Feral Pig Distribution Survey Report

for the

The Nature Conservancy

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EXECUTIVE SUMMARY

From an introduction of up to 20 pigs released near the El Capitan Reservoir during 2004–2006 (CBI 2009), the feral pig has spread over much of central San Diego County. The population is concentrated along the San Diego River and Conejos Creek above El Capitan Reservoir, but dispersers have moved to several areas at least 14 miles from the point of introduction, and as much as 23 miles to Lake Henshaw. The population cannot be estimated precisely on the basis of current data, but by the time of this study, December 2009–February 2010, had increased over the numbers originally released, by a factor of perhaps 4–7. Habitat degradation from pigs (rooting through soil, damaging or eliminating plants) is considerable although still less than in areas of California where feral pigs are well established. Reductions of populations of rare plants and animals, impaired viability of oak woodland, riparian woodland, and marshes, and damage to agriculture are to be expected if the increase of feral pigs in San Diego County continues.

The majority of information contained in this report is of February 20, 2010. Subsequently, additional sightings have been reported, including one from Lake Henshaw of one adult and two juveniles on March 23, 2010.

1.0 INTRODUCTION

1.1 Purpose of the Report

The purpose of this report is to document the distribution and status of the feral pig (*Sus scrofa*) in San Diego County on the basis of baseline data recorded by the San Diego Natural History Museum (SDNHM) for the Nature Conservancy and all relevant parties.

1.2 Project Location

Surveys were focused on the suspected range of feral pigs along the upper San Diego River from the El Capitan Reservoir upstream to the Inaja Memorial, including all major tributaries. The suspected range was estimated from previous habitat-suitability models that identified habitat of medium to high suitability contiguous with known occurrences

(CBI 2009). To delineate the current distribution, SDNHM also surveyed adjacent areas with suitable habitat or new reports of sightings.

Introductions of the pig are responsible for ecological disruption worldwide, and California, including the Channel Islands, is not immune to this problem. Where the information is relevant, this report cites to studies outside of California. But the niche that feral pigs currently occupy in San Diego County may be unique in the variability of the habitat.

1.3 Project Description

The goal of this project was to identify the current status and distribution of the feral pig in San Diego County. Tasks included the creation of a geodatabase, strategizing access, reconnaissance surveys, baseline surveys, follow-up on all recent and additional reports of sightings, coordination with CDFG and other agencies, and summarizing data for this report. Baseline surveys, from December 2009 to February 2010, included density estimates in core areas on the basis of records from motion-detecting cameras, surveys along routes within core areas to determine the pigs' abundance, activity, and potential effects on sensitive species and habitats, and surveys along routes to detect presence around the periphery of core areas.

2.0 STUDY AREA

2.1 Physical and Climatic Conditions

2.1.1 Geography, Hydrology & Topography

The study area is centered on the upper San Diego River and its tributaries, one of the primary watersheds of San Diego County. It includes the El Capitan Reservoir, the San Diego River above the reservoir, and its major tributaries, including Coleman Creek, Orinoco Creek, Sentenac Creek, Temescal Creek, Ritchie Creek, Cedar Creek, Boulder Creek, Cuyamaca Reservoir, Isham Creek, Sand Creek, Conejos Creek, King Creek, and Alpine Creek.

The topography is very rugged with steep-sided canyons, mountainous terrain, and several waterfalls. The elevation ranges from 500 feet just below El Capitan Dam at El Monte County Park up to 6512 feet at the summit of Cuyamaca Peak.

Lake Cuyamaca lies east of the San Diego River, to which it drains via Boulder Creek. The Helix Irrigation District periodically releases water from it to supply El Capitan Reservoir. Pools persisting throughout the length of Boulder Creek are thereby periodically flushed and refilled.

Other drainages are fed by rainfall and groundwater. Most rain falls from November to April.

Several communities, including Flynn Springs, Lakeside, Ramona, Julian, and Alpine, lie within or adjacent to the study area.

2.1.2 Climate

San Diego County and southern California have a Mediterranean climate characterized by mild wet winters and arid summers. The growing season is generally considered to be 365 days per year in this area. Climate data from the Western Regional Climate Center (WRCC 2010) recorded at El Capitan Dam (lower end of the study area) and Julian Wynola (upper end of the study area), are presented in Tables 1 and 2. At lower elevations of the study area, annual average minimum and maximum temperatures are 49.8 °F and 80.0 °F, respectively, and average annual precipitation is 16 inches (Table 1). At upper elevations, annual average minimum and maximum temperatures are 41.7 °F and 70.8 °F, respectively, and average annual precipitation is 26 inches (Table 2).

Table 1. Climatological data for El Capitan Dam, California (042709, elevation 600 ft.), from the Western Regional Climate Center (period of record 7/1/1948 to 12/31/2005, accessed February 23, 2010).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	68.6	70.4	70.6	75.5	78.8	86.3	93.0	93.6	91.4	84.4	76.6	70.2	80.0
Average Min. Temperature (F)	41.2	42.9	44.5	47.5	50.9	54.3	58.1	59.2	58.1	52.9	46.4	41.8	49.8
Average Total Precipitation (in.)	3.09	2.88	3.23	1.29	0.51	0.12	0.06	0.15	0.28	0.63	1.56	2.01	15.82
Average Total SnowFall (in.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. Climatological data for Julian Wynola, California (044418, elevation 3650 ft.), from the Western Regional Climate Center (period of record 9/1/1949 to 8/17/1988, accessed February 23, 2010).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	55.6	58.2	59.3	64.8	71.3	81.4	90.1	89.6	84.6	74.2	63.4	57.4	70.8
Average Min. Temperature (F)	34.5	34.7	34.8	37.0	40.6	45.8	53.0	53.7	49.3	43.3	38.1	35.6	41.7
Average Total Precipitation (in.)	4.68	4.09	4.51	2.41	0.97	0.14	0.39	0.74	0.83	0.98	2.86	3.27	25.89
Average Total SnowFall (in.)	1.90	1.40	2.50	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.00	8.20

2.1.3 Fire Cycles

In this region, wildfire is a natural disturbance, but catastrophic fires may be increasing in severity and frequency (Keeley et al. 2009). Two recent fires, the Cedar Fire (October 2003) and the Witch Creek Fire (October 2007), burned much of the study area. These were the largest and second-largest accurately measured fires in California history, respectively.

3.0 METHODS

3.1 Background Literature Review

Prior to surveys in the field, we reviewed the literature with a primary focus on the effects of introductions of the pig on native habitats and species and the pig's dispersal behavior. The possibility of establishment is a great concern because pigs have had deleterious effects on many environments, both native and agricultural, in which they have been introduced, and wild pigs are very difficult to control or eradicate (Mayer and Brisbin 1991). Many potential and known effects have been identified in California, including San Diego County (CBI 2009).

Pigs have a strong association with water sources, including streams, ponds, marshes, irrigated agriculture, and any damp or muddy area where they are able to wallow, which aids their thermoregulation. However, pigs are not restricted to riparian habitat and will make use of a wide variety of available habitat. In the Sierra foothills, pigs generally prefer areas with denser vegetation for cover, and proximity to water sources is more critical during summer months when they are also more nocturnal (Barrett 1982). On Santa Catalina Island, Baber and Coblentz (1986) found that pigs used all available habitats during both dry and wet seasons, and although pigs preferred the cooler, moist canyon bottoms during the dry season, they actually avoided riparian habitat during the wet season.

In California, feral pigs are often associated with oak woodland, as acorns are an important food (Barrett 1982, Waithman et al. 1999), and effects on many other native plants have been identified (e.g., Kotanen 1995, Tierney and Cushman 2006). Rooting by pigs not only disturbs the soil physically and destroys plants, but pigs' consuming mast significantly reduces the supply of acorns, inhibiting regeneration of oak woodland reducing the food available to the many other species that rely on acorns or oaks (Sweitzer and Van Vuren 2002).

Feral pigs are omnivorous, the majority of their diet consisting of grasses, forbs, and mast such as shoots, roots, tubers, fruit, and seeds. They also eat many invertebrates and small vertebrates (Seward at al. 2004). Feral pigs prey actively on many vertebrates including herpetofauna, small mammals, birds, and young of larger mammals including deer and livestock (Schley and Roper 2003). In the Diablo Range of California, Wilcox and Van Vuren (2009) found the stomachs of 40.4% of pigs examined to contain remains of vertebrates, including 20 native species that were likely actively depredated. In semi-arid parts of Australia, lambs are a particularly frequent prey of feral pigs and may even be a preferred food (Choquenot et al. 1997).

Feral pigs tend to form semi-territorial, dynamic, mobile groups ("sounders" or "mobs") containing an average of four individuals, usually composed of adult females and juveniles, while adult males tend to be solitary and disperse widely (Gabor et al. 1999, Spencer et al. 2005). In California, feral pigs breed year round and can produce two litters per year with average litter size of 5.6 young (Barrett 1978). In a genetic study in Australia, Spencer et al. (2005) found males that sired young were, on average, 42.0 ± 6.1 km from their progeny (26.1 ± 3.8 miles). In Texas, Gabor et al. (1999) found that the genetic structure of groups of feral pigs implied that the animals likely disperse long distances through the available habitat. In California, Barrett (1978) estimated the average size of a male's range at 54 km^2 (21 mi^2), that of a female at 13 km^2 (5 mi^2). A review of feral pig studies found a wide range of reported densities ranging up to 60 pigs/km^2 (247 acres), but in arid areas densities tended to be relatively low (Gabor et al. 1999).

Once established, feral pigs are difficult to eradicate, and efforts at population control have been largely ineffective because of long distances of dispersal and quick recovery of populations following culling (e.g., Cowled et al. 2006, Hanson et al. 2009). Considering the environmental impacts and costs, intense efforts at eradication are favored over sustained programs of control (Cruz et al. 2005).

3.2 Surveys

3.2.1 Motion-Detection Cameras

In this study, motion-detection cameras trained on baited lures or trails were deployed at eight locations (Table 3, Figure 1). Because of public use of the area, most cameras were set away from trails so they were not easily visible. However, two cameras were placed adjacent to well-used trails to determine if pigs used the trails as movement corridors. When photographs were triggered, the date, time, and temperature were automatically recorded.

Table 3. Deployment of eight motion-detection cameras, San Diego River watershed.

Camera ID	Lat	Long	Set date	Pull date	Location
CC	33.001151	-116.709233	12/30/2009	2/20/2010	Cedar Creek, below Cedar Creek Rd.
CCF	32.989531	-116.730385	12/3/2009	1/14/2010	Cedar Creek Falls
CYM 1	32.976592	-116.573721	12/31/2009	1/10/2010	Cuyamaca Lake, south end
CYM 2	32.969428	-116.559538	1/15/2010	2/11/2010	Cuyamaca Lake area, by Little Stonewall Peak
SDR 1	32.989465	-116.740360	12/3/2009	active	San Diego River, at Cedar Creek
SDR 2	33.001091	-116.730231	12/3/2009	active	San Diego River, below Mildred Falls
USDR 1	33.088127	-116.676189	12/16/2009	1/28/2010	Drainage from Santa Ysabel Valley into San Diego River
USDR 2	33.071192	-116.680176	12/16/2009	1/28/2010	Upper San Diego River, 2 miles south of Inaja Memorial

3.2.2 Route Surveys

All areas surveyed were mapped, and locations of all pig encounters and pig sign were recorded by GPS. Twenty-four survey routes, ranging in length from 0.6 to 18 miles, were established within and adjacent to the target area (Figure 2, Table 4). Survey routes were typically walked by a survey team consisting of one team leader and no more than two volunteers. However, two surveys were conducted by boat (El Capitan Reservoir and San Vicente Reservoir) and one by car (Lower Cuyamaca Lake to Stonewall Creek). Survey route locations were determined by accessibility so that they may be repeated if future monitoring is desired, and were placed both within and adjacent to the suspected occupied range. Data recorded during route surveys included GPS tracklog, type, age, and location of all pig sign, distance to water, description of water source, and habitat descriptions.

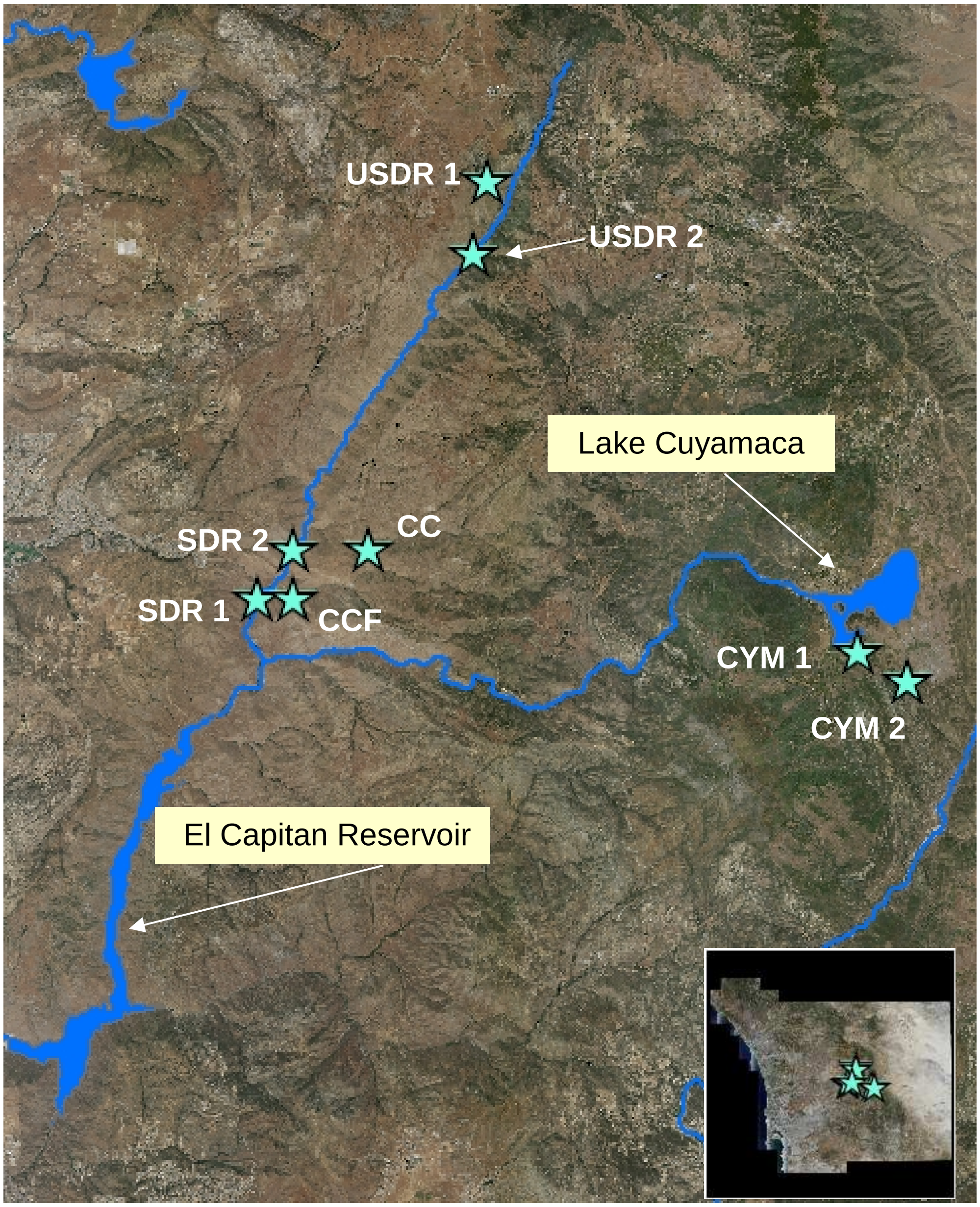

Figure 1. Locations of eight motion-detection camera stations in the San Diego River watershed.

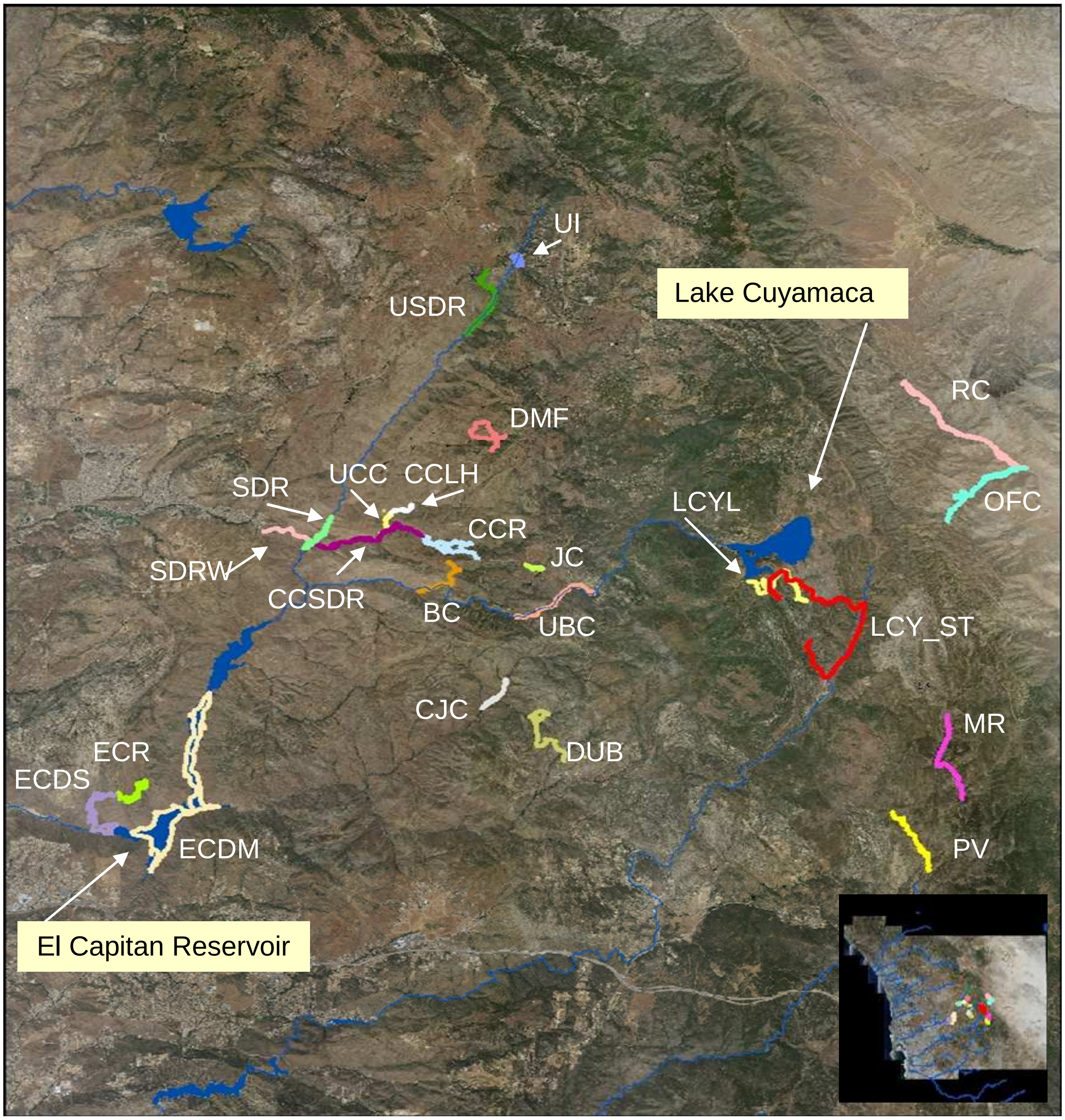

Figure 2. Locations of 24 survey routes, San Diego River watershed and vicinity. (Not shown is San Vicente Reservoir to the west.)

