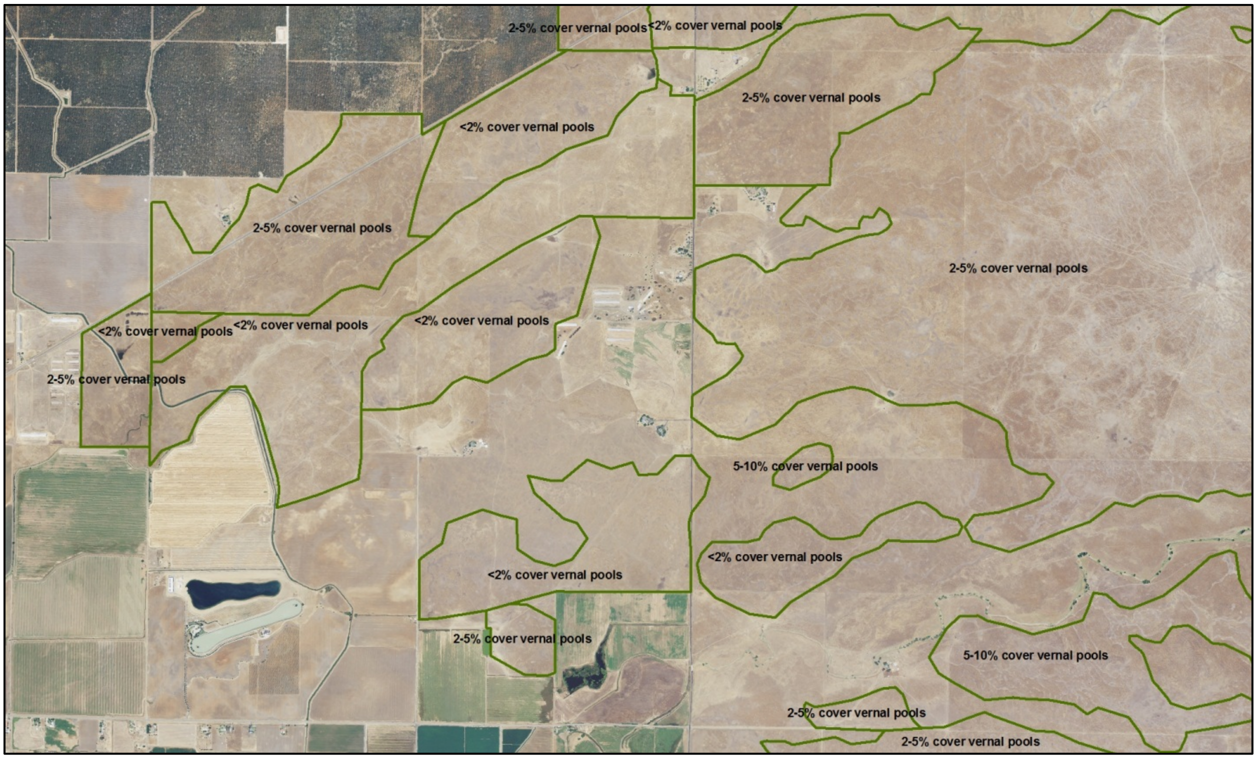
2005 Great Valley Vernal Pool Map, Plus Merced, Placer and Sacramento County Losses 2005-2010

USFWS Grant Agreement 80270-A-G509



Aerial photograph showing mapped polygons of vernal pool habitat and their cover class.

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FINAL REPORT
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Abstract

We mapped vernal pool distribution within a 21.4 million acre area surrounding the Great Valley from 2005 National Agricultural Imaging Program (NAIP) county photomosaics using ESRI ArcMap 9.x in a double-blind protocol. Each mapped polygon was scored for classes of habitat cover, habitat density, habitat diversity, disturbance cover, and disturbance intensity. Ground truth sampled 25% of the polygons we drew; the double blind protocol lowered our error rate to about 2 percent. We mapped 807,820 acres of vernal pool landscape in 1,909 polygons and present various tabular summaries of polygon number and acreage by recorded attribute. We overlaid our results with a map of Core Recovery Areas (CRAs), finding 452,012 acres within the CRAs, and an additional 120,137 acres immediately contiguous to the CRAs. We remapped Placer, Sacramento, and Merced counties using 2010 NAIP imagery to calculate rates of habitat loss and gain in the five years since the Vernal Pool Recovery Plan was released. Direct losses in these three counties totaled 9,515 acres (~1,900 acres/year), primarily converted to orchards and vineyards. These losses are partially off-set by newly constructed habitat. For example, in Placer and Sacramento counties 1,261 acres of low cover, low density natural habitat were converted to high cover, high density mitigation banks, and 838 acres of newly built habitat appeared on lands formerly under intensive agriculture.

1 Introduction

The fiscal year 2010 funding opportunity announcement prioritized quantifying the acreage of currently occupied and suitable habitat, and occupied and suitable habitat that was present in 2005 (the time that the vernal pool ecosystems recovery plan (USFWS 2005) was published). Mapping of the core areas in Sacramento, Placer and Merced counties were deemed to have the highest priority. Vollmar et al submitted a proposal to map the Sacramento and San Joaquin valleys as of 2005 and to remap Sacramento, Placer and Merced counties based on 2009 (or 2010) aerial imagery.

The first GIS map of vernal pool habitat (Holland 1998a) was based on interpretation of Department of Water Resources aerial photography in the form of slides that encompassed approximately 1 by 1.4 miles per slide. These slides dated from 1987 through 1995 depending on the county. Subsequent updating of that GIS mapping (Holland 1998b, 2009) has focused on land use changes within the originally mapped polygons. During peer review of the most recent update of the mapping based on the high resolution 2005 imagery, it became evident that while the land-use changes within the mapped polygons were accurate, Holland's habitat polygons may under- or over-represent the amount of extant vernal pool habitat.

Since the initial Holland mapping efforts, new high resolution geo-referenced imagery and data layers (such as soil surveys and endangered species locations) have become readily available for GIS use. Additionally, several counties have undergone vernal pool mapping efforts in support of regional conservation planning. These efforts mapped vernal pools at various scales from individual pools (Sacramento County) to vernal pool complexes (Placer County) and a hybrid of pools and complexes (Merced County). These GIS data were used to assist interpretation of the aerial imagery.

1.1 Objectives

The primary objectives are listed below and more details on methodology are provided in the Methods Section.

1. Map the San Joaquin and Sacramento valleys (collectively Great Valley) vernal pool landscapes as of the 2005 high-resolution National Agriculture Imaging Program (NAIP) geo-referenced aerial photography.
   a. Conduct quality control checking on the GIS datalayer including topology and completeness of data,
   b. Conduct ground truth of the map through an opportunistic driving windshield survey of the Great Valley.
2. Re-map Sacramento, Placer and Merced counties using the 2010 NAIP imagery and annotate the cause of losses or gains in acreage.
   a. Conduct quality control checking on the GIS datalayer including topology, completeness of data,
   b. Conduct ground truth of the map through an opportunistic driving windshield survey of the three counties.
3. Provide summary analysis and tabulation of the data and suggest additional analyses of the dataset.

2 Description of Study Area

The study area encompassed the entire Great Valley and surrounding foothills. Vernal pools are most typically associated with grasslands, but they are known to extend well into the surrounding foothills. We used the upper elevation limit of blue oak – digger pine woodland as mapped by Kuchler (1976) as our study area boundary. In eastern Tehama County, this transition to yellow pine forest is at about 2,500 – 3,000 feet. In Tulare County, the same transition is at about 6,000 feet. In western Sacramento Valley the transition is to chaparral at 1,800 – 2,500 feet. In the Inner South Coast Ranges, the grasslands and woodlands rise to the topographic divide at 2,500 – 3,000 feet. The entire survey area covered about 21.4 million acres. It is illustrated in Figure 1 (page 14).

3 Methods and Materials

Prior to beginning any mapping, the authors (Carol Witham, Robert Holland and John Vollmar) and key Vollmar Natural Lands Consulting staff (Jake Schweitzer, Cassie Pinnell) held several meetings to help refine the scope, details and process to accomplish our goals. The team also met with Cheryl Hickman at USFWS and Todd Keeler-Wolf at DFG to solicit input on mapping methods and final data configuration. Together the team then worked out the structure of the geodatabase and a schedule for accomplishing the mapping.

We drew habitat boundaries on-screen using ESRI ArcMap 9.x GIS software. This software allows one to display air photos at any scale, and to superimpose additional information such as topography, soils, roads, precipitation, or any other environmental parameter that may be of interest. Unlike most other mapping projects of this scale, we chose to map double-bind. Each mapper (Holland and Witham) independently covered each county in turn. As counties were completed, we would meet and collaboratively reconcile our mapping. Once all the counties had been reconciled, the maps were collated into a single valley-wide file and subjected to various quality control reviews.

3.1 Materials

Existing GIS data layers that might be informative to this mapping project were compiled from various sources including the Department of Fish and Wildlife Data Portal and the National Resources Conservation Service GeoSpatialDataGateway. Other information was obtained from independent sources including county planning staff and researchers. The data layers used include:

- 2005 NAIP Mosaics by county (color aerials).
- 2009 NAIP Mosaics by county (color aerials).
- 2010 NAIP Mosaics by county (color aerials).
- Digital Ortho County Mosaics by county (b&w aerials from the 1990s).
- Digital Raster Graphic Mosaics (TIFF topographic maps).
- Digital Raster Graphic County Mosaics by county (SID topographic maps).
- Great Valley Vernal Pool Distribution – Photorevised 2005 (Holland 2009).
- California Natural Diversity Database rare, threatened and endangered element occurrence locations for species known to occur in vernal pools (CNDDB 2012).
- Soil Survey Spatial and Tabular Data (SSURGO 2.2) by county.

