Resource Management Baseline Information Synthesis: Technical Support for Potential Climate Change Effects and Soil Inventory for Death Valley National Park
Final Report
Rocky Mountains Cooperative Ecosystem Studies Unit (RM-CESU)
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Introduction

This research project was initiated to support Death Valley National Park (DEVA) resource management by providing structured, summarized, and quality-controlled information on the following subjects identified by management staff as important to DEVA operations. Two general subject areas were addressed: the effects of climate change on individual species and the lack of a structured, usable soil inventory. Project objectives and justification are quoted here from the funding document.

> "Recent and predicted climate change will probably affect plant and animal species in DEVA, particularly on those near the edges of their habitat ranges. We need to estimate the nature and extent of these changes to plan management activities to adapt to or mitigate those changes, particularly for T and E species. As a first step we need to develop preliminary guidance for assessments of the effects of current and future climate change on important species. We will develop some preliminary projects that could be most efficiently implemented given the state of our data and that will meet our management objectives. Our primary data sources and project designs will be from local NPS technical and management staff. We will synthesize these concerns and available data into a scientifically-defensible study plan and/or preliminary results that can be used to solidify further proposals.
>
> There is also no ongoing soil survey program for DEVA and the NPS vegetation inventory is just beginning, though there are some data on both resources. For management to be more effective in dealing with current issues, we need interpretations from these existing but scattered data. Our objective is to synthesize existing information into the best possible inventory of soils and vegetation for DEVA. In cooperation with our specialists we will research current state of spatial soils and vegetation knowledge, including university research, agency work, NPS internal studies, and existing data in DEVA. Using these data, we will synthesize the best possible inventory subject to scientific and administrative criteria. Management interpretations will be provided subject to limitations of the resulting synthesis and the scope of this project.
>
> Both studies are preliminary in nature and their scope is limited by the funding level, which controls available time and materials. Within that funding level, relevant, applicable scientific literature will be reviewed, interviews with NPS specialists and management staff in the applicable fields will be conducted, and available information synthesized in a format usable by management. Analysis will be limited by available data.. Data limitations will be described, and appropriate interpretations made. Results will be based on existing data, with limited field review.
>
> This project may be extended depending on changing conditions and adequacy of findings. Not included in this scope of work are additional tasks needed to finalize recommendations, develop field designs, run field tests, or a more general literature search."

Methods

Six subject areas were developed in consultation with Park staff. They are all of immediate concern to Park management, have at least some existing data or date sources associated with them, and can be addressed, at least in a preliminary manner in a short time frame. They all utilize the landscape spatial information synthesized in Subject Area One below.

Subject Area One: Soil and Vegetation - Interim Development of Inventories for Management

Systematic and easily-accessed knowledge of the landscape of DEVA is critical to resource decision making. In many cases, understanding the components of the landscape (vegetation, topography, landforms, surficial materials, and soils) can make decision making more applicable and effective. At present, knowledge of that landscape is generally informal and contained in many different publications and locations. The purpose of this part of the project is to obtain all those sources and integrate as many as are feasible in the project time frame (eg. landforms, soils and surficial material, vegetation, and topography, and detailed digital aerial orthophotography from the National Agricultural Imagery Program (NAIP) from 2009). This integration is both spatial and tabular, with an emphasis on 1) quality of the data sources (based on internal consistency and ground truth via NAIP photography, 2) completeness of coverage (spatial data, attribute data, metadata, and geographic extent), 3) consistency of scale and detail, and 4) usability for interpretations. This "landscape model" will be used to make some preliminary interpretations and displays of resource values. It is designed to be preliminary, but can be improved with further work.

Subject Area Two: Rare plants on high elevation sites

Telescope Peak Bedstraw (Galium hypotrichium ssp. Tomentellum) is a very rare species associated with the highest elevations in the Park. It may be at risk for extinction if climate change eliminates its limited habitat. On-site investigations have provided some field data, and the landscape/soils model will be used to predict its present habitat.

Subject Area Three: Rare plants on low elevation, unstable dunes

Eureka Valley Dune grass (Swallenia alexandrae)and Eureka Valley evening primrose (Oenothera californica ssp. Eurekensis)are rare species that occur on unstable sand dune fields. It is apparently in decline on large dune fields, in particular on the Eureka Dunes. However, smaller, less accessible fields may have potential for refugia for the species. These smaller fields surrounding the larger, more accessible fields will be mapped using recent NAIP photography to provide potential sites for field review.

Subject Area Four: Potential invasive species increase on stabilized dunes

Tumbleweed or Russian Thistle (Salosla spp.) is an invasive species whose individuals tend to migrate to semi-stabilized sand dunes (characterized by a veneer of vegetation on a sand substrate and having generally low gradient slopes) that are also used by native species. Mapping these stabilized areas will provide a measure of its potential habitat. This will be limited to the Eureka and the Mesquite (Stovepipe) dunes, the major dune fields in the Park, using recent NAIP photography and slope models.

Subject Area Five: Fire Management

Climate change will probably influence vegetation patterns in the Park. Wildfire may be a strong influence in this change and parts of the Park have a potential for increased fire activity. Though spatial data for fire history exists, it has not been related to landscape parameters. A preliminary analysis will be made using the existing vegetation layers, a fire history layer, and elevation. This baseline is needed for planning purposes, in particular for the higher elevation juniper woodlands that have a strong potential for wildfire if precipitation patterns change.

Subject Area Six: Topographic effects on precipitation

In a highly moisture-limited environment, small changes in groundwater and runoff may strongly influence species in the Park. A climatically-related change in storm patterns (from the current winter storm dominance to a more "flashy" monsoonal effect) may change these parameters. Currently, precipitation patterns are modeled by elevation. It is apparent that aspect also influences these patterns since observations indicate a strong windward vs. leeward influence on vegetation. A weather station network is being planned to provide a better indication of these influences, and station locations should relate well to the aspect and elevation classes dominant in the Park. Hypsometric curves of elevation and aspect will be generated to help define the dominant aspect and elevation using a seamless 10m digital elevation model (DEM). Aspect, elevation, and slope will be spatially modeled to help select station locations.

Results

Subject Area One Results: Interim Development of Inventories for Management

A systematic, consistent model of those landscape parameters important to management is useful in answering geographic questions. For example, it can help answer the question "Where are resources that might be affected by climate change", rather than just "What resources might be affected?"

To address this need, a preliminary spatial model was developed from existing data. It consists of important landscape parameters (elevation, slope, aspect, soils, vegetation, landforms, surficial deposits, geology, and human features). The model exists as a series of coordinated layers in a GIS, with appropriate analytical products. Each layer was added only after it met certain geographic criteria (appropriateness of scale, presence of metadata, coincidence, and consistency with other layers). Additionally each layer met was modified if necessary for geographic projection, reviewed for quality relating to the ground, and coverage of the study area.

Ground truth was provided by a complete coverage of 2009 NAIP digital georegistered aerial photography (usable at 1:1200). Samples of each area were reviewed for reasonable accuracy and precision relating to NAIP imagery. This imagery is also a part of the landscape model, since it shows aspects of the landscape unclassified by the other components.

Each component is discussed below. “Usable scale” indicates the minimum geographic scale at which polygons fit reasonably well with the base ground truth (NAIP) and whose delineations and attributes reflect the complexity of the mapped resource.

Geology encompasses both the nature of surface rock as well as thicker surficial materials covering those rocks. A geologic layer was obtained from the U. S. Geological Survey (USGS). It is usable at 1:12000, and has more detailed delineations than those of the landform layer described below. It has extensive attributing, including formation name and age. However, there is little information as to the lithology (rock types) of the mapped formations, so is of limited use to landscape interpretations. Documentation on lithology is available, but only as text in various documents. An exception is for categories involving thick surficial materials. Information is given on depth of unconsolidated material, minerals present, and soil characteristics. Primary attributes for the spatial layer were only given in text form in PDF format (not attached to the layer). These attributes were extracted from MS WORD documents provided by the authors to a database for use in joining with the spatial data. Coverage of DEVA is about 90%, missing the NE portion of the Park.

Landforms (geomorphology) describe not only the slope and form of the landscape, but what kinds of surficial materials are present. A landform/geology layer was obtained from MDEI (the Mojave Desert Ecosystem Initiative). It is usable at a scale of 1:24000. This was used for a base landscape layer. It has good coincidence with ground control, though variable near surficial deposits. Attributes include rock types (lithology), but limited information on geologic formation names. The geology layer described above should be used if this kind of detail is needed. In addition, a previously completed mapping project on the Eureka dunes was compared to dunes mapped on the landform layer. Coincidence was quite good, considering the dunes project was on a scale of 1:3,000.

Because of these layer differences, a combined layer was created using surficial material information from both layers, and geologic information from the landform layer to provide the optimal information about the nature of the landscape. Coincidence of polygons is adequate for this project, but could benefit from some editing.

Soils influence many land use decisions. However, only a limited amount of direct soil information is available. See Figure 1 for the extent of detailed soil surveys. A general soil map was obtained for the area (Figure 1, dark blue) from the Natural Resources Conservation Service (NRCS) , and is useful in resource evaluations involving the entire Park, but is not completely attributed. Light blue indicates detailed surveys on the boundaries of the Park. Pink indicates a small detailed soils report done in 2002 (Hunter Mountain Soils). There are also a small survey of the native American reservation inholding and scattered soils descriptions completed by the USGS and the University of Los Vegas. Until a detailed soil survey is completed, I recommend using the landscape model with expert interpretation to infer soil properties for project-level work.

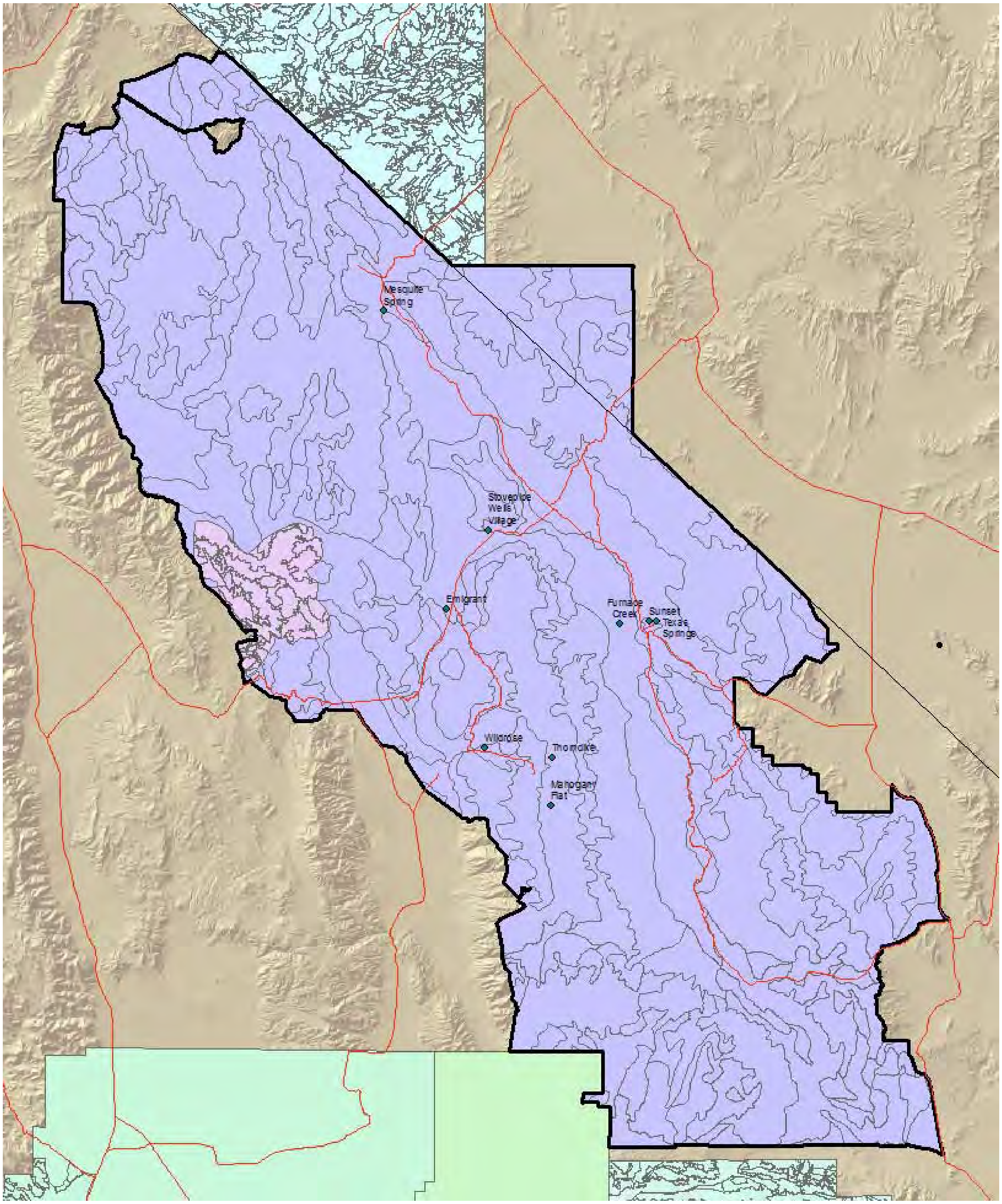


Figure 1. Status of Soil Surveys for Death Valley National Park (1:800,000).

Vegetation information is available at a usable scale of 1:24000. It was also obtained from the Mojave Desert Ecosystem Initiative (MDEI). Figure 2 shows the general vegetation groups in the Park, though much more detail is available through attributes. See Table 1 for the available detail, and Table 2 for extent of the generalized groups. It was judged to be adequate for use through ground control (NAIP), for general vegetation form and presence/absence of ground cover. The layer was made more usable by dissolving polygons on a data quality field where that field was the only variable. Coverage is about 90%.

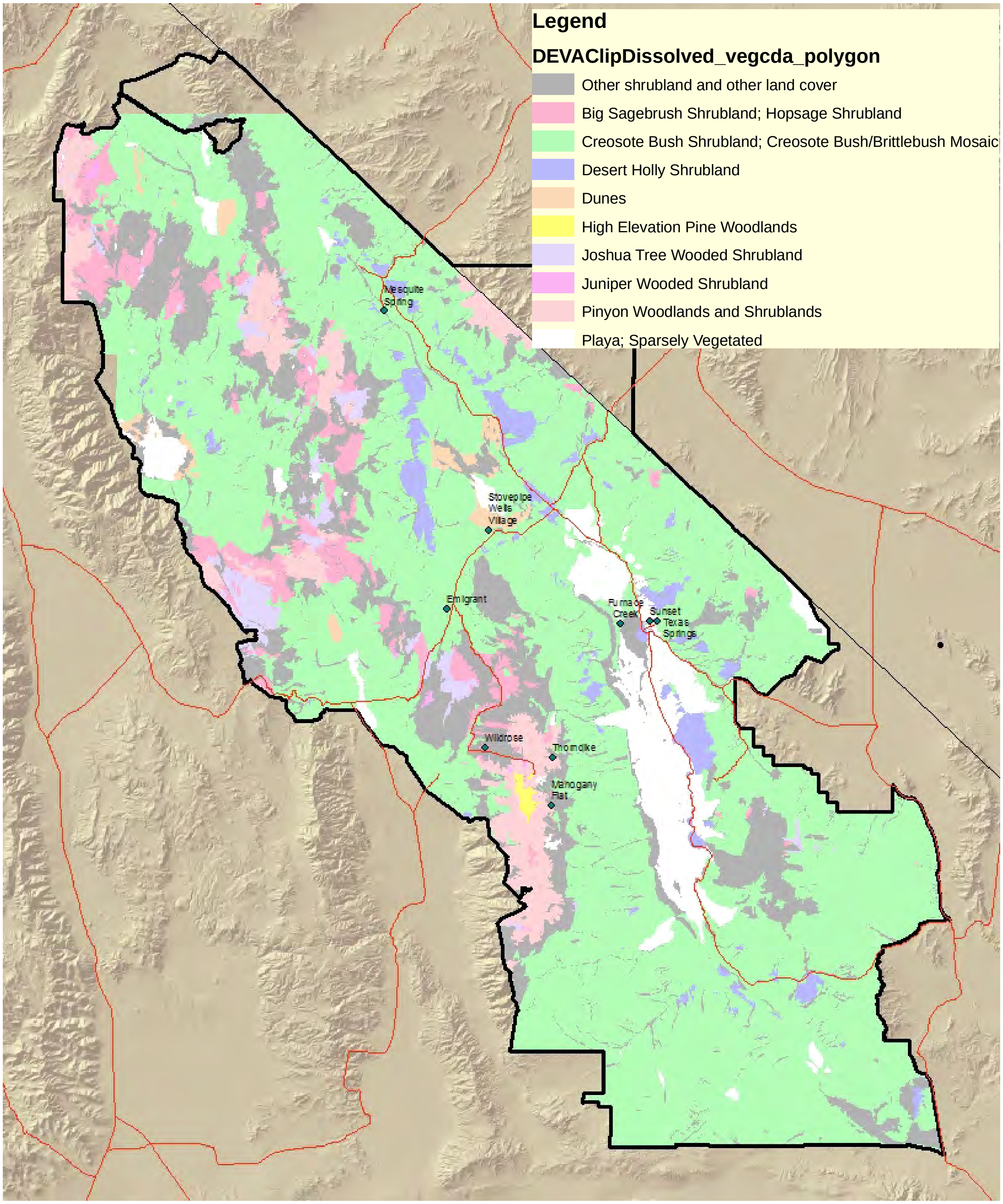


Figure 2. Generalized Vegetation of Death Valley National Park (1:800,000).