Table 4. Locations of 24 survey routes, San Diego River watershed and vicinity.

Route ID	Starting point Lat	Long	Elevation range (ft.)	Location
BC	33.29842	-116.68790	1790-2730	Boulder Creek, at Sheep Camp Creek
CCLH	33.00241	-116.70874	1785-1920	Cedar Creek, above Cedar Creek Rd.
CCR	23.98496	-116.67750	2185-2945	Cedar Creek Road and Kelly Creek
CCSDR	32.99357	-116.69736	900-2200	Cedar Creek to San Diego River
CJC	32.93410	-116.67040	2080-2360	Upper Conejos Creek
DMF	33.02540	-116.67250	2880-3560	Deadman's Flat
DUB	32.90921	-116.64638	2480-3200	Dubois Road off Boulder Creek Road
ECDM	32.86854	-116.79635	770	El Capitan Reservoir (by boat)
ECDS	32.88440	-116.81600	600-1987	El Capitan Reservoir area below dam
ECR	32.89680	-116.81010	1987-2000	El Capitan Reservoir, West Side Road
LCY_ST	33.01771	-116.55484	4600-4770	Lower Cuyamaca Lake to Stonewall Creek (by car)
LCYL	32.95432	-116.55815	4140-4860	Lower Cuyamaca Lake, horse camps and vicinity
OFC	33.01850	-116.47980	2525-3255	Oriflamme Canyon, lower
PV	32.89420	-116.50478	4825-4980	Pine Valley Creek and Deer Park Road
MR	32.86717	-116.51608	3840-4050	Miners Road, Pine Valley Creek
RC	33.01850	-116.47980	2525-3645	Rodriguez Canyon
SDR	32.99146	-116.73789	880-1070	San Diego River, north of Cedar Creek
SVL	32.91450	-116.92950	650	San Vicente Reservoir (by boat)
UBC	32.96331	-116.66410	2645-3060	Boulder Creek, above Boulder Creek Road
JC	32.98345	-116.66027	3140-3280	Johnson Creek
UCC	33.00241	-116.70874	1595-1785	Cedar Creek to Kelly Creek
UI	33.09860	-116.66532	3180-3340	Inaja Memorial area
USDR	33.09361	-116.67460	2200-3120	Upper San Diego River, south of Inaja Memorial
SDRW	32.99562	-116.75591	1000-1800	Westside Road to San Diego River at Cedar Creek

3.3 Assessments of Potential Impacts

Lists of plants and vertebrates occurring within the study area were compiled from SDNHM records, including the *San Diego County Bird Atlas* (Unitt 2004), and historic botanical, mammal, and herpetological collections housed at SDNHM. All evidence of damage to habitats and potential direct and indirect effects on other species were recorded and photographed.

3.4 Estimates of Distribution and Abundance

The current extent of distribution was determined from route surveys and additional targeted surveys around the periphery of the area known to be occupied. Additional peripheral locations were checked by car and by foot, and additional areas were targeted based on reported sightings. All pig sign and sightings from route surveys and additional targeted surveys were mapped, and occupied areas were inferred from likely corridors of dispersal between the core of the occupied area and peripheral locations. Areas likely to be occupied in the near future were identified from the current distribution and likely dispersal corridors at the periphery.

Within the occupied area, we established standardized survey routes from which relative abundance can be estimated and that, if desired, can be repeated over time for changes in abundance to be tracked (Wilson et al. 1996). Relative abundance or density can be estimated from the number of pigs sighted and the amount of pig sign per walked distance. Pig sign is counted as a unique record whenever it is a different type of sign in a given area (approximately 50–100 m^2 or 60–120 yd^2) or when it is the same type of sign in the area but likely caused by an additional pig. Examples: (1) tracks from two pigs in the same area count as two records, (2) one set of tracks and one scat in the same area count as two records, (3) one set of tracks in one area plus another set of tracks 100 m (110 yd) away counts as two records. It is often not possible to tell how many animals are associated with pig sign, but standardization gives an index of relative abundance. The area effectively sampled can be adjusted on the basis of the terrain of the survey route, so that the index of relative abundance = (number of records of sign detected along route/effective sampling area of route)/maximum value. Expressed as an index of relative abundance by survey route, a score of 0.0 indicates no pig sign, while the route with the greatest amount of pig sign per area sampled receives a score of 1.0. These scores can then be aggregated to categorize the relative abundance of pigs along the route as absent (0.0), low (>0.0–0.33), medium (0.33–0.66), and high (0.66–1.0).

To estimate actual abundance or overall population size, index surveys need to be coupled with more intensive surveys or with mark–recapture surveys that allow for a true estimate of abundance. The percentage difference between the index estimate and the true estimate for an area sampled by both methods can then be used as a correction factor for all index estimates. Overall population size can then be estimated by summing all corrected estimates for surveyed areas and multiplying by the difference between the sampled area and the entire distribution.

If pigs are found to have any unique identifying marks or characteristics (size, color pattern, scars, etc.), it may be possible to estimate relative density, herd size, and movements by camera detections. Using a modified mark–recapture analysis, Sweitzer et al. (2000) were successful in estimating sizes and density of populations of feral pigs photographed at baited camera stations. However, this technique relies on at least some marked or identifiable individuals to estimate the rate of resighting.

If identification of individual pigs is not possible or if detections are very low, then an estimate of the possible overall population size for the occupied area can be made on the basis of the amount of pig sign detected in comparison with that in other areas in California where the densities of the population of feral pigs is known.

4.0 RESULTS AND DISCUSSION

4.1 Occupied Vegetation Communities

Feral pig sign was found in each major habitat type visited: riparian, oak woodland, chaparral, coastal sage scrub, grassland, agriculture, and open canopy coniferous forest. The two habitat types strongly preferred were riparian and oak woodland, on the basis of frequent pig sign with heavy rooting and damage (Figures 3 and 4). Pig sign was most commonly found near water sources, along canyons, oak woodlands, and along roads, but our survey efforts also targeted these areas. Rocky areas and steep slopes appeared to be mostly avoided, except for possible dispersal.

4.2 Surveys

Feral pigs as well as some non-target species were detected by the two types of survey methods (camera station surveys and route surveys). The results of each survey type are reported below.

Figure 3. Heavily rooted soil in oak woodland habitat.

Figure 4. Cattails trampled by feral pigs in riparian habitat.

4.2.1 Motion-Detection Cameras

Motion-detection cameras were deployed at eight locations during different time periods beginning on December 3, 2009 to February 20, 2010, two in the San Diego River are still active (Figure 1, Table 3). Seven pig photographs were taken by motion-detection, all but one during night hours, and at a temperature range of 40–59 °F (Table 4). Photographed pigs were not individually distinguishable (Figures 5 and 6), so it was possible that individual pigs were photographed multiple times.

Table 4. Pigs photographed by motion-detection cameras between 12/3/2009–2/20/2010, San Diego River watershed. (These two cameras remain active.)

Camera ID	Date	Location	Time	Temperature
SDR 1	12/11/2009	San Diego River, at Cedar Creek	3:41 PM	57° F
SDR 1	12/19/2009	San Diego River, at Cedar Creek	6:48 PM	59° F
SDR 1	12/20/2009	San Diego River, at Cedar Creek	10:10 PM	45° F
SDR 2	12/16/2009	San Diego River, below Mildred Falls	3:22 AM	41° F
SDR 2	12/16/2009	San Diego River, below Mildred Falls	4:16 AM	40° F
SDR 2	12/18/2009	San Diego River, below Mildred Falls	12:11 AM	45° F
SDR 2	12/23/2009	San Diego River, below Mildred Falls	6:27 PM	45° F

The morphology of the feral pigs photographed is consistent with some hybrid combination of Eurasian wild boar × feral hog with domestic ancestry, generally referred to as "wild boar" (Mayer and Brisbin 1991).

Figure 5. Feral pig detected by motion-detection camera, San Diego River, near confluence of Cedar Creek, 19 December 2009.

Figure 6. Feral pig detected by motion-triggered camera, San Diego River drainage, approximately ½ mile south of Mildred Falls, 23 December 2009 (1 mile from location represented by Figure 5).

Other species photographed incidentally included bobcat, coyote, mule deer, California ground squirrel, striped skunk, desert cottontail, domestic dog, wild turkey, and other unidentifiable mammals and birds (Figure 7).

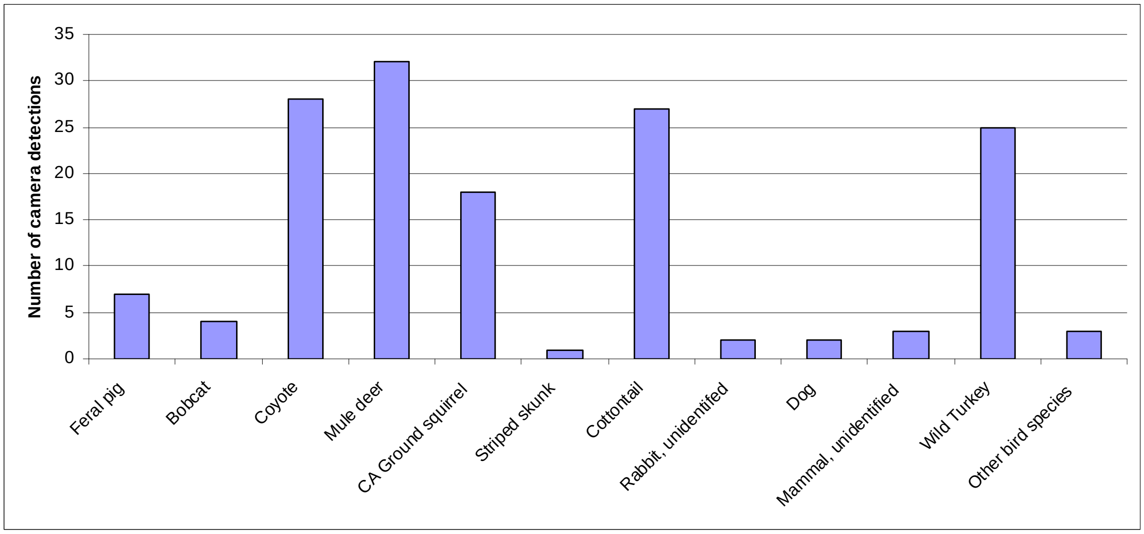

Figure 7. Number of camera detections by species, San Diego River watershed, 12/3/2009 to 2/20/2010. (Two cameras remain active.)

4.2.2 Route Surveys

We conducted 24 route surveys from 12/3/09–2/17/10 (Figure 2, Table 4). Each route was surveyed in its entirety a single time, but many areas were incidentally visited on more than one occasion. Routes varied from 0.6 to 18 miles in length. All routes were walked, except LCY_ST survey was driven slowly by car, and two surveys by boat around the perimeters of El Capitan and San Vicente reservoirs. No pigs were directly observed during route surveys, but sign was often detected (Table 5).

Table 5. Feral pig sign detected, central San Diego County.

Pig sign	# observations on survey routes	# incidental observations	Total # of observations
Bedding area	1	0	1
Photo/visual	0	10	10
Road kill	0	1	1
Rooting	24	5	29
Rub	1	1	2
Scat	46	0	46
Tracks	96	10	106
Trail	4	0	4
TOTAL	172	27	199

Pig sign included tracks (Figure 7), trails (Figure 8), scat (Figure 9), rooting or trampling (Figures 3, 4, 10, 15, 16, and 17), rubs, and a bedding area. Pig sign was detected on 16 of the 24 survey routes (Table 6).

A database was created for all pig sign, including sign detected on survey routes, incidental off-route, and by confirmed reports and photographs. Unique sign, including from off survey routes, was recorded at a total of 199 points (Table 5). This included a report of 1 road kill. The most frequently encountered sign were pig tracks (n = 106), followed by scat and rooting. Because of recent heavy rains, most pig sign was fresh.

Figure 7. Two pig tracks superimposed in wet sand.

Figure 8. Pig trail leading to oak/riparian habitat.

Figure 9. Pig scat.

Figure 10. Pig rooting along a road bank, causing an erosion problem.

Table 6. Relative amount of pig sign detected on survey routes. "RA" is relative abundance for walked survey routes (categorized as 0, low, medium, and high). For car and boat surveys, pigs are reported as present or absent.

Route ID	Date	Location	# pig sign	Length (mi.)	RA index	RA category
BC	2/12/2010	Boulder Creek at Sheep Camp Creek	7	1.7	0.18	Low
CCLH	12/30/2009	Cedar Creek, above Cedar Creek Rd.	0	0.7	0.00	0
CCR	1/12/2010	Cedar Creek Road and Kelly Creek	8	4.5	0.08	Low
CCSDR	1/14/2010	Cedar Creek to San Diego River	9	2.7	0.14	Low
CJC	1/29/2010	Upper Conejos Creek	35	1.5	1.00	High
DMF	12/19/2010	Deadman's Flat	0	2.4	0.00	0
DUB	1/12/2010	Dubois Road off Boulder Creek Road	11	3.3	0.14	Low
ECDM	2/8/2010	El Capitan Reservoir (by boat)	12	18.0	n/a	Present
ECDS	12/17/2009	El Capitan Reservoir area below dam	4	4.6	0.04	Low
ECR	1/14/2010	El Capitan Reservoir, West Side Road	11	2.7	0.17	Low
LCY_ST	12/19/2010	Lower Cuyamaca Lake to Stonewall Creek (by car)	0	7.0	n/a	Absent
LCYL	12/31/2009	Lower Cuyamaca Lake, horse camps and vicinity	14	3.0	0.20	Low
OFC	2/4/2010	Oriflamme Canyon, lower	2	4.9	0.02	Low
PV	2/4/2010	Pine Valley Creek and Deer Park Road	1	2.8	0.02	Low
MR	2/4/2010	Miners Road, Pine Valley Creek	0	2.2	0.00	0
RC	2/4/2010	Rodriguez Canyon	0	3.7	0.00	0
SDR	12/3/2010	San Diego River, north of Cedar Creek	28	1.3	0.92	High
SVL	2/17/2010	San Vicente Reservoir (by boat)	0	13.1	n/a	Absent
UBC	2/16/2010	Boulder Creek, above Boulder Creek Road	6	2.1	0.12	Low
JC	2/16/2010	Johnson Creek	0	0.8	0.00	0
UCC	12/30/2009	Cedar Creek to Kelly Creek	2	0.6	0.14	Low
UI	1/12/2010	Inaja Memorial area	2	0.8	0.11	Low
USDR	12/16/2009	Upper San Diego River, south of Inaja Memorial	31	2.0	0.66	High
SDRW	12/3/2009	Westside Road to San Diego River at Cedar Creek	0	1.2	0.00	0

4.2.3 Distribution and Abundance

The distribution of feral pigs detected by this study extended south to the southern tip of El Capitan Reservoir at the mouth of Chocolate Canyon, north to lower Coleman Creek at Wynola, west to just below El Capitan Dam, and east to Oriflamme Canyon (Table 7, Figure 11). Areas confirmed occupied included El Capitan Reservoir, San Diego River from El Capitan Reservoir upstream to Wynola, Anderson Road just north of Alpine, all of Conejos Creek, Echo Valley, Kelly Creek, all of Boulder Creek (from the San Diego River up to Cuyamaca Reservoir), Cedar Creek from the San Diego River up to the Pine Hills Fire Station, Deadman's Flat at Ritchie Creek, Cuyamaca Reservoir, and Oriflamme Canyon (appendix). The most rugged terrain between occupied areas excluded, this is an occupied area of at least 75 square miles. The lowest elevation was at 670 feet just below the dam of the El Capitan Reservoir, the highest at 4720 feet at the north and south ends of Lake Cuyamaca. A single set of pig tracks were also found at the desert edge in Oriflamme Canyon at 3055 feet.

Table 7. Maximum extent of feral pig distribution (north, south, east, and west), central San Diego County, as of February 20, 2010.

Maximum extent	Location	Lat	Long	Elev (ft)
North	Coleman Creek at Wynola	33.09707	-116.66123	3585
South	El Capitan Reservoir at Chocolate Canyon	32.86838	-116.79657	754
East	Oriflamme Canyon	33.00243	-116.50700	3055
West	Below the dam of the El Capitan Reservoir	32.88690	-116.81816	669

Although feral pigs were found as high as 4720 feet in elevation at Lake Cuyamaca, they were not found in this area on repeat visits after snowfall. Feral pigs occur as high as 3030 meters (9900 ft) on Hawaiian volcanoes (Stone 1985) but are thought to be limited by frost or snow cover (Hanson and Karstad 1959, Coblentz and Bouska 2004). In Europe, however, wild boars commonly use high-elevation sites during the spring and summer and migrate to lower elevations during the winter (Singer 1981).

