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A Framework for Restoration to Support Agassiz's Desert Tortoise Recovery in the Western Mojave Desert

A Group Project submitted in partial satisfaction of the requirements for the degree of
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by

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A Framework for Restoration to Support Desert Tortoise Recovery in the Western Mojave

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List of Abbreviations

ACEC	Area of critical environmental concern
APN	Assessor Parcel Number
BLM	Bureau of Land Management
CDFW	California Department of Fish and Wildlife
Council	Desert Tortoise Council
desert tortoise	Agassiz's Desert Tortoise
DTPC	Desert Tortoise Preserve Committee, Inc.
DTRNA	Desert Tortoise Research Natural Area
DTRO	Desert Tortoise Recovery Office
DWMA	Desert Wildlife Management Area
EEA	Eastern Expansion Area
ESA	Environmental Species Act
OHV	Off-highway vehicle
Plan	*The Revised Recovery Plan for the Mojave Desert Tortoise*
SER	Society for Ecological Restoration
Tool	Assessment Tool
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

Abstract

Our Bren School Master's group project – done in collaboration with the Desert Tortoise Council – centers on designing a framework for restoration to support recovery of the Agassiz's Desert Tortoise (*Gopherus agassizii*) (desert tortoise) in the Western Mojave Desert. The desert tortoise, a federally threatened species endemic to the Mojave Desert, is emblematic of the widespread impact humans have on desert ecosystems. Though significant emphasis has been placed on species recovery and a number of projects have demonstrated successful outcomes, populations of the desert tortoise continue to decline across much of their home range. In the Western Mojave Desert, an area that continues to see extensive human impact, the population declined an average of 51% between 2004 and 2014. Much of this decline can be directly attributed to habitat degradation, which is considered to be the single biggest threat to the species' continued vitality. Consequently, successful strategies for habitat restoration and protection from future threats are vital to species recovery. Here, we propose a framework for habitat restoration that includes: guidance document, a site assessment tool, and a site-specific restoration plan for the eastern expansion parcels of the Desert Tortoise Research Natural Area. Overall, our framework seeks to increase the amount of viable desert tortoise habitat by defining a method and application for strategic restoration, providing an assessment tool that can help land managers evaluate a site's potential for restoration, and by presenting a case study that serves as an example of how these principles can be applied to on-the-ground actions. Using this type of framework for future restoration efforts, land managers can more efficiently select site appropriate and cost-effective treatments for restoration. Although the restoration plan is site-specific, the goal-action-outcome approach and accompanying decision-making process can be replicated at other sites. It is our hope, that by using this framework, land managers can increase the effectiveness of future restoration efforts, ultimately increasing tortoise populations and creating a success story for the Agassiz's Desert Tortoise.

Executive Summary

The Agassiz's (Mojave) desert tortoise (*Gopherus agassizii*) (desert tortoise or tortoise) is a species in decline. Listed as threatened under the Endangered Species Act (ESA) since 1990, the desert tortoise faces extensive threats primarily stemming from anthropogenic disturbances to its habitat. In the last 10 years, desert tortoise populations have declined between 27-67% (USFWS 2015), and experts in the desert tortoise community are concerned that if this trend is not reversed, species recovery may not be possible. Recovery efforts for the desert tortoise have identified the significance of habitat loss and degradation as contributing greatly to the species decline, and management of these threats has been an important consideration since the desert tortoise was listed. More recently, habitat restoration has been identified as an important tool for combatting tortoise declines attributed to habitat loss, but targeted restoration for the sake of the desert tortoise is rare and not always effective. In the Western Mojave Recovery Unit (WMRU), the largest of the five recovery units which compose the desert tortoises' extensive range, the high density of anthropogenic threats and unique vegetative patterns make restoration especially important. The purpose of this project is to establish a framework which can be used to promote effective habitat restoration for the desert tortoise in the Western Mojave Desert.

Of the five recovery units, the WMRU is the largest and possibly the most at risk to habitat loss. This higher risk is partly due to a high abundance of anthropogenic activity, especially recreational off-highway vehicle (OHV) use and livestock grazing, and partly due to a uniquely sensitive vegetation pattern which has adapted to extremely dry summers, and a large proportion of annual precipitation occurring in winter. The combination of sensitivity and threats in the WMRU has resulted in a substantial need for restoration. There is also a large amount of public land in the Western Mojave Desert, which can potentially be suitable for restoration efforts, including: The Desert Tortoise Research Natural Area (DTRNA) and the extensive lands owned by the Bureau of Land Management (BLM).

The project framework encompasses three specific objectives which together can improve the effectiveness of habitat restoration for the desert tortoise in the Western Mojave. First is the development of a strategic guidance document which defines the tenets of strategic restoration which need to be considered for effective habitat restoration, and how those tenets specifically apply to desert tortoise habitat. Second is the development of an Assessment Tool, which can provide land managers support in assessing whether specific sites are likely to be suitable for restoration. Third is the design of a site-specific restoration plan which can be used to inform on-the-ground restoration efforts, and also provide a template for future restoration plans which may be created using this framework. All three of these project objectives can also be adapted for habitat restoration in other parts of the desert tortoise range, although they have been designed based on the specific habitat needs within the WMRU.

The *Strategic Approach to Restoration* document (Guidance Document) is based on a synthesis of literature which defines key components of ecological restoration. Many attempts to define what constitutes strategic ecological restoration are based on the Society for Ecological Restoration's (SER) Primer on Ecological Restoration (SER 2002). Since its publishing, attempts

to expand on the foundation provided in the SER Primer have revealed two key threads of ecological restoration which have served as the basis for the framework in this document. The first of these is the four categories of Form, Function, Stability, and Feasibility, which serve as a structure for establishing the goals of restoration projects. Form and Function both refer to site condition, with Form referring to the physical structure of a restored ecosystem and Function encompassing the systems and processes that allow a healthy ecosystem to operate. Stability refers to the ability of a restored habitat to resist threats and Feasibility incorporates the many different aspects that allow restoration work to be practical given existing constraints. Consideration of each of these four categories is critical for the success of restoration projects, and ensuring their inclusion in restoration planning will increase the effectiveness of restoring habitat for the desert tortoise.

Connecting these four categories to needed actions for desert tortoise habitat restoration is the other key component of the Guidance Document. This is accomplished using another key thread from the ecological restoration literature: the simple format of setting strategic goals, planning appropriate suites of actions, and managing outcomes. Strategic goals, in this instance, are ones that are based in the four categories. Identifying which components of desert tortoise habitat fit within these critical categories ensures that all important aspects of desert tortoise habitat are represented, and that all four categories are considered in restoration planning. The Guidance Document then maps these goals to the specific restoration actions which can best meet the needs of desert tortoise habitat. Along with continued monitoring of the outcomes of these restoration actions, establishing these goals and actions allows restoration planning to be effective and comprehensive.

Deciding which sites should be selected for restoration activities is a difficult process. Managers are often tasked with considering all of the different components of effective strategic restoration planning at multiple disparate sites. Considering the present difficulty and complexity of restoration planning, the second objective of this project was to create a site specific Assessment Tool (Tool) which could be used by land managers and other decision makers to help choose restoration sites. This Tool was developed using a Microsoft Excel user interface, making it versatile and easy to use. Characteristics of a site considered fundamental to restoration planning restoration were determined from the strategic guidelines and desert tortoise literature with additional input from desert tortoise experts. These 18 characteristics fit into four general groups: Biological Features, Physical Features, Threats, and Disturbance History. For each of these characteristics, the conditions that constitute a “Poor”, “Fair”, or “Good” site assessment are defined. Users of the Tool are instructed to enter assessments (or categorical scores) for each of the site characteristics, for a potential restoration site, where scores are based on which of the definitions in these three assessment categories best represents the current condition at the site. The Tool then generates a graphic dashboard which offers a visual representation of which important aspects of a site can support desert tortoise recovery and which aspects might need further consideration. This graphic output provides land managers with simple yet structured information, which can help them decide whether a site should be selected for restoration and which aspects of a site are most in need of attention.

The third objective of this project is the design of a site specific Restoration Plan which employs strategic restoration principles to support desert tortoise recovery. This Restoration Plan also serves a dual purpose of both being an implementable plan at a site and serving as a blueprint for other comprehensive restoration planning efforts for the desert tortoise in the Western Mojave. The creation of this Restoration Plan follows the strategic guidelines by setting goals which align with the four categories of Form, Function, Stability, and Feasibility; and using the framework of intended goals, most effective actions to meet those goals, and projected outcomes of those actions.

A driving force in the creation of this restoration plan is the desire of our client, the Desert Tortoise Council (Council), to create a restoration success story for the desert tortoise. Based on the strength of previous relationships with the Council, the Desert Tortoise Preserve Committee, Inc. (DTPC) was consulted when choosing which site should be selected for restoration. The DTPC manages the DTRNA, a key fixture in desert tortoise research and recovery located in the Western Mojave just north of California City, California. With plans to expand the confines of the DTRNA, the DTPC has begun the process of purchasing land just outside the historical borders. Some of this land has been subjected to anthropogenic disturbances and is in need of restoration. With this history, and with the advice of experts from the Council and the DTPC, three parcels within the Eastern Expansion Area (EEA) of the DTRNA were chosen as the restoration site. These parcels are in need of restoration due to existing physical and biological site conditions, and the threat of proximity to a major access road. With the partnership of the DTPC, restoration of these parcels can provide a unique opportunity for tortoise habitat recovery that can potentially extend further into the EEA.

The three parcels for the site total 461.65 acres, of which 173.5 acres have been targeted for specific restoration actions. Of these, 28 acres were identified as being the most devoid of vegetation necessary for desert tortoise recovery, and will be the target of revegetation efforts. These revegetation efforts include a combination of planting and seeding, depending on what was most appropriate for existing vegetation in the plots identified for revegetation efforts. In addition to the highly degraded areas, 141.5 acres of buffer zones were designated around the revegetation plots. In these areas, site preparation such as invasive species removal will take place, both protecting the areas being revegetated from threats, and preparing these areas for potential future restoration work. Restoration actions are also planned to address the existing off-highway vehicle trails present in the site. There are 42 of these trails that have been identified within the site, 21 of which intersect the fence line surrounding the Eastern Expansion Area at the site's border. The main restoration action for these trails is trail camouflage which can discourage cutting the fence to access old recreation sites. Four acres of trail within a 100-meter buffer from the fence line will be targeted for the camouflage techniques.

In addition to these targeted actions, the restoration plan also includes several other measures to ensure the strategic effectiveness of restoration actions. The inclusion of associated costs for recommended actions allows for effectively planning the feasibility of comprehensive restoration efforts. A monitoring plan and detailed adaptive management considerations allow decision makers for the Council and the DTPC to periodically reevaluate the most effective measures for the site as actions restoration move forward. Together these pieces allow for effective implementation of on-the-ground restoration efforts and furthermore provide a template for future strategic restoration efforts for the desert tortoise in the Western Mojave.

With the objectives detailed here, the goal of this project is to provide land managers with a framework that streamlines strategic restoration efforts for desert tortoise habitat. The combination of the Guidance Document, Assessment Tool, and site-specific Restoration Plan provides restoration practitioners with a blueprint for strategically and effectively planning restoration efforts. The population recovery of desert tortoises that can be directly tied to the results of this project is relatively small, as the recovery of desert habitat and desert tortoise re-habitation can take decades; none the less, this framework will best serve the recovery of the desert tortoise if land managers and other restoration practitioners use and share this project as a blueprint for future strategic habitat restoration projects.

1. Objectives and Background

1.1 Project Objectives

The Agassiz's desert tortoise (*Gopherus agassizii*) (desert tortoise or tortoise) is a species in decline, but there is still hope for recovery through carefully planned management actions. The purpose of this project is to understand desert tortoise habitat requirements, and how such requirements may be optimized through strategic restoration to improve habitat for the species. Thus, we have four primary objectives:

1. Develop a guidance document for strategic planning of habitat efforts in the western Mojave Desert.
2. Develop an assessment tool to inform when and where environmental conditions are likely to be suitable for restoration in the Western Mojave, expanding on prior restoration assessments for arid landscapes.
3. Design a site-specific restoration plan to inform on-the-ground restoration efforts, including assessment of the benefits and outcomes of restoration practices relative to costs.
4. Package objectives 1, 2, and 3 as a framework for employing strategic habitat restoration in the western Mojave Desert.

This report outlines critical background material related to these objectives, the methodology we followed to meet these objectives, and our conclusions and recommendations.

1.2 Significance

With an extreme population decline and severe habitat degradation, the desert tortoise is listed as a threatened species under the Endangered Species Act (ESA). Threats to the desert tortoise are substantial, primarily stemming from direct and indirect human disturbance of the species and its habitat. Particularly in the Western Mojave Recovery Unit, anthropogenic threats such as off-highway vehicle use and sheep grazing have negatively impacted the desert tortoise and its inhibit recovery.

Current restoration efforts in the Western Mojave Desert have generally focused on broad application of best management practices (BMPs) for restoring desert habitat. These methods have not succeeded in reversing population decline because their overarching goal was to improve general desert biodiversity and were not specifically designed to support desert tortoise recovery. Additionally, the persistence of existing threats has limited the effectiveness of habitat restoration.

Targeting restoration efforts to specifically support desert tortoise habitat recovery has been identified as an important management strategy; yet, to date, these efforts have occurred only sporadically for research purposes in isolated experimental plots. Our framework for strategic restoration includes a guidance document as well as a site assessment tool and site-specific restoration plan, which together will help land managers effectively identify sites and plan for strategic restoration, specifically with the tortoise in mind. This two-pronged approach includes providing land managers with a tool to evaluate the suitability of a site in terms of desert tortoise needs, while also providing an example of how restoration actions could be applied to their site to improve the suitability for desert tortoises.

1.3 Background

1.3.1 Range and Listing under ESA

The Agassiz's Desert Tortoise (desert tortoise) is found throughout much of the southwestern United States. In particular, the range of the desert tortoise extends from the deserts of southern California and Nevada to southwestern Utah, and a small portion of northwestern Arizona (USFWS 2011, Murphy et al. 2011). The tortoise has been classified as threatened under the federal Endangered Species Act and California's equivalent since 1990 and 1989, respectively (BLM and CDFG 1988). Due to its listing, the tortoise's range was divided in 1994 into six recovery units, but was combined to five in 2011 (USFWS 2011). The five recovery units are as follows: Upper Virgin River, Colorado Desert, Western Mojave, Eastern Mojave and Northeastern Mojave (USFWS 2011). Combined, these five units make up the entirety of the tortoise's range, and have been managed separately to preserve the tortoise. In 1994, the federal government delineated more than 26,087 square kilometers of designated critical habitat (USFWS 2011).

1.3.2 Population Decline

The severe and concerning population trends of the desert tortoise have been well documented. When the desert tortoise was listed as threatened under the ESA of 1990, scientific research and anecdotal evidence suggested human impacts were chiefly responsible for the population decline— which was estimated to have driven desert tortoise populations down by as much as 90% in the preceding 100 years. Additionally, research looking at the status of the desert tortoise since 2004, has revealed a continued decline, despite the efforts of many conservation groups and agencies to stabilize its population. In fact, only one of the five recovery units, has experienced population increase between 2004 and 2014, and breeding densities in four of the five recovery units are extremely low, ranging from 1.5 to 15.3 tortoises per square kilometer in 2015 (USFWS 2015). Overall, range-wide population decline is estimated at 32%, with the Western Mojave Recovery Unit declining by an average of 51% between 2004 and 2014 (USFWS 2015). Breeding densities in four of the five recovery units are extremely low, ranging from 1.5 to 15.3 tortoises per square kilometer in 2015 (USFWS 2015). Considering the severity of these estimates, it is clear that these population declines pose a significant concern to the continued vitality of the species. Additionally, experts in the desert tortoise community are concerned that if desert tortoise populations are further reduced, recovery may not be possible.

1.3.3 Threats

Overview

Population declines can be directly attributed to the continued presence of threats in desert tortoise habitat. Currently, the greatest threats to the desert tortoise are related to habitat loss and degradation attributed to increased human activities. Specifically, urbanization, agricultural development, military training, off-highway vehicle (OHV) use, mining, livestock grazing, alternative energy development, and a lack of enforcement of existing regulatory mechanisms all contribute to habitat loss and degradation of prime desert tortoise habitat (Boarman and Coe 2002, USFWS 2011). Other threats to desert tortoise include predation, collection by humans for pets, fire, collisions with vehicles on paved and unpaved roads, invasive plant species, and disease (Boarman and Coe 2002, USFWS 2011). These threats are widespread and many are present in the critical habitat region of the Western Mojave Recovery Unit. Considering both the prevalence and severity of threats, it is no shock that habitat restoration in the Western Mojave is critical for the species' recovery. In response to declining populations, the US Fish and Wildlife Service has stated that, "Aggressive management needs to be applied within existing [critical habitat] to ensure that populations remain distributed throughout the species' range". A brief overview of these threats in order of significance and contribution to habitat loss and degradation is further detailed below.

Urbanization

Urbanization results in long term impact because it permanently reduces desert tortoise habitat (Boarman 2002). An increase in human populations near desert habitats results in high habitat fragmentation and alteration that affects tortoise behavior and survival (Boarman 2002, Berry et al. 2006).

Mining & Alternative Energy Development

Mining and alternative energy development impact desert tortoises because they increase the amount of human traffic in the area. These types of developments usually increase the presence of utility lines, transmission lines, gas pipelines, solar development and pits for extraction of minerals; this in turn results in an increase nonnative species introduction, erosion, habitat fragmentation and degradation and tortoise mortality (Lovich and Bainbridge 1999, Boarman 2002).

Livestock Grazing

Livestock grazing is one of the biggest contributors to tortoise habitat degradation. Grazing, specifically from sheep and cattle, can cause severe soil compaction and brush trampling which leads to unfavorable burrowing conditions for tortoises (Brooks et al. 2006, Berry et al. 2014). Grazing also allows for nonnative plant species to more easily be introduced into a landscape; it also disturbs the soil and hinders the ability for native species to thrive (Brooks et al. 2006). Sheep grazing, in particular, has detrimental effects on the habitat because sheep will use creosote scrub bushes (*Larrea tridentata*) as shade relief, squashing creosote into conical shapes and trampling areas beneath creosote that tortoises would normally use for burrows (Berry et al. 2014). Grazing has occurred throughout the tortoise's range since the 1800s, with intensive grazing occurring from the 1960s to present day (Berry et al. 2014). Research has demonstrated that even after these land-altering disturbances have ceased, their impacts on landscape hydrology, soil and vegetation can persist for many decades (Carpenter et al. 1986, Abella 2010, Berry et al. 2015, 2016).

OHV Use

OHV use also contributes greatly to desert tortoise habitat degradation. The detrimental effects of OHVs on the condition of habitat have been well documented as both severe and long lasting (Lovich and Bainbridge 1999, Berry et al. 2014). Since soil condition and plant community composition can take a long time to recover from severe disturbance (Lovich and Bainbridge 1999), sites with heavy and recent OHV use may take an especially large amount of effort to restore as desert tortoise habitat. Considering this, sites with heavy and recent OHV use have a higher chance of restoration failure (Brooks 1995, Abella 2010). More specifically, OHV use crushes plants, compacts the soil, and opens up avenues for nonnative species introduction (Brooks et al. 2006, Berry et al. 2014, 2016).

Nonnative Species (Invasive Species, Weeds)

The introduction of nonnative species through natural or accidental means has had a lasting effect on the habitat diversity and stability for desert tortoises. The most abundant nonnative annual plants found in desert tortoise habitat include: red brome (*Bromus rubens*), cheatgrass (*Bromus tectorum*), Mediterranean grass (*Schismus barbatus*) and filaree (*Erodium cicutarium*). Nonnative plants may act in combination with other threats, such as increasing the proliferation of wildfires and competing with native forage, decreasing both the quantity and quality of forage, which can negatively affect the tortoise's nutritional needs (Oftedal 2002, Hazard et al. 2009, 2010).

Predation

There are several major predators of the desert tortoise. The most important are humans and ravens, although coyotes and wild dogs can have an impact as well. Human predation occurs indirectly through habitat degradation, and directly by illegally taking tortoises as pets or inadvertently crushing tortoises with vehicles on or near roads (Lovich and Bainbridge 1999). Raven predation is also a common occurrence due in part from the urbanization of desert landscapes (Boarman 2002). An increase in power lines, utility corridors, urbanization and landfills has increased the abundance of raven populations by expanding their habitat range into the desert where they would otherwise not be found (Boarman 2002).

Agricultural Development

The main impact of agriculture development on desert tortoises is that it reduces viable habitat. When desert land is used for agriculture, it makes the area unusable for forage or burrowing. Impacts that are exacerbated by agricultural development include: increased raven predation, increase in dust, decrease in the water table - which in turn can affect vegetation cover, introduction of toxic chemicals for fertilizing and an increase in nonnative plant species (Boarman 2002).

Military Training

Military training zones used for military exercises are common in the desert as far back as 1859 (Boarman 2002). These training zones usually include the construction of bases and support facilities (urban, industrial, commercial, etc.), field maneuvers for weapons testing and chemical distribution which can all have long lasting impacts on the desert tortoise (Boarman 2002). These impacts include decreases in useful vegetation, declines in tortoise populations, increase in noise disturbance resulting in auditory damages and actual deaths of desert tortoises from traffic incidents (Lovich and Bainbridge 1999, Boarman 2002, Berry et al. 2006).

1.3.4 Recovery efforts

Since the time of the desert tortoise's listing under the ESA, federal agencies have made significant strides in planning and prioritizing areas in which to focus recovery efforts. A *Species Recovery Plan for the Agassiz's Desert Tortoise* (Recovery Plan) was published in 1994 and updated in 2011 by the US Fish and Wildlife Service. In this plan, the home range for the desert tortoise is divided into five distinct recovery units, each of which contain designated critical habitat— a term used by land managers to describe specific areas occupied by the species at the time it was listed, that contain the physical or biological features that are "essential to the conservation of…species and that may need special management or protection" (USFWS 2015). The ultimate goal of the Recovery Plan is to recover and delist the desert tortoise by developing, supporting and building partnerships, protecting existing populations and habitat through habitat restoration, augmenting depleted populations, monitoring recovery progress, conducting applied research and modeling and implementing adaptive management (USFWS 2011). Thus, with the designation of critical habitat, recovery efforts can be specifically focused in regions where habitat that has been historically valuable or is potentially valuable to the species is known to occur.

In the Western Mojave Recovery Unit, critical habitat is located in 2 distinct areas: (1) Death Valley National Park- which has been identified as potential habitat for the desert tortoise, given its large size and protect status and (2) an area in the southwestern portion of the Western Mojave- where tortoises are known to be present, and which contains some private, protected, and restored habitat, such as the DTRNA.

Aggressive management in the form of habitat restoration has the potential to provide added support to desert tortoise populations. Unfortunately, to date, many habitat restoration projects have suffered from poor planning and limited scope. For example, many restoration projects seek to restore habitat by focusing on a single or limited number of treatments over an entire landscape —based on their success in other areas or their limited cost— without properly assessing the area's physical and biological characteristics or its current or past threats and impacts to desert tortoise populations. For example, without an assessment of current habitat conditions, the need for topsoil salvaging treatments or the need to do weed abatement, may be over or under emphasized. In reality, many desert restoration projects have spent millions of dollars on non-strategic restoration projects and seen little no improvement (USFWS 2011). Furthermore, though habitat recovery efforts have been attempted, none have been sufficiently monitored to assess their effectiveness for desert tortoise recovery (Abella and Berry 2016).

1.3.5 Western Mojave Recovery Unit

Introduction

The Western Mojave Recovery Unit is the largest of the five defined recovery units. The recovery unit extends from the western edge of the Mojave Desert to the border of the Eastern Mojave Recovery Unit along Death and Salinas Valleys, and south to the border of the Colorado Recovery Unit along California State Highway 62 (USFWS 2011). The Western Mojave has distinct vegetative patterns which are linked to higher proportions of annual rainfall occurring in the winter, with only brief and rare summer rain. This leads to a population of desert tortoises that are adapted to diets of winter annuals that bloom in spring, and are less active in other seasons. The Western Mojave also has a large amount of public land, including the western portion of Death Valley national park, the DTRNA, and extensive lands owned by the Bureau of Land Management (BLM).

