DOCKET
09-AFC-8
DATE JUL 07 2010
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STATE OF CALIFORNIA
ENERGY RESOURCES CONSERVATION
AND DEVELOPMENT COMMISSION

In the Matter of:) Docket No. 09-AFC-8
)
Application for Certification for)
the Genesis Solar Energy Project)

Staff's Additional Exhibits 425-432

Exhibit List: In addition to the exhibits listed in staff's Prehearing Conference Statement of June 25, 2010, staff plans to present the following exhibits:

Exhibit 425. Biological Resources—Tetratech. Map of Mojave Fringe-Toed Lizard habitat, May 13, 2010; Google Earth Figure of sand shadow, November 5, 2005-May 25, 2009.

Exhibit 426. Biological Resources—Collison. Memorandum (including figures), Revised Wind Shadow Estimates, June 1, 2010, docketed June 8, 2010.

Exhibit 427. Biological Resources— Philip Williams & Associates, Ltd. Map, Genesis Project location, June 30, 2010.

Exhibit 428. Biological Resources—NatureServe. Conservation Status Assessments: Factors for Assessing Extinction Risk, April 2009.

Exhibit 429. Soil & Water Resources—USGS. Use of Superposition Models to Simulate Possible Depletion of Colorado River Water, 2008.

Exhibit 430. Soil & Water Resources—Blythe Solar Power Project. Response to CEC Staff Data Request 179 regarding recharge of the Palo Verde Mesa Groundwater Basin, January 6, 2010, docketed January 7, 2010.

Exhibit 431. Soil & Water Resources—Metzger. Map of Groundwater Basins in the Blythe area, 1964.

Exhibit 432. Soil & Water Resources—CEC Staff. Blythe II Soil and Water Resources, Final Staff Assessment Technical Report, p. 4.9-11. Schematic Diagram Showing the River Aquifer and Accounting Surface, June 2005, docketed June 2, 2005.

Respectfully Submitted,

Robin M Mayer

Date: July 7, 2010

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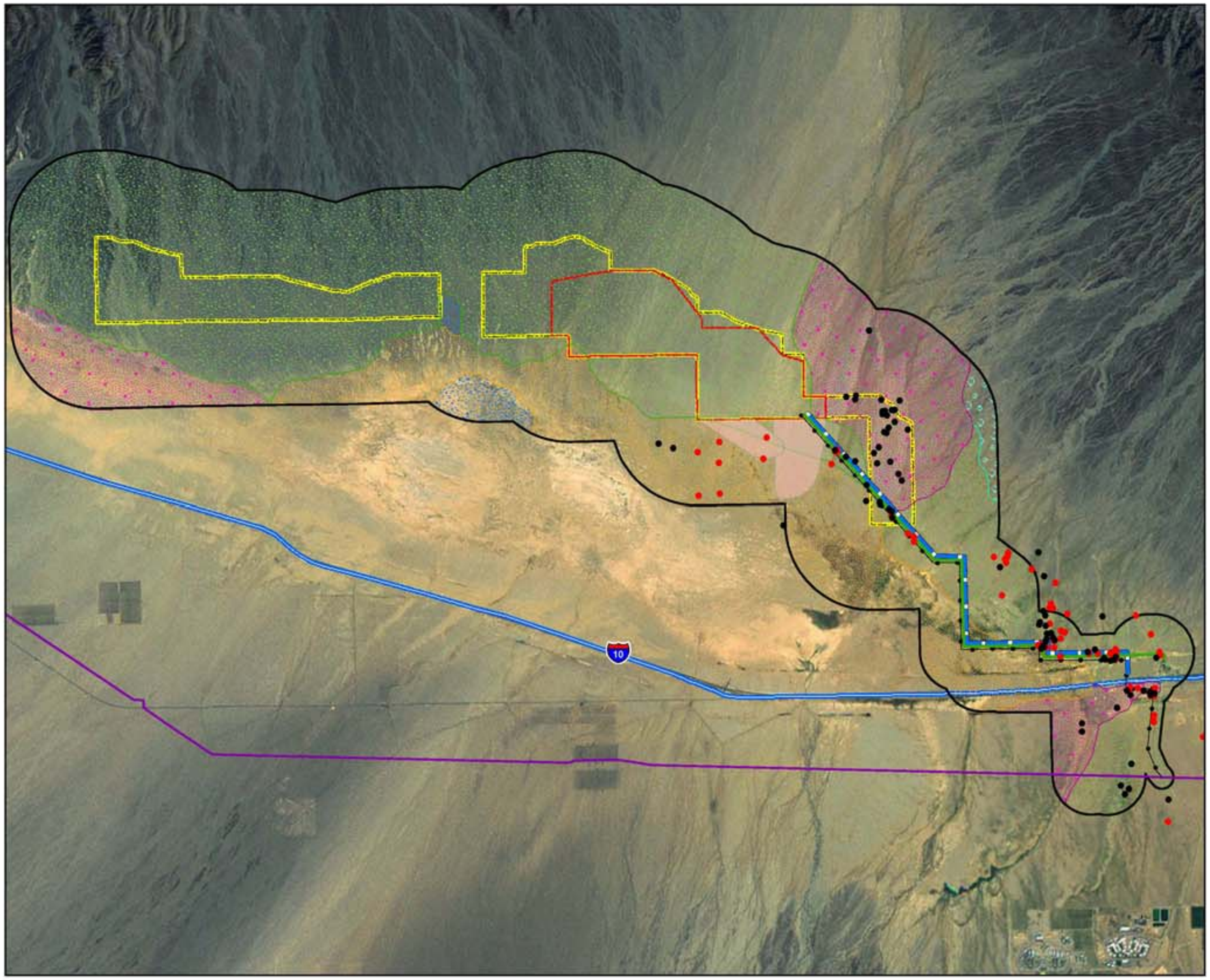

Genesis Solar, LLC

GENESIS SOLAR ENERGY PROJECT
RIVERSIDE COUNTY, CALIFORNIA

- ● *Uma scoparia* Observations, '09 - '10
- ● *Cryptantha costata* Spring 2010 Observations
- ▨ Sand Shadow Area
- ▨ Chenopod Scrub
- ▨ Sonoran Creosote Bush Scrub
- ▨ Dry Desert Wash Woodland
- ▨ Playa and Sand Drifts over Playa
- ▨ Stabilized and Partly-Stabilized Sand Dune
- ☐ Facility Footprint
- ☐ Project Site
- ☐ Extent of Surveyed Area
- — Blythe Energy Project Transmission Line
- —•— Proposed Transmission Interconnect (7.5 Miles)
- — Proposed Gas Line (5.9 Miles)
- — Proposed Access Road (6.1 Miles)

N

0 0.5 1 1.5 2
Miles

Notes:
(a) UTM Zone 11, NAD 1983 Projection.
(b) Source data: A. Karl & Assoc., CEC, ESRI, TTEC, USDA

Biological Survey Sesults for *Uma scoparia and Cryptantha costata* and Previously Mapped Natural Community Types

Figure 1.

Figure 2. Area under the 151-acre sand shadow. The arrow indicates the wash in which ribbed cryptantha was observed in 2010. Note that there are a few linear patches of sandy habitat associated with drainages interspersed with largely non-sandy habitat.

PWA
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DOCKET
09-AFC-8
DATE JUN 01 2010
RECD. JUN 08 2010

MEMORANDUM

Date: June 1, 2010
To: Susan Sanders, Mike Monasmith
CC: CEC work group for Genesis project
From: Andrew Collison
PWA Project #: 2006.00
Subject: **Revised wind shadow estimations for Genesis Solar Energy Project**

Summary

In PWA's memo of February 26th 2010 (PWA 2010) we presented preliminary results for areas of dunes supporting Mojave Fringe Toed Lizard (MFTL) that would be impacted by sand transport delivery from the proposed Genesis Project. We identified two sand transport corridors that supply dunes and habitat areas near the project; one that crossed the easternmost part of the proposed project footprint from north to south (the Palen-McCoy corridor) and one that crossed the southeastern corner of the proposed project from west to east (the Chuckwalla corridor). We identified two 'sand shadows' associated with the project's intrusion into these wind transport corridors. Research by Turner et al. (1984) showed that dune habitat downwind of wind breaks exhibited deflation (loss of sand to wind erosion) and armoring by coarse sediment within a few years, resulting in the absence of MFTL from areas downwind.

In our initial report we made a qualitative assessment of the area impacted based on wind direction evidence and the project footprint provided by the applicant (Worley Parsons, 2010). We have subsequently developed a quantitative model of sand transport based on wind patterns from Blythe airport, which we have applied to the Palen proposed power site (Solar Millennium Palen) and to an area close to the Genesis project footprint. Although we have not been able to modify the model to directly simulate the Genesis project site in the time available, our experience applying the model close by has led to a more refined understanding of sand mixing processes that we have used to revise the analysis of indirect impacts for the Genesis project. In addition, the project proponent NextEra has responded by redesigning the proposed eastern solar array to remove a 41.4-acre 'toe' that intruded to the east of the project into the Palen-McCoy corridor (TTEC 2010). We have refined our assessment of potential indirect project impacts due to wind transport disruption to reflect these two developments since the initial assessment was carried out. The predicted area of indirect impact due to reduction in wind-blown sand input is 151 acres due to disruption to the Chuckwalla sand transport corridor and zero impact in the Palen-McCoy corridor, compared to the original estimate of 157 acres of indirect impact to the Chuckwalla transport corridor and 309 acres of impact to the Palen-McCoy corridor. The removal of the 'toe' should allow fluvial processes to replenish sand for the area formerly assessed as indirectly impacted.

Methodology for Assessing Indirect Project Impacts to Sand Transport

The original assessment of wind transport impacts was based on a qualitative estimate of the extent of the sand shadow. This led to the areas shown in Figure 1.

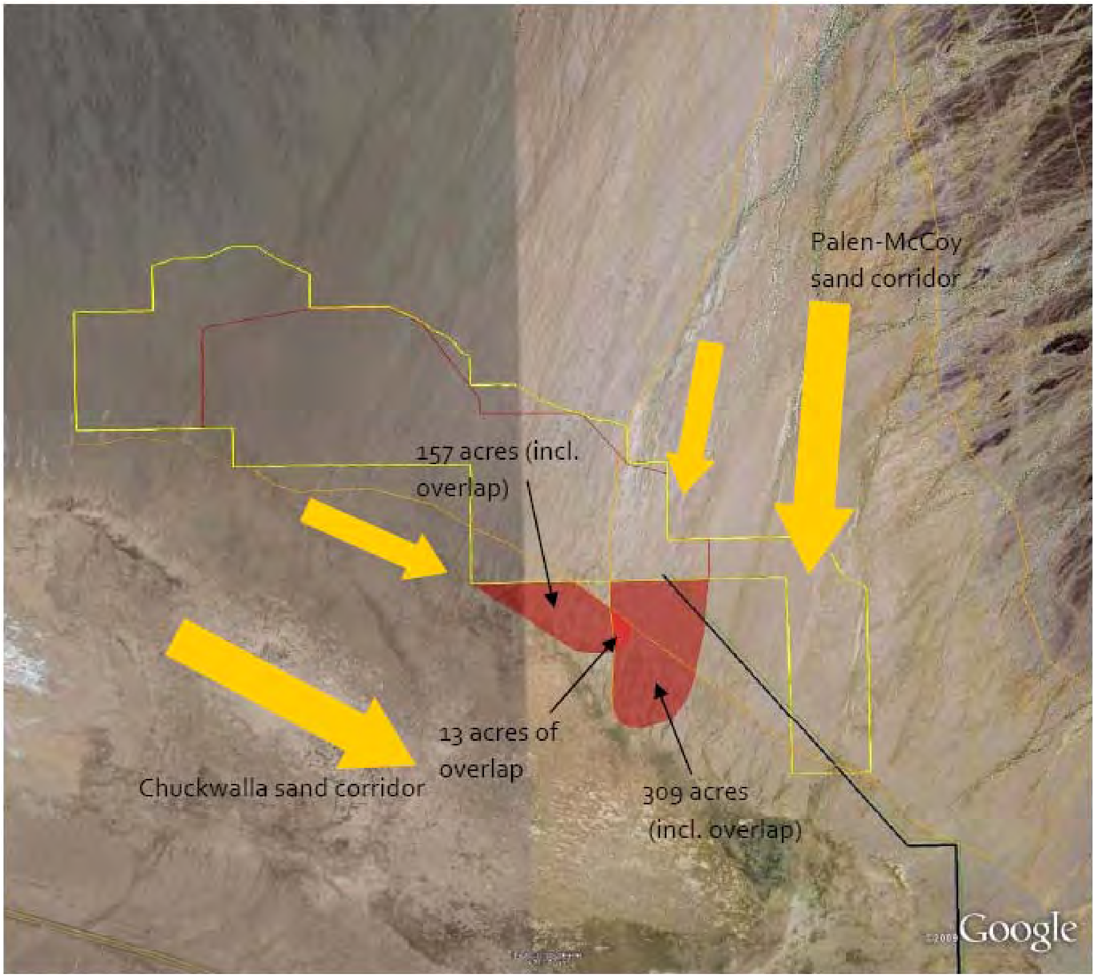


Figure 1. Original estimate of sand transport shadow (now superseded by this memo). Source: PWA, 2010 (February 26th).

Subsequently we developed a quantitative sand shadow model that takes data on the pattern of wind directions and strengths from Blythe (located 20 miles east of the project site) and combines this with data on prevailing sand transport direction collected by the applicant. The combined model uses a mixture of prevailing sand transport direction (shown by sand dunes in the field, and representing the resultant vector of all the different wind directions encountered over the course of several years) and diffusion (representing the variations around that prevailing transport direction). We applied this model to the nearby Solar Millennium Palen project site (located 12 miles west of the Genesis site). A description of the model is given in PWA, 2010b (Revised wind shadow calculations for Palen Solar Energy Project, June 2nd 2010b). Given sufficient time it is our intention to adapt the quantitative model from Palen to the Genesis site so as to make a comparable assessment of project impacts to sand transport, but it has not been possible to make these modifications within the project timetable. However, in developing and applying the model southeast of the Palen project we simulated an area northwest of the Genesis project site that has the same wind direction and we were able to make observations about the pattern and extent of sand disruption that would very likely have been found had we extended the model to the Genesis project footprint. This provides us with a means of refining our initial estimations of indirect project impact.

We observed in the course of the analysis that the variations in wind direction and strength around a prevailing wind direction resulted in zones of different degrees of sand transport reduction downwind of obstacles that had consistent and predictable lengths and widths. We applied these zone patterns to the Genesis footprint, adjusting the orientation of the zones to conform to the prevailing wind direction of N68W estimated by the applicant in the vicinity of the area of project under discussion (see Figure 2).

We assumed that a line drawn from the outer edge of the project footprint intrusion into the Chuckwalla sand transport corridor and extending downwind with an orientation of S68E (180 degrees from N68W) would delineate the line of 50% sand reduction, per our observations made using the quantitative sand transport model. Zones of 25% and 75% sand reduction were drawn diverging from the point of maximum project intrusion so that they widened from the 50% reduction line at a rate of 0.12 miles per linear mile, again per our observations of the Palen model. This produced the fan shaped areas of different impact shown in Figures 3 and 4. The downwind limit of the impact area is taken as the point at which fluvial transport from the McCoy valley is no longer disrupted by the project footprint. We assume that an area shown in blue on Figures 3 and 4 will see a substantial disruption in fine sediment delivered by the alluvial fan (the area is not extended further west because the alluvial fan channels here are much smaller). East of this area we assume that the alluvial fan channels and the McCoy wind transport corridor will dominate fine sediment delivery, making the reduction in sediment transport from the Chuckwalla valley insignificant.

The refined assessment of the indirect impacts to the Chuckwalla transport corridor is as follows:
75 – 100% reduction in sand transport = 54 acres
50 – 75% reduction in sand transport = 50 acres
25 – 50% reduction in sand transport = 47 acres
Total indirect impact = 151 acres

The removal of the ‘toe’ should allow fluvial processes to continue supplying sediment to the area identified in the original memo as the 309 acre Palen-McCoy impact area, so this area has been removed from the impact calculations. Our refined assessment is in contrast with the original finding of 157 acres of indirect impact to the Chuckwalla transport corridor and 309 acres of impact to the Palen-McCoy corridor.

