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MOJAVE BASIN AND RANGE

RAPID ECOREGIONAL ASSESSMENTS
FINAL MEMORANDUM I-3-C

Prepared for:
Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

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List of Acronyms

AADT	Annual Average Daily Traffic
ACEC	Area of Critical Environmental Concern
AGI	Annual Grasses Index
AMT	Assessment Management Team
AR4	International Panel on Climate Change - Fourth Assessment Report
AWC	Available Water Capacity
AWS	Associate Weather Services
BLM	Bureau of Land Management
BpS	Biophysical Settings
CAGAP	California Gap Analysis Project
CA	Change Agent
CBR	Central Basin and Range
CCVI	Climate Change Vulnerability Index
CE	Conservation Element
CVS	Conservation Value Summary
DEM	Digital Elevation Model
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EFC	Environmental Flow Components
EIA	Ecological Integrity Assessment
EIS	Environmental Impact Statement
EO	Element Occurrence
EPCA	Energy Policy and Conservation Act
ESA	Endangered Species Act
ESD	Ecological Site Descriptions
ET	Evapotranspiration
EVT	Existing vegetation type
FAO	Food and Agriculture Organization
FCC	Federal Communications Commission
FO	Field Office
FRC	Fire Regime Condition Class
FRI	Fire Return Interval
GA	Grazing Allotment
GBPJW	Great Basin Pinyon-Juniper Woodland
GCM	Global Climate Model
GFDL	Geophysical Fluid Dynamics Laboratory
GIS	Geographic Information System
HMA	Herd Management Area
HRV	Historic Range of Variation
HUC	Management Question
ICLUS	Integrated Climate and Land Use Scenarios
IPCC	Intergovernmental Panel on Climate Change
Kw	K factor (soil erodibility) Values
LCM	Landscape Condition Model
LF	Landfire
MBR	Mojave Basin and Range
MLRA	Multiple Resource Land Area

MRDS	Mineral Resource Data System
NCEP	National Centers for the Environmental Prediction
NHD	National Hydrological Dataset
NPMS	National Pipeline Mapping System
NRCS	Natural Resource Conservation Service
NREL	National Renewable Energy Laboratory
NRV	Natural Range of Variability
NTAD	National Transportation Atlas Database
NVDEP	Nevada Department Environmental Protection
NWI	National Wetland Inventory
ORV	Off-road Vehicle
PJ	Pinyon-Juniper
PRISM	Parameter-elevation Regressions on Independent Slopes Model
REA	Rapid Ecoregional Assessments
RegCM	International Centre for Theoretical Physics Regional Climate Model
ROC	Receiver Operating Characteristic
SAR	Sodium Adsorption Ratio
SClass	Succession class
SDM	Species Distribution Model
AUC	Area Under the (ROC) Curve
SERGoM	Spatially Explicit Regional Growth Model
SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic Database
SUNY	State University of New York
SW ReGAP	Southwest Regional Gap Analysis Project
SWAP	State Wildlife Action Plan
USGS	United States Geological Survey
USGS-CD	USGS 15km dynamically downscaled climate model outputs
VDDT	Vegetation Dynamics Development Tool

Executive Summary

Rapid Ecoregional Assessments (REAs) are the first step in the Bureau's Landscape Approach. REAs are intended to synthesize existing knowledge and information applicable to all lands and waters within the ecoregion. This synthesis aims to inform subsequent decision-making, implementation, and monitoring by BLM and partners within the ecoregion, and should interact with ongoing scientific research as a foundation for science-based land management. REAs are organized into a series of phases and component tasks. Phase 1 includes tasks that clarify the scope, expected data and analytic approaches to be used, and culminates in a detailed work plan for the assessment. Phase 2 completes the preparation of data, conducts agreed-upon analyses, and documents assessment results.

This memorandum summarizes the work and decisions for Task 3, Phase 1 for the Mojave Basin and Range (MBR) ecoregion. Here we identify, evaluate, and recommend models, methods, and tools to answer management questions. This memorandum is the final version (I-3-c) which has been revised and finalized by incorporating comments provided at AMT Workshop 3 or submitted separately to BLM.

Task 3 Objectives

The objectives of Task 3 are:

1. List the Conservation Elements to be addressed, describing the approaches and categories in which they will be treated
2. Build *prototypical* conceptual models for Conservation Elements
3. Describe the models, methods, and tools for characterizing Conservation Elements, Change agents, and their interactions
4. Describe the models, methods, and tools for conducting assessments to answer the Management Questions
5. Evaluate methods and tools for their ability to perform as intended

Recommendations for "Fine-Filter" Conservation Element Selection and Treatment

We have established several distinct approaches to treating species that meet established criteria for inclusion in the REA. We propose to address species according to these categories:

a) ***Species assumed to be adequately represented indirectly through the assessment of major "coarse-filter"*** ecological systems of the ecoregion. Habitat requirements for these species align closely with coarse-filter CEs. We propose to treat 160 species in this category.

b) ***Species assumed to be adequately represented indirectly as ecologically-based assemblages***. That is, due to similar group behavior and habitat requirements, a recognizable species assemblage is defined and treated as the unit of analysis. We propose to treat 85 species in 17 named categories.

c) ***Landscape Species which should be best addressed as individuals*** in the assessment. These include vertebrate species with moderate to large home ranges that tend to include a diversity of coarse-filter CEs as important habitat components. These species occur over large proportions of the ecoregion and have habitat requirements that are clearly distinct from all other taxa of concern. We propose to treat 37 species in this category.

d) ***Local Species of concern that have very narrow distributions;*** typically limited to one BLM management jurisdiction. These species do not fall within categories a-c. We are gathering current locational information, but will not aim to develop conceptual models for these elements. We propose to treat 184 species in this category.

Spatial Models for Conservation Elements

CE Distribution Models

CE distributions will be expressed using either existing suitable spatial information or modeled using a combination of inductive and deductive methods.

CA Distribution Models

Invasive CAs

We outline two primary approaches for addressing invasive species change agents applicable to terrestrial and aquatic species. In most instances, invasive species are appropriately addressed as species assemblages that share common ecological traits (e.g., invasive annual grasses or forbs), rather than individual species. This enables effective utilization of locational information for modeling current distributions, abundance, and vulnerability of sites to future infestation.

Wildfire CAs

Wildfire is a key natural process for many terrestrial CEs within each ecoregion but land use patterns commonly result in significant departure from expected fire frequency and intensity. In a limited way, we will develop spatial models of wildfire risk based on lightning strike and landscape information, as was completed in the Northern Basin and Range ecoregion. However, most aspects of these CAs are best addressed within the context of major coarse-filter CEs since existing knowledge and modeling centers around their characteristic fire regimes. This knowledge forms the basis for conceptual tabular and spatial models of fire regime departure and enables us to summarize these effects by appropriate landscape units (e.g., watersheds by 5th level hydrologic unit codes or HUC10). Fire regime models also provide one key mechanism for translating measured and predicted trends in climate regimes as they affect these critical ecological dynamics.

Hydrologic Regime Alteration CAs

Hydrologic regime is a key ecological attribute for all aquatic ecosystem types and we propose a set of approaches and tools for documenting reference regimes for each CE within the ecoregion. The reference regimes can then be compared to observations over time to gauge the degree of alteration and effects on ecosystem integrity. Hydrologic regime alteration may be reported at 4th or 5th HUC level (HUC 8 or HUC 10). These same approaches and tools have been applied to climate forecasts to assess the most likely hydrologic impacts of climate change on aquatic CEs.

Development Change Agent Distribution Models

We focused this section on development CAs that require modeling; in particular dispersed recreation, surface mines, and landfills. These and other CAs are then incorporated into condition models which calculate a relative value of the landscape condition as 0.0-1.0 values. Landscape condition incorporates a site intensity effect for where a CA is located as well as a distance decay function to model the offsite effects of CAs.

Ecological Integrity Assessment and Reporting

We illustrate here the NatureServe Ecological Integrity Framework for application to REAs using two main examples: one for terrestrial CEs and one for aquatic CEs, to clarify the organizational criteria and selection of measurable indicators of ecological integrity. We propose a series of indicators of relative ecological condition and ecosystem stressors normalized to a 0.0-1.0 scale for aggregation and reporting purposes. They will also be segmented for reporting on levels of ecological integrity, using categories of "Sustainable," "Transitioning," and "Degraded." Indicators falling within their hypothesized natural range of variation are categorized as "Sustainable." Indicators falling well outside of their hypothesized natural range of variation – to the degree that they suggest imminent loss of the element in that location – are categorized as “Degraded.” Indicators falling intermediate between these values are categorized as “Transitioning.” These indicators may be totaled and averaged, then summarized to 5th level watersheds, to provide a scorecard of ecological integrity for each CE. These index scores may be further aggregated for summarizing ecological integrity at broader conceptual scales as needed and desired for REA reporting.

Assessment Models

Assessment models address the management questions directly. A number of them are incorporated in our CE model discussion. Remaining assessment models are summarized below.

Basic Assessment Models

Many MQs can be summarized as “Where will X coincide with Y?” seeking to identify areas where, for example, CEs will be coincident with CAs that may cause impacts. These types of MQs can be answered by a basic assessment model that will intersect existing data or distributions of a CE with a mapped or modeled CA. Areas of overlap between the CA and CE area can be displayed as a map and accompanied by summary statistics.

Significance-Based Assessment Models

The meaning of “significance” for MQs had considerable discussion in the AMT 1 workshop and there was lack of consensus about the need or appropriateness of finding significance in the REA outputs. In AMT 3 we revisited this issue and gained some additional clarity but we envision further refinement in Tasks 4 through 6. We identified twelve unique MQs that include an indication of significance. Because of the breadth of MQ issues addressed, no single model or measure of significance is practical and must be unique to the MQ or group of similar MQs (e.g., several MQs ask where a class of CEs will experience significant deviations in climate). Generally, findings of significance utilize approaches such as:

- Setting *a priori* thresholds applied to calculated values (e.g., on a range of scores of integrity from 0.0-1.0 any values below 0.5 would indicate a significant level of impact)
- Using natural data breaks among the values. This is a post-assessment analysis of the data that would identify data groupings such that values are partitioned into the categories Sustainable, Transitioning, and Degraded.
- Conducting statistical analyses to identify significant differences in the outcomes. For example, in our discussion of climate change effects on terrestrial CEs, we indicate our intention to report on predicted change in climate variable between time steps where the predicted values are outside of one and two standard deviations of the mean value for the baseline time period.

The calculation of integrity measures (or condition scores), as 0.0 – 1.0 index scores can support all of these approaches but we interpret the AMT’s desire for significance to primarily be a “flagging” approach to identify CEs or places that require additional attention. Where practicable, we have included a recommendation on significance in individual models but some MQs will require further discussion at the AMT 3 workshop to get more clarity about the AMT’s desires. Note also per agreement at AMT 3, we will provide all calculated scores such that users can apply their own interpretation to significance depending on their decision needs.

Climate Change Assessment Models

Assessing the impacts of future climate change is an inherently uncertain endeavor. We must rely on the results from global or regional circulation models attempting to capture the behavior of Earth’s climate system. However, some degree of climate change has already occurred, and the trends in recent climate can be examined relative to multiple future projections, allowing a time series analysis of past, present, and future climates. Our objectives in assessing the ecological impacts of climate change are to identify a robust climatic baseline for the Mojave Basin & Range ecoregion, to analyze the spatial and temporal nature of recent and future climate trends relative to the distributions of selected CEs, to determine which CEs are most vulnerable to climate change impacts, and to characterize the spatio-temporal nature and degree of certainty of that vulnerability.

The magnitude of future climate impacts can only be assessed relative to a baseline that characterizes regional climatic norms, so that the degree of departure from normal can be estimated. Establishing historical climatic baselines is thus the first step in the climate change analysis. Trends in recent climate have already been observed that are consistent with the predictions from climate change models. These recent observations can be analyzed relative to baseline climates to assess whether today's climate is *already* significantly departing from climate norms, and if so, to determine the spatial and temporal patterns of these departures.

To assess the degree of projected change in climates within each ecoregion, seasonal temperature and precipitation values from climate models will be compared to observed historical and recent climate space. Because there may be a large degree of uncertainty in modeled projections of future climate, we will map future climate space as derived from a large number of climate models vetted for the IPCC's 4th Assessment Report (IPCC 2007). Two time steps will be represented in future climate space analyses for each ecoregion – a near-term future time step (2020's) and a mid-century future time step (2050's). Only the A2 greenhouse gas emissions scenario is being examined in the climate space trend analyses. These graphs will demonstrate the magnitude of change between modeled future seasonal climates and observed historical and recent climates, as defined by seasonal characterization of temperature and precipitation.

There are aspects of the relationship between climate and biodiversity that cannot be easily summarized by only examining temperature and precipitation. Dynamically downscaled climate model outputs provided by the USGS (Steve Hostetler) offer additional biophysical parameters such as soil moisture, humidity, and evapotranspiration. From these outputs, we can further derive meaningful values such as the climatic water deficit, although the spatial resolution of these data is quite coarse (15 x 15 km grids). For these biophysical variables, we rely on model outputs both to establish a baseline (from the 1968-1999 NCEP-driven runs), as well as to project future conditions (from three independent climate models).

We also propose several approaches for translating patterns in temperature and precipitation into CE-specific models of fire regime and succession (for terrestrial CEs) and hydrologic regime (for aquatic CEs) both of which enable reporting on predicted climate-change effects on key ecological processes.

<u>Other Specific Assessment Models</u>

In addition to the basic assessment models that are fairly standard across CEs and CAs, we idenitified several MQs that required specialized assessment models:

- Restoration suitability assessment. These models address general habitat restoration, landscape connectivity restoration, linear feature (e.g., wildlife corridor) restoration, and restoration of areas impacted by invasive species.
- Energy development assessment. This will include the modeling necessary to portray current and future (2025) traditional and renewable energy development and total potential renewable energy development. Those models will be used to address MQs related to 1) the intersection of energy development and CEs, and subsequently, 2) the identification of areas of least conflict with CEs as well as mitigation opportunities.
- The high biodiversity site assessment model treats these areas as reporting units per earlier AMT guidance but addresses the MQ related to identifying those that may experience significant climate change.

Managing Uncertainty

A rapid ecoregional assessment must take advantage of many existing data sets, often applying them for purposes never contemplated by their original developers. This fact, and strong need for transparency and repeatability, requires that we carefully consider ways to document and manage for uncertainty. In order to manage this uncertainty, the REA process includes a series of mechanisms for documenting the data sets, information sources, processing steps, and outputs. The steps of this process offer opportunities to manage the inherent uncertainties associated with REAs. We have taken an approach that maximizes these opportunities, including:

- **Data Documentation.** Throughout tasks 2-3 of the REA, we have documented several hundred extant data sets in terms of their thematic and spatial precision, accuracy, and completeness, relative to the ecoregion. FGDC metadata will be provided for all data sets ultimately used in the REA, and our project database provides additional opportunities to capture expert perspective on the relative utility of each data set for the intended modeling purposes of the REA.
- **Repeatability.** Conceptual modeling provides an important mechanism for stating the many assumptions that apply in any complex process. We are systematically organizing scientific references that are drawn upon in the REA for easy access by subsequent users. All spatial models will include documentation of processing steps, including using ESRI ModelBuilder™ so that spatial models may be repeated, analyzed in detail, and updated when new input layers become available.
- **Calibration.** In some instances, during the course of spatial model development, there are opportunities for sensitivity analysis, comparison of similar models, and error documentation.
- **Interpretation.** Finally, inherent in the design of the REA is a series of judgments about the appropriate interpretation of analysis results. For example, the selection of 5th level watersheds as primary reporting units reflects a judgment about the expected resolution of analysis - based on the resolution of modeling inputs – and appropriate spatial scale for interpreting results. Therefore, we will clearly communicate the importance of avoiding over-interpretation of results. This design aims to limit the potential for misinterpretation by subsequent users and is our responsibility as expert contractors to implement.

Issues and Limitations

The following issues and limitations were identified in our model development process. This list isn't exhaustive but highlights the key and common issues we identified. It is important to note as a primary limitation that there are still data sets awaiting delivery for us to review for suitability which may affect our model recommendations or feasibility. Also, we have yet to investigate certain tools and while we expect to follow the same workflows illustrated in our models, we may substitute tools or manual methods for those described. Another primary limitation is that all of the model outputs are subject to the error of the input data sets as well as the assumptions made by our team and other subject matter experts consulted. Additional issues and limitations include:

1. Not all issues could be made transparent in the draft of this memo nor discussed at the AMT 3 workshop. While we endeavor to provide as much detail as practicable, there will remain many details at finer levels of concepts, models, inputs, and outputs that likely will require several specialized interim web meetings with select AMT members to resolve. We will work with the REA/AMT leadership to schedule these throughout tasks 5-7 to receive AMT feedback to complete the work.
2. We and the AMT have yet to settle on all final reporting units and reporting metrics. There is likely some mismatch in expectations of the precision of the analyses relative to input data sets and reporting units. At the scale of an ecoregion, most reporting units will be large and many input data sets (particularly for climate forecasts) are coarse.
3. Inclusion of the energy mitigation MQ and model is under REA leadership consideration.
4. A large number of comments (primarily from USGS) regarding needs for measuring, evaluating, and communicating uncertainty require further guidance from the REA leadership. We provided an uncertainty framework as requested by USGS but note that not all uncertainty assessments or measures are practical for the REA.
5. Much of the aquatic section received a large number of comments, primarily from USGS. Generally, data availability is extremely limited to answer many of the MQs as stated with

any precision. We encourage a fresh review of this section by USGS (and any other interested AMT members) consistent with the objectives of the REA.

6. Soils and surficial geology data are highly variable in completeness and spatial resolution and thus the ability to answer the sensitive soils MQs is somewhat compromised. We have proposed a modeling approach to address this to the greatest degree feasible within time and resources of the REA.
7. Mining data (current and historic) is primarily represented by point locations. We have proposed a modeling method to create a realistic footprint for these features but historic mining sites that have partially revegetated will likely be highly underrepresented by our model.
8. Answering many MQs related to integrity and significance necessarily involve scoring, categorization, and/or thresholding of data and are largely based on team expert knowledge and experience. There was some AMT concern about the rigor and transparency of such an approach. We will document inputs (data and expert judgment) and provide all of the original inputs so that users may reanalyze the data and come to their own conclusions. It is, however, infeasible for an REA with many dozens of MQs and hundreds of inputs to conduct highly rigorous, empirically based analyses for all MQs.

Task 3: Identify, Evaluate, and Recommend Models, Methods, and Tools

Introduction

Rapid Ecoregional Assessments (REAs) are the first step in the Bureau's Landscape Approach. REAs are intended to synthesize existing knowledge and information applicable to all lands and waters within the ecoregion. This synthesis aims to inform subsequent decision-making, implementation, and monitoring by BLM and partners within the ecoregion, and should interact with ongoing scientific research as a foundation for science-based land management. REAs are organized into a series of phases and component tasks. Phase 1 includes tasks that clarify the scope, expected data and analytic approaches to be used, and culminates in a detailed work plan for the assessment. Phase 2 completes the preparation of data, conducts agreed-upon analyses, and documents assessment results.

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Memorandum I-3-C Organization

This memorandum summarizes our investigation and evaluation of models, methods and tools to represent the conservation elements and change agents and provide the assessments to answer the management questions. As an ecological assessment, many of the components are interlinked and thus we present them in ways consistent with an ecological approach. Some management questions (MQs) are addressed in the

Conservation Element Models section because the questions are intertwined with the conceptual operation of the Conservation Elements (CEs). We then present models to represent the distribution of the Change Agents (CAs) and then models to assess other MQs. Our approach to assessing MQs that address the interaction of CEs with CAs uses a scenarios approach that is described below along with our approach to identifying model components and categories.

In each section we provide a description of our approach and relevant issues and references. We then provide diagrams of proposed models supported by references and identify any specific software tools proposed to implement the model. We conclude with a section on limitations to our current recommendations.

Components and Categories of Models

To identify the needed models, we created a taxonomy of model components and then built a generic model descriptor for each MQ as found in Appendix III. Management Questions: Referenced to Modeling

Categories Analysis of the table (in that appendix) identified the variety and number of models needed to represent CEs and CAs and assess MQs. We used this information to identify the common and unique components of the models that required description. Note that we continued to receive a number of comments about the MQs themselves in the AMT written review of Memo 3a. We have not had time to fully address those but will provide a proposed final MQ table in the Task 4 work plan.

Scenario-Based Approach

CAs occur or are planned or forecast to occur during different timeframes. Each timeframe of CAs is represented by a scenario according to the following requested in BLM's scope of work:

- Current: represented by mapped CAs or those for which we can model their distribution as of 2011.
- 2025: includes all current CAs and those forecast to occur by 2025.
- 2050's: includes all of the above CA distributions plus climate change forecasts for 2050's.

While several MQs are interested in individual CAs or groups of CAs, the scenario approach also supports a cumulative effects assessment of the interaction of all identified CAs.

Model Conventions

To illustrate and describe the models we've employed the following conventions:

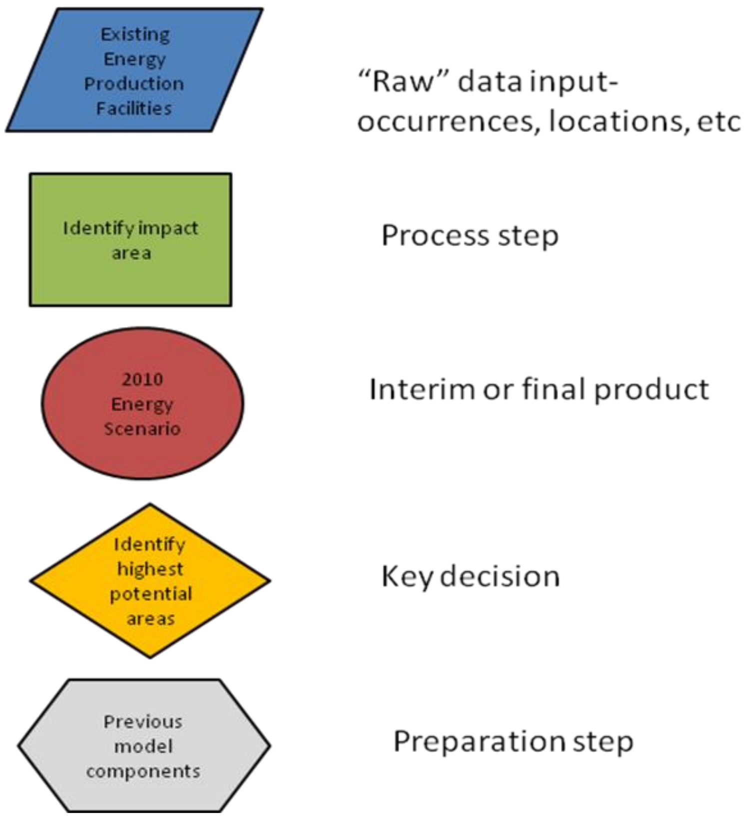
Diagrams use the shapes associated with common model components, and specific inputs, outputs, and processes are identified within the boxes (Figure 1). When we used modeling software to diagram the models (e.g., VDDT), we utilized the outputs directly and thus those models will not follow this convention.

Model descriptions generally provide the following information with references as appropriate:

- **Inputs**: these can be raw data inputs, non-data inputs, or results of other models. In the latter case we identify which other models would feed into the described model.
- **Analytic process & tools**: these describe transformations to the data to achieve intermediate or final outputs. Tools and methods are referenced that we recommend for implementing the model.
- **Outputs:** this describes the spatial and non-spatial outputs of the model.
- **Issues:** this area identifies issues requiring clarification or further work prior to implementing the model.

Some models are output from modeling software and will use the conventions of that software.

Figure 1. Conventions for conceptual model diagrams.



Managing Uncertainty in REA Models

A rapid ecoregional assessment must take advantage of many existing data sets, often applying them for purposes never contemplated by their original developers. This fact, along with the strong need for transparency and repeatability, requires that we carefully consider ways to document and manage for uncertainty. Uncertainty within an REA takes many forms. There is variation in the accuracy, precision, and completeness of model inputs. There is uncertainty in the combinations of these data sets within spatial models, where error propagation may occur. There is also uncertainty driven by our limited knowledge of conservation elements, change agents, and their myriad interactions. Uncertainty may also be viewed from varying perspectives; e.g., from the scientists involved in model development, testing, and peer review. Perhaps most importantly, uncertainty should be viewed from the perspective of land managers and policy-makers who will receive and utilize the REA, but will have limited exposure to the science and technology involved in its development.

In order to manage this uncertainty, the REA process includes a series of mechanisms for documenting the data sets, information sources, processing steps, and outputs. The steps of this process offer opportunities to manage the inherent uncertainties associated with REAs. We have taken an approach that maximizes these opportunities, including:

- **Data Documentation.** Throughout tasks 2-3 of the REA, we have documented several hundred extant data sets in terms of their thematic and spatial precision, accuracy, and completeness, relative to the ecoregion. FGDC metadata will be provided for all data sets ultimately used in the REA, and our project database provides additional opportunities to capture expert perspective on the relative utility of each data set for the intended modeling purposes of the

REA. Of course, since our intent is to provide the best available information for the REA, this requires combining many extant data sets for complete coverage. In a number of these instances, while the original data set may have been assessed for accuracy with independent field observations, there will remain a shortage of independent samples for reporting on the accuracy of the combined data set. In each of these cases, expert qualitative review of the updated data sets will be sought and documented. This process will identify data gaps, i.e., needs for additional field observations for use in model development and assessment.

- **Repeatability.** Conceptual modeling provides an important mechanism for stating the many assumptions that apply in any complex process. They may include narrative text, tables, conceptual diagrams, and citations of scientific literature. We are systematically organizing scientific references that are drawn upon in the REA for easy access by subsequent users. Conceptual models form the foundation for subsequent spatial models. All spatial models will include documentation of processing steps; e.g., using ESRI ModelBuilder™ so that spatial models may be repeated, analyzed in detail, and updated when new input layers become available.
- **Calibration.** In some instances, during the course of spatial model development, there are opportunities for sensitivity analysis, comparison of similar models, and error documentation. For example, climate forecasts include multiple model simulations that may be compared with each other to identify areas of strong agreement or disagreement. Inductive spatial models of habitat distribution, using tools like Maxent, provide probability and error surfaces as standard model output for use in model evaluation and potential calibration.
- **Interpretation.** Finally, inherent in the design of the REA is a series of judgments about the appropriate interpretation of analysis results. For example, the selection of 5th level watersheds as primary reporting units reflects a judgment about the expected resolution of analysis - based on the resolution of modeling inputs – and appropriate spatial scale for interpreting results. Therefore, we will clearly communicate the importance of avoiding over-interpretation of results; e.g., the presumption that summary scores applied to 5th level watersheds apply equally to more localized portions of that watershed. Likewise, it is important for model reviewers to recognize that model inputs need to be of sufficient resolution to report at this same level, and no finer.

  Another example of this type of judgment is the use of 3 categories for reporting on ecological integrity. There will remain substantial uncertainty in all aspects of our ability to gauge ecological integrity, but the selection of 3 rather than 4 categories for reporting reflects our expert judgment on the feasibility of doing so. This design aims to limit the potential for misinterpretation by subsequent users, and is our responsibility as expert contractors, to implement.

Conservation Element Models

Recommendations for "Fine-filter" Conservation Element Selection and Treatment

The "fine-filter" includes species that, due to their conservation status and/or specificity in their habitat requirements, are likely vulnerable to being impacted or lost from the ecoregion unless resource management is directed towards their particular needs. For species to be addressed in this assessment, we proposed, and the AMT accepted, several selection criteria for their inclusion and treatment in the assessment. These criteria include:

a. All taxa listed under Federal or State protective legislation (including species, subspecies, or designated subpopulations)

b. Full species with NatureServe Global Conservation Status rank of G1-G3[1]
c. Full species or subspecies listed as BLM Special Status and those listed by applicable SWAPs with habitat included within the ecoregion
d. Full species and subspecies scored as *Vulnerable* within the ecoregion according to the NatureServe Climate Change Vulnerability Index (CCVI)[2].

One additional species, mule deer (*Odocoileus hemionus*), was included as a desired conservation element. Appendix Ib. List of fine-filter CEs for the Mojave Basin and Range REA includes a current list of species meeting criteria a-d above for the MBR ecoregion. A total of 610 taxa are listed for this ecoregion. Finalizing the list of species meeting these criteria is an ongoing effort to be concluded during Phase I of this REA.

We have established several distinct approaches to treating species that meet established criteria for inclusion in the REA. These include:

a) ***Species assumed to be adequately represented indirectly through the assessment of major "coarse-filter"*** ecological systems of the ecoregion. Habitat requirements for these species align closely with coarse-filter CEs. While typically uncommon, these selected "fine-filter" CEs have a moderate probability of being found among any extant and high-quality occurrence of the affiliated coarse-filter element across the majority of the ecoregion, but a very low probability of being found in any other environment. For example, species strongly affiliated with desert springs may be adequately treated in the REA through assessment of desert springs themselves. We propose to treat approximately 160 species in this category; a list of their associated ecological systems and the number of species affiliated with each is provided in Table 1. Individual species to be treated within these coarse-filter CEs are flagged within the overall list of species CEs (Appendix Ib. List of fine-filter CEs for the Mojave Basin and Range REA).
b) ***Species assumed to be adequately represented indirectly as ecologically-based assemblages***. That is, due to similar group behavior and habitat requirement, a recognizable species assemblage is defined and treated as the unit of analysis. These species do not correspond to the a)-group above because they are typically affiliated with specialized components of the major coarse-filter CEs (e.g., sandy soils and localized outcropping among one of the desert scrub systems) and/or are not reliably affiliated with any one of the coarse-filter CEs. Examples including bat caves, migratory bird stopover sites, and carbonate rock outcrops; these will be treated as multi-species assemblages. We propose to treat 85 species in these 17 assemblages; Table 2 summarizes the number of species associated with each habitat assemblage Individual species to be treated as part of these assemblages are flagged within the overall list of species CEs (Appendix Ib. List of fine-filter CEs for the Mojave Basin and Range REA).
c) ***Landscape Species which should be best addressed as individuals*** in the assessment. These include vertebrate species with moderate to large home ranges that tend to include a diversity of coarse-filter CEs as important habitat components. These species occur over large proportions of the ecoregion and have habitat requirements that are clearly distinct from all other taxa of concern. We propose to treat 37 species in this category (Table 3).
d) ***Local Species of concern that have very narrow distributions;*** typically limited to one BLM management jurisdiction. These species do not fall within categories a-c. We are gathering current locational information, but will not aim to develop conceptual models for these elements. We propose to treat 184 species, primarily flowering plants, in this category; Table 4 summarizes the number of species, by taxonomic group, that fit in this category.

[1] See http://www.natureserve.org/explorer/ranking.htm for NatureServe Conservation Status Rank definitions
[2] See http://www.natureserve.org/prodServices/climatechange/ccvi.jsp for more on the NatureServe CCVI

We have developed a habitat-relationships database that facilitates documentation of current knowledge for most candidate species CEs. Information captured within this database provides a reference for placement of each species into the above-mentioned categories for treatment within each REA. The database contains lists of the candidate taxa, coarse-filter ecosystems, and species assemblages, as well as a list of habitat attributes that can be used for developing species assemblages. Each taxon can be assigned to one or more ecosystems, assemblages, or habitat attributes, using the approach that best suits that taxon within the ecoregion. We anticipate that this database will contribute towards subsequent BLM ecoregional direction and management phases where specialized knowledge of habitat requirements for at-risk species is desired.

Biologists from the Nevada Natural Heritage Program used the database to designate a species to either a coarse filter or a species assemblage, based on the knowledge of experts within the program as well as known distributions. Throughout the ecoregion, there are certain groups of species that naturally occur in certain habitats but those habitats are spread throughout multiple ecosystems. For example, cave and mine-roosting bats can be found throughout the ecoregion in a variety of habitats, from high elevations to low elevations as long as there is a suitable cave or mine to occupy. Using our knowledge of such groups, biologists created 20 species assemblages. Species that were strongly affiliated with a coarse filter were assigned to a coarse filter rather than a species assemblage. We prioritized "wet" designated species as we assumed *a priori* that these species would all readily fall within either a coarse filter or an assemblage. As input to this expert-attribution process, we used GIS layers of the coarse filters and overlaid known rare species occurrences. Habitat descriptions from published sources were also used and compared to coarse filter descriptions.

Table 1. Number of species assessed through coarse-filter CEs

Model Group	Conservation Element Name (MBR)	# of Taxa
Basin Dry	Great Basin Xeric Mixed Sagebrush Shrubland	1
Basin Dry	Mojave Mid-Elevation Mixed Desert Scrub	9
Basin Dry	North American Warm Desert Bedrock Cliff and Outcrop	1
Basin Dry	North American Warm Desert Pavement	1
Basin Dry	Sonora-Mojave Creosotebush-White Bursage Desert Scrub	2
Basin Dry	Sonoran Mid-Elevation Desert Scrub	1
Montane Dry	Great Basin Pinyon-Juniper Woodland	4
Montane Dry	Sonora-Mojave Semi-Desert Chaparral	2
Basin Wet	Mojave Desert Lake/Reservoir	12
Basin Wet	Mojave Desert Springs and Seeps	59
Basin Wet	North American Arid West Emergent Marsh and Pond	21
Basin Wet	North American Warm Desert Playa	1
Basin Wet	North American Warm Desert Riparian Mesquite Bosque	5
Basin Wet	North American Warm Desert Riparian Woodland and Shrubland/Stream	19
Basin Wet	North American Warm Desert Wash	6
Basin Wet	Sonoran Fan Palm Oasis/Stream	2
Montane Wet	North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream	7
Total # of taxa (some have not been assigned to a coarse filter, and some are assigned to >1)		160

Table 2. Number of species assessed through habitat-based assemblages

Habitat Assemblage	Taxonomic Group	# of taxa
Alkaline spring influenced soils	Flowering Plants	8
Azonal carbonate rock crevices	Flowering Plants	20
Azonal non-carbonate rock crevices	Flowering Plants	4
Basin river & riparian (higher level)	Mammals	1
	Reptiles	1
Carbonate (Limestone/Dolomite) alpine	Flowering Plants	3
Cave and mine roosting animals (bats)	Mammals	4
Clay soil patches	Flowering Plants	2
Desert scrub (higher level)	Reptiles	5
Gypsum soils	Ants, Wasps, and Bees	1
	Flowering Plants	5
	Mosses	1
Migratory Shorebirds	Birds	7
Migratory waterfowl stopovers	Birds	14
Montane conifer	Flowering Plants	3
	Mammals	3
Playa, Greasewood flats, washes (xero-riparian) (higher level)	Reptiles	1
Rocky outcrops	Reptiles	4
Sand dunes/sandy soils (when deep and loose)	Flowering Plants	7
	Reptiles	4
Subalpine mountain-tops	Flowering Plants	1
Talus and Scree	Flowering Plants	4
Total # of taxa (some occur in > 1 assemblage)		85

Table 3. Landscape species

Taxonomic Group	MBR Landscape Species
Birds (13)	Bald Eagle, Brewer's Sparrow, Cooper's Hawk, Ferruginous Hawk, Golden Eagle, Loggerhead Shrike, Northern Harrier, Prairie Falcon, Sage Sparrow, Sage Thrasher, Savannah Sparrow, Swainson's Hawk, Burrowing owl
Mammals (8)	American Badger, Bighorn Sheep - Peninsular Ranges, Brazilian Free-tailed Bat, Desert Bighorn Sheep, Kit Fox, Mohave Ground Squirrel, mule deer, Sierra Nevada Bighorn Sheep
Reptiles (16)	Coachwhip, Common Kingsnake, Desert Horned Lizard, Desert Tortoise - Mohave Population, Desert Tortoise - Sonoran Population, Gila Monster, Glossy Snake, Great Basin Collared Lizard, Mohave Rattlesnake, Nightsnake, Northern Sagebrush Lizard, Western Banded Gecko, Desert Iguana, Sidewinder, Common Chuckwalla, Mojave Fringe Toed Lizard

Table 4. Number of species assessed as local species by taxonomic group

Taxonomic Group	# of taxa
Ants, Wasps, and Bees	8
Birds	2
Butterflies and Skippers	4
Grasshoppers	1
Katydids and Crickets	3
Mammals	2
Other Beetles	13
Other Insects	3
Reptiles	7
Terrestrial Snails	1
Conifers and relatives	1
Ferns and relatives	1
Flowering Plants	135
Mosses	3
Total	184

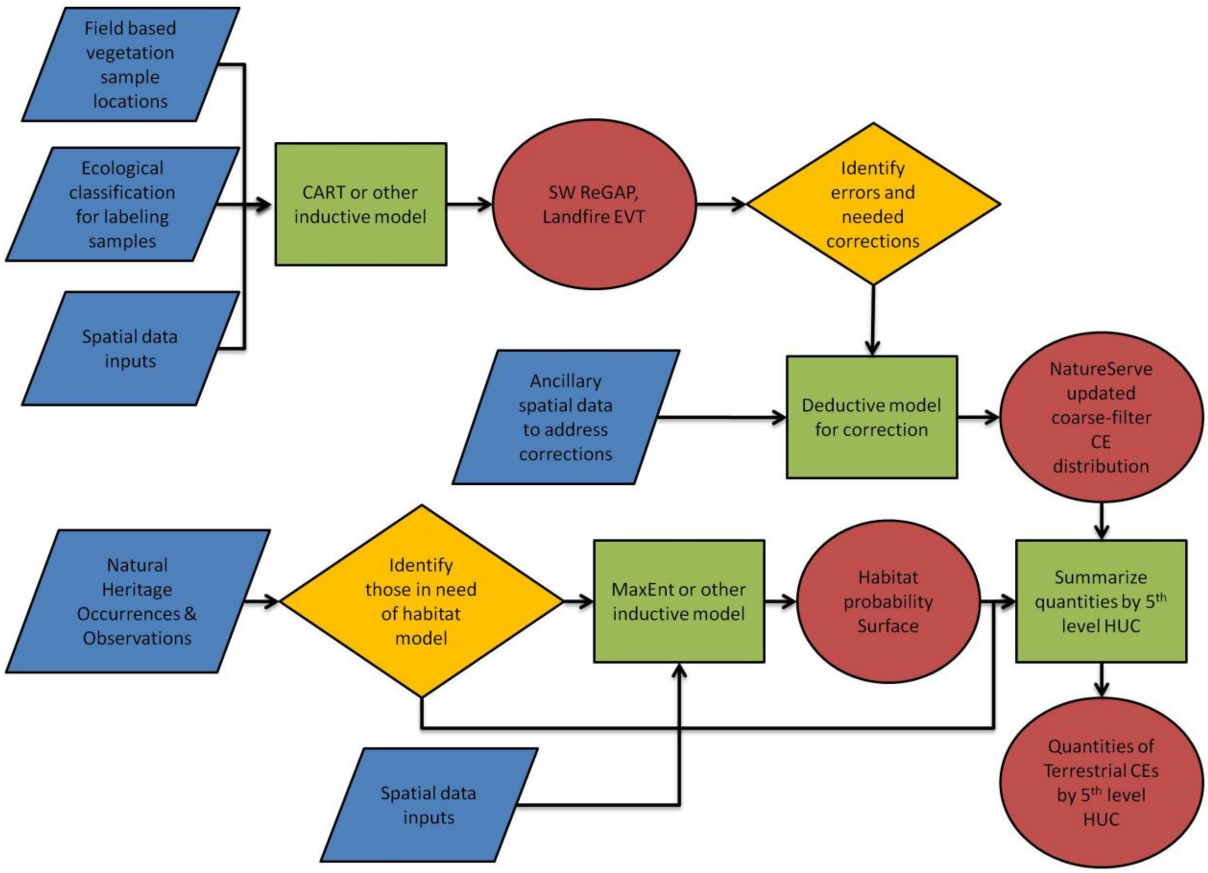
Terrestrial CEs (coarse and fine filter)

Distribution Models

See MBR Memorandum 2c for details on proposed data sets for use in distribution modeling. Distributions for terrestrial CEs take several forms. Terrestrial coarse-filter units are defined using the NatureServe ecological systems classification and depicted initially with data derived from SW ReGAP, the central Mojave California Vegetation Map, CAGAP, and LANDFIRE EVT (for CA portions) using inductive modeling methods. As depicted in Figure 2, each of these current distributions was reviewed to determine, from an expert point of view, where error occurred that could be addressed using other ancillary spatial data (e.g., landforms, soils, hydrography, elevation, etc.).

Terrestrial fine-filter CE distributions can be derived through two distinct modeling steps; both beginning with field observations and/or Element Occurrence records from Natural Heritage programs. Species presumed to be addressed in the REA through assessment of coarse-filter CEs, and those local-scale species to be treated within summaries by watershed, will require no additional modeling steps. Summary statistics of known observation/occurrences by 5th level HUC will be the primary output (Figure 2). For species to be treated within ecologically-based assemblages, or as individual landscape species, additional modeling steps are appropriate either through use/refinement of existing habitat location/suitability models or through development of new models for the ecoregion. Landscape species may be treated spatially using multiple habitat components (e.g., winter range vs. summer range). These distinctions will be established in conceptual models and then articulated as distinct spatial models. Inductive modeling tools such as Maxent use georeferenced observations combined with map surfaces to produce - typically through statistical regression trees - a probability surface for suitable habitat that might support a given CE (e.g., Guisan & Thuiller, 2005; Liu et al. 2005). Map surface inputs can include vegetation type, vegetation structure, climate variables, landform, landscape position, and soil variables among others. These models provide limited predictive power for the actual occurrence of CE populations but can provide a powerful indication of the location of habitats that are most similar to known occupied habitat. Once these individual surfaces are created and or refined from existing models, the areal extent of habitat will be summarized by 5th level HUC (Figure 2).

Figure 2. Concept diagram for modeling distributions of terrestrial CEs.



Sensitive Soils Distribution

As a desired CE, sensitive soils were defined by BLM. Sensitive soils are those which are extremely susceptible to impact and difficult to restore and reclaim, including those with high erosion potential, shallow depths, high salinity, high gypsum content, low water-holding capacity, or hydric qualities (Bryant, L. BLM internal communication). Our approach is designed to identify soils with these characteristics given the best available data at any given location. We have investigated the use of SSURGO and other soils-related data sets for their ability to map distributions of these CEs within each ecoregion.

Inputs: Where available, the SSURGO 1:24,000 dataset provided by NRCS provides one of the best means for identifying these soils (see Table 5). In portions of the study area for which SSURGO is unavailable, 1:250,000 scale STATSGO data will be utilized if finer-scale draft soil survey data cannot be obtained. A 10-meter resolution digital elevation model (DEM), processed for landform characteristics (slope, aspect, concavity, surface flow character, etc), will be used in conjunction with SSURGO/STATSGO to identify soils vulnerable to water erosion.

Analytic process & tools: As a first step, sensitive soils will be identified separately based on (a) erosion potential (water and wind) (b) droughty characteristics, (c) hydric characteristics, (d) salinity (excess salt and excess sodium), (e) gypsum content, and (f) rooting depth by querying the SSURGO or STATSGO database using the NRCS Soil Viewer in GIS. Table 5 summarizes the values used to define sensitive soils for (a) through (f) above.

A GIS join will then be performed to generate a single shapefile of sensitive soils that contains attribute information specifying the source of vulnerability. The overall analytical process is shown in Figure 3.

Output: A summary map showing location of all sensitive soil areas with embedded attributes for the relative degree of sensitivity for characteristics where that is feasibly reported.

Issues: SSURGO provides a good means for identifying sensitive soils in those locations where it is available. Where SSURGO is not available, our ability to accurately map sensitive soil areas is somewhat compromised. Where possible (e.g., for some National Forests and selected counties), we are pursuing obtaining draft soil survey data to fill these data gaps (Bryant, L. BLM internal communication). Where that is not possible, STATSGO and DEM-derived landform data will be utilized. While soil attributes analogous to those available from SSURGO can be used to define sensitive soils based on STATSGO map units, the coarse resolution of that data increases the potential for errors of omission regarding occurrences of sensitive soils in these areas. Because we have yet to document the full extent of these data sets across the ecoregion, we also intend to further investigate the use of Quaternary surface geology, available for the study area from the national coverage developed by Soller et al. (2009) at a 1:5,000,000 scale to address certain sensitive soil classes not readily addressed through SSURGO and STATSGO. There will undoubtedly be error introduced by the use of these spatial inputs of distinct spatial and thematic resolutions. Investigation of this proposed method has thus far indicated that these issues are likely to be manageable for the purposes of the REA.

Table 5. Sensitive Soil Criteria[1]

Vulnerability Category	SSURGO Attribute	Criteria for Defining Sensitive Soils[a]
Water Erosion	K Factor, Whole Soil	Kw < 0.20[2,3,] AND slope > 40, or Kw 0.20 – 0.36[2,3] AND slope >35, or Kw >0.36[2,3] AND slope >25
Wind Erosion	Wind Erodibility Group[4], Surface Layer	Group = 1, 2[4]
Droughty Soils	Available Water Capacity[3] (depth range 0-40 inches) (in/in)	AWC < 0.05
Hydric Soils	Hydric rating	Soils classified as “all hydric”
Salinity	Calcium Carbonate (CaCO3), Surface Layer (mmhos/cm)	CaCO3 >16
Excess Sodium	Sodium Adsorption Ratio[3], Surface Layer	SAR >13
Gypsum	Gypsum[2] , Surface Layer (% by weight of hydrated calcium sulfates in the fraction of soil less than 20mm in size)	Gypsum > 10%[5]
Rooting Depth	Depth to Any Soil Restrictive Layer (inches)	Depth < 10 in

1 Table content, with the exception of gypsum and hydric soils, is based on values developed by BLM Soil Specialist Bill Ypsilantis (Bryant, L. BLM internal communication).

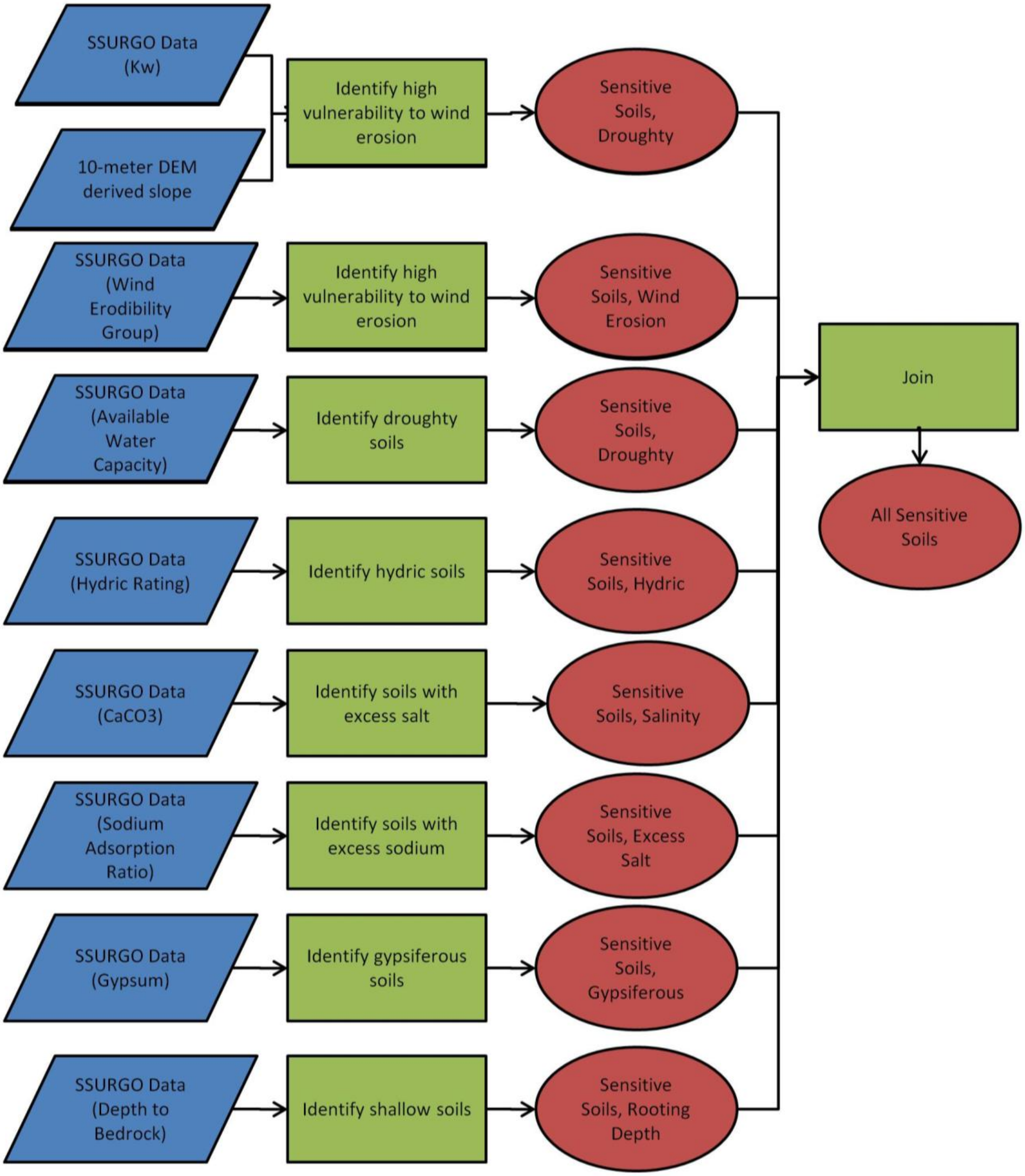
2 K Factor of surface layer adjusted for the effect of rock fragments (Kw).

3 The representative value for the range in soil properties.

4 For Central Great Basin, include soils in WEG 3 that have formed from volcanic parent materials or Bonneville Lake Sediments in the “high” category.

5 Food and Agriculture Organization of the United Nations (FAO) 1990.

Figure 3. Conceptual model for spatial modeling of sensitive soils.



Terrestrial CE Characterization and Conceptual Models

See MBR Memorandum 2c for details on proposed data sets for use in conceptual and spatial modeling for gauging ecological integrity. The following section provides an illustration of conceptual modeling components for terrestrial CEs. This basic format will be applied with some variation for each of the terrestrial coarse-filter CEs, landscape species CEs, and ecologically-based species assemblage CEs. Our conceptual models combine text, concept diagrams, and tabular summaries in order to clearly state our assumptions about the ecological composition, structure, dynamic processes, and interactions with major CAs within the ecoregion. These conceptual models lead then to spatial models to enable us to gauge the relative ecological integrity of each CE within 5th level HUCs. Here we use Great Basin Pinyon-Juniper Woodlands, a characteristic terrestrial coarse-filter type for purposes of illustration. Additional examples of these conceptual models, applicable to Mojave Basin and Range ecoregion will be found in Appendix II. Conceptual Models for Selected Conservation Elements for the MBR REA.

Each model begins by characterizing what the CE is and how it nests within the broader conceptual model already established for each ecoregion. In this illustrative example of the Montane Dry Land System component of the MBR Ecoregional concept model (see Memo 1), submodels include all Subalpine/Montane Forests and Woodlands. Within this submodel, Great Basin Pinyon-Juniper Woodland is located.

MONTANE DRY LAND SYSTEM

Subalpine/Montane Forests & Woodlands

Great Basin Pinyon-Juniper Woodland (CES304.773)
Biophysical Setting: **1310190**

The next component of the model clarifies relevant taxonomic relationships, with "(CES304.773)" referring to the standard NatureServe element code for this ecological system type. LANDFIRE Biophysical Settings, also utilizing the NatureServe classification, use codes **1310190** for this type as it occurs in the MBR (Landfire map zone 13).

Conservation Element Characterization

This section of the conceptual model includes a narrative of the CE distribution, biophysical setting, and floristic composition. For terrestrial coarse-filter CEs, we also provide a direct linkage between the CE concept and Ecological Site Descriptions (ESDs) applicable to the ecoregion. For example:

Great Basin Pinyon-Juniper Woodland

This system occurs on dry mountain ranges of the Great Basin region and eastern foothills of the Sierra Nevada extending south into the Mojave Desert and southwest in to the northern Transverse Ranges and San Jacinto Mountains (Figure 4).

These woodlands occur on warm, dry sites on mountain slopes, mesas, plateaus, and ridges ranging from 1600-2600 m elevations. They generally occur on sites with shallow rocky soils or rock dominated sites that are protected from frequent fire (rocky ridges, broken topography, and mesa tops). Severe climatic events occurring during the growing season, such as frosts and drought, are thought to limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides. Soils supporting this system vary in texture ranging from stony, cobbly, gravelly sandy loams to clay loam or clay.

These woodlands are characterized by an open to moderately dense tree canopy typically composed of a mix of *Pinus monophylla* and *Juniperus osteosperma*, but either tree species may dominate to the exclusion of the other. In some regions of southern California, *Juniperus osteosperma* is replaced by *Juniperus californica*. *Cercocarpus ledifolius* is a common associate and may occur in tree or shrub form. On the east slope of the Sierra Nevada range in California, *Pinus jeffreyi* and *Juniperus occidentalis var. australis* may be components of these woodlands. Understory layers are variable, but shrubs such as *Artemisia tridentata* frequently form a moderately dense short-shrub layer. Other associated shrubs include *Arctostaphylos patula, Artemisia arbuscula, Artemisia nova, Cercocarpus intricatus, Coleogyne ramosissima, Quercus gambelii* and, *Quercus turbinella*. Bunchgrasses such as *Poa fendleriana*, *Hesperostipa comata*, *Festuca idahoensis*, *Pseudoroegneria spicata*, *Leymus cinereus (= Elymus cinereus)*, and *Bouteloua gracilis* are commonly present and may form an herbaceous layer.

In the southern extent *Arctostaphylos patula*, *Ceanothuss greggii*, *Garrya flavescens*, *Quercus john-tuckeri*, *Juniperus californica*, *Purshia stansburiana*, *Quercus chrysolepis*, *Yucca baccata*, and *Yucca brevifolia* are common. Adjacent upland systems include Inter-Mountain Basins Montane Sagebrush Steppe, Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland, Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland. At lower elevations, it occurs adjacent to Great Basin Xeric Mixed Sagebrush Shrubland, Inter-Mountain Basins Big Sagebrush Shrubland, and Mojave Mid-Elevation Mixed Desert Scrub. This system occurs at lower elevations than the Colorado Plateau Pinyon-Juniper Woodland system where sympatric at the eastern and southeastern edge of its range.

A crosswalk of this system type to approved ESDs by NRCS Multiple Resource Land Area (MLRA) that overlap the adjacent Central Basin and Range ecoregion is provided in Table 6. NRCS Site ID identifies each type as determined by NRCS. This list is not a complete cross-walk as some MLRAs do not have approved ESDs; including that pertaining to the MBR. Additionally, the user should consider that ESDs are based on landform/soil concepts, so the match between these concepts and ecological system concepts - defined as an integration between biophysical and natural floristic composition - will be imperfect and may vary from type to type. This crosswalk, and the potential for developing additional models for a given CE (e.g., Great Basin Pinyon –Juniper Woodlands in northern vs. southern MRLAs of the MBR ecoregion), provides a mechanism to translate more generalize conceptual and spatial models for use in the REA to subsequent phases of land management. Analysis at the broader ecological systems scale will necessarily mask some variability in the natural character of the CE, and its response to change agents across the ecoregion. Subsequent analysis using more localized concepts can address these deficiencies, while enabling us to accomplish the objectives of the REA.

Figure 4. Great Basin Pinyon – Juniper Woodland relative to the MBR ecoregion.

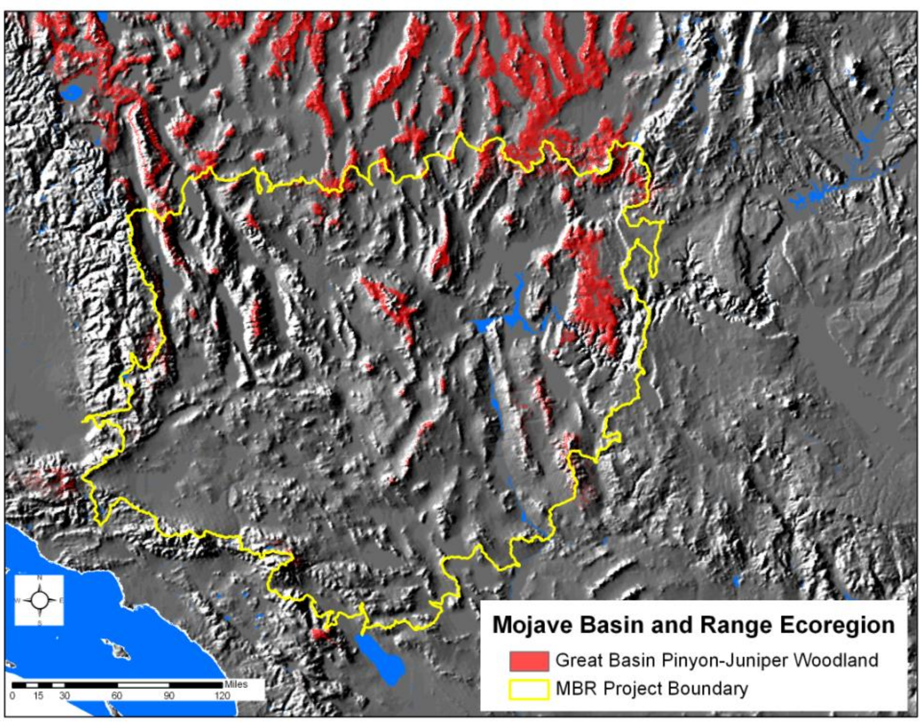


Table 6. Great Basin Pinyon – Juniper Woodland ecological system crosswalk with approved Ecological Site Descriptions.

MLRA applicable to adjacent CBR ecoregion	Ecological Site Description Name	NRCS Site ID
025-Owyhee High Plateau	Upland Shallow Stony Loam (Utah Juniper) -*Purshia tridentata/Pseudoroegneria spicata*	R025XY326UT
026-Carson Basin and Mountains	*Pinus monophylla/Artemisia tridentata* ssp. *vaseyana/Poa fendleriana-Achnatherum*	F026XY071NV
028A-Great Salt Lake Area	*Semidesert Sand (Utah Juniper) Juniperus osteosperma*	R028AY223UT
029-Southern Nevada Basin and Range	Upland Shallow Loam (Singleleaf Pinyon-Utah Juniper) /*Achnatherum hymenoides-Poa fendleriana*	R029XY320UT
047-Wasatch and Uinta Mountains	Upland Stony Loam (Utah Juniper) J*uniperus osteosperma-Pseudoroegneria spicata*	R047XA305UT

Change Agent Effects on the CE

In this section we characterize the primary change agents and current knowledge of their effects on this CE. Here for illustration, we include expected effects of common forms of development on the integrity of Great Basin Pinyon-Juniper Woodlands.

Some CAs have specific effects on each CE such as the alteration of expected fire regimes and the interacting effects of introduced weed infestations. Therefore, for terrestrial CEs, Wildfire and Invasive Plant CAs are described and modeled within the context of their effects on coarse filter CEs. We illustrate first with wildfire and its expected natural regime followed by the common alterations to that regime as they occur within the ecoregion.

Wildfire CA in Great Basin Pinyon-Juniper Woodland

Pinus monophylla is a long-lived tree (~800 years) that is killed by severe fire because of thin bark and lack of self-pruning; however, mature trees can survive low intensity fires (Sawyer et al. 2009, Zouhar 2001). Although there is variation in fire frequency because of diversity of site characteristics, stand-replacing fire was uncommon in this ecological system historically with an average fire return interval (FRI) of 100-1000 yrs and occurred primarily during extreme fire behavior conditions and during long droughts (Zouhar 2001, LF BpS model 1210190 or 1310190). Mixed severity fire (average FRI of 100-500 yrs) was characterized as a mosaic of replacement and surface fires distributed through the patch at a fine scale (<0.1 acres). Figure 5 shows the conceptual model of Great Basin Pinyon-Juniper Woodland system with natural disturbance regime or natural range of variation (NRV).

Fire rotation in the San Bernardino Mountains was determined to be 480 years (Wangler and Minnich 2006). These woodlands have a truncated long fire return interval 200+ years with surface to passive crown fires of medium size, low complexity, high intensity, and very high severity (Sawyer et al. 2009). After a stand-replacing fire, the site is usually colonized by herbaceous plants and shrubs that act as nurse plants for *Pinus monophylla* seedling establishment. Establishment takes 20-30 years post fire after shrub density increases and then a tree canopy forms after 100-150 years (Minnich 2007). As tree canopy becomes denser, there is a decline in shrub cover (Minnich 2007). Fires are associated with herbaceous fuel buildup following wet periods (Minnich 2007).

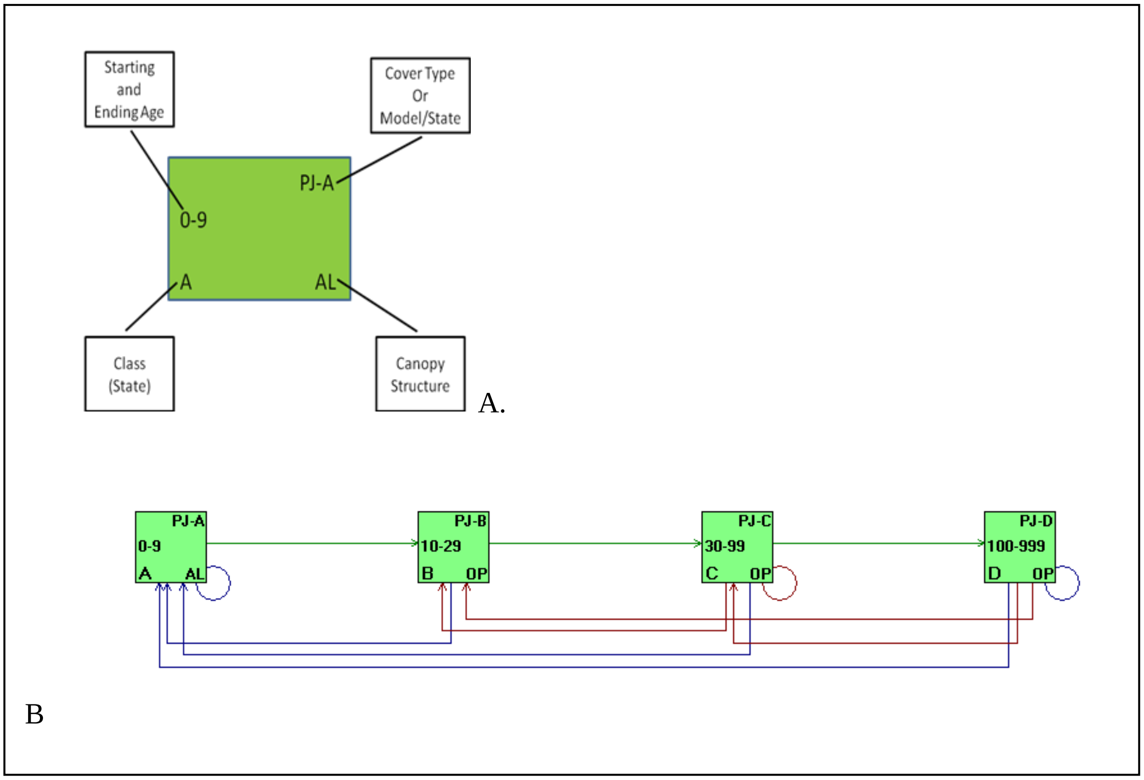
Other change agents include the current epidemic of Ips beetles in many areas that has killed many pinyons and has created high fuel loads that further threaten stands (Thorne et al. 2007). Severe weather (usually drought) and insects and tree pathogens are coupled disturbances that thin trees to varying degrees and kills small patches every 250-500 years on average, with greater frequency in more closed stands (LF BpS model 1210190).

Model Description

The following model description is for illustration, and applies to Pinyon-Juniper woodland occurring in the adjacent western Central Basin and Range ecoregion (LANDFIRE BpS 1210190). Here, this ecological system type was modeled using the Vegetation Dynamics Development Tool (VDDT, ESSA Technologies). VDDT allows users to translate simple box-and-arrows conceptual models into probabilistic quantitative models. The Pinyon-Juniper model consists of 4 ecological states with both deterministic and probabilistic drivers. These drivers result in transitions from one ecological state to another. Deterministic drivers simulate successional changes. The deterministic transitions in the model specify the time until a transition must occur, and the class (state) it will move to after this time has passed. Figure 5 illustrates this conceptual model. In this model, deterministic transitions are illustrated by green arrows. Probabilistic transitions, represented by red and black arrows, specify the type of transition driver, its transition probability (which is the mathematical inverse of return frequency) and its impact on the vegetation cell. Probabilistic transitions represent natural disturbances (e.g., fire, wind, insects), changes resulting from land management, or probabilistic succession.

Figure 5. Conceptual Ecological Model for the Pinyon-Juniper Woodland under natural conditions and disturbance regimes.

Panel A defines the codes in each state box. Panel B illustrates the transitions among states. The green arrows represent deterministic transitions (successional change). The red and black arrows represent retrogression as a result of drought and fire, respectively.



For each simulation, the landscape is partitioned into a number of cells or simulation units; each initially assigned a class and age. For each time step the model simulates the probability of each cell being affected by one of probabilistic transition types, and if a transition does occur, moves the cell to the class defined in the pathway diagram. Transition probabilities (Table 7) are dependent on the current state of the cell, defined by its class. They are independent of the state of the neighboring cells.

The Great Basin Pinyon-Juniper Woodland model for natural conditions has four boxes that represent early, mid1, mid2 and late seral stages.

Class A: Initial post-fire community dominated by annual grasses and forbs. Later stages of this class contain greater amounts of perennial grasses and forbs, up to ~10% cover. Evidence of past fires (burnt stumps and charcoal) should be observed. Duration 10 years with succession to class B, mid-development open. Replacement fire occurs every 200 yrs on average.

Class B: Dominated by shrubs (up to 20% cover), perennial forbs and grasses (up to 40% cover). Tree seedlings are starting to establish on favorable microsites. Total cover remains low due to shallow unproductive soil. Duration is 20 years with succession to class C unless infrequent replacement fire (FRI of 200 yrs) returns the vegetation to class A.

Class C: Shrub and tree-dominated community (up to 40% tree canopy cover and 10-40% shrub cover) with young juniper and pinyon seedlings becoming established. Herbaceous cover is less than class B at 10-20%. Duration 70 years with succession to class D unless replacement fire (average FRI of 200 yrs) causes a transition to class A. Mortality from insects, pathogens, and drought occurs at a rotation of approximately 165 yrs and cause a transition to class B by killing older trees.

Class D: Community dominated by young (100-300 yrs) to old (>300 yrs) juniper and pine of mixed age structure. Trees are considered old once they reach an age of 400 years. Tree cover, ranging from 30-50% and height does not vary appreciably beyond 100 yrs, although tree diameter increases greatly. Juniper and pinyon trees are becoming competitive on site and beginning to affect understory composition. Duration 900+ years unless replacement fire (average FRI of 500 yrs) causes a transition to class A. Tree pathogens and insects such as pinyon Ips become more important for woodland dynamics occurring at a rotation of 250 yrs, including both patch mortality and thinning of isolated individual trees. However, mass mortality resulting in state retrogression to class C or class B is very rare, occurring at return intervals of 2500 or 5000 years respectively.

Table 7. Transition probabilities and return intervals for the two major drivers of the PJ Woodland system under NRV.

These probabilities are used in the VDDT model to estimate the relative abundance of each class over time.

From Class	To Class	Transition Type	Probability	Return Interval (years)
C	B	Drought	0.0006	1670
C	C	Drought	0.0050	200
D	B	Drought	0.0002	5000
D	C	Drought	0.0004	2500
D	D	Drought	0.0050	200
A	A	Replacement fire	0.0050	200
B	A	Replacement fire	0.0050	200
C	A	Replacement fire	0.0050	200
D	A	Replacement Fire	0.0020	500
D	D	Surface fire	0.0010	1000

Altered Dynamics

Before 1900, this system was mostly open woodland restricted to fire safe areas on rocky ridges, etc where low fine fuels reduced the spread of fires. Currently, much of the distribution of this system has a more closed canopy. Fire suppression has lead to a buildup of fuels that in turn increase the likelihood of stand-replacing fires. Heavy grazing, in contrast to fire, removes the grass cover and tends to favor shrub and conifer species. Fire suppression combined with grazing creates conditions that support invasion by pinyon and juniper trees into adjacent shrublands and grasslands. Under most management regimes, typical tree size decreases and tree density increases in these areas.

Change agents for pinyon-juniper woodlands include invasion by introduced annual grasses, livestock grazing, development, and fire suppression. These woodlands have expanding into adjacent steppe grasslands and shrubland in many areas, reportedly in connection with livestock grazing and altered fire regimes (Blackburn 1970, Wangler and Minnich 2006). Historic fire suppression has resulted in denser tree canopy and a pinyon-juniper woodland expansion especially into big sagebrush shrublands (Wangler and Minnich 2006) and shrub steppe and grassland (Blackburn 1970). Fire severity also increases in denser canopied pinyon-juniper woodland as well as increased soil erosion because of reduction in ground cover (Zouhar 2001). Recently, significant losses in PJ woodlands are a result of shortening of fire return interval (FRI) frequent fires because of invasion by introduced *Bromus tectorum* and other annuals that provide fine fuels that carry fire. Figure 6 shows a conceptual model of Great Basin Pinyon-Juniper Woodland system with uncharacteristic disturbance regimes.

In addition, many of these communities have been severely impacted by past range practices of chaining, tilling, and reseeding with exotic forage grasses. Although the dominant trees appear to regenerate after such disturbances, the effects on understory species are poorly known (Thorne et al. 2007).

Altered Model Description

The introduction of exotic annual grasses (e.g., *Bromus tectorum)* has resulted in the appearance of two uncharacteristic states. Figure 6 illustrates the conceptual model including these states, and has transition probabilities used in the model.

Class F reflects the initial invasion of PJ woodlands by cheatgrass. The cover of trees and shrubs remains unchanged relative to classes C and D. However the native herbaceous cover is progressively replaced by cheat, which can reach 20% cover.

Class E reflects the result of a stand-replacement fire in class F. Class E is annual grassland that is self-maintained by frequent (FRI 10 years) replacement fires that prevent the recruitment of native species. Intensive active restoration can transform this stable state to class A. However, continued management of these sites is required to prevent restoration failure and retrogression back to class E.

Figure 6. Conceptual Ecological Model for the Pinyon-Juniper Woodland under current conditions. This model includes two "uncharacteristic" states (classes E & F), both reflecting the invasion of exotic annual grasses.

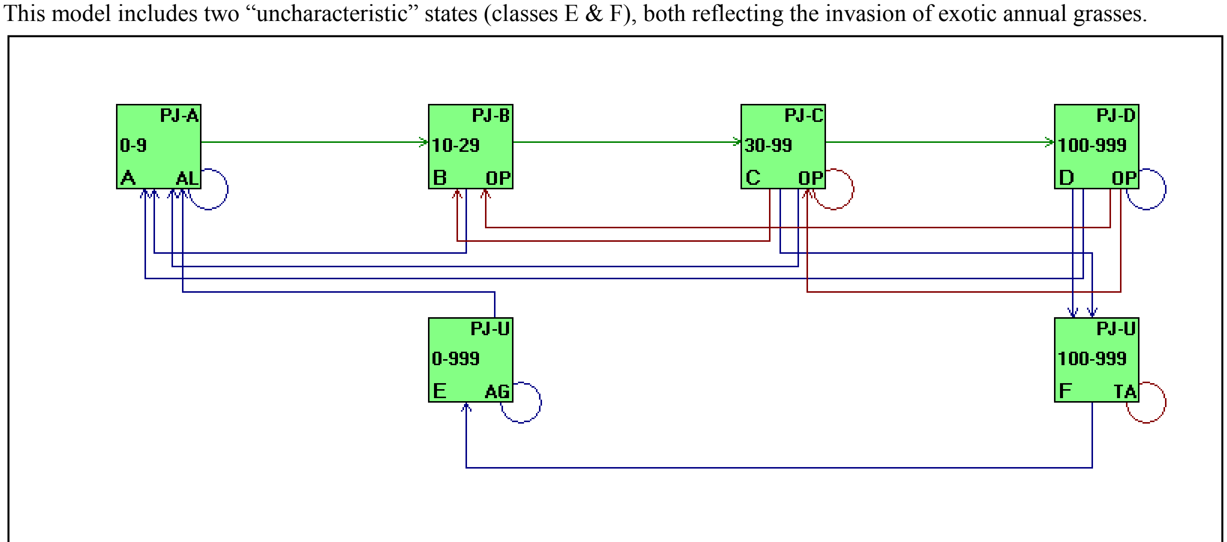


Table 8. Transition probabilities under current conditions.
These transition probabilities were used in the VDDT model illustrated in Figure 6 to calculate departure estimates.