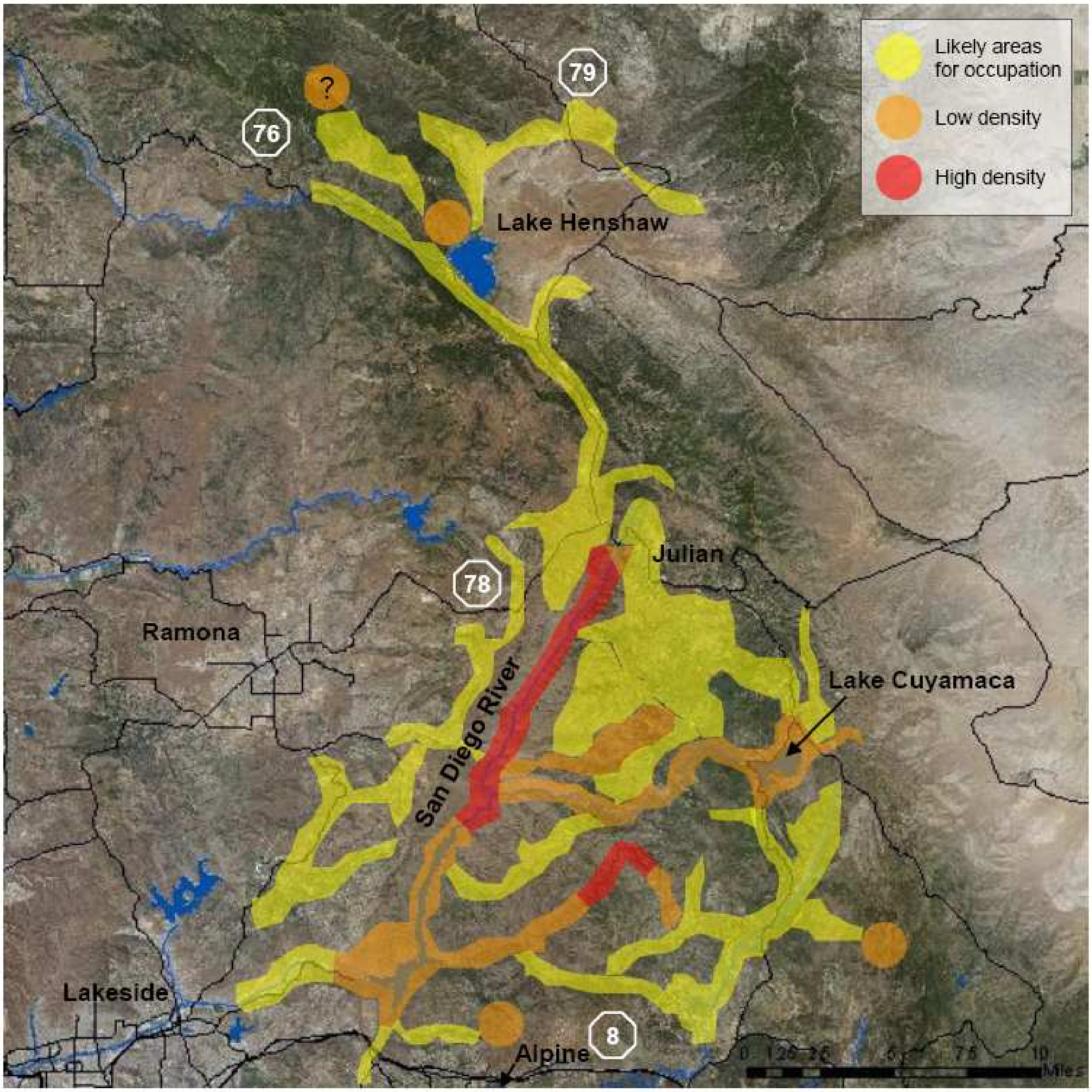

Figure 11. Extent of feral pig distribution in central San Diego County, based on pig sign as of February 20, 2010, plus two records near Lake Henshaw in March and May 2010. Orange and red shading represent confirmed occupied areas, at low and high relative density, respectively. Density is assumed to be low in areas with incidental reports not covered by survey routes. Yellow shading represents areas immediately adjacent to the confirmed occupied area with the most suitable habitat and dispersal routes, which are likely to be occupied soon if not already.

On the basis of the relative-abundance index estimated for each survey route (Table 6), concentrations of pig sign were highest at the lower section of the San Diego River just north of Cedar Creek (Figure 12), the upper section of the San Diego River below the Inaja Memorial (Figure 13), and at upper Conejos Creek (Figure 14).

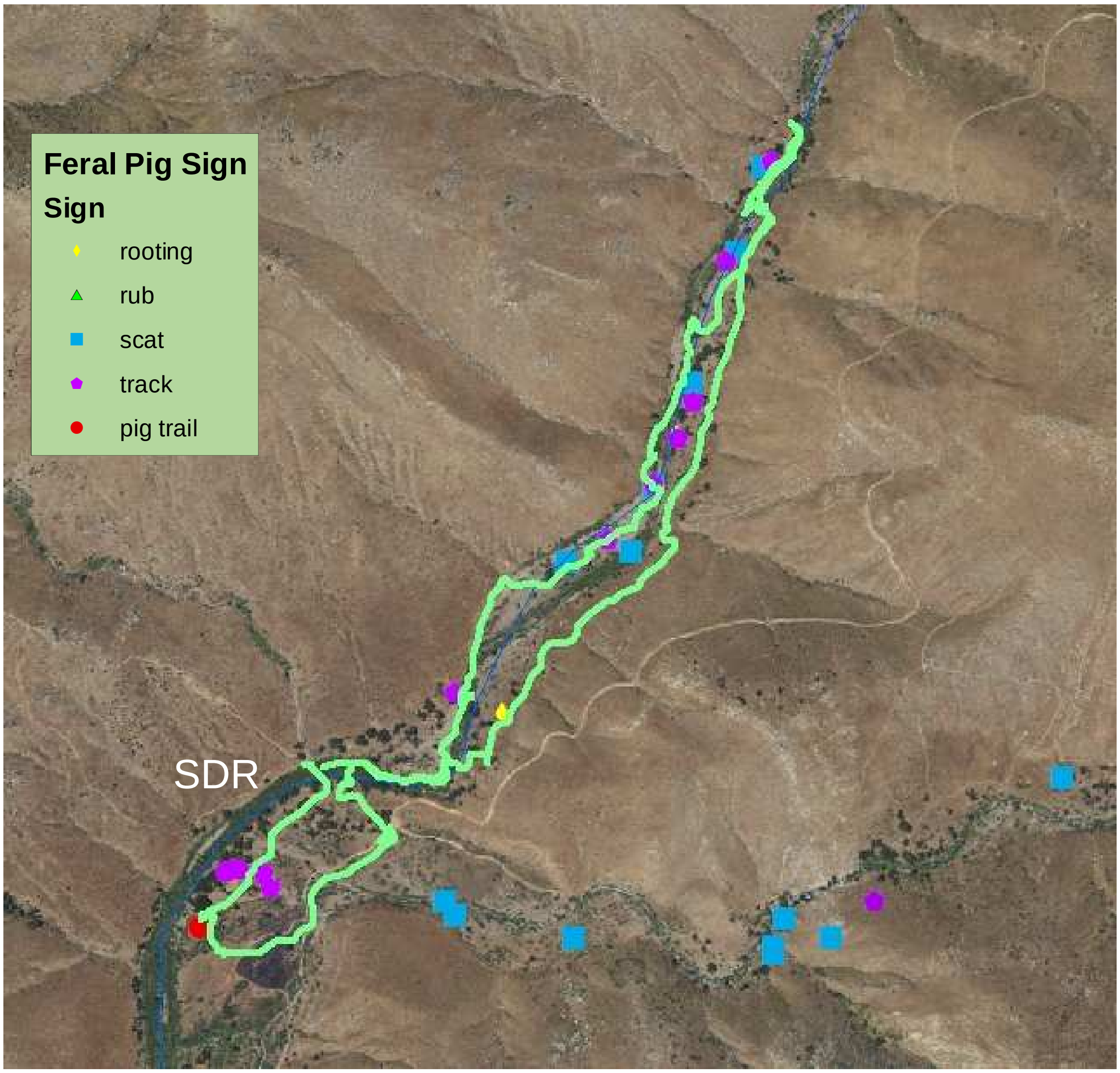

Figure 12. Feral pig sign detected along survey route at the San Diego River at Cedar Creek.

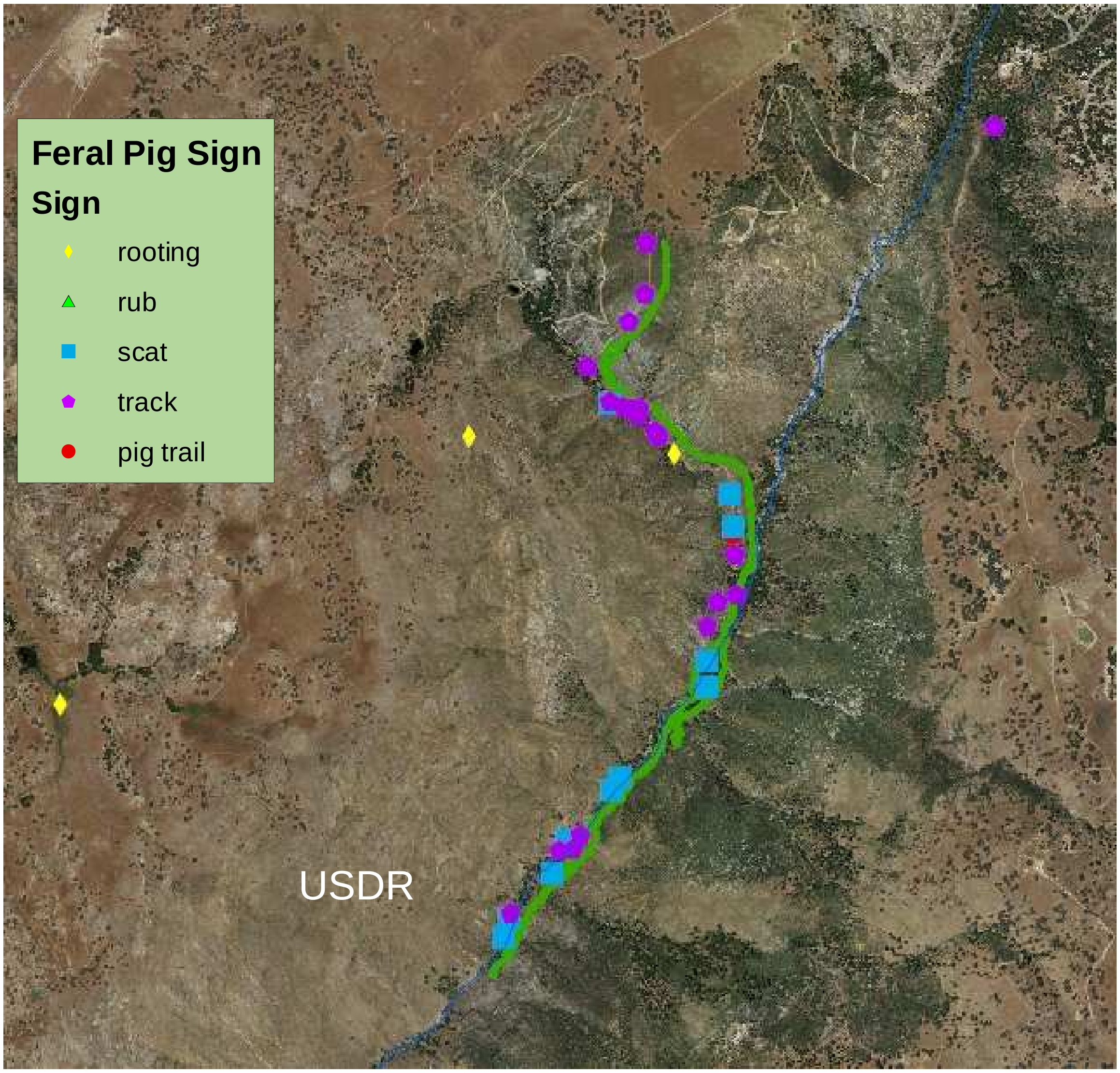

Figure 13. Feral pig sign detected along survey route at the upper San Diego River just below the Inaja Memorial.

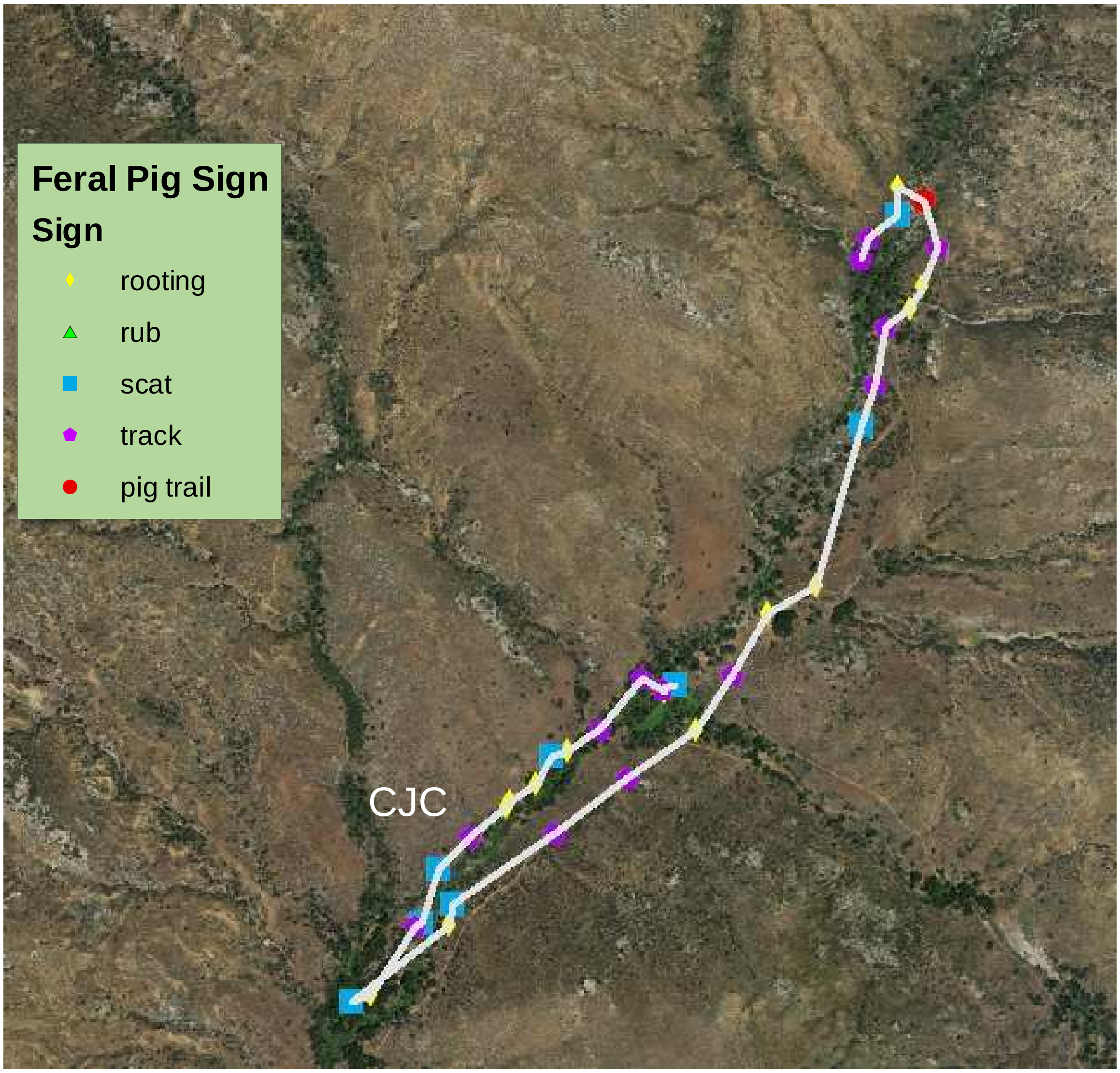

Figure 14. Feral pig sign detected along survey route at upper Conejos Creek.

Lower density areas were found near Inaja Memorial Park, along Cedar Creek Road, sections of Cedar Creek, sections of Boulder Creek, El Capitan Reservoir, Westside Road, Dubois Road, areas around Lake Cuyamaca, Oriflamme Canyon, and Deer Park Road (Table 6). No pig sign was found at some sections of Boulder Creek, Cedar Creek, Johnson Creek, or Deadman's Flat, but surveys were after heavy rains, and pigs had been reported in these areas previously. Pigs likely move along both Boulder and Cedar creeks because sign was found intermittently in sections, including their lower ends at their confluences with the San Diego River, and near the upper end of Cedar Creek near the Pine Hills Fire Station, and near the upper end of Boulder Creek at Lake Cuyamaca.

The absence of pig sign at San Vicente Reservoir, Rodriguez Canyon, and Miner's Road, which are all outside of the known occupied range, likely reflects true absence as of February 20, 2010.

Because individual pigs were not identifiable in the photographs and the number of photographs taken (7) was low, the population density cannot be estimated with accuracy. On the basis of sign as an index of relative abundance, however, the density was highest along the San Diego River and Conejos Creek (Figure 11), directly connected to the site of reported release. Upper San Diego River scored high, at least 10 miles from the original release site and dispersers had to navigate past a 100 ft. waterfall. Densities at other, more peripheral locations were low. Interestingly, there were no areas of intermediate density. This pattern suggests that there is a core area of relatively high density surrounded by areas of low abundance with wide dispersal.