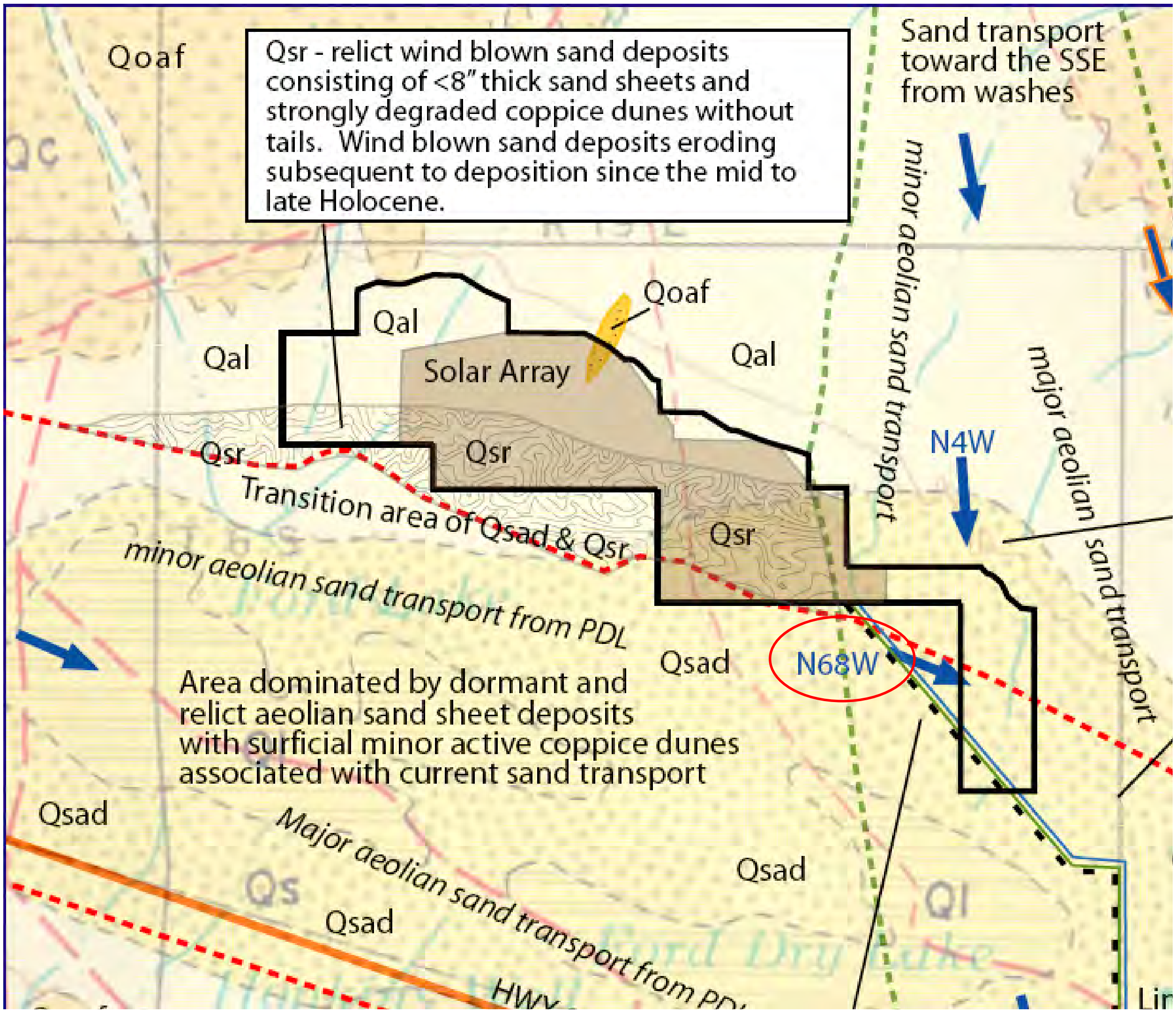


Figure 2. Prevailing wind transport evidence based on orientation of sand dunes in the project area (Worley Parsons, 2010).

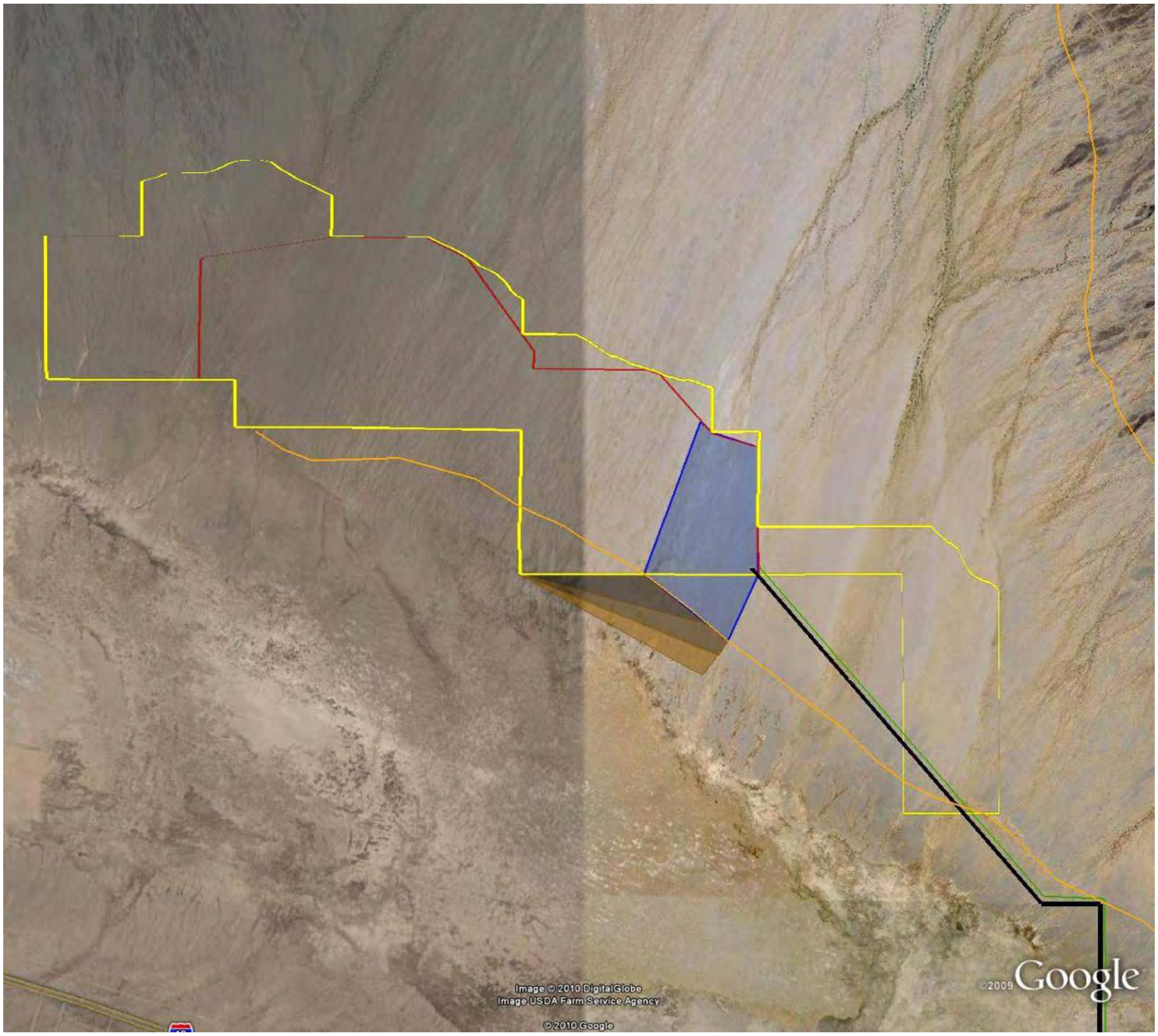


Figure 3. Refined indirect impact areas due to sand transport disruption (overview). Area in blue is area where fluvial sediment is disrupted by project. Areas in brown are different levels of sediment reduction from wind transport. Orange line is the NECO land use boundary for sand dunes (coincides with applicant's delineation of the northern boundary of the Chuckwalla sand transport corridor).

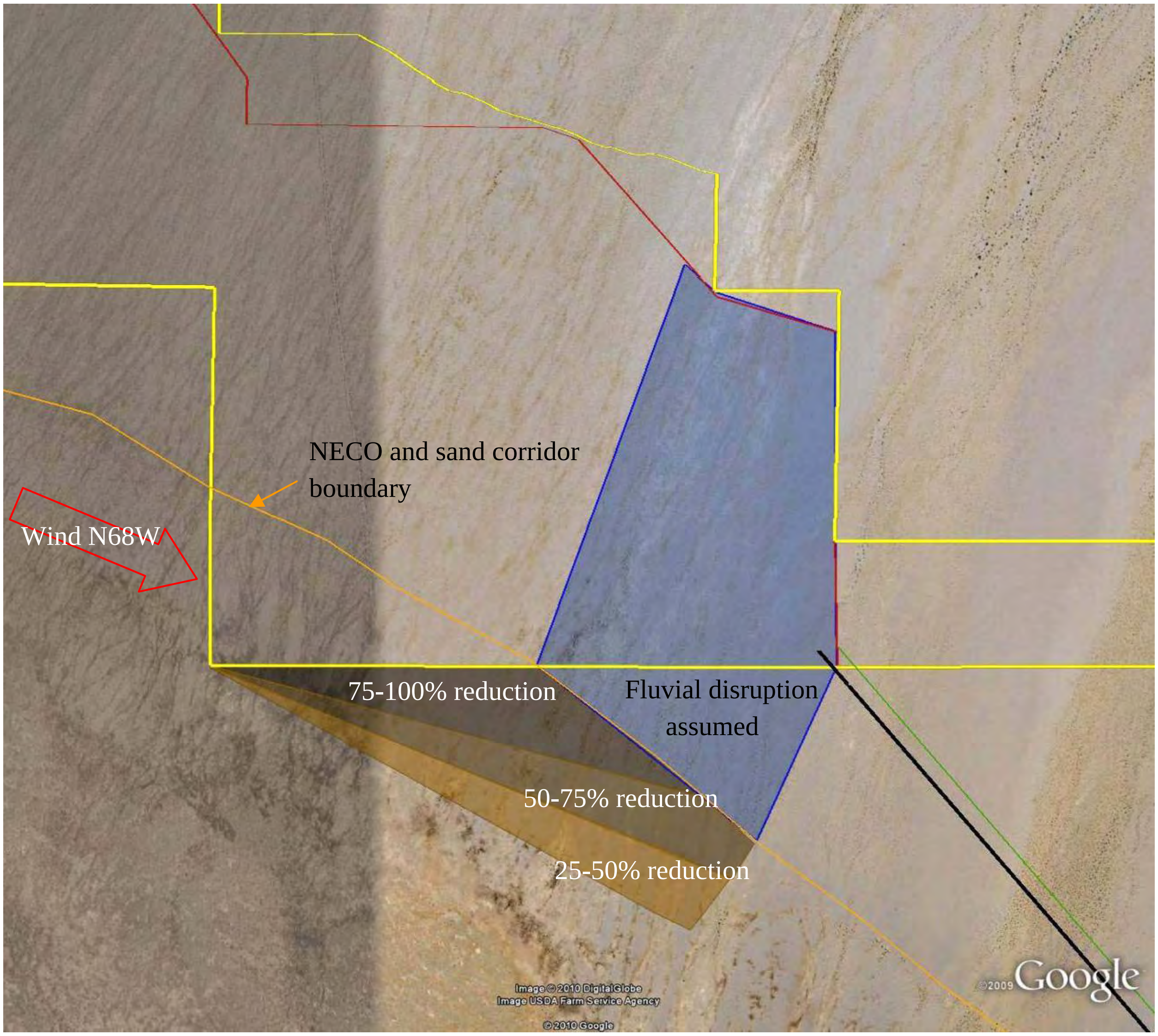


Figure 4. Refined indirect impact areas due to sand transport disruption (detail). Area in blue is area where fluvial sediment is disrupted by project. Areas in brown are different levels of sediment reduction from wind transport. Orange line is the NECO land use boundary for sand dunes (coincides with applicant’s delineation of the northern boundary of the Chuckwalla sand transport corridor).

References

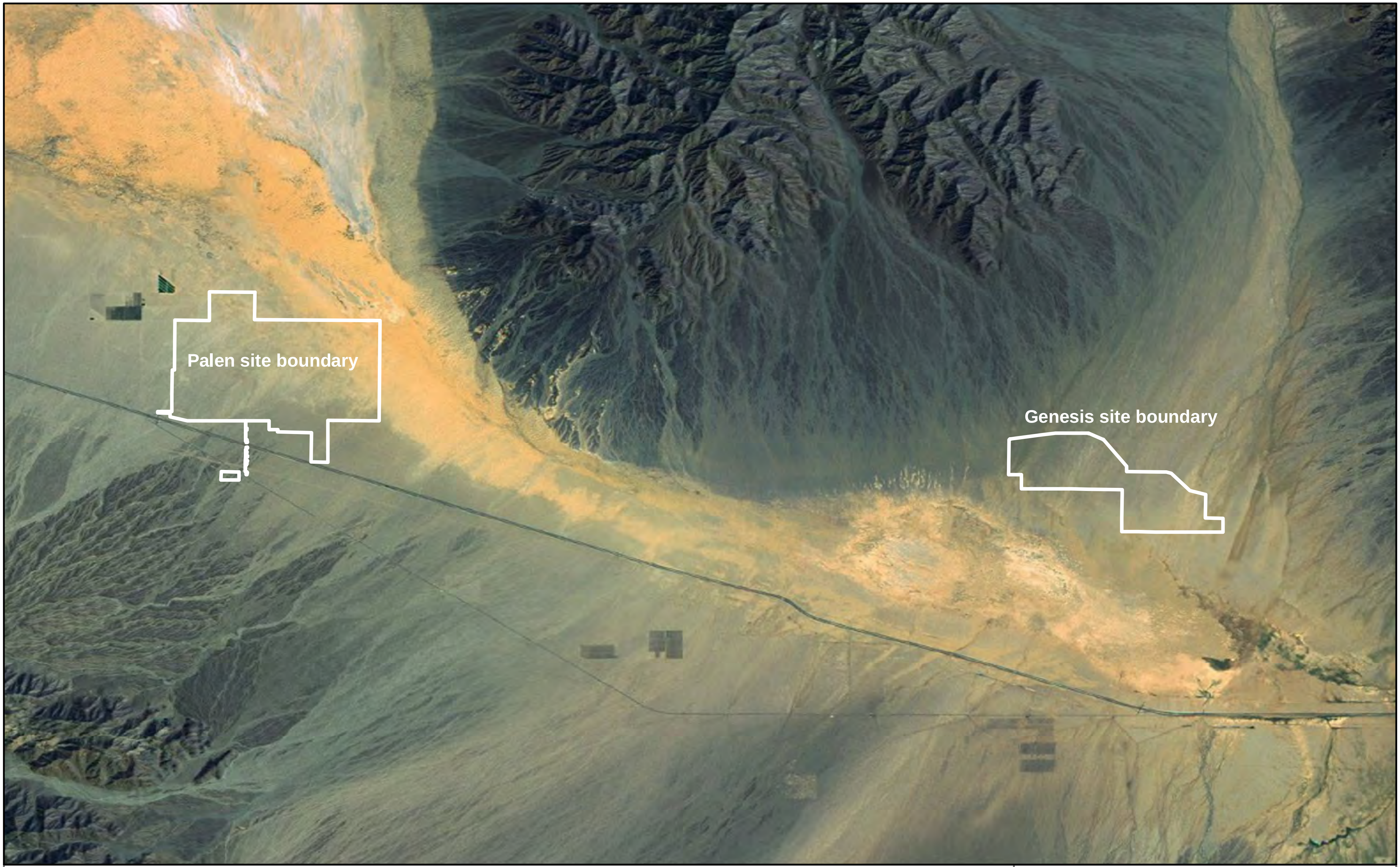
PWA 2010. Philip Williams & Associates, Ltd. Environmental Hydrology. Genesis Solar Energy Project Staff Assessment/Draft Environmental Impact Statement, Soil & Water Appendix A, memo from A. Collison to S. Sanders, Geomorphic Assessment of Genesis Solar Project Site, February 26, 2010.

PWA 2010b. Philip Williams & Associates, Ltd. Environmental Hydrology. memo from A. Collison to S. Sanders, A. Solomon. Revised wind shadow calculations for Palen Solar Energy Project June 2, 2010.

TTEC 2010o -Tetra Tech/T. Bernhardt (tn: 56826) Minor Changes to the Genesis Solar Energy Project Description: 6-pole Extension of Transmission Line; Inclusion of Distribution and Telecommunications Line; Removal of “Toe” Area from Plant Facility Submitted by Genesis Solar, LLC Dated May 21, 2010

Turner, F.B., Weaver, D.C. and Rorabaugh, J.C. Effects of reduction in windblown sand on the abundance of the Fringe_toed Lizard (*Uma inornata*) in the Coachella Valley, California. Copeia, 1984(2), pp. 370-378.

Worley Parsons. Aeolian transport evaluation and ancient shoreline delineation report, Genesis solar energy project, Riverside County, CA. February 5th 2010.



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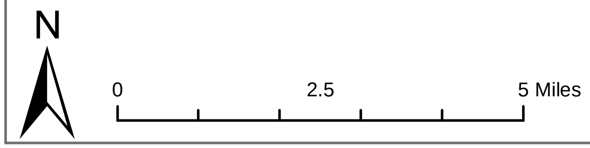

figure X

Project Name

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PWA Ref# - 2006.00

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NatureServe Report · April 2009

NatureServe Conservation Status Assessments:

Factors for Assessing Extinction Risk

NatureServe
A Network Connecting Science With Conservation

NatureServe is a non-profit organization dedicated to providing the scientific basis for effective conservation.

Citation: Master, L., D. Faber-Langendoen, R. Bittman, G. A. Hammerson, B. Heidel, J. Nichols, L. Ramsay, and A. Tomaino. 2009. NatureServe Conservation Status Assessments: Factors for Assessing Extinction Risk. NatureServe, Arlington, VA.

Cover photo: Polar bear (*Ursus maritimus*) © Larry Master (www.MasterImages.org)

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NatureServe Conservation Status Assessments:

Factors for Assessing Extinction Risk

Lawrence L. Master, Don Faber-Langendoen,
Roxanne Bittman, Geoffrey A. Hammerson, Bonnie Heidel,
Jennifer Nichols, Leah Ramsay, and Adele Tomaino

NatureServe

April 2009

Acknowledgments

This 2009 revision of guidance for documentation of NatureServe conservation status was developed in consultation with the Element Ranking Work Group: Larry Master, Don Faber-Langendoen, Adele Tomaino, Kristin Snow, Jennifer Nichols, Larry Morse, Leah Ramsay, Steve Rust, Bonnie Heidel, Roxanne Bittman, Geoff Hammerson, Troy Weldy, Paul Hendricks, Bryce Maxell, and Ben Wigley. More recently, Bruce Young has joined as a co-chair and commented on revisions to this draft. Most recently, the draft has been reviewed by the NatureServe network of natural heritage programs and conservation data centers.

This revision draws heavily from the Standards and Petitions Working Group of IUCN SSC Biodiversity Assessments Sub-Committee and from the IUCN-CMP alliance to develop standard taxonomies of threats and actions. Alan Weakley and Larry Morse were key NatureServe staff who, for many years, contributed their ideas to this document. Previous revisions were done in consultation with Syd Cannings, Gwen Davis, Kathy Goodin, Kat Maybury, Leah Oliver, Donna Reynolds, Dale Schweitzer, and Steve Taswell of NatureServe; participants at the National Center for Ecological Analysis and Synthesis (NCEAS) workshops (2000-2004) on methods for assessing extinction risk; and NatureServe ecologists at a workshop in November 2000.