3.2 Create Mapping Geodatabase

While existing data were being compiled, the team met several times to discuss what attributes would describe each mapped polygon. We determined through review of the baseline 1 meter aerial photography that the aerial cover of vernal pools and aerial cover of disturbance were quantifiable using cover classes. Qualitative information on density of vernal pools, diversity of vernal pools, plus type and intensity of disturbance could also be obtained from aerial interpretation. And finally, because large pools may have separate importance to certain vernal pool species, we chose to quantify–and separately map as points–the large pools in each of the mapped polygons.

A geodatabase was then designed to capture the information and attributes we believed could be assessed from aerial interpretation. Using the geodatabase ensured that both mappers were using the same cover classes, quantitative/qualitative categories and disturbance terminology in annotating the mapped polygons. We tried the geodatabase in a pilot study of part of Sacramento County and found several opportunities to improve its design and performance. An outline of the final geodatabase structure is provided as Appendix A.

3.3 Conduct Double Blind Mapping

During the design and testing of the geodatabase, we decided to conduct the mapping on a county-by-county basis to maximize computing speed and for the purposes of tracking. For each county, all of the pertinent data layers were compiled into a project. Additionally, to facilitate tracking progress within each county, a 1 mile by 1 mile polygon grid was created. As each area was inspected and mapped, the overlying grid polygon was deleted.

Holland and Witham calibrated their mapping early in the project by choosing two areas to map and compare. These were southeast Sacramento County, where both mappers had extensive field experience, and Tulare County, which was relatively unknown to both mappers. After reviewing and discussing similarities and discrepancies between these maps, both Holland and Witham felt confident that their independent mapping efforts would be highly similar. They then proceeded to independently map the remainder of the Great Valley.

Elimination of unsuitable areas–such as intensive irrigated agriculture or metropolitan areas–usually was done at a scale of 1:24,000 which was the equivalent of about 15 square miles being visible on a 24-inch monitor. Where possible habitat was detected, the mapper would simply zoom in to a more appropriate scale. Most mapping of vernal pool areas was conducted at approximately 1:12,000 scale, which was the equivalent to having two square miles of aerial photography on the monitor. However, when appropriate the mapper may have zoomed to raster resolution of the image, which was approximately 1:4,000. For each mapped polygon, the geodatabase fields for all of the required attributes were completed, and habitat notes or mapping notes were added as appropriate.

No minimum mapping unit–for the polygons or cutouts–was determined in advance. Each mapper digitized what they interpreted from the aerial photography at whatever polygon size was appropriate for the setting. The benefits and limitations of this approach are discussed later in this report.

3.4 Reconciliation of Independent Mapping

As each county was completed, the two independent maps for each county were combined into a signal geodatabase. Holland and Witham then conducted a series of meetings to reconcile the mapping. This reconciliation was done on a polygon-by-polygon basis. Any discrepancies were discussed and the best fitting polygon shape and attribution were determined for each polygon. This reconciliation resulted in each polygon being reviewed at least three times (in the few cases where one of the mappers missed the feature), but usually four times. Reconciling each county usually took 2-5 hours, depending on how much habitat had been mapped.

The meetings to discuss the mapped polygons also allowed Holland and Witham to explore other information that might inform decisions about a particular polygon. For example, if a polygon was annotated “possibly just slope wetlands” by one mapper, and not mapped at all by the other, various additional data layers could be reviewed and discussed to inform the decisions to keep or discard the polygon, what its final shape would be, and how it’s attributes would be scored. Every single polygon we drew was subjected to the same review; each was considered and resolved before moving on to the next. These meetings also had the unanticipated benefit of continually calibrating both mappers.

3.5 Topology Checking and Quality Control Methods

Topology checking of the mapping was conducted in two phases. First each county was checked for internal topology issues (inadvertent overlaps and slivers). Then, once all the counties were compiled into a single geodatabase, additional topology checking was conducted along county lines to ensure that continuous mapped areas did not overlap or have slivers.

The topology-corrected “all counties” file was then carefully evaluated by inspecting each polygon that was adjacent to any county lines. In some cases, the cover, density or other attribution differed across a county line. These were checked to verify that the different condition was actually present and appropriately attributed.

Quality control on the final compiled map was conducted by Witham during the course of compiling tabular data results. All fields were checked for completeness and numerous queries were conducted for field entries which should be mutually exclusive with other entries. Once confident that the data set was as complete and accurate as possible, acreages were calculated for each polygon. These were used to compile results presented in Section 4.

3.6 Ground Truth Methods

Mapped polygons for each county were exported from the geodatabases into shapefiles and additional fields were added to facilitate tracking of whether or not a polygon was visited and what was observed. These shapefiles were then loaded into an iPad running an iGIS application (Geometry Pty Ltd 2012). The iPad displayed our polygons superimposed on Google Earth, complete with a blue dot indicating our current position. Holland and Witham then plotted out driving routes that would allow windshield surveys of as many polygons as possible. John Vollmar participated in part of the San Joaquin Valley ground truth trip. One team member drove while the other navigated and annotated the shapefiles. In eight long days we drove nearly 2,200 miles between Redding and Bakersfield, visiting a quarter of the polygons we had drawn.

3.7 Remapping Methods

Sacramento, Placer and Merced counties were remapped using the 2010 NAIP imagery to document losses since the 2005 Recovery Plan. Additional habitat, in the form of mitigation banks (created vernal pool landscapes), also was mapped. Again, these were mapped independently by Holland and Witham with the final map being the result of comparing both maps.

Remapping began with the maps based on the 2005 photo interpretation. Each polygon was carefully searched in the 2010 imagery for detectable changes in land use. Losses were annotated as to the type of land conversion. Areas outside the 2005 basemap polygons also were searched for new mitigation banks.

4 Results and Discussion

4.1 Ground Truth Results

Initial heads-up digitizing identified 1,994 polygons of potential habitat. However, both mappers questioned the aerial interpretation related to several specific polygons and to the alkali lands of Kern, Kings and Tulare counties in general. During August 2012, two trips were made to spot check the mapping and to visit the areas with questions. One trip was made into the San Joaquin Valley and one trip was made into the Sacramento Valley. All the survey work was conducted from roads and none of the sites were accessed on foot.

We visited 501 polygons during ground truth. This is >25% of the polygons mapped, which is a very large sample. Not including the alkali lands of Kern, Kings and Tulare counties, we found a total of 10 mis-mapped polygons for an error rate of just 2 percent. Eight of these were not vernal pool landscapes and two small areas (<5 acres) not previously mapped were added. Extrapolating to the entire population of mapped polygons, there may be about 32 false positives (mapped areas where no habitat actually is present) and there may be about eight areas that escaped detection (areas that should have been mapped, but were missed). Additionally, 24 of the 501 polygons had been converted to other land use, and 44 others were annotated as being partially converted or having increased disturbance. This shows that land use change is a larger source of error than our mapping [(24+44)/10 = 6.8x].

Using the information and experience gained from the ground truth trip into the San Joaquin Valley, Holland and Witham again reviewed all of the mapped polygons for Kern, Kings and Tulare counties. Each polygon was carefully searched for vernal pool features and the soil surveys were reviewed for information related to soil drainage. Several polygons for which we did not see vernal pools from the road were retained following more careful aerial interpretation and 82 polygons were removed as simply being alkali land and not containing vernal pools. Table 1 (page 20) is a tabular summary of polygons mapped before and after the ground truth exercise.

4.2 2005 Mapping Results

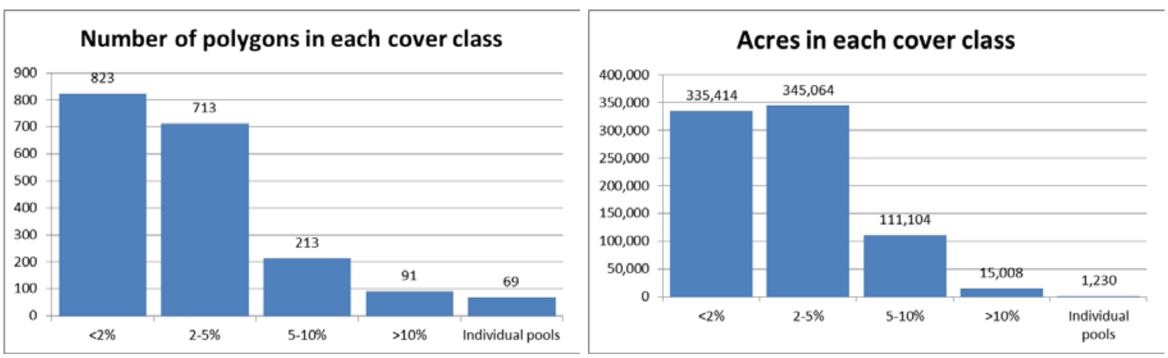
Following adjustments from ground truth and reassessment of the alkali areas of the southern San Joaquin Valley, a total of 807,820 acres of vernal pool landscapes were mapped. This included 1,909 polygons in 26 counties with some continuous areas split into multiple polygons if they cross county lines. See Figure 2 (page 15) for a map of the distribution of vernal pool areas.

