monitoring provides integral data for determining whether the management objectives and goals for the plant communities at the Site are being achieved (K-H 1997a,b). Annual reports are produced to synthesize and interpret the information, providing the DOE with important and timely information necessary for wise stewardship and best management of the Site's ecological resources.

This report summarizes the results of the vegetation monitoring conducted during 2000. Several monitoring techniques were used to evaluate the status and condition of the plant communities on the Site. General descriptions of the methods used are outlined in the following section, with summaries of the monitoring results presented in subsequent sections. Detailed technical reports for each of the specific monitoring activities conducted in 2000 are found in Appendix B.

2. Methods

Vegetation monitoring is conducted at the Site using several methods designed to meet the monitoring objectives. During 2000, monitoring included species richness inventories, noxious weed and rare plant species mapping, photographic documentation, qualitative habitat assessment surveys, quantitative monitoring of long-term plant community changes, quantitative assessments to determine the effectiveness of herbicide applications and potential associated impacts to the native plant communities, and quantitative evaluations of the prescribed burn on the xeric tallgrass prairie.

2.1 High-Value Vegetation Surveys

The goal of the high-value vegetation monitoring is to qualitatively assess the status and condition of the high-value plant communities (xeric tallgrass prairie, tall upland shrubland, selected wetlands, and Great Plains riparian woodland) on the Site and to document any changes in these areas. The high-value plant communities at the Site that are monitored are those identified by the K-H Ecology Group and the CNHP as containing significant or rare ecological resources at both the local and regional scale (K-H 1997b; CNHP 1994, 1995). Small inclusions of other increasingly rare plant communities that are tracked by the CNHP also occur on Site, but these are not currently monitored. Table 1 presents the dominant and subdominant plant communities listed by the CNHP that occur at the Site (CNHP 1999). The ranking system used by the CNHP to indicate the global and state rarity of the communities is explained in Appendix A.

The objectives of the high-value vegetation monitoring are to qualitatively:

- Assess the species richness of the plant communities
- Identify any rare plant populations
- Document the locations and continued presence of any rare plant populations
- Identify and document any infestations of noxious weeds
- Document the effectiveness of weed control applications
- Assess the impacts of disturbance on the plant communities
- Provide a general assessment of the overall status and quality of the plant communities at the Site.

2.1.1 Species Richness Surveys

The tall upland shrubland community was monitored in 2000 as part of the rotating schedule for monitoring high-value vegetation communities on the Site. This community was monitored previously in 1998. Species richness was inventoried in each of the ten tall upland shrubland management units (Figure 2). Inventories were conducted by traversing each management unit twice during the growing season (in spring and late summer) and recording all vascular plant species observed. Attempts were made to visit, as completely as possible, all areas and microhabitats that occur within each management unit.

2.1.2 Weed Mapping Surveys

Sitewide weed mapping continued for selected species, as a means of monitoring the distribution of specific noxious weed species on the Site, identifying high-priority treatment areas, and tracking the effectiveness of weed control efforts. Weed mapping was conducted on foot during the high-value vegetation surveys in the tall upland shrubland and from a vehicle using binoculars for the remainder of the Site. Species were mapped during their respective flowering periods and/or when they were most visible. The species mapped during 2000 included diffuse knapweed (*Centaurea diffusa*), musk thistle (*Carduus nutans*), common mullein (*Verbascum thapsus*), Russian knapweed (*Centaurea repens*), annual rye (*Secale cereale*), Scotch thistle (*Onopordum acanthium*), dame's rocket (*Hesperis matronalis*), bouncing bet (*Saponaria officinalis*), and jointed goatgrass (*Aegilops cylindrica*). Canada thistle (*Cirsium arvense*) was not mapped because it is common throughout most of the wetlands on the Site, and the wetlands map therefore provides a good indication of the infested areas.

Three species—diffuse knapweed, musk thistle, and common mullein—were mapped based on infestation densities. The other species listed above were mapped by presence/absence only. Infestation areas were classified in general density categories of high, medium, low, and scattered, based on a subjective interpretation of the extent, visual density, need for control, and aggressive nature of the species. In general, a high-density category indicated an area that was dominated by a nearly solid infestation and/or very high cover of the species. A medium-density category was used where the infestation provided less cover and was less homogeneous in the distribution of the species. The low-density category was used where the species was present in fewer numbers and did not visually dominate the landscape, but was beginning to establish a foothold in the community and was in need of control. The scattered-density category indicated a sporadic occurrence of the species. The noxious weed populations and distributions were drawn in the field on 44×34-inch sitewide base maps. It should be noted that the boundaries shown on the maps are approximate and are based on professional judgement. They should not be interpreted as a precise outline of the distribution of these species, because no surveying or global positioning system (GPS) equipment was used to locate boundary edges, nor do the maps necessarily represent every location of the species on the Site.

2.1.3 Photographic Documentation Surveys

Photographs were taken at selected permanent high-value vegetation photo-point locations during 2000. Photographs were taken in the same compass directions as past photographs from these photo points. Comparisons were made to past photographs to evaluate changes in the plant communities.

2.1.4 Qualitative Habitat Assessment and Rare Plant Surveys

Qualitative habitat assessments were made in each of the high-value vegetation community management units on the Site during 2000. Assessment objectives dealt primarily with habitat loss, threats to the plant community, weed issues, rare plant species, the health of dominant plant species in the community, and general community quality. Attempts were also made to revisit each of the locations where CNHP-listed plant species of special concern are known to occur. These species include the mountain-loving sedge (*Carex oreocharis*), forktip three-awn (*Aristida basiramea*), dwarf wild indigo (*Amorpha nana*), and carrionflower greenbriar (*Smilax herbacea* var. *lasioneuron*). Population locations were originally mapped during the 1997 field season. Locations are revisited annually to confirm the continued presence of these species on the Site and to evaluate any concerns regarding them.

Further details on the qualitative methods used in 2000 are found in the document *High-Value Vegetation Survey Plan for the Rocky Flats Environmental Technology Site* (K-H 1997c) and *The Environmental Management Department Operating Procedures Manual* (DOE 1995a).

2.2 Quantitative Vegetation Monitoring Techniques

The objectives of the quantitative vegetation monitoring are to assess plant community changes over time (i.e., trends) and/or changes in response to management actions (e.g., herbicide application, prescribed fire). In 2000, quantitative vegetation monitoring was used for evaluating long-term trends on the mesic mixed grassland, evaluating the effects of herbicide applications on the noxious weed diffuse knapweed and on native prairie species, and evaluating the effect of a prescribed burn on the xeric tallgrass prairie at the Site.

Quantitative methods used to assess plant communities included:

- Belt transects (species richness, woody plant and cactus density)
- Point-intercept transects (foliar and basal cover)
- Quadrats (species frequency and selected plant densities).

General descriptions of these methods are provided below. For more detailed information on the quantitative methods used in 2000 for specific projects, refer to the technical reports in Appendix B or the *Environmental Monitoring Department Operating Procedures Manual* (DOE 1995a) and the *High Value Vegetation Survey Plan for the Rocky Flats Environmental Technology Site* (K-H 1997c).

2.2.1 Belt Transects

Species richness was measured in a 2-m-wide belt centered along each permanent 50-m transect. Every plant species rooted within the 100-m^2 area was recorded. In addition, the densities of woody plant and cactus stems were counted by species for the 100-m^2 area and recorded.

2.2.2 Point-Intercept Transects

Basal cover and foliar cover estimates were made using a point-intercept method along each of the 50-m transects. A 2-m-long rod, with a 6-mm diameter, was dropped vertically at 50-cm increments along the transect to record a total of 100 intercept points. Two types of hits were recorded:

- Basal cover hits indicated what material the rod contacted at the ground surface. Hits could be vegetation (live plants), litter (fallen dead material), rock (pebbles and cobbles that were greater than the rod diameter), bare ground, or water, in that order of priority based on the protection from erosion provided by each type of cover. A basal vegetation hit was recorded only if the rod was touching the stem or crown of the plant where the plant entered the ground.
- Foliar vegetation hits (defined as a portion of a plant touching the rod) were recorded in three categories, as defined by height and growth form. The topmost hit of each growth form was recorded. The growth forms measured were herbaceous, woody <2 m in height, and woody >2 m in height.

2.2.3 Quadrats

Frequency information by species was gathered by randomly locating five 1-m^2 quadrats along each transect and recording all species present in each plot. Density counts were made of selected weed species (which varied depending on the individual study) within each of the quadrats.

2.3 Data Analyses

Prior to analysis, all data were checked for quality assurance and quality control (QA/QC), following accepted methods for ecological data at the Site (K-H 1997d). Descriptive and graphical comparisons and summaries of the data were prepared for most data sets. Appropriate statistical analyses were also conducted on the data where feasible. Further details on the specific analyses conducted on particular data sets are found in the technical reports in Appendix B.

3. Results and Discussion

3.1 Tall Upland Shrubland

During 2000, species richness and qualitative abundance were sampled in the tall upland shrubland management units (Figure 2) at the Site. A total of 363 plant species were recorded in the tall upland shrubland at the Site during 2000 (Table 2). Of these, 82 percent were native species. This was an increase over past inventories of the tall upland shrubland, which documented 352 species in 1997 and 333 species in 1996. The percentage of native species has not changed since 1997. The tall upland shrubland continues to be the richest plant community at the Site, despite the fact that it represents less than one percent of the Site's total area. To compare past years' results with the 2000 inventory, a Sorensen similarity index (an index that is used to compare the similarity of species composition between samples; Brower and Zar 1977) was conducted, using presence/absence data. Comparisons between all combinations of years yielded values ranging from 0.90 to 0.92, indicating a very high floristic similarity between years, as would be expected. The small differences in species observed during the different years are mostly a result of the slight differences in routes used to traverse the management units, and of the natural variability in abundance of individual species from year to year.

Examination of the qualitative habitat assessment data from the tall upland shrubland management units in 2000 revealed concerns similar to those reported previously (K-H 1997e; K-H 1998). The most critical management issue in the tall upland shrubland, as well as the greatest threat, is from noxious weeds. Canada thistle is common throughout the tall upland shrubland patches, particularly on the downhill sides where more moisture is available. Diffuse knapweed is present on the grasslands surrounding most of the tall upland shrubland and is invading into the openings within the tall upland shrubland patches. In May 2000, most of the xeric tallgrass prairie areas on the pediments above the tall upland shrubland in Rock Creek were treated by helicopter with Tordon 22K, to control the diffuse knapweed infestations on the grasslands. On the hillsides, however, the proximity to the shrubland and wetland areas and the steepness of the hillsides precluded aerial spraying. Without effective control in these upper drainages of Rock Creek, diffuse knapweed will become increasingly problematic, and will be more difficult to control near the tall upland shrubland.

One other weed species of particular concern is bouncing bet (*Saponaria officinalis*). Small patches were observed in four of the ten tall upland shrubland management units. This species is just beginning to establish at the Site, and with active control efforts, it can be eradicated before it becomes a bigger problem. Numerous other weed species found in the tall upland shrubland included stinging nettle (*Urtica dioica*), mullein (*Verbascum thapsus*), dalmatian toadflax (*Linaria dalmatica*), musk thistle (*Carduus nutans*), and smooth brome (*Bromus inermis*). Further discussion concerning weed control is found later in this report.

Some small areas of erosion were noted, primarily from deer use and a coyote den located at one tall upland shrubland management unit. None of these areas warranted any corrective action. Some of the management units have retained trash that has blown in from offsite locations. The aesthetic value of these areas would be improved by removing this trash.

Aside from these concerns, the tall upland shrubland appeared generally healthy. There were a few observations of tent caterpillars on some of the chokecherry (*Prunus virginiana*), but they did not appear any more abundant than in the past. Besides this, no substantial signs of disease, predation, injury, or die-off of any of the dominant tall upland shrubland species were observed. Most appeared to have flowered and produced fruit during 2000.

In general, the tall upland shrubland continues to be a plant community of high importance at the Site. It contains a high diversity of plant life, with more than half the plant species known to occur at the Site being found in association with this community. Many species of plants are restricted to this community at the Site. In addition, the tall upland shrubland provides important forage and wildlife habitat for many birds, as well as the deer population on the Site.

The detailed technical report for the tall upland shrubland and other high-value plant community monitoring conducted in 2000 is found in Appendix B.

3.2 Mesic Mixed Grassland Monitoring

During 2000, three permanent monitoring sites (TR02, TR04, and TR11; Figure 3) in the mesic mixed grassland community at the Site were monitored to reassess conditions and determine whether changes observed in the 1999 data were simply an anomaly or part of a longer-term change (DOE 1995b; K-H 1997b, 2000). The 1999 data showed a large compositional shift from dominance by cool-season species to warm-season species since the sites were last monitored in 1995. Monitoring in 2000 was conducted to determine whether this shift could be documented for a second year.

A total of 138 species were recorded at all three mesic mixed grassland sites that were monitored in 2000. The number of species found at each site varied from 89 (TR02) to 110 (TR11) (Table 3). The percentage of native species found across all sites combined was 80 percent, with individual sites ranging from 76 to 83 percent (Table 3). Total community species richness was little changed in 2000 as compared to previous years. At specific sites, however, some differences were noted. At TR04, a loss of 11 species from the number recorded in 1999 was observed. The 89 species recorded at TR04 was the lowest number reported since 1993 (Table 3). Many of these were native species, but were species that typically occur very infrequently, so their disappearance for a season is not cause for alarm. The decrease may have been due to the summer drought in 2000 and the hot, southwest-facing aspect of this site. At TR02, the number of species observed in 1999 was lower by 15, compared to 1995, but the number rebounded by 10 species in

2000 (Table 3). The loss of richness in 1999 was a response to the application of Tordon 22K as part of the weed control program at the Site. The rebound in species richness the year following the Tordon 22K herbicide application correlates well with data from other monitoring at the Site that have shown a similar response (K-H 1998, 1999, 2000). At TR11, no difference in species richness was noted in 2000 compared to the past several years (Table 3).

Total foliar cover for the mesic mixed grassland community declined in 2000 compared to past measurements and was, in fact, the lowest ever recorded at these monitoring sites (Figure 4). Both total graminoid cover and total forb cover across all sites combined showed similar responses (Table 4). The best explanation for the decline in cover is the drought conditions that occurred during the summer of 2000. Qualitative observations of the prairie in 2000 showed that many species withered and went dormant in mid-summer. Species diversity (a measure that combines species richness and abundance; Shannon-Weaver; Brower and Zar 1977) showed little change from that in 1999 and still remained higher than that from 1993–1995. The relative cover of native plant species continued to increase in 2000 and reached nearly 80 percent, the highest recorded in the community since monitoring began in 1993 (Table 4). The decrease in non-native cover is largely a result of the loss of cover of Japanese brome, an exotic grass species, which has shown a similar pattern of decline since 1995 (Figure 5). These data suggest that the quality of the mesic mixed grassland has improved over the past several years.

While total non-native foliar cover has decreased in the community, non-native forb cover has changed little across all sites combined, indicating that the weeds (mostly forbs) are still a problem in general (Table 4). However, at TR02, where the aerial herbicide application was conducted in 1999, declines in both native and non-native forb cover were observed (Table 5). In 2000, native forb cover began to increase while non-native cover continued to decline (Table 5). Forb cover should return to pre-treatment levels at TR02 over the next few years, based on other studies at the Site and elsewhere (K-H 1998, 1999, 2000; Rice and Toney 1996; Rice et al. 1997).

The cool- versus warm-season graminoid composition of the mesic mixed grassland continued to shift further toward the warm-season component in 2000 (Table 4, Figure 6). In 1993–1995, cool-season graminoids dominated the grassland, providing approximately 70 percent of the relative cover, while warm-season graminoids accounted for 5–14 percent. However, in 1999, cool-season graminoid cover dropped to about 50 percent of the total cover, while warm-season graminoid cover increased to approximately 32 percent. In 2000, the cool-season graminoids accounted for only 40 percent of the relative cover, and warm-season graminoid species became the dominant cover, at approximately 45 percent. The loss of cool-season graminoid cover on the mesic mixed grassland is due largely to the 36-percent reduction in the cover of Japanese brome and 7-percent loss of western wheatgrass observed from 1995 to 2000 (Table 4). In 1994 and 1995, Japanese brome had the highest cover of all species on the mesic mixed grassland (Table 4).

The graminoid species accounting for the increase in warm-season cover are blue grama and side-oats grama, both native grasses. Figure 7 illustrates the change in foliar cover for the dominant species on the mesic mixed grassland from 1993 to 2000. Although relative cover values are mentioned here because they are the best measure of actual species composition of the vegetation present, the absolute or actual cover of these species also declined or increased by similar amounts. The lack of data from 1996–1998, however, limits understanding whether the increases in warm-season graminoid cover actually started prior to 1999. This illustrates the difficulty of interpreting change when continuous data sets are not available.

Taken separately, individual sites also showed these differences, although with some variation. The change in cool-season versus warm-season graminoid composition was most pronounced at TR04, where the warm-season cover has increased by over 50 percent and cool-season species have declined by the same amount from 1995 to 2000 (Table 6). The species that accounts for nearly 39 percent of the increase is blue grama.

At TR02, the change in cool- vs. warm-season graminoid composition has also been dramatic. Relative foliar cover of warm-season graminoids increased from 8 percent in 1995 to just over 50 percent in 2000, with most of this increase coming from blue grama and sideoats grama (Table 5). Relative foliar cover of cool-season graminoids decreased from 66 percent to 38 percent during the same time period (Table 5). This site received an aerial herbicide treatment of Tordon 22K (applied in mid-May 1999), which could account for some of this change. Due to the timing of the herbicide application in 1999, most of the cool-season graminoid species would have been growing and getting ready to flower. Thus, by the time the herbicide actually took effect on the target species and some of the non-target species, the opportunity for the cool-season graminoid species to take advantage of the reduced competition would have passed. Instead, the warm-season graminoid species, which would have just started their growth period, would have been able to take advantage of the reduced competition and higher summer precipitation, thus accounting for much of the increase in cover.