The ideas presented also draw upon discussion with and input from staff of the member programs of the NatureServe network. In addition, external data users and agency staff have provided much useful input. Some of the concepts incorporated here draw from draft invasiveness assessment factors (Randall et al. 2001).

Funding for the most recent revisions has been generously provided by the National Council for Air and Stream Improvement (NCASI), Office Depot, U.S. Fish and Wildlife Service, U.S. Forest Service, and the Sarah K. de Coizart Article TENTH Perpetual Charitable Trust. Marta VanderStarre edited, designed and produced this publication.

Contents

Appendices

Ursus maritimus (Polar Bear)	
RARITY	
Range Extent	>2,500,000 sq km
Area of Occupancy	> 20,000 sq km
Number of Occurrences	19 occurrences
Population Size	20,000–25,000 individuals
Environmental Specificity	Narrow – specialist, key requirement polar sea ice
TRENDS	
Short-term Trend	Decline of <30% to relatively stable
THREATS	
Intrinsic Vulnerability	Highly vulnerable
Primary Threat	Global warming
Threat – Scope	Pervasive – affects 71-100% total population or occurrences
Threat – Severity	Serious – likely to reduce total population by 31-70% within 3 generations
Threat - Impact	High
Overall Threat	Substantial, imminent
NatureServe Conservation Status Rank: G3 - Vulnerable	

Photo: © Larry Master (www.MasterImages.org)

Executive Summary

The primary purpose of Conservation Status Assessments is to evaluate the potential extinction or extirpation risk to elements of biodiversity, including regional extinction or extirpation. NatureServe and its member programs and collaborators use a suite of factors to assess the conservation status of species of plants, animals, and fungi, as well as ecosystems—ecological communities and systems. Conservation status is summarized as a series of ranks from "critically imperiled" to "secure," and these ranks may be derived at global, national, or subnational (state/provincial) levels. This document details the factors that are used to assess extinction risk.

NatureServe's methods, which have been evolving since 1978, are used by its network of natural heritage programs and conservation data centers throughout North America. The NatureServe network compiles the data and information needed to assess extinction risk both subnationally and globally. In recent years, NatureServe has worked with the International Union for the Conservation of Nature (IUCN) to standardize the ratings for shared information fields, such as "Range Extent," "Area of Occupancy," "Population Size," and "Threats." This standardization permits the sharing of information between organizations and countries, and allows the information to be used in IUCN as well as NatureServe assessments. NatureServe has also developed a "rank calculator" to increase the repeatability and transparency of its ranking process. Ten status factors are grouped by **rarity**, **threats**, and **trends** categories, and information is recorded for each of the status factors, insofar as is possible. The rank calculator then computes a numeric score, based on weightings assigned to each factor and some conditional rules, which is translated to a calculated status rank. This calculated rank is reviewed and adjusted if deemed appropriate, with documentation of the reasons for adjustment, before it is recorded as the final assigned conservation status rank.

NatureServe conservation status assessment methodology contains a number of features, most notably that it

1. Considers all of the status factor data collectively in assigning a status;
2. May produce "range-ranks" (e.g., G1G3 = globally critically imperiled to vulnerable) to transparently reveal the degree of uncertainty in a status when the available information does not permit a single status rank;
3. Explicitly considers threats in the assessment;
4. Assesses conservation status for both species and ecosystems; and
5. Is sufficiently complete for North American species[1] that global, national, and subnational ranks are routinely linked to facilitate setting conservation priorities.

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[1] More than 50,000 species and ecological communities are tracked and ranked at global and subnational levels by NatureServe and its network of natural heritage programs and conservation data centers.

Introduction

The primary purpose of Conservation Status Assessments is to evaluate potential extinction risk of elements of biodiversity—species, communities, and systems—including regional extinction or extirpation risk. Extinction risk is an essential piece of information to inform biodiversity conservation; however, it must be used with other information (e.g., genetic distinctness, importance of area, immediacy of threats, inclusive benefits, feasibility) to guide conservation planning, priority setting for reserve selection, inventory, official national and subnational listings, and recovery and management planning (see Appendix D).

NatureServe and its member programs and collaborators use a suite of factors to assess the conservation status of species of plants, animals, and fungi, as well as ecosystems—ecological communities and systems. The outcome of researching and recording information on the conservation status factors is the assignment of a conservation status (rank) with supporting documentation. (A summary of the conservation status categories is provided in Appendix A.) Data gathered on these status factors form the backbone of information used to assess extinction risk.

This document provides an overview of each of the status factors used in NatureServe conservation status assessments. Along with the detailed status factor descriptions, definitions of key terms are provided, and some guidance is offered on how to assign values to each of the factors. Procedures for how to combine the status factor values into a conservation status rank are provided in Faber-Langendoen et al. (2009a).

A Brief History of NatureServe Conservation Status Assessment

This edition of the NatureServe Conservation Status Assessments document is the latest version in a series of substantive changes to the conservation status factors since the early 1980s, when NatureServe's conservation status assessment process was first developed.

- 1978 – System initially developed, combining global and local considerations into one "rank" (A1, A2, B1, B2, B3, C); used only for species.
- 1982 – Current system of global, national, and subnational "ranks;" eight factors considered and scored; used for both species and ecosystems; qualitative in its application (The Nature Conservancy 1988, Master 1991).
- 1994 – Guidance on how to apply conservation status assessments to communities; release of a list of G1 and G2 community types in the U.S.
- 2000 – Eight factors subdivided into eleven factors, each "scored" into a larger number of ranges to better coincide with International Union for the Conservation of Nature (IUCN) Red List break points (see Appendix B), and to facilitate development of a quantitative ranking process.
- 2003 – Separation of Conservation Status (risk of extinction or extirpation) from Distribution Status (origin, regularity, currency, and confidence of presence) for national and subnational status assessments.
- 2009 – Revisions to data structure needed for application in Red List assessments, and to better match break points, weightings, and definitions for factors that are used for both NatureServe and Red List assessments. Note that the coded rating values for a number of the factors are exponential, especially at the higher ends (i.e., Population Size, Range Extent, and Area of Occupancy). Exponential scaling at the high ends for these values helps to reasonably distinguish one to two categories used for species and communities at lower risk of extinction (the LC and G4-G5 ranks used by IUCN and NatureServe, respectively), while a finer subdivision helps to distinguish

three to four categories used for species and communities that are at some risk of extinction (the CR-NT and G1-G3 ranks), respectively.

In addition to changes made to status factors in 2000 and 2007 related to compatibility with IUCN Red List methodology (IUCN 2001, IUCN Standards and Petitions Working Group 2008, Mace et al. 2008), NatureServe is seeking to improve element conservation status ranking by increasing the transparency, repeatability, consistency, and trainability of the assessment process. To achieve this, the current “black box” ranking method is being replaced with a set of rules and point weightings structured to utilize status factor information to assign one to five ranks and range rank categories for indicating conservation status. To that end, a “rank calculator” has been developed that automates and standardizes the process, computing a numeric score from factor ratings, which is automatically translated to a calculated status rank. This calculated rank is reviewed, and adjusted if deemed appropriate (with reasons for adjustment documented), before it is recorded as the final assigned conservation status rank. A companion document describes the calculator (Faber-Langendoen et al. 2009a).

Revisions to Fields since 1999

- “Abundance” is separated into “Population Size” (species only) and “Area of Occupancy.”
- “Area of Occupancy” is measured for species using a grid system (4 km^2). As a result, “Linear Distance of Occupancy” is no longer needed as a coded field.
- A companion field named “Percent Area with Good Viability/Ecological Integrity” has been provided for the “Number of EOs with Good Viability” field. The minimum coded value of the two fields is used, if both are completed.
- Trends are divided into “Long-term Trend” and “Short-term Trend.”
- “Overall Threat” now has a comprehensive list of general and specific threats, each of which can be evaluated independently based on scope, severity, and timing. The impact of each threat is calculated based on scope and severity. Overall impact of threat is then calculated based on the impacts of the individual threats.
- “Fragility” is redefined somewhat and renamed as “Intrinsic Vulnerability,” but is only used as a factor when information on threat impact is not available.
- “Environmental Specificity” is added as a formal factor, but is only used when values for rarity factors are not available.
- “Number of Protected and Managed Occurrences” is no longer used as a status factor, although this information may still be of interest for status assessments.

Revisions to Field Values

- Adjustments to match all IUCN (2001) breakpoints to improve compatibility in both documentation of status and exchange of information, as well as to more readily permit conversion of existing NatureServe network program data. See Appendix B for the IUCN categories and a summary of the criteria, and Appendix C for a comparison of NatureServe, IUCN, and COSEWIC (Canada only) statuses.
- Finer division of value choices to more readily permit the use of a rule/point-based status assessment algorithm.
- Zero distinguished as a separate value where pertinent (e.g., for extinct or extirpated or possibly extinct species or extirpated ecosystems, i.e., ecological communities and systems).

The NatureServe Network

NatureServe is a non-profit conservation organization whose mission is to provide the scientific basis for effective conservation action. NatureServe represents an international network of biological inventories—known as natural heritage programs or conservation data centers—operating in all 50 U.S. states, Canada, Latin America and the Caribbean. The NatureServe network is the leading source for information about rare and endangered species and threatened ecosystems. Together with these network member programs, we not only collect and manage detailed local information on plants, animals, and ecosystems, but also develop information products, data management tools, and conservation services to help meet local, national, and global conservation needs.

- Changes in C-, D-, and E-level values for the “Number of Occurrences” factor address the long-recognized need to have the C-level cutoff lower than 100 to provide a better breakpoint for species and communities that are vulnerable versus those that are apparently secure. This change to a breakpoint at 80 then led to another breakpoint at 300 (based on roughly a four-fold increase at each level), which may be helpful in distinguishing apparently secure versus secure species or ecosystems (i.e., ecological communities and systems).

Revisions to Weightings of Status Factors

Traditionally, much weight was given to rarity status factors when assigning conservation status rank. In particular, the Number of Occurrences, and either “Area of Occupancy” (communities) or “Population Size” (species), were considered the primary factors that established the possible range of ranks. Final determination of the overall status rank was then based on consideration of the remaining status factors. Past and ongoing long- and short-term trends and projected trends (i.e., threats) were given insufficient weight relative to their importance in most other analyses of extinction risk factors and in other conservation status assessment methodologies (e.g., IUCN 2001, COSEWIC 2006, Musick 2004, Andelman et al. 2004, O’Grady et al. 2004).

Within the cluster of rarity factors, NatureServe ranking has traditionally given special weight to the Number of Occurrences. But an analysis of this factor indicates that it should be used cautiously and not weighted as much as other rarity factors in determining conservation status, for several reasons, including:

- There are substantial inherent difficulties in delineating populations and stands or patches;
- For some groups of taxa (e.g., large-ranging carnivores, long-distance migrants), the delineation of the occurrences is arbitrary and would not correspond to populations or subpopulations (see Occurrence definition on page 5);
- Occurrences are typically not recorded for species that are not at risk;
- Only exemplary occurrences are recorded for ecosystems that are not at risk;
- Occurrences are frequently delineated inconsistently between jurisdictions and across the range of a species or ecosystem;
- The number of occurrences increases as a species’ or community’s range becomes more fragmented and the species or ecosystem becomes more at risk (not less at risk, as is implied by an increase in the number of occurrences).

The first four of these considerations also apply to the “Number of Occurrences or Percent Area with Good Viability/Ecological Integrity.” For species at risk, the number of good occurrences typically decreases as the species becomes more imperiled. However, see footnote on page 21 regarding widespread and ubiquitous (e.g., euryecious) species, which may have very few large occurrences.

Through development of the rank calculator, it is now suggested that **rarity** status factors be given a weight of 50%, **trends** (both the Long-term and Short-term Trend factors) weighted 30%, and **threats** factors 20%. Within the set of rarity factors, the Number of Occurrences is weighted less than the other factors, namely, 1) Population Size, 2) Number of Occurrences or Percent Area with Good Viability/Ecological Integrity, and 3) Area of Occupancy, such that the number of occurrences now will contribute less to the overall rank if other rank factor information is available.

Some General Definitions

Definitions, for purposes of this document, are provided below for several terms that are used generally in the conservation status factors descriptions and discussions found in this document. A few additional, more specialized terms are defined in the discussions of particular factors. In general, these definitions are consistent with those used by IUCN (2001).

Extinction Risk: Extinction risk indicates the likelihood that a species or ecosystem will totally vanish or die out. The time frame should fall within the scope of human planning and policy setting, including the ability to judge the success of restoration efforts. Extinction risk is assessed for species using ten years or three generations, whichever is longer, up to a maximum of 100 years (IUCN 2001). For ecosystems, extinction (or extirpation) risk is assessed using a 30-year time period (Rodriguez et al. 2007).

Geographical Level (Global, National, Subnational): NatureServe conservation status assessments have been developed primarily at three geographical levels. Global status, along with the corresponding individual factors, pertains to a species or ecosystem over its entire range (i.e., globally). A particular species or ecosystem can have only a single NatureServe global conservation status. National status applies to a portion of a species or ecosystem range that occurs in a specified nation or comparable geographically distinct area (e.g., a disjunct portion of a nation that is customarily treated separately for biogeographic or conservation purposes, such as Puerto Rico). Subnational status applies to a principal subdivision of a nation, such as a state or province, but sometimes a nonpolitical region customarily treated as a subnational unit (e.g., insular Newfoundland is treated separately from mainland Labrador, but together they form the Canadian province of Newfoundland and Labrador). NatureServe conservation status may also be used for other clearly bounded geographic areas (e.g., national parks). For long-distance migrants, the subnational status may apply to a breeding, non-breeding, or migratory population within the jurisdiction.

Occurrence: An occurrence is an area of land and/or water in which a species or ecosystem is, or was, present. An occurrence should have practical conservation value for the species or ecosystem as evidenced by historical or potential continued presence and/or regular recurrence at a given location. For further discussion of the species or ecosystem occurrence concept, see NatureServe's "Element Occurrence Data Standard" (NatureServe 2002).

For species, the occurrence often corresponds with the local population, but when appropriate may be a portion of a population (e.g., long-distance dispersers) or a group of nearby populations (e.g., metapopulation). *For many taxa, occurrences are similar to "subpopulations" (but considered to be 'populations' in this document and in much of the conservation biology literature) as defined by IUCN* (2001): "Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less)."[1]

For ecosystems, the occurrence may represent a stand or patch of a type, or more typically, a cluster of stands or patches, that can range in size from a few to many thousands of hectares.[2] This definition applies primarily to terrestrial ecosystems, but in principle can also be used for freshwater-aquatic and marine occurrences (NatureServe 2006).

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[1] Note that IUCN (2001) also uses the somewhat different concept of "location" referring to "…a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations."

[2] Note that counting the number of plots sampled for an ecosystem rarely equates directly to the number of occurrences, as multiple plots can fall within a single large occurrence.

Population: A population is a geographically or otherwise distinct group of individuals of a particular species between which there is little demographic or genetic exchange (equivalent to the IUCN definition above for a "subpopulation"). For animals, metapopulation structure may arise when habitat patches are separated by distances that the species is physically capable of traversing, but that exceed the distances most individuals move in their lifetime (that is, the patches support separate subpopulations, or "demes"). If habitats are sufficiently close together that most individuals visit many patches in their lifetime, the individuals within and among the patches will tend to behave as a single continuous population.

Viability and Ecological Integrity: Estimated viability indicates the likelihood that a species will persist for a number of generations or over a designated period of time. However, viability is a term that is generally used to describe species, not ecosystems. A somewhat analogous term that can be applied to ecosystems is ecological integrity, which is "an assessment of the degree to which, under current conditions, an occurrence of an ecosystem matches reference conditions for structure, composition, and function, operating within the bounds of natural or historic disturbance regimes, and is of exemplary size" (Faber-Langendoen et al. 2008; see also Parrish et al. 2003).

Relative viability and ecological integrity are dependent on the size, condition (both biotic and abiotic), and landscape context of the species or ecosystem occurrence. For species, population size has been demonstrated to be of paramount importance in assessing viability (e.g., O'Grady et al. 2004, Reed 2005), while for ecosystems, all three factors are of comparable importance for maintaining integrity. Ecosystems with the greatest integrity—i.e., with native species structure and composition unchanged, and natural ecosystem processes intact—have the highest likelihood of retaining integrity over time.

Entities Eligible for Assessment

Ecological communities and ecological systems are collectively referred to as "ecosystems" in a generic sense. **Ecological communities** are assemblages of species and growth forms that co-occur in defined habitats at certain times and that have the potential to interact with each other (McPeek and Miller 1996). They are typically classified using ecologically based vegetation classifications, at multiple scales, from formations (biomes) to alliances and associations, based on the International Vegetation Classification (Grossman et al. 1998, Faber-Langendoen et al. 2009b, Faber-Langendoen et al. in prep.). **Ecological systems** are defined by integrating multiple ecological criteria at meso-scales, including vegetation composition and structure, driving processes, and local environmental setting. They are classified using the International Terrestrial Ecological Systems Classification (Comer et al. 2003, Josse et al. 2003). Currently, conservation status assessments use the association as the unit of assessment (which is similar in scale to the "natural community" scale of various NatureServe network program community classifications), but future applications will include types at multiple scales (see also Nicholson et al. 2009). Note that while ecosystem types include terrestrial, freshwater, and marine types, the above-referenced standard classifications are primarily terrestrial. Conservation status assessments will be applied to freshwater and marine types as standard classifications become available.

Plants, animals, fungi, and other organisms are **species** (in contrast to ecological communities or systems). In this document, the term "species" includes all entities at the taxonomic level of species (including interspecific hybrids), as well as all subspecies and plant varieties. (Subspecies and varieties are sometimes collectively termed "infraspecific taxa.") Other subsets of species (e.g., geographically distinct and evolutionarily significant population segments) may also be assessed, as well as recurrent, transient, mixed species animal assemblages (e.g., shorebird concentration areas).

Species in this document includes both single species as well as these multiple species assemblages.