Table 1. Vegetation (Land_Cover) and Elevation

LAND_COVER	Area (ha)	MIN_Elevation (m)	MAX_Elevation (m)	RANGE_Elevation (m)	MEAN_Elevation (m)	STD_Elevation (m)	MEDIAN_ Elevation (m)
No data	46,243	347	2,661	2,314	1,408	366	1,355
Big Sagebrush Shrubland	30,748	574	3,045	2,471	1,805	226	1,834
Blackbrush Shrubland	84,980	(73)	2,482	2,555	1,561	292	1,606
Creosote Bush Shrubland	822,411	(83)	2,520	2,603	803	458	848
Mid Elevation Wash System	5,875	737	1,954	1,217	1,203	166	1,195
Pinyon Woodlands and Shrublands	60,073	1,200	3,188	1,988	2,122	244	2,116
Saltgrass	756	(81)	(62)	19	(78)	3	(79)
Dunes	11,560	(24)	1,406	1,430	318	389	26
Galleta Grasslands	130	1,627	2,232	605	1,976	164	2,033
High Elevation Wash System	2,516	1,090	2,584	1,494	1,664	186	1,647
Low Elevation Wash System	20,130	(65)	1,538	1,603	486	309	496
Nevada Joint-fir Shrubland	12,463	907	2,448	1,541	1,606	275	1,574
Desert Holly Shrubland	36,805	(83)	1,711	1,794	440	319	417
Hopsage Shrubland	23,443	943	2,088	1,145	1,574	119	1,571
Joshua Tree Wooded Shrubland	20,899	1,179	2,645	1,466	1,767	250	1,733
Creosote Bush/Brittlebush Mosaic	3,929	(81)	1,761	1,842	464	473	353
Iodine Bush-Bush Seepweed Complex	9,465	(83)	956	1,039	(25)	100	(74)
Juniper Wooded Shrubland	1,164	1,373	2,451	1,078	1,795	206	1,842
Lava Beds and Cinder Cones	641	(59)	1,923	1,982	1,125	437	858
Mesquite Shrublands	6,829	(82)	570	652	111	176	35
Playa	34,229	(85)	1,742	1,827	132	344	(78)
Rural Development	463	(77)	1,319	1,396	714	560	1,104
Shadscale Shrubland	48,549	705	2,520	1,815	1,504	228	1,496
High Elevation Pine Woodlands	1,718	1,824	3,368	1,544	2,726	269	2,737
Menodora Shrubland	1,145	1,502	1,934	432	1,725	86	1,708
Mining	656	(83)	1,820	1,903	1,020	516	720
Mojave Yucca Shrubland	11	1,095	1,234	139	1,172	36	1,174
Saltbush Complex	3,466	(80)	1,912	1,992	423	512	127

Sparsely Vegetated	47,163	(84)	2,669	2,753	211	438	2
White Burrobush Shrubland	13,277	130	2,045	1,915	1,208	440	1,304
Urban	45	(54)	92	146	1	45	(15)
Total:	1,351,781						

Table 2. Generalized Vegetation Groups Areal Extent

Generalized Vegetation Group	Area (ha)
Other shrubland and other land cover	257,639
Big Sagebrush Shrubland; Hopsage Shrubland	54,191
Creosote Bush Shrubland; Creosote Bush/BrittleBrush Mosaic	826,340
Desert Holly Shrubland	36,805
Dunes	11,560
High Elevation Pine Woodlands	1,718
Joshua Tree Wooded Shrubland	20,899
Juniper Wooded Shrubland	1,164
Pinyon Woodlands and Shrublands	60,073
Playa; Sparsely Vegetated	81,392
Total	1,351,781

Few lines of the above described polygon layers are completely coincident. Adjusting these lines to fit landscape boundaries is beyond the scope of this project. However, for the subject area analyses described below coincidence was adequate or was removed by symbology modification or classification. Autocorrelation may be present, but was not reviewed here, pending more information on the development of the layers.

Human features were obtained from the USGS and DEVA. Roads from the USGS were adequately georeferenced at 1:12,000. Campgrounds and developed areas were less precise, and could only be used at scales smaller than 1:100,000. Better information on local developed areas was available from the vegetation layer.

Slope, aspect, and elevation were obtained from DEVA (at 10 m resolution) and compared with independently-downloaded elevation data, as well as NAIP. Errors on the elevation model occur on gently-sloping areas as reflected in the derived hillshade layer, but appear to be restricted to small elevation changes. The 10 meter DEM (Digital Elevation Model) was clipped to the Park boundary and used for all computations. For context and small scale display, a hillshade was made from a 30 m resolution DEM downloaded for the area surrounding the Park.

The preliminary landscape model consists of the geographic union of the landform, vegetation, and geology (surficial materials only) overlaid on slope, aspect, and elevation models, and supplemented by detailed aerial imagery and cultural feature data. See Figure 3 for coverage. Through use of geoprocessing tools, the various layers can be combined where needed to determine landscape features important to management and science. For example, Table 1 has elevation statistics (in m) for vegetation types calculated from an overlay of elevation on vegetation type (using the field Land_Cover).

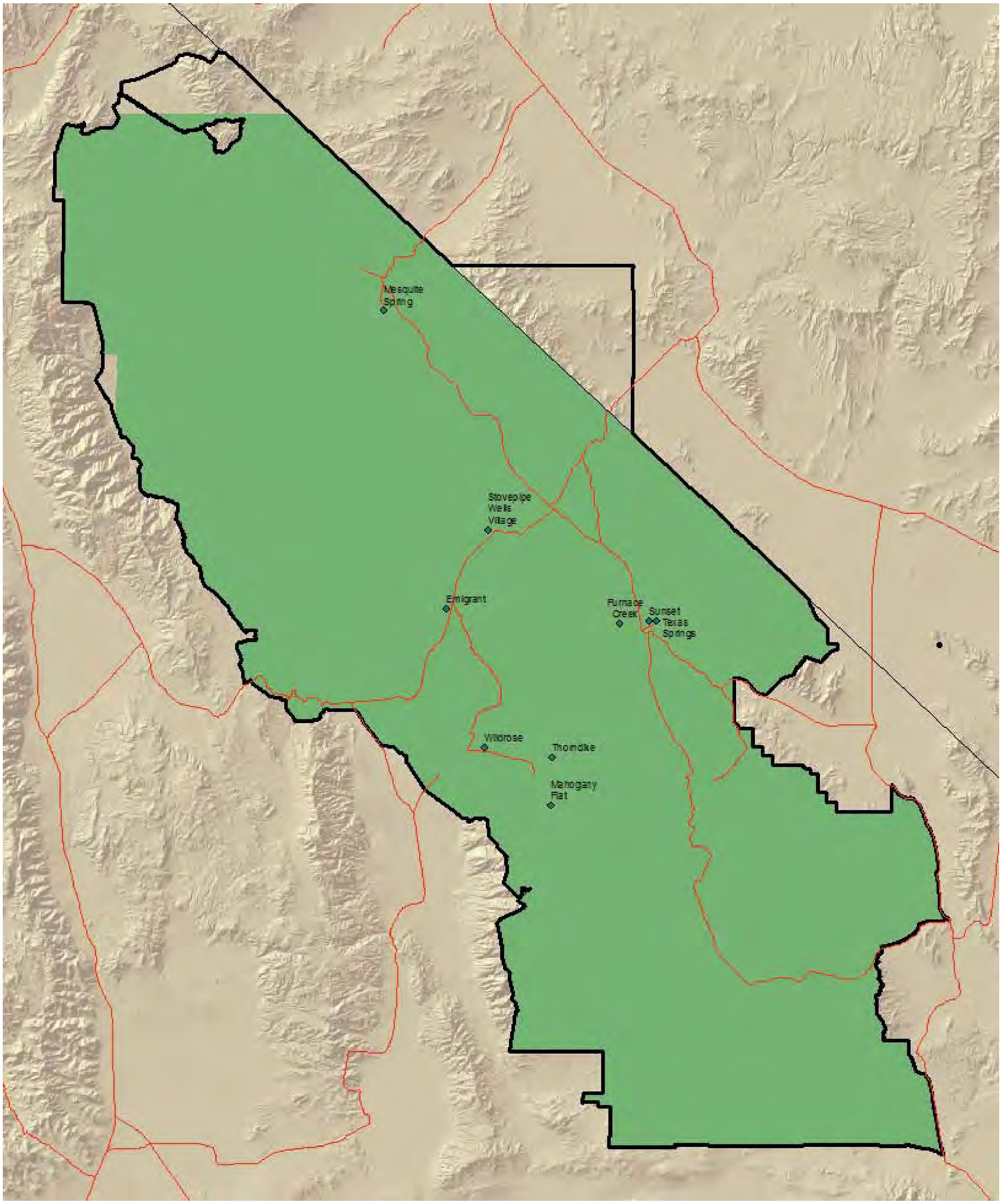


Figure 3. Coverage of the Landscape Model (1:800,000)

The subject areas described below are examples of uses of the landscape model. This model, used with due concern for its limitations, has a high potential for the integration and display of the resources and management opportunities in DEVA. The landscape model is projected in UTM zone 11, NAD1983. Some layers were adjusted for datum shift between NAD 1927 and NAD 1983 to improve fit. The datum of NAD 1983 and WGS 1984 were concluded to be equivalent, so no transformation was made between layers having these datums.

Subject Area Two Results: Rare plants on high elevation sites: Telescope Peak Bedstraw (Galium hypotrichium ssp. Tomentellum)

This analysis is primarily based on the DEVAFLORA species database, a field investigation by Favero and Hibbard in 2010 (Appendix One), and the landscape model described above. These sources were used to determine spatial parameters for potential habitat.

The DEVAFLORA species database shows eight observations, all on Telescope Peak. Favero and Hibbard's survey area was limited to the Telescope Peak ridgetop between 2939 m and 3368 m, and the lone found specimen was unexpectedly somewhat off the ridge at 3170 m in calcareous scree on a western slope. The landscape model was used to spatially locate potential habitat that fits these parameters.

The analysis was park-wide in scope, but narrowed down to the area in Figure 4 by elevation (> 3170 m).

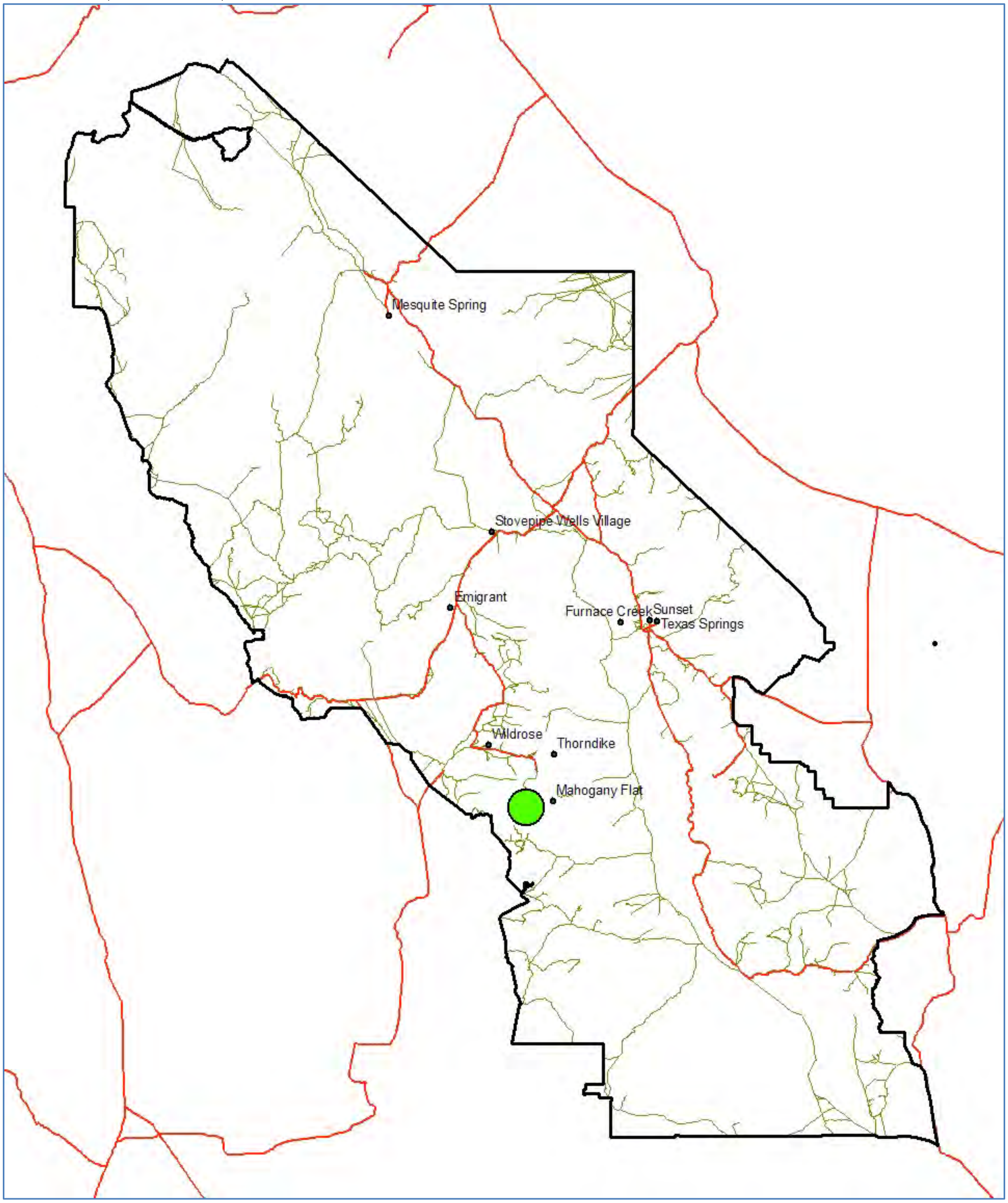


Figure 4. Telescope Peak Study Area Location

Two areas meeting the elevation criterion were found both near Telescope Peak. Further study was limited to this area. Areas of scree in calcareous material were delineated at a scale of

1:1,800 using NAIP color infrared imagery. See Figure 5 for an example. The red line is the 3170 m elevation limit. Only areas not under forest canopy were selected, based on ground images by Favero and Hibbard.

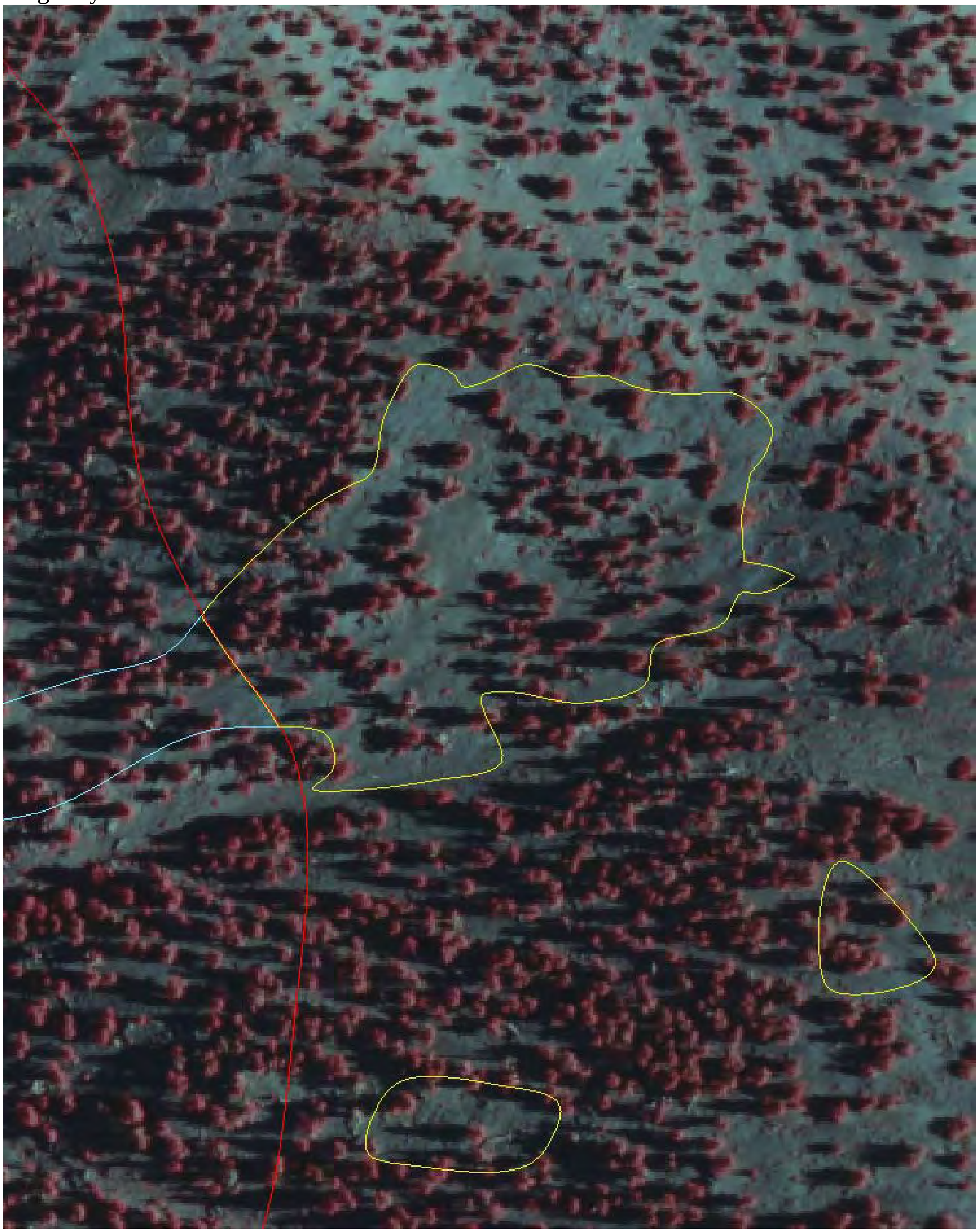


Figure 5. Closeup of Scree Delineation (scale 1:1,800)

Scree was delineated down to an elevation of about 3000 m to provide context. Figure 6 shows the total area of potential habitat. Total is 25.7 ha, with 6.2 ha above the 3170 m boundary. Yellow is habitat above the 3170 m elevation and blue is habitat down to about 3000 m. The green marker is Telescope Peak and the red marker is the site of the specimen found by Favero and Hibbard. Note the potential on a peak south of the Telescope Peak area.