At TR11, increased warm-season and decreased cool-season graminoid cover has also been observed, with warm-season cover increasing by 24 percent and cool-season cover decreasing by 19 percent from 1995 to 2000 (Table 7). Here, increases in the cover of blue grama, side-oats grama, and big bluestem largely account for the increase in warm-season cover (Table 7). Thus, although a shift in cover composition was noted across all sites, the shift was not of equal magnitude at every site.

From a management standpoint, the shift in graminoid composition observed in 1999 and 2000 is a beneficial one. Japanese brome and downy brome, commonly referred to as cheatgrasses, are both non-native species that have taken over millions of acres across the western United States (Pellant and Hall 1994). Areas infested by these cool-season annual grasses often have lower species richness and diversity, less ecosystem stability, increased potential for soil erosion, more frequent wildfires, and lower wildlife and livestock utilization (Rosentreter 1994). Infestation by these grasses has been mentioned previously as a potential management concern for the Site (DOE 1995b). The concern is

lessened by the reduction of these species in the mesic mixed grassland, as seen in the last two years of data, and a shift to a more perennial, warm-season graminoid composition. Whether cheatgrass cover will continue to remain low or begin to increase at some point is uncertain at this time. The reason for the loss of cheatgrass cover is unknown, but it could be due to climatic variations or possibly a cyclic response of the different species over time. Monitoring of these locations in the future will assess the status of this trend over time.

In general, the quality of the mesic mixed grassland at these sites has improved over the past several years, due to the loss of cover of exotic species and the increase in cover of native species. Future monitoring will evaluate whether these trends continue. The detailed technical report for the mesic mixed grassland monitoring conducted in 2000 is found in Appendix B.

3.3 Rare Plants

Observations were made during 2000 of each of the plant species of concern listed by the CNHP as rare or imperiled that occur on the Site. Populations of mountain-loving sedge, forktip three-awn, carrionflower greenbriar, and dwarf wild indigo were visited and evaluated. All four species were observed in vegetative, flowering, and fruiting condition, and their populations appeared to be doing well. Figure 8 shows the known locations where these species have been observed on the Site.

3.4 Site Flora

As a result of the 2000 field work, a total of seven new records of vascular plant species are reported for the Site. Plant nomenclature follows that of GPFA (1986), Weber (1976), and Weber (1990), in that order of determination. The new plant species reported for the Site are:

Astragalus parryi Gray	Parry's Milkvetch
Cyperus acuminatus Torr. & Hook.	Taperleaf Flatsedge
Eleocharis obtusa (Willd.) J.A. Schult.	Blunt Spikerush
Limosella aquatica L.	Mudwort
Lygodesmia juncea (Pursh) Hook	Skeleton-weed
Panicum dichotomiflorum Michx.	Fall Panicum
Stipa robusta (Vasey) Scribn.	Sleepy Grass

None of the new species recorded on the Site in 2000 is a rare species or state-listed noxious weed. The total number of vascular plant species recorded for the Site is now 592. The complete list of plant species known to occur at Rocky Flats as of the end of the 2000 field season is found in Appendix C. Voucher specimens of these species are maintained in the Site herbarium.

3.5 Vegetation Management

Active natural resource management is an important component of the Site's ecology program. In order to achieve the DOE's goal of preserving and sustaining the natural resources in the Buffer Zone at the Site, it has become essential to apply an adaptive ecosystem management approach. At present, the most serious threat to the native plant communities on the Site is from noxious weed infestations. Although many species of weeds exist in the plant communities at the Site, most are not especially problematic. However, under the Colorado Noxious Weed Act (CRS 1996), a number of particularly noxious weeds must be controlled by property owners to prevent their spread to surrounding lands. Some of these weeds pose a significant threat to the plant communities at the Site. During 2000, the Site's vegetation management program used a variety of methods to address these problems. In addition, monitoring was conducted to ascertain the effectiveness of ground and aerial herbicide applications on diffuse knapweed, and to assess any associated impacts to native species, evaluate the effectiveness of a prescribed burn for prairie restoration and management, and map the distribution of various weed species. A general synopsis of the activities and monitoring conducted during 2000 for vegetation management is presented below. Additional, more detailed information outlining the Site's vegetation management program and related monitoring activities conducted in 2000 can be found in the technical reports in Appendix B.

3.5.1 Vegetation Management at the Site in 2000

During 2000, the vegetation management program at the Site continued to work toward controlling infestations of several noxious weed species in the Buffer Zone. Several methods were applied to control current infestations and prevent new ones from starting. These included the use of administrative and cultural controls, physical and mechanical methods, biological controls, and chemical controls. Strides were made in controlling several large infestations of diffuse knapweed, musk thistle, and mullein, in addition to other, smaller infestations of scotch thistle, annual rye, bouncing bet, and dame's rocket. A 48-acre prescribed burn was conducted to improve the quality of the xeric tallgrass prairie at a location in the south Buffer Zone (see Appendix D for photographic documentation of the prescribed burn and associated monitoring).

During 2000, one project disturbed a previously reclaimed area (approximately ½ acre) on a hillside in the Woman Creek drainage at the Site. It was revegetated using a site-specific native seed mix. Photographs were taken after the revegetation and will be used for comparison to future photographs to document the progress of the reclamation. Monitoring of several large revegetation projects that were done in 1999 (K-H 2000) was continued in 2000. Results at these projects were mixed, and consequently, current administrative and cultural controls were modified. At one revegetation effort, most of the grasses that initially came up in 2000 were non-native reclamation grasses that were not in the specified seed mix provided to the project. An investigation into the cause of this problem was inconclusive, and as a result, Site projects that involve revegetation are now required to have the seed mix visually inspected by a qualified ecologist prior to

planting. At other locations, the straw used for mulch contained viable seed heads. As a result, virtually none of the desired native seed species germinated, but instead, a wheat monoculture resulted (Figure 9). Straw used for projects on the Site now must be threshed (i.e., seed heads removed). For each of these projects, photo monitoring and qualitative assessments of the resulting revegetation effort were initiated in 1999 and continued in 2000, to evaluate the effectiveness of the revegetation efforts and to continue learning what works best for conditions at the Site. Results of the photo monitoring efforts are found in Appendix E.

As part of the ongoing vegetation management program, the sharing of information and planning strategies with other local agency weed coordinators and resource managers is important, because coordination of efforts between land owners is essential for long-term control. During 2000, the K-H Ecology Group disseminated information on weed control and vegetation management to onsite personnel, through meetings, personal communication, and Site newspaper articles. In addition, K-H ecologists attended regional weed control meetings with other agencies' weed control specialists, and the annual 2000 Colorado Weed Management Association conference, to keep up to date with the most recent knowledge and advances in weed control.

Physical and mechanical controls used at the Site in 2000 consisted of mowing, grading, and selective hand control. Mowing was done along the margins of the main east and west access roads, in addition to several miles of firebreak roads in the Buffer Zone, to prevent the roadside weeds from going to seed and spreading further, and for safety purposes as well (Figure 10). Mowing was also conducted on the xeric tallgrass prairie adjacent to a firebreak road in the northern Buffer Zone, where annual rye has begun to invade the prairie. Mowing was conducted at the time when the seed heads were starting to form. The plan is to continue to mow the annual rye annually until the seed bank is exhausted.

Grading was conducted along approximately 18 miles of firebreak roads in the Buffer Zone, to maintain these firebreak roads and to prevent roadside weeds from going to seed and spreading further (Figure 10). Additional grading efforts were conducted along a few sections of Buffer Zone road to lower the height of the rock rows on either side of the road, so that the mowing equipment can be used more effectively in these areas. One problem that was observed in late summer in these latter areas, however, was that a prolific crop of jointed goatgrass (*Aegiliops cylindrica*), an exotic grass, was now coming up. This species has become an increasing problem along the Buffer Zone firebreak road edges as the grading has spread the seeds around the roads.

Hand control in 2000 was conducted at several locations to control localized infestations of scotch thistle, annual rye, bouncing bet, and dame's rocket. Hand control consisted of hand pulling, using sickles or sling blades, and spot herbicide spraying. The use of hand control has proven valuable in preventing these small infestations from becoming larger, much more costly problems.

During 2000, a new biological control insect for Canada thistle was released at the Site. Approximately 200 adults of *Urophora carduii*, a gall-forming fly, were released at two locations in the Rock Creek drainage where other methods of controlling Canada thistle are impractical. The insects were obtained from the Colorado Department of Agriculture in an attempt to establish a reproducing population at the Site. The release sites will be observed during 2001 to see if the flies have become established and to determine the level of impact on the thistles, if any. Sixty-six biocontrol beetles (*Chrysolina quadrigemina*) for St. John's-wort (*Hypericum perforatum*) were collected on Site and re-released at an infestation near the Lindsay Ranch where very few of these beetles were present to help control it.

Also during 2000, observations were made of one of the biological control species (*Urophora quadrifasciata*) used for controlling diffuse knapweed. Most of the diffuse knapweed populations in the northern Buffer Zone had these seed-head flies on them in low numbers. Although not released on Site, it is likely that they have migrated from a biocontrol research project being conducted north of the Site, on Boulder County Open Space, and from other releases conducted by Boulder County (Owsley 2000). Their presence at the Site is a positive development, and they may help to lower the number of seeds produced per plant.

Previously, biological control insects have also been released at the Site to control musk thistle, St. John's-wort, dalmatian toadflax, and diffuse knapweed. The insects continue to generally do a good job of containing infestations of musk thistle and St. John's-wort. They have been much less effective, however, at controlling infestations of dalmatian toadflax and diffuse knapweed. All the biological control insects released at the Site have been approved by the U.S. Department of Agriculture.

Herbicide applications were used to control several hundred acres of noxious weed–infested grasslands at the Site during 2000. Figures 11 and 12 show the locations of ground and aerial applications of the herbicides Tordon 22K and Transline in 2000. Primary target species were diffuse knapweed, musk thistle, and common mullein; however, other less aggressive exotic species such as goatsbeard (*Tragopogon dubius*), curly-top gumweed (*Grindelia squarrosa*), alyssum (*Alyssum minus*), wild lettuce (*Lactuca serriola*), small-seeded false flax (*Camelina microcarpa*), and some of the tansymustards (*Descurania* ssp.) were also controlled. Approximately 75 acres were treated on the ground, while almost 1,022 acres were treated with a helicopter during 2000 (Figures 11 and 12).

The residual effect of the Tordon 22K is expected to help provide continuing control of these species for the next few years, precluding the need for annual retreatment at these locations. However, because diffuse knapweed will return to pre-treatment levels if nothing else is done, and because some spots were missed at many treatment locations, a feasibility study was conducted to evaluate using spot control to keep infestations at these locations from returning as quickly. Hand control using a backpack sprayer with Roundup was conducted at a location treated by helicopter in 1999. During a one-hour period, an area of approximately 2–3 acres was spot treated to control individual plants

coming up. Most plants treated were found growing in association with old small-mammal burrows and mounds where continuing disturbance reduces the long-term viability of the applications. Results suggest that spot control of this type on foot would be very time consuming and costly for large areas. It would be more feasible to use a truck or 4-wheel all-terrain vehicle with a mounted spray bar system to cover larger areas in shorter periods of time for spot control. Plans are being developed to initiate larger-scale spot control during 2001 to control the noxious weeds that have begun to return to previously treated areas. More information on the aerial and ground herbicide monitoring results follows below and can also be found in the technical reports in Appendix B.

A 48-acre prescribed burn was conducted in April 2000, on the xeric tallgrass prairie in the south Buffer Zone, to improve the quality of the prairie habitat. More detailed results of the prescribed burn are discussed later in this report and can also be found in Appendices B and D.

3.5.2 Weed Monitoring

3.5.2.1 Weed Mapping

The 2000 weed distribution maps for diffuse knapweed, musk thistle, and common mullein are shown in Figures 13 through 15, respectively. Six additional species—annual rye, Russian knapweed, Scotch thistle, dame's rocket, bouncing bet, and jointed goatgrass—were mapped in 2000 because of their aggressive nature and their recent appearance at various locations on the Site. The distributions of these species are shown in Figures 16 and 17. After being entered into the Site Geographic Information System (GIS), the overall extent of these species across the Site was estimated by species and by infestation level. Table 8 contains the estimated total acreage and acreage-by-density category for each of the listed species, based on the 2000 maps. The species with the greatest extent on the 6,485-acre Site (K-H 1997c) were diffuse knapweed (2,223 acres), common mullein (1,010 acres), and musk thistle (792 acres). The total acreages for annual rye, Russian knapweed, Scotch thistle, dame's rocket, bouncing bet, and jointed goatgrass are also shown in Table 8. It should be noted that all these acreages are approximate and should not be interpreted as exact areas. These values also represent only known locations of these species. It is possible that unmapped infestations are present as well.

Table 9 shows the annual total infested acreages for diffuse knapweed, musk thistle, and common mullein from 1997 to 2000. Most of the large increases in infestation acreages from 1997 to 1998 were a result of the time of year in which mapping was conducted. Mapping in 1997 was conducted in August for each of the species. Beginning in 1998, weed mapping was conducted for each species when that species was in flower and/or most visible. Therefore, the higher visibility of the species at the time of mapping allowed more accurate estimates of their infestation levels in 1998, 1999, and 2000, and thus the resulting higher acreages mapped.

Since 1998, the total Site acreage infested by diffuse knapweed and musk thistle has decreased, largely due to the aerial herbicide applications conducted in May 1999 and May 2000. Diffuse knapweed acreage across the Site has decreased by almost 700 acres during this time, and musk thistle has decreased by almost 900 acres. Common mullein distribution has not been affected as much by the herbicide applications, however—from 1999 to 2000, a decrease of approximately 58 acres was observed.

The effectiveness of the herbicide applications has been monitored largely through the use of the GIS. Analyses using the GIS have proven useful not only for determining the effectiveness of the control efforts, but also for showing problems with the application techniques and helping improve the weed control efforts at the Site. Figures 18 through 20 show the locations of the aerial herbicide application in 1999, and the pre- and post-treatment diffuse knapweed densities at these locations in 1998, 1999, and 2000, respectively.

Approximately 1,500 acres were treated by helicopter with Tordon 22K in 1999. In 2000, approximately 1,022 acres were treated aerially with Tordon 22K and Transline. Figures 21 and 22 show the locations of the 2000 aerial herbicide application and the pre- and post-treatment diffuse knapweed densities from 1999 and 2000, respectively. The maps illustrate the dramatic reduction in the amount of diffuse knapweed in response to the spraying. As reported in the 1999 annual vegetation report, the total amount of diffuse knapweed was reduced by 683 acres, from 878 acres in 1998 to 195 acres at the locations treated in 1999 (Table 10). This represented a 78 percent reduction in the total number of diffuse knapweed–infested acres in the areas that were sprayed in 1999. Figure 23 shows graphically how the diffuse knapweed has been affected in the 1999 spray areas. At the 2000 spray locations, an 80 percent decline in the total number of diffuse knapweed–infested acres was observed (Table 11; Figure 24). In practical terms, this means that essentially no adult diffuse knapweed plants were observed at these locations.

The elimination of adult plants from these areas meant that no new seed was added to the seed bank and no plants were available to blow away from these infestations, further infesting other areas. The 2000 mapping effort, however, revealed that diffuse knapweed has begun to return to several of the areas treated in May 1999 (Figure 20). Figure 23 shows that the lower density categories had the greatest increases in diffuse knapweed density in 2000. Although Tordon 22K is known to typically have a 3- to 4-year residual impact on diffuse knapweed, several reasons might explain the shortened control period in the treated areas.

Control at the Site has typically been best on the flat areas on top of the pediment, where the herbicide was applied most evenly. However, variations exist in the evenness of the herbicide application, even from the air, and missed flight lines and continued disturbances (largely from burrowing mammals) remain problematic (Figure 20). Without spot control to continually treat the missed or disturbed areas within the larger treated areas, diffuse knapweed begins to return almost immediately. Observations of

some of the treated burrow mounds have shown that, a year after treatment, they can support a solid stand of diffuse knapweed again. Additionally, missed flight lines that were not observed during the first year after treatment have appeared during the second year, continuing to decrease the overall effectiveness of the treatment (Figure 25).

Control on the hillsides is less consistent than on the flat areas, and overall diffuse knapweed densities have been reduced by lesser amounts at these locations. It is unknown why control has been less effective on the hillsides. Perhaps the steepness of the hillsides forces the helicopter to fly slightly higher, thus reducing the amount of herbicide that reaches the ground surface. Possibly, using a larger droplet size during applications on the hillsides might improve the effectiveness there.

Overall, the aerial application of Tordon 22K for control of diffuse knapweed and other noxious weed species has been beneficial and generally improved the quality and appearance of the Site's grasslands. The initial response has been increased vigor, health, and flowering of the grasses, reduced abundance of diffuse knapweed and other weeds, and an initial decline in the abundance of some native forbs. Other studies on the grasslands at the Site have shown that the native forb component returns to the level found in untreated areas after approximately 3 years. (For more specific information on the longer-term effects of Tordon 22K on the grasslands at the Site, from both aerial and ground-based applications, see the following sections below, the Technical Reports in Appendix B of this report, and past annual vegetation reports for the Site [K-H 1998, 1999, 2000]).