While native, naturally occurring populations are the primary targets for conservation, in some cases other populations comprised of individuals not native and/or naturally-occurring at a location should also be considered. Such ‘other’ populations can be described using definitions from the *IUCN Guidelines for Re-Introductions* (IUCN 1998):

- **Benign introduction** – an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area.
- **Re-introduction** – an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct.
- **Translocation** – deliberate and mediated movement of wild individuals or populations from one part of their range to another.

Following IUCN (2008), conservation status assessments should only be applied to wild populations inside their natural range, and to populations resulting from benign introductions. However, under some circumstances re-introduced and translocated populations may be included in the concept of ‘wild populations within their natural range’ and should then be assessed. To be included in an assessment, re-introduced, translocated, and benignly introduced populations should be established and have produced viable offspring, thus providing evidence of persistence at that location with probable future reproduction. However, such populations should not be included if there are no data to support the persistence of viable progeny.

In cases where individuals have been used to supplement wild populations, these individuals and their naturally produced offspring should be included as part of the population being assessed, provided these individuals are predicted to have a positive impact on that population. However, individuals re-introduced or translocated for short-term sporting or commercial purposes without intention of establishing a viable population should be excluded from the population being assessed.

In many cases, species have successfully expanded their natural ranges outside their historical ranges. Indeed, it will be critical for many species to move beyond their historical ranges to cope with climate change. In these instances, the expansion areas should be considered part of the species’ natural range as they were not intentionally introduced.

If the only remaining individuals of a species exist in a naturalized population (i.e., resulting from human introduction outside the natural range), in a benignly introduced population, or in a re-introduced population not yet established, then the species should be considered “Presumed/Possibly Extinct in the Wild” but extant in these populations (global conservation status = GXC or GHC). If a species’ assessed status is GXC or GHC but a naturalized population of the species exists within a region (nation or state/province), this regional population should be considered to have resulted from a benign introduction and, thus, should be assigned a national or subnational conservation status based on assessment of the factors described in this document. The rationale for this exception is that when a species is extinct over its entire natural range, its presence within a region must be considered important to highlight and preserve, despite its location outside the species’ natural range.

Populations undergoing natural **hybridization** are eligible for inclusion in species assessments, but hybridization also can be a direct or indirect consequence of human activities. As described in Hutchings et al. (2008):

> "Where human-mediated hybridization occurs, F1 hybrids and their introgressed progeny should generally be considered a loss to the species and a threat to its persistence; hybrids do not represent either original taxonomic group, and they do not contribute to the evolutionary lineage of either group. If introgression is known or suspected, one should consider whether it is likely to negatively affect the conservation of the species. A negative impact is one predicted to result in a reduction in the average fitness of individuals of the species being assessed (reflected, for example, by a reduced probability of survival, reduced population growth rate, and/or reduced ability to adapt to environmental change). Under these circumstances, F1 hybrids, if identifiable, and their progeny would not be included in the assessment. Where introgression in a population is considered extensive, it may be prudent to exclude the entire population from the species being assessed. Exceptions may exist where the gene pool of a species is so small that inbreeding depression is evident, and genetic variability cannot be increased using individuals from the same genetic pool. In such situations, it may be prudent to interbreed the species with another closely related population of the same species to increase genetic variability and benefit from hybrid vigour, particularly where the species in question is otherwise expected to go extinct. This will at least preserve some of the genetic composition of the species and may restore its ecological role. However, the resultant recombinant population may be assessed as a separate population, with the original one considered extinct. Furthermore, this recombinant population would only be eligible for assessment if it is not dependent on continued introductions to persist and it does not pose a threat to the donor species contributing to the interbreeding efforts."

See Hutchings et al. (2008) for more details on hybridization issues.

Deriving Conservation Status from the Status Factors

Conservation status factors guide the consistent and rigorous recording of information to facilitate the assignment of a conservation status. This process of assigning a conservation status has been qualitative to date due to the challenges of assessing many thousands of species and ecosystems in a timely fashion. This qualitative approach to status assessment has led to issues with consistency, repeatability, and transparency of the status assessments. Extensive training and review have been used to minimize these problems, but subjective assessments are nonetheless influenced by personal judgments, perceptions of risk, and systemic biases. The effort to minimize these biases and inconsistencies has led to clearer guidance on the definitions of the status factors (this report) and to a more transparent, repeatable, and objective approach—a "rank calculator" that utilizes rules and point weightings to calculate conservation status based on information recorded for status factors (Faber-Langendoen et al. 2009a).

As NatureServe transitions to using the newly refined status factors and rank calculator, there are several considerations to keep in mind:

- The current conservation status ranks (available at www.natureserve.org/explorer) will not be in synchrony with the revised conservation status factors until those factors are evaluated for each species and ecosystem type, and the status rank is reassessed using the calculator. A new data field for recording the method that was used to assign conservation status will be utilized as a means of tracking how the status rank was determined.

- In the absence of sufficient data to use the calculator, some status ranks will remain temporarily subjective, although the assignment of range ranks helps to mitigate some of these unknowns.
- As has always been the case, some status assessments are based on less information than others (e.g., an assessment may be based simply on a review of published distribution, habitat, or museum collection information). Because the assessment is made on the known, available data, it may not necessarily reflect current status.
- In the absence of better information, some NatureServe global conservation status assessments have been based on review of national or subnational statuses, and some national status assessments have been based on review of subnational statuses.

Summary of the Status Factors and their Conditional Use

Table 1 summarizes the conservation status factors used by NatureServe, its member programs, and their collaborators to assess the conservation status of species and ecosystems. The factors are organized into three broad categories—**rarity**, **trends**, and **threats**—and a series of conditions (rules) are specified for whether, and how, each status factor should be used.

TABLE 1
Summary of NatureServe Conservation Status Factors.

Factor Category	Factor	Condition (Rule)
Rarity	Range Extent	Always use, if available
	Area of Occupancy	Always use, if available
	Population	Always use, if available (species only)
	Number of Occurrences	Always use, if available
	Number of Occurrences or Percent Area with Good Viability/Ecological Integrity	Always use, if available
	Environmental Specificity	Only use if both the Number of Occurrences ***and*** Area of Occupancy are Unknown or Null
Trends	Long-term Trend	Always use, if available
	Short-term Trend	Always use, if available
Threats	Threats	Always use, if available
	Intrinsic Vulnerability	Only use if Threats is Unknown or Null

Factor Data Types

The ten conservation status factors are each represented by at least two types of data fields, as follows.

- Coded value field(s) with associated words or short phrases; values can be expressed as either single capital letters (e.g., A, B) or as combinations to indicate an estimated range of uncertainty (e.g., AB, BD)
- Text comment field.

Additional Information of Interest

In addition to the ten NatureServe conservation status factors, several types of information may be recorded that could potentially influence the assignment of a conservation status. These information fields, described in more detail later in this document, are summarized in Table 2.

Definitions and guidance for use are provided individually for each factor in the "Conservation Status Factors" section beginning on page 11. See also "Some General Definitions" on page 5 for terms used in the discussion of multiple factors.

TABLE 2
Other Information Useful for Assessing Conservation Status.

Information of Interest	Description
Other Considerations	Optional text field for recording potentially relevant information, such as the results of a PVA analysis.
Number of Protected and Managed Occurrences	No longer used as a status factor, but may be used to record information potentially relevant to threats.
Rescue Effect	Used only at national and subnational (e.g., state/provincial) levels to potentially up-rank or down-rank a species.
Comparison of Global and National/Subnational Rank Information	Useful when assigning conservation status, especially when the national/subnational information is more current or detailed than the global information, or vice versa. A subnational rank cannot imply that a species or ecosystem is more secure at the state/province level than it is nationally or globally (e.g., a rank of G1S3 is invalid), and similarly, a national rank cannot exceed the global rank. Subnational ranks are assigned and maintained by state or provincial NatureServe network programs.

Picking a Coded Value

Assessors should adopt a moderate attitude, taking care to identify the most likely plausible range of values, excluding extreme or unlikely values. This is also the approach endorsed by the IUCN Standards and Petitions Working Group (2008). In many cases this will mean picking a code range (e.g., BC, BD) as the factor rating. Note that the "U = Unknown code" cannot be included in an estimated range of uncertainty.

■ ■ ■

This section details the Conservation Status Factors used by NatureServe, its member programs, and their collaborators to assess the conservation status of species and ecosystems (ecological community or system). Along with the detailed status factor descriptions, some guidance may be offered on how to assign values to each of the factors.

Range Extent

A Rarity Factor

Range extent for taxa can be defined as (modified from the International Union for the Conservation of Nature 2001):

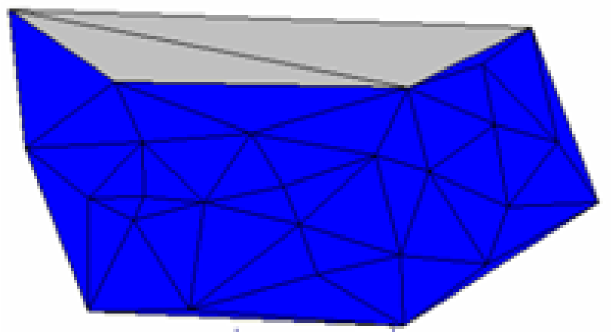
> Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary that can be drawn to encompass all the known, inferred, or projected sites of present occurrence of a taxon or ecosystem, excluding cases of vagrancy. While this measure may exclude discontinuities or disjunctions within the overall distribution of a taxon or type (e.g., large areas of obviously unsuitable habitat), such exclusions are discouraged except in extreme cases because these disjunctions and outlying occurrences accurately reflect the extent to which a large range size reduces the chance that the entire population of the taxon will be affected by a single threatening process. Risks are spread by the existence of outlying or disjunct occurrences irrespective of whether the range extent encompasses significant areas of unsuitable habitat. (emphasis added) (See also Area of Occupancy.)

The range extent criterion measures the spatial spread of areas currently occupied by a species or ecosystem, however it “is not intended to be an estimate of the amount of occupied or potential habitat, or a general measure of the taxon’s range” (IUCN 2001). The rationale behind the use of this parameter in assessing conservation status is to determine the degree to which risks from threatening factors are spread spatially across the geographic distribution of the species or ecosystem.

While range extent can be measured by a minimum convex polygon (or “convex hull”)—that is, the smallest polygon in which no internal angle exceeds 180 degrees and which contains all the sites of occurrence—there can be inaccuracies with the resulting estimates of range extent. When there are significant discontinuities or disjunctions in a species distribution, a minimum convex polygon yields a boundary with a very coarse level of resolution on its outer surface, resulting in a substantial overestimate of the range, particularly for irregularly shaped ranges (Ostro et al. 1999). The bias associated with range estimates based on convex hulls, and their sensitivity to sampling effort, may also cause problems when assessing trends if outliers are detected at one time and not another. To avoid either significantly overestimating range extent when there are sizeable disjunctions or discontinuities in a distribution, or misrepresenting the extent to which a taxon or type may be affected by a threat by reducing range size through exclusion of disjunctions and discontinuities, using a method such as the α-hull is recommended as it may substantially reduce the biases that can result from the spatial arrangement of occurrences.

The α-hull technique involves first drawing lines between all known or inferred points of occurrence for the species or ecosystem (i.e., drawing the convex hull). Next, any lines longer than a multiple, typically twice the average line length, are deleted from the first polygon (i.e., lines joining points that are relatively distant are deleted), such that the total range may be subdivided into more than one polygon. The final step is to calculate the range extent by summing the areas of all remaining triangles. For more

FIGURE 1.
Illustration of α-hull.
The lines show the Delauney triangulation (the intersection points of the lines are the species' or ecological community's occurrence locations). The sum of the areas of darker triangles is range extent based on the α-hull. The two lighter colored triangles that are part of the convex hull are excluded from the α-hull. (IUCN Standards and Petitions Working Group 2008)



details, see guidance provided by the IUCN Standards and Petitions Working Group (2008) and Burgman and Fox (2003). When using a GIS to measure the area of a polygon, it is important that the polygon is projected using an equal-area projection (e.g., Albers) for an accurate calculation.

Note that the use of α-hulls for determining range extent for a taxon or type with only one or two occurrences is not warranted as there are no disjunctions or discontinuities. For a single occurrence, the range extent may equal, or be slightly larger than, the area of known, inferred, or projected occupancy. Additional guidelines for the use of α-hulls will be forthcoming as additional tests are completed.

In the case of migratory species, range extent should be based on the minimum size of either the breeding or non-breeding (wintering) areas, whichever is smallest. For freshwater species and ecosystems, the extent of occurrence can be estimated by summing the areas of the eight-digit U.S. Geological Survey hydrologic units or watersheds of equivalent scale in which extant occurrences are located. This procedure is used by the IUCN Freshwater Species Specialist Group and is acceptable when the species range is the size of a watershed or larger.

Range Extent Fields

Enter the estimated range extent (a range is acceptable): ________ sq km. Also enter the rating code that best describes the estimated current range of the species or ecosystem in the area of interest (globe, nation, or subnation). See Figure 1 for a comparison with Area of Occupancy. Use only rating values pertinent to the size of the area of interest; for example, only the A, B, C, or D values would be used in the subnational status assessment for Delaware (area = 5,004 km^2) or for Prince Edward Island (area = 5,657 km^2). Use a value range (e.g., DE) to indicate uncertainty. (See "Picking a Coded Value" on page 10.)

Select from the following values:

Z = Zero (no occurrences believed extant; species presumed extinct or ecosystem believed eliminated throughout its range)[1]

A = <100 km^2 (less than about 40 square miles)

B = 100–250 km^2 (about 40–100 square miles)

C = 250–1,000 km^2 (100–400 square miles)

D = 1,000–5,000 km^2 (400–2,000 square miles)

E = 5,000–20,000 km^2 (2,000–8,000 square miles)

F = 20,000–200,000 km^2 (8,000–80,000 square miles)

G = 200,000–2,500,000 km^2 (80,000–1,000,000 square miles)

H = >2,500,000 km^2 (greater than 1,000,000 square miles)

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[1] Use a range rating that includes Z (e.g., ZA) when the species or ecosystem may be possibly extant.

U = Unknown

Null = Factor not assessed

Range Extent Comments

Discuss any uncertainties in estimating the Range Extent.

TABLE 3
Examples of Land Areas Approximating Each Range Extent Value Threshold.

Rating Values	Threshold (km^2)	Threshold (miles^2)	Examples	Approx. Area (km^2)	Approx. Area (miles^2)
North America					
A/B	100	~40	Montserrat	98	38
			Nantucket, MA	121	47
B/C	250	~100	Martha's Vineyard, MA	250	96
C/D	1,000	~400	Rocky Mountain National Park, CO	1,077	416
D/E	5,000	~2,000	Delaware	5,004	1,932
			Prince Edward Island	5,657	2,184
E/F	20,000	~8,000	New Jersey	19,342	7,468
			Massachusetts	20,264	7,824
F/G	200,000	~80,000	Nebraska	198,507	76,644
			Minnesota	206,028	79,548
G/H	2,500,000	~1,000,000	Combined area of Ontario and Quebec	2,609,271	1,007,500
Latin America					
A/B	10	4	Old growth forest of La Selva Biological Station, Costa Rica	11.7	4.5
	100	~40	Monteverde Cloud Forest Preserve, CR	105	41
B/C	250	~100	St. Kitts and Nevis	269	104
C/D	1,000	~400	Kalakmul Biosphere Reserve, Mexico	998	385
	2,000	~800	Cotacahi-Cayapas Natural Reserve, Ecuador	2,044	789
D/E	5,000	~2,000	Trinidad and Tobago	5,130	1,981
	10,000	~4,000	Puerto Rico	9,104	3,515
			Jamaica	10,990	4,243
E/F	20,000	~8,000	Belize	22,960	8,865
	50,000	~20,000	Costa Rica	51,100	19,730
	100,000	~40,000	Guatemala	108,890	42,042
			Cuba	110,860	42,803
F/G	200,000	~80,000	Uruguay	176,220	68,038
	1,000,000	~400,000	Venezuela	912,050	352,142
G/H	2,500,000	~1,000,000	Mexico	1,972,550	761,602
			Argentina	2,766,890	1,068,296

Area of Occupancy

A Rarity Factor

Area of occupancy for taxa can be defined as (modified from the International Union for the Conservation of Nature 2001):

> "…the area within its 'extent of occurrence', which is occupied by a taxon or ecosystem type, excluding cases of vagrancy. The measure reflects the fact that a taxon or type will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats. In some cases, (e.g., irreplaceable colonial nesting sites, crucial feeding sites for migratory taxa) the area of occupancy is the smallest area essential at any stage to the survival of existing populations of a taxon. The size of the area of occupancy will be a function of the scale at which it is measured, and should be at a scale appropriate to relevant biological or ecological aspects of the taxon or type, the nature of threats and the available data."

Distribution or habitat maps can be derived from interpretation of remote imagery and/or analyses of spatial environmental data, using either simple combinations of GIS data layers or by more formal statistical models. These maps can provide a basis for directly estimating area of occupancy and range extent for ecosystems, provided an accuracy assessment shows the map to be of sufficient reliability for the purpose of estimating area. Distribution and habitat maps can also provide an indirect estimate of area of occupancy (and range extent) for species; however, the following conditions must be met (IUCN Standards and Petitions Working Group 2008):

1) Maps must be justified as accurate representations of the habitat requirements of the species, and validated by a means that is independent of the data used to construct them.
2) The mapped area of suitable habitat must be interpreted (e.g., using an estimate of the proportion of habitat occupied) to produce an estimate of the area of occupied habitat.
3) The estimated area of occupied habitat derived from the map must be scaled to the grid size that is appropriate for the area of occupancy of the species (described below).

Estimating Area of Occupancy for Ecosystems

For ecosystems, measure or estimate area of occupancy based on the best available information. In linear habitats (e.g., riverine shorelines, riparian habitats, or cliffs), estimate the length of all currently occupied habitat segments. The area can be estimated by multiplying the length by the average width.