Although pig densities varied from route to route, and density levels are naturally limited to some extent by territorial behavior (in California, typically no more than 3 adults per sounder; Sweitzer et al. 2000), in San Diego County all density levels appeared to be substantially lower than in other parts of California where pigs have been established longer. For example, in Henry Coe State Park in Santa Clara and Stanislaus counties in 2000, Sweitzer and Van Vuren (2002) found that 92% of 2-m^2 (2.4 yd^2) quadrats had been damaged by rooting pigs. Elsewhere, they found that pig density was correlated with extent of damage by rooting and that in habitats where the pigs' density was high, they had damaged over 36–65% of the ground area. In San Diego County, even within the areas where pig sign was densest, rooting damage was limited to less than 2% of the habitat in which pigs could dig.

On the basis of comparisons to other sites in California with known densities, the current population size in San Diego County is probably within the range of 65 to 140 pigs, at an average density between 0.35 and 0.7 pigs/km^2 (247 acres), across an overall occupied area of 200 km^2 (75 mi^2). This estimate is conservative, as it assumes that the average density is between half of and equal to the lowest density found by Sweitzer et al. (2000) in their study of seven California sites. The lowest density they estimated was 0.7 pigs/km^2 (247 acres) at Bradford Ranch in 1994, based on an average of 3.3 pigs photographed per night. This estimate also does not include any area around Lake Henshaw, as it is unclear whether there is an established population there.

Reportedly, there were up to 20 pigs released near the El Capitan Reservoir during 2004–2006 (CBI 2009). So the population appears to have most likely increased by a factor of

4 to 7 over the last 4–5 years. Although this increase in numbers is moderate, the distribution has expanded quickly to at least 75 square miles, not including Lake Henshaw. The numbers are expected to multiply more rapidly in 2010–2011 because of the ample winter rainfall of 2009–2010 and the high productivity and yield of acorns expected to follow.

4.3 Potential impacts

4.3.1 Impacts on Native Habitats and Ecosystems

Pigs have had deleterious effects on many environments, both native and agricultural, in which they have been introduced. Due to their high impact factor on natural and agricultural systems, pigs are considered one of the most serious pests requiring control or eradication (West et al. 2009).

Oak woodland, riparian woodland, and marsh as habitats are especially susceptible to damage and degradation by feral pigs. Decreased recruitment of oaks (Sweitzer and Van Vuren 2002) is a concern especially as the trees attempt to recover after the fires of 2003 and 2007. In San Diego County, oak woodlands are already under stress from oak-boring beetles (Coleman and Seybold 2008) and reduced survival of seedlings because of drought (Mahall et al. 2009). Thus the further reduction of seedling recruitment and survival resulting from feral pigs are of great concern, especially during post-fire recovery.

Riparian and marshy areas can be severely degraded by wallowing and trampling (Figure 4), and these are scarce resources in this arid region that provide critical habitat for many species. If the pigs spread to areas of vernal pools, they could destroy these delicate habitats as well.

Although the extent of their effects on ecosystems as a whole are poorly understood, pigs are expected to cause strong and long-lasting alterations, including facilitation of other invasive species through disturbance (West et al. 2009), and alteration of the communities of invertebrates and microbes of soils and streams (Kaller and Kelso 2006).

Numerous sensitive species of flora and fauna lie within or adjacent to the currently occupied area (Figure 15). In the following sections we consider the potential direct and indirect impacts to individual species in this region, followed by additional potential impacts to agriculture and watersheds.

Figure 15. Feral pig sign in relation to sensitive flora and fauna, according to CNDDB records.

4.3.2 Impacts on Vertebrate Species

Many species of vertebrates may be affected by feral pigs, either directly through predation on small ground-dwelling or ground-nesting species, or indirectly through damage to riparian habitat and marshes and long-term degradation of oak woodland. Species known to occur in the section of the San Diego River basin currently occupied by the pig and expected to be adversely affected are listed in (Tables 8, 9, and 10).

Table 8. Birds of the San Diego River watershed expected to be affected most negatively by feral pigs.

Common name	Latin name	Ground-nester	Riparian/marsh habitat	Oak woodland habitat	Status
California Quail	*Callipepla californica*	X			
Pied-billed Grebe	*Podilymbus podiceps*		X		
White-tailed Kite	*Elanus leucurus*			X	
Northern Harrier	*Circus cyaneus*	X			CSC2
Cooper's Hawk	*Accipiter cooperii*			X	
Red-shouldered Hawk	*Buteo lineatus*			X	
Spotted Sandpiper	*Actitis macularius*	X	X		
Band-tailed Pigeon	*Patagioenas fasciata*			X	
Mourning Dove	*Zenaida macroura*	X			
Western Screech-Owl	*Megascops kennicottii*			X	
Lesser Nighthawk	*Chordeiles acutipennis*	X			
Common Poorwill	*Phalaenoptilus nuttallii*	X			
Acorn Woodpecker	*Melanerpes formicivorus*			X	
Southwestern Willow Flycatcher	*Empidonax traillii extimus*		X		E
Least Bell's Vireo	*Vireo bellii pusillus*		X		E
Hutton's Vireo	*Vireo huttoni*			X	
Western Scrub-Jay	*Aphelocoma californica*			X	
Horned Lark	*Eremophila alpestris*	X			CSC3
Oak Titmouse	*Baeolophus inornatus*			X	
Marsh Wren	*Cistothorus palustris*		X		
Orange-crowned Warbler	*Vermivora celata*	X			
Common Yellowthroat	*Geothlypis trichas*		X		
Yellow-breasted Chat	*Icteria virens*		X		CSC3
Spotted Towhee	*Pipilo maculatus*	X			
Rufous-crowned Sparrow	*Aimophila ruficeps*	X			
Lark Sparrow	*Chondestes grammacus*	X			
Grasshopper Sparrow	*Ammodramus savannarum*	X			CSC2
Song Sparrow	*Melospiza melodia*	X	X		
Lincoln's Sparrow	*Melospiza lincolnii*		X		
Dark-eyed Junco	*Junco hyemalis*	X			
Blue Grosbeak	*Passerina caerulea*		X		
Red-winged Blackbird	*Agelaius phoeniceus*		X		
Western Meadowlark	*Sturnella neglecta*	X			

Table 9. Mammals of the San Diego River watershed expected to be affected most negatively by feral pigs.

Common name	Latin name	Vulnerable ground-dweller	Competition for water	Transfer of disease	Status
Ornate Shrew	*Sorex ornatus*	X			
Desert Shrew	*Notiosorex crawfordi*	X			
Broad-footed mole	*Scapanus latimanus*	X			
Brush rabbit	*Sylvilagus bachmani*	X			
Desert cottontail	*Sylvilagus audubonii*	X			
Merriam's chipmunk	*Tamias merriami*	X			
California ground squirrel	*Spermophilus beecheyi*	X			
Botta's pocket gopher	*Thomomys bottae*	X			
San Diego pocket mouse	*Chaetodipus fallax*	X			CSC
California pocket mouse	*Chaetodipus californicus*	X			CSC
Dulzura kangaroo rat	*Dipodomys simulans*	X			
California vole	*Microtus californicus*	X			
Bryant's woodrat	*Neotoma bryanti*	X			
Large-eared woodrat	*Neotoma macrotis*	X			
California mouse	*Peromyscus californicus*	X			
Cactus mouse	*Peromyscus eremicus*	X			
Deer mouse	*Peromyscus maniculatus*	X			
Brush mouse	*Peromyscus boylii*	X			
Southern grasshopper mouse	*Onychomys torridus*	X			CSC
Western harvest mouse	*Reithrodontomys megalotis*	X			
Southern mule deer	*Odocoileus hemionus*		X	X	
Desert bighorn sheep	*Ovis canadensis*		X	X	FE

CSC- California Species of Special Concern. Rankings are currently under review.

Table 10. Reptiles and amphibians of the San Diego River watershed expected to be affected most negatively by feral pigs.

Common name	Latin name	Vulnerable ground-dweller	Aquatic	Sandy soil obligate	Status
Arroyo Toad	*Anaxyrus californicus*	X	X		FE
Coast Horned Lizard	*Phrynosoma blainvillei*	X			CSC
Pacific Pond Turtle	*Actinemys marmorata*		X		CSC
Orange-throated Whiptail	*Aspidoscelis hyperythra*	X			CSC
Western Spadefoot	*Spea hammondii*	X	X		CSC
California Newt	*Taricha torosa*		X		CSC
Two-striped Gartersnake	*Thamnophis hammondii*	X	X		CSC
California Legless Lizard	*Anniella pulchra*			X	CSC
Large-blotched Ensatina	*Ensatina klauberi*	X	X		CSC
San Diego Mountain Kingsnake	*Lampropeltis zonata pulchra*	X			CSC
Coast Patch-nosed Snake	*Salvadora hexalepis virgultea*	X			CSC
Red Diamond Rattlesnake	*Crotalus ruber*	X			CSC
Western Skink	*Plestiodon skiltonianus*	X			CSC

Birds

Many species of birds potentially impacted occur in the areas occupied by feral pigs, as shown in the *San Diego County Bird Atlas* (Table 8, Unitt 2004). This list includes 15 species that are directly vulnerable as ground-nesters (exclusive or significant proportion of nests on the ground), such as the Lesser Nighthawk, Horned Lark, and Grasshopper Sparrow. Other species, such as the Song Sparrow, Least Bell's Vireo, and Yellow-breasted Chat, rely primarily on riparian and/or marsh habitat while others, such as the White-tailed Kite, Band-tailed Pigeon, and Acorn Woodpecker, rely strongly on oak woodland. Note, however, that many other species may be affected by feral pigs directly or indirectly. For example, many additional species found in this area, including the California Gnatcatcher (*Polioptila californica*), often nest low to the ground, and are thus susceptible to direct depredation or damage to nests.

Six sensitive bird species are likely to be negatively impacted by feral pigs (Table 8). Although our surveys were conducted in winter, when some migratory species are absent, rather than during their breeding season when they occur in the area, from our observations of damage to habitat, the following species are most likely to be strongly affected: Southwestern Willow Flycatcher, Least Bell's Vireo, Yellow-breasted Chat, Horned Lark, and Grasshopper Sparrow. Three of these rely on riparian habitat for breeding (Southwestern Willow Flycatcher, Least Bell's Vireo, and Yellow-breasted Chat) so should be adversely affected by feral pigs damaging riparian habitat (Figure 4). Two of these species (Horned Lark and Grasshopper Sparrow) are obligate ground-nesters, and are likely to be adversely affected by rooting of feral pigs in open grassland (Figure 16).

Figure 16. Rooting from pigs in an open grassy field.

Mammals

Mammals, especially rodents, are vulnerable to the effects of feral pigs Ground-dwelling rodents are subject to direct predation by pigs while also being vulnerable to persistent destruction of burrows and habitat.

The San Diego pocket mouse (*Chaetodipus fallax*) and California pocket mouse (*Chaetodipus calfornicus*), both California species of special concern, inhabit the known range of the feral pigs in San Diego County. Other rodents, including the California vole (*Microtus californicus*) and Botta's pocket gopher (*Thomomys bottae*), are known to be consumed by feral pigs (Wilcox and Van Vuren 2009). During this study, pocket gopher mounds were often observed near feral pig diggings.

The bighorn sheep (*Ovis canadensis*), another sensitive species, now may be in direct contact with feral pigs after sign was detected in Oriflamme Canyon. Many diseases , including pseudorabies, which usually results in death of the infected animal, may be transmitted by pigs to wildlife (West et al. 2009). Predation on lambs may also be expected as feral pigs are known to take young of deer and domestic sheep (Choquenot et al. 1997, Schley and Roper 2003).

Amphibians

Disturbance of creekside and riverbed habitat adversely affects the Arroyo Toad (*Anaxyrus californicus*) and Western Toad (*Anaxyrus boreas*). Secondary channels and areas with standing ponds or pools farther from the central channel constitute habitat for the Western Spadefoot (*Spea hammondii*). All three of these species are soil burrowers, so rooting in the creek and river channels is a direct effect. For the Disturbance of aquatic vegetation would affect the Pacific Treefrog (*Pseudacris regilla*), as well, though this species is fairly resilient to disturbance. The California Treefrog (*Pseudacris cadaverina*) is present in the area but prefers rocky stream courses with large boulders, so pig activity is will likely not affect it. The California Red-legged Frog (*Rana draytonii*) is known historically from the upper tributaries of the San Diego River but is now believed extirpated from San Diego County. Much of the San Diego River's upper watershed is remote and rugged, so rediscovery of this species still remains possible, although not likely. Disturbance of the river and stream channel has the potential of opening up areas for standing pools, which would give the Bullfrog (*Lithobates catesbeianus*) the opportunity to expand upstream from El Capitan Reservoir, to the detriment of native amphibians.

The California Newt (*Taricha torosa*) has an isolated population along middle Boulder Creek and middle to lower Cedar Creek. It spends half the year in terrestrial retreats and the other half submerged in pools Little is known of its terrestrial habitat preferences, but it disperses during its terrestrial phase. Feral pigs' disturbance of fallen logs and rocks could reduce the retreats available for the two ensatinas (*E. eschscholtzii* and *E. klauberi*), the Arboreal Salamander (*Aneides lugubris*), and the Garden Slender Salamander (*Batrachoseps major*). All but the Large-blotched Ensatina (*E. klauberi*) are found throughout the watershed, with *E. klauberi* found in only the higher reaches.

Reptiles

Establishment of feral pigs raises concerns for the more fossorial lizards and snakes. Three species, the California Legless Lizard (*Anniella pulchra*), the Black-headed Snake (*Tantilla planiceps*), and the Western Threadsnake (*Leptotyphlops humulis*) would be directly disturbed by pigs' rooting. Other species, such as the Coast Horned Lizard (*Phrynosoma blainvillei*), the Southern Alligator Lizard (*Elgaria multicarinata*), Orange-throated Whiptail (*Aspidoscelis hyperythra*), Western Whiptail (*Aspidoscelis tigris*), Gilbert's Skink (*Plestiodon gilberti*), Western Skink (*Plestiodon skiltonianus*), Two-striped Gartersnake (*Thamnophis hammondii*), and Red Diamond Rattlesnake (*Crotalus ruber*) are expected within the river channels.

The Pacific Pond Turtle (*Actinemys marmorata*) excavates shallow nests in the loamy and sandy soils typical of those found along the rivers and creeks below the level of sporadic flooding. Because of changes in habitat quality due to periodic seasonal flooding, each of species listed likely experiences natural population fluctuations. But each times its reproductive cycle to avoid the high water flows that typically come with winter rains. The aquatic species reproduce in the stream courses during the late winter and early spring when flows subside, while the terrestrial species build nests in later spring and early summer. Each likely responds to the shifting of the stream channel and likely can withstand low levels of additional disturbance, such as cattle grazing. If numbers of the pig are low, pig rooting may not cause too much habitat alteration, no more than what occurs naturally during high water flows. If the pig population is larger, however, it may alter the habitat continuously and degrade the retreats of species such as the Arroyo Toad and places that serve as nesting sites for most of the egg-laying reptiles that inhabit the watershed.

4.3.3 Impacts on Plant Species

The San Diego River watershed is a botanically rich area with a diversity of habitats and native plants. According to the Consortium of Herbaria, there are at least 15 species listed as sensitive by the California Native Plant Society (CNPS) known to occur in this area (Table 11).

The sensitive species that are most likely affected by pig damage include *Astragalus deanei* (Dean's Milk Vetch), *Clarkia delicata* (Delicate Clarkia), *Piperia cooperi* (Cooper's Rein Orchid), *Quercus engelmannii* (Engelmann Oak), and *Monardella hypoleuca* ssp. *lanata* (Felt-leaf Monardella).

Table 11. List of sensitive plant species that occur within the study area.

Family	Genus	Species	Infraname		CNPS List
Aspleniaceae	*Asplenium*	*vespertinum*			List 4.2
Asteraceae	*Grindelia*	*hirsutula*	var.	*hallii*	List 1B.2
Asteraceae	*Holocarpha*	*virgata*	ssp.	*elongata*	List 4.2
Asteraceae	*Hulsea*	*californica*			List 1B.3
Asteraceae	*Symphyotrichum*	*defoliatum*			List 1B.2
Fabaceae	*Astragalus*	*deanei*			List 1B.1
Fabaceae	*Astragalus*	*oocarpus*			List 1B.2
Fagaceae	*Quercus*	*engelmannii*			List 4.2
Geraniaceae	*California*	*macrophylla*			List 1B.1
Lamiaceae	*Monardella*	*hypoleuca*	ssp.	*lanata*	List 1B.2
Lamiaceae	*Monardella*	*nana*	ssp.	*leptosiphon*	List 1B.2
Onagraceae	*Clarkia*	*delicata*			List 1B.2
Orchidaceae	*Piperia*	*cooperi*			List 4.2
Orchidaceae	*Piperia*	*leptopetala*			List 4.3
Pteridaceae	*Pentagramma*	*triangularis*	ssp.	*rebmannii*	None

Astragalus deanei is endemic to San Diego County, including parts of the project area. It is very rare, with few known populations. It is often found on the lower slopes of riparian areas where much of the pig activity was recorded.

Clarkia delicata is known from San Diego County and Baja California. This annual favors the shade and mesic soils of oak woodlands on the periphery of cismontane chaparral, habitat in which much of the heavily rooted areas were observed.

Monardella hypoleuca ssp. *lanata* is known from San Diego and Orange counties and northern Baja California. This perennial is found on the edges of chaparral mostly in rare gabbro soils.

Piperia cooperi is known from southern California and Baja California and often occurs under chaparral and in oak woodlands. Its delicate and fragile bulb/caudex is vulnerable to disturbance.

Quercus engelmannii is known primarily from southern California; it is rare in Baja California. Uncommon throughout its range, this tree is a constituent of oak and riparian woodlands. The rate at which its seedlings are established is low. Seedlings were observed along creeks in the study area but rarely where pigs had rooted intensively. Given the strong impacts of feral pigs on other oak populations in California, and damage observed in oak woodland in this study area (Figure 17), this species is likely to be strongly impacted.

Figure 17. Rooting was commonly found directly under oak trees. The start of a probable rub mark is present on the trunk.