From Class	**To Class**	**Transition Type**	**Probability**	Return Interval (years)
C	F	Annual grass invasion	0.0010	1000
D	F	Annual grass invasion	0.0010	1000
C	B	Drought	0.0006	1670
C	C	Drought	0.0050	200
D	B	Drought	0.0002	5000
D	C	Drought	0.0004	2500
D	D	Drought	0.0050	200
F	E	Drought	0.0006	1670
F	F	Drought	0.0050	200
A	A	Replacement fire	0.0050	200
B	A	Replacement fire	0.0050	200
C	A	Replacement fire	0.0050	200
D	A	Replacement fire	0.0020	500
E	E	Replacement fire	0.1000	10
F	E	Replacement fire	0.0050	200
D	D	Surface fire	0.0010	1000

Ecological Departure

Based on the best available information, the natural range of variation (NRV) of ecological states with the PJ Woodland within the adjacent Central Basin and Range ecoregion is shown in the historic range of variation (HRV) column in Table 9. The VDDT model was run for 150 years, starting at HRV, to examine the expected departure of the PJ Woodland from NRV as a result of cheatgrass invasion. The model did not include any ecological restoration activities. Table 5 shows the relative abundances of each of the 6 states for approximate years 1910, 2010 and 2050, following the introduction of exotic grasses in the early 1900s. Ecological departure is a measure of dissimilarity from NRV and provides a measure of overall ecosystem change. It is calculated as:

$$1 - \sum_{class=A}^{F} Min(class\_abundance_{NRV}, class\_abundance_{Time\,X})$$

$$1 - \sum_{class=A}^{F} Min(class\_abundance_{NRV}, class\_abundance_{Time\,X})$$

Table 9. Departure from Historic Range of Variation in the relative abundance of ecological states as a result of the invasion of exotic annual grasses in two randomly sampled watersheds (HUC1 and HUC2).
Departure values for 2010 are based on the distribution of states in the SClass map of current conditions, and departure values for 2060 are modeled by running VDDT simulations for 50 years beyond current conditions.

Class	**Cover: Structure**	**1910 (HRV)**	**2010 (SClass data)**		**2060 (modeled)**	
			HUC1	**HUC2**	**HUC1**	**HUC2**
A	Early: All	5%	1%	2%	0%	1%
B	Mid1: Open	10%	2%	1%	3%	4%
C	Mid2: Open	30%	19%	14%	11%	13%
D	Late: Open	55%	11%	58%	18%	55%
F	Uncharacteristic: Annual Grass	0%	37%	1%	44%	7%
E	Uncharacteristic: Trees/Annual Grass	0%	30%	23%	24%	20%
Ecological Departure			67%	27%	69%	27%

Because class E is an "absorbing state," that is natural dynamics cannot transition this state back into a natural state, the model clearly shows a gradual increase in the abundance of exotic annual grasslands and the loss of the later stages of the PJ woodland. These trends vary widely by watershed, as shown by the two sampled HUCs in Table 9. However, one could anticipate a self-reinforcing cycle in which the abundance of cheat grass increases the fire frequency throughout the system accelerating this transition to exotic annual grasslands.

The departure measure used here is the LANDFIRE FRCC Departure Index. This indicator gives a summary of how departed the final conditions resulting from each model run are from the reference landscape conditions. This can be departure for modeled NRV or departure of future modeled system from current conditions. It is calculated by comparing the reference percentage of each succession class (S-Class) to the percentage resulting from a given model run. The smaller percentages for each class are summed, and the total is subtracted from 100 to determine the departure index. These smaller percentages are the amount of each system occurrence that is similar. Conversely, the differences represent the amount that particular class differs between the two time periods. For example, if a class is currently at 40% and it is predicted to increase to 55% over the next 50 years, the future state will share the original 40% of the landscape, and will increase by 15%.

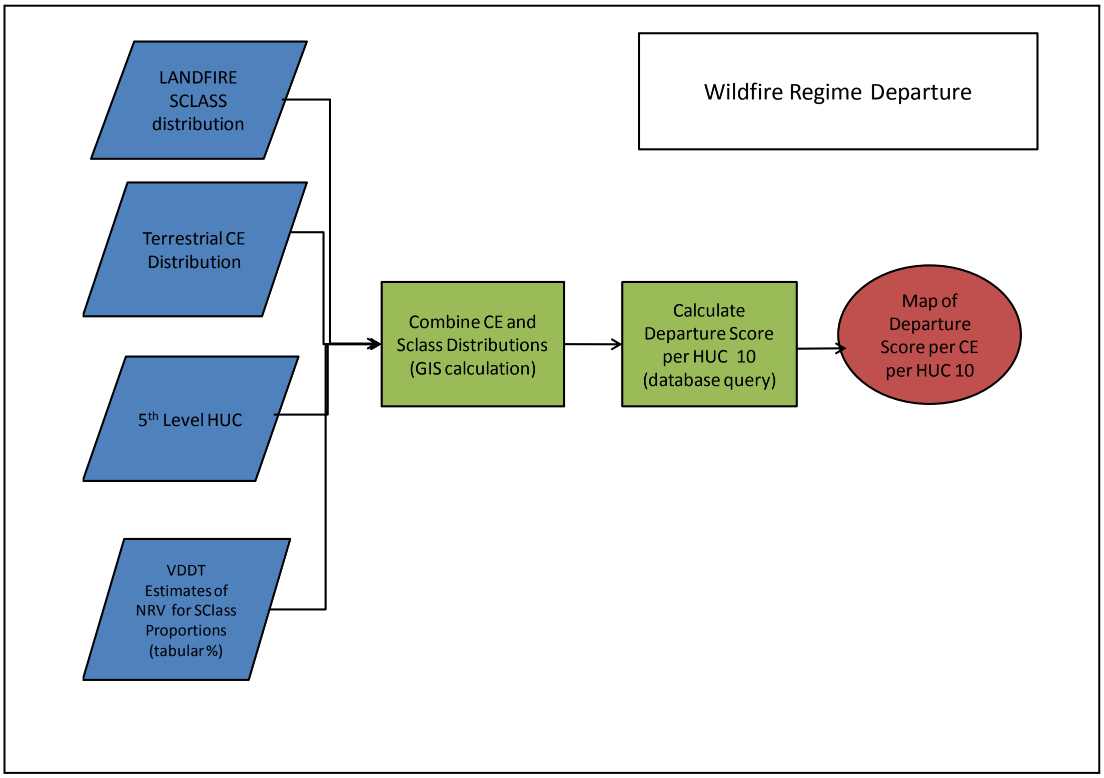
This departure index is represented using a zero to 100 percent scale, with zero representing a landscape identical to the reference conditions and 100 representing maximum departure. Ecological departure is included here as a helpful shorthand assessment of how much various management options would move the landscape toward or away from reference or desirable conditions.

Gauging Fire Regime Departure for Ecological Integrity Measurement in the REA

As one primary indicator of ecological integrity for Great Basin Pinyon-Juniper Woodland within each ecoregion, we propose to calculate and compare tabular estimates of NRV Succession Class

Distributions against observed SClass distributions from LANDFIRE SClass maps (*circa* mid-2000s) for each 5th level HUC across the ecoregion (Figure 7). This calculation of departure provides a 0-100 relative score for this important measure across the ecoregional distribution of each CE where fire regime is a key ecological driver.

Figure 7. Spatial model for calculating and summarizing fire regime departure for each CE.



Terrestrial Invasive CAs

Here we illustrate modeling methods applicable to terrestrial invasive plants in the MBR ecoregion using cheatgrass as an example. Over 50 Terrestrial invasive species are documented with occurrences within the defined boundary of these ecoregions. By many accounts, the largest invasive species threat to native shrub and grassland ecosystems throughout the Western U.S. is the spread of annual grasses, primarily *Bromus tectorum*, or cheatgrass (Mack 1981). Flourishing in an onslaught of landscape disturbances such as fire and overgrazing, the population of cheatgrass has increased rapidly since its introduction in mid 1800s (Billings 1990).

A Mediterranean native, cheatgrass pushed westward following the 1st recorded sightings in 1861 in Pennsylvania with a life history that is closely tied to development of cattle ranching, primarily due to the ecological conditions created by overgrazing and fire. Once established the species life history makes it a particularly effective competitor with native grasses and forbs. Typically, the seeds germinate in the fall, continue root growth throughout all but coldest parts of winter, show above ground shoots in late winter and have a higher relative growth rate compared to many native plants (Arredondo *et al*. 1998). This strategy gives cheatgrass multiple advantages over native species, but, primarily in its aggressive competition for early growth season soil moisture.

The extent of cheatgrass in North America encompasses most of the U.S., Canada, Greenland, and Northern Mexico (Mosely et al. 1999). Primarily a roadside weed in the Eastern U.S. (U. Montana 2001), cheatgrass is most prominent west of the Rocky Mountains to the Cascades and north from Nevada to Canada. Throughout the 5 primary western states at the greatest risk from cheatgrass, Nevada shoulders the brunt of the risk ranging from complete monoculture to future risk as a dominate feature on the landscape with a dominate biomass estimate (Table 10).

Table 10. Acres of BLM-administered rangelands either infested or at risk of infestation by cheatgrass in a 5-state area as of 1992 (from Pellant et al. 1994 and Zouhar 2003).

State	Cheatgrass monoculture (>60%*)	Major understory component (10-59%*)	Potential future dominant (<10%*)
Idaho	1,082,880	1,751,040	1,221,120
Nevada	1,004,000	9,006,000	40,000,000
Oregon	437,760	2,004,480	9,169,920
Utah	297,600	1,082,880	11,635,200
Washington	85,500	142,500	72,000
Total	2,822,240	13,844,400	62,026,240

*Percent values refer to the estimated composition of cheatgrass by weight in the plant community

While most widespread in sagebrush communities (Young 2000), cheatgrass is present throughout most ecosystems in the west, and in some opinions, considered a naturalized vegetation community (Stewart and Hull 1949). In natural communities where cheatgrass has come to dominate, it can maintain its dominance for generations where the natural land cover has been reduced by other change agents (Concannon 1978). Additional communities of concern within the MBR that cheatgrass currently pose a risk to range from low-elevation Intermountain Basins Mixed Salt Desert Scrub (Lewis 1971, West 1988, Zamora 1973) thru higher elevation systems such as Great Basin Pinyon-Juniper (Hull and Pechanec 1947, Mosely et al. 1999, Young et al. 1987, Young 2000).

Cheatgrass is present under a variety of climatic conditions and may be found in precipitation ranges from the Intermountain Basins Mixed Salt Desert Scrub with 6 inches (150mm) to a variety of high elevation conifer forests exceeding 25 inches (640mm) (Daubenmire 1970, Mosely et al. 1999). Generally, cheatgrass is most prevalent in regions receiving from 12-22 inches (300-560mm) of late winter precipitation (Pyke and Novak 1994). In some drier communities in Nevada such as black sagebrush, cheatgrass was present in periods with substantial spring moisture (Young and Palmquist 1992). In periods of severe drought where little vegetative production is occurring, cheatgrass still produces enough seeds to contribute to future recruitment (Steward and Hull 1949).

The general elevation range shows cheatgrass to be most abundant between 2,000 and 6,000 feet (600-1,820m), but has been found in high elevation communities ranging from 9,000 to 13, 100 feet (2,700-4,000 m) (Stewart and Hull 1949, Hunter 1991). Multiple communities face the risk of cheatgrass reaching a dominant/co-dominant status (Table 11).

Table 11. Elevation and precipitation ranges for communities in which cheatgrass may be dominant or co-dominant as reported for Nevada (from Zouhar 2003).

State	Plant community dominants or co-dominants	Elevation	Mean annual precipitation	References

State	Plant community dominants or co-dominants	Elevation	Mean annual precipitation	References
	shadscale	4,320 to 5,400 feet (1,310-1,640 m)	6.7 to 11.4 inches (168-285 mm)	Blackburn et al 1969, Blackburn et al. 1968, Blackburn et al. 1969.
	spiny hopsage/green rabbitbrush (*Chrysothamnus viscidiflorus*)	5,250 to 5,500 feet (1,590-1,670 m)	8.4 inches (210 mm)	Blackburn et al 1969, Blackburn et al. 1968, Blackburn et al. 1969, Blackburn et al. 1969.
	black sagebrush	4,900 to 6,400 feet (1,485-1,940 m)	7.6 to 17.1 inches (190-428 mm)	Blackburn et al 1969, Blackburn et al. 1968, Blackburn et al. 1969.
	big sagebrush and various co-dominants	4,590 to 7,350 feet (1,390-2,230 m)	6.8 to 14.9 inches (170-373 mm)	Blackburn et al 1969, Blackburn et al. 1968, Blackburn et al. 1969.
	mountain snowberry-mountain big sagebrush/bluebunch wheatgrass	7,260 to 10,230 feet (2,200-3,100 m)	----	Tueller and Eckert 1987.
NV	Utah juniper	5,500 to 6,200 feet (1,670-1,880 m)	11.4 to 17.7 inches (285-443 mm)	Blackburn et al. 1969, Blackburn et al. 1969.
	ponderosa pine/rubber rabbitbrush	5,600 to 5,900 feet (1,700-1,790 m)	16.6 inches (415 mm)	
	desert peach/shrub live oak (*Prunus andersonii*/*Quercus turbinella*)	6,125 feet (1,860 m)	16.7 inches (418 mm)	Blackburn et al

Generally, cheatgrass is associated with deep sandy soils, loamy or coarse-textured soils where shrublands occurs in flat upland and valley bottom landforms (Beatley 1966, Doescher 1986, Link et al. 1994, Young 2000). Cheatgrass is not limited to these soil types and can be competitive in low-fertility soils or areas low in nitrogen (Doescher et al. 1986, Link et al. 1994, Young 2000). Cheatgrass adapts across the nutrient profile and in soils with increasing nitrogen availability it can dominate the community (Dakheel et al. 1993, Harris 1967, Harris and Goebel 1976, Lowe el al 1992, Young and Allen 1997).

The topographic relationship of cheatgrass is dependent upon the main ecological system present in the region. For instance, in the Great Basin Pinyon Juniper Woodlands of Nevada and California, cheatgrass tends to occur on southern and western aspects, rather than the cooler/ wetter northern exposures (Goodrich 1999, Goodrich and Rooks 1999).

Cheatgrass is clearly a disturbance-driven element, and where grazing and agricultural practices have significantly altered the landscape, the grass can gain a foothold. Once established in regions with native perennial grasses and forbs (Pickford 1932) or in the understory of sagebrush and rabbitbrush communities (Peters and Bunting 1994, Whisenant 1990), the fire cycle is decreased and the native species are burned out. Following fires, species like sagebrush experience a decrease in coverage and the cheatgrass cover increase which leads into an increase in fire frequency. Sagebrush fire intervals between 20 and 50 years, or greater are required to maintain sagebrush presence in the community (Peters and Bunting 1994). Rabbitbrush may experience a increase in initial extent following the first cheatgrass fueled fire, but once the fire frequency falls below 5 years the interval the species in eliminated from the community (Peters and Bunting 1994, Pickford 1932).

Diverse communities such as Great Basin Pinyon-Juniper Woodlands are characterized by longer fire cycles of 100 years or more (Gottfried et al. 1995). In more open stands the fire frequency is substantially shorter with more productive sites experiencing a frequency of 10 years or less. Stand development and age is also a likely contributor to fire frequency with young, open stands of juniper mixed with shrubs and forbs experiencing a higher frequency which allows cheatgrass to become established, or expand, within the native community (Paysen et al. 2000).

Inputs:

While no single source of data on annual grasses can be considered ideal for the entire MBR, there are a number of well documented field survey datasets, and predictive surface models of annual grass extent. Both Bradley and Mustard (2006), and Nevada Natural Heritage (2006) described high-resolution maps of cheatgrass extent for areas of Northern Nevada, but neither completely encompasses the overall extent of the MBR. Bradley (2009) and Bradley et al. (2009) further described both cheatgrass and other invasive species in a broader context of climate change risk which are encompassing of the MBR, but each of these studies is performed using a much coarser resolution of data with the intent of developing predictive models at a minimum of ~4 km^2. This resolution may be adequate for summation at the HUC 10 level but does not meet the needs of defining the effects of specific CAs directly to CEs.

Both the Landfire Sample Points Database, Southwest Exotic Mapping Program (SWEMP) 2007 Dataset consist of documented field observations of annual grass presence and extent. In support of the field data is the Annual Grasses Index (AGI) of Nevada (Nevada Natural Heritage 2006) in which the extent of all annual grasses, as dominated by cheatgrass, is modeled as a continuous surface representing the predicted percent coverage of annual grasses on a per pixel basis. Because the AGI map layer does not cover the complete extent, additional surface representation of the annual grasses will be developed to fill in the holes with a representative model of potential invasive risk.

To address the potential risk of current and future scenarios of invasive CAs we propose to follow a similar model protocol to Bradley and Mustard (2006) and Comer et al. (2009) in which substantial and validated models were developed for cheatgrass risk and potential natural vegetation extent. An advantage of this methodology is the repeatability of the model application across multiple temporal and climatic scenarios in which several of the predictor variables are static and any future changes are driven by the estimates of land use/climatic change. In Bradley and Mustart (2006) the model derives the estimates of extent based upon the physical environment as utilized as predictor variables (Table 12).

Table 12. Predictor variable from Bradley and Mustard (2006) used to predict cheatgrass/ landscape relationships.

Name	**Description**	**Source**
Elevation	elevation (m)	USGS (NED)
Aspect	aspect (eight cardinal directions)	USGS (NED)
Distance to channel	distance to any hydrographic channel (m)	2000 census
Distance to cultivation	distance to any cultivated area identified in 1973 or 2001 Landsat imagery (m)	Landsat imagery
Distance to road	distance to any paved or unpaved road (m)	2000 census

Distance to power line	distance to any major utility line (m)	2000 census
Distance to 1973 cheatgrass	distance to cheatgrass present in 1973 (m)	1973 cheatgrass map

Note: NED, National Elevation Data Set.

In partnership with USGS, Comer et al. (2009) described similar results in applying inductive modeling methodology in predicting the potential natural vegetation for the adjacent CBR ecoregion. Using predictor variables based upon easily obtained spatial data including bioclimatic, surficial lithology, land surface forms, and several topographic variables derived from digital elevation (Table 13), a highly representative model (overall accuracy = 69%) of ecological systems was derived. As described by Bradley and Mustard (2006), there are several synonymous predictor variables and most of the predictor variables are static and model changes can be described to applying alternative land use and climatic predictor variables. While the model does not specifically derive the extent of any invasive species, it clearly shows the value of applied models to predicting vegetation pattern across a broad landscape. The inclusion of both the Ombrotype and the Thermotype within the modeling protocol allows the models to be modified for future climatic shifts. The inclusion of disturbance variables, such as depicted in the NatureServe Landscape Condition Model, to the available predictor variables will allow for a reasonable representation of the risk of invasive across the landscape.

Table 13. Predictor variables for modeling potential distributions of natural vegetation types in the CBR; similar variables can be used in the MBR (Comer et al. 2009).

Landforms	Surficial Lithology	Ombrotypes	Thermotypes	Slope (degree)	Elevation (m)	Aspect (degree)
Flat Plains	Carbonate (sedimentary/ metasedimentary), generally porous, and generally >6pH	Arid	Lower Inframediterranean	0-78.5	193-4337	360
Smooth Plains	Karst	Semiarid	Upper Inframediterranean			
Irregular Plains	Non-Carbonate (sedimentary/ metasedimentary), generally porous, generally <6pH	Dry	Lower Thermomediterranean			
Escarpments	Alkaline Intrusive Volcanic, generally non-porous, generally >6 pH	Subhumid	Upper Thermomediterranean			
Low Hills	Silicic (including most/all granites and non-alkaline intrusive volcanics), generally non-porous, generally <6pH	Humid	Lower Mesomediterranean			
Hills	Ultramafic	Hyperhumid	Upper Mesomediterranean			

Landforms	Surficial Lithology	Ombrotypes	Thermotypes	Slope (degree)	Elevation (m)	Aspect (degree)
Breaks	Extrusive Volcanic, generally porous		Lower Supramediterranean			
Low Mountains	Colluvium (Talus & Scree Slopes, Boulder Fields)		Upper Supramediterranean			
High Mountains/ Deep Canyons	Glacial Till-Clay		Lower Oromediterranean			
	Aeolian Sediments-Sand Dune, Coarse Textured		Lower Supratemperate			
	Aeolian Sediments-Loess, Fine Textured		Upper Supratemperate			
	Non-Glacial Alluvium-Saline		Lower Orotemperate			
	Non-Glacial Alluvium-Other, Fine Textured		Upper Orotemperate			
	Non-Glacial Alluvium-Other, Coarse Textured		Lower Cryorotemperate			
	Volcanic Tuff/Mudflows					

Analytic process & tools:

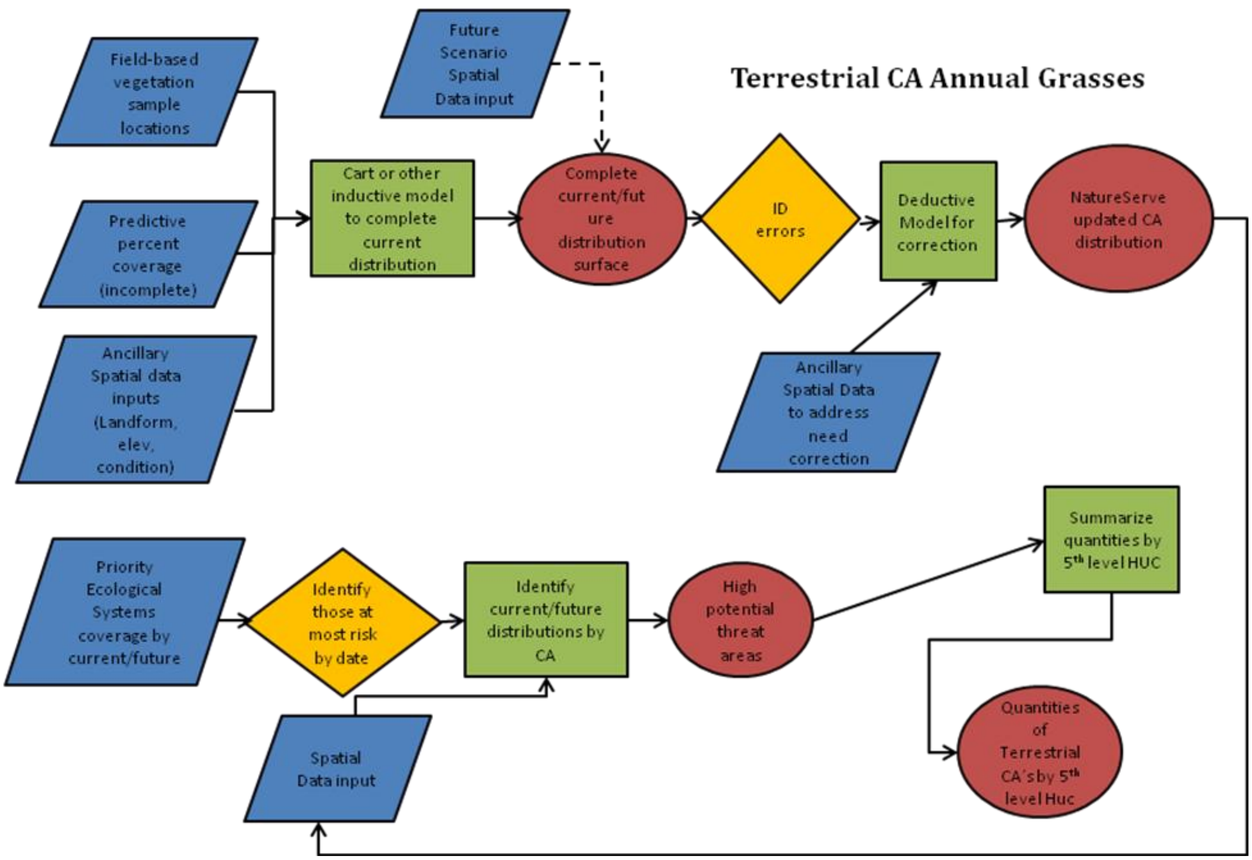
Both current distribution, and potential future distribution, of invasive plants will require the application of both inductive and deductive modeling methodologies. Each scenario will utilize the conceptual model described in Figure 8. Utilizing variables described in Table 13, we will develop probability risk models using inductive model methodology using, but not limited to, tools such as Maximum Entropy (Phillips et al. 2004). The product of these types of models are defined as a 0-1 probability surface which may be defined with scenario specific threshold values that allow the user to either confine or expand the reflective risk profile of the CA.

The required basic data layer needed for addressing annual grasses will build upon the Annual Grasses Index of Nevada with regions of Utah and California being addressed via the existing field sample and National Ecological Systems of the U.S. (NatureServe 2009). The models however, will not necessarily be representative of the percent cover of the CA, but rather display the probable potential occurrence of the CA. Individual models can be custom tailored for multiple categorical representations of specific percent cover thresholds as defined by the relative/absolute percent cover of the CA as defined by the Landfire Comprehensive Points database. Models will utilize existing field samples (n=4514 cheatgrass) and ancillary data layers including landscape condition, soils, elevation and landform to address the lack of comprehensive extent. Inductive and deductive modeling will be applied to address future scenarios representing potential shifts in annual grasses extent and range as they apply to both current and future distributions of ecological systems. By withholding a sub-sample of the existing field data and utilizing the Southwest Exotic Mapping Program (SWEMP) 2007 Dataset we will be able to estimate the accuracy and validity of the current distribution models. Future scenario distributions by their nature cannot be validated, but correlations can be made with future climate scenario for year 2100 developed by Bradley (2009).

Outputs: A spatial representation of current and future annual grasses distributions will be generated by each modeling exercise.

Issues: While predictive maps are a useful surrogate for large landscape the data poses a risk of misinterpretation when the analysis unit is too fine grained. Additionally, uneven distributions in available field samples may limit our ability to validate and assess the model in certain portions of the ecoregion.

Figure 8. Concept for modeling the distribution and effects of terrestrial CAs.



Development Impacts on Terrestrial CEs

Although these effects are often localized in the ecoregion, development has impacted many locations of Pinyon-juniper woodlands throughout the ecoregion. High and low density urban and industrial developments also have large impacts. For example, residential development has significantly impacted stands within commuting distance to urban areas. Impacts may be direct as trees are removed for building sites or fire suppression, or indirect such as introduction of invasive species. Mining operations can drastically impact woodlands. Road-building and power transmission line development continues to fragment woodlands and provides vectors for weeds.

Major effects of development and management actions are to be captured in the Landscape Condition Model (LCM) using the approach developed by NatureServe (Comer and Hak 2009). The LCM is composed of the GIS spatial layers of transportation, urban and industrial development, and managed & modified land cover layers. Each input layer is given a relative weighting for its relative impact at its precise location, and with distance away from its location. A composite scoring and map surface (at 30m spatial resolution) result from combining all input layers. This model provides an overall index surface of Landscape Condition for the ecoregion. See the following section on Development Change Agents for detailed explanation of the landscape condition model.

Connectivity for Terrestrial CEs

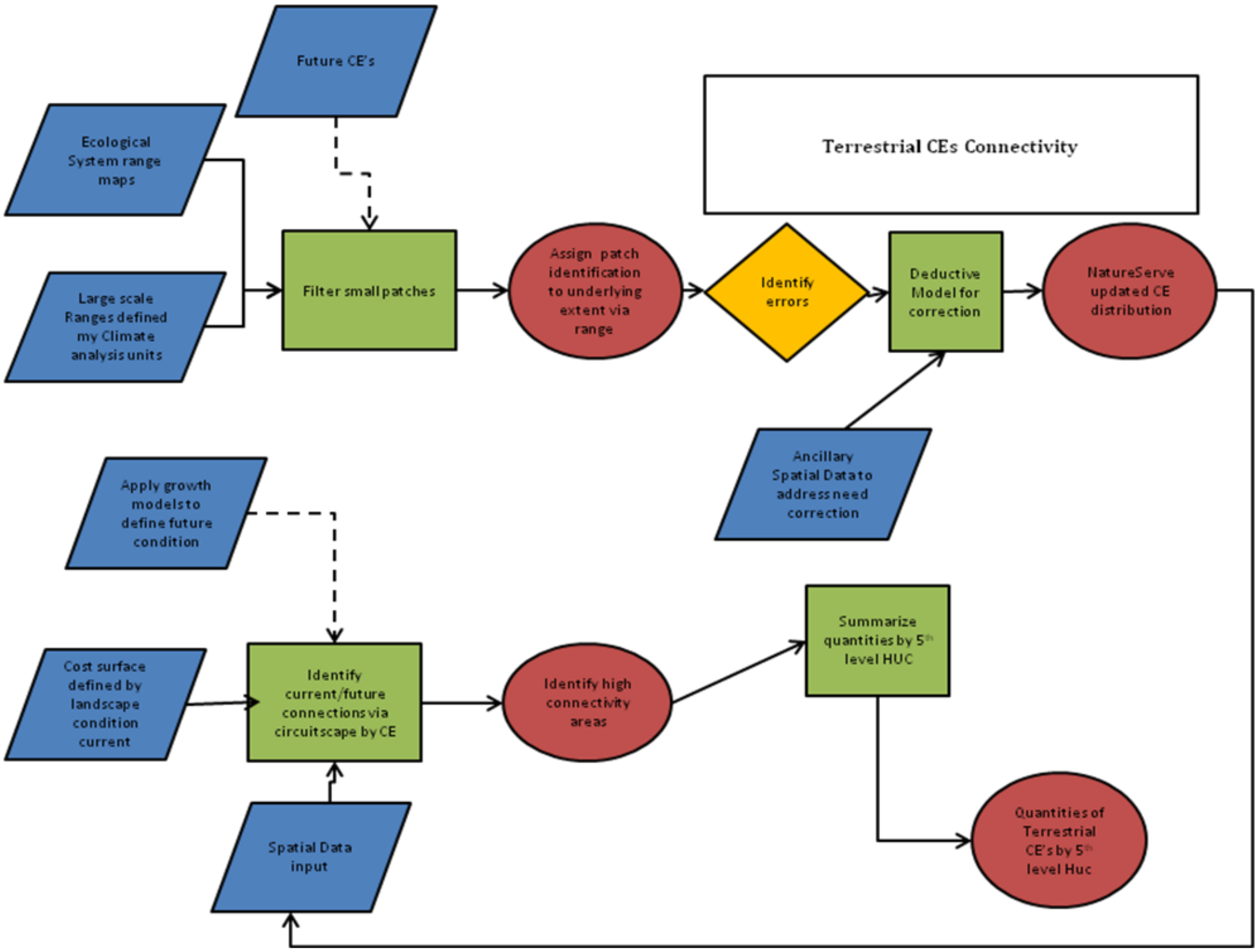
For selected CEs, connectivity models have been developed that will be applied directly to this and adjacent REAs (e.g., Aldridge et al. 2008, Wisdom et al. 2011, Knick and Hanser 2011). However, since habitat fragmentation is one primary factor affecting ecological integrity, we propose to develop and apply a series of additional spatial models aimed at depicting habitat connectivity from the perspective of species with clear habitat affinities. In particular, landscape species CEs not already addressed, and species CEs that we have chosen to treat through analysis of coarse-filter CEs, would all benefit from these types of spatial models. For illustration here, we use PJ woodlands as the CE within their distribution in the adjacent CBR ecoregion.

Inputs: Basic inputs for addressing connectivity include information on source nodes (e.g., habitat patches) and a theoretical cost surface. We propose to use a two pronged approach to evaluate both existing, and future scenario, connectivity of selected CEs.

Analytic process & tools: To assess the connectivity of selected conservation elements occurring with the ecoregion, we are proposing to use the CircuitScape modeling environment developed by McRae and Shah (2009). CircuitScape was developed by Brad McRae and Viral Shah through the University of California, Santa Barbara and builds upon the application of electrical circuit theory to predict connectivity in a complex landscape.

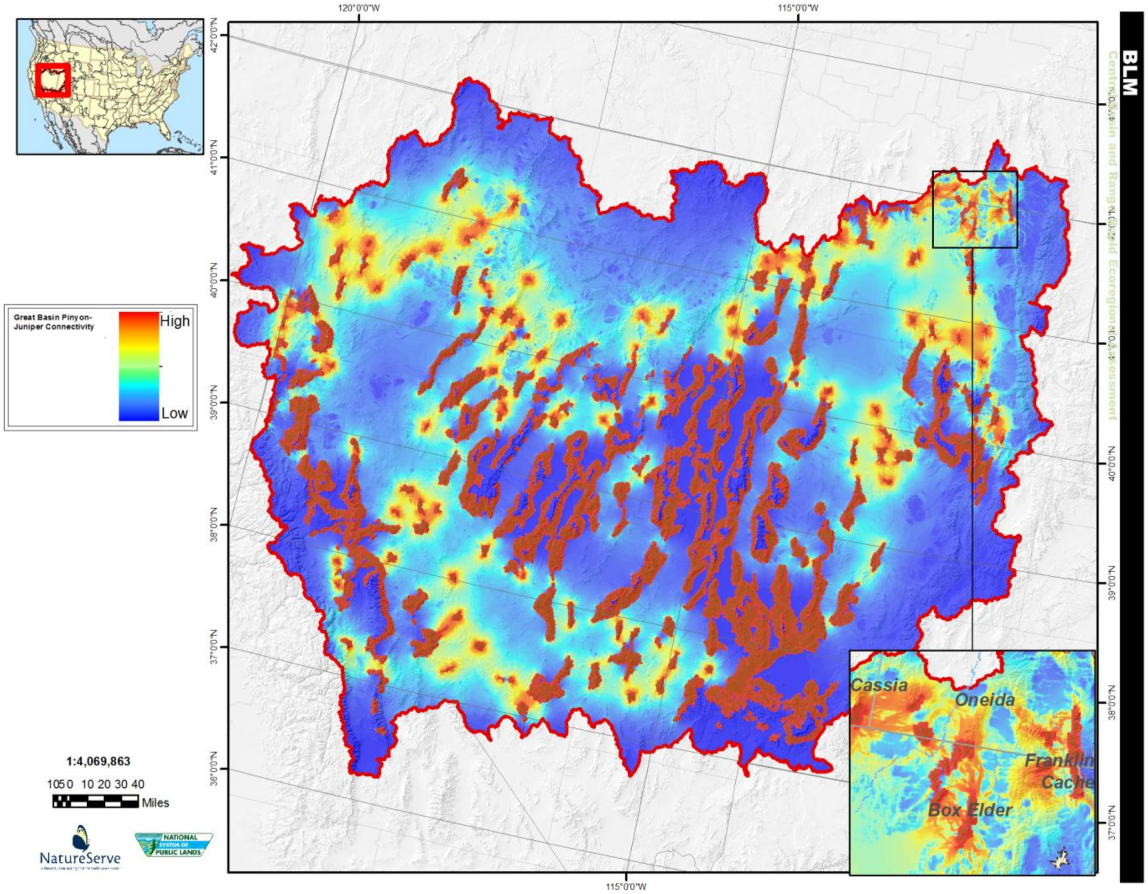
An advantage of using circuit theory for predicting landscape connectivity is the ability to define the connections via multiple channels of passage that better simulate the naturally occurring connections in landscape. Sources and a “resistance surface” for CircuitScape can be defined with a distance decay-based model of disturbance, such as that described in the NatureServe method for modeling landscape condition (Comer and Hak 2009). Future source nodes could be defined based upon habitat distributions from current and predicted extents as constrained by future climatic effects. The cost surface may be defined using a modified version of the landscape condition surface modified by results of the future growth models. Connectivity analysis is described in the conceptual model shown in Figure 9.

Figure 9. Conceptual model of connectivity as applied to CAs.



Outputs: The advantage of using a tool like CircuitScape is the creation of a continuous data model that is customized for individual CAs. Beyond the customized nature of the results, each product often detects multiple paths of landscape conductance (Figure 10) which allows for highly adaptable connections to be defined that meet the needs of the CE. We propose to summarize connectivity scores for each CE by 5th level watershed.

Figure 10. CircuitScape result representing the potential connection points of Great Basin Pinyon-Juniper Woodlands (in dark red).



Ecological Integrity Assessment and Reporting – Terrestrial CEs

In order to assess ecological integrity for each CE within the ecoregion, we propose to begin the assessment at the level of each CE as it is distributed within each 5th level watershed. NatureServe's ecological integrity framework sets up practical criteria and indicators for this purpose (Faber-Langendoen et al. 2006, Unnasch et al. 2008). This framework provides a scorecard for reporting on the ecological integrity of a given CE within a given location, and facilitates aggregation and synthesis of the component results for broader measures of ecological integrity at landscape and ecoregional scales. Using this framework, indicators are chosen to provide a measurement for a limited set of key ecological attributes, or ecological drivers for each CE. Ecological attributes may include natural characteristics, such as native species composition, or stressors such as effects of relevant change agents, that are well known to affect the natural function and integrity of the CE. The key ecological attributes are organized by "rank factors" of **Landscape Context**, **Condition** and **Relative Extent**. For this REA, the reporting unit is at the Watershed 5th Level (HUC – 10). The NatureServe EIA framework also organizes indicators into categories based on required effort, with "Level 3" indicators addressed through quantitative field measurement, "Level 2" indicators emphasizing qualitative field review, and "Level 1" indicators addressed through remote sensing. In part because of project constraints, indicators that we recommend emphasize ecosystem stressors that can be more readily measured using remotely sensed data – "Level 1" indicators. Spatial models that reflect these indicators serve as the link between the conceptual models and the spatial representation of ecological integrity. Below we provide further illustration using criteria and indicators organized for the Great Basin Pinyon-Juniper Woodland. Table 14 provides a concise summary, or scorecard, for describing each indicator.

Landscape Context

The key ecological attributes of landscape condition, relative to effects of human alteration, and landscape connectivity fall within this rank factor of "Landscape Context." Here we propose two primary indicators, both reported as numerical indices to contribute to our scorecard for ecological integrity.

Landscape condition model (LCM) index – The indicator is measured in a GIS by intersecting the mapped area of the Great Basin Pinyon-Juniper Woodland system with a spatial model derived from the NatureServe LCM approach (Comer and Hak 2009, see Development Change Agent section below) and reporting the mean LCM index score for the system distribution within each HUC 10 unit. The results are an index of landscape condition from 0.0 to 1.0 with 1.0 being very high landscape condition (apparently unaltered natural conditions) and 0.0 having extremely altered condition (e.g., dense urban areas).

Connectivity index - This indicator is assessed using *CircuitScape*, a GIS program described above that uses circuit theory to predict connectivity in heterogeneous landscapes for individual movement, gene flow, and conservation planning (McRae 2006, McRae et al. 2008). Here it provides an indication of connectivity for species CEs that we are treating through assessment of their affiliated coarse-filter CEs. CircuitScape will use the LCM as a resistance surface for scoring relative connectivity across all overlapping portions of the CE distribution. The program results are an index of connectivity for each 90m pixel from 0.0 to 1.0 with 0.0 having no connectivity (barrier) or 1.0 having very high connectivity. Pixel values are summed for each CE distribution within each 5th-level HUC and the ecoregion.

Condition

The key ecological attributes of ecological condition comprise ecological drivers that underlie natural food web dynamics and native species composition. Given human alteration, indicators of ecological composition, structure, and function for a CE fall within this rank factor of "Condition." Here we propose two primary indicators, both reported as numerical indices to contribute to our scorecard for ecological integrity. Ecological condition for terrestrial CEs where fire regime alteration and invasive plant infestation introduce substantial ecosystem stress

SCLASS departure index – This indicator is assessed by calculating and summarizing the Landfire Succession classes (SCLASS) layer which characterizes current vegetation succession classes for the distribution of each CE within each 5th-level HUC. The resulting proportional calculation for current conditions is compared to the output of the VDDT and/or Path Landscape Model (http://www.essa.com/tools/path/index.html) characterizing the expected natural range of variation (NRV). This comparison defines the degree of departure (%). The SClass Departure Index is calculated by subtracting the Departure percent from 1 to produce a normalized scale from 0 to 1 with 1 being no departure from NRV in distribution of succession classes and 0 being complete departure from NRV.

Invasive Plant Index – While it would be desirable to measure native plant composition and structure for gauging ecological integrity (e.g., native grass understory in sagebrush), data are clearly lacking for use in this REA. However, stressor based indicators – centered on invasive species – are more tractable. This indicator is measured using the mapped area of Great Basin Pinyon-Juniper Woodland ecological system with an abundance map of introduced invasive annual vegetation. The output is percent cover of invasive annual vegetation for the CE within each 5th level HUC. The Invasive Annual Cover Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 1 being invasive annuals absent to 0 which is >15% or greater cover of invasive annuals. This indicator should be robust for circumstances where, e.g., cheatgrass has minimal effect on Pinyon-juniper woodlands at the northern end of the CBR; since the model will in all likelihood indicate a low abundance of invasive plants in these portions of the PJ distribution.

Relative Extent

Change in Extent – Where a substantial change in extent for a given CE has occurred, it provides an indication of past/current land use practices and/or changing environmental conditions that could limit the provision of ecological services. It therefore serves an appropriate indicator, among others, for gauging ecological integrity for each CE, within each watershed, and across the ecoregion. In this example, this indicator is assessed by intersecting the mapped current extent (*circa* early 2000s) of Great Basin Pinyon-Juniper Woodland system with the a biophysical setting (BpS) layer for this same system and reporting the percent change between the predicted area under natural disturbance regime (BpS) and the current extent. As noted in MBR Memo 2c, review and refinement of the LANDFIRE BpS map will be accomplished in parallel with refinements to the existing distribution layer. In the MBR, there are also alternative models for us in comparison to the LANDFIRE BpS map (e.g., Sayre et al. 2009) that will enable a better gauge of relative accuracy for each layer used in this analysis. A positive change would indicate invasion of pinyon and juniper vegetation into non-pinyon – juniper woodland BpS areas such as sagebrush shrublands likely as a result of increased fire return interval (FRI). A negative change would indicate loss of Great Basin Pinyon-Juniper Woodland from expected BpS area likely from decreased FRI. The output is percent area of change in extent of the current extent from the extent predicted under a natural disturbance regime (NRV). The Change in Extent Index is calculated by subtracting the Change in Extent percent from 1 to produce a normalized scale from 0 to 1with 1 being no change in extent and 0 being A 100% change of CE in extent.

Ecological Integrity Assessment

The Ecological Integrity Assessment (EIA) is designed to organize and apply indicators for individual CE and combined CEs at various spatial levels and reporting units, from 5th level watersheds (HUC - 10) to broader scales. The assessment indicators or indicators with justifications and rating thresholds are presented in Table 14, organized by Rank Factors (Landscape Context, Condition and Relative Extent) and Key Ecological Attributes. The indicators measure the key ecological attributes for the conceptual ecological model above and the index thresholds permit interpretation of the results.

Scorecard and Integrity Categories

Each indicator is scored according to criteria described above and then the score is either used directly as an index or a indicator index is calculated between 0 and 1 with 1 being 100% sustainable and 0 being totally degraded (and presumably transitional to a wholly different ecological state). With concurrence from the AMT, we will aim to report ecological integrity scores within 3 categories, effectively segmenting the 0.0-1.0 scale with two distinct numerical thresholds. These categories include Sustainable, defined as the indicator falls within the expected range of natural variation as hypothesized by NRV. At the other extreme, Degraded status occurs where the indicator is well outside its expected range as hypothesized by NRV, to the degree that conditions suggest imminent loss of the CE at that location. The third category, Transitioning, occurs where a given indicator is outside its expected range, as hypothesized by NRV, but to a measurably lesser degree than the Degraded condition, so that imminent loss of the CE is not predicted.

The mean index scores of these indicators can then summarized and averaged by each Key Ecological Attribute and each Rank Factor if there are multiple indicators for each. For example, one might be interested in reporting on the management implications of succession class regime departure as one distinct assessment result. These mean scores are then averaged for an overall index of ecological integrity for the CE within each assessment area. A hypothetical set of mean index scores are included in the far right column of Table 14. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving change in ecological integrity of the CE.

Table 14. Great Basin Pinyon-Juniper Woodland EIA Scorecard.

Indicator	Justification	Rating			Index Score
		Sustainable	Transitioning	Degraded	
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Attribute: *Landscape Connectivity*					
Connectivity predicted by CircuitScape	Intact natural conditions support physical and biological dynamics occurring across diverse environmental conditions	Connectivity is moderate to high and adequate to sustain most CEs. Connectivity index is >0.6	Connectivity is moderate to low and will not sustain some CEs. Connectivity index is 0.6-0.2	Connectivity is low and will not sustain many CEs. Connectivity index is <0.2	0.73
Key Ecological Attribute: *Landscape Condition*					
Landscape Condition Model Index	Land use impacts vary in their intensity, affecting ecological dynamics that support ecological systems.	Cumulative level of impacts is sustainable. Landscape Condition Model Index is > 0.8	Cumulative level of impacts is transitioning system between a sustainable and degraded state. Landscape Condition Model Index is 0.8 – 0.5	Cumulative level of impacts has degraded system. Landscape Condition Model Index is< 0.5	0.88
Rank Factor: CONDITION					
Key Ecological Attribute: *Succession Class Departure*					
SCLASS Departure	Mixed of age classes among patches of the system is result of disturbance regime. Departure from mixture predicted under NRV indicates uncharacteristic disturbance regime and declining integrity.	Mixed of age classes indicate system is functioning inside or near NRV. System is in a sustainable state. Departure is < 20%. SCLASS Departure Index is > 0.8	Mixed of age classes indicate system is functioning near, but outside NRV. System is transitioning to degraded state. Departure is 20 - 50%. SCLASS Departure Index is 0.8 – 0.5	Mixed of age classes indicate system is functioning well outside NRV. System is degraded. Departure is > 50%. SCLASS Departure Index is < 0.5	0.50
Key Ecological Attribute: *Abundance of Invasive Annual Vegetation*					
Invasive Annual Cover	Invasive annual vegetation displaces natural composition and provides fine fuels that significantly increase spread of catastrophic fire.	System is sustainable with low cover of invasive annual vegetation. Mean cover of annuals is <5%. Invasive Annual Cover Index is >0.8.	System is transitioning to degraded state by abundant invasive annual vegetation. Mean cover of annuals is 5-10%. Invasive Annual Cover Index is 0.8-0.5.	System is degraded by abundant invasive annual vegetation. Mean cover of annuals is >15%. Invasive Annual Cover Index is <0.5)	0.40
Rank Factor: Relative Extent					
Key Ecological Attribute: *Change in Extent*					

Indicator	Justification	Rating			Index Score
Change in Extent	Indicates the proportional change due to conversion to or of other land cover or land use, altering provision of ecological services and affecting ecological integrity.	Extent is at or minimally is only modestly changed from its original natural extent (<20% change) Change in Extent Index is > 0.8.	Extent is substantially changed from its original natural extent (20-50% change). Change in Extent Index is 0.8-0.5	Extent is severely changed from its original natural extent (>50% change). Change in Extent Index is < 0.5.	0.90
Overall Ecological Integrity Rank					
(3.41 / 5 = 0.68)	**Mean Index Score**				**0.68**

In this hypothetical example, we see that a combined index score for Pinyon-Juniper Woodland within a given 5th level watershed at a given point in time (e.g., currently) is 0.68. When speaking of relative significance and reporting on ecological integrity for the REA, we can choose to report along either a 0.0-1.0 relative scale, or we can chose to use our segmented scoring options (now applying threshold values from the scorecard) to report on relative integrity within Sustainable, Transitioning, or Degraded categories. With a composite score of 0.68, this hypothetical example would be reported as Transitioning.

While we propose to report on relative ecological integrity for terrestrial CEs in terms of 5th level HUCs, we can also aim for analogous reporting within a limited set of other spatial reporting units, such as established managed land units (e.g., ACECs, grazing allotments, etc.). However, for this REA, we propose to report only using 5th level watersheds, leaving reporting with additional units to subsequent efforts by BLM (e.g., under ecoregional direction).

Climate Change Effects on Terrestrial Conservation Elements

As a change agent, climate change is predicted to have a range of effects on individual CEs, and these effects are likely to vary considerably across the distribution of a given CE within the ecoregion. Here we propose several methods for gauging climate-change effects, both on terrestrial CEs and across the geography of each ecoregion. The principal goals of our approach are to 1) assess the magnitude of climate change for a given CE or ecoregion, 2) analyze the spatial and temporal distribution of projected future climate change, 3) use a wide range of future climate model outputs in conducting #1 and #2 to understand the degree of certainty of projected changes across models, and 4) identify geographic areas within an ecoregion or within the distribution of a CE where there is high model agreement of significant future change – that is, the most vulnerable areas, and identify regions where there is high model agreement of relatively less change – that is, high model agreement for relative climatic stability.

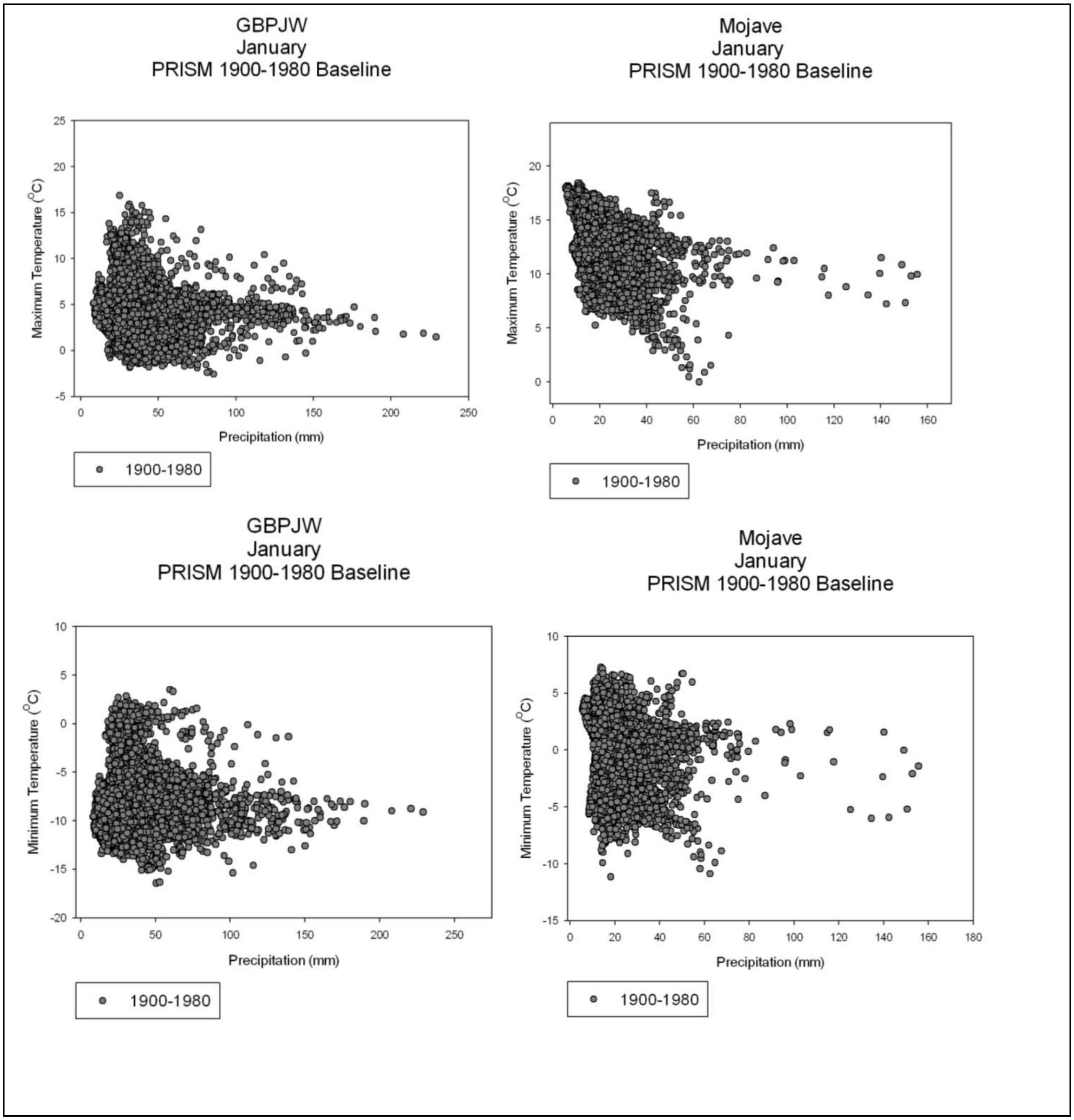
Following are sample data outputs that we intend to produce for CEs within a given ecoregion. Climate envelope analysis aims to provide needed input to formulate hypotheses of change for a given terrestrial CE with regards to important ecological process (e.g., fire regimes), and to indicate probable directional shifts in distribution for terrestrial CEs.

Step 1. Establish historical bioclimatic envelope. This step establishes a meaningful characterization of baseline "climate space" across the spatial extent of an ecoregion or across the known distribution of a CE. "Climate space" can be defined as the range of values for primary climate data that occur across the spatial extent of the target. This is necessarily a "back casting" step to establish a baseline from which to measure current trends in climate change, and future projections of further change.

Data: PRISM 4 KM, monthly Tmax, Tmin, Precip; Georeferenced sample locations of each CE from across the ecoregion (and beyond), or gridded shape file of ecoregion.

Methods: From PRISM 4 km data, we will use the 36 climate variables of monthly maximum temperature, monthly minimum temperature, and monthly total precipitation to build a queryable database for spatial climate analyses. We will create a baseline climate data layer from 1900-1980, representing an 80-year record of average climate for each variable for each month, and the standard deviation for that month and variable over the same 80-year interval. For each 4 km pixel within an ecoregion (Mojave graphs, bottom of figure) or each 4 km pixel that overlaps with the known distribution of a terrestrial CE (Great Basin Pinyon Juniper Woodland, top of figure), we will map climate space on graphs of monthly temperature vs. precipitation, their standard deviations, and annual averages (Figure 11).

Figure 11. Example of 20th century baseline climate envelope (January) for a given CE within the ecoregion (GBPJW) or a given ecoregion (MBR).
First row, January monthly maximum temperature vs. January precipitation; 2nd row, January monthly minimum temperature vs. precipitation.



Step 2. Conduct PRISM "departure" analysis for the current time period relative to 20th century baseline. From the queryable PRISM database, we will create a time series representing very recent climate trends, 1995-2010. When compared against the baseline, mapping recent climate space can

reveal the magnitude and directionality of **observed** trends in climate space, that is, the climate change that is already occurring in these ecoregions and across the distributions of the CEs (Figure 12). To quantify how recent changes compare to baseline climates, and as one measure of significance, we will identify the extent of change that is >=1 standard deviation from the mean of baseline climate (Figure 13). We can then project these statistically significant changes back onto geographic space, so that the specific locations of the greatest observed climate change can be identified (Figure 14).

Figure 12. Analyzing observed trends in current climate space.
The graph on the left illustrates January minimum temperature vs. January precipitation for pinyon-juniper; the graph on the right shows the same monthly climate variables for the entire MBR ecoregion. Gray dots represent baseline climate space, and blue dots represent recent trends in climate space. Note the recent loss of the lowest January minimum temperatures across both the MBR ecoregion and the distribution of GBPJW.

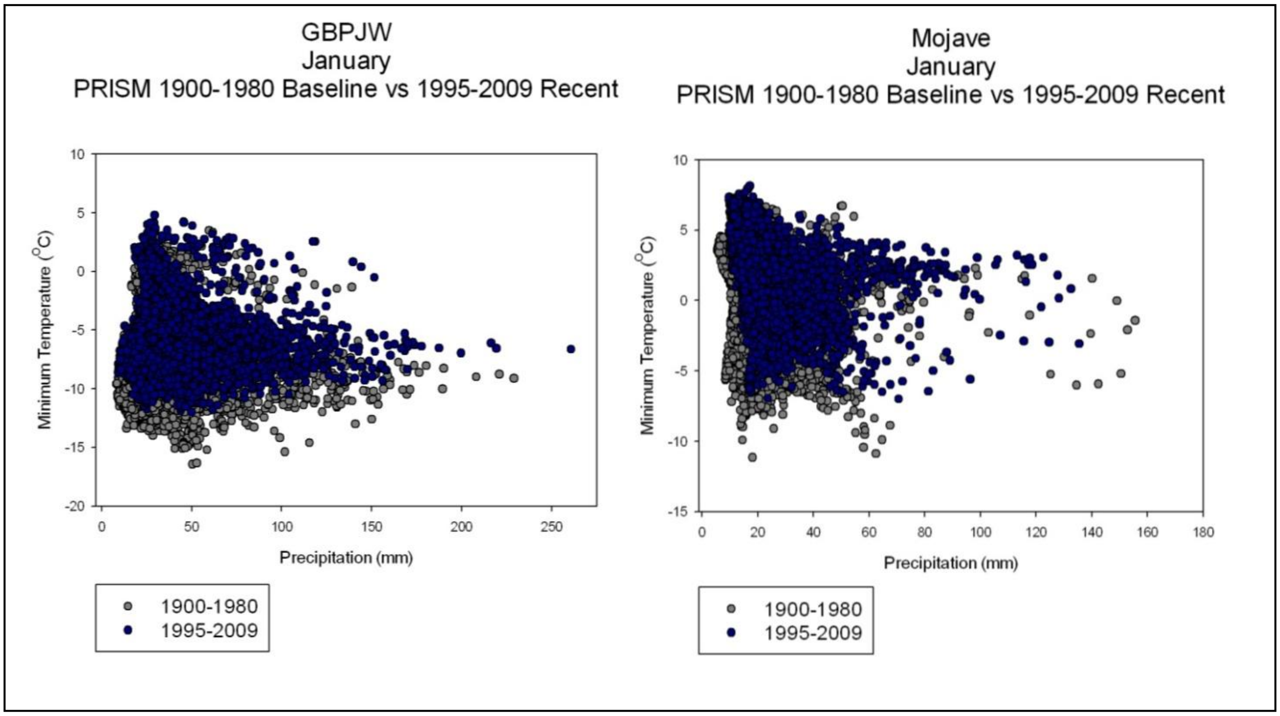


Figure 13. Determining statistically significant trends in recent climate vs. historical baseline. On the left, purple dots represent each 4km pixel within the distribution of pinyon-juniper for which recent January precipitation is one standard deviation beyond the mean of the January precipitation baseline. On the right, the same calculation is shown for January minimum temperatures.

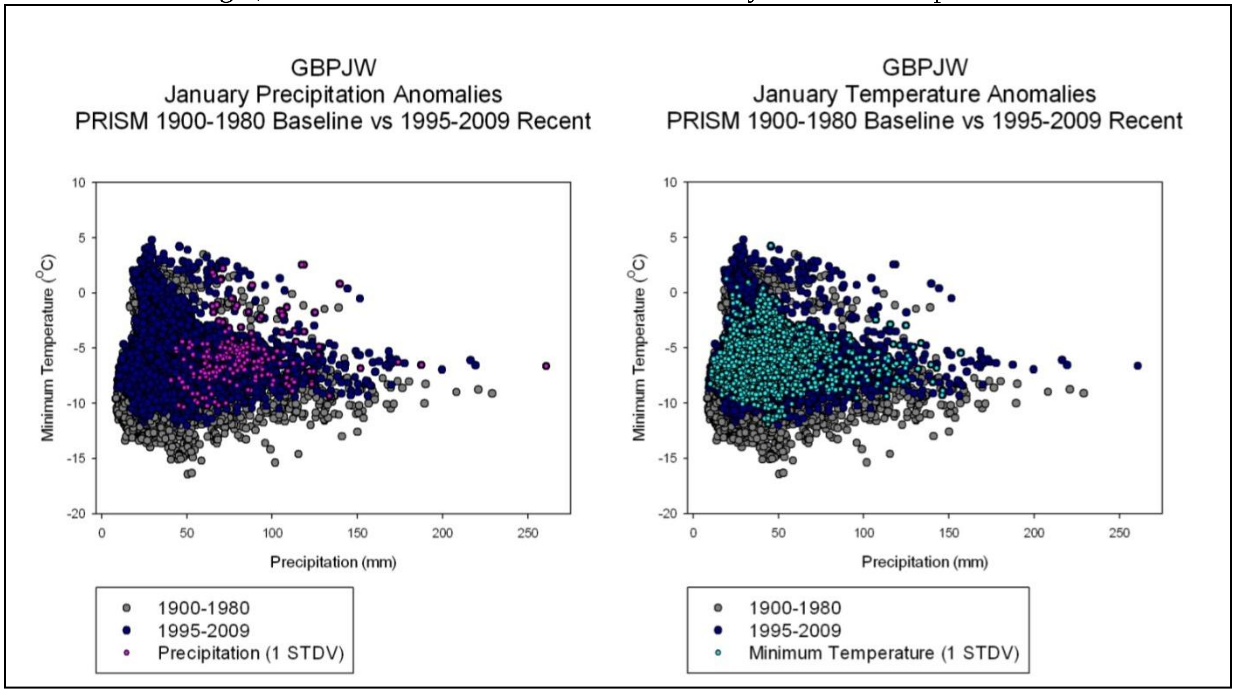
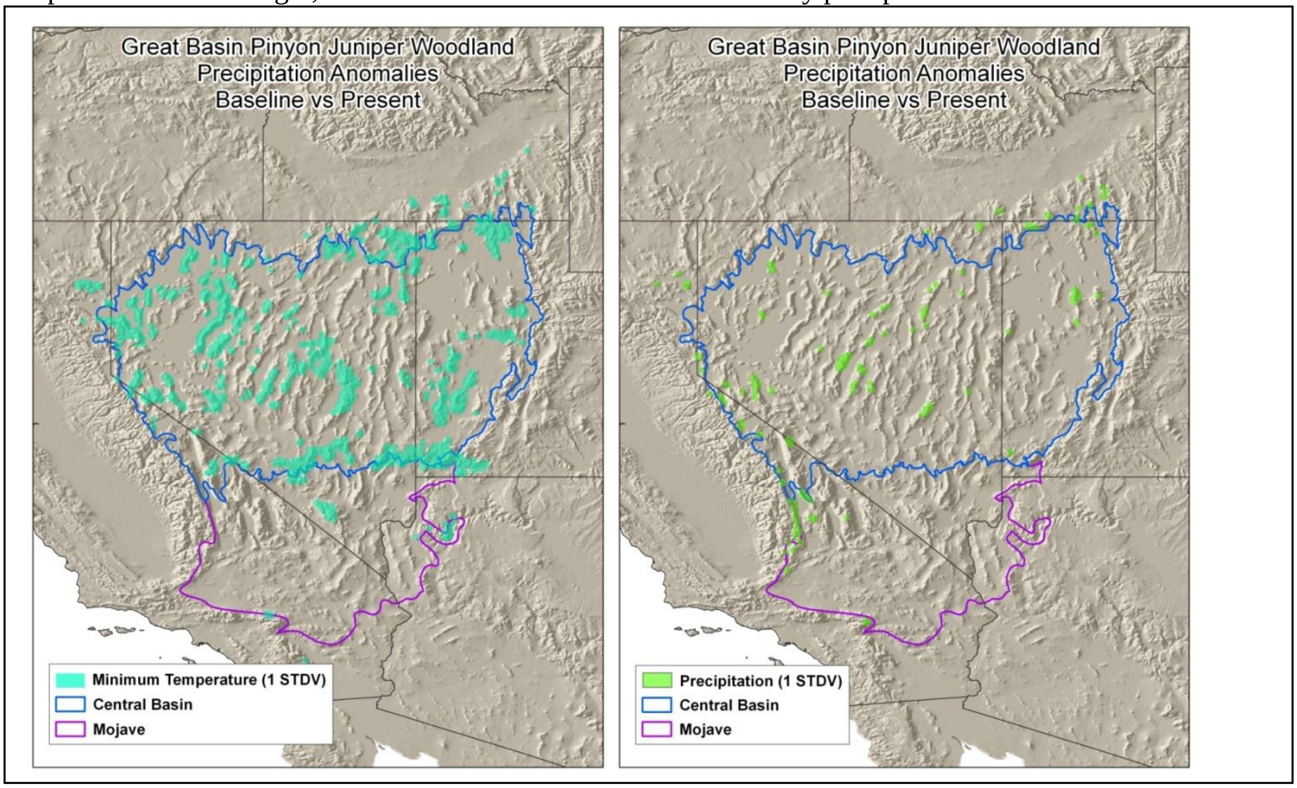


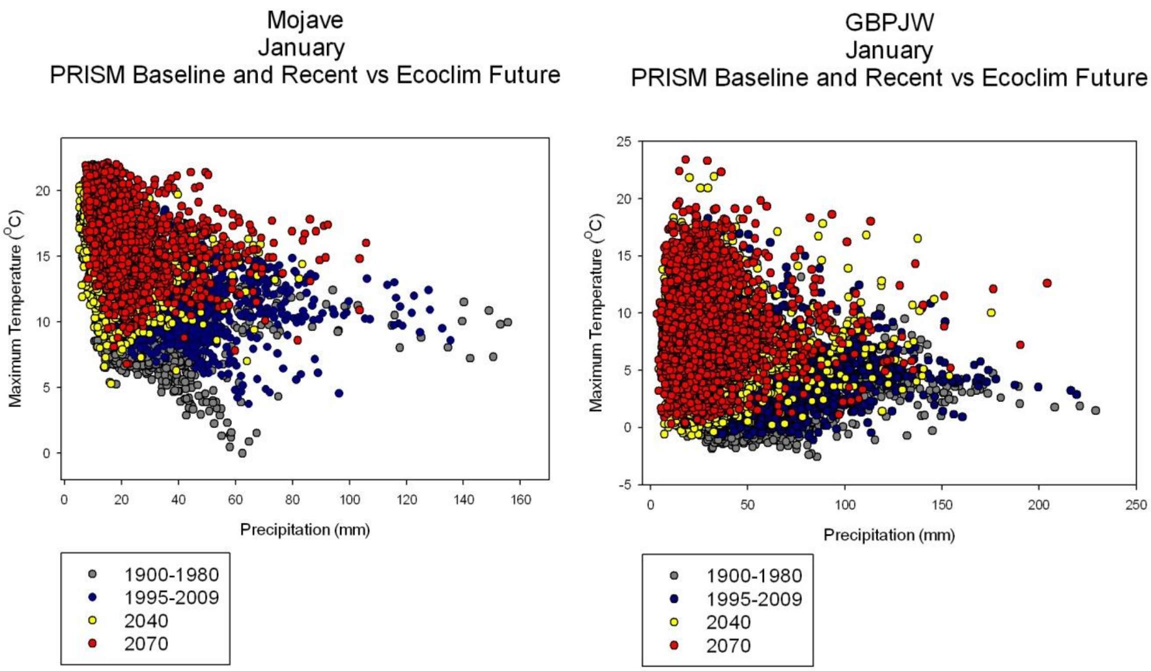
Figure 14. The spatial distribution of significant January climate change from 1995-2010 compared to a baseline of 1900-1980 for GBPJW in and surrounding both the MBR and CBR ecoregions. On the left, turquoise regions identify all 4km pixels of significant change in January minimum temperatures. On the right, the same calculation is shown for January precipitation.



This step will reveal the spatial and temporal distribution of climate change as it is already occurring across each ecoregion, and across the distribution of a CE.

Step 3: Project future climate envelope. To explore climate change impacts to ecoregions and CEs, we will use two separate future climate datasets – USGS 15km dynamically downscaled climate model outputs (USGS-CD), and EcoClim, a 10km statistically downscaled climate dataset created in the California Academy of Sciences lab. The USGS-CD offers 3 alternative modeled outputs for future climate conditions, and will create two 15-year time slices, a series of monthly averages for 2015-2030 and 2045-2060. While the USGS-CD offers a wide range of climatic and biophysical variables as outputs, we will use basic temperature and precipitation variables for characterizing changes in climate space, so that future changes can be interpreted relative to the PRISM baseline (but see step 4, below, for use of full suite of USGS-CD data). The EcoClim dataset provides 16 different downscaled global climate models (GCMs), and offers decadal averages for each monthly variable: maximum temperature, minimum temperature, average temperature, and total precipitation. The modeled outputs from the 2020's and the 2050's will be used from the EcoClim dataset. Future trends in climate space from this broad range of climate model outputs will be graphed for a qualitative understanding of the direction and magnitude of climate change as forecast by a large and diverse set of climate models (Figure 15). Agreement across many climate models for significant changes in climate space for a given ecoregion or CE indicates high vulnerability to climate change with relative certainty.

Figure 15. Future climate space compared to baseline for January maximum temperature vs. total precipitation for the MBR ecoregion (left) and the GBPJW CE (right).
The time series graphed represents 20th century baseline, 1995-2010, 2040s, and 2070s. Note the loss of the lowest January maximum temperatures into the future, which is consistent with the changes already observed in baseline vs. recent climate trends.



Mapping Climate-Induced Stress on CEs. From the envelope analysis output, we can identify portions of the climate space for each ecoregion or CE where climate variables are predicted to change by >=1 standard deviation and by >=2 standard deviations from the mean. This approach will reveal the temporal and spatial distribution of climate change that exceeds the normal range of natural climatic variability to which the CEs are already plausibly adapted. Where these exist, they will be summarized by 5th level watershed.

Fire Regime Effects. Changes in climate are anticipated to be reflected in changes in fire probability. Estimated change in temperature and precipitation can be summarized statistically and utilized to formulate hypotheses of their effects on fire regime and successional dynamics. We propose to apply this interaction between predicted climate envelope outputs and their predicted effects on fire regimes for each coarse-filter CE where fire regime is a dominant ecological process. These changes will be captured as changes in the fire probabilities for each fire severity class. Changing fire frequency and intensity then translates into new predictions of future departure using the simulation tools described previously. We will attempt to model the relationship between temperature/precipitation and the probability of fire based on available fire data for the past 25 years. Because we anticipate that the available data will not result in a clearly understood relationship between changes in climate and fire probability, we will change fire probabilities based on the proportional change in the distribution of temperature shifts to simulate a range of fire probabilities. We will then be able to report on the range of changes in successional classes by HUC 10.

Step 4: Model spatial distributions of the bioclimatic envelope for each CE

The intent of this step is to provide an indication of directionality in range shift that may occur among species (either as components of coarse-filter or species assemblage CEs or as individual species CEs). Output of this step can be used in subsequent analysis of changing landscape conditions from predicted future land uses.

This step will use multiple datasets: PRISM 4 km, USGS 15km downscaled climate model outputs (USGS-CD), and EcoClim, a 10km downscaled climate dataset created in the CA Academy lab. Using Maxent, a species distribution modeling algorithm, we will generate two sets of current bioclimatic envelopes. The first set will use PRISM 4 km monthly data, for temperature and precipitation only. The second set will use the "NCEP reanalysis" of the USGS-CD 15km for a mid-20th century time slice - 1968-1999 - representing the baseline version of the USGS-CD (this dataset is still being generated). The USGS data includes many additional variables beyond temperature and precipitation – soil moisture, solar radiation, etc., but at coarser spatial resolution.

These two sets of current bioclimatic envelopes will be compared to two sets of range shift projections, also using Maxent. Future ranges **based only on temperature and precipitation** will be generated using EcoClim, a large dataset of downscaled spatial climate surfaces from 16 different AR4 GCMs. The large number of GCMs allows an assessment of the degree of agreement across a wide range of global climate models, thereby offering an assessment of uncertainty. Two time slices will be explored: 2020's and 2050's. This will complete a time series of data from 1900 to mid-century based on temperature and precipitation envelopes.

The second set of range shift projections will be based on the USGS-CD 15km for the full suite of available variables, which includes soil moisture, humidity, evapotranspiration, monthly extreme temperature and precipitation, and other relevant biophysical variables. Again, two time slices will be explored. For the USGS-CD, these are 15-year averages for two future time slices (2015-2030; 2045-2070). This will result in a time series of 3 modeled ranges based on a wide range of environmental parameters – 1968-1999, 2015-2030, and 2045-2060.

SDM algorithm: Maxent version: 3.3.3e

<u>Maxent parameters/settings:</u>

Replicate runs: 10 bootstrapping

Test points: 20% of localities (pixels) will be set aside for testing model validity using AUC and ROC indicators.

Random seed (which selects a different 20% for test for each replicate run)

Output format: logistic (For ease of interpretation: probability of presence from 0 to 1)

Threshold selection: will be based on integrating 1) results of fractional predicted area, 2) training omission rate, 3) test omission rate and 4) comparison to current known distributions.