When assessing area of occupancy, consider what the typical spatial pattern of the type is across its range (i.e., its patch type), whether small patch, large patch, or matrix (if variable, choose the larger spatial pattern; see Table 4). The spatial pattern of the type may affect the relative role of the area of occupancy rating scale in assessing extinction risk. For example, extensive matrix types may require greater minimal areas than the current values for A and B ratings codes, whereas small patch types may require very little overall area and still be considered abundant. Observations related to how spatial patterns may affect the rating for this field should be recorded in the Comments field.

Patch Type	Definition
Matrix	Ecosystems that form extensive and contiguous cover, occur on the most extensive landforms, and typically have wide ecological tolerances. Disturbance patches typically occupy a relatively small percentage (e.g., <5%) of the total occurrence. In undisturbed conditions, **typical occurrences range in size from 2,000 to 10,000 ha (100 km^2) or more**.
Large Patch	Ecosystems that form large areas of interrupted cover and typically have narrower ranges of ecological tolerances than matrix types. Individual disturbance events tend to occupy patches that can encompass a large proportion of the overall occurrence (e.g., >20%). Given common disturbance dynamics, these types may tend to shift somewhat in location within large landscapes over time spans of several hundred years. In undisturbed conditions, **typical occurrences range from 50 to 2,000 ha**.
Small Patch	Ecosystems that form small, discrete areas of vegetation cover, typically limited in distribution by localized environmental features. In undisturbed conditions, **typical occurrences range from 1 to 50 ha**.
Linear	Ecosystems that occur as linear strips. They are often ecotonal between terrestrial and aquatic ecosystems. In undisturbed conditions, **typical occurrences range in linear distance from 0.5 to 100 km**.

TABLE 4
Definitions of Various Patch Types that Characterize the Spatial Patterning of Ecosystems.

Estimating Area of Occupancy for Species

> "Classifications of risk based on the area of occupancy are complicated by problems of spatial scale. There is a logical conflict between having fixed range thresholds and the necessity of measuring range at different scales for different taxa. The finer the scale at which the distributions or habitats are mapped, the smaller the area that they are found to occupy and the less likely that range estimates … exceed the thresholds specified in the criteria. Mapping at finer scales reveals more areas in which the taxon is unrecorded. The choice of scale may thus influence the outcome of the assessments and could be a source of inconsistency and bias." (IUCN Standards and Petitions Working Group 2008)

For species, the coded value for the area of occupancy should be obtained by "counting the number of occupied cells in a uniform grid that covers the entire range of a taxon and then tallying the number of occupied cells" (IUCN Standards and Petitions Working Group 2008). A grid of size 2 km (a cell area of 4 km^2) appears to provide a satisfactory grid scale as the basis for an estimate or index of area occupied. Thus, in line with IUCN, a scale of 2 km (grid of 4 km^2 cells) is recommended in order to ensure consistency and comparability of results. Ideally, the grid should be "moved" around and the minimum number of grid cells used in calculating area of occupancy.

The following two documents developed by NatureServe network program staff describe processes currently being tested which provide guidance for using a GIS to both create a grid, and then utilize the grid to calculate the area of occupancy automatically for use in conservation status assessments.[2]

- Using a GIS to Calculate Area of Occupancy Part 1: Creating a Shapefile Grid (R. Elliott, California Natural Diversity Database)
- Using a GIS to Calculate Area of Occupancy Part 2: Automated Calculation of Area (E. Prescott, British Columbia Conservation Data Centre)

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[2] Technical guidance on use of the grid is available from NatureServe upon request.

In the case of migratory species, estimates of area of occupancy (as with range extent) should be based on the minimum size of either the breeding or non-breeding (e.g., wintering, migratory stopover) areas, whichever is smallest. That is, the smallest area essential at any stage to the survival of existing populations of a taxon should be used for estimating area of occupancy.

For species occurring in and confined to linear habitats (e.g., shorelines, streams) and for which one has relatively precise locations and a relatively complete inventory, the Chair of the IUCN Standards and Petitions Working Group states (pers. comm.) that a 1x1 km grid can be used for estimating area of occupancy, rather than a 2x2 km grid or a measure of length x average breadth, as are used for ecosystems. Thus, for species, the linear distance of occupancy previously used as a status factor will no longer be needed in the assessment calculation. A 1 km^2 grid may be employed as described above instead of the 4 km^2 grid or, more simply (unless the linear features are meandering or densely dendritic), the length of occupied stream miles can be estimated and multiplied by 1 km.[3]

Area of Occupancy Fields

Enter the estimated area of occupancy (a range is acceptable): ________ km^2.

Enter the estimated linear distance of occupancy if appropriate: ________ km.

Enter the scale used for species (4 km^2 or 1 km^2 recommended): ________ km^2.

Also enter the rating code for the estimated current area of occupancy of the species or ecosystem in the area of interest (globe, nation, or subnation). Use a value range (e.g., DE) to indicate uncertainty (see "Picking a Coded Value" on page 10).

Select from the rating values for Area of Occupancy shown below, using Table 5a codes for species assessments and Table 5b codes for assessing ecosystems.

TABLE 5a
Species Area of Occupancy Codes Based on the Number of Occupied Grid Cells.

Species Area of Occupancy		
Code	**Number of 4 km^2 grid cells**	**Number of 1 km^2 grid cells**
Z	0	0
A	1	1–4
B	2	5–10
C	3–5	11–20
D	6–25	21–100
E	26–125	101–500
F	126–500	501–2,000
G	501–2,500	2,001–10,000
H	2,501–12,500	10,001–50,000
I	>12,500	>50,000
U	Unknown	Unknown

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[3] In addition to occurrences in linear habitats, the use of a 1 km^2 grid is also appropriate when occurrences are relatively well inventoried with relatively precise locational information and are confined to discrete well-mapped habitat patches (e.g., rock outcrops).

TABLE 5b

Ecosystem Area of Occupancy Codes Based on the Number of Km^2, Hectares or Acres.

Ecosystem Area of Occupancy			
Code	**Number of km^2**	**Number of hectares**	**Number of acres**
Z	0	0	0
A	<1	<100	<250
B	1–4	100–400	250–1,000
C	4–10	400–1,000	1,000–2,500
D	10–20	1,000–2,000	2,500–5,000
E	20–100	2,000–10,000	5,000–25,000
F	100–500	10,000–50,000	25,000–125,000
G	500–2,000	50,000–200,000	125,000–500,000
H	2,000–20,000	200,000–2,000,000	500,000–5,000,000
I	>20,000	>2,000,000	>5,000,000
U	Unknown	Unknown	Unknown

Note: The Z rating code implies the species is presumed extinct or the ecosystem is believed to be extirpated throughout its range. A range rank that includes Z (e.g., ZA) should be used for species or ecosystem where the only known occurrences have not been verified as extant, but they are still possibly extant (i.e., they are considered historical).

Area of Occupancy Comments

Discuss any uncertainties in estimating the Area of Occupancy.

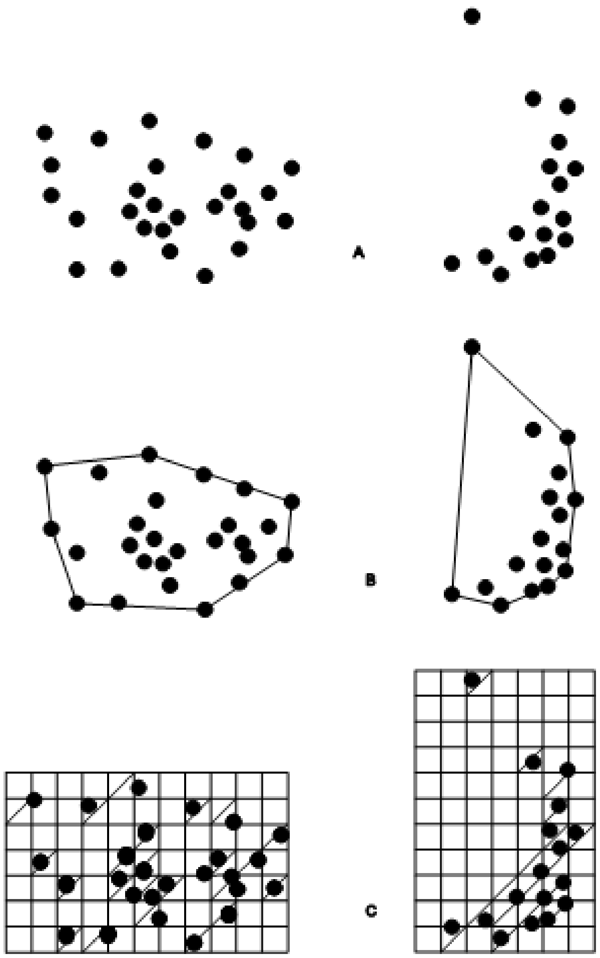

FIGURE 2.

Illustration of the Distinction Between Range Extent and Area of Occupancy.

(A) Is the spatial distribution of known, inferred, or projected sites of present occurrence.

(B) Shows one possible boundary to the Range Extent, which is the measured area within this boundary using a minimum convex hull or, preferably, an α-hull to avoid significant overestimates (right side of example B) in range.

(C) Shows one measure or index of Area of Occupancy, which can be achieved by the sum of the occupied grid squares.

For species, IUCN recommends that area should be estimated using 2 x 2 km grid cells. (IUCN Standards and Petitions Working Group 2008)

For ecological communities and systems estimates of absolute area are preferred for area of occupancy, given the greater accuracy in mapping stands.

(IUCN 2001)

Population Size

A Rarity Factor, Used Only for Species

Population size is the estimated current total population of the species which is naturally occurring and wild within the area of interest (globe, nation, or subnation), and that is of reproductive age or stage (at an appropriate time of the year), including mature but currently non-reproducing individuals, which should be included in counts or estimates.

As guidance, consider the following points (from IUCN 2001) when estimating population numbers (see also IUCN Standards and Petitions Working Group 2008):

- Juveniles, senescent individuals, and individuals in subpopulations whose densities are too low for fertilization to occur and who will never produce new recruits should not be counted as mature individuals. (See note below regarding clones.)
- In the case of populations with biased adult or breeding sex ratios, it is appropriate to use lower estimates for the number of mature individuals, which take this into account (e.g., the estimated effective population size).
- Where the population size fluctuates, use a lower estimate. In most cases this will be much less than the mean.
- Reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone (e.g., corals).
- In the case of taxa that naturally lose all or a subset of mature individuals at some point in their life cycle, the estimate should be made at the appropriate time, when mature individuals are available for breeding.
- Re-introduced individuals must have produced viable offspring before they are counted as mature individuals.

In addition, consideration should also be given to the following:

- For species that produce more than one generation per year, use the size of the smallest annual reproducing generation in estimations.
- For organisms that are only intermittently countable, consider population size to be the number of mature individuals in a typical 'good' year, but not a 'poor' year or an extraordinarily productive year. Although data will rarely be available, population size for such species should be conceptually considered as the median of the population over a ten-year or three-generation time span, whichever is longer.
- For seed-banking annual plants, consider whether number of individuals in a population is a potentially misleading factor; if so, this should be discussed in comments and the coded value left as null.[4]
- For clone-forming organisms that persist or spread locally but rarely, if ever, reproduce, consider the population size to be the number of distinct, self-maintaining clonal patches (approximating the number of genets), rather than the number of physiologically separate individuals (ramets).

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[4] For some types of organisms, such as some annual plants and invertebrates, for which thousands to millions of individuals typically may occur in a very small area, a coded value for the number of individuals should be left as null and the reason for this noted in the Population Size Comments field. This is because the number of individuals is used in calculating a conservation status, and a large number of individuals indicate a sense of security that is not warranted in this situation.

Population Size Fields (for Species)

Enter the population size (a range is acceptable): _________.

Select also from the following rating values. Use a value range (e.g., DE) to indicate uncertainty (see "Picking a Coded Value" on page 10).[4]

Z = Zero, no individuals believed extant (i.e., species presumed extinct)[5]
A = 1–50 individuals
B = 50–250 individuals
C = 250–1,000 individuals
D = 1,000–2,500 individuals
E = 2,500–10,000 individuals
F = 10,000–100,000 individuals
G = 100,000–1,000,000 individuals
H = >1,000,000 individuals
U = Unknown
Null = Factor not assessed

Population Size Comments

Discuss any difficulties or peculiarities in the assessment of population size. Note and justify a decision not to calculate a coded value for population size.[4]

Number of Occurrences

A Rarity Factor

An occurrence is an area of land and/or water in which a species or ecosystem is, or was, present. They represent "on-the-ground" locations where an element of biodiversity is found (i.e., the occurrence is extant or known to have recently occurred at a given location). (See detailed definition on page 5.) Guidance on how to delineate an occurrence is provided in NatureServe's "Element Occurrence Data Standard" (NatureServe 2002).

The significance of the Number of Occurrences factor relates to additional risks faced by taxa or ecosystems where the species or ecosystem is either fragmented into many small occurrences (units), or where most individuals are concentrated into one occurrence (unit). Issues regarding the viability or integrity of the occurrences are assessed separately in the Number of Occurrences or Percent Area with Good Viability/Ecological Integrity factor that follows.

For many taxa, information on number of populations, rather than occurrences, will be more available and can be used in addition to or instead of occurrence information. For purposes of this factor (as well as the Number of Occurrences or Percent Area with Good Viability/Ecological Integrity factor) and as related to species, the two terms are interchangeable. For more information, see the definitions of both occurrence and population in "Some General Definitions" on page 5.

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[5] Use a range including Z (e.g., ZA) where there may be extant individuals even though none are currently known.

Number of Occurrences Fields

Enter the estimated number of occurrences (a range is acceptable): ________.

Enter also the coded rating value for the estimated, inferred, or suspected number of occurrences believed extant for the species or ecosystem in the area of interest (globe, nation, or subnation). Use a value range (e.g., DE) to indicate uncertainty (see "Picking a Coded Value" on page 10). Select from the following values:

Z = 0 (zero) (i.e., species presumed extinct or ecosystem believed eliminated throughout its range)[6]

A = 1–5

B = 6–20

C = 21–80

D = 81–300

E = >300

U = Unknown

Null = Factor not assessed

Number of Occurrences Comments

Discuss any uncertainties in estimating the number of occurrences.

Number of Occurrences or Percent Area with Good Viability/Ecological Integrity

A Rarity Factor

For species, an occurrence with at least good (i.e., excellent-to-good) viability exhibits favorable characteristics with respect to population size and/or quality and quantity of occupied habitat; and, if current conditions prevail, the occurrence is likely to persist for the foreseeable future (i.e., at least 20–30 years) in its current condition or better. See Hammerson et al. (2008) for more details. For ecosystems, an occurrence has excellent-to-good ecological integrity when it exhibits favorable characteristics with respect to reference conditions for structure, composition, and function, operating within the bounds of natural or historic disturbance regimes, and is of exemplary size (Faber-Langendoen et al. 2008). One would expect only minor to moderate alterations to these characteristics for an occurrence to maintain good ecological integrity.

For many occurrences, viability or ecological integrity assessments or ranks have been applied by biologists and ecologists throughout the NatureServe network. For species, these Element Occurrence (EO) ranks estimate the probability of persistence of the occurrence. For ecosystems, the rank is a succinct assessment of the degree to which, under current conditions, an occurrence of an ecosystem matches reference conditions for that system, without any presumptions made about future status or persistence. Ranks for species and ecosystems are based on a set of "occurrence rank factors," namely size (including population size and/or occupied area), abiotic and biotic condition, and landscape context. These factors may be further refined to specific indicators or metrics. The overall ranks range from A = Excellent viability/integrity, to D = Poor viability/integrity.

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[6] Use a range including Z (e.g., ZA) where there may be extant occurrences even though none are currently known.

Occurrences ranked A or B indicate excellent or good viability/ecological integrity, respectively. Future threats are not used to 'downgrade' an occurrence rank, but ongoing events (e.g., successional changes, periodic unfavorable management) that are resulting in inexorable degradation of occurrence quality should be considered. See NatureServe's "Element Occurrence Data Standard" (NatureServe 2002 and subsequent revisions), Brown et al. (2004), Hammerson et al. (2008), and Faber-Langendoen et al. (2008) for additional explanation of occurrence viability and ecological integrity assessments.

For many taxa, information on number of 'populations' with good viability, rather than occurrences, will be more available and can be used in addition to or instead of occurrence information. For purposes of this factor (as well as the Number of Occurrences factor) and as related to species, the two terms are interchangeable. For more information, see the definitions of occurrence and of population on page 5.

As an alternative to using the estimated number of good occurrences, a companion field is provided based on "percentage of area with excellent or good viability or ecological integrity." This does not require knowledge of the number of occurrences (or populations). Instead, the total area occupied is recorded (see the Area of Occupancy status factor), and an estimate is made of the percentage of that area which has excellent-to-good viability/ecological integrity.

Number of Occurrences or Percent Area with Good Viability/Ecological Integrity Fields

Complete one or both of the following:

- Enter the estimated number of occurrences with excellent-to-good viability or ecological integrity (a range is acceptable): ________.
- Enter the estimated percentage of area occupied with excellent-to-good viability or ecological integrity (a range is acceptable): ________.

Select also from either or both of the following coded rating fields. As confidence in particular occurrence ranks will degrade with the passage of time, consider using a value range (e.g., BC, BD) to indicate the range of uncertainty in the fields below (see "Picking a Coded Value" on page 10).[7] Note that when both the Number of Occurrences with Good Viability/Ecological Integrity and Percent Area with Good Viability/Ecological Integrity fields below have assigned rating values, the more restrictive of the two values (i.e., indicating greater rarity) will be used for calculating conservation status.

Number of Occurrences with Good Viability/Ecological Integrity

A = No occurrences with excellent or good (assessed as A or B) viability or ecological integrity

B = Very few (1–3) occurrences with excellent or good viability or ecological integrity

C = Few (4–12) occurrences with excellent or good viability or ecological integrity

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[7] Widespread and ubiquitous (e.g., euryecious) species may have very few occurrences and, as with the Number of Occurrences, the number of occurrences with excellent or good viability may increase as the species habitats are fragmented. For these species, a coded value for the Number of Occurrences with Good Viability/Ecological Integrity should be left as null and the reason for this noted in the Comments field. This is because the number of occurrences with good viability is used in calculating a conservation status, and a small number of occurrences with good viability indicate a sense of concern that is not warranted in this situation.