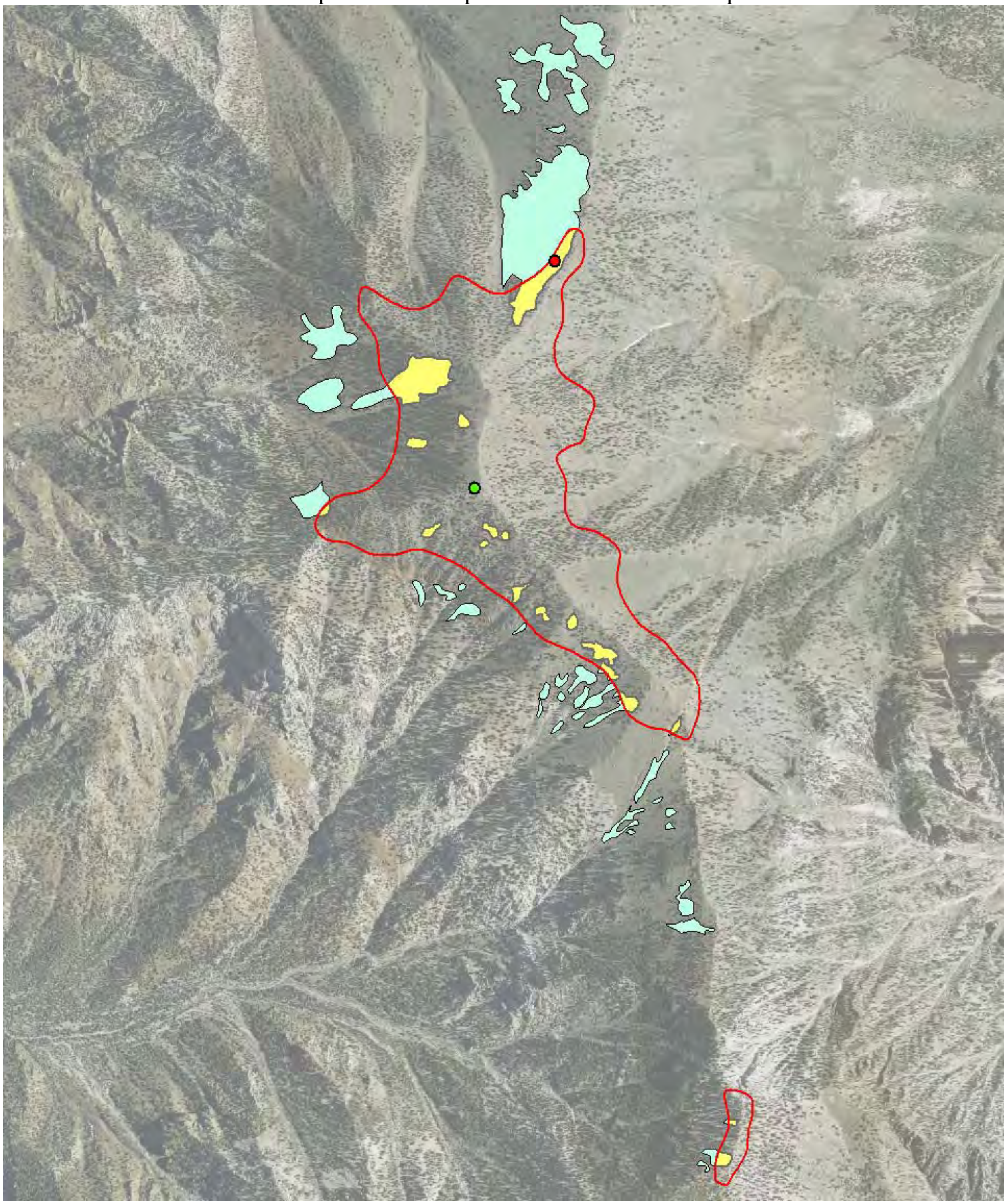


Figure 6. Telescope Peak Study Area Potential Habitat (Scale ca. 1:15,000)

Figure 7 shows the landscape context of the analysis obtained from other aspects of the landscape model. The crosshatch indicates either limestone or dolomite bedrock, supporting the delineation of "calcareous" scree. The single hatch indicates granitic rocks. The vegetation type is shown with green indicating "high elevation pine woodlands", and pink indicating "pinyon pine woodlands and shrublands". The slope model reports all slopes are 45 to 100 percent.

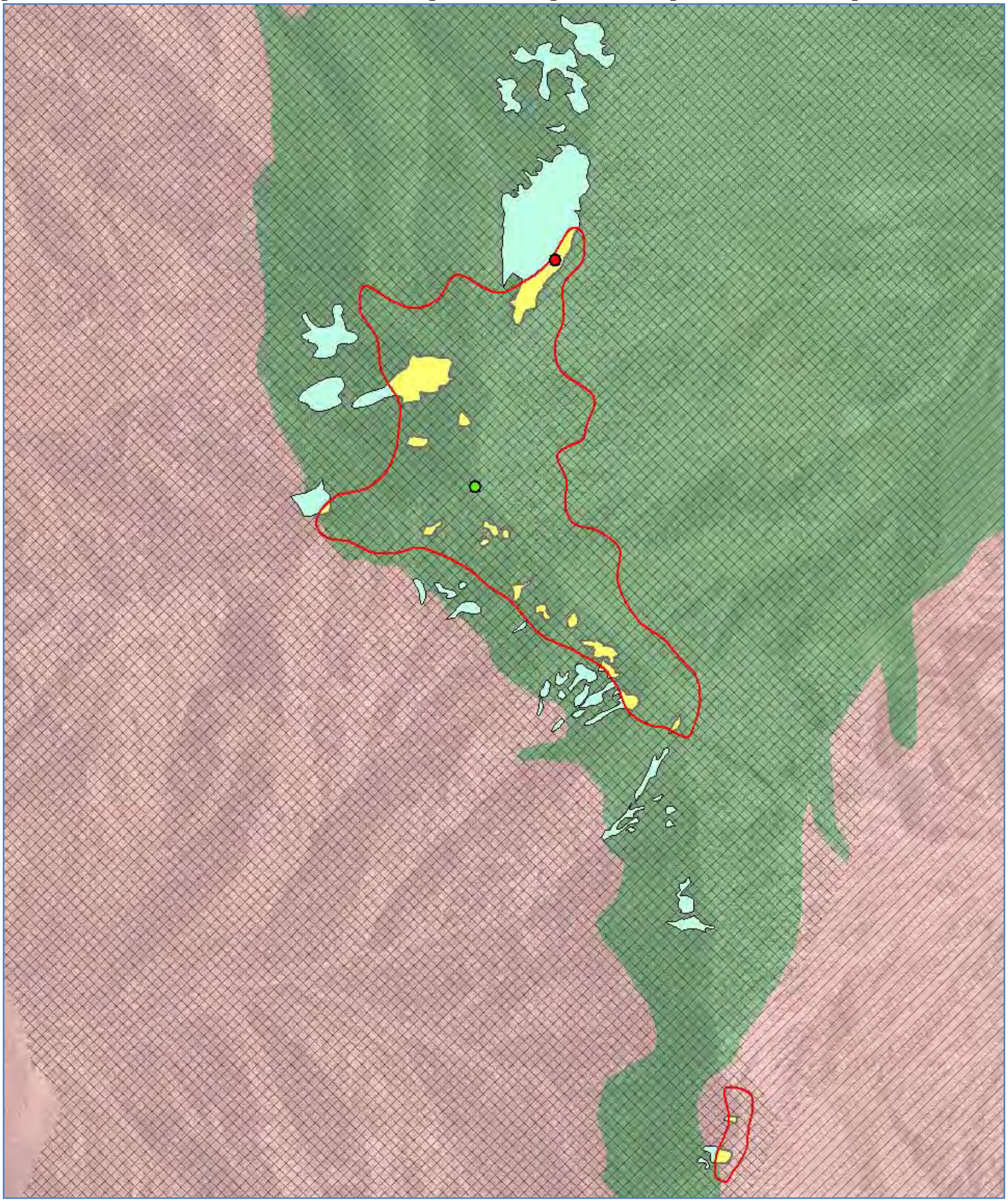


Figure 7. Telescope Peak Study Area Potential Habitat Landscapes (Scale ca. 1:15,000)

This analysis can support this species' management by showing the probable maximum habitat range and its landscape context, and helping to focus searches for specimens on areas of high potential, since both elevation and slope are highly limiting. Since georeferenced pdf files of these figures are provided with these projects, field excursions can be made more efficient by using the maps to select locations to visit and verify locations in the field.

Subject Area Three and Four Results: Rare plants on low elevation, unstable dunes and potential invasive species on stabilized dunes.

Both subjects were addressed by one project activity so are combined here. In a previous study, extent of the Eureka dune area (Marble, Saline, and Main fields) was mapped in detail using 2009 NAIP photography and a slope model (Figure 8).

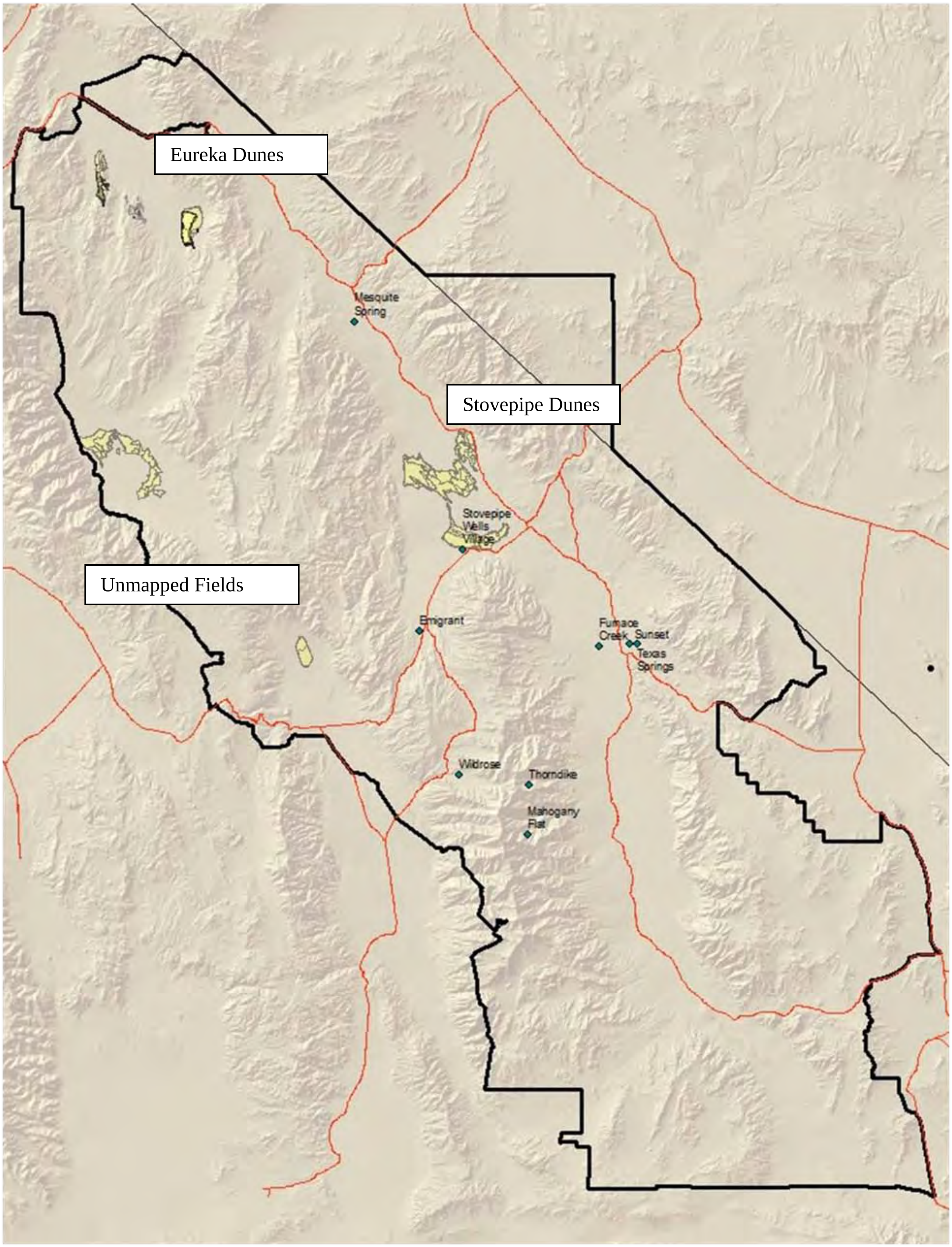


Figure 8. Location Of Dune Fields (1:800,000)

Only relatively contiguous polygons were mapped. That project's objectives included mapping of rare species (Eureka Valley Dune grass (Swallenia alexandrae) for two imagery dates. Though shrubs were visible, this grass was not visible at the provided image resolution (1 m). However, other data show that this species is probably in decline. Those central fields are subject to disturbance and invasive species, which may exacerbate their decline. Therefore, the search area for these three fields was expanded about 1200 m from the mapped boundaries to catch potential small, isolated fields that may provide refugia for this species (Figure 9)

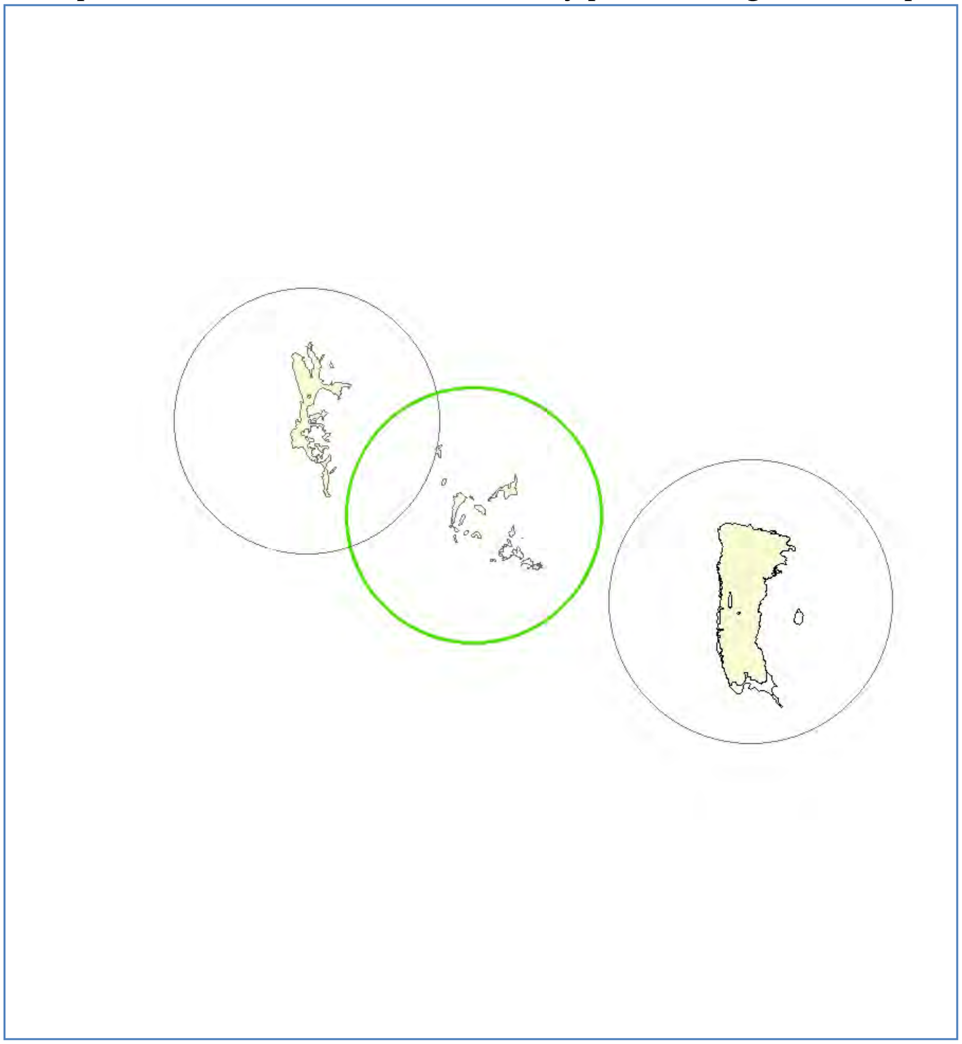


Figure 9. Search Areas for Additional Dune Refugia (1:250,000) Right to Left: Marble, Saline, Main fields

Areas were mapped at a scale of 1:3,000 using both color infrared and natural color NAIP imagery and a slope model. As in the previous study, recognition of dunes included slope distribution, lack of continuous vegetation, color signature, and topographic position. Results are shown in Figures 10, 11, and 12.