Table 2 (page 21) shows the number and acreage of vernal pool polygons mapped by cover class by county. Table 3 (page 22) presents the number and acreage of vernal pool polygons mapped by density class by county. Table 4 (page 23) presents the number and acreage of vernal pool polygons mapped by diversity class by county. These three categories of aerial interpretation are related, but convey different assessments of the landscape.

- Cover is the relative amount of the landscape covered by vernal pool features. Classes were used to simplify estimating cover. Data in Table 2 indicate that polygons mapped as <2 percent cover were smaller (average 408 acres) than polygons mapped as 5-10 percent cover (522 acres), and that polygons mapped at 2-5 percent cover were intermediate (484 acres). Polygons mapped as >10 percent cover were rare, just 2 percent of the acreage. Two thirds of the >10 percent cover polygons were mitigation banks with unnaturally high wetted acreage.

- Density reflects an assessment of the number of pools per unit area where a landscape with a lot of small pools would score higher than a similar area with only a few large pools. Data in Table 3 indicate that “low density” polygons are smaller (average 406 acres) than “medium density” polygons (487 acres) and “high density” polygons (748 acres).
- Diversity is meant to convey a sense of the complexity of the system. A system with pools that are all pretty much alike in size and shape would rank low, while one with a broad range of sizes and shapes would rank high. Data in Table 4 indicate that “low diversity” polygons were smaller (average 392 acres) then “medium diversity” polygons (507 acres) and “high diversity” polygons (999 acres).

One of the additional assessments made during aerial interpretation was the cover, intensity and type of disturbance that was evident within any given mapped polygon. Table 5 (page 24) presents the number of polygons and acreage by cover class of disturbance by county. This is provided simply to illustrate how the dataset might be further analyzed.



Example of analyses from the data presented in Table 2.

4.3 2005 Mapping Results by Core Recovery Areas

The foregoing results are presented on a county-by-county basis. However, the funding opportunity announcement emphasized analysis of habitat within the Core Recovery Areas of the Recovery Plan (USFWS 2005). To that end, we intersected our final map with a map of the Core Recovery Areas. Table 6 (page 25) lists the Core Recovery Areas by region and provides the number of polygons and two acreage figures. The number listed for “Acres Within Core Area” is the acreage of vernal pool polygons contained entirely within the Core Area. The second number is for the acreage of all polygons that intersect the Core Area including any area that falls outside the mapped boundary of the Core Area. Figure 3 (page 16) illustrates how polygons can fall within and have additional area adjacent; the adjacent area is included in the calculation of polygons that intersect the Core Recovery Area.

4.4 2010 Remapping Results

Following completion of the 2005 mapping, Sacramento, Placer and Merced counties were remapped using the most recent available high resolution aerial imagery. The 2010 NAIP

County Mosaics were used for this mapping. Losses in habitat due to land conversion were mapped. Vernal pool areas created (mitigation) since the 2005 mapping were also mapped.

4.4.1 2010 Remapping Results for Sacramento County

The 2005 map for Sacramento County included 292 polygons. The 2010 map has 360 polygons. This includes 16 new mitigation areas and 48 polygons where habitat has been lost. Figure 4 (page 17) shows the results of the 2010 remapping of Sacramento County. Below is a summary of the changes between 2005 and 2010.

- 2,204 acres (3.4% change from 2005) were converted to incompatible land use:
  - 1,529 acres are now bare agricultural land, primarily in the Cosumnes/Rancho Seco Core Recovery Area,
  - 610 acres were converted to urban uses, primarily within the Sunrise Douglas area of the Mather Core Recovery Area, and
  - 65 acres were converted to other uses (ag residential, other agriculture).
- 719 acres were converted from low cover, low density mapped vernal pool habitat to new mitigation banks, primarily within the Cosumnes/Rancho Seco Core Recovery Area.
- 636 acres of new mitigation banks were created outside of previously mapped habitat, in or adjacent to the Cosumnes/Rancho Seco Core Recovery Area.

4.4.2 2010 Remapping Results for Placer County

The 2005 map for Placer County included 163 polygons. The 2010 map has 209 polygons. This includes 5 new mitigation areas and 26 polygons where habitat has been lost. Figure 5 (page 18) shows the results of the 2010 remapping of Placer County. Below is a summary of the changes between 2005 and 2010, most of which occurred within or adjacent to the Western Placer Core Recovery Area.

- 688 acres (2.2% change from 2005) were converted to incompatible land use:
  - 542 acres were converted to urban land use,
  - 131 acres are now bare agricultural land, and
  - 15 acres were converted to new ag residential.
- 542 acres were converted from low cover, low density mapped vernal pool habitat to new mitigation banks.
- 202 acres of new mitigation banks were created outside of previously mapped habitat.

4.4.3 2010 Remapping Results for Merced County

The 2005 map for Merced County included 326 polygons. The 2010 map has 344 polygons. This includes one newly mapped area which was missed in the 2005 mapping and 22 polygons where habitat has been lost. Figure 6 (page 19) shows the results of the 2010 remapping of Merced County. Below is a summary of the changes between 2005 and 2010.

- 6,623 acres (3.3% change from 2005) were converted to incompatible land use:
  - 3,522 acres were converted to orchards or vineyards, primarily in the Madera Core Recovery Area,
  - 2,054 acres were converted to alfalfa or other irrigated crops,

- 1,040 acres are now bare agricultural lands, with a small portion within both the Madera and San Joaquin Valley Core Recovery Areas, and
- 8 acres were converted to urban/industrial.

5 Summary and Conclusions

The primary objective of this project was to produce a new map of the vernal pool areas of the Sacramento and San Joaquin valleys. The new map is based on improved technology and high resolution aerial imagery. The authors believe that the new map is superior to any previously produced maps that encompass a similar area. However, the map was produced by interpretation of aerial imagery and may not have captured small or isolated features which do not have a distinct soil signature. Indeed, we stumbled upon two such sites during ground truth. Conversely, the mapping may have overstated vernal pool areas on the volcanic tablelands and mudflows. These areas support vernal pools, but perhaps not distributed evenly throughout the mapped areas.

Despite this mapping being a 12,000 foot assessment of the vernal pools of the Great Valley, the data set included as part of this mapping effort contains a variety of information that can and should be used to interpret the extent and condition of vernal pool areas within the Great Valley as of 2005. Some factoids that can be gleaned from the data set include:

- 14% of all acreage mapped consists of occasional pools within a landscape managed for waterfowl habitat. In Merced County 47% of the mapped 203,567 acres is within areas managed for waterfowl. These areas have been included in the mapping because they can and do provide habitat for listed species, but are not of the highest quality. These areas formerly supported extensive freshwater marshes that have desiccated since flood control measures were instated in the 1940s and 1950s.
- 24% of all of the polygons mapped are impacted to various levels and intensities by plowing, disking or grading. During ground truth we observed many extensive areas of vernal pool habitat where hay production was an active land use. (Farmers frequently drill right through vernal pools when they plant dry grains in the fall because it is easier than going around. The grain germinates and drowns while water stands in the pool over winter.). Again these lower quality areas are included in the map because they can and do provide habitat for listed species.
- 7% of the polygons mapped are impacted to varying degrees by altered hydrology usually in the form of agricultural runoff. In many cases it appears that some vernal pools have been converted to marshes.
- 9,176 acres, or just over 1%, of the area mapped valley-wide were mitigation banks in 2005. Of the mitigation areas mapped in 2005, 69% were mapped as having vernal pool cover >10%. Only 1% of natural landscapes were mapped at such high cover. An additional 2,099 acres of mitigation banks were created in Placer and Sacramento counties during the period between 2005 and 2010. This included conversion of 1,261 acres of low cover and low density habitat.

5.1 Opportunities for Additional Analysis

It was outside the scope of this project to perform extensive analysis on the data set. However, during the course of creating the 2005 map, we included a variety of quantitative and qualitative observations of the landscape within each polygon. The shapefile and associated tabular data are available to anyone who wants to use the data, furthermore, the authors encourage additional analyses.

5.2 Caveats to Use of Data

Although this map is thought to be a better baseline for determining Recovery Plan implementation actions, it is based on seven year old imagery. Even the remapping of Sacramento, Placer and Merced counties is based on two year old imagery. Specific actions on a local scale should include more up-to-date mapping information and locally gathered on-the-ground data. We note that the 2012 NAIP imagery recently has become available and should be used to determine current conditions wherever appropriate.

5.3 Retrospective Comments

During the course of finalizing the mapping, preparing tabular summaries and writing this report, the authors reflected on several items that might have improved the quality and consistency of the map and aided further analyses of the data set. The two primary items are discussed below.

5.3.1 Land Use Adjacent to Mapped Habitat

The authors now wish we had collected information related to land use and condition adjacent to the polygons that we mapped. This might have allowed additional assessment of potential threats and indirect impacts to each mapped unit. A polygon completely surrounded by incompatible use is subject to more stressors than one adjacent to another mapped vernal pool unit or otherwise surrounded by natural landscape. While some inferences might be derived from the shape of a polygon and its proximity to other polygons, it would have been good to have collected data on adjacent land use at the time of mapping.

5.3.2 Minimum Mapping Unit

Establishing a minimum mapping unit on the onset of the project, particularly related to cutouts (ag residential, roads, canals), would have increased the internal consistency of the map. Because that was not done, the map suffers from shortfalls related to economy of scale. In small polygons, the mappers were more likely to subtract small cutouts for buildings, corrals or staging areas. In larger polygons, the same size cutout was often overlooked simply because it was small in proportion to the landscape being mapped.