D = Some (13–40) occurrences with excellent or good viability or ecological integrity

E = Many (41–125) occurrences with excellent or good viability or ecological integrity

F = Very many (>125) occurrences with excellent or good viability or ecological integrity

U = Unknown number of occurrences with excellent or good viability or ecological integrity

Null = Factor not assessed

Percent Area with Good Viability/Ecological Integrity

A = No area with excellent or good (assessed as A or B) viability or ecological integrity

B = Very small percentage (<5%) of area with excellent or good viability or ecological integrity

C = Small percentage (5–10%) of area with excellent or good viability or ecological integrity

D = Moderate percentage (11–20%) of area with excellent or good viability or ecological integrity

E = Good percentage (21–40%) of area with excellent or good viability or ecological integrity

F = Excellent percentage (>40%) of area with excellent or good viability or ecological integrity

U = Unknown percentage of area with excellent or good viability or ecological integrity

Null = Factor not assessed

Number of Occurrences or Percent Area with Good Viability/Ecological Integrity Comments

Discuss specific details and provide additional information, such as the number of occurrences with fair or poor viability or ecological integrity.

Environmental Specificity

A Rarity Factor

Note that this status factor is only used if information on other Rarity factors is not available. (See Table 1.)

Environmental Specificity is the degree to which a species or ecosystem depends on a relatively scarce set of habitats, substrates, food types, or other abiotic and/or biotic factors within the overall range. Relatively narrow requirements are thought to increase the vulnerability of a species or ecosystem. This factor is most important when the number of occurrences, and the range extent or area of occupancy, are largely unknown.

Environmental Specificity Fields

Select from the following values:

A = Very Narrow. Specialist or ecosystem with key requirements scarce. For species, specific habitat(s), substrate(s), food type(s), hosts, breeding/non-breeding microhabitats, or other abiotic and/or biotic factor(s) are used or required by the species or ecosystem in the area of interest, with these habitat(s) and/or other requirements furthermore being scarce within the generalized range of the species or ecosystem within the area of interest, and the population (or the number of breeding attempts) expected to decline significantly if any of these key requirements become unavailable. For ecosystems, environmental requirements are both narrow and scarce (e.g., calcareous seepage fens).

B = Narrow. Specialist or ecosystem with key requirements common. Specific habitat(s) or other abiotic and/or biotic factors (see above) are used or required by the species or ecosystem, but these key requirements are common and within the generalized range of the species or ecosystem within the area of interest. For ecosystems, environmental requirements are narrow but common (e.g., floodplain forest, alpine tundra).

C = Moderate. Generalist or community with some key requirements scarce. Broad-scale or diverse (general) habitat(s) or other abiotic and/or biotic factors are used or required by the species or ecosystem, but some key requirements are scarce in the generalized range of the species or ecosystem within the area of interest. For ecosystems, environmental requirements are broad but scarce (e.g., talus or cliff forests and woodlands, alvars, many rock outcrop communities dependent more on thin, droughty soils per se than specific substrate factors).

D = Broad. Generalist or community with all key requirements common. Broad-scale or diverse (general) habitat(s) or abiotic and/or biotic factors are used or required by the species or ecosystem, with all key requirements common in the generalized range of the species or ecosystem in the area of interest. For animals, if the preferred food(s) or breeding/non-breeding microhabitat(s) become unavailable, the species switches to an alternative with no resulting decline in numbers of individuals or number of breeding attempts. For ecosystems, environmental requirements are broad and common (e.g., forests or prairies on glacial till, or forests and meadows on montane slopes).

U = Unknown

Null = Factor not assessed

Environmental Specificity Comments

Describe the reasons for the value selected to indicate Environmental Specificity, such as how and why Environmental Specificity affects vulnerability of the species or ecosystem. Fields in the CHARACTERIZATION ABSTRACTS files in the NatureServe Biotics 4 data management system should be used to record detailed habitat requirements; specifically, for species use the “Global Habitat Comments” field on the HABITAT tab, and for ecosystems, use the “Key Environmental Factors” field on the ENVIRONMENTAL SUMMARY tab.

Long-term Trend

A Trends Factor

Long-term Trend Fields

Enter the rating code that best describes the observed, estimated, inferred, or suspected degree of change in population size, extent of occurrence (range extent), area of occupancy, number of occurrences, and/or number of occurrences or percent area with good viability or ecological integrity over the long term (ca. 200 years) in the area of interest (globe, nation, or subnation). Use a value range (e.g., DE) to indicate uncertainty (see "Picking a Coded Value" on page 10).

A = Decline of >90%

B = Decline of 80–90%

C = Decline of 70–80%

D = Decline of 50–70%

E = Decline of 30–50%

F = Decline of 10–30%

G = Relatively Stable (≤10% change)

H = Increase of 10–25%

I = Increase of >25%

U = Long-term trend unknown

Null = Factor not assessed

Enter the estimated Long-term Trend (a range is acceptable): _________.

Long-term Trend Comments

Specify the time period for the change noted, as well as a longer-term view (e.g., back to European or Polynesian exploration) if information is available. If there are data on more than one aspect, specify which aspect is most influential.

Short-term Trend

A Trends Factor

Short-term Trend Fields

Enter the rating code that best describes the observed, estimated, inferred, or suspected degree of change in population size, extent of occurrence (range extent), area of occupancy, number of occurrences, and/or number of occurrences or percent area with good viability or ecological integrity over the short term, whichever most significantly affects the conservation status assessment in the area of interest (globe, nation, or subnation). Consider short-term historical trend within ten years or three generations (for long-lived taxa), whichever is the longer (up to a maximum of 100 years), or, for communities and systems, typically 30 years, depending on the characteristics of the type.

The trend may be recent or current, and the trend may or may not be known to be continuing. Trends may be smooth, irregular, or sporadic. Fluctuations will not normally count as trends, but an observed change should not be considered as merely a fluctuation rather than a trend unless there is evidence for this.

In considering trends, do not consider newly discovered but presumably long existing occurrences, nor newly discovered individuals in previously poorly known areas. Also, consider fragmentation of previously larger occurrences into a greater number of smaller occurrences to represent a decreasing area of occupancy as well as decreasing number of good occurrences or populations.

Select from the following rating values. Use a value range (e.g., DE) to indicate uncertainty (see "Picking a Coded Value" on page 10).

A = Decline of >90%

B = Decline of 80–90%

C = Decline of 70–80%

D = Decline of 50–70%

E = Decline of 30–50%

F = Decline of 10–30%

G = Relatively Stable (≤10% change)

H = Increase of 10–25%

I = Increase of >25%

U = Short-term trend unknown

Null = Factor not assessed

Enter the estimated Short-term Trend (a range is acceptable): ________.

Short-term Trend Comments

Specify what is known about various pertinent trends, including trend information for particular factors, more precise information, regional trends, etc. Also comment, if known, on whether the causes of decline, if any, are understood, reversible, and/or have ceased. If there is knowledge that a trend is not continuing, that should also be specified.

Threats: Severity, Scope, Impact, and Timing

A calculation of overall Threat impact indicates the degree to which a species or ecosystem is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest (globe, nation, or subnation). Direct threats are defined as "the proximate (human) activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity and natural processes" (Salafsky et al. 2008). For example, a direct threat may be trawling or logging. The term is synonymous with sources of stress and proximate pressures (Salafsky et al. 2008) or with "stressors" as used by the U.S. Environmental Protection Agency (Young and Sanzone 2002). In the categorization of Threats and the calculation of overall Threat, what may be called "indirect threats" are not included. Synonymous with drivers or root causes, indirect threats are "the ultimate factors, usually social, economic, political, institutional, or cultural, that enable or otherwise add to the occurrence or persistence of proximate direct threats (e.g., a factory [indirect threat] discharges heavy metals [direct threat] into a stream). There is typically a chain of contributing factors behind any direct threat" and the negative contributing factors are indirect threats (Salafsky et al. 2008).

For the most part, direct threats are related to human activities, but they may be natural. The impact of human activity may be direct (e.g., destruction of habitat) or indirect (e.g., invasive species introduction). Effects of natural phenomena (e.g., fire, hurricane, flooding) may be especially important when the species or ecosystem is concentrated in one location or has few occurrences, which may be a result of human activity. Strictly speaking, these natural phenomena may be part of natural disturbance regimes, but they need to be considered a Threat if a species or habitat is damaged from other threats and has lost its resilience, and is thus vulnerable to the disturbance (Salafsky et al. 2008). In the absence of information on Threats, characteristics of the species or ecosystem that make it inherently susceptible to threats should be considered under the NatureServe status factor Intrinsic Vulnerability (on page 33).

For purposes of status assessment, Threat impact is calculated considering only present and future threats. Past threats are recorded under "timing" but are not used in the calculation of threat impact. For conservation status assessment purposes, effects of past threats (if not continuing) are addressed indirectly under the Long-term Trend and/or Short-term Trend factors. (For species or ecological communities and systems known only historically in the area of interest but with significant likelihood of rediscovery in identifiable areas, current or foreseeable threats in those areas may be addressed here where appropriate if they would affect any extant [but unrecorded] occurrences of the species or ecosystem.)

Threats may be observed, inferred, or projected to occur in the near term, and they may be characterized in terms of scope, severity, and timing. Threat "impact" is calculated from Threat scope and severity (see below). The draft[8] scheme presented here for characterizing scope, severity, and timing (immediacy) is being developed by IUCN-CMP (Conservation Measures Partnership), and is very loosely derived from a scheme used by Birdlife International.

Scope

Scope is defined herein as the proportion of the species or ecosystem that can reasonably be expected to be affected (that is, subject to one or more stresses) by the Threat within ten years with continuation of current circumstances and trends (Table 6). Current circumstances and trends include both existing as well as potential new threats. The ten-year time frame can be extended for some longer-term threats, such as global warming, that need to be addressed today. For species, scope is measured as the proportion of the species' population in the area of interest (globe, nation, or subnation) affected by the Threat. For ecosystems, scope is measured as the proportion of the occupied area of interest (globe, nation, or subnation) affected by the Threat. If a species or ecosystem is evenly distributed, then the proportion of the population or area affected is equivalent to the proportion of the range extent affected by the Threat; however, if the population or area is patchily distributed, then the proportion differs from that of range extent.

TABLE 6
Proposed IUCN-CMP Scoring of the Scope of Threats.

IUCN-CMP [draft] Scope of Threats Scoring	
Pervasive	Affects all or most (71–100%) of the total population or occurrences
Large	Affects much (31–70%) of the total population or occurrences
Restricted	Affects some (11–30%) of the total population or occurrences
Small	Affects a small (1–10%) proportion of the total population or occurrences

Note: Scope is typically assessed within a ten-year time frame.

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[8] This IUCN-CMP threat characterization and impact calculation scheme is expected to be finalized in 2009.

Severity

Within the scope (as defined spatially and temporally in assessing the scope of the Threat), severity is the level of damage to the species or ecosystem from the Threat that can reasonably be expected with continuation of current circumstances and trends (including potential new threats) (Table 7). Note that severity of Threats is assessed within a ten-year or three-generation time frame, whichever is longer (up to 100 years).

For species, severity is usually measured as the degree of reduction of the species' population. Surrogates for adult population size (e.g., area) should be used with caution, as occupied areas, for example, will have uneven habitat suitability and uneven population density. For ecosystems, severity is typically measured as the degree of degradation or decline in integrity (of one or more key characteristics).

TABLE 7
Proposed IUCN-CMP Scoring of the Severity of Threats.

IUCN-CMP [draft] Severity of Threats Scoring	
Extreme	Within the scope, the Threat is likely to destroy or eliminate the occurrences of an ecological community, system or species, or reduce the species population by 71–100%
Serious	Within the scope, the Threat is likely to seriously degrade/reduce the effected occurrences or habitat or, for species, to reduce the species population by 31–70%
Moderate	Within the scope, the Threat is likely to moderately degrade/reduce the effected occurrences or habitat or, for species, to reduce the species population by 11–30%
Slight	Within the scope, the Threat is likely to only slightly degrade/reduce the effected occurrences or habitat or, for species, to reduce the species population by 1–10%

Note: Severity is assessed within a ten-year or three-generation time frame, whichever is longer (up to 100 years).

Impact

Threat impact (or magnitude) is the degree to which a species or ecosystem is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest (globe, nation, or subnation). The impact of a Threat is based on the interaction between assigned scope and severity values, and includes categories of Very High, High, Medium, and Low. Details on calculating impacts from both individual Threats and all Threats collectively are provided in the Threats Assessment Process described below.

Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. As shown in Table 8, the median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of Threat impact: Very High (75% declines), High (40%), Medium (15%) and Low (3%).

TABLE 8
The Relationship of Threat Impact and Population Reduction or Ecosystem Decline or Degradation.

		Scope (%)			
		Pervasive	Large	Restricted	Small
Severity (%)	Extreme	🟥 50–100	🟨 22–70	⬜ 8–30	🟩 1–10
	Serious	🟨 22–70	🟨 10–49–	⬜ 3–21	🟩 1–7
	Moderate	⬜ 8–30	⬜ 3–21	🟩 1–9	🟩 0.1–3
	Slight	🟩 1–10	🟩 0–7	🟩 1–3	🟩 <1

🟥 Very High
🟨 High
⬜ Medium
🟩 Low

For species, these impacts should correspond to ongoing and projected population reductions resulting from combinations of scope and severity. Impacts to ecological communities and systems should represent ongoing and projected declines or degradation of area.

Timing

Although timing (immediacy) is recorded for Threats to the area of interest (globe, nation, or subnation), it is not used in the calculation of Threat impact.

TABLE 9
Birdlife International and Proposed IUCN-CMP (and NatureServe) Scoring of Threat Timing.

IUCN-CMP [draft] Timing of Threats Scoring	
High	Continuing
Moderate	Only in the future (could happen in the short term [less than ten years or three generations]), or now suspended (could come back in the short term)
Low	Only in the future (could happen in the long term), or now suspended (could come back in the long term)
Insignificant/ Negligible	Only in the past and unlikely to return, or no direct effect but limiting

Recording Threats and Calculating Threat Impacts

The scope, severity, and timing of any individual Threats observed, inferred, or suspected to be directly or indirectly affecting a species or ecosystem are recorded using the IUCN-CMP Classification of Threats presented in Table 14 on page 31 (see also Salafsky et al. 2008). There are 11 broad (“Level 1”) categories of Threats, and each of these Level 1 Threats includes 3–6 more specific, finer (“Level 2”) Threats. The process for recording the Threats identified for a species or ecosystem and calculating the impacts of these Threats is described below as a series of steps. Table 13 (page 31) summarizes the values (including value ranges to express uncertainty) to be used for recording scope, severity, impact, and timing.

Threats Assessment Process

1. Record in the Classification of Threats (Table 14) an estimate of the scope, severity, and timing for applicable individual Threats to the species or ecosystem that are either:

- Level 2 Threats; or
- Level 1 Threat categories for which Level 2 Threats will not be recorded.

Note: If only Level 1 Threat categories are being recorded for the species or ecosystem, skip step 3 below.

2. Apply the scope and severity values recorded in step 1 to the matrix below (Table 10) to calculate and record the impact (i.e., magnitude) for each assessed Threat. If the assigned scope or severity value is a range, evaluate the highest values in the range for scope with the highest for severity and then evaluate the pair of lowest values to determine the range of Threat impact.

TABLE 10
Calculation of Threat Impact.

		Scope			
		Pervasive	Large	Restricted	Small
Severity	Extreme	Very High	High	Medium	Low
	Serious	High	High	Medium	Low
	Moderate	Medium	Medium	Low	Low
	Slight	Low	Low	Low	Low

3. Record an estimate of scope, severity, and impact for each Level 1 Threat category that contains one or more assessed Level 2 Threats, based on the values of these Level 2 Threats as follows:

- If there is only one Level 2 Threat recorded in the Level 1 category, assign the scope, severity, impact, and timing values of this Level 2 Threat to the Level 1 Threat in which it is included;
- If there are multiple Level 2 Threats recorded in the Level 1 category, evaluate their degree of overlap:
    - » If the Level 2 Threats overlap, identify which of them has the highest impact and assign the scope, severity, and impact values of this Level 2 Threat to the Level 1 category in which it is included;
    - » If the Level 2 Threats are substantially non-overlapping, then higher scope and severity values may be justified for the Level 1 category in which they are included, and best professional judgment should be used to assign scope, severity, impact, and timing values to that Level 1 Threat.

Range values may be appropriate for a Level 1 Threat category when one or more of the Level 2 Threats contained within have an assigned range value.

4. After impact has been recorded for all applicable Level 1 Threat categories, use these impact values to calculate an overall Threat impact for the species or ecosystem according to the guidelines in Table 12. These guidelines were developed by taking the midpoint range of a particular impact rating and determining how many additional independent Threats would be needed to increase the overall impact to the midpoint of the next level (see Table 11).

TABLE 11
Median Impact Values for Each Matrix Cell, and the Resulting Midpoint of Each Threat Impact Level.

		Scope (%)				**Impact Level Midpoints**	
		Pervasive	Large	Restricted	Small		
Severity (%)	Extreme	75.0	46.0	19.0	5.5	75.0%	🟥 Very High
	Serious	46.0	29.5	12.0	4.0	40.5%	🟨 High
	Moderate	19.0	12.0	5.0	1.6	15.5%	⬜ Medium
	Slight	5.5	3.5	2.0	0.5	3.4%	🟩 Low

Note: Median values are based on the population reduction or ecosystem decline or degradation percentages shown in Table 8.

Using the above table, for example, four Threats with Low impact ratings (thus each with midpoint of 3.4%) would be estimated to have an overall impact of 14%, which is very near the midpoint of the Medium impact level (15%). Note that if the value for one or more Level 1 impacts is a range, evaluate the highest (single and range) values for every Level 1 Threat using Table 12 and then evaluate the lowest values to determine the range of overall Threat impact. For example, three Medium–Low Threat impacts indicate an overall Threat impact of High–Low, and four Medium–Low impacts indicate an overall Threat impact of High–Medium.