Desert Tortoise Research Natural Area

The initial boundaries of the DTRNA were established in 1973, but its boundaries were not formalized until early 1980, after the creation of the DTPC (Berry et al. 2014). In 1980, the federal government removed mining from the DTRNA, and the BLM officially designated the DTRNA as a research natural area and area of critical environmental concern (ACEC), which made it illegal for sheep grazing and OHVs to use the land (Berry et al. 2014). The DTRNA in its current form consists of over 25,000 acres of fenced land owned and maintained by the DTPC. In addition, land acquisition and expansion of the DTRNA has occurred since the 1990s to the east and west of the ACEC (Berry et al. 2014).

Selected Restoration Site

A restoration plan was developed for this project to demonstrate the application of strategic restoration, and the site targeted by the plan was selected from the Eastern Expansion Area (EEA) of the DTRNA within the boundaries of the Western Mojave Recovery Unit.

The site is comprised of three parcels under the management and ownership of the Desert Tortoise Preserve Committee, Inc. The site is within the EEA of the DTRNA and is located in the Western Mojave Desert, north of California City, California. The site’s three parcels are approximately 160 acres each. The parcels can be identified by the following Assessor Parcel Numbers (APNs): 269-170-06, 269-170-11, and 269-170-12, hereafter referenced as 06, 11, and 12, respectively.

Vassar Avenue runs east-west, separating parcels 11 and 12, while Santa Clara Street runs north-south along the boundary between parcels 06 and 11, and Randsburg Mojave Road crosses through the southeastern corners of parcels 06 and 12. The entire EEA has recently been fenced and all three parcels are within this fence line boundary. Parcels 06 and 12 have a small amount of acreage outside of the established fence line because the fence line does not cross Randsburg Mojave Road. Due to this separation, the actual acreage of parcels 06 and 12 inside the fence line equal 158.9 and 142.75, respectively.

2. Methods and Results

2.1 Study Region

2.1.1 Western Mojave Recovery Unit

The Western Mojave Recovery Unit (WMRU) was selected as this project's widest region of study because of several reasons. First, the WMRU is the largest of the five units. Additionally, WMRU has exhibited a substantial decline in desert tortoise populations; in fact, on average, desert tortoise populations have decreased approximately 51% in the past several decades (USFWS 2011). There is thus a strong need for restoration actions within this region.

2.1.2 Desert Tortoise Research Natural Area (DTRNA) as a Reference Site

The DTRNA was designated critical desert tortoise habitat due to its high density of desert tortoises, diversity of vegetation, and relatively stable ecosystem condition throughout the past 40 years (Berry et al. 2014). The southeast portion of the DTRNA is used within the site specific restoration plan as reference site because it has a high diversity and density of vegetation which can be used as a comparison. Additionally, the DTRNA is also useful as a reference for the selected restoration site because it contains similar substrate properties to the restoration site, but increased vegetation alliances, thus setting a high standard for measuring the progress of the restoration effort as the plan is implemented.

2.1.3 Restoration Site Selection

The restoration site was chosen based on its high potential for desert tortoise habitat restoration, and feasibility of partnerships with the DTPC. The restoration site has similar substrate properties to areas within the DTRNA, yet due to its high degradation, the site has fewer vegetation alliances. By removing the stressors that cause degradation, and restoring the site through supplemental measures, the site has a high likelihood of increasing its plant species diversity and densities to levels similar to those in the DTRNA.

2.2 Framework

This project centers around the creation of a framework that highlights habitat restoration specifically focused on the desert tortoise. This framework includes three distinct components, which combine ecologically-based goals, planned actions, and managed outcomes to define, evaluate, and restore habitat. These components, though distinct, are intended to be used in combination, providing support to land managers involved in restoration efforts focused on supporting desert tortoise recovery.

Component 1: Guidance Document

A Strategic Approach to Restoration: Using the Science of Ecological Restoration to Guide Habitat Restoration for the Mojave Desert Tortoise

Photo of Desert Tortoise Research Natural Area, courtesy of Desert Tortoise Preserve Committee

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1. Abstract

Ecological concepts provide insight into understanding how ecosystem and human dynamics together influence habitat restoration for the Agassiz's Desert Tortoise. Here, we identify attributes of restored ecosystems that are fundamental to desert tortoise habitat. These attributes are represented in four categories: form, function, stability, and feasibility. Using a conceptual framework, we identify the pathways through which these categories and their associated attributes can influence the effectiveness of habitat restoration. Furthermore, we detail how these attributes can be strategically applied to on-the-ground restoration actions. This guidance document, used together with a site assessment tool and site-specific restoration plan, is meant to serve as a framework for strategic habitat restoration. Using this approach, we show that the outcomes of habitat restoration can be both efficient and effective; thus, our framework provides useful information for managers focused on habitat restoration for the desert tortoise.

2. Background

Restoration Ecology is a relatively young yet rapidly growing scientific field. In 2002, the Society of Ecological Restoration (a group composed of scientists and policy makers) published the first edition of *The SER Primer on Ecological Restoration* (Primer). Referred to by many as a foundational document in the field of restoration ecology (Shackelford et al 2013; Hallett et al 2013), the Primer aimed to clearly define ecological restoration and to describe the process in terms of its attributes (SER 2002). Since the Primer was published, the science of restoration ecology has become a well-represented academic field, with a significant increase in research and publications in peer-reviewed journals (Young et al 2005). Along with this growth, has come an increasing desire to define a scientific identity for restoration ecology and its relationship to ecological restoration. Following this movement, a number of academics have sought to update the Primer, as the concepts, methods, and goals of ecological restoration continue to evolve (Shackelford et al 2013; Hallett et al 2013). Together, the Primer and its successors provide essential background for studying ecological restoration.

Understanding the principles of ecological restoration is key to proper application of the science. According to the Primer, ecological restoration refers to an "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" or "the process of assisting in the recovery of an ecosystem that has been degraded, damaged, or destroyed". In these simple statements, the need to intentionally establish goals, apply actions, and manage outcomes becomes clear. Hence, goals should be based on recovering an ecosystem's health and integrity and promoting its sustainability. This requires an understanding of present ecological condition and potential or, put another way, the attributes that support the desired condition and potential. Actions should be applied in support of goals; therefore, the present ecological condition should serve as the basis for determining appropriate actions. Additionally, comprehensive and informative restoration planning can be delivered by explicitly accounting for the benefits, costs, and risks of different restoration techniques, as opposed to considering restoration as a single monolithic action (Shackelford et al. 2013). Records of past restoration efforts provide a wealth of knowledge as to the potential outcomes of various actions; and though many factors may influence outcomes, past efforts can serve as a basis for anticipated outcomes. Used together with effective monitoring, evaluation and adaptive management, this goal - action - outcome approach can be thought of as the backbone of strategic restoration. As stated in the Primer, the science of restoration ecology provides clear concepts, models, methodologies, and tools for practitioners in support of their practice; as such, linking theory to application is essential to employing ecological restoration in a strategic manner.

In addition to the general scoping of ecological restoration, other fundamental concepts are detailed in the literature. First discussed in the Primer, and echoed throughout the literature, are important concepts concerning appropriate scales and the inclusion of reference ecosystems. Selecting an appropriate scale, both in space and time, is key to successful restoration. Choosing a spatially explicit landscape perspective will ensure that energy flows, interactions, and exchanges are suitable with contiguous ecosystems. Similarly, choosing an appropriate time scale will be based on the ecological trajectory for restoration, as it dictates the developmental pathway of an ecosystem through time (SER 2002). Choosing a comparable and appropriate reference ecosystem is another important consideration. Notably, with an increased understanding and appreciation of global environmental change, comes the realization that the restoration of historical conditions is often unrealistic (Hallett et al. 2013). In light of this perspective, many projects have shifted focus from returning the ecosystem to a historical reference and instead focus on restoring specific functional attributes (Hallett et al. 2013). Stochasticity and uncertainty are also important to consider, as they represent natural ecosystem processes that cannot be predicted, but may have significant effects on restoration activities. In reality, the possibility that desired outcomes will not be realized is seldom dealt with, although accounting for the possibility of failure will likely influence which sites are prioritized for restoration and when the restoration should occur (McBride et al. 2010). Though these concepts are not the focus of this document, they are important to consider. Here, we integrate these concepts as they relate to key ecological attributes.

Restoration would not be complete without explicitly considering monitoring, evaluation and adaptive management. Monitoring of a restoration site should take place throughout the restoration process from concept to completion. Through monitoring, objectives can be evaluated on the basis of performance standards or success criteria. These standards may be conceived, in part, from an understanding of the reference ecosystem (SER 2002). Next, based on the results of evaluation, adaptive management may be employed — providing a strategy for altering or changing current management actions and thus adapting to the present conditions. Even when the restoration process is complete and the future health and integrity of the site can be sustained without manipulation, monitoring and management remain essential to continued success. In fact, both restored and undamaged natural ecosystems may be vulnerable to threats from invasive species, human activities, or climate change; and therefore require continued monitoring and management (SER 2002). What’s more, the use of imperfect reference ecosystems and natural variations in the ecosystem from stochasticity and uncertainty highlight the need to explicitly monitor, evaluate, and adapt throughout the restoration process (SER 2002). Through incorporating these fundamental components of ecological restoration, we can ensure that habitat restoration is well-informed and flexible, increasing the chance of success.

Alongside the application of ecological principles, the attributes of a restored ecosystem serve to guide strategic restoration. In the Primer, nine attributes of restored ecosystems are identified, and then grouped into three distinct categories: form, function, and stability. Through the process of ecological restoration, the ecosystem will: contain sufficient biotic and abiotic resources to continue its development without further assistance or subsidy, demonstrate resilience to normal ranges of environmental stress and disturbance, and interact with neighboring ecosystems in terms of biotic and abiotic flows and cultural interactions (SER 2002). Though these attributes remain central to employing strategic restoration, they do not adequately address a key element of restoration: the human element (Hallet et al. 2013, Shackelford et al. 2013). A number of research articles, including an update to the Primer published by Hallett et al. (2013) in *The Journal of the Society for Ecological Restoration*, have stressed that the explicit inclusion of social goals is critical to the success and value of ecological restoration (Hallet et al. 2013). Here, we will represent this attribute by the addition of a fourth category, referred to as feasibility. Thus, these four categories: form, function, stability and feasibility, serve to represent the fundamental attributes of restored ecosystems.

3. Method

The principles and attributes of ecological restoration serve as the foundation for application. From this foundation, other attributes of restored ecosystems may be added or adapted based on goals of the restoration project (SER 2002). Here, we aim to restore habitat for the desert tortoise, with the term habitat referring to "the dwelling place of an organism or community that provides the requisite conditions for its life processes." As detailed above, we will use the categories of form, function, stability, and feasibility to represent the essential components of restored ecosystems. These categories are further described in Table 1, *Components of Restored Ecosystems*. Using these categories as a starting point, we developed a conceptual model to explore and identify the attributes of restored ecosystems that are fundamental to desert tortoise habitat (Figure 1). By mapping these four categories to the attributes of desert tortoise habitat, we are able to represent all essential features of desert tortoise habitat in an ecologically and scientifically sound way.

Table 1. Components of Restored Ecosystems

Category	Description
Form	Form refers to the form or structure of the ecosystem. It is based on a characteristic assemblage of the species that naturally occur in an ecosystem and provide appropriate community structure. It consists of indigenous species to the greatest practicable extent. Additionally, it contains the physical features that naturally occur based on the ecosystem type.
Function	Function refers to the ecological processes of the ecosystem. It is based on the presence of functional groups (or potential presence) necessary for systems to remain stable or persist without outside interference. It consists of the dynamic processes that act on the structural components (form) of the ecosystem.
Stability	Stability refers to the resilience of an ecosystem, based on its ability to maintain integrity and be self-sustaining. This resilience is measured by the restored ecosystem's ability to endure normal periodic stress events and resist threats. It also includes the physical environment and climatic features that function to sustain reproducing populations of the species necessary for its continued stability or development along a desired trajectory.
Feasibility	Feasibility refers to the practicality of restoring the ecosystem. Obstacles to ecological restoration may limit success and make restoration impractical.

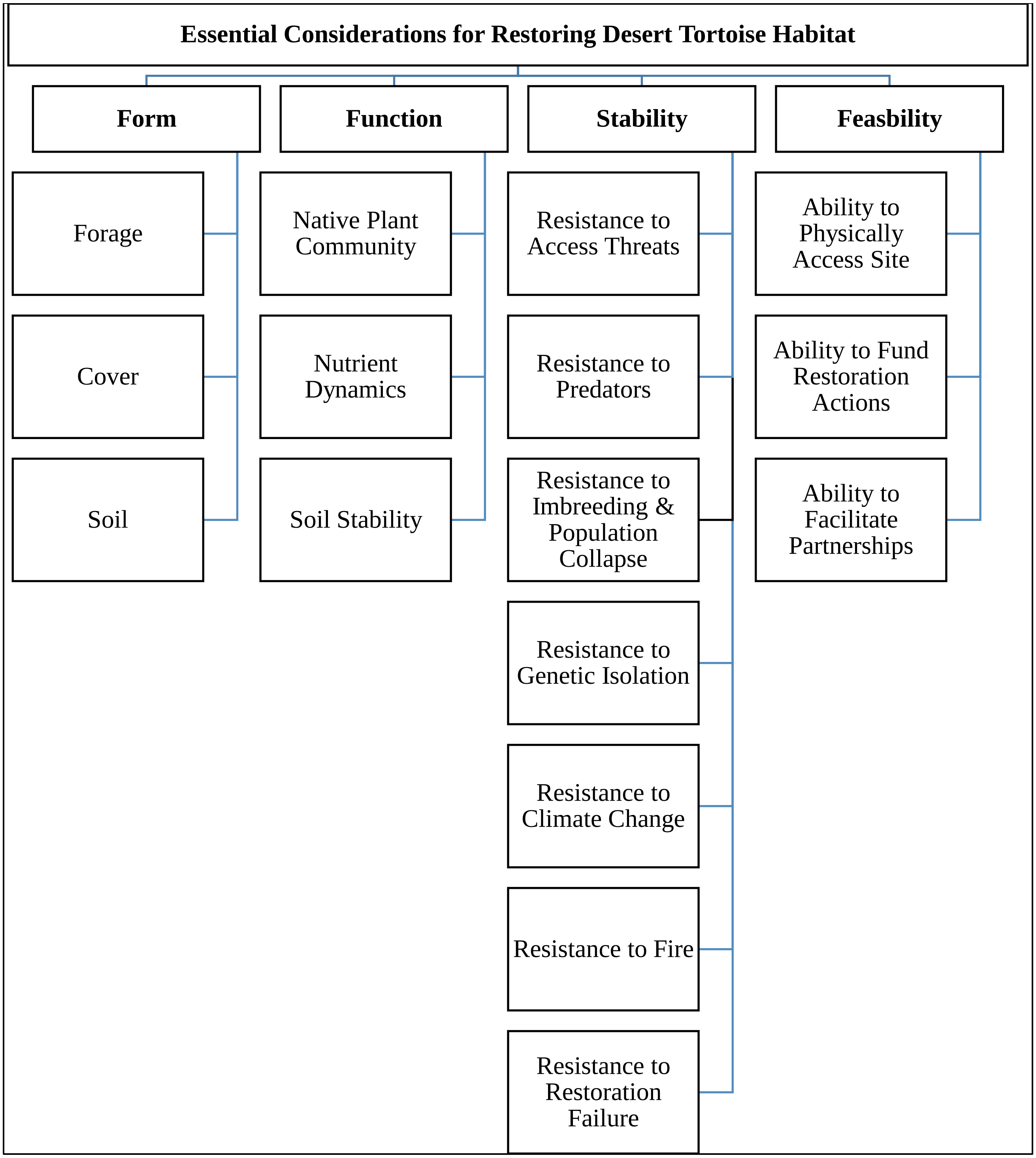

Figure 1. Conceptual Model

4. Application

The conceptual model (Figure 1) is used as the foundation for applying strategic habitat restoration. The features represented in each of the four categories refer to attributes that are important for healthy desert tortoise habitat, and thus, are essential considerations for restoring desert tortoise habitat. Here, we discuss the significance of each attribute as well as the management actions that should be considered for restoration. Table 2 defines and describes management actions that may be considered based on the current conditions of the habitat.

4.1 Form

4.1.1 Forage

Desert tortoise habitat should contain a variety of native annual and herbaceous perennial forbs that are favored as forage by the desert tortoise, which are known to be very selective foragers (Henen 1998, Esque et al. 2014, Jennings and Berry 2015, Abella and Berry 2016). Preferences for these plants can often be species-specific and usually overlap with the diets of other non-native animals (e.g., herbivores such as sheep and cattle). Tortoises of different age have been observed to prefer different species, based on varying sizes and, more specifically, leaf heights (Morafka and Berry 2002, Oftedal et al. 2002). Invasive plants can decrease both the quantity and quality of forage, by competing with native forage as well as increasing other threats, such as the proliferation of wildfires, which negatively affect the tortoise's nutritional needs (Oftedal 2002, Hazard et al. 2009, 2010). Overall, there is extensive literature detailing the importance of quality forage for the desert tortoise (Drake et al. 2015, Jennings and Berry 2015). Therefore, annual and herbaceous perennial forbs must be augmented and competition with non-native species must be reduced.

Management actions that may be considered for improving forage include: seeding, planting, excluding non-native herbivores, removing invasive plant species, and caging. These, and all other management actions, are further described in Table 2.

4.1.2 Cover

Desert tortoise habitat contains a mix of native perennial shrubs. Perennial plant species (representing canopy and shrub species) act as an obligatory source of cover for desert tortoises, providing protection from both predators and the harsh desert environment. Studies suggest tortoises avoid areas of very low plant cover (Andersen et al 2000; Drake et al 2015). Thus, by increasing the density of best performing shrub species and decreasing competition with non-native species, adequate cover can be maintained.

Management actions that may be considered for improving cover include: seeding, planting, excluding non-native herbivores, removing invasive plant species, and caging.

4.1.3 Soil

Desert tortoise habitat contains soil that supports the appropriate forage and cover species. In addition, soils must be friable (or malleable), allowing for burrow creation. Burrows are an essential components of desert tortoise habitat as they provide shelter from predators and help with thermoregulation (Germano et al. 1994, Andersen et al. 2000, Abella and Berry 2016). These burrows are important for survival, and tortoises spend the majority of the year inside burrows in order to escape predation and temperature extremes (Andersen et al. 2000, Mack et al. 2015). The ability for a tortoise to burrow is dependent on a site having soil which is easy for a tortoise to move aside when digging, but is not so fine that burrow structures collapse (Andersen et al. 2000, Abella and Berry 2016). Soil compaction from off-road highway vehicle (OHV) access and non-native herbivores can greatly reduce the quality of desert tortoise habitat, compacting them to levels unsuitable for forage and cover species establishment (Lovich and Bainbridge 1999).

Management actions that may be considered for improving soil condition include: salvaging topsoil, vertical mulching, ripping, imprinting, and re-contouring berms.

4.2 Function

4.2.1 Native Plant Community

A functioning native plant community is a crucial component of desert tortoise habitat. As stated above in ‘forage’, desert tortoises prefer native annual and herbaceous perennial forbs and tend to be selective foragers. The re-establishment of a functioning native plant community, which includes the reproduction and growth of organisms, is what leads recovery to being autogenic (SER 2002), where self-sustaining feedback loops lead to continued improvement of functional attributes. In low resource ecosystems, like deserts and rangelands, resource loss is mediated abiotically. Therefore, to initiate autogenic recovery in severely degraded systems, restoring abiotic functions such as nutrient dynamics and soil stability is a priority (King and Hobbs 2006). Overall, recovering autogenic processes to the point where external manipulation of the system is no longer needed, is a common goal for restoration. In desert tortoise habitat, focusing on actions that restore abiotic processes may serve as a starting point for ecosystem restoration.

Management actions that may be considered for promoting the establishment of the native plant community include: seeding, planting, excluding non-native herbivores, removing invasive plant species, and caging.

4.2.1 Nutrient Dynamics

The balance of nutrients is vital to a functioning biotic system and crucial to desert tortoise habitat. The term ‘nutrient dynamics’ specifically refers to the process through which nutrients like nitrogen and phosphorus move between the soil and plant communities. In desert tortoise habitat, nutrient dynamics may be improved by increasing soil stability. This in turn increases the diversity of soil microorganisms, increases infiltration, and promotes nutrient cycling and balance. If the balance of nutrients is lost, the native plant community may lose its capacity to function, potentially creating a shortage of forage or allowing increased proliferation of invasive species.

Management actions that may be considered for improving nutrient dynamics include: salvaging topsoil, vertical mulching, ripping, imprinting and re-contouring berms.

4.2.2 Soil Stability

Soil stability refers to the ability of the soil to support nutrient dynamics, a native plant community, and tortoise burrows, and is therefore an essential feature of desert tortoise habitat. See section 4.1.3 *Soil* for more information on the significance of soil in desert tortoise habitat.

Management actions that may be considered for improving soil stability include: salvaging topsoil, vertical mulching, ripping, imprinting, re-contouring berms.

4.3 Stability

4.3.1 Resistance to Access Threats

Access threats such as OHV use, grazing, and access roads are some of the most important factors leading to degradation of desert tortoise habitat. OHVs and grazing animals harm habitat by crushing vegetation and compacting soil to levels unsuitable for plant establishment (Lovich and Bainbridge 1999). Roads provide easier access routes for both OHVs and grazing animals, while also creating linear disturbance corridors which allow invasive plants to penetrate habitat (Abella and Berry 2016). Roads also have detrimental effects on tortoise densities, most likely due to direct kill from vehicles (Boarman and Sazaki 2006, Nafus et al. 2013), but possibly from effects such as high noise levels. Dirt trails made by OHVs further contribute to these same direct detrimental effects. In addition to threats from OHV use, grazing animals may selectively browse important forage plants (Abella 2008, Berry et al. 2014), compact soils (Lovich and Bainbridge 1999), and are correlated with an increase in invasive plant abundance (Brooks and Berry 2006).

Management actions that may be considered for promoting resistance to access threats include: fencing, road camouflage, signage, and siting restoration sites further away from access roads.

4.3.2 Resistance to Predators

Predators subsidized by human activities can have significant effects on desert tortoise survival. Ravens are known predators of the desert tortoise (e.g. Boarman 1995), and due to resource subsidies from human dominated areas, have undergone population booms which make them difficult to manage for apart from site selection. Ravens are opportunistic and often congregate around landfills which provide consistent food and water resources (Boarman et al. 2006) and utility corridors which provide structures for building nests (Boarman 2003).

Management actions that may be considered for promoting resistance to predators include: exclusionary fencing, selecting restoration sites away from landfills and utility corridors, and capturing/caging known repeat predators with the purpose of relocating them far away from tortoise populations. Lethal control of predators such as coyotes or ravens is also an option to consider for repeat predator individuals who are not deterred by nonlethal methods.

4.3.3 Resistance to Inbreeding and Population Collapse

Desert tortoise habitat must contain viable desert tortoise populations to be considered successful. When populations are small in size, they face increased risk from threats such as inbreeding which lead to unviable populations and population collapse. The desert tortoise also has more complex concerns related to slow maturation rates and the need for viable populations to contain multiple age structures. Regardless, the viability of a population is closely related to its size. Sites which are not large enough to sustain a viable population cannot be considered good tortoise habitat.

Management actions that may be considered for promoting resistance to inbreeding and population collapse include selecting sites with existing tortoise populations and selecting sites which are large enough to promote genetic diversity.

4.3.4 Resistance to Genetic Isolation

The viability of tortoise populations can also be influenced by genetic isolation of a population. When there is a lack of gene flow between populations, separate populations can become more homogenous and be less adaptable to stochastic events or changes in the environment. Gene flow can also mitigate against population collapse from inbreeding and genetic depression. Successful tortoise habitat should be close to other habitat patches to foster movement between populations.

Management actions that may be considered for promoting resistance to genetic isolation include: selecting sites with existing tortoise populations, select sites near known tortoise populations, and carefully considering translocation.

4.3.5 Resistance to a Changing Climate

Climate change is an impending reality which will have unknown but potentially drastic effects on desert tortoise habitat. Without precise knowledge of the way climate change will affect desert tortoise habitat, restoration efforts need to consider and manage for risks associated with climate change. Some areas will undoubtedly be more severely affected by climate change than others. Distributing restoration efforts in different areas of the desert tortoise’s known range can serve to spread out the risk of areas being severely affected by climate change. Therefore, risk management for desert tortoise habitat will need to center around fostering habitat diversity - both diversity within sites which are being restored and diversity in choosing areas to restore.

Management actions that may be considered for promoting resistance to climatic change include: planting and seeding diverse assemblages of plants and selecting sites across the desert tortoise's range.