A similar minimum mapping unit should have been established for mapping individual large pools within the landscape. In reviewing the final maps, it is obvious that there are inconsistencies from county to county in when or if individual pools were mapped within a larger polygon of habitat. However, we did create a separate point shapefile of large pools and stockponds and will make those data available.

6 Recommendations

The authors have a second year of funding on this project intended specifically to remap Glenn, Madera, San Joaquin, Stanislaus and Tehama counties as of the most recent high resolution aerial photography. Should funding permit, that project should be expanded to as many additional counties as possible.

If others undertake updating of the map or any portion thereof, we strongly recommend that some data related to adjacent land use be recorded during the process of aerial interpretation. This will greatly improve the ability to assess stressors and threats to the remaining vernal pool habitats.

7 Summary of Expenditures

A final financial report using SF-425 has been prepared and submitted along with the final report for this project.

8 Raw Data

Two geodatabases are provided as part of this report.

- 2005GreatValleyVernalPools.mdb contains all data pertaining to mapping the Great Valley as of the 2005 NAIP imagery. The database structure is provided as Appendix A.

- 2010RemapVernalPools_MER_PLA_SAC.mdb contains the data related to remapping Merced, Placer and Sacramento counties as of the 2010 NAIP imagery.

In addition to the geo databases, two shapefiles are provided: county boundaries and study area.

All GIS files are in the NAD 1983 California Teale Albers projection coordinate system.

8.1 Analytical Tools

We used ESRI ArcMap 9.x GIS software throughout this project. Tabular analyses were done with Microsoft Excel and Access. Several of the graphics have been burnished in Adobe Photoshop or Corel Draw. Final report production was compiled in Adobe Acrobat.

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10 Definitions

This document uses several GIS-specific expressions that may be unfamiliar to readers who lack much GIS experience

24,000 scale: Map scale is described as a fraction. One inch on a map at 1:24,000 scale represents 24,000 inches (2,000 feet) on the ground.

Geodatabase: A collection of geographic datasets managed within a relational database. It is the industry standard storage model, with highly engineered data management and performance. Many different types of geographic data can be added.

Ground truth: The process of physically visiting a sample of mapped polygons to verify that habitat really was present.

Heads-up digitizing: Sketching polygon boundaries on-screen. Early in GIS development, features were sketched onto paper maps, then digitized on a special table. The equipment was finicky and the process was cumbersome and error-prone.

MrSID or SID: Multiple resolution Seamless Interleave Display. A proprietary format that displays images over a remarkable range of scales without loss of resolution.

NAIP: USDA's National Agriculture Imagery Program provides digital orthophoto coverage for the continental USA. The photos are 1- or 2-meter resolution true color SID images. Images of each county are available within a year of image acquisition.

Raster: Rasters represent geography as a regular grid, just like the pixels in a camera or TV. Each cell has a value that represents some characteristic (elevation, temperature, etc.) within the cell.

Shapefile: An early file format that combines a feature's geography (point, line, or polygon) with its attributes in a table, with one line in the table for each feature on the map. Shapefiles today serve as a "least common denominator" for transfer of geographic information between users.

SSURGO: USDA Natural Resource Conservation Service provides soil survey data at three scales. SSURGO (Soil Survey Geographic data base) is the most detailed, typically covering a county or part of a county. The data are more progressively more generalized, showing soils at state-wide and nation-wide scale.

Topology: A rule-driven set of tools and techniques that allow the mapper to control geometric relationships among features and to maintain the map's geometric integrity. It is particularly useful in finding and correcting small overlaps or gaps between adjacent features.

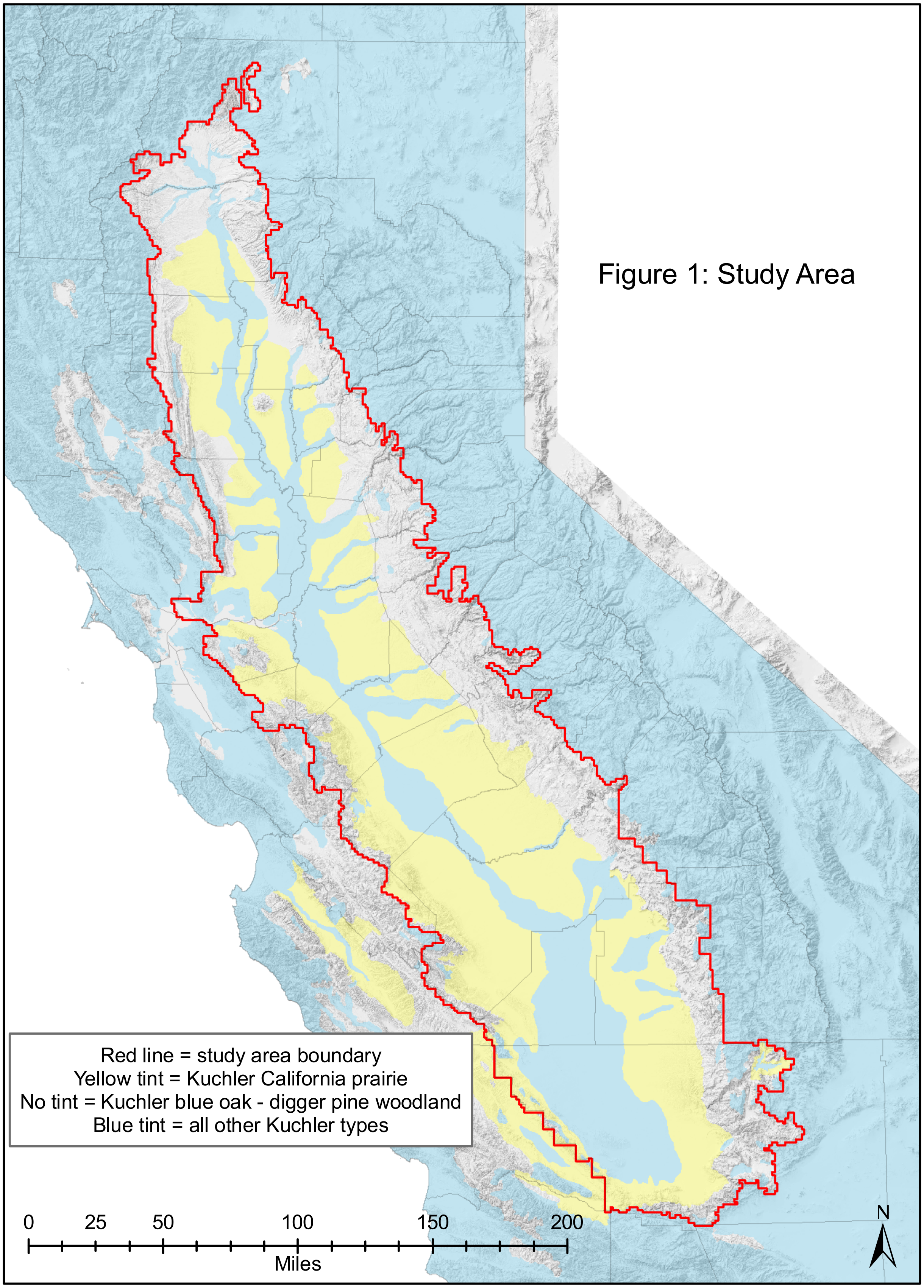
Figure 1: Study Area
Red line = study area boundary
Yellow tint = Kuchler California prairie
No tint = Kuchler blue oak - digger pine woodland
Blue tint = all other Kuchler types
0
25
50
100
150
200
Miles
N

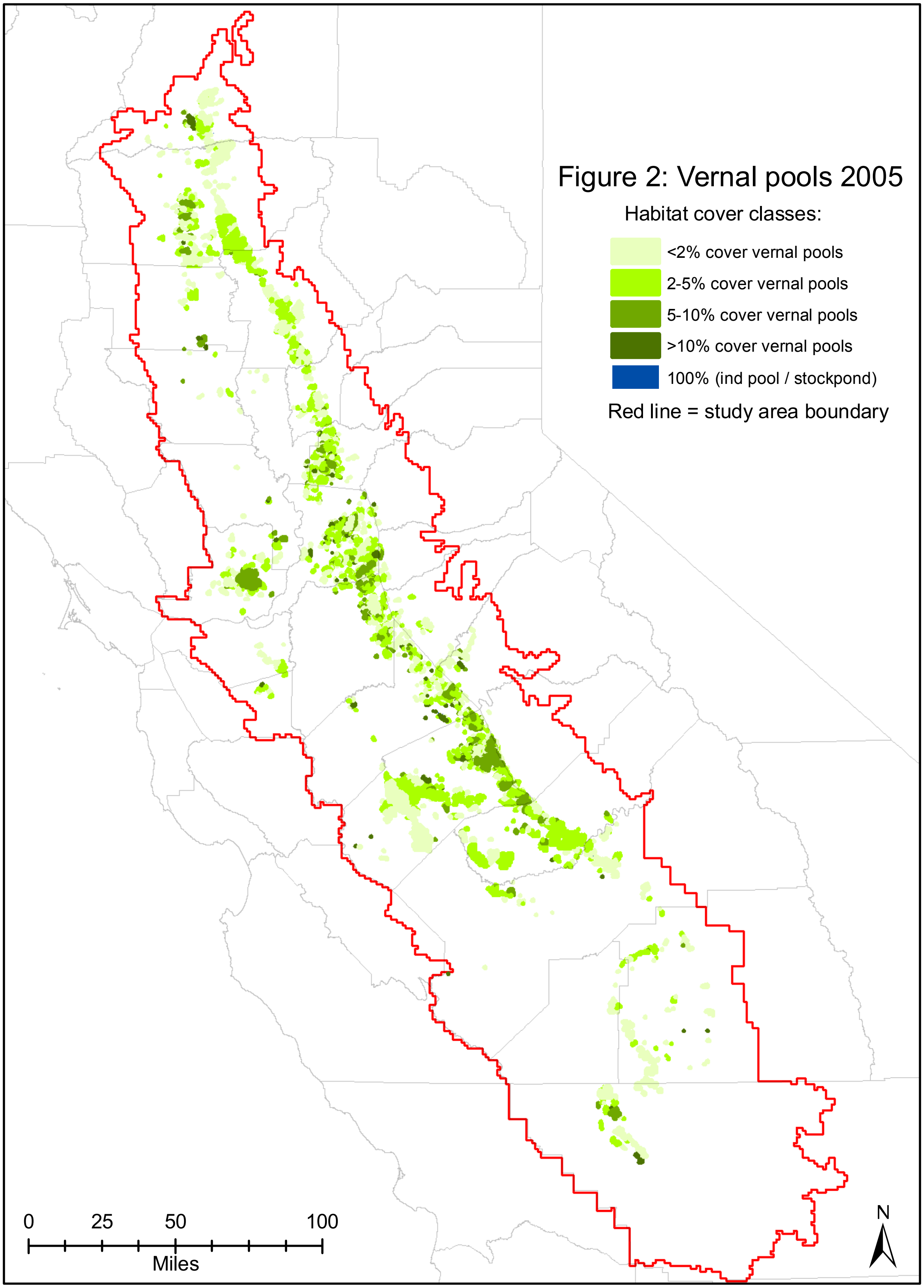
Figure 2: Vernal pools 2005
Habitat cover classes:
<2% cover vernal pools
2-5% cover vernal pools
5-10% cover vernal pools
>10% cover vernal pools
100% (ind pool / stockpond)
Red line = study area boundary
0
25
50
100
Miles
N