3.5.2.2 Aerial Herbicide Application Monitoring

Monitoring continued in 2000 at the plots that were used to evaluate the 1999 aerial herbicide application and its effects on diffuse knapweed density and frequency. A total of 30 control and 30 treatment plots were set out at three locations in the Buffer Zone prior to the aerial herbicide application in May 1999 (Figure 26). Monitoring of diffuse knapweed density and frequency was conducted pre- and post-treatment. Results in 2000 continued to show excellent control of the diffuse knapweed at these locations. Initial cover amounts for diffuse knapweed (seedlings and rosettes) at the control and treatment plots prior to aerial herbicide application were not statistically different, averaging approximately 7 and 9 percent, respectively (Figure 27). However, approximately 3 months after the herbicide application, diffuse knapweed cover amounts (seedlings, rosettes, and adults) were statistically different between the late summer control and treatment plots, averaging 25 and less than 1 percent, respectively (Figure 27). In 2000, diffuse knapweed cover in the treatment plots remained significantly lower than in the control plots in both the spring and summer (Figure 27). Diffuse knapweed frequency in the control plots has decreased only slightly over time and was not significantly different (Figure 28). In the treatment plots, however, the frequency of diffuse knapweed dropped substantially, from 83 percent before treatment to 10 percent, where it remains 1½ years after treatment (Figure 28). One of the control quadrats, photographed the year following the herbicide application, is shown in Figure 29. Figures 30 and 31 show the diffuse knapweed infestation in the area at the AS-2 plot before and after herbicide application.

Drift-card results from the 2000 aerial herbicide application showed that no substantial herbicide drift was observed in any sensitive habitats adjacent to the spray areas. These results continue to underscore the value of the large-scale herbicide applications for controlling the diffuse knapweed at the Site. While the use of chemical controls has dramatically improved the quality of the grasslands at the Site, in the long term, integration with other weed control techniques is ultimately the goal. Further information on the aerial herbicide monitoring results is contained in the technical reports found in Appendix B.

3.5.2.3 Ground Herbicide Application Monitoring on Diffuse Knapweed and Native Plant Species

The use of herbicides for weed control, while usually effective on the target species, also typically affects other species as well. Because of the importance of the xeric tallgrass prairie at the Site, the effect of the herbicide Tordon 22K on the noxious diffuse knapweed, as well as on native species that occur on the xeric tallgrass prairie, was examined to provide important information for weed control and resource management activities at the Site. The study was initiated in 1997 and used both a control plot (unsprayed) and a treatment plot (sprayed), each with five 50-m transects (Figure 32). The variables measured included species richness, cover, frequency, and diffuse knapweed density. The treatment plot was sprayed with Tordon 22K (application rate: 1 pint/acre) in June 1997. Monitoring was conducted pre-treatment in 1997 and post-treatment during each year since then.

In 1997 and 1998, after the herbicide application, a number of measured plant-community variables showed declines as a result of the herbicide application. In addition to diffuse knapweed, forbs in general were affected. Overall forb cover decreased considerably, and species richness, cactus density, and species diversity all declined initially (K-H 1998, 1999). Data from the 1999 and 2000 field seasons, however, have shown the expected reversal of many of these initial responses (K-H 2000).

Although overall species richness in the treatment plot declined by 12 species immediately after the herbicide application in 1997, overall species richness had essentially returned to pretreatment levels by 1999 (only one species less than the original number; Figure 33). Currently, species richness is higher in the treatment plot than in the control plot. The declines observed in both the control and treatment plots in 2000, relative to 1999, are best explained by the very dry winter and summer in 2000. A Sorensen coefficient of similarity index (an index used to evaluate species similarity between locations), was used to evaluate the species composition similarity within the control and treatment plots from spring 1997 to summer 2000. Index values of 0.82 for the control plot and 0.86 for the treatment plot suggest a very high similarity in species richness between pre- and post-treatment for both plots. Additional comparisons of similarity between the control plot and the treatment plot, for spring 1997 and summer 2000, showed essentially no difference either, thus indicating that no long-term loss of species occurred as a result of the herbicide application. Examination of the species lists

through time (from 1997 through 2000) for both the control and treatment plots (Tables 12 and 13), shows little difference in the overall species richness of either plot. The data show numerous species in both plots that appear and disappear during different years. For those few species, in either plot, that were present to begin with but disappeared during the course of the study, examination of the cover and frequency data showed that these species occurred in very small amounts to begin with. Thus, it is not really possible to attribute their disappearance to the herbicide or any other factor, but rather, it is most likely just part of the natural variation on the grassland.

Species diversity (a measure combining species richness and abundance; Shannon-Weaver) declined immediately after the herbicide application in the treatment plot, reaching its lowest level in summer 1998, when it was significantly different from the control plot (Figure 34). However, in 1999, species diversity in the treatment plot was no longer significantly different from the control plot. Continued gains in spring 2000 were reversed, however, in summer 2000. The loss of species diversity is largely attributable to the loss of forb cover; both measures showed parallel responses (Figure 35). It is interesting that the control plot showed no loss in either species diversity or forb cover as a result of the drought in summer 2000 (Figures 34 and 35)—in fact, both measures increased. This suggests that the loss shown in the treatment plot is either a response to the combined stresses from the drought and the herbicide, or perhaps increased competition from the graminoids. Continued monitoring will reveal whether species diversity on the xeric tallgrass prairie at the Site returns to pre-treatment levels next year.

The effect on diffuse knapweed, the primary target species of the herbicide application, has been dramatic. The herbicide application reduced and continues to control the diffuse knapweed in the treatment plot, where diffuse knapweed densities remain far below their original values (Figure 36). Diffuse knapweed cover also remains at less than 2 percent of the total relative foliar cover (Table 14). In the control plot, however, diffuse knapweed densities have fluctuated widely on a seasonal and annual basis, and continue to increase from pre-treatment levels (Figure 36).

The effective control of diffuse knapweed observed in the treatment plot is critical, because the longer the control continues, the fewer adult plants there are to produce additional seeds and blow across the landscape spreading the seeds. Thus, the control of diffuse knapweed documented from 1997 through 2000 in the treatment plot has reduced and continues to control diffuse knapweed seed production in the area. This has substantially reduced the chances for spread of the species from this area. Both of these criteria are important for controlling diffuse knapweed. Another important consideration, however, is that with time, diffuse knapweed density will begin to increase again in the treatment plot as a result of the seed bank that remains, and from immigration of new seed from offsite sources (e.g., grasslands and mining areas to the west). If no further control measures are taken, the densities will again reach, and could potentially exceed, pre-treatment levels in a few years. In fact, although diffuse knapweed densities continue to be controlled to low levels, frequency data for diffuse knapweed in the treatment plot showed that, after bottoming out at 20 percent in 1998, diffuse knapweed frequency

increased to 44 percent in 1999, and to 48 percent in 2000 (Table 15). Clearly, diffuse knapweed is slowly returning to the area.

It is also important to recognize that these data are from a small area of the grassland. Therefore, monitoring should be done at various scales to better evaluate the overall effectiveness of the herbicide application. In the larger area surrounding the treatment plot, which received the same herbicide application, weed mapping results have begun to show an increase and return of diffuse knapweed to the larger area. Thus, although the herbicide application in the treatment plot continues to control the diffuse knapweed, long-term integrated weed control using multiple methods is necessary for sustainable control of this species. Additionally, spot control of missed areas or small locations where infestations have begun to return would help extend the length of effective control across the larger area. The use of spot control methods becomes especially important because of the potential long-term impacts to the native plants in the community in response to repeated large-scale, long-term herbicide applications. Cooperative weed control in conjunction with surrounding landowners would help address the issue of seed being transported onto the Site. More details on the weed mapping that has been done at the Site during the same time frame as this study are available elsewhere in this and earlier versions of the Annual Vegetation Report for the Site (K-H 1998, 1999, 2000).

The response of the non-target species on the xeric tallgrass prairie varied but fell within generally expected parameters. Total absolute (actual) cover on the xeric tallgrass prairie was not substantially affected by the herbicide treatment—changes in the treatment plot generally paralleled changes in the control plot (Figure 37). This is important because it demonstrates that no large, barren, unvegetated areas were created on the prairie as a result of the herbicide application. Instead, other species (graminoids) expanded, moving in and filling in the canopy to replace the species that were reduced by the spraying.

The forb, or non-grass, component of the prairie, both non-native and native, was affected by the herbicide treatment. This was not unexpected, because the herbicide Tordon 22K, though considered a selective herbicide, affects a number of plant families. Two growing seasons after the herbicide application, however, total relative forb cover in the treatment plot was no longer significantly different from the control plot (Figure 35). The significant loss of forb cover observed in the treatment plot during the summer of 2000 may have resulted from either the combined stress from the drought and the herbicide application or increased competition from the graminoids.

Although native relative forb cover was equal in the control and treatment plots prior to the herbicide application, after treatment, the native relative forb cover dropped significantly in the treatment plot (Figure 38). However, by 1999, native relative forb cover was no longer significantly different from the control plot, and it remained that way through spring 2000. Examination of the non-native relative forb cover showed that by spring 2000, the difference in total forb cover between the control and treatment plots was due to the higher non-native forb cover in the control plot. The non-native forb cover in the treatment plot was still being controlled by the herbicide treatment and was significantly below that found in the control plot. The loss of native forb cover in the

treatment plot during the late summer of 2000 is likely explained by the reasons mentioned above.

The information on the forbs is important because it is not desirable to re-treat the area with a broadleaf herbicide if the native forb component of the community has not returned to its former level of abundance. Repeated broadcast applications of herbicide without allowing appropriate time for the native forbs to rebound could potentially stress them to the point of elimination from the grassland—an undesirable result. In a situation where the native species have not completely returned to pre-treatment levels, a broadcast application of a more species-specific herbicide—such as Transline, which controls diffuse knapweed very effectively, with less impact on other species—might be useful as a follow-up. This would continue to give the native species a chance to return. Drawbacks to Transline, however, are its higher cost and its lack of a multi-year residual effect. Therefore, more frequent retreatment would be required to maintain effective control.

The loss of forb cover in the treatment plot did not cause a loss of overall foliar cover—as mentioned above, the total foliar cover in the treatment plot paralleled the response in the control plot. The loss of relative forb cover was offset by an increase in relative graminoid cover in response to reduced competition from forb species (Figure 39). The increase in relative graminoid cover in the treatment plot began after the herbicide application, and it continues four growing seasons after the herbicide treatment.

One of the most affected non-target species groups was cacti. The density of the twistspine prickly pear cactus has been reduced by about 87 percent, and hedgehog cactus by over 50 percent, since the herbicide application in 1997 (Figures 40 and 41). Most of the cacti turned yellow after the herbicide application and later died. Continued monitoring will document whether the cacti begin to return to the treatment plot, but any return will be gradual because cacti grow slowly.

Data from the Site are consistent with data from other studies that have shown an initial decline in species diversity, loss of forb and weed cover, and increase in graminoid vigor and cover after spraying with Tordon 22K. Rice and Toney (1996) reported decreases in forb cover due to herbicide treatments on native prairie in Montana. They reported that these responses were transitory, however, and that forb values returned to pre-treatment levels after about three years. Rice et al. (1997) found that species diversity also declined after spraying with Tordon 22K, but recovered after 2–3 years. Both of these studies also indicated that, as a result of lost weed and other forb cover (i.e., reduced competition), the graminoid component of the community responded vigorously. In the Lolo National Forest in Montana, Henry (1998) reported that, two years after spraying with Tordon 22K, a mountain grassland community had a 95 percent reduction in weed biomass and an 86 percent decrease in forb biomass. Associated with this was a 714 percent increase in grass biomass.

In general, the use of Tordon 22K on the xeric tallgrass prairie at the Site has proven beneficial, with little long-term impact to species richness and diversity, or loss of native

forb cover. Continued monitoring will document the recovery of the xeric tallgrass prairie under the conditions present at the Site. This information will be useful for developing improved weed-control strategies and provide for better long-term management of the Site's grassland communities. More detailed information on these monitoring results is available in Appendix B.

3.5.3 Prescribed Burn Monitoring

Monitoring was conducted on the xeric tallgrass prairie at the Site during the summers of 1999 and 2000 to collect pre- and post-burn vegetation data at locations where a 48-acre prescribed burn was conducted in April 2000 (Figure 42). Data were collected from ten 50-m transects in the control (unburned) area, and ten in the treatment (burned) area, for comparison. All control and treatment monitoring areas were treated with the herbicide Tordon 22K, applied by helicopter, in May 1999.

Analysis of the data shows that species richness was not affected by the fire. Both control and treatment plots increased by six species from 1999 to 2000 (Table 16). Species diversity increased only slightly as a result of the burn—from 0.931 in 1999 to 0.963 in 2000. Cactus densities declined, but similar declines were observed in both the control and treatment areas; therefore, these declines are best explained as a response to the herbicide application, rather than to the prescribed burn (Table 17). Similar losses of cactus density have been observed at other monitoring locations for herbicide effects where no prescribed fire has been used (see other sections of this annual report or K-H 1999, 2000).

One of the objectives of the prescribed burn was to reduce the amount of dead plant litter on the prairie, thereby reducing the potential for a wildfire and also recycling nutrients back to the plants. Ground cover data showed that surface litter decreased significantly, by approximately 7 percent, with a corresponding increase in rock and bare ground cover. Although a 7 percent reduction in litter cover at the ground surface doesn't sound significant, it must be remembered that this value was determined using a point-intercept method of measuring cover, and thus records only what is present at the ground surface. This method does not measure the actual amount or depth of the litter present. The biomass data, on the other hand, showed that overall biomass was reduced by 77 percent (from 4,152 lbs/acre to 963 lbs/acre) in the burned areas, so it is clear that the fuel available for a wildfire was reduced (Figure 43). The fact that the cover of litter at the ground surface was not completely removed is actually beneficial, because it means there was still some cover protecting the ground surface from wind and/or water erosion. For these reasons, the fire accomplished what it was designed to do. The amount of biomass available as fuel on the grassland was reduced, but the ground surface itself remained protected from wind and water erosion as the vegetation returned throughout the summer. Additionally, the fire recycled nutrients that were tied up in the dead plant litter and stimulated the growth of the perennial grass species.

By the end of the growing season, total foliar cover on the grassland was essentially unchanged by the fire. Total foliar cover was approximately 2.5 percent less in 2000 than

in 1999, in both the control and treatment plots (Tables 18 and 19). Forb cover increased only slightly in the treatment area, compared to the control (Tables 18 and 19). In general, however, forb cover was depressed in both the control and treatment plots, most likely as a result of the herbicide application from 1999 and/or the low precipitation received during the spring and early summer of 2000.

Overall graminoid cover also remained essentially unchanged as a result of the fire (Tables 18 and 19). However, the ratio of cool-season to warm-season graminoids was changed as a result of the burn. One of the goals of the prescribed burn was to increase the dominance of the warm-season graminoid species, especially those that are the characteristic species of the xeric tallgrass prairie. This was done by timing the fire so that it would have the greatest detrimental effect on the cool-season species. In the unburned control plot, neither cool-season nor warm-season graminoid cover changed significantly from 1999 to 2000 (Table 18, Figure 44). In the treatment plot, however, cool-season cover was reduced significantly after the fire, and warm-season graminoid cover increased significantly (Table 19, Figure 44). The prescribed burn shifted the species composition of the treatment plots from a cool-season-dominated community to a warm-season-dominated community. The warm-season species that showed increases in the treatment areas included big bluestem, little bluestem, blue grama, and side-oats grama (Table 19). Big bluestem and little bluestem showed declines in cover at the unburned control locations (Table 18). The cool-season graminoids that showed decreases in the treatment plot were Canada bluegrass, Kentucky bluegrass (*Poa pratensis*), and sun sedge (Table 19). The data show that the prescribed burn helped push the species composition in the direction of one of the management goals. Continued prescribed burns in the same area every few years would help continue to promote the dominance of the warm-season species.

One dominant warm-season species that did not increase as a result of the fire was mountain muhly, a montane warm-season species (Tables 18 and 19). Why this is the case is unknown. It actually showed a slight increase in the control plots, but a slight decline in the treatment plots. Perhaps the timing of the fire was not appropriate for this species, or some other factor(s) affected its response. Studies from ponderosa pine forests in Arizona have shown that mountain muhly generally decreases in density after a fire, but fully recovers after approximately three years (FEIS 2001). It would be useful to gather further information on the response of mountain muhly to fire under the prairie conditions here at the Site, because this species forms a dominant and unique part of the xeric tallgrass prairie species composition on the Rocky Flats Alluvium—a species composition that is not found elsewhere along the Front Range (Buckner 2000).

In general, the warm-season graminoids responded to the burn as anticipated, although the dry spring and early summer caused the height and overall flowering response to be somewhat less than optimum. Had normal precipitation occurred, it is likely that a greater response of the warm-season graminoids would have been seen, because many species began to wither and go dormant in late July and August (Figures 45 and 46). The response of the dominant warm-season species frequency in the treatment area generally paralleled that of the cover data (Table 20). Big bluestem frequency remained

unchanged, while little bluestem, blue grama, hairy grama, and side-oats grama increased. Mountain muhly frequency decreased in the burn area, while increasing in the control area.

With respect to the noxious weed diffuse knapweed, both the control and treatment areas showed no significant changes (Tables 18, 19, and 20). The slight increases in the cover and frequency of diffuse knapweed were not statistically significant in either the control or treatment plots, suggesting that the fire did not affect diffuse knapweed abundance. The significant loss of twistspine cactus density shown in both the control and treatment plots is best explained by the herbicide application at all the monitoring locations in spring 1999. Results from studies elsewhere at the Site have shown a similar decline in response to the herbicide alone.