4.3.6 Resistance to Fire

Fire has the potential to severely degrade desert tortoise habitat and is tightly coupled with the invasion of invasive grasses in arid ecosystems (D'antonio and Vitousek 1992). The ability for invasive grasses to recover rapidly after fire allows them to outcompete native cover and forage. Desert tortoises have been shown to recolonize areas that have recently undergone a single fire (Drake et al. 2015), but plant communities can take decades to recover from burns (Abella 2009, Engel and Abella 2011). Due to the heightened ability of invasive grasses to recolonize quickly after fire, multiple fires can change the plant composition of a site drastically enough that it may no longer be suitable for desert tortoise habitat without large amounts of restoration effort (D'antonio and Vitousek 1992, Abella 2009).

Management actions that may be considered for promoting resistance to fire include: removing invasive plant species to decrease ignition sources.

4.3.7 Resistance to Restoration Failure

Despite best efforts, restoration does not always succeed in creating stable habitat for the desert tortoise. While many of the factors that contribute to a restoration project failing can be directly managed for, there are potential stochastic events which are difficult to predict but provide additional unforeseen stress to habitats. The management of these stressors must be adaptive, as they are unknowns but still need to be considered in the planning of restoration activities.

Management actions that may be considered for promoting resistance to restoration failure include: monitoring restoration sites and creating adaptive management plans.

4.4 Feasibility

4.4.1 Ability to physically access site

The ability to physically access a site is necessary to conduct restoration. Sites located near existing infrastructure such as roads may still be considered for restoration, though threats from access may be present. Having an access point during active restoration activities can help contain vehicle movement and safely deliver equipment at a proposed restoration site. Post-restoration access to a site should be minimized as the negative impacts of roads on desert tortoises is well documented (see section 4.3.1, *Threats from Access*).

Management actions that may be considered for ensuring the ability to physically access the site include: carefully planning access points for facilitating restoration, fencing, road camouflage, and signage.

4.4.2 Ability to fund restoration actions

The ability to fund restoration actions is a fundamental component of any restoration project, as restoration cannot occur without proper funding. Restoration requires sufficient funding both to accomplish planned actions, monitor success, and adapt to changing conditions. More intensive restoration such as soil decompaction and planting is more expensive than less intensive actions because they require specific materials, equipment, and labor that would not be possible without funding.

Surveys and site assessments should occur at the start of a project to assess the current condition of the site. These activities are an essential part of restoration planning as they can help determine appropriate restoration actions and subsequently can inform funding needs. If necessary, fundraising should be considered prior to the start of restoration to ensure the highest likelihood of success. Fundraising may also need to occur in phases depending on the type and length of restoration occurring onsite.

The creation and use of adaptive management is an important consideration for funding restoration actions. Creating an adaptive management plan that is responsive to changing levels of funding, for example, could be designed from inception to be implemented in phases as funding becomes available.

Management actions that may be considered for ensuring the ability to fund restoration actions include: budgeting based on best available information, fundraising early in the restoration planning process, and creating an adaptive management plan.

4.4.3 Ability to facilitate partnerships

The ability to facilitate and maintain relationships with fellow stakeholders is critical to performing restoration. Neighboring landowners, managers, and/or community members with similar goals should be considered for potential partnerships, as partnerships can increase the likelihood of restoration success.

Management actions that may be considered for ensuring the ability to facilitate partnerships include: engaging managers and landowners, community outreach, and education.

Table 2. Restoration Management Actions (listed in alphabetical order)

Action	Description
Budgeting based on best available information	Best available information may refer to researching past restoration efforts in similar ecosystems or local areas and/or utilizing local vendors and labor. It may also refer to accounting for monitoring time and potential adaptive management strategies. Using best available information to budget will ensure the most effective and efficient use of project funding.
Caging	One of the biggest threats to planted species is herbivory by other animals. Wire cages and other protective enclosures provide the best protection from herbivores, increasing the rate of growth and likelihood of successful establishment.
Creating adaptive management plans	Adaptive management calls for the consideration of multiple different restoration techniques, with the adoption of the most effective techniques at a given site. Monitoring of these techniques is important, but means little without a plan for how to incorporate that information into management decisions.
Educating	Education is an important activity for supporting restoration effects. Through education, additional stakeholders, volunteers and partnerships may be gained.
Engaging in community outreach	Community outreach involves engaging local community members. This activity can translate to additional stakeholders and volunteers or potential partnerships.
Engaging landowners	Landowners should be engaged with both the process of planning and implementing restoration. In order to complete successful restoration, open communication of goals and the establishment of a working relationship should occur as part of restoration planning.
Excluding non-native herbivores	Removing non-native herbivores from a restoration site will ensure the availability of preferred forage for the desert tortoise by reducing competition. Non-native herbivores

	can be excluded through the use of fencing surrounding the entire site.
Fencing	Physical barriers that prevent access to a site are the most effective way to minimize habitat disturbance. Effective fencing should fully enclose a site and potentially allow for tortoise movement into and out of the site.
Fundraising	Fundraising should be considered prior to implementing a restoration plan. This activity should be conducted following the design of a restoration project with a carefully calculated budget. Fundraising can be used to raise funds to support restoration actions.
Imprinting	Imprinting refers to the indentation of soil in a pattern which can be used to enhance water retention, de-compact soil and promote plant establishment on a decommissioned road, OHV trail, or other area severely damaged by grazing and/or OHV use. The most common tool for this technique is a machine known as an Imprinter.
Monitoring restoration sites	Monitoring an essential action effective restoration. Monitoring throughout restoration process allows for managers to adapt to stochastic events and changing conditions.
Outplanting	Outplanting is the process by which nursery-grown plants are translocated to a restoration site. Plants used for outplanting must be in good health before translocation as this will increase the chances of survival.
Planning access points for facilitating restoration	The ability to access a site is important for facilitating restoration activities such as irrigating and ripping. At the same time, however, redundant and unnecessary access points can increase threats from access.
Planting & seeding diverse assemblages of plants	Plant responses to climate change are one of the most important, and difficult, aspects of a changing climate to predict. Therefore, it is important for a diversity of plants to

	be selected for restoration efforts, allowing for a greater chance that some plants survive despite climate change.
Ripping	Ripping refers to the process of decompacting the surface soil. Common tools for this technique include a subsoiler or rock ripper. When considering ripping, it is best practice to focus on the surface soil, represented by the upper 15 cm, to avoid disrupting the subsoil and potentially changing the soil properties. In general, ripping can be used to roughen compacted soil and promote plant recruitment, but this action can also promote nonnative plant recruitment.
Re-contouring berms	Re-contouring berms refers to the reshaping of contour lines along slopes or road sides. The most common tool for this technique is a dozer. This method can be used to re-connect washes and reestablish drainage patterns.
Removing invasive plant species	Non-native forbs and grasses can often outcompete native forbs and must therefore be removed to the greatest extent possible from the restoration site. Some removal techniques include manual removal of non-natives and the use of properly timed herbicide.
Road camouflage	Camouflaging dirt roads and trails can help prevent fencing from being cut or run over, which can occur as a means of accessing what people perceive to be roads. Road camouflage involves techniques such as soil ripping, vertical mulching, and rock placement to make roads resemble the rest of the habitat. These techniques should be done on road extents within line of sight of fence lines.
Salvaging topsoil	Salvaging topsoil is among the most ecologically beneficial ways to enhance recovery, and specifically ecosystem function, after disturbance. The upper 5-10 cm (2-4 inches) of soil contains most of the soil organic matter, nutrients, and microorganisms and the upper 5 cm (2 inches) of soil contains the entire or nearly entire viable soil seed bank. Planting on salvaged topsoil can greatly increase survivability of new established plant species.

Seeding	Seeding can often be expensive and result in low success, but it can produce the desired results under the right conditions. Seeds must be collected onsite or at the nearest location possible to ensure proper adaptability and can be done in conjunction with other practices, such as pelleting, or encapsulating the seed in a biodegradable coating to protect the seed. The augmentation of annual and perennial plant forage through seeding can help maintain a diverse menu of forbs preferred by the desert tortoise.
Selecting restoration sites away from landfills and utility corridors	Raven predation is difficult to manage due to the ability of ravens to travel long distances and fly over physical barriers. Siting restoration efforts a minimum of 1km away from utility lines and landfills can reduce the effects of raven predation on recovering desert tortoise populations.
Selecting sites across tortoise range	Some areas will undoubtedly be more severely affected by climate change than others. Siting restoration efforts across the entire range of the desert tortoise can mitigate the risk of areas being severely affected by climate change to the point that they are unsuitable habitat.
Selecting sites near known tortoise populations	Restoring sites near existing good habitat decreases the likelihood of genetic isolation. This allows for gene flow between tortoises in different habitat patches, while also allowing tortoises in both patches to move across a larger area in response to stochastic events and environmental stressors.
Selecting sites which are large enough to promote genetic diversity	Not all sites are large enough to support the long term goal of restoration efforts. How large a site needs to be changes depending on the goals of a restoration project. Restoration efforts that expand or enhance existing habitat patches can be focused on smaller areas than more isolated projects which need to be large enough to support tortoise populations by themselves.
Selecting sites which have existing tortoise populations	Sites with existing tortoise populations, even when at low density, can be good targets for restoration efforts. By increasing the amount of suitable habitat, tortoise density at

	a site may increase, resulting in a more stable tortoise population.
Signage	Signs are designed to display important information and educate people. In the case of desert tortoise restoration, signs may be used to both education visitors and warn trespassers of areas where restoration is set to occur and where desert tortoises may be present.
Vertical Mulching	Vertical mulching is the insertion of dead creosote branches into the ground in a vertical orientation to resemble a living plant. Vertical mulching serves multiple purposes, including: camouflaging the road from passersby, decompacting the soil, and providing additional shade for tortoises. The soil is loosened through the insertion of the dead creosote materials, thus breaking up compacted soils to allow for better nutrient and water retention. As a result of vertical mulching, fertile islands of native plant communities can be established, aiding in the reestablishment of a native plant community.

5. Conclusion

This guidance document shows how the principles of ecological restoration can be used to employ strategic restoration of desert tortoise habitat. Through thoughtfully establishing goals, applying actions, and managing outcomes, we can ensure that restoration efforts are both efficient and effective. Using the established principles of ecological restoration as a foundation, we adapted the attributes of a restored ecosystem to represent important features for restoring desert tortoise habitat. Using a conceptual model, we mapped out the pathways through which these features are represented, based on four categories: form, function, stability and feasibility. We described the significance of the features as they relate to habitat restoration and detailed how they can be represented by management actions. Through the process of: (1) understanding the essential features for strategically restoring desert tortoise habitat, (2) using the Site Assessment Tool to make prioritize restoration actions, and (3) applying the necessary actions for restoration through restoration planning, desert tortoise habitat can be restored efficiently and effectively. It is our hope, that managers focused on habitat restoration for the desert tortoise adopt the used of strategic restoration for future projects.

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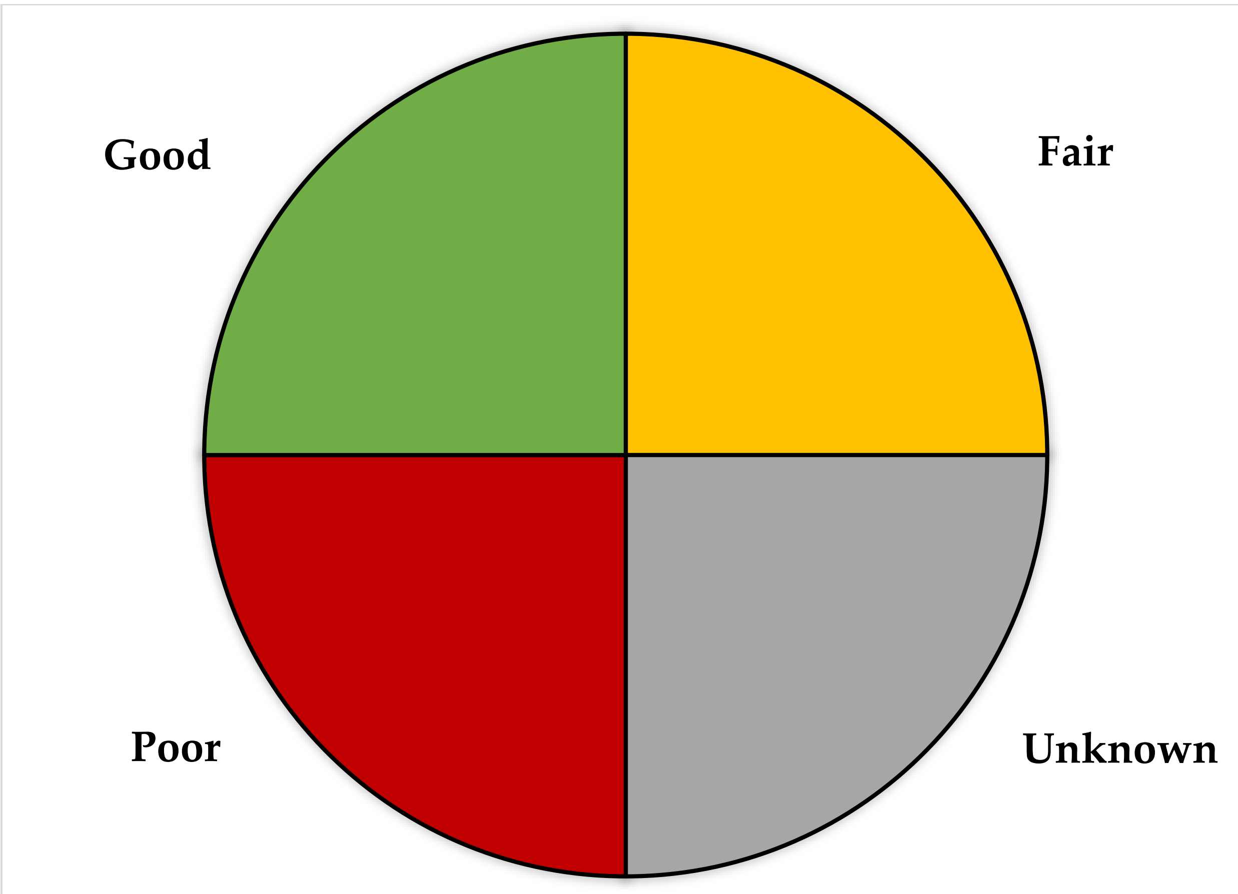
Component 2: Assessment Tool

Site Assessment Tool



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1. Abstract

The Assessment Tool (Tool) is a decision support tool that allows land managers to evaluate potential restoration sites in the Western Mojave Desert, based on the condition of habitat characteristics important to successful restoration for the desert tortoise. The Tool was created in Microsoft Excel, and uses a simple intuitive user interface which will allow a broad range of land managers to use it effectively. Habitat characteristics were chosen based on an extensive literature review to understand what makes good desert tortoise habitat, as well as the expert opinions of researchers and site managers from the Council and DTPC as to what characteristics need be considered for the success of restoration efforts. For each characteristic, conditions that constitute a “Poor”, “Fair”, or “Good” site assessment are defined and tool users are instructed to assess a potential restoration site based on which category best fits their site. The Tool will then generate graphs which offer visual representations of which aspects of a site are in good condition, and which aspects might need further consideration. This will allow land managers more information to choose whether a site should be selected for restoration efforts, and which aspects of a site might be most in need of attention.

2. Background and Instructions

2.1 What is this Tool?

This Assessment Tool (Tool) is a decision support tool that allows land managers to evaluate potential restoration sites for Agassiz's Desert Tortoise (*Gopherus agassizii*) habitat. This evaluation is based on the condition of habitat characteristics that are important for successful restoration. Habitat characteristics were chosen based on an extensive literature review focused on key features of desert tortoise habitat. Similarly, the expert opinions of researchers and professionals from the Desert Tortoise Council and Desert Tortoise Preserve Committee, Inc. were consulted to determine what characteristics need be considered for successful restoration.

2.2 How does this Tool work?

In the 'Habitat Assessment' tab, conditions that constitute a “Poor”, “Fair”, or “Good” site assessment are defined for 18 habitat characteristics. For each characteristic, users can choose the category (“Poor”, “Fair”, or “Good”) that best describes the present condition at their site, using the drop down list provided (Note: users can also enter the category manually). The "Unknown" category may be chosen if not enough information is available to assess a particular characteristic. Once all characteristics have been assessed, the Tool generates a dashboard in the 'Reports' tab which offer visual representations of present conditions onsite; using this visualization, managers can see which characteristics of a site provide good tortoise habitat and which characteristics might need further consideration. Users can consult the 'Resources' tab for links to useful information on improving habitat characteristics.

2.3 Where should this Tool be used?

This Tool is intended for use in the Western Mojave Recovery Unit as defined in the 2011 Revised Recovery Plan for the Desert Tortoise (USFWS 2011). While some of the habitat considerations in this Tool can be applied more broadly to other areas of desert tortoise habitat, the specific needs of desert tortoise habitat are different in other recovery units and the Tool was not developed to be used in those areas.

2.4 How do I get started?

If you would like to use this Tool for your restoration project, navigate to the 'Habitat Assessment' tab and start by choosing the category (“Poor”, “Fair”, “Good”, or "Unknown") that best describes the present condition at your site for each of the 18 habitat characteristics.

3. Characteristics

3.1 Biological Factors

3.1.1 Vegetation Association

The dominate vegetation associated with desert tortoise habitat in the Western Mojave Desert is the white bursage and creosote bush (*Ambrosia dumosa-Larrea tridentata*) association (Berry et al. 2006, Berry et al. 2014, Abella & Berry 2016). This vegetation matrix is represented by the Ambrosia dumosa-Larrea tridentata Shrubland Alliance, the most widespread and abundant desert alliance in California (Thomas et al. 2004). Characteristic features of this alliance include shrubs that are less than three meters tall and open canopy (Thomas et al. 2004).

3.1.2 Vegetative Cover

Perennial plant species (representing canopy and shrub species) act as an obligatory source of cover for desert tortoises, providing protection from both predators and the harsh desert environment. Studies suggest tortoises avoid areas of very low plant cover (Andersen et al 2000; Drake et al 2015); although, it is difficult to determine how much shrub cover tortoises actually require (Abella & Berry 2016). According to a study conducted by Dr. Berry and colleagues at the National Training Center in the Central Mojave Desert, tortoises may be present in areas with as little as 4.0% plant cover (Berry et al. 2006); though this result is meaningful as it represents the lowest known percent plant cover known to support desert tortoises, the landform is characterized as an alluvial fan, suggesting that there may be scree and other rock features that are used as supplement cover areas. In studies conducted in other areas with similar vegetation, the average density of mature perennial plants (>10 cm tall) were 17 plants per square kilometer for creosote and 5.9 plants per square kilometer for white bursage (Abella & Berry 2016).

3.1.3 Native Forage

Native forbs are a fundamental component of desert tortoise habitat, providing nutritious and suitable forage species for the desert tortoise. Though diet analyses and observations of foraging indicate that desert tortoises eat dozens of plant species, they are known to be selective foragers (Henen 2002; Esque et al. 2014; Jennings and Berry 2015, Abella & Berry 2016). In addition, tortoises of different age have been observed to prefer different species, based on varying sizes and, more specifically, leaf heights (Morafka & Berry 2002; Oftedal et al. 2002). Furthermore, there is extensive evidence in the literature stating the importance of quality forage for the desert tortoise (Drake et al. 2015; Jennings and Berry 2015).

Though forage species may vary by timing and availability, several studies have reported on preferred forage in the Western Mojave Desert. In one study, desert tortoises preferred to consume certain herbaceous perennial forbs, even though annuals were available (Jennings and Berry 2015); in this study, preferred forbs included: wishbone-bush (*Mirabilis laevis*), Layne Locoweed (*Astragalus layneae*), whitemargin sandmat (*Chamaesyce albomarginata*), Mojave lupine (*Lupinus odoratus)*, foothill deervetch (*Acmispon brachycarpus*), dwarf milkvetch (*Astragalus didymocarpus*), lacy phacelia (*Phacelia tanacetifolia*), and desert dandelion (*Malacothrix coulteri*). Other preferred species in the Western Mojave may include: Hairy Lotus (*Lotus humistratus*), Four O'Clock (*Mirabilis laveis*), Rattlesnake Sandmat (*Chamaesyce albomarginata*), Layne Locoweed (*Astragalus layneae*), Egbertia (*Prenanthella exigua*), Two-seeded Milkvetch (*Astragalus didymocarpus*), Booth's Evening Primrose (*Eremothera boothii*), Brittle Spineflower (*Chorizanthe brevicornu*), and Lacy Phacelia (*Phacelia tanacetifolia*) (Jennings 2002). In addition, native perennial grasses are also foraged on by the desert tortoises, but herbaceous perennial forbs are preferred when available (Hazard et al. 2009, 2010).

3.1.4 Invasive Plants

The presence of invasive plant species can negatively affect desert tortoise habitat. The most abundant invasive annual plants found in desert tortoise habitat include: red brome (*Bromus rubens*), cheatgrass (*Bromus tectorum*), Mediterranean grass (*Schismus barbatus*) and filaree

(*Erodium cicutarium*). Invasive plants may act in combination with other threats, such as increasing the proliferation of wildfires and competing with native forage, decreasing both the quantity and quality of forage, which can negatively affect the tortoise's nutritional needs (Oftedal 2002; Hazard et al. 2009, 2010).

3.1.5 Desert Tortoise Density

Historically, population densities in the Western Mojave Desert were quite large. In a survey conducted in the Desert Tortoise Research Natural Area conducted between 1979 and 1982, population densities were 150 tortoises per square kilometer (Berry and Medica 1995; Brown et al. 1999; Keith et al. 2008). However, subsequent studies suggest that the population densities in the area declined by over 90% in the early 1990s (Berry and Medica 1995; Brown et al. 1999; Keith et al. 2008) In the Desert Tortoise Recovery Plan published by the US Fish and Wildlife Service, a density of 3.86 adult tortoises per square kilometer was cited as a minimum density to support genetic viability.

3.1.6 Proximity to Current Desert Tortoise Habitat

The proximity to known desert tortoise habitat is an important consideration for assessing potential habitat, as it serves to promote genetic viability, which is fundamental to recovery efforts. In the Desert Tortoise Recovery Plan published by the US Fish and Wildlife Service, along with a minimum density requirement, a habitat area of 518-1295 km2 was estimated for genetic viability. In addition, past genetic work also suggests that, historically, levels of gene flow among subpopulations were likely high, corresponding to high levels of connectivity among habitat types (Murphy et al. 2007; USFWS 2011). Since desert tortoises possess the capability for long-distance dispersal, are long-lived and can reproduce annually throughout adulthood, they possess a high potential for gene exchange outside of local areas (USFWS 2011). According to tortoise expert Dr. Kristin Berry, large males are known to occupy home ranges of over 0.75 square miles. Translating this to a diagonal distance of travel, male tortoises may travel up to 0.87 miles or approximately 1.4 kilometers within their home range. Therefore, we may safely assume tortoises can travel this distance to other areas of suitable habitat.

3.2 Physical Features

3.2.1 Geologic Substrate

The ability for desert tortoises to burrow is an important consideration for habitat suitability (Germano et al. 1994, Andersen et al. 2000, Abella and Berry 2016). Suitability of a site for burrowing is linked to soil parent material and geologic substrate (Andersen et al. 2000). Due to this linkage and the importance of burrows, suitable tortoise habitat usually contains loamy soils and alluvial fans (Rautenstrauch and O'Farrell 1998, Andersen et al. 2000, Murphy et al. 2011, USFWS 2011).

3.2.2 Soil Composition

Desert tortoises create burrows which provide shelter from predators and help with thermoregulation (Germano et al. 1994, Andersen et al. 2000, Abella and Berry 2016). These burrows are important for the survival of the desert tortoise, and tortoises spend the majority of the year inside burrows in order to escape predation and temperature extremes (Andersen et al. 2000, Mack et al. 2015). The ability for a tortoise to burrow is dependent on a site having friable soil which is easy for a tortoise to move aside when digging burrows, but is not so fine that burrow structures collapse (Andersen et al. 2000, Abella and Berry 2016).

3.2.3 Elevation

Desert tortoises have a wide range of elevations, and are commonly found between elevations of 500 and 1500 meters (Rautenstrauch and O'Farrell 1998, USFWS 2011). Although desert tortoises have been found outside of these ranges (USFWS 2011), it is rare case.

3.2.4 Slope

Desert tortoise thrive in a variety of habitats from flatlands to slopes (Germano et al. 1994), but are not typically found on slopes greater than 45° (Keith et al. 2008).