Our surveys for feral pigs took place in winter, so many of the sensitive species were either dormant (perennials and bulbs) or not yet germinated (annuals). Therefore, we were not able to assess the effects of pigs on known populations of sensitive plants. However, some areas where the sensitive plants have been documented previously were adjacent to heavily rooted areas that could have disturbed or destroyed these plants. Furthermore, Jon Rebman, curator of botany at SDNHM, observed pig damage during rare-plant surveys on another project in the Cleveland National Forest in April 2010. He observed severe pig rooting among *Piperia cooperi*, *Monardella hypoleuca* ssp. *lanata* and seedlings of *Quercus engelmannii* northwest of El Capitan Reservoir, noting that the extent of the rooting had most likely destroyed part of the populations of these species.

During surveys for the pig, we observed damage to native plants. The bark of several trees of *Quercus agrifolia* var. *oxyadenia* (Interior Live Oak) had been rubbed off (Figure 17). Pigs tend to rub on objects to scratch themselves or to remove mud and grass from their skin. The destruction of several plants of *Hesperoyucca whipplei* (Chaparral Yucca) was also observed (Figure 18). The pigs had dug up the center of the plants, possibly to get to the nutrient-rich bud of the flowering stalk. (Riparian species are particularly prone to direct damage from trampling and rooting (Figure 4). Large areas of uprooted vegetation were observed in the floodplain of the San Diego River, especially under oaks. Pig rooting inhibits or precludes the establishment of seedlings and favors non-native plants that compete with the native and sensitive plants in disturbed ground.

Figure 18. Many damaged yucca (*Hesperoyucca whipplei*) were found in heavily rooted areas, apparently from pigs eating the "heart" of the yucca.

4.3.4 Other Potential Impacts

Agriculture

Besides major ecological costs, feral pigs are also expected to have a major economic cost. Pimental et al. (2000) estimated that feral pigs caused $800 million annually in damage to agriculture in the United States, while costs of control (eradication or management) were only $1 million. Thus the cost of agricultural damage far exceeds the costs of control and far exceeds any revenue from hunting. Because of the pig's omnivorous diet and rooting behavior, all crops and agriculture are at risk. In western Europe, of crops destroyed by wild boars, 5–10% were lost to direct consumption, while the rest were lost to trampling and rooting (Schley and Roper 2003). In San Diego

County, although there is rather little agriculture within the area feral pigs currently occupy, we observed rooting in a fruit orchard. Major agricultural areas, including San Pasqual Valley only 13 miles away, are within the distance feral pigs disperse. Agriculture is the fourth largest industry in San Diego County, with an annual value over $1.5 billion (San Diego County Dept. of Agriculture 2008).

Watershed

Although there has been little study of the effect of feral pigs on watersheds, feral pigs have been shown to change the microbial composition of streams in Louisiana, increasing fecal coliform counts and a variety of pathogens (Kaller and Kelso 2006). The area feral pigs currently occupy in and around the San Diego River is within one of the primary watersheds of San Diego County, a significant source of drinking water for local urbanized areas. Potential problems include water contamination, trampling riparian habitat, bank destabilization, and increased sedimentation and detritus.

Disease Transmission

Wild pigs are known to carry parasites and disease that are threats to human beings, livestock, and wild animals. Transmission of salmonellosis, brucellosis, *E. coli*, leptospirosis, toxoplasmosis, trichinosis, trichostrongylosis, balantidiasis, and sarcoptic mange from wild pig to human are all known (Forrester 1991, Williams and Barker 2001, Sweeney et al 2003). Diseases affecting livestock and wild animals include: pseudorabies, tuberculosis, swine fever, brucellosis, vesicular stomatis (Williams and Barker 2001, Nettles et al. 1989, Davidson and Nettles 1997, Davidson 2006).

4.4 Habitat Connectivity and Wildlife Corridors

Given our findings of considerable dispersal, and given the extensive suitable habitat and connectivity identified by habitat models, spread of feral pigs throughout San Diego County is likely unless the population is eradicated (CBI 2009). The expansion could easily continue north into the San Jacinto Mountains in Riverside County and south into Baja California. The only areas where expansion is unlikely are the desert regions at lower elevations and heavily urbanized areas along the coast. However, identification of pig tracks in Oriflamme Canyon far from oak woodland at an elevation of 3055 feet suggests that expansion into desert-edge habitat is possible wherever water is available, and sightings of pigs on the north side of the town of Alpine, and frequent pig sign along roads, suggest that pigs can expand into and through semi-urbanized areas.

We often found pig tracks along dirt roads and trails, and the most activity was in riparian corridors and open oak woodland. Thus, to identify the areas pigs are most likely to occupy within the next 12 months, we examined the periphery of the current distribution for likely expansion routes in the form of dirt roads and oak/riparian corridors into adjacent suitable habitat (listed below, Figure 11). Expansion will likely occur into only a subset of these areas, but all of these areas should be included in any future survey or eradication efforts. Note, however, that within the next 12 months dispersal over even longer distances is possible. If there is no eradication effort soon, the area of dispersal will likely become much broader.

Although individual male feral pigs may disperse long distances (50 km or 30 miles is not unusual, Gabor et al. 1999) and sightings beyond the areas listed below are likely, eradication may be successful if focused on females and their likely distribution. However, females also disperse and can have large ranges, so sightings of males may provide clues for females' possible dispersal routes.

Areas most likely to become occupied within the next 12 months (clockwise from the southwest side of the current range):

- San Diego River below El Monte County Park
- Silverwood Wildlife Sanctuary
- Featherstone Canyon
- Padre Barona Creek
- Klondike Creek
- Barona Mesa
- San Vicente Creek, on the east side of San Vicente Valley
- San Vicente Creek, in Himmel Canyon
- Dye Canyon
- Collier Flat
- Wash Hollow Creek at Little Page Road
- Witch Creek
- Section 32, east of Witch Creek
- Santa Ysabel Valley
- Area surrounding Lake Henshaw including the San Luis Rey River
- Santa Ysabel Creek, west of Highway 79
- Santa Ysabel Creek, between Highway 79 and Volcan Road
- Wynola

- Sentenac Creek
- Orinoco Creek, both sides of Pine Hills Road
- Paine Bottom
- Pine Hills, including Dehr Creek
- Cedar Creek, east of Boulder Creek Road
- William Heise County Park
- Harrison Park
- Chariot Canyon
- Mountain Meadows
- Marston Meadow
- Johnson Creek
- Milk Ranch Road and La Puerta Springs
- Paso Picacho Campground
- Stonewall Creek
- Upper Green Valley
- Cold Stream
- Sweetwater River at Green Valley Area Campground
- Tule Springs Road east of Rancho Alegria
- West Fork King Creek
- King Creek, east of Boulder Creek Road
- Poverty Gulch
- Descanso
- King Creek, both sides of Conejos Valley Road
- Sand Creek
- Pine Grove, including sections 18 and 19
- Peutz Valley
- Chocolate Canyon

There are many additional areas with suitable habitat immediately adjacent to this region that are within dispersal distance, including: Pauma Valley, Mesa Grande, Sutherland Lake, San Pasqual Valley, Ramona, San Vicente Reservoir, Sweetwater River, Loveland Reservoir, Pine Valley Creek, and Corte Madera. In the absence of any eradication effort, many of these areas are likely to become occupied within the next 1–3 years, depending on the rate of spread and establishment patterns.

5.0 Conclusions and Management Recommendations

It appears that the feral pig population has only had a moderate growth rate in San Diego County, consistent with an early phase pre-establishment. The early population growth may also be naturally slowed by water supply, low seasonal temperatures, and predation upon young, but these factors are not expected to have a significant limiting effect, and the mild climate of San Diego County should support rapid population growth and expansion, which will make any control efforts difficult and costly. The extent of distribution has increased widely due to dispersing individuals. Dispersers are expected to become established in other suitable habitat that can support populations over time, similar to habitat found in the San Diego River watershed, and including agricultural areas.

For this year the current rainfall totals are near normal and acorn production is higher than normal. In previous years it appears that dispersal was rare outside of the original translocation site. However, many new observations are now being reported outside of the San Diego River drainage. As a result the population is expected to greatly increase this spring/summer as dispersers become established in other suitable habitat. The combination of potential impacts, extent of suitable habitat, strong dispersal, and the potential for rapid population growth is of great concern for San Diego County.

The lack of direct observations of feral pigs during route surveys suggests both nocturnal and shy/reclusive behavior, which is corroborated by comments by several hunters who were interviewed during the study. All but one camera detection were during nighttime hours. However, pig sign is easy to identify, and motion-detection cameras are effective, so a combination of repeated route surveys and motion-detection cameras can be used for monitoring.

Feral pig management is difficult and costly. Campbell and Long (2009) offered these concluding points based on their recent review of feral pig management programs:

(1) The value of using a variety of techniques in an integrated fashion cannot be overstated.

(2) There is value in using indices for both feral swine populations and their damage pre and post management activities.

(3) Innovative technologies will increasing be of value in the pursuit of feral swine damage reduction.

(4) Though not appropriate in every situation, there is value in involving the public in feral swine damage management decisions and activities.

In summary, there are three options for feral pig management in San Diego County:

(1) No action.

Given the rapid population growth rate and dispersal behavior of feral pigs, this would likely result in a very large population spread over much of the county that would be extremely difficult or impossible to eradicate or control in any way. There would be major economic and ecological costs.

(2) Control/containment.

These programs have proven largely ineffective, with feral pig populations easily rebounding, reestablishing, and spreading after culling. There would be little difference between this action and no action, except temporary decreases in density, and possibly slowing the rate of spread.

(3) Eradication.

A swift and intensive eradication effort would be the least costly alternative. Given the rugged terrain of the occupied area, trapping combined with hunting with dogs and aerial culling would probably be the most effective eradication strategy. Ongoing monitoring to ensure complete eradication should use a combination of baited camera stations, repeated survey routes for pig sign, and checking additional outlying areas.

<u>Management recommendation</u>

Although eradication is difficult, population control efforts have been largely ineffective because of high dispersal and quick recovery of populations following culling (e.g., Cowled et al. 2006, Hanson et al. 2009). Considering the potential environmental impacts and costs, intense eradication efforts are favored over sustained control programs (Cruz et al. 2005). Intensive eradication efforts should be focused on areas of highest activity, with complementary surveys to monitor persistence and dispersal. Any eradication or control efforts may be more effective during summer months when pigs are likely to be restricted to water sources. Monitoring is best accomplished by remote cameras in occupied areas combined with surveys by foot in peripheral areas to detect fresh sign. If an intensive eradication program is not forthcoming within the next few months, we recommend continued monitoring in conjunction with a public-relations campaign to deter additional releases of feral pigs and encourage reports of sightings. All new data will help estimate abundance in known areas and determine the routes of dispersal.

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APPENDIX

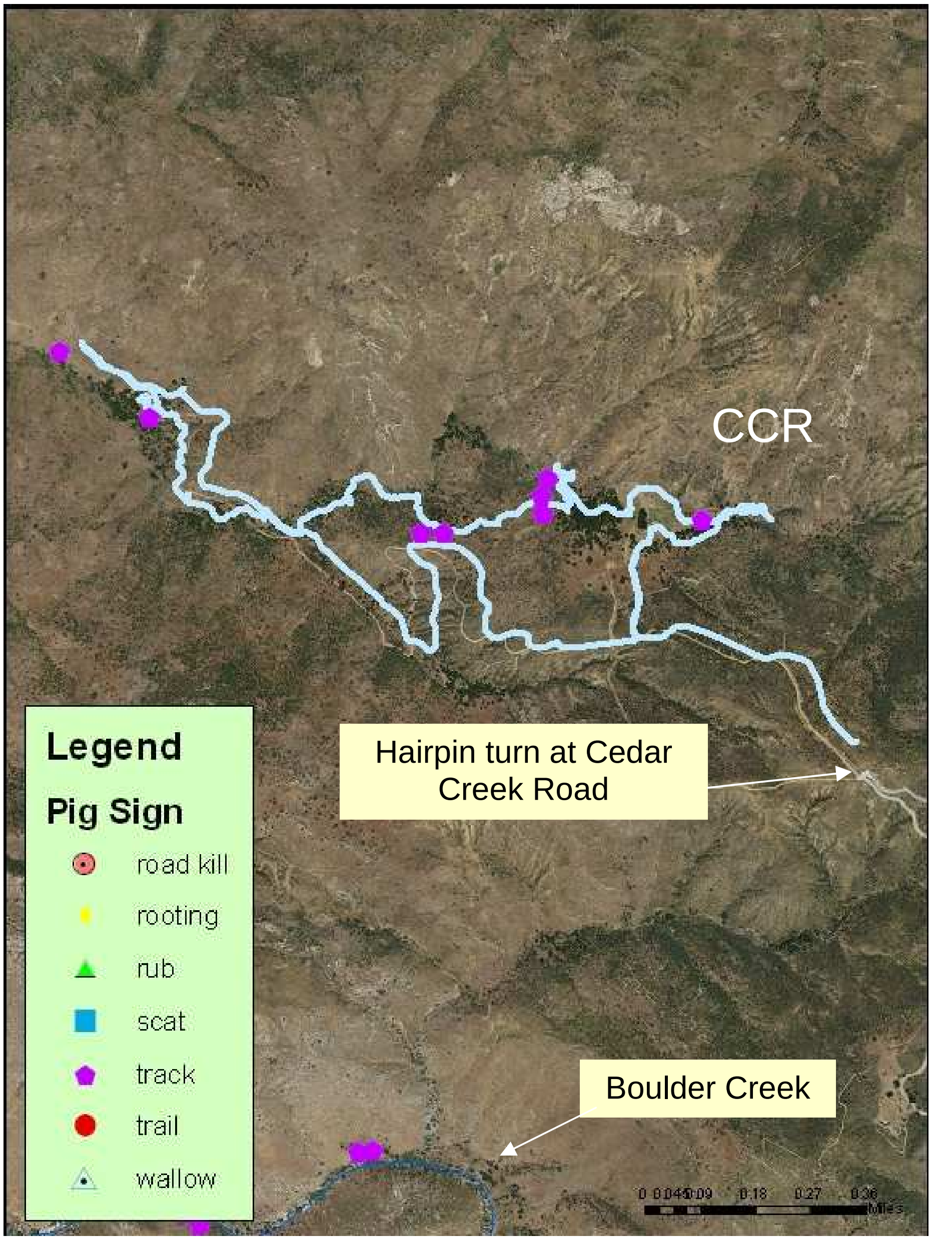

Figure A.1. Feral pig sign detected along the survey route in the Cedar Creek Road area.

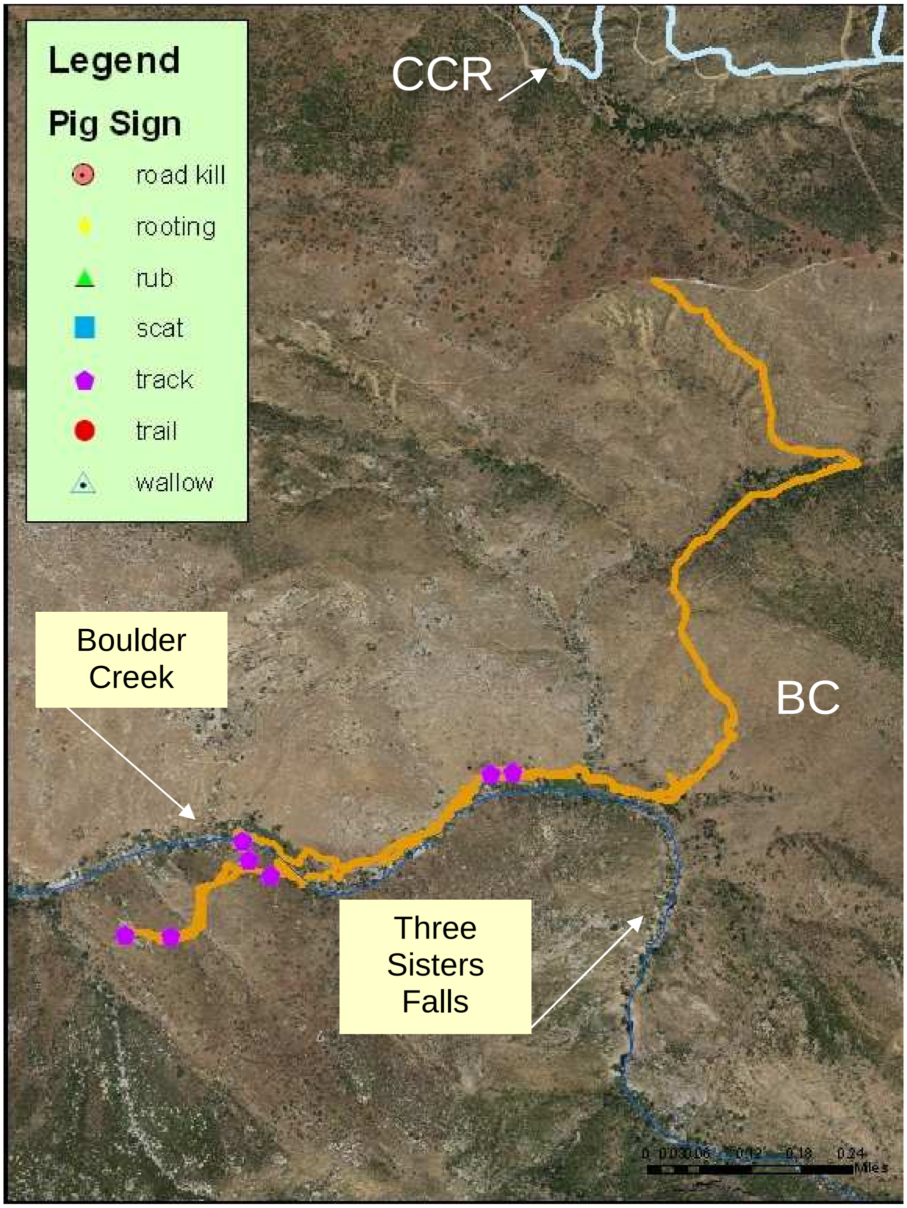

Figure A.2. Feral pig sign detected along the survey route in the Boulder Creek area below Three Sisters Falls.