Direct comparisons to studies conducted elsewhere on the response of the tallgrass prairie to fire are difficult to make because of differences in location, soil types, precipitation amounts, community composition, variation in conditions before and after burning, fire frequency, and monitoring methods. No other comparable data were available on the response of the xeric tallgrass prairie to fire. However, an attempt was made to compare the Site data to responses of the mesic tallgrass prairie to fire that have been recorded elsewhere around the country (Collins and Wallace 1990).

With respect to species richness, Collins and Gibson (1990) state that there "appears to be no clear relationship between fire and species richness during the year in which the fire occurred." They report results from several studies, some showing increases in species richness and others showing decreases in response to fire. Data from the Site burn showed no difference in species richness in the burned area compared to the unburned locations.

Collins and Gibson (1990) also report that most studies show a loss of species diversity after a fire because of an increase in dominance by the matrix species (i.e., species occupying the greatest amount of space in a community). Data from the Site showed a slight increase in species diversity in response to the burn. This response may have been confounded, however, by the herbicide application in the year before the fire. It is also well documented that a spring fire enhances the productivity and vigor of warm-season graminoids, while reducing that of the cool-season species (Ewing and Engle 1988; Collins and Wallace 1990). The increase in warm-season graminoid cover and reduction in cool-season graminoid cover from the Site burn substantiate this occurrence on the xeric tallgrass prairie in Colorado as well. Qualitative observations also concurred with the literature that there appeared to be an increase in flowering of many of the warm-season species within the burn area compared to those outside the burn area (Svejcar 1990).

The results of the spring 2000 prescribed burn on the xeric tallgrass prairie demonstrate the utility of fire as a tool for effective management and restoration of the prairie ecosystems at the Site. Continued monitoring of these transects will provide a better understanding of the longer-term implications for fire on the xeric tallgrass prairie at the

Site. With clearly stated objectives, the use of prescribed burns, integrated with other resource management techniques, can help maintain the viability and sustainability of the prairie ecosystems at the Site.

3.5.4 Photographic Monitoring

Photographic monitoring at selected permanent photo-point locations continued to show good control of diffuse knapweed at those locations where herbicide applications have been made over the past few years. These and other photo monitoring results are presented in Appendix E.

4. Conclusions

Vegetation monitoring in 2000 continued to document the generally high quality of the native plant communities at the Site. The Site continues to provide a haven for many increasingly rare plant communities that are disappearing rapidly from the Front Range of Colorado. The results, however, also continue to underscore the issues that threaten the quality and long-term sustainability of the Site's ecological resources. These threats come primarily from noxious weeds, human disturbances, and plant litter build up. Active resource management being practiced at the Site has helped alleviate some of these threats. Aerial and ground herbicide applications have dramatically reduced the amount of diffuse knapweed and other weeds on the prairie, enhanced the vigor and health of many native graminoid species, and improved the aesthetic appearance of the grasslands. Integration of the chemical controls with administrative, cultural, mechanical, and biocontrol weed control methods has continued to work to control and prevent introduction of other noxious weed infestations. A prescribed burn on the xeric tallgrass prairie in April 2000 demonstrated the usefulness of fire as a prairie management and restoration tool at the Site. The response of the grassland in the burn area has been positive, and the use of prescribed burns should be pursued in the future for management of the ecological resources at the Site.

Although recent herbicide applications have successfully controlled diffuse knapweed in the treated areas, with minimal impact on other prairie species, long-term noxious weed control and management of the plant communities at the Site requires the integration of multiple management techniques. Sole reliance on herbicide applications for resource management is not wise. Integration of current weed control methods with prescribed burns, increased use of available biocontrol agents, and potentially carefully controlled grazing, would increase the options available to help enhance the quality and vigor of the native plant communities. This would further enhance conditions for the native species, thus allowing them to better compete with the noxious weed species that threaten the sustainability of these communities. Without an integrated approach, diffuse knapweed levels will return to pre-treatment levels every few years, requiring ongoing, continual herbicide applications. Long-term reliance on herbicides is not a practical solution, because repeated applications are likely to be detrimental to many of the native prairie species, and to be prohibitively expensive. Additionally, coordinated efforts with offsite agencies and property owners, as well as onsite projects, are needed to prevent the constant reintroduction of noxious weed seed into treated areas from offsite sources.

Despite these concerns, however, the data from 2000 continue to indicate that beneath the sometimes visually dominant weedy appearance, the native plant communities are still present and viable. The Site represents some of the last remaining strongholds for many of the increasingly rare plant communities that were once more common along the base of the Front Range. Monitoring results indicate that management actions are having their

desired effects. Continued proactive integrated management of these native communities should provide a lasting legacy for future generations.

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6. Glossary

Annual – A plant that lives its entire life cycle during the course of a single growing season.

Biocontrol – A method of weed control that uses insects or fungi to stress, damage, or destroy the plant tissue of undesirable species.

Biodiversity – The existence of a wide range of different types of organisms in a given place at a given time.

Biomass – A measure of the productivity of a community, usually measured by clipping the vegetation and obtaining the dry weight of the vegetation; expressed per unit area (grams/square meter).

Control – The plot, quadrat, transect, site, or location, that receives no treatment or management action (e.g., weed control, prescribed burning, mowing). It serves as an unaffected plot that can be compared to the treatment plot to evaluate whether or not the treatment had any impact.

Cool-season graminoids – Grasses that green up early in the growing season (March–May) and produce mature fruits by late June or early July.

Cover – Vegetation cover is a measure of abundance for individual plant species in a specified area. The cover of different species can be grouped and summed to provide the cover for that grouping of species (e.g., graminoid cover or forb cover).

Density – A measure of the number of individuals per unit area.

Diversity – A measure of the number of species present and their relative abundance in a community.

Dominant plant species – One or more species that occur in the greatest abundance (usually based on cover or biomass) in a given plant community.

Ecotonal – An ecotone is the boundary area between two different plant communities.

Forbs – Herbaceous, broad-leaved, non-woody plant species.

GIS – Geographic information system

GPS – Global positioning system

Graminoids – Grasses, sedges, or rushes.

Litter – Dead plant matter that has accumulated on the surface of the ground.

Management units – Arbitrary divisions of the different plant communities at the Site used to facilitate vegetation sampling. Roads, fence lines, and streams were often used as boundaries.

Mesic – Referring to conditions of moderate moisture or water availability.

Perennial – A plant whose lifecycle spans multiple years.

Prescribed burn or fire – A planned, controlled fire, intentionally set to burn off the vegetation to meet a set of management objectives.

Relict – Persistent remnants of a pre-existing, once more widespread flora or fauna that now exist in more restricted or isolated areas.

Riparian – On or pertaining to the banks of a stream (e.g., riparian vegetation or riparian woodland).

Species richness – The complete list and number of species found in a given area.

Species richness similarity – A mathematical coefficient that quantifies how similar or dissimilar the species composition of two communities is. A common coefficient is the Sorensen coefficient of similarity index, which compares species lists between two areas by taking into account the total number of species present in each community and the number in common between them.

Target species – Species specifically chosen for weed control (e.g., diffuse knapweed or musk thistle).

Treatment – The plot, quadrat, transect, site, or location, that receives a specific management action (e.g., weed control, prescribed burn, mowing).

Vascular plants – Plants that have xylem and phloem (i.e., conductive tissue) for internal movement of water, minerals, and nutrients. This excludes plants such as mosses, liverworts, and hornworts that have no such tissues.

Warm-season graminoids – Grasses that green up later in the growing season (late May–June) and don’t produce mature fruits until September.

Xeric – Dry or characterized by scant moisture; tolerating or adapted to arid conditions.

Figures

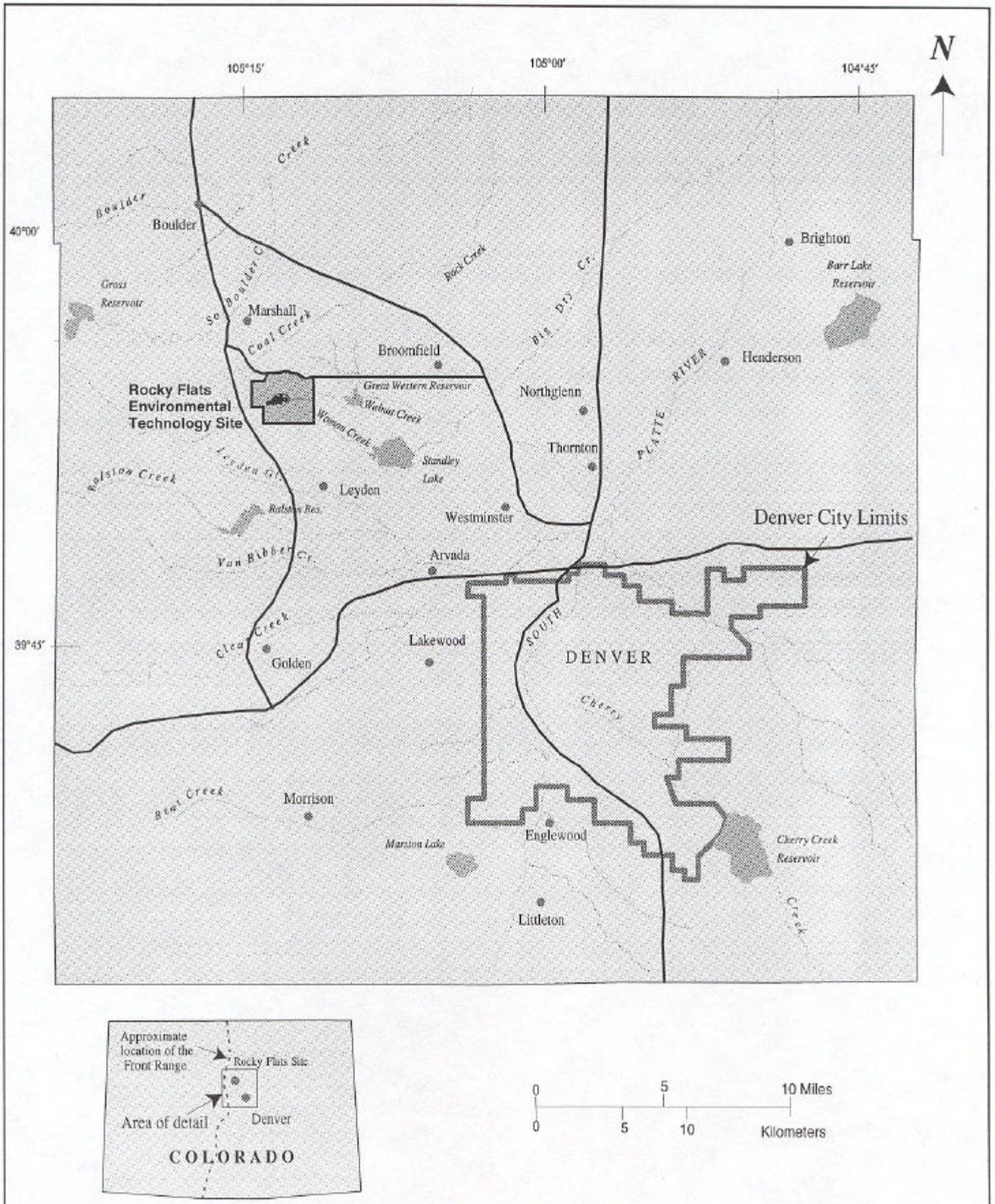
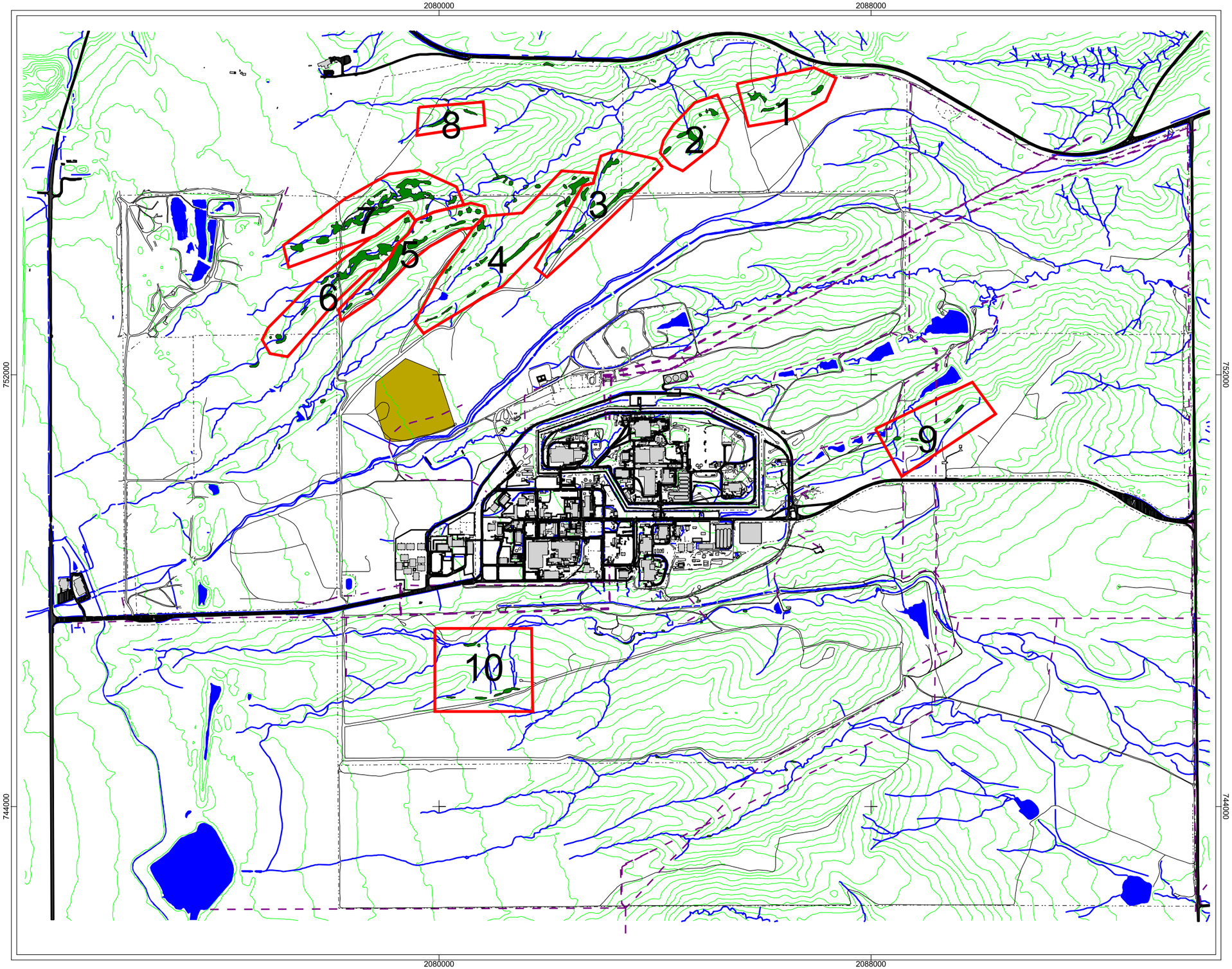


Figure 1

LOCATION OF THE ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE



Tall Upland Shrubland Management Units

Figure 2

LEGEND

- Management Unit Boundary w/Number
- Tall Upland Shrubland

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)
- Power Lines

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Management unit and tall upland shrubland data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

N

1:23552

1000 0 1000 2000 Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Exponent®

For: Kaiser-Hill Company, LLC

RFETS GIS Dept. 303-966-7707

MAP ID: 2K-0158

May 3, 2001

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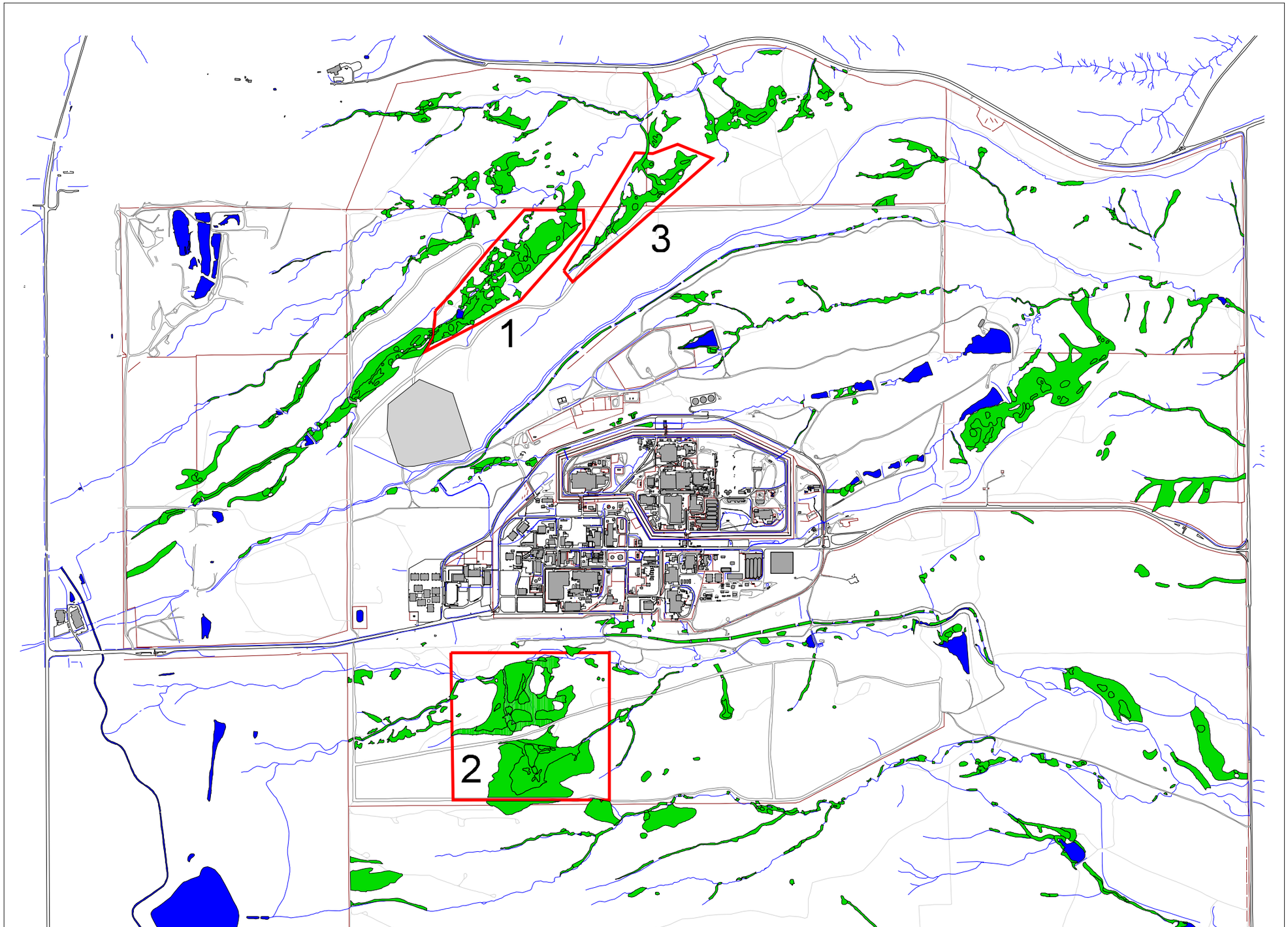

Wetland Management Units

Figure 3

MAP LEGEND

- Wetlands (Combined Wet Meadow/Marsh, Short Marsh, and Tall Marsh Habitat Types)
- Wetland Management Units

Standard Map Features

- New Landfill
- Buildings
- Lakes & Ponds
- Streams & ditches
- Fences
- Paved roads
- Dirt roads

DATA SOURCE:
Management Unit and wetland boundaries provided by Exponent.
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Note:
These locations approximate the boundaries of the Management Units. The boundaries are not exact and should not be treated as such.