3.3 Threats

3.3.1 Off Highway Vehicle Access

Off highway vehicle (OHV) use is one of the most detrimental activities to desert tortoise habitat (Lovich and Bainbridge 1999, Berry et al. 2014). OHVs crush important vegetation (Berry et al. 2014), compact soil to levels unsuitable for plant establishment (Lovich and Bainbridge 1999), and directly cause some desert tortoise deaths (Ruby et al. 1994). Since desert habitat recovers slowly from these sorts of disturbances, limiting these disturbances in the first place is critical to the health of a site (Brooks 1995, Lovich and Bainbridge 1999, Abella 2010,).

The effects of further OHV use is largely dependent on the ability of OHV users to have continued access to a site (Berry et al. 2014). Fencing is the most important method for limiting OHV access to a site (Ruby et al. 1994, Berry et al. 2014). Sites which are fully fenced show decreased impacts of OHV use than unfenced sites (Brooks 1995, Berry et al. 2014). The ability to limit access to a site is also dependent on proximity to access roads (Lovich and Bainbridge 1999, Brooks and Berry 2006). Roadways serve as the main arteries for OHV users to access desert habitat, and sites nearer to these roads may have continued OHV issues even if fully fenced.

3.3.2 Grazing

Grazing is one of the most detrimental activities to desert tortoise habitat (Lovich and Bainbridge 1999, Berry et al. 2014). Grazing animals selectively browse important forage plants (Abella 2008, Berry et al. 2014), compact soils (Lovich and Bainbridge 1999), and are correlated with an increase in invasive plant abundance (Brooks and Berry 2006). Since desert habitat recovers slowly from these sorts of disturbances, limiting these disturbances in the first place is critical to the health of a site (Brooks 1995, Lovich and Bainbridge 1999, Abella 2010). Fencing is the most important method for limiting grazing access to a site (Ruby et al. 1994, Berry et al. 2014).

3.3.3 Raven Predation

Ravens are known predators of the desert tortoise (e.g. Boarman 1995), and due to the resource subsidies of human dominated areas have undergone population booms which make them difficult to manage for apart from site selection. Ravens are opportunistic and often congregate around landfills which provide consistent food and water resources (Boarman et al. 2006) and utility corridors which provide structures for building nests (Boarman 2003). While raven populations have wide ranges, individuals are unlikely to be found more than 2000 meters from their home sites in open ecosystems (Coates et al. 2014). Ravens are most likely to prey on desert tortoise in order to feed young, but are also likely to stay within 500 meters of nesting sites when they have fledglings (Kristan and Boarman 2003).

3.3.4 Proximity to Roads

Roadways have detrimental effects on both desert tortoise habitat and desert tortoises themselves (Boarman and Sazaki 2006). The ability for invasive plants and off highway vehicles to traverse down roadways contributes to habitat degradation (Abella and Berry 2016), and vehicles along roadways also often directly kill tortoises (Boarman and Sazaki 2006, Nafus et al. 2013). The effects of off highway vehicles and invasive plants are important but can be managed (see “Off Highway Vehicles” and “Invasive Plants”), whereas tortoises killed by vehicles is correlated with proximity to roads (Boarman and Sazaki 2006) and is largely difficult to manage for outside of site selection.

The effect of roads on substantial reduce tortoise density somewhere between 400 and 800 meters from the roadway (Boarman and Sazaki 2006, Nafus et al. 2013). The amount of traffic on a roadway can also play a role in detrimental effects on the desert tortoise (Nafus et al. 2013). Low traffic volume roads (<30 vehicles traveled per day) have less detrimental effects on desert tortoise populations than intermediate or high volume roads (Nafus et al. 2013). Roads with high traffic volume (>300 vehicles per day) can contribute to population declines (Nafus et al. 2013), and decline may be seen at traffic volumes as low as 100 vehicles per lane per day (Gibbs and Shriver 2002).

3.4 Disturbance History

3.4.1 Trash

Both toxic and non-toxic waste materials can affect the health of the desert tortoise (Abella and Berry 2016). Toxic contaminants from illegal dumping or historic mining activities can be ingested by tortoises either directly or through vegetation which has absorbed harmful chemicals in the soil (Abella and Berry 2016, Chaffee and Berry 2006). These contaminants are difficult to manage for outside of detection in site selection. Non-toxic contaminants also are detrimental to tortoises who sometimes eat litter, leading to illness or death (Walde et al. 2007). These non-toxic contaminants are possible to remove however, and can be managed for if present on a selected restoration site.

3.4.2 Off Highway Vehicles

The detrimental effects of OHVs on the condition of tortoise habitat are severe and long lasting (Lovich and Bainbridge 1999, Berry et al. 2014). Since soil condition and plant community composition can take large amounts of time to recover from severe disturbance (Lovich and Bainbridge 1999), sites with heavy and recent OHV use may take an especially large amount of effort to make suitable for desert tortoise habitat, and potentially have a higher chance to suffer restoration failure (Brooks 1995, Abella 2010).

3.4.3 Grazing

The effects of grazing activity on a site can be severe and long lasting (Lovich and Bainbridge 1999, Berry et al. 2014). Grazing can drastically alter the plant community composition of a site by removing native forage (Abella 2008, Berry et al. 2014), and increasing the abundance of invasive plants (Brooks and Berry 2006). Grazing animals can also compact soil, altering the ability for plants to establish (Brooks et al. 2006). Since soil condition and plant community composition can take large amounts of time to recover from severe disturbance (Lovich and Bainbridge 1999), sites with heavy and recent grazing history may take a large amount of effort to make suitable for desert tortoise habitat (Brooks 1995, Abella 2010).

3.4.4 Fire History

Fire is tightly coupled with the invasion of invasive grasses in arid ecosystems (D'Antonio and Vitousek 1992). The ability for invasive grasses to recover rapidly after fire allows them to outcompete native cover and forage. Desert tortoises have been shown to recolonize areas that have recently undergone a single fire (Drake et al. 2015), but plant communities can take decades to recover from burns (Abella 2009, Engel and Abella 2011). Due to the heightened ability of invasive grasses to recolonize quickly after fire, multiple fires can change the plant composition of a site drastically enough that it cannot be suitable for desert tortoise habitat without large amounts of restoration effort (D'Antonio and Vitousek 1992, Abella 2009).

4. Interpreting Results

Results produced by the Assessment Tool (Tool) are meant to help land managers prioritize restoration efforts. As the Tool is intended to be used in areas in need of restoration, potential sites are expected to contain features assessed as being in “fair” or “poor” condition; otherwise, there would be no need for restoration. When the tool is used to assess a potential restoration site, a land manger can visualize the features in need of restoration and subsequently decide whether an improvement of current conditions is feasible given present constraints. In addition, a land manager may also use the Tool to visualize conditions at a number of potential sites, as a means of comparison. The Tool itself does not prioritize one site over another, but can assist a land manager in choosing a best-suited site based on their current situation and set of constraints. It is recognized that constraints may vary widely based on funding, stakeholders, time, etc. As the purpose of the tool is to provide decision support as opposed to a means of prioritization, it is important that users are knowledgeable about the desert tortoise and its habitat needs. It is also worth noting that certain conditions, like for example, proximity to a road, may be unchangeable; in this case, the present condition of the feature is taken with face value as something that restoration will have to address indirectly or work around. In the case of a road: if site contains an active road, the road may not be subject to removal, but the area adjacent to the road may be fenced for added protection for the tortoise. This would be considered an indirect way of addressing the condition. By creating a tool to assess and visualize the conditions present at potential restoration sites, land managers can quickly and efficiently prioritize restoration efforts.

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Appendix A - Assessment Tool Graphics

Feature	Poor Site	Fair Site	Good Site	Assessment	Notes
		Biological Factors			
Vegetation Association*	Site contains little to no white bursage (*Ambrosia dumosa*)/creosote bush (*Larrea tridentata*) vegetation.	Site may contain some white bursage/creosote bush vegetation, but it is not the dominant asosciation (<50% of site).	Site is dominated by white bursage/creosote bush vegetation. Site may additionally contain Box-thorn, Indigo bush, Nevada ephedra and emergent Joshua trees.	Fair	
Vegetative Cover	Site is highly denuded; has less than 4% density of creosote, white bursage and/or other cover flora; most of the area is bare earth.	Site is partially denuded; has low density of creosote, white bursage and/or other cover flora; there are some patches of bare earth, but they do not dominate the site.	Site has high density (>17 plants/km^2) of creosote, white bursage (> 6 plants/km^2) and/or other cover flora; there are limited patches of bare earth.	Fa	
Native Forage	Site contains very few or no native perennial plant species.	Site contains small amounts of (Chylismia claviformis) and desert plantain (Plantago Ovata) and a low diversity of native forage.	Site contains a large abundance of native perennial plant species. Broweyes (Chylismia claviformis) and desert plantain (Plantago Ovata) are present onsite.	Poor	
Invasive Plants	Site contains a high abundance of invasive grasses and mustards such as red brome (*Bromus rubens*), cheatgrass (*Bromus tectorum*), Mediterranean grass (*Schismus barbatus*) and filaree (*Erodium cicutarium*). These species are visibly present over the majority of the site.	Site contains an appreciable amount of invasive species, such as red brome , cheatgrass, Mediterranean grass and filaree.	Site contains no or very little invasive species, such as red brome, cheatgrass , Mediterranean grass, and filaree.	Fair	
Tortoise Density	No tortoise sign is present onsite.	Tortoise sign is present onsite, but may be minimal.	Tortoise sign indicates densities of at least 3.86 tortoises/km^2	Unknown	
Proximity to Current Tortoise Habitat	Site is not within 1.4 km of current tortoise habitat or protected lands	Site is within 1.4 km of potential tortoise habitat or protected lands with suitable habitat features	Site is within 1.4 km of current tortoise habitat	Good	

Assess your site:
Choose which category of Poor, Fair, or Good best matches your site. Choose Unknown if there is not enough information.

	Physical Features				
Geologic Substrate*	Site lacks loamy soils, fine grained alluvial fan deposits	Site contains some loamy soils, fine grained alluvial fan deposits, but this substrate is not dominant at the site	Site contains a high proportion of loamy soils and fine grained alluvial fan deposits	**Good**	
Soil Composition*	Site lacks sand and fine gravel	Site contains minimal or patchy patchy areas of friable soil: sand and fine gravel	Site contains a high proportion of friable soil: sand and fine gravel.	**Fa**	
Elevation*	The majority of the site (>50%) is above 1500m or below 500m.	Some of the site is located above 1500m or below 500m, but the majority (>50%) is below 1500m.	100% of the site is contained in the expected elevation range of 500-1500 meters above sea level.	**Good**	
Slope*	Site is entirely located on slope greater than 45°	The majority (>50%) of the site is located on slopes greater than 45°	100% of the site is located on slope less than 45°	**Good**	
	Threats				
Off Highway Vehicles Access	Site is not fenced. Site is near major access roads. Site has signs of recent OHV and dirt bike use.	Site is fully fenced. Site is near major access roads and has signs of recent OHV and dirt bike use.	Site is fully fenced, and has no active OHV or dirt bike trails.	**Fair**	
Grazing Access	Site is not fenced and contains scat or other signs of active grazing.	Site is not fully fenced but contains no scat or other signs of active grazing.	Site is fully fenced and has no scat or other signs of active grazing.	**Good**	
Raven Predation	Site is within 500m of a utility corridor or a landfill. Ravens are common at site.	Site is between 500 and 2000m from any utility corridors or landfills. Ravens are not common at the site.	Site is at least 2000m away from any utility corridors or landfills.	**Fair**	
Proximity to Roads	Site is within 400m of roadways with high traffic volume (>100 vehicles per day).	Site is 400 - 800m from roadways. Roadways near site have intermediate traffic volume (30-100 vehicles per day).	Site is at least 800m from roadways. Roadways near site have low traffic volume (<30 vehicles per day).	**Poor**	

Assess your site: Choose which category of Poor, Fair, or Good best matches your site. Choose Unknown if there is not enough information.

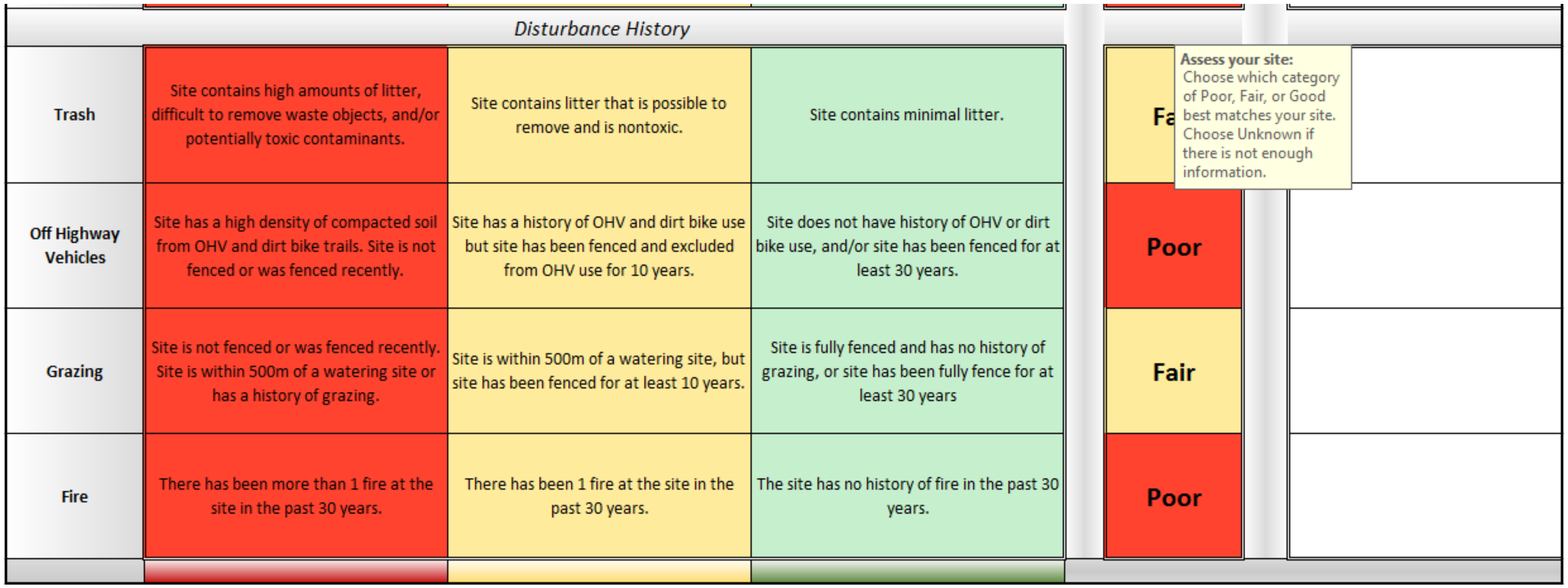

Figure 1. User interface of Assessment Tool

Figure 2. Graphical Outputs of Assessment Tool

Component 3: Restoration Plan

Restoration plan for site within the Eastern Expansion Area of Desert Tortoise Research Natural Area

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May 5, 2017

1. Abstract

The Restoration Plan (RP) is a site-specific restoration plan for three contiguous parcels within the EEA of the DTRNA. The RP encompasses a variety of restoration actions based on the best management practices available for desert tortoise recovery and habitat restoration. The ultimate purpose of the RP is to improve and ultimately restore degraded or disturbed habitat to meet the cover, forage and soil needs of the desert tortoise. To achieve this purpose, the RP utilizes the two structures defined in the Guidance Document by organizing the elements into intended goals, restoration actions, and expected outcomes through demonstrating the form, function, stability, and feasibility of restoration at this location. This RP embodies a complete example of how strategic restoration may be completed in the western Mojave Desert, and includes descriptions of actions, monitoring and maintenance efforts, and a breakdown of supply costs which land managers may find helpful.

2. Purpose

The Agassiz's desert tortoise (*Gopherus agassizii*) ('desert tortoise' or 'tortoise') has experienced populations decline an average of 51% in the past ten years (USFWS 2015). Desert tortoise experts are concerned about the feasibility of species recovery if populations continue to decline. Two groups, the Desert Tortoise Council (Council) and the Desert Tortoise Preserve Committee, Inc. (DTPC), seek to increase the viability of desert tortoise populations within the Western Mojave Desert through a combination of science-motivated conservation and restoration actions. Our client, the Council, has requested the development of a restoration plan that focuses on restoration of habitat specifically for the desert tortoise. To this end, three parcels within the Eastern Expansion Area (EEA) of the Desert Tortoise Research Natural Area (DTRNA) were selected for restoration. Due to their highly visible levels of soil and vegetative degradation, proximity to existing habitat (the DTRNA), and potential for partnership with the DTPC, these parcels provide a unique opportunity for tortoise habitat recovery. Additionally, with Randsburg Mojave road crossing through southeastern corners of the restoration site, this area is a potential access point for many disturbances into the rest of the EEA. Restoration efforts at this site could therefore expand potential tortoise habitat, with this restoration site serving as a catalyst for future restoration efforts within the EEA. This restoration plan lays out a framework of goals, actions, and expected outcomes for beginning restoration for approximately 460 acres at this site, as well as the costs of implementing these actions. A copy of this restoration plan may be found on an accompanied CD version and is held by the Council.

3. Significance

The greatest threat to the desert tortoise is habitat loss and degradation from increased human activities, including urbanization, agricultural development, military training, recreation, mining, livestock grazing, and a lack of enforcement of existing regulatory mechanisms (Boarman and Coe 2002, USFWS 2011). Research shows that even after these land-disturbing activities have ceased, their impacts on landscape hydrology, soil and vegetation can persist for many decades (Carpenter et al. 1986, Abella 2010, Berry et al. 2015, 2016). As such, on-the-ground efforts to preserve and restore habitat are critical for tortoise recovery. Restoration actions have been implemented to restore vegetation in the Mojave Desert region (e.g. Wallace et al. 1980, Abella and Newton 2009, Scoles-Sciulla et al. 2015), but these efforts have not specifically focused on the needs of the desert tortoise (Abella and Berry 2016). This restoration plan is designed specifically to address these needs with habitat considerations of the desert tortoise as the primary targets.

4. Involved Parties

4.1 Desert Tortoise Council

"The Desert Tortoise Council (Council) was established in 1975 to promote conservation of the desert tortoise in the deserts of the southwestern United States and Mexico. The Council is a non-profit organization comprised of hundreds of professionals and laypersons who share a common concern for desert tortoises in the wild and a commitment to advancing the public's understanding of the species" (deserttortoise.org). The Council is responsible for generating this restoration plan and for partially raising the necessary funds to support its implementation.

4.2 Desert Tortoise Preserve Committee, Inc.

"The Desert Tortoise Preserve Committee, Inc. (DTPC) is a non-profit organization formed in 1974 to promote the welfare of the desert tortoise (*Gopherus agassizii*) in its native wild state. Committee members share a deep concern for the continued preservation of the tortoise and its habitat in the southwestern deserts" (www.tortoise-tracks.org). The DTPC is the owner of land on which this restoration plan is designed for and will be working with the Council to implement the restoration plan.

4.3 Bren School of Environmental Science and Management Master's Group

The Bren School Master's Group is working with the Council and DTPC to design a restoration plan for the eastern expansion parcels of the DTRNA. Through the restoration plan, the Group seeks to improve the quality of existing habitat for the desert tortoise and lay the groundwork for future research opportunities with the Council and DTPC.

5. Site Background

The three parcels that comprise the site for this restoration project are under the ownership and management of the DTPC. The site is within the confines of the EEA of the DTRNA, located in the Western Mojave Desert north of California City, California (Figure 1), and consists of three parcels that are approximately 160 acres each. As shown in Figure 2, the parcels can be identified by the following Assessor parcel numbers (APNs): 269-170-06, 269-170-11, and 269-170-12, hereafter referenced as 06, 11, and 12, respectively.

The restoration site consists of three of the four parcels that form Section 16 in the EEA (Figure 2). Two active county roads run partially within the boundaries of the restoration site. Vassar Avenue runs east-west, separating parcels 11 and 12, while Santa Clara Street runs north-south along the boundary between parcels 06 and 11, and Mojave Randsburg Road crosses through the southeastern corners of parcels 06 and 12 (Figure 2). The entire EEA has recently been fenced and all three parcels are within this fence line boundary. Small portions of Parcels 06 and 12 are outside of the established fence line because the fence line does not cross Mojave Randsburg Road. Due to this separation, the actual acreage of these two parcels inside the fence line total 158.9 and 142.75, respectively. For the purpose of this project, the restoration plan will only consider the acreage of the parcels within the fence line, approximately 461.65 acres.

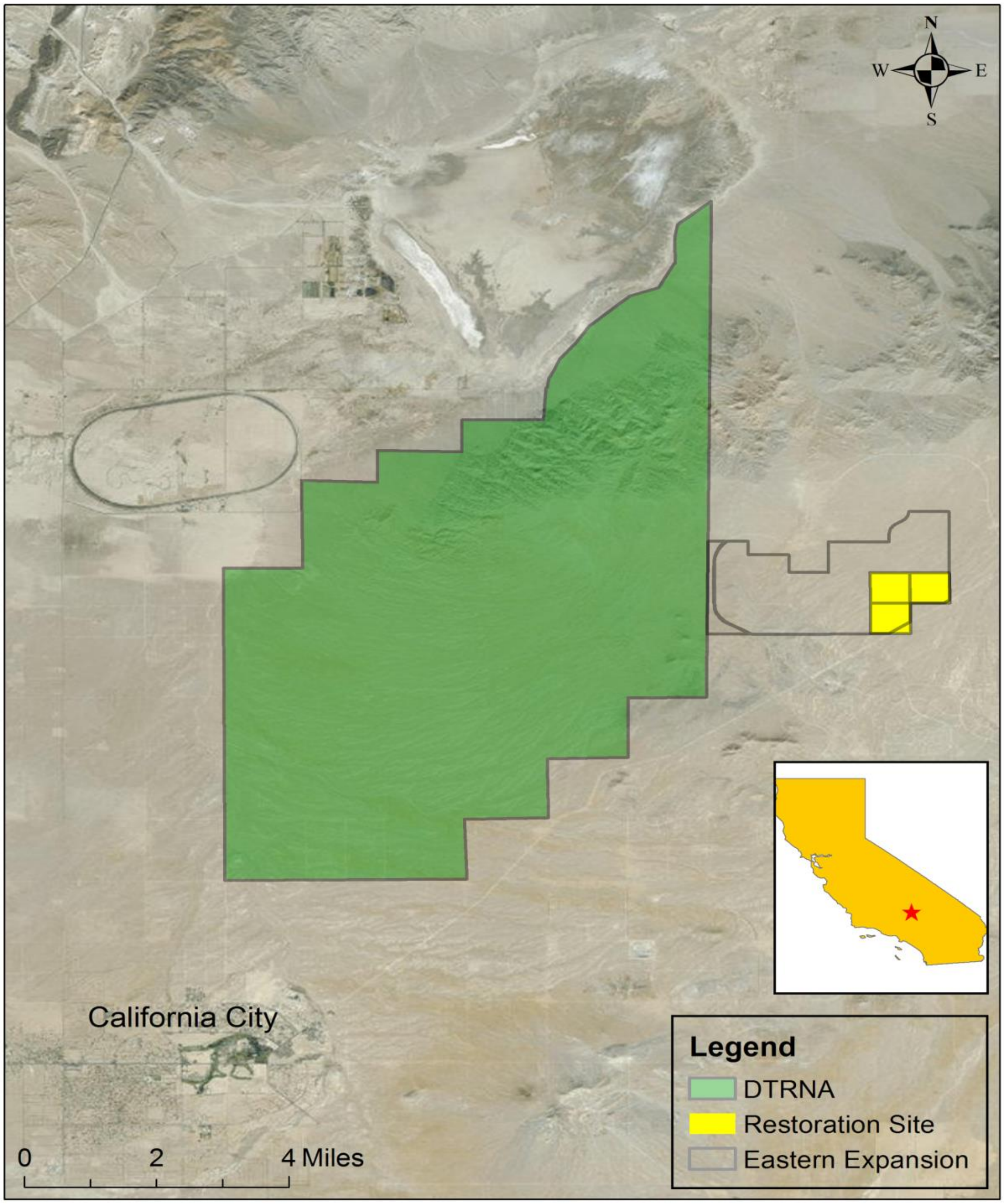

Figure 1. Regional map of the restoration site (yellow) in relation to the EEA (gray outline) and the DTRNA(green), north of California City, CA.