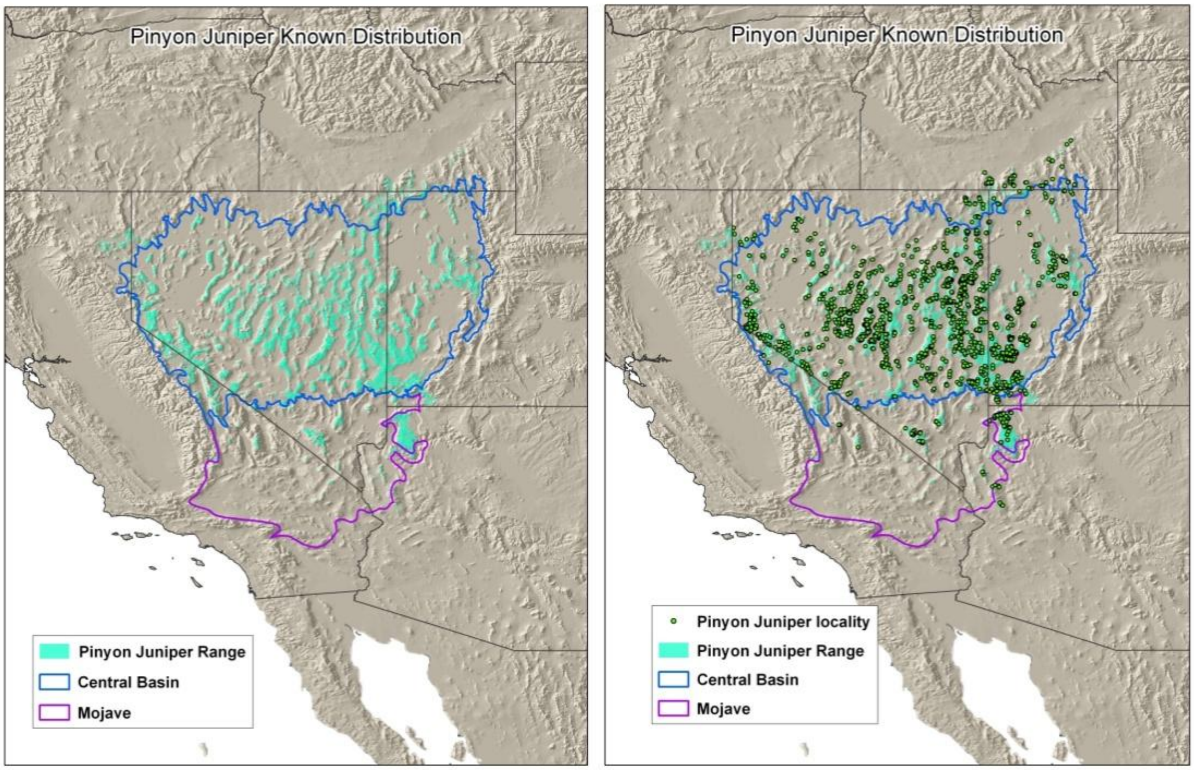
Analysis of variable contribution (information about the contribution of each variable toward the predictive spatial model: which variable(s) most important?)

Map outputs from Step 4 will be evaluated to gauge the relative degree of predicted range shift for each CE by the 2050s time period. These outputs will be post-processed to remove portions of predicted ranges known to be excludable; e.g., expansion onto inhospitable substrates, as currently documented by scientific literature. Additionally, overlay of climate envelope maps from current and 2050 time periods with biophysical landform maps will provide an indication of relative biophysical variability. These may serve as an initial indication of adaptive or buffering capacity, as a diversity of apparent biophysical environments will tend to provide a buffer of micro-environments suitable for easing adaptation by species. All results of these analyses (i.e., degree of range shift, level of biophysical buffering capacity) will be summarized by 5th level watershed.

Range-Shift Example

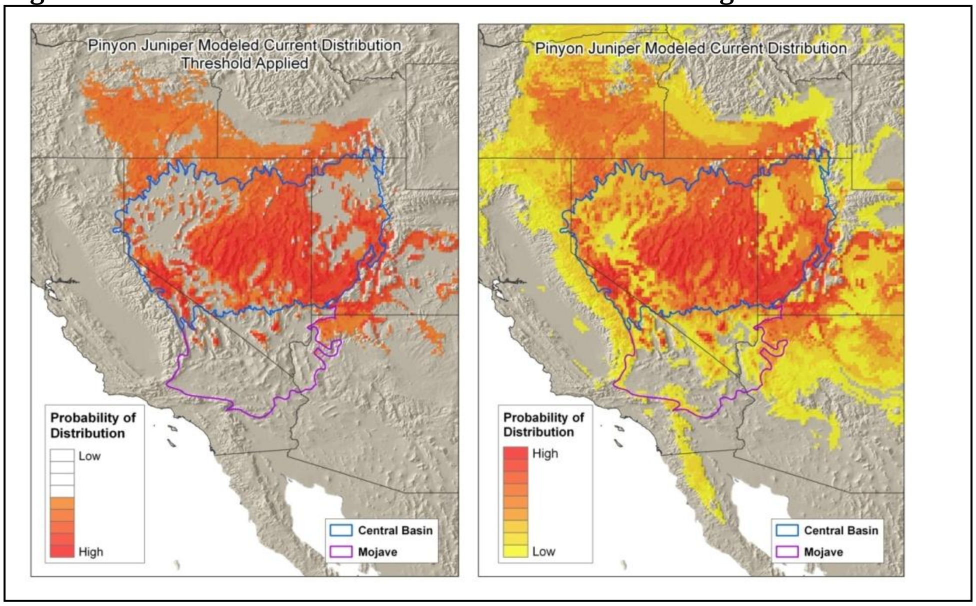
The following series of figures illustrate the proposed process. The distribution of pinyon-juniper based on verified point localities (Figure 16) is used as input into the Maxent spatial distribution modeling algorithm, with 20% of the localities set aside for model validation.

Figure 16. Known distributions of Great Basin Pinyon-Juniper woodland in and around the MBR and CBR ecoregions.



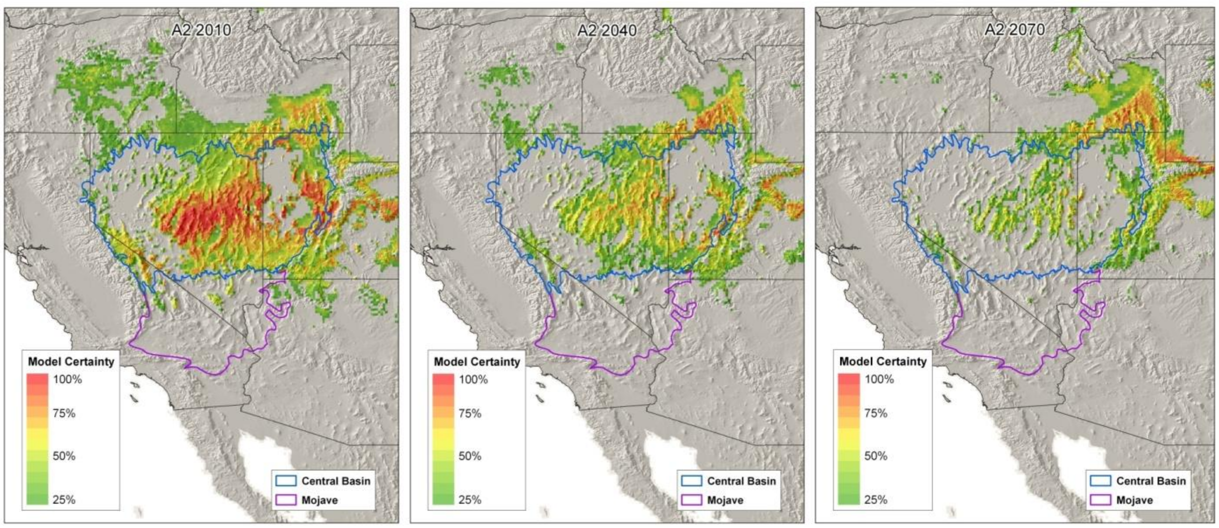
The probability distribution here ("modeled current distribution" in Figure 17) is based only on 24 variables, monthly average temperature and monthly total precipitation, from the WorldClim dataset. Applying a threshold converts the probability to a presence-absence output. Using the same 24 climatic variables but derived from 2010 climate model outputs from 16 GCMs, we can see that the highest degree of model agreement across 16 GCMs for high probability of suitable GBPJW habitat coincides reasonably well with the known distribution.

Figure 17. Modeled current distributions of GBPJW using 16 Global Circulation Models.



Projecting the degree of model agreement for the spatial distribution of suitable bioclimate into the future (for example, as a 2040 time slice and a 2070 time slice as illustrated in Figure 18, provides insight into the potential areas of sustained suitable environments for GBPJW, and the areas of significant climate shifting beyond the range of bioclimate to which GBPJW is currently located (2010 map in Figure 18). While these examples are generated with only monthly temperature and precipitation variables, we will repeat this approach using the broader range of biophysical variables offered by the USGS climate model dataset. With the USGS data, we increase the number of variables for species distribution modeling, but we decrease spatial resolution to 15km grid cells, and we have 3 instead of 16 climate models to explore model agreement. In addition, we are using a modeled dataset (the NCEP reanalysis driving RegCm3) to generate current distributions, which we will compare with Maxent outputs generated by the PRISM observation dataset.

Figure 18. Current and projected suitable bioclimate for Great Basin Pinyon-Juniper woodland.

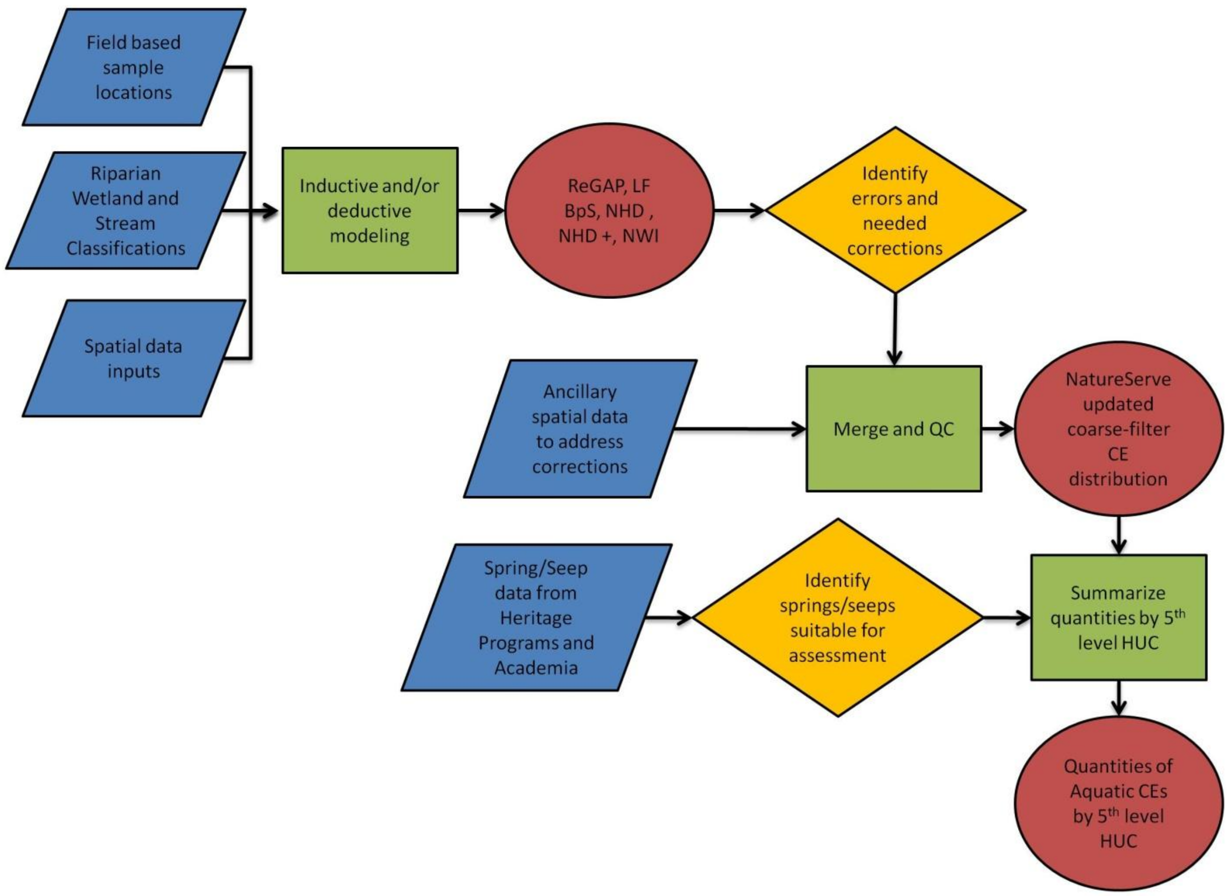


Aquatic CEs (coarse and fine filter)

Distribution Models

As established in memorandum I-1-c, aquatic coarse-filter CEs are categorized based on the ecoregion-wide conceptual model that defines all "wet" ecosystem types. These types include what are commonly referred to as aquatic habitats (streams, rivers, lakes, etc.); wetland communities (marsh, swamp, floodplain bottomlands); and riparian communities (mosaic of wetland and intermittently flooded habitats). Our aim is to provide a map depicting historical and current distributions for each of the nine coarse-filter aquatic CEs. The NatureServe composite ecological systems map (NatureServe 2009) depicts current distributions of the primary wetland and riparian components of aquatic coarse-filter (ecosystem) CEs. This coverage derives largely from the SW ReGAP, west Mojave California vegetation map, and LANDFIRE EVT maps. In the MBR, it will be augmented with the central Mojave California vegetation map. The LANDFIRE Biophysical Settings (BpS) map depicts the generalized potential or historical distribution of the CEs. We propose to complete additional review and refinement of these two maps to improve the mapping of aquatic coarse-filter CEs using several primary data sources. These include SSURGO, where available, for depicting hydric soils with natural land cover; National Wetland Inventory (NWI) for wetlands locations; and NHD Plus (1:100K and 1:24K scale data) for streams, lakes, intermittent washes, and playas. Data on desert spring and seep locations exist primarily for Nevada, but we continue to identify data from surrounding states. Figure 19 diagrams our process for mapping the distribution of aquatic coarse-filter CEs.

Figure 19. Concept diagram for modeling distributions of aquatic CEs.



Aquatic Coarse-Filter CE Characterization and Conceptual Models

The following section provides an illustration of conceptual modeling components for aquatic coarse-filter CEs. This basic format will be applied, with some variation, for each of the aquatic coarse-filter CEs and ecologically-based species assemblage CEs. Our conceptual models combine text, concept diagrams, and tabular summaries in order to clearly state our assumptions about the ecological composition, structure, dynamic process, and interactions with common CAs within the ecoregion. These conceptual models lead then to spatial models that enable us to gauge the relative ecological integrity of each aquatic coarse-filter CE within 5th level HUCs. Here we illustrate this process using a single aquatic coarse-filter CE – the *North American Warm Desert Riparian Woodland and Shrubland / Stream* system type – a characteristic aquatic coarse-filter CE in portions of the Mojave Basin and Range ecoregion. Additional examples of these conceptual models, applicable to the Mojave Basin and Range ecoregion are presented in Appendix II. Conceptual Models for Selected Conservation Elements for the MBR REA.

Each model begins by characterizing what the CE is, and how it nests within the broader conceptual model already established for each ecoregion. In this illustrative example, the North Americal Warm Desert Riparian Woodland and Shrubland/Stream CE nests within the Mojave Basin Wet Ecosystems component of the Mojave Basin and Range ecoregional conceptual model (see Memo 1c).

MOJAVE Basin Wet Ecosystems

Woody Wetlands and Riparian
North American Warm Desert Riparian Woodland and Shrubland/Stream

Conservation Element (CE) Characterization

CES302.753 North American Warm Desert Riparian Woodland and Shrubland / Stream

Summary: This ecological system consists of low-elevation (<1200 m) riparian corridors and the aquatic ecosystems within medium to large perennial streams throughout canyons and desert valleys of the southwestern United States and adjacent Mexico. The riparian vegetation is a mix of riparian woodlands and shrublands. Vegetation is dependent upon annual or periodic flooding and associated sediment scour and/or annual rise in the water table for growth and reproduction. Mojave stream systems are generally disconnected stream segments that may be seasonally ephemeral, but includes perennial flow and intermitant flow regimes. This variability maintains unique aquatic species assemblages in each flow system. The riparian components of this system often occur as a mosaic of multiple communities that are tree-dominated with a diverse shrub component; the aquatic component may be continuous or fragmented by natural barriers including intermittent reaches (see Appendix IId. Conceptual Model for North American Warm Desert Riparian Woodland and Shrubland/Stream for the full CE description).

Natural Dynamics: The hydrology of riparian-stream ecosystems in the arid western U.S. varies widely from one stream ecosystem type to another. The pattern of natural high, median (baseflow), and low flows varies with season, watershed size, and geomorphology; watershed soils and vegetation; the spatial distribution and magnitude of connection to snowpack and snowmelt and to both deep (e.g., basin-fill aquifer) and shallow (i.e., alluvial) groundwater; and channel and floodplain morphology. The waters that support perennial flow mostly originate in the higher elevations where precipitation and snowmelt support both runoff and recharge.

Ecological Integrity Aquatic Indicators

In this section we characterize the primary change agents and current knowledge of their effects on this CE. Here for illustration, we include expected effects of common forms of development on the integrity of North American Warm Desert Riparian Woodland and Shrublands/ Streams.

Some CAs have specific expressions for each aquatic coarse-filter CE such as alteration of the expected hydrologic regime and the interacting effects of introduced aquatic species and terrestrial weed infestations. Therefore, for aquatic coarse-filter CEs, we discuss the effects of development on surface and groundwater hydrology (via changes in land- and water-use patterns); and discuss the effects of invasive aquatic species as change agents for aquatic coarse-filter CEs. We discuss these change agents and their indicators according to their effects on the size, landscape context, and condition of the biological and physical characteristics (key ecological attributes) of the CE, including the hydrology, and its expected natural regime followed by the common alterations to that regime as they occur within the ecoregion.

1. **Key Ecological Attribute: Extent / Size–** Changes in riparian corridor connectivity affect the flow of animals and nutrients with larger, longer corridors providing greater extent of habitat for wildlife and increased buffering capacity to the aquatic resource.
   a. Indicator: *Corridor Connectivity*—a measure of riparian corridor connectivity, size and extent
2. **Key Ecological Attribute: Surrounding Land Use Context** —we measure several aspects of landscape condition related to land use that affect aquatic and wetland conditions:
   a. Indicator: Landscape Connectivity—the amount (% area) of natural landscape vs. developed area within the 10 digit HUC. This is a measure of connectivity from the animal movement perspective.

b. Indicator: Nutrient/Pollutant Loading Index—a measure of the likely intensity of nutrient and pollutant loading to a stream corridor based on surrounding land uses that may be sources for such pollution.
c. Indicator: Surface Water Runoff Index—a measure of the effect of land surface development in general on runoff. Increased surface runoff can increase the potential for surface erosion, sediment loading in streams, and can change the hydrology of streams during and immediately after storm events, affecting aquatic species.
d. Indicator: Sediment Loading Index—a measure of the likely intensity of sediment runoff to a stream corridor based on surrounding land uses. Some land uses, such as active and fallow agricultural fields and other non-vegetated surfaces (such as dirt roads), can be active sources of sediment and suspended solids that degrade water quality and aquatic life habitat.
e. Indicator: Atmospheric Deposition—a measure of the annual rate of deposition of a characteristic acidic/nutrient contaminant (Nitrogen) and a characteristic toxic contaminant (Mercury) based on data from the National Atmospheric Deposition Program. Atmospheric deposition introduces pollutants into watersheds and their aquatic ecological systems from distant sources. Deposition of nitrogen (N) and sulfur (S) can cause acidification in poorly chemically buffered waters such as exist in alpine and upper montane zones in the Mojave Basin and Range ecoregion and act as nutrient pollutants at lower elevations and in well-buffered waters. Deposition of toxic substances such as mercury (Hg) can lead to impairment of organism function and reproduction at higher levels in food webs that affect macroinvertebrate productivity.
f. Indicator: Point-Source Pollution— a measure of the likely intensity of inputs from point sources of pollutants. The density of point-source discharges of chemical pollutants to water bodies in a watershed directly affects water quality within receiving waters unless permitted dischargers prevent all releases. Permitted and otherwise state-listed point sources in a watershed are identified using regulatory data and their density calculated per HUC-10 setting for each riparian-aquatic coarse-filter CE.

3. **Key Ecological Attribute: Surface Hydrology** — The surface hydrologic regime of stream ecosystems is often termed a "master variable" that shapes the biological conditions within the stream. Flow conditions – including their magnitude, timing, and duration – create a range of habitat opportunities, disturbances, and constraints that determine what organisms can persist within a stream ecosystem. These conditions also shape the geomorphology of the system which in turn imposes its own opportunities and constraints on the biology and ecology of the system. The integrity of stream flow regimes is assessed conventionally using stream gage data, comparing current conditions to historic or modeled reference conditions. Unfortunately, stream gage data are very sparse within this ecoregion. Few streams across the ecoregion have gages and these gage records rarely provide the kinds of long-term records needed to assess change in environmental flows (and are mostly located only on the largest rivers). Therefore, the "best" indicator for this key ecological attribute – an Index of Hydrologic Integrity – cannot be implemented for purposes of this REA, which must provide information across the entire ecoregion rather than for a small number of spatially non-representative gage locations. We will instead assess this key ecological attribute using indicators of water resource infrastructure and water uses. Several of the indicators for Landscape Condition discussed above also provide information on the likely effects of human activities on HUC hydrology, specifically impacts on recharge zone integrity and surface runoff. The three direct indicators of water use and one indicator of recharge zone surface integrity, below, provide additional, crucial information on the likelihood that hydrologic conditions are altered, and to what approximate extent.
   a. Indicator: Flow Modification by Dams – a measure of the magnitude of dam infrastructure within a watershed using the "F" Index developed by Theobald et al. (2010) to assess the cumulative storage capacity of dams within a HUC relative to annual stream discharge from

that HUC. The greater this cumulative capacity, the greater the potential of these dams to alter environmental flows.

b. Indicator: Surface Water Change – Upstream and within-System Augmentation / Diversion – a measure of the amount of surface water use upstream within a HUC based on published data on flow diversions, consumptive use, and augmentation (where applicable) as a percentage of the annual median discharge of the HUC. In the absence of gage data, the annual median discharge of each HUC will be estimated using output data from the Flint and Flint (2007) Basin Characterization Model.

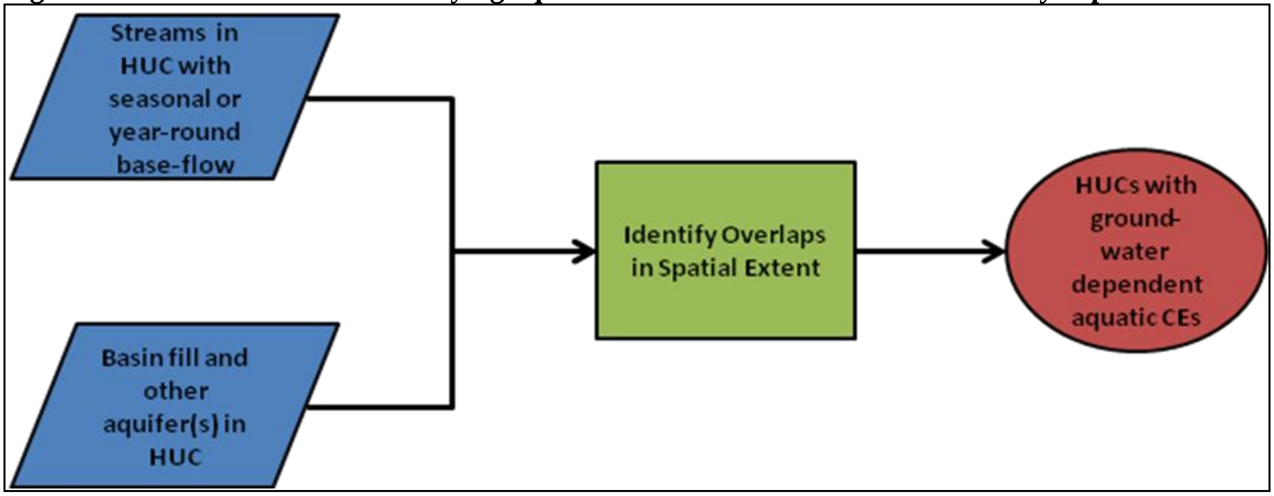
c. Indicator: Ground Water Change: Augmentation/Withdrawal of Aquifers – a measure of the amount of groundwater use within a HUC that potentially could affect aquatic CEs based on published data on groundwater withdrawals and augmentation (i.e., artificial recharge, where applicable) as a percentage of the annual median surface discharge of the HUC. In the absence of gage data, the annual median discharge of each HUC will be estimated using output data from the Flint and Flint (2007) Basin Characterization Model. Implementation of this indicator requires identifying the aquifer(s) on which stream baseflow depends. The following paragraphs describe the process by which that assessment will be carried out:

(1) Perennial stream flow in the arid West depends on groundwater discharges. The resulting baseflow may be altered by groundwater withdrawals (well pumping) and, occasionally, by the artificial introduction of water into the aquifer(s) that support a given stream. The specific aquifers on which stream baseflow potentially depends in each HUC will be identified, and evidence of withdrawals and augmentation will be extracted from the results of the USGS Southwest Principal Aquifers study and from state and USGS reports on water use, where available. Identification of the likely aquifer(s) supporting baseflow in riparian-stream systems will proceed as follows (see Figure 20). (Similar logic does not apply to the identification of the likely aquifer(s) supporting water levels in springs and seeps, because they may be supported by deeper, e.g., bedrock groundwater systems for which simple GIS overlay methods of identification are not suitable):

- Use NHD StreamStats and Baseflow Index data to identify streams with perennial baseflow, where possible.
- Overlay mapped locations of perennial streams with a map of basin fill aquifer areal extent based on the Southwest Principal Aquifers database and state databases on aquifer locations (and other characteristics, if available).
- Where there is overlap, the basin fill aquifers which the perennial streams intersect will be identified as the mostly likely candidates for the sources of baseflow to the streams in question (see Figure 20). HUCs where there are no mapped perennial streams may represent either: (a) areas where there may be groundwater resources available for exploitation without degrading groundwater-dependent stream ecosystem CEs; or (b) areas for which the data are not sufficient. (Because of this uncertainty, any project area proposed for groundwater development requires a careful ground survey to assess whether groundwater-dependent CEs are present and their likely source(s) of groundwater).

d. Indicator: Ground Water Recharge Zone Integrity—measurement of the amount of impervious cover of over a recharge zone—a measure of the extent of hardened surfaces over recharge zones (mapped based on data from Flint and Flint 2007), which decreases infiltration to soil moisture and groundwater in these zones, thereby potentially influencing groundwater hydrology and stream flow characteristics.

Figure 20. Process model for identifying aquifers on which stream CE baseflow may depend.



4. **Key Ecological Attribute: Water Quality**—This key ecological attribute focuses on direct evidence of water quality rather than on indirect evidence based on the likely sources of impairment. Three indicators originally were proposed for this key ecological attribute: (a) Turbidity; (b) Temperature; and (c) Non-Nutrient Contamination. However, it is not yet clear that these three indicators can be implemented for the Mojave Basin & Range ecoregion. Aquatic systems within this ecoregion are not sampled often enough to provide an adequate database with which to develop consistent, spatially and temporally representative water chemistry data for these three indicators. An alternative is to use:
   a. <u>Indicator: State Impaired Waters</u> — listings that categorize waters as impaired relative to their “designated uses” due to individual water quality properties. The state listings register the effects of degraded water quality due to altered turbidity, altered temperature, and a wide range of chemical contaminants. Some waters in the ecoregion contain naturally high levels of some minerals including salts of arsenic and other metals, as well as high levels of salinity in general. State standards do not apply to such naturally chemically rich waters.
   b. <u>Indicator: Buffer Sediment Loading Index</u> —The type of land use within a 200 m buffer area to streams and springs, and a nationally standard index for that type of land use sediment index can be applied to each CE in the watershed. This is a surrogate measure for direct amount of suspended solid sediment. It is important to estimate both the surrounding landscape (see Key Ecological Attribute Surrounding Land Use Context: Sediment Loading Index) and the immediate buffer area to get a more accurate picture of impact on the aquatic resources, because the amount of natural vegetative cover within the buffer area can decrease the surrounding use impacts, or lack of natural cover can increase the impact.
5. **Key Ecological Attribute: Wetland Terrestrial Biotic Condition** — This key ecological attribute focuses on the integrity of native vegetation cover – a critical biological condition.
   a. <u>Indicator: Cover of Exotic/Non-native Invasive Plant Species</u> — a measure of the impacts of non-native plant species on native plant cover. This indicator measures the presence and abundance of aggressive non-native plant species known to invade wetlands, especially those associated with human disturbance. Species such as *Tamarix* and cheat grass may drive out native species, altering habitat invertebrate composition and food trophic levels of riparian ecosystems.

6. **Key Ecological Attribute: Aquatic Biotic Condition** — This key ecological attribute focuses on the integrity of the faunal community within the water – a critical biological condition.

   a. Indicator: Benthic Macroinvertebrate Assemblage Composition Index — Benthic macroinvertebrate assemblages in desert streams are naturally variable. However, systematic surveys are feasible and routinely used by state and federal agencies responsible for regulating water quality and stream condition. These surveys can produce consistent results that support comparisons if focused on specific habitats (e.g., riffles) and sampled during a consistent hydrologic season (e.g., early summer low-flow season) during consistent flow conditions (e.g., baseflow) using standard field methods followed with standard lab and statistical methods. Standard data available are: 1) multi-indicator indices of assemblage biotic integrity, or 2) a multivariate methodology to establish statistical expectations for reference conditions against which individual samples are compared. Both approaches produce an overall score that places samples along a continuum from least- (reference-quality) to most-altered. Benthic macroinvertebrate assemblage monitoring in western streams is commonly carried out as a component of stream water quality assessment for regulatory purposes, often through systematic state-wide or ecoregion-wide sampling programs.

   b. Indicator: Native Fish Composition Index**-** This indicator was requested at the AMT 3 workshop. We have not had the opportunity to explore what data are available and the regional extent of the data for the Mojave Basin and Range ecoregion. However we assume that federal and state water quality regulatory programs in our ecoregions have native fish species databases. Water quality programs include a fish assessment index in their suite of biotic indices. In addition, fish species of concern and threatened and endangered species are more closely monitored by individual state fisheries programs, Natural Heritage Programs, and the U.S. Fish and Wildlife Service. Databases that contain information on species of concern and threatened and endangered fish species are particularly important for assessing ecological integrity because of their sensitivity to impairment. We will access all relevant state and federal databases in our ecoregion that contain location data for native fishes. Threatened and Endangered fish species are by far and away better indicators of ecosystem health than any other index of water quality. They are by nature more sensitive to impairment (including changes in ecosystem function and invasive species impacts and/or have smaller niche breadth (narrow habitat requirements), or are habitat specialists.

   c. Indicator: Aquatic Invasive Species Impact Index – a measure of the likely impact of aquatic invasive species on stream biotic integrity. The aquatic invasive species (taxon) impact index includes indicators that focus on the most important ecological and landscape factors identified in invasive species life history from ecological and invasion theory (Barney and Whiltlow 2008; McKinney and Lockwood 1999; Parker et al. 1999; Pimm 1989; Shigesada and Kawasaki 1997; and Williamson 1996). Indicators in this model are separated into two major categories: 1) Within HUC and 2) Surrounding HUCs. For full discussion with tables of individual indicator scores, see Appendix IV. Aquatic Invasive Species Impact Index

      (1) Within HUC indicators--The within HUC indicators address factors that influence impact once an invasive species is present in a HUC. The indicators are broken down into several categories: number of invasives, % area of HUC infected, infection levels, relative taxa impact, connectivity, use, and time since infection.

         a) Number of invasives and Percent CEs infected**--** The three most important indicators in the entire suite of indicators are: 1) the number of invasive taxa present in a CE within a HUC, 2) the number of invasive taxa present in different CEs within a HUC that are likely to invade the target CE and, 3) the percent area of HUC infected, relative to the mean HUC size. This is simply because the greater the number of invasive taxa there are in a CE or similar CEs and the greater the percentage of CEs that are infected within a HUC (represented by the percent area), the greater the loss of ecological integrity. Percent area of HUC infected will apply only to stream CEs. Obviously, if no invasive taxa are in a CE or in similar CEs within a HUC there is no invasive impact to that CE although there is always potential.

b) Infection levels and relative taxa impact

- In addition, the level of infection (density or biomass of the invasive taxon) in a CE and HUC is important to the ecological integrity of that CE and HUC. Higher densities of invasive taxa increase dispersal rates and are strongly correlated with impact severity. Higher densities increase potential propagules (Veltman et al. 1996; Lockwood et al. 2005; Colautti et al.2007) and are nearly always incorporated into data rich invasion models (Shigesada and Kawasaki 1997). For this indicator we identified a data gap: the level of infection data are not currently available. Only one of our databases reported densities of invasives and that was for only one of the invasive taxa. None of our databases reported biomass of invasives.
- Some invasive taxa are considered to be more harmful than others; what we describe as "the relative invasive taxa impact." In addition to agreeing on the definition of harmful (which in itself is extremely problematic), relative impact (harm) is dependent on an invasive taxon's density or more significantly, its biomass. Pound- for- pound, gram- for- gram, each invasive taxon has its unique impact on an ecosystem. Without estimates of densities or biomass we will be unable to model these two important factors that determine an invasive taxon's impacts on ecological integrity.

c) Connectivity and Use

- The connectivity of CEs is important to aquatic invasive impact. The more connected a water body type is the more an invasive is likely to spread throughout it or into it from other infected areas. In general, springs and lakes are less connected than streams or rivers. Invasives also tend to disperse more readily downstream than upstream, however we will not have the ability to measure amount of downstream CE available from each invasive point location due to data and resource limitations. The connectivity indicator will utilize the Riparian Corridor Continuity Measurement but will be scored inversely to indicate that connectivity is undesirable in the presence of invasives.
- The more recreational use, road density, and human encroachment, the more likely a CE is to be impacted by invasives. We are exploring using state designated fishing access points as data sources.

d) Time

- Time is inherent in any ecological model. Time since first invasion in a CE and HUC can affect the level of impact. The longer a taxon has been in a CE in a HUC the more time it has had to elicit a negative impact and to reduce ecological integrity. In general, very recent arrivals have not had time to cause impacts but given enough time they may.

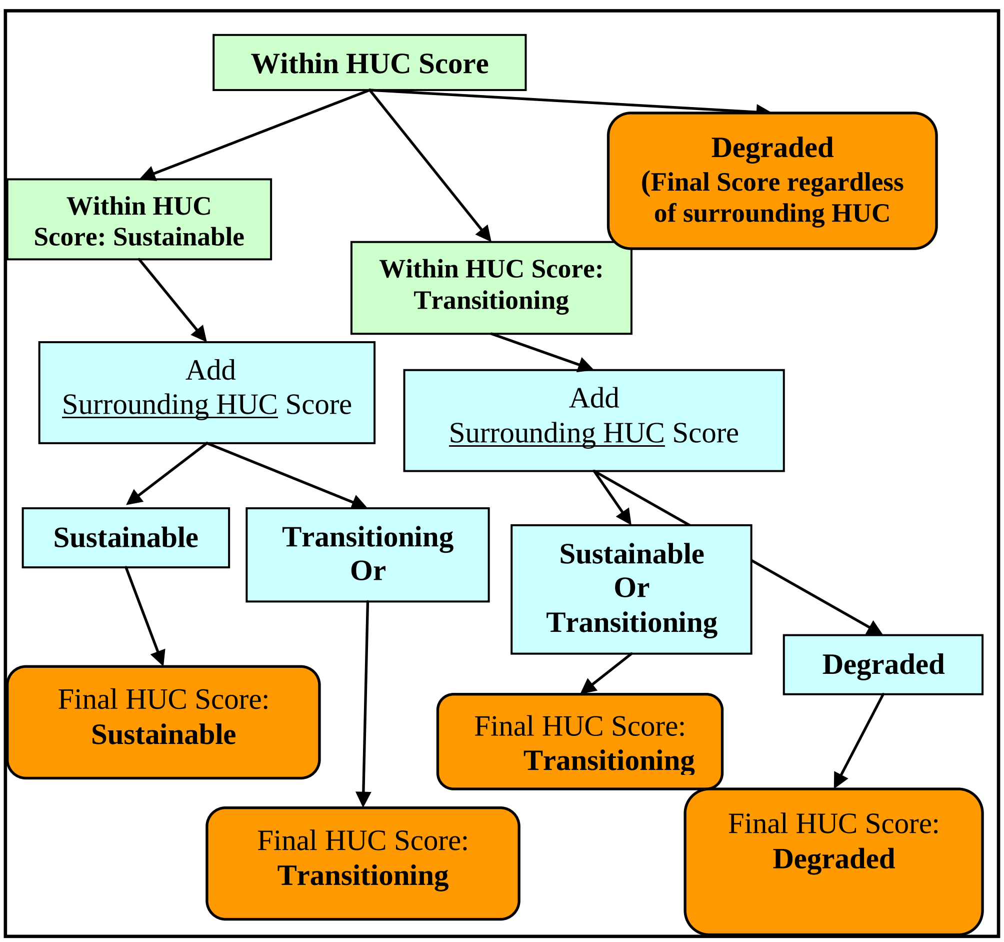
(2) Surrounding HUC indicators -- Since no HUC is an island and invasion potential is strongly related to conditions in other areas, we have included indicators from surrounding HUCs.

a) Distance-- Invasion potential is directly correlated with distance from nearest invaded location. This is one of the most important factors in invasion biology (Shigesada and Kawasaki 1997). We cannot measure this on an ecoregional scale; however, we will apply the same indicators (as outlined above) to the HUC 8 level. For any invasive species that is present in a HUC 8 that is not present in the HUC 10, we will rank the likelihood of invasion to the HUC 10 watershed. We will compare the HUC

8 level to the HUC 10 level, with the HUC 8 as the "surrounding HUCs". We will apply the same indicators as used for the within HUC and then compare HUC 8 results with each HUC 10 to determine final HUC 10 score.

(3) Indicator selection and scoring --The indicators that we are considering are tentative at this time, particularly their score values. It should be noted that almost all indicator scores in any rapid assessment are subjective. Indicator scores require thought and consideration before selection and need to be carefully scrutinized and validated after their selection. We have not fully determined scoring value criteria for any of the proposed invasive species indicators and will continue this process with the AMT. As such, each indicator score is only divided into three categories (values): Sustainable (= 3), Transitioning (= 2), or Degraded (= 1). Although it is generally recognized that some indicators are more influential for invasive impact levels than others, it can often differ between taxa. We are presently evaluating and considering assigning weighting factors for each of the indicators and/or groupings of indicators. Figure 21 illustrates the process of indicator scoring: Combine and average the scores of the indicators and indicator categories in the Within HUC indicators, and then combine with the Surrounding HUC Score.

Figure 21. Flow chart of aquatic invasive species impact index scores.



7. **Key Ecological Attribute: Landform Condition**— Natural stream bank slopes, and connectivity between the stream and its floodplain (where geological conditions permit formation of a floodplain), are crucial to proper function in riparian-stream ecosystems.
   a. Indicator: Floodplain Hydrologic Connectivity — a measure of the amount of development and road crossing in the riparian zone itself, also called land use encroachment. Such encroachment can confine streams to narrower channels through levee constructions, channelization and building in the floodplain (Theobald et al. 2010). While road crossings and agricultural fields can allow flooding to occur, these land uses still replace and reduce the area of native riparian vegetation and habitat, which creates conflict for fish and other wildlife use, as well as the direct impact of loss of riparian habitat. Reduction of riparian vegetation and channelization causes changes in the timing and velocity of flood waters downstream of impacted reaches, which in turn can change stream discharge rates and ground water volumes for the catchment as a whole. Sideslope influences and floodplain connectivity change from headwater segments to larger meandering reaches. These processes could be influenced by climate change through altered rates of hillslope failure, debris flow, tributary sediment inputs and stream ability to move additional sediment loads and maintain or change channel configurations (Theobald et al. 2010). Increased encroachment into riparian zones and the loss of the floodplain and sideslope processes reduces the capacity of riparian ecosystems to sustain their biological integrity while they adjust physically to changes in flow regimes, including those caused by climate change.

Aquatic Integrity Scorecard

Table 15 lists the key attributes, their indicators, and threshold values for ecological integrity assessment. The table includes indicators that would be preferred but cannot be implemented in the Mojave Basin and Range ecosystem due to the reasons noted above. The last column contains a score for a hypothetical HUC such as the White River but the values are for illustration purposes only. We summarize all of the indicator values into a single final score for the Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland /Stream CE.

Table 15. Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland /Stream CE Aquatic Ecological Integrity Indicators, with example score for hypothetical HUC.

Key Ecological Attribute and Indicator(s) n=20		Definition and Measurement	Sustainable	Transitioning	Degraded	Score
Used in CBR REA		Index Value (unless otherwise stated)	0.9	0.6	0.25	
Extent / Size (1 indicator)						
Yes	**Riparian Corridor Continuity**	Indicates the degree to which the riparian areas exhibit an uninterrupted vegetated corridor. A measure of the linear, continuous unfragmented riparian corridor. Calculated by *CircuitScape*	>20% of riparian reach with gaps/breaks due to cultural alteration	>20-50% of riparian reach with gaps/breaks due to cultural alteration	>50% of riparian reach with gaps/breaks due to cultural alteration	**.6**

Key Ecological Attribute and Indicator(s) n=20		Definition and Measurement	Sustainable	Transitioning	Degraded	Score
Surrounding Land Use Context (7 indicators)						
Yes	**Landscape Connectivity** (Surrounding HUC 8 Digit)	A measure of the percent of unaltered (natural) habitat within a 1,000 ha ($10km^2$) or surrounding HUC (8 digit). Also measured by CircuitScape for each reporting unit.	Intact to Variegated: Embedded in 60-100% natural habitat; habitat connectivity is generally high, but lower for species sensitive to habitat modification.	Fragmented: Embedded in 10-60% natural habitat; connectivity is generally low, but varies with mobility of species and arrangement on landscape.	Relictual: Embedded in < 10% natural habitat; connectivity is essentially absent.	**.6**
Yes	**Nutrient/ Pollutant Loading Index** (From surrounding Landscape)	Cumulative effect of land use within the watershed contribution to runoff to the aquatic CE. A measure of the varying degrees to which different land uses contribute excess nutrients and pollutants via surface water runoff and overland flow into a wetland (As measured by NPSECT	Nutrient Pollutant Loading Index = 0.8 – 1.0	Nutrient Pollutant Loading Index = 0.51 – 0.79	Nutrient Pollutant Loading Index <0.5	**.9**
yes	**Surface Water Runoff Index** (from surrounding landscape)	Cumulative effect of land use within the watershed contribution to runoff to the aquatic CE. A measure of the varying degrees to which different land uses contribute excess nutrients and pollutants via surface water runoff and overland flow into a wetland (As measured by NPSECT	Surface Water Runoff Index = 0.8-1.0	Surface Water Runoff Index = 0.51 - .79	Surface Water Runoff Index <0.5	**.9**
Yes	**Sediment Loading Index** (from surrounding landscape)	Cumulative effect of land use within the watershed contribution to runoff to the aquatic CE. A measure of the varying degrees to which different land uses contribute excess nutrients and pollutants via surface water runoff and overland flow into a wetland (As measured by NPSECT	Sediment Loading Index = 0.8 – 1.0	Sediment Loading Index = 0.51– 0.79	Sediment Loading Index <0.5	**.6**
Yes	**Atmospheric Deposition**	Rate of deposition of NO_x and Hg per unit area within HUC.	TBA	TBA	TBA	
Yes	**Point-Source Pollution** (known mapped points)	Density of permitted and legacy point discharges within HUC10.	None	1-2	>2	**.9**

Key Ecological Attribute and Indicator(s) n=20		Definition and Measurement	Sustainable	Transitioning	Degraded	Score
Hydrology Condition (5 Indicators)						
No	**Index of Hydrological Integrity** *(not feasible in CBR due to data gaps)*	Compares current hydrologic regime as represented by 9 “environmental flow component” (EFC) sub-indicators that capture information on the frequency distribution of seasonal high, median and low flow magnitudes for a period of record (stream gauge data) to frequency distributions to expected natural distributions. This requires long term gage records with are not available throughout the ecoregion. This indicator will not be applied ecoregion wide.	Average similarity between observed and expected EFC frequency distributions 0.67-1.00	Average similarity between observed and expected EFC frequency distributions 0.34-0.66	Average similarity between observed and expected EFC frequency distributions 0.00-0.33	**.6**
Yes	**Flow Modification by Dams**	"F" Index (Theobald et al. 2010)-- Dams and their storage capacity relative to annual stream discharge	F index >0.90	F index = 0.75- 0.90	F Index <0.75	**.9**
Yes	**Surface Water Change: Upstream and within-System Augmentation / Diversion**	Cumulative percent of annual median discharge augmented or removed.	Percent added/removed is <10% of average annual natural median flow	Percent added/removed is 10-25% of average annual natural median flow	Percent added/removed is >25% of average annual natural median flow	**.9**
Yes	**Ground Water Change: Augmentation/ Withdrawal of Aquifers**	Cumulative percent of annual median discharge augmented or withdrawn by artificial recharge to the aquifer(s) on which stream baseflow depends.	Percent added/withdrawn is <10% of average annual natural median flow	Percent added/withdrawn is 10-25% of average annual natural median flow	Percent added/withdrawn is >25% of average annual natural median flow	**.6**
Yes	**Groundwater Recharge**	Measures the integrity of the groundwater recharge zone (HUC 4 or 5) by percent area in natural land cover.	Average percent >67% across all 270 x 270m pixels identified as recharge areas	Average percent 34-66% across all 270 x 270m pixels identified as recharge areas	Average percent <34% across all 270 x 270m pixels identified as recharge areas	**.9**
Water Quality Condition (3 indicators)						
Yes	**Stream Other Water Quality Conditions: State-Listed Water Quality Impairment**	Measures the integrity of water quality conditions in individual water bodies based on the presence and severity of state listings of water quality impairments for State 303(d) reporting requirements under the federal Clean Water Act – excluding nutrient enrichment, which is addressed by a separate key ecological attribute.	Natural or Native reference conditions or Minimal changes in the structure of the biotic community and minimal changes in ecosystem function	Evident to moderate changes in structure of the biotic community and minimal to moderate changes in ecosystem function	Major to severe changes in structure of the biotic community and moderate changes to major loss in ecosystem function	**.9**

Key Ecological Attribute and Indicator(s) n=20		Definition and Measurement	Sustainable	Transitioning	Degraded	Score
No	**Stream Nutrient Condition: Nitrogen and Phosphorus Availability Data Gap**	Measures the integrity of the stream chemistry regime based on the biological availability of N and P relative to reference conditions. While this is an important indicator for aquatic health, the data are not available. This indicator will not be used.	Average concentration of biologically available N and P falls within range of water quality reference sites of this system type in the ecoregion.	Average concentration of biologically available N and P exceeds range of water quality reference sites of this system type in the ecoregion but falls within the middle 50% (25th to 75th percentile) of all sites of this system type in the ecoregion.	Average concentration of biologically available N and P exceeds range of water quality reference sites of this system type in the ecoregion and falls in the bottom 25% of all sites of this system type in the ecoregion.	**.9**
Yes	**Sediment Loading Index** (From immediate buffer area 200 m)	Cumulative Sediment Loading by Index Coefficients measured by percent different land uses contribute excess sedimentation and suspended solids via surface water runoff and overland flow into a wetland, as measured by NSPECT	Sediment Loading Index = 0.8 – 1.0	Sediment Loading Index = 0.51– 0.79	Sediment Loading Index <0.5	**.6**
Wetland Terrestrial Biota Condition (1 Indicator)						
Yes	**Cover of Exotic/Non-native Invasive Plant Species**	Not all non-native species are aggressive. These indicators measure the presence and estimate the abundance of aggressive non-native plant species known to invade wetlands, especially those with human disturbance.	Exotic invasive plant species absent or, if present no more than 1-2% cover.	Exotic invasive plant species prevalent (3–10% cover).	Exotic invasive plant species abundant (>10% cover).	**.25**
Aquatic Biota Condition (3 Indicators)						
Yes	**Benthic Macro-invertebrate Assemblage Composition Index**	Measures the integrity of the benthic macroinvertebrate assemblage based on a multivariate "O/E" methodology or a multi-indicator index of biological integrity (IBI) and state aquatic life use standards	Natural or Native reference conditions or Minimal changes in the structure of the biotic community and minimal changes in ecosystem function	Evident to moderate changes in structure of the biotic community and minimal to moderate changes in ecosystem function	Major to severe changes in structure of the biotic community and moderate changes to major loss in ecosystem function	**.6**
tbd	**Native Fish Composition Index**	Index of expected fish for the stream reach. Have data for Utah, still exploring data availability from Nevada, Arizona and California	TBA	TBA	TBA	
Yes	**Invasive Aquatic Index**	A sum of the within HUC and surrounding HUC Aquatic Invasive Index for Stream CE.	See Aquatic Invasive Index (see Appendix IV)	See example scoring for HUC and Surrounding HUC (Appendix IV)		**.25**

Key Ecological Attribute and Indicator(s) n=20		Definition and Measurement	Sustainable	Transitioning	Degraded	Score
Landform Condition (1 indicator)						
Yes	**Lateral Floodplain Hydrologic Connectivity**	Riparian zone/Valley Confinement Index (Theobald 2010). This measures what land uses occur within the floodplain that separate the stream channel from its adjacent floodplain.	Completely connected to floodplain; no geomorphic modifications made to contemporary floodplain. OR Minimally disconnected from floodplain; up to 25% of streambanks are affected.	Moderately disconnected from floodplain due to multiple geomorphic modifications; 25 – 75% of streambanks are affected.	Extensively disconnected from floodplain; > 75% of streambanks are affected.	**.6**
∑ sum of 19 indicator scores = 13.40 Divided by 19 = 0.70 **'Transitioning'**						**0.70**

Climate Change Effects on Aquatic CEs – Hydrologic Regime Alteration

The effects of climate change on the hydrology of aquatic coarse-filter CEs will vary; however, current broad patterns of climate change are being detected and are widely expected to have the following effects:

- Snow accumulation will begin later in the fall and snowmelt will conclude earlier in the spring although the total water content of snowpack itself may not change. As a result, for streams that depend in part on a spring snowmelt pulse, the duration of that pulse will shrink. Depending on how abruptly snowmelt concludes, its timing may shift out of synchronization with the reproductive needs of some aquatic species. These effects would be expected to emerge nearly in synchrony with the changes in climate.
- Higher air temperatures will result in higher rates of evapotranspiration (ET) during the growing season reducing the amount of soil moisture that infiltrates to sufficient depth to recharge near-surface aquifers. In addition, the predicted shift to less frequent but more intense warm-season precipitation events will result in a greater proportion of rainfall becoming runoff rather than infiltration. The combination of these shifts will result in a reduction in groundwater recharge which in turn, over the course of decades to centuries, will result in lower aquifer water levels. Therefore there may be lower discharge rates to springs and lower baseflow in streams that receive discharges from basin-fill and bedrock aquifers.
- The predicted higher rates of ET will affect riparian as well as upland vegetation. Higher riparian ET rates will contribute to lower baseflow in their associated streams as more groundwater is intercepted by riparian root systems. The shortened timing of the spring snowmelt pulse (where this is present) would also reduce the ability of this pulse to recharge alluvial aquifers. This shift would add to the stress on riparian vegetation and, in combination with the increase in riparian ET rates, further reduce the availability of alluvial aquifer groundwater to sustain baseflow later in the warm season. These effects would be expected to emerge nearly in synchrony with the changes in climate. Similar effects are expected for other kinds of wetlands, including those supported by spring and seep discharges: higher rates of ET will consume more of the available water potentially leading to smaller wetland areas, shorter wet seasons (for seasonal wetlands), and associated shifts in vegetation.

- The predicted shift to less frequent but more intense warm-season precipitation events may initially increase the frequency of intense flow pulses within stream channels and associated flooding in riparian zones. However, over time-spans of years to decades, the shift in warm-season runoff and high-flow events is likely to result in channel erosion and entrenchment followed (over a timeframe of several decades or more) by the establishment of a new, lower floodplain and stable channel. Throughout the time-span of these changes in-stream habitat will be unstable and of poor quality along many reaches.
- The predicted shift to warmer air temperatures and greater watershed-scale and riparian ET, and a possible reduction in average annual precipitation overall, are likely to result in lower annual average total stream discharges. This change in overall discharge would be expected to emerge nearly in synchrony with the changes in climate.
- The predicted shifts in snowmelt and rainfall runoff events and stream baseflow are likely to immediately increase sediment transport into and along stream courses and raise average and maximum stream water temperatures.

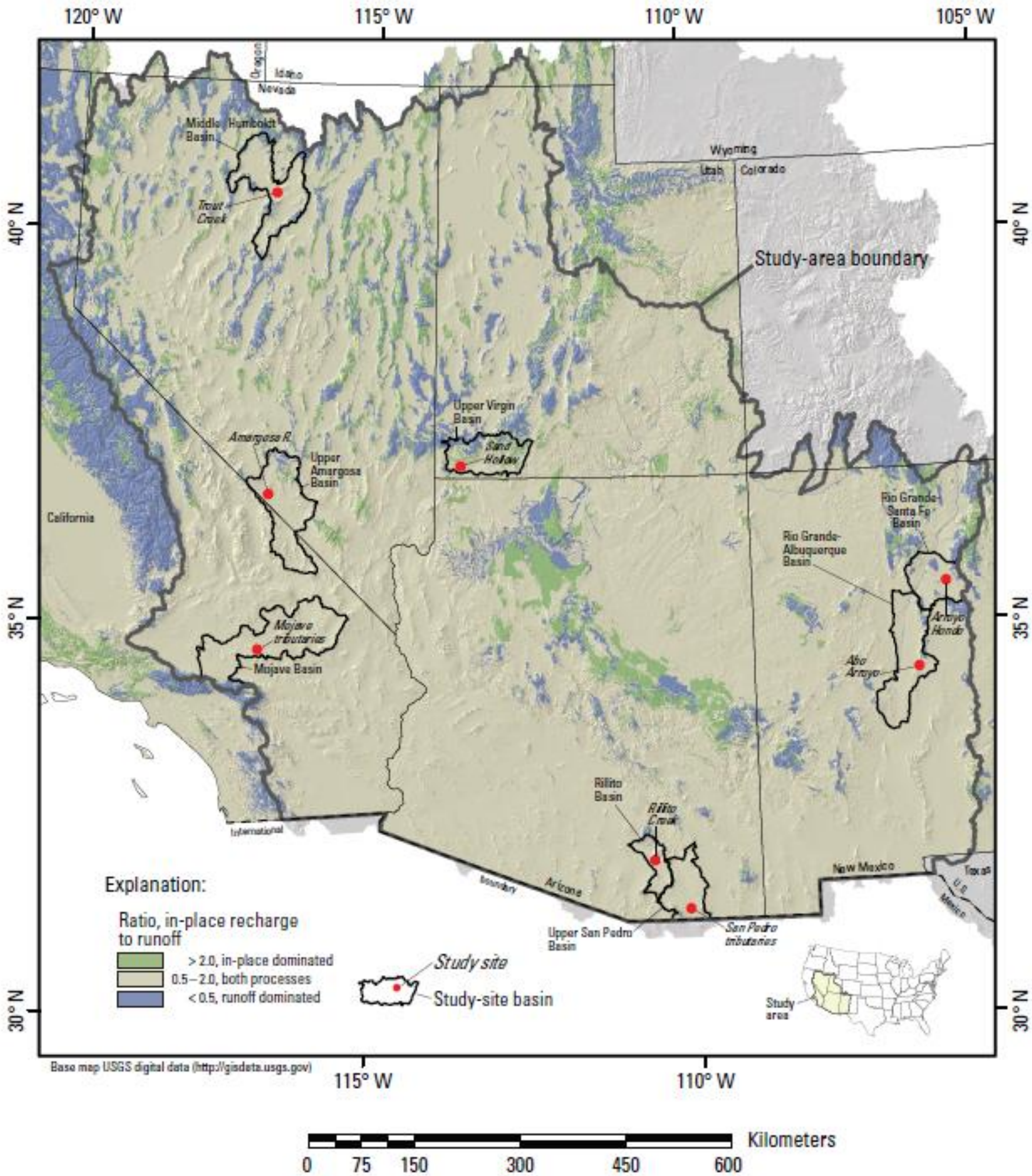
The assessment of the potential effects of climate change on aquatic coarse-filter CEs will follow that described earlier in this Memo for the assessment of terrestrial coarse-filter CEs. Specifically, it will build directly on Steps 1 and 2 of that latter assessment in order to:

1) Establish the historical bioclimatic envelope;
2) Assess the pattern of departure of the current bioclimatic envelope from the historic baseline;
3) Assess the pattern of departure of the future bioclimatic envelope from historic and current conditions; and
4) Assess the potential consequences of these departures for watershed hydrology.

The assessment for aquatic coarse-filter CEs will differ in one significant way from that for terrestrial CEs. The mapped distributions of terrestrial coarse-filter CEs establish large areas across which the grid of climate data (e.g., 4km PRISM) can be overlaid to identify all climate grid units within the ecoregion in which each terrestrial coarse-filter CE is present. The “bioclimatic envelope” approach for each terrestrial coarse-filter CE then plots the bioclimatic space for its climate grid units as a set of graphs of temperature vs. precipitation for three ecological seasons (early growing, late growing, non-growing), and the annual average (see Climate Change Effects on Terrestrial CEs, above). In contrast, most aquatic coarse-filter CEs consist of linear and point features – e.g., riparian-stream networks, springs, wetlands – rather than as areas over which one can lay a grid of climate data. Further, every aquatic coarse-filter CE depends for its hydrology not on climate conditions immediately overhead, but on the climate conditions that affect the entire surface watershed and/or groundwater zone from which it receives its water. *As a result, the appropriate spatial frame for assessing the potential effects of climate change on aquatic coarse-filter CEs is the zone(s) within each HUC primarily responsible for producing surface runoff and groundwater recharge*.

Flint and Flint (2007) have used their Basic Characterization Model methodology to identify the land surface ares principally responsible for producing surface runoff and groundwater recharge across the entire Mojave Basin and Range ecoregion (and beyond), on a 270m grid, as illustrated in Figure 22. As would be expected for the arid regions of the interior western U.S., runoff and recharge arise primarily at higher elevations.

Figure 22. Ratio of in-place recharge to runoff-dominated ground water recharge zones.
(from Flint and Flint 2007, Figure 13, p.51).



The findings from the Flint and Flint (2007) study suggest two options for delineating and assessing the bioclimatic envelope for each aquatic coarse-filter CE: (1) use the combined recharge-runoff zone within each HUC within which each CE occurs; or (2) use the HUC12 catchments in which each CE occurs AND their uphill neighbors within the same HUC10. The former approach would focus the bioclimatic assessment on the factors that generate runoff and recharge; the latter approach would also incorporate information on areas within the watershed for each CE in which evapotranspiration dominates over either runoff or recharge. The latter approach is more comprehensive and therefore is recommended.

Thus, *the spatial frame for assessing the bioclimatic envelope for each aquatic coarse-filter CE will consist of the HUC12 watersheds in which each CE occurs AND all other HUC12 watersheds that lie uphill from these core HUCs within the same HUC10 watershed*. For alpine and montane riparian-stream CEs the resulting spatial frame will be nearly identical to the spatial frame that would be defined using the runoff and recharge zones identified by Flint and Flint (2007). For lower-elevation CEs – including spring and seep systems, natural lakes, playas, and lower-elevation riparian-stream systems – the resulting spatial frame will include portions of the landscape across which ET dominates over runoff and recharge.

The specific steps proposed for the assessment of the potential effects of climate change on aquatic coarse-filter CEs are as follows:

1) <u>Establish the historical bioclimatic envelope</u>

For each aquatic coarse-filter CE, identify the 12-digit (level 6) HUCs that meet the criteria specified above. The methods for tabulating the bioclimatic envelope then follow those described above for the assessment of the potential effects of climate change on terrestrial CEs, Step 1. This step focuses on the historic period of 1900-1980 and tabulates data on temperature vs. precipitation for three ecological seasons (early growing, late growing, non-growing), as well as for the annual average (see Step 1, Climate Change Effects on Terrestrial CEs, above).

2) <u>Assess the pattern of departure of the current bioclimatic envelope from the historic baseline</u>

This step uses the same spatial frame established for Step 1 for each aquatic coarse-filter CE. The methods for tabulating the current bioclimatic envelope then follow those described above for the assessment of the potential effects of climate change on terrestrial CEs, Step 2. This step focuses on the "current" period of 1995-2010, the findings for which will then be compared to those for the historic baseline period (see Step 2, Climate Change Effects on Terrestrial CEs, above).

3) <u>Assess the pattern of departure of the future bioclimatic envelope from historic and current conditions</u>

This step uses the same spatial frame established for Steps 1 and 2 for each aquatic coarse-filter CE. The methods for tabulating the current bioclimatic envelope then follow those described above for the assessment of the potential effects of climate change on terrestrial CEs, Step 3. As described above for the assessment of terrestrial CEs, this step focuses on two separate future climate datasets – USGS 15km downscaled climate model outputs (USGS-CD) and EcoClim, a 10km downscaled climate dataset created in the CA Academy of Science lab; and two future time steps, 2020's and 2050's (see Step 3, Climate Change Effects on Terrestrial CEs, above).

4) <u>Assess the potential consequences of these departures for watershed hydrology.</u>

The climate variables addressed in Steps 1-3 are key *drivers* of watershed hydrology rather than direct measures of watershed hydrology. In order to assess the potential effects of these drivers on actual watershed hydrology, it is necessary to identify the ways in which historic change in the bioclimatic envelope for an individual aquatic coarse-filter CE affected historic watershed hydrology. This historic relationship will then provide a basis for estimating how additional changes in the climate drivers, due to climate change, would likely affect watershed hydrology in the future.

The ideal method for assessing how historic change in the bioclimatic envelope for an individual aquatic coarse-filter CE affected historic watershed hydrology would be to examine stream gage and spring water level data for the same historic period encompassed by the climate data analyzed for Steps 1 and 2 above. Unfortunately, few such long-term records exist and the stream gage records are heavily affected by patterns of human land and water use. Assessing the effects of climate change on these gage records requires subtracting out the effects of human alterations to the watershed and water budget. While modeling tools exist for this purpose they are beyond the scope of the REA.

Fortunately an alternative exists from the Flint and Flint (2007) study. Their results provide modeled estimates of monthly runoff, groundwater recharge, snowpack, and other hydroclimatic variables on a 270m grid which can be aggregated to HUC12 and HUC10 monthly values for the historic and "current" periods defined above for the bioclimatic envelope assessment. These values provide an estimate of watershed function independent of the effects of other human alterations to the watersheds and their water budgets. These estimates will support an assessment of the ways that watershed hydrologic variables (e.g., monthly runoff, groundwater recharge and snowpack) may have changed in relationship to any changes in their bioclimatic envelope between the baseline and current periods. These relationships will then provide the basis for a qualitative assessment of the ways in which future climate change, i.e., change in the bioclimatic envelope for each CE as assessed in Step 3 above, potentially could affect watershed hydrology.

Note: It would be preferable to also use the Flint and Flint Basin Characterization Model (BCM) methodology to develop projections of the watershed hydrologic variables themselves under different possible future climatic regimes. This is fully within the methodology and in fact the Flints are using their BCM methodology to assess climate futures in many western regions (Lorraine and Alan Flint, personal communications, 2010-2011). Unfortunately, the Flint and Flint team have so far completed future climate estimates using only a single GCM-Emissions Scenario combination (GFDL+A2) and resources are not presently available to support their completion of additional runs using other GCMs. Achieving compatibility with the terrestrial methodology and with the methods of climate change assessment proposed by the BLM across all REAs dictates the methods proposed here. Should additional climate-futures estimates become available from the Flint and Flint team, however, we will incorporate them into this assessment.

Step 4 therefore will include the following sub-steps for each aquatic coarse-filter CE:

a. Aggregate the Flint & Flint (2007) 270m monthly output data for the baseline and current time periods by the spatial frame for each aquatic coarse-filter CE as described above, and by season (also see above). The remainder of this discussion focuses on riparian-stream systems, but similar analyses will apply to the springs and seeps, lakes, and playas.
b. Use the aggregated watershed data to calculate the following three "environmental flow components" (EFCs) for each water-year in the two periods: (1) Seasonal maximum monthly discharge, (2) Seasonal minimum monthly discharge, and (3) Seasonal median monthly discharge.
c. Use the aggregated watershed data to calculate the following three additional hydrologic values for each water-year in the same periods: (1) Cumulative snowpack (water equivalent), (2) Date of snow accumulation onset, and (3) Date of snowmelt end.
d. Prepare a qualitative assessment of how these six hydrologic variables have changed in relationship to the changes seen in the bioclimatic envelopes between the baseline and current periods. This qualitative assessment will be accompanied by a review of the findings of Flint and Flint on changes in watershed hydrology in relationship to changes in hydroclimatic conditions over this same time-span.
e. Prepare a qualitative assessment of how these six hydrologic variables are likely to change in relationship to the changes seen in the forecasts for the bioclimatic envelope for each CE based on the findings in Step 4.d

Development Change Agent (CA) Models

In this section we present models necessary for the generation of development CAs for the current or 2025 scenarios. In cases where a CA is represented completely by existing data that CA will not be presented here, please see Memorandum I-2-c. Renewable energy development CAs are dealt with in the **Other Specific Assessment Models** section below.

Grazing

USGS commented that grazing should be included as a CA. This issue was discussed thoroughly in AMT1 and 2 workshops and it was decided to defer inclusion because there was no known data to adequately represent grazing on the landscape despite its importance. Because grazing is a fairly ubiquitous use, the REA would not likely benefit from spatial analyses of grazing and it is suggested that this be a special assessment outside of the REA.

Recreation

We will estimate the relative levels of dispersed recreation use through established modeling approaches (e.g., Theobald 2008) that combine data on traffic volume with accessibility (Figure 23). This assumes that the majority of visitors to BLM and other public lands accessed these areas via the road transportation infrastructure via an automobile. In this case, a rough surrogate for visitor use is the "push" factor as measured by highway traffic volume estimates (based on Average Annual Daily Traffic; AADT), which can be thought of as the number of automobiles that pass by a given location per day. We will use estimated AADT from the NTAD from 2010 which is available for most interstate and state highways. We will also use urban population in nearby towns to complement the "push" factor. This will average the relative loads of nearby urban pressures with those driving from other urban centers. We will contact state DMV to try to adjust estimates of off-road vehicle (ORV) use based on registration statistics (at county-level). We will also work with the AMT and NOC to contact BLM field offices to request information that we can use to identify special use areas reported in land use management plans as well as areas that are known to have high use (e.g., Gold Butte area south of Mesquite) based on data collected by specific studies and expert knowledge from recreation specialists.

An accessibility model is then used to route the traffic volume through the remaining transportation network consisting of remaining highways, secondary roads, local roads, designated OHV route network, and other "linear disturbances". Accessibility is a common GIS analysis (e.g., Theobald et al. 2010) and measures travel time (e.g., miles per hour) based on typical speed limits for given functional road classes (i.e. interstate=65, highway=55, secondary road=45, local road=30, unimproved/4WD road=10). For off-road travel, we will estimate travel time based on walking speeds, adjusted by the steepness of the terrain (using Tobler's equations; Theobald et al. 2010). To generate the accessibility surface, we will use the "linear disturbance" dataset currently being constructed by the BLM. We will assume that all areas except designated wilderness areas and DOD lands will be accessible.

We will investigate the use of "attraction" factors such as topographic roughness (e.g., hills and ravines that are often used by ORV and mountain bike enthusiasts) or designated ORV recreation areas (e.g. Johnson Valley, California, Dry Valley, NV). Based on literature estimates of trail use as a function of distance from trailhead, we will apply a distance decay function where use declines by half with every 30 minutes of travel. We will calibrate this model with visitor use data from available protected areas, mostly from National Park and National Forest estimates.

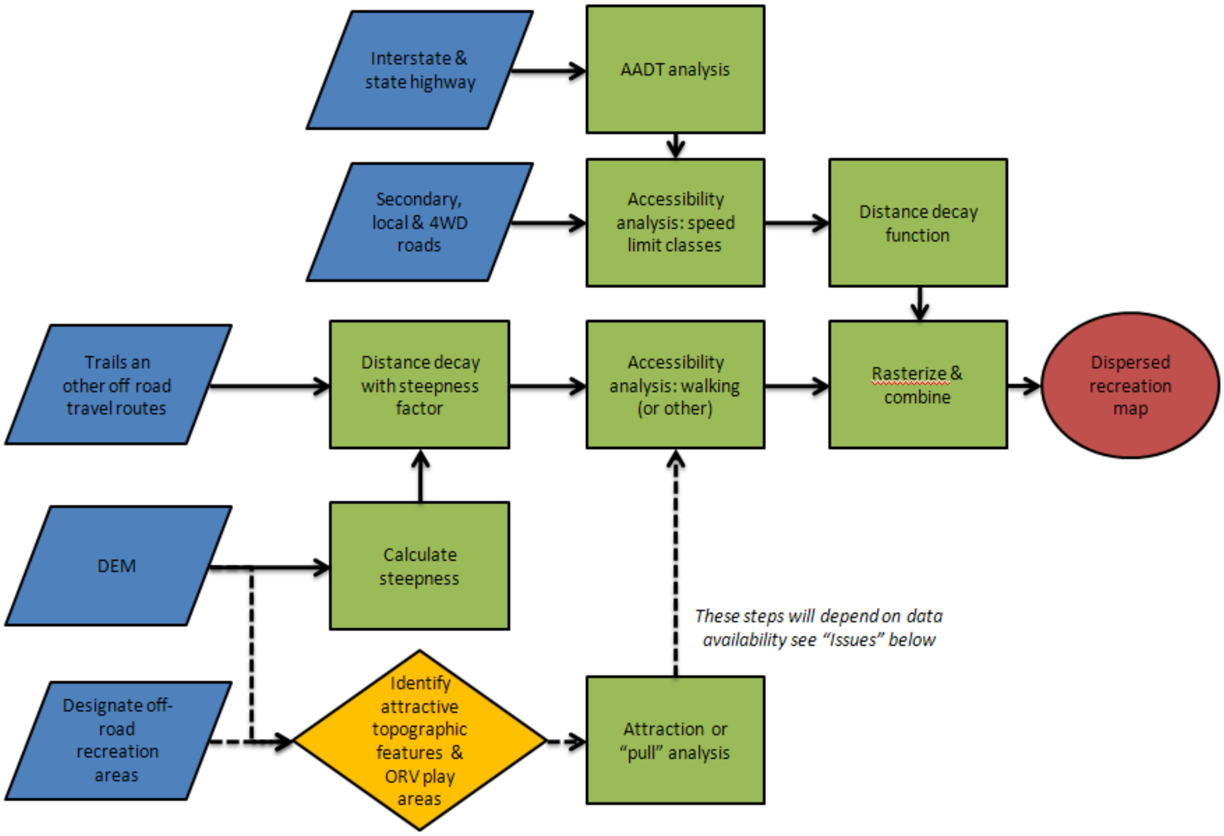
In response to comments and suggestions obtained at the workshops, we will generate 4 runs of the recreation model (see Table 16) to distinguish aquatic (fishing, boating) from land-based recreation, and motorized from non-motorized recreation. Although there is interest in examining future potential impacts associated with likely increases in motorized recreational use, we lack enough data and knowledge to adequately model future scenarios. Additionally, we will schedule a webinar for interested AMT members (and designees) to review our draft model results and assist in calibrating models.

Table 16. Recreation model inputs by recreation type.

Name	Travel mode	Push factors	On-highway/road transportation	Off-highway/off-road transportation	Pull factors*
Boater/fisher	Aquatic/Motorized	Urban populations, highway traffic volume, marinas and boat launches**	Road speed (Interstate=65; highway=55; secondary=45; local=30)	Publicly-accessible lakes, reservoirs, & rivers; navigable; (average boat speed 20-30 mph)	beach sites, ruins, caves, fishing spots
OHV enthusiast	Motorized (2W & 4W ATVs/OHVs)	Urban populations, highway traffic volume; designated OHV use areas in land management plan; Study-specific use levels	Road speed (Interstate=65; highway=55; secondary=45; local=30)	Designated OHV use, race courses, tracks, etc. OHV designated route network; Informal high concentration areas***; Linear disturbances	Race courses; topography, washes, terrain
OHV hunter/rock hounding, etc.	Motorized (2W & 4W ATVs/OHVs)	Urban populations, highway traffic volume; ATV/OHV sales	Road speed (Interstate=65; highway=55; secondary=45; local=30)	OHV designated route network; linear disturbances; washes	Caves, abandoned mines, ruins, peaks, lakes, springs/seeps
Hiking/biking	Non-motorized (hiking/biking)	Urban populations, highway traffic volume	Road speed (Interstate=65; highway=55; secondary=45; local=30)	Dirt roads, trails, linear disturbances, washes, slope	Topography, springs, ruins, slot canyons, peaks

*As suggested by feedback on earlier memos, we will try to incorporate these landscape features into the model, to the degree that electronic spatial data are available. We will coordinate with BLM AMT to further identify possible data from field offices.
**We are compiling accessible reservoirs as well as marina locations.
***e.g., Rand Mountains, Jawbone-Butterbredt, Ridgecrest, Twenty-nine Palms, etc. and routes from Motor groups.