Table 12 provides general guidance for determining overall impact, and values resulting from its use should be considered first approximations. For example, these guidelines may be too liberal if the Level 1 Threat categories mostly overlap geographically, or too conservative if the scope and severity ratings for Level 1 Threats are mostly greater than the median value for each range and thus mostly greater than the median values shown in Table 11 for Threat impact. Best professional judgment should always be applied when assigning the final overall Threat impact.

TABLE 12
Guidelines for Assigning Overall Impact Value.

Impact Values of Level 1 Threat Categories	**Overall Threat Impact**
≥1 Very High, ***or*** ≥2 High, ***or*** 1 High + ≥2 Medium	Very High
1 High, ***or*** ≥3 Medium, ***or*** 2 Medium + 2 Low, ***or*** 1 Medium + ≥3 Low	High
1 Medium, ***or*** ≥4 Low	Medium
1–3 Low	Low

Once calculated, record the assigned overall impact value or value range in the Overall Threat Impact field, and add notes to the Threat Comments field, particularly if the overall Threat impact value was adjusted.

Note that for long-distance migratory animals, the calculation of overall Threat impact should be based on the combination of highest impact Level 1 Threat categories at any one season (e.g., breeding, wintering, migration) rather than an aggregation of all the Level 1 impacts that occur throughout the different seasons. Use the Threat Comments field to discuss the Threats at different seasons.

Threats Fields

At a minimum, the Overall Threat Impact and Threat Comments fields should be recorded for a species or ecosystem, as well as the scope, severity, impact, and timing of applicable Level 1 Threat categories in the Classification of Threats (Table 14).

Record information on specific Threats and the calculated Threat impacts in the IUCN-CMP Classification of Threats provided in Table 14 (see also Salafsky et al. 2008) according to the Threats Assessment Process described above. Values to be assigned for scope, severity, impact, and timing in the Threats classification table are provided in Table 13, along with plausible ranges of values that can be used to indicate uncertainty. For definitions of the scoring values, see Table 6 for scope, Table 7 for severity, and Table 9 for timing. See Table 10 for the calculation of impact.

Note that value ranges should not be used to indicate an estimated range of variation, but rather to indicate uncertainty. In cases where there is a range of variation, an average should be used instead of a value range (e.g., if the severity of a Threat varies across its scope, an average severity should be used instead of a range).

TABLE 13
Values Proposed by IUCN-CMP for Scoring Individual Threats.

Proposed IUCN-CMP Individual Threats Scoring Values			
Scope	**Severity**	**Impact**	**Timing**
Pervasive	Extreme	Very High	High
Large	Serious	High	Moderate
Restricted	Moderate	Medium	Low
Small	Slight	Low	Insignificant/ Negligible
Value ranges that can be used to express uncertainty			
Pervasive–Large	Extreme–Serious	Very High–High	High–Moderate
Pervasive–Restricted	Extreme–Moderate	Very High–Medium	High–Low
Large–Restricted	Serious–Moderate	High–Medium	Moderate–Low
Large–Small	Serious–Slight	High–Low	Moderate–Insignificant/ Negligible
Restricted–Small	Moderate–Slight	Medium–Low	Low–Insignificant/Negligible

In transitioning from the pre-2009 NatureServe conservation status assessment process to that described in this document, the proposed IUCN-CMP values for scope and severity are sufficiently close to those used by NatureServe that no conversion will be necessary. However, the IUCN-CMP values for timing differ enough that it is recommended that the NatureServe data recorded for immediacy be discarded and new timing values recorded.

TABLE 14
Classification of Threats (adopted from IUCN-CMP, Salafsky et al. 2008).

Threat No.	Threat Description	Scope	Severity	Impact	Timing
1	Residential & Commercial Development				
1.1	Housing & Urban Areas				
1.2	Commercial & Industrial Areas				
1.3	Tourism & Recreation Areas				
2	Agriculture & Aquaculture				
2.1	Annual & Perrenial Non-Timber Crops				
2.2	Wood & Pulp Plantations				
2.3	Livestock Farming & Ranching				
2.4	Marine & Freshwater Aquaculture				
3	Energy Production & Mining				
3.1	Oil & Gas Drilling				
3.2	Mining & Quarrying				
3.3	Renewable Energy				
4	Transportation & Service Corridors				
4.1	Roads & Railroads				
4.2	Utility & Service Lines				
4.3	Shipping Lanes				
4.4	Flight Paths				

TABLE 14 (cont.)

Threat No.	Threat Description	Scope	Severity	Impact	Timing
5	Biological Resource Use				
5.1	Hunting & Collecting Terrestrial Animals				
5.2	Gathering Terrestrial Plants				
5.3	Logging & Wood Harvesting				
5.4	Fishing & Harvesting Aquatic Resources				
6	Human Intrusions & Disturbance				
6.1	Recreational Activities				
6.2	War, Civil Unrest & Military Exercises				
6.3	Work & Other Activities				
7	Natural System Modifications				
7.1	Fire & Fire Suppression				
7.2	Dams & Water Management/Use				
7.3	Other Ecosystem Modifications				
8	Invasive & Other Problematic Species & Genes				
8.1	Invasive Non-Native/Alien Species				
8.2	Problematic Native Species				
8.3	Introduced Genetic Material				
9	Pollution				
9.1	Household Sewage & Urban Waste Water				
9.2	Industrial & Military Effluents				
9.3	Agricultural & Forestry Effluents				
9.4	Garbage & Solid Waste				
9.5	Air-Borne Pollutants				
9.6	Excess Energy				
10	Geological Events				
10.1	Volcanoes				
10.2	Earthquakes/Tsunamis				
10.3	Avalanches/Landslides				
11	Climate Change & Severe Weather				
11.1	Habitat Shifting & Alteration				
11.2	Droughts				
11.3	Temperature Extremes				
11.4	Storms & Flooding				

Overall Threat Impact

- Very High
- High
- Medium
- Low
- Unknown
- Null = Factor not assessed

The following overall impact ranges are also permissible for expressing uncertainty:

- Very High–High
- Very High–Medium
- High–Medium
- High–Low
- Medium–Low

Threat Comments

Discuss individual threats as well as overall threat impact. Whenever possible, use the standardized IUCN-CMP names for threats (shown in the Classification of Threats, Table 14).

Intrinsic Vulnerability

A Threats Factor

Note that this factor is not used if the Threats status factor has been assessed. (See Table 1 on page 9.)

Intrinsic Vulnerability is the observed, inferred, or suspected degree to which characteristics of the species or ecosystem (such as life history or behavior characteristics of species, or likelihood of regeneration or recolonization for ecosystems) make it vulnerable or resilient to natural or anthropogenic stresses or catastrophes. For ecosystems, Intrinsic Vulnerability is most readily assessed using the dominant species and vegetation structure that characterize the ecosystem, but it can also refer to ecological processes that make an ecosystem vulnerable or lack resiliency (e.g., shoreline fens along estuarine and marine coasts subject to rising sea levels).

Since geographically or ecologically disjunct or peripheral occurrences may show additional vulnerabilities not generally characteristic of a species or ecosystem, characteristics of Intrinsic Vulnerability are to be assessed for the species or ecosystem throughout the area of interest, or at least for its better occurrences. Information on population size, number of occurrences, area of occupancy, extent of occurrence, or environmental characteristics that affect resiliency should not be considered when assessing Intrinsic Vulnerability; these are addressed using other status factors.

Note that the Intrinsic Vulnerability characteristics exist independent of human influence, but may make the species or ecosystem more susceptible to disturbance by human activities. The extent and effects of current or projected extrinsic influences themselves should be addressed in the comments field of the Threats status factor.

Intrinsic Vulnerability Fields

Select from the following values:

A = Highly Vulnerable. Species is slow to mature, reproduces infrequently, and/or has low fecundity such that populations are very slow (>20 years or five generations) to recover from decreases in abundance; or species has low dispersal capability such that extirpated populations are unlikely to become reestablished through natural recolonization (unaided by humans). Ecosystem occurrences are highly susceptible to changes in composition and structure that rarely if ever are reversed through natural processes even over substantial time periods (>100 years).

B = Moderately Vulnerable. Species exhibits moderate age of maturity, frequency of reproduction, and/or fecundity such that populations generally tend to recover from decreases in abundance over a period of several years (on the order of 5–20 years or 2–5 generations); or species has moderate dispersal capability such that extirpated populations generally become reestablished through natural recolonization (unaided by humans). Ecosystem occurrences may be susceptible to changes in composition and structure but tend to recover through natural processes given reasonable time (10–100 years).

C = Not Intrinsically Vulnerable. Species matures quickly, reproduces frequently, and/or has high fecundity such that populations recover quickly (<5 years or 2 generations) from decreases in abundance; or species has high dispersal capability such that extirpated populations soon become reestablished through natural recolonization (unaided by humans). Ecosystem occurrences are resilient or resistant to irreversible changes in composition and structure and quickly recover (within 10 years).

U = Unknown

Null = Factor not assessed

Intrinsic Vulnerability Comments

Describe the reasons for the value selected to indicate Intrinsic Vulnerability. Examples for species include reproductive rates and requirements, time to maturity, dormancy requirements, and dispersal patterns. For ecosystems, describe the characteristics of the community that are thought to be intrinsically vulnerable and the ecological processes on which these characteristics depend. For example, an ecosystem type may be defined by old growth features that require more than150 years to recover its structure and composition after a blowdown; a pine forest type may be highly dependent on timing of masting or availability of seed sources to recover after a catastrophic fire; a wetland may be dependent on periodic drawdowns or flash flooding for regeneration of its species; a desert shrubland ecosystem with an abundant cryptogram crust (important for nutrient cycling, N-fixation, and moisture retention) may take a long time (>50 years) to recover an intact crust after disturbance due to the slow growth of the cryptogram layer.

Other Considerations

Not a status factor, but a field for recording information not captured in the status factors.

Other Considerations Field

Provide and comment on any other information that should be considered in the assignment of NatureServe conservation status. Including comments in this field is particularly important when the conservation status resulting from the overall assessment is different from the status that the values for the formal status factors, taken alone, would suggest. This field may also be used for other general notes pertinent to multiple status factors.

The following are some examples of Other Considerations:

- A population viability analysis may indicate that the species has x-percent probability of surviving for y years (or an equivalent number of generations) in the same area of interest (globe, nation, or subnation).
- NatureServe global conservation status is based primarily on particular national or subnational status(es), or national status is based on particular subnational status(es).

Rescue Effect

Note that this factor and its associated data are used only for national- and subnational-level conservation status assessments for species.

Rescue Effect is the process by which immigrating propagules result in a lower extinction risk for the population being assessed (see IUCN 2003). Questions to be considered in making this judgment are shown below.

For example, if the jurisdictional population being assessed experiences any significant immigration of propagules capable of reproducing in the jurisdiction and the immigration is not expected to decrease, changing the conservation status to a lower risk category may be appropriate. Normally, such a downgrading will involve a half-step or one-step change in status, such as changing the status from Imperiled (S2) to Vulnerable (S3), but for expanding populations whose global range barely touches the edge of the jurisdiction, a change of two or more ranks may be appropriate. Similarly, if the jurisdiction is very small and not isolated by barriers from surrounding regions, downgrading by two or more ranks may be appropriate. Conversely, if the population within the jurisdiction is a demographic sink that is unable to sustain itself without immigration from populations outside the region, ***and*** if the extra-jurisdictional source is expected to decrease, the extinction risk of the target population may be underestimated by the criteria. In such exceptional cases, changing the status to a higher risk category may be appropriate.

For non-breeding (e.g., wintering) migratory species, changing the conservation status to a lower risk category may be appropriate if the breeding population could rescue the target population should it decline, and assuming that conditions inside and outside the jurisdiction are not deteriorating.

Questions to be Considered

Breeding populations:

- Does the national/subnational population experience any significant immigration of propagules likely to reproduce in the region? (Y/N/U)
- Is the immigration expected to decrease? (Y/N/U)
- Is the national/subnational population a sink (an area where the local reproduction of a taxon is lower than local mortality)? (Y/N/U)
- What is the distance to the next population, if not contiguous? ________ km.

Visiting populations (i.e., populations that are regularly occurring but non-breeding in the jurisdiction):

- Are the conditions outside the nation/subnation deteriorating? (Y/N/U)
- Are the conditions within the nation/subnation deteriorating? (Y/N/U)
- Can the breeding population rescue the national/subnational population should it decline (plausibility of a Rescue Effect)? (Y/N/U)

Rescue Effect Fields

Enter the Rescue Effect (e.g., -1, -½, 0, +½, +1, +1½, +2): ________.

Rescue Effect Comments

Discuss any uncertainties in estimating the Rescue Effect.

■ ■ ■

Conservation Status Rank Qualifiers

As briefly described in Appendix A, there are three qualifiers that may be appended to conservation status ranks: **?** = imprecision, **Q** = questionable taxonomy, and **C** = captive or cultivated (for species only). These qualifiers are used either to indicate the degree of uncertainty associated with an assigned status rank, or to provide additional information about the ecosystem or taxon that has been assessed.

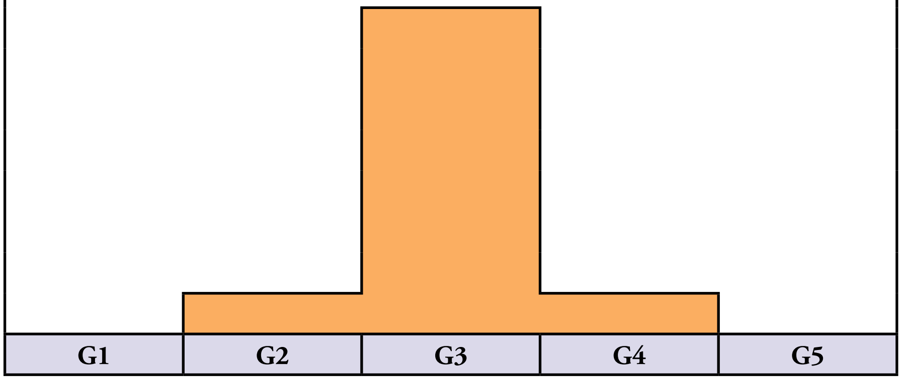
? – Inexact Numeric Rank. The addition of a ? qualifier to a 1–5 conservation status rank denotes that the assigned rank is imprecise. This qualifier is used only with the numeric status ranks, not with X, H, or U ranks, or range ranks. As described in previous sections, uncertainty about the exact status of a species or ecosystem is usually denoted by a range rank, with the range indicating the degree of uncertainty; however a #? may also be used. Figure 3 illustrates the uncertainty associated with different status ranks.

FIGURE 3

Comparison of Uncertainty Associated with Examples of an Exact Status Rank, Rank with "?" Qualifier, and Range Ranks. (Credit: Larry Morse.)

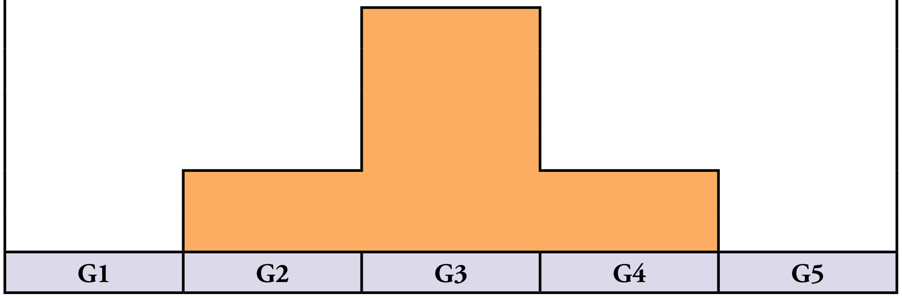
Exact Rank (G3)

Available information indicates G3 rank, but slight probability of either G2 or G4.



Estimated Single Rank (G3?)

Believed most likely a G3, but significant chance of either G2 or G4. Eventual change to G3 most likely, but change to G2 or G4 would not be unexpected.



Two-Range Rank (G3G4)

Roughly equal chance of G3 or G4, but other ranks much less likely. Eventual change to either G3 or G4 most likely.

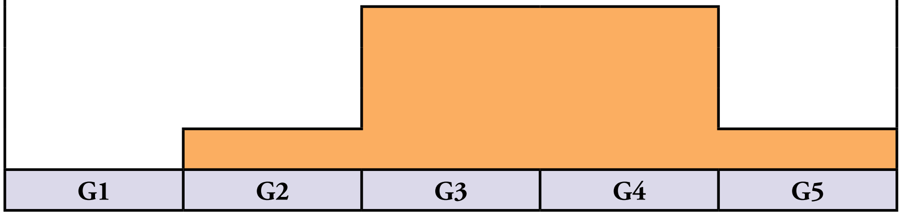
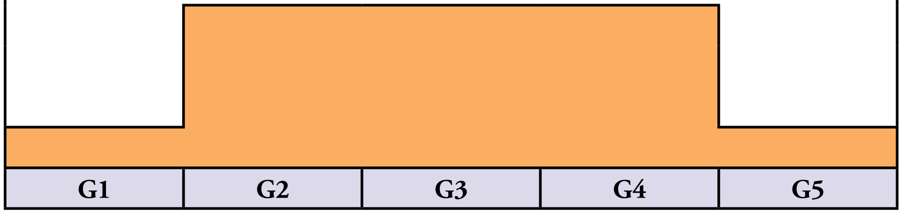


FIGURE 3 (cont.)

Three-Range Rank (G2G4)

Roughly equal chance of G2, G3 or G4, but other ranks much less likely. Considerable further information needed to resolve. Eventual change to either G2, G3 or G4 expected.