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State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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MAP ID: 2k-0158

March 14, 2000

\\GisrvVGIS\ECO-projects\projects\2k-0158\management units.apr\Wetland Management Unit view

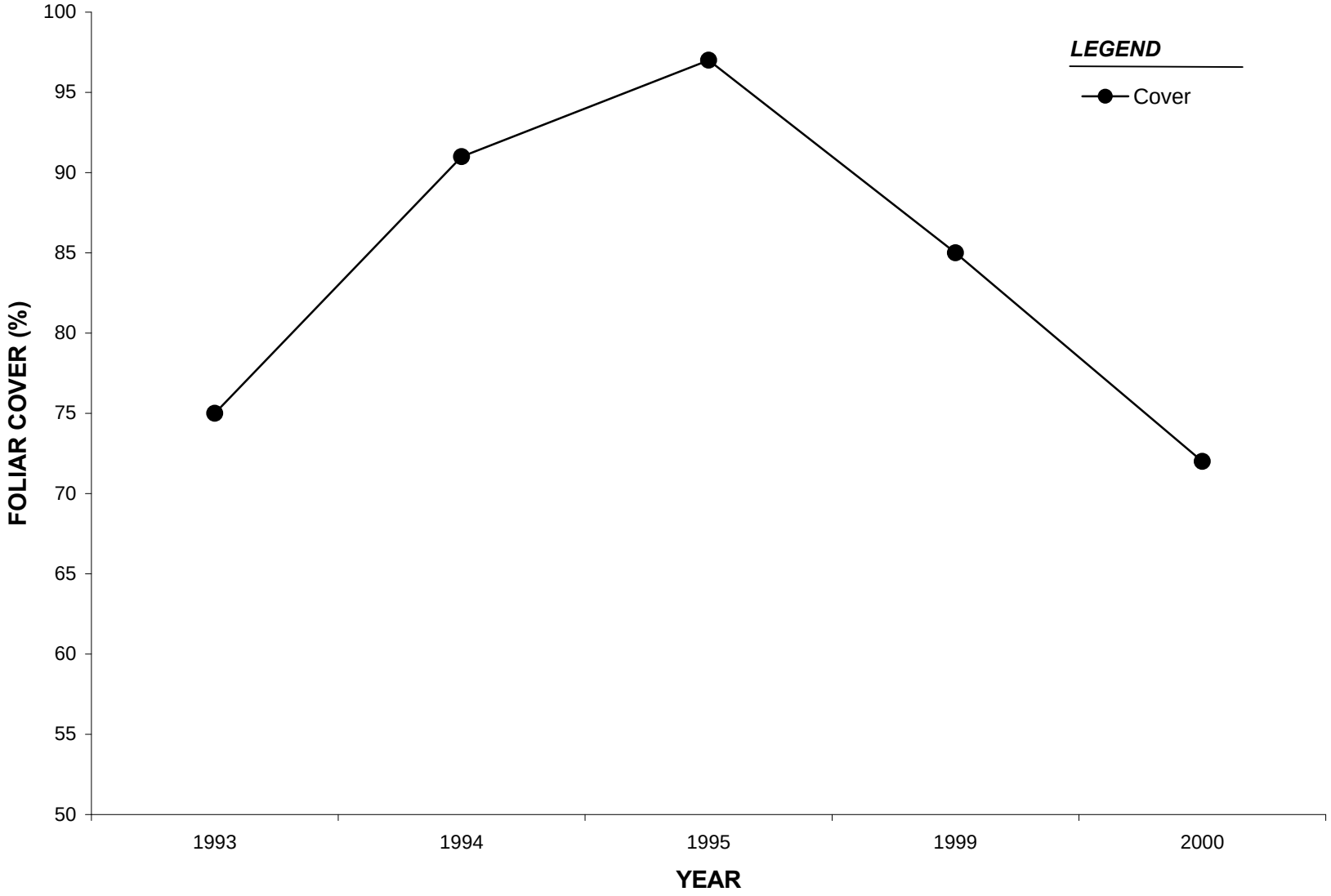


Figure 4. Mesic mixed grassland total foliar cover.

\\Boulder1\Groups\Graphics\1454\2001\mesic final tables for report.xls Fig. 2 Foliar Cover figure 5/3/01 CO

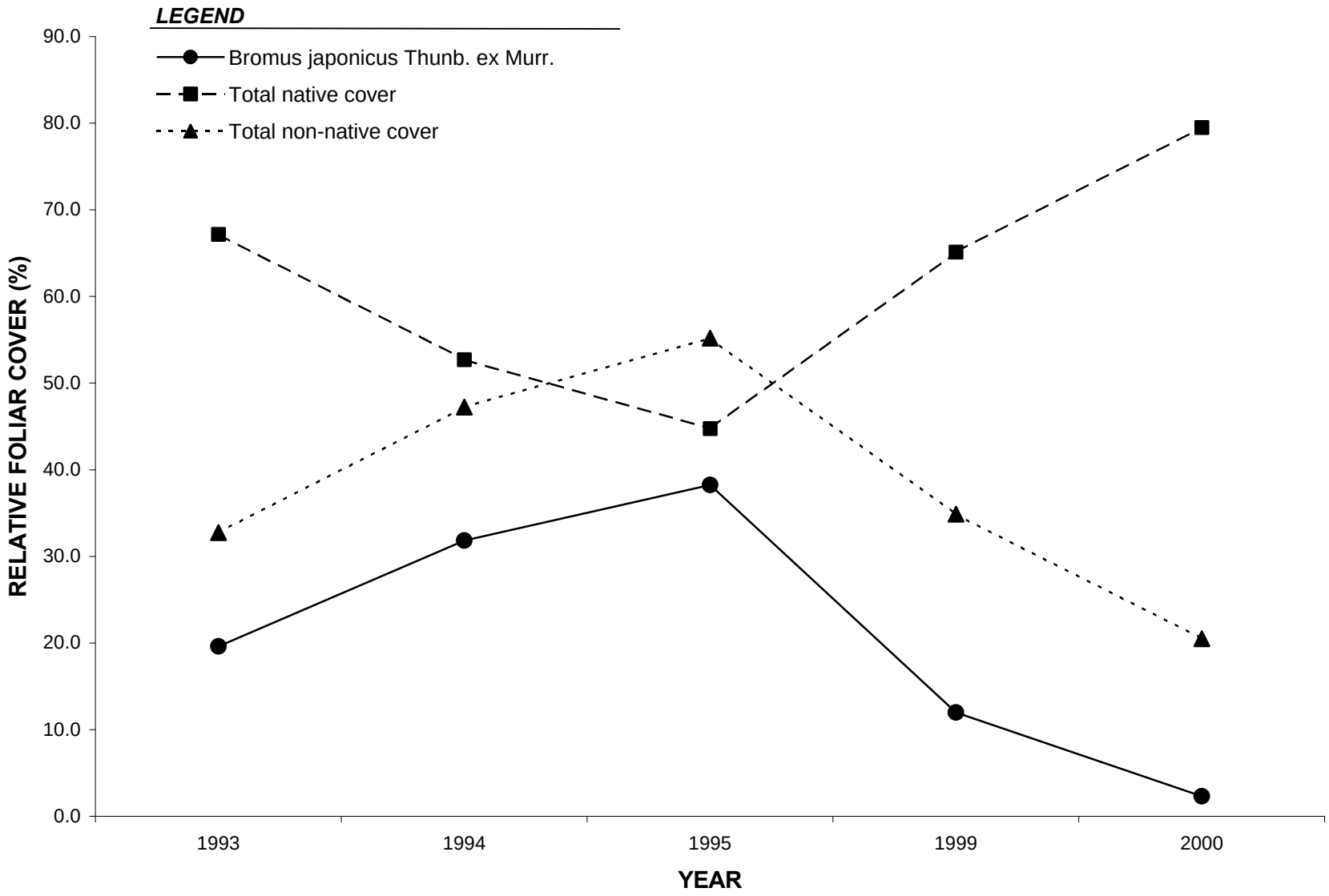


Figure 5. Native vs. non-native cover changes in relation to Japanese Brome on the mesic mixed grassland.

\\Boulder1\Groups\Graphics\1454\2001\mesic final tables for report.xls Fig 3 Native, nonnative, BRJA1 5/3/01 CO

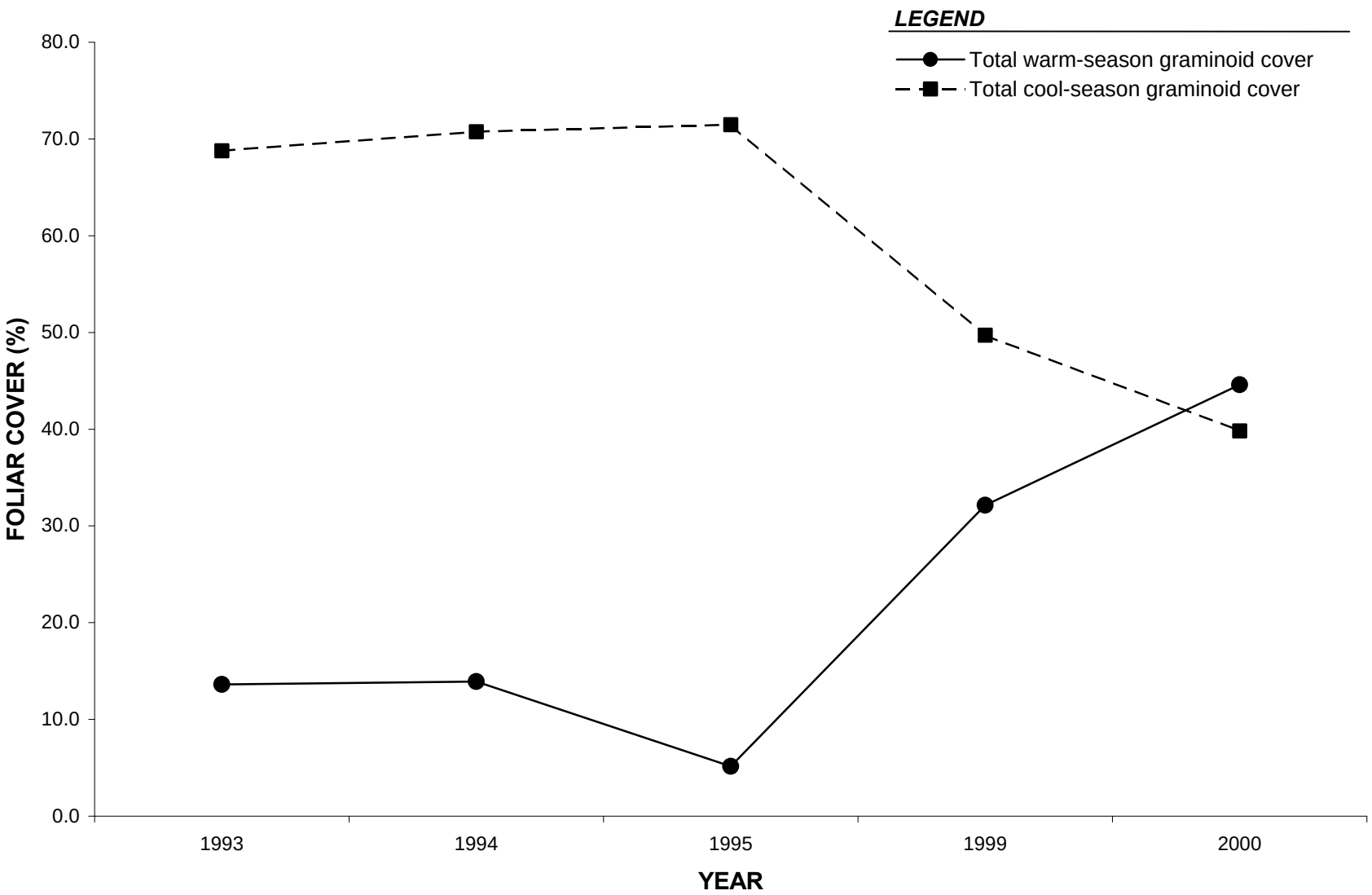
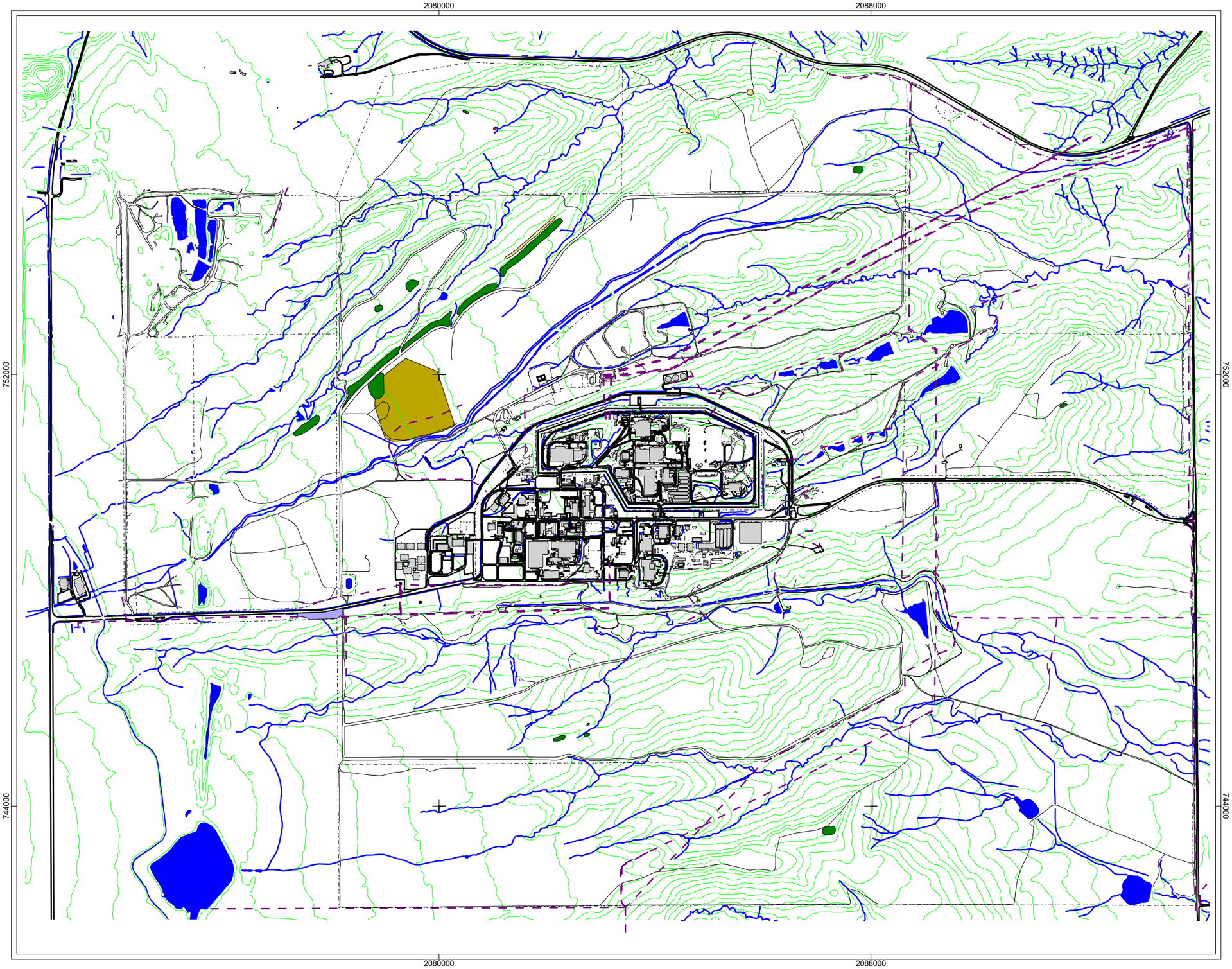


Figure 6. 1993-2000 mesic grassland graminoid cover changes.