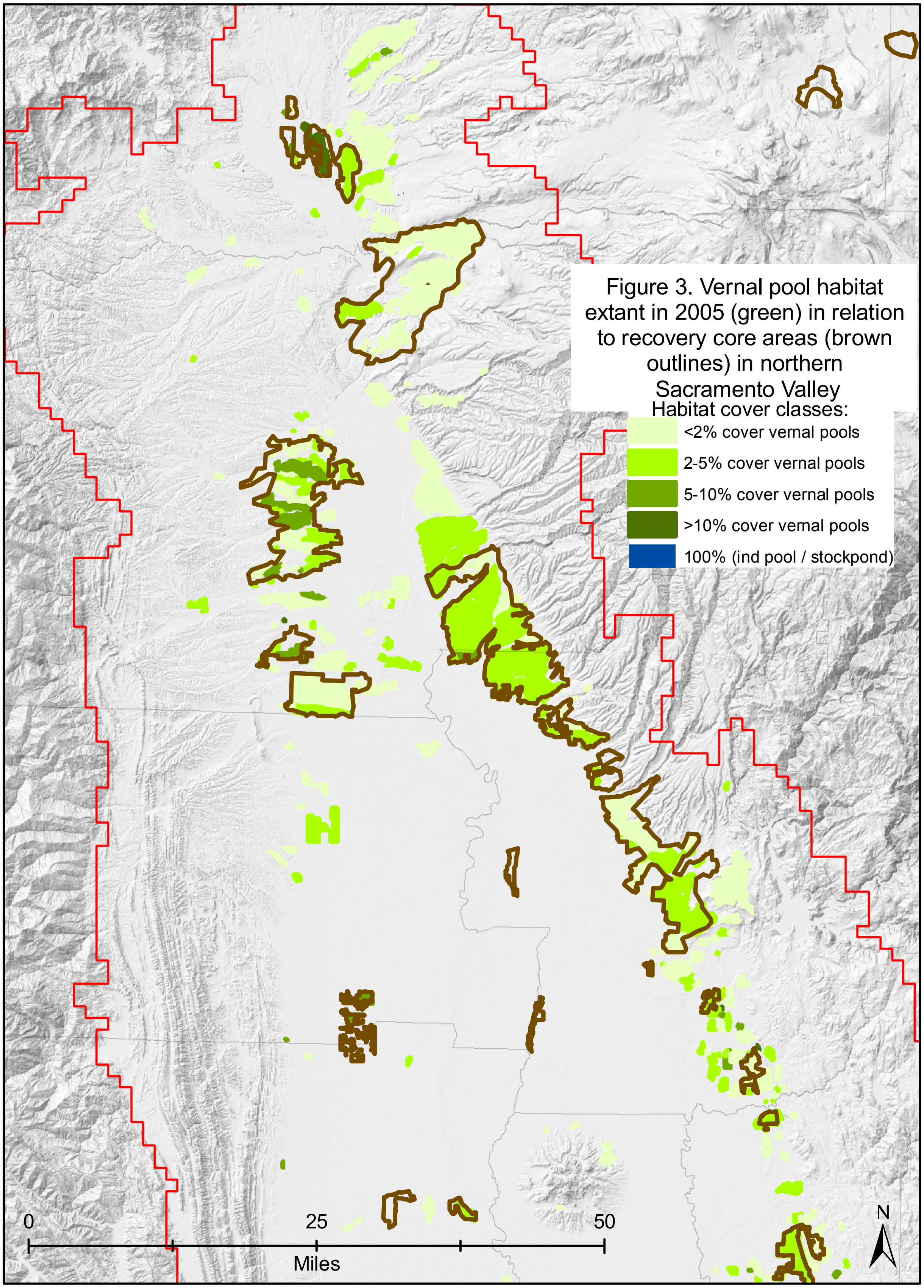
Figure 3. Vernal pool habitat extant in 2005 (green) in relation to recovery core areas (brown outlines) in northern Sacramento Valley
Habitat cover classes:
<2% cover vernal pools
2-5% cover vernal pools
5-10% cover vernal pools
>10% cover vernal pools
100% (ind pool / stockpond)
0
25
50
Miles
N

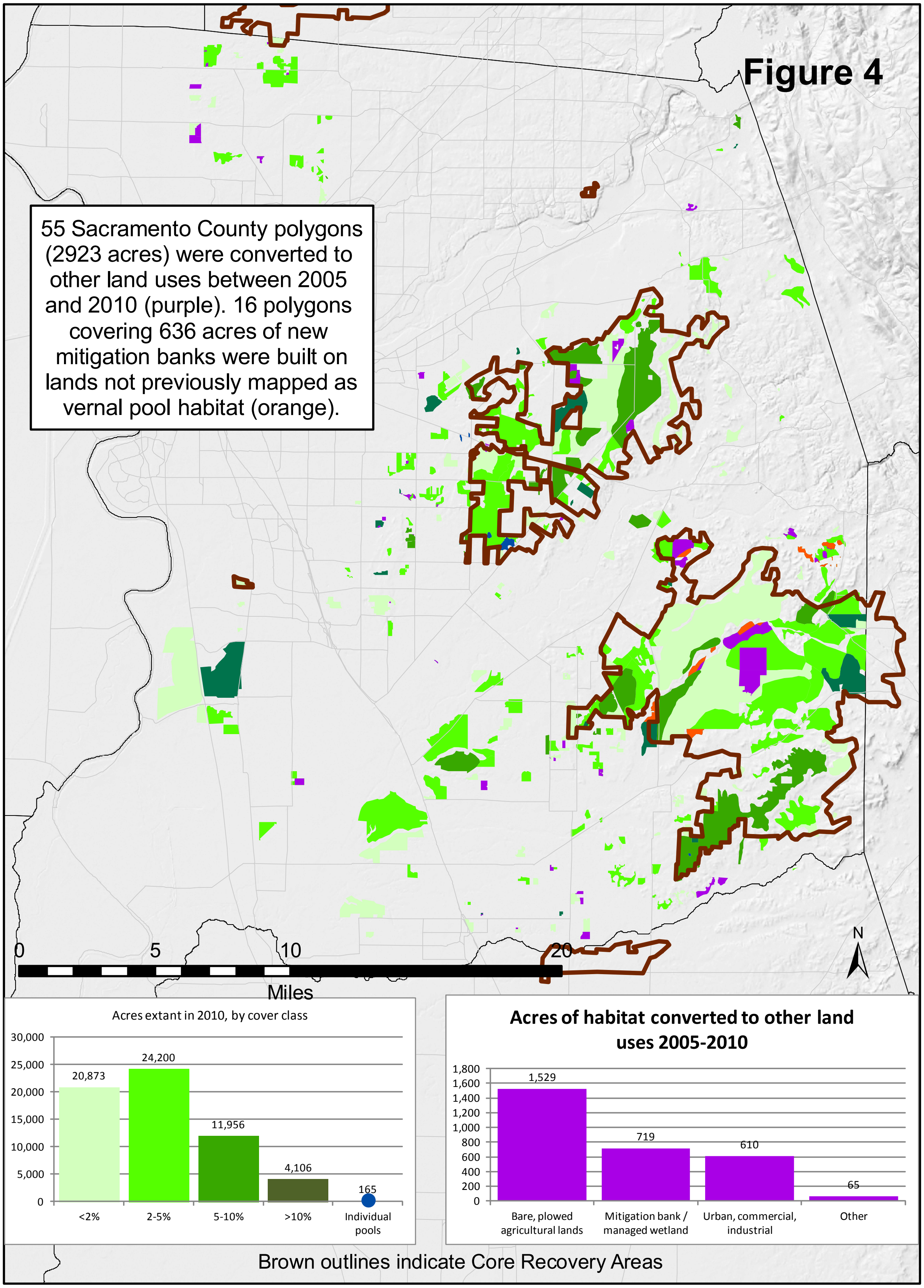
Figure 4
55 Sacramento County polygons (2923 acres) were converted to other land uses between 2005 and 2010 (purple). 16 polygons covering 636 acres of new mitigation banks were built on lands not previously mapped as vernal pool habitat (orange).
0
5
10
20
Miles
N
Acres extant in 2010, by cover class
30,000
25,000
20,000
15,000
10,000
5,000
0
20,873
24,200
11,956
4,106
165
<2%
2-5%
5-10%
>10%
Individual pools
Acres of habitat converted to other land uses 2005-2010
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1,529
719
610
65
Bare, plowed agricultural lands
Mitigation bank / managed wetland
Urban, commercial, industrial
Other
Brown outlines indicate Core Recovery Areas