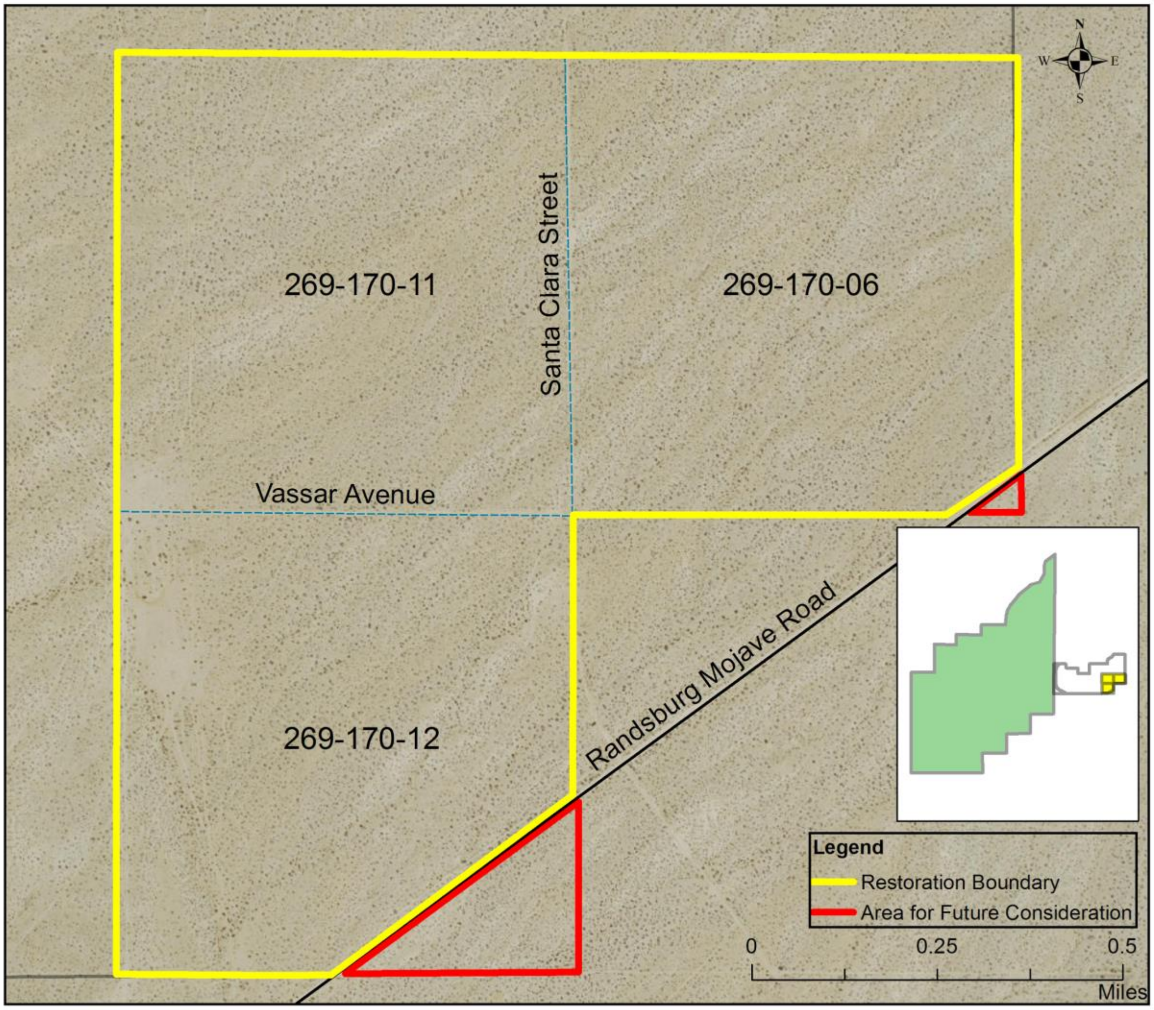

Figure 2. Targeted restoration site (yellow) with parcel labels. Areas outlined in red represent portions of parcels owned by Desert Tortoise Preserve Committee, Inc. that will not be included in the restoration plan. The inset map shows the restoration site (yellow) in relation to the EEA (gray outline) and the DTRNA (green).

5.1 Site Selection

Site selection was based on expert recommendations, levels of current and historic degradation, and proximity to threats. Initial consideration of the DTRNA expansion areas was based on the expert opinion and guidance of Dr. Kristin Berry, Council board member, and Ms. Jillian Estrada, DTPC's Conservation Coordinator and DTRNA Preserve Manager. The site within Section 16 of the EEA was recommended by Ms. Jillian Estrada due to the need for restoration with high densities of off-highway vehicle (OHV) traffic and severe denudation, in addition to the site's unique location at the eastern edge of the EEA.

This site in particular is distinct because of its proximity to Randsburg Mojave Road and the presence of Vassar Avenue and Santa Clara Street running through the parcels. Parcels 06 and 12 have the boundaries of their fence line directly adjacent to Randsburg Mojave Road, which means these parcels have had increased contact with access threats, specifically with OHV users. The presence of the road so close to the site may have led to increased disturbance of soils and spread of nonnative plant species into the site and the rest of the EEA. Restoring this site will allow for a more stable native plant community to better resist future disturbances and stressors.

This site is also a good candidate for habitat restoration because the existing vegetation alliances, although sparse and degraded, are preferred by the desert tortoise. A survey conducted by the DTPC in 2015 found that creosote and white bursage were common throughout the site. In addition, the survey found tortoise sign in Parcels 06 and 11, therefore, highlighting the potential for the site to be restored for tortoise (DTPC 2015). Through restoration, this site's viability for desert tortoise habitat should be increased.

5.2 Historical Land Use

Starting in the mid-1800s, the regions now known as the DTRNA and EEA were heavily used for grazing by sheep, cattle, horses and burros that were used to support mining exploration and ranching (Lovich and Bainbridge 1999). Following the 1950s, the Mojave and Colorado Deserts experienced an increase in off-highway vehicle (OHV) recreation (Brooks and Esque 2002), further altering the plant communities found in the area. It was not until the 1970s that efforts to limit the use of recreational vehicles began and initial boundaries for the DTRNA were considered in a management plan (BLM 1973). In 1974, the DTPC was created to assist with the establishment of the DTRNA to promote the welfare of the desert tortoise (BLM 1980, Berry et al. 2014). The area was withdrawn from mining and livestock grazing by the U.S. Congress in 1980, and the Bureau of Land Management (BLM) formally designated the land as both a research natural area and an Area of Critical Environmental Concern (ACEC). In the same year, the DTRNA was completely fenced to exclude recreational vehicles and sheep (BLM 1980)

Land acquisition efforts to increase the DTRNA began in 1978 and continued in the 1990s with the purchase of inholdings both in and outside of the DTRNA boundaries by the BLM, DTPC and California Department of Fish and Game (CDFG) (BLM and CDFG 1988). The land adjacent to the area comprised a few large and many small parcels of private land that were intended for a housing development project. The development project fell through and these parcels were left under the ownership of absentee landowners who were often unaware of their location, leaving the area open to unauthorized grazing and intense OHV recreation (Berry et al. 2014). From 1995 to 2011, the DTPC and the CDFG successfully acquired some of these private parcels, including the restoration site, and added them to the DTRNA. In 2011, these parcels remained unfenced, but contained protective signage to help deter unauthorized use (Berry et al. 2014). The EEA was fenced in January 2017.

5.3 Anthropogenic Disturbances

The site contains a total of 42 identified OHV trails (Figure 4) that will be addressed later in the restoration plan. Twenty-one of these intersect the EEA fence line, thirteen of which intersect the fence line twice. These OHV trails are a direct result of OHV use throughout the site as can be seen by the repeated tire markings and tread. Severe denudation in several areas of the site are clearly visible as a result from OHV and recreational use. These types of human disturbance may have also contributed to soil compaction and invasive species introduction on the site.

Trash may also be found scattered throughout the site. In addition to its environmental health impacts, trash can have a detrimental effect on desert tortoises because they can choke from attempting to consume it (Boarman 2002). Trash is most likely a result from human recreation and camping within the site, although some items, such as balloons, found on site could have been blown onto a site after accidentally being released.

5.4 Existing Physical Resources

An accurate analysis of the existing physical resources, specifically the soil and hydrological conditions at the restoration site is necessary for a successful restoration project. This section describes the existing soil properties and hydrologic conditions based on recent literature and available data.

5.4.1 Soil Properties

The restoration site is predominantly Cajon loamy sand [0-5% slope] combined with Neuralia sandy loam [2-5% slope] (USDA 2013). Mixed in with the Cajon loamy sand and Neuralia sandy loam is a small amount of Alko-Neuralia sandy loam [0-9% slope] and Muroc-Randsburg sandy loam [5-9% slope] (USDA 2013).

Because nonnative species rapidly establish in a nitrogen rich environments, nonnative species have an advantage that allows them to outcompete native species (DeFalco et al. 2001, Brooks and Berry 2006). It can be assumed that the location of the restoration site near Randsburg Mojave Road makes the soil more susceptible to nitrogen loading, helping explain the abundance of nonnative plant species throughout the site. In addition, the disturbance of soils through events such as livestock grazing or OHV use also facilitate the spread of nonnative species throughout the site.

5.4.2 Hydrology

Desert washes are present within the restoration site and the greater EEA. There are 4.198 acres (34,491 linear feet) of State-jurisdictional waters that cross through the restoration site (DTPC 2015). Two ephemeral (currently dry) streambeds cross through parcels 06 and 11, running northeast to southwest across the parcels (USDA 2013). This information only accounts for two of the three parcels on site, additional surveys should be done on parcel 12.

5.5 Existing Biological Resources

The list of existing biological species on the site was compiled from two sources: (1) a biological assessment conducted by the DTPC, and (2) observations of plant abundance from a vegetation survey conducted on three management areas in the Western Mojave. Appendix A - Table 1 shows plant species observed in a survey conducted in March 2015 on parcels 11 and 06 through funding from the DTPC. Wildlife observations listed in Appendix A - Table 2 are also based on the survey conducted by the DTPC.

Additional existing resources such as observed abundant species were identified in a survey conducted by Berry et al. (2014) in a study area that encompasses three types of managed lands: the DTRNA, USFWS-designated critical habitat for desert tortoise, and private land, which comprise the restoration site. The survey was conducted by establishing 240 1-ha plots using random sampling with each of the management areas containing 80 plots (Berry et al. 2014). For this study, four main types of vegetation associations were identified: (1) creosote bush/white bursage (creosote); (2) creosote bush/white bursage/Anderson box-thorn (box-thorn); (3) creosote bush/white bursage/Mojave indigo bush (indigo bush); and (4) creosote-bush/white bursage/Nevada ephedra (Nevada ephedra). The Nevada ephedra vegetation association had the highest diversity with 11 abundant species, indigo bush had 9 abundant species, box-thorn had 5 and the creosote bush association was the least diverse with only 2 abundant species (Berry et al. 2014). Within the private lands, including the location of our restoration site, the creosote bush vegetation association dominated, demonstrating that the restoration site has less diversity. Because Berry et al.’s (2014) survey was based on random sampling, it is safe to assume that the species list in Appendix A - Table 3 is representative of the region, including the restoration site.

5.6 Reference Site

A reference site is used in ecological restoration to evaluate whether restoration has been successful at a targeted site by acting as a good comparison of soil and vegetation composition, and various ecosystem functions.

A good reference site should identify a region where healthy soil and vegetation are present. The southeast region of the DTRNA will act as a suitable reference site for the purposes of this restoration plan because of its high diversity and density of vegetation. The reference site and restoration site both are dominated by the creosote-white bursage vegetation association, but the reference site has a greater diversity of annual and perennial forbs that are preferred by the desert tortoise and a higher density of creosote-white bursage cover species (Berry et al. 2014). Therefore, it will be a primary goal of Phase 1 in this restoration plan to increase the abundance and diversity of native forage and cover for desert tortoises, particularly in areas where denudation is high.

6. Phase 1

6.1 Goals and Objectives

Goal 1 - Maintain exclusion of anthropogenic activities that contribute to habitat disturbances.

Objectives

- Maintain fence integrity.
- Maintain current signs along fence line boundary.
- Decommission Vassar Avenue and Santa Clara Street.
- Decrease the visibility of the OHV trails within the restoration site from the fence line up to 100 meters.

Goal 2 - Promote healthier habitat.

Objectives

- Decrease the amount of unwanted and unnatural debris by 100%.

Goal 3 - Remove or reduce target nonnative plant species.

Objectives

- Decrease targeted nonnative annual forbs (Table 2) by 100%.
- Thin nonnative grasses by a minimum of 50%.
- Maintain reduction throughout maintenance and monitoring periods.

Goal 4 - Improve soil retention for water and nutrients.

Objectives

- Perform vertical mulching on OHV trails up to 100 meters from EEA fence line.
- Ensure minimal to no reestablishment of nonnative plants occurs through the process of vertical mulching.

Goal 5 - Promote native plant species preferred by the tortoise for cover and forage.

Objectives

- Plant native annual and perennial species on 28 acres of denuded habitat.

- Augment planting with seeding after plants are established.
- Increase diversity of vegetation on aforementioned 28 acres.

Goal 6 - Monitor inhabitancy by Agassiz's desert tortoises.

- Perform annual surveys to assess the return of desert tortoises to restored areas.

6.2 Success Criteria

The following success criteria is broken down by how the goals and their objectives can be measured and met throughout the length of the restoration plan.

Goal 1
Visibility of OHV trails from the fence line should be minimal for road camouflage techniques to be deemed successful. There should be no visible signs of trespassing or new OHV trails within the site. Maintaining the fence line's integrity will be considered successful given no signs of trespass are found within the restoration site. This may be demonstrated by no cut fences, no signs of continued OHV use through fresh tracks or trails, and minimal to no disturbance to the soon-to-be decommissioned roads, Vassar Avenue and Santa Clara Street. Current signs along the fence line will be deemed effective for the same reasons of the fence line integrity. Perimeter checks and surveying of the site should be able to demonstrate that these objectives are being met and the goal achieved.

Goal 2
The absence of all trash and debris from within the restoration site will suitably demonstrate that this goal and objective are being met.

Goal 3
Restoration efforts at the site will be considered successful when the targeted nonnative species are 100% absent from the identified areas requiring nonnative species reduction or removal. Observations after grass thinning should be compared to initial site surveys to determine whether a 50% reduction has taken place. If seasonal removal and reduction of nonnative species and monitoring occur throughout all five years of the restoration plan, then the objectives of this goal will be met.

Goal 4
Water retention can be measured through measuring soil moisture or observing an increase in vegetation where the method occurred.

Goal 5
This goal and its objectives will be successfully achieved if the prescribed planting and seeding actions result in less than 20% failure. Because the planting and seeding actions seek to increase the diversity of the existing vegetation, increased diversity of the site would occur if plantings becomes sustainably established (i.e. they are able to persist on their own without aid).

Goal 6
Success may be appropriately defined as observing an increase in tortoises, or tortoise sign within the restoration site as tortoise sign is positively correlated to tortoise densities (Krzysik 2002). This would require establishing a more robust baseline for the current tortoise sign at the site through annual biological surveys.

6.3 Actions

This section will include a brief description of each restoration action (Section 6.3.1) followed by the implementation plan (Section 6.3.2) that identifies the location of where each action will be performed.

The actions recommended in this restoration plan are scheduled to occur seasonally (i.e. winter, spring, summer, fall). Fall season will be defined as October through December, winter will be January through March, spring will be termed April through June, and finally summer begets July through September. These season definitions coincide with the expectation that fall-winter rainfall is commonly known to be October 1st through March 31st with these months marking a significant time as they determine production of annual and perennial flora.

Table 1. Restoration action schedule beginning the month of January of Year 1. (W = Winter, S = Spring, S = Summer, F = Fall, respectively).

Restoration Actions	Year 1				Year 2				Year 3				Year 4				Year 5				Notes
	W	**S**	**S**	**F**	**W**	**S**	**S**	**F**	**W**	**S**	**S**	**F**	**W**	**S**	**S**	**F**	**W**	**S**	**S**	**F**	
Site Preparation																					
Site Survey	x				x				x				x				x			x	Should be done initially, and then annually.
Fencing	x																				Site is fenced by the EEA fence line.
Signs	x																				Signs are already in place by DTPC.
Decommissioning of Roads	x																				In progress action by DTPC.
Removal																					
Trash Removal	x				x				x				x				x				Primary removal should be done Year 1.
Nonnative Species Removal																					
Removal of Nonnative Forbs	x	x		x	x	x		x	x	x		x	x	x		x	x	x			Should occur in primary bloom seasons.
Reduction of Nonnative Grasses	x	x		x	x	x		x	x	x		x	x	x		x	x	x			Multiple applications will be necessary.
Road Camouflage																					
Vertical Mulching	x	x	x			x				x				x				x			Maintain annually if needed.
Horizontal Mulching	x	x				x				x				x				x			Maintain annually if needed.
Rock Scattering	x	x																			Should not require maintenance.
Soil Remediation																					
Vertical Mulching	x	x	x			x				x				x				x			Highly recommended. Maintain annually if needed.

Ripping																					Not recommended.
Imprinting																					Not recommended.
Re-Contouring																					
Berms																					Not recommended.
Topsoil Salvage																					Not recommended.
Planting																					
Outplanting Preparation	x			x	x																Year 2 actions only required if Year 1 fail.
Seed Collection & Storage	x	x	x	x	x																Local seed only from species approved list.
Planting	x			x	x																Plants will need to be grown prior to Year 1.
Seeding																					
Seed Collection & Storage	x	x	x	x	x																Local seed only from species approved list.
Seeding					x				x												Seeding should be done after plants establish.
Irrigation																					
Irrigation	x	x			x	x															Should occur on an as needed basis only.
Maintenance																					
Maintenance	x		x	x	x	x			x	x			x				x				Need for maintenance should decline over time.
Site Monitoring																					
Monitoring	x	x			x	x			x	x			x	x			x	x		x	Should be done seasonally through Yeas 1-5.

6.3.1 Site Preparation

Site preparation will include the following actions: site surveying, preliminary fencing, posting of appropriate signs and the recommendation of decommissioning any roads. These actions should have already been completed by Year 1 of the restoration plan's action schedule (refer to Table 1 above).

Site Survey

The site survey can take place after the site preparation measures but must be conducted prior to the implementation of all other actions to ensure the most current and accurate information is used as a baseline for the plan. The site survey should include a brief overview of the existing physical and biological characteristics, particularly focusing on the abundance and diversity of native species, the abundance and diversity of nonnative species, the presence of anthropogenic threats, and the presence of desert tortoises and their sign.

Fencing

Soil and vegetation disturbance can have long lasting detrimental effects on desert tortoise populations. Eliminating future disturbance is critical to support future populations. Fencing is a common method used to remove stressors from a site. Fencing enables land managers to keep out unwanted OHVs, recreational users, and sheep grazing, and still allow for flow of wildlife species through its boundaries because of inclusion fencing (Ruby et al. 1994, Brooks 1995, USFWS 2011). Inclusion fencing consists of field fencing that has a gap typically 9-12 inches between the fence and the ground surface to allow for passage of wildlife (Ruby et al. 1994). Although fencing does not stop nonnative plant species from existing on the landscape, studies have shown that disturbances from OHV and grazing promote the spread of nonnative species, and removing these stressors may limit the spread of nonnative species (Hobbs 1989, Brooks and Berry 2006, Grime 2006). This allows greater opportunity for native species to recolonize the restoration site while requiring minimal effort on the part of land managers.

The DTPC began fencing on the EEA in 2016, and fencing of the southern and eastern boundaries of parcels 12 and 06 has occurred as of January of 2017. Best management practices suggest that fencing should consist of field fencing that is wildlife inclusionary (Ruby et al. 1994). This means that wildlife can pass through the bottom portion (typically 9-12 inches) or jump over fences, but that livestock and OHV use will be excluded (Ruby et al. 1994, USFWS 2011). Inclusionary fencing would be important if this area was known to be free The DTPC used exclusionary field fencing for the EEA boundary fence line, and this is key because it will not allow the movement of wildlife through the bottom portion of the fence, thus keeping tortoises safe from being run over by passing cars on Randsburg Mojave Road. Maintenance of the existing fence line boundary is crucial to minimizing common anthropogenic threats and maintaining a rehabilitated soil and plant communities.

Signs

Current signage at the site includes signs identifying the land as private property owned by the DTRNA (Figure 3). Use of these signs, in addition to newly installed fencing, will serve as a reminder to OHV users and recreational visitors that the land is off limits to certain activities, and help prevent further unauthorized access. No additional signs are recommended in this restoration plan.

Figure 3. Signs from the Desert Tortoise Research Natural Area, December 2016.

Decommission Roads

There are currently two existing public roads that intersect the restoration site. Vassar Avenue acts as the boundary to parcels 11 and 12, running east and west, and Santa Clara Street serves as the boundary to 11 and 06, travelling north and south. Decommissioning these roads is imperative to creating a contiguous habitat for the desert tortoise and other species. The roads currently fragment the landscape and create unfavorable conditions for the foraging and cover species that are important to the desert (Brooks and Lair 2005, Brooks and Berry 2006). Through Kern County, the DTPC is currently in the process of officially decommissioning, or vacating, these roads and expects the process to move forward in the near future.

These roads are considered public, but because the roads dead-end into the privately owned parcels, the DTPC does not have to provide public access to them. These roads have been removed from public use through a locked gate placed at the convergence of the roads, but legally decommissioning them will result in increased protection from any future disturbances.

Trash Removal

All trash and debris shall be removed from the site prior to implementation of any restoration measures. Trash removal will occur during an initial site cleanup in the early spring of Year 1, and all trash will be disposed of properly.

6.3.2 Nonnative Species Removal

Nonnative species (invasive species, weeds) have the ability to negatively influence the diets of desert tortoises (Nagy et al. 1998, Jennings 2002, Hazard et al. 2009, 2010) and outcompete native plants for resources (Berry et al. 2014). Thus, nonnative plant species should be immediately managed through reduction or removal. Removal of nonnative species can have a variety of benefits including: reducing the size and frequency of fires (Brooks and Berry 2006), reducing the use of herbicides, and protecting existing habitat by reducing competition with natives (Berry et al. 2014).

Table 2 lists nonnative species that may be found within the restoration site that should be targeted for reduction or removal. These species should be reduced or removed throughout the duration of the restoration efforts as nonnative seeds may persist in the soil's seed bank for many years (DeFalco et al. 2001). Nonnative seeds may lie dormant in the existing seed bank until circumstance enables them to sprout, and thus removal of nonnative species needs to occur throughout the duration of site restoration to lessen the amount of seed that may persist in the seed bank (DeFalco et al. 2001). Removal of nonnative species such as those that are suggested in Table 2 is not possible through a onetime removal event, but rather seasonal removal and hypervigilance for new stands of nonnative species should occur to truly eradicate these species.

Nonnative species removal and reduction will occur on all acres associated with Phase 1 of the restoration plan. Removal should occur primarily in the late winter and spring months as nonnative species tend to emerge with the winter rains. Removal should also be considered for late fall nonnative species may still be visible during these seasons (refer to Table 1 above). Removal should begin immediately in Year 1, and continue through Year 5 on a seasonal basis, especially prior to any planting and seeding efforts.

Table 2. High-priority nonnative species in the Desert Tortoise Research Natural Area to reduce or remove within the restoration site.

Common Name	Scientific Name	Type	Bloom Period	% Reduction	Removal Method
Mediterranean Grass	*Schismus spp.*	*Grass*	March - May	50%	Could consider thinning rather than eradication (Brooks 2000)
Red Brome	*Bromus rubens*	*Grass*	April - May	50%	Could consider thinning rather than eradication (Brooks 2000).
Saharan Mustard	*Brassica tournefortii*	*Annual forb*	February - April	100%	Hand-pulling, potential use of herbicide, Glyphosate (Abella et al. 2015).

Russian Thistle	*Salsola tragus*	*Annual forb*	July - October	100%	Manual removal
Saltcedar (Tamarisk)	*Tamarix ramosissima*	*Annual forb*	June - August	100%	Manual removal

Best Management Practices for Nonnative Species Removal
All best management practices designed and recommended by the California Invasive Plant Council (Cal IPC 2012) should be followed to the best of abilities in order to prevent the spread of invasive species within and outside of the restoration site. Adaptation from these practices may be necessary if certain situations are not applicable to removing invasive species from the restoration site.