Figure 23. Estimated visitor use (dispersed recreation) model.



Inputs: National Transportation Atlas Database (NTAB), urban population, BLM linear features map, 10m DEM, designated off road vehicle areas

Analytic process & tools: Accessibility analysis, distance decay functions using ArcGIS v10

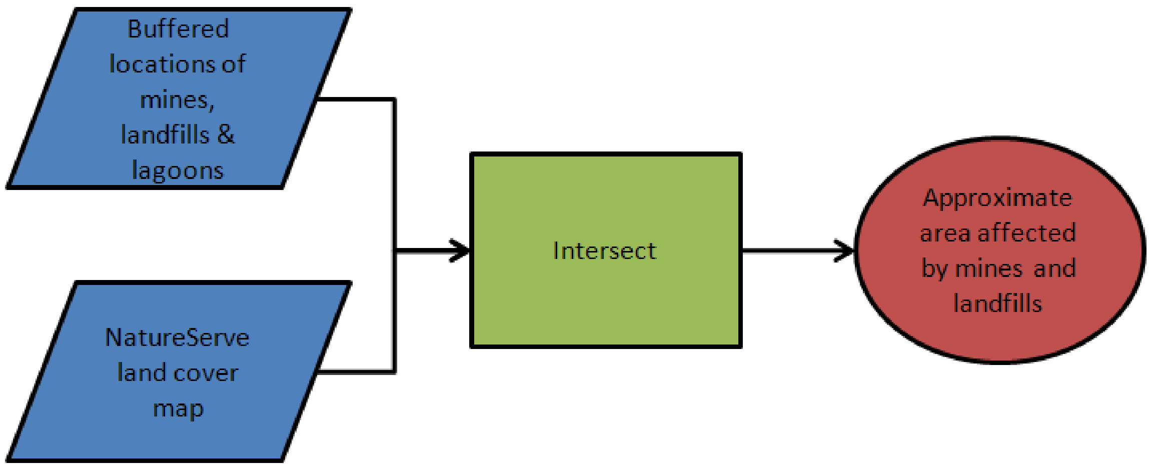
Outputs: The output of this model is a map at 90 m resolution, with values containing units of automobiles (or people, assuming a certain number of people per car). Values will be large along busy, well-travelled state highways and interstates, and then dissipate throughout the remaining transportation infrastructure, and off-road as well.

Issues: data availability of the linear features inputs and completeness of other access and attraction features.

Mining and Refuse Management

Areas that are currently used for mining and refuse management (including tailings lagoons) are only represented by point locations in the available data. This requires a simple modeling effort to represent these features in a way that more accurately represents the infrastructure footprint.

Figure 24. Mines and refuse management model.



Inputs: For mining we will use the USGS Mineral Resource Data System (MRDS) which includes past and present mines, prospects and processing plants. We will add additional abandoned mine properties from the California Bureau of Mines Mineral Industries Location System (MILS). These layers will be enriched by point locations from the Nevada Department Environmental Protection (NVDEP) which incorporate point locations for tailings piles, open pits, leach pads and abandoned mine locations. For refuse management we will use USGS SAGEMAP landfills and NVDEP tailings ponds and pit lakes.

Analytic process & tools: Buffer the point features by 1km then intersect these buffers with areas identified as "Non-specific disturbed" land cover class as identified by the NatureServe (2009) land cover map. Intersected areas will be reclassified as mining or refuse management, depending on the source of the point buffer.

Outputs: A summary map that combines all past and current mining developments

Issues: Areas that are currently used for mining and refuse management (including tailings lagoons) are only represented by point locations. This requires a simple modeling effort to represent these features in a way that more accurately represents the infrastructure footprint. We propose to buffer the point features by 1km then intersect these with areas identified as "Non-specific disturbed" land cover class as identified by the NatureServe (2009) land cover map. Where the mining buffers intersect this land cover class, the class will be reclassified as mining or refuse management. We compared historical mining points, land cover classes and aerial photography and found that while intersecting active mines with "barren/disturbed" land cover classes is adequate, for historical mining, disturbance is underrepresented. We discussed this with a member of the AMT who suggested using a simple kernel density estimation of the point pattern and applying a least-squares cross validation (LSCV) for a smoothing parameter. The point patterns of historic mining sites appear highly clustered. An appropriate probability contour can be identified and tested against comparisons with land cover and aerial photo data. This data can also be relativized and brought into our landscape condition model. We will evaluate this method and consider it for use.

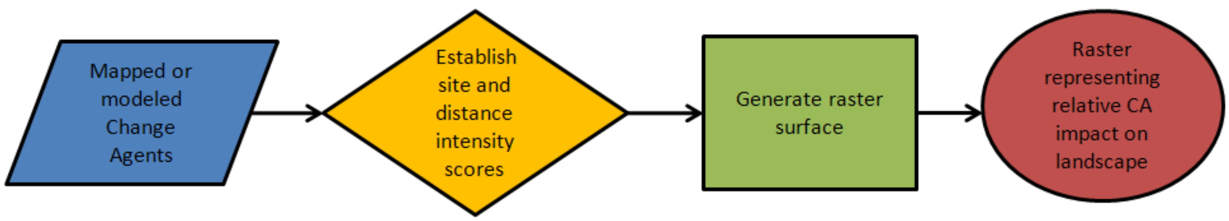
Landscape Condition Model

CA effects can be summarized through a spatial model of relative landscape condition. When assessing ecological integrity of CEs, we can address attributes of the CE itself using indicators that best distinguish a degraded state from an intact state. Natural heritage "Element Occurrence Ranks" or BLM Proper Functioning Condition ranks are a good example of this. For CAs, we need to identify attributes that reflect the types and degrees of stressors that may be impacting the condition of the system which may be driving changes.

The CAs in the ecoregion come in many forms, from non-native annual grasses or climate-induced ecosystem change, to local-scale patterns of urban land conversion, and transportation corridors, among others. Our landscape condition model incorporates multiple stressors of varying individual intensities, the combined and cumulative effect of those stressors, and some measure of distance away from each stressor where negative effects remain likely.

There are growing sets of information on various kinds of stressors that impact ecosystems. Danz et al. (2007) noted that "Integrated, quantitative expressions of anthropogenic stress over large geographic regions can be valuable tools in environmental research and management." When they take the form of a map, or spatial model, these tools initially characterize ecological conditions on the ground; from highly disturbed to apparently unaltered conditions. This conceptual approach, documented in Comer and Hak (2009), is very similar to Theobald's (2008) *Natural Landscapes* model and the USGS *Human Footprint in the West* (Leu et al. 2008).

Figure 25. Landscape condition model.



Inputs: All development and terrestrial invasive species CAs (Table 17)

Analytic process & tools: **Analytic process & tools**: NatureServe will establish site and distance intensity scores for CAs (Table 18) which may be reviewed and modified by AMT science members and partners. The source of information for the scores will accompany the process documentation and the output metadata. The mapped or modeled CA distributions will be combined and transformed into a single raster surface. We will use the Landscape Condition Modeler, a Python-based toolbox for ArcGIS 10 written by NatureServe. We investigated using NatureServe Vista which is designed specifically for this type of assessment and incorporates the Condition Modeler tool. We built a current (2010) scenario of CAs and attempted to run a condition assessment for a broadly distributed ecoregion. Unfortunately as an ArcView extension, Vista does not have sufficient computing power for ecoregion-wide assessment and modeling at the required 30 m resolution. We believe, however, that Vista will be ideal for downscaling assessments and planning work to subregions (e.g., Field Offices).

Outputs: A continuous raster surface with values from 0-1 representing relative CA induced stress on the landscape. When assessing ecological integrity of CEs, we can address attributes of the CE itself using indicators that best distinguish a degraded state from a sustainable state. For CAs, we will identify attributes that reflect the types and degrees of stressors that may be impacting the condition of the system which may be driving changes.

Issues: The concept of landscape condition modeling is highly simplified resulting in relative indices of condition that take into account a fairly narrow set of considerations. The model does not calculate synergistic effects among CAs but instead utilizes the most intense CA where they co-occur. Distance (offsite) effects from neighboring CAs are additively included however. Table 19 depicts the distance effects from different intensity scores. The model does not incorporate the shielding effect of features such as topography that may reduce the distance effects. The model may not reflect observed condition levels for features on the landscape and does not directly incorporate field observations of condition although these can be used to calibrate the model. It is also important to note that the model will only reflect the inputs stated here; there are stressors on the landscape that are not included, namely environmental conditions such as erosion, drought, etc. The model scores are provided in Table 18 so that the AMT may provide feedback. During the next two phases of the REA process we will continue to adjust the site and distance intensity weights with specific input from the AMT as desired. The condition model is a relative scoring model and thus does not incorporate a number of issues related to habitat or species viability.

The CA stressors in the ecoregion come in many forms, from non-native annual grasses or climate induced ecosystem stress, to local-scale patterns of urban land-conversion and transportation corridors, among others. For this regional model, we have selected a set of CAs for inclusion (see Table 17). Each CA was given a **relative site intensity** score, between 0.0 and 1.0 to represent our assumptions of stress induced by each CA on CEs. As depicted in Table 18, a relative site intensity score near 0.0 indicates our assumption that the CA induces very high levels of stress on nearby ecosystems (i.e., removes nearly all condition value). Scores closer to 1.0 are assumed to induce a minimal amount of stress (i.e., retains nearly all condition value). Typically, only one CA occurs at each pixel, but where more than one can occur, the lowest score is applied (e.g. the highest-impact use determines the pixel value).

Table 17. Proposed CA inputs to the Landscape Condition Model, their sources, and approximate resolutions.

CA Category	Change Agent	Source	Spatial resolution
Infrastructure - Roads	Primary Highways	2009 Tiger/Line or BLM linear features	1:100,000
	Secondary and connecting roads	2009 Tiger/Line or BLM linear features	1:100,000
	Local roads, jeep trails	BLM linear features	Unknown/Pending
	Trails and other non motorized routes	BLM linear features	Unknown/Pending
Infrastructure – Transmission lines	Transmission lines	BLM linear features, USGS SAGEMAP, West-wide Energy Corridor Programmatic EIS	1:100,000 or finer
	Communications towers	FCC point locations	1:100,000 or finer
Infrastructure-Pipelines	Pipelines	National Pipeline Mapping System (NPMS) or BLM linear features	1:24,000
Infrastructure- Water Transmission	Canals, ditches	USGS NHDplus	1:24,000
Infrastructure - Railroads	Railroads	NTAD	1:100,000
Developments - Urbanization	High Density Development	ICLUS/SERGoM	30m pixel/ 1:100,000
	Medium Density Development	ICLUS/SERGoM	30m pixel/ 1:100,000

CA Category	Change Agent	Source	Spatial resolution
	Low Density Development	ICLUS/SERGoM	30m pixel/ 1:100,000
Energy Development	Wind	Operating & authorized wind facilities	1:100,000
	Solar	Solar Energy Study Areas	1:100,000
	Geothermal	Operating & authorized geothermal facilities	1:100,000
	Biomass	No current facilities known; save for future REAs	NA
	Oil and Gas Wells	Detailed oil and gas maps	30m pixel/ 1:100,000
Mining	Active Mines	Mines and refuse management model	Unknown/Pending
	Historical (inactive) mines	Mines and refuse management model	Unknown/Pending
Military Use	Urbanized areas	National Land Cover Data/ LANDFIRE Existing Vegetation/Gap Analysis Program 2001-2003 United States	30m pixel/ 1:100,000
	Heavily disturbed areas	National Land Cover Data/ LANDFIRE Existing Vegetation/Gap Analysis Program 2001-2003 United States	30m pixel/ 1:100,000
Refuse Management	Landfills, industrial lagoons	Mines and refuse management model	Unknown/Pending
Agriculture	Crops and irrigated agriculture	National Land Cover Data/ LANDFIRE Existing Vegetation/Gap Analysis Program 2001-2003 United States	30m pixel/ 1:100,000
Terrestrial Invasives	Impacted areas (5-15% cover exotic non-native species)	Terrestrial invasive species model	30m pixel/ 1:100,000
	Degraded areas (>15% cover exotic non-native species)	Terrestrial invasive species model	30m pixel/ 1:100,000
Recreation	Designated motorized recreation area or natural landscape score <0.3	Natural Landscapes model, existing data	30m pixel/ 1:100,000
	Recreation class medium	Natural Landscapes model	30m pixel/ 1:100,000

Table 18. Proposed site intensity and distance decay values for ecoregion change agents.

Change Agent		Relative Site Intensity	Relative stress at site	Distance Decay Function (meters)	Distance Decay (function)
Infrastructure - Roads	Primary Highways	0.05	Very High	2000	0.05
	Secondary and connecting roads	0.2	High	500	0.2
	Local roads, jeep trails	0.5	Medium	200	0.5
	Trails and other non motorized routes	0.9	Low	111	0.9
Infrastructure – Transmission lines	Transmission lines	0.5	Medium	200	0.5
	Communications towers	0.5	Medium	200	0.5
Infrastructure-Pipelines	Pipelines	0.5	Medium	200	0.5
Infrastructure- Water Transmission	Canals, ditches	0.8	Low	125	0.9
Infrastructure - Railroads	Railroads	0.2	High	500	0.2
Developments - Urbanization	High Density Developed	0.05	Very High	2000	0.05
	Medium Density Development	0.2	High	500	0.5
	Low Density Development	0.5	Medium	200	0.5
Energy Development	Wind	0.05	Very High	2000	0.2
	Solar	0.05	Very High	2000	0.2
	Geothermal	0.05	Very High	2000	0.2
	Oil and Gas Wells	Unknown			
	Active Mines	0.2	High	500	0.5
Mining	Historical (inactive) mines	0.05	Very High	2000	0.05
	Urbanized areas	0.8	Low	125	0.5
Military Use	Heavily disturbed areas	0.05	Very High	2000	0.05
	Landfills, industrial lagoons	0.5	Medium	200	0.5
Refuse Management	Crops and irrigated agriculture	0.05	Very High	2000	0.05

Change Agent		**Relative Site Intensity**	**Relative stress at site**	**Distance Decay Function (meters)**	**Distance Decay (function)**
Agriculture	Impacted areas (3-10% cover exotic non-native species)	0.8	Low	125	0.5
Terrestrial Invasives	Degraded areas (>10% cover exotic non-native species)	0.8	Low	125	0.8
	Designated motorized recreation area or natural landscape score <0.3	0.5	Medium	200	0.5
Recreation	Recreation class medium	0.3	High	333	0.5
	Recreation class low	0.5	Medium	200	0.8
		0.8	Low	125	0.8

Table 19. Distance Intensity Scores and the maximum distance where distance effects reach zero.

Distance Intensity Score	**Distance Decay to Zero (meters)**	**Km**
1	0	0
0.9	111	0.1
0.8	125	0.1
0.7	143	0.1
0.6	167	0.2
0.5	200	0.2
0.4	250	0.3
0.3	333	0.3
0.2	500	0.5
0.1	1000	1
0.05	2000	2
0.04	2500	2.5
0.03	3333	3.3
0.02	5000	5
0.01	10000	10
0.003	33333	33.3

Distance Intensity Score	Distance Decay to Zero (meters)	Km
0.004	25000	25
0.005	20000	20
0.006	16667	16.7
0.007	14286	14.3
0.008	12500	12.5
0.009	11111	11.1
0.002	50000	50
0.001	100000	100

For the condition model, each CA is also given a **distance decay function**, scaled between 0.0 and 1.0, to represent our assumptions of decreasing stress-effects of each CA with distance away from each impacting feature (see Table 19). When combined with site intensity, the decay function may be adjusted to represent CA types such as 4-lane highways where the assumed stress at the site is high and the distance effect from the feature is long vs. a single track dirt road. For example, if the site intensity score is low indicating a high stress site (e.g., 0.3) and the distance decay function is relatively high (e.g., 1.0), the resulting spatial model would depict the circumstance where the effect of the high stress CA is expected to decrease rapidly over short distances. A lower distance decay value would extend the effect further away from the site. This effect decays to zero within distances ranging from 200-800 meters from the impacting land cover.

As depicted in Table 19, the distance intensity score determines the rate of decay in condition values for each CA to a given distance where that effect reaches zero. This table serves as a basic guide to distance decay effects, especially where documented experience has indicated a specific distance where effects can be presumed to have reached zero. A clear example of this has been identified for ground-nesting birds where research has identified clear patterns of avoidance and higher predation near the presence of development, especially power lines (Braun 1998, 2002, Ellis 1984, Hagen et al. 2004, Pruett et al. 2009).

Assessment Models

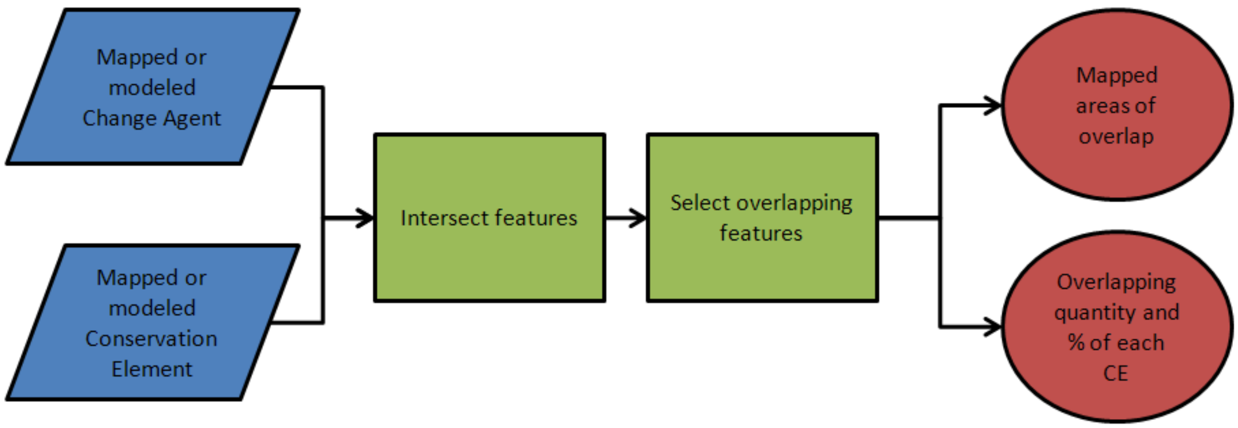
Assessment models specifically address the requirements for answering MQs. In this section we describe the components of assessment models followed by diagrams and descriptions of the various models required to conduct the assessments. We do not present every permutation of models needed to address every MQ, rather we describe the component models and then reference these to the MQs in Appendix III. Management Questions: Referenced to Modeling CategoriesNote that some assessment models that are highly interactive with CE distributions are described in the section Conservation Element Models.

Key model components include inputs, assessment/analytical processes, and outputs. Inputs are generally composed of existing data or may include outputs from other models. Most of the assessment processes are quite simple despite the fact that the models themselves may be quite complex. Many MQs can be answered by simply intersecting or adding the inputs with an assessment model in a simple GIS process. Outputs are typically maps and summary statistics for the entire ecoregion and by reporting unit.

Basic Assessment models

Many MQs can be summarized as "Where will X coincide with Y?" seeking to identify areas where, for example, CEs will be coincident with CAs that may cause impacts. These types of MQs can be answered by a basic assessment model (Figure 26) that will intersect existing data or distributions of a CE with a mapped or modeled CA. Areas or portions of overlap between the CA and CE area can be displayed as a map and accompanied by summary statistics.

Figure 26. Basic assessment model.



Inputs: Spatial distributions of CAs and CEs.
Analytic process & tools: GIS intersect function will be used to integrate these layers.
Outputs: A summary map that shows areas of overlap and summary statistics.
Issues: This simple assessment model is used to answer MQs about where CEs overlap with CAs. It does not model actual response of the CEs to the CAs; those more complex issues are addressed in different MQs and through different models. This model, however, is foundational in many other models which first require the intersection between CEs and CAs.

Significance-Based Assessment Models

The meaning of "significance" for MQs had considerable discussion in the AMT 1 workshop and there was lack of consensus about the need or appropriateness of finding significance in the REA outputs. In AMT 3 we revisited this issue and gained some additional clarity but we envision further refinement in Tasks 4 through 6. We identified twelve unique MQs that include an indication of significance. Because of the breadth of MQ issues addressed, no single model or measure of significance is practical and must be unique to the MQ or group of similar MQs (e.g., several MQs ask where a class of CEs will experience significant deviations in climate). Generally, findings of significance utilize approaches such as:

- Setting *a priori* thresholds applied to calculated values (e.g., on a range of scores of integrity from 0.0-1.0 any values below 0.5 would indicate a significant level of impact)
- Using natural data breaks among the values. This is a post-assessment analysis of the data that would identify data groupings such that values are partitioned into categories of Sustainable, Transitioning, and Degraded.
- Conducting statistical analyses to identify significant differences in the outcomes. For example, in our discussion of climate change effects on terrestrial CEs, we indicate our intention to report on

predicted change in climate variable between time steps where the predicted values are outside of one and two standard deviations of the mean value for the baseline time period.

The calculation of integrity measures (or condition scores), as 0.0 – 1.0 index scores can support all of these approaches but we interpret the AMT's desire for significance to primarily be a "flagging" approach to identify CEs or places that require additional attention. Where practicable, we have included a recommendation on significance in individual models but some MQs will require further discussion at the AMT 3 workshop to get more clarity about the AMT's desires. Note also per agreement at AMT 3, we will provide all calculated scores such that users can apply their own interpretation to significance depending on their decision needs.

Grazing Allotments (GAs) and Herd Management Areas (HMAs)

The AMT concluded that these management units should be used as reporting units where we will summarize the assessment results across the three scenarios. The MQs addressing these features, however, did include the desire to identify "significant" effects from climate change and other CAs. For the climate change MQs we will utilize the results of the climate change modeling (described above) to identify GAs and HMAs that have already significantly deviated from past climate and those forecast to in the future. The significance of effects of other CAs (in particular fire and invasives) will require further discussion during Tasks 5 and 6.

Other Specific Assessment Models

Restoration Suitability Assessment

There are three restoration related MQs stated by the AMT that seek to identify areas suitable for restoration. While restoration activities will vary considerably depending on the land cover type that is to be restored, general principles can inform where restoration may be most effective. The AMT clarified that the purpose of the restoration models is to identify restoration sites where those investments would not be precluded by development forecast in the 2025 scenario.

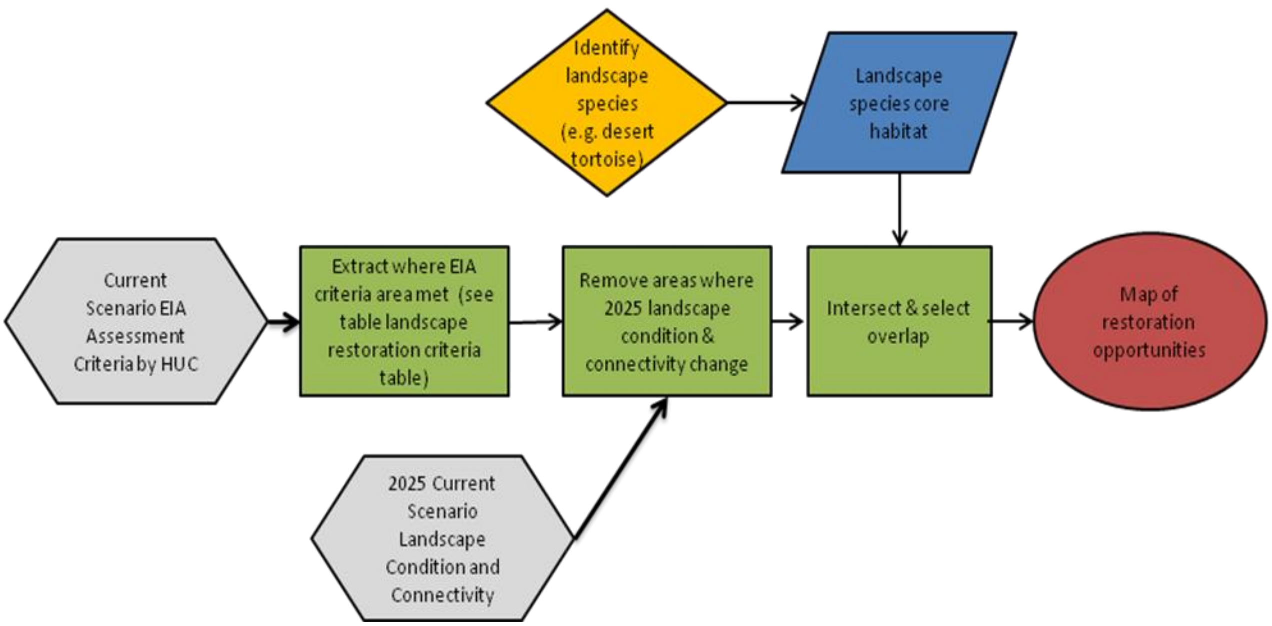
Our criteria build on Meinke et al. (2009) and NatureServe's ecological integrity assessment (EIA) scorecard. Meinke et al. included multiple environmental variables that are important to sagebrush obligate species; this model (Figure 27) will focus on measures of general applicability to the ecosystem CEs. The criteria include: 1) EIA scorecard factors that include landscape context, condition and relative extent; 2) potential restoration failure due to invasion by non-native species; and alternately 3) critical habitat areas of landscape indicator species.

The EIA scorecard attributes will guide restoration to areas that are consistently rated as Sustainable or Transitioning. This logic is consistent with Meinke et al. where they prioritized areas where restoration could increase habitat connectivity, accelerate habitat expansion, and avoid locations that would restore only isolated areas of habitats within larger areas already converted or heavily degraded. Locating restoration activities near areas that are regarded as sustainable may increase restoration success as the sustainable areas could provide wildlife habitat and seed sources, especially in rangeland areas (Hemstrom et al. 2002; Longland & Bateman 2002). Given the need to identify anticipated future locations of CAs we will select only those areas that show little or no change in EIA criteria between the current and 2025 scenarios.

Potential restoration failure due to invasion by weedy species will be identified with the Terrestrial Invasive CA model. The inclusion of this model will guide restoration towards the margins of areas that are not already heavily impacted by non-natives. As Meinke et al. noted for sagebrush species and cheatgrass, many areas may be suitable for invasive species. However by focusing on areas where invasives are unlikely to become dominant, restoration may have a better chance of success.

We recommend a restoration strategy that benefits landscape indicator species such as greater sage-grouse or desert tortoise for example, while acknowledging that the BLM needs to restore lands for the multiple uses that occur within their jurisdictional boundaries. The inclusion of important landscape species' critical habitat is based on the BLM and other federal agencies existing management preferences, as these species are already found to be threatened or in danger of becoming so. The following model combines general habitat restoration and connectivity restoration. These aspects can be separated out if desired to identify areas specifically for connectivity restoration.

Figure 27. General landscape restoration opportunities.



Inputs: Current scenario CE condition-based assessment models, 2025 scenario CE condition-based assessment models, focal landscape species critical habitat areas,

Analytic process & tools: Select areas where EIA attributes meet all the following indicators for the 2025 scenario (see Table 20). Then remove areas that show a significant change in landscape condition and invasive annual cover (e.g. from one rating class to another) in the 2025 scenario indicating anticipated future change. Finally intersect areas of key landscape species core habitat.

Table 20. Landscape restoration criteria table.

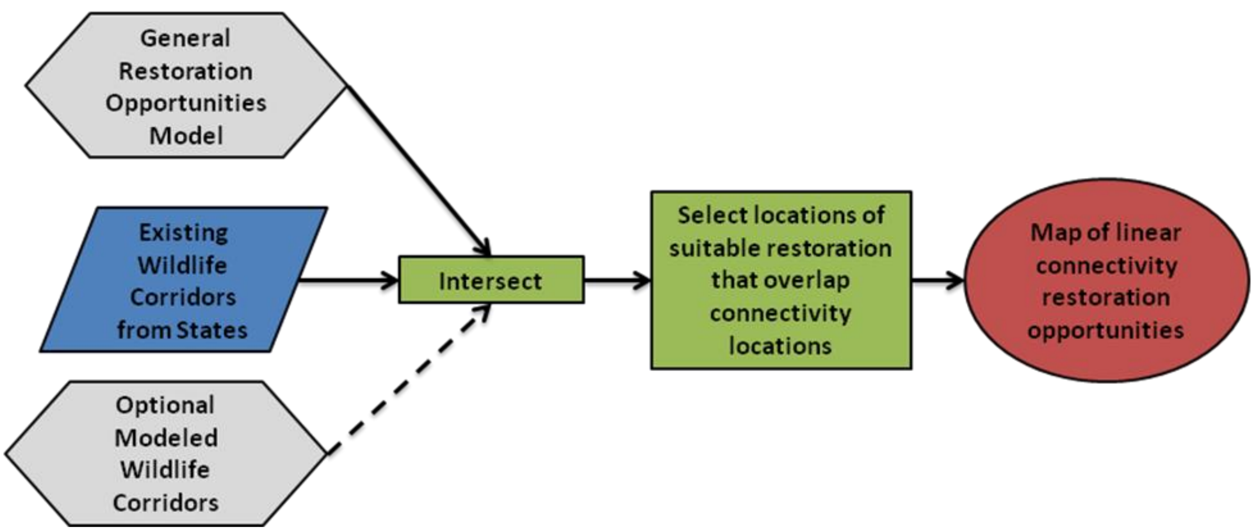
Indicator	Rating	Rating Explanation
Landscape Connectivity	Transitioning (>0.6)	Connectivity is moderate to low and will not sustain CEs.
Landscape Condition	Transitioning (0.8-0.5)	Cumulative level of impacts is transitioning, opportunity to make sustainable.
sCLASS Departure	Transitioning (0.8-0.5)	Mix of age classes indicates system is functioning near, but outside NRV. System is transitioning to degraded state. Departure is 20 -50%.
Invasive Annual Cover	Transitioning (0.8-0.5)	System is transitioning to degraded state by abundant invasive annual vegetation. Mean cover of annuals is 5-10%
Change in Extent	Transitioning (0.8-0.5)	Occurrence is substantially reduced from its original natural extent (50-80% remains).

Outputs: A summary map that shows current habitat restoration opportunities based on current and anticipated location of CAs by HUC reporting unit.

Issues: The model will produce generalized areas where restoration opportunities may be more successful based on broad landscape criteria. Species or ecological system specific restoration sites will need to be evaluated with more specific models that include additional environmental variables and finally evaluated in the field.

The above model deals with general habitat restoration and landscape connectivity. Following is our model for linear connectivity (Figure 28) dealing with wildlife corridors.

Figure 28. Linear connectivity restoration model.



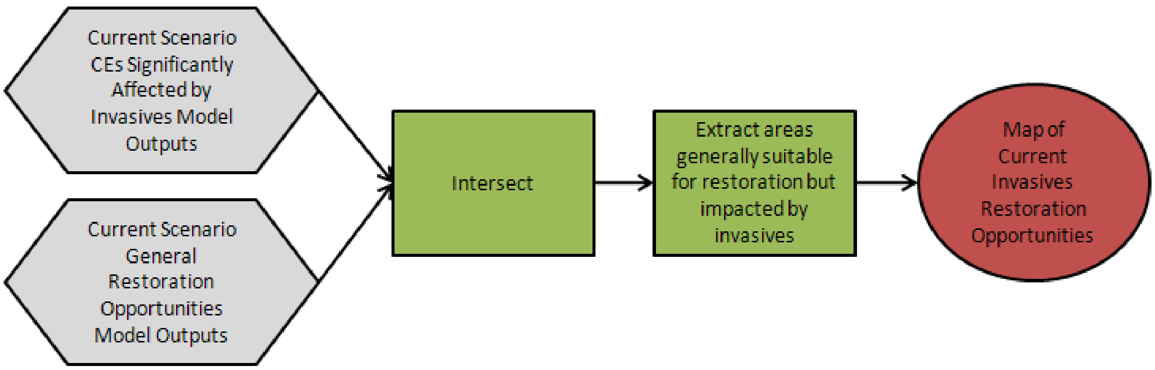
Inputs: Existing wildlife corridors to be obtained from state wildlife agencies; general restoration opportunities model.

Analytic process & tools: A simple intersect of these inputs is required.

Outputs: Map of existing connectivity locations that have good restoration potential as modeled in the General Restoration Opportunities Model will indicate those areas specifically able to benefit linear connectivity (wildlife corridors) through restoration.

Issues: issues from the other input models. Also, wildlife corridor maps and models are very incomplete throughout the west and many modeled corridors have not been validated.

Figure 29. 2010 invasives restoration opportunities.



Inputs: Current scenario general restoration opportunities model, Current scenario CEs significantly affected by invasives.

Analytic process & tools: We intend to extract from this model areas where condition would indicate moderate levels of disturbance caused by invasive species.

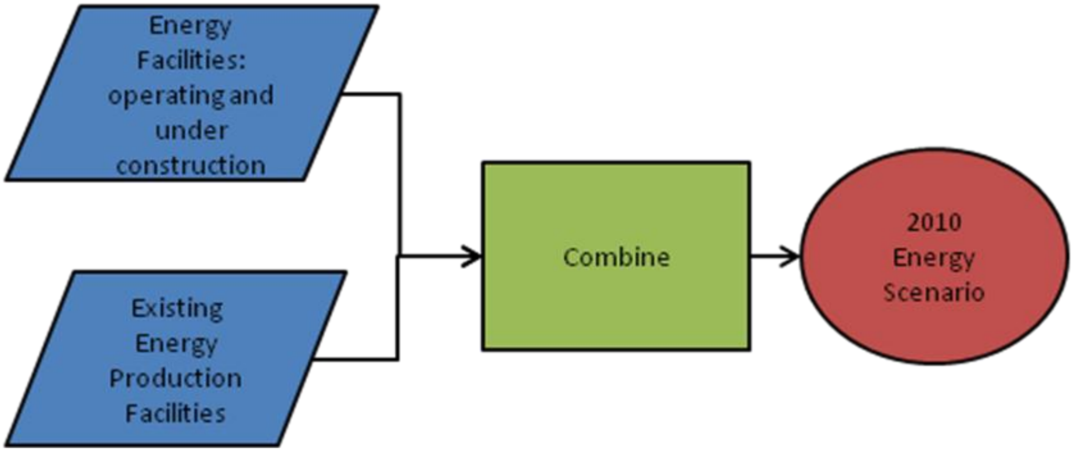
Outputs: A raster map of areas of invasives restoration opportunities.

Issues: This model will intersect an intermediary product from the restoration model (Figure 27) Current Scenario Areas of Restoration Potential and key coarse filter CE distributions that are significantly affected by invasive species. We will then extract areas suitable for restoration that are also impacted by invasives. This model serves as an initial opportunities flagging tool, it does not contain more complex modeling to determine potential for invasives restorability.

Energy Development Assessment

Several MQs deal with traditional and renewable energy development. While some of these models fall under or contribute to other assessment models described earlier, we present them as a set here to maintain the cohesiveness of the presentation. One set of models deal with the established scenarios (current and 2025) while others are free of a particular timeframe and assess the total potential energy development footprint. We do not attempt to model suitability of energy development from the perspective of physical or economic factors but rather utilize energy development inputs from other organizations and focus on the interaction of energy development with CEs. One AMT member requested that new transmission for energy development be included in the energy development CA. As stated in the AMT 3 workshop, transmission is its own CA and will thus be treated separately. In addition, data representing transmission tie-ins for proposed renewable projects have not been identified in most cases.

Figure 30. Current (2010) energy development scenario.



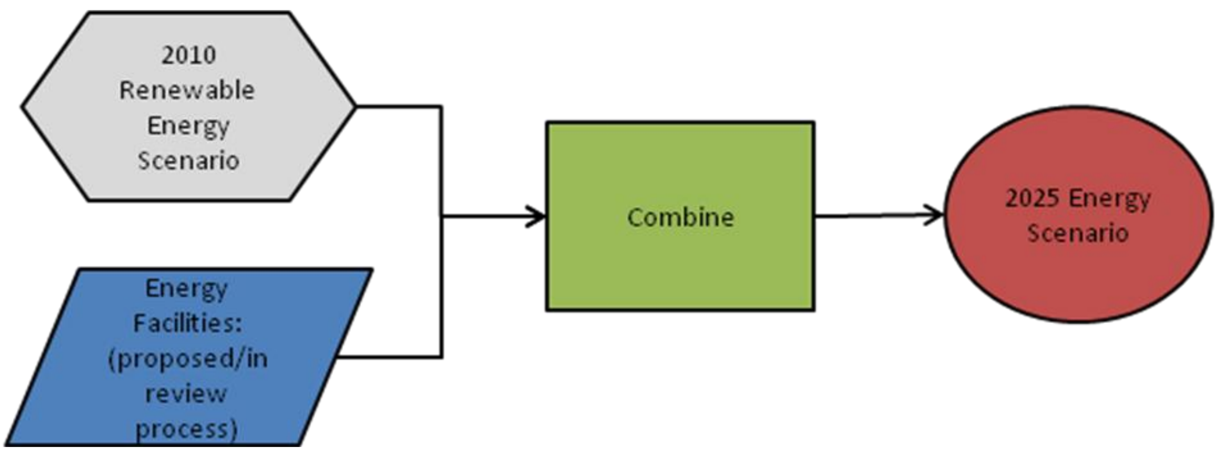
Inputs: This model is duplicated for renewable and non-renewable energy. For renewables, wind, solar and geothermal energy facilities that are operating or currently under construction are input. For non-renewable we will utilize maps of existing oil and gas development.

Analytic process & tools: GIS combine function will be used to integrate these layers.

Outputs: A summary map that combines all existing and under construction energy developments, as of 2010.

Issues: none

Figure 31. 2025 renewable energy scenario model.



Inputs: The 2010 energy model output (utilizing only the renewable energy locations and all proposed renewable energy projects in the pipeline as of May 1, 2011 as provided by BLM and other REA partners.

Analytic process & tools: GIS combine function will be used to integrate these layers.

Outputs: A map of all renewable energy development projects that are current, under construction, and in the review pipeline.

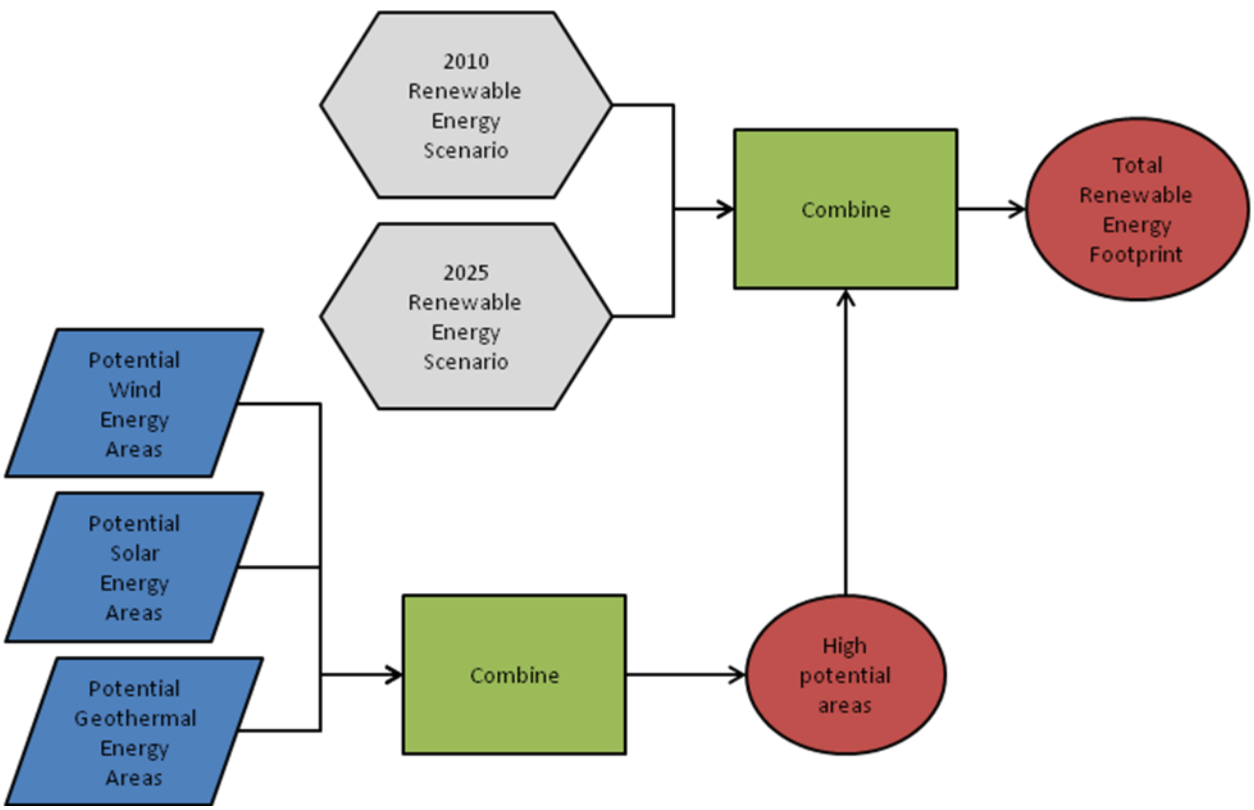
Issues: Renewable energy specialists from the AMT have indicated that not all proposed energy products are likely to come to fruition. This will also not reflect any likely projects filed with the BLM after May 1, 2011.

The following series of models answer individual MQs but also lead up to the assessment of suitable locations for energy development and mitigation. The energy suitability model draws from existing datasets of renewable and convential extractive energy facilities that are operating, under construction and proposed for private and public land. Areas of energy potential or favorability have been obtained from best available expert sources: NREL (AWS Truewind 2010, SUNY & NREL 2007), Great Basin Center for Geothermal Energy (Zehner et al 2009) and DOI EPCA Phase III (DOI et al 2008). Potential areas are refined by incorporating Section 368 corridor maps provided by West-wide Energy Corridor Programmatic EIS (DOE & BLM 2008).

Existing and high favorability areas will be combined and intersected with a conservation value summary (CVS). The CVS aggregates all of the individual CE distributions including their associated ecological integrity values. This result will show relative biodiversity value highlighting the places most appropriate and inapproptiate for energy development. With input from the AMT, the CVS can be categorized and filtered according the legal status of the conservation element (ESA or wetland status), degree of imperilment or endemism.

The output products will include a continuous surface map of relative potential for renewable energy and a tabular output report. Note that in AMT 3 the decision was made to drop biomass as an energy type because there is too much uncertainty about its potential and another regional group is addressing this issue.

Figure 32. Total renewable energy footprint model.



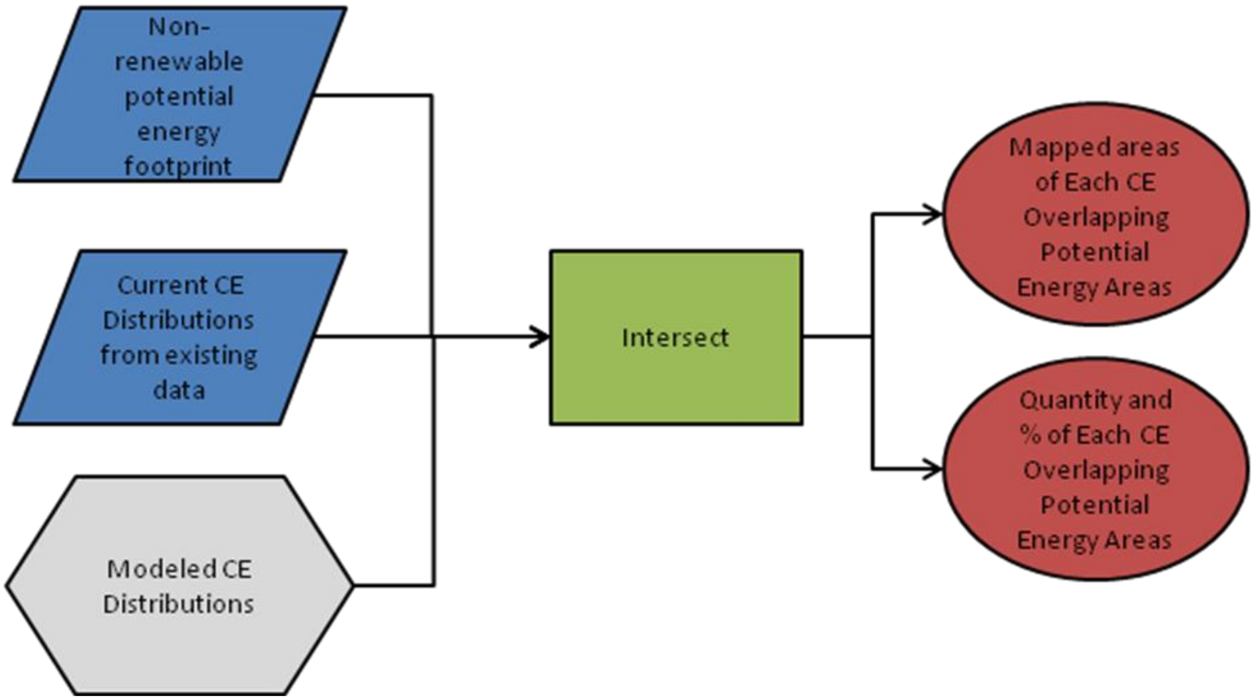
Inputs: The 2010 renewable energy model output, the 2025 renewable energy model output, and the potential energy maps for wind, solar, geothermal, and biomass.

Analytic process & tools: GIS combine function will be used to integrate these layers. Depending on the final form of the potential energy maps, we may also include a filtering process to extract the high potential areas (e.g., class 4 and higher wind potential).

Outputs: A map of all current, under construction, in the pipeline, and high potential renewable energy development projects.

Issues: See issues for other input models. We are currently uncertain if filtering will need to be applied to the potential energy maps and or if further processing will be needed to normalize them for combination.

Figure 33. Intersection of CEs and non-renewable energy development.



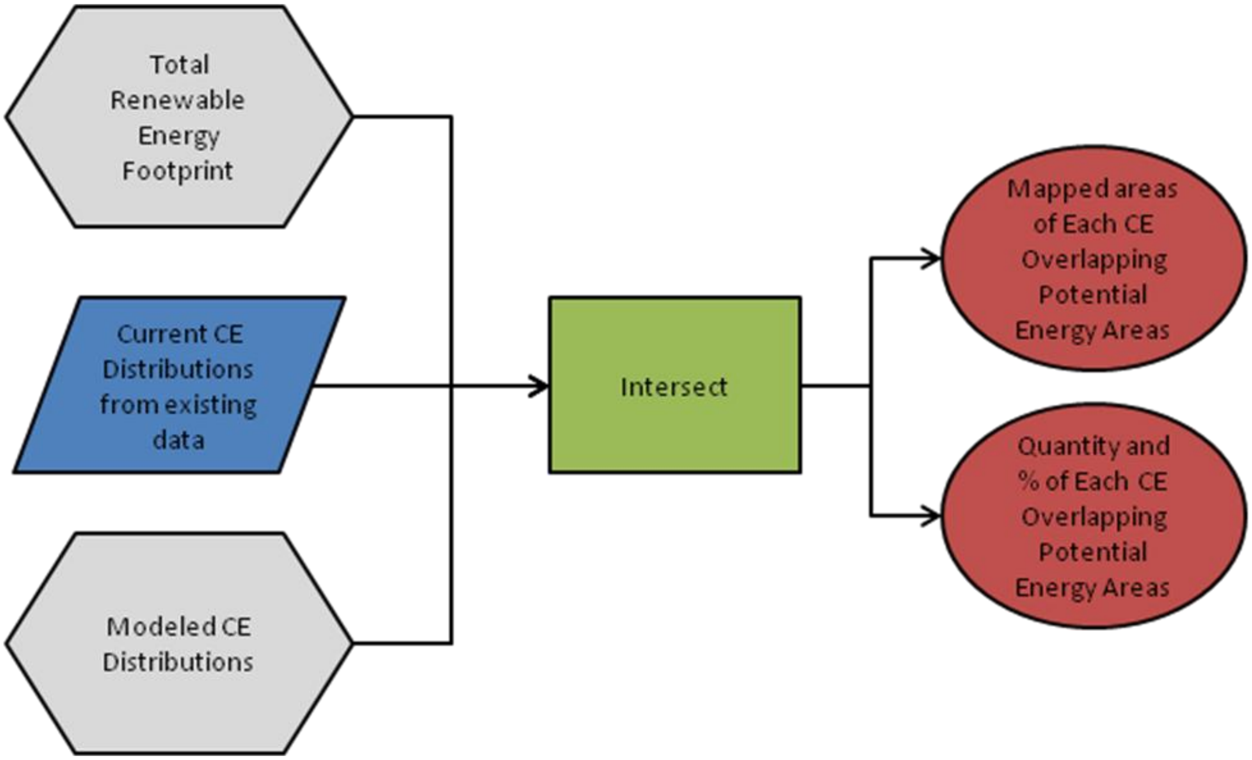
Inputs: Oil and gas well map (from 2010 energy scenario model), CE distributions from existing data and modeled CE distributions.

Analytic process & tools: A GIS intersect will be used to extract the overlap of these features.

Outputs: A map of each CE identifying where it overlaps with non-renewable energy development.

Issues: see issues of other input models

Figure 34. Intersection of CEs with total renewable energy development.



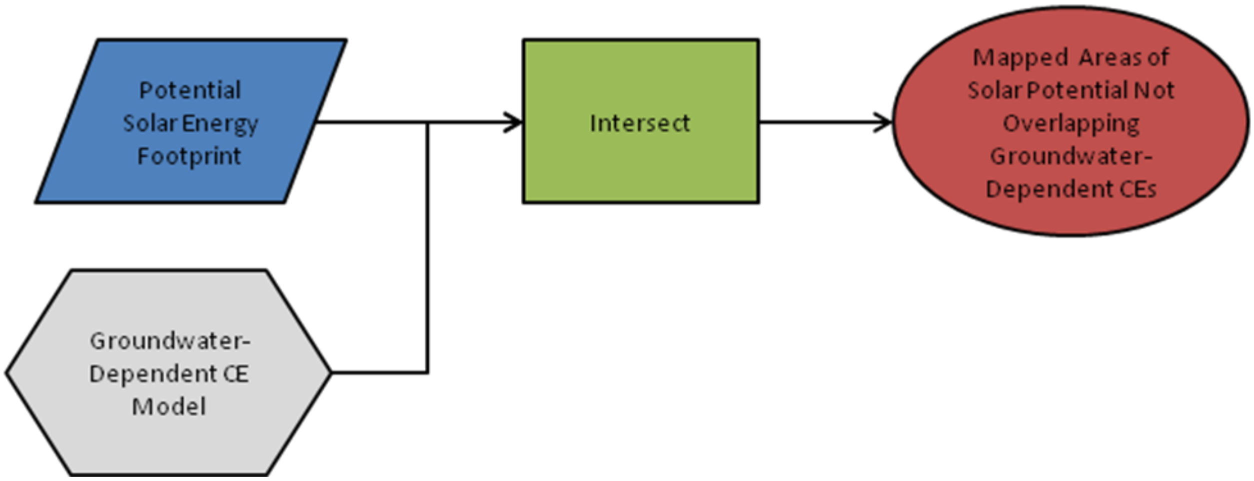
Inputs: Total renewable energy development model output, current CE distributions from existing data or from distribution models.

Analytic process & tools: A GIS intersect will be used

Outputs: The distribution of each CE overlapping potential energy areas and the quantity and percent of each CE that overlaps those areas.

Issues: see issues of other input models

Figure 35. Areas of solar development without groundwater-dependent CE conflicts.



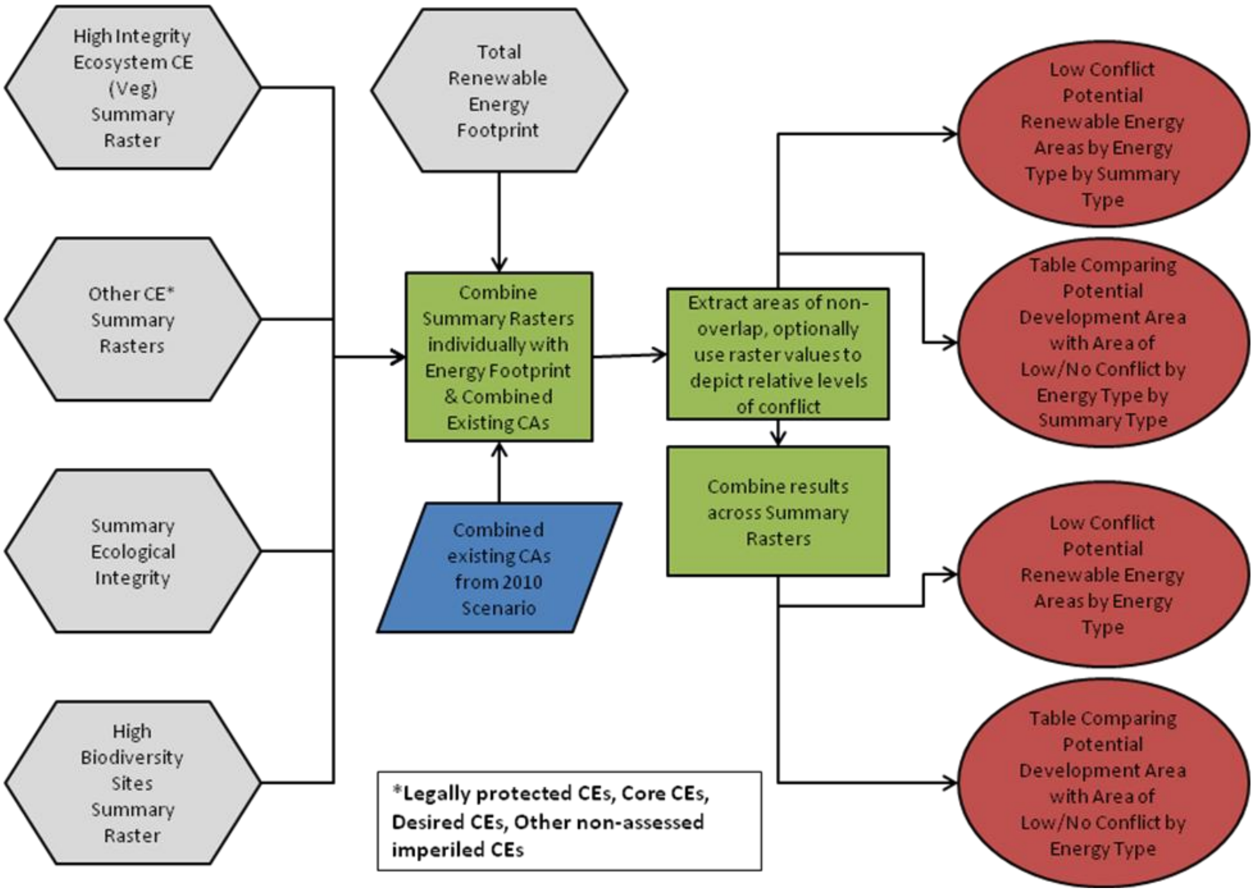
Inputs: The potential solar energy footprint map obtained from NREL and the groundwater-dependent CE model (Figure 20) presented earlier.

Analytic process & tools: A simple GIS intersect will be used to identify the coincidence between the input layers.

Outputs: Areas with solar potential but not overlapping groundwater-dependent CEs will be extracted as a map.

Issues: see issues of other input models

Figure 36. Areas of potential renewable energy development with fewest environmental conflicts.



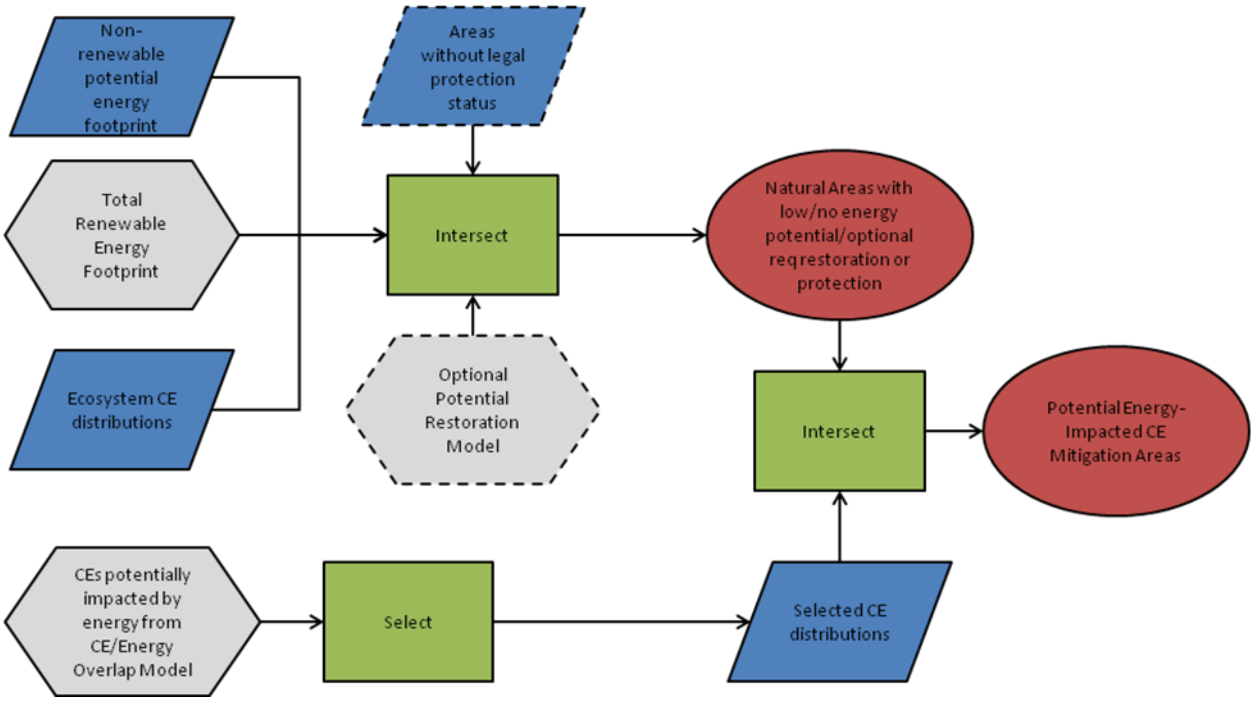
Inputs: A large number of possible inputs including vegetation (ecosystem) CEs, various other groups or categories of CEs, summary ecological integrity, and high biodiversity sites as features to be assessed for conflicts. Other required inputs include the output of the Total Renewable Energy Footprint model and the combined existing CAs from the 2010 scenario.

Analytic process & tools: We will first conduct individual GIS combines of the different environmental inputs with the energy footprint and the existing CAs. We will then extract from the combined spatial data those areas of non-overlap between the environmental inputs and the energy footprint. We will also identify those areas of the energy footprint overlapping areas containing existing CAs. Those operations will be used to generate the top two outputs (see below). Finally we will combine the individual results of the environmental/energy footprint combinations to develop the bottom two outputs (see below).

Outputs: The first output identifies areas of low conflict with potential renewable energy sites by energy type and by environmental input layer. The second output calculates the proportion of non-conflicted energy development, by energy type under the individual environmental input categories (e.g., how much wind energy would remain after removing areas in conflict with high biodiversity sites). The third output identifies the areas in sum that would have low conflict with with renewable energy summed across all of the environmental inputs. The fourth output calculates remaining areas of each energy types without conflict.

Issues: We used the term “low” rather than “no” conflict to indicate that there are likely few to no areas that would have no conflicts. Because the environmental inputs are raster summaries, they will contain continuous values that would allow a depiction of relative degree of conflict which may be more useful for energy planning. The specific type of outputs should be resolved by the AMT.

Figure 37. Areas of potential mitigation for all energy development.



Note that this model was in dispute by the AMT if it should be conducted or not. REA leadership to provide direction to the contractor.

Inputs: Outputs from the Total Renewable Energy Footprint, CEs Potentially Impacted, and (optionally) the Potential Restoration models. Other inputs include non-renewable potential energy layer(s), the Ecosystem CE distributions and the selection of those from the CEs Potentially Impacted model, and (optionally) areas without legal protection status, extracted from the protected area database.

Analytic process & tools: Analytical processes consist of intersecting the layers and selecting relevant features/attributes. The intersection of the optional Potential Restoration Model addresses legal requirements for some regulated (e.g., wetland) CEs to only be mitigated through restoration of currently degraded sites. This will act as a filter on the outputs (for such CEs) to only include relevant areas. The intersection of the *Areas without legal status protection* layer addresses requirements for endangered species that they be mitigated either through restoration or sometimes by protecting currently unprotected areas.

Outputs: An intermediate output is a map of natural areas with low-no energy potential. Intersecting that output with the distributions of CEs potentially affected by energy development identifies locations that contain CEs that may need mitigation and have low potential for future energy development. The final map then serves as a potential mitigation sites map.

Issues: Contractor requires guidance on whether to include the optional inputs/filters and may need additional information about which CEs these filters would apply to. This model does not address the quantity of mitigation required as this would entail project level decisions but merely provides the envelope of potential mitigation sites.

High Biodiversity Sites Assessment

The AMT concluded that these sites should be treated as reporting units where we will summarize the assessment results across the three scenarios. All forms of assessment described here that include reporting by 5th level watershed can be assessed using existing high biodiversity site boundaries as reporting units in the exact same manner. The MQs addressing these features, however, did include the desire to identify "significant" effects from climate change. We will utilize the results of the climate change effects modeling (described earlier) to identify sites where these effects results might best be reported. In Task 4 (work plan) we will provide complete details on the intended reporting units and reporting metrics.

Issues and Limitations

The following issues and limitations were identified in our model development process. This list isn't exhaustive but highlights the key and common issues we identified. It is important to note as a primary limitation that there are still data sets awaiting delivery for us to review for suitability which may affect our model recommendations or feasibility. Also, we have yet to investigate certain tools and while we expect to follow the same workflows illustrated in our models, we may substitute tools or manual methods for those described. Another primary limitation is that all of the model outputs are subject to the error of the input data sets as well as the assumptions made by our team and other subject matter experts consulted. Additional issues and limitations include:

1. Not all issues could be made transparent in the draft of this memo nor discussed at the AMT 3 workshop. While we endeavor to provide as much detail as practicable, there will remain many details at finer levels of concepts, models, inputs, and outputs that likely will require several specialized interim web meetings with select AMT members to resolve. We will work with the REA/AMT leadership to schedule these throughout tasks 5-7 to receive AMT feedback to complete the work.
2. We and the AMT have yet to settle on all final reporting units and reporting metrics. There is likely some mismatch in expectations of the precision of the analyses relative to input data sets and reporting units. At the scale of an ecoregion, most reporting units will be large and many input data sets (particularly for climate forecasts) are coarse.
3. Inclusion of the energy mitigation MQ and model is under REA leadership consideration.
4. A large number of comments (primarily from USGS) regarding needs for measuring, evaluating, and communicating uncertainty require further guidance from the REA leadership. We provided an uncertainty framework as requested by USGS but note that not all uncertainty assessments or measures are practical for the REA.
5. Much of the aquatic section received a large number of comments, primarily from USGS. Generally, data availability is extremely limited to answer many of the MQs as stated with any precision. We encourage a fresh review of this section by USGS (and any other interested AMT members) consistent with the objectives of the REA.
6. Soils data are highly variable across the ecoregion and thus the ability to answer the sensitive soils MQs is somewhat compromised. We have proposed a modeling approach to address this to the greatest degree feasible within time and resources of the REA.
7. Mining data (current and historic) is primarily represented by point locations. We have proposed a modeling method to create a realistic footprint for these features but historic mining sites that have partially revegetated will likely be highly underrepresented by our model.
8. Answering many MQs involving assessment of integrity and significance necessarily involve scoring, categorization, and or thresholding of data and are largely based on team expert opinion. There was some AMT concern about the rigor and transparency of such an approach. We will document inputs (data and expert judgment) and provide all of the original inputs so that users may reanalyze the data and come to their own conclusions. It is, however, infeasible for an REA

with many dozens of MQs and hundreds of inputs to conduct highly rigorous, empirically-based analyses for all MQs.