\\Boulder1\Groups\Graphics\1454\2001\mesic final tables for report.xls Fig 4 93-2k Gram Cover Changes 5/3/01 CO

Figure 7. 1993-2000 mesic grassland graminoid changes.

\\Boulder1\Groups\Graphics\1454\2001\mesic final tables for report.xls Fig 5 93-2k Graminoid Changes 5/3/01 CO



Rare and Imperiled Plants Distribution
Colorado Natural Heritage Program
Species of Concern

Figure 8

LEGEND

- Dwarf Wild Indigo (Amorpha nana)
- Forktip Three-awn (Aristida basiramea)
- Mountain-Loving Sedge (Carex oreocharis)
- Carrionflower Greenbriar (Smilax herbacea)

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)
- Power Lines

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Location data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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State Plane Coordinate Projection
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MAP ID: 2k-0074

May 3, 2001

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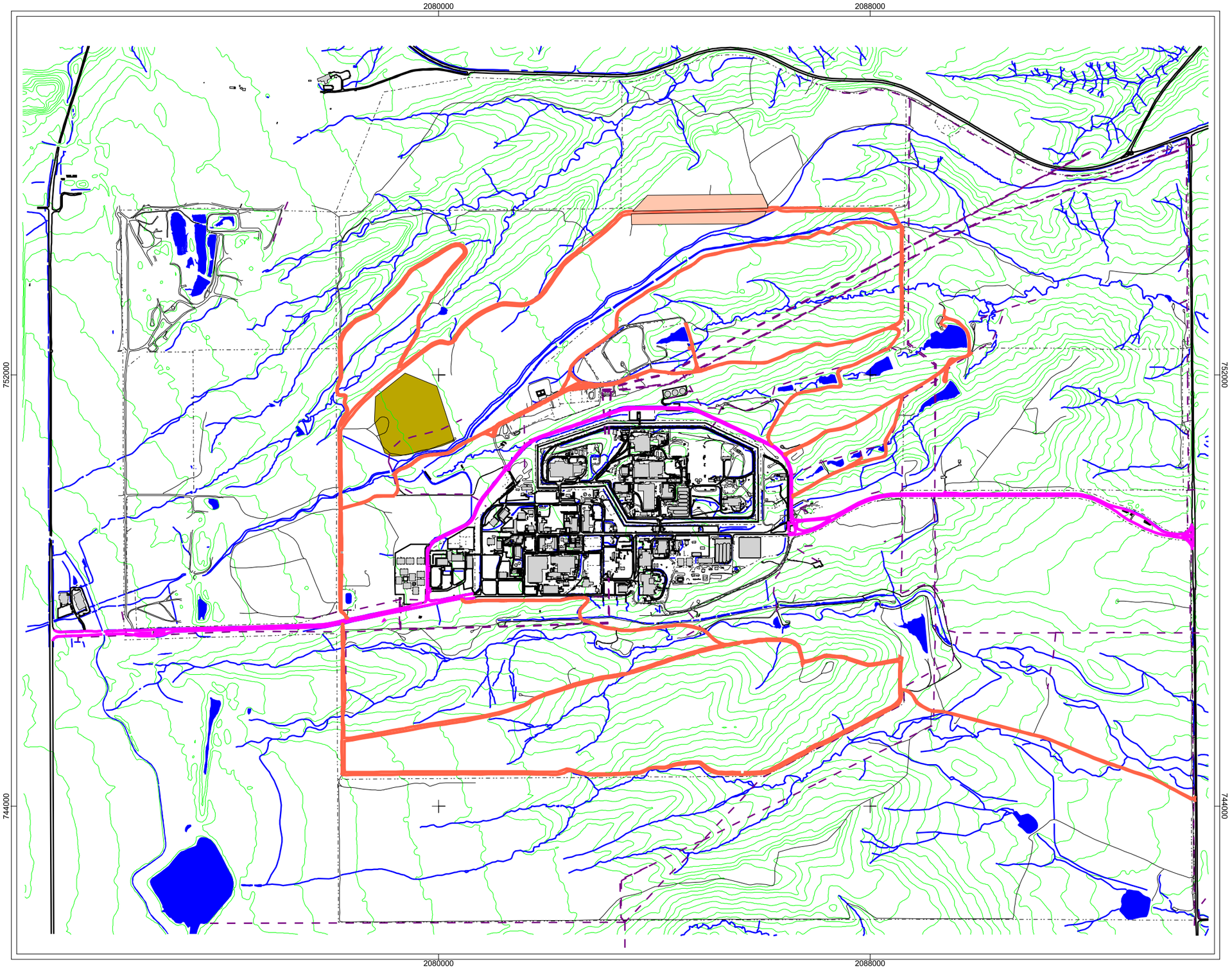
Figure 9. Wheat monoculture.

A wheat (*Triticum aestivum*) monoculture resulted at this revegetation location in 2000 when the crimped wheat straw used for mulch contained viable seedheads. Monitoring in 2001 will determine whether any of the seeded species begin to germinate.



FY2000 Road Grading and Mowing Operation Locations for Weed Control

Figure 10

LEGEND

- Annual Rye Mowing
- Roadside Mowing
- Roadside Mowing and Grading

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)
- Power Lines

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours.
The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution.
The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Weed distribution data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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Rocky Flats Environmental Technology Site

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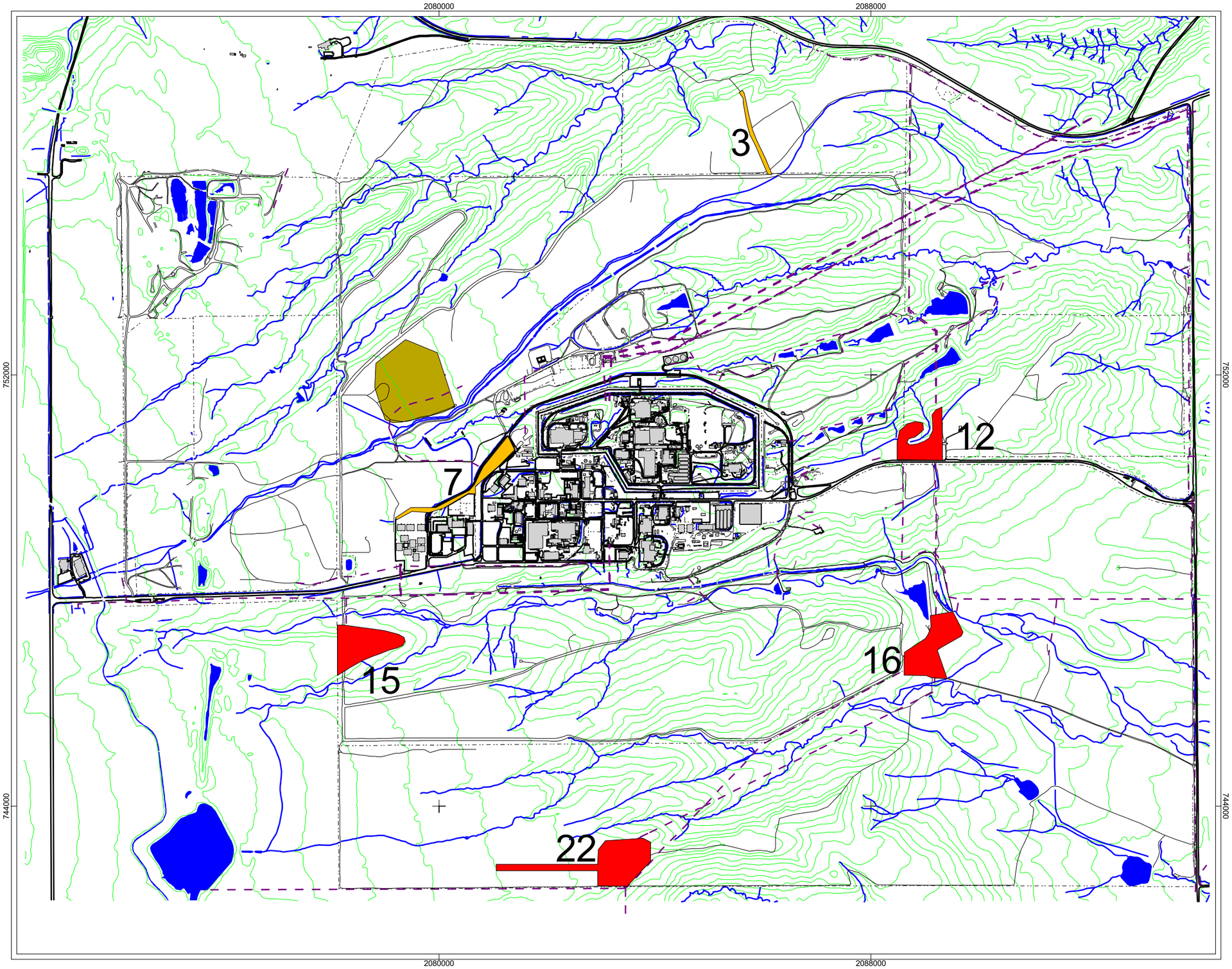
\\Gissrv\GIS\ECO-projects\01-0404\figures 2-4 and 2-5.apr 2k roadside mowing and grading figure 2-2



FY2000 Ground Herbicide Application Locations

Figure 11

LEGEND

- Tordon Spray Locations
- Transline Spray Locations

(Numbers are acres treated)

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)
- Power Lines

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours.
The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution.
The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Location data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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1000 0 1000 2000 Feet

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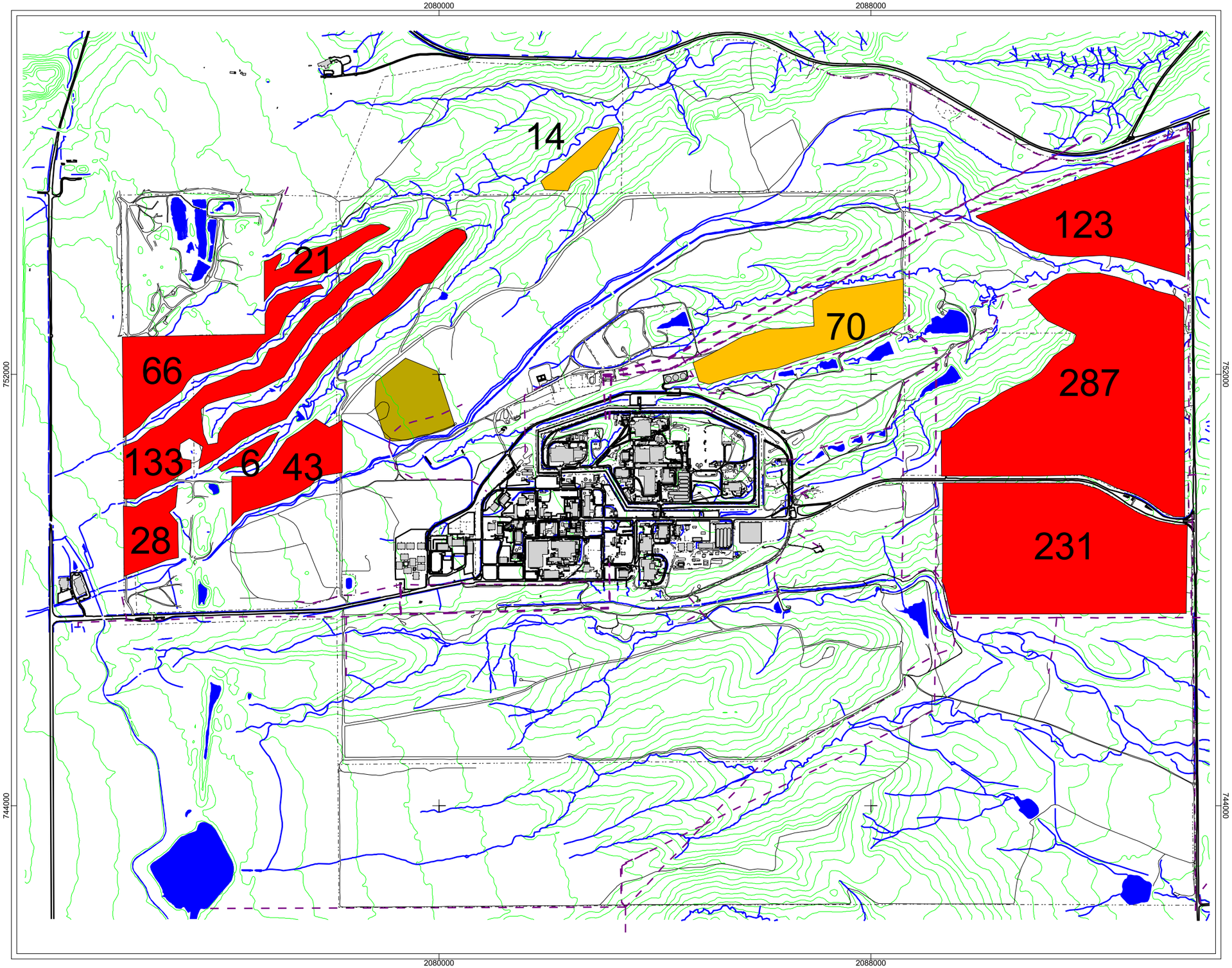
\\Gissrv\GIS\ECO-projects\projects\01-0404\2000 ground applications locations (actual)



FY2000 Aerial Herbicide Application Locations

Figure 12

LEGEND

- Tordon Spray Locations
- Transline Spray Locations

(Numbers are acres treated)

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)
- Power Lines

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Location data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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State Plane Coordinate Projection
Colorado Central Zone
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RFETS GIS Dept. 303-966-7707

MAP ID: 01-0404

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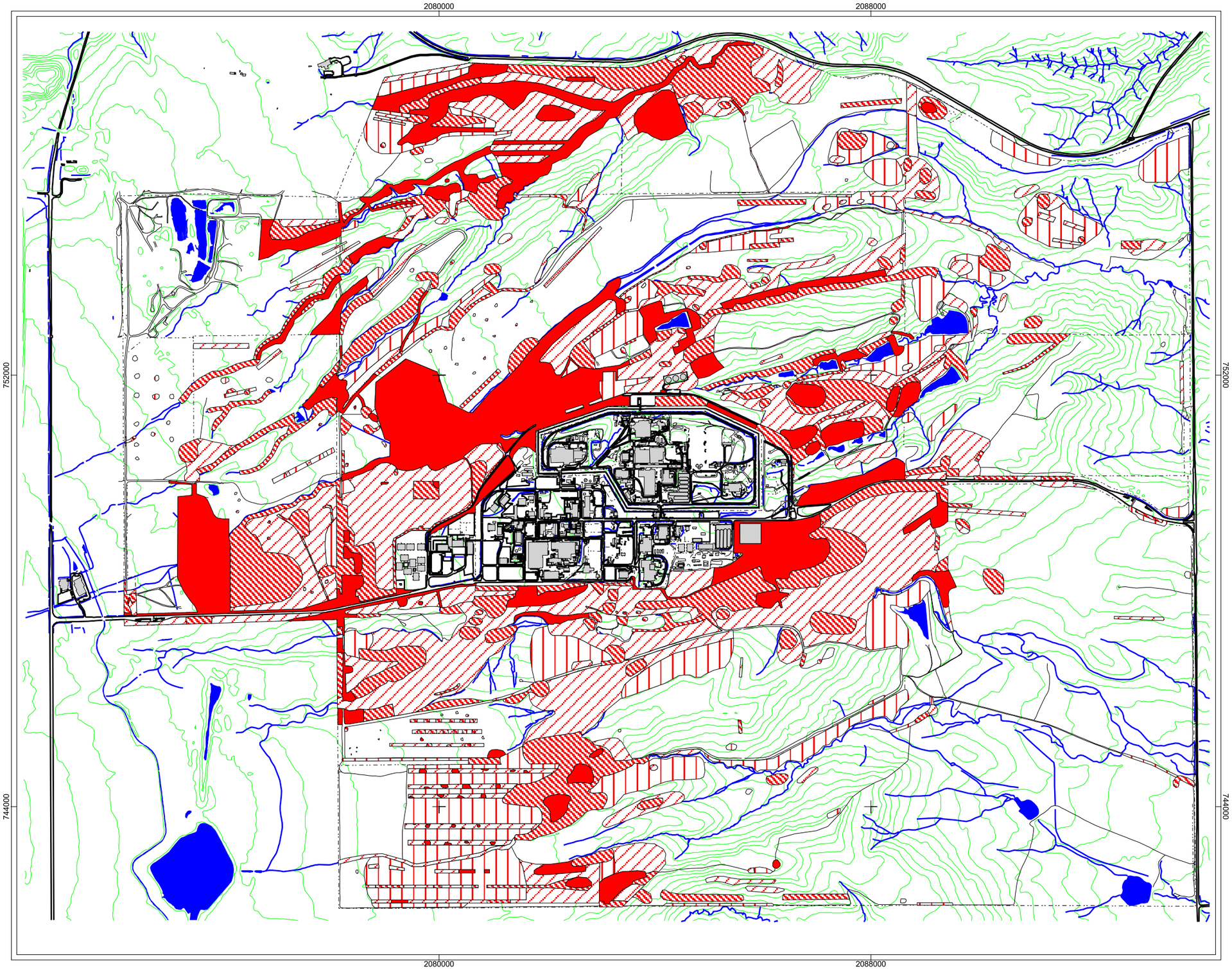
\\Gissrv\GIS\ECO-projects\01-0404\2000 aerial herbicide locations