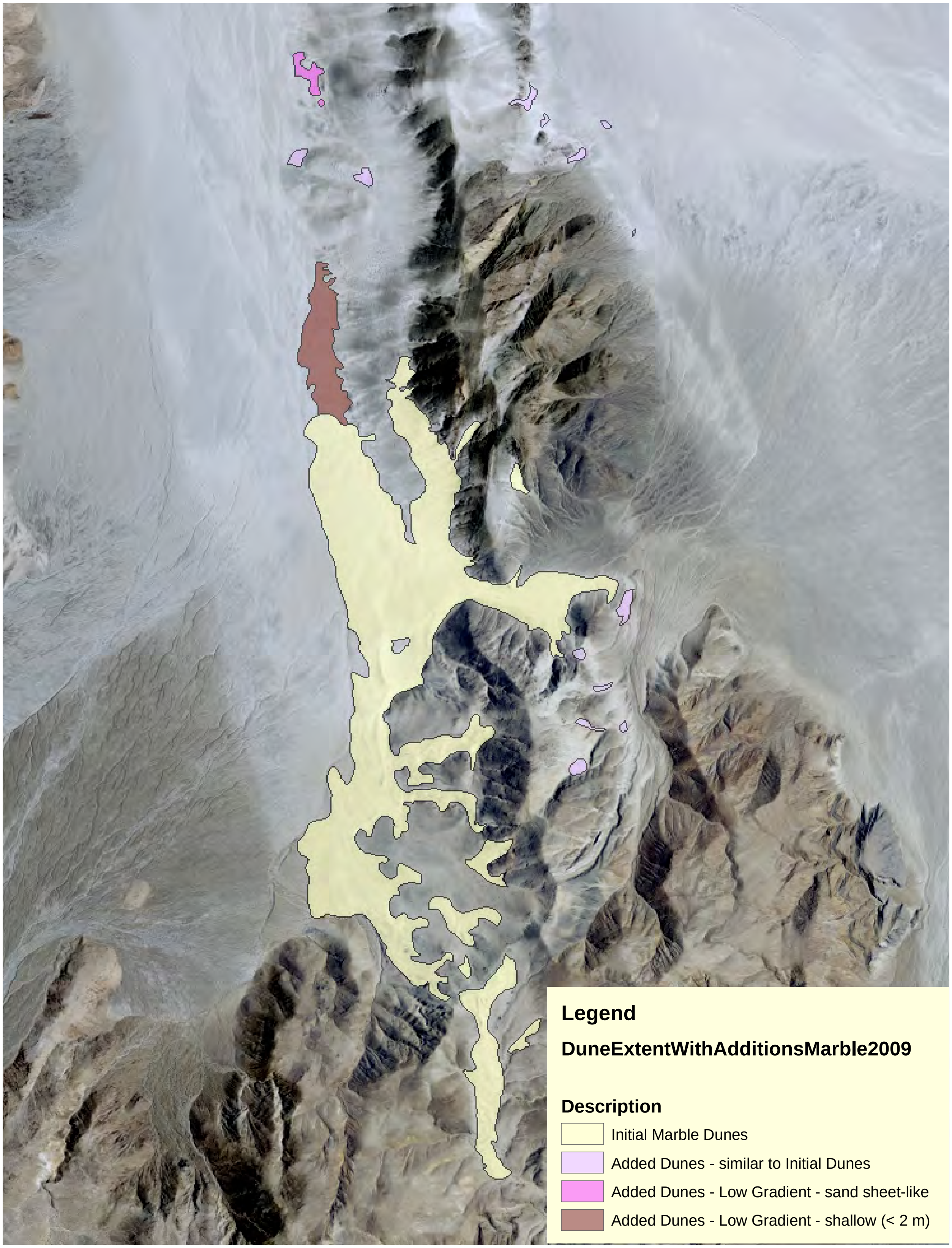


Figure 10. Marble Dune Mapping (1:30,000)

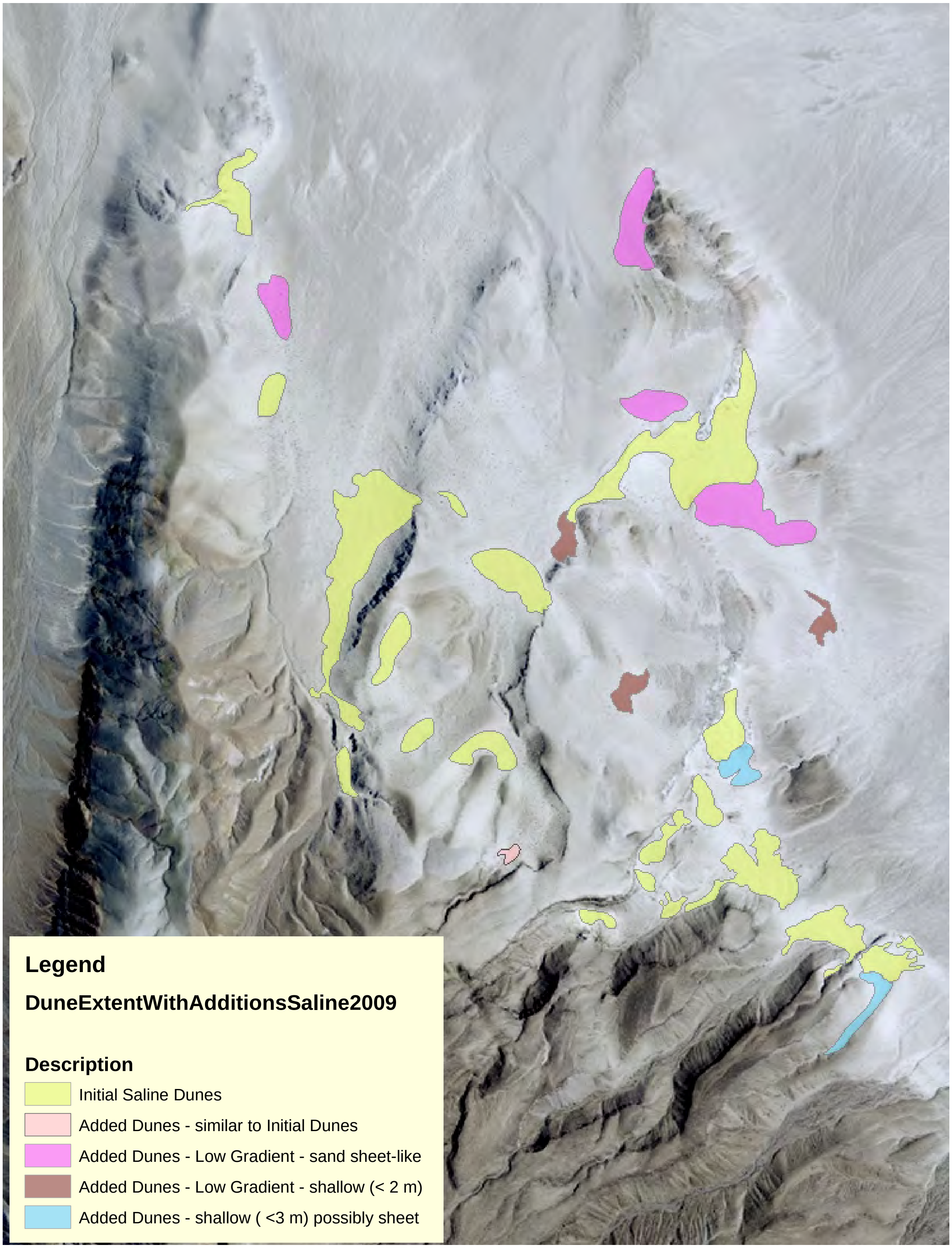


Figure 11. Saline Dune Mapping (1:24,000)

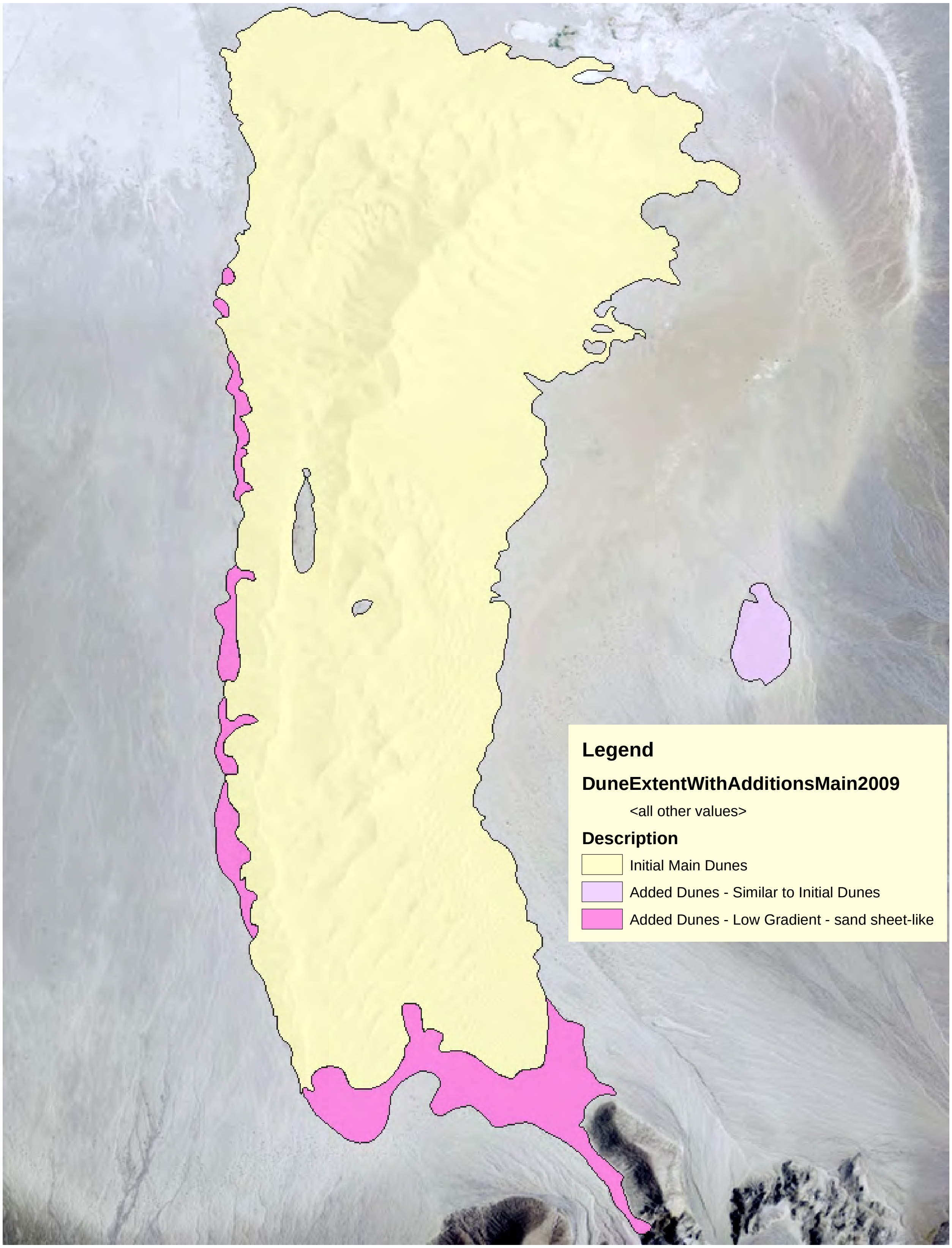


Figure 12. Main Dune Mapping (1:24,000)

Table 3 has areal summaries by dune type. In all three fields the added dunes having primarily low slope gradients are probably shallow. In some cases, they appear more as sand sheets with little dune character. None have a significant veneer of vegetation. However, some small dune added dune areas are relatively isolated by topography, particularly in Saline and Marble. One larger dune area occurs apart from the larger Main dune field, but may be near a road.

Table 3. Area Summary of Eureka Dunes

Marble Summary	
Description	**Ha**
Added Dunes	7.0
Added Dunes - Low Gradient - sand sheet-like	2.3
Added Dunes - Low Gradient - shallow (< 2 m)	17.1
Initial Marble Dunes	246.9
Total	273.3
Saline Summary	
Description	**Ha**
Added Dunes	0.5
Added Dunes - Low Gradient - sand sheet-like	23.5
Added Dunes - Low Gradient - shallow (< 2 m)	5.7
Added Dunes - shallow (<3 m) possibly sheet	5.4
Initial Saline Dunes	96.9
Total	132
Main Summary	
Description	**Ha**
Added Dunes	10.7
Added Dunes - Low Gradient - sand sheet-like	66.7
Initial Main Dunes	810.6
Total	888

Dunes that are stabilized by vegetation may be a source of invasive species. This was not mapped in the Eureka dunes, because a reliable signature using the criteria above could not be developed, ie, dunes were, by definition, mostly barren of vegetation. More ground truth will be needed to map these areas in the Eureka fields.

This was also true for the Stovepipe dunes (Figure 8). The lack of ground truth made it unfeasible to map stabilized areas, and this project did not include detailed mapping of the dunes themselves. However, the landscape model provided at least some data from a presumably ground-truthed publication, and was used to estimate possible stabilized dune fields. At a scale of 1:3,000 using NAIP imagery, the mapped dune fields appear relatively vegetation-free. The mapping of sand sheets included a variety of vegetation types, so are apparently more stable than the dunes themselves. Mesquite shrublands appear to be the most stable of those sand sheet vegetation types (Figure 13).

The landscape model provided information on sand dunes, sand sheets, and associated vegetation. The query used for sandsheets, dune fields, and a presumably stable vegetation type are as follows: [LF_LEVEL3] = 'Sand Sheet'; ([LF_LEVEL3] = 'Dune Field' OR [LAND_COVER] = 'Dunes') and [LF_LEVEL3] <> 'Sand Sheet'; and [LF_LEVEL3] = 'Sand Sheet' AND [LAND_COVER] = 'Mesquite Shrublands'.

Figure 13. Sand sheets (cross hatch) and Mesquite Vegetation (green).

The queries described above provided the following results (Figure 14). Total dune area is 9,053 Ha, total sand sheet area is 6,632 Ha, and of that, Mesquite shrubland is 244 Ha. These relatively-stable areas still have a probable sandy-substrate, and may be good areas to review for presence of invasive species.