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Appendices

Appendix I. List of coarse-filter CEs for the Mojave Basin and Range REA

Model Group	Land Cover Class	Conservation Element Name	Percent o Ecoregio
Montane Dry	Evergreen Forest and Woodland	Great Basin Pinyon-Juniper Woodland	1.9%
Montane Dry	Tall Shrubland	Mogollon Chaparral	0.5%
Montane Dry	Tall Shrubland	Sonora-Mojave Semi-Desert Chaparral	0.2%
Basin Dry	Short Shrubland	Sonora-Mojave Creosotebush-White Bursage Desert Scrub	33.8%
Basin Dry	Short Shrubland	Mojave Mid-Elevation Mixed Desert Scrub	32.5%
Basin Dry	Sparsely Vegetated	North American Warm Desert Pavement	8.8%
Basin Dry	Sparsely Vegetated	North American Warm Desert Bedrock Cliff and Outcrop	2.4%
Basin Dry	Short Shrubland	Sonoran Mid-Elevation Desert Scrub	2.2%
Basin Dry	Short Shrubland	Sonora-Mojave Mixed Salt Desert Scrub	1.7%
Basin Dry	Sparsely Vegetated	North American Warm Desert Badland	1.0%
Basin Dry	Short Shrubland	Great Basin Xeric Mixed Sagebrush Shrubland	0.7%
Basin Dry	Sparsely Vegetated	North American Warm Desert Active and Stabilized Dune	0.2%
Basin Dry	Short Shrubland	Inter-Mountain Basins Mixed Salt Desert Scrub	0.1%
Montane Wet	Woody Wetlands and Riparian	North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream	0.0%
Basin Wet	Sparsely Vegetated	North American Warm Desert Playa	4.5%
Basin Wet	Short Shrubland	North American Warm Desert Wash	1.5%
Basin Wet	Aquatic	Mojave Desert Lake/Reservoir	0.6%
Basin Wet	Woody Wetlands and Riparian	North American Warm Desert Riparian Woodland and Shrubland/Stream	0.2%
Basin Wet	Woody Wetlands and Riparian	North American Warm Desert Riparian Mesquite Bosque	0.0%
Basin Wet	Herbaceous Wetlands	North American Arid West Emergent Marsh and Pond	0.0%
Basin Wet	Aquatic	Mojave Desert Springs and Seeps	0.0%
Basin Wet	Woody Wetlands and Riparian	Sonoran Fan Palm Oasis/Stream	0.0%

Appendix Ib. List of fine-filter CEs for the Mojave Basin and Range REA

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
Landscape	Dry	Birds	Cooper's Hawk	Accipiter cooperii	No	Yes	G5	CA				
Landscape	Dry	Birds	Sage Sparrow	Amphispiza belli	No	Yes	G5	NV, UT		MV		
Landscape	Dry	Birds	Golden Eagle	Aquila chrysaetos	No	Yes	G5	CA	CA, UT			
Landscape	Dry	Birds	Ferruginous Hawk	Buteo regalis	No	Yes	G4	AZ, CA, NV, UT	UT	PS		
Landscape	Dry	Birds	Swainson's Hawk	Buteo swainsoni	No	Yes	G5	CA, NV	CA	PS		
Landscape	Dry	Birds	Northern Harrier	Circus cyaneus	No	Yes	G5	AZ, CA				
Landscape	Dry	Birds	Prairie Falcon	Falco mexicanus	No	Yes	G5	CA				
Landscape	Dry	Birds	Bald Eagle	Haliaeetus leucocephalus	No	Yes	G5	AZ, CA, NV, UT	CA, UT	PS		
Landscape	Dry	Birds	Loggerhead Shrike	Lanius ludovicianus	No	Yes	G4	CA, NV		IL		
Landscape	Dry	Birds	Sage Thrasher	Oreoscoptes montanus	No	Yes	G5	AZ, UT				
Landscape	Dry	Birds	Savannah Sparrow	Passerculus sandwichensis	No	Yes	G5	AZ				
Landscape	Dry	Birds	Brewer's Sparrow	Spizella breweri	No	Yes	G5	CA, NV, UT		MV		
Landscape	Dry	Mammals	mule deer	Odocoileus hemionus	No	Yes	G5	NV, UT	CBR, MBR	PS		
Landscape	Dry	Mammals	Desert Bighorn Sheep	Ovis canadensis nelsoni	No	Yes	T4	CA, NV	CA	PS		
Landscape	Dry	Mammals	Bighorn Sheep - Peninsular Ranges	Ovis canadensis pop. 2	Yes	Yes	T3					
Landscape	Dry	Mammals	Sierra Nevada Bighorn Sheep	Ovis canadensis sierrae	Yes	Yes	T1	CA, NV	CA			
Landscape	Dry	Mammals	Mohave Ground Squirrel	Spermophilus mohavensis	No	Yes	G2	CA	CA			
Landscape	Dry	Mammals	Brazilian Free-tailed Bat	Tadarida brasiliensis	No	Yes	G5	AZ				
Landscape	Dry	Mammals	American Badger	Taxidea taxus	No	No	G5	CA				
Landscape	Dry	Mammals	Kit Fox	Vulpes macrotis	Yes	Yes	G4	NV, UT	UT	PS		
Landscape	Dry	Reptiles	Glossy Snake	Arizona elegans	No	No	G5	UT				
Landscape	Dry	Reptiles	Western Banded Gecko	Coleonyx variegatus	No	Yes	G5	NV, UT	UT			
Landscape	Dry	Reptiles	Mohave Rattlesnake	Crotalus scutulatus	No	Yes	G5	UT	UT			
Landscape	Dry	Reptiles	Great Basin Collared Lizard	Crotaphytus bicinctores	No	Yes	G5	NV				
Landscape	Dry	Reptiles	Desert Tortoise - Mohave Population	Gopherus agassizii pop. 1	Yes	Yes	T3					
Landscape	Dry	Reptiles	Desert Tortoise - Sonoran Population	Gopherus agassizii pop. 2	Yes	Yes	T4					
Landscape	Dry	Reptiles	Gila Monster	Heloderma suspectum	No	Yes	G4	UT	CA, UT			
Landscape	Dry	Reptiles	Nightsnake	Hypsiglena torquata	No	No	G5	UT				
Landscape	Dry	Reptiles	Coachwhip	Masticophis flagellum	No	No	G5	UT				
Landscape	Dry	Reptiles	Desert Horned Lizard	Phrynosoma platyrhinos	No	No	G5	NV		PS		
Landscape	Dry	Birds	Burrowing Owl	Athene cunicularia	No	Yes	G4	CA, UT	CA, UT			
Landscape	Dry	Reptiles	Sidewinder	Crotalus cerastes	No	Yes	G5	UT	UT			
Landscape	Dry	Reptiles	Desert Iguana	Dipsosaurus dorsalis	No	Yes	G5	NV, UT	UT	MV		
Landscape	Dry	Reptiles	Common Chuckwalla	Sauromalus ater	No	Yes	G5	CA, NV, UT	UT			
Landscape	Dry	Reptiles	Mojave Fringe-toed Lizard	Uma scoparia	No	Yes	G3	AZ, CA	CA			
Species Assemblage	Dry	Ants, Wasps, & Bees	Mojave Gypsum Bee	Andrena balsamorhizae	No	No	G2				Gypsum soils	
Species Assemblage	Dry	Mammals	Mexican Long-tongued Bat	Choeronycteris mexicana	No	Yes	G4	AZ, CA			Cave and mine roosting animals (bats)	
Species Assemblage	Dry	Mammals	Townsend's Big-eared Bat	Corynorhinus townsendii	No	Yes	G4	CA, NV, UT	CA, UT	PS	Cave and mine roosting animals (bats)	
Species	Dry	Mammals	Allen's Big-eared Bat	Idionycteris phyllotis	No	Yes	G3	NV, UT	AZ, UT	PS	Montane conifer	

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
Assemblage												
Species Assemblage	Dry	Mammals	Silver-haired Bat	Lasionycteris noctivagans	No	No	G5	CA			Montane conifer	
Species Assemblage	Dry	Mammals	Hoary Bat	Lasiurus cinereus	No	No	G5	CA, NV		IL	Montane conifer	
Species Assemblage	Dry	Mammals	Californian Leaf-nosed Bat	Macrotus californicus	No	Yes	G4	AZ, CA, NV	CA	PS	Cave and mine roosting animals (bats)	
Species Assemblage	Dry	Mammals	Cave Myotis	Myotis velifer	No	No	G5	CA, NV	AZ, CA	PS	Cave and mine roosting animals (bats)	
Species Assemblage	Dry	Flowering Plants	Charleston Pussytoes	Antennaria soliceps	No	No	G1				Carbonate (Limestone/Dolomite) alpine	
Species Assemblage	Dry	Flowering Plants	Las Vegas Bear-poppy	Arctomecon californica	No	Yes	G3		NV		Gypsum soils	
Species Assemblage	Dry	Flowering Plants	Ackerman's Milkvetch	Astragalus ackermanii	No	No	G2				Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Geyer's Milkvetch	Astragalus geyeri var. geyeri	No	No	T4		CA		Sand dunes/sandy soils (when deep and loose)	
Species Assemblage	Dry	Flowering Plants	Sand Milkvetch	Astragalus geyeri var. triquetrus	No	Yes	T2		AZ, NV		Sand dunes/sandy soils (when deep and loose)	
Species Assemblage	Dry	Flowering Plants	Mottled Milkvetch	Astragalus lentiginosus var. stramineus	No	No	T2		NV		Sand dunes/sandy soils (when deep and loose)	
Species Assemblage	Dry	Flowering Plants	Charleston Milkvetch	Astragalus oophorus var. clokeyanus	No	No	T2		NV		Montane conifer	Great Basin Pinyon-Juniper Woodland
Species Assemblage	Dry	Flowering Plants	Ash Meadows Milkvetch	Astragalus phoenix	Yes	Yes	G2		NV		Alkaline spring influenced soils	
Species Assemblage	Dry	Flowering Plants	Last Chance Rock Cress	Boechera yorkii	No	No	G1				Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Alkali Mariposa-lily	Calochortus striatus	No	No	G2		CA, NV		Alkaline spring influenced soils	
Species Assemblage	Dry	Flowering Plants	Spring-loving Centaury	Centaurium namophilum	Yes	Yes	G2		NV		Alkaline spring influenced soils	
Species Assemblage	Dry	Flowering Plants	Pintwater Rabbitbrush	Chrysothamnus eremobius	No	No	G1				Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Silver-leaf Sunray	Enceliopsis argophylla	No	No	G2		AZ		Gypsum soils	
Species Assemblage	Dry	Flowering Plants	Ash Meadows Sunray	Enceliopsis nudicaulis var. corrugata	Yes	Yes	T2		NV		Alkaline spring influenced soils	
Species Assemblage	Dry	Flowering Plants	Nevada Willowherb	Epilobium nevadense	No	No	G2		NV		Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Deer Goldenweed	Ericameria cervina	No	No	G3		NV		Azonal carbonate rock crevices, Azonal non-carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Charleston Mountain Heath-goldenrod	Ericameria compacta	No	No	G2				Montane conifer	
Species Assemblage	Dry	Flowering Plants	Sheep Fleabane	Erigeron ovinus	No	No	G2		NV		Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Darin Buckwheat	Eriogonum concinnum	No	No	G2		NV		Sand dunes/sandy soils (when deep and loose)	
Species Assemblage	Dry	Flowering Plants	Crispleaf Wild Buckwheat	Eriogonum corymbosum var. nilesii	Yes	No	T2		NV		Gypsum soils	
Species Assemblage	Dry	Flowering Plants	Sticky Buckwheat	Eriogonum viscidulum	No	Yes	G2		AZ, NV		Sand dunes/sandy soils (when deep and loose)	
Species Assemblage	Dry	Flowering Plants	Ripley's Gilia	Gilia ripleyi	No	No	G3				Azonal carbonate rock crevices	

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
Species Assemblage	Dry	Flowering Plants	Clokey's Greasebush	Glossopetalon clokeyi	No	No	G2				Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Pacific Greasebush	Glossopetalon pungens	No	No	G2		CA		Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Smooth Dwarf Greasebush	Glossopetalon pungens var. glabrum	No	No	T1		CA, NV		Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Pacific Greasebush	Glossopetalon pungens var. pungens	No	No	T2		NV		Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Utah Sunflower	Helianthus deserticola	No	No	G2				Sand dunes/sandy soils (when deep and loose)	
Species Assemblage	Dry	Flowering Plants	Spring Mountain Ankle-aster	Ionactis caelestis	No	No	G1		NV		Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Rock Purpusia	Ivesia arizonica var. saxosa	No	No	T1		NV		Azonal non-carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Hidden Ivesia	Ivesia cryptocaulis	No	No	G2				Carbonate (Limestone/Dolomite) alpine	
Species Assemblage	Dry	Flowering Plants	Jaeger's Ivesia	Ivesia jaegeri	No	No	G2		CA, NV		Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Hitchcock's Bladderpod	Lesquerella hitchcockii	No	No	G3				Carbonate (Limestone/Dolomite) alpine, Montane conifer, Subalpine mountain-tops	
Species Assemblage	Dry	Flowering Plants	Ash Meadows Blazingstar	Mentzelia leucophylla	Yes	Yes	G1		NV		Alkaline spring influenced soils	
Species Assemblage	Dry	Flowering Plants	Blue Diamond Cholla	Opuntia whipplei var. multigeniculata	No	Yes	T2		NV		Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	White-margin Beardtongue	Penstemon albomarginatus	No	Yes	G2		AZ, CA, NV		Sand dunes/sandy soils (when deep and loose)	
Species Assemblage	Dry	Flowering Plants	Pahute Mesa Beardtongue	Penstemon pahutensis	No	No	G3		NV		Azonal non-carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Beatley's Phacelia	Phacelia beatleyae	No	No	G3				Talus and Scree	
Species Assemblage	Dry	Flowering Plants		Phacelia filiae	No	No	G2		NV		Clay soil patches, Gypsum soils	Inter-Mountain Basins Playa
Species Assemblage	Dry	Flowering Plants	Geranium-leaf Scorpionweed	Phacelia geraniifolia	No	No	G2				Azonal carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Nodding-flower Scorpionweed	Phacelia laxiflora	No	No	G2				Azonal carbonate rock crevices, Azonal non-carbonate rock crevices	
Species Assemblage	Dry	Flowering Plants	Death Valley Sage	Salvia funerea	No	No	G3		NV		Azonal carbonate rock crevices	North American Warm Desert Wash
Species Assemblage	Dry	Flowering Plants	Eureka Dunes Grass	Swallenia alexandrae	Yes	Yes	G1				Sand dunes/sandy soils (when deep and loose)	North American Warm Desert Active and Stabilized Dune
Species Assemblage	Dry	Mosses		Didymodon nevadensis	No	No	G2		NV		Gypsum soils	
TBD	Dry	Birds	Northern Goshawk	Accipiter gentilis	No	Yes	G5	CA, NV, UT	CA, UT	MV		
TBD	Dry	Birds	Sharp-shinned Hawk	Accipiter striatus	No	Yes	G5	CA				
TBD	Dry	Birds	White-throated Swift	Aeronautes saxatalis	No	Yes	G5	NV				
TBD	Dry	Birds	Grasshopper Sparrow	Ammodramus savannarum	No	Yes	G5	AZ, CA, UT	UT			
TBD	Dry	Birds	American Pipit	Anthus rubescens	No	Yes	G5	AZ				
TBD	Dry	Birds	Short-eared Owl	Asio flammeus	No	Yes	G5	CA, NV, UT	UT	PS		
TBD	Dry	Birds	Long-eared Owl	Asio otus	No	Yes	G5	CA				

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
TBD	Dry	Birds	Western Burrowing Owl	Athene cunicularia hypugaea	No	Yes	T4	NV	AZ	PS		
TBD	Dry	Birds	Verdin	Auriparus flaviceps	No	Yes	G5	NV				
TBD	Dry	Birds	Oak Titmouse	Baeolophus inornatus	No	No	G5	CA				
TBD	Dry	Birds	Juniper Titmouse	Baeolophus ridgwayi	No	Yes	G5	NV				
TBD	Dry	Birds	Common Black-Hawk	Buteogallus anthracinus	No	Yes	G4	AZ				
TBD	Dry	Birds	Lark Bunting	Calamospiza melanocorys	No	Yes	G5					
TBD	Dry	Birds	Gambel's Quail	Callipepla gambelii	No	Yes	G5	UT				
TBD	Dry	Birds	Costa's Hummingbird	Calypte costae	No	Yes	G5	CA, NV		IL		
TBD	Dry	Birds	Northern Cardinal	Cardinalis cardinalis	No	Yes	G5	CA				
TBD	Dry	Birds	Cassin's Finch	Carpodacus cassinii	No	Yes	G5	AZ, NV				
TBD	Dry	Birds	Turkey Vulture	Cathartes aura	No	Yes	G5					
TBD	Dry	Birds	Swainson's Thrush	Catharus ustulatus	No	Yes	G5	AZ				
TBD	Dry	Birds	Vaux's Swift	Chaetura vauxi	No	Yes	G5	CA				
TBD	Dry	Birds	Lark Sparrow	Chondestes grammacus	No	Yes	G5	CA				
TBD	Dry	Birds	Lesser Nighthawk	Chordeiles acutipennis	No	Yes	G5					
TBD	Dry	Birds	Evening Grosbeak	Coccothraustes vespertinus	No	Yes	G5	AZ				
TBD	Dry	Birds	Gilded Flicker	Colaptes chrysoides	No	Yes	G5	CA	CA			
TBD	Dry	Birds	Inca Dove	Columbina inca	No	Yes	G5					
TBD	Dry	Birds	Olive-sided Flycatcher	Contopus cooperi	No	Yes	G4	AZ, CA, NV				
TBD	Dry	Birds	Grace's Warbler	Dendroica graciae	No	Yes	G5	NV				
TBD	Dry	Birds	Black-throated Gray Warbler	Dendroica nigrescens	No	Yes	G5	UT				
TBD	Dry	Birds	Hermit Warbler	Dendroica occidentalis	No	Yes	G4	CA, NV				
TBD	Dry	Birds	White-tailed Kite	Elanus leucurus	No	Yes	G5	CA	CA			
TBD	Dry	Birds	Gray Flycatcher	Empidonax wrightii	No	Yes	G5					
TBD	Dry	Birds	California Horned Lark	Eremophila alpestris actia	No	No	T3	CA				
TBD	Dry	Birds	Merlin	Falco columbarius	No	Yes	G5	CA				
TBD	Dry	Birds	Peregrine Falcon	Falco peregrinus	No	Yes	G4	NV, UT		PS		
TBD	Dry	Birds	Common Moorhen	Gallinula chloropus	No	Yes	G5					
TBD	Dry	Birds	Greater Roadrunner	Geococcyx californianus	No	Yes	G5					
TBD	Dry	Birds	Pinyon Jay	Gymnorhinus cyanocephalus	No	Yes	G5	NV		PS		
TBD	Dry	Birds	Yellow-breasted Chat	Icteria virens	No	Yes	G5	CA				
TBD	Dry	Birds	Hooded Oriole	Icterus cucullatus	No	Yes	G5					
TBD	Dry	Birds	Scott's Oriole	Icterus parisorum	No	Yes	G5	NV		PS		
TBD	Dry	Birds	Gray-headed Junco	Junco hyemalis caniceps	No	No	T5	CA				
TBD	Dry	Birds	Acorn Woodpecker	Melanerpes formicivorus	No	Yes	G5					
TBD	Dry	Birds	Lewis's Woodpecker	Melanerpes lewis	No	Yes	G4	AZ, CA, NV, UT	UT	PS		
TBD	Dry	Birds	Gila Woodpecker	Melanerpes uropygialis	No	Yes	G5	CA	CA			
TBD	Dry	Birds	Lincoln's Sparrow	Melospiza lincolnii	No	Yes	G5	AZ				
TBD	Dry	Birds	Elf Owl	Micrathene whitneyi	No	Yes	G5	CA	CA			
TBD	Dry	Birds	Brown-crested Flycatcher	Myiarchus tyrannulus	No	Yes	G5	CA				
TBD	Dry	Birds	MacGillivray's Warbler	Oporornis tolmiei	No	Yes	G5	AZ				
TBD	Dry	Birds	Flammulated Owl	Otus flammeolus	No	Yes	G4	CA				

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
TBD	Dry	Birds	Osprey	Pandion haliaetus	No	Yes	G5	AZ, CA, UT				
TBD	Dry	Birds	Blue Grosbeak	Passerina caerulea	No	Yes	G5					
TBD	Dry	Birds	Band-tailed Pigeon	Patagioenas fasciata	No	Yes	G4	UT				
TBD	Dry	Birds	Phainopepla	Phainopepla nitens	No	Yes	G5	NV		PS		
TBD	Dry	Birds	Ladder-backed Woodpecker	Picoides scalaris	No	Yes	G5					
TBD	Dry	Birds	Pine Grosbeak	Pinicola enucleator	No	Yes	G5	AZ				
TBD	Dry	Birds	Abert's Towhee	Pipilo aberti	No	Yes	G3	CA, NV, UT		IL		
TBD	Dry	Birds	Green-tailed Towhee	Pipilo chlorurus	No	Yes	G5	AZ				
TBD	Dry	Birds	Summer Tanager	Piranga rubra	No	Yes	G5	CA				
TBD	Dry	Birds	Black-tailed Gnatcatcher	Polioptila melanura	No	Yes	G5	CA				
TBD	Dry	Birds	Purple Martin	Progne subis	No	Yes	G5	AZ, CA				
TBD	Dry	Birds	Vermilion Flycatcher	Pyrocephalus rubinus	No	Yes	G5	CA				
TBD	Dry	Birds	Ruby-crowned Kinglet	Regulus calendula	No	Yes	G5	AZ				
TBD	Dry	Birds	Golden-crowned Kinglet	Regulus satrapa	No	Yes	G5	AZ				
TBD	Dry	Birds	Bank Swallow	Riparia riparia	No	Yes	G5	CA	CA			
TBD	Dry	Birds	Black Phoebe	Sayornis nigricans	No	Yes	G5	NV		IL		
TBD	Dry	Birds	Broad-tailed Hummingbird	Selasphorus platycercus	No	Yes	G5	UT				
TBD	Dry	Birds	Rufous Hummingbird	Selasphorus rufus	No	Yes	G5	CA, NV				
TBD	Dry	Birds	Allen's Hummingbird	Selasphorus sasin	No	Yes	G5	CA				
TBD	Dry	Birds	Pygmy Nuthatch	Sitta pygmaea	No	Yes	G5					
TBD	Dry	Birds	Red-naped Sapsucker	Sphyrapicus nuchalis	No	Yes	G5	AZ				
TBD	Dry	Birds	Williamson's Sapsucker	Sphyrapicus thyroideus	No	Yes	G5	UT				
TBD	Dry	Birds	Lawrence's Goldfinch	Spinus lawrencei	No	Yes	G3	CA				
TBD	Dry	Birds	Lesser Goldfinch	Spinus psaltria	No	Yes	G5					
TBD	Dry	Birds	Black-chinned Sparrow	Spizella atrogularis	No	Yes	G5	CA, NV				
TBD	Dry	Birds	Chipping Sparrow	Spizella passerina	No	Yes	G5	CA				
TBD	Dry	Birds	Calliope Hummingbird	Stellula calliope	No	Yes	G5					
TBD	Dry	Birds	Mexican Spotted Owl	Strix occidentalis lucida	Yes	Yes	T3	AZ, UT				
TBD	Dry	Birds	Tree Swallow	Tachycineta bicolor	No	Yes	G5	AZ				
TBD	Dry	Birds	Bendire's Thrasher	Toxostoma bendirei	No	Yes	G4	CA, NV, UT	CA	PS		
TBD	Dry	Birds	Crissal Thrasher	Toxostoma crissale	No	Yes	G5	CA, NV, UT		IL		
TBD	Dry	Birds	Le Conte's Thrasher	Toxostoma lecontei	No	Yes	G4	AZ, CA, NV	CA	PS		
TBD	Dry	Birds	Winter Wren	Troglodytes troglodytes	No	Yes	G5	AZ				
TBD	Dry	Birds	American Robin	Turdus migratorius	No	Yes	G5					
TBD	Dry	Birds	Cassin's Kingbird	Tyrannus vociferans	No	Yes	G5					
TBD	Dry	Birds	Orange-crowned Warbler	Vermivora celata	No	Yes	G5	AZ				
TBD	Dry	Birds	Lucy's Warbler	Vermivora luciae	No	Yes	G5	CA, NV, UT	CA	PS		
TBD	Dry	Birds	Virginia's Warbler	Vermivora virginiae	No	Yes	G5	CA, NV, UT		PS		
TBD	Dry	Birds	Gray Vireo	Vireo vicinior	No	Yes	G4	CA, NV, UT	CA	PS		
TBD	Dry	Birds	White-winged Dove	Zenaida asiatica	No	Yes	G5					
TBD	Dry	Birds	White-crowned Sparrow	Zonotrichia leucophrys	No	Yes	G5	AZ				
TBD	Dry	Butterflies & Skippers	Spring Mountains Acastus	Chlosyne acastus robusta	No	No	T1		NV			

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			Checkerspot									
TBD	Dry	Butterflies & Skippers	Giuliani's Blue	Euphilotes ancilla giulianii	No	No	T3		NV			
TBD	Dry	Butterflies & Skippers	Square-dotted Blue	Euphilotes battoides	Yes	No	G5					
TBD	Dry	Butterflies & Skippers	Mojave Blue	Euphilotes mojave virginensis	No	No	T1		NV			
TBD	Dry	Butterflies & Skippers	Eunus Skipper	Pseudocopaeodes eunus alinea	No	No	T2		NV			
TBD	Dry	Mammals	Pallid Bat	Antrozous pallidus	No	Yes	G5	CA	CA			
TBD	Dry	Mammals	Ringtail	Bassariscus astutus	No	No	G5	NV		PS		
TBD	Dry	Mammals	Dulzura California Pocket Mouse	Chaetodipus californicus femoralis	No	No	T3	CA				
TBD	Dry	Mammals	Northwestern San Diego Pocket Mouse	Chaetodipus fallax fallax	No	No	T3	CA				
TBD	Dry	Mammals	Pallid San Diego Pocket Mouse	Chaetodipus fallax pallidus	No	No	T3	CA				
TBD	Dry	Mammals	Desert Pocket Mouse	Chaetodipus penicillatus	No	No	G5	NV		MV		
TBD	Dry	Mammals	Desert Kangaroo Rat	Dipodomys deserti	No	No	G5	NV, UT		PS		
TBD	Dry	Mammals	Merriam's Kangaroo Rat	Dipodomys merriami	Yes	No	G5					
TBD	Dry	Mammals	Earthquake Merriam's Kangaroo Rat	Dipodomys merriami collinus	No	No	T1	CA				
TBD	Dry	Mammals	Panamint Kangaroo Rat	Dipodomys panamintinus	No	No	G5	NV				
TBD	Dry	Mammals	Argus Mountains Kangaroo Rat	Dipodomys panamintinus argusensis	No	No	T2	CA				
TBD	Dry	Mammals	Panamint Kangaroo Rat	Dipodomys panamintinus panamintinus	No	No	T3	CA				
TBD	Dry	Mammals	Big Brown Bat	Eptesicus fuscus	No	No	G5		NV			
TBD	Dry	Mammals	California Bonneted Bat	Eumops perotis californicus	No	Yes	T4	AZ	CA			
TBD	Dry	Mammals	San Bernardino Flying Squirrel	Glaucomys sabrinus californicus	No	No	T2	CA				
TBD	Dry	Mammals	Amargosa Vole	Microtus californicus scirpensis	Yes	Yes	T1	CA	CA			
TBD	Dry	Mammals	Owens Valley Vole	Microtus californicus vallicola	No	No	T1	CA	CA			
TBD	Dry	Mammals	Ash Meadows Montane Vole	Microtus montanus nevadensis	No	Yes	TH			PS		
TBD	Dry	Mammals	Western Small-footed Myotis	Myotis ciliolabrum	No	No	G5	CA, NV	AZ, CA	PS		
TBD	Dry	Mammals	Long-eared Myotis	Myotis evotis	No	No	G5	CA	AZ, CA	IL		
TBD	Dry	Mammals	Little Brown Myotis	Myotis lucifugus	No	No	G5	CA, NV	AZ	IL		
TBD	Dry	Mammals	Arizona Myotis	Myotis occultus	No	No	G3	CA				
TBD	Dry	Mammals	Fringed Myotis	Myotis thysanodes	No	Yes	G4	CA, NV, UT	AZ, CA, UT	IL		
TBD	Dry	Mammals	Long-legged Myotis	Myotis volans	No	No	G5	CA	AZ			
TBD	Dry	Mammals	Yuma Myotis	Myotis yumanensis	No	No	G5	CA, UT	CA			
TBD	Dry	Mammals	Cliff Chipmunk	Neotamias dorsalis	No	Yes	G5					
TBD	Dry	Mammals	Kingston Mountain Chipmunk	Neotamias panamintinus acrus	No	No	T1	CA				
TBD	Dry	Mammals	Lodgepole Chipmunk	Neotamias speciosus speciosus	No	No	T2	CA				
TBD	Dry	Mammals	Hidden Forest Chipmunk	Neotamias umbrinus nevadensis	No	Yes	TH	NV		MV		
TBD	Dry	Mammals	Colorado Valley Woodrat	Neotoma albigula venusta	No	No	T3	CA				
TBD	Dry	Mammals	San Diego Desert Woodrat	Neotoma lepida intermedia	No	No	T3	CA				
TBD	Dry	Mammals	Stephens's Woodrat	Neotoma stephensi	No	No	G5	UT				
TBD	Dry	Mammals	Crawford's Gray Shrew	Notiosorex crawfordi	No	No	G5	UT				
TBD	Dry	Mammals	Pocketed Free-tailed Bat	Nyctinomops femorosaccus	No	No	G4	CA	AZ			
TBD	Dry	Mammals	Big Free-tailed Bat	Nyctinomops macrotis	No	Yes	G5	AZ, CA, NV, UT	AZ, UT	PS		

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TBD	Dry	Mammals	Common Muskrat	Ondatra zibethicus	No	Yes	G5	AZ				
TBD	Dry	Mammals	Western Pipistrelle	Parastrellus hesperus	No	Yes	G5	AZ				
TBD	Dry	Mammals	White-eared Pocket Mouse	Perognathus alticolus alticolus	No	No	TH	CA				
TBD	Dry	Mammals	Tehachapi Pocket Mouse	Perognathus alticolus inexpectatus	No	No	T1	CA				
TBD	Dry	Mammals	San Joaquin Pocket Mouse	Perognathus inornatus inornatus	No	No	T2	CA				
TBD	Dry	Mammals	Palm Springs Little Pocket Mouse	Perognathus longimembris bangsi	No	No	T2	CA	CA			
TBD	Dry	Mammals	Los Angeles Pocket Mouse	Perognathus longimembris brevinasus	No	No	T1	CA				
TBD	Dry	Mammals	Yellow-eared Pocket Mouse	Perognathus parvus xanthonotus	No	No	T2	CA	CA			
TBD	Dry	Mammals	Brush Deermouse	Peromyscus boylii	No	No	G5	NV				
TBD	Dry	Mammals	Piñon Deermouse	Peromyscus truei	No	No	G5					
TBD	Dry	Mammals	Merriam's Shrew	Sorex merriami leucogenys	No	No	T5	NV		PS		
TBD	Dry	Mammals	Inyo Shrew	Sorex tenellus	No	No	G3	NV		PS		
TBD	Dry	Mammals	Palm Springs Round-tailed Ground Squirrel	Spermophilus tereticaudus chlorus	No	No	T2	CA	CA			
TBD	Dry	Mammals	Rock Squirrel	Spermophilus variegatus	No	Yes	G5					
TBD	Dry	Other Beetles	Valley Elderberry Longhorn Beetle	Desmocerus californicus dimorphus	Yes	No	T2					
TBD	Dry	Other Beetles	Devil's Hole Warm Spring Riffle Beetle	Stenelmis calida calida	No	No	T1		NV			
TBD	Dry	Reptiles	Silvery Legless Lizard	Anniella pulchra pulchra	No	No	T3	CA				
TBD	Dry	Reptiles	Plateau Striped Whiptail	Aspidoscelis velox	No	No	G5	UT				
TBD	Dry	Reptiles	Zebra-tailed Lizard	Callisaurus draconoides	No	Yes	G5	UT	UT			
TBD	Dry	Reptiles	Western Diamond-backed Rattlesnake	Crotalus atrox	No	No	G5	NV				
TBD	Dry	Reptiles	Speckled Rattlesnake	Crotalus mitchellii	No	Yes	G5	UT	UT			
TBD	Dry	Reptiles	Red Diamond Rattlesnake	Crotalus ruber ruber	No	No	T5	CA				
TBD	Dry	Reptiles	Ring-necked Snake	Diadophis punctatus	No	Yes	G5	UT				
TBD	Dry	Reptiles	Gilbert's Skink	Eumeces gilberti	No	No	G5	NV				
TBD	Dry	Reptiles	Long-nosed Leopard Lizard	Gambelia wislizenii	No	No	G5	NV, UT		PS		
TBD	Dry	Reptiles	Common Kingsnake	Lampropeltis getula	No	No	G5	UT				
TBD	Dry	Reptiles	Western Threadsnake	Leptotyphlops humilis	No	Yes	G5	UT	UT			
TBD	Dry	Reptiles	Rosy Boa	Lichanura trivirgata	No	No	G4	CA	AZ			
TBD	Dry	Reptiles	Flat-tailed Horned Lizard	Phrynosoma mcallii	Yes	Yes	G3	AZ, CA	CA			
TBD	Dry	Reptiles	Spotted Leaf-nosed Snake	Phyllorhynchus decurtatus	No	No	G5	UT				
TBD	Dry	Reptiles	Western Skink	Plestiodon skiltonianus	No	No	G5	UT				
TBD	Dry	Reptiles	Long-nosed Snake	Rhinocheilus lecontei	No	Yes	G5	UT				
TBD	Dry	Reptiles	Western Patch-nosed Snake	Salvadora hexalepis	No	No	G5	UT				
TBD	Dry	Reptiles	Western chuckwalla	Sauromalus obesus obesus	No	No	GNR		AZ (at species level)			
TBD	Dry	Reptiles	Northern Sagebrush Lizard	Sceloporus graciosus graciosus	No	No	T5	CA	AZ, CA			
TBD	Dry	Reptiles	Groundsnake	Sonora semiannulata	No	Yes	G5	UT				
TBD	Dry	Reptiles	Smith's Black-headed Snake	Tantilla hobartsmithi	No	No	G5	AZ, UT				
TBD	Dry	Reptiles	Two-striped Gartersnake	Thamnophis hammondii	No	No	G4	CA	CA			
TBD	Dry	Reptiles	Western Lyresnake	Trimorphodon biscutatus	No	No	G5	UT				

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TBD	Dry	Reptiles	Sonoran Lyresnake	Trimorphodon lambda	No	No	G5	NV				
TBD	Dry	Reptiles	long-tailed brush lizard	Urosaurus graciosus	No	No	G5	NV		MV		
TBD	Dry	Reptiles	Desert Night Lizard	Xantusia vigilis	No	Yes	G5	AZ, UT	UT	MV		
TBD	Dry	Tiger Beetles	Mojave Giant Tiger Beetle	Amblycheila schwarzi	No	No	G3					
Coarse Filter	Dry	Ants, Wasps, & Bees	Red-tailed Blazing Star Bee	Megandrena mentzeliae	No	No	G2					North American Warm Desert Wash
Coarse Filter	Dry	Ants, Wasps, & Bees	Big-headed Perdita	Perdita cephalotes	No	No	G2					Mojave Mid-Elevation Mixed Desert Scrub
Coarse Filter	Dry	Ants, Wasps, & Bees	Mojave Poppy Bee	Perdita meconis	No	No	G2					Mojave Mid-Elevation Mixed Desert Scrub
Coarse Filter	Dry	Mammals	Spotted Bat	Euderma maculatum	No	Yes	G4	AZ, CA, NV, UT	CA, UT	PS		Inter-Mountain Basins Cliff and Canyon
Coarse Filter	Dry	Mammals	Western Red Bat	Lasiurus blossevillii	No	Yes	G5	AZ, CA, NV, UT	UT	PS		Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream, North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream
Coarse Filter	Dry	Mammals	Western Yellow Bat	Lasiurus xanthinus	No	Yes	G5	AZ, CA, NV		PS		Sonoran Fan Palm Oasis/Stream
Coarse Filter	Dry	Conifers & relatives	Bristlecone Pine	Pinus longaeva	No	Yes	G4					Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland
Coarse Filter	Dry	Flowering Plants	White Bear-poppy	Arctomecon merriamii	No	No	G3					Mojave Mid-Elevation Mixed Desert Scrub, North American Warm Desert Bedrock Cliff and Outcrop, Sonora-Mojave Creosotebush-White Bursage Desert Scrub
Coarse Filter	Dry	Flowering Plants	Clokey's Milkvetch	Astragalus aequalis	No	No	G2		NV			Great Basin Pinyon-Juniper Woodland
Coarse Filter	Dry	Flowering Plants	Sheep Mountain Milkvetch	Astragalus amphioxys var. musimonum	No	No	T2		NV			Mojave Mid-Elevation Mixed Desert Scrub
Coarse Filter	Dry	Flowering Plants	Inyo Milkvetch	Astragalus inyoensis	No	No	G3					Great Basin Pinyon-Juniper Woodland
Coarse Filter	Dry	Flowering Plants	Mokiah Milkvetch	Astragalus mokiacensis	No	No	G2		NV			Mojave Mid-Elevation Mixed Desert Scrub
Coarse Filter	Dry	Flowering Plants	Spring Mountain Milkvetch	Astragalus remotus	No	No	G2		NV			Mojave Mid-Elevation Mixed Desert Scrub, North American Warm Desert Wash
Coarse Filter	Dry	Flowering Plants		Coryphantha chlorantha	No	No	G2					Mojave Mid-Elevation Mixed Desert Scrub
Coarse Filter	Dry	Flowering Plants	Forked Buckwheat	Eriogonum bifurcatum	No	No	G2		CA, NV			North American Warm Desert Playa
Coarse Filter	Dry	Flowering Plants	California flannelbush	Fremontodendron californicum	No	Yes	G4		AZ			Sonora-Mojave Semi-Desert Chaparral
Coarse Filter	Dry	Flowering Plants	Owens Valley Checker-mallow	Sidalcea covillei	No	Yes	G3		CA			Inter-Mountain Basins Playa
Coarse Filter	Dry	Flowering Plants	Charleston Kittentails	Synthyris ranunculina	No	No	G2					Rocky Mountain Alpine-Montane Wet Meadow and Pond, Rocky Mountain Subalpine-Montane Riparian Shrubland/Stream, Rocky Mountain Subalpine-Montane Riparian Woodland/Stream
Local	Dry	Ants, Wasps, & Bees	A Chrysidid Wasp	Ceratochrysis gracilis	No	No	G1					
Local	Dry	Ants, Wasps, & Bees	Menke's Chrysidid Wasp	Ceratochrysis menkei	No	No	G1					
Local	Dry	Ants, Wasps, & Bees	Redheaded Sphecid Wasp	Eucerceris ruficeps	No	No	G2					
Local	Dry	Ants, Wasps, & Bees	An Ant	Lasius nevadensis	No	No	G1					
Local	Dry	Ants, Wasps, & Bees	An Ant	Neivamyrmex nyensis	No	No	G1					
Local	Dry	Ants, Wasps, & Bees	A Cleptoparasitic Bee	Paranomada californica	No	No	G1					
Local	Dry	Ants, Wasps, & Bees	Borrego Parnopes Chrysidid Wasp	Parnopes borregoensis	No	No	G1					

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Local	Dry	Ants, Wasps, & Bees	A Cleptoparasitic Bee	Rhopalolemma robertsi	No	No	G1					
Local	Dry	Birds	California Condor	Gymnogyps californianus	Yes	Yes	G1	AZ, CA, UT				
Local	Dry	Butterflies & Skippers	Desert Green Hairstreak	Callophrys comstocki	No	No	G2					
Local	Dry	Butterflies & Skippers	Mcneill's Saltbush Sootywing	Hesperopsis gracielae	No	No	G2		AZ			
Local	Dry	Butterflies & Skippers	San Emigdio Blue	Plebulina emigdionis	No	No	G2					
Local	Dry	Butterflies & Skippers	Carol's Fritillary	Speyeria carolae	No	No	G2					
Local	Dry	Grasshoppers	Desert Monkey Grasshopper	Psychomastax deserticola	No	No	G1					
Local	Dry	Katydids & Crickets	Kelso Jerusalem Cricket	Ammopelmatus kelsoensis	No	No	G1					
Local	Dry	Katydids & Crickets	Coachella Giant Sand Treader Cricket	Macrobaenetes valgum	No	No	G1					
Local	Dry	Katydids & Crickets	Coachella Valley Jerusalem Cricket	Stenopelmatus cahuilaensis	No	No	G1					
Local	Dry	Mammals	Stephens's Kangaroo Rat	Dipodomys stephensi	Yes	Yes	G2	CA	CA			
Local	Dry	Mammals	Palmer's Chipmunk	Neotamias palmeri	No	Yes	G2	NV		HV		
Local	Dry	Other Beetles	Aegialian Scarab Beetle	Aegialia knighti	No	No	G1					
Local	Dry	Other Beetles	Large Aegialian Scarab Beetle	Aegialia magnifica	No	No	G1					
Local	Dry	Other Beetles	Big Dune Aphodius Scarab Beetle	Aphodius sp. 1	No	No	G1		NV			
Local	Dry	Other Beetles	Casey's June Beetle	Dinacoma caseyi	Yes	No	G1					
Local	Dry	Other Beetles	Kelso Dune Glaresis Scarab Beetle	Glaresis arenata	No	No	G2					
Local	Dry	Other Beetles	Simple Hydroporus Diving Beetle	Hydroporus simplex	No	No	G1					
Local	Dry	Other Beetles	Nelson's Miloderes Weevil	Miloderes nelsoni	No	No	G2					
Local	Dry	Other Beetles	Rulien's Miloderes Weevil	Miloderes sp. 1	No	No	G1					
Local	Dry	Other Beetles	Saline Valley Snow-front Scarab Beetle	Polyphylla anteronivea	No	No	G1					
Local	Dry	Other Beetles	Spotted Warner Valley Dunes Scarab Beetle	Polyphylla avittata	No	No	G2					
Local	Dry	Other Beetles	A Polyphyllan Scarab Beetle	Polyphylla erratica	No	No	G1					
Local	Dry	Other Beetles	Giuliani's Dune Scarab Beetle	Pseudocotalpa giulianii	No	No	G1					
Local	Dry	Other Beetles	Brown-tassel Trigonoscuta Weevil	Trigonoscuta brunnotesselata	No	No	G1					
Local	Dry	Other Insects	Nevares Spring Naucorid Bug	Ambrysus funebris	Yes	No	G1					
Local	Dry	Other Insects	Saratoga Springs Belostoman Bug	Belostoma saratogae	No	No	G1					
Local	Dry	Other Insects	Lacewing or Ally	Oliarces clara	No	No	G2		AZ			
Local	Dry	Reptiles	Southern Rubber Boa	Charina umbratica	No	Yes	G2	CA				
Local	Dry	Reptiles	Panamint Alligator Lizard	Elgaria panamintina	No	No	G2	CA	CA	PS		
Local	Dry	Reptiles	Coachella Valley Fringe-toed Lizard	Uma inornata	Yes	Yes	G1	CA	CA			
Local	Dry	Terrestrial Snails	Morongo Desertsnail	Eremarionta morongoana	No	No	G2					
Local	Dry	Conifers & relatives	Death Valley Mormon-tea	Ephedra funerea	No	No	G2					
Local	Dry	Ferns & relatives	Utah Spike-moss	Selaginella utahensis	No	No	G2					
Local	Dry	Flowering Plants		Allium marvinii	No	No	G1					
Local	Dry	Flowering Plants	Spanish Needle Onion	Allium shevockii	No	No	G1		CA			
Local	Dry	Flowering Plants	Western Sand-parsley	Ammoselinum giganteum	No	No	G2					
Local	Dry	Flowering Plants	Unequal Rockcress	Arabis dispar	No	No	G3					
Local	Dry	Flowering Plants	Parish's Rockcress	Arabis parishii	No	No	G2					
Local	Dry	Flowering Plants	Darwin Rock Cress	Arabis pulchra var. munciensis	No	No	T4		CA			
Local	Dry	Flowering Plants	Shockley's Rockcress	Arabis shockleyi	No	No	G3					

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Local	Dry	Flowering Plants	Dwarf Bear-poppy	Arctomecon humilis	Yes	No	G1					
Local	Dry	Flowering Plants	Meadow Valley Sandwort	Arenaria stenomeres	No	No	G2					
Local	Dry	Flowering Plants	Bear Valley Sandwort	Arenaria ursina	Yes	No	G2					
Local	Dry	Flowering Plants	California Silverbush	Argythamnia californica	No	No	G2					
Local	Dry	Flowering Plants	Cushenbury Milkvetch	Astragalus albens	Yes	No	G1		CA			
Local	Dry	Flowering Plants		Astragalus ampullarioides	Yes	No	G1					
Local	Dry	Flowering Plants	Gumbo Milkvetch	Astragalus ampullarius	No	No	G2					
Local	Dry	Flowering Plants	Darwin Mesa Milkvetch	Astragalus atratus var. mensanus	No	No	T2		CA			
Local	Dry	Flowering Plants	Beatley's Milkvetch	Astragalus beatleyae	No	No	G2					
Local	Dry	Flowering Plants	Cima Milkvetch	Astragalus cimae var. cimae	No	No	T2		NV			
Local	Dry	Flowering Plants	Pagumpa Milkvetch	Astragalus ensiformis var. gracilior	No	No	T1		NV			
Local	Dry	Flowering Plants	Ertter's Milkvetch	Astragalus ertterae	No	No	G1		CA			
Local	Dry	Flowering Plants	Black Milkvetch	Astragalus funereus	No	No	G2		CA, NV			
Local	Dry	Flowering Plants	Gilman's Milkvetch	Astragalus gilmanii	No	No	G2					
Local	Dry	Flowering Plants	Holmgren's Milkvetch	Astragalus holmgreniorum	Yes	Yes	G1					
Local	Dry	Flowering Plants	Lane Mountain Milkvetch	Astragalus jaegerianus	Yes	No	G1		CA			
Local	Dry	Flowering Plants	Coachella Valley Milkvetch	Astragalus lentiginosus var. coachellae	Yes	No	T2		CA			
Local	Dry	Flowering Plants	Big Bear Valley Woollypod	Astragalus leucolobus	No	No	G2					
Local	Dry	Flowering Plants	Half-ring Pod Milkvetch	Astragalus mohavensis var. hemigyrus	No	No	T2		NV			
Local	Dry	Flowering Plants	Nye Milkvetch	Astragalus nyensis	No	No	G3					
Local	Dry	Flowering Plants	Pink Egg Milkvetch	Astragalus oophorus var. lonchocalyx	No	No	T2		NV			
Local	Dry	Flowering Plants	Raven's Milkvetch	Astragalus ravenii	No	No	G1					
Local	Dry	Flowering Plants	Silver Reef Milkvetch	Astragalus straturensis	No	No	G2					
Local	Dry	Flowering Plants	Triple-rib Milkvetch	Astragalus tricarinatus	Yes	No	G1		CA			
Local	Dry	Flowering Plants		Atriplex argentea var. longitrichoma	No	No	T1		NV			
Local	Dry	Flowering Plants	Parish's Saltbush	Atriplex parishii	No	No	G1					
Local	Dry	Flowering Plants	Kofka Barberry	Berberis harrisoniana	No	No	G1		AZ, CA			
Local	Dry	Flowering Plants	Inyo County Mariposa-lily	Calochortus excavatus	No	No	G3		CA			
Local	Dry	Flowering Plants	Panamint Mountain Mariposa Lily	Calochortus panamintensis	No	No	G3					
Local	Dry	Flowering Plants	Plummer's Mariposa-lily	Calochortus plummerae	No	No	G3					
Local	Dry	Flowering Plants	Peirson's Morning-glory	Calystegia peirsonii	No	No	G3					
Local	Dry	Flowering Plants	Baird's Camissonia	Camissonia bairdii	No	No	G1					
Local	Dry	Flowering Plants	Diamond Valley Suncup	Camissonia gouldii	No	No	G1					
Local	Dry	Flowering Plants	Kern River Evening-primrose	Camissonia integrifolia	No	No	G3		CA			
Local	Dry	Flowering Plants	Intermountain Evening-primrose	Camissonia megalantha	No	No	G3		NV			
Local	Dry	Flowering Plants	White Canbya	Canbya candida	No	No	G3					
Local	Dry	Flowering Plants	Hays' Sedge	Carex haysii	No	No	G1					
Local	Dry	Flowering Plants	Crucifixion Thorn	Castela emoryi	No	Yes	G3					
Local	Dry	Flowering Plants	Ash Grey Indian-paintbrush	Castilleja cinerea	Yes	No	G2					
Local	Dry	Flowering Plants	Mt. Gleason Indian Paintbrush	Castilleja gleasoni	No	Yes	G2					

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Local	Dry	Flowering Plants	San Bernardino Owl's-clover	Castilleja lasiorhyncha	No	No	G2					
Local	Dry	Flowering Plants	Payson's Caulanthus	Caulanthus simulans	No	No	G3					
Local	Dry	Flowering Plants	Jaeger's Caulostramina	Caulostramina jaegeri	No	No	G1		CA			
Local	Dry	Flowering Plants	Flatseed Spurge	Chamaesyce platysperma	No	No	G3		CA			
Local	Dry	Flowering Plants	San Fernando Valley Chorizanthe	Chorizanthe parryi var. fernandina	Yes	Yes	T1					
Local	Dry	Flowering Plants	Parry's Spineflower	Chorizanthe parryi var. parryi	No	No	T2		CA			
Local	Dry	Flowering Plants	Clokey's Thistle	Cirsium clokeyi	No	No	G2					
Local	Dry	Flowering Plants	Pygmy Pussy-paws	Cistanthe pygmaea	No	No	G2					
Local	Dry	Flowering Plants	Temblor Range Clarkia	Clarkia tembloriensis ssp. calientensis	No	No	T1		CA			
Local	Dry	Flowering Plants	Clokey's Cat's-eye	Cryptantha clokeyi	No	No	G1		CA			
Local	Dry	Flowering Plants	Unusual Cat's-eye	Cryptantha insolita	No	Yes	GH		NV			
Local	Dry	Flowering Plants	Bristle-cone Cryptantha	Cryptantha roosiorum	No	Yes	G1		CA			
Local	Dry	Flowering Plants	Pipe Springs Cryptantha	Cryptantha semiglabra	No	No	G1					
Local	Dry	Flowering Plants	Desert Cymopterus	Cymopterus deserticola	No	No	G3		CA			
Local	Dry	Flowering Plants	Sanicle Biscuitroot	Cymopterus ripleyi var. saniculoides	No	No	T3		CA			
Local	Dry	Flowering Plants	July Gold	Dedeckera eurekensis	No	Yes	G2		CA			
Local	Dry	Flowering Plants	Unexpected Larkspur	Delphinium inopinum	No	No	G3					
Local	Dry	Flowering Plants	Kern County Larkspur	Delphinium purpusii	No	No	G2		CA			
Local	Dry	Flowering Plants	Byron Larkspur	Delphinium recurvatum	No	No	G2		CA			
Local	Dry	Flowering Plants	Jaeger Whitlowgrass	Draba jaegeri	No	No	G2					
Local	Dry	Flowering Plants	Charleston Draba	Draba paucifructa	No	No	G1					
Local	Dry	Flowering Plants	Mt. Whitney Draba	Draba sharsmithii	No	No	G1					
Local	Dry	Flowering Plants	Panamint Dudleya	Dudleya saxosa ssp. saxosa	No	No	T3		CA			
Local	Dry	Flowering Plants	Engelmann's Hedgehog Cactus	Echinocereus engelmannii var. armatus	No	Yes	T2					
Local	Dry	Flowering Plants	Howe's Hedgehog Cactus	Echinocereus engelmannii var. howei	No	No	T1		CA			
Local	Dry	Flowering Plants	Panamint Daisy	Enceliopsis covillei	No	No	G3		CA			
Local	Dry	Flowering Plants	Hoover's Eriastrum	Eriastrum hooveri	No	No	G3		CA			
Local	Dry	Flowering Plants	Pine Valley Goldenbush	Ericameria crispa	No	No	G2					
Local	Dry	Flowering Plants	Gilman Goldenweed	Ericameria gilmanii	No	No	G1		CA			
Local	Dry	Flowering Plants	Hall's Daisy	Erigeron aequifolius	No	No	G2		CA			
Local	Dry	Flowering Plants	Bald Daisy	Erigeron calvus	No	No	G1					
Local	Dry	Flowering Plants	Mound Daisy	Erigeron compactus	No	No	G2					
Local	Dry	Flowering Plants	Parish's Daisy	Erigeron parishii	Yes	No	G2		CA			
Local	Dry	Flowering Plants	Zion Daisy	Erigeron sionis	No	No	G2					
Local	Dry	Flowering Plants	Tehachapi Buckwheat	Eriogonum callistum	No	No	G1					
Local	Dry	Flowering Plants	Reveal's Buckwheat	Eriogonum contiguum	No	No	G2		CA			
Local	Dry	Flowering Plants	Wildrose Canyon Buckwheat	Eriogonum eremicola	No	No	G1		CA			
Local	Dry	Flowering Plants	Thorne's Buckwheat	Eriogonum ericifolium var. thornei	No	Yes	T1					
Local	Dry	Flowering Plants	Gilman's Buckwheat	Eriogonum gilmanii	No	No	G2					
Local	Dry	Flowering Plants	Heermann's Buckwheat	Eriogonum heermannii var. clokeyi	No	No	T2		NV			

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Local	Dry	Flowering Plants	Hoffmann's Buckwheat	Eriogonum hoffmannii var. hoffmannii	No	No	T2		CA			
Local	Dry	Flowering Plants	Jointed Buckwheat	Eriogonum intrafractum	No	No	G2					
Local	Dry	Flowering Plants	Southern Mountain Buckwheat	Eriogonum kennedyi var. austromontanum	Yes	No	T2					
Local	Dry	Flowering Plants	Cache Peak Buckwheat	Eriogonum kennedyi var. pinicola	No	No	T1		CA			
Local	Dry	Flowering Plants	Panamint Mountains Buckwheat	Eriogonum microthecum var. panamintense	No	No	T2		CA			
Local	Dry	Flowering Plants	Cushenbury Buckwheat	Eriogonum ovalifolium var. vineum	Yes	No	T1		CA			
Local	Dry	Flowering Plants	Wire-stem Buckwheat	Eriogonum pharnaceoides var. cervinum	No	No	T2		NV			
Local	Dry	Flowering Plants	Barstow Wooly-sunflower	Eriophyllum mohavense	No	No	G2		CA			
Local	Dry	Flowering Plants	Largeleaf Filaree	Erodium macrophyllum	No	No	G3					
Local	Dry	Flowering Plants	Twisselmann's Poppy	Eschscholzia minutiflora ssp. twisselmannii	No	No	T2		CA			
Local	Dry	Flowering Plants	Cushion Fox-tail Cactus	Escobaria alversonii	No	No	G3					
Local	Dry	Flowering Plants	Viviparous Foxtail Cactus	Escobaria vivipara var. rosea	No	Yes	T3					
Local	Dry	Flowering Plants	Onyx Bedstraw	Galium angustifolium ssp. onycense	No	No	T2		CA			
Local	Dry	Flowering Plants	San Gabriel Bedstraw	Galium grande	No	No	G2		CA			
Local	Dry	Flowering Plants	Kingston Bedstraw	Galium hilendiae ssp. kingstonense	No	No	T2		CA			
Local	Dry	Flowering Plants	Little San Bernardino Mountains gilia	Gilia maculata	No	No	G1					
Local	Dry	Flowering Plants	Golden Carpet	Gilmania luteola	No	No	G1					
Local	Dry	Flowering Plants	Sharsmith's Stickseed	Hackelia sharsmithii	No	No	G3					
Local	Dry	Flowering Plants	Red Rock tarplant	Hemizonia arida	No	Yes	G1					
Local	Dry	Flowering Plants	Mohave Tarplant	Hemizonia mohavensis	No	Yes	G2					
Local	Dry	Flowering Plants	Jones Golden-aster	Heterotheca jonesii	No	No	G2					
Local	Dry	Flowering Plants	Shaggy-hair Alumroot	Heuchera hirsutissima	No	No	G2					
Local	Dry	Flowering Plants	Parish's Alumroot	Heuchera parishii	No	No	G2					
Local	Dry	Flowering Plants	Rock Lady	Holmgrenanthe petrophila	No	Yes	G1					
Local	Dry	Flowering Plants	Sanderson's Cheesebush	Hymenoclea sandersonii	No	No	G1					
Local	Dry	Flowering Plants	Silver-haired Ivesia	Ivesia argyrocoma	No	No	G2					
Local	Dry	Flowering Plants	Field Ivesia	Ivesia campestris	No	No	G3					
Local	Dry	Flowering Plants	Kingston Mountains Ivesia	Ivesia patellifera	No	No	G1		CA			
Local	Dry	Flowering Plants	Coulter's Goldfields	Lasthenia glabrata ssp. coulteri	No	No	T3		CA			
Local	Dry	Flowering Plants	Bullfrog Hills Sweetpea	Lathyrus hitchcockianus	No	No	G2		NV			
Local	Dry	Flowering Plants	Pale-yellow Layia	Layia heterotricha	No	No	G2		CA			
Local	Dry	Flowering Plants	San Joaquin Woolly Threads	Lembertia congdonii	Yes	No	G3					
Local	Dry	Flowering Plants	Ross' Pitcher Sage	Lepechinia rossii	No	No	G1					
Local	Dry	Flowering Plants	San Jacinto Prickly Phlox	Leptodactylon jaegeri	No	No	G2					
Local	Dry	Flowering Plants	San Bernardino Mountains Bladderpod	Lesquerella kingii ssp. bernardina	Yes	No	T1					
Local	Dry	Flowering Plants	Yosemite Lewisia	Lewisia disepala	No	No	G2					
Local	Dry	Flowering Plants	Lemon Lily	Lilium parryi	No	Yes	G3					
Local	Dry	Flowering Plants	San Gabriel Linanthus	Linanthus concinnus	No	No	G2					

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Local	Dry	Flowering Plants	Baldwin Lake Linanthus	Linanthus killipii	No	No	G2					
Local	Dry	Flowering Plants	Orcutt's Linanthus	Linanthus orcuttii	No	No	G4		CA			
Local	Dry	Flowering Plants	Sage-like Loeflingia	Loeflingia squarrosa ssp. artemisiarum	No	No	T2		NV			
Local	Dry	Flowering Plants	Owen's Peak lomatium	Lomatium shevockii	No	No	G1		CA			
Local	Dry	Flowering Plants	Wright's Hosackia	Lotus argyraeus var. multicaulis	No	No	T1		CA, NV			
Local	Dry	Flowering Plants	Holmgren Lupine	Lupinus holmgrenianus	No	No	G2		NV			
Local	Dry	Flowering Plants	Panamint Mountains Lupine	Lupinus magnificus var. magnificus	No	No	T1		CA			
Local	Dry	Flowering Plants	Father Crowley's Lupine	Lupinus padre-crowleyi	No	Yes	G2					
Local	Dry	Flowering Plants	Peirson's Lupine	Lupinus peirsonii	No	No	G2					
Local	Dry	Flowering Plants	Davidson's Bushmallow	Malacothamnus davidsonii	No	No	G1					
Local	Dry	Flowering Plants	Polished Blazingstar	Mentzelia polita	No	No	G2		CA, NV			
Local	Dry	Flowering Plants	Three-tooth Blazingstar	Mentzelia tridentata	No	No	G2		CA			
Local	Dry	Flowering Plants	San Bernardino Mountain Monkeyflower	Mimulus exiguus	No	No	G2					
Local	Dry	Flowering Plants	Mojave Monkeyflower	Mimulus mohavensis	No	No	G2		CA			
Local	Dry	Flowering Plants	Calico Monkeyflower	Mimulus pictus	No	No	G2		CA			
Local	Dry	Flowering Plants	Little Purple Monkeyflower	Mimulus purpureus	No	No	G2					
Local	Dry	Flowering Plants	Kelso Creek Monkeyflower	Mimulus shevockii	No	No	G2		CA			
Local	Dry	Flowering Plants	Bashful Four-o'clock	Mirabilis pudica	No	No	G3					
Local	Dry	Flowering Plants	sweet-smelling monardella	Monardella beneolens	No	No	G1		CA			
Local	Dry	Flowering Plants	Robison's Monardella	Monardella robisonii	No	No	G2		CA			
Local	Dry	Flowering Plants	California Muhly	Muhlenbergia californica	No	No	G3					
Local	Dry	Flowering Plants	Piute Mountains Navarretia	Navarretia setiloba	No	No	G1		CA			
Local	Dry	Flowering Plants	Eureka Dunes Evening-primrose	Oenothera californica ssp. eurekensis	Yes	Yes	T1					
Local	Dry	Flowering Plants	Cave Evening-primrose	Oenothera cavernae	No	No	G2					
Local	Dry	Flowering Plants	Golden Prickly-pear	Opuntia aurea	No	Yes	G3					
Local	Dry	Flowering Plants	Short Joint Beavertail	Opuntia basilaris var. brachyclada	No	No	T3		CA			
Local	Dry	Flowering Plants	Bakersfield Beavertail Cactus	Opuntia basilaris var. treleasei	Yes	Yes	T2		CA			
Local	Dry	Flowering Plants	Woolly Mountain-parsley	Oreonana vestita	No	No	G3					
Local	Dry	Flowering Plants	Cushenbury Oxytheca	Oxytheca parishii var. goodmaniana	Yes	No	T1					
Local	Dry	Flowering Plants	San Bernardino Butterweed	Packera bernardina	No	No	G2					
Local	Dry	Flowering Plants	Fringed Grass-of-Parnassus	Parnassia cirrata	No	No	G2					
Local	Dry	Flowering Plants	Siler Pincushion Cactus	Pediocactus sileri	Yes	Yes	G3					
Local	Dry	Flowering Plants	Beaver Scurf-pea	Pediomelum castoreum	No	No	G3					
Local	Dry	Flowering Plants	Limestone Beardtongue	Penstemon calcareus	No	No	G2					
Local	Dry	Flowering Plants	Death Valley Beardtongue	Penstemon fruticiformis ssp. amargosae	No	No	T3		NV			
Local	Dry	Flowering Plants	Petiolate Beardtongue	Penstemon petiolatus	No	No	G2		AZ			
Local	Dry	Flowering Plants	Stephen's Beardtongue	Penstemon stephensii	No	No	G2		CA			
Local	Dry	Flowering Plants	Jaeger's Beardtongue	Penstemon thompsoniae ssp. jaegeri	No	No	T2		NV			

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Local	Dry	Flowering Plants	Inyo Rock Daisy	Perityle inyoensis	No	No	G2		CA			
Local	Dry	Flowering Plants	Hanaupah rock daisy	Perityle villosa	No	No	G1		CA			
Local	Dry	Flowering Plants	Parry Sandpaper-plant	Petalonyx parryi	No	No	G2					
Local	Dry	Flowering Plants	Death Valley Sandpaper-plant	Petalonyx thurberi ssp. gilmanii	No	No	T2		CA			
Local	Dry	Flowering Plants	marble rockmat	Petrophyton acuminatum	No	No	G1					
Local	Dry	Flowering Plants	Aven Nelson's Phacelia	Phacelia anelsonii	No	No	G2					
Local	Dry	Flowering Plants	Death Valley Roundleaf Phacelia	Phacelia mustelina	No	No	G2		CA, NV			
Local	Dry	Flowering Plants	Nash's Phacelia	Phacelia nashiana	No	No	G3		CA			
Local	Dry	Flowering Plants	Nine Mile Canyon Phacelia	Phacelia novenmillensis	No	No	G2		CA			
Local	Dry	Flowering Plants	Bear Valley Phlox	Phlox dolichantha	No	No	G2					
Local	Dry	Flowering Plants	Parish's Popcorn-flower	Plagiobothrys parishii	No	No	G1					
Local	Dry	Flowering Plants	San Bernardino Bluegrass	Poa atropurpurea	Yes	No	G2					
Local	Dry	Flowering Plants	Spiny Milkwort	Polygala heterorhyncha	No	No	G3					
Local	Dry	Flowering Plants	Pygmy Poreleaf	Porophyllum pygmaeum	No	No	G2					
Local	Dry	Flowering Plants		Prunus eremophila	No	No	G1					
Local	Dry	Flowering Plants	Parish's Alkali Grass	Puccinellia parishii	No	Yes	G2		CA			
Local	Dry	Flowering Plants	Muir's Raillardiopsis	Raillardiopsis muirii	No	No	G2					
Local	Dry	Flowering Plants		Saltugilia latimeri	No	No	G2		CA			
Local	Dry	Flowering Plants	Clokey's Mountain Sage	Salvia dorrii var. clokeyi	No	No	T3		NV			
Local	Dry	Flowering Plants	Orocopia Sage	Salvia greatae	No	No	G2		CA			
Local	Dry	Flowering Plants	Mohave Fishhook Cactus	Sclerocactus polyancistrus	No	Yes	G4					
Local	Dry	Flowering Plants	Davidson's Stonecrop	Sedum niveum	No	No	G3					
Local	Dry	Flowering Plants	Pedate Checker-mallow	Sidalcea pedata	Yes	Yes	G1					
Local	Dry	Flowering Plants	Clokey's Catchfly	Silene clokeyi	No	No	G2					
Local	Dry	Flowering Plants		Sphaeralcea gierischii	Yes	No	G1					
Local	Dry	Flowering Plants	Charleston Tansy	Sphaeromeria compacta	No	No	G2					
Local	Dry	Flowering Plants	Zion Tansy	Sphaeromeria ruthiae	No	No	G2					
Local	Dry	Flowering Plants	California Jewelflower	Stanfordia californica	Yes	Yes	G1					
Local	Dry	Flowering Plants	Laguna Mountains Streptanthus	Streptanthus bernardinus	No	No	G3					
Local	Dry	Flowering Plants	Southern Jewelflower	Streptanthus campestris	No	No	G2					
Local	Dry	Flowering Plants	Piute Mountains Jewelflower	Streptanthus cordatus var. piutensis	No	No	T1		CA			
Local	Dry	Flowering Plants	Alpine Jewelflower	Streptanthus gracilis	No	No	G3					
Local	Dry	Flowering Plants	San Bernardino Aster	Symphyotrichum defoliatum	No	No	G3		CA			
Local	Dry	Flowering Plants	Greata's Aster	Symphyotrichum greatae	No	No	G2					
Local	Dry	Flowering Plants	Welsh's American-aster	Symphyotrichum welshii	No	No	G2					
Local	Dry	Flowering Plants	California Dandelion	Taraxacum californicum	Yes	No	G2					
Local	Dry	Flowering Plants	Holly-leaf Tetracoccus	Tetracoccus ilicifolius	No	No	G1					
Local	Dry	Flowering Plants	Slender-petal Thelypody	Thelypodium stenopetalum	Yes	Yes	G1					
Local	Dry	Flowering Plants	Aravaipa woodfern	Thelypteris puberula var. sonorensis	No	No	T3		AZ			
Local	Dry	Flowering Plants	Charleston Ground-daisy	Townsendia jonesii var. tumulosa	No	No	T3		NV			
Local	Dry	Flowering Plants	Black Rock Ground-daisy	Townsendia smithii	No	No	G1		AZ			

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Local	Dry	Flowering Plants	Three hearts	Tricardia watsonii	No	No	G4		AZ			
Local	Dry	Flowering Plants	Clausen's Violet	Viola clauseniana	No	No	G1					
Local	Dry	Flowering Plants	Mecca Aster	Xylorhiza cognata	No	No	G2		CA			
Local	Dry	Mosses		Entosthodon planoconvexus	No	No	G1					
Local	Dry	Mosses		Grimmia americana	No	No	G1					
Local	Dry	Mosses		Orthotrichum shevockii	No	No	G1		CA, NV			
Local	Dry	Mosses		Orthotrichum spjutii	No	No	G1					
Local	Dry	Mosses		Pohlia tundrae	No	No	G2					
Local	Dry	Mosses		Trichostomum sweetii	No	No	G2					
Coarse Filter	Wet	Amphibians	Arroyo Toad	Bufo californicus	Yes	No	G2	CA				North American Warm Desert Riparian Woodland and Shrubland/Stream, North American Warm Desert Wash
Coarse Filter	Wet	Amphibians	Great Plains Toad	Bufo cognatus	No	Yes	G5	NV, UT	UT	PS		Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Amphibians	Black Toad	Bufo exsul	No	Yes	G1	CA	CA			North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Amphibians	Arizona Toad	Bufo microscaphus	No	Yes	G3	AZ, NV, UT	UT	PS		Great Basin Pinyon-Juniper Woodland, North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream, North American Warm Desert Riparian Woodland and Shrubland/Stream, North American Warm Desert Wash
Coarse Filter	Wet	Amphibians	Amargosa Toad	Bufo nelsoni	No	Yes	G2	NV		PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Amphibians	Pacific Chorus Frog	Pseudacris regilla	No	No	G5	AZ, UT				Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream, Great Basin Lake/Reservoir, Great Basin Springs and Seeps, Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland, Mojave Desert Lake/Reservoir, Mojave Desert Springs and Seeps, North American Arid West Emergent Marsh and Pond, North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream, North American Warm Desert Riparian Mesquite Bosque, North American Warm Desert Riparian Woodland and Shrubland/Stream, Rocky Mountain Alpine-Montane Wet Meadow and Pond, Rocky Mountain Subalpine-Montane Riparian Shrubland/Stream, Rocky Mountain Subalpine-Montane Riparian Woodland/Stream, Sonoran Fan Palm Oasis/Stream
Coarse Filter	Wet	Amphibians	Relict Leopard Frog	Rana onca	Yes	Yes	G1	AZ, NV, UT		MV		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Amphibians	Northern Leopard Frog	Rana pipiens	No	Yes	G5	AZ, CA, NV, UT	UT	PS		Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream, Great Basin Springs and Seeps, Mojave Desert Springs and Seeps, North American Arid West Emergent Marsh and Pond

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Coarse Filter	Wet	Amphibians	Sierra Nevada Yellow-legged Frog	Rana sierrae	No	No	G1	NV		PS		Rocky Mountain Alpine-Montane Wet Meadow and Pond
Coarse Filter	Wet	Amphibians	Yavapai Leopard Frog	Rana yavapaiensis	No	Yes	G4	AZ, CA	CA			Mojave Desert Springs and Seeps, North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Amphibians	Western Spadefoot	Spea hammondii	No	No	G3	CA				North American Warm Desert Wash
Coarse Filter	Wet	Amphibians	Great Basin Spadefoot	Spea intermontana	No	No	G5	AZ	CA			North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Clark's Grebe	Aechmophorus clarkii	No	Yes	G5	AZ, NV				Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	Western Grebe	Aechmophorus occidentalis	No	Yes	G5	AZ, NV				Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	Tricolored Blackbird	Agelaius tricolor	No	Yes	G2	CA, NV	CA	PS		North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Great Egret	Ardea alba	No	Yes	G5	AZ, CA				North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Great Blue Heron	Ardea herodias	No	Yes	G5	CA				North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Cattle Egret	Bubulcus ibis	No	Yes	G5	AZ				Inter-Mountain Basins Semi-Desert Grassland, North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Green Heron	Butorides virescens	No	Yes	G5					North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Mountain Plover	Charadrius montanus	Yes	Yes	G3	AZ, CA, UT	AZ, CA, UT			Inter-Mountain Basins Semi-Desert Grassland
Coarse Filter	Wet	Birds	Black Tern	Chlidonias niger	No	Yes	G4	CA, NV		PS		Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	American Dipper	Cinclus mexicanus	No	Yes	G5	AZ				Rocky Mountain Subalpine-Montane Riparian Shrubland/Stream
Coarse Filter	Wet	Birds	Western Yellow-billed Cuckoo	Coccyzus americanus occidentalis	Yes	Yes	T3	AZ, CA, NV	CA	MV		Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream, North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Birds	A Yellow Warbler	Dendroica petechia brewsteri	No	No	T3	CA				Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream, North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream, North American Warm Desert Riparian Mesquite Bosque, Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland/Stream, Rocky Mountain Subalpine-Montane Riparian Shrubland/Stream, Rocky Mountain Subalpine-Montane Riparian Woodland/Stream
Coarse Filter	Wet	Birds	Snowy Egret	Egretta thula	No	Yes	G5	AZ, CA, NV		PS		North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Southwestern Willow Flycatcher	Empidonax traillii extimus	Yes	Yes	T1	AZ, CA, NV, UT	CA	PS		North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Birds	Wilson's Snipe	Gallinago delicata	No	Yes	G5	AZ				North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Common Loon	Gavia immer	No	Yes	G5	CA, NV		PS		Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	Common Yellowthroat	Geothlypis trichas	No	Yes	G5					North American Arid West Emergent

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
												Marsh and Pond
Coarse Filter	Wet	Birds	Caspian Tern	Hydroprogne caspia	No	Yes	G5	CA, UT				Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	Western Least Bittern	Ixobrychus exilis hesperis	No	Yes	T3	NV		PS		North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	California Gull	Larus californicus	No	Yes	G5	CA				Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	California Black Rail	Laterallus jamaicensis coturniculus	No	Yes	T1	AZ, CA	CA			North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Long-billed Curlew	Numenius americanus	No	Yes	G5	CA, NV, UT	UT	PS		Inter-Mountain Basins Semi-Desert Grassland, North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Black-crowned Night-Heron	Nycticorax nycticorax	No	Yes	G5	CA				North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	American White Pelican	Pelecanus erythrorhynchos	No	Yes	G4	CA, NV, UT		MV		Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	Double-crested Cormorant	Phalacrocorax auritus	No	Yes	G5	CA				Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	Wilson's Phalarope	Phalaropus tricolor	No	Yes	G5					North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Horned Grebe	Podiceps auritus	No	Yes	G5					Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir, North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Eared Grebe	Podiceps nigricollis	No	Yes	G5	AZ, NV		PS		North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Yuma Clapper Rail	Rallus longirostris yumanensis	Yes	Yes	T3	AZ, CA, NV	CA	PS		North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Birds	Forster's Tern	Sterna forsteri	No	Yes	G5	CA, NV		PS		Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir
Coarse Filter	Wet	Birds	Bell's Vireo	Vireo bellii	Yes	Yes	G5	UT				North American Warm Desert Riparian Mesquite Bosque, North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Birds	Arizona Bell's Vireo	Vireo bellii arizonae	No	Yes	T4	CA, NV	CA	PS		North American Warm Desert Riparian Mesquite Bosque, North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Birds	Least Bell's Vireo	Vireo bellii pusillus	Yes	Yes	T2	CA	CA			North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Birds	Yellow-headed Blackbird	Xanthocephalus xanthocephalus	No	Yes	G5	CA				North American Arid West Emergent Marsh and Pond
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Desert Sucker	Catostomus clarkii	No	Yes	G3		AZ, UT			Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Flannelmouth Sucker	Catostomus latipinnis	No	Yes	G3		AZ, UT	PS		North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	White River Springfish	Crenichthys baileyi baileyi	Yes	Yes	T1			PS		Great Basin Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Moapa White River Springfish	Crenichthys baileyi moapae	No	Yes	T2			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Devil's Hole Pupfish	Cyprinodon diabolis	Yes	Yes	G1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Desert Pupfish	Cyprinodon macularius	Yes	Yes	G1		CA			Mojave Desert Springs and Seeps, North American Arid West Emergent Marsh and Pond

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Amargosa Pupfish	Cyprinodon nevadensis amargosae	No	No	T1		CA			Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Ash Meadows Pupfish	Cyprinodon nevadensis mionectes	Yes	Yes	T2			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Warm Springs Amargosa Pupfish	Cyprinodon nevadensis pectoralis	Yes	Yes	T1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Cottonball Marsh Pupfish	Cyprinodon salinus milleri	No	Yes	T1					Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Pahrump poolfish	Empetrichthys latos	Yes	Yes	G1			MV		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Pahrump Poolfish	Empetrichthys latos latos	Yes	Yes	T1			MV		Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Humpback Chub	Gila cypha	No	Yes	G1		NV			North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Bonytail	Gila elegans	Yes	Yes	G1			PS		North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Virgin River Chub	Gila seminuda	Yes	Yes	G1			PS		North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Virgin River Chub - Muddy River Population	Gila seminuda pop. 2	Yes	Yes	T1					North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Virgin Spinedace	Lepidomeda mollispinis	Yes	Yes	G1					Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Virgin River Spinedace	Lepidomeda mollispinis mollispinis	No	Yes	T1		UT	PS		Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Moapa Dace	Moapa coriacea	Yes	Yes	G1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Woundfin	Plagopterus argentissimus	Yes	Yes	G1			PS		North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Colorado Pikeminnow	Ptychocheilus lucius	Yes	Yes	G1		CA			North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Speckled Dace	Rhinichthys osculus	Yes	No	G5		AZ			Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Moapa Speckled Dace	Rhinichthys osculus moapae	No	Yes	T1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Ash Meadows Speckled Dace	Rhinichthys osculus nevadensis	Yes	Yes	T1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Meadow Valley Speckled Dace	Rhinichthys osculus ssp. 11	No	No	T2		NV			North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Oasis Valley Speckled Dace	Rhinichthys osculus ssp. 6	No	Yes	T1	NV	NV	PS		Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater & Anadromous Fishes	White River Speckled Dace	Rhinichthys osculus ssp. 7	No	No	T2			MV		Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream, North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater & Anadromous Fishes	Razorback Sucker	Xyrauchen texanus	Yes	Yes	G1		CA	IL		North American Warm Desert Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Freshwater Snails	Badwater Snail	Assiminea infima	No	No	G1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Moapa Pebblesnail	Pyrgulopsis avernalis	No	No	G1		AZ	PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Blue Point Pyrg	Pyrgulopsis coloradensis	No	No	GH		AZ			Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Crystal Springsnail	Pyrgulopsis crystalis	No	No	G1		AZ	PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Spring Mountains Pyrg	Pyrgulopsis deaconi	No	No	G1		AZ	HV		Mojave Desert Springs and Seeps

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
Coarse Filter	Wet	Freshwater Snails	Desert Springsnail	Pyrgulopsis deserta	No	Yes	G2		AZ			Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Ash Meadows Pebblesnail	Pyrgulopsis erythropoma	No	No	G1		AZ	PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Fairbanks Springsnail	Pyrgulopsis fairbanksensis	No	No	G1		AZ	PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Corn Creek Pyrg	Pyrgulopsis fausta	No	No	G1		AZ	MV		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Elongate-gland Springsnail	Pyrgulopsis isolata	No	No	G1		AZ	PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Toquerville Springsnail	Pyrgulopsis kolobensis	No	No	G5		AZ			Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Oasis Valley Springsnail	Pyrgulopsis micrococcus	No	No	G3		AZ	MV		Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Distal-gland Springsnail	Pyrgulopsis nanus	No	No	G1		AZ	PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Median-gland Springsnail	Pyrgulopsis pisteri	No	No	G1		AZ	PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Southeast Nevada Pyrg	Pyrgulopsis turbatrix	No	No	G2		AZ	HV		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Wong's Springsnail	Pyrgulopsis wongi	No	No	G2		AZ	MV		Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Sportinggoods Tryonia	Tryonia angulata	No	No	G1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Grated Tryonia	Tryonia clathrata	No	No	G2			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Point of Rocks Tryonia	Tryonia elata	No	No	G1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Minute Tryonia	Tryonia ericae	No	No	G1			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Grapevine Springs Elongate Tryonia	Tryonia margae	No	No	G1					Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Grapevine Springs Squat Tryonia	Tryonia rowlandsi	No	No	G1					Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Freshwater Snails	Amargosa Tryonia	Tryonia variegata	No	No	G2			PS		Mojave Desert Springs and Seeps
Coarse Filter	Wet	Mammals	American Beaver	Castor canadensis	No	Yes	G5	AZ				Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream, Great Basin Lake/Reservoir, Mojave Desert Lake/Reservoir, North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream, Rocky Mountain Alpine-Montane Wet Meadow and Pond, Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Other Beetles	Ash Springs riffle beetle	Stenelmis lariversi	No	No	G1					Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Other Beetles	Moapa Warm Springs Riffle Beetle	Stenelmis moapa	No	No	G1					Mojave Desert Springs and Seeps
Coarse Filter	Wet	Other Insects	Ash Meadows Naucorid	Ambrysus amargosus	Yes	No	G1					Mojave Desert Springs and Seeps
Coarse Filter	Wet	Other Insects	Amargosa Naucorid Bug	Pelocoris shoshone	No	No	G2					Mojave Desert Springs and Seeps
Coarse Filter	Wet	Other Insects	Pahranagat Naucorid Bug	Pelocoris shoshone shoshone	No	No	T1		NV			Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Other Insects	A Naucorid Bug	Usingerina moapensis	No	No	G1					Mojave Desert Springs and Seeps
Coarse Filter	Wet	Turtles	Western Pond Turtle	Actinemys marmorata	No	No	G3	CA	CA			Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Ferns & relatives	Upward-lobed Moonwort	Botrychium ascendens	No	No	G2					Rocky Mountain Alpine-Montane Wet Meadow and Pond
Coarse Filter	Wet	Ferns & relatives	Crenulate Moonwort	Botrychium crenulatum	No	No	G3					Rocky Mountain Alpine-Montane Wet Meadow and Pond

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
Coarse Filter	Wet	Flowering Plants	Rough Angelica	Angelica scabrida	No	No	G2		NV			North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream
Coarse Filter	Wet	Flowering Plants	Sodaville Milkvetch	Astragalus lentiginosus var. sesquimetralis	No	Yes	T1		NV			Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Flowering Plants	Virgin Thistle	Cirsium virginense	No	Yes	G2		NV			Mojave Desert Springs and Seeps
Coarse Filter	Wet	Flowering Plants	Tecopa Bird's-beak	Cordylanthus tecopensis	No	No	G2		CA, NV			Great Basin Springs and Seeps, Mojave Desert Springs and Seeps
Coarse Filter	Wet	Flowering Plants	Catchfly Prairie-gentian	Eustoma exaltatum	No	No	G5		NV			Mojave Desert Springs and Seeps
Coarse Filter	Wet	Flowering Plants	California Satintail	Imperata brevifolia	No	No	G2		NV			Mojave Desert Springs and Seeps
Coarse Filter	Wet	Flowering Plants	Ash Meadows Mousetail	Ivesia kingii var. eremica	Yes	Yes	T1		NV			Mojave Desert Springs and Seeps
Coarse Filter	Wet	Flowering Plants	Funeral Mountain Blue-eyed-grass	Sisyrinchium funereum	No	No	G2					Mojave Desert Springs and Seeps
Coarse Filter	Wet	Flowering Plants	Big-root Blue-eyed-grass	Sisyrinchium radicatum	No	No	G2		NV			Mojave Desert Springs and Seeps
Coarse Filter	Wet	Flowering Plants	Ash Meadows Ladies'-tresses	Spiranthes infernalis	No	No	G1					Mojave Desert Springs and Seeps
Species Assemblage	Wet	Birds	Northern Pintail	Anas acuta	No	Yes	G5	AZ, NV			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	American Wigeon	Anas americana	No	Yes	G5	AZ			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Northern Shoveler	Anas clypeata	No	Yes	G5	AZ			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Cinnamon Teal	Anas cyanoptera	No	Yes	G5	NV			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Blue-winged Teal	Anas discors	No	Yes	G5	AZ			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Lesser Scaup	Aythya affinis	No	Yes	G5				Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Redhead	Aythya americana	No	Yes	G5	NV		PS	Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Canvasback	Aythya valisineria	No	Yes	G5	AZ, CA, NV			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Canada Goose	Branta canadensis	No	Yes	G5	AZ			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Barrow's Goldeneye	Bucephala islandica	No	Yes	G5	CA			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Least Sandpiper	Calidris minutilla	No	Yes	G5	NV			Migratory Shorebirds	
Species Assemblage	Wet	Birds	Black-necked Stilt	Himantopus mexicanus	No	Yes	G5	NV, UT		PS	Migratory Shorebirds	
Species Assemblage	Wet	Birds	Long-billed Dowitcher	Limnodromus scolopaceus	No	Yes	G5	NV			Migratory Shorebirds	
Species Assemblage	Wet	Birds	Hooded Merganser	Lophodytes cucullatus	No	Yes	G5				Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	Common Merganser	Mergus merganser	No	Yes	G5	AZ			Migratory waterfowl stopovers	
Species Assemblage	Wet	Birds	red-necked phalarope	Phalaropus lobatus	No	Yes	G4	NV		MV	Migratory Shorebirds	
Species Assemblage	Wet	Birds	White-faced Ibis	Plegadis chihi	No	Yes	G5	CA, NV		PS	Migratory Shorebirds	
Species Assemblage	Wet	Birds	American Avocet	Recurvirostra americana	No	Yes	G5	AZ, NV, UT		PS	Migratory Shorebirds	
Species Assemblage	Wet	Birds	Willet	Tringa semipalmata	No	Yes	G5	NV			Migratory Shorebirds	
Species	Wet	Flowering Plants	Ash Meadows Gumweed	Grindelia fraxinopratensis	Yes	Yes	G2		NV		Alkaline spring	

Assessment Approach	Model Group	Taxonomic Group	Common_Name	Scientific Name	Federally Listed	State Protected	Global Rank	Relevant SWAPs	Relevant BLM Special Status	CCVI	Species Assemblage(s)	Coarse Filter(s)
Assemblage											influenced soils	
Species Assemblage	Wet	Flowering Plants	Amargosa Niterwort	Nitrophila mohavensis	Yes	Yes	G1		CA, NV		Alkaline spring influenced soils	North American Warm Desert Playa
Species Assemblage	Wet	Flowering Plants	Parish's Phacelia	Phacelia parishii	No	No	G2		AZ, CA, NV		Alkaline spring influenced soils, Clay soil patches, Gypsum soils	Inter-Mountain Basins Greasewood Flat, Inter-Mountain Basins Playa, North American Warm Desert Playa
TBD	Wet	Amphibians	Inyo Mountains Salamander	Batrachoseps campi	No	No	G2	CA	CA			
TBD	Wet	Amphibians	Kern Plateau Salamander	Batrachoseps robustus	No	No	G2	CA				
TBD	Wet	Amphibians	Tehachapi Slender Salamander	Batrachoseps stebbinsi	No	Yes	G2	CA	CA			
TBD	Wet	Amphibians	Yellow-blotched Salamander	Ensatina eschscholtzii croceator	No	No	T2	CA	CA			
TBD	Wet	Amphibians	Mount Lyell Salamander	Hydromantes platycephalus	No	No	G3	CA				
TBD	Wet	Amphibians	Canyon Treefrog	Hyla arenicolor	No	No	G5	AZ, UT				
TBD	Wet	Amphibians	Southern Mountain Yellow-legged Frog	Rana muscosa	Yes	No	G2	CA				
TBD	Wet	Birds	Sonoran Yellow Warbler	Dendroica petechia sonorana	No	No	T2	CA				
TBD	Wet	Caddisflies	Denning's Cryptic Caddisfly	Cryptochia denningi	No	No	G1					
TBD	Wet	Freshwater & Anadromous Fishes	Bluehead Sucker	Catostomus discobolus	No	Yes	G4		UT			
TBD	Wet	Freshwater & Anadromous Fishes	Arroyo Chub	Gila orcuttii	No	No	G2					
TBD	Wet	Freshwater Snails	Robust Tryonia	Ipnobius robustus	No	No	G1					
TBD	Wet	Other Beetles	Death Valley Agabus Diving Beetle	Agabus rumppi	No	No	G2					
TBD	Wet	Other Beetles	Furnace Creek Riffle Beetle	Microcylloepus formicoideus	No	No	G1					
TBD	Wet	Tiger Beetles	Riparian Tiger Beetle	Cicindela praetextata	No	No	G2					
TBD	Wet	Flowering Plants	Horn's Milkvetch	Astragalus hornii var. hornii	No	No	T2		CA			
TBD	Wet	Flowering Plants	Wasatch Draba	Draba brachystylis	No	No	G1					

Appendix II. Conceptual Models for Selected Conservation Elements for the MBR REA

Ecological Integrity Assessment
Criteria and Indicators

Selected Conservation Elements

February 28, 2011

by
NatureServe

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Appendix IIa. Conceptual Model for Great Basin Pinyon-Juniper Woodland

MONTANE DRY LAND SYSTEM
Subalpine/Montane Forests & Woodlands

Great Basin Pinyon-Juniper Woodland (CES304.773)
Biophysical Setting: 1310190

Conservation Element (CE) Characterization

Summary

This system occurs on dry mountain ranges of the Great Basin region and eastern foothills of the Sierra Nevada extending south into the Mojave Desert and southwest in to the northern Transverse Ranges and San Jacinto Mountains (Figure 1). These woodlands occur on warm, dry sites on mountain slopes, mesas, plateaus and ridges ranging from 1600-2600 m elevations. Adjacent upland systems include Inter-Mountain Basins Montane Sagebrush Steppe, Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland, Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland above and at lower elevations, Great Basin Xeric Mixed Sagebrush Shrubland, Inter-Mountain Basins Big Sagebrush Shrubland, and Mojave Mid-Elevation Mixed Desert Scrub.