2000 Diffuse Knapweed (Centaurea diffusa) Distribution

Figure 13

MAP LEGEND

- High Density Areas
- Medium Density Areas
- Low Density Areas
- Scattered Density Areas

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Weed distribution data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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1000 0 1000 2000 Feet

State Plane Coordinate Projection
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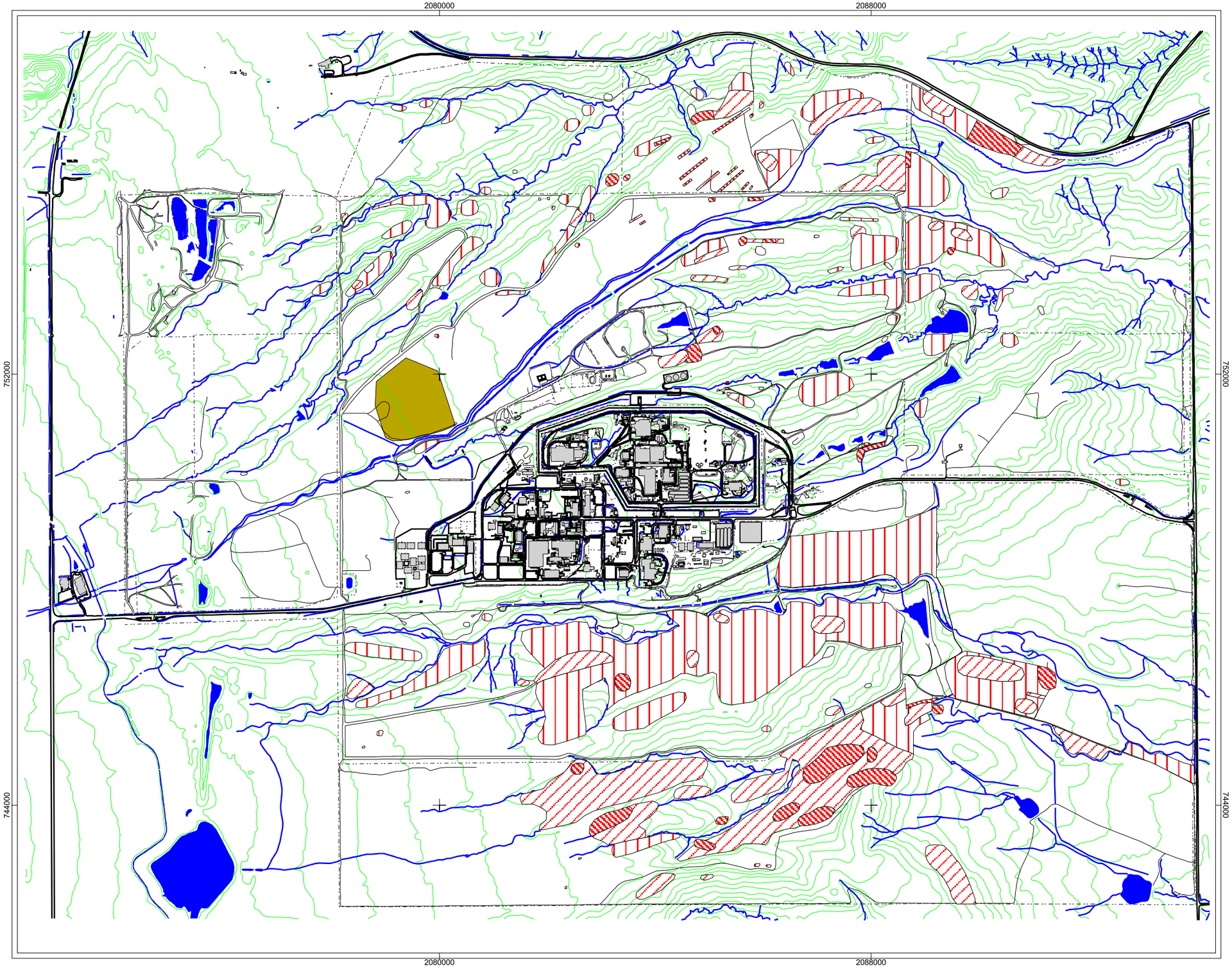
RFETS GIS Dept. 303-966-7707

MAP ID: 2K-0419

May 3, 2001

\\Gissrv\GIS\ECO-projects\projects\2k-0419\ced00.apr\2000 CEDI Distribution



2000 Musk Thistle (Carduus nutans) Distribution

Figure 14

MAP LEGEND

- High Density Areas
- Medium Density Areas
- Low Density Areas
- Scattered Density Areas

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Weed distribution data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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State Plane Coordinate Projection
Colorado Central Zone
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MAP ID: 01-0063

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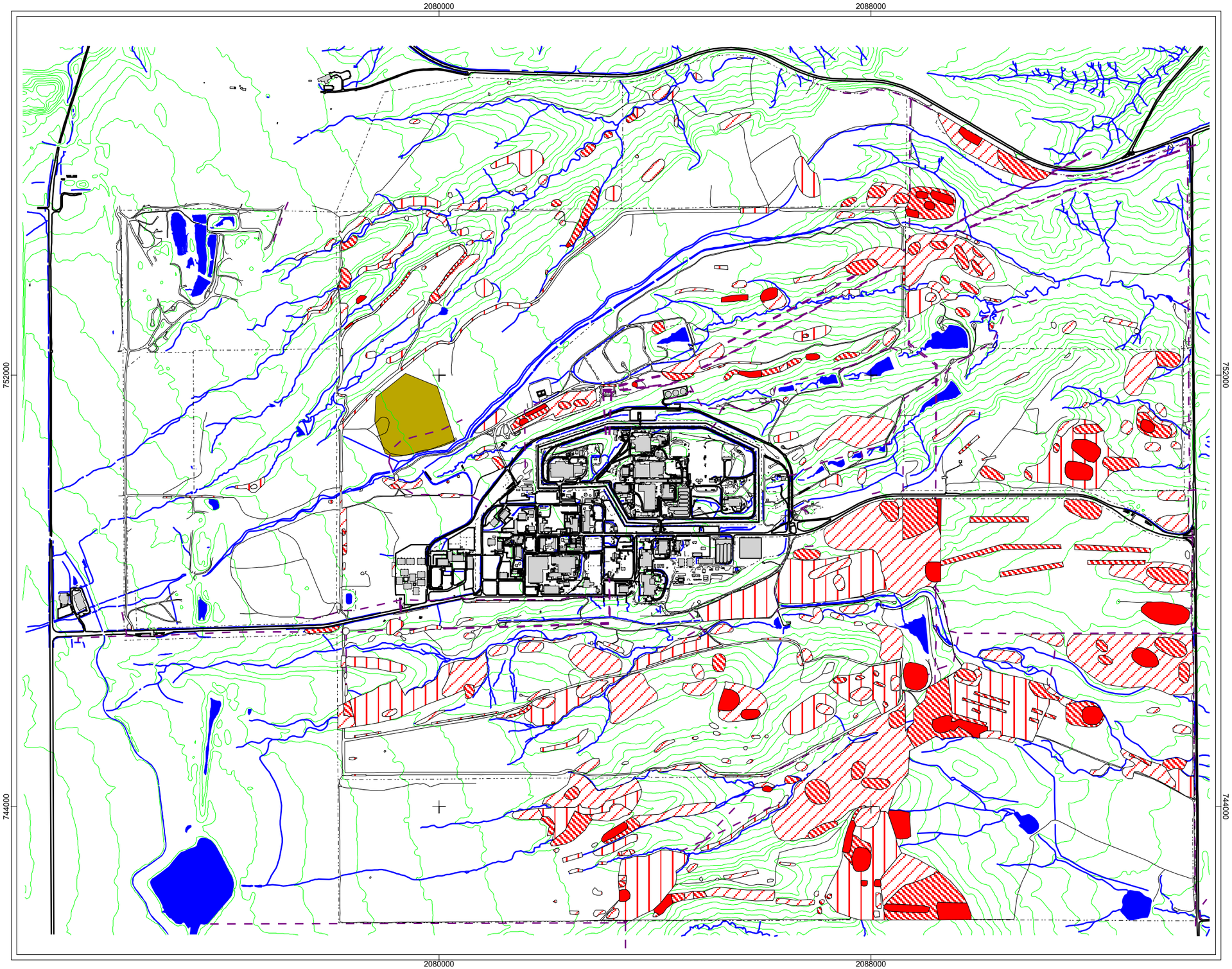
\\Gissrv\GIS\ECO-projects\01-0063\canu00.apr\2000 CANU1 Distribution



2000 Mullein (Verbascum thapsus) Distribution

Figure 15

LEGEND

- High Density Areas
- Medium Density Areas
- Low Density Areas
- Scattered Density Areas

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)
- Power Lines

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours.
The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution.
The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Weed distribution data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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State Plane Coordinate Projection
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Rocky Flats Environmental Technology Site

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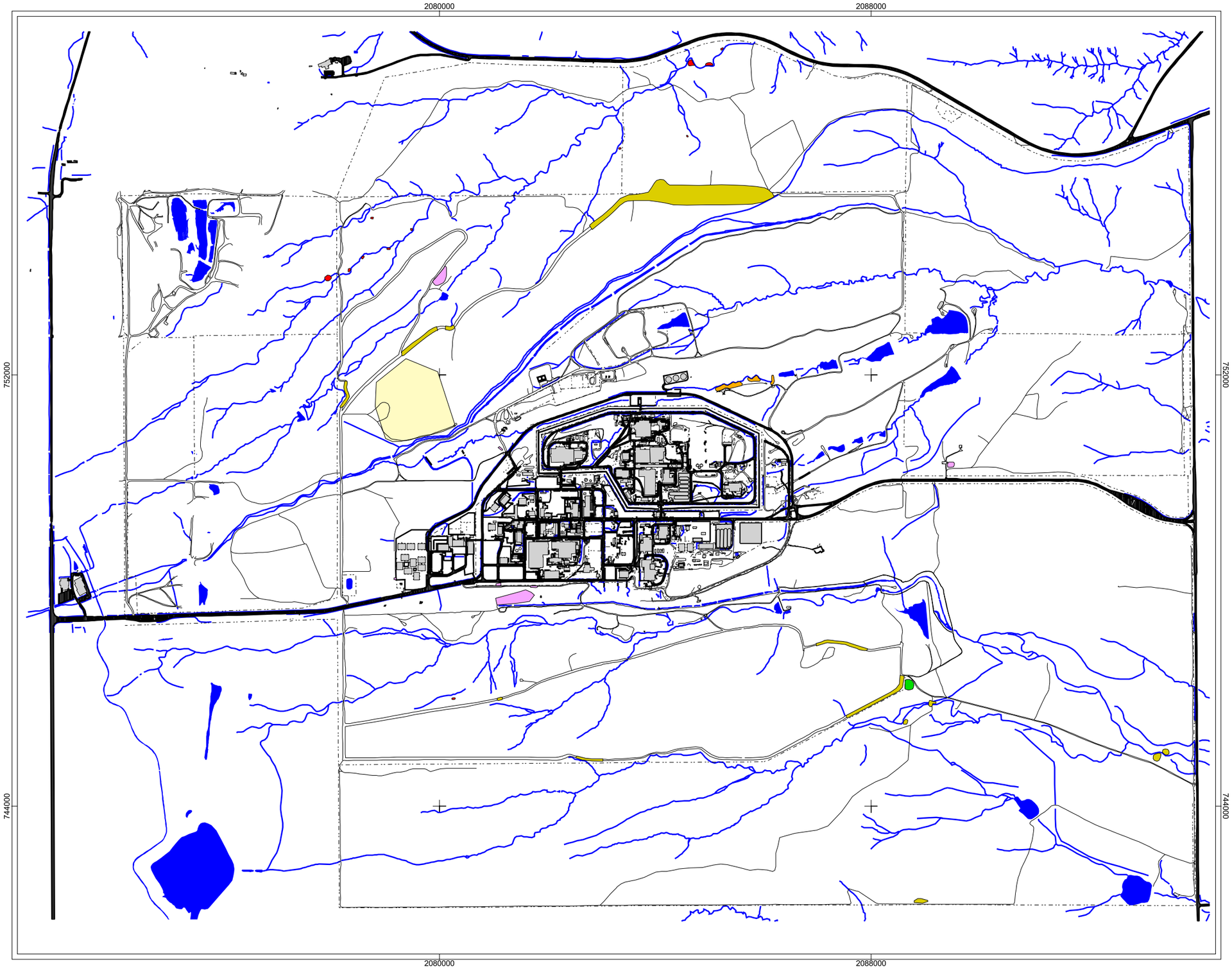
RFETS GIS Dept. 303-966-7707

MAP ID: 01-0081

May 3, 2001

\\Gissrv\GIS\ECO-projects\projects\01-0081\veth00.apr\ 2000 Mullein Distribution



2000 Scotch Thistle (Onopordim acanthium), Russian Knapweed (Centaurea repens), Dame's Rocket (Hesperis matronalis), Bouncing Bet (Saponaria officinalis), and Annual Rye (Secale cereale) Distribution

Figure 16

LEGEND

- Scotch Thistle Infestations
- Russian Knapweed Infestations
- Dame's Rocket Infestations
- Annual Rye Infestations
- Bouncing Bet Infestations

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours.
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The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Weed distribution data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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State Plane Coordinate Projection
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U.S. Department of Energy
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Prepared by: Exponent®
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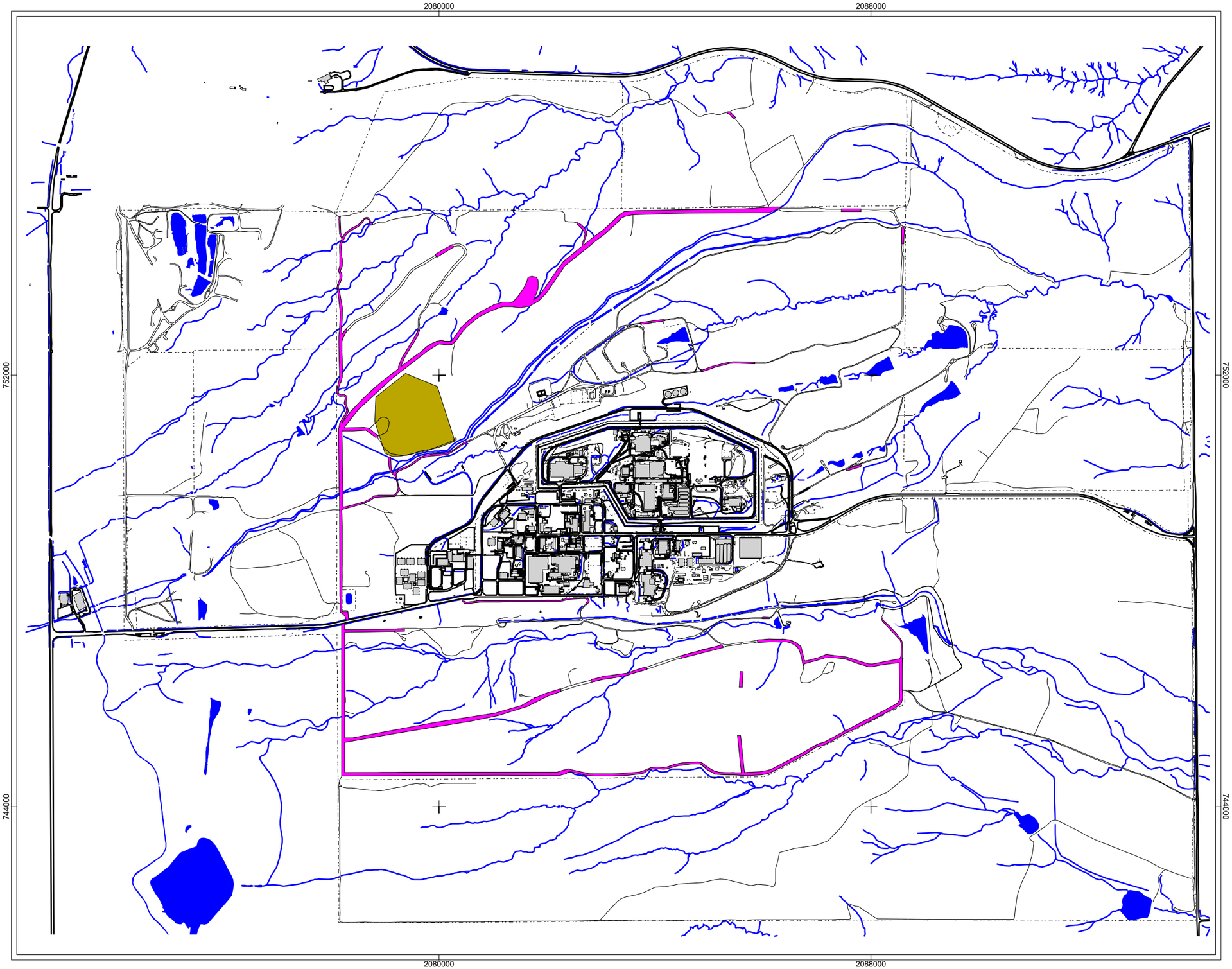
RFETS GIS Dept. 303-966-7707