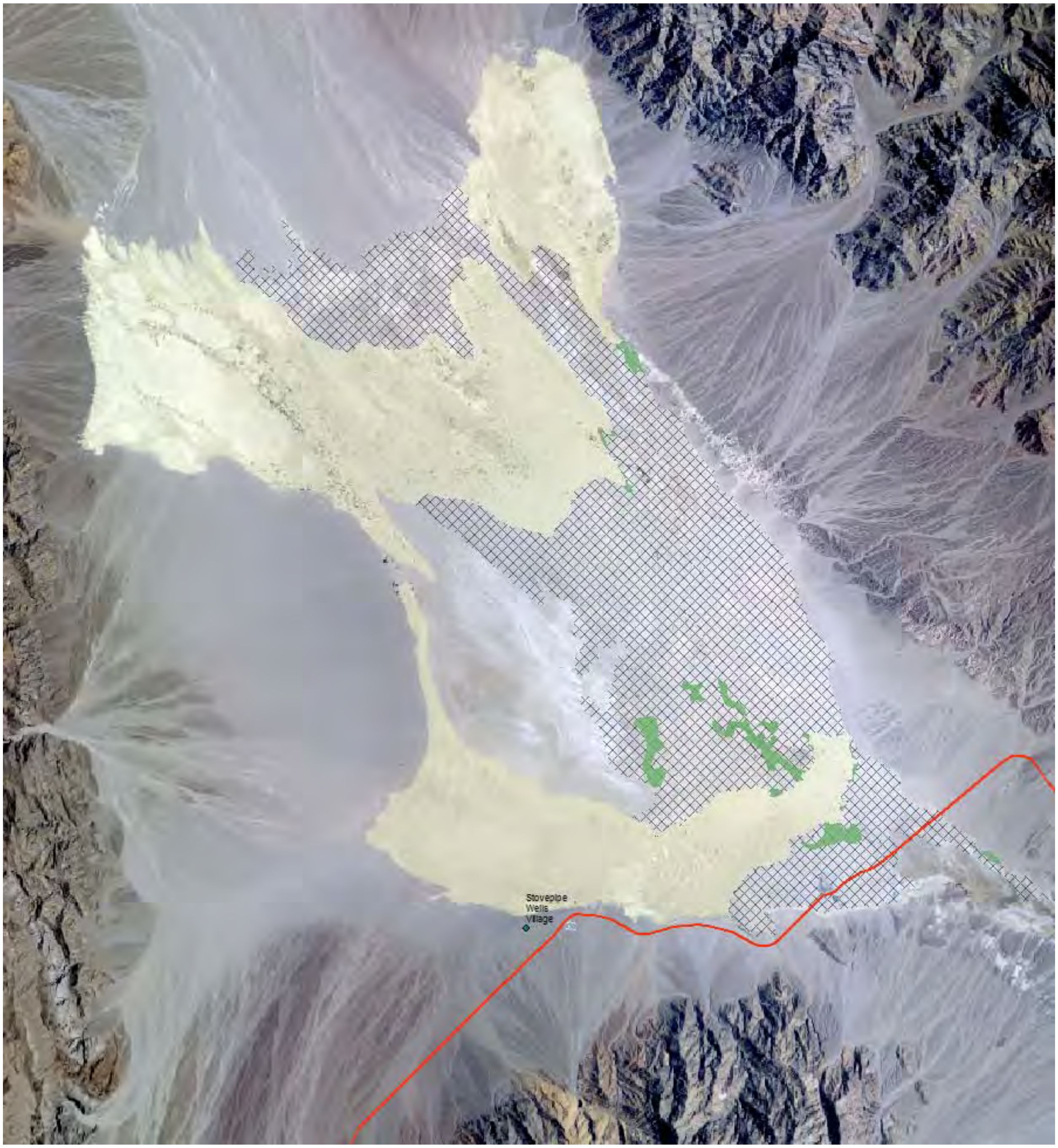
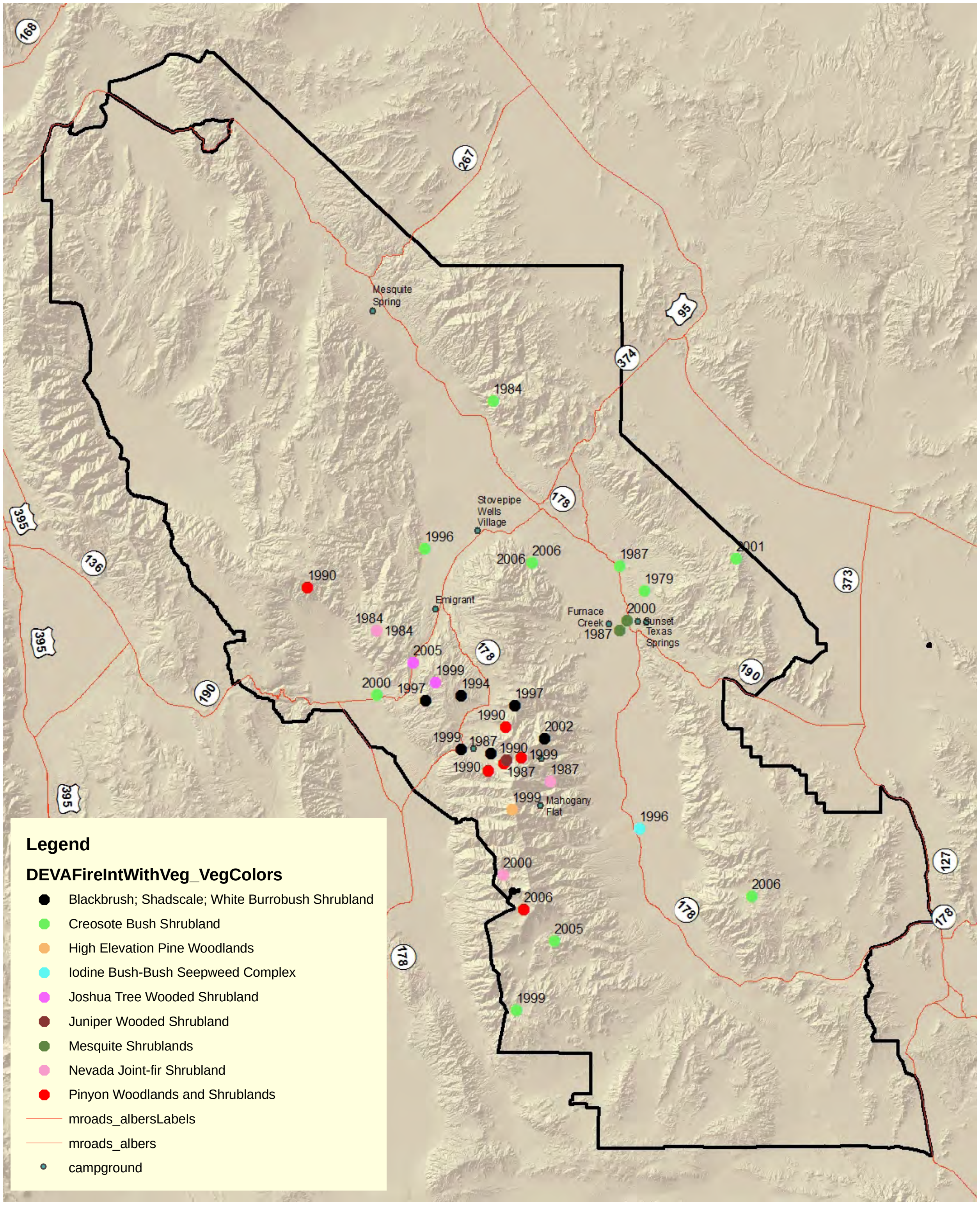


Figure 14. Stovepipe Dunes (yellow), Sand Sheets (cross hatch), and Relatively Stable Areas (green) (1:100,000).

Subject Area Five Results: Fire Management

Vegetation patterns in the Park (Figure 2), elevation, aspect, location and human use all influence wildfire occurrence. And, as climate change occurs, their characteristics and locations may change. To begin a systematic evaluation of wildfires and their landscape context, a point layer of wildfire occurrence was obtained from DEVA. This layer contained 55 points of which 35 were determined to have valid geography and geometry and were within DEVA boundaries. The remainder lacked location, elevation, and size data (16 points) or were outside DEVA boundaries (4 points). The date range of the data is 1979 to 2006. The 35 points are not numerous enough for statistical analysis, and they are probably not a random sample of fires in DEVA. They probably represent only those having a significant size and those that required suppression or monitoring resources. They also represent only those that have been input to the database, so later fires are probably over-represented. However, when used with the landscape model they can provide a general picture about the present and historical situation.

These point locations were intersected with vegetation (the Land_Cover field) from the landscape model (Figure 15). Recognizing data limitations, some apparent patterns are still recognizable. It's apparent that most wildfires occur clustered around Telescope Peak. Given this is not because detection is concentrated there, it may be due to the presence of burnable vegetation, lightning, and steeper slopes. These fires also tend to occur in woodland vegetation (either pinyon, juniper, or high elevation pine woodlands rather than in brushland or shrubland).



Mesquite Spring
Stovepipe Wells Village
Emigrant
Furnace Creek
Sunset
Texas Springs
Mahogany Flat
Legend
DEVAFireIntWithVeg_VegColors
Blackbrush; Shadscale; White Burrobush Shrubland
Creosote Bush Shrubland
High Elevation Pine Woodlands
Iodine Bush-Bush Seepweed Complex
Joshua Tree Wooded Shrubland
Juniper Wooded Shrubland
Mesquite Shrublands
Nevada Joint-fir Shrubland
Pinyon Woodlands and Shrublands
mroads_albersLabels
mroads_albers
campground

As climate changes, patterns of vegetation at risk may also change. Given some form of climate change has been occurring in the last 20 years, some generalized patterns appear. Table 4 shows fire locations, size class, and elevation, sorted by date. Classes are assumed to be from standard wildfire definitions (Class A - one-fourth acre or less; Class B - more than one-fourth acre, but less than 10 acres; Class C - 10 acres or more, but less than 100 acres; Class D - 100 acres or more, but less than 300 acres; Class E - 300 acres or more, but less than 1,000 acres; Class F - 1,000 acres or more, but less than 5,000 acres; Class G - 5,000 acres or more). Elevation ranges given for the classes are not known, but it is apparent the lower numbers are lower elevations.

Grouping by size class shows that from 1990 to 1999 (10 years), there were 14 wildfires (an average of 1.4 per year), with 9 in Class A, 3 in B, 1 in C, and 1 in D. For the 6 year period from 2000 to 2006 there were 12 fires (averaging 1.7 fires per year), with 4 in Class A, 1 in B, 1 in C, 1 in D, 2 in E, 1 in F, and 2 in G. It is apparent that the fire frequency is increasing, as well as size class. Of course, this must be tempered with knowledge of changes in detection efficiency and variations in weather, but these are not considered here.

Table 4. Wildfire Occurrence Sorted by Date.

DEVAFireIntWithVeg			
LAND_COVER	**SIZECLASS**	**CALENDAR YEAR**	**ELEVATION**
Creosote Bush Shrubland	B	1979	0
Nevada Joint-fir Shrubland	E	1984	0
Nevada Joint-fir Shrubland	E	1984	0
Creosote Bush Shrubland	G	1984	0
Creosote Bush Shrubland	A	1987	0
Juniper Wooded Shrubland	B	1987	6
Mesquite Shrublands	B	1987	0
Nevada Joint-fir Shrubland	B	1987	9
Blackbrush Shrubland	E	1987	7
Pinyon Woodlands and Shrublands	A	1990	7
Pinyon Woodlands and Shrublands	A	1990	7
Juniper Wooded Shrubland	C	1990	7
Pinyon Woodlands and Shrublands	D	1990	7
Shadscale Shrubland	B	1994	6
Creosote Bush Shrubland	A	1996	4
Iodine Bush-Bush Seepweed Complex	B	1996	7
Blackbrush Shrubland	A	1997	8
Blackbrush Shrubland	A	1997	8
Creosote Bush Shrubland	A	1999	3
High Elevation Pine Woodlands	A	1999	9
Pinyon Woodlands and Shrublands	A	1999	7
White Burrobush Shrubland	A	1999	0
Joshua Tree Wooded Shrubland	B	1999	5
Creosote Bush Shrubland	A	2000	2
Mesquite Shrublands	A	2000	0
Pinyon Woodlands and Shrublands	A	2000	6

DEVAFireIntWithVeg			
LAND_COVER	SIZECLASS	CALENDAR YEAR	ELEVATION
Nevada Joint-fir Shrubland	G	2000	6
Creosote Bush Shrubland	B	2001	1
Blackbrush Shrubland	A	2002	7
Creosote Bush Shrubland	D	2005	5
Joshua Tree Wooded Shrubland	E	2005	7
Creosote Bush Shrubland	C	2006	7
Creosote Bush Shrubland	E	2006	4
Pinyon Woodlands and Shrublands	F	2006	4
Creosote Bush Shrubland	G	2006	4

Sorting the data by size class (Table 5), shows the largest fires tend to occur in Creosote shrublands. This is expected as this vegetation type makes up most of the landscape (822,411 ha from Table 1), and is relatively continuous (Figure 2). However, large fires also occur in Nevada Joint-fir shrubland, which is unexplained, given it is only a small part of the Park's vegetation (12,463 ha from Table 1), and is widely scattered (Figure 2).

Table 5. Wildfire Occurrence sorted by Size Class

DEVAFireIntWithVeg			
LAND_COVER	SIZECLASS	CALENDAR YEAR	ELEVATION
Creosote Bush Shrubland	A	1987	0
Pinyon Woodlands and Shrublands	A	1990	7
Pinyon Woodlands and Shrublands	A	1990	7
Creosote Bush Shrubland	A	1996	4
Blackbrush Shrubland	A	1997	8
Blackbrush Shrubland	A	1997	8
Creosote Bush Shrubland	A	1999	3
High Elevation Pine Woodlands	A	1999	9
Pinyon Woodlands and Shrublands	A	1999	7
White Burrobush Shrubland	A	1999	0
Creosote Bush Shrubland	A	2000	2
Mesquite Shrublands	A	2000	0
Pinyon Woodlands and Shrublands	A	2000	6
Blackbrush Shrubland	A	2002	7
Creosote Bush Shrubland	B	1979	0
Juniper Wooded Shrubland	B	1987	6
Mesquite Shrublands	B	1987	0
Nevada Joint-fir Shrubland	B	1987	9
Shadscale Shrubland	B	1994	6
Iodine Bush-Bush Seepweed Complex	B	1996	7
Joshua Tree Wooded Shrubland	B	1999	5
Creosote Bush Shrubland	B	2001	1
Juniper Wooded Shrubland	C	1990	7
Creosote Bush Shrubland	C	2006	7
Pinyon Woodlands and Shrublands	D	1990	7
Creosote Bush Shrubland	D	2005	5
Nevada Joint-fir Shrubland	E	1984	0
Nevada Joint-fir Shrubland	E	1984	0
Blackbrush Shrubland	E	1987	7
Joshua Tree Wooded Shrubland	E	2005	7

DEVAFireIntWithVeg			
LAND_COVER	SIZECLASS	CALENDAR YEAR	ELEVATION
Creosote Bush Shrubland	E	2006	4
Pinyon Woodlands and Shrublands	F	2006	4
Creosote Bush Shrubland	G	1984	0
Nevada Joint-fir Shrubland	G	2000	6
Creosote Bush Shrubland	G	2006	4

Sorting the data by elevation class (Table 6) does not appear to provide much new information as it appears the average elevation of the vegetation class (Table 1) is quite closely related to the elevation of the wildfire occurrence.

Table 6. Wildfire Occurrence Sorted by Elevation

DEVAFireIntWithVeg			
LAND_COVER	SIZECLASS	CALENDAR YEAR	ELEVATION
Creosote Bush Shrubland	A	1987	0
White Burrobush Shrubland	A	1999	0
Mesquite Shrublands	A	2000	0
Creosote Bush Shrubland	B	1979	0
Mesquite Shrublands	B	1987	0
Nevada Joint-fir Shrubland	E	1984	0
Nevada Joint-fir Shrubland	E	1984	0
Creosote Bush Shrubland	G	1984	0
Creosote Bush Shrubland	B	2001	1
Creosote Bush Shrubland	A	2000	2
Creosote Bush Shrubland	A	1999	3
Creosote Bush Shrubland	A	1996	4
Creosote Bush Shrubland	E	2006	4
Pinyon Woodlands and Shrublands	F	2006	4
Creosote Bush Shrubland	G	2006	4
Joshua Tree Wooded Shrubland	B	1999	5
Creosote Bush Shrubland	D	2005	5
Pinyon Woodlands and Shrublands	A	2000	6
Juniper Wooded Shrubland	B	1987	6
Shadscale Shrubland	B	1994	6
Nevada Joint-fir Shrubland	G	2000	6
Pinyon Woodlands and Shrublands	A	1990	7
Pinyon Woodlands and Shrublands	A	1990	7
Pinyon Woodlands and Shrublands	A	1999	7
Blackbrush Shrubland	A	2002	7
Iodine Bush-Bush Seepweed Complex	B	1996	7
Juniper Wooded Shrubland	C	1990	7
Creosote Bush Shrubland	C	2006	7
Pinyon Woodlands and Shrublands	D	1990	7
Blackbrush Shrubland	E	1987	7
Joshua Tree Wooded Shrubland	E	2005	7
Blackbrush Shrubland	A	1997	8
Blackbrush Shrubland	A	1997	8
High Elevation Pine Woodlands	A	1999	9
Nevada Joint-fir Shrubland	B	1987	9

Subject Area Six Results: Topographic effects on precipitation

Topographically-related precipitation cannot be directly described with the landscape model, unless there are data relating landscape position to weather parameters. A pre-proposal has been developed to address this (Appendix Two) and this Subject Area is designed to support its completion. The storm patterns over DEVA are probably distinctly related to its topography (Figure 16). In general, there is a distinct difference in precipitation on NW, W, SW aspects vs. NE, E, and SE. (See Appendix Two).

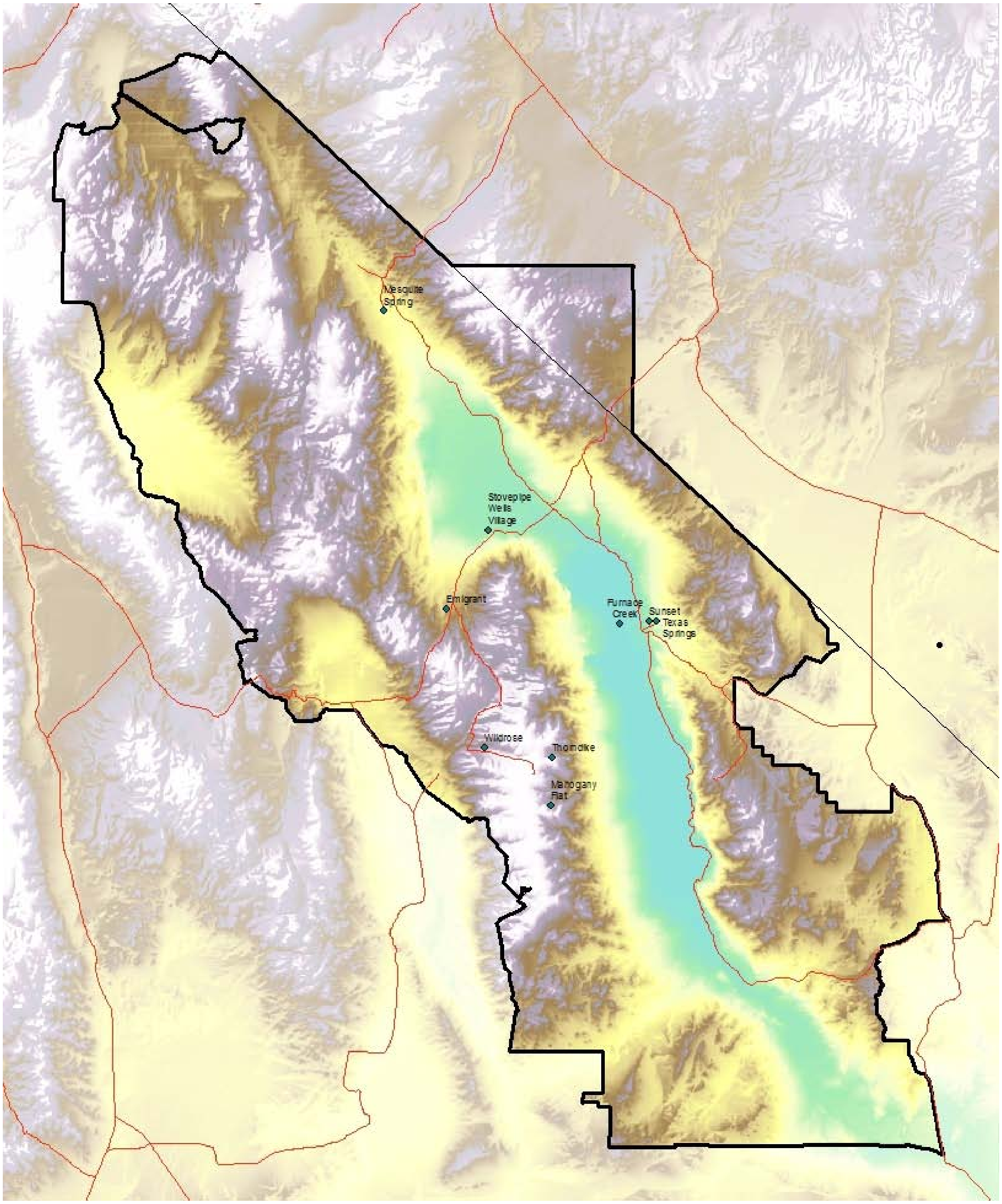


Figure 16. Elevation and Topography of Death Valley National Park and Surrounding Areas (1:800,000).