It generally occurs on sites with shallow rocky soils or rock dominated sites that are protected from frequent fire (rocky ridges, broken topography and mesa tops). Severe climatic events occurring during the growing season, such as frosts and drought, are thought to limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides. Soils supporting this system vary in texture ranging from stony, cobbly, gravelly sandy loams to clay loam or clay.

These woodlands are characterized by an open to moderately dense tree canopy typically composed of a mix of *Pinus monophylla* and *Juniperus osteosperma*, but either tree species may dominate to the exclusion of the other. In some regions of southern California, *Juniperus osteosperma* is replaced by *Juniperus californica*. *Cercocarpus ledifolius* is a common associate and may occur in tree or shrub form. On the east slope of the Sierras in California, *Pinus jeffreyi* and *Juniperus occidentalis var. australis* may be components of these woodlands. Understory layers are variable, but shrubs such as *Artemisia tridentata* frequently form a moderately dense short-shrub layer. Other associated shrubs include *Arctostaphylos patula, Artemisia arbuscula, Artemisia nova, Cercocarpus intricatus, Coleogyne ramosissima, Quercus gambelii* and, *Quercus turbinella*. Bunchgrasses such as *Poa fendleriana, Hesperostipa comata, Festuca idahoensis, Pseudoroegneria spicata, Leymus cinereus (= Elymus cinereus)*, and *Bouteloua gracilis* are commonly present and may form an herbaceous layer.

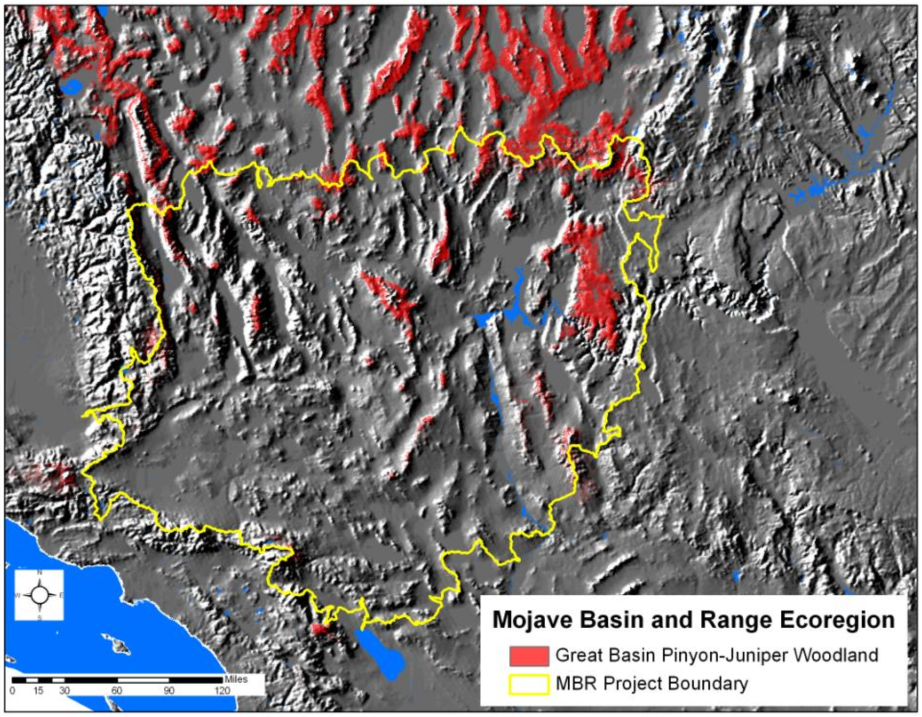
In the southern extent *Arctostaphylos patula, Ceanothuss greggii, Garrya flavescens, Quercus john-tuckeri, Juniperus californica, Purshia stansburiana, Quercus chrysolepis, Yucca baccata,* and *Yucca brevifolia* are common. This system occurs at lower elevations than Colorado Plateau Pinyon-Juniper Woodland where sympatric at the eastern and southeastern edge of its range. A crosswalk of this system to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) has been developed. However, no approved ESDs for this type apply to the MBR.

Natural Dynamics:

Change Agents

Pinus monophylla is a long lived tree (~800 years) that is killed by severe fire because of thin bark and lack of self-pruning, however mature trees can survive low intensity fires (Sawyer et al. 2009, Zouhar 2001). Although there is variation in fire frequency because of diversity of site characteristics, stand-replacing fire was uncommon in this ecological system historically with an average fire return interval (FRI) of 100-1000 yrs and occurred primarily during extreme fire behavior conditions and during long droughts (Zouhar 2001, LF BpS model 1310190). Mixed severity fire (average FRI of 100-500 yrs) was characterized as a mosaic of replacement and surface fires distributed through the patch at a fine scale (<0.1 acres). Figure 2 shows the conceptual model of Great Basin Pinyon-Juniper Woodland system with natural disturbance regime (NRV).

Figure 1. Great Basin Pinyon – Juniper Woodland relative to the MBR ecoregion.



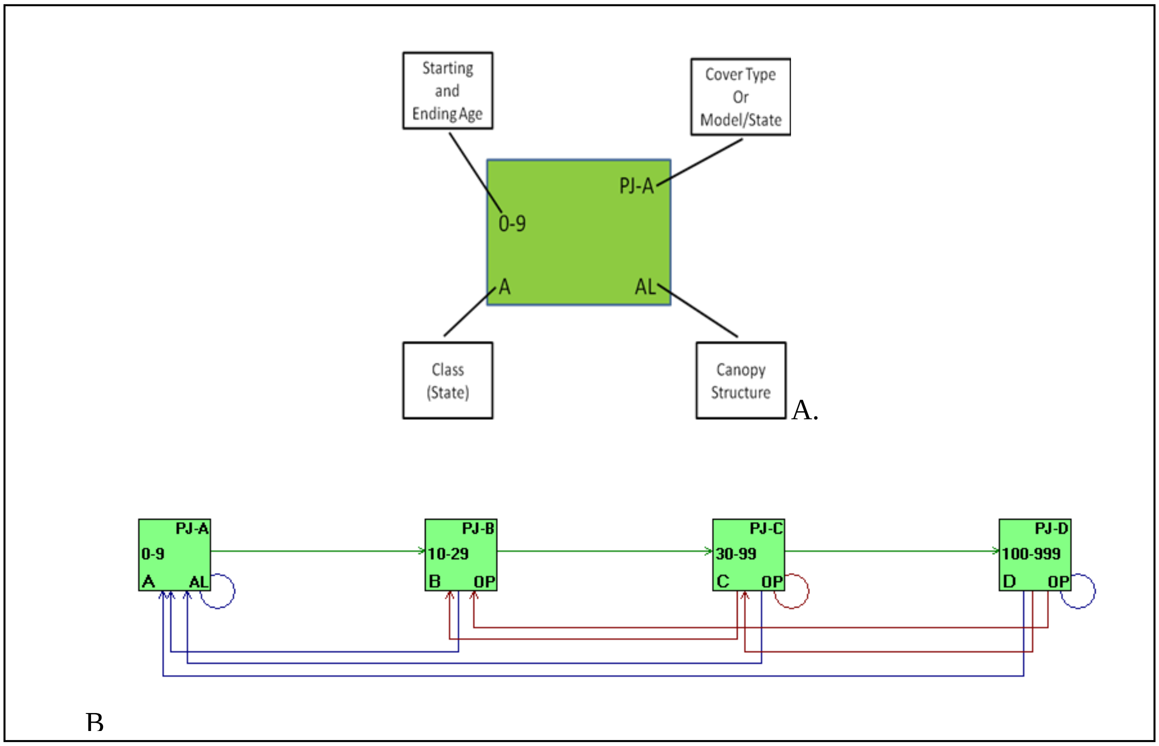
Fire rotation in San Bernardino Mountains is determined to be 480 years (Wangler and Minnich 2006). These woodlands have a truncated long fire return interval 200+ years with surface to passive crown fires of medium size, low complexity, high intensity, and very high severity (Sawyer et al. 2009). After a stand replacing fire, the site is usually colonized by herbaceous plants and shrubs. The shrubs act as nurse plants with *Pinus monophylla* seedling establish 20-30 years post fire after shrubs density increases and then a tree canopy forms after 100-150 years (Minnich 2007). As tree canopy becomes denser there is a decline in shrub cover (Minnich 2007). Fires are associated with herbaceous fuel buildup following a wet period (Minnich 2007).

Other change agents include the current epidemic of Ips beetles in many areas that has killed many pinyons and has created high fuel loads that further threaten stands (Thorne et al. 2007). Severe weather (usually drought) and insects and tree pathogens are coupled disturbances that thin trees to varying degrees and kills small patches every 250-500 years on average, with greater frequency in more closed stands (LF BpS model 1310190).

Model Description

The Pinyon-Juniper woodland was modeled using the Vegetation Dynamics Development Tool (ESSA Technologies). VDDT allows users to translate simple box-and-arrows conceptual models into probabilistic quantitative models. The Pinyon-Juniper model consists of 4 ecological states with both deterministic and probabilistic drivers. These drivers result in transitions from one ecological state to another. Deterministic drivers simulate successional changes. The deterministic transitions in the model specify the time until a transition must occur, and the class (state) it will move to after this time has passed. Figure 2 illustrates this conceptual model. In this model, deterministic transitions are illustrated by green arrows. Probabilistic transitions, represented by red and black arrows, specify the type of transition driver, its transition probability (which is the mathematical inverse of return frequency) and its impact on the vegetation cell. Probabilistic transitions represent natural disturbances (e.g. fire, wind, insects), changes resulting from land management, or probabilistic succession.

Figure 2. Conceptual Ecological Model for the Pinyon-Juniper Woodland under natural conditions and disturbance regimes. Panel A defines the codes in each state box. Panel B illustrates the transitions among states. The green arrows represent deterministic transitions (successional change). The red and black arrows represent retrogression as a result of drought and fire, respectively.



For each simulation, the landscape is partitioned into a number of cells or simulation units; each initially assigned a class and age. For each time step the model simulates the probability of each cell being affected by one of probabilistic transition types, and if a transition does occur, moves the cell to the class defined in the pathway diagram. Transition probabilities are dependent on the current state of the cell, defined by its class. They are independent of the state of the neighboring cells (Table 1).

The Great Basin Pinyon-Juniper Woodland model for natural conditions has four boxes that represent early, mid1, mid2 and late seral stages.

Class A, Initial post-fire community dominated by annual grasses and forbs. Later stages of this class contain greater amounts of perennial grasses and forbs, up to ~10% cover. Evidence of past fires (burnt stumps and charcoal) should be observed. Duration 10 years with succession to class B, mid-development open. Replacement fire occurs every 200 yrs on average.

Class B, Dominated by shrubs (up to 20% cover), perennial forbs and grasses (up to 40% cover). Tree seedlings are starting to establish on favorable microsites. Total cover remains low due to shallow unproductive soil. Duration is 20 years with succession to class C unless infrequent replacement fire (FRI of 200 yrs) returns the vegetation to class A.

Class C, Shrub and tree-dominated community (up to 40% tree canopy cover and 10-40% shrub cover) with young juniper and pinyon seedlings becoming established. Herbaceous cover is less than class B at 10-20%. Duration 70 years with succession to class D unless replacement fire (average FRI of 200 yrs) causes a transition to class A. Mortality from insects, pathogens, and drought occurs at a rotation of approximately 165 yrs and cause a transtion to class B by killing older trees.

Class D, Community dominated by young (100-300 yrs) to old (>300 yrs) juniper and pine of mixed age structure. Trees are considered old once they reach an age of 400 years. Tree cover, ranging from 30-50%, and height does not vary appreciably beyond 100 yrs, although tree diameter increases greatly. Juniper and pinyon trees are becoming competitive on site and beginning to affect understory composition. Duration 900+ years unless replacement fire (average FRI of 500 yrs) causes a transition to class A. Tree pathogens and insects such as pinyon Ips become more important for woodland dynamics occurring at a rotation of 250 yrs, including both patch mortality and thinning of isolated individual trees. However, mass mortality resulting in state retrogression to class C or class B is very rare, occurring at return intervals of 2500 or 5000 years respectively.

Table 1. Transition probabilities and return intervals for the two major drivers of the PJ Woodland system under NRV. These probabilities are used in the VDDT model to estimate the relative abundance of each class over time.

From Class	To Class	Transition Type	Probability	Return Interval (years)
C	B	Drought	0.0006	1670
C	C	Drought	0.0050	200
D	B	Drought	0.0002	`5000
D	C	Drought	0.0004	2500
D	D	Drought	0.0050	200
A	A	Replacement fire	0.0050	200
B	A	Replacement fire	0.0050	200
C	A	Replacement fire	0.0050	200
D	A	ReplacementFire	0.0020	500
D	D	Surface fire	0.0010	1000

Change Agent (CA) Characterization

Altered Dynamics

Before 1900, this system was mostly open woodland restricted to fire safe areas on rocky ridges, where low fine fuels reduced the spread of fires. Currently, much of this system occurs with a more closed canopy. Fire suppression has lead to a buildup of fuels that in turn increase the likelihood of stand-replacing fires. Heavy grazing, in contrast to fire, removes the grass cover and tends to favor shrub and conifer species. Fire suppression combined with grazing creates conditions that support invasion by pinyon and juniper trees into adjacent shrublands and grasslands. Under most management regimes, typical tree size decreases and tree density increases in this habitat.

Change agents for pinyon-juniper woodlands include invasion by introduced annual grasses, livestock grazing, development, and fire suppression. These woodlands have expanding into adjacent steppe grasslands and shrubland in many areas, reportedly in connection with livestock grazing and altered fire regimes (Blackburn 1970, Wangler and Minnich 2006). Historic fire suppression has resulted in denser tree canopy and a pinyon-juniper woodland expansion especially into big sagebrush shrublands (Wangler and Minnich 2006) and shrub steppe and grassland (Blackburn 1970). Fire severity also increases in denser canopied pinyon-juniper woodland as well as increased soil erosion because of reduction in ground cover (Zouhar2001). Recently, significant losses in PJ woodlands are a result of shortening of fire return interval (FRI) frequent fires because of invasion by introduced *Bromus tectorum* and other annuals that provide fine fuels the carry fire. Figure 3 shows a conceptual model of Great Basin Pinyon-Juniper Woodland system with uncharacteristic disturbance regimes.

In addition, many of these communities have been severely impacted by past range practices of chaining, tilling, and reseeding with exotic forage grasses. Although the dominant trees appear to regenerate after such disturbances, the effects on understory species are poorly known (Thorne et al. 2007).

Altered Model Description

The introduction of exotic annual grasses (e.g., *Bromus tectorum)* has resulted in the appearance of two uncharacteristic states. Figure 3 illustrates the conceptual model including these states. Table 2 includes these altered transition probabilities.

Class F reflects the initial invasion of PJ woodlands by cheatgrass. The cover of trees and shrubs remains unchanged relative to classes C and D. However the native herbaceous cover is progressively replaced by cheat, which can reach 20% cover.

Class E reflects the result of a stand-replacement fire in class F. Class E is annual grassland that is self-maintained by frequent (FRI 10 years) replacement fires that prevent the recruitment of native species. Intensive active restoration can transform this stable state to class A. However, continued management of these sites is required to prevent restoration failure and retrogression back to class E.

Figure 3. Conceptual Ecological Model for the Pinyon-Juniper Woodland under current conditions. This model includes two "uncharacteristic" states (classes E & F), both reflecting the invasion of exotic annual grasses.

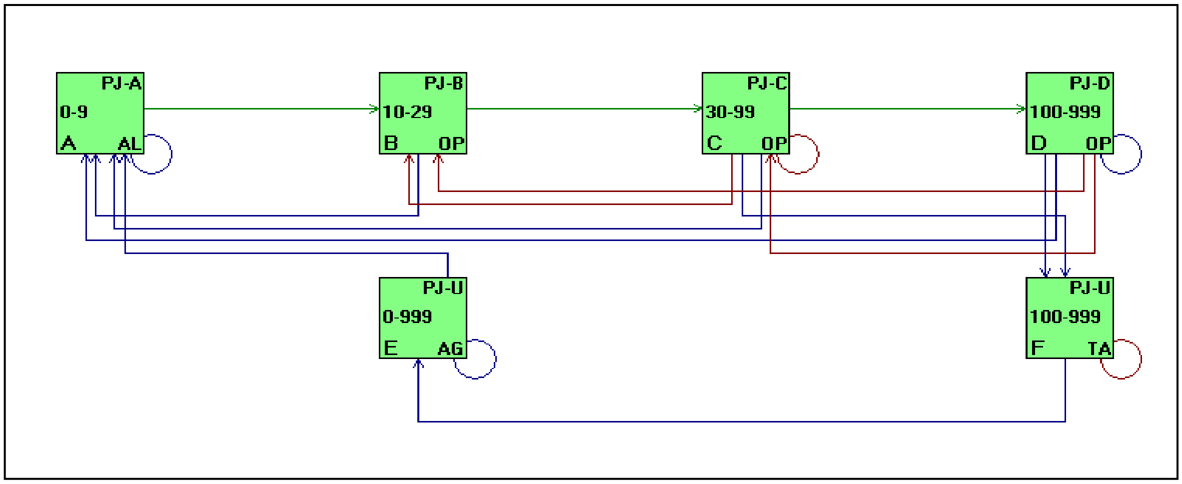


Table 2. Transition probabilities under current conditions. These transition probabilities were used in the VDDT model illustrated in Figure 3 to calculate departure estimates.

From Class	To Class	Transition Type	Probability	Return Interval (years)
C	F	Annual grass invasion	0.0010	1000
D	F	Annual grass invasion	0.0010	1000
C	B	Drought	0.0006	1670
C	C	Drought	0.0050	200
D	B	Drought	0.0002	5000
D	C	Drought	0.0004	2500
D	D	Drought	0.0050	200
F	E	Drought	0.0006	1670
F	F	Drought	0.0050	200
A	A	Replacement fire	0.0050	200
B	A	Replacement fire	0.0050	200
C	A	Replacement fire	0.0050	200
D	A	Replacement fire	0.0020	500
E	E	Replacement fire	0.1000	10
F	E	Replacement fire	0.0050	200
D	D	Surface fire	0.0010	1000

Ecological Departure

Based on the best available information, the natural range of variation (NRV) of ecological states with the PJ Woodland is shown in the HRV column of Table 3. The VDDT model was run for 150 years, starting at HRV, to examine the expected departure of the PJ Woodland from NRV as a result of cheatgrass invasion. The model did not include any ecological restoration activities. Table 3 shows the relative abundances of each of the 6 states for 50, 100, and 150 years following the introduction of exotic grasses. Ecological departure is a measure of dissimilarity from NRV and provides a measure of overall ecosystem change. It is calculated as:

$$1 - \sum_{class=A}^{F} Min(class\_abundance_{NRV}, class\_abundance_{TimeX})$$

Table 3. Departure from Historic Range of Variation in the relative abundance of ecological states as a result of the invasion of exotic annual grasses.

Class	Cover: Structure	HRV	HRV+50	HRV+100	HRV+150
A	Early: All	5%	2%	3%	3%
B	Mid1: Open	10%	7%	5%	5%
C	Mid2: Open	30%	23%	20%	16%
D	Late: Open	55%	53%	53%	53%
E	Uncharacteristic: Trees/Annual Grass	0%	12%	14%	15%
F	Uncharacteristic: Annual Grass	0%	3%	5%	7%
Ecological Departure			**14%**	**20%**	**23%**

Because class E is an "absorbing state", that is natural dynamics cannot transition this state back into a natural state, the model clearly shows a gradual increase in the abundance of exotic annual grasslands and the loss of the later stages of the PJ woodland. Continuing the simulation out for 500 years shows class E at 25%, class F at 12% and classes C and D at 13% and 46% respectively. However, one could anticipate a self-reinforcing cycle in which the abundance of cheat grass increases the fire frequency throughout the system accelerating this transition to exotic annual grasslands.

Development Impacts

Although effects are generally localized, development has impacted many stands throughout the ecoregion. High and low density urban and industrial development also have large impacts. For example, residentual development has significantly impacted stands within commuting distance to urban areas. Impacts may be direct as trees are removed for building sites or fire suppression, or indirect such as introduction of invasive species. Mining operation can drastically impact woodlands. Road building and power tranmission lines continues to fragment woodlands and provides vectors for weeds.

Major impacts of development and management actions were captured in the Landscape Condition Model (LCM) developd by NatureServe (Comer and Hak 2009). The LCM is composed of the GIS spatial layers of transportation, urban and industrial development, and managed & modified land cover layers. This model used expert-based judgment to compile and create an overall Landscape Condition Model for the conterminous United States. See Comer and Hak (2009) for methods.

Ecological Integrity Criteria & Indicators

The indicators are organized by rank factors Landscape Context, Condition and Relative Extent and assessed using indicators that can be evaluated at the appropriate spatial scale. For terrestrial CEs the reporting unit is at the Watershed 5th Level (HUC – 10) and ecosystem level using remotely sensed GIS layers. This is the link between the conceptual models and the spatial models in assessing the ecological integrity of the Great Basin Pinyon-Juniper Woodland ecological system type. Indicators for the key ecological attributes are described below.

Landscape Context

Landscape condition model (LCM) index **-** This indicator is measured in a GIS by intersecting the mapped area of the Great Basin Pinyon-Juniper Woodland system with the NatureServe LCM layer (Comer and Hak 2009) and reporting the overall LCM index for that system. The program results are an index of landscape condition from 0 to 1 with 1 being very high landscape condition and 0 having very poor condition.

***Connectivity index* -** This indicator is assessed using *CircuitScape*, a GIS program that uses circuit theory to predict connectivity in heterogeneous landscapes for individual movement, gene flow, and conservation planning (McRae 2006, McRae et al. 2008). CircuitScape will use the LCM as a resistance surface for scoring relative connectivity across all overlapping portions of the CE distribution. The program results are an index of connectivity for each 90m pixel from 0 to 1 with 0 having no connectivity (barrier) or 1 having very high connectivity. . Pixel values are summed for each CE distribution within each 5th-level HUC and the ecoregion.

Condition

***SCLASS departure index* -** This indicator is assessed by calculating and summarizing the LandFire Succession classes (SCLASS) layer which characterizes current vegetation succession classes for the distribution of each CE within each 5th-level HUC. The resulting proportional calculation for current conditions is compared to the output of the VDDT or Path-Tools model characterizing the expected natural range of variation (NRV). This comparison defines the degree of departure (%). The SClass Departure Index is calculated by subtracting the Departure percent from 1 to produce a normalized scale from 0 to 1 with 1being no departure from NRV in distribution of succession classes and 0 being complete departure from NRV.

***Abundance of invasive plant species* -** This indicator is measured using the mapped area of Great Basin Pinyon-Juniper Woodland ecological system with an abundance map of introduced invasive annual vegetation. The output is percent cover of invasive annual vegetation for the CE within each 5th level HUC. The Invasive Annual Cover Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 1 being invasive annuals absent to 0 which is 25% or greater cover of invasive annuals.

Relative Extent

***Change in Extent* -** This indicator is assessed by intersecting the mapped current extent (*circa* early 2000s) of Great Basin Pinyon-Juniper Woodland system with the updated LandFire biophysical setting (BpS) layer for this same system and reporting the percent change between the predicted area under natural disturbance regime (BpS) and the current extent. A positive change would indicate invasion of pinyon and juniper vegetation into non-pinyon – juniper woodland BpS areas such adjacent shrublands likely as a result of increased fire return interval (FRI). A negative change would indicate loss of Great Basin Pinyon-Juniper Woodland from expected BpS area likely from decreased FRI. The output is percent area of change in extent of the current extent from the extent predicted under a natural disturbance regime (NRV). The Change in Extent Index is calculated by subtracting the Change in Extent percent from 1 to produce a normalized scale from 0 to 1with 1 being no change in extent and 0 being complete loss of CE in extent.

Ecological Integrity Assessment

The Ecological Integrity Assessment (EIA) is designed to develop ecological integrity indicators for individual CE and composite CE at two spatial levels: Watershed 5th Level (HUC - 10) and ecoregion. The assessment indicators or indicators with justifications and rating threasholds are presented in Table 5, organized by Rank Factors (Landscape Context, Condition and Relative Extent) and Key Ecogical Attributes. The indicators measure the key ecological attributes for the conceptual ecological model above and the index thresholds permit interpretation of the results.

Summary of Scoring

Each indicator is scored according to criteria described above and then the score is either used directly as an index or an indicator index is calculated between 0 and 1 with 1 being 100% sustainable and 0 being totally degraded. The mean index scores of these indicators can then summarized and averaged by each Key Ecological Attribute and each Rank Factor if there are multiple indicators for each. These mean scores are then averaged for an overall index of ecological integrity for the CE within each assessment area. See hypothetical index scoring on right hand column of Table 4. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological integrity of the CE. Using the rating factors in Table 4 allows the user to rate the CE as Sustainable, Transitioning or Degraded for each Rank Factor and calculate an Overall Integrity Rank.

Table 4. Great Basin Pinyon-Juniper Woodland EIA Scorecard

Indicator	Justification	Rating: Sustainable	Rating: Transitioning	Rating: Degraded	Index Score
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Attribute: *Landscape Connectivity*					
Connectivity predicted by Circuitscape	Intact natural conditions support physical and biological dynamics occurring across diverse environmental conditions	Connectivity is moderate to high and adequate to sustain most CEs. Connectivity index is >0.6	Connectivity is moderate to low and will not sustain some CEs. Connectivity index is 0.6-0.2	Connectivity is low and will not sustain many CEs. Connectivity index is <0.2	0.73
Key Ecological Attribute: *Landscape Condition*					
Landscape Condition Model Index	Land use impacts vary in their intensity, affecting ecological dynamics that support ecological systems.	Cumulative level of impacts is sustainable. Landscape Condition Model Index is > 0.8	Cumulative level of impacts is transitioning system between a sustainable and degraded state. Landscape Condition Model Index is 0.8 – 0.5	Cumulative level of impacts has degraded system. Landscape Condition Model Index is< 0.5	0.88
Rank Factor: CONDITION					
Key Ecological Attribute: *Fire Regime*					
SCLASS Departure	Mix of age classes among patches of the system is result of disturbance regime. Departure from mixture predicted under NRV indicates uncharacteristic disturbance regime and declining integrity.	Mix of age classes indicates system is functioning inside or near NRV. System is in a sustainable state. Departure is < 20%. SCLASS Departure Index is > 0.8	Mix of age classes indicates system is functioning near, but outside NRV. System is transitioning to degraded state. Departure is 20 -50%. SCLASS Departure Index is 0.8 – 0.5	Mix of age classes indicates system is functioning well outside NRV. System is degraded. Departure is > 50%. SCLASS Departure Index is < 0.5	0.50
Key Ecological Attribute: *Native Species Composition*					
Invasive Annual Cover	Invasive annual vegetation displaces natural composition and provides fine fuels that significantly increase spread of catastrophic fire.	System is sustainable with low cover of invasive annual vegetation. Mean cover of annuals is <5%. Invasive Annual Cover Index is >0.8.	System is transitioning to degraded state by abundant invasive annual vegetation. Mean cover of annuals is 5-10%. Invasive Annual Cover Index is 0.8-0.5.	System is degraded by abundant invasive annual vegetation. Mean cover of annuals is >15%. Invasive Annual Cover Index is <0.5)	0.40
Rank Factor: Relative Extent					
Key Ecological Attribute: *Extent*					
Change in Extent	Indicates the proportion of change due to expansion or conversion to other land cover or land use, decreasing provision of ecological services provided previously.	Site is at or minimally is only modestly changed (+/-) from its original natural extent. Change in Extent Index is > 0.8.	Occurrence is substantially changed (+/-) from its original natural extent. Change in Extent Index is 0.8-0.5	Occurrence is severely changed (+/-) from its original natural extent. Change in Extent Index is < 0.5.	0.90
Overall Ecological Integrity Rank					
			(3.41 / 5 = 0.68)	**Mean Index Score**	**0.68**

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Appendix IIb. Conceptual Model for Mojave Mid-Elevation Mixed Desert Scrub

BASIN DRY LAND SYSTEM

Desert Scrub

Mojave Mid-Elevation Mixed Desert Scrub (CES302.742)

Biophysical Setting: 1310820

Conservation Element (CE) Characterization

Summary

This ecological system is found in the Mojave Desert and in the transition zone into the southern Great Basin on upper bajada and lower piedmont slopes with smaller patches occurring rocky ridges and outcrops. It represents the extensive mid-elevation desert scrub in the transition zone above desert scrub and generally below the foothill and lower montane woodlands (700-1850 m elevations (Sawyer et al. 2009) (Figure 1). Adjacent ecological systems include Great Basin Pinyon–Juniper woodland and Intermountain Basins Big Sagebrush Shrubland above and Creosotebush-White Bursage Desert Scrub below. Substrates are a mixture of alluvium and colluvium and are variable, ranging from silt to loam to coarse sand, but often shallow, well drained, sandy and rocky. Many stands occur on alkaline, calcareous substrates and often have biological crusts and shallow caliche layer (Sawyer et al. 2009). The environmental description is based on several references including Anderson 2001.Beatley1976, Barbour et al. 2007, Brown 1982, Gucker 2006a, 2006b, Keeler-Wolf 2007, Holland et al. 1995, MacMahon 1988, NatureServe Explorer 2009, Ostler et al.2000, Reid et al. 1999, and Sawyer et al. 2009, and Turner 1980.

The vegetation in this ecological system is quite variable. Major communities include Joshua tree and blackbrush scrub. Dominant and diagnostic species include *Coleogyne ramosissima, Ephedra nevadensis, Ericameria parryi, Ericameria teretifolia, Eriogonum fasciculatum, Grayia spinosa, Krameria* spp., *Lycium* spp., *Nolina* spp., *Opuntia acanthocarpa, Peucephyllum schottii, Salazaria mexicana, Viguiera parishii, Yucca brevifolia*, or *Yucca schidigera* (Sawyer et al. 2009). Less common are stands with scattered Joshua trees and a saltbush short-shrub layer dominated by *Atriplex canescens, Atriplex confertifolia*, or *Atriplex polycarpa*, or occasionally *Hymenoclea salsola*. In some areas in the western Mojave, *Juniperus californica* is common with the *Yucca brevifolia*. Desert grasses, including *Achnatherum hymenoides, Achnatherum speciosum, Muhlenbergia porteri, Pleuraphis jamesii, Pleuraphis rigida*, or *Poa secunda*, may form an herbaceous layer. Scattered *Juniperus osteosperma* or desert scrub species may also be present. Stands dominated by *Ericameria parryi,Eriogonum fasciculatum, Nolina bigelovii, N. parryi, Lycium andersonii, Menodora spinescens*, or, *Viguiera parishii* occur on rocky ridge, outcrop, and dry wash sites and may be to sparse to burn except under extreme conditions (Sawyer et al. 2009). This description is based on several references including Anderson 2001, Beatley1976, Barbour et al. 2007, Brown 1982, Gucker 2006a, 2006b, Keeler-Wolf 2007, Holland et al. 1995, MacMahon 1988, NatureServe Explorer 2009, Ostler et al.2000, Reid et al. 1999, Sawyer et al. 2009, and Turner 1980. A crosswalk of this system to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table 1. This list is not a complete cross-walk as some MLRAs do not have approved ESDs.

Figure 1. Map of Mojave Mid-Elevation Mixed Desert Scrub ecological coarse filter CE. This desert scrub extends north into Central Basins and Range ecoregion.

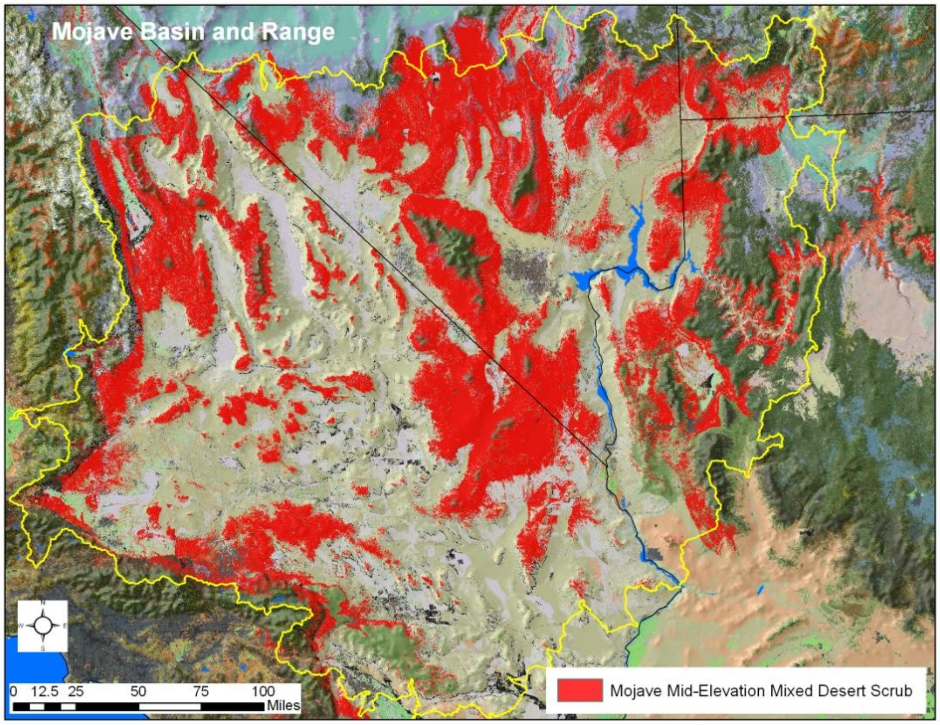

Table 1. Mojave Mid-Elevation Mixed Desert Scrub ecological system crosswalk with approved Ecological Site Descriptions.

MLRA	Ecological Site Description Name	Site ID
030-Mojave Desert	SHALLOW GRAVELLY LOAM 7-9 P.Z. /*Coleogyne ramosissima/Achnatherum speciosum*	R030XC007NV
030-Mojave Desert	SHALLOW LIMESTONE SLOPE 7-9 P.Z. /Coleogyne ramosissima/Achnatherum aridum-Achnatherum speciosum	R030XC008NV
030-Mojave Desert	SHALLOW SANDSTONE HILL 7-11 P.Z. /Coleogyne ramosissima/Achnatherum parishii var. depauperatum-Achnatherum hymenoides	R030XC010NV
030-Mojave Desert	*GRAVELLY INSET FAN /Coleogyne ramosissima-Prunus fasciculata/Achnatherum speciosum*	R030XC011NV
029-Southern Nevada Basin and Range	*Semidesert Shallow Hardpan (Blackbrush) /Coleogyne ramosissima-Stipa speciosa*	R029XY220UT

Natural Dynamics

Change Agents

Disturbance dynamics in this system are variable because of variation in the structure and compositions, being dominated open to closed canopy scrub to desert grasslands dominated by *Pleuraphis rigida* (<1400 m) and *Pleuraphis jamesii* (>1400 m) sometimes with Joshua tree overstory (Sawyer *et al.* 2009). Except for the relatively few stands with an herbaceous layer, fire return intervals also tend to be long because the open stands only burn under extreme condition. Older *Yucca brevifolia* trees can tolerate low severity fires with fire resistant bark and both *Y. brevifolia* and *Y schidigera* can sprout if burned (Gucker 2006a, 2006b).

However, fire sensitive shrub species such as the long-lived *Coleogyne ramosissima*, *Menodora spinescens*, *Nolina bigelovii*, or *Nolina parryi* will convert to ruderal and intermediate shrublands dominated by *Abrosia salsola*, *Grayia spinosa*, *Gutierrezia sarothrae*, *Ephedra nevadensis*, *Ericameria teretifolia*, *Menodora spinescens*, *Opuntia acanthocarpa*, *Salazaria mexicana*, *Tetradymia* species or *Yucca schidigera* which have shorter FRI (Anderson 2001, Keeler-Wolf 2007, Sawyer *et al.* 2009).

Model Description

The Mojave mid-elevation desert scrub was modeled using the Vegetation Dynamics Development Tool (VDDT), developed by ESSA Technologies. VDDT allows users to translate simple box-and-arrows conceptual models into probabilistic quantitative models. The Mojave desert scrub model consists of several ecological states with both deterministic and probabilistic drivers. These drivers result in transitions from one ecological state to another. Deterministic drivers simulate successional changes. The deterministic transitions in the model specify the time until a transition must occur, and the class (state) it will move to after this time has passed. Figure 2 illustrates this conceptual model. In this model, deterministic transitions are illustrated by the green arrow. Probabilistic transitions, represented by red and black arrows, specify the type of transition driver, its transition probability (which is the mathematical inverse of return frequency) and its impact on the vegetation cell. Probabilistic transitions represent natural disturbances (e.g., fire, wind, insects), changes resulting from land management, or probabilistic succession.

For each simulation, the landscape is partitioned into a number of cells or simulation units; each initially assigned a class and age. For each time step the model simulates the probability of each cell being affected by one of probabilistic transition types, and if a transition does occur, moves the cell to the class defined in the pathway diagram. Transition probabilities are dependent on the current state of the cell, defined by its class. They are independent of the state of the neighboring cells.

The Mojave desert scrub model has two states (Figure 2, Table 2), representing early and late-successional stages.

Class A: Although this ecological system is characterized by *Coleogyne ramosissima* (blackbrush), post-fire stands in class A tend to be dominated by other desert scrub species such as *Gutierrezia sarothrae*, *Menodora spinescens*, *Ephedra nevadensis*, and *Tetradymia* species. Shrub cover ranges from 0-50% across the range of this system, but in thermic sites characterized by this model, shrub cover is typically only 10-15%, occasionally increasing up to 35%. Fires in class B are rare but generally result in stand replacement when they occur. Blackbrush cover increases over time.

Class B: After 500 years without fire or other major disturbance, blackbrush becomes the dominant shrub and tends to attain a stable state. Shrub cover is often fairly dense, commonly ranging up to 50%. Several other species can occur as subordinates but blackbrush typically dominates stands, composing 50-70% of the shrub cover. Fires in class B are rare but generally result in stand replacement when they occur.

Figure 2. Conceptual Model of Mojave Mid-Elevation Mixed Desert Scrub ecological coarse filter CE under the historic range of variation (HRV). Panel A defines the codes in each state box. Panel B illustrates the transitions among states. The green arrow represents deterministic transitions (successional change). The black arrows represent probabilistic transitions due to various disturbances.

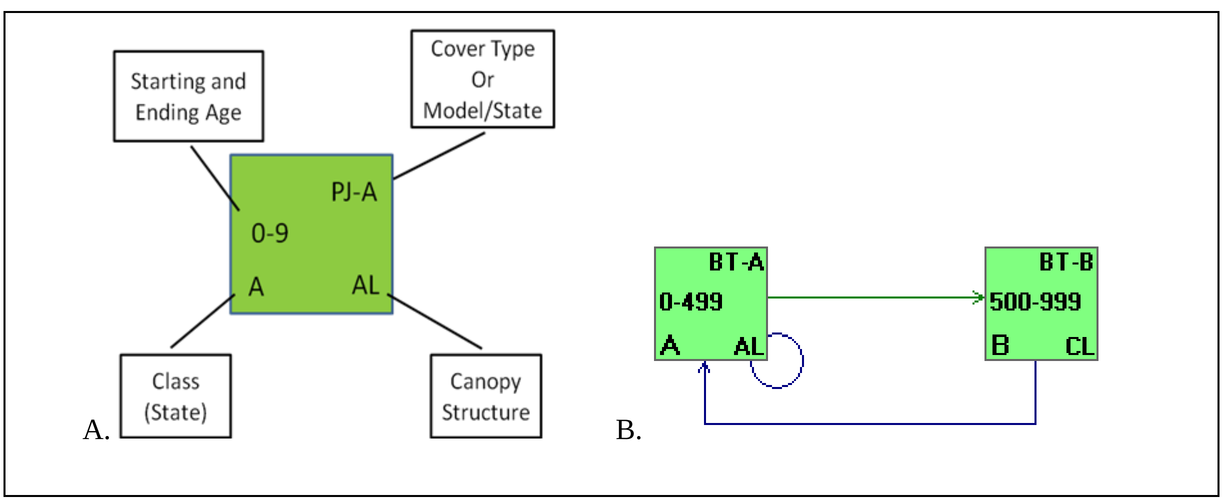

Table 2. Transition probabilities and return intervals for the major drivers of the Mojave desert scrub system under NRV. These probabilities are used in the VDDT model to project the relative abundance of each class over time.

From Class	To Class	Transition Type	Probability	Return Interval (years)
A	A	Replacement fire	0.0001	10000
B	A	Replacement fire	0.0001	10000

Change Agent (CA) Characterization

Altered Dynamics

Natural fire regimes may have been altered because of grazing by livestock and fire suppression over the last 100 years. This may allow the presence of relatively fire-intolerant species such as *Artemisia tridentata, Coleogyne ramosissima*, or *Larrea tridentata* in stands of this system in relatively mesic sites (Keeler-Wolf and Thomas 2000). In sites throughout the range of the Mojave mid-elevation desert scrub, annual grass invasion has also substantially altered the fire frequency. Fine fuel adjacency from alien annual grasses, such as *Bromus madritensis (B. rubescens), Bromus tectorum,* and *Schismus* spp. currently represent the most important fuelbed component in desert scrub, and can substantially increase the fire frequency. After a moderate to high rainfall year the annual vegetation converts into fine fuels that can carry fire through these open scrub stands, killing fire sensitive species with moderate to long FRI and covert to exotic annual grasslands (Keeler-Wolf et al. 1998).

Altered Model Description

Two additional states are added to the model to represent uncharacteristic contemporary conditions caused by exotic annual grass invasion.

Class C: This state represents exotic annual grass monocultures that result from burning of shrub/annual grass states. Exotic annual grasses burn more frequently than native grasses due to their early spring growth and ability to rapidly form a continuous fine fuel bed. Invasion of annual grass grasses represents one of the largest threats to this ecosystem, and can overtake large areas of native shrubland and shrub steppe.

Class D: The shrub/annual grass uncharacteristic state represents areas that retain native shrub cover but where annual grasses have assumed dominance of the herbaceous layer. This state is at high risk of fire because of the increased fine fuel continuity provided by the annual grasses. When this state burns, it transitions to class D.

Figure 3. Conceptual Model of Mojave Mid-Elevation Mixed Desert Scrub ecological coarse filter CE with uncharacteristic disturbance regimes. Difference between distribution of age classes under historic range of variation (HRV) and current management is shown as a percent departure.

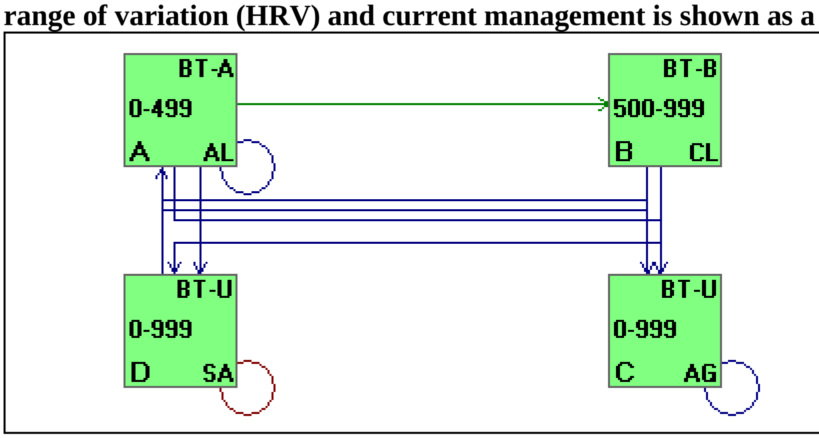

Table 3. Transition probabilities under current conditions. These transition probabilities were used in the VDDT model for current conditions (Figure 3) to calculate departure estimates (Table 4).

From Class	To Class	Transition Type	Probability	Return Interval (years)
A	C	Annual grass invasion	0.0050	200

A	D	Annual grass invasion	0.0050	200
B	D	Annual grass invasion	0.0050	200
D	C	Drought	0.0003	3333
D	D	Drought	0.0053	189
A	A	Replacement fire	0.0001	10000
B	A	Replacement fire	0.0001	10000
C	C	Replacement fire	0.0500	20
D	C	Replacement fire	0.0020	500

Ecological Departure

Based on the best available information, the historic range of variation (HRV) of ecological states with the creosote bursage scrub is shown in the HRV column of Table 4. The VDDT model was run for 150 years, starting at HRV, to examine the expected departure of the creosote-bursage scrub from HRV as a result of cheatgrass invasion. The model did not include any ecological restoration activities. Table 3 shows the relative abuncances of each of the 6 states for 50, 100, and 150 years following the introduction of exotic grasses and other contemporary disturbances. Ecological departure is a measure of dissimilarity from HRV and provides a measure of overall ecosystem change. It is calculated as:

$$1 - \sum_{class=A}^{F} Min(class\_abundance_{NRV}, class\_abundance_{Time X})$$

Table 4. Departure from Historic Range of Variation (HRV) in the relative abundance of ecological states as a result of the invasion of exotic annual grasses at three time steps, 50, 100 and 150 years.

Class	Cover: Structure	HRV	HRV+50	HRV+100	HRV+150
A	Early: Open	2%	1%	1%	1%
B	Late: Closed	98%	77%	60%	47%
C	Uncharacteristic: Annual grass	0%	1%	3%	5%
D	Uncharacteristic: Shrub/annual grass	0%	20%	36%	47%
Ecological Departure			**21%**	**39%**	**52%**

The model projections and departure calculations indicate an expansion of uncharacteristic annual grass states over time and an increase in ecological departure from historic conditions. Due to their early spring growth, fecundity, and ability to quickly form a continuous fine fuel bed, annual grasses are perpetuated over time in a cycle of fire and post-fire invasion. Unlike in many other Mojave desert systems, however, model projections indicate that shrub/annual grass states may be more common than annual grass monocultures. The fire frequency in shrub/annual grass states is not sufficient to rapidly convert shrub/annual grass to annual grass. Annual grass monocultures remain fairly uncommon, except in areas where shrub/annual grass has burned.

<u>**Development Impacts**</u>

Although effects are generally localized, development has impacted some occurrences within the ecoregion. Conversion also occurs through high and low density urban and industrial development. For example, residentual development has significantly impacted stands within commuting distance to urban areas. Mining operation can be drastically impact this desert scrub. Road building and power transmission lines continue to fragment Mojave Mid-Elevation Mixed Desert Scrub and provide vectors for weeds.

The primary land uses that alter the natural processes of this system are associated with livestock practices, annual exotic species, fire regime alteration, direct soil surface disturbance, and fragmentation. Excessive grazing stresses the system through soil disturbance (ORV use), diminishing or eliminating the biological soil crust, altering the composition of perennial species, and increases the establishment of native disturbance increasers and annual grasses, particularly *Bromus madritensis (B. rubescens)* and other exotic annual bromes.

Major impacts of development and management actions were captured in the Landscape Condition Model (LCM) developd by NatureServe (Comer and Hak 2009). The LCM is composed of the GIS spatial layers of transportation, urban and industrial development, and managed & modified land cover layers. This model used expert-based judgment to compile and create an overall Landscape Condition Model for the conterminous United States. See Comer and Hak (2009) for methods.

Ecological Integrity Criteria & Indicators

The indicators are organized by rank factors Landscape Context, Condition and Relative Extent and assessed using indicators that can be evaluated at the appropriate spatial scale. For terrestrial CEs the reporting unit is at the Watershed 5th Level (HUC – 10) and ecosystem level using remotely sensed GIS layers. This is the link between the conceptual models and the spatial models in assessing the ecological integrity of the Mojave Mid-Elevation Mixed Desert Scrub ecological system type. Indicators for the key ecological attributes are described below.

Landscape Context

***Landscape condition model (LCM) index* -** This indicator is measured in a GIS by intersecting the mapped area of the Mojave Mid-Elevation Mixed Desert Scrub system with the NatureServe LCM layer (Comer and Hak 2009) and reporting the overall LCM index for that system. The program results are an index of landscape condition from 0 to 1 with 1 being very high landscape condition and 0 having very poor condition.

***Connectivity index* -** This indicator is assessed using *CircuitScape*, a GIS program that uses circuit theory to predict connectivity in heterogeneous landscapes for individual movement, gene flow, and conservation planning (McRae 2006, McRae et al. 2008). CircuitScape will use the LCM as a resistance surface for scoring relative connectivity across all overlapping portions of the CE distribution. The program results are an index of connectivity for each 90m pixel from 0 to 1 with 0 having no connectivity (barrier) or 1 having very high connectivity. . Pixel values are summed for each CE distribution within each 5th-level HUC and the ecoregion.

Condition

***SCLASS departure index* -** This indicator is assessed by calculating and summarizing the LandFire Succession classes (SCLASS) layer which characterizes current vegetation succession classes for the distribution of each CE within each 5th-level HUC. The resulting proportional calculation for current conditions is compared to the output of the VDDT or Path-Tools model characterizing the expected natural range of variation (NRV). This comparison defines the degree of departure (%). The SClass Departure Index is calculated by subtracting the Departure percent from 1 to produce a normalized scale from 0 to 1 with 1being no departure from NRV in distribution of succession classes and 0 being complete departure from NRV.

***Abundance of invasive plant species* -** This indicator is measured using the mapped area of Mojave Mid-Elevation Mixed Desert Scrub ecological system with an abundance map of introduced invasive annual vegetation. The output is percent cover of invasive annual vegetation for the CE within each 5th level HUC. The Invasive Annual Cover Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 1 being invasive annuals absent to 0 which is 25% or greater cover of invasive annuals.

Relative Extent

***Change in Extent* -** This indicator is assessed by intersecting the mapped current extent (*circa* early 2000s) of Mojave Mid-Elevation Mixed Desert Scrub system with the LandFire biophysical setting (BpS) layer for this same sytem and reporting the percent change between the predicted area under natural disturbance regime (BpS) and the current extent. A positive change may indicate succession of blackbrush vegetation into a disturbed BpS likely as a result of decreases fire return interval (FRI). A negative change would indicate loss of Mojave Mid-Elevation Mixed Desert Scrub from expected BpS area likely from increased FRI. The output is percent area of change in extent of the current extent from the extent predicted under a natural disturbance regime (NRV). The Change in Extent Index is calculated by subtracting the Change in Extent percent from 1 to produce a normalized scale from 0 to 1with 1 being no change in extent and 0 being complete loss of CE in extent.

Ecological Integrity Assessment

The Ecological Integrity Assessment (EIA) is designed to develop ecological integrity indicators for individual CE and composite CE at two spatial levels: Watershed 5th Level (HUC - 10) and ecoregion. The assessment indicators or indicators with justifications and rating threasholds are presented in Table 5, organized by Rank Factors (Landscape Context, Condition and Relative Extent) and Key Ecogical Attributes. The indicators measure the key ecological attributes for the conceptual ecological model above and the index thresholds permit interpretation of the results.

Summary of Scoring

Each indicator is scored according to criteria described above and then the score is either used directly as an index or a indicator index is calculated between 0 and 1 with 1 being 100% sustainable and 0 being totally degraded. The mean index scores of these indicators can then summarized and averaged by each Key Ecological Attribute and each Rank Factor if there are multiple indicators for each. These mean scores are then averaged for an overall index of ecological integrity for the CE within each assessment area. See hypothetical index scoring on right hand column of Table 5. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological integrity of the CE. Using the rating factors in Table 5 allows the user to rate the CE as Sustainable, Transitioning or Degraded for each Rank Factor and calculate an Overall Integrity Rank.

Table 5. Mojave Mid-Elevation Mixed Desert Scrub EIA Scorecard

Indicator	Justification	Rating			Index Score
		Sustainable	Transitioning	Degraded	
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Attribute: *Landscape Connectivity*					
Connectivity predicted by Circuitscape	Intact natural conditions support physical and biological dynamics occurring across diverse environmental conditions	Connectivity is moderate to high and adequate to sustain most CEs. Connectivity index is >0.6	Connectivity is moderate to low and will not some sustain CEs. Connectivity index is 0.6-0.2	Connectivity is low and will not sustain many CEs. Connectivity index is <0.2	0.73
Key Ecological Attribute: *Landscape Condition*					
Landscape Condition Model Index	Land use impacts vary in their intensity, affecting ecological dynamics that support ecological systems.	Cumulative level of impacts is sustainable. Landscape Condition Model Index is > 0.8	Cumulative level of impacts is transitioning system between a sustainable and degraded state. Landscape Condition Model Index is 0.8 – 0.5	Cumulative level of impacts has degraded system. Landscape Condition Model Index is< 0.5	0.88
Rank Factor: CONDITION					
Key Ecological Attribute: *Fire Regime*					
SCLASS Departure	Mix of age classes among patches of the system is result of disturbance regime. Departure from mixture predicted under NRV indicates uncharacteristic disturbance regime and declining integrity.	Mix of age classes indicates system is functioning inside or near NRV. System is in a sustainable state. Departure is < 20%. SCLASS Departure Index is > 0.8	Mix of age classes indicates system is functioning near, but outside NRV. System is transitioning to degraded state. Departure is 20 -50%. SCLASS Departure Index is 0.8 – 0.5	Mix of age classes indicates system is functioning well outside NRV. System is degraded. Departure is > 50%. SCLASS Departure Index is < 0.5	0.50
Key Ecological Attribute: *Native Species Composition*					
Invasive Annual Cover	Invasive annual vegetation displaces natural composition and provides fine fuels that significantly increase spread of catastrophic fire.	System is sustainable with low cover of invasive annual vegetation. Mean cover of annuals is <5%. Invasive Annual Cover Index is >0.8.	System is transitioning to degraded state by abundant invasive annual vegetation. Mean cover of annuals is 5-10%. Invasive Annual Cover Index is 0.8-0.5.	System is degraded by abundant invasive annual vegetation. Mean cover of annuals is >15%. Invasive Annual Cover Index is <0.5)	0.40
Rank Factor: Relative Extent					
Key Ecological Attribute: *Extent*					
Change in Extent	Indicates the proportion of change due to expansion or conversion to other land cover or land use, decreasing provision of ecological services provided previously.	Site is at or minimally is only modestly changed from its original natural extent (80-100% remains) Change in Extent Index is > 0.8.	Occurrence is substantially changed from its original natural extent (50-80% remains). Change in Extent Index is 0.8-0.5	Occurrence is severely changed from its original natural extent (<50% remains). Change in Extent Index is < 0.5.	0.90
Overall Ecological Integrity Rank					
			(3.41 / 5 = 0.68)	**Mean Index Score**	**0.68**

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Appendix IIc. Conceptual Model for Sonora-Mojave Creosotebush-White Bursage Desert Scrub

BASIN DRY LAND SYSTEM

Desert Scrub

Sonora-Mojave Creosotebush-White Bursage Desert Scrub (CES302.756)

Biophysical Setting: 1310870

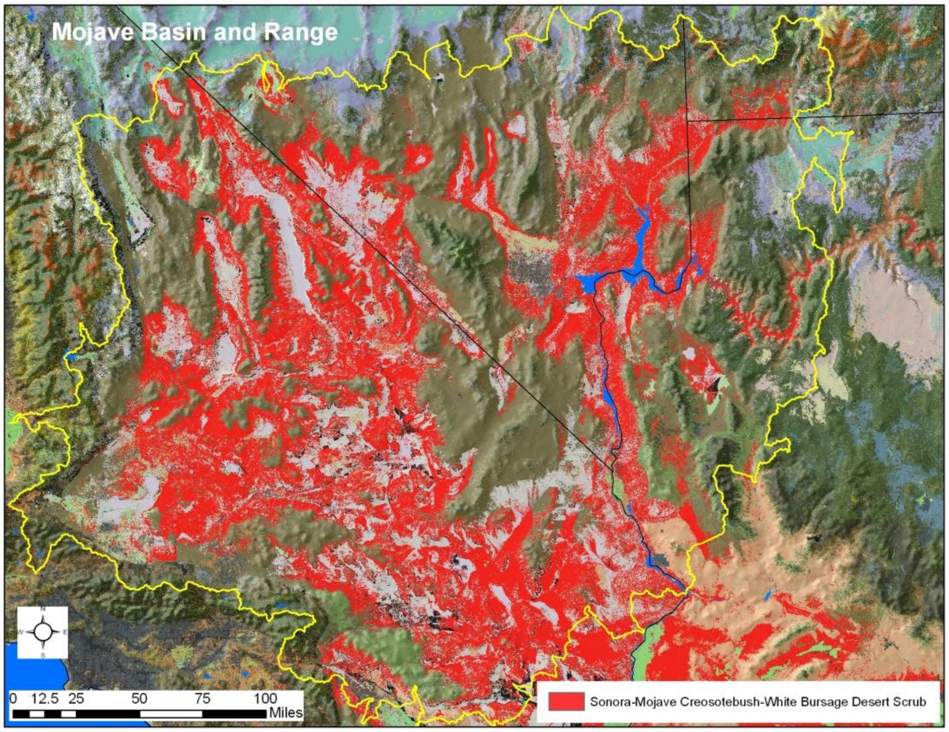
Conservation Element (CE) Characterization

Summary

This ecological system occupies broad valleys, lower bajadas, plains, flats and low hills in the lower Sonoran (Colorado) and Mojave deserts extending into the southeastern Great Basin where it forms the vegetation matrix. Other habitats include minor washes and rills, alluvial fans, and upland slopes. Elevation ranges from -75m to 1200 m. Adjacent ecological systems include Mojave Mid-Elevation Mixed Desert Scrub above and Inter-Mountain Basins Playa below. Substrates are typically well-drained, sandy soils derived from colluvium or alluvium, and are often calcareous with a caliche hardpan and/or a pavement surface that are derived from limestone and dolomite (Sawyer et al. 2009, Turner 1980). This description is based on several references including Barbour et al. 2007, Beatley 1976, Brown 1982, Keeler-Wolf 2007, Holland et al. 1995, MacMahon1988, Marshall 1995, NatureServe Explorer 2009, Reid et al. 1999, Sawyer et al. 2009, Schoenherr and Burk 2007, and Turner 1980.

This desert scrub system occurs as open to intermittent vegetation cover, with the mostly barren ground surface being the predominant feature (Sawyer et al. 2009). It is characterized by a sparse to moderately dense layer (2-50% cover) of xeromorphic microphyllous and broad-leaved shrubs is typically dominated or codominated by *Larrea tridentata* usually with *Ambrosia dumosa.* However, several other shrubs may dominate or co-dominate this system, including *Atriplex* spp., *Ephedra viridis, Ephedra* spp., *Grayia spinosa* or *Lycium* spp. Low elevation stands typically have low cover and diversity, whereas in higher elevation stands many different shrubs, dwarf-shrubs, and cacti may be present to codominate or form sparse understories. Associated species may include *Atriplex canescens, Atriplex hymenelytra, Atriplex polycarpa, Croton californicus, Dalea* spp., *Echinocactus polycephalus, Encelia* spp.*, Ephedra funerea, Ephedra nevadensis, Lycium andersonii, Opuntia basilaris, Krameria grayi, Krameria erecta, Psorothamnus arborescens, P. fremontii, Salazaria mexicana, Senna armata,* and *Viguieria parishii*. Some common disturbance related species include *Acampthopappus sphaerocephalus, Bebbia juncea, Cylindroopuntia acanthocarpa, Ericameria teretefolia, Grayia spinosa* or *Hymenoclea salsola* (Sawyer et al. 2009). If *Encelia farinosa* or *Yucca schidigera* is present, cover is generally low (<1-2% cover). Occasional emergent *Fouquieria splendens* or *Yucca brevifolia* may be present with very low cover. The herbaceous layer is typically sparse and intermittent, but may be seasonally abundant with ephemerals. Herbaceous species such as *Chamaesyce* spp., *Eriogonum inflatum, Dasyochloa pulchella, Aristida* spp., *Cryptantha* spp., *Nama* spp., and *Phacelia* spp. are common. A crosswalk of all CE systems to approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is being conducted for all CEs. There are currently no approved creosotebush scrub ESDs available for MLRAs in this ecoregion.

Figure 1. Map of Sonora-Mojave Creosotebush-White Bursage Desert Scrub ecological coarse filter CE.



<u>**Natural Dynamics:**</u>

Change Agents

This system covers vast areas of sandy alluvial fans and bajadas and rocky slopes ranging from NW Sonoran Desert, Mojave desert and Colorado deserts (Keeler-Wolf 2007, Sawyer et al. 2009). The dominant shrub, *Larrea tridentata* is very long-lived with clones living > 10,000 years (Keeler-Wolf 2007) and is very tolerant of drought and high temperatures with small, evergreen, resinous (highly flammable) leaves reducing evapotranspiration (Hamerlynck et al. 2002). It may die-back during extreme drought, but can sprout from the base (Meinzer et al. 1990). It has low recruitment and is slow to re-establish from seed (Keeler-Wolf 2007).

The main codominant shrub, *Ambrosia dumosa*, is short-lived with a relatively shallow root system, and tends to dominate sandy and rocky sites. It can quickly establish after disturbance or drought (Vasek 1980). Post fire, it has a limited ability to sprout, and will re-establish from seed (Sawyer et al. 2009). Fire return interval for this typically open shrub canopied system is long to truncated long. When it burns fires have high intensity and moderate severity (Sawyer et al. 2009).

Fires in historic creosote-bursage stands were thought to be infrequent except along the margins of the ecological system where it mixed with shrub steppe containing greater grass fuel loading. Although bunchgrasses can fill in some of the interspaces between shrubs with fine fuels, their distribution is generally patchy and rarely provides fuel continuity sufficient to carry fire (Brooks et al. 2007). Periodic drought is occasionally sufficient to thin grass and shrub cover. Creosotebush is sensitive to both fire and drought, but has the ability to sprout if initial mortality is low.

Model Description

The creosote-bursage scrub was modeled using the Vegetation Dynamics Development Tool (VDDT), developed by ESSA Technologies. VDDT allows users to translate simple box-and-arrows conceptual models into probabilistic quantitative models. The creosote-bursage model consists of several ecological states with both deterministic and probabilistic drivers. These drivers result in transitions from one ecological state to another. Deterministic drivers simulate successional changes. The deterministic transitions in the model specify the time until a transition must occur, and the class (state) it will move to after this time has passed. Figure 2 illustrates this conceptual model. In this model, deterministic transitions are illustrated by the green arrow. Probabilistic transitions, represented by red and black arrows, specify the type of transition driver, its transition probability (which is the mathematical inverse of return frequency) and its impact on the vegetation cell.

Probabilistic transitions represent natural disturbances (e.g. fire, wind, insects), changes resulting from land management, or probabilistic succession.

For each simulation, the landscape is partitioned into a number of cells or simulation units; each initially assigned a class and age. For each time step the model simulates the probability of each cell being affected by one of probabilistic transition types, and if a transition does occur, moves the cell to the class defined in the pathway diagram. Transition probabilities are dependent on the current state of the cell, defined by its class. They are independent of the state of the neighboring cells.

The Creosotebush-bursage model has two states (Figure 2, Table 1), representing early and late-successional stages.

Class A: Early successional creosote-bursage scrub in class A consists of open shrub cover <20%. Grass and forb cover is sparse enough to keep fires from being a dominant force in this system. After 20 years without major disturbance, class A transitions into class B through succession.

Class B: Late successional creosote-bursage scrub is characterized by 20-30% shrub cover. Grass and forb cover is sparse enough to keep fires from being a dominant force in this system. Under severe circumstances, drought can thin shrub cover sufficiently to return to class A.

Figure 2. Conceptual Model of Sonora-Mojave Creosotebush-White Bursage Desert Scrub ecological coarse filter CE under the historic range of variation (HRV). Panel A defines the codes in each state box. Panel B illustrates the transitions among states. The green arrow represents deterministic transitions (successional change). The red and black arrows represent disturbance transitions.