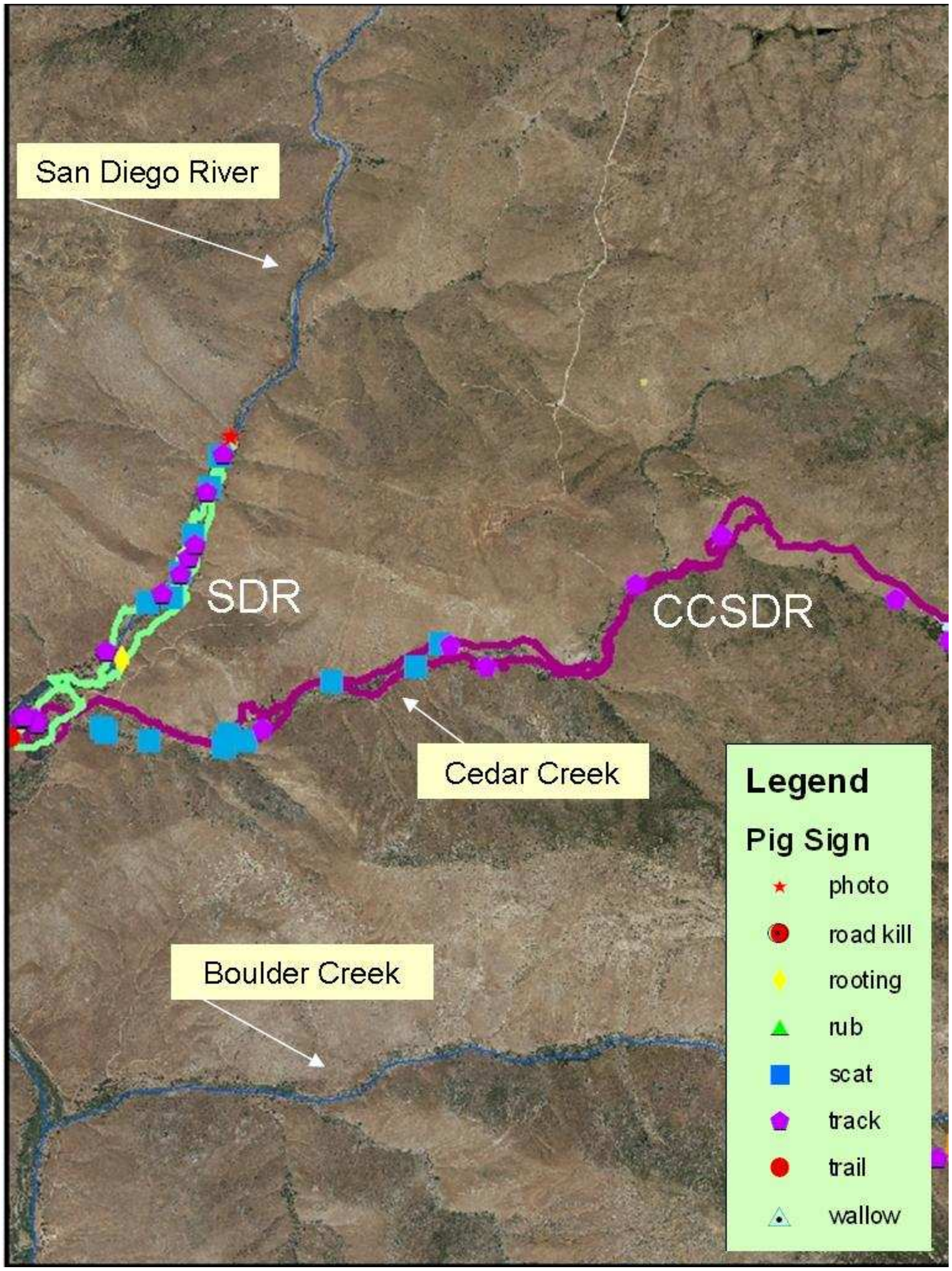

Figure A.3. Feral pig sign detected along the survey route at lower Cedar Creek.

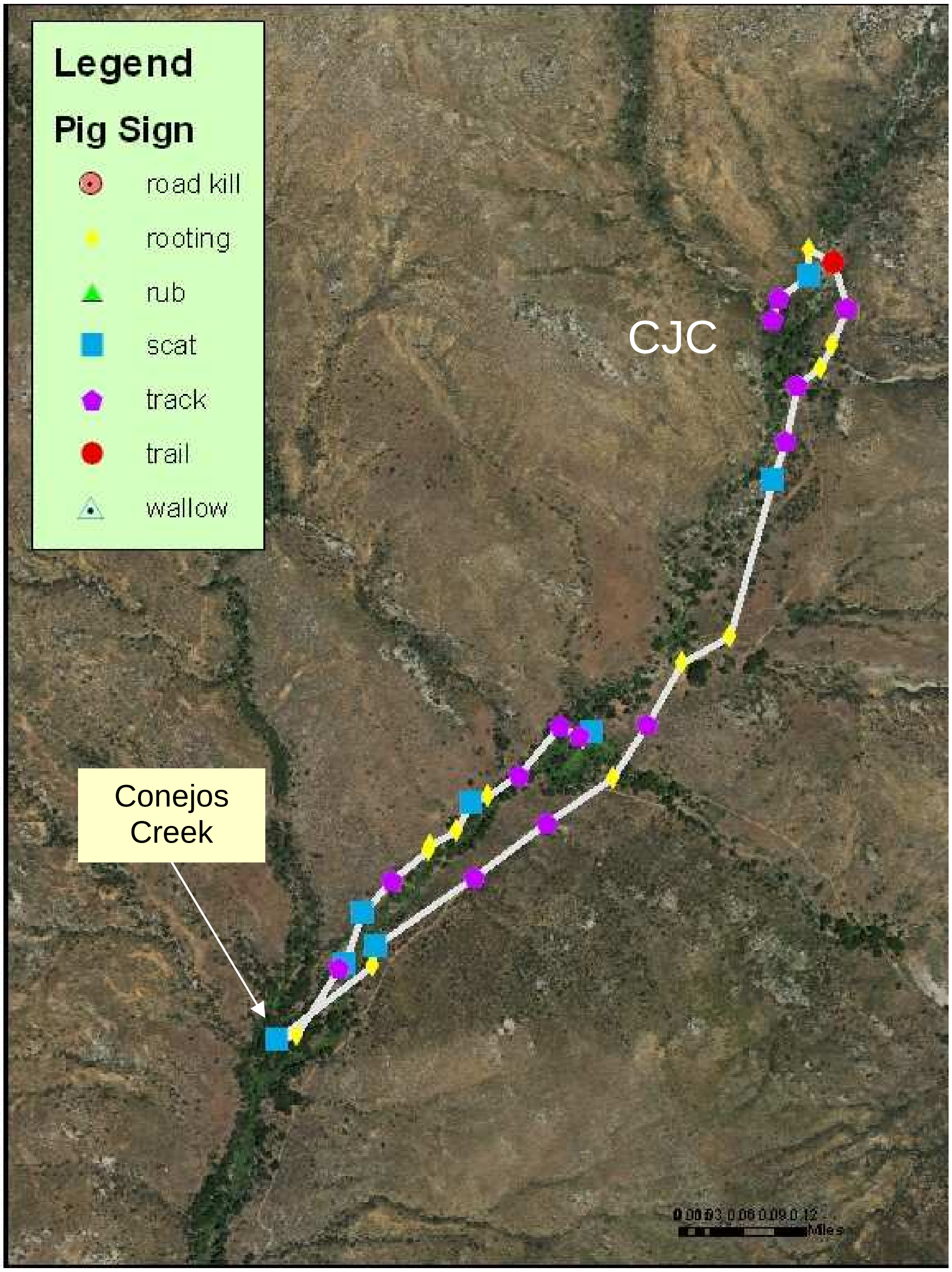

Figure A.4. Feral pig sign detected along the survey route at upper Conejos Creek.

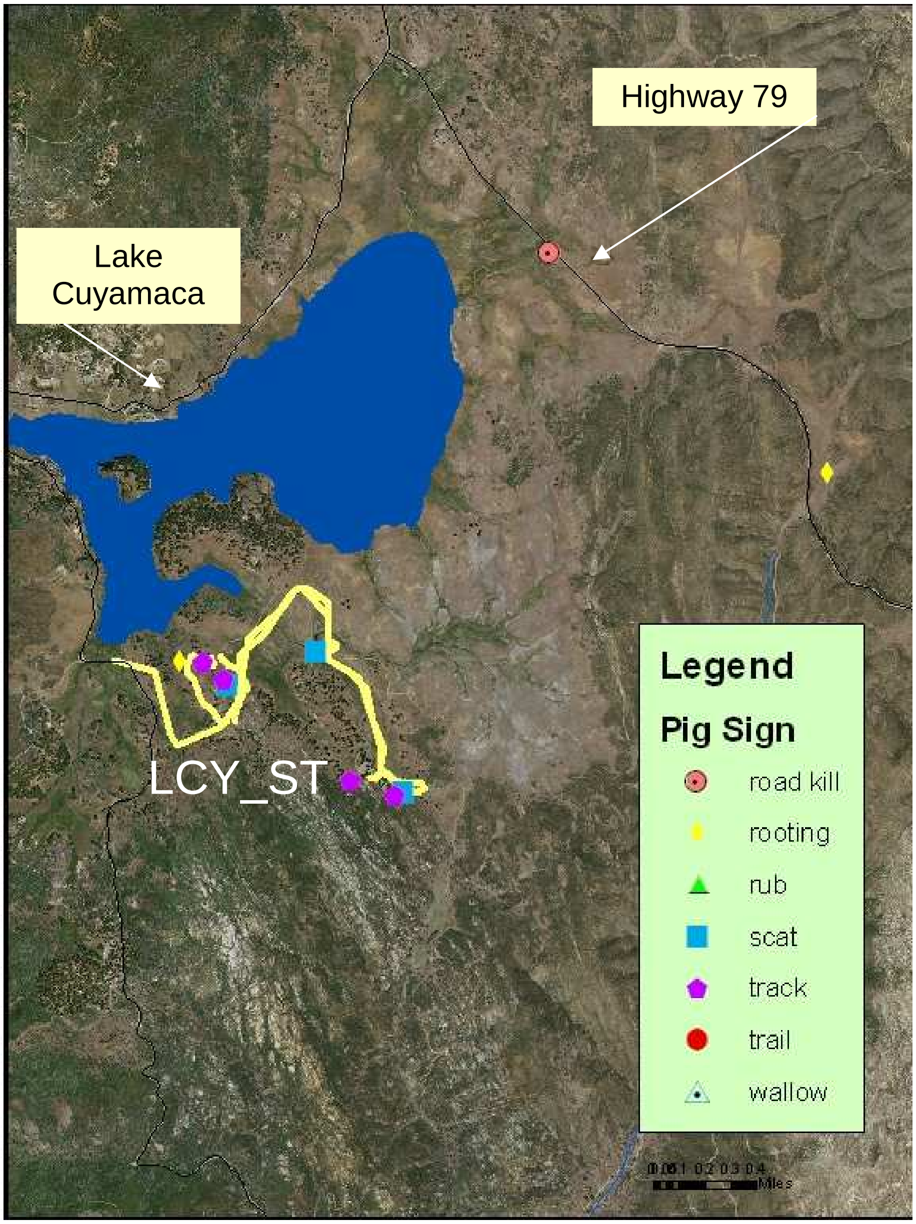

Figure A.5. Feral pig sign detected in the area around Lake Cuyamaca.

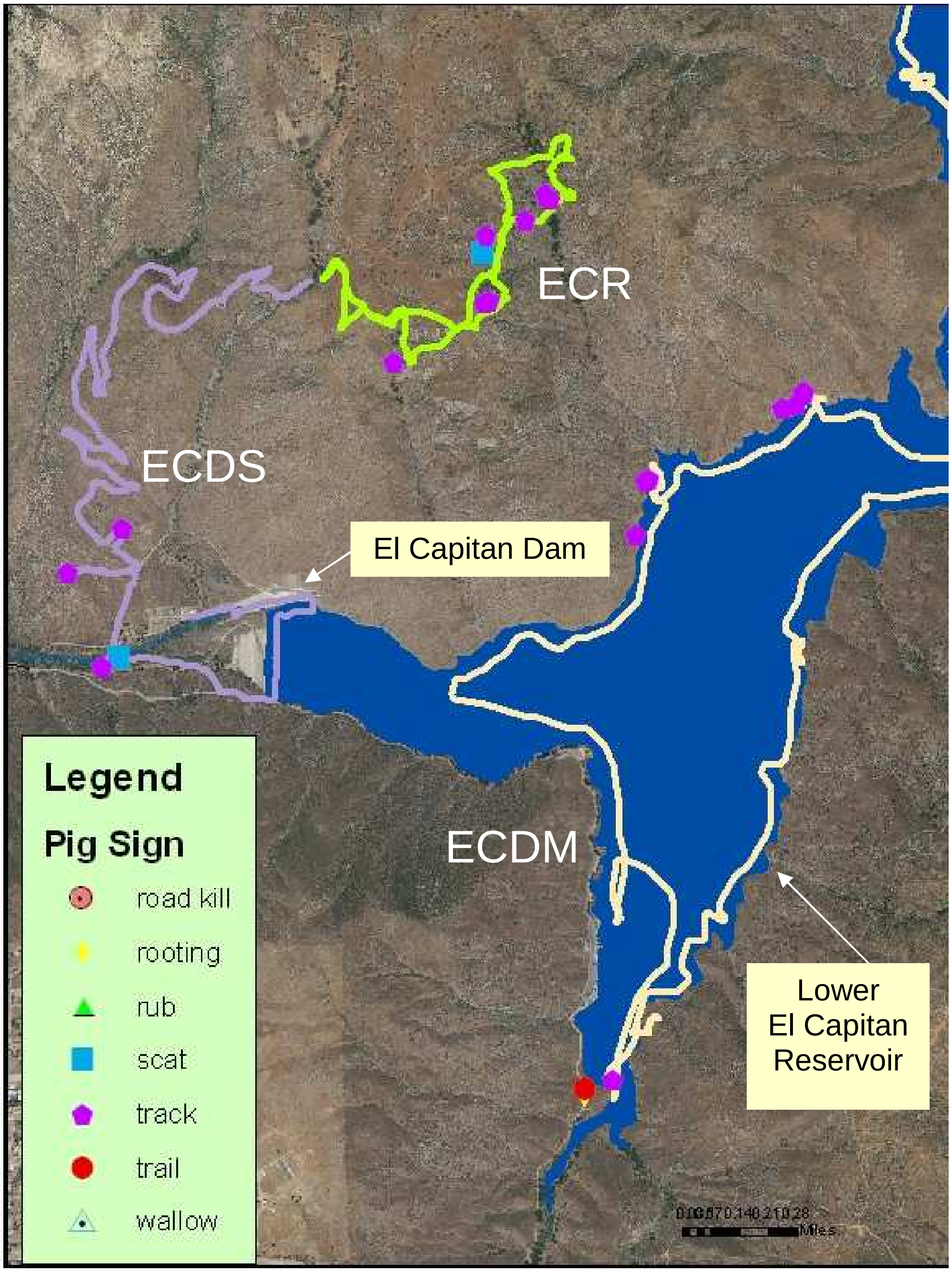

Figure A.6. Feral pig sign detected in the area around lower El Capitan Reservoir.

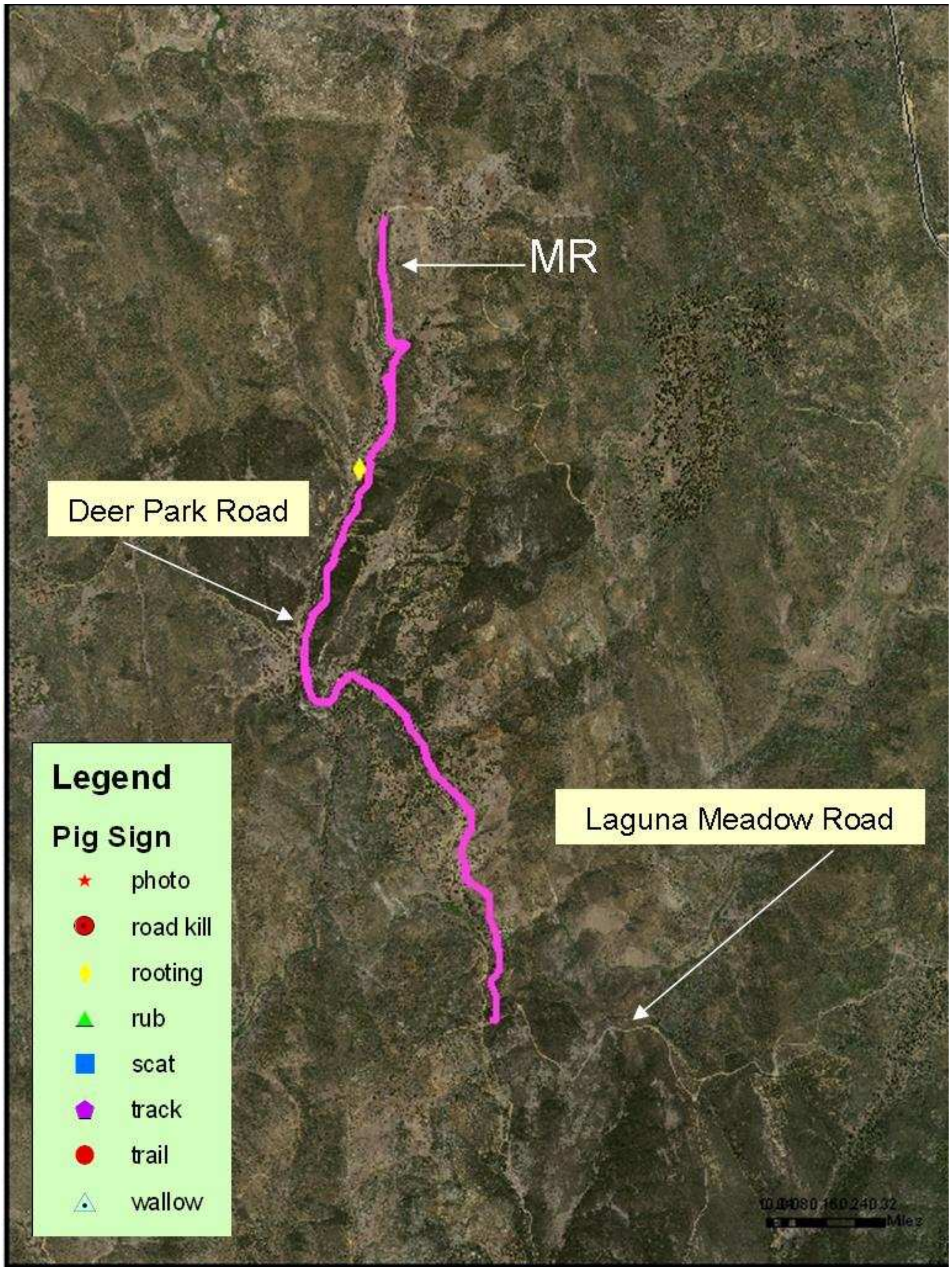

Figure A.7. Feral pig sign detected in the area of Deer Park Road near Pine Valley.