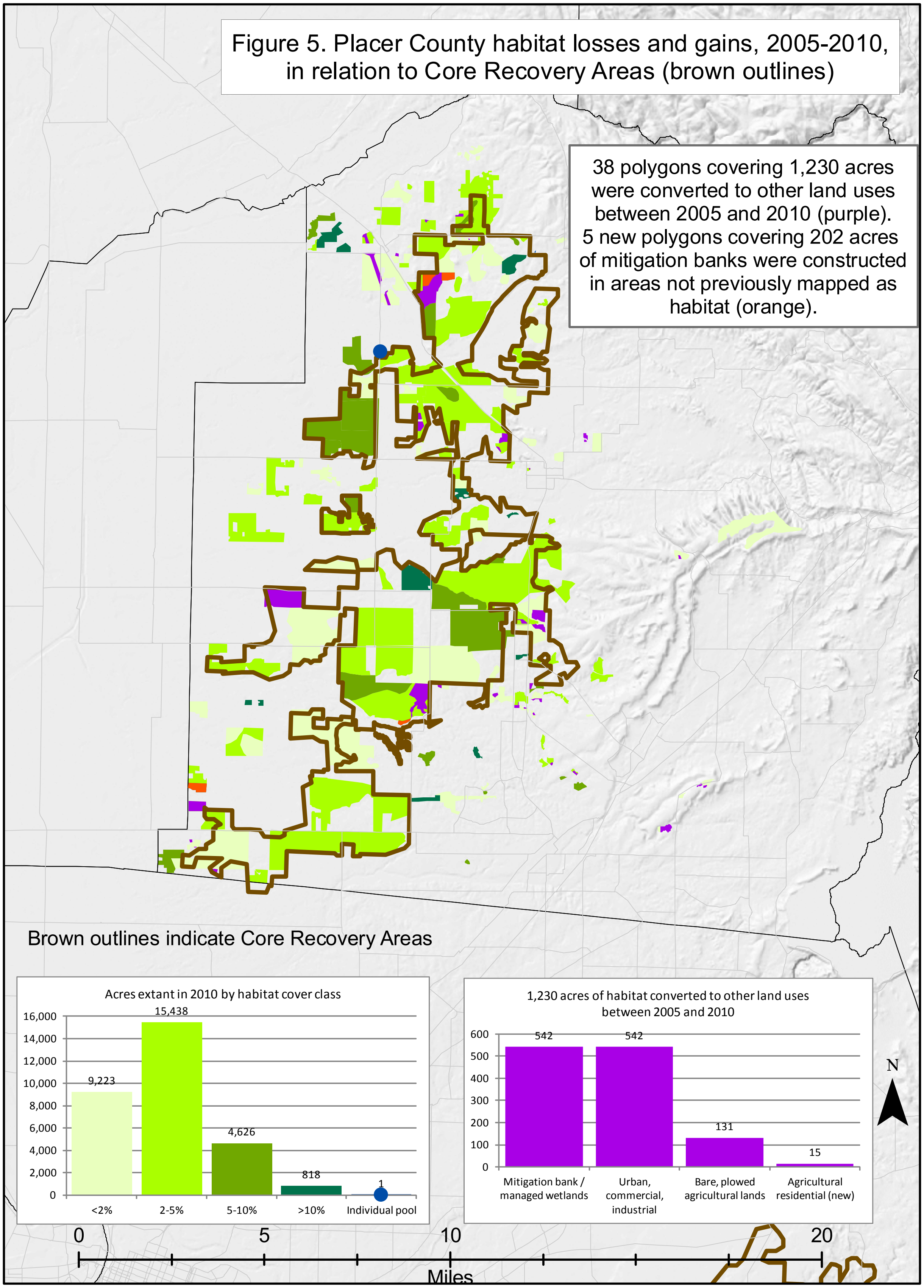

Figure 5. Placer County habitat losses and gains, 2005-2010, in relation to Core Recovery Areas (brown outlines)

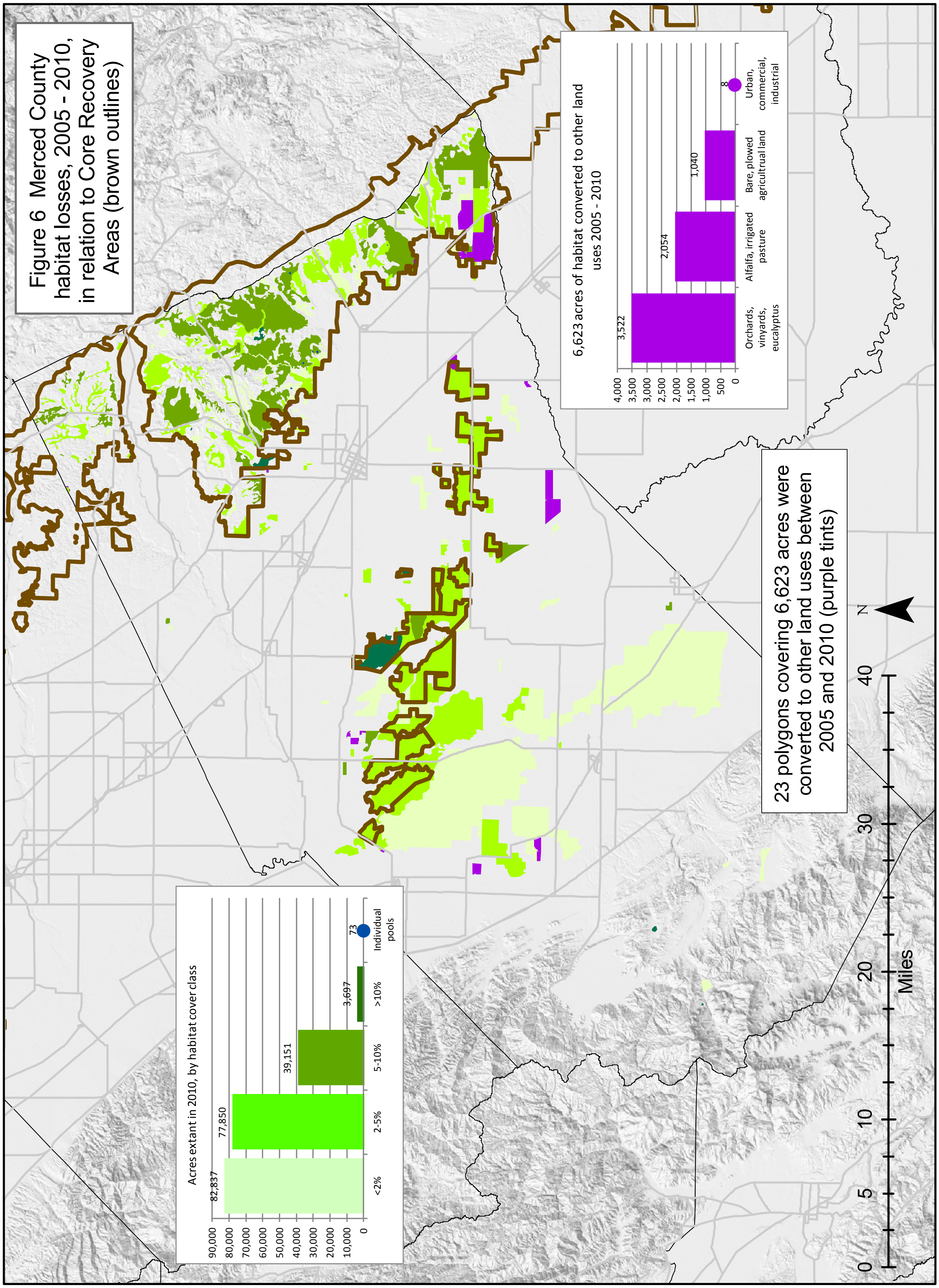
Figure 6 Merced County habitat losses, 2005 - 2010, in relation to Core Recovery Areas (brown outlines)
6,623 acres of habitat converted to other land uses 2005 - 2010
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
3,522
2,054
1,040
8
Orchards, vinyards, eucalyptus
Alfalfa, irrigated pasture
Bare, plowed agricultural land
Urban, commercial, industrial
23 polygons covering 6,623 acres were converted to other land uses between 2005 and 2010 (purple tints)
Acres extant in 2010, by habitat cover class
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
82,837
77,850
39,151
3,697
73
<2%
2-5%
5-10%
>10%
Individual pools
N
0
5
10
20
30
40
Miles

Table 1: Polygons visited during ground truth by county.