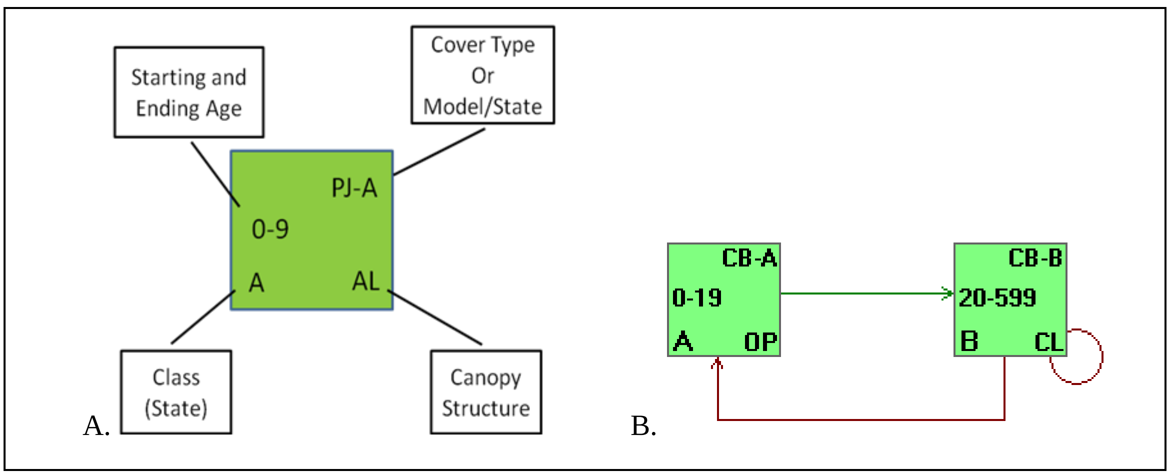


Table 1. Transition probabilities and return intervals for the major drivers of the Mojave desert scrub system under HRV. These probabilities are used in the VDDT model to project the historic relative abundance of each class over time.

From Class	To Class	Transition Type	Probability	Return Interval (years)
B	A	Drought	0.0006	1667
B	B	Drought	0.0050	200

Change Agent (CA) Characterization

Altered Dynamics

The primary land uses that alter the natural processes of this system are associated with direct vegetation and soil surface disturbance and fragmentation, and annual exotic species invasion. Excessive stresses the system through soil disturbance from off-road vechicle (ORV) use and heavy grazing can alter the composition of perennial species, and increase the establishment of native disturbance increasers and exotic annual grasses. Fine fuels adjacency from alien annual grasses, such as *Bromus madritensis (B. rubescens)*, *Bromus tectorum*, and *Schismus* spp., currently represent the most important fuelbed component in creosotebush scrub, and can substantially increase the fire frequency. In years of good moisture, alien annual grasses can comprise 66-97%

of the total annual biomass in this system (LandFire BpS 1310870). In contrast to native annuals, exotic annual plants produce fine fuelbeds that persist throughout the summer and greatly increase the continuity of fuels for much of the fire season (Brooks et al. 2007). In addition, historic year round livestock grazing has contributed to the deterioration of this system.

Altered Model Description

Three additional states are added to the model to represent uncharacteristic contemporary conditions due to invasion by exotic annual grasses and recreational off-road vehicle use (Figure 3, Table 3).

Class C: The shrub/annual grass uncharacteristic state represents areas that retain native shrub cover but where annual grasses have assumed dominance of the herbaceous layer. This state is at high risk of fire because of the increased fine fuel continuity provided by the annual grasses. When this state burns, it transitions to class D.

Class D: This state represents exotic annual grass monocultures that result from burning of shrub/annual grass states. Exotic annual grasses burn more frequently than native grasses due to their early spring growth and ability to rapidly form a continuous fine fuel bed. Invasion of annual grass grasses represents one of the largest threats to this ecosystem, and can overtake large areas of native shrubland and shrub steppe.

Class E: This state represents bare ground, and is reached through heavy use of off-road vehicles or other major disturbance. Once vegetative cover has been removed and soil has been compacted, it is difficult or impossible to reestablish native vegetation, and erosion by water and wind causes further degradation to the site.

Figure 3. Conceptual Model of Sonora-Mojave Creosotebush-White Bursage Desert Scrub ecological coarse filter CE with uncharacteristic disturbance regimes.

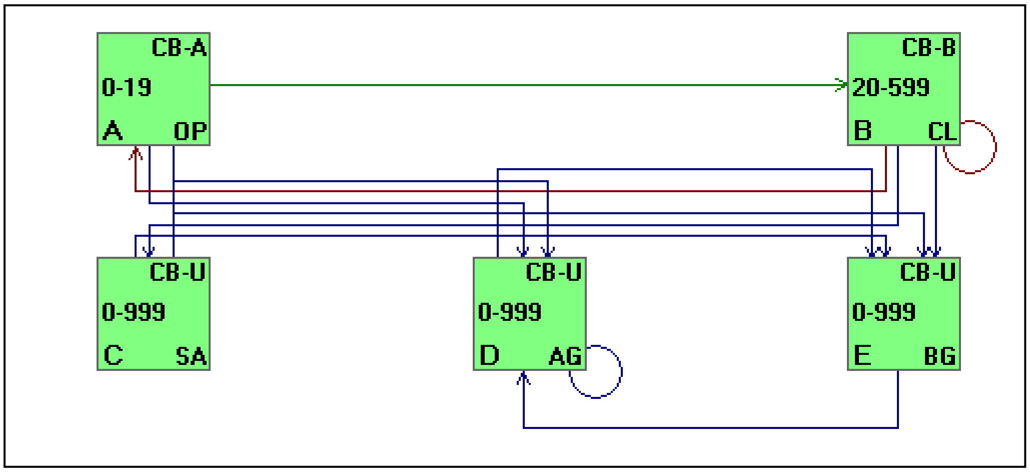


Table 3. Transition probabilities under current conditions. These transition probabilities were used in the VDDT model for current conditions (Figure 3) to calculate departure estimates (Table 4).

From Class	To Class	Transition Type	Probability	Return Interval (years)
A	D		0.0050	200
B	C	Annual grass invasion	0.0050	200
E	D	Annual grass invasion	0.0050	200
B	A	Drought	0.0006	1667
B	B	Drought	0.0050	200
A	E	Off-road vehicle traffic	0.0010	1000
B	E	Off-road vehicle traffic	0.0010	1000
C	E	Off-road vehicle traffic	0.0010	1000
D	E	Off-road vehicle traffic	0.0010	1000
C	D	Replacement fire	0.0500	20
D	D	Replacement fire	0.1000	10

Ecological Departure

Based on the best available information, the historic range of variation (HRV) of ecological states with the creosote bursage scrub is shown in the HRV column of Table 4. The VDDT model was run for 150 years, starting at HRV, to examine the expected departure of the creosote-bursage scrub from HRV as a result of cheatgrass invasion. The model did not include any ecological restoration activities. Table 3 shows the relative abuncances of each of the 6 states for 50, 100, and 150 years following the introduction of exotic grasses and other contemporary disturbances. Ecological departure is a measure of dissimilarity from HRV and provides a measure of overall ecosystem change. It is calculated as:

$$1-\sum_{class=A}^{F} Min(class\_abundance_{NRV}, class\_abundance_{Time\,X})$$

Table 4. Departure from Historic Range of Variation (HRV) in the relative abundance of ecological states as a result of the invasion of exotic annual grasses at three time steps, 50, 100 and 150 years.

Class	**Cover: Structure**	**HRV**	**HRV+50**	HRV+100	HRV+150
A	Early: Open	1%	1%	1%	0%
B	Late: Closed	99%	74%	55%	41%
C	Uncharacteristic: Shrub/annual grass	0%	11%	12%	10%
D	Uncharacteristic: Annual grass	0%	10%	25%	39%
E	Uncharacteristic: Bare ground	0%	4%	7%	10%
Ecological Departure			**25%**	45%	59%

Development Impacts

Although effects are generally localized, development has impacted many stands throughout the ecoregion. High and low density urban and industrial development also has large impacts. For example, residential development has significantly impacted stands within commuting distance to urban areas. Impacts may be direct as trees are removed for building sites or fire suppression, or indirect such as introduction of invasive species. Mining operation can drastically impact desert scrub. Road building and power transmission lines continue to fragment Sonora-Mojave Creosotebush-White Bursage Desert Scrub and provide vectors for weeds.

Major impacts of development and management actions were captured in the Landscape Condition Model (LCM) developed by NatureServe (Comer and Hak 2009). The LCM is composed of the GIS spatial layers of transportation, urban and industrial development, and managed & modified land cover layers. This model used expert-based judgment to compile and create an overall Landscape Condition Model for the conterminous United States. See Comer and Hak (2009) for methods.

Ecological Integrity Criteria & Indicators

The indicators are organized by rank factors Landscape Context, Condition and Relative Extent and assessed using indicators that can be evaluated at the appropriate spatial scale. For terrestrial CEs the reporting unit is at the Watershed 5th Level (HUC – 10) and ecosystem level using remotely sensed GIS layers. This is the link between the conceptual models and the spatial models in assessing the ecological integrity of the Sonora-Mojave Creosotebush-White Bursage Desert Scrub ecological system type. Indicators for the key ecological attributes are described below.

Landscape Context

***Landscape condition model (LCM) index* -** This indicator is measured in a GIS by intersecting the mapped area of the Sonora-Mojave Creosotebush-White Bursage Desert Scrub system with the NatureServe LCM layer (Comer and Hak 2009) and reporting the overall LCM index for that system. The program results are an index of landscape condition from 0 to 1 with 1 being very high landscape condition and 0 having very poor condition.

***Connectivity index* -** This indicator is assessed using *CircuitScape*, a GIS program that uses circuit theory to predict connectivity in heterogeneous landscapes for individual movement, gene flow, and conservation planning (McRae 2006, McRae et al. 2008). CircuitScape will use the LCM as a resistance surface for scoring relative connectivity across all overlapping portions of the CE distribution. The program results are an index of connectivity for each 90m pixel from 0 to 1 with 0 having no connectivity (barrier) or 1 having very high connectivity. . Pixel values are summed for each CE distribution within each 5th-level HUC and the ecoregion.

Condition

***SCLASS departure index* -** This indicator is assessed by calculating and summarizing the LandFire Succession classes (SCLASS) layer which characterizes current vegetation succession classes for the distribution of each CE within each 5th-level HUC. The resulting proportional calculation for current conditions is compared to the output of the VDDT or Path-Tools model characterizing the expected natural range of variation (NRV). This comparison defines the degree of departure (%). The SClass Departure Index is calculated by subtracting the Departure percent from 1 to produce a normalized scale from 0 to 1 with 1being no departure from NRV in distribution of succession classes and 0 being complete departure from NRV.

***Abundance of invasive plant species* -** This indicator is measured using the mapped area of Sonora-Mojave Creosotebush-White Bursage Desert Scrub ecological system with an abundance map of introduced invasive annual vegetation. The output is percent cover of invasive annual vegetation for the CE within each 5th level HUC. The Invasive Annual Cover Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 1 being invasive annuals absent to 0 which is 25% or greater cover of invasive annuals.

Relative Extent

***Change in Extent* -** This indicator is assessed by intersecting the mapped current extent (*circa* early 2000s) of Sonora-Mojave Creosotebush-White Bursage Desert Scrub with the LandFire biophysical setting (BpS) layer for this same sytem and reporting the percent change between the predicted area under natural disturbance regime (BpS) and the current extent. A positive change may indicate succession of creosotebush vegetation into a disturbed BpS. A negative change would indicate loss of Sonora-Mojave Creosotebush-White Bursage Desert Scrub from expected BpS area likely from increased FRI or orther disturbance. The output is percent area of change in extent of the current extent from the extent predicted under a natural disturbance regime (NRV). The Change in Extent Index is calculated by subtracting the Change in Extent percent from 1 to produce a normalized scale from 0 to 1with 1 being no change in extent and 0 being complete loss of CE in extent.

Ecological Integrity Assessment

The Ecological Integrity Assessment (EIA) is designed to develop ecological integrity indicators for individual CE and composite CE at two spatial levels: Watershed 5th Level (HUC - 10) and ecoregion. The assessment indicators or indicators with justifications and rating threasholds are presented in Table 5, organized by Rank Factors (Landscape Context, Condition and Relative Extent) and Key Ecogical Attributes. The indicators measure the key ecological attributes for the conceptual ecological model above and the index thresholds permit interpretation of the results.

Summary of Scoring

Each indicator is scored according to criteria described above and then the score is either used directly as an index or a indicator index is calculated between 0 and 1 with 1 being 100% sustainable and 0 being totally degraded. The mean index scores of these indicators can then summarized and averaged by each Key Ecological Attribute and each Rank Factor if there are multiple indicators for each. These mean scores are then averaged for an overall index of ecological integrity for the CE within each assessment area. See hypothetical index scoring on right hand column of Table 5. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological integrity of the CE. Using the rating factors in Table 5 allows the user to rate the CE as Sustainable, Transitioning or Degraded for each Rank Factor and calculate an Overall Integrity Rank.

Table 5. Sonora-Mojave Creosotebush-White Bursage Desert Scrub EIA Scorecard

Indicator	Justification	Rating			Index Score
		Sustainable	Transitioning	Degraded	
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Attribute: *Landscape Connectivity*					
Connectivity predicted by Circuitscape	Intact natural conditions support physical and biological dynamics occurring across diverse environmental conditions	Connectivity is moderate to high and adequate to sustain most CEs. Connectivity index is >0.6	Connectivity is moderate to low and will not some sustain CEs. Connectivity index is 0.6-0.2	Connectivity is low and will not sustain many CEs. Connectivity index is <0.2	0.73
Key Ecological Attribute: *Landscape Condition*					
Landscape Condition Model Index	Land use impacts vary in their intensity, affecting ecological dynamics that support ecological systems.	Cumulative level of impacts is sustainable. Landscape Condition Model Index is > 0.8	Cumulative level of impacts is transitioning system between a sustainable and degraded state. Landscape Condition Model Index is 0.8 – 0.5	Cumulative level of impacts has degraded system. Landscape Condition Model Index is< 0.5	0.88
Rank Factor: CONDITION					
Key Ecological Attribute: *Fire Regime*					
SCLASS Departure	Mix of age classes among patches of the system is result of disturbance regime. Departure from mixture predicted under NRV indicates uncharacteristic disturbance regime and declining integrity.	Mix of age classes indicates system is functioning inside or near NRV. System is in a sustainable state. Departure is < 20%. SCLASS Departure Index is > 0.8	Mix of age classes indicates system is functioning near, but outside NRV. System is transitioning to degraded state. Departure is 20 -50%. SCLASS Departure Index is 0.8 – 0.5	Mixed of age classes indicates system is functioning well outside NRV. System is degraded. Departure is > 50%. SCLASS Departure Index is < 0.5	0.50
Key Ecological Attribute: *Native Species Composition*					
Invasive Annual Cover	Invasive annual vegetation displaces natural composition and provides fine fuels that significantly increase spread of catastrophic fire.	System is sustainable with low cover of invasive annual vegetation. Mean cover of annuals is <5%. Invasive Annual Cover Index is >0.8.	System is transitioning to degraded state by abundant invasive annual vegetation. Mean cover of annuals is 5-10%. Invasive Annual Cover Index is 0.8-0.5.	System is degraded by abundant invasive annual vegetation. Mean cover of annuals is >15%. Invasive Annual Cover Index is <0.5)	0.40
Rank Factor: Relative Extent					
Key Ecological Attribute: *Extent*					
Change in Extent	Indicates the proportion of change due to conversion to other land cover or land use, decreasing provision of ecological services provided previously.	Site is at or minimally is only modestly changed from its original natural extent (80-100% remains) Change in Extent Index is > 0.8.	Occurrence is substantially changed from its original natural extent (50-80% remains). Change in Extent Index is 0.8-0.5	Occurrence is severely changed from its original natural extent (<50% remains). Change in Extent Index is < 0.5.	0.90
Overall Ecological Integrity Rank					
			(3.41 / 5 = 0.68)	**Mean Index Score**	**0.68**

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Appendix IId. Conceptual Model for North American Warm Desert Riparian Woodland and Shrubland/Stream

MOJAVE Basin Wet Ecosystems

Woody Wetlands and Riparian

North American Warm Desert Riparian Woodland and Shrubland/Stream

Conservation Element (CE) Characterization

CES302.753 North American Warm Desert Riparian Woodland and Shrubland

Summary: This ecological system consists of low-elevation (<1200 m) riparian corridors and the aquatic ecosystems within medium to large perennial streams throughout canyons and desert valleys of the southwestern United States and adjacent Mexico. Rivers include the lower Colorado (into the Grand Canyon), Gila, Santa Cruz, Salt, lower Rio Grande (below Elephant Butte Reservoir in New Mexico to the Coastal Plain of Texas), and the lower Pecos (up to near its confluence with Rio Hondo in southeastern New Mexico). The riparian vegetation is a mix of riparian woodlands and shrublands. Dominant trees include *Acer negundo, Fraxinus velutina, Populus fremontii, Salix gooddingii, Salix lasiolepis, Celtis laevigata var. reticulata, Platanus racemosa*, and *Juglans major*. Shrub dominants include *Salix geyeriana*, *Shepherdia argentea*, and *Salix exigua*. Vegetation is dependent upon annual or periodic flooding and associated sediment scour and/or annual rise in the water table for growth and reproduction. Much of the Colorado River system that has not been inundated by major power dams has seen its riparian plant communities invaded by saltcedar. Where saltcedar has successfully invaded the floodplains, it has largely replaced native woody vegetation due to its ability to successfully outcompete native vegetation on altered floodplains with more saline soils, lower groundwater tables. Aquatic systems vary tremendously and include segments of the main stem Colorado River, the Virgin River and Muddy River. Riverine reaches of the Colorado River are highly modified and channelized with variable flows and many reservoir-like characteristics. The Virgin River is a semi-ephemeral system dependent on seasonal runoff to maintain aquatic habitat characteristics compared to the Muddy River which is a relatively stable flow system dependent on spring discharge. The great variability maintains unique aquatic species assemblages in each flow system. Mojave stream systems are generally disconnected stream segments that may be seasonally ephemeral, such as the Amargosa River in Oasis Valley, or represent lower order segments of primarily spring-fed discharge systems such as in Pahranagat Valley or Meadow Valley Wash. Again, the isolation and variable aquatic habitat characteristics of these stream systems have resulted in their support of unique aquatic species assemblages across the landscape.

Aquatic species in larger, perennial streams include: in the Colorado River: bonytail, Razorback sucker, Flannelmouth sucker; in the Virgin River: Virgin River chub, woundfin, flannelmouth sucker, Virgin spinedace, relict leopard frog; in the Muddy River: Moapa dace, Moapa White River springfish, Virgin River chub, Moapa speckled dace and southwestern toad. In smaller, often ephemeral streams : Oasis Valley/Amargosa River: Amargosa Toad, Oasis Valley speckled dace, Pahranagat Valley, Pahranagat roundtail chub, Pahranagat speckled dace; Meadow Valley Wash: Meadow Valley Wash desert sucker and the Meadow Valley Wash speckled dace.

Similar CEs: Riparian and other mesic sites dominated by mesquite Bosque (*Prosopis* spp.) are covered by a separate CE, the North American Warm Desert Riparian Mesquite Bosque System, because of its rarity, conservation focus and unique species habitat affinities.

Natural Dynamics: The hydrologic regime is naturally highly variable temporally and spatially. The pattern of natural high, median (baseflow) and low flows varies with season, watershed size and geomorphology, watershed soils and vegetation, the spatial distribution and magnitude of connection to groundwater, the spatial distribution and magnitude of connection to snowpack and snowmelt, and channel and floodplain morphology. The natural variability of flow conditions in streams and rivers is ecologically very important. Aquatic species adapt not only to average flow conditions and to the patterns of change in those average conditions by season, but to the occurrence of natural extreme flow conditions. Likewise riparian vegetation is also dependent on variation in stream flow levels. Many plant species require flooding, scour and deposition for germination and maintenance. Therefore this is system is dependent on a naturally dynamic hydrologic regime, especially annual to episodic flooding with increasing magnitude that results in more stand replacement events. In upper watershed reaches beaver (*Castor canadensis*) frequently influence the hydrologic regime through construction of dams, and will move from areas when wood availability is depleted. Fire disturbances occur, but are infrequent catastrophic events (100yrs).

Stressors: Riparian areas and their aquatic communities are affected by concentrated grazing, cutting for timber and firewood, residential development, river channelization, diversion, regulation of flows or diversion of flows for agriculture industrialization, log drives, wildfire suppression, trapping (principally beaver), exotic species (both terrestrial and aquatic plants and animals), unregulated recreation (both motorized and nonmotorized),road building, mining, pollution, farming, channel dredging, bank armoring, and construction of dams and levees. Invasive species may be one of the greatest agents of change in these systems, such as Saltcedar and Russian olive that have invaded nearly all of the riparian systems to varying degrees and their ability to convert many miles of riparian zone into undesirable monotypes. Aquatic invasive species such as Common carp and American Bullfrog can out-compete native aquatic species for space and nutrient resources.

Key Ecological Attributes (in no particular order):

1. **Continuity Condition—** Continuity of riparian corridors and streams connect habitat within the drainage to their floodplains.
2. **Landscape Condition—**Natural intactness of surrounding landscape. Land conversion affects surface water runoff amount and timing, nutrients and sediments flowing into the riparian area and aquatic resources.
3. **Hydrologic Condition—**The natural variability in surface flow and groundwater recharge.
4. **Biotic Condition—**The native flora/fauna and intact food webs and structural characteristics.

Table 1. Key attributes, their indicators and threshold values for ecological integrity assessment. We have included additional indicators (noted with an *) that do not appear in the main body of the memo. These are fine-scale indicators that are ecologically important but difficult to assess on the ecoregional and watershed scales .

Key Ecological Attribute		**Rating**		
Indicator **(* denotes fine scale not used ecoregion-wide)**	**Justification**	**Sustainable (0.9)**	**Transitioning (0.6)**	**Degraded (0.25)**
Key Ecological Attribute: *Continuity Condition (5 indicators)*				
Absolute Extent (size) for Linear Features*	A measure of the current size (ha) of the contiguous riparian corridor that includes the stand or polygon.	>1 km in length	0.5 – 0.9 km in length	<0.5 km in length
Absolute Extent (size) For non-Linear features*	Measure current size/extent relative to the physical potential for a site to support wetlands within reporting huc	Large compared to other examples of the same type (e.g. within 10-30%, based on known and historic occurrences, or most area-sensitive indicator species very to moderately abundant).	Moderate compared to other examples of the same type, (e.g., within 30-70% of known or historic sizes; or many area-sensitive indicator species are able to sustain a minimally viable population, or many characteristic species are sparse but present).	Too small to sustain full diversity and full function of the type. (e.g., smallest 30% of known or historic occurrences, or both key area-sensitive indicator spp. and characteristic spp. sparse to absent).

Key Ecological Attribute		Rating		
Indicator (* denotes fine scale not used ecoregion-wide)	**Justification**	**Sustainable (0.9)**	**Transitioning (0.6)**	**Degraded (0.25)**
Relative Extent (size) (Linear and non-linear features)*	The current size of the wetland divided by the total potential size of the wetland multiplied by 100. And % known reduction in wetland extent/size from human activities	Wetland area < abiotic potential; relative size is 90-100%; <10% of the wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, human-induced drainage, etc.	Wetland area < Abiotic potential; Relative size = 75-90%; 10-25% of the wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, human-induced drainage, etc.	Wetland area < Abiotic potential; Relative size = >75; >25% of the wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, human-induced drainage, etc.
Riparian Corridor Continuity	Measures the degree to which the riparian areas exhibits an uninterrupted vegetated corridor. Via CircutScape	>20% of riparian reach with gaps/breaks due to cultural alteration	>20-50% of riparian reach with gaps/breaks due to cultural alteration	>50% of riparian reach with gaps/breaks due to cultural alteration
Aquatic Network Connectivity	Dendritic Connectivity Index -- Indicates the degree to which the aquatic habitat exhibits an uninterrupted flow lines	TBA	TBA	TBA
Key Ecological Attribute: *Landscape Condition (8 indicators)*				
Landscape Connectivity	Measures percent of unaltered (natural) habitat within a 1,000 ha or surrounding HUC8	60-100% natural habitat; habitat connectivity is generally high, but lower for species sensitive to habitat modification.	10-60% natural habitat; connectivity is generally low, but varies with mobility of species and arrangement on landscape.	< 10% natural habitat; connectivity is essentially absent.
Surrounding Land Use Index	Sum of Land Use Coefficients. Not all land use has equal impact on adjacent wetlands. An coefficient of impact has been developed for broad categories of land use (modified from Haurer et al. 2002, see Land Use Coefficient Table below). See Table 3.	Land Use Index = 0.80 - 1.0	Land Use Index = 0.4-0.79	Land Use Index < 0.4
Nutrient/ Pollutant Loading Index	Measures extent of specific land uses that can contribute excess nutrients and pollutants via surface water runoff and overland flow into a wetland	Nutrient Pollutant Loading Index >0.79	Nutrient Pollutant Loading Index = 0.5 – 0.79	Nutrient Pollutant Loading Index <0.5
Surface Water Runoff Index	Measures extent of specific land uses (i.e. hard surfaces) that can contribute excess surface flow into a wetland	Surface Water Runoff Index >0.79	Surface Water Runoff Index = 0.5 - .79	Surface Water Runoff Index <0.5

Key Ecological Attribute		Rating		
Indicator (* denotes fine scale not used ecoregion-wide)	**Justification**	**Sustainable (0.9)**	**Transitioning (0.6)**	**Degraded (0.25)**
Impervious Cover	Measures extent of impervious surface within runoff catchment of a stream; rating based on correlations between stream biotic index and catchment imperviousness	% impervious cover in HUC 0-10%,	% impervious cover in HUC 11-25%	% impervious cover in HUC >26%
Sediment Loading Index for entire HUC	Measures extent of specific land uses within HUC that can contribute excess sediment to a wetland via surface water runoff and overland flow	Sediment Loading Index = >0.79	Sediment Loading Index = 0.5–0.79	Sediment Loading Index <0.5
Atmospheric Pollutant Deposition	Measures rates of deposition of NO_x and Hg per unit area within HUC.	TBA	TBA	TBA
Point-Source Pollution	Assess density of permitted and legacy point discharges within HUC10.	None	1-2	>2
Key Ecological Attribute: *Hydrologic Condition (4 Indicators)*				
Flow Modification "F" Index (Theobald et al. 2010)	Measures cumulative storage capacity of dams relative to annual stream discharge in a watershed	F index >0.90	F index = 0.75-0.90	F Index <0.75
Surface Water Modification	Measures augmentation and diversion as percentages of HUC long-term median annual surface discharge. This requires long term gag data, which is not readily available for many stream reaches	Average percent added and removed <10% of long-term median annual discharge	Average percent added and removed 10-25% of long-term median annual discharge	Average percent added and removed >25% of long-term median annual discharge
Ground Water Modification	Measures artificial recharge to and withdrawals from aquifer(s) that supply stream baseflow, as percentages of HUC long-term median annual surface discharge	Average percent added and removed <10% long-term median annual discharge	Average percent added and removed 10-25% long-term median annual discharge	Average percent added and removed >25% long-term median annual discharge
Groundwater Recharge Zone Integrity	Measures percent recharge area in natural land cover within HUC	Average percent >66% across all 270 x 270m pixels identified as recharge areas	Average percent 34-66% across all 270 x 270m pixels identified as recharge areas	Average percent <34% across all 270 x 270m pixels identified as recharge areas
Key Ecological Attribute: *Hydrologic Condition-- Water Quality (3 indicators)*				

Key Ecological Attribute		Rating		
Indicator (* denotes fine scale not used ecoregion-wide)	**Justification**	**Sustainable (0.9)**	**Transitioning (0.6)**	**Degraded (0.25)**
Stream Water Quality Conditions via State Reporting of Impaired Waters	Presence and severity of water quality impairments identified in State 303(d) report (except nutrient enrichment addressed by separate key ecological attribute)	No impairments that could degrade aquatic life use support (conditions support natural or native references conditions or cause only minimal changes in the structure of the biotic community and ecosystem function	Impairments that could moderately degrade aquatic life use support (conditions sufficient to cause evident to moderate changes in structure of biotic community and minimal to moderate changes in ecosystem function)	Impairments that could severely degrade aquatic life support use (conditions sufficient to cause major to severe changes in structure of the biotic community and moderate changes to major loss in ecosystem function)
Stream Nutrient Condition: Nitrogen and Phosphorus Availability	Measures the integrity of the stream chemistry regime based on the biological availability of N and P relative to reference conditions.	Average concentration of biologically available N and P falls within range of water quality reference sites of this system type in the ecoregion.	Average concentration of biologically available N and P exceeds range of water quality reference sites of this system type in the ecoregion but falls within the middle 50% (25th to 75th percentile) of all sites of this system type in the ecoregion.	Average concentration of biologically available N and P exceeds range of water quality reference sites of this system type in the ecoregion and falls in the bottom 25% of all sites of this system type in the ecoregion.
Sediment Loading Index for 200 m Buffer area	Measures extent of specific land uses within 200 m buffer radius that can contribute excess sediment to a wetland via surface water runoff and overland flow	Sediment Loading Index = >0.79	Sediment Loading Index = 0.5–0.79	Sediment Loading Index <0.5
Key Ecological Attribute: ***Biotic Condition-- Wetland Terrestrial Biota (9 indicators)***				
Vegetation Structure (Naturally Forested)*	Measure of the size distribution and structure of vegetation relative to undisturbed references site data.	Canopy a mosaic of patches of different tree sizes, with variation in gap sizes OR Canopy largely heterogeneous tree sizes; some variation in gap sizes,, AND ·# of live stems of medium size (30-50 cm / 12-20") and large size (> 50 cm / >20" dbh) well within or very near expected range. expected range.	Canopy somewhat homogeneous in size, AND ·# of live stems of medium and large size below but moderately near expected range.	Canopy very homogeneous in size, AND ·# of live stems of medium and large size well below expected range.
Vegetation Structure (Naturally Shrub and Herbaceous)*	Measures the vegetation cover and structure and compares values to undisturbed references site data	Vegetation structure is at or near minimally disturbed conditions. No structural indicators of degradation evident.	Vegetation structure is moderately altered from minimally disturbed conditions. Several structural indicators of degradation evident.	Vegetation structure is greatly altered from minimally disturbed conditions. · Many structural indicators of degradation evident

Key Ecological Attribute		Rating		
Indicator **(* denotes fine scale not used ecoregion-wide)**	**Justification**	**Sustainable (0.9)**	**Transitioning (0.6)**	**Degraded (0.25)**
Ground Surface Organic Matter Accumulation (Naturally Forested)*	Measure of the amount of litter and downed woody debris, which is an indication of the amount of organic matter produced and recycled in the wetland. Standing litter also slows surface water flow and retains soil moisture. Disturbed areas generally have less organic accumulation than references sites.	Wide size-class diversity of standing snags and CWD (downed logs). Larger size class (>30 cm dbh/12" dbh and > 2 m/6' long) present with 5 or more snags per ha (2.5 ac), but not excessive #s. CWD in various stages of decay.	Moderate size-class diversity of standing snags or downed CWD. Larger size class present with 1-4 snags per ha, or moderately excessive #s. CWD in various stages of decay. Larger size class present with 1-4 snags per ha, or moderately excessive #s.	Low size-class diversity of downed CWD and snags. Larger size class present with <1 snag per ha, or very excessive #s. CWD mostly in early stages of decay.
Ground Surface Organic Matter Accumulation (Naturally Shrub and Herbaceous)*	Measure of the amount of herbaceous litter and small woody debris which is an indication of the amount of organic matter produces and recycled in the area. Standing litter also slows surface water flow and retains soil moisture. Disturbed areas generally have less organic accumulation than references sites.	Site characterized by moderate amount of litter (fine organic matter), occasional CWD, various sizes. New litter seems more prevalent than old litter. Litter and duff layers and leaf piles in pools or topographic lows are thin.	Site characterized by either patchy areas of little to no litter or somewhat excessive amounts of fine organic matter or CWD. · Old litter seems more prevalent than new litter	Site lacks litter accumulation, OR contains excessive litter accumulation.
Cover of Native Plant Increasers*	Measure of the presence and percent Cover (to nearest 5%) of native increaser species at site	**Absent OR Present with** <10% total cover and 5-20% relative dominance in any dominant layer (=any layer with >25% cover)	**Common**: <20% total cover and <30% relative dominance in any dominant layer(=any layer with >25% cover).	**Dominant**: >20% total cover and >30% relative dominance in any dominant layer(=any layer with >25% cover).
Relative Cover of Native Plant Species*	Measure of percent plant canopy cover by native species. Increased anthropogenic disturbance tends to decrease the amount of native cover, as non-native species invade and can dominate the wetland	Relative Cover of native plants 89 to 100%	Relative Cover of native plants 50 to 89%.	Relative Cover of native plant spp. < 50%
Cover of Exotic/Non-native <u>Invasive</u> Plant Species	Measure presence and estimates the abundance of aggressive non-native plant species known to invade wetlands, especially those with anthropogenic disturbance.	Aggressive non-native plant species absent or, if present no more than 1-2% cover.	Aggressive non-native plant species prevalent (3–10% cover).	Aggressive non-native plant species abundant (>10% cover).
Vegetation Regeneration (for Naturally Forested Riparian and Wetlands)*	For meandering riparian channels, the presence of many age classes of native tree species is an indication of natural fluvial geomorphic processes. Many native tree species, especially cottonwoods, rely on channel migration for successful stand regeneration.	Native saplings and/or seedlings common to the type present in expected amounts OR present but less than expected.	Native saplings and/or seedling common to the type present but low amounts; little regeneration.	No reproduction of native woody species common to the type.

Key Ecological Attribute		Rating		
Indicator (* denotes fine scale not used ecoregion-wide)	**Justification**	**Sustainable (0.9)**	**Transitioning (0.6)**	**Degraded (0.25)**
Native Plant Species Composition *	Measures ratio of species that are sensitive versus tolerant of anthropogenic disturbance, and the similarity of vegetation composition to undisturbed references sites	i) Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are absent or if present are minor in abundance (<10%), AND ii) Typical range of diagnostic species present, including those native species sensitive to anthropogenic degradation	i) Species are still largely native and characteristic of the type, but they also include increasers, weedy or ruderal species, AND ii) Many diagnostic species absent or substantially reduced in abundance.	i) Species from entire strata may be absent or species are dominated by ruderal ("weedy") species, or comprised of planted stands of non-characteristic species, or unnaturally dominated by single species, OR ii) Most or all diagnostic species absent, a few may remain in very low abundance.
Key Ecological Attribute: *Biotic Condition -- Aquatic Biota (4 indicators)*				
Aquatic Native Flora Composition *	Measure of the native aquatic plant species such as algae and compares to reference locations	Natural or Native reference conditions or Minimal changes in the structure of the biotic community and minimal changes in ecosystem function	Evident to moderate changes in structure of the biotic community and minimal to moderate changes in ecosystem function	Major to severe changes in structure of the biotic community and moderate changes to major loss in ecosystem function
Fish Assemblage Composition	Measures the integrity of the fish assemblage based on a multi-indicator index of biological integrity (IBI) and state tiered aquatic life use standards	Index value is consistent with Natural or Native reference conditions or Minimal changes in the structure of the biotic community and minimal changes in ecosystem function	Index value is consistent with evident to moderate changes in structure of the biotic community and minimal to moderate changes in ecosystem function	Index value is consistent with major to severe changes in structure of the biotic community and moderate changes to major loss in ecosystem function
Benthic Macro-invertebrate Assemblage Composition Index	Uses best available regional, state or subregional O/E ratio or multi-metric index of benthic macro-invertebrate assemblage integrity	Index value is consistent with natural reference conditions or with only minimal changes in biotic community structure and ecosystem function	Index value is consistent with evident to moderate changes in structure of the biotic community and minimal to moderate changes in ecosystem function	Index value is consistent with major to severe changes in structure of the biotic community and moderate changes to major loss in ecosystem function
Invasive Aquatic Index	A sum of the within HUC and surrounding HUC Aquatic Invasive Index for Stream CE.	See Aquatic Invasive Index	See Aquatic Invasive Index	See Aquatic Invasive Index
Key Ecological Indicator: *Soils and Landform Condition (4 indicators)*				

Key Ecological Attribute		Rating		
Indicator (* denotes fine scale not used ecoregion-wide)	**Justification**	**Sustainable (0.9)**	**Transitioning (0.6)**	**Degraded (0.25)**
Substrate /Soil Disturbance *	Disturbance to soil surface is an indication of soil compaction with can damage vegetation roots and reduce infiltration and organic matter retention in soils. Measured by remote or on site ocular estimation of non-natural bare ground percent cover.	Bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails at natural densities. OR Some bare soil due to human causes but the extent and impact is minimal. The depth of disturbance is limited to only a few inches and does not show evidence of ponding or channeling water.	Bare soil areas due to human causes are common. There may be bare soil trampling due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts.	Bare soil areas substantial & contribute to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock soil trampling and/or trails are widespread. Water will be channeled or ponded.
Physical Small Scale Landform Patch Diversity*	The number and type of small scale land forms such as hummocks, ponds, ridges expected relative to references site data. This assessment is based on site physical parameters and is not generally tied to the wetland type.	Physical patch types typical of wetland type at site are present [e.g. riverine features, hummocks, wallows, pools, channels.	Some physical patch types at site are lacking based on expected natural conditions at site	Many physical patch types at site are lacking based on expected natural conditions at site.
Channel configure-tion*	Riparian areas with perennial or intermittent stream channels. Indicators of disturbance are increased erosion through bank sloughing or failure and downcutting or aggregation of channel bed that is beyond the range of natural variation for the channel type and size. Measured bank to width ratio, number of meanders, entrenchment ratio (Rosgen 1996)	Natural channel; no evidence of severe aggradation or degradation OR Most of the channel has some aggradation or degradation, none of which is severe	Evidence of severe aggradation or degradation of most of the channel	Concrete, or artificially hardened, channels through most of the site
Riparian Confinement Index (Theobald et al. 2010)	Measures extent of modifications to floodplain & streambanks that result in stream-floodplain disconnection	No or minimal disconnection from floodplain; no or minimal geomorphic modifications to floodplain; <25% of streambanks affected	Moderately disconnected from floodplain due to multiple geomorphic modifications; 25 – 75% of streambanks are affected.	Extensively disconnected from floodplain; > 75% of streambanks are affected.

Table 2. Land Use Coefficients for Land Use ESLF Codes (NatureServe)

ESLF	LABEL	A. Land Use Coefficient	B. Natural / Non-Natural	C. Buffer
1	Non-Specific Disturbed	0.5	1	1
2	Recently Burned	0.5	1	1
8	Introduced Upland Vegetation - Annual Grassland	0.5	1	1
10	Recently Logged Areas	0.4	1	1
11	Open Water (within the Buffer area this is neutral)	1.0	1	0
21	Developed-Open Space	0.2	0	0

ESLF	LABEL	A. Land Use Coefficient	B. Natural / Non-Natural	C. Buffer
22	Developed-Low Intensity	0.1	0	0
23	Developed-Medium Intensity	0.0	0	0
24	Developed-High Intensity	0.0	0	0
32	Quarries/Strip Mines/Gravel Pits	0.0	0	0
61	Orchards/Vineyards	0.4	1	1
80	Agriculture-General	0.3	0	0
81	Agriculture-Pasture/Hay	0.4	0	0
82	Agriculture-Cultivated Crops and Irrigated Agriculture	0.2	0	0
2181	Introduced Upland Vegetation-Annual Grassland	0.5	1	1
2182	Introduced Upland Vegetation - Perennial Grassland and Forbland	0.5	1	1
2183	Introduced Upland Vegetation - Perennial Grassland and Forbland	0.5	1	1
2184	California Annual Grassland	1.0	1	1
2185	Introduced Wetland Vegetation	0.5	1	1
2191	Recently Logged Timberland-Herbaceous Cover	0.4	1	1
2192	Recently Logged Timberland-Shrubland Cover	0.7	1	1
2193	Recently Logged Timberland-Woodland Cover	0.8	1	1
2195	Recently Burned Herbaceous	0.5	1	1
2196	Recently Burned Shrubland	0.5	1	1
8301	Successional Shrub/Scrub (Other)	0.7	1	1
8304	Ruderal Forest - Southeast Hardwood and Conifer	0.7	1	1
8310	Ruderal Upland - Old Field	0.5	1	1
8311	Ruderal Forest	0.7	1	1
8401	Introduced Upland Vegetation - Treed	0.5	1	1
8402	Introduced Upland Vegetation - Shrub	0.5	1	1
8403	Introduced Upland Vegetation - Annual and Biennial Forbland	0.5	1	1
8404	Introduced Upland Vegetation - Annual Grassland	0.5	1	1
8405	Introduced Upland Vegetation - Perennial Grassland and Forbland	0.5	1	1
8412	Introduced Wetland Vegetation - Treed	0.5	1	1
8480	Introduced Riparian Vegetation	0.5	1	1
8490	Introduced Wetland Vegetation	0.5	1	1
8501	Recently Burned Forest and Woodland	0.5	1	1
8503	Harvested Forest-Grass Regeneration	0.4	1	1
8508	Clearcut - Grassland/Herbaceous	0.3	1	1
8509	Successional Shrub/Scrub (Clear Cut)	0.4	1	1
8512	Recently Burned Forbland	0.5	1	1
8513	Managed Tree Plantation	0.5	1	1
8514	Managed Tree Plantation	0.5	1	1
8516	Modified/Managed Southern Tall Grassland	0.9	1	1

ESLF	LABEL	A. Land Use Coefficient	B. Natural / Non-Natural	C. Buffer
8601	Harvested forest-tree regeneration	0.7	1	1
8602	Recently Logged Timberland	0.4	1	1
8604	Harvested forest-herbaceous regeneration	0.4	1	1
	Any Ecological System (or aggregate)	1.0	1	1

Table 3. Surrounding Land Use, or On-Site Land Use Coefficients

Land Use Coefficient Table (modified from Hauer et al. 2002) for Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/mining (gravel pit, quarry, open pit, strip mining).	0
Unpaved Roads (e.g., driveway, tractor trail) / abandoned mines	0.1
Agriculture (tilled crop production) / intensively developed vegetation (golf courses, lawns, etc).	0.2
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	0.3
Heavy logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Intense recreation (ATV use/camping/sport fields/popular fishing spot, etc.) / Military training areas (armor, mechanized)	0.4
Heavy grazing on rangeland or pastures	0.4
Agriculture - permanent crop (vineyards, orchards, nurseries, berry production, introduced hay field and pastures etc)	0.4
Commercial tree plantations / christmas tree farms	0.5
Dam sites and flood disturbed shorelines around water storage reservoirs	0.5
Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species.	0.5
Moderate grazing on rangeland	0.6
Moderate recreation (high-use trail)	0.7
Mature old fields and other fallow lands with natural composition	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail) / haying of native grassland.	0.9
Natural area / land managed for native vegetation	1
	Total

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Appendix IIe. Conceptual Model for Desert Horned Lizard (Phrynosoma platyrhinos)

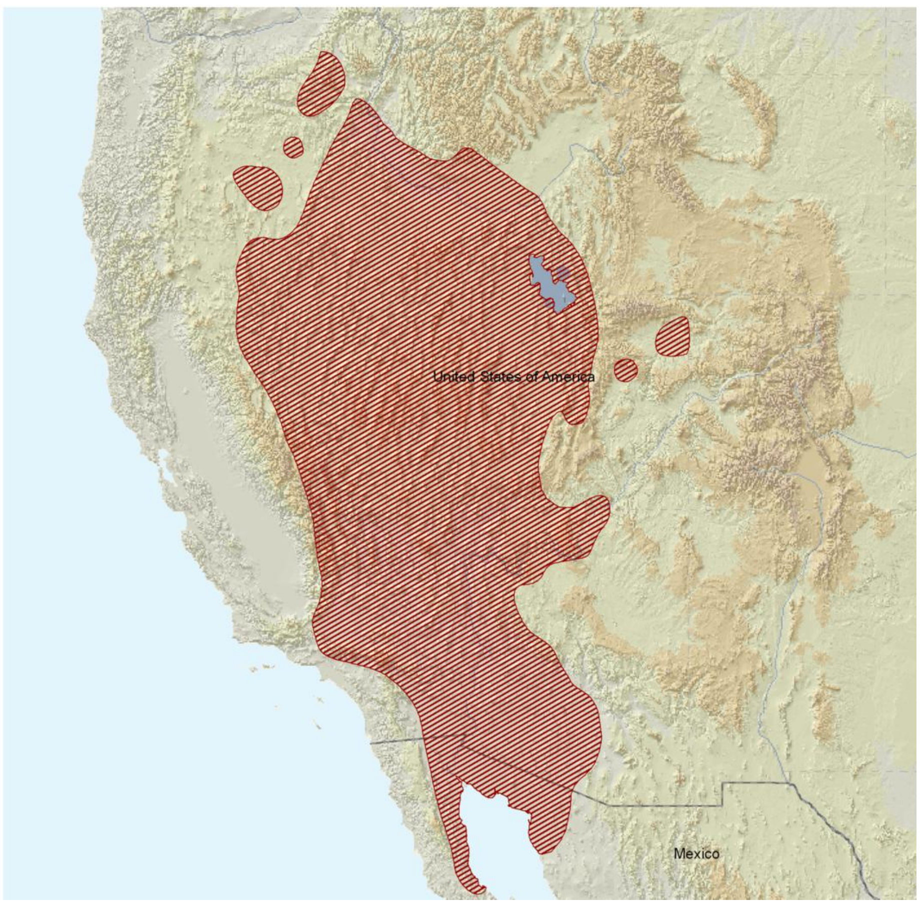
[*for illustration purposes, as an example of material to be produced for landscape species CEs*]

Conservation Element (CE) Characterization

Summary

The range of the desert horned lizard extends from southeastern Oregon, southwestern Idaho, and northern Utah south through eastern and southern California, Nevada, and western Arizona to northeastern Baja California, Mexico (Pianka 1991, Grismer 2002, St. John 2002, Stebbins 2003, Mulcahy et al. 2006) (Figure 1). Isolated populations exist in the vicinity of dry lakebeds in Lake and Harney counties in Oregon. Old records for northeastern Utah need verification (St. John 2002). Elevational range extends from below sea level in desert sinks to about 1,980 meters (6,500 feet) (Linsdale 1940, Stebbins 2003).

Figure 1. Coarse-level range extent of the desert horned lizard (*Phrynosoma platyrhinos*). Populations south of the Gila River in southwestern Arizona and northwestern Sonora, Mexico, are now recognized as a distinct species, *Phrynosoma goodei* (Mulcahy et al. 2006). Records from northeastern Utah are based on old records and may not represent extant (or even historical) populations. Source: IUCN Red List (http://www.iucnredlist.org/apps/redlist/details/64080/0/rangemap).



This species is represented by a large number of collection sites that are well distributed throughout the geographic range (Pianka 1991). Populations likely are extant in most of these locations, but population sizes or densities have been documented in only a few locations. In southern Nevada, Tanner and Krogh (1973) determined that density was around 5 individuals (adults and subadults) per hectare (Tanner and Krogh 1973). Also in southern Nevada, Medica et al. (1973) found spring densities of up to at least 6.6 adults and subadults per hectare on large plots and as high as 32 per hectare on small fenced plots. Density in the large plots actually may have been higher (e.g., because some individuals were overlooked) whereas small-plot density may have been artifically high (if the fence prevented normal dispersal). Neither study attempted to associate population density with characteristic environmental variations.

This lizard inhabits all sorts of semi-desert shrublands, such as those dominated by sagebrush, shadscale, hopsage, creosotebush, or greasewood, on sandy flats, alluvial fans, washes, or brushy dunes or dune edges (Grismer 2002, St. John 2002, Stebbins 2003). It is most consistently found where areas of bare ground exist among openly spaced shrubs. It occurs where summers are hot and winters are cold or mild; winter temperatures generally are too cold for activity.

In Nevada, *P. platyrhinos* is common in sandy or gravelly valleys and flat areas throughout most of the state at elevations of 610-1,980 meters (mainly above 1,220 meters) (Linsdale 1940). In Arizona, *P. platyrhinos* inhabits Sonoran, Mohave, and Great Basin desertscrub communities and the lower reaches of interior chaparral and Great Basin conifer woodland, usually in relatively flat, open areas with sandy or loamy soil, less frequently on rocky bajadas and foothills (Brennan and Holycross 2006).

Duration of the annual activity period varies with local climate. For example, in southern Nevada, activity begins usually in March, and adults become scarce above ground after mid-July (Tanner and Krogh 1973). Activity occurs primarily during daylight hours, but in the southernmost part of the range, some individuals may be active on warm nights. During periods of inactivity the lizards bury themselves in the soil or occupy existing burrows.

Desert horned lizards derive their body heat from the environment. They require warm body temperatures for activity, feeding, digestion, and reproduction, but conditions on the surface can become too warm. Lizards attain suitable body temperatures by basking in the sun, moving within the sun-shade mosaic produced by plants, and by burying in the soil or entering a burrow.

Desert horned lizards avoid predators through crypsis (they are very difficult to see unless in motion) and by rapid running into vegetative cover (e.g., Linsdale 1938). The lizards' head spines may interfere with attempted ingestion (and also likely enhance crypsis). This species does not exhibit the defensive blood squirting mechanism present in some horned lizard species (Middendorf and Sherbrooke 1992, Sherbrooke and Middendorf 2004).

Horned lizards in general tend to have small home range sizes, usually less than 0.5 ha (often much less) and rarely more than 1 ha. However, Tanner and Krogh (1973) found that many individuals in study plots in southern Nevada were somewhat nomadic and did not stay within small home ranges. Dispersal distances are poorly known, and most studies have not been designed to detect long distance movements.

The diet consists primarily of slow-moving terrestrial insects (e.g., ants, beetles) but also sometimes includes spiders and some plant material (e.g., *Lycium* fruits) (Banta 1961, Tanner and Krogh 1973). Generally this lizard is regarded as an ant specialist (Pianka 1991). In a shrub-steppe bajada in northwestern Utah, desert horned lizards ate 14 of the 20 ant species that were present in the study areas but showed a distinct preference for species with the largest body sizes, including but not restricted to harvester ants (Newbold and MacMahon 2009).

This lizard is an egg layer. Females bury eggs in the soil. In southern Nevada, egg deposition occurs April-July (apparently mainly early June). Clutch size averages about 7. Individual females produce one or two clutches per year. Incubation lasts about 50-60 days. Hatchlings appear from mid-July to August in southern Nevada, and as late as mid-September in some areas. Individuals become sexually mature in about 22 months (Tanner and Krogh 1973, Nussbaum et al. 1983). Studies in Nevada indicate that some individuals live 7-8 years, occasionally longer (Medica et al. 1973, Tanner and Krogh 1973).

Dynamics:

Drought

Drought may affect populations of horned lizards and other insectivorous reptiles by causing changes in body condition and survival. For example, Texas horned lizards (*Phrynosoma cornutum*) appear to be sensitive to climate-associated variations in food supply, and drought may reduce food availability and result in lizard weight losses (Whitford and Bryant (1979). In tree lizards (*Urosaurus ornatus*), reduced growth rate, body condition, and juvenile survival were associated with drought (Tinkle and Dunham (1983). The snake *Coluber constrictor*, the diet of which includes many insects, exhibited decreased survival during drought conditions in Utah, and juvenile growth was best in years with relatively high rainfall (Brown and Parker 1984).

Drought may also result in reduced reproduction. Fat bodies in the abdominal cavity provide most of the nutrition for reptilian reproduction. Reduced food supplies may reduce reproductive output due to inadequate fat storage. Periods of drought and food shortage may result in smaller clutch sizes. In southern New Mexico, Worthington (1982) found that drought may result in a one-egg reduction in the average clutch size of the side-blotched lizard (*Uta stansburiana*).

The effects of drought on survival and reproduction are manifested in reduced population density. For example, in Texas, tree lizard density declined greatly during periods of drought (Ballinger 1977, 1984), evidently due to effects of reduced food resources (Dunham 1981). In California, western whiptail (*Aspidoscelis tigris*) populations tended to increase with periods of increased arthropod abundance associated with increased precipitation (Anderson 1994). Similarly, *A. tigris* density varied with drought conditions in southwestern Texas (Milstead 1965).

Thus it is likely that drought results in reduced density of desert horned lizards through the following scenario: Drought reduces plant productivity (including seed production), which in turn reduces insect populations and horned lizard food resources. Reduced food resources result in reduced horned lizard survival and reproduction, which result in reduced population density. In southern Nevada, Medica et al. (1973) observed substantial variation in *P. platyrhinos* reproduction. Individual females produced one clutch per year in most years and multiple clutches in one year; no evidence of reproduction was observed in one year. The authors did not attempt to associate these variations with environmental parameters but simply speculated that “these deviations may be intimately associated with various density-dependent regulating mechanisms or with differences in net primary production and availability of food.”

Change Agent (CA) Characterization

Altered Dynamics

Urbanization and Agriculture

Habitats subject to intensive urbanization and agricultural development do not provide suitable horned lizard habitat and eliminate lizard populations from affected areas. Desert horned lizards may persist where low intensity urban or agricultural development occurs, but population density generally is much reduced, probably due to increased mortality resulting from road kills, predation or lethal injuries caused by domestic animals or unnaturally high populations of human-associated native predators, and collection by humans who wish to possess a rather unique pet (which invariably dies).

Urbanization and agriculture may also negatively affect desert horned lizard populations by fragmenting populations into units that are too small for long-term viability. Because intensive development creates barriers that prevent dispersal, resulting population fragments must function independently and cannot be “rescued” by immigration. The population size required for long-term viability is unknown.

A relatively small part of the range of the desert horned lizard is affected by large-scale urbanization or agriculture.

Renewable energy development

Most of the habitat of *P. platyrhinos* is highly suitable for solar energy development (e.g., http://solareis.anl.gov/maps/alternatives/index.cfm). Since solar energy collectors necessarily must intercept sunlight before it reaches vegetation or the ground, they negatively affect desert horned lizards in several direct and indirect ways, the most obvious being reduced plant productivity and associated reductions in food resources, and reduced opportunities for basking and normal thermoregulatory behavior. In the Mohave Desert, conflicts already exist between solar energy development and protection of endangered reptile habitat (e.g., flat-tailed horned lizard and desert tortoise).

Most of the habitat of *P. platyrhinos* also has high potential for geothermal energy development (e.g., http://www1.eere.energy.gov/tribalenergy/guide/geothermal_resources.html) and has good wind energy generation potential (http://www.epa.gov/oswercpa/maps/pdfs/utility_wind_us.pdf). Development of these energy resources may have significant impacts on the species, but the nature and degree of the impacts are poorly known. On the other hand, like other horned lizards, *P. platyrhinos* favors sparsely vegetated habitats (Pianka and Parker 1975, Sherbrooke 2003) and so might actually benefit from a low degree of development.

Experimental continuous gamma irradiation

In southern Nevada, Medica et al. (1973) documented a decline in desert horned lizard populations exposed to continuous gamma irradiation. Female sterility and consequent curtailed reproduction were judged to be the cause of the decline. This is not a significant factor in the conservation status of the species.

Off-road vehicular use of desert shrubland

Use of motor vehicles in the Great Basin and Mohave Desert probably has eliminated or reduced populations of desert horned lizards in some areas (Busack and Bury 1974). Vehicles may negatively affect lizard populations by directly killing them or by destroying cover (shrubs, burrows) or reducing food supplies (e.g., by destroying ant colonies). As mentioned, horned lizards favor areas with sparse vegetation (such as might result from a modest level of vehicular activity), but the other detrimental effects of vehicle use likely would override any possible enhancements to vegetation structure.

Non-native grasses

Field studies in the eastern Great Basin in nothwestern Utah indicate that desert horned lizards may avoid areas invaded by cheatgrass (*Bromus tectorum*) and that presence of *B. tectorum* reduces lizard running speed (and thus probability to avoid predation) (Newbold 2005). Given the widespread occurrence of *B. tectorum* in the Great Basin (Billings 1990, Knapp 1996) and Mohave Desert (Brooks 1999), it is likely that invasive grasses have substantially reduced desert horned lizard distribution and abundance in these ecoregions.

Seeding of non-native perennial grasses such as crested wheatgrass (*Agropyron cristatum*) has been widely used to treat burned areas that may be vulnerable to invasion by exotic annual grasses such as cheatgrass. Although no pertinent studies have been conducted, it is likely that dense stands of *A. cristatum* degrade desert horned lizard habitat in the same way that *B. tectorum* does.

Livestock grazing

Desert horned lizard distribution and abundance appear to be affected by livestock grazing. In shrub-steppe habitat in the eastern Great Basin in northwestern Utah, experimental studies indicated that horned lizards abandoned areas protected from grazing (in ungrazed exclosures) and presumably moved into grazed areas (Newbold and MacMahon (2009). Lizard avoidance of ungrazed plots coincided with a decline in shrub and grass cover on grazed plots, with no significant change in relative abundance or richness of prey (ants) on grazed plots (Newbold and MacMahon 2009). Overall, the results indicated that the lizards' response to grazing was largely due to changes in habitat structure (i.e., vegetation cover) rather than changes in prey availability (Newbold and MacMahon 2009). The results were consistent with the basic pattern of horned lizard preference for areas with sparse vegetation (Pianka and Parker 1975, Sherbrooke 2003).

Given the importance of ants to desert horned lizards, it is relevant to ask whether the results of Newbold and MacMahon (2009) can be generalized (i.e., ant populations exhibit no significant response to grazing). A review by Underwood and Fisher (2006) found no consistent trends in grazing impacts on ant assemblages or particular ant species. Grazing could enhance habitat structure but might reduce, increase, or have no effect on food resources, so it will be difficult to predict the overall impact of grazing on *P. platyrhinos* populations. However, given the quite consistent horned lizard preference for areas with sparse vegetation already mentioned, moderate grazing generally would be expected to enhance or not affect *P. platyrhinos* habitat and populations.

Habitat Integrity Criteria & Indicators

This analysis will be based on a habitat distribution spatial model or habitat probability surface model, which is a required input for assessing habitat integrity. We will build upon the habitat distribution models developed by the SW ReGap program for *Phrynosoma platyrhinos.* Our models will include both a predicted current habitat distribution (factoring in current land use variables), as well as a predicted historic habitat distribution, where land use variables are not included. The indicators are organized by the rank factors Landscape Context, Condition, and Relative Extent and assessed using indicators that can be evaluated at the appropriate spatial scale. For conservation elements the reporting unit is at the Watershed 5^{th} Level (HUC – 10).

Landscape Context

Connectivity Condition- This indicator is assessed using *CircuitScape*, a GIS program that uses circuit theory to predict connectivity in heterogeneous landscapes for individual movement, gene flow, and conservation planning (McRae 2006, McRae et al. 2008). The program results are an index of connectivity from 0 to 1 for each 90-meter pixel. Pixel values are summed for the conservation element's (desert horned lizard in this case) distribution within each 5^{th}-level HUC.

Landscape condition model (LCM) index - This indicator is measured in a GIS by intersecting the habitat distribution map for *P. platyrhinos* with the NatureServe LCM layer (Comer and Hak 2009) and reporting the overall LCM index for the habitat. The program results are an index of landscape condition from 0 to 1 with 1 being very high landscape condition and 0 having very poor condition.

Condition

***Abundance of invasive plant species* -** This indicator is measured using the habitat distribution with an abundance map of introduced invasive annual vegetation. The output is percent cover of invasive annual vegetation within each 5th level HUC. The Invasive Annual Cover Index is calculated by multiplying the invasive annual cover percent by 4 then subtracting the product from 1 to produce a normalized scale from 0 to 1 with 1 being invasive annuals absent to 0 which is 25% or greater cover of invasive annuals.

Relative Extent

***Change in Extent* -** This indicator is assessed by intersecting the mapped current habitat distribution for the species with the historic habitat distribution map and reporting the percent change between the historic and current habitat distribution. The Change in Extent Index is calculated by subtracting the Change in Extent percent from 1 to produce a normalized scale from 0 to 1with 1 being no change in extent and 0 being complete loss of CE in extent.

Ecological Integrity Assessment

The Ecological Integrity Assessment (EIA) is designed to develop ecological integrity indicators for individual CE and composite CE at two spatial levels: Watershed 5th Level (HUC - 10) and ecoregion. The assessment indicators or indicators with justifications and rating thresholds are presented in Table 6, organized by Rank Factors (Landscape Context, Condition and Relative Extent) and Key Ecological Attributes. The indicators measure the key ecological attributes for the conceptual ecological model above and the index thresholds permit interpretation of the results.

Summary of Scoring

The Habitat Integrity Assessment is designed to develop habitat integrity indicators at two spatial levels: Watershed 5th Level (HUC - 10) and ecoregion. This starts with summarizing the mean scores of indicators by Landscape Context, Condition and Relative Extent. This is because individual scores are valuable for assessment of particular attributes in the reporting area. Each indicator is scored according to criteria described above and then the score is either used directly as an index or a indicator index is calculated between 0 and 1 with 1 being 100% sustainable and 0 being totally degraded. . See hypothetical index scoring on right hand column of Table 6.

These rank factor rankings can then be combined into an Overall Population Viability Rank. This enables one to report scores or ranks from the various hierarchical scales of the assessment depending on which best meets the user's objectives. Displaying the indicators with individual scores allows user to interpret which particular ecological attributes in a reporting area is driving the ecological integrity of the CE. Using the rating factors in Table 5 allows the user to rate the CE as Sustainable, Transitioning or Degraded for each Rank Factor and calculate an Overall Integrity Rank.

Table 6. *Phrynosoma platyrhinos* Habitat Integrity Assessment Scorecard.

Indicator	Justification	Rating			Index
		Sustainable	Transitioning	Degraded	Score
Rank Factor: LANDSCAPE CONTEXT					
Key Ecological Indicator: *Landscape Connectivity*					
Connectivity predicted by Circuitscape	Intact natural conditions support physical and biological dynamics occurring across diverse environmental conditions	Connectivity is moderate to high and adequate to sustain most populations. Connectivity index is >0.6	Connectivity is moderate to low and will not sustain some populations. Connectivity index is 0.6-0.2	Connectivity is low and will not sustain many populations. Connectivity index is <0.2	**0.4**
Key Ecological Indicator: *Landscape Condition*					
Landscape Condition Model Index	Land use impacts vary in their intensity, affecting ecological dynamics that support species habitat.	Cumulative level of impacts is sustainable. Landscape Condition Model Index > 0.8	Cumulative level of impacts is transitioning habitat between sustainable and degraded state. Landscape Condition Model Index 0.75 – 0.5	Cumulative level of impacts has degraded habitat. Landscape Condition Model Index < 0.5	**0.6**
Rank Factor: CONDITION					

Indicator	Justification	Rating			Index Score
		Sustainable	Transitioning	Degraded	
Key Ecological Indicator: *Native Species Composition*					
Invasive Annual Cover	Invasive annual vegetation fills in required bare ground and provides fine fuels that significantly increase spread of catastrophic fire..	Habitat is sustainable with low cover of invasive annual vegetation. Mean cover of annuals is <5%. (= index of 1)	Habitat is transitioning to degraded state by abundant invasive annual vegetation. Mean cover of annuals is 5-10%.(=index score of .5)	Habitat is degraded by abundant invasive annual vegetation. Mean cover of annuals is >15%. (=index score of 0.2)	**0.5**
Rank Factor: Relative Extent					
Key Ecological Indicator: *Extent*					
Change in Extent	Indicates the proportion of suitable habitat lost due to conversion to other land cover or land use, decreasing provision of ecological services provided previously.	Suitable habitat is at or minimally is only modestly reduced from its original natural extent (80-100% remains) Index >0.8	Suitable habitat is substantially reduced from its original natural extent (50-80% remains) Index .75-0.5	Suitable habitat is severely reduced from its original natural extent (<50% remains) Index <0.5	**0.5**
Overall Ecological Integrity Rank					
			(2/4)	**Mean Index Score**	**0.38**

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Appendix III. Management Questions: Referenced to Modeling Categories

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
Species						
1	What is the current distribution of occupied habitat for each CE, including seasonal habitat, and movement corridors?	Each CE	Existing data or distribution model (tight association to known distribution?)			**Terrestrial Coarse Filter CEs**: Central Mojave Veg Map plus NatureServe map (ReGAP and LANDFIRE EVT); with addt'l refinement. **Aquatic Coarse Filter CEs**: NatureServe map plus NHD Plus, and NWI. Fine-filter CEs: Natural Heritage, FWS, SWAP, and Misc. sources data. **Data for Movement Corridors not yet identified.**
2	Where are current CE populations potentially affected by change agents (and potentially at risk)?	Each CE crossed with CAs	Existing data or distribution model + intersect scenarios + condition model	All CAs		Criteria for evaluating ecological integrity exist in some form for most Coarse Filter CEs. These finer-grain conceptual models enable us t state assumptions about effects of Change agents. It wil be feasible to complete review and refinement of these criteria for subsequent application to spatial modeling.
3	What is the current distribution of suitable habitat for each CE?	Each CE	Existing data or distribution model (potential habitat)			The same data sets from the first two questions apply to answer these questions.
4	Where are change agents potentially affecting this habitat and/or movement corridors?	Each CE crossed with CAs	Existing data or distribution model (potential habitat) + intersect scenarios	All CAs		We do NOT yet have all corridor-related data identified.
5	Where are CEs whose habitats are systematically threatened by CAs (other than climate change)?	Subset of CEs with restricted habitats	Existing data or distribution model (potential habitat) + intersect scenarios	All CAs	During Task 3, select CE subset	The same data sets from the first two questions apply to answer these questions.
6	What areas have been surveyed and what areas have not been surveyed (i.e., data gap locations)?	Each CE	Existing data + intersect with distribution model			This is a Task 3 activity once species CEs are finalized.
7	Given current and anticipated future locations of change agents, which habitat areas remain as opportunities for habitat enhancement/restoration?	Subset of CEs	Existing data or distribution model + intersect scenarios + restoration model		During Task 3, select CE subset or specific habitats.	In addition to the same data sets referenced in the first two questions, SSURGO and LANDFIRE BpS data sets will be useful for this application.

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
8	Where are potential areas to restore connectivity?	Selected subset of habitats and locations.	Existing data or connectivity model + restoration model		Determine which CEs have connectivity as a relevant concern. Select subset of habitats or locations.	This will be explored and documented as methodology in Task 3. We will answer remaining data input questions at that point.
9	Where will CEs experience climate outside their current climate envelope?	Each CE	Existing data or distribution model + intersect future climate data	Climate Change	Standard climate envelope analysis	We are reasonably well postitioned to address this for major CEs using climate effects models that build on PRISM (4km data) and downscaled future projects (15 km data). Confidence in outputs will vary depending on natural characteristics of CEs and spatial resolution of climate data.
Native Plant Communities						
10	Where are intact CE vegetative communities located?	All CEs that are vegetative communities	Existing data + intersect scenarios + condition model			Terrestrial Coarse Filter CEs: Central Mojave Vegetation plus NatureServe map (ReGAP and LANDFIRE EVT); with merge and addt'l refinement.
11	Where are the locations that most likely include the highest-integrity examples of each major terrestrial ecological system type?	All CEs that are vegetative communities	Existing data + intersect scenarios + condition model		Develop indicator for Integrity that can be applied to CE communities with available data.	Criteria for evaluating ecological integrityprovide conceptual model detail. Spatial information to be derived from various landscape condition models and LANDFIRE spattial outputs (raw and refined).
12	Where will these current communities be potentially affected by Change Agents?	All CEs that are vegetative communities crossed with CAs	Existing data + intersect scenarios + condition model	All CAs		Data referenced above for current location of all CEs.
13	Where will current locations of these communities experience significant and abrupt deviations from normal climate variation?	All CEs that are vegetative communities	Existing data + intersect scenarios + condition model	Climate Change	TBD: Climate models to use and the definition of "significant". This could evolve into a standard climate envelope analysis.	Georeference sample data (from ReGAP & LANDFIRE LFRDB) represent current distributions of types and dominant species for climate envelope models with PRISM data. These then for source material for analysis of future climate envelopes using USGS 15 km data.
Terrestrial Sites of High Biodiversity						
14	Where are High Biodiversity sites?	Ecoregion-wide	Existing data		During Task 3, develop a specific working definition of "high biodiversity". For example, is it just species richness, R? Or richness of CEs?	These have been defined as priority sites identfied through previous planning efforts. These can be covered adequately with SWAP locations (not yet acquired) TNC ecoregional portoflio sites, and other selected sources.

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
15	Where will these High Biodiversity sites be potentially affected by Change Agents?	All High Biodiversity sites (working definition required) crossed with CAs	Existing data intersect current scenario or 2025 scenario + condition model	All CAs		same as above, in combination with CA data.
16	Where will current locations of these High Biodiversity sites experience significant and abrupt deviations from normal climate variation?	All High Biodiversity sites (working definition required)	Existing data intersect future climate models	Climate Change, potentially other CAs	TBD: Climate models to use and the definition of "significant". This could evolve into a standard climate envelope analysis.	Same as above, with climate effects model outputs (and inherent limitations based on spatial resolution and uncertainty stemming from climate data).
Aquatic Sites of High Biodiversity						
17	Where are Aquatic High Biodiversity sites?	All Aquatic High Biodiversity sites (working definition required)	Existing data		During Task 3, develop a specific working definition of "high biodiversity". For example, is it just species richness, R? Or richness of CEs?	These have been defined as priority sites identfied through previous planning efforts. These can be covered adequately with SWAP locations (not yet acquired) TNC ecoregional portoflio sites, and other selected sources.
18	Where will these Aquatic High Biodiversity sites be potentially affected by Change Agents?	All Aquatic High Biodiversity sites (working definition required) crossed with CAs	Existing data	All CAs		Same as above, in combination with CA data
19	Where will current locations of these Aquatic High Biodiversity sites experience significant and abrupt deviations from normal climate variation?	All Aquatic High Biodiversity sites (working definition required)	Existing data or distribution model + aquatic change model	Climate Change	TBD: Climate models to use and the definition of "significant". This could evolve into a standard climate envelope analysis.	Same as above, with climate effects model outputs (and inherent limitations based on spatial resolution and uncertainty stemming from climate data).
Specially Designated Areas of Ecological Value						

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
20	Where are specially designated areas of ecological value?	Ecoregion-wide	Existing data		Define subset from the list of CEs or other designated locations.	The 2010 Protected Areas Database provides a foundation for this. Additional selected data sets can fill this out.
Grazing, Wild Horses and Burros						
21	Where are the current Herds of Wild Horses?	Wild horses	Deferred		Will be represented as HAs and HMAs as in the data sources indicated to the right.	These are shown in the BLM herd and herd management area maps
22	Where are the current Herds of Burros?	Burros	Deferred		As above.	Same as above
23	Where are the current Herd Management Areas (HMAs)?	Wild horses, Burros	Existing data			Same as above
24	Which HMAs are exceeding AML?	Wild horses, Burros	Deferred	Grazing	Can not be answered with the information available.	Additional data on herd numbers and range conditions are required to answer this MQ
25	Which current HMA will experience significant effects of Change Agents?	HMAs, Grazing	Existing data + intersect scenarios	All CAs		This will be addressed further as change agent datasets are identified and compared against HMAs.
26	Which current Allotments will experience significant effects of Change Agents?	Allotments, Grazing	Existing data + intersect scenarios	All CAs		This will be addressed further as change agent datasets are identified and compared against allotment areas
27	Which Allotments and HMA will experience climate outside their current climate envelope?	HMAs, Allotments, Grazing	Existing data + intersect future climate models	Climate Change, Grazing	Standard climate envelope analysis	This will be addressed further as climate change data is developed and compared against those target areas
Soils						
28	Where are target and sensitive soil types within the ecoregion?	Ecoregion-wide	Existing data or distribution model		Develop list of relevant soil types. MQ modified to include sensitive soil types. Possible additional analyses: What is the relationship between sensitive soils and areas of high biodiversity significance? Are areas of endemism related to unique soils, for example which are related to unique pollinators, etc? There are groups in Clark County that are trying to get at this.	SSURGO, with gap-filling using STATSGO, surficial geology and 10m DEM-derived landforms. A BLM key for identifying sensitive soil types have been obtained.

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
29	Where will these target soil types be potentially affected by Change Agents?	All target soil types (working definition required) crossed with CAs	Existing data or distribution model + intersect scenarios	All CAs		Same as above, in combination with CA data.
30	Where will current locations of these High Biodiversity sites experience significant and abrupt deviations from normal climate variation?	All target soil types (working definition required)	Existing data + future climate models		TBD: Climate models to use and the definition of "significant". This could evolve into a standard climate envelope analysis.	All agreed-upon locational data for these PLs, plus climate data from PRISM (4km) and projections (15km)
Surface and Subsurface Water Availability						
31	Where are current water resources, both natural and man-made?	All surface water bodies	Existing data		Note: coordinate with a related question in Groundwater Extraction.	NHD, NHDPlus, NID (the latter to help identify artificial impoundments)
32	Of these water resources, which are perennial, ephemeral, etc?	All surface water bodies	Existing data			NHD, NHDPlus
33	Of these water resources, what is their surface water/groundwater connectivity?	All surface water bodies	Existing data			Not directly measurable at regional scale; surrogate for streams will be: (a) USGS-SWPA data to identify basin fill aquifers surrounding water bodies; (b) USGS baseflow index data, either organized by grid (bfi48grd) or for NHDPlus (nhd_bfi) or extracted from the standard streamflow statistics included in NHD, to assess the relative contribution of groundwater discharge to coarse-filter aquatic CE stream hydrology. For springs/seeps, we will use the source identified in spring/seep site assessment data if available.