Reduction of Nonnative Grasses
Reduction of nonnative grass species is especially important to encouraging native species establishment at the restoration site. Thinning of Mediterranean grasses (*Schismus spp.*) and red brome (*Bromus rubens*) in particular have resulted in significant increases in diversity and abundance of native annuals (Brooks 2000). Thinning may be done manually or through mechanical measures, but mechanical removal in a sensitive area such as the desert is not recommended as it will cause increased soil disturbance and degradation that may reintroduce nonnative species to the site. Fire is not a recommended tool in removing nonnative grasses as recolonization of the site by nonnative annuals increases with fire (Brooks and Esque 2002).

Herbicide treatments may be used in cases where traditional methods have failed and no viable alternatives exist. Herbicides are not explicitly recommended due to unclear effects on desert tortoises (Abella and Berry 2016), but they may be an effective strategy for reducing alien grasses if applied early in the growing season (Marushia et al. 2010), and when tortoises are most inactive (Esque et al. 2014). Careful planning, observation of the site, and implementation will be conducted with extreme attention to detail. More research should be undertaken to determine the necessity of herbicidal treatments at this site. The safest herbicide should be selected based on existing literature and studies looking at the effects to the tortoise, other wildlife species, and effectiveness at reducing invasive grasses. If herbicide is applied, a nontoxic dye should be added to the herbicide solution prior to spraying on the ground to be able to observe where and how thick the herbicide is being applied.

Removal of Nonnative Annual Forbs
It is imperative to remove as much of the existing nonnative annual species as possible from the restoration site because they compete with the same resources as native annuals (DeFalco et al. 2001). Removal of nonnative forbs should be done prior to their blooming season, as this is the time the seeds are dispersed. For the nonnative species listed in Table 2, this means removal should occur during winter-spring seasons. Removal should occur primarily at the sites where road camouflage techniques are planned. This means the first 100-200 m of each OHV trail from where it intersects with the EEA fence line should be cleared of nonnative annuals. Typical methods of removal include manual methods, such as hand pulling. Although Glyphosate has

been proven effective at removing certain annual forbs (Brooks 2000), manual methods are preferred to chemical as to minimize any impacts to the desert tortoise and other native species.

6.3.3 Road Camouflage

Road camouflage is important for reducing the threat of OHV trespasses at the restoration site. Roads are a source of mortality for tortoises, both directly and indirectly, as they contribute to mortality from vehicle traffic and they subsidize the prey of common ravens, a known predator of the desert tortoise (Boarman 2002). Furthermore, roads that continue to be used after being decommissioned will further degrade habitat quality by denuding native vegetation, altering patterns of surface water flow and negatively impacting plant productivity, limiting dispersal and movements of desert tortoises, and facilitating access that may lead to additional human disturbances (Brooks and Lair 2005, Brooks and Berry 2006). With the goal of reducing the impacts of roads in mind, the actions associated with road camouflage should limit future disturbance.

Road camouflage will occur in Year 1 between the seasons of winter and spring. It is integral to the condition of the site that the existing OHV trails are hidden as soon as weather permits to prevent potential illegal trespassing from OHV and recreational visitors.

Vertical Mulching
Vertical mulching refers to the creation of false cover plants on vacated roads, OHV trails, and other disturbed areas. This technique involves first collecting dead creosote plant material and later “planting” or establishing the material in a vertical orientation, buried upright in the soil, to resemble a live creosote plant and disguise the areas.

Horizontal Mulching
Similar to vertical mulching, horizontal mulching refers to the creation of false ground cover on vacated roads, OHV trails, and other disturbed areas. This technique involves first collecting dead plant material and later dispersing the material in a horizontal orientation, to resemble native ground cover and disguise the areas.

Rock Scattering
Rock scattering refers to dispersing rocks in a random pattern on and around vacated roads, OHV trails, and other disturbed areas to help camouflage these areas. Rocks are typically collected onsite.

6.3.4 Soil Remediation

Highly compacted soils and soils without sufficient seed banks may revegetate very slowly (Ghose 2001, Gibson et al. 2004, Abella et al. 2015). Establishment of mature native vegetation can be greatly accelerated through the use of proper soil remediation techniques such as ripping, vertical mulching, imprinting, re-contouring berms and topsoil salvage.

Ripping
Ripping refers to the process of decompacting the surface soil. Common tools for this technique include a subsoiler or rock ripper. When considering ripping, it is best practice to focus on the surface soil, represented by the upper 15 cm, to avoid disrupting the subsoil and potentially changing the soil properties (DTC 2015a). In general, ripping can be used to roughen compacted soil and promote plant recruitment, but this action can also promote nonnative plant recruitment. Because the location of our site is sensitive to nonnative species invasions, and the fact that a rock ripper is fairly ineffective in desert conditions, ripping is not a recommended action.

Vertical Mulching
Vertical mulching serves a dual purpose of camouflaging the road from passersby and decompacting the soil. The soil is loosened through the insertion of the dead creosote material, thus breaking up compacted soils to allow for better nutrient and water retention. As a result of vertical mulching, fertile islands of native plant communities can be established that aid abundance of annual forbs (DTC 2015a).

Imprinting
Imprinting refers to the creation indentation of soil in a pattern which can be used to enhance water retention, decompact soil and promote plant establishment on a decommissioned road, OHV trail, or other area severely damaged by grazing and/or OHV use (DTC 2015a). The most common tool for this technique is a machine known as an Imprinter. Due to the expense, and the amount of disturbance an Imprinter would cause, this action is not recommended for use on this site because we believe the benefits of increased water retention would not outweigh the environmental and economic costs.

Re-contouring Berms
Re-contouring berms refers to the reshaping of contour lines along slopes or road sides. The most common tool for this technique is a dozer. This method can be used to re-connect washes and reestablish drainage patterns (Abella and Berry 2016). Because this action is expensive, requires the use of heavy machinery like a bulldozer or tractor, and we are trying to work in an area that is very sensitive to disturbance, we are not recommending berms be re-contoured.

Topsoil Salvage
Topsoil in the Mojave Desert contains much of the available soil organic matter as well as the viable seed bank (Scoles-Sciulla and DeFalco 2009). Sites with disturbed topsoil may lack these important features and could benefit from the salvaging of topsoil from other areas (Ghose 2001, Abella et al. 2015). Any topsoil for salvaging should be carefully sourced from a nearby area in the summer to capture a portion of the seedbank which can help the vegetation reestablish in the restoration site. Only the top few (5-10) cm of soil should be collected to avoid diluting the soil with deeper subsoils (Scoles-Sciulla and DeFalco 2009). Care must also be taken to salvage topsoil from a site without nonnative plants which could become established in the restoration site. Because our site contains high potential for nonnative species occurrence, topsoil salvage may not be an effective action to take in this restoration plan. In addition, the costs to retrieving, storing, and spreading the topsoil do not outweigh the benefits the action has to revegetated

areas, especially as other preparation actions to the planting and seeding areas may yield similar results.

6.3.5 Planting

To restore the selected site to contain vegetation useful to the desert tortoise, priority native perennial and annual plant species were identified (refer to Table 3 below). These species were identified by using bite count studies (Jennings 2002, Jennings and Berry 2015, Abella and Berry 2016) within the DTRNA and a site survey conducted by the DTPC. The priority plant species were also vetted for soil draining requirements (i.e. fast to very fast drainage). These species will help increase native plant forage and shrub cover beneficial for the desert tortoise. Additionally, the planting of shrub species will help create vegetation patches that can help jumpstart natural processes by increasing soil stabilization and the establishment of native forage species.

Native seed for each of the identified priority plant species should be obtained as locally as possible. Several of the native plants required are not readily available at nurseries, therefore S&S Seeds is recommended for the collection of seeds. S&S Seeds will collect appropriate seeds from the area near the restoration site, some from other appropriate areas in the Mojave, and will provide commercial seeds for one plant species (*Plantago ovata*). Once all seeds are collected, they should be used to produce greenhouse grown seedlings. The first round of seedlings should focus on perennial shrub species such as white bursage (*Ambrosia dumosa*), fourwing saltbush (*Atriplex canescens*), Nevada jointfir (*Ephedra nevadensis*), creosote bush (*Larrea tridentata*), and Anderson thornscrub (*Lycium andersonii*) which are the best performing perennial species planted from nurseries (Abella and Berry 2016). These perennial species are medium to large shrubs that can provide the protective cover necessary for the annual forage species and the desert tortoise to thrive. Post disturbance colonizers such as desert globemallow (*Sphaeralcea ambigua*) and desert dandelion (*Malacothrix glabrata*) should also be considered for outplanting since they are able to compete with non-native annuals and can serve as cover and forage (Abella and Berry 2016). Other annual and perennial species that can be planted after cover is established in year one are desert calico (*Loeseliastrum matthewsii*), desert plantain (*Plantago ovata*) and rattlesnake sandmat (*Euphorbia albomarginata*). Table 4 provides a list of additional annual and perennial species that can be considered for planting given their presence in the DTRNA and their relationship with the creosote and white bursage vegetation association.

Because plant biomass is heavily influenced by winter rainfall, the best time for planting is prior to desert winter rains as the water will help the plants establish (Brooks 2002, Longshore et al. 2003, Berry et al. 2006, Medica et al. 2012). Therefore, planting should start no later than November of Year 1 of implementation before rainfall reaches its highest levels in December (Brooks 2002). It is recommended that all seedlings be grown in containers using a partner such as Antelope Valley Resource Conservation District's Conservation Nursery, given their experience and capacity to produce nursery grown native plants (Contact: Tom Florence, (661) 942-7306; Website: www.avrcd.org).

All containerized plants should be planted in a hole that is seven to eight inches deep and twice the width of the rootball. The lower part of the roots should be loosened before the plant is placed into the hole with the top of the rootball being at or slightly below ground level. All plants should receive one liter of water before the hole is backfilled with soil. In order to provide protection from herbivory, each plant should be surrounded by a chicken wire cage (1 in hex mesh) of about two feet in diameter (~112-inch length double wrapped) that is staked into the ground using garden staples. Protective chicken wire fencing is the more cost effective option when compared to establishing temporary fencing around planting plots and is listed as a best management practice essential to avoid planting failure (DTC 2015b).

Table 3. Priority plant species for seeding and planting at the restoration site at the expansion area of the DTRNA. *Sources: Jennings 2002, Jennings and Berry 2015, Abella and Berry 2016, Berry et al. 2014*

Common Name	Scientific Name	Type	Bloom Period
Anderson thornscrub	*Lycium andersonii*	*Perennial Shrub*	March-May
Creosote bush	*Larrea tridentata*	*Perennial Shrub*	April-May
Desert calico	*Loeseliastrum matthewsii*	*Annual Herb*	March-July
Desert dandelion	*Malacothrix glabrata*	*Annual Herb*	March-June
Desert globemallow	*Sphaeralcea ambigua*	*Perennial Herb*	February-March
Desert plantain	*Plantago ovata*	*Annual Herb*	January-April
Fourwing saltbush	*Atriplex canescens*	*Perennial Shrub*	May-June
Nevada jointfir	*Ephedra nevadensis*	*Perennial Shrub*	March-April-May
Rattlesnake sandmat	*Euphorbia albomarginata*	*Perennial Herb*	April-November
White bursage	*Ambrosia dumosa*	*Perennial Shrub*	January-February

6.3.6 Seeding

As mentioned before, S&S Seeds will collect seeds as locally as possible and run seeds through state of the art cleaning equipment to process seeds. After cleaning, they will also test for purity, germination and pure live seed counts using a certified seed laboratory. Compared to planting, seeding does not have very high long term success rates, but has produced short term success in some experiments (Abella and Newton 2009, Abella et al. 2015, Abella and Berry 2016).

When conducting seeding practices, seeding treatments such as pelletizing, using protective coatings and using germination stimulants to increase germination are an option, but are not very well studied (Abella and Berry 2016). They can produce varying results and can increase restoration costs (Kay et al. 1977, Abella et al. 2015, Abella and Berry 2016). For this reason, seeding bare seeds may be the best practice for this restoration plan since it is only secondary measure for augmenting annual and perennial plant species. If treatments are desired, then each treatment should be tailored for each individual plant species to increase possible success rate (Abella and Berry 2016). However, this will increase initial project costs.

Species considered for seeding can be found on Table 4 below. These annual and perennial species are forbs that are favored by the desert tortoise have the potential to grow within our restoration site. These species are plants that have been found within the DTRNA (Jennings and Berry 2015) and may have the potential to grow within our site once conditions are made more favorable (i.e. reduction of nonnative species, creation of fertile islands and exclusion of OHV access).

When seeding, soil preparation should only occur around planted bushes to minimize soil disturbance and the creation of a nonnative seedbed given that the success of soil preparation methods are not well established (Abella and Newton 2009). Once soil is loosened, seeds should be planted one centimeter in depth to optimize emergence (Kay et al. 1977). Seeding should occur between November and December to ensure that seeds get exposed to fall/winter rainfall that could help trigger germination. However, seeding this early will increase the susceptibility of seeds to granivory (Abella et al. 2015).

Table 4. Additional annual and perennial species to be considered for seeding. Source: Jennings 2002, Jennings and Berry 2015, Abella and Berry 2016, Berry et al. 2014

Common Name	Scientific Name	Type	Bloom Period
Foothill deervetch	*Acmispon brachycarpus*	*Annual Herb*	March-June
Stiff-haired lotus	*Acmispon strigosus*	*Annual Herb*	February-June
Two-seeded milkvetch	*Astragalus didymocarpus*	*Annual Herb*	March-June
Layne locoweed	*Astragalus layneae*	*Perennial Herb*	March-June
Booth’s evening primrose	*Eremothera boothii*	*Annual Herb*	June-August
Browneyes	*Chylismia claviformis*	*Annual Herb*	February-May
Brittle spineflower	*Chorizanthe brevicornu*	*Annual Herb*	February-July
Mojave lupine	*Lupinus odoratus*	*Annual Herb*	April-May
Four o’clock	*Mirabilis laevis*	*Perennial herb*	February-March
Lacy phacelia	*Phacelia tanacetifolia*	*Annual Herb*	March-May
Bright white	*Prenanthella exigua*	*Annual Herb*	March-June

6.3.7 Irrigation

Irrigation should occur between planting and seeding seasons, typically late fall through winter on an as needed basis. Generally, irrigation is applied twice per month during the first year of planting and seeding during the growing season (Ann McLuckie, pers. comm. 2017). Due to the precipitation patterns within the Mojave Desert, rain occurs during the fall and winter months. Thus planting and seeding should occur at the start of these rains to capture the most of the natural precipitation regime, thus lessening the need for irrigation. If irrigation is needed to supplement lack of rainfall, it should occur via distribution from a water truck. Irrigation equipment such as a water truck may be rented from United Rentals (Website: https://www.unitedrentals.com) and distributed using backpack sprayers purchased from Gempler's, an online vendor (Website: http://www.gemplers.com). Monitoring of soil moisture should be considered after the initial application to ensure irrigation is effectively supporting the native or restored vegetation. If changes in the number of applications or the length of application need to be made, adaptive management considerations should be consulted.

6.4 Implementation

Implementation of the aforementioned actions are critical to successful restoration. This section will explain in detail how the actions described above will be applied to each area of Phase 1. Figure 4 demonstrates all of the areas that will be restored through the actions taken in Phase 1. Descriptions of each of the locations and how the actions will be applied to the site are supplied herein.

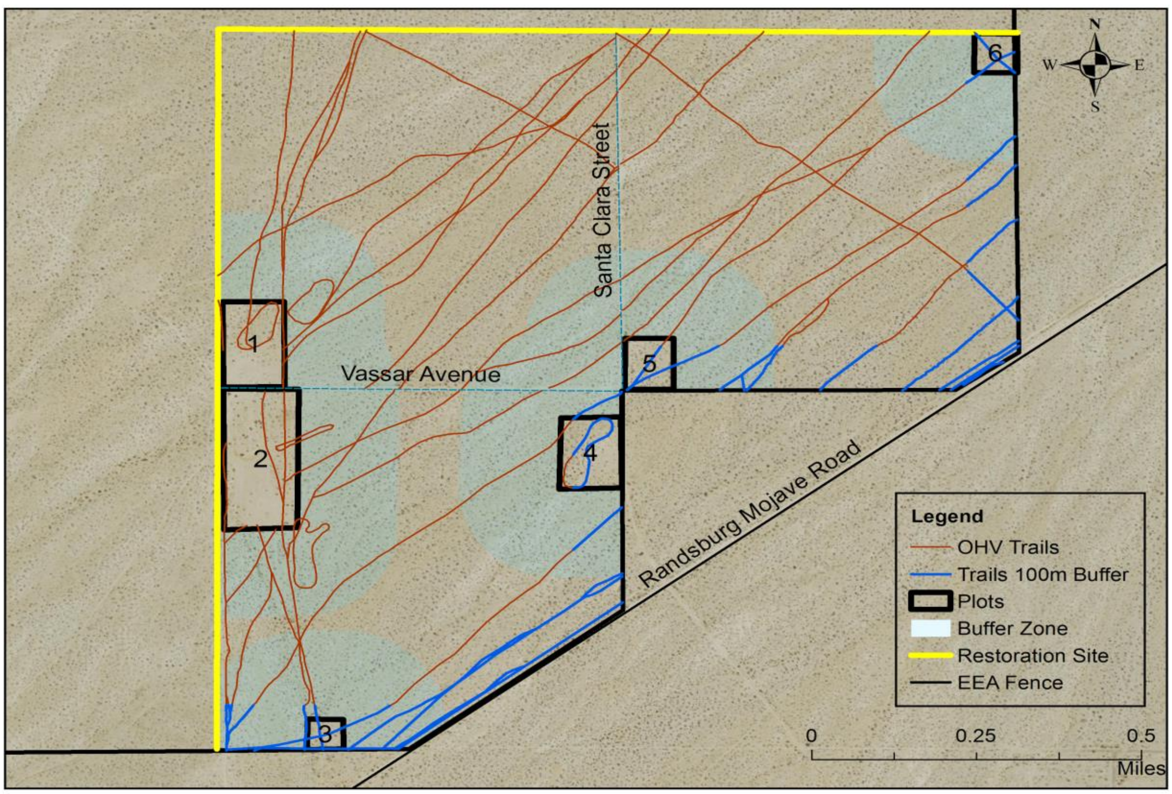

Figure 4. Locations of restoration areas for Phase 1 at site. Location divided into three categories: OHV trails (brown and blue lines), buffer zones (light blue) and plots (outlined in black).

6.4.1 OHV Trails

There are a total of 42 OHV trails that have been identified through aerial survey within the boundaries of the restoration site (Figure 4). Twenty-one of these trails intersect the EEA fence line and will be the focus of road camouflage and soil remediation actions. Thirteen of these OHV trails intersect the fence line twice, and one of them intersects the fence line three times. A distance of 100 meters was calculated from the EEA fence line on the assumption that this distance is the maximum perceived line of sight passerby can see along the OHV trail from the road. From the centerline of the OHV trail, road camouflage should occur up to two meters on either side as this will cover all variations of OHV trail widths. Road camouflage such as vertical and horizontal mulching, and rock scattering should occur within Year 1 of the restoration plan, preferably beginning by early spring (i.e. April), weather permitting.

This restoration plan seeks to calculate the maximum restored acreage that could be possible, and thus the actual restored acreage from road camouflage may be less if the road does not require restoration up to the full 100 meters from the EEA fence line. The resources available to conduct vertical and horizontal mulching (i.e. dead creosote sticks and other organic material) may also limit the amount of road camouflage that can occur in these areas. If road camouflage occurs up to the full 100 x 4 meters for each of the 21 OHV trails, approximately nine acres will be restored through natural succession. Five acres of which are already within the buffer zone areas around each of the six plots. To avoid double-counting, only four acres of remediated habitat will be counted based on road camouflage and soil remediation techniques. The other five acres will be totaled as a result of the buffer zones' restoration actions.

6.4.2 Buffer Zones

There are six buffer zones designed around the highly denuded areas within the restoration site (Figure 4). These buffer zones, not including the six plots, account for the majority of the restoration efforts, and if successful, 141.5 acres will be partially restored through primarily nonnative species removal actions. Soil remediation and road camouflage through vertical mulching will occur in buffer zones that contain OHV trails 100 meters from the EEA fence line. These areas are represented in Figure 4 by the dark blue lines within the light blue shaded buffers.

6.4.3 Plots

There are a total of six plots within our restoration site that will be targeted for planting and seeding actions using priority annual and perennial species identified in Table 3. Before planting begins, each plot will contain site preparation actions such as nonnative species removal and trash removal. In Year 1, trash removal will occur in the spring season whereas the first round of nonnative species removal should occur within the winter and spring. Another round of nonnative species removal should occur late fall or early winter prior to any planting or seeding of plots to reduce competition. Following Year 1, surveying to assess the necessity of trash removal should be conducted for Years 2, 3, 4 and 5 during the spring season while nonnative species removal should occur in the fall, winter or spring season of each year (refer to Table 1 above). Additionally, road camouflage should be performed in plots 3, 4, 5 and 6 since they all include OHV trails within their boundaries.

Once all plots have been prepared, planting should occur between late fall and early winter (November) of Year 1 to ensure plant exposure to winter rain. Each plot will be planted using 10x10 meter grid using perennial shrub species identified in Table 3. Each plant should be protected by a chicken wire mesh cage to protect from herbivory. Cages should be in place for the first one to two years depending on the plant's growth, intensity of herbivory in the plot, and condition of the plant.

In Year 2, additional planting of perennial shrubs may occur to replace any failed plantings. During this time, annual and perennial herb species could be planted as well near the established shrub species to create vegetation islands and ensure species diversity. Additionally, seeding using bare seeds should be implemented around the established shrub species. This will involve conducting soil ripping around the shade radius of each bush's canopy. Once the soil is loosened, seeds should be planted no deeper than one centimeter in depth.

Year 3, 4 and 5 will include monitoring and maintenance of all planted species. Irrigation should be applied as described in Section 5.3.1.

Below, each plot includes a description of the total number of plant to be planted, the total number of each shrub species: white bursage, fourwing saltbush, Nevada jointfir, creosote bush, and Anderson thornscrub and the total acres restored.

Plot 1

Plot 1 will include 330 plant individuals: 66 of white bursage, 66 of fourwing saltbush, 66 of Nevada jointfir, 66 of creosote bush and 66 of Anderson thornscrub. Planting will occur in the approximate locations of the 10x10 meter grid intersections. If all plantings are successful, about 5.80 acres of denuded habitat will be restored (Figure 5).

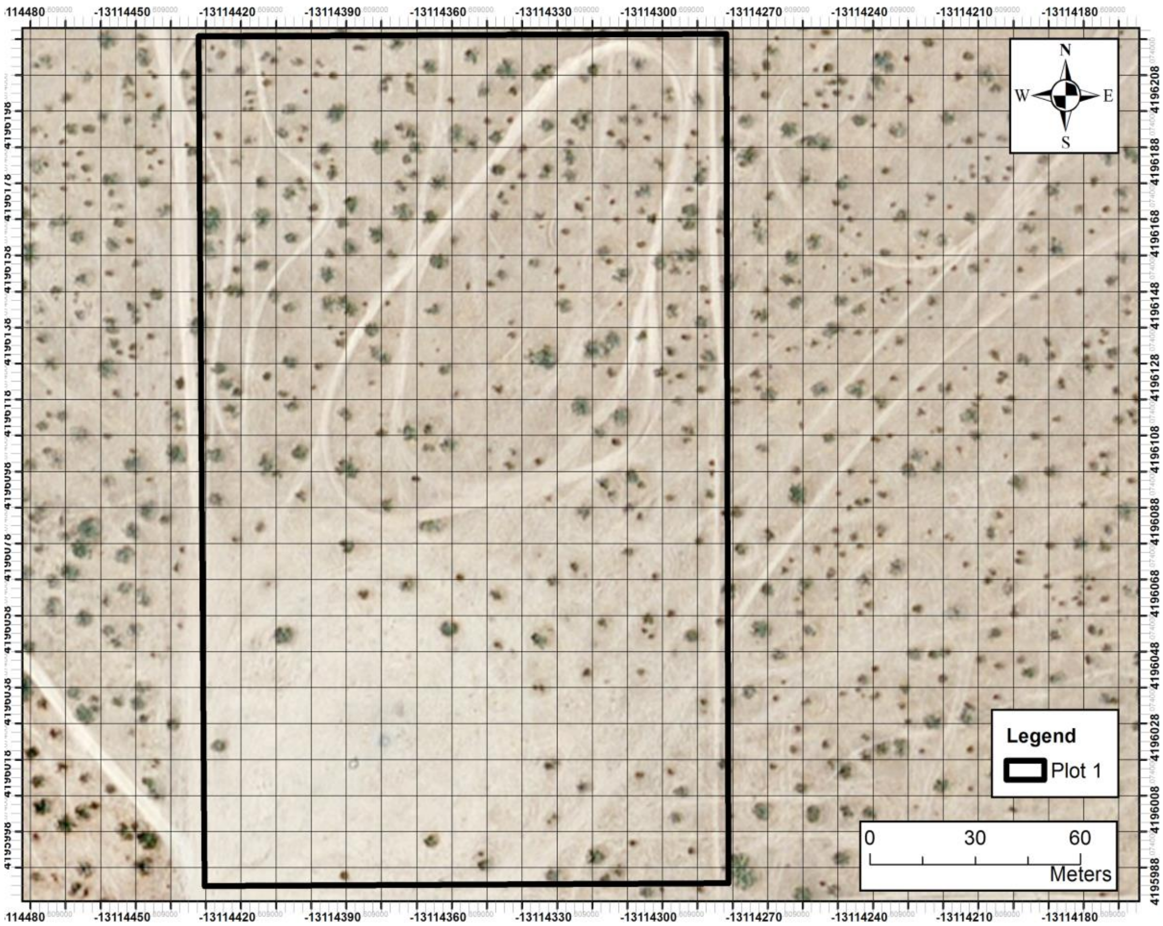

Figure 5. Plot 1 within restoration site with a 10x10 meter grid marking the location of each planting.