County	# polygons	0,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	1,10	1,11	Subtract*	Added	#visited	%visited	NewCount
Alameda	10	10														0	0%	10
Amador	12	12														0	0%	12
Butte	98	48	47					1					2	-2		50	51%	96
Calaveras	28	28														0	0%	28
Colusa	8	6	2													2	25%	8
Contra Costa	18	17														0	0%	18
El Dorado	7	7														0	0%	7
Fresno	47	26	20		1											21	45%	47
Glenn	17	13			1			1								2	12%	17
Kern	66	51	2								11	2		-34		15	23%	32
Kings	31	17	5		1					1	7			-25		14	45%	6
Madera	68	38	28	2												30	44%	68
Mariposa	26	26														0	0%	26
Merced	326	247	78		1											79	24%	326
Placer	163	115	48													48	29%	163
Sacramento	292	254	48													48	16%	292
San Joaquin	143	113	19	6	1	1										27	19%	143
Shasta	50	31	20													20	40%	50
Solano	47	28	19													19	40%	47
Stanislaus	217	187	27	1			1	1	1					-2	1	32	15%	216
Sutter	17	14														0	0%	17
Tehama	155	108	45		1								1	-1		47	30%	154
Tulare	74	44	19					1		1	5		3	-23	1	30	41%	52
Tuolumne	27	27														0	0%	27
Yolo	11	7	4													4	36%	11
Yuba	36	23	13													13	36%	36
Col Sum	1994	1497	444	9	6						23	2	6	-87	2	501	25%	1909

0,0	Polygon not visited
1,1	Polygon visited, habitat extant
1,2	Polygon visited, converted to hay ground
1,3	Polygon visited, converted to orchard
1,4	Polygon visited, converted to vineyard
1,5	Polygon visited, no vernal pools, but clay flats
1,6	Polygon visited, bare plowed ground
1,7	Polygon visited, lots of topo, dead ground
1,8	Polygon visited, converted to alfalfa
1,9	Polygon visited, alkali grassland and alkali sink, no pools visible from road
1,10	Polygon visited, converted to intensive ag.
1,11	Polygon visited, no habitat visible

*Polygons subtracted from Kern, Kings and Tulare counties were removed during another round of aerial photography interpretation following the ground-truthing exercise. While natural or semi-natural landscapes, these polygons were determined to be alkali soils and not vernal pools.

Grey indicates actual mapping errors. These were polygons that were incorrectly mapped as habitat, or areas where we saw habitat during ground truth which were not mapped.

Table 2: Number of polygons and acres mapped by cover class by county.

Vernal Pools by Cover Class by County												
County	<2% Cover		2-5% Cover		5-10% Cover		>10% Cover		Individual Pools		Total	
	Count	Acres	Count	Acres	Count	Acres	Count	Acres	Count	Acres	Count	Acres
Alameda	3	411	6	1,432			1	133			10	1,976
Amador	7	1,227	2	1,248	2	1,234	1	21			12	3,729
Butte	45	23,959	42	28,789	7	2,012	2	98			96	54,857
Calaveras	17	4,732	9	1,075	1	135			1	0	28	5,942
Colusa	5	883	2	672	1	38					8	1,592
Contra Costa	10	1,598	7	1,899					1	2	18	3,499
El Dorado	5	877			1	9	1	16			7	903
Fresno	29	16,698	13	8,521	2	2,085	2	79	1	23	47	27,405
Glenn	7	1,608	5	2,760	3	1,301	2	351			17	6,020
Kern	15	19,939	11	6,532	2	3,866	4	866			32	31,202
Kings	4	3,994	2	1,086							6	5,080
Madera	19	15,752	37	71,067	11	5,470	1	35			68	92,324
Mariposa	16	1,272	6	1,555	4	229					26	3,055
Merced	127	82,837	132	77,850	51	39,110	8	3,697	8	73	326	203,567
Placer	64	9,808	64	16,068	22	4,642	12	818	1	1	163	31,338
Sacramento	102	21,998	129	25,296	32	12,646	22	4,118	7	165	292	64,224
San Joaquin	45	9,348	64	16,083	29	6,116	3	132	2	13	143	31,692
Shasta	21	14,923	13	3,248	3	203	1	2,285	12	73	50	20,732
Solano	23	8,858	17	9,829	5	19,341	1	10	1	1	47	38,039
Stanislaus	83	7,072	66	9,622	19	4,173	19	1,831	29	768	216	23,464
Sutter	11	1,069	4	77	1	73	1	35			17	1,254
Tehama	91	51,035	48	42,952	7	6,975	3	123	5	111	154	101,196
Tulare	33	23,377	15	4,922	2	173	2	14			52	28,487
Toulumne	16	4,062	4	754	3	86	3	271	1	1	27	5,174
Yolo	4	1,466	2	2,142	3	1,069	2	77			11	4,753
Yuba	21	6,612	13	9,585	2	119					36	16,315
Totals	823	335,414	713	345,064	213	111,104	91	15,008	69	1,230	1909	807,819

Table 3: Number of polygons and acres mapped by density class by county.

Vernal Pools by Density Class by County										
County	Low		Medium		High		Individual Pools		Total	
	Count	Acres	Count	Acres	Count	Acres	Count	Acres	Count	Acres
Alameda	7	1,003	3	973					10	1,976
Amador	9	1,844	3	1,886					12	3,729
Butte	72	37,324	23	17,476	1	57			96	54,857
Calaveras	24	5,709	3	233			1	0	28	5,942
Colusa	8	1,592							8	1,592
Contra Costa	15	2,317	2	1,180			1	2	18	3,499
El Dorado	7	903							7	903
Fresno	30	16,141	12	9,042	4	2,200	1	23	47	27,405
Glenn	10	4,679	6	553	1	789			17	6,020
Kern	20	20,619	10	6,718	2	3,866			32	31,202
Kings	5	4,371	1	709					6	5,080
Madera	50	75,983	18	16,341					68	92,324
Mariposa	22	2,827	1	17	3	211			26	3,055
Merced	224	136,859	74	44,047	20	22,589	8	73	326	203,567
Placer	124	24,110	25	5,112	13	2,114	1	1	163	31,338
Sacramento	208	37,012	54	16,690	23	10,357	7	165	292	64,224
San Joaquin	104	21,567	29	8,112	8	2,000	2	13	143	31,692
Shasta	30	15,846	5	2,380	3	2,433	12	73	50	20,732
Solano	34	13,838	9	5,926	3	18,275	1	1	47	38,039
Stanislaus	152	14,123	29	7,021	6	1,553	29	768	216	23,464
Sutter	16	1,219	1	35					17	1,254
Tehama	125	84,854	20	13,846	4	2,385	5	111	154	101,196
Tulare	40	23,416	12	5,071					52	28,487
Toulumne	25	4,742	1	431			1	1	27	5,174
Yolo	11	4,753							11	4,753
Yuba	32	12,427	3	3,851	1	37			36	16,315
Totals	1404	570,077	344	167,647	92	68,866	69	1,230	1,909	807,819

Table 4: Number of polygons and acres mapped by diversity class by county.

Vernal Pools by Diversity Class by County										
County	Low		Medium		High		Individual Pools		Total	
	Count	Acres	Count	Acres	Count	Acres	Count	Acres	Count	Acres
Alameda	7	1,003	2	784	1	189			10	1,976
Amador	10	1,856	2	1,874					12	3,729
Butte	76	37,594	16	16,015	4	1,248			96	54,857
Calaveras	24	5,736	3	206			1	0	28	5,942
Colusa	8	1,592							8	1,592
Contra Costa	14	2,080	3	1,417			1	2	18	3,499
El Dorado	7	903							7	903
Fresno	28	15,700	13	9,527	5	2,156	1	23	47	27,405
Glenn	11	4,689	5	542	1	789			17	6,020
Kern	20	20,619	8	5,372	4	5,212			32	31,202
Kings	3	376	2	3,994	1	709			6	5,080
Madera	51	67,120	15	23,566	2	1,637			68	92,324
Mariposa	21	2,605	4	292	1	159			26	3,055
Merced	226	133,747	81	57,505	11	12,242	8	73	326	203,567
Placer	130	26,346	29	4,554	3	436	1	1	163	31,338
Sacramento	197	32,642	73	18,237	15	13,180	7	165	292	64,224
San Joaquin	104	22,208	29	6,078	8	3,393	2	13	143	31,692
Shasta	31	15,875	6	4,665	1	119	12	73	50	20,732
Solano	37	14,629	8	5,203	1	18,207	1	1	47	38,039
Stanislaus	134	12,847	46	8,406	7	1,444	29	768	216	23,464
Sutter	17	1,254							17	1,254
Tehama	124	78,506	23	15,887	2	6,693	5	111	154	101,196
Tulare	44	25,335	8	3,153					52	28,487
Toulumne	23	4,635	3	538			1	1	27	5,174
Yolo	10	4,652			1	102			11	4,753
Yuba	32	10,019	4	6,296					36	16,315
Totals	1389	544,565	383	194,109	68	67,915	69	1,230	1909	807,819

Table 5: Number of polygons and acres mapped by disturbance cover class by county.