There are also distinct elevational relations. Therefore the weather station system should be situated to reflect the dominant elevational range. A hypsometric curve for the elevational range in DEVA was calculated from the clipped 10 m elevation model (Figure 17). From this graph, the areally dominant range of elevations is estimated to be 300 m to 1900 m.

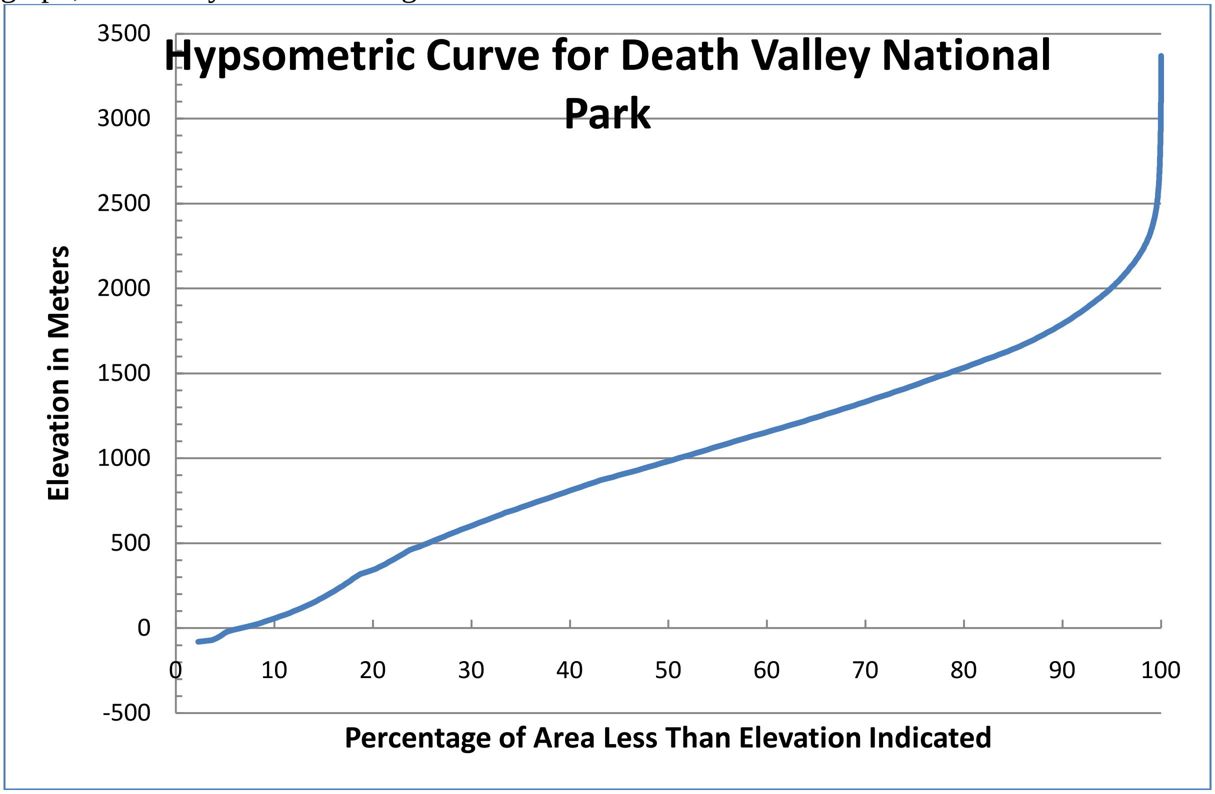


Figure 17. Hyspometric Curve For Death Valley National Park

Any weather station system should reflect these elevational and aspect ranges. The directional range used the following parameters:

- N - North (0 to 22.5 and 337.5 to 360)
- NE - North East (22,5 to 67.5)
- E - East (67.5 to 112.5)
- SE - South East (112.5 to 157.5)
- S - South (157.5 to 202.5)
- SW - South West (202.5 to 247.5)
- W - West (247.5 to 292.5)
- NW - North West (292.5 to 337.5)
- U - Undefined - Slope = 0

Since the objective includes emphasizing orographically dependent precipitation, rather than that occurring on low slope areas, a 20% minimum slope was used. Elevation and aspect were translated into two spatial selection queries: ([DEVAClipped10MAspFromDEVA.img] > 202.5 & [DEVAClipped10MAspFromDEVA.img] < 337.5) & ([DEVAClipped10MDEMFromDEVA.img] > 300 & DEVAClipped10MDEMFromDEVA.img] < 1900) & [DEVAClipped10MSlopeFromDEVA.img] > 20) and

([DEVAClipped10MAspFromDEVA.img] > 22.5 & [DEVAClipped10MAspFromDEVA.img] < 157.5) & ([DEVAClipped10MDEMFromDEVA.img] > 300 & [DEVAClipped10MDEMFromDEVA.img] < 1900) & [DEVAClipped10MSlopeFromDEVA.img] > 20).

Results are shown as a map of possible locations for weather stations (Figure 18). These reflect the places where the aspects are dominantly NW, W, SW or 292.5 – 202.5 degrees and NE, E, SE or 22.5 – 157.5 degrees; within the dominant elevation range in DEVA, and on at least moderately-sloping areas. The Telescope Peak (3170 m) area (star on Figure 18) shows as outside the dominant elevation range. Though this prominent area may certainly be considered for weather station installation, data from it should be qualified as being less useful for extrapolation to other areas. Figures 18, 19, and 20 are also provided as GEOPDF's, which have embedded georeferencing for use in location (See Appendix Three).

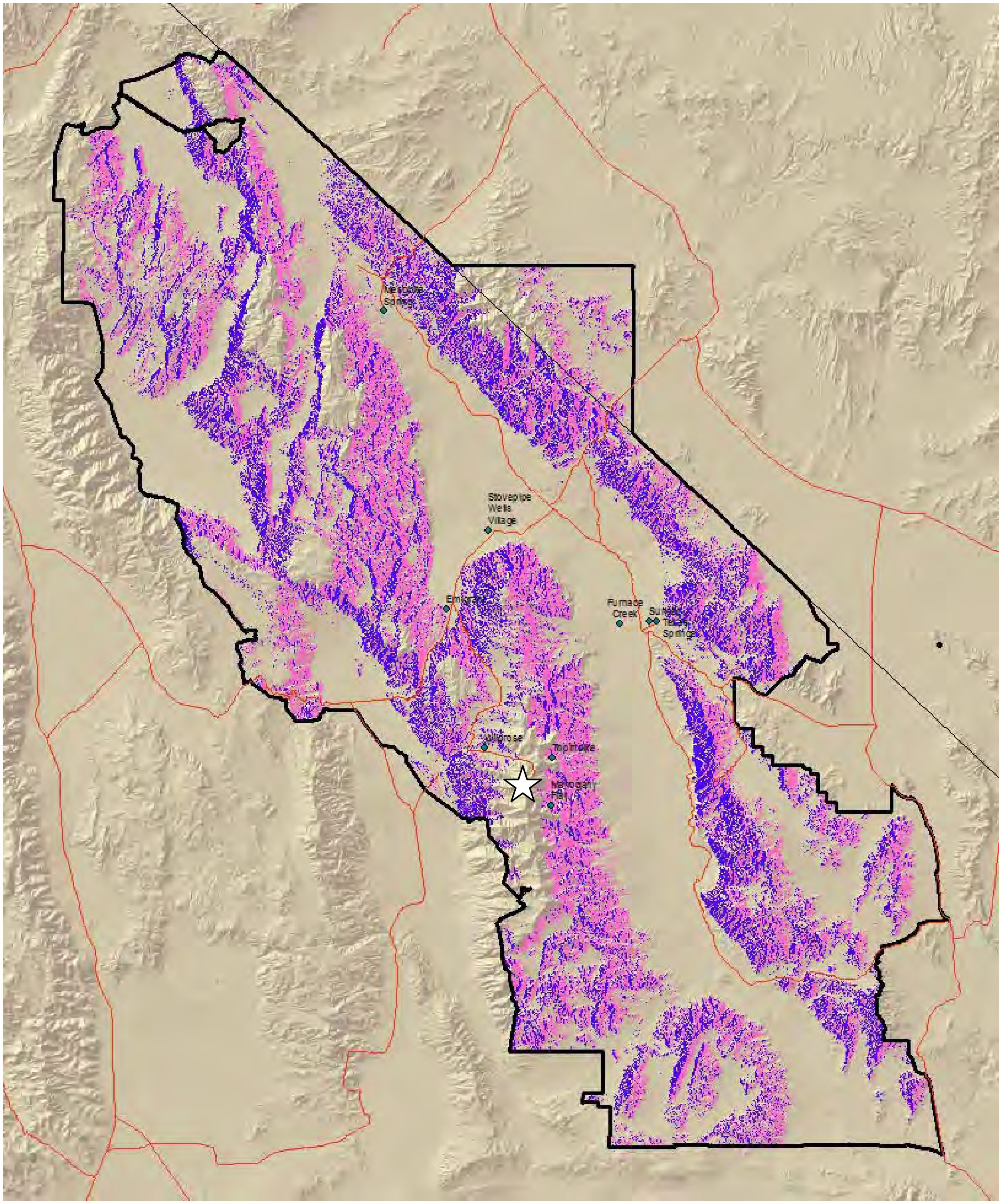


Figure 18. Candidate Areas for Weather Collection Stations based on Aspect and Elevation Ranges (1:800,000) (Star is Telescope Peak area).

Road access is also important to weather station location. Distance from a road layer obtained from the USGS for all locations in DEVA was created (Figure 19). Station accessibility could be estimated from this layer and the aspect map (Figure 18). Elevational change could be added to each aspect pixel for a more realistic estimate. A combined display is in Figure 20. Though this may be enough for planning, the layer attributes could be used in a decision support model to better optimize station location.

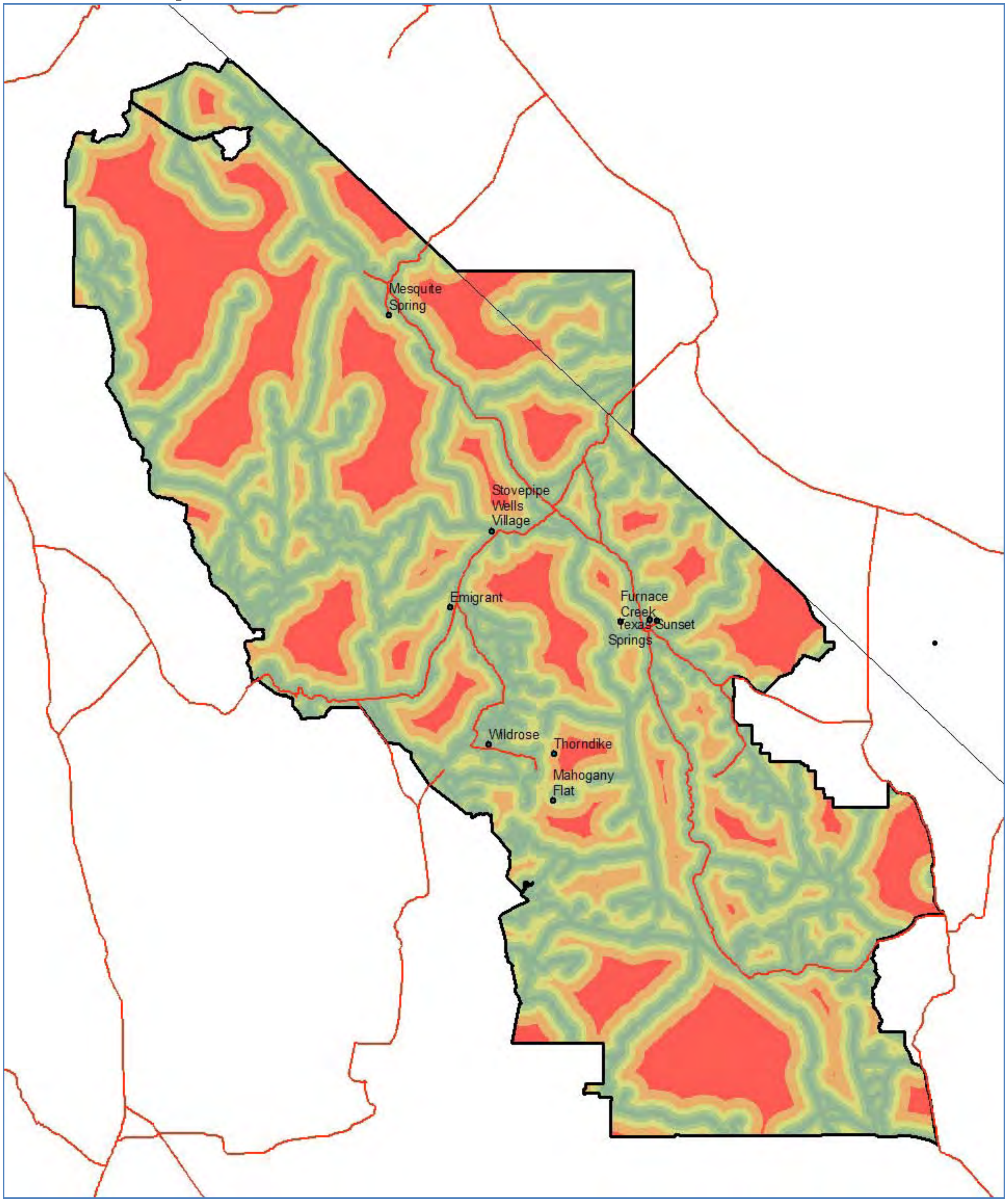


Figure 19. Distance From Roads (red indicates most isolation)

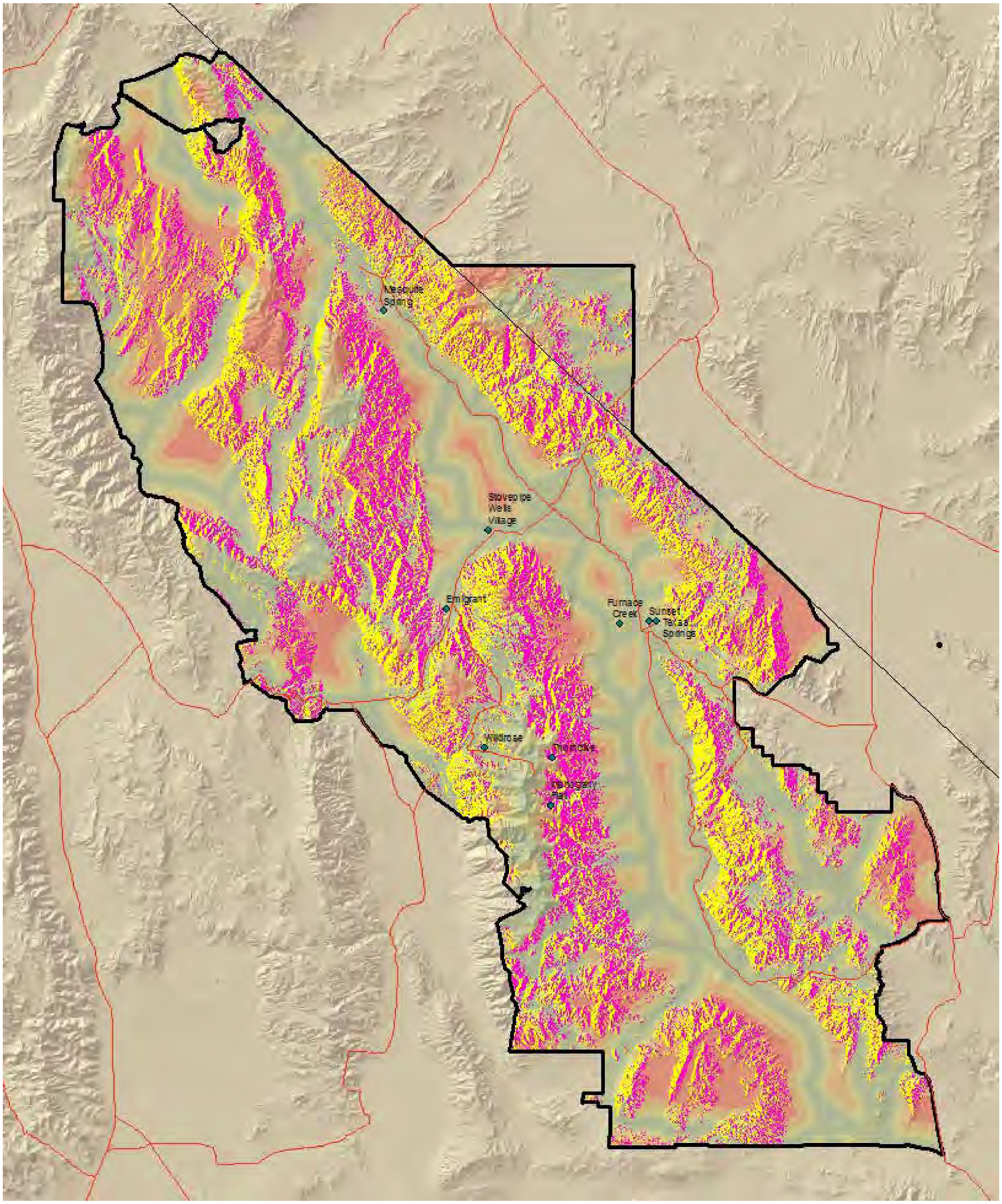


Figure 20. Aspect Elevation Ranges with Overlaid Distance from Roads (1:800,000)

Conclusions

This research project was initiated to support Death Valley National Park (DEVA) resource management by providing structured, summarized, and quality-controlled information on subjects identified by management staff as important to DEVA operations. Two general subject areas were addressed: the lack of a structured, usable soil inventory, and the effects of climate change on individual species. This is a small, preliminary project, designed to provide some initial information; and a structure and context for further work.