Plot 2

Plot 2 will include 650 plant individuals: 130 of white bursage, 130 of fourwing saltbush, 130 of Nevada jointfir, 130 of creosote bush and 130 of Anderson thornscrub. Planting will occur in the approximate locations of the 10x10 meter grid intersections. If all plantings are successful, about 11.60 acres of denuded habitat will be restored (Figure 6).

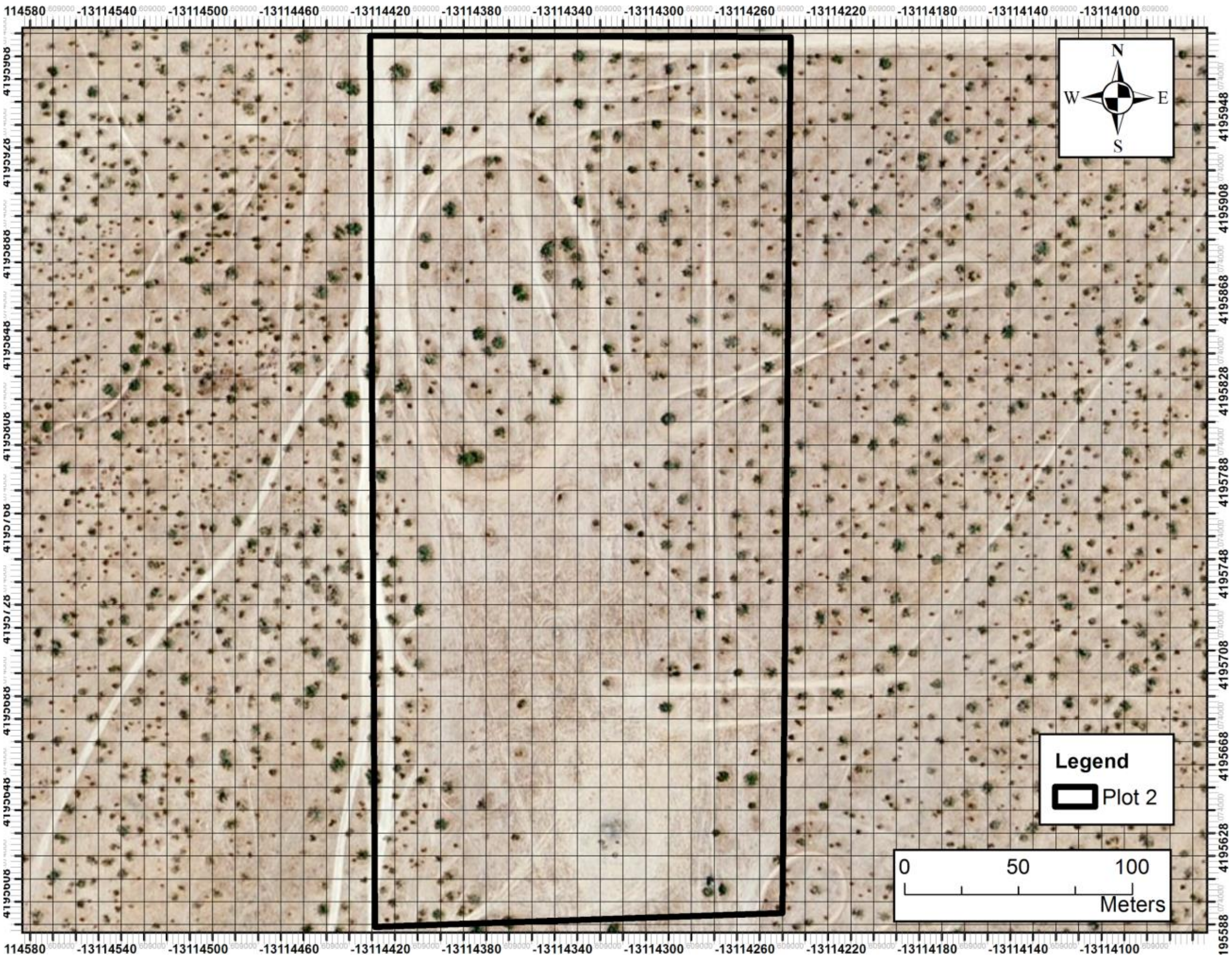

Figure 6. Plot 2 within restoration site with a 10x10 meter grid marking the location of each planting.

Plot 3

Plot 3 will include 65 plant individuals: 13 of white bursage, 13 of fourwing saltbush, 13 of Nevada jointfir, 13 of creosote bush and 13 of Anderson thornscrub. Planting will occur in the approximate locations of the 10x10 meter grid intersections. If all plantings are successful, about 1.20 acres of denuded habitat will be restored (Figure 7).

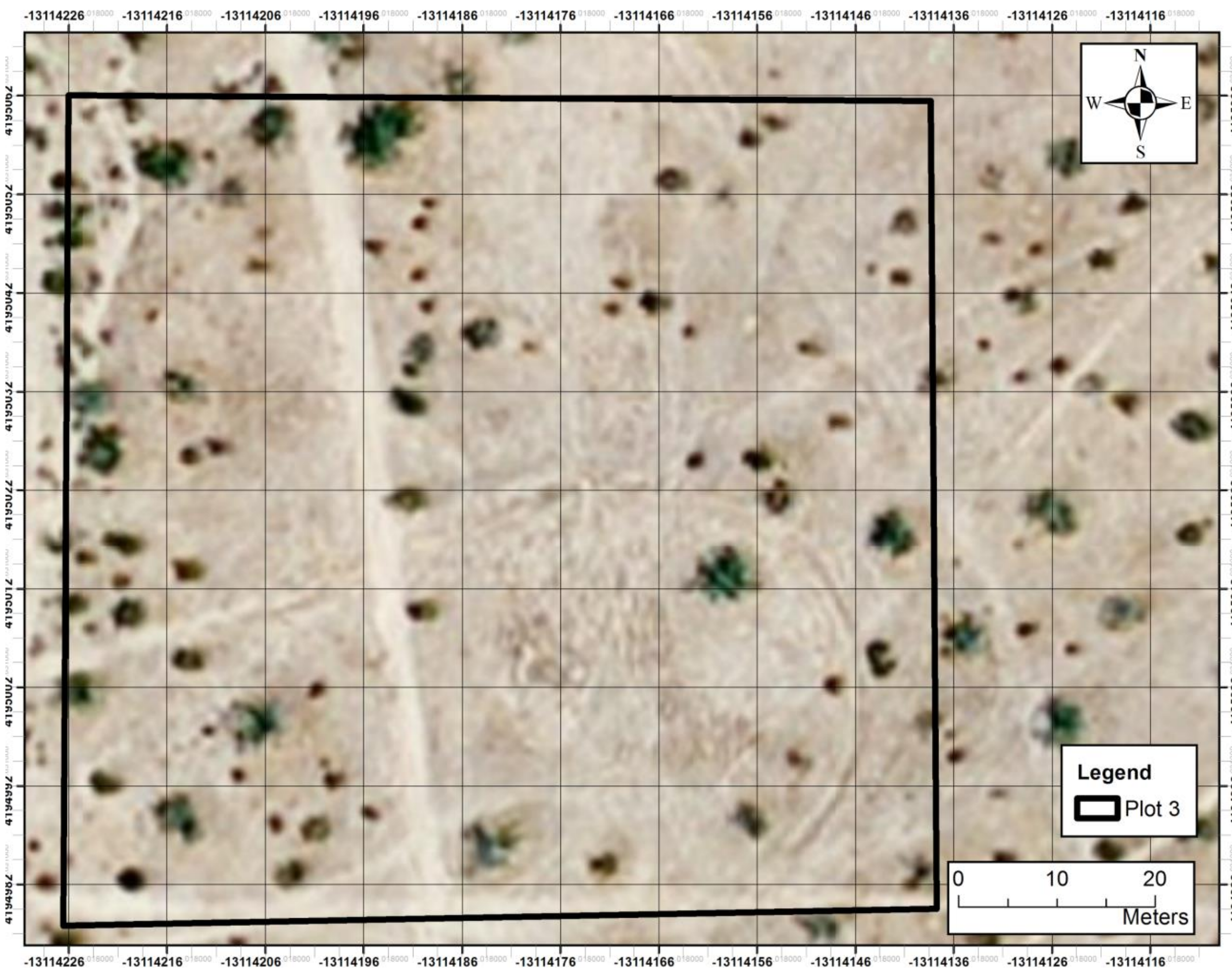

Figure 7. Plot 3 within restoration site with a 10x10 meter grid marking the location of each planting.

Plot 4

Plot 4 will include 265 plant individuals: 53 of white bursage, 53 of fourwing saltbush, 53 of Nevada jointfir, 53 of creosote bush and 53 of Anderson thornscrub. Planting will occur in the approximate locations of the 10x10 meter grid intersections. If all plantings are successful, about 5 acres of denuded habitat will be restored (Figure 8).

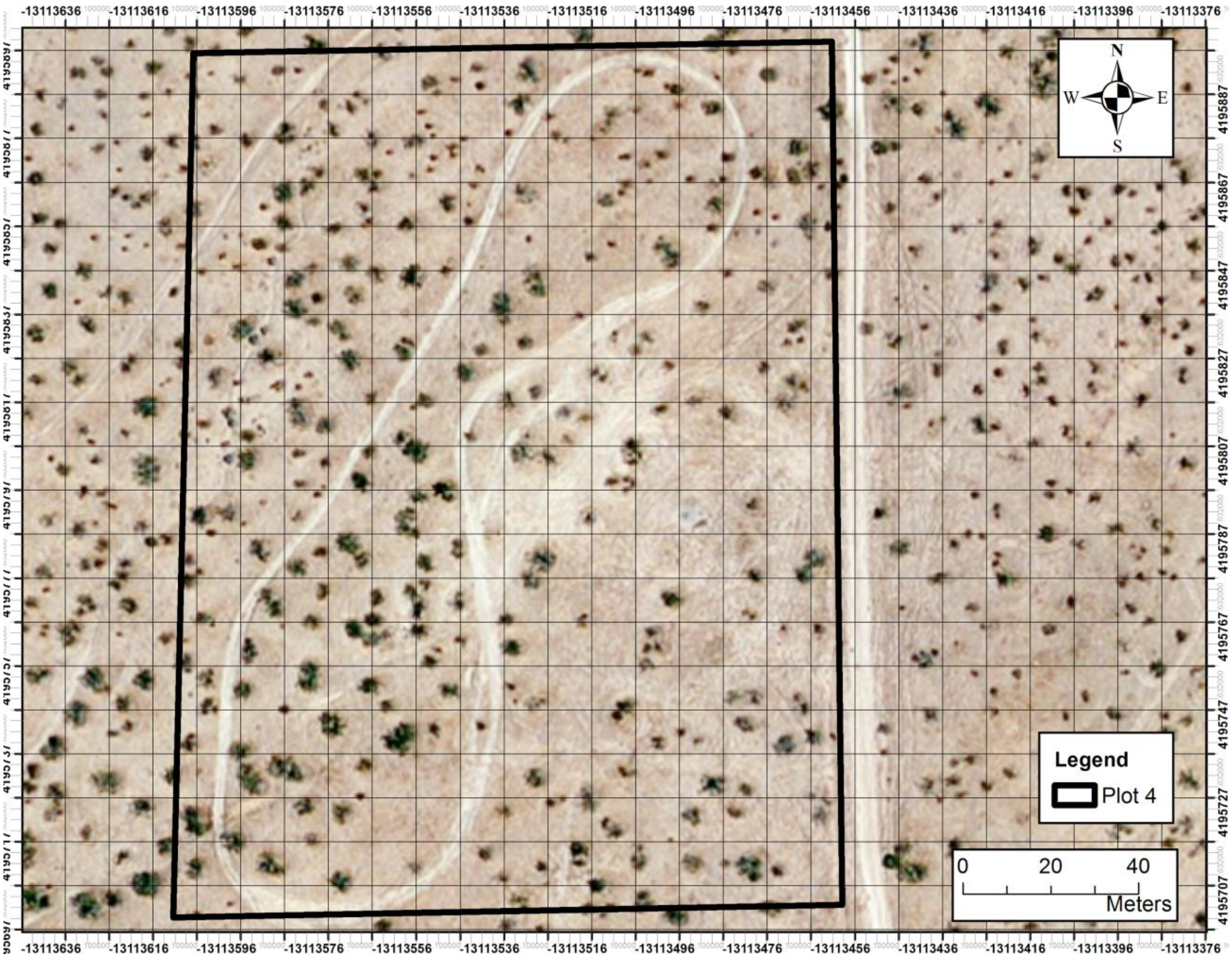

Figure 8. Plot 4 within restoration site with a 10x10 meter grid marking the location of each planting.

Plot 5

Plot 5 will include 145 plant individuals: 29 of white bursage, 29 of fourwing saltbush, 29 of Nevada jointfir, 29 of creosote bush and 29 of Anderson thornscrub. Planting will occur in the approximate locations of the 10x10 meter grid intersections. If all plantings are successful, about 2.70 acres of denuded habitat will be restored (Figure 9).

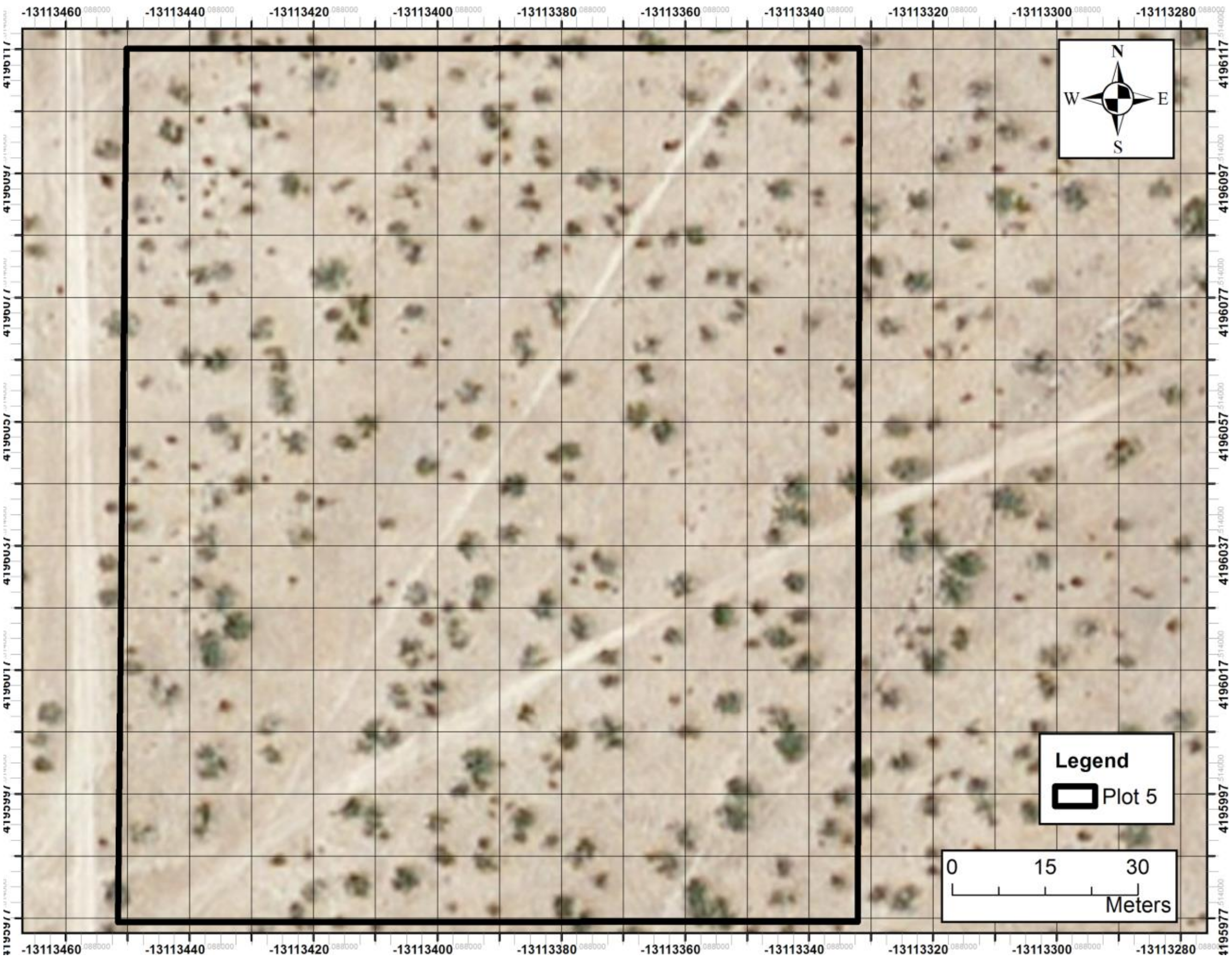

Figure 9. Plot 5 within restoration site with a 10x10 meter grid marking the location of each planting.

Plot 6

Plot 6 will include 100 plant individuals: 20 of white bursage, 20 of fourwing saltbush, 20 of Nevada jointfir, 20 of creosote bush and 20 of Anderson thornscrub. Planting will occur in the approximate locations of the 10x10 meter grid intersections. If all plantings are successful, about 2.70 acres of denuded habitat will be restored (Figure 10).

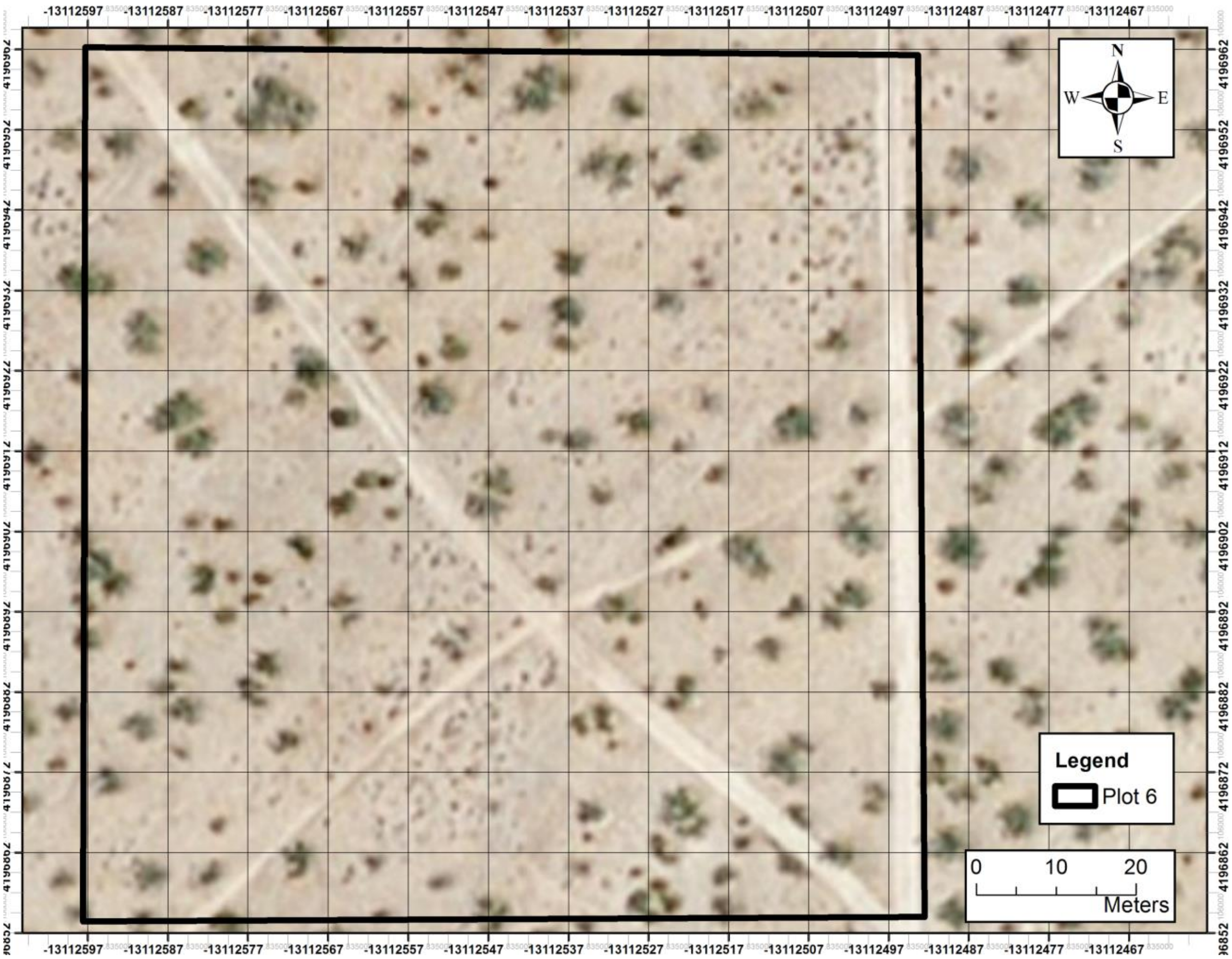

Figure 10. Plot 6 within restoration site with a 10x10 meter grid marking the location of each planting.

6.5 Maintenance

6.5.1 Site Preparation

The current fence line boundary of the site should be regularly checked for breaks and deficiencies. Without interference, the fence should last approximately 40 years; therefore, replacement costs for repairs would ideally be minimal (Jared Queen, pers. comm. 2017). Fence lines should be checked based on visible observations made from vehicles along the main road or walking the fence line boundary on the outside of the restoration site, preferably from a distance because continuous checking of outside the fence line disturbs the space inside the fence line due to the potential for edge effects.

According to the DTRNA Land Manager and Conservation Coordinator, Ms. Jillian Estrada, a non-profit corporation called Friends of Jawbone, which is dedicated to promoting OHV recreation in tandem with education and cooperation between all public land users, has begun voluntarily patrolling the fence lines of the DTRNA using OHVs. Although helpful in checking for breaks in the fence or illegal activities, the use of OHVs continuously along the fence lines is not recommended and should be discouraged as this action creates edge effects that negatively impact the desert tortoise and its habitat (Webb and Wilshire 1983).

Signs within the confines of the restoration site should only need replacing if they become altered beyond recognition, including but not limited to the effects of graffiti, bullet punctures, broken posts, and/or mangled signs. Decommissioned roads will be watched to ensure that these areas are not being illegally used. The locked access gate should be checked and the roads should be cleared of nonnative species along the roads. It is the hope that natural succession will occur on these roads given time. No restoration actions should occur or be considered until Kern County has officially decommissioned these roads.

6.5.2 Nonnative Species Removal

Maintenance will include constant vigilance against nonnative species reintroduction. Nonnative species should be removed upon observation, and areas where restoration actions are occurring should be free of all listed nonnative species. Weeding is a necessary part of maintaining the integrity of the site, and should occur as needed, at least once a month.

6.5.3 Road Camouflage

Maintenance will include ensuring the road camouflage techniques are functional and effective. If human disturbance has recently occurred through camouflaged areas, alternative methods of road camouflage may need to occur.