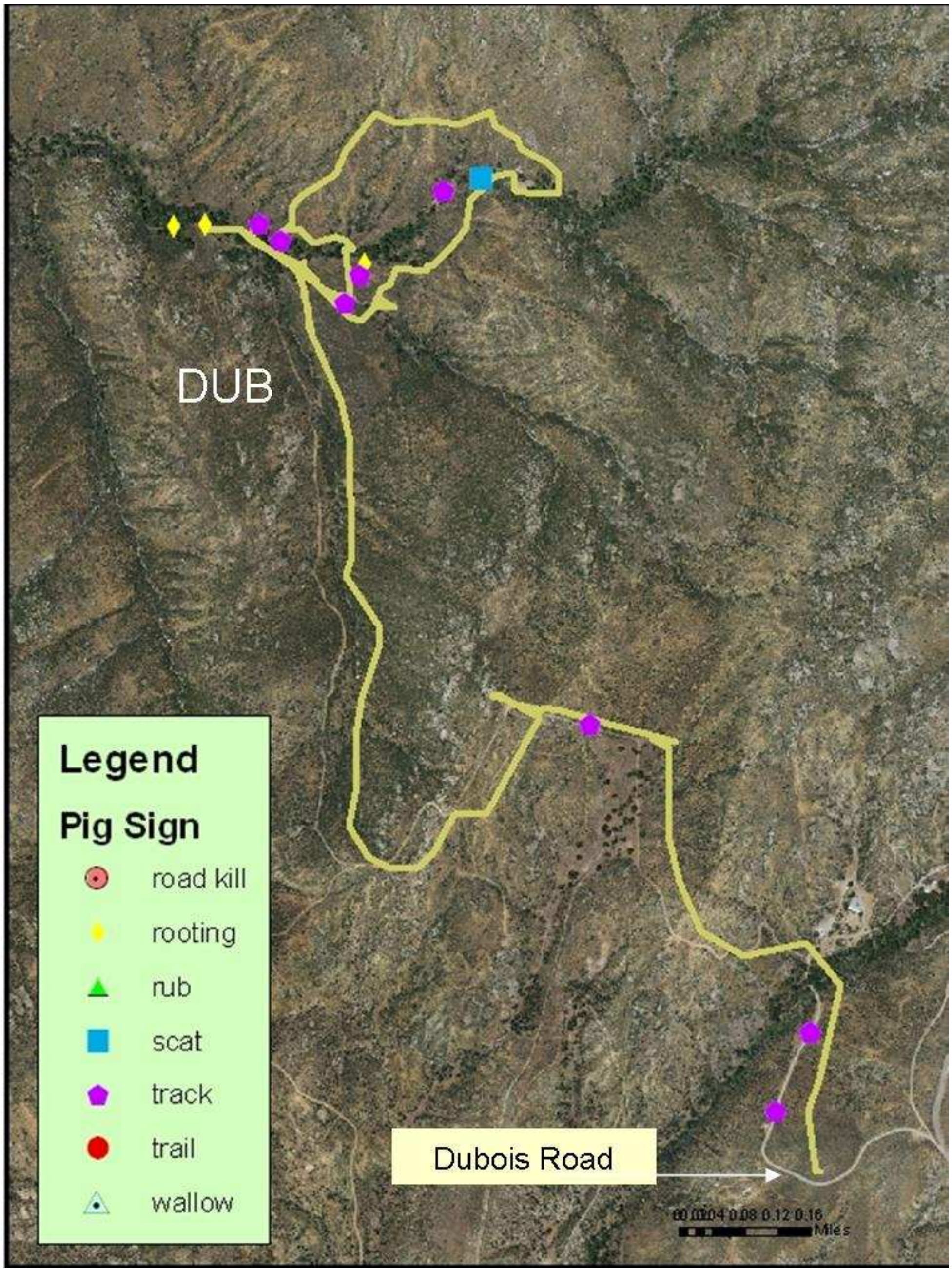

Figure A.8. Feral pig sign detected in the area of Dubois Road.

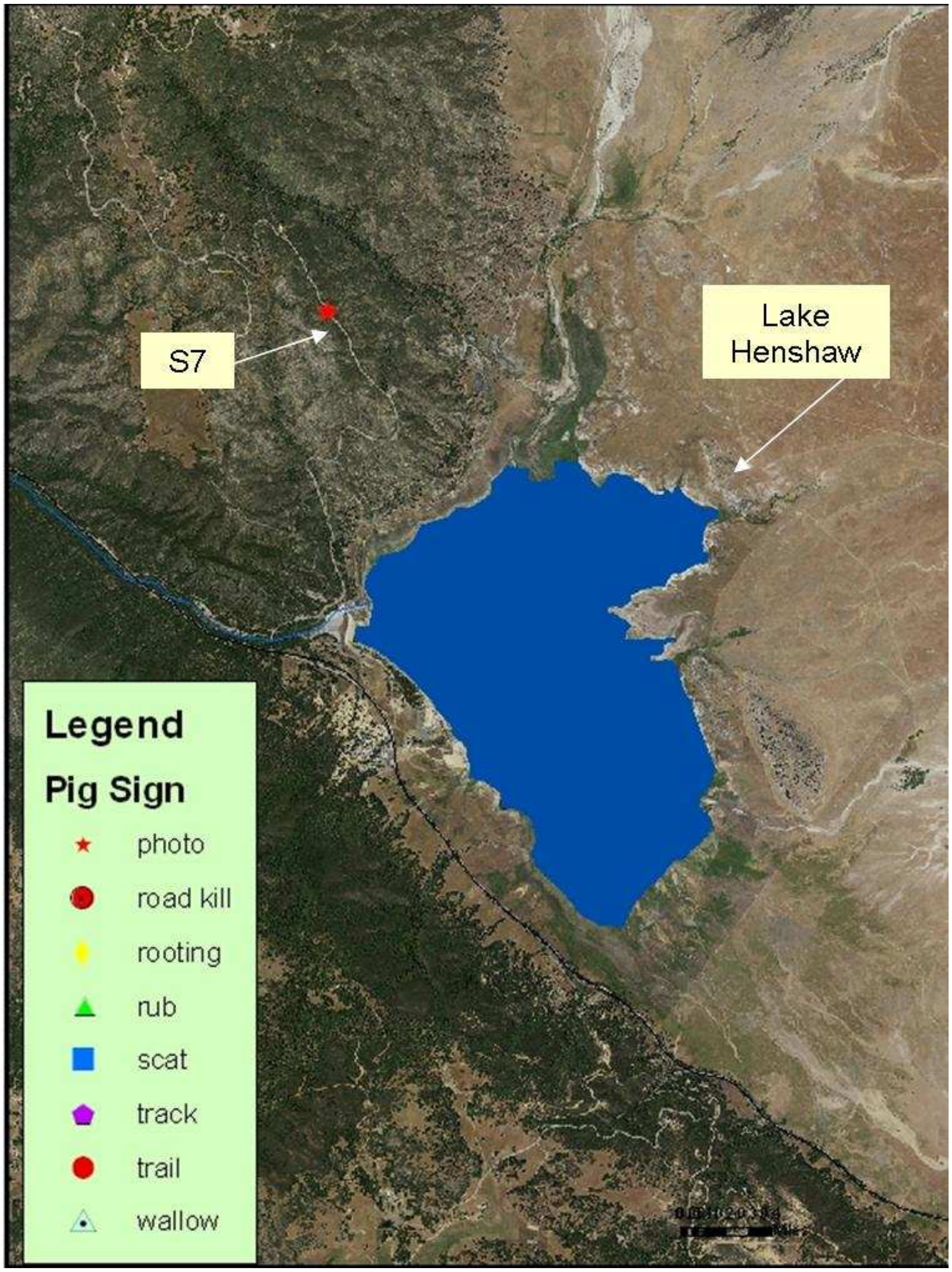

Figure A.9. Feral pig sign detected in the area of Lake Henshaw (sighting of one adult and two juveniles on March 23, 2010).

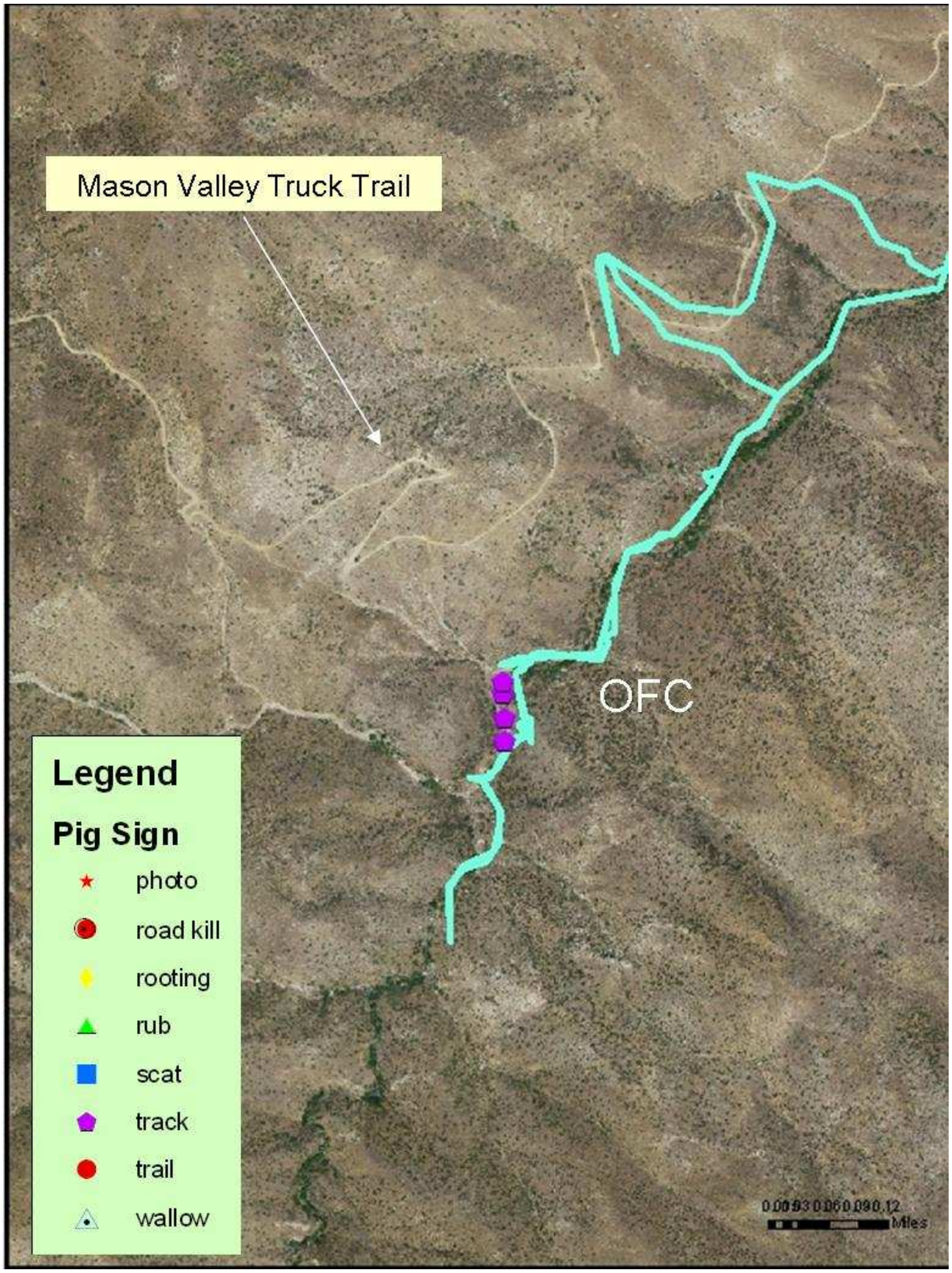

Figure A.10. Feral pig sign detected in the area of Oriflamme Canyon.

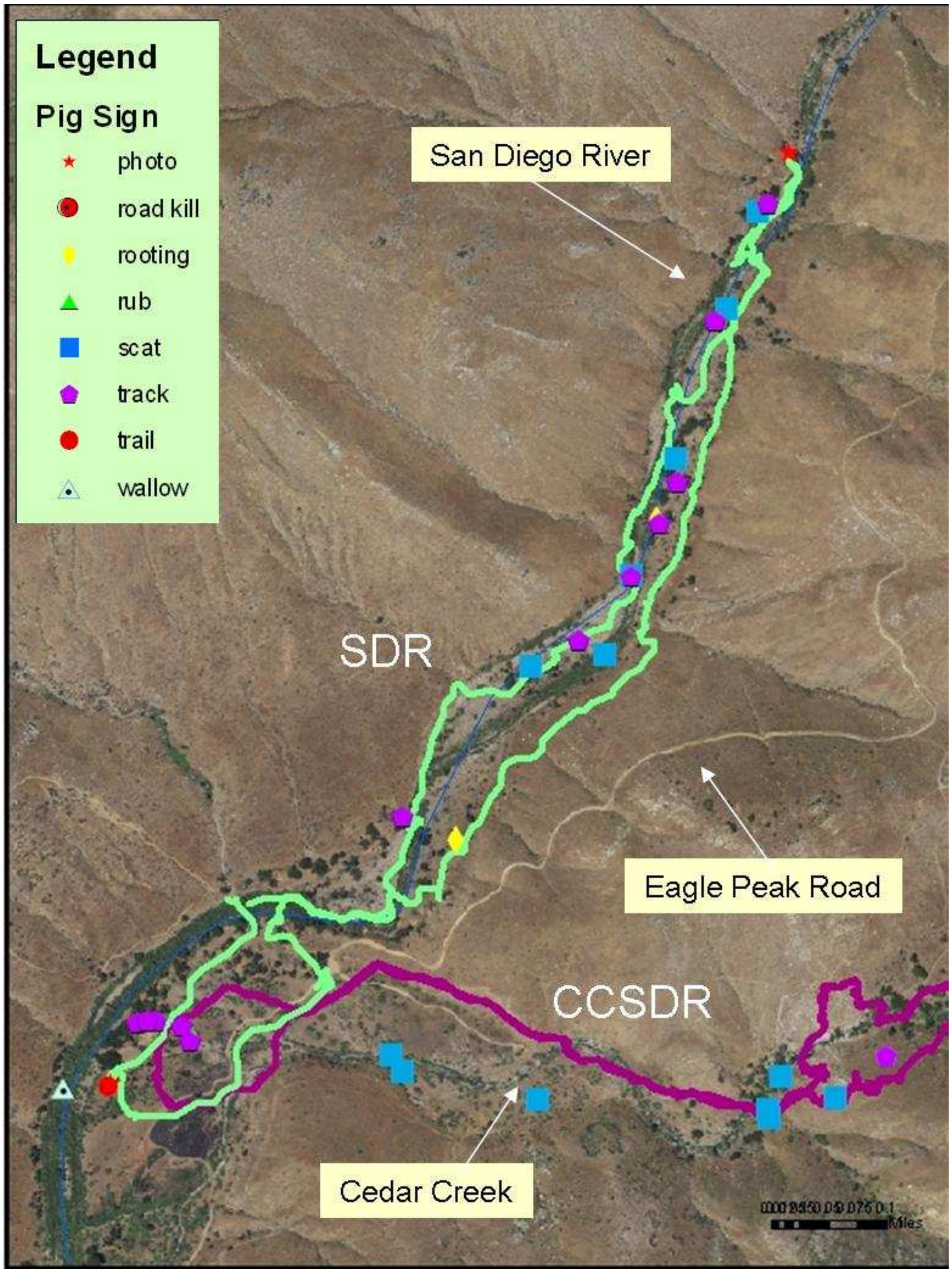

Figure A.11. Feral pig sign detected along the San Diego River near Cedar Creek.