From a literature search it is apparent there is no available soil inventory at a level of detail sufficient for management interpretations. Therefore, a model was developed that incorporated features that approximate that inventory. The "landscape model" developed here can be used (with expert help) to make some interpretations until a soil inventory can be completed. The model created contains features important for management: surficial materials, landforms, lithology, vegetation, cultural (human) features, imagery, and topography (elevation, slope, and aspect). It was integrated to the extent feasible and used to address the subject areas. These uses show the usefulness of this kind of structured, coordinated, and integrated model in addressing Park issues.

Potential habitat was located for a very rare species using field data, elevation, vegetation, and image interpretation. This kind of use can make future investigations much more efficient and provide scientific background for management actions.

Species of concern on dune fields are difficult to inventory. Access is limited and specimens are difficult to locate directly using remote techniques. However, their habitat can be mapped, as well as potential isolated habitat that may provide a refugia for their survival. And potential threats can be mapped using imagery, topography, and other aspects of the landscape model. These maps provide a picture of their potential future, both in terms of potential success and failure.

The effects of climate change on the landscape may first be apparent in the characteristics of wildfires. Even with the limitations of the available data, some trends are apparent, including an increase in frequency and size.

Finally, determination of limiting features is critical to any future modeling of the effects of climate change. And measurement of the limiting features is of first importance. Water is obviously limiting in DEVA's environment. Use of the landscape model can make its measurement more efficient through use of landscape data to help develop a weather station network that quantifies those limiting factors.

The above examples show the usefulness of a structured, scientific approach to management issue support using available data and principals of geographic analysis. Though it may have appeared at first glance that little information was available to address any of these issues, this study shows that useful information can indeed be extracted from an integration of a variety of already-available data.

Most of this study was completed using remote methods. One might suggest that much more interpretation could have been done in each subject area. That is possible, but one of the tenets of the use of remote sensing is that "it's just pretty pictures unless there is ground truth". Hence the answers provided here are indeed limited, as they are all tempered by that reality check.

Appendix One: Field Investigation of Telescope Bedstraw

Survey for *Galium hypotrichium* ssp. *tomentellum*, August 10, 2010
Death Valley National Park, Resources Management Division

Surveyors:
Steven Del Favero and Dashiell Hibbard

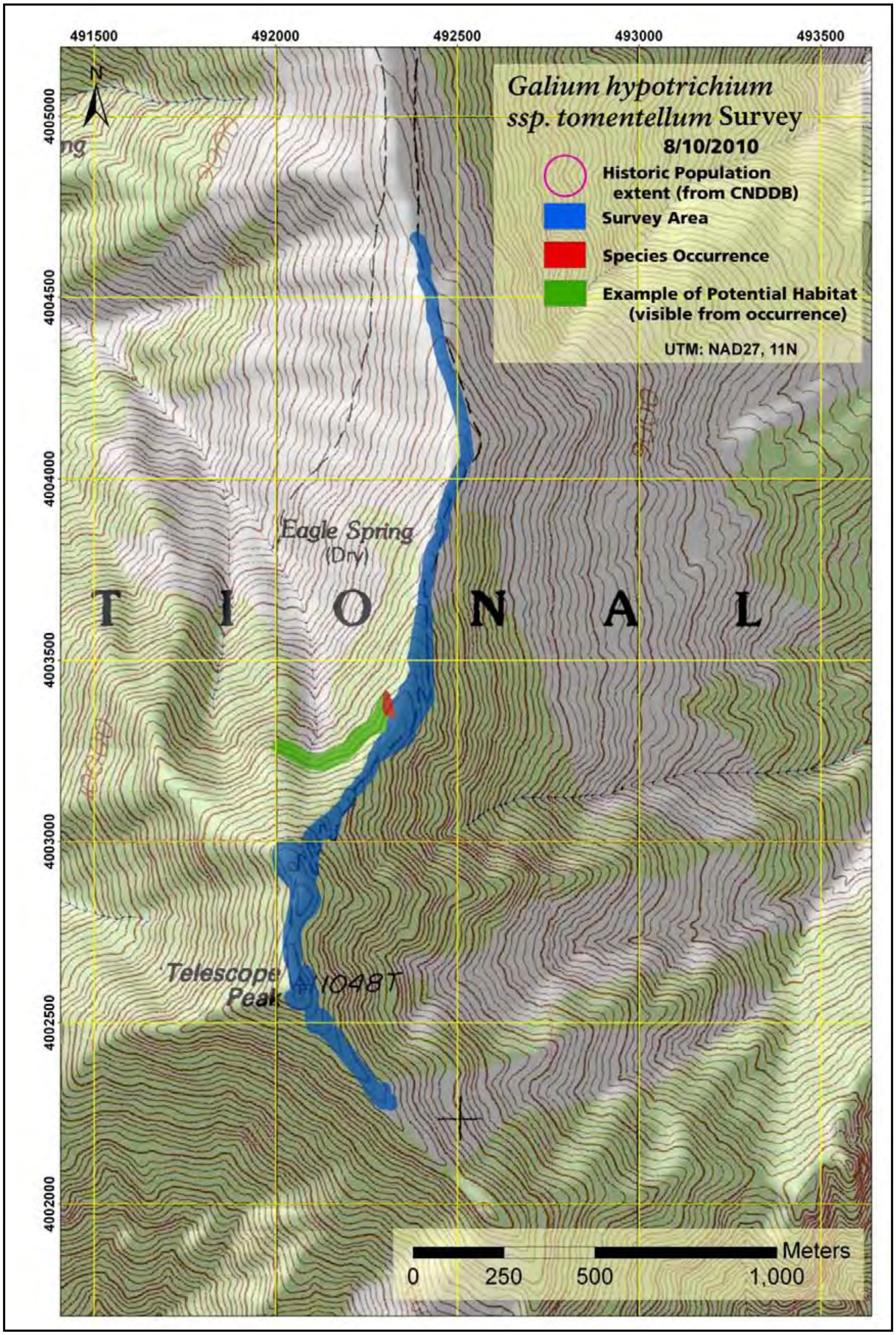
Galium hypotrichium ssp. *tomentellum* is a rare plant endemic to the Panamint Mountains in Death Valley National Park. This survey for the species was conducted on the highest ridge in the Panamint Mountains, north and south of Telescope Peak. The survey was tracked by GPS units (*Garmin eTrex Vista* and *Trimble GeoXT*) carried by both surveyors and recorded in UTMs (NAD27 11N).

The area surveyed was based on the ranges and habitat descriptions of the species given in *The Jepson Manual: Higher Plants of California*, *Contributions From the Dudley Herbarium,* and from collection/observation records as entered in Death Valley's *DEVAflora* geodatabase, which includes data from the California Native Diversity Database(CNDDB). No record of the species was found dating from anytime after 1983.

The entirety of this species habitat and range given by these sources can be summed up as talus slopes between 10,800 and 11,050ft around Telescope Peak. The 2010 survey was conducted between 9,640 and 11,050 feet (Figure 1). The species was not observed anywhere in topmost 200ft of the Panamints. Instead it was found unexpectedly, well off the main trail on a western slope just below the ridge north of Telescope Peak at only 10,400 ft (Figure 2). The species was not growing among talus, but rather calcareous scree. Further details on the habitat and associate species of this occurrence can be found in the *DevaFlora* geodatabase and the GalHypT folder on the Botany sharedrive. A specimen was also collected and is to be placed in the Park Herbarium.

Similar habitat of this occurrence was present at a similar elevation further south on the slope below Telescope Peak and is likely present on other faces below the summit. This subspecies of *Galium hypotrichium* has a larger range than previously thought and its habitat is more abundant. Concerns over imminent impact to this species from global climate change should be slightly diminished by these findings, but further study to determine population extent and health should still be pursued in the near future.

Figure 1. Survey area and new occurrence of *Galium hypotrichium* ssp. *tomentellum.*



Galium hypotrichium ssp. tomentellum Survey
8/10/2010
Historic Population extent (from CNDDB)
Survey Area
Species Occurrence
Example of Potential Habitat (visible from occurrence)
UTM: NAD27, 11N
491500
492000
492500
493000
493500
4005000
4004500
4004000
4003500
4003000
4002500
4002000
N
Eagle Spring (Dry)
T I O N A L
Telescope Peak
Meters
0
250
500
1,000

Figure 2. Photos of *Galium hypotrichium* ssp. *tomentellum* and its habitat at the single occurrence found during the 8/10/2010 survey.


2
1

Appendix Two: Draft Preproposal for Weather Network

Mojave Network Two Page Pre-Proposal September 2010

Description of Project

This project will examine variations in aquatic communities, spring hydrology, and weather across a range of elevations on opposing slopes (eastern and western aspects) and the windward and leeward basins surrounding DEVA's central mountain ranges.

Portable weather stations will be installed at low, mid, and high elevations on opposing slopes of DEVA's central mountain ranges and in the surrounding basins. These stations will generate data that will be used to create mathematical precipitation-elevation relationships, which model the changes in precipitation amounts with elevation on each slope. These relationships will be used with hypsometric curves (graphs relating elevation to the area above a given elevation) to estimate the precipitation totals on each slope. These are expected to be quite variable across different slopes because of the extreme orographic effects—the influence of mountains on climates. The seasonal variation of the orographic effects will also be analyzed to demonstrate the changes between winter storms (which generally track west to east) and the more random monsoonal storms.

Spring sites will be selected low, mid, and high elevations on opposing slopes of DEVA's central mountain ranges for biologic and hydrologic monitoring. Spring sites in the windward and leeward basins surrounding the central mountains will also be monitored. The springs will be instrumented (if possible) or manually sampled to track physical and chemical responses to storm events and seasonal changes. Inventories of aquatic species will also be conducted to establish the connections between physical and chemical conditions and species success. Climate change scenarios can then be applied to predict changes in weather patterns, and the associated impacts to spring ecology.

Justification

Death Valley encompasses 3.3 million acres ranging in elevation from -282 ft below sea level at Badwater to 11,049 ft at Telescope Peak. DEVA's vast wilderness, its high relief, and extreme climates present a unique opportunity to model precipitation changes with slope-aspect and elevation. DEVA also has between 600 and 800 springs; depending on the antecedent weather conditions. While the majority of these springs discharge near the valley floor, there are many mid- and upland springs. Springs within the central mountain ranges of DEVA (Panamint, Cottonwood, Last Chance, and Saline) are likely to show responses to weather and seasonal changes, because their recharge is derived locally, in contrast to the regionally fed springs closer to DEVA's boundaries. Furthermore, connections between weather and spring conditions are easier to establish in localized rather that regional springs, because of the unquantifiable variables (e.g. groundwater pumping) in the vast area contributing to the regional system. Presently DEVA's precipitation-elevation relationship is modeled as a simple linear relationship that does not capture the actual changes in precipitation across various slopes. It is expected that these relationships are not linear, and they would be more accurately represented by curves. Furthermore, the shapes of these curves are expected to be different on windward and leeward slopes. Once these relationships are defined, they can be used to predict the effects of climate change on the precipitation regime, which is currently dominated by winter storms. Most climate change models predict warmer conditions that will likely result in a decrease in winter storms and an increase in monsoonal moisture. Winter storms (especially snows) provide a more consistent recharge input to replenish aquifers that feed springs. Summer precipitation is characterized by intense localized storms that generate flashy runoff which evaporates quickly. This predicted shift in the precipitation regime presents a number of concerns for DEVA resources and operations. It could result in a decrease in the amount of water available to support aquatic systems, even though there may not be a decrease in annual precipitation totals.

DEVA resources management is obligated to protect the Park's natural resources. The impacts of climate change on spring ecology are expected be highly dependent on elevation and aspect. Changes in aquatic communities will have direct effects on sensitive endemic desert pupfishes (four species), migratory birds, and resident rodents and reptiles. Aquatic species that are able to migrate through aerial life stages would most likely be able to move to more suitable habitats. Those species endemic to a particular spring or spring complex that can't migrate would become locally extirpated or extinct. It may be deemed necessary to introduce immobile species to higher elevation springs before conditions develop that would guarantee the species extinction. Such decisions cannot be made without a careful evaluation and a thorough understanding of the systems, including a clear understanding of the relationships between aquatic communities and the weather-dependent conditions of the springs. Highly generalized relationships between elevation and precipitation are inadequate to guide DEVA resources management. There must be an understanding how global climate change will interact with DEVA's localized orographic effects to guide adaptive management plans for protecting aquatic communities in the face of climate change.

Measureable Results

This study will help predict the effects of climate change different climate change scenarios on 1) mean annual precipitation totals on opposing slopes of DEVA's central mountain ranges, 2) water availability to sensitive aquatic populations, 3) hydrologic, physiochemical and ecological conditions of springs.

The results will be used not only to guide DEVA's resources management, but to also educate the public on the potential impacts to DEVA's springs from climate change. The technical report will be available DEVA Interpretation as a reference for preparing climate change programs. There will also be a report written for non-technical readers that may be published as an article. A poster will be made for display at the visitor center and climate change conferences.

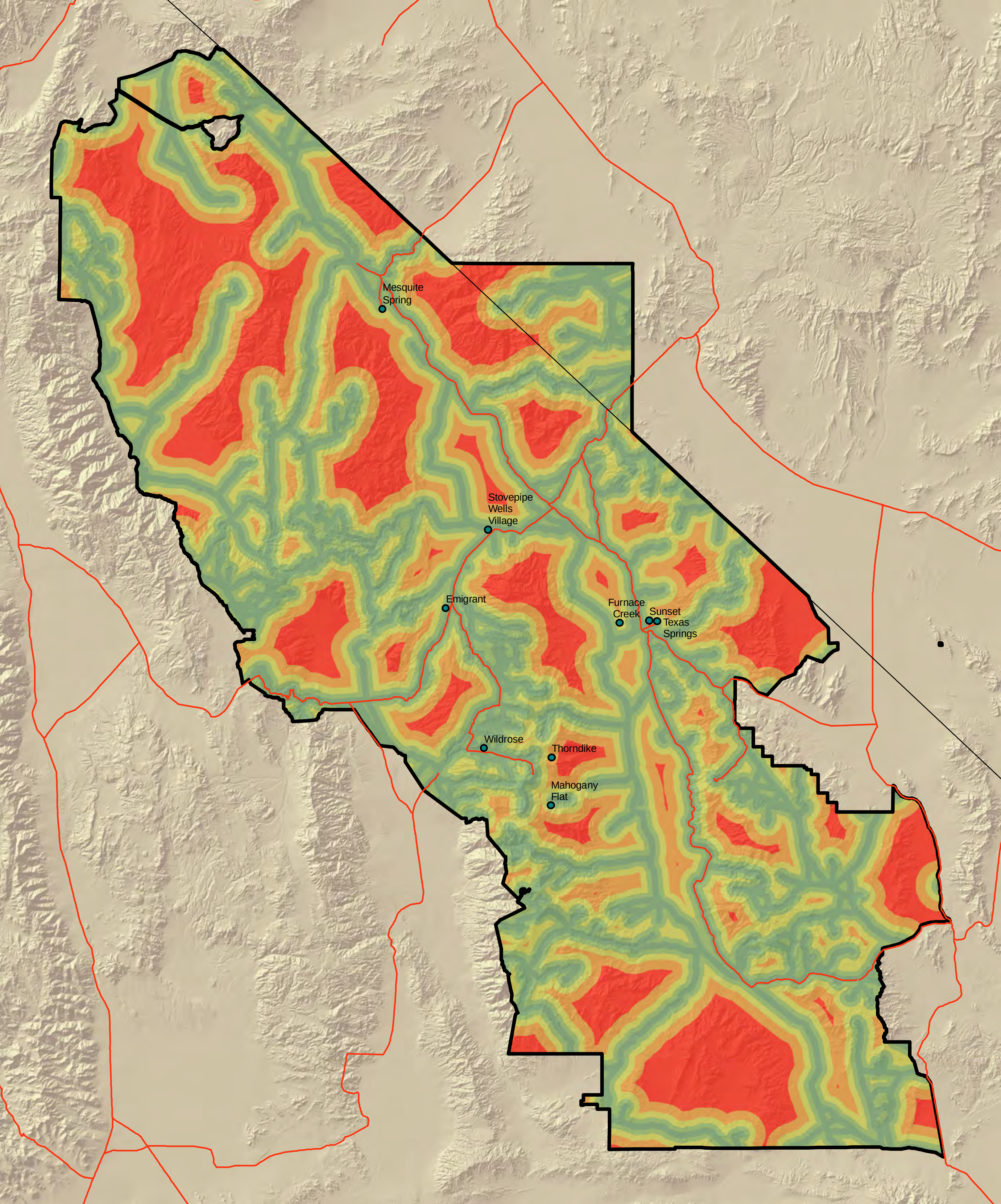
Appendix Three: Spatial Data and maps provided with this report

Deva34x48mapLandscapesCompressed.pdf: A large map showing aspects of the landscape model.