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
34					In CA, ground water and surface water are treated very differently from a legal perspective. From a scientific standpoint they are obviously connected. Where is surface development going to affect groundwater, which may affect surface water (See SNWA)? These issues are not directly meaureable (see right) at regional scales. Proposed revision to the MQ is as follows: "Among these surface water resources, which streams have baseflows that indicate a significant contribution of groundwater to stream hydrology, and what basin fill aquifers may be the source(s) of this contribution; and what aquifers may be the sources for base water levels in springs or seeps?"	
35	What is the natural range of variation in high and low water levels or flows (e.g., frequency, timing, duration of high and low water levels or flows)?	All surface water bodies	Existing data			Not directly measurable at regional scale; surrogate will be: (a) monthly catchment runoff estimates from USGS Flint & Flint (2007) data; or (b) catchment runoff estimate from the NHDPlus attribute layer for overland flow (nhd_ieof); and/or (c) baseflow estimation from the NHDPlus attribute layer for USGS Baseflow Index (nhd_bfi) or gridded bfi values (USGS bfi48grd) or streamflow statistics from NHD depending on which we find most easily manipulable
36					Proposed revision to the MQ is as follows: "What is the natural variation of monthly discharge and monthly baseflow for streams and rivers?"	
37	Where are the aquifers and their recharge areas?	All relevant areas	Existing data			USGS SWPA and Flint & Flint 2007

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
38	Where will these water resources be potentially affected by Change Agents?	All surface water bodies crossed with CAs	Existing data + intersect scenarios + aquatic integrity model	Many CAs	Will address the "where" not the "how" component of this MQ	(see discussion of CAs)
Aquatic Ecological Function and Structure						
39	What is the condition of target aquatic systems? OR What is the condition of target aquatic systems in terms of PFC?	All surface water bodies (may require a subset)	Existing data + intersect scenarios + aquatic integrity model	Hydrologic alternation, Invasive species, Development	Many may not have "PFC" defined, especially if they are not riparian. Need to look beyond "function and structure" to look at factors that may contribute to resistance and resilience in the face of disturbances and change agents. This requires a conceptual model: What are the ecological and environmental factors that contribute the most to ecological structure and function, including resistance and resilience in the face of disturbances and change agents? To be developed further during Task 3.	• Biotic condition: aquatic bioassessment data from federal and state monitoring programs (federal data include EMAP-WSA and other data from Utah State University Western Monitoring Center and Utah State University-BLM National Monitoring Center [aka BLM "Buglab"]. State data come from individual state aquatic bioassessment programs); and data on native aquatic species distributions (from Heritage pgms) and aquatic non-native (nuisance) species distributions (see Invasives CA discussion)
40						• Abiotic condition: data on the proportion of annual stream flow resulting from groundwater discharge (baseflow) via USGS bfi datasets (see above); the spatial extent of perennial versus intermittent flow via NHDPlus (see above); the intensity of monthly runoff across associated watershed catchment via Flint & Flint (2007) data and via NHDPlus (nhd_ieof); water quality via USEPA database on USEPA State Impaired Waters data (linked to NHD); the distribution of dams (Army Corps NID); and habitat quality (from Utah State University Western Monitoring Center data and BLM "Buglab" data).

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
41						• Landscape context: data on snowpack, runoff and recharge dynamics from the USGS (Flint & Flint 2007 data), near-stream and watershed land cover and land use (same as source of Landscape Condition data for terrestrial CEs), water use in the surrounding surface watershed and contributing groundwater zone (from USGS SWPA and state publications), atmospheric deposition of N (a representative potential acidification agent as well as a nutrient) and Hg (a representative potential bioaccumulative pollutant) (from NADP data. To support the analysis of landscape context, we have also identified sources of data with which to identify the basin fill aquifers potentially responsible for sustaining base flow or base water elevations in aquatic CEs, and the watershed zones within each HUC potentially most responsible for generating surface runoff to streams and recharge to basin fill aquifers (USGS SWPA; Flint & Flint 2007 data).
42	Where are the degraded aquatic systems (e.g., water quality)?	All surface water bodies	Existing data + aquatic integrity model	Hydrologic alteration, Invasive species, development	Requires a working definition of degraded. TBD in a conceptual model.	See notes above on biotic, abiotic condition; landscape context for hydrologic and water quality degradation; see Invasives for the latter.
Fire History						
43	What areas have experienced significant fire?	Ecoregion-wide	Existing data	Wildfire (increased and/or decreased frequency)	Requires a working definition of "significant fire" effects. To be addressed in the modeling in Task 3.	GeoMac, Fire Perimeters, Fire Occurrence, and Burn Severity data sets
44	In places that have experienced fire, where does the resulting vegetative structure and composition differ from the desired state?	Among locations that have experience significant fire	Existing data	Wildfire (increased and/or decreased frequency)	Requires, for each location, a definition of what constitutes "desired state". TBD in Task 3.	LANDFIRE FRCC and subsequent spatial model outputs.
Fire Potential						
45	Where are current areas with high potential for fire?	Ecoregion-wide	Existing data	Wildfire (increased and/or decreased frequency)		LANDFIRE FRCC and subsequent spatial model outputs; National Lightening Detection Network.
46	Where are areas that in the future will have high potential for fire?	Ecoregion-wide	Existing data + interesect scenarios + fire model	Wildfire (increased and/or decreased frequency)	Devise a working definition of "potential for fire". TBD in Task 3. Based on climate changes and potential changes in vegetation. Coordinate with other relevant MQs.	LANDFIRE FRCC and subsequent spatial model outputs, in combination with Climate Change effects models; severely lmited by spatial resolution and uncertainty inherent with use of future climate projections.
Invasive Species						

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
47	What is the current distribution of invasive species included as CAs?	Ecoregion-wide	Existing data or distribution model	All invasive species CAs	Note: there is often a large time lag between real-time,current distributions and reported locations in databases; particularly for remote, seldom-visited water bodies	A very diverse selection of datasets are available, most of which are highly localized or state-level. Will likely require modeling for many species. Aquatics: USGS Nonindigenous Aquatic Species Program, supplemental datasets, supplemental datasets from Montana State University, USGS Ft Collins, Desert Research Institute
48	What areas are significantly ecologically affected by invasive species?	Ecoregion-wide	From other MQs	All invasive species CAs	Requires a working definition of “significantly ecologically affected.” Especially the word, “significantly,” which is usually reserved for statistical evaluation. Various definitions of “ecologically affected” are possible (e.g., loss of biodiversity, reduced number of native species of concern, dominance, alterations of ecological function, (e.g. trophic level impacts, primary and secondary production, trophic cascades, etc.), in some cases mere presence. AMT should discuss possible definitions. Although ecologists justifiably assume that invasive aquatic species have “ecological effects,” very few scientific studies or assessments have been made on the ecological effects (what ever definition we use) of invasive aquatic species in MBR; particularly in remote, isolated aquatic habitats.	Conservation element databases and the resulting models, invasive species locations and resulting models

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
49	Where are areas (significantly affected by invasives) that have restoration potential?	Areas identified as significantly affected by invasives.	Existing data or distribution model + intersect scenarios + condition model + restoration model	All invasive species CAs	Requires working definition of "restoration potential. There should be specific definitions for each invasive species under consideration. Also, areas and methods for restoration consideration should be selected based, in part, on whether restoration methods are evaluated as being less harmful than the presence of the invasive species. There are several real life examples where restoration attempts have caused more ecological damage than the invasive species	Data and model development will reveal areas where restoration is possible however guidence and further development of "restoration potential" is required to target and refine this MQ.
50	Given current patterns of occurrence and expansion, what is the potential future distribution of invasive species included as CAs?	Ecoregion-wide	Existing data + intersect scenarios + distribution model	All invasive species CAs	Based on climate changes and recent patterns of occurrence and expansion. Future distribution is primarily dependent on an invasive species' biological and environmental niche (including niches that become more favorable due to climate changes); dispersal ability (including human related dispersal i.e. mostly recreational activities); and present and future suitability of habitat (including available food resources, competition with natives, parasites, and predator interactions). Is this as far as we want or can take this? Can address this as relative degrees of susceptibility.	Data and model development will suggest where future distribution will take place.
51	Where are areas of nitrogen deposition?	Ecoregion-wide	Existing data		See MQ Section"Atmospheric Deposition" at the end of this appendix.	
Development						

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
52	Where are current locations of relevant development types?	Ecoregion-wide	Existing data	Development, Transportation and Energy Infrastructure		Spatially explicit datasets of different development types are available for most development CAs. Raster datasets of LU/LC may needed to fill in data gaps.
53	Where are areas of planned or potential development (outside of current urban areas) (e.g., under lease, plans of operation, governmental planning), including transmission corridors?	Ecoregion-wide	Existing data	Development, Transportation and Energy Infrastructure	Based on available planning documents.	Some planned development areas are thoroughly documented and available (proposed energy transmission corridors, planned pipelines, etc). Off-the-shelf models (SURGoM, ICLUS) can be customized for ecoregion.
54	Where are the areas of significant ecological change from these anthropogenic activities?	Ecoregion-wide	From other MQs	Development, Transportation and Energy Infrastructure	Based on areas thought to be the targets of development. Develop a working definition of "potential development" that incorporates proximity to existing urban areas, roads, or power lines. Develop a working definition of "significant ecological changed". TBD in Task 3.	Need to clarify several terms, this will likely be answered later in the process. Focus on identifying ecological areas most vulnerable to change and their relative contribution to overall system(s).
55	Where do locations of current CEs overlap with areas of potential change from anthropogenic activities?	All CEs	From other MQs	Development, Transportation and Energy Infrastructure	Coordinate with Species and other CE-related MQs. This MQ may obviate the MQ "Where are the areas of significant ecological change from these anthropogenic activities?"	Urban growth models can be intersected with CEs to identify locations where resource and development conflicts are likely to occur.
56	Where are ecological areas with significant recreational use?	Ecoregion-wide	Existing data intersect	Recreation (land-based, water-based)		See text on Theobald's Natural Landscape's model. Additional data is pending from the BLM on designated ORV use areas.
Oil, Gas, and Mining Development						
57	Where are the current locations of Oil, Gas, and Mining (including gypsum) development?	Ecoregion-wide	Existing data	Extractive energy development	Based on available data and planning documents.	BLM oil, gas and solid mining lease areas, USGS Mineral Resource Data System, additional data (yet to be identified) from federal and state authorities.
58	Where are areas under plans of operation?	Ecoregion-wide	Existing data	Extractive energy development	Based on available data and planning documents.	Current locations of oil and gas drilling are forethcoming from the NOC. Active mine and quarry areas will need to be obtained from state or federal authorities.
59	Where are areas under lease?	Ecoregion-wide	Existing data	Extractive energy development	Based on available data and planning documents.	BLM oil, gas and mining lease areas

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
60	Where are areas with mineral deposits, free use permits, or community pits?	Ecoregion-wide	Existing data	Extractive energy development	Based on available data and planning documents.	Solid mineral lease areas, free-use areas and community pit data may not be digital, spatially explicit or accumulated at a regional level.
61	Where are the areas of potential future locations of Oil, Gas, and Mining (including gypsum) development (locatable, salable, and fluid and solid leasable minerals?	Ecoregion-wide	Existing data	Extractive energy development	Based on available planning documents and known distributions of resources.	EPCA3, mineral lease areas, MBR has a very diverse range of mineral deposits, may be difficult to identify these areas, will request all locations of all established mining and quarrying claims locations
62	Where are the areas of low non-renewable energy development that could potentially mitigate impacts to CEs from potential energy development?	Among current and potential development sites.	Existing data + energy suitability model	Non-renewable energy development	Requires a working definition of suitable mitigation. Should be developed during Task 3, and specific to CEs and locations.	Not identified yet; will be able to address this as data is modeled and analyzed
63	Where do locations of current CEs overlap with areas of potential future locations of non-renewable energy development (MQ 61)?	All CEs, relevant other resources (including water resources)	Existing data + energy suitability model	Extractive energy development	Coordinate with Species and other CE-related MQs. Specifically relates to MQ 61	all relevant CE locational data, relevant energy development maps
Renewable Energy Development						
64	Where are the current locations of renewable energy development (solar, wind, geothermal, transmission)?	Ecoregion-wide	Existing data	Renewable energy development	Based on available data and planning documents. NOTE: The phrase "and any upcoming renewable energies" has been removed from the MQ; this is inappropriate for us to speculate on.	Solar Energy Study Areas, apart from geothermal facilities, existing solar and wind sites have not been identified yet but should be easy to obtain
65	Where are the areas identified by NREL as potential and physically possible locations for renewable energy development?	Ecoregion-wide	Existing data	Renewable energy development	Based on planning documents. Also potentially requires definitions of minimum physical conditions for certain development types (e.g., wind maps, etc). Coordinate with Groundwater Extraction MQs.	NREL solar and wind potential areas, Great Basin Geothermal potential and exploration data

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
66	Where are the areas of low renewable and non-renewable energy development that could potentially mitigate impacts to CEs from potential energy development?	Among current and potential development sites.	Existing data + energy suitability model	Renewable energy development	Requires a working definition of suitable mitigation. Should be developed during Task 3, and specific to CEs and locations.	Not identified yet; will be able to address this as data is modeled and analyzed
67	Where do locations of current CEs overlap with areas of potential future locations of renewable energy development (MQ 65)?	All CEs, relevant other resources (including water)	Exisitng data + energy suitability model	Renewable energy development	Coordinate with Species and other CE-related MQs. Specifically relates to MQ 65	all relevant CE locational data, relevant energy development maps
Groundwater Extraction and Transportation						
68	Where are aquifers and their recharge zones?	Ecoregion-wide	Existing data		Coordinate with Surface and Subsurface Water Availability MQs	USGS SWPA, Flint & Flint 2007 and nhd_recharge data; backup datasets include USGS Great Basin 1:1,000,000 aquifer study and USGS-Nevada joint aquifer study (2006)
69	Where will change agents be more powerful if groundwater is extracted?	Ecoregion-wide	Existing data + interesect scenarios + condition model	All CAs		(see discussion of CAs)
70	Where are areas with groundwater resources available to sustain renewable energy projects that would not degrade aquatic ecosystems that also depend on these groundwater resources. PROPOSED: "Where are the principal aquifers that potentially support perennial water levels or flows in aquatic ecosystem CE occurrences?"	Ecoregion-wide	Existing data + intersect scenarios + condition model	Hydrologic Alteration, Renewable Energy Development	Coordinate with Renewable Energy MQs. Will not be able to directly answer this and needs to be reframed. Some spotty data exists but only for Sonoran. We have revised the original version of this MQ for consistency with the kinds of data available. Proposed revision to the MQ is as follows: ""Where are the principal aquifers that potentially support perennial water levels or flows in aquatic ecosystem CE occurrences?"	The original version of this MQ was too fine-detailed a question to be answered with an REA, because the groundwater zones contributing to any individual surface aquatic feature may be quite localized or identifiable only via detailed hydrogeologic field investigations. We will pursue a coarser, surrogate approach in which we overlay aquatic CE locations with aquifer locations (from USGS SWPA), filtered for aquatic CE occurrences with perennial water (from NHDPlus, including via nhd_bfi) to identify principal aquifers that potentially support perennial water levels/flows in these CE occurrences.

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
71	Where are the areas showing effects from existing groundwater extraction?	Ecoregion-wide	Existing data	Hydrologic Alteration	Requires a working definition of "effects".	NWIS for water level declines, but more importantly USGS SWPA, and state water atlas publications for water level dclines and ground collapses
72	Where are artificial water bodies including evaporation ponds, etc.?	Ecoregion-wide	Existing data		Note: Coordinate with an MQ in Surface Water.	Not sure how we would distinguish "artificial" except as impoundments behind dams (US Army Corps NID)
73	Where are the areas with groundwater basins in an overdraft condition?	Ecoregion-wide	Existing data	Hydrologic Alteration	This is not a question about areas where existing groundwater extraction is having ecological effects (already addressed elsewhere) but a question of where groundwater extraction exceeds the long-term potential for recharge.	This is essentially the same question as the one about "areas showing effects from existing groundwater extraction" with the same answer as above.
Surface Water Consumption and Diversion				Existing data		
74	Where are the areas of potential future change in surface water consumption and diversion?	Ecoregion-wide	Existing data + intersect scenarios	Hydrologic alteration, Climate change, Development	This should show up in any analysis of where “development” growth is most likely; and in the mapping of where water-intensive energy development is most likely.	This will be an output of the analysis of development/urbanization CA

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
75	Where are the areas with surface water resources available to sustain solar power, and other forms of development without degrading aquatic ecosystems that also depend on these groundwater resources?	Ecoregion-wide	Existing data + intersect scenarios + condition model	Renewable energy development	Coordinate with Renewable Energy MQs. This is an extension of the mapping of where surface waters exist that support aquatic CEs, combined with the mapping of development potential and existing proposals for water resource development. Determining where surface water resources are "available" for development in any given localityrequires locality-specific, spatially and hydro-geologically detailed data on water rights and water resources, the acquisition and analysis of which lie outside the scope of this REA. However, since this is the arid west, it can safely be assumed that every surface water body in the ecoregion is fully appropriated for water rights under state and federal law. In fact, some may be over-appropriated, i.e., some junior rights can be exercised only during wet years when all more senior rights are fully served. For this reason, it can safely be assumed that no surface waters are available for such development without transfer or private lease from an existing rights holder. Proposed revision to the MQ is as follows: "Where are the areas with surface water resources available to sustain solar power, and other forms of development without degrading aquatic ecosystems that also depend on these surface water resources?"	We will assemble information on existing plans for surface water resource development, to identify localities where the planned areas of water diversion and use overlap with occurrences of aquatic CEs and their supporting surface water catchments and, if identifiable, the groundwater basins that support baseflows or base water elevations for these CE occurrences.

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
76	Where are the areas showing ecological effects from existing surface water exploitation?	Relevant CEs	Existing data	Hydrologic alteration, Development	Generate this information by coupling map information on density of surface water use (diversions as well as consumption) from state and USGS reports, with information on degree of degradation of aquatic ecological integrity.	We have to rely on comparisons of historic published records (rather than GIS data) on the distribution of perennial flows and perennial water levels in springs, to records of their distribution today; we have not identified GIS data layers for this purpose.
77	Where are artificial water bodies including evaporation ponds, etc.?	Ecoregion-wide	Existing data		Coordinate with an MQ in Surface Water.	We will see what we can get from NHD, but this may simply be too fine-detailed a question for a REA.
78	Where are the areas with existing surface water extraction that has caused natural aquatic communities to become entirely dry, either seasonally or perennially?	Relevant CEs	Existing data	Hydrologic alteration, Development	Generate this information by coupling map information on existence of formerly perennial streams with where they don't exists anymore, and overlay information on intensity of upstream and adjacent surface water extraction.	This is essentially the same question as the one about "areas showing effects from existing surface water exploitation" with the same answer as above.
Climate Change: Terrestrial Resource Issues						
79	Where will changes in climate be greatest relative to normal climate variability?	Ecoregion-wide	Existing data future climate model	Climate Change	Climate change will affect every location, but affect different locations in different ways. So the issue is not where any effects will occur, but where these effects will potentially cause significant ecological change affecting priority conservation elements. Exact climate models are TBD.	Current climate envelopes for CEs based on 4 km PRISM data and change measured through 15 km downscaled data. Climate Change effects models are severely lmited by spatial resolution and uncertainty inherent with use of future climate projections.
80	Given anticipated climate shifts and the direction shifts in distributions, where are areas of potential habitat fragmentation?	Ecoregion-wide	Existing data + intersect scenarios future climate model	Climate Change	Fragmentation may be difficult to assess. Consider species-specific responses/perceptions of fragmentation.	Current CA data, project CA data, and Projected CE distribution models. Confidence decreases rapidly with future projections as bth sptail resolution gets coarser and confidence in predicted patterns decreases approaching 2060. Climate Change effects models are severely lmited by spatial resolution and uncertainty inherent with use of future climate projections.

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
81	Which native plant communities will experience climate completely outside their normal range?	CEs that are plant communities.	Existing data + intersect scenarios future climate model	Climate Change	Climate envelope studies are complicated by the likelihood that assemblages will not move intact, but shift and reform based on the movements of individual species. This MQ needs further refinement during Task 3 and the analysis. Coordinate with MQ in "Native Plant Communities".	Current climate envelopes for CEs based on 4 km PRISM data and change measured through 15 km downscaled data. Climate Change effects models are severely lmited by spatial resolution and uncertainty inherent with use of future climate projections.
82	Where will wildlife habitat experience climate completely outside its normal range?	Select relevant wildlife species	Existing data or distribution model + intersect scenarios future climate model	Climate Change	Requires a working definition of "wildlife habitat". Coordinate with the "plant communities and climate change MQ".	Current climate envelopes for CEs based on 4 km PRISM data and change measured through 15 km downscaled data. Climate Change effects models are severely lmited by spatial resolution and uncertainty inherent with use of future climate projections.
83	Where are wildlife species ranges (on the element list) that will experience significant and abrupt deviations from normal climate variation?	Select relevant wildlife species	Existing data or distribution model + intersect scenarios future climate model	Climate Change	Consider further reframe as standard climate envelope analysis.	Current climate envelopes for CEs based on 4 km PRISM data and change measured through 15 km downscaled data. Climate Change effects models are severely lmited by spatial resolution and uncertainty inherent with use of future climate projections.
84	Based on recent distributions and expansion patterns of insect pests and disease, what are expected distributions in the future?	Select relevant pest species		Climate Change, Invasive species	This is a research questions that possibly requires speculation beyond the scope of the REA. This MQ remains provisional, and be dropped and listed as a gap in research.	Current climate envelopes for CAs based on 4 km PRISM data and change measured through 15 km downscaled data. Climate Change effects models are severely lmited by spatial resolution and uncertainty inherent with use of future climate projections.
Climate Change: Aquatic Resource Issues						

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
85	Where are aquatic resources that will experience significant and abrupt deviations from normal climate variation?	Ecoregion-wide	Existing data + intersect scenarios future climate model	Climate Change, Hydrologic alteration	Climate change will affect every location, but affect different locations in different ways. So the issue is not where any effects will occur, but where these effects will potentially cause significant ecological change affecting priority conservation elements.	It is not clear if this MQ refers to aquatic CE occurrences or "resources" for human use, or both. Going by our "Notes" from Memo 1C, we propose using the Flint & Flint climate-impact data associated with the model they developed for their 2007 USGS publication (USGS Flint & Flint Climate Impact data requested) to assess where and to what extent major changes are forecast for monthly runoff, recharge, and snowmelt patterns. As a backup, we can use NHDPlus attributes from the USGS (nhd_bfi; nhd_ieof; nhd_recharge; nhd_ppt30yr; nhd_tmax30yr; nhd_tmin30yr) to develop a rough empirical, annual model of how runoff and recharge hydrology (the first three of these NHDPlus attribute sets) might vary in relation to climate (the last three of these NHDPlus attribute sets). This empirical model would allow us to plug in forecast future climate estimates for the latter three, to produce rough estimates of future conditions for the former three, if we found strong empirical relationships are present. In either case, we won't be able to identify "abrupt" deviations unless we work with large numbers of time steps. Since the Flint & Flint data will allow us to assess whatever time increments we need, we can decide with the BLM what increments might be most useful.
86	Where are aquatic resources that will experience significant and abrupt deviations from normal flow regime or mean water levels?	Ecoregion-wide	Existing data or distribution model + intersect scenarios future climate model	Climate Change, Hydrologic alteration	There will potentially include effects on water levels in wetlands and groundwater-driven systems, and changes in riparian inundation patterns. Plus the changes won't be in simple magnitude but may also be in the timing, duration, and frequency of different hydrologic conditions.	Same as above, but linked to identification of which aquifers support baseflow/base water levels in which water bodies (see above). Note, however, that aquifer recharge/discharge is a process taking decades to centuries (or millennia) to unfold, and so the effects of climate change on aquifer discharge rates will take a long time to become evident.
87	Where will aquatic resources experience significant and abrupt deviations from normal temperature regime?	Ecoregion-wide	Existing data + intersect scenarios	Climate Change, Hydrologic alteration	Both "flow" and "hydrologic change will occur. Includes not just "temperature change" but change in the temperature regime.	Same as above vis Flint & Flint projections

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
88	Where are aquatic resources that will experience additional effects on physical habitat such as channel morphology due to significant and abrupt deviations in climate and hydrologic regimes?	Ecoregion-wide	Existing data + intersect scenarios	Climate Change, Hydrologic alteration		This is a secondary effect of changes in runoff and recharge, per above
Military Constrained Areas						
89	Where are military constrained areas?	Ecoregion-wide	Existing data	Military use areas, conflict of use areas, areas of moratoria, potential military expansion, DOE contracted areas, installation boundaries	Military flight areas will show areas of potential conflict with other development types (wind). Surface disturbance can be shown with LU/LC classifications. What does contrained mean? Includes any development on BLM lands constrained by military low-flying areas. No. This may be addressed by military document which identifies suitability for tall structure development.	Military expansion areas for Twentynine Palms and Fort Irwin have been identified; military training and low flight path areas have been identified but not obtained by the team. DOD will be providing additional data early in 2011.
90	Where might these areas change in the future?	Ecoregion-wide	Existing data	Military use areas, conflict of use areas, areas of moratoria, potential military expansion, DOE contracted areas, installation boundaries	Coordinate with various other MQs on climate change and water resources. Consult INRMP of the relevant installations to determine available data and potential presence of CEs and CAs.	Difficult to predict as the armed forces have no official plans to change or expand land use beyond existing plans at Twentynine Palms and Fort Irwin.
91	Where are areas of possible expansion of military use?	Ecoregion-wide	Existing data	Potential military expansion	Based on BRAC or other planning documents.	As in 86.
Atmospheric Deposition						

Number	Management Question	Relevant CEs or other unit		Relevant Change Agents	Memo 1C Notes	Data Sources & Recommendations
92	Where are areas affected by atmospheric deposition of pollutants (nutrient deposition, acid deposition, mercury deposition)?	Ecoregion-wide	Existing data	Air and Water Quality: Fugitive dust, air pollution, atmospheric deposition	Atmospheric deposition affects ecosystems via both nutrient enrichment and via acid deposition; and affects some individual species through these effects and through mercury deposition. This is a known problem in the higher elevations of the western US.	We will use NADP data on Nitrogen as a stand-in for all air pollutants that involve acid deposition AND result in nutrient enrichment once buffered. We will use NHDPlus nhd_no3 and USGS-Nitrogen Groundwater Risk (gwrisk) data sets as cross-checks on the NADP regional estimates. We will use NADP data on Mercury as a stand-in for all air pollutants that can bio-accumulate and cause physiological or developmental harm.

Appendix IV. Aquatic Invasive Species Impact Index

Development of an Aquatic Invasive Species Impact Index

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<u>Prepared for:</u>

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Introduction

Water quality biotic indices have undergone considerable development and refinement since the establishment of the Clean Water Act (1972) and its mandate to maintain and improve the biological integrity of our nation's waters. Most of these indices (e.g. state and federal **I**ndices of **B**iological **I**ntegrity) have been developed using fish, macroinvertebrates, and periphyton data separately. These indices use very large databases gathered over many years with total funding for development in the tens of millions of dollars (USEPA 2011).

Most water quality bioassessment indicators focus on ecological concepts such as organism diversity, abundance, community composition, functional feeding group composition, biotic tolerance indices, etc. and their responses to water quality impairment. However, most water quality, non-fish related, bioassessments fail to include invasive species indicators. None of these bioassessments that we are aware of combine indicators from multiple taxonomic groups such as algae, invertebrates, fish, and amphibians.

Development of aquatic invasive species impact indices by state and federal agencies is sorely lacking even though impacts from invasive species are considered to be of equal importance with habitat loss and global climate change as the primary causal factors responsible for the world's rapidly decreasing biodiversity and altered ecosystem functioning (Sala et al. 2000; Lockwood & McKinney 2001; Lodge 2001; Mack *et al.* 2001; McKinney, M. L. and J. L. Lockwood. 1999) and even though ample funding is available. This lack of development of invasive species impact indices is particularly true for aquatic invasive macroinvertebrates and for aquatic ecosystems in the desert southwest. Major reasons for the lag in development of aquatic invasive species impact indices are:

1) Insufficient information of known threshold affects of aquatic invasive species on native biota and ecosystem integrity,

2) Densities of invasive species needed to cause ecological impacts

3) Limited knowledge of invasive species ecology and life histories

4) Rapidly increasing number of new introductions of aquatic invasive species

5) Reluctance of aquatic managers to fully equate invasive species impacts with loss of habitat and global climate change and the

6) Focus on wadeable streams and lakes.

Given the acknowledged negative ecological impacts of aquatic invasive species and the scarcity of aquatic invasive species bioassessments, we are creating an index of aquatic invasive species impact. We will summarize the index for each Conservation Element (CE) within a HUC and for each HUC.

CE (coarse-filter Conservation Elements) and CA (Change Agents)

Most of the reported locations of invasive species in our databases included latitude and longitude coordinates and verbal descriptions of the water body infected (e.g. Anderson Springs). This will allow us to model which CE type is infected in a HUC. However, some of the reported invasive species locations were not at a high enough resolution to determine the exact type of water body (CE) that the species occurred in (i.e. data were reported at the HUC8 level or verbal description was vague, e.g. Muddy River drainage). We suggest that there are enough ecological data available on each invasive species' (CAs) habitat requirements and preferences to reasonably narrow the possible water body types (CEs) where they occurred and for us to predict which CEs they will likely impact or invade (see Table 4). We will default to the invasive species habitat requirements (Table 4) whenever we encounter these discrepancies.

We will develop aquatic invasive species indices for each CE individually (see Tables 1 and 2) within each HUC because the types of water bodies (CE) in our ecoregions vary in their susceptibility and impacts from invasion. Others in our group are categorizing indicators for CEs and other CAs. Where feasible we will cross reference and mesh our data.

Aquatic Invasive Species and Fine Filter CEs

The Fine Filter aquatic CEs in our ecoregions include; endemic, rare, threatened, and endangered vertebrate and invertebrate species. Invasive species can negatively affect these species. We suggest that if any of the Coarse Filter CEs are affected by aquatic invasive species, so too are the Fine Filter CEs. Thus, the Course Filter CE models (indicators) will also encompass the Fine Filter CEs.

Underrepresentation of aquatic invasive species impacts in the index

This aquatic invasive species impact index most certainly underestimates the full impacts that occur within the CEs and HUCs. There are two major reasons for this underestimate of impacts: 1) delayed and non- reporting and 2) invasive species not considered in the models.

1) There are often large lag times between a) when a private citizen, researcher, or manager observes an aquatic invasive species, b) when it is reported to the appropriate agency, and c) when it is verified and entered into a useable database. There are also large differences in observational and survey effort between water- body types. Invasive species are more likely to be reported and monitored in easily accessible or popular fisheries than in other locations. Thus, our databases cannot represent the full impacts.

2) Many invasive species, mostly game fish, which occur in our ecoregions have been granted clemency by management agencies due to recreational and economic concerns. The ecological impacts of these species are well known and often very large. CEs and HUCs that we rate as Sustainable or Transitioning could very well be considered Degraded due to the presence of these invasive species.

Proposed Aquatic Invasive Species Impact Index

Our proposed aquatic invasive species[3] impact index includes indicators that focus on the more important ecological and landscape factors identified in invasive species life history, ecological, and invasion theory (Barney and Whiltlow 2008; McKinney and Lockwood 1999; Parker et al. 1999; Pimm 1989; Shigesada and Kawasaki 1997; and Williamson 1996). Indicators in this model are separated into two major categories: 1) Within HUC and 2) Surrounding HUCs.

Within HUC indicators

The within HUC indicators address factors that influence impact once an invasive species is present in a HUC. The indicators are broken down into several categories: number of invasives, number of reference CEs infected, infection levels, relative taxa impact, connectivity, use, and time.

Number of invasives and Percent CEs infected

The three most important indicators in the entire suite of indicators are: 1) the number of invasive taxa present in a CE within a HUC, the number of invasive taxa present in different CEs that are likely to invade CE and, 2) number of CEs infected/mean HUC size This is simply because the greater the number of invasive taxa there are in a CE or similar CEs and the greater the number of CEs relative to mean HUC size; the greater the loss of ecological integrity. Obviously, if no invasive taxa are in a CE within a HUC there is no invasive impact to that CE, although there is always potential.

Infection levels and Relative taxa impact

[3]We use the terms species, taxa, and taxon throughout this narrative. When referring to species we are essentially referring to taxa unless it is for a specific species. Taxa is the plural form of taxon and refers to taxonomic categories. For example, we combined all species of mollies and guppies into one taxon and all species of crayfish into one taxon, crayfish.

In addition, the level of infection (density of the invasive taxon) in a CE and HUC is very important to the ecological integrity of that CE and HUC. Higher densities are strongly correlated with dispersal rates and impact severity. Higher densities increase potential propagules (Veltman et al. 1996; Lockwood et al. 2005; Colautti et al.2007) and are nearly always incorporated into data rich invasive models (Shigesada and Kawasaki 1997).

“All animals are equal, but some animals are more equal than others."(Orwell 1951). Some invasive taxa are considered to be more harmful than others, what we describe as “the relative invasive taxa impact.” In addition to agreeing on the definition of harmful (which in itself is extremely problematic), relative impact (harm) is dependent on an invasive taxon’s density or more significantly, its biomass. Pound- for- pound, gram- for- gram, each invasive taxon has its unique impact on an ecosystem.

Unfortunately only one of our databases reported densities and that was for only one of the invasive taxa. None of our databases reported biomass. Without estimates of densities or biomass we will be unable to model these two important factors that determine an invasive taxon’s impacts to ecological integrity.

Connectivity and Use

The connectivity of CEs is important to aquatic invasives. The more connected a water body type is the more an invasive is likely to spread throughout it or into it from other infected areas. In general, springs are less connected than streams or rivers. Invasives also tend to disperse more readily downstream than upstream.

The amount of human use a CE and HUC receives is strongly related to its invasiveness. The more recreational use, road density, and human encroachment, the more likely a CE is to be impacted by invasives.

Time

Time is inherent in any ecological model. Time since first invasion in a CE and HUC can affect the level of impact. The longer a taxon has been in a CE in a HUC the more time it has had to elicit a negative impact and to reduce ecological integrity. In general, very recent arrivals have not had time to cause impacts but given enough time they may.

Surrounding HUC indicators

Since no HUC is an island and invasion potential is strongly related to conditions in other areas, we have included indicators from surrounding HUCs. For example, invasion potential is directly correlated with distance from nearest invaded location. This is one of the most important factors in invasion biology (Shigesada and Kawasaki 1997).

However, invasion potential is also a function of human use and activity in nearby areas. The popularity of a CE for recreational use can supersede distance for many invasive taxa. Popular recreational areas attract users from long distances who may inadvertently (or intentionally) harbor aquatic invasives.

Invasion potential into a HUC from surrounding HUCs is also strongly related to: 1) number of invasive taxa, 2) infection levels, and 3) life history and ecologies of invasive taxa in the surrounding HUCs (Lockwood et al. 2005; Colautti et al.2007; Shigesada and Kawasaki 1997). Greater numbers of invasive taxa in nearby HUCs, that are not already present in a HUC (i.e. novel taxa), increases the chance of at least one or more of these novel taxa making it into an uninfected HUC. The level (densities) of invasive taxa in nearby HUCs is also obviously important; the more individuals there are the greater the likelihood of transport into uninfected HUCs. Unfortunately, only one of our databases includes density estimates for only one of the invasive taxa, the New Zealand mudsnail (NZMS). Therefore, we will not be able to incorporate this important indicator into our index.

Invasion potential is also related to the amount of time an invasive taxon has resided in nearby HUCs. HUCs that have been invaded by a taxon for long periods of time are less likely to spread to non-invaded nearby HUCs. This is because if an invasive taxon has occurred in an area for long periods of time (many decades or generations) and has not already spread to nearby areas; its likelihood of spread is diminished. Likewise, taxa that recently arrived in an area have a greater probability of spreading to uninfected HUCs.

There are other postulated and known avenues of spread of invasives. These include dispersal by: waterfowl, biologists, irrigational use, city water supply, fire fighting water use, or other types of diversions (Aquatic Nuisance Species Task Force 2011). Invasive spread for these uses are difficult to evaluate but are assumed to be less critical than the uses that we are proposing in our index. At this time, we elected not to explicitly incorporate other avenues of spread other than what we have listed in Tables 1 and 2.

Indicator selection and scoring

The indicators we are considering are highly tentative at this time particularly indicator score values. It should be noted that almost all indicator scores in any rapid assessment are subjective. Indicator scores require thought and consideration before selection and need to be carefully scrutinized and validated after their selection. We are in the beginning stages of this evaluation and have not fully determined scoring value criteria for any of the proposed invasive species indicators.

As such, each indicator score is only divided into three categories (values): Sustainable (= 3), Transitioning (= 2), or Degraded (= 1). Although it is generally recognized that some indicators are more influential for invasive impact levels than others, it can often differ between taxa. We are presently evaluating and considering assigning weighting factors for each of the indicators and/or groupings of indicators.

Table 1. Aquatic invasive species impact index: within HUC indicators.
Level, indicator category, indicators, justification, data source, and proposed evaluation and scoring criteria for each CE within a HUC. Scoring: 3 = Sustainable, 2 = Transitioning, and 1 = Degraded. At this time scores are subjectively based on ecological literature and professional judgment. These scores most likely will be revised, pending further analysis. This index does not take into consideration future invasions by as yet unknown species. We also assume that biologists and managers have become more aware of the impacts of invasive species in the last decade and that invasives are more often than not reported and therefore, our databases are somewhat representative of invasive species status.

Within HUC					
Level	Indicator category	Indicator	Justification	Data Source	Evaluation and score
Biotic	**Number of invasives**	1a. Number of invasive taxa present in CE	The greater the number of invasive taxa there are in a CE, the greater the impairment	USGS NAS, USGS didymo database, Natural Heritage Programs	0 taxa = 3 1 taxon = 2 > 1 taxon = 1
		1b. Number of invasive taxa not in CE but likely to invade from other infected CEs in HUC	Most of the invasive taxa in our list can infect more than one CE type depending on their habitat requirements[1].	USGS NAS, USGS didymo database, Natural Heritage Programs, Table 3	0 taxa = 0 1 taxon = 0.5 > 1 taxon = 1.0
		2. Number of probable invasives in CE	See indicators 1a and 1b	See indicators 1a and 1b	Subtract indicator 1b from 1a
	Number of CEs infected/mean HUC size[2]	3. Number of CE's infected relative to mean HUC size (not used for springs)	The greater the number of CEs infected, the greater the impairment	USGS NAS, USGS didymo database, Natural Heritage Programs	Number of CEs infected/mean HUC area 0 to 10% = 3 11 to 30% = 2 > 30% = 1
	Trophic levels	4a. Number of trophic levels	Shared trophic levels between natives and invasives equates to decreased integrity (e.g. interspecific competition), multiple trophic levels by several invasive	Ecological literature	None = 3 1 trophic level = 2 >1 trophic level = 1

			species also equates to decreased integrity (e.g. predation + primary production)		
		4b. Number of novel trophic levels of invasive taxa present in different CE that are likely to invade CE	See above justification	Ecological literature	0 taxa = 0 1 taxon = 0.5 > 1 taxon = 1.0
		5. Number of probable infected trophic levels in CE	See indicators 4a and 4b	See indicators 4a and 4b	Subtract indicator 4b from 4a
Abiotic	**Connectivity**	6. Flow network connectivity	Connected water bodies are more likely to become infected by obligate aquatic invasive taxa.	Inverse of Riparian Corridor Continuity Measurement	Inverse of Riparian Corridor Continuity Measurement
		7. Upstream or downstream from infected site	Most invasive taxa are better able to disperse downstream (drift) than upstream	Data not available	NA
Landscape context	**Use**	8. Recreational use	Increased recreation strongly correlates with increased infection rates to other CEs	State designated recreational and fishing access sites	None = 3 Limited = 2 > Limited = 1
		9. Road density	Number of potential propagules is related to amount of roads	GIS	Will combine with indicator 10.
		10. Urbanization	The greater the urbanization within a HUC, the greater the	The same urbanization models that terrestrial groups are using	Will combine with indicator 9.

			rate of spread[3]		
Time	**Time since invasion**	11. Time since first invasion	The longer an invasive taxa has been in a CE, the more impact it has had [4]	USGS NAS, USGS didymo database, Natural Heritage Programs	Absent or newly arrived (≤ 5 yrs) = 3 Moderate history (> 5 ≤ 20 yrs) = 2 Long history (> 20 yrs) = 1

[1]See Table 3 for list of potential CEs an invasive taxon may infect. Also, if they are know to occur in ecologically similar habitats to the CE within the HUC, they may already be present in the CE but not reported

[2]We are searching for data or publications that will help model the relationship between number of CEs infected relative to HUC mean area size and impacts to ecological integrity

[3]Scoring criteria and values based Harju 2007 for one invasive species, New Zealand mudsnail.

[4]Elton (1958) suggested that often the full ecological impacts of an invasive species are not realized until 50 to 100 years after introduction.

Table 2. Aquatic invasive species impact index: surrounding HUC indicators.
Level, indicator category, indicators, justification, data source, and proposed evaluation and scoring criteria for each CE within a HUC. Scoring: 3 = Sustainable, 2 = transitioning, and 1 = degraded. At this time scores are subjectively based on ecological literature and professional judgment. These scores most likely will be revised, pending further analysis.

Surrounding HUC					
Level	**Indicator category**	**Indicator**	**Justification**	**Data Source**	**Evaluation and score**
Landscape context	**Number of invasives**	12. Number of novel[1] invasive taxa present at the HUC 8 level	More invasives nearby equals greater potential impact	USGS NAS, USGS didymo database, Natural Heritage Programs	HUC 8 level: 0 = 3 1 = 2 > 1 = 1
	Invasiveness ecology and life history of nearest invasive(s)	13. Dispersal ecology and ability of novel invasive taxa at the HUC 8 level	Dispersal ecology and dispersal ability are correlated to infection rates	Ecological literature	Dispersal ability: Absent/Low = 3 Moderate = 2 High = 1
		14. Trophic level impacts of novel invasive taxa at the HUC 8 level	Shared trophic levels between natives and invasives equates to decreased integrity (e.g. interspecific competition), multiple trophic levels by several invasive species also equates to decreased integrity (e.g. predation + primary production)	Ecological literature	Trophic levels not already present in HUC 0 = 3 1 = 2 >1 = 1
		15. Life history of novel invasive taxa at the HUC 8 level	Species with higher fecundity, higher survival rates, wide environmental niches, etc. are more likely to degrade CEs	Ecological literature	Invasive Type of Life History: Absent/Weak = 3 Moderate = 2 Strong = 1
	Proximity to infection	16. Least number of HUCs to nearest	Nearby infected	Not feasible	NA

	and connectivity	infected HUC with novel taxa [3]	HUCs are more likely to spread to uninfected HUC (e.g. propagule pressure). Invasive species spread by many methods.		
		17. Proportion of adjacent HUCs infected with novel taxa in CE[3]	Increased number of surrounding HUCs infected equates to increased impairment potential and continued reinfestation (e.g. propagule pressure)	Not feasible to evaluate for all HUCs in ecoregion	NA
		18. Flow network connectivity[3]	Connected water bodies are more likely to become infected by obligate aquatic invasive species.	NA	NA
		19. Upstream/downstream from infected site[3]	Most invasive species are better able to disperse downstream (drift) than upstream	NA	NA
	Use	20. Recreational use[3]	Increased recreation strongly correlates with increased infection rates	State designated recreational/fishing access sites in CE/HUC	None = 3 Limited = 2 > Limited = 1
		21. Road accessibility[3]	Greater road access equates to increased likelihood of infection.	NA	NA

		22. Distance to nearest city > 25,000 population[3]	The greater the urbanization within a HUC, the greater the rate of spread[2]	GIS measure from perimeter of HUC	>125 km = 3 26-125 km = 3-(125-km)*0.02 0-25 km = 1
		23. Distance to nearest city > 100,000 population[3]	The greater the urbanization within a HUC, the greater the rate of spread[2]	GIS measured from perimeter of HUC	>500 km = 3 51 – 500 km = 3-(500-km)*0.0044 0-50 km = 1
Time	**Time since invasion of nearest invasive**	24. Time since first invasion and rate of spread of novel invasive taxa[4]	Some species spread rapidly, others spread slowly or their rate of spread has declined. Often a time lag between introduction and ecological impact.	USGS NAS, USGS didymo database, Natural Heritage Programs	Long history (> 20 yrs) = 3 moderate (< 20 > 5 yrs) = 2 Newly arrived (< 5 yrs) = 1

[1] Novel invasive taxa are not reported in the CE being evaluated within a HUC but occur in adjacent HUCs.

[2]Evaluation and Scoring criteria is based on Harju 2007 models of New Zealand mudsnail invasive probabilities.

[3]These indicators will not be used because of the difficulty and complexity of explicitly incorporating into the model for each CE and every HUC within the ecoregion. They are implicitly incorporated in the Within HUC indicators (Table 1).

[4]Rate of spread typically starts out slowly when the species is first introduced, then increases exponentially once more locations are invaded where there are more potential propagules and then the rate of spread gradually decreases once easily invaded habitats are occupied, and then stops when available habitats diminish. Ex. Asian clam was first introduced in U.S. at least 70 years ago. Once it became established it rapidly spread. Now its rate of spread has decreased because most available habitats are already infected. This suggests that if a CE in a HUC is not infected with Asian clams, it is less likely to become infected.

Proposed Scoring

The following is the general, preliminary scoring method:

1) Combine and average the scores of the indicators and indicator categories in the Within HUC indicators using the following method:

[(Indicator 2 + Indicator 3 + Indicator 5)/3 + (Indicator 6 + Indicator 7)/2 + (Indicator 8 + Indicator 9 + Indicator 10)/3 + Indicator 11]/4

If the overall score of a CE in the Within HUC indicators is rated as Degraded, then its final score is Degraded and no further analysis is required.

2) If the overall score of a CE in the Within HUC indicators is rated as Transitional, then it becomes a function of its score in the Within HUC indicators combined with the scores from Surrounding HUC indicators. The final score can remain unchanged at Transitional or be rated as Degraded for its final score.

3) If the overall score of a CE in the Within HUC indicators is rated as Sustainable, then it becomes a function of its score in the Within HUC indicators combined with the scores from Surrounding HUC indicators. The final score can remain unchanged at Sustainable or it can be rated Transitional for its final score.

4) The Surrounding HUC final score is calculated as follows:

[(Indicator 12) + (Indicator 13 + Indicator 14 + Indicator 15)/3 + (Indicator 24)]/3

(Note: Indicators 16-23 are implicitly included in the Within HUC indicator scores)

5) The Final Score is the average of the Within HUC Final Score and the Surrounding HUC Final Score

6) Suggested Final Score Ranges are: 2.50 to 3.00 = Sustainable; 1.50 to 2.49 = Transitioning; and 1.00 to 1.49 = Degraded. We are currently comparing and evaluating weighting factors for each of the individual indicators and grouping of indicators. See flow chart (Figure 1) on next page.

Figure 1. Flow chart of aquatic invasive species impact index scores.

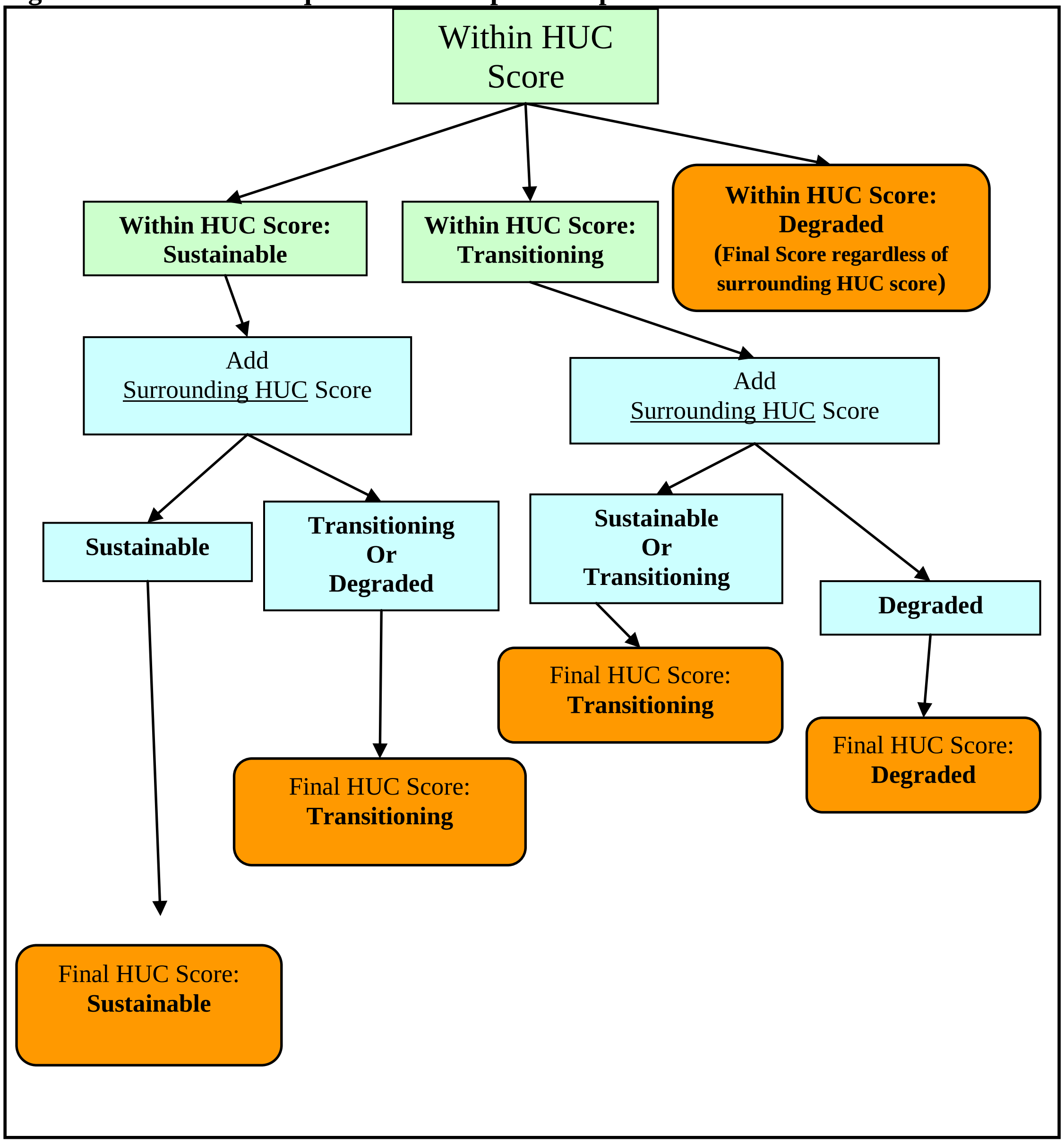

Table 3. List of Coarse Filter Aquatic CE for MBR and CBR ecoregions and CE numbers used in Table 4.

Coarse Filter Aquatic CEs for CBR

1. Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland/Stream
2. Rocky Mountain Subalpine-Montane Riparian Woodland/Stream
3. Rocky Mountain Alpine-Montane Wet Meadow and Pond
4. Rocky Mountain Subalpine-Montane Riparian Shrubland/Stream
5. Great Basin Lake/Reservoir
6. North American Arid West Emergent Marsh and Pond
7. Great Basin Springs and Seeps

Coarse Filter Aquatic CEs for MBR

8. North American Warm Desert Lower Montane Riparian Woodland and Shrubland/Stream
9. North American Warm Desert Playa
10. North American Warm Desert Wash
11. Mojave Desert Lake/Reservoir
12. North American Warm Desert Riparian Woodland and Shrubland/Stream
13. North American Warm Desert Riparian Mesquite Bosque
14. North American Arid West Emergent Marsh and Pond
15. Mojave Desert Springs and Seeps
16. Sonoran Fan Palm Oasis/Stream

The following tables (Table 4, 5, and 6) are the trophic levels, potential aquatic CEs, life history characteristics and ratings, and dispersal ecologies and ratings of the invasive species modeled in our index. The CEs are the known or presumed habitat preferences of each species. A species is not expected to become established in habitats that are not conducive to its survival or reproduction. The CE invasive potential column (Table 4) contains default values for when there is not enough information in a database to determine which specific CE within a HUC an invasive species was found.

Table 4. Trophic level or functional feeding group and CE invasive potential.
CE invasive potential is the types of CEs that an invasive taxon is likely to infect.

Taxon	Trophic level/Functional Feeding group	CE invasive potential
Diatoms		
Didymo, rock snot *Didymosphenia gemenata*	Primary producer	1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 15, 16
Macrophytes		
Curlyleaf pondweed	Primary producer	3, 5, 6, 7, 8, 11, 14, 15, 16
Eurasian watermilfoil	Primary producer	3, 5, 6, 7, 8, 11, 14, 15, 16
Gastropods (snails)		
Applesnails *Pomacea* sp.	Grazer/scraper	3, 5, 6, 7, 11, 14, 15, 16
European ear snail *Radix auricularia*	Grazer/scraper	3, 5, 6, 7, 11, 14, 15, 16
Red-rim melania *Melanoides tuberculatus*	Grazer/scraper	3, 5, 6, 7, 11, 14, 15, 16
New Zealand mudsnail *Potamopyrgus antipodarum*	Grazer/scraper	1, 2, 3, 4, 5, 7, 8, 11, 12, 15, 16
Chinese mystery snail *Cipangopaludina chinensis malleata*	Grazer/scraper	3, 5, 6, 7, 11, 14, 15, 16
Bivalves (clams/mussels)		
Asian clam *Corbicula fluminea*	Filterer	5, 11
Zebra and Quagga mussels *Dreissena* sp.	Filterer	1, 2, 3(?), 4(?), 5, 6(?), 7(?), 8, 11, 12, 15(?), 16(?)[a]
Amphibians		
African clawed frog *Xenopus laevis*	Adult = Predator Larvae = filterer/grazer	1,2, 3,4, 5, 6, 7, 8, 10 (?), 11, 12, 14, 15, 16
American bullfrog *Lithobates* (=*Ranus*) *catesbeianus*	Adult = predator Larvae = grazer	1, 2 ,3, 4 , 5, 6, 7, 8, 11, 12, 14, 15, 16
Fish		
Mollies and guppies *Poecilia* sp.	Predators	1, 5, 6, 7, 8, 11, 12, 14, 15, 16
Tilapia *Oreochromis* sp	Omnivore; plankton/macrophytes	1, 5, 6, 7, 8, 11, 12, 14, 15, 16
Asian/European carp Family Cyprinidae	Grazer/Predator/Molluscivore/Omnivore	1, 5, 6, , 8, 11, 12, 14

[a]Zebra and Quagga mussels have only recently invaded western USA waters. Thus, the types of water bodies (CEs) that they can invade in the western USA are unknown.

Table 5. Life history characteristics, type of reproduction and fecundity, and environmental niche widths of invasive taxa.

Fecundity is dependent on: environmental conditions, age at maturity, condition of female, density dependence, etc. Survivability of live born can be an order of magnitude or more than egg survivability. The fecundity values and environmental niche width descriptions in this table are generalizations.

Taxon	Life History		Rating
	Type of Reproduction Fecundity (number of propagules produced/year)[1]	Environmental niche width (e.g. habitats, physical/chemical tolerances)	
Diatoms			
Didymo, rock snot *Didymosphenia gemenata*	Asexual, sexual Exponential growth[2]	Tolerate wide variety of environmental conditions Can survive in damp condition > 40 days, Cold to warm lotic and lentic	**Extreme**
Macrophytes			
Curly leaf pondweed *Potamogeton crispus*	Asexual apices, sexual seeds > 900 apices[3]	Tolerate wide variety of environmental conditions Restricted to alkaline calcareous waters, tolerant of slightly brackish and polluted water.	**High**
Eurasian watermilfoil *Myriophyllum spicatum*	Asexual fragmentation, sexual seeds	Cold to warm lentic and low velocity lotic	**High**
Gastropods (snails)			
Applesnails *Pomacea* sp.	Sexual, egg layer 800 to 7000	Survives temporary adverse environmental conditions[4] Warm lentic, warm low to moderate velocity lotic	**High**
European ear snail *Radix auricularia*	Hermaphroditic, egg layer 1300	Warm lentic	**Moderate**
Red-rim melania *Melanoides tuberculatus*	Asexual, parthenogenic, sexual, live- bearer 365	Survives temporary adverse environmental conditions[4] Cool to warm lentic and lotic. Most commonly occurring invasive in spring habitats[5]	**High**
New Zealand mudsnail *Potamopyrgus antipodarum*	Asexual, parthenogenic, sexual, live- bearer 230	Survives temporary adverse environmental conditions[4] Cold to cool lentic and lotic	**High**
Chinese mystery snail *Cipangopaludina chinensis malleata*	Sexual live-bearer 65	Survives temporary adverse environmental conditions[4] Warm slow lotic, lentic	**High**
Bivalves (clams/mussels)			
Asian clam *Corbicula fluminea*	Hermaphroditic 68,000	Tolerate wide variety of environmental conditions Need DO $\geq$ 70% Cool to warm lentic and lotic	**High**
Zebra and 212nvisi mussels *Dreissena* sp.	Dioecious; fertilization occurs in the water column 960,000	Tolerate wide variety of environmental conditions Cool to warm lentic and lotic	**Extreme**
Amphibians			

African clawed frog *Xenopus laevis*	Sexual egg layer > 100,000	Extremely broad environmental tolerances[6] Lentic and slow lotic	**High**
American bullfrog *Lithobates* (=*Ranus*) *catesbeianus*	Sexual egg layer 4000 to 100,000	Broad environmental tolerances Lentic and slow lotic	**High**
Fish			
Mollies and guppies *Poecilia* sp.[7]	Sexual live bearers 100-500	Moderate environmental tolerances Warm lentic and low velocity lotic	**Moderate**
Tilapia *Oreochromis* sp	Sexual egg layer, mouth-brooder 1000 -18,000	Moderate environmental tolerances Cool to warm lentic and low velocity lotic	**High**
Asian/European carp Family Cyprinidae	Sexual egg layers $1x10^5 – 4x10^6$	Moderate environmental tolerances Cool to warm lentic and low velocity lotic	**Extreme**

[1]Keller et al. 2007 suggested that fecundity was the most important factor for modeling a species invasive ability. However, Keller et al. 2007 only modeled single deterministic values (without ranges) for fecundity for each of their invasive taxa. They also did not adjust for viability differences in reproduction strategies such as eggs vs. live born vs. parental care. Taking these omissions into account, Keller et al. 2007 modeling results would still classify all of the above taxa as exceedingly invasive based on their high fecundity rates.

[2]Excessive biomass accumulations associated with didymo result from asexual reproduction. When the diatom divides, the stalk that was attaching the diatom to a rock or some other hard surface divides also. A mass of branched interconnected stalks results as this process repeats itself. It is the aggregation of these stalks that are highly resistant to degradation, which causes the formation of large mats of didymo (rock snot).

[3]Apices are vegetative asexual nodules that can detach and form new plants

[4]These snails have opercula (operculum singular) that act as calcareous trap doors to seal themselves into their shells thus avoid adverse conditions and predators. They can often survive for several weeks outside of the water under damp conditions and several days under dry conditions.

[5]Dr. Don Sada, Desert Research Institute, NV personal communication

[6]African toed frog is not generally known as an invasive species to biologists and managers in our ecoregions. However, it has the potential to be one of the most destructive to ecological integrity in almost all of our CEs. It is highly fecund and has very broad environmental tolerances. The African toed frog is extremely salt tolerant (40% sea water) and has successfully established populations near sea cliffs subject to high sea spray. Adults can tolerate temperature ranges of 0-30 ^oC and tadpoles can survive temperature ranges of 10-30^oC. Populations persist under winter ice and in climates near the frog's upper viable temperature range in Arizona. The species can aestivate for up to eight months during periods when waters completely dry up and can tolerate periods of total starvation lasting up to one year. It can breed successfully in both acidic and alkaline waters with pH ranges of 5 to 9.

[7]Molly and guppy taxa were combined at the family level because of very similar ecologies

Table 6. Short and long distance dispersal ecology and ratings for invasive taxa.

Taxon	Dispersal Ecology (pathways)				Rating
	Short Distance Dispersal		**Long Distance Dispersal**		
	Primary	Secondary	Primary	Secondary	
Diatoms					
Didymo, rock snot *Didymosphenia gemenata*	Passive via human activities, passive downstream	Passive on birds, wind	Passive via human activities	Passive on birds	**Extreme**
Macrophytes					
Curlyleaf pondweed *Potamogeton crispus*	Passive via human activities, passive downstream	NA	Passive via human activities	Passive seeds in bird guts?	**High**
Eurasian watermilfoil *Myriophyllum spicatum*	Passive via human activities, passive downstream	NA	Passive via human activities	Passive seeds in bird guts?	**High**
Gastropods (snails)					
Applesnails *Pomacea* sp.	Passive via human activities, active/passive downstream	Active upstream	Passive via human activities	NA	**Moderate**
European ear snail *Radix auricularia*	Passive via human activities, active/passive downstream	Active upstream	Passive via human activities	NA	**Moderate**
Red-rim melania *Melanoides tuberculatus*	Passive via human activities, active/passive downstream	Active upstream	Passive via human activities	NA	**Moderate**
New Zealand mudsnail *Potamopyrgus antipodarum*	Passive via human activities, active/passive downstream	Active upstream	Passive via human activities	NA	**High**
Chinese mystery snail *Cipangopaludina chinensis*	Passive via human activities, active/passive downstream	Active upstream	Passive via human activities	NA	**Moderate**
Bivalves (clams/mussels)					
Asian clam *Corbicula fluminea*	Passive via human activities, passive downstream	NA	Passive via human activities	Passive downstream	**High**
Zebra and quagga mussels *Dreissena* sp.	Passive via human activities, passive downstream	NA	Passive via human activities	Passive downstream	**High**
Amphibians					
African clawed frog *Xenopus laevis*	Passive via human activities, active upstream and downstream	Active terrestrial	Passive via human activities	NA	**Moderate**
American bullfrog *Lithobates catesbeianus*	Passive via human activities,	Active terrestrial	Passive via human	NA	**Moderate**

	active upstream and downstream		activities		
Fish					
Mollies and guppies *Poecilia* sp.	Passive via human activities, active upstream and downstream	NA	Passive via human activities	NA	**Moderate**
Tilapia *Oreochromis* sp	Passive via human activities, active upstream and downstream	NA	Passive via human activities	NA	**Moderate**
Asian/European carp Family Cyprinidae	Passive via human activities, active upstream and downstream	NA	Passive via human activities	NA	**High**

Appendix IVb. Examples of Aquatic Invasive Species Impact Index by Pilot HUC

Table 1. Aquatic invasive species reported in the pilot HUCs[1]

HUC8	**HUC Name**	**Common Name (Scientific name)**
15010011	White	American Bullfrog (*Lithobates* (=*Ranus*) *catesbeianus*)
		Common carp (*Cyprinus carpio*)
		Mollies and guppies (Family Poecilidae)
15010012	Muddy	American Bullfrog (*Lithobates* (=*Ranus*) *catesbeianus*)
		Common carp (*Cyprinus carpio*)
		Mollies and guppies (Family Poecilidae)
		Blue tilapia (*Oreochromis aureus*)
15010013	Meadow Valley Wash	American Bullfrog (*Lithobates* (=*Ranus*) *catesbeianus*)
		Common carp (*Cyprinus carpio*)
		Mollies and guppies (Family Poecilidae)

[1] From USGS NAS database. Other databases are currently being assessed for invasive species in these HUCs

Evaluation of HUC Number: 15010011 (White River); CE = SPRINGS

Within HUC				
Indicator category	Indicator	**Value**	**Score**	**Condition**
Number of invasives	1a. Number of invasive taxa present in CE	2	1	Degraded
	1b. Number of invasive taxa not in CE but likely to invade from other infected CEs in HUC	1	0.5	NA
	2. Number of probable invasives in CE	3	0.5	Degraded
Percent reference CEs infected	3. Percent reference CEs infected	100%	1	Degraded
Trophic levels	4a. Number of trophic levels	1	2	Transitioning
	4b. Number of novel trophic levels of invasive taxa present in different CE that are likely to invade CE	1	0.5	NA
	5. Number of probable infected trophic levels in CE	2	1.5	Transitioning
Connectivity	6. Flow network connectivity	NA	NA	NA
	7. Upstream or downstream from infected site	NA	NA	NA
Use	8. Recreational use	NA	NA	NA
	9. Road density	NA	NA	NA
	10. Urbanization	NA	NA	NA
Time	11. Time since first invasion	Long history (> 40 yrs)	1	Degraded
Within HUC Score			**1.00**	**Degraded**

Final Score HUC Number: 15010011 (White River); CE = SPRINGS
= 1.00 = Degraded

Evaluation of HUC Number: 15010012 (Muddy River); CE = SPRINGS

Within HUC				
Indicator category	Indicator	**Value**	**Score**	**Condition**
Number of invasives	1a. Number of invasive taxa present in CE	1	2	Transitioning
	1b. Number of invasive taxa not in CE but likely to invade from other infected CEs in HUC	1	0.5	NA
	2. Number of probable invasives in CE	1	1.5	Transitioning
Percent CEs infected	3. Percent reference CEs infected	40%	1	Degraded
Trophic levels	4a. Number of trophic levels	1	2	Transitioning
	4b. Number of novel trophic levels of invasive taxa present in different CE that are likely to invade CE	1	0.5	NA
	5. Number of probable infected trophic levels in CE	1	1.5	Transitioning
Connectivity	6. Flow network connectivity	NA	NA	NA
	7. Upstream or downstream from infected site	NA	NA	NA
Use	8. Recreational use	NA	NA	NA
	9. Road density	NA	NA	NA
	10. Urbanization	NA	NA	NA
Time	11. Time since first invasion	Long History (> 40 yrs)	1	Degraded
Within HUC Score			**1.25**	**Degraded**

Final Score for HUC Number: 15010012 (Muddy River); CE = SPRINGS
1.25 = Degraded

Evaluation of HUC Number: 15010013 (Meadow Valley Wash); CE = SPRINGS

Within HUC				
Indicator category	Indicator	**Value**	**Score**	**Condition**
Number of invasives	1a. Number of invasive taxa present in CE	0	3	Sustainable
	1b. Number of invasive taxa not in CE but likely to invade from other infected CEs in HUC	2	1	NA
	2. Number of probable invasives in CE	2	2	Transitioning
Percent CEs infected	3. Percent reference CEs infected	0	3	Sustainable
Trophic levels	4a. Number of trophic levels	0	3	Sustainable
	4b. Number of novel trophic levels of invasive taxa present in different CE that are likely to invade CE	2	1	NA
	5. Number of probable infected trophic levels in CE	2	2	Transitioning
Connectivity	6. Flow network connectivity	NA	NA	NA
	7. Upstream or downstream from infected site	NA	NA	NA
Use	8. Recreational use	NA	NA	NA
	9. Road density	NA	NA	NA
	10. Urbanization	NA	NA	NA
Time	11. Time since first invasion	Absent	3	Sustainable
Within HUC Score[1]			**2.5**	**Sustainable**

[1]Warning: NVHP reported only one spring in this HUC. Because our invasive species databases probably do not contain all invaded CEs due to reasons explained in the introduction, caution should be made when interpreting this score.

Surrounding HUC				
Indicator category	**Indicator**	**Value**	**Score**	**Condition**
Number of invasives	12. Number of novel[1] invasive taxa present	2	1	Degraded
Invasiveness ecology and life history of nearest invasive(s)	13. Dispersal ecology and ability of novel invasive taxa	Moderate/High	1.5	Transitioning
	14. Trophic level impacts of novel invasive taxa	2	1	Degraded
	15. Life history of novel invasive taxa	Moderate/High	1.5	Transitioning
Proximity to infection and connectivity	16. Least number of HUCs to nearest infected HUC with novel taxa	1	1	Degraded
	17. Proportion of adjacent HUCs infected with novel taxa in CE	2	1	Degraded
	18. Flow network connectivity	NA	NA	NA
	19. Upstream/downstream from infected site	NA	NA	NA
	20. Recreational use	NA	NA	NA
Use	21. Road accessibility	NA	NA	NA
	22. Distance to nearest city > 25,000 population	NA	NA	NA
	23. Distance to nearest city > 100,000 population	NA	NA	NA

Time since invasion of nearest invasive	24. Time since first invasion and rate of spread of novel invasive taxa[3]	Long history (> 40 yrs)	3	Sustainable
Surrounding HUC score[4]			**1.42**	**Degraded**

Final Score for HUC Number: 15010013 (Meadow Valley Wash); CE = SPRINGS = 1.96 = Transitioning

Evaluation of HUC Number: 15010011 (White River); CE = STREAMS/RIVERS

Within HUC				
Indicator category	Indicator	**Value**	**Score**	**Condition**
Number of invasives	1a. Number of invasive taxa present in CE	2	1	Degraded
	1b. Number of invasive taxa not in CE but likely to invade from other infected CEs in HUC	1	0.5	NA
	2. Number of probable invasives in CE	3	0.5	Degraded
Percent CEs infected	3. Percent reference CEs infected	NA	NA	NA
Trophic levels	4a. Number of trophic levels	2	1	Degraded
	4b. Number of novel trophic levels of invasive taxa present in different CE that are likely to invade CE	1	0.5	NA
	5. Number of probable infected trophic levels in CE	3	0.5	Degraded
Connectivity	6. Flow network connectivity	NA	NA	NA
	7. Upstream or downstream from infected site	NA	NA	NA
Use	8. Recreational use	NA	NA	NA
	9. Road density	NA	NA	NA
	10. Urbanization	NA	NA	NA
Time	11. Time since first invasion	Long history (> 40 yrs)	1	Degraded
Within HUC Score			**0.67**	**Degraded**

Final Score for HUC Number: 15010011 (White River); CE = STREAMS/RIVERS = 0.67 = Degraded

Evaluation of HUC Number: 15010012 (Muddy River); CE = STREAMS/RIVERS

Within HUC				
Indicator category	Indicator	**Value**	**Score**	**Condition**
Number of invasives	1a. Number of invasive taxa present in CE	4	1	Degraded
	1b. Number of invasive taxa not in CE but likely to invade from other infected CEs in HUC	0	0	NA
	2. Number of probable invasives in CE	4	1	Degraded
Percent CEs infected	3. Percent reference CEs infected	NA	NA	NA
Trophic levels	4a. Number of trophic levels	2	1	Degraded
	4b. Number of novel trophic levels of invasive taxa present in different CE that are likely to invade CE	0	0	NA
	5. Number of probable infected trophic levels in CE	2	1	Degraded
Connectivity	6. Flow network connectivity	NA	NA	NA
	7. Upstream or downstream from infected site	NA	NA	NA
Use	8. Recreational use	NA	NA	NA
	9. Road density	NA	NA	NA
	10. Urbanization	NA	NA	NA
Time	11. Time since first invasion	Long History (> 40 yrs)	1	Degraded
Within HUC Score			**1.00**	**Degraded**

Final Score for HUC Number: 15010012 (Muddy River); CE = STREAMS/RIVERS = 1.00 = Degraded

Evaluation of HUC Number: 15010013 (Meadow Valley Wash); CE = STREAMS/RIVERS

Within HUC				
Indicator category	Indicator	**Value**	**Score**	**Condition**
Number of invasives	1a. Number of invasive taxa present in CE	3	1	Degraded
	1b. Number of invasive taxa not in CE but likely to invade from other infected CEs in HUC	0	0	NA
	2. Number of probable invasives in CE	3	1	Degraded
Percent CEs infected	3. Percent reference CEs infected	NA	NA	NA
Trophic levels	4a. Number of trophic levels	2	1	Degraded
	4b. Number of novel trophic levels of invasive taxa present in different CE that are likely to invade CE	0	0	N
	5. Number of probable infected trophic levels in CE	3	1	Degraded
Connectivity	6. Flow network connectivity	NA	NA	NA
	7. Upstream or downstream from infected site	NA	NA	NA
Use	8. Recreational use	NA	NA	NA
	9. Road density	NA	NA	NA
	10. Urbanization	NA	NA	NA
Time	11. Time since first invasion	Long History (> 40 yrs)	1	Degraded
Within HUC Score			**1.00**	**Degraded**

Final Score HUC Number: 15010013 (Meadow Valley Wash); CE = STREAMS/RIVERS = 1.00 = Degraded

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