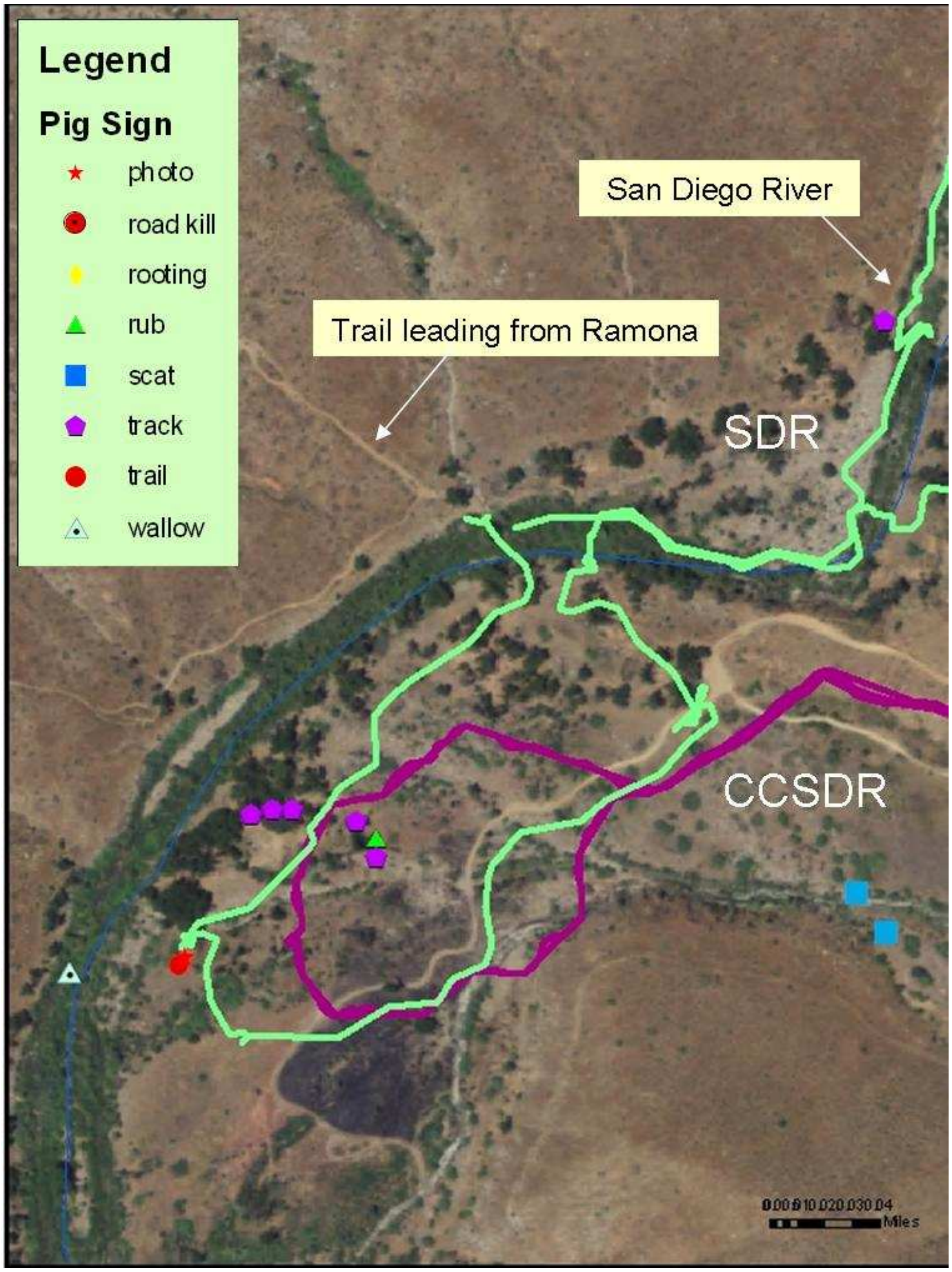

Figure A.12. Feral pig sign detected along the San Diego River at Cedar Creek.

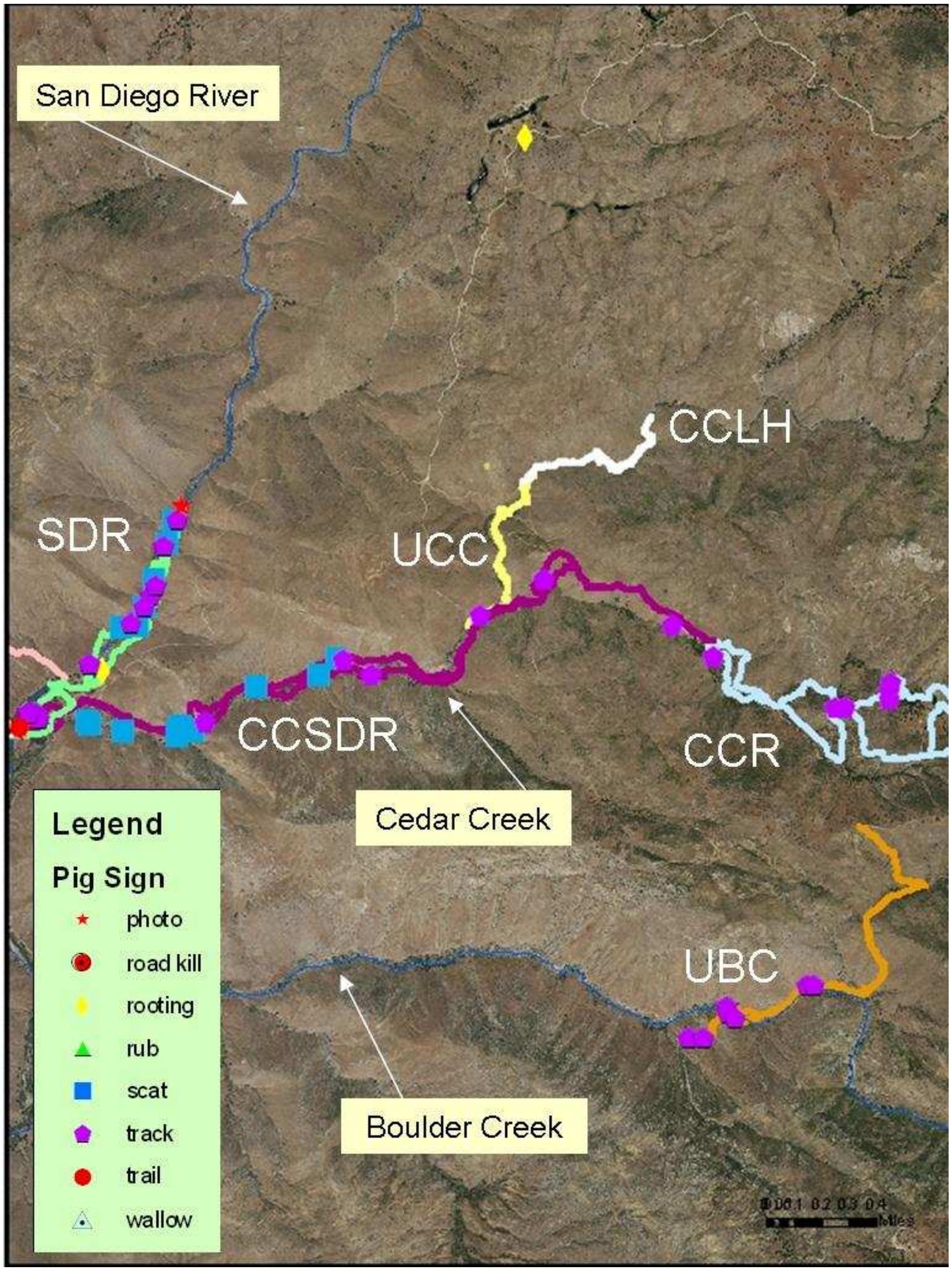

Figure A.13. Feral pig sign detected along the San Diego River and Cedar Creek.

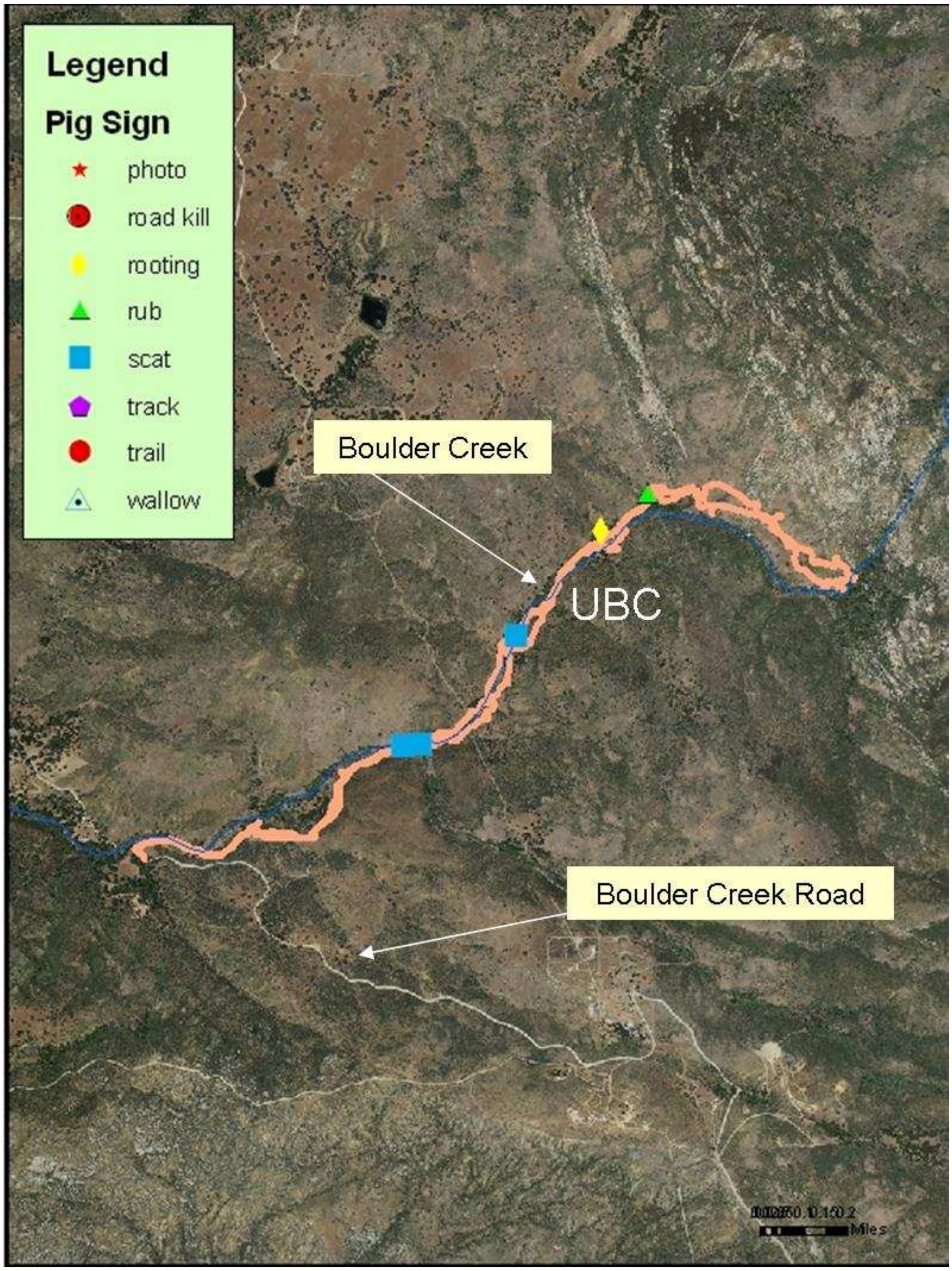

Figure A.14. Feral pig sign detected along upper Boulder Creek.

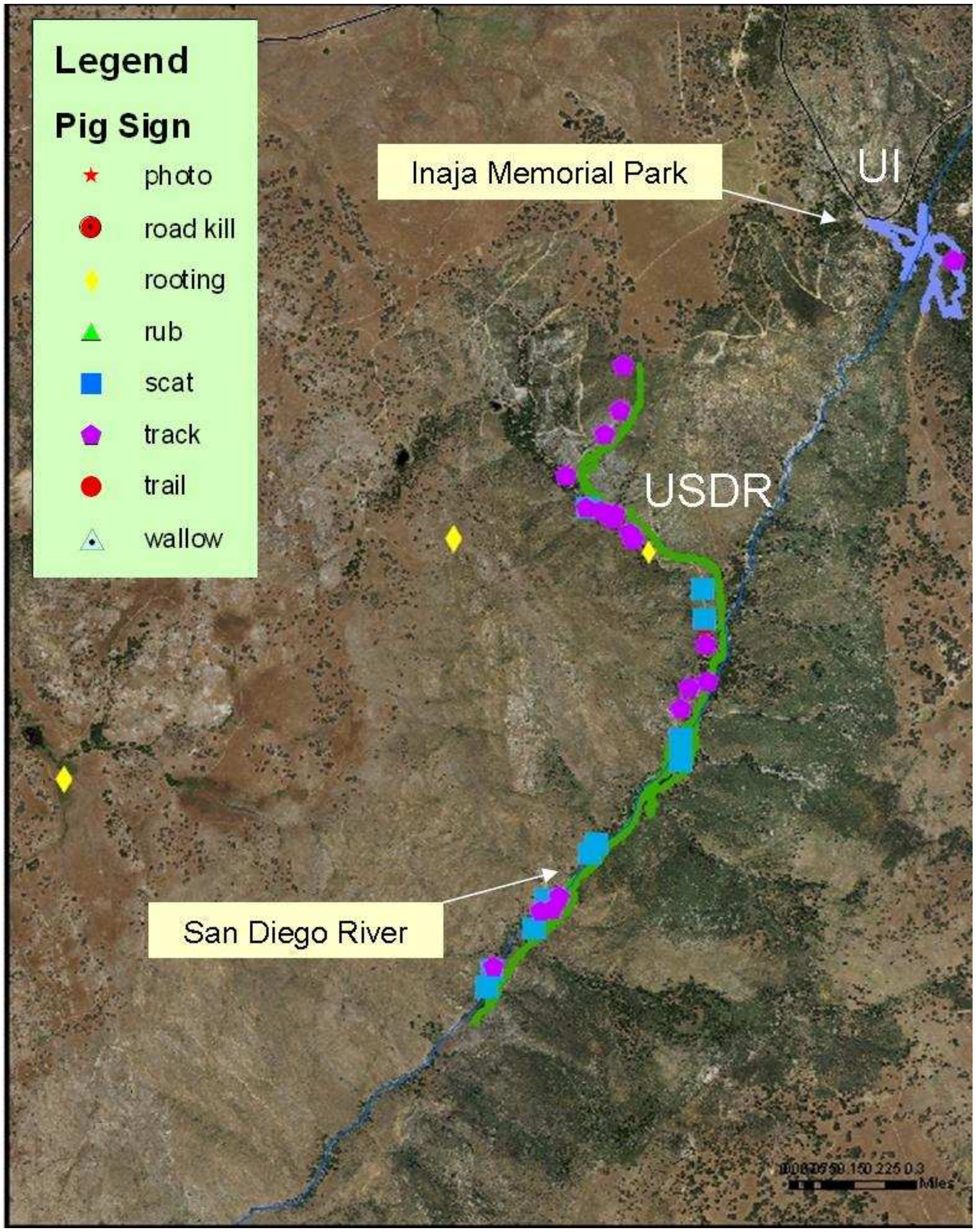

Figure A.15. Feral pig sign detected along the area of the upper San Diego River.

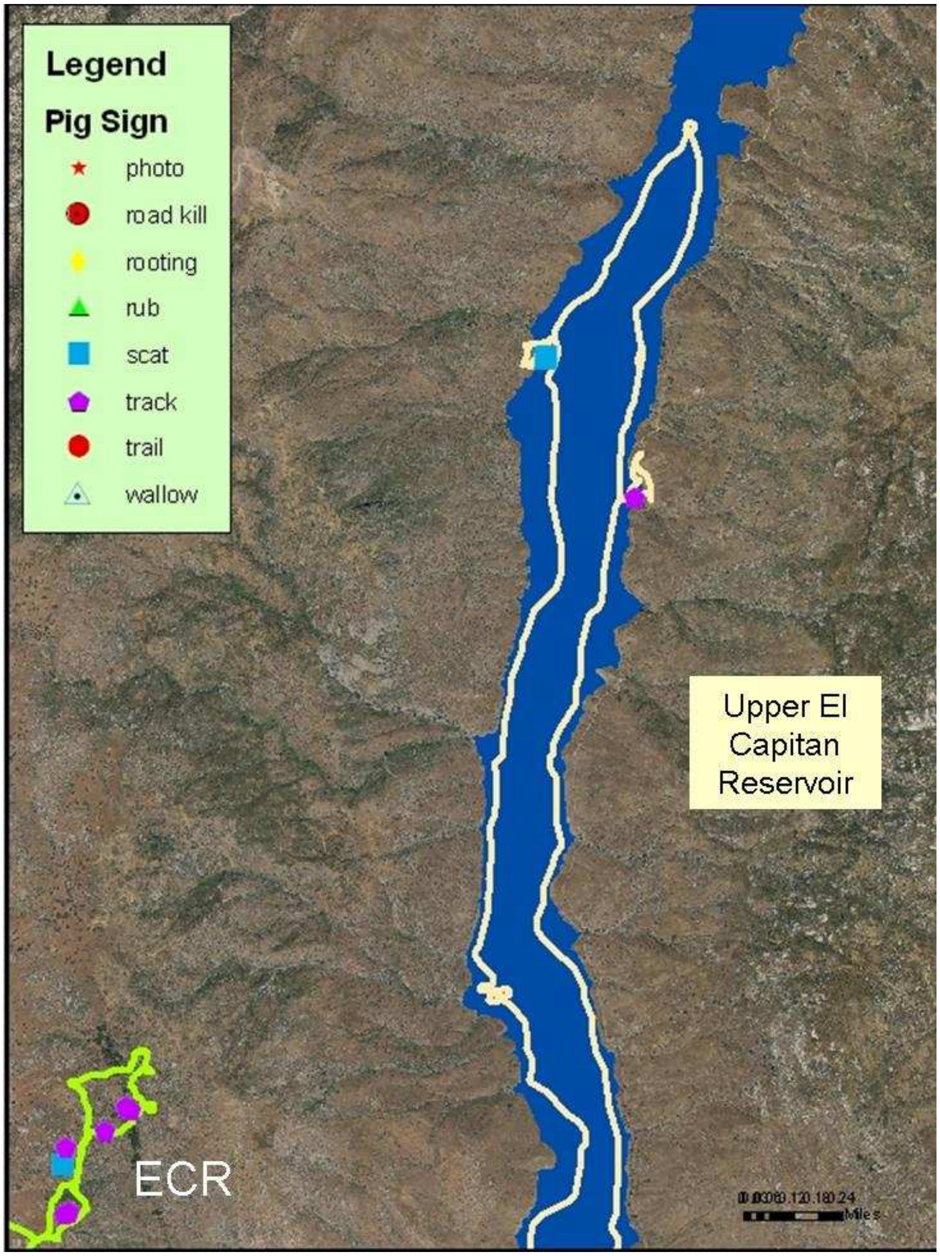

Figure A.16. Feral pig sign detected at the upper El Capitan Reservoir.