MAP ID: 01-0036
May 3, 2001

\\Gissrv\GIS\ECO-projects\projects\01-0036\weedmaps2k.apr\misc weeds mapped



2000 Jointed Goatgrass (Aegilops cylindrica) Distribution

Figure 17

LEGEND

Jointed Goatgrass Infestations

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Weed distribution data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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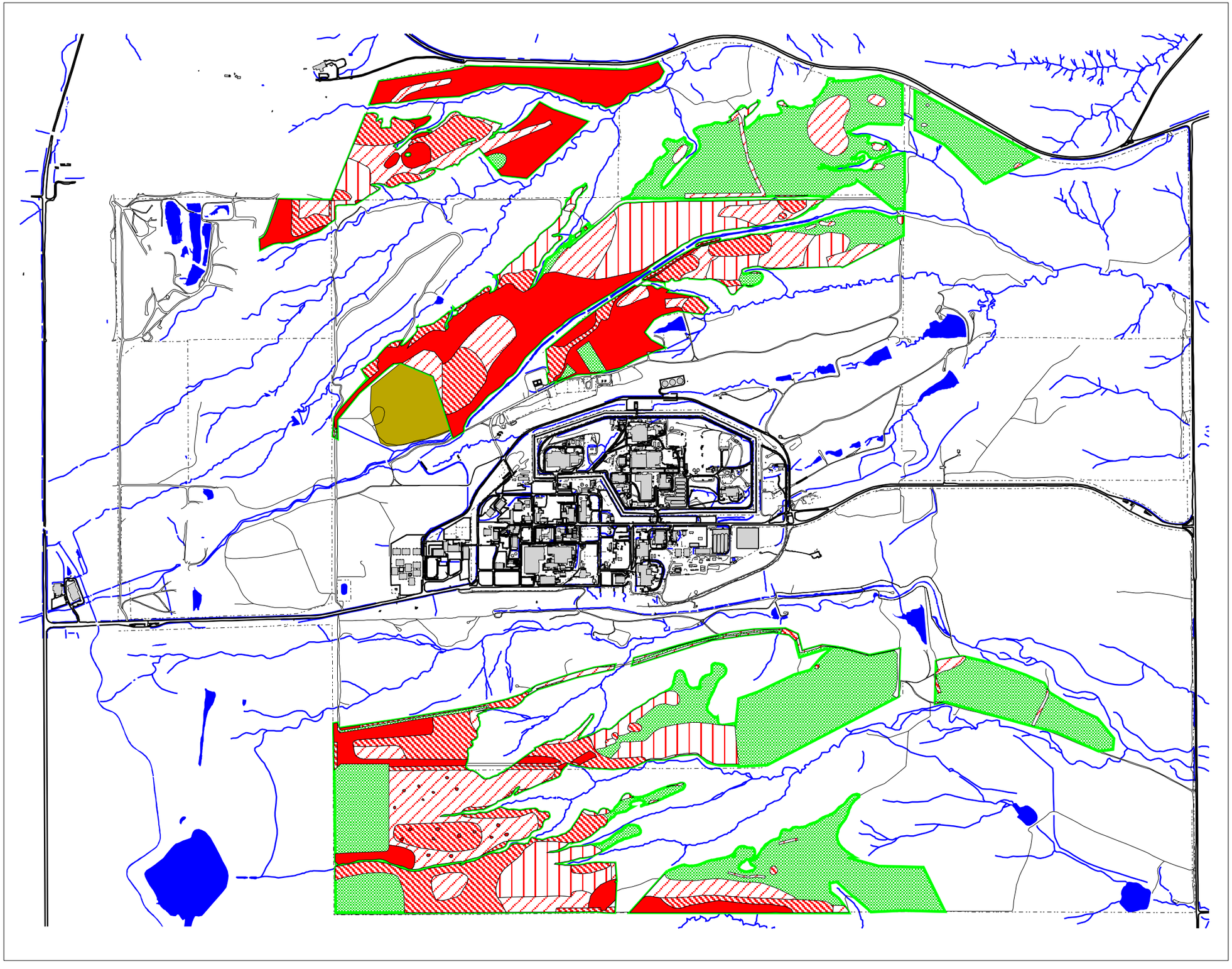
MAP ID: 01-0036
May 3, 2001

\\Gissrv\GIS\ECO-projects\projects\01-0036\weedmaps2k apr\jointed goatgrass 2000



1998 Diffuse Knapweed Pre-Aerial Herbicide Application Distribution (1999 Application)

Figure 18

MAP LEGEND

- High Density Areas
- Medium Density Areas
- Low Density Areas
- Scattered Density Areas
- 1999 Aerial Spray Areas

Standard Map Features

- Buildings
- Lakes & Ponds
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- New landfill

DATA SOURCE:
1999 weed distributions provided by Exponent.
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution.
The DEM post-processing performed by MK, Winter 1997.

Note:
These locations approximate the boundaries of infestation areas. Infestation areas shown on this map only represent those that overlapped with the aerial herbicide application locations (i.e. this map does not represent the extent of diffuse knapweed at the Site). K-H Ecology Group POC: Karan North 303-966-9876.

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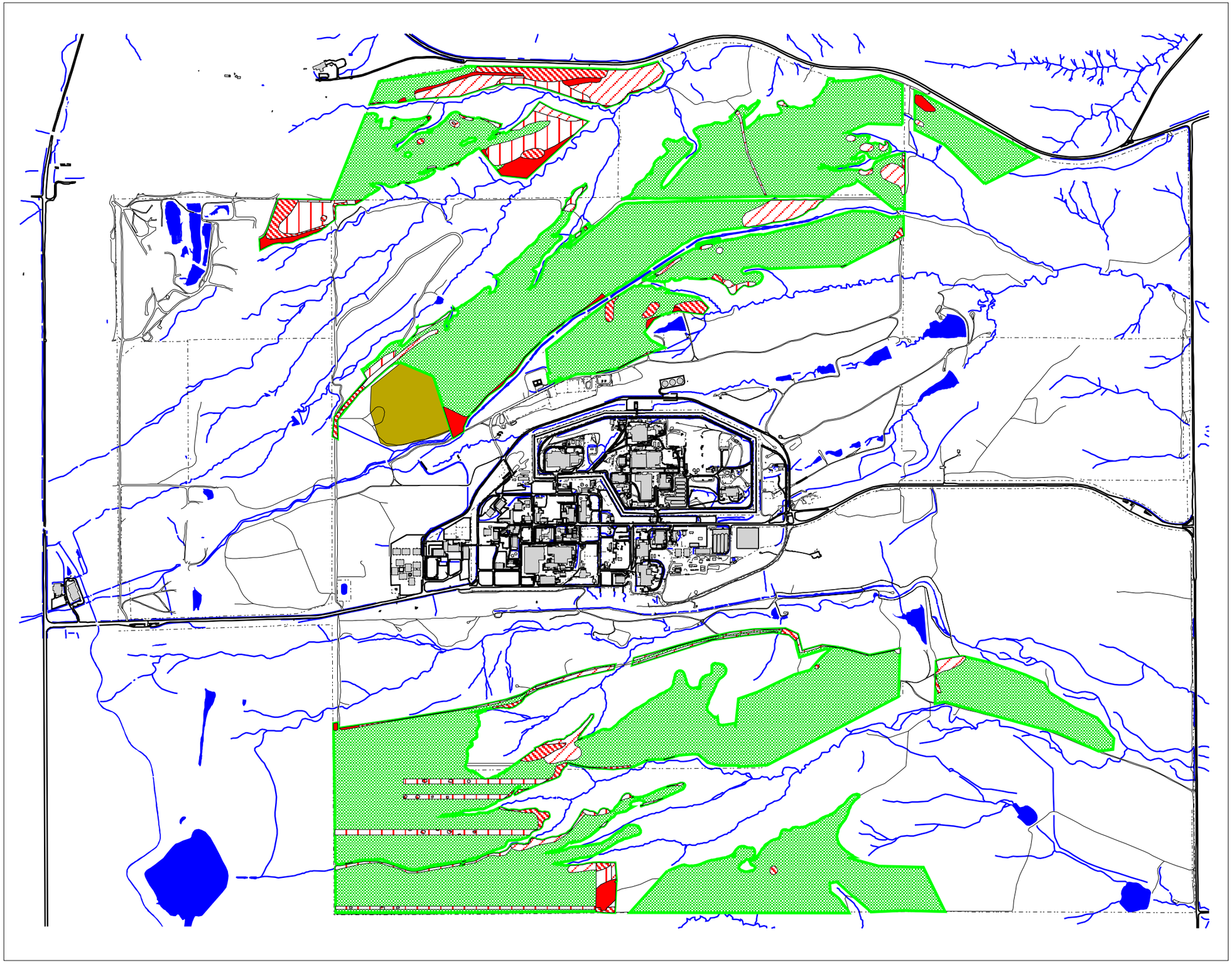
RFETS GIS Dept. 303-966-7707

MAP ID: K2-0017

May 3, 2001

\\Gissrv\GIS\ECO-projects\k2-0017\cedi299.apr\1998 Diffuse Knapweed Pre-Herbicide Application



1999 Diffuse Knapweed Post-Aerial Herbicide Application Distribution (1999 Application)

Figure 19

MAP LEGEND

- High Density Areas
- Medium Density Areas
- Low Density Areas
- Scattered Density Areas
- 1999 Aerial Spray Areas

Standard Map Features

- Buildings
- Lakes & Ponds
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- New landfill

DATA SOURCE:
1999 weed distributions provided by Exponent.
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
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MAP ID: K2-0017

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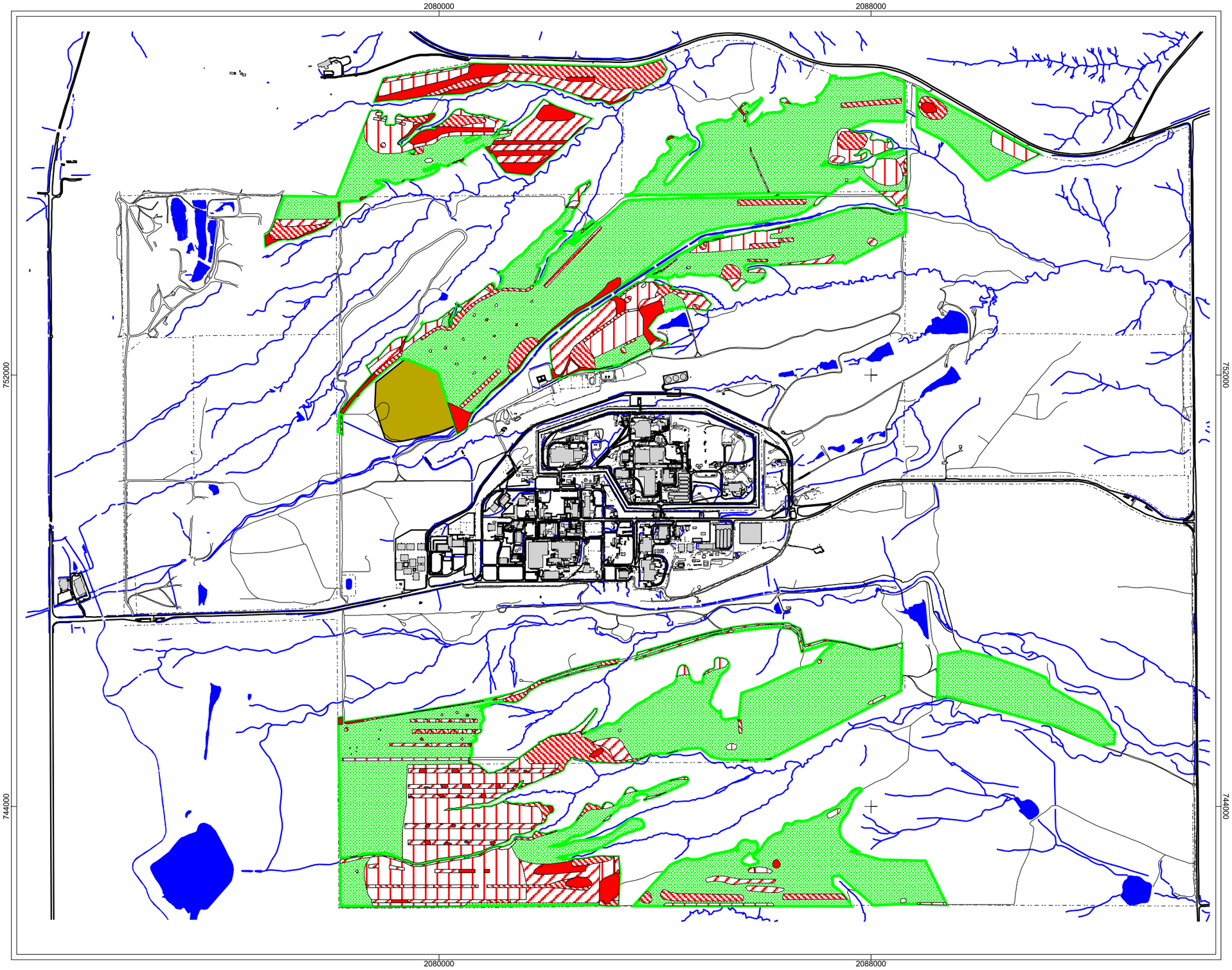

2000 Diffuse Knapweed Post-Aerial Herbicide Application Distribution (1999 Application)

Figure 20

MAP LEGEND

- High Density Areas
- Medium Density Areas
- Low Density Areas
- Scattered Density Areas
- 1999 Aerial Spray Areas

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
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The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Weed distribution data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

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U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Exponent®

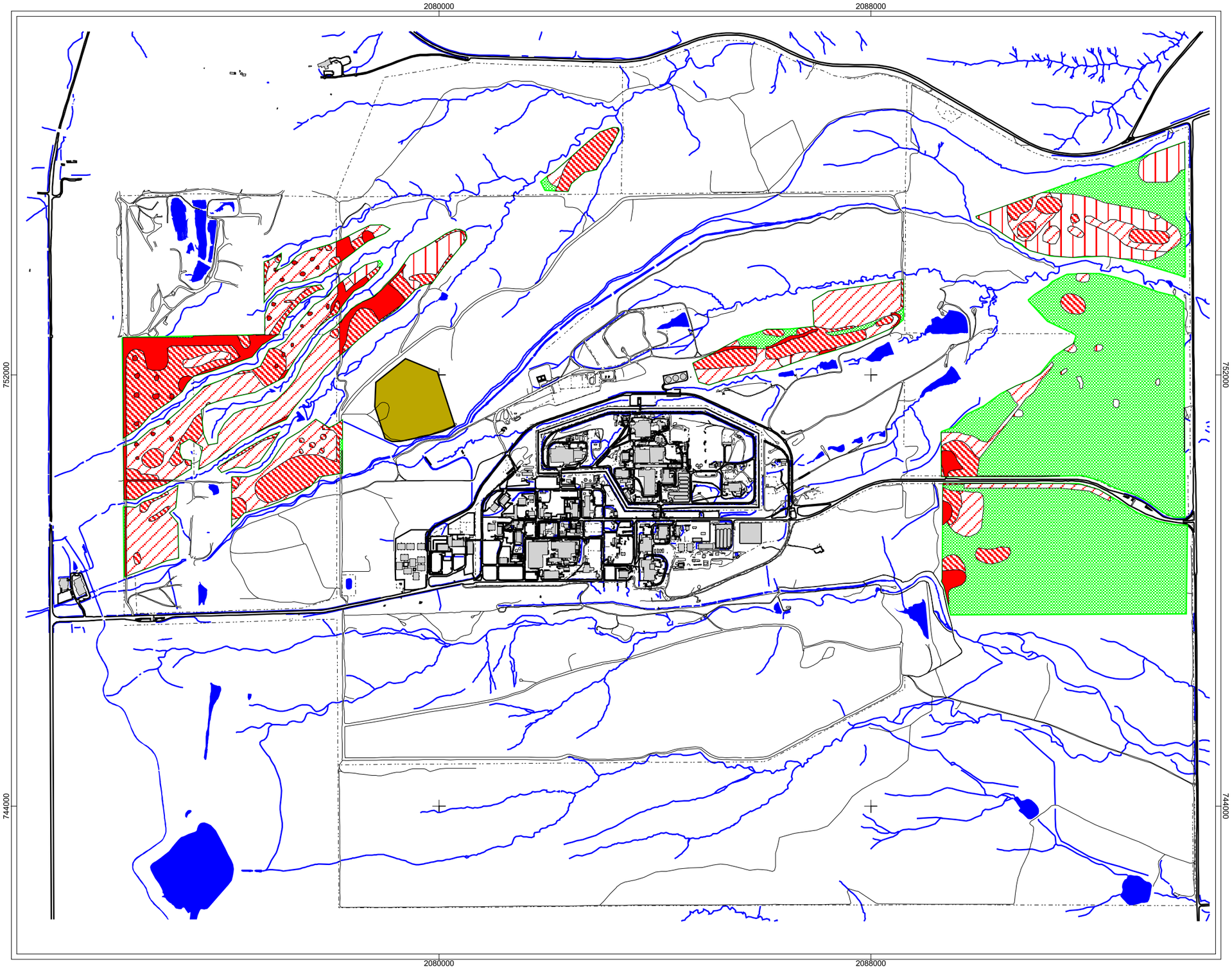
For: Kaiser-Hill Company, LLC

RFETS GIS Dept. 303-966-7707

MAP ID: 2K-0419

May 3, 2001

\\Gisrv\GIS\ECO-projects\projects\2k-0419\cedi00.apr\2000 CEDI (1999 Aerial Clip Map)



1999 Diffuse Knapweed Pre-Aerial Herbicide Application Distribution (2000 Application)

Figure 21

MAP LEGEND

- High Density Areas
- Medium Density Areas
- Low Density Areas
- Scattered Density Areas
- 2000 Aerial Spray Areas

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Weed distribution data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

N

1:23552

1000 0 1000 2000 Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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