6.5.4 Soil Remediation

Maintenance of vertical mulch piles should be minimal. Maintenance may occur through removal of any nonnative plant species around the base of these piles, and re-planting any fallen dead creosote branches to better break up the compacted soil.

6.5.5 Planting and Seeding

Maintenance of planting and seeding actions includes checking the intactness of chicken wire cages to ensure no herbivory is occurring within the confines of the cage. Stakes should be checked to make sure they are secured firmly in the ground. Nonnative species should be removed from within the cage radius of the plants and the seeded areas. Cages should be removed 1-2 years following planting once plants have successfully established.

6.5.6 Irrigation

Irrigation should only occur on an as needed basis. If plants or seeds require additional measures to help their establishment, then additional irrigation may be considered. Supplemental irrigation by hand should be conducted on an as needed basis with irrigation ending by Year 2 for individuals planted in Year 1, and Year 3 by individuals planted in Year 2.

6.6 Monitoring

Monitoring will be completed by a qualified Biologist for a minimum of five years following the implementation of the action measures. A monitoring report should be submitted annually.

6.6.1 Site Preparation

Monitoring for passive restoration will include checking the fence line boundary monthly to ensure there are no breaks or repairs needed. Any damages will be noted and the cause of the damage, if possible, should be determined and included in the annual monitoring report.

Posted signs will be monitored to ensure intactness. Any vandalism and/or damaged signs will be noted for future replacement depending on severity.

Upon success of decommissioning Vassar Avenue and Santa Clara Street, the roads should be monitored to ensure no trespassing has occurred on site. In addition, the roads should be monitored for signs of natural succession of native plant species and decreased presence of nonnative species.

6.6.2 Nonnative Species Removal

Monitoring of nonnative species will occur during multiple growing seasons, but especially during germination and flowering periods (Cal-IPC Council 2012). Monitoring will look for signs of nonnative species spreading to new areas of the restoration site, and will examine the effectiveness of the selected techniques for removal. Densities of nonnative species should be compared to densities of native species within the site to detect any potential changes in population abundances.

6.6.3 Road Camouflage

Monitoring of areas within the restoration site where road camouflage has occurred will occur at a minimum of twice a year. Monitoring efforts will focus on the effectiveness and completeness of the road camouflage methods, and will monitor the densities of new native plant populations that may result from these efforts. Alterations to the position of one or more mulching piles may occur if human-related disturbances persist and the road remains visible from the fence line boundary. Evidence of trespass, such as new OHV tracks, should be evaluated to examine the effectiveness of camouflage actions.

6.6.4 Soil Remediation

Monitoring of soil remediated areas will occur at a minimum of twice a year for the first year, and annually for every consecutive year. Monitoring of soil remediation should evaluate whether there has been an observed increase in water retention or nutrients. This may include visually assessing changes to vegetation abundance compared to baseline surveys.

6.6.5 Planting and Seeding

Monitoring should occur monthly during the first winter season as the newly planted and seeded areas will be especially vulnerable to their environment, and thus the health of the plants should be carefully evaluated. Monitoring will examine whether the planted native species are fully establishing. Survivorship within the first month of planting should be assessed. Monitoring should specifically observe species composition and abundance of plants resulting from the implemented seeding and planting. Furthermore, monitoring should include observing and responding to the presence of any nonnative species present at newly seeded or planted sites within the plots.

6.6.6 Irrigation

Monitoring of irrigation should begin during implementation. Observations of the condition of the planted and seeded areas should occur, and adjustments should be made to improve the condition of planted and seeded areas. Time constraints permitting, the health of individual plants should be monitored and irrigation requirements should be adjusted as needed. Irrigation should be concluded 1-2 years after implementation, but given desert habitat and drought, the usefulness of irrigation should be assessed during monitoring visits, and irrigation should conclude as soon as realistically possible.

6.6.7 Rare and Sensitive Species

Monitoring of the restoration site should include watching for sign or presence of rare and sensitive plant and wildlife species. If any are observed, the restoration plan should be adapted to factor in the presence of these rare and sensitive species.

6.6.8 Monitoring Reports

Monitoring reports should be submitted annually by January 1 of every year beginning on the first year following the start of the implementation measures. Monitoring reports should be submitted to the DTPC Conservation Coordinator or project manager.

6.7 Costs

The costs calculated in this restoration plan are only taking into consideration the costs associated with supplies needed for the recommended restoration actions. Labor costs are difficult to assess at this stage of planning due to our inexperience with labor contracts and the potential variability of using paid versus volunteer labor throughout this project. An initial estimate of $10,000 for labor in Year 1 was provided to the Council. This estimate stems from personal communication with Dr. Ann McLuckie, who shared that her desert tortoise habitat restoration project spent approximately 400 hours on plant delivery, cage construction, and plantings of 1008 plants (Ann McLuckie, pers. comm. 2017). Because we are proposing to plant 1555 plants, we are estimating it will take approximately 600 hours over the course of a week to complete the initial planting proposed in Year 1. At $15 an hour, which is the hourly wage paid by the Desert Tortoise Preserve Committee for contracted work (Jillian Estrada, pers. comm. 2016), this comes out to a total initial labor cost of $9000. We would propose an extra $1000 be added to this labor budget to account for any delays that may increase additional costs.

In order to keep initial labor costs low, it is recommended that the Council contract volunteer labor from restoration organizations such as American Conservation Experience. Another labor cost that is not factored into this analysis is the salary of a qualified biologist to monitor and maintain the restoration site throughout the length of its proposed five-year schedule. This cost estimate varies greatly and would best be determined by the Council and/or the DTPC when the hiring of the qualified biologist becomes necessary to moving forward in the project.

Table 5. Summary of costs for restoration actions based on supplies only.

Actions	Cost	
Trash Removal (Supplies only)	$	379.70
Nonnative Species Removal (Supplies only)	$	499.86
Road Camouflage	$	-
Soil Remediation	$	-
Planting in all Plots	$	31,843.97
Seeding	$	1,518.00
Irrigation Supplies	$	3,197.40
Overall Total	**$**	**37,438.93**

6.8 Adaptive Management

Phase 1 has tremendous potential to improve current conditions within the restoration site because it combines careful site preparation with strong management actions. The restoration plan applies actions that have been proven effective within desert ecosystem restoration by researchers, land managers, and experimental research. However, there are special circumstances and uncertainties associated within the restoration plan that will need to be continually monitored and evaluated. These circumstances can impact the outcomes of these actions and the projected amount of acreage associated with them.

6.8.1 Unexpected Increases in Restoration Costs

This restoration plan has carefully considered and budgeted for all currently known costs associated with Phase 1 actions. This includes site preparation methods, planting, seeding, irrigating, maintenance, and human capacity. To mitigate any potential price increases, we are proposing to utilize multiple sources for restoration (local native farm, contract farming, and local seed collection) and implementation tasks (DTPC volunteer labor, paid DTPC staff, and contracted non-profits such as American Conservation Experience or Great Basin Institute). If, for example, any one of the seed sources is insufficient in one year, the plan as it is now will compensate by utilizing one of the other sources. In terms of additional materials, road camouflage methods will mostly involve collection of materials from within the restoration site, and possibly surrounding parcels that are also owned by the DTPC. Equipment for soil remediation, ripping and imprinting is costly and should be avoided because of the severe disturbance this would cause to the site's habitat.

6.8.2 Occurrence of Fire

Given that fires can occur within desert ecosystems, there is the potential for fire to impact the progress of the restoration site. The above actions involve altering the landscape in a multitude of ways to promote natural and planned recovery, and as such, fire may still severely set back the success of native plant species that have been seeded or planted at the site. This is because after fire nonnative species reestablish quicker than native species (D'Antonio and Vitousek 1992, Brooks and Esque 2002, Brooks and Berry 2006). Strong site preparation and quick re-seeding or planting may give natives a solid foothold to bounce back after the occurrence of fire. Fire will delay the success of the project, and it may also affect the overall budget in that additional seed or grown plants may need to be redone. Road camouflage techniques may also have to be redone and/or increased as fire will make OHV trails more visible from outside of the fence line.

6.8.3 Ongoing Site Disturbance

With these actions, there is a focus on securing the landscape with fencing and signs, and then conducting all of the necessary steps to restore the site for use by the desert tortoise. Adjustment or expansion of these options may be required in the future if current methods of reducing disturbance variables and seeding or planting fail. Signs may need adjustment if OHV users and recreational visitors do not respect the no trespassing signs currently in place. Responses to these signs will need to be monitored with adjustments or stricter enforcing measures put into place if necessary. It is recommended that local authorities be contacted and utilized by the DTPC in the event of continued trespassing problems.

Road camouflage may need to occur beyond the proposed 100 meters (line of sight) as the length of trail visible from the fence line will actually vary, and it may be deemed critical to extend that range in certain instances. This would require more organic material, but would not be an added expense as the dead creosote branches are abundant on the ground of the parcels. Additional seeding and planting may need to occur in the event the first round does not take or establishment rates remain low. Irrigation considerations may also impact the budget if water is required more than estimated.

6.8.4 Rare and Sensitive Species Provision

This restoration project will benefit the desert tortoise, and it has the potential to benefit other rare and sensitive species that may coexist within the desert tortoise's habitat. Appendix B – Table 1 identifies rare and sensitive species that may be found within the targeted restoration site based on an analysis of existing rare and sensitive desert species and their known habitats. If these species are found within the site, extreme care should be taken to ensure the safety and continued survival of these species throughout the restoration project. This may mean altering where restoration occurs within the restoration site to mitigate any potential impacts to the species.

6.9 Outcomes

Phase 1 of the restoration plan seeks to restore a starting total of 173.5 acres of highly degraded habitat. As is shown in Table 6, restoration of the identified six plots will restore a total of 28 acres through revegetation in Years 1 and 2, while restored OHV trails through road camouflage and soil remediation will contribute a total of 4 acres. The buffer zones are areas where site preparation will take place, restoring a total of 141.5 acres.

Table 6. Summary of restoration areas in Phase 1, including their associated actions, expected restored acreage and total cost.

Restoration Area	Actions	Restored Acreage
OHV Trails	Road camouflage; Soil remediation; Trash removal; Nonnative species removal	4*
Buffer Zones	Road camouflage on first 100 meters of OHV trails within buffer zones; Nonnative species removal; Trash removal	141.5
Plot 1	Soil remediation; Irrigation; Planting 330 cover species plants; Seeding of forage species plants; Nonnative species removal; Trash removal	5.8
Plot 2	Soil remediation; Irrigation; Planting 650 cover species plants; Seeding of forage species; Nonnative species removal; Trash removal	11.6
Plot 3	Road camouflage; Soil remediation; Irrigation; Planting 65 cover species plants; Seeding of forage species; Nonnative species removal; Trash removal	1.2
Plot 4	Soil remediation; Irrigation; Planting 265 cover species plants; Seeding of forage species; Nonnative species removal; Trash removal	5
Plot 5	Soil remediation; Irrigation; Planting 145 cover species plants; Seeding of forage species; Nonnative species removal; Trash removal	2.7
Plot 6	Road camouflage; Soil remediation; Irrigation; Planting 100 cover species plants; Seeding of forage species; Nonnative species removal; Trash removal	1.7
	Total Acreage Restored	173.5

Total Cost for Restoration**	$37,438.93

*OHV trail restoration actions restore nine acres, but five of those are accounted for in the buffer zones restored acreage. ** Cost is based on supplies only.

7. Phase 2

Following the successful completion of Phase 1, the next steps would to consider a Phase 2 in which the rest of the approximately 285 acres would be restored. These areas were less prioritized than those identified in Phase 1 because they are in fair condition with the exception of the OHV trails traversing the site. Approximately 35 OHV trails would still need to be remediated throughout the site. While road camouflage plays less of a role in these areas, soil remediation may still be required to help return these trails to a more natural state. Nonnative species removal will be necessary throughout the restoration areas, but no other planting and seeding plots were identified beyond Phase 1 plots.

8. Conclusions

Using strategic restoration in the format of goals, actions and outcomes as supplied in the Guidance Document (*presented in section 2.2.1*), this restoration plan can serve as an example of how restoration actions can be applied for the recovery of desert tortoise habitat. The actions proposed in this plan are based off of best management practices and studies that have demonstrated the success of each action. To increase the probability of this restoration plan, actions were combined to increase their effectiveness. If all recommendations are followed, a total of 173.5 acres will be restored for the benefit of the desert tortoise, jump starting natural succession within the area.

8.1 Future Research

Opportunities for future research within the context of this restoration project include:

1. Post-restoration surveying for mammalian species other than the desert tortoise to examine the effects of habitat restoration in which the restoration is focused solely on the recovery of a single species.
    a. For example, increases in kangaroo rat density levels may indicate successful restoration.
2. Comparisons of the effectiveness of using a multi-pronged restoration approach (i.e. combinations of partial and full restoration) to restore desert tortoise habitat.
3. Pursuing further research on the soil compaction across roads.
4. Agassiz's desert tortoise abundance densities following the conclusion of this restoration plan. Determinations will need to be made to evaluate the effectiveness of this plan for future tortoise populations.
5. Conduct studies on soil compaction across OHV trails.

6. Conduct studies to test blood of tortoises at the restoration site before and after restoration to examine how their blood chemistry, shell thickness, etc., change as a result of the restoration.

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Appendix A – Existing Biological Resources

Table 1. Plant Species Observations from March 17, 2015 from the DTPC's Biological Assessment of DTRNA EEA parcels.
Source: DTPC, 2015

Common Name	Scientific Name
Creosote bush	*Larrea tridentata*
White bursage	*Ambrosia dumosa*
Anderson thorn bush	*Lycium andersonii*
Spiny hopsage	*Grayia spinosa*
Winterfat	*Krascheninnikovia lanata*
Cheesebush	*Ambrosia salsola*
Indigo bush	*Psorothamnus arborescens*
Mojave horsebrush	*Tetradymia stenolepis*
Cooper's goldenbush	*Ericameria cooperi*
Goldfields	*Lasthenia ssp.*
Checker fiddleneck	*Amsinckia tessellata*
Rayless goldenhead	*Acamptopappus sphaerocephalus*
Saharan mustard	*Brassica tournefortii*
Rattlesnake weed	*Chamaesyce albomarginata*
Paper bag bush	*Scutellaria mexicana*
Nonnative dried grass	*Schismus sp.*
Golden cholla	*Cylindopuntia echinocarpa*
Green rabbitbrush	*Ericameria teretifolia*
California buckwheat	*Eriogonum fasciculatum*
Peach thorn	*Lycium cooperi*
Dried perennial bunch grass	*Stipa sp.*
Mojave aster	*Xylorhiza tortifolia*
Mojave rabbitbrush	*Ericameria nauseosa*
Desert candle	*Caulanthus inflatus*
Desert trumpet	*Eriogonum inflatum*
Dried exotic annual grass	*Bromus sp.*
Slender-stemmed buckwheat	*Eriogonum gracillimum*

Table 2. Wildlife Observations from March 17, 2015 DTPC Biological Assessment of DTRNA EEA parcels**.** *Source: DTPC, 2015.*

Common Name	Scientific Name	Type of Observation
Western whiptail lizard	*Aspidoscelis tigris*	Animal sign
Coyote	*Canis latrans*	Scat
Desert kit fox	*Vulpes macrotis arsipus*	Scat and burrows
Black-tailed jackrabbit	*Lepus californicus*	Scat
Agassiz’s desert tortoise	*Gopherus agassizii*	Burrows and shell
Lesser nighthawk	*Chordeiles acutipennis*	Visual observation, flying east to west
Common raven	*Corvus corax*	Visual observation
Sheep	*Ovis aries*	Scat

Table 3. Compilation of abundant species observed in a survey conducted by Dr. Kristin Berry, Lisa M. Lyren, Julie L. Yee and Tracy Y. Bailey in a study area that encompasses three types of managed lands: the DTRNA, critical habitat and private land, which includes the restoration site. (Berry et al. 2014)

Common Name	Scientific Name
Creosote bush	*Larrea tridentata*
White bursage	*Ambrosia dumosa*
Anderson boxthorn	*Lycium andersonii*
Cheesebush	*Ambrosia salsola*
Goldenhead	*Acamptopappus sphaerocephalus*
Mojave indigo bush	*Psorothamnus arborescens*
Desert trumpet	*Eriogonum inflatum*
Hop-sage	*Grayia spinosa*
Mojave aster	*Xylorhiza tortifolia*
Nevada ephedra	*Ephedra nevadensis*
Mojave California buckwheat	*Eriogonum fasciculatum*
Winter fat	*Krascheninnikovia lanata*

Appendix B – Rare and Sensitive Species

Table 1. Rare and sensitive wildlife and plant species that may exist within the restoration site. Sources: DTPC website, IUCN Redlist

Wildlife Species			
Common Name	**Scientific Name**	**Listing Status**	**Presence Observed Onsite?**
Agassiz's desert tortoise	*Gopherus agassizii*	Threatened	Burrows and shells
Mohave ground squirrel	*Xerospermophilus mohavensis*	State Threatened	
Desert kit fox	*Vulpes macrotis arsipus*	Rare, State Threatened	Scat & burrows observed
Black-tailed jackrabbit	*Lepus californicus deserticola*	Least Concern	Scat
Coyote	*Canis latrans*	Least Concern	Scat presence
Badger	*Taxidea taxus*	Least Concern	
Desert woodrat	*Neotoma lepida*	Least Concern	
Kangaroo rat	*Dipodomys deserti*	Least Concern	
Collared lizard	*Crotaphytus collaris*	Least Concern	
Side-blotched lizard	*Uta stansburiana*	Least Concern	
Leopard lizard	*Gamelia wislizenii*	Least Concern	
Chuckwalla	*Sauromalus ater*	Least Concern	
Western whiptail	*Aspidoscelis tigris*	Least Concern	Presence of individual
Cactus wren	*Campylorhynchus brunneicapillus*	Least Concern	
LeConte's thrasher	*Toxostoma lecontei*	Least Concern	
Ash-throated flycatcher	*Myiarchus cinerascens*	Least Concern	
Red-tailed hawk	*Buteo jamaicensis*	Least Concern	
Lesser nighthawk	*Chordeiles acutipennis*	Least Concern	Individual spotted
Ladderback woodpecker	*Dryobates scalaris*	Least Concern	

Coachwhip snake	*Masticophis flagellum*	Least Concern	
Gopher snake	*Pituophis melanoleucus*	Least Concern	
Sidewinder	*Crotalus cerastes*	Least Concern	
Mojave rattlesnake	Crotalus scutulatus	Least Concern	

Plant Species

Species Common Name	Scientific Name	Listing Status	Presence Observed Onsite?
Barstow woolly sunflower	*Eriophyllum mohavense*	Rare and Endangered	
Desert cymopterus	*Cymopterus deserticola*	Rare and Endangered	

Appendix C – Phase 1 Supply Budget

Table 1. Itemized budget for restorations actions based on supplies only.

Year	Actions	Units	Cost/Unit	Total Cost
1	Trash Removal (All Locations)			
	10 Gallon Commercial Trash Container	10	17.99	179.90
	EZ Reach and Grab Pickup Tool	20	9.99	199.80
	Total cost for Trash Removal (Supplies only)			**379.70**
1 - 5	Nonnative Species Removal (All Locations)			
	Ace Steel Wheelbarrel	4	79.99	319.96
	Long Handle Round Point Shovel	10	17.99	179.90
	Total Cost for Nonnative Species Removal (Supplies only)			**499.86**
1	Road Camouflage			
	Vertical Mulching	0	0	0
	Horizontal Mulching	0	0	0
	Rock Scattering	0	0	0
	Total for Road Camouflage			**0**
1 & 2	Soil Remediation			
	Vertical Mulching	0	0	0
	Ripping	0	0	0
	Imprinting	0	0	0
	Recontouring Berms	0	0	0
	Topsoil Salvage	0	0	0
	Total for Soil Remediation			**0**
1 & 2	Planting			
	Plot 1	330	10	3300.00
	Plot 2	650	10	6500.00
	Plot 3	65	10	650.00
	Plot 4	265	10	2650.00

	Plot 5	145	10	1450.00
	Plot 6	100	10	1000.00
	150 ft Poultry Netting, 1in Hex Mesh (2ft diameter/plant)	103	139.99	14418.97
	Heavy Duty Steel Garden Staples (50 pack; 4/cage)	125	15	1875.00
	Total for Planting in all Plots			**31843.97**
2	Seeding (Cost/bulk lb)			
	Ambrosia dumosa	1	40	40.00
	Atriplex canescens	1	18	18.00
	Chamaesyce albomarginata	1	500	500.00
	Ephedra nevadensis	1	36	36.00
	Larrea tridentata	1	30	30.00
	Loeseliastrum matthewsii	1	240	240.00
	Lycium andersonii	1	500	500.00
	Malacothrix glabrata	1	120	120.00
	Plantago ovata	1	2	2.00
	Sphaeralcea ambigua	1	32	32.00
	Total for Seeding			**1518.00**
1 & 2	Irrigation			
	Trailer Water Tank 1,000 Gallon (Weekly rental price)	2	1343	2686.00
	Solo Deluxe Shoulder Saver Sprayer Harness	4	31	124.00
	Solo 4-Gal. Standard Backpack Sprayer w/ Diaphragm Pump	4	96.85	387.40
	Total for Irrigation Supplies			**3197.40**
	Total			**$37,438.93**

*****Actions are not recommended in Phase 1 of this plan and have an associated cost of $0 as costs were not collected.

3. Conclusion

The goal of this analysis was to provide land managers with a framework that would streamline efforts for desert tortoise habitat restoration. This framework includes a guidance document that defines the restoration principles for the desert tortoise, a case study that serves as an example of strategic restoration for desert tortoise habitat, and an assessment tool that helps evaluate sites for habitat restoration potential. Overall, this framework can serve as a decision support tool for land managers to use when deciding where and how to allocate limited resources.

Each component of the framework was developed to incorporate the use of strategic restoration to identify restoration actions that would help in the recovery of desert tortoise populations. Actions were structured in a "goals, actions, outcomes" fashion to provide a clear thought process and structure that could be easily replicated across the documents to target the four categories of form, function, stability and feasibility defined in the guidance document. In response to future environmental changes, adaptive management was incorporated into the restoration plan to improve the success potential of restoration actions.

Should all actions be implemented in the restoration plan, 173.5 acres could be restored to serve as suitable habitat for the desert tortoise. However, because desert recovery can take decades to recover natural processes after disturbances, habitation of these recovered areas by desert tortoises may not occur for at least 50 years (Lovich and Bainbridge 1999). Successful restoration would support about 10 desert tortoises per square km (USFWS 2011). Therefore, it is recommended the DTPC and the Council implement restoration actions as soon as resources become available.

In its current state, the assessment tool can evaluate sites within Western Mojave Recovery Unit for restoration potential. Each category and feature was derived using information specifically for the Western Mojave Desert, and should not be used for other areas as habitat requirements may change based on geographic location. To expand the use of the tool, land managers are encouraged to adapt and expand the tool based on information available for their area.

Below is a list of assumptions, limitation and future research areas that should be taken into consideration when using this report.

3.1 Assumptions

The following assumptions have been identified throughout the course of designing this research project:

1. This framework is meant for land managers who have the prerequisite knowledge and ability to accurately assess their site in terms of potential desert tortoise habitat.
2. The framework assumes the restoration efforts will be focused within the Western Mojave Recovery Unit.
3. The projected effectiveness of the restoration plan within the framework assumes that each of the steps listed in the restoration plan are fully implemented, including all actions, maintenance and monitoring of the site.

3.2 Limitations

The following limitations have been identified throughout the course of creating this research project:

1. Reliance on funding is a large limitation in that it will dictate the ability for this framework to be fully implemented, especially considering the ability to conduct restoration such as described in the restoration plan.
2. This framework is focused specifically on the Western Mojave Recovery Unit, and therefore other parts of the desert tortoise's range is outside of the scope of the assessment tool and site specific restoration plan.
3. Feasibility was the main focus of this framework, despite its incredible importance.

3.3 Future Research

This research project seeks to define, evaluate, and restore habitat for the Agassiz's Desert Tortoise, but due to its assumptions and possible limitations, additional research should be conducted on various topics to ensure the framework is reaching its full potential. Future research should be considered to assess the following:

1. Considerations for how this framework could be expanded to include other recovery units.
2. Prioritizing regional assessments.
3. How to prioritize costs of restoration efforts in a more systematic way.
4. Applying strategic restoration to other types of habitat restoration.
5. As stated in *The Revised Recovery Plan for the Mojave Desert Tortoise*, research related to the effectiveness of management actions is a high priority.

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