Vernal Pools by Cover of Disturbance by County												
County	<1% Cover		1-5% Cover		5-25% Cover		25-50% Cover		>50% Cover		Total	
	Count	Acres	Count	Acres	Count	Acres	Count	Acres	Count	Acres	Count	Acres
Alameda	7	1,482	2	361					1	133	10	1,976
Amador	7	3,129	4	580					1	21	12	3,729
Butte	51	40,249	21	9,878	17	3,933	2	209	5	587	96	54,857
Calaveras	22	3,259	2	2,473	1	18	1	63	2	130	28	5,942
Colusa	1	71			3	663			4	858	8	1,592
Contra Costa	9	975	3	1,450	1	237	3	606	2	231	18	3,499
El Dorado	5	802	2	100							7	903
Fresno	21	12,897	10	5,180	10	7,522	4	1,352	2	455	47	27,405
Glenn	6	485	1	267	2	351	1	789	7	4,128	17	6,020
Kern	10	5,100	6	6,243	10	8,398	1	2,900	5	8,561	32	31,202
Kings	2	763	1	79	3	4,237					6	5,080
Madera	32	25,512	9	53,453	2	4,265	6	4,541	19	4,553	68	92,324
Mariposa	25	2,945							1	110	26	3,055
Merced	225	82,614	28	5,416	21	21,251	10	7,434	42	86,852	326	203,567
Placer	51	7,351	19	2,404	22	5,633	17	5,341	54	10,609	163	31,338
Sacramento	141	39,704	43	10,117	29	6,551	23	3,677	56	4,175	292	64,224
San Joaquin	98	21,257	4	805	17	6,693	1	151	23	2,785	143	31,692
Shasta	21	14,923	13	3,248	3	203	1	2,285	12	73	50	20,732
Solano	11	4,621	8	20,256	4	2,133	4	4,346	20	6,682	47	38,039
Stanislaus	165	19,129	17	1,366	7	1,217	5	571	22	1,181	216	23,464
Sutter	4	285	3	163	2	122	1	503	7	181	17	1,254
Tehama	109	76,119	25	20,433	10	3,569	4	589	6	486	154	101,196
Tulare	25	7,211	9	4,779	11	11,898	3	3,943	4	656	52	28,487
Toulumne	23	4,570	4	604							27	5,174
Yolo	2	135			4	1,354	2	2,439	3	826	11	4,753
Yuba	11	6,482	6	3,988	4	701	8	4,358	7	787	36	16,315
Totals	1084	382,070	240	153,644	183	90,948	97	46,098	305	135,061	1909	807,819

Table 6: Number of polygons and acres mapped by core recovery area.

Vernal Pool Region	Core Recovery Area	Polygons	Acres	
			Within Core Area	Intersecting Core Area
Livermore	Altamont Hills	12	3,526	3,849
Northeastern Sacramento Valley	Chico	8	3,153	3,358
Northeastern Sacramento Valley	Dales	28	19,162	19,223
Northeastern Sacramento Valley	Doe Mill	3	444	466
Northeastern Sacramento Valley	Honcut	6	2,472	4,482
Northeastern Sacramento Valley	Llano Seco	0	0	0
Northeastern Sacramento Valley	Oroville	15	19,576	20,291
Northeastern Sacramento Valley	Palermo	4	842	1,076
Northeastern Sacramento Valley	Phoenix Field and Park	2	18	18
Northeastern Sacramento Valley	Richvale	3	151	160
Northeastern Sacramento Valley	Stone Lake	1	61	66
Northeastern Sacramento Valley	Upper Butte Basin	0	0	0
Northeastern Sacramento Valley	Vina Plains	26	34,596	42,097
Northwestern Sacramento Valley	Black Butte	2	1,361	1,496
Northwestern Sacramento Valley	Millville Plains	5	1,752	1,753
Northwestern Sacramento Valley	Orland	10	10,172	10,435
Northwestern Sacramento Valley	Red Bluff	46	17,079	17,439
Northwestern Sacramento Valley	Redding	13	1,812	2,639
San Joaquin Valley	Caswell	2	395	399
San Joaquin Valley	Cross Creek	6	3,799	3,826
San Joaquin Valley	Grasslands Ecological Area	33	30,832	122,040
San Joaquin Valley	Pixley	4	10,745	14,048
Solano-Colusa	Collinsville	1	410	454
Solano-Colusa	Davis Comm. Annex	1	100	102
Solano-Colusa	Dolan	1	566	588
Solano-Colusa	Jepson Prairie	27	31,467	32,682
Solano-Colusa	Montezuma Hills	0	0	0
Solano-Colusa	Sacramento N.W.R.	4	1,530	1,641
Solano-Colusa	Suisun Marsh	1	251	345
Solano-Colusa	Vacaville	1	164	169
Solano-Colusa	Woodland	3	337	389
Southeastern Sacramento Valley	Beale	4	4,979	5,919
Southeastern Sacramento Valley	Cosumnes/Rancho Seco	64	30,747	31,918
Southeastern Sacramento Valley	Jenny Lind	1	117	245
Southeastern Sacramento Valley	Mather	54	14,035	14,806
Southeastern Sacramento Valley	S.E. Sacramento Valley	3	922	938
Southeastern Sacramento Valley	Western Placer County	91	22,613	26,403
Southern Sierra Foothills	Cottonwood Creek	5	1,048	1,069
Southern Sierra Foothills	Farmington	54	4,373	4,433
Southern Sierra Foothills	Fresno	16	15,786	16,706
Southern Sierra Foothills	Kaweath	0	0	0
Southern Sierra Foothills	Kings	5	660	729
Southern Sierra Foothills	Madera	264	127,815	128,771
Southern Sierra Foothills	Merced	168	20,417	20,637
Southern Sierra Foothills	San Joaquin	24	7,259	7,478
Southern Sierra Foothills	Shotgun Creek	4	927	2,891
Southern Sierra Foothills	Table Mountain	6	1,738	1,760
Southern Sierra Foothills	Tulare	5	1,585	1,697
Southern Sierra Foothills	Turlock	2	7	7
Southern Sierra Foothills	Turlock Lake	0	0	0
Southern Sierra Foothills	Waterford	2	214	214
Southern Sierra Foothills	Yokohl	0	0	0
		1,040	452,012	572,149

2005 MAPPING PRIMARY GEODATABASE (POLYGONS)		
OBJECTID	Object ID	
SHAPE	Geometry	
SHAPE_Length	Perimeter	
SHAPE_Area	Area	
FEATURE	Feature	
	0	Vernal pool matrix
	1	Individual vernal pool
COVER_VPs	Cover_VP	
	0	<2% cover of vernal pools
	1	2-5% cover of vernal pools
	2	5-10% cover of vernal pools
	3	>10% cover of vernal pools
	4	100% (individual pool / stockpond)
DENSITY_VPs	Qualitative	
	0	Low
	1	Medium
	2	High
DIVERSITY_VPs	Qualitative	
	0	Low
	1	Medium
	2	High
NUMBER_LargePools	Large_pools	
	0	None in polygon
	1	<1 per 640 acres
	2	1-3 per 640 acres
	3	4+ per 640 acres
DISTURBANCE_Area	Dist_Area	
	0	<1% of polygon
	1	1-5% polygon
	2	5-25% of polygon
	3	25-50% of polygon
	4	50-99% of polygon
	5	100% of polygon
DISTURBANCE_Type	Dist_Type	
	0	None / unknown
	1	Plowing, disking or grading
	2	OHV use
	3	Ranch roads
	4	Paved roads
	5	Ag runoff (altered hydrology)
	6	Agricultural residential
	7	Managed wetlands (duck ponds)
	8	Mitigation banks (created vernal pools)

DISTURBANCE_Intensity	Qualitative 0 – Low 1 – Medium 2 – High
HABITAT_Notes	Text
MAPPING_Notes	Text
COUNTY	Text

2010 REMAPPING ADDITIONS TO PRIMARY DATABASE (POLYGONS)	
CONVERTED_2010	2010_Conv 0 – No 1 – Yes 2 – NewBank 3 – ConvBank
CONVERTED_To	Conv_To 0 – Not Converted 1 – Urban, commercial & industrial 2 – Orchards, vineyards, Eucalyptus 3 – Alfalfa and irrigated pasture 4 – Bare, plowed agricultural lands 5 – Other ag (rice, row crops, dairy, nurseries) 6 – Agricultural residential 7 – Mitigation banks / managed wetlands
CONVERTED_Notes	Text

GROUND TRUTHING ADDITIONS TO PRIMARY DATABASE (POLYGONS)	
VISITED	Visited 0 – No 1 – Yes
OBSERVED	Observed 0 – Not visited 1 – Habitat extant 2 – Converted to hay ground 3 – Converted to orchard 4 – Converted to vineyard 5 – No vernal pools, but clay flats (REMOVED) 6 – Bare plowed ground 7 – Lots of topo, no vernal pools (REMOVED) 8 – Converted to alfalfa 9 – Alkali sink, no pools observed from road 10 – Converted to intensive ag 11 – No vernal pool habitat (REMOVED) 12 – Converted to urban/commercial
GT_Notes	Text

<table>
<tr><th colspan="2">SECONDARY GEODATABASE (POINTS)</th></tr>
<tr><td>OBJECTID</td><td>Object ID</td></tr>
<tr><td>SHAPE</td><td>Geometry</td></tr>
<tr><td>FEATURE_Type</td><td><table><tr><th colspan="2">Dot_Type</th></tr><tr><td>0</td><td>Vernal pool</td></tr><tr><td>1</td><td>Stockpond</td></tr></table></td></tr>
<tr><td>FEATURE_Size</td><td><table><tr><th colspan="2">Dot_Size</th></tr><tr><td>0</td><td><1 acre</td></tr><tr><td>1</td><td>1-3 acres</td></tr><tr><td>2</td><td>3-5 acres</td></tr><tr><td>3</td><td>5-10 acres</td></tr><tr><td>4</td><td>>10 acres</td></tr></table></td></tr>
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