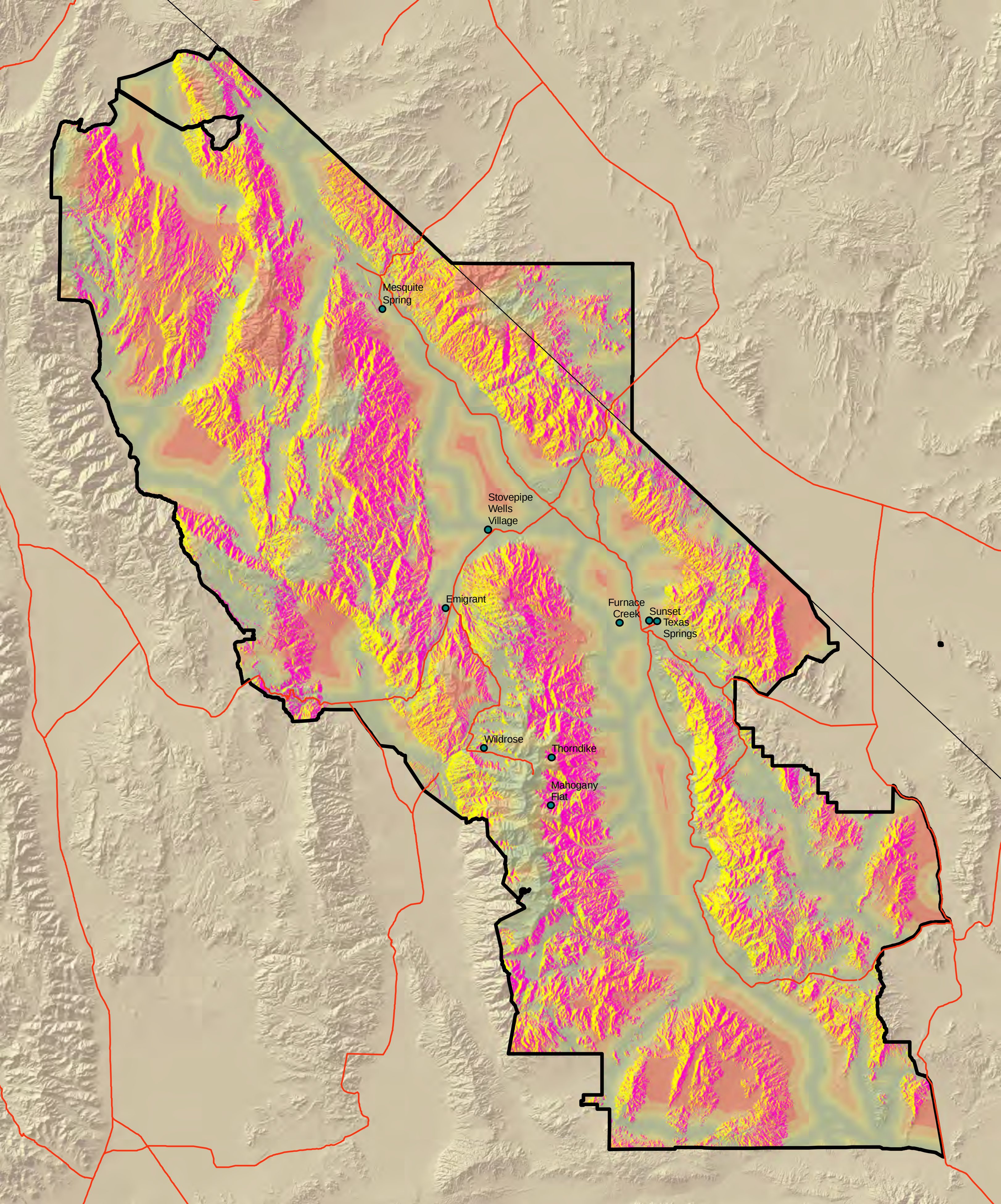
DEVAClip_veg_surf_landform: The polygon portion of the Landscape Model in the geodatabase DEVAGeneralPublicationGeoDB.mdb

GeoPDF's that duplicate maps in this report, usable with Adobe Viewer standard Analysis tools (appended to this report below).

DEVAWeatherModelDistanceToRoads.pdf
DEVAWeatherModelAspectSlopeDistanceCombo.pdf
DEVATelescopeBedstrawAnalysisLandscape.pdf
DEVATelescopeBedstrawAnalysis.pdf
DEVADunesAnalysisStovePipeDunes.pdf
DEVADunesAnalysisSalineAdditions24000.pdf
DEVADunesAnalysisMarbleAdditions30000.pdf
DEVADunesAnalysisMainAdditions24000.pdf



Mesquite Spring
Stovepipe Wells Village
Emigrant
Furnace Creek
Sunset
Texas Springs
Wildrose
Thorndike
Mahogany Flat



Mesquite Spring
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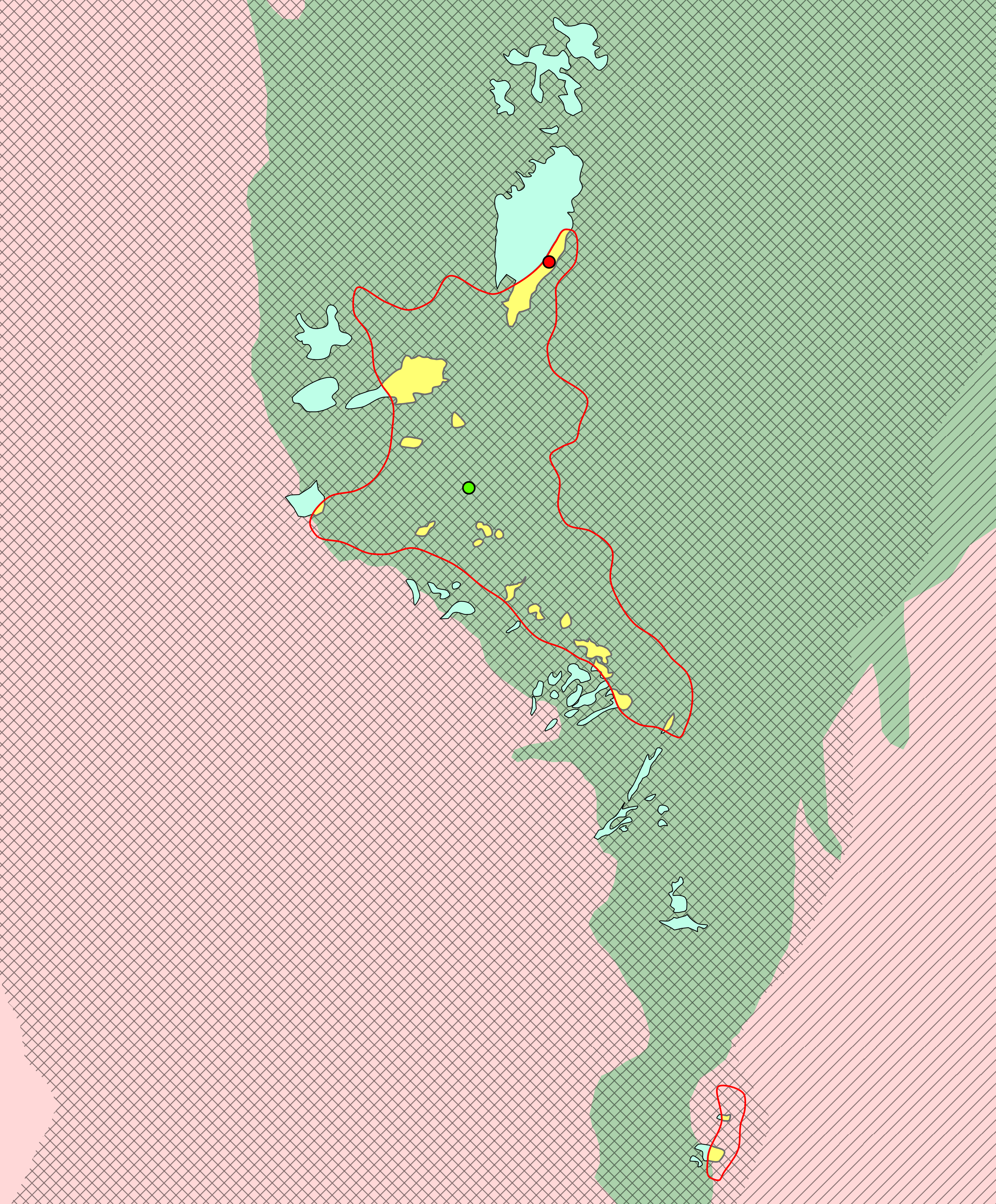

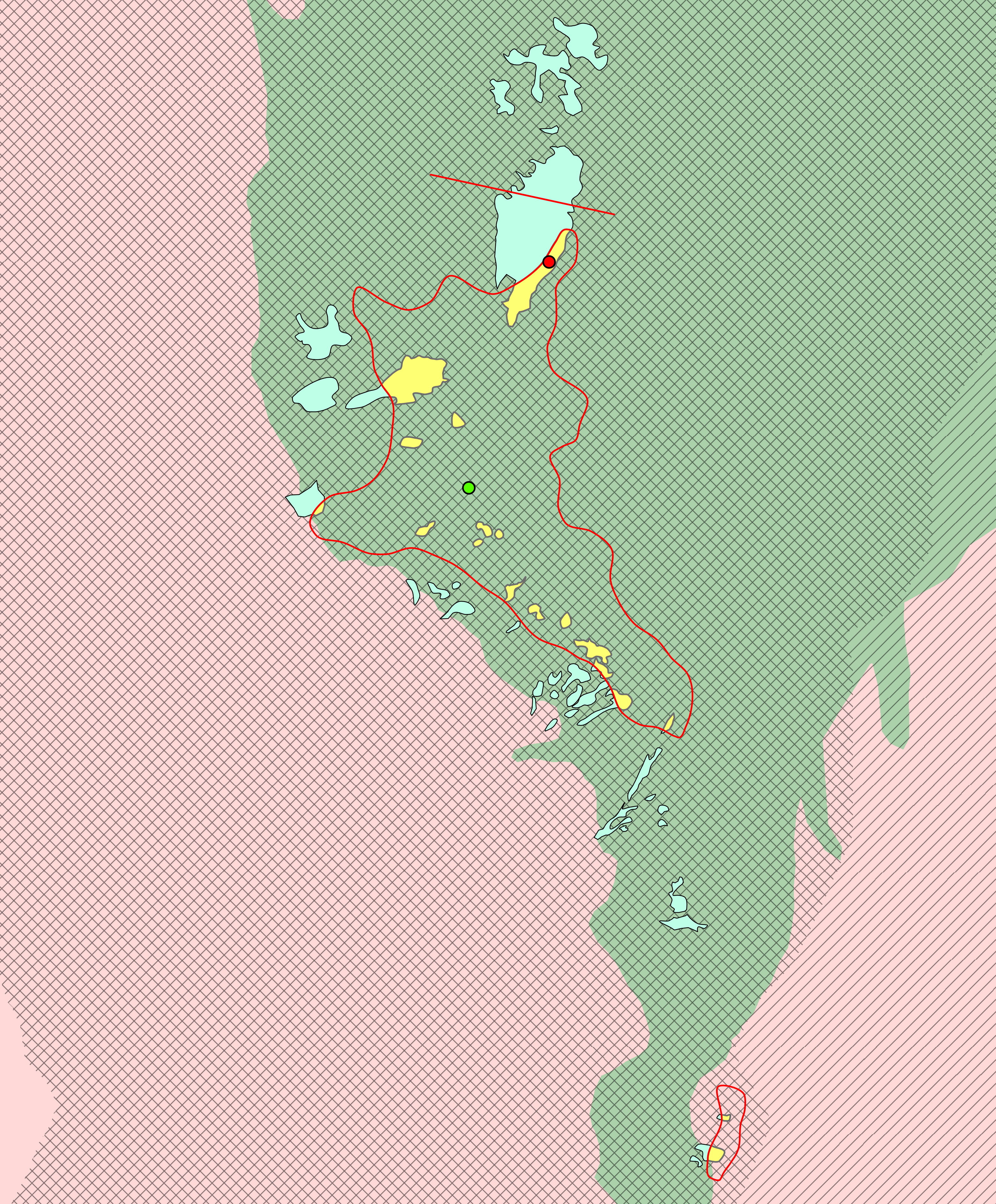

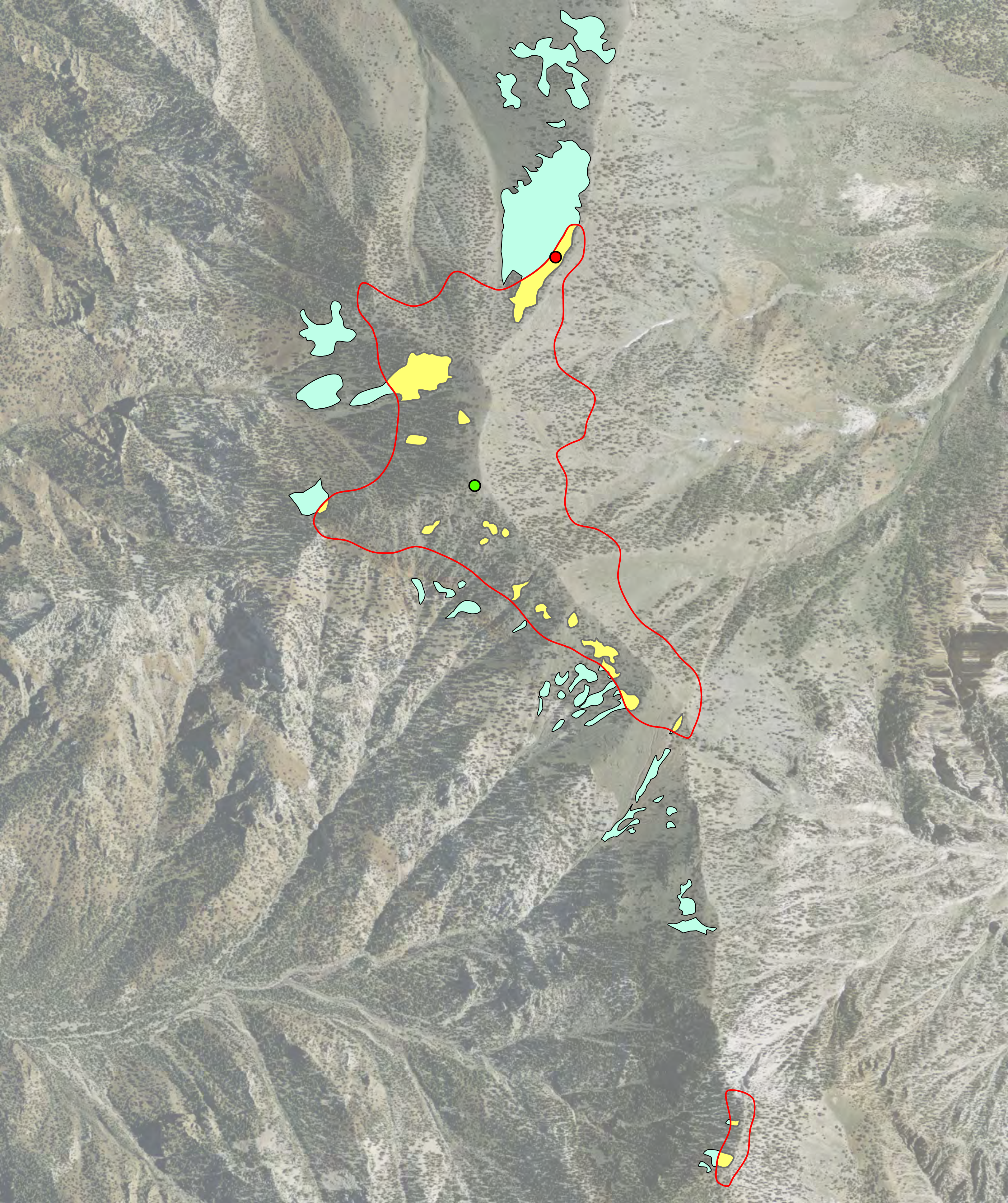


Stovepipe
Wells
Village