Q – Questionable taxonomy, which may reduce conservation priority. Use of the Q qualifier denotes that the distinctiveness of the assessed entity as a taxon or ecosystem type at the current level is questionable. More importantly, use of the Q further indicates that *resolution of this uncertainty may result in a change, either from a species to a subspecies or hybrid, or inclusion of the assessed taxon or ecosystem type in another taxon or type, such that the resulting taxon/type will have a lower-priority (numerically higher) conservation status rank than that originally assigned.*

An example of an invalid use of the Q qualifier would be a G5Q, which is not appropriate since resolution of the uncertainty associated with the assessed taxon or ecosystem type could not result in a taxon or type with a conservation status that is lower priority (higher numerically)—the assigned status (5) is already the lowest priority. Similarly, a taxon or type that may be split into several new species or types would not qualify for a Q qualifier as the conservation statuses of the resulting entities would either stay the same or have higher priority (become numerically lower); for example, a G4 taxon or type is split into three G2 and G3 ranked (higher-priority) taxa/types. Note that the Q modifier is only used with global level conservation status ranks, and not at a national or subnational level. Note also that other data fields are available at a global level to specify taxonomic uncertainties, regardless of resolution of the taxonomic uncertainty on the conservation status.

C – Captive or Cultivated Only. The C qualifier is used to indicate that a taxon, at present, is extinct in the wild across its entire native range, but is extant in cultivation, in captivity, as a naturalized population (or populations) outside its historical native range, or as a reintroduced population not yet established. Note that the C modifier is only used for species status ranks at the global level, and not at a national or subnational level.

Additional Information of Interest

Number of Protected and Managed Occurrences Field

This field is no longer included in the set of core factors used for NatureServe conservation status assessments. The degree of threat to a species or ecosystem that is indirectly assessed for this field is largely addressed, and better captured, in the Threats conservation status factor. However, this field may still provide useful supplemental information for conservation status assessments.

Enter the estimated number of protected and managed occurrences (a range is acceptable): _________.

Enter the code that best describes the observed, estimated, inferred, or suspected number of occurrences that are appropriately protected and managed for the long-term persistence of the species or ecosystem in the area of interest (globe, nation, or subnation). Note that both the protection and management criteria must be met in order to assign a rating code value. If the values are different for protected versus managed occurrences, assign the code that represents the more restrictive of the two. For example, if several occurrences are protected but none are appropriately managed, select the A = None code.

Select from the following values:

A = None (no occurrences appropriately protected and managed)

B = Few (1–3) occurrences appropriately protected and managed

C = Several (4–12) occurrences appropriately protected and managed

D = Many (13–40) occurrences appropriately protected and managed

E = Very many (>40) occurrences appropriately protected and managed

U = Unknown whether any occurrences are appropriately protected and managed

Null = Not assessed

■ ■ ■

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Appendix A. NatureServe Conservation Status Ranks

NatureServe Global Conservation Status Definitions

Listed here are definitions for interpreting NatureServe's global (range-wide) conservation status ranks. Global conservation status ranks are assigned by NatureServe scientists or by a designated lead office in the NatureServe network.

Global (G) Conservation Status Ranks

Rank	Definition
GX	**Presumed Extinct** (species) – Not located despite intensive searches and virtually no likelihood of rediscovery. **Extinct** (ecological communities and systems) – Eliminated throughout its range, with no restoration potential due to extinction of dominant or characteristic taxa and/or elimination of the sites and ecological processes on which the type depends.
GH	**Possibly Extinct** – Known from only historical occurrences but still some hope of rediscovery. There is evidence that the species may be extinct or the ecosystem may be eliminated throughout its range, but not enough to state this with certainty. Examples of such evidence include (1) that a species has not been documented in approximately 20-40 years despite some searching or some evidence of significant habitat loss or degradation; (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is extinct or eliminated throughout its range.[1]
G1	**Critically Imperiled** – At very high risk of extinction or elimination due to extreme rarity, very steep declines, or other factors.
G2	**Imperiled** – At high risk of extinction or elimination due to very restricted range, very few populations or occurrences, steep declines, or other factors.
G3	**Vulnerable** – At moderate risk of extinction or elimination due to a restricted range, relatively few populations or occurrences, recent and widespread declines, or other factors.
G4	**Apparently Secure** – Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5	**Secure** – Common; widespread and abundant.

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[1] Possibly Eliminated ecosystems (ecological communities and systems) may include ones presumed eliminated throughout their range, with no or virtually no likelihood of rediscovery, but with the potential for restoration, for example, American chestnut forests.

Variant Global Conservation Status Ranks

Rank	Definition
G#G#	**Range Rank** – A numeric range rank (e.g., G2G3, G1G3) is used to indicate uncertainty about the exact status of a taxon or ecosystem type. Ranges cannot skip more than two ranks (e.g., GU should be used rather than G1G4).
GU	**Unrankable** – Currently unrankable due to lack of information or due to substantially conflicting information about status or trends. *Note:* Whenever possible (when the range of uncertainty is three consecutive ranks or less), a range rank (e.g., G2G3) should be used to delineate the limits (range) of uncertainty.
GNR	**Unranked** – Global rank not yet assessed.
GNA	**Not Applicable** – A conservation status rank is not applicable because the species or ecosystem is not a suitable target for conservation activities.[2]

Rank Qualifiers

Rank	Definition
?	**Inexact Numeric Rank** – This should not be used with any of the Variant Global Conservation Status Ranks or GX or GH.
Q	**Questionable taxonomy that may reduce conservation priority** – Distinctiveness of this entity as a taxon or ecosystem type at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon or type in another taxon or type, with the resulting taxon having a lower-priority (numerically higher) conservation status rank. The "Q" modifier is only used at a global level and not at a national or subnational level.
C	**Captive or Cultivated Only** – Taxon at present is extinct in the wild across their entire native range but is extant in cultivation, in captivity, as a naturalized population (or populations) outside their native range, or as a reintroduced population not yet established. The "C" modifier is only used at a global level and not at a national or subnational level. Possible ranks are GXC or GHC.

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[2] A global conservation status rank may be not applicable for several reasons, related to its relevance as a conservation target. In such cases, typically the species is a hybrid without conservation value, of domestic origin, or the ecosystem is non-native, for example, ruderal vegetation, a plantation, agricultural field, or developed vegetation (lawns, gardens, etc).

Infraspecific Taxon Global Conservation Status Ranks

Infraspecific taxon status ranks apply to species only; these ranks do not apply to ecological communities or systems.

Rank	Definition
T#	**Infraspecific Taxon (trinomial)** – The status of infraspecific taxa (subspecies or varieties) are indicated by a "T rank" following the species' global rank. Rules for assigning T ranks follow the same principles outlined above. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1. A T rank cannot imply the subspecies or variety is more abundant than the species, for example, a G1T2 rank should not occur. A vertebrate animal population (e.g., listed under the U.S. Endangered Species Act or assigned candidate status) may be tracked as an infraspecific taxon and given a T rank; in such cases a Q is used after the T rank to denote the taxon's informal taxonomic status.

NatureServe National and Subnational Conservation Status Definitions

Listed here are definitions for interpreting NatureServe conservation status ranks at the national (N-rank) and subnational (S-rank) levels. The term "subnational" refers to state- or province-level jurisdictions (e.g., California, Ontario).

Assigning national and subnational conservation status ranks for species and ecosystems (ecological communities and systems) follows the same general principles as used in assigning global status ranks. A subnational rank, however, cannot imply that a species or ecosystem is more secure at the state/province level than it is nationally or globally (e.g., a rank of G1S3 is invalid), and similarly, a national rank cannot exceed the global rank. Subnational ranks are assigned and maintained by state or provincial NatureServe network programs.

National (N) and Subnational (S) Conservation Status Ranks

Rank	Definition
NX **SX**	**Presumed Extirpated** – Species or ecosystem is believed to be extirpated from the jurisdiction (i.e., nation, or state/province). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered. (= "Regionally Extinct" in IUCN Red List terminology)
NH **SH**	**Possibly Extirpated** – Known from only historical records but still some hope of rediscovery. There is evidence that the species or ecosystem may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include (1) that a species has not been documented in approximately 20–40 years despite some searching or some evidence of significant habitat loss or degradation; (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.
N1 **S1**	**Critically Imperiled** – Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction.
N2 **S2**	**Imperiled** – Imperiled in the jurisdiction because of rarity due to very restricted range, very few populations or occurrences, steep declines, or other factors making it very vulnerable to extirpation from the jurisdiction.
N3 **S3**	**Vulnerable** – Vulnerable in the jurisdiction due to a restricted range, relatively few populations or occurrences, recent and widespread declines, or other factors making it vulnerable to extirpation.
N4 **S4**	**Apparently Secure** – Uncommon but not rare; some cause for long-term concern due to declines or other factors.
N5 **S5**	**Secure** – Common, widespread, and abundant in the jurisdiction.

Variant National and Subnational Conservation Status Ranks

Rank	Definition
N#N# **S#S#**	**Range Rank** – A numeric range rank (e.g., S2S3 or S1S3) is used to indicate any range of uncertainty about the status of the species or ecosystem. Ranges cannot skip more than two ranks (e.g., SU is used rather than S1S4).
NU **SU**	**Unrankable** – Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
NNR **SNR**	**Unranked** — National or subnational conservation status not yet assessed.
NNA **SNA**	**Not Applicable** – A conservation status rank is not applicable because the species or ecosystem is not a suitable target for conservation activities.[3]
Not Provided	Species or ecosystem is known to occur in this nation or state/province. Contact the appropriate NatureServe network program for assignment of conservation status.

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[3] A conservation status rank may be not applicable for some species, including long-distance aerial and aquatic migrants, hybrids without conservation value, and non-native species or ecosystems, for several reasons:

Rank Qualifier

Rank	Definition
N#? S#?	**Inexact Numeric Rank–** This should not be used with any of the Variant National or Subnational Conservation Status Ranks, or NX, SX, NH, or SH.

Breeding Status Qualifiers[4]

Qualifier	Definition
B	**Breeding** – Conservation status refers to the breeding population of the species in the nation or subnation.
N	**Non-breeding** – Conservation status refers to the non-breeding population of the species in the nation or subnation.
M	**Migrant** – Migrant species occurring regularly on migration at particular staging areas or concentration spots where the species might warrant conservation attention. Conservation status refers to the aggregating transient population of the species in the nation or subnation.

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Long distance migrants: Assigning conservation status to long-distance aerial or aquatic migrant animals (e.g., species like migrant birds, bats, butterflies, sea turtles, and cetaceans) during their migrations is typically neither practical nor helpful to their conservation. During their migrations, most long-distance migrants occur in an irregular, transitory, and dispersed manner. Some long-distance migrants occur regularly, while others occur only as accidental or casual visitors to a subnation or nation. Some long-distance migrants may regularly occur as rare breeding or non-breeding seasonal (e.g., winter) species, but in an inconsistent, spatially irregular fashion, or as breeders that die out apparently with no return migration and no overwintering (e.g., some Lepidoptera). In all these circumstances, it is not possible to identify discrete areas for individual species that can be managed so as to significantly affect their conservation in a nation or subnation. The risk of extinction for these species is largely dependent on effective conservation of their primary breeding and non-breeding grounds, notwithstanding actions that may benefit species collectively such as protecting migratory "hotspots," curbing pollution, minimizing deaths from towers and other obstructions, etc.

An exception is those species, such as shorebirds, whose populations concentrate at particular areas during migration, and species occurring in multiple species assemblages at migration "funnels" or hotspots. Such species may be collectively treated within "Animal Assemblage" elements, for which conservation status assignment would be appropriate. Examples of such assemblages are Shorebird, Waterfowl, Landbird, and Raptor Migratory Concentration Areas. Species considered within assemblage elements differ from the more common situation during migration, whereby most long-distance migrants are tied to particular places and habitats during their breeding season, as well as during the non-breeding [e.g., wintering] season when they are not in transit. For these species, conservation of both types of places is important to minimize their risk of extinction.

Hybrids without conservation value and non-natives: It is not appropriate to assign a conservation status to hybrids without conservation value, or to non-native species or ecosystems. However, in the rare case where a species is presumed or possibly extinct in the wild (GXC/GHC) but is extant as a naturalized population outside of its native range, the naturalized population should be treated as a benign introduction, and should be assessed and assigned a numeric national and/or subnational conservation status rank. The rationale for this exception for naturalized populations is that when a species is extinct over its entire natural range, the presence of that species within an area must be considered important to highlight and preserve, even if the area is not part of the species' natural range.

[4] A breeding status is only used for species that have distinct breeding and/or non-breeding populations in the nation or subnation. A breeding-status S rank can be coupled with its complementary non-breeding-status S rank if the species also winters in the nation or subnation. In addition, a breeding-status S rank can also be coupled with a migrant-status S rank if, on migration, the species occurs regularly at particular staging areas or concentration spots where it might warrant conservation attention. Multiple conservation status ranks (typically two, or rarely three) are separated by commas (e.g., S2B,S3N or SHN,S4B,S1M).

Appendix B. Summary of IUCN Red List Categories and Criteria

The IUCN Red List Categories

Extinct (EX)

A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), and throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Extinct in the Wild (EW)

A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity, or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), and throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Critically Endangered (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E (see below) for Critically Endangered, and it is therefore considered to be facing an extremely high risk of extinction in the wild.

Endangered (EN)

A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild.

Vulnerable (VU)

A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable, and it is therefore considered to be facing a high risk of extinction in the wild.

Near Threatened (NT)

A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered, or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

Least Concern (LC)

A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable, or Near Threatened. Widespread and abundant taxa are included in this category.

Data Deficient (DD)

A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required, and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

Not Evaluated (NE)

A taxon is Not Evaluated when it has not yet been evaluated against the criteria.

Summary of the IUCN Red List Criteria

Summary of the five criteria (A–E) used to evaluate if a taxon belongs in a threatened category (Critically Endangered, Endangered, or Vulnerable).

Use any of the criteria A–E	**Critically Endangered**	**Endangered**	**Vulnerable**
A. Population reduction Declines measured over the longer of ten years or three generations			
A1	>90%	>70%	>50%
A2, A3, and A4	>80%	>50%	>30%
A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible ***and*** understood ***and*** ceased based on (and specifying) any of the following: (a) direct observation (b) an index of abundance appropriate to the taxon (c) a decline in area of occupancy (AOO), extent of occurrence and/or habitat quality (d) actual or potential levels of exploitation (e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.			
A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased ***or*** may not be understood ***or*** may not be reversible, based on (and specifying) any of (a) to (e) under A1.			
A3. Population reduction projected or suspected to be met in the future (maximum 100 years) based on (and specifying) any of (b) to (e) under A1.			
A4. An observed, estimated, inferred, projected or suspected population reduction (maximum 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased ***or*** may not be understood ***or*** may not be reversible, based on (and specifying) any of (a) to (e) under A1.			
B. Geographic range in the form of either B1 (extent of occurrence) *or* B2 (area of occupancy)			
Either (B1) extent of occurrence	< 100km^2	< 5,000km^2	< 20,000km^2
Or (B2) area of occupancy	< 10km^2	< 500km^2	< 2,000km^2
and at least two of (a) to (c):			
(a) severely fragmented, or number of locations	= 1	≤ 5	≤ 10
(b) continuing decline in (i) extent of occurrence, (ii) area of occupancy, (iii) area, extent, and/or quality of habitat, (iv) number of locations or subpopulations, and (v) number of mature individuals.			
(c) extreme fluctuations in any of (i) extent of occurrence, (ii) area of occupancy, (iii) number of locations or subpopulations, and (iv) number of mature individuals.			

Use any of the criteria A–E	**Critically Endangered**	**Endangered**	**Vulnerable**
C. Small population size and decline			
Number of mature individuals and either C1 or C2:	<250	<2,500	<10,000
C1. An estimated continuing decline of at least (maximum 100 years)	25% in three years or one generation	20% in five years or two generations	10% in ten years or three generation
C2. A continuing decline and (a) and/or (b):			
(a.i) number of mature individuals in largest subpopulation	<50	<250	<1,000
(a.ii) or percentage of mature individuals in one subpopulation	90–100%	95–100%	100%
(b) extreme fluctuations in the number of mature individuals			
D. Very small or restricted population			
Either (D1) number of mature individuals	<50	<250	<1,000
Or (D2) restricted area of occupancy	n/a	n/a	typically: <20km^2 or # locations ≤5
E. Quantitative Analysis			
Indicating the probability of extinction in the wild to be at least	50% within 10 years or three generations (100 yrs max)	20% within 20 years or five generations (100 yrs max)	10% in 100 years

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Appendix C. NatureServe, IUCN Red List, and COSEWIC Statuses Compared

The tables below provide comparisons between the different conservation status categories used by NatureServe and the IUCN Red List (each compared at multiple geographic levels), and those used by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In both tables, rough equivalencies are indicated through the display of statuses in the same row.

Comparison of NatureServe and IUCN Red List Global Statuses

NatureServe Global Status	IUCN Red List Status
Presumed Extinct (GX)	Extinct (EX)
Presumed Extinct in the Wild[1] (GXC)	Extinct in the Wild[1] (EW)
Possibly Extinct (GH)	Critically Endangered (CR) (possibly extinct)
Possibly Extinct in the Wild[1] (GHC)	Critically Endangered (CR) (possibly extinct)
Critically Imperiled (G1)	Critically Endangered (CR)
Critically Imperiled (G1)	Endangered (EN)
Imperiled (G2)	Vulnerable (VU)
Vulnerable (G3)	Near Threatened (NT)
Apparently Secure (G4)	Least Concern (LC)
Secure (G5)	Least Concern (LC)
Unrankable (GU)	Data Deficient (DD)

Comparison of NatureServe National/Subnational Statuses with the IUCN Regional Red List and COSEWIC Statuses

NatureServe National/ Subnational Status	IUCN Regional Red List Status	COSEWIC Status[2]
Presumed Extirpated (NX/SX ***and*** GX)	Extinct (EX)	Extinct (X)
Presumed Extirpated (NX/SX ***and not*** GX)	Regionally Extinct (RE)	Extirpated (XT)
Possibly Extirpated (NH/SH)	Critically Endangered (CR) (possibly extinct)	Endangered (EN)
Critically Imperiled (N1/S1)	Critically Endangered (CR)	Endangered (EN)
Critically Imperiled (N1/S1)	Endangered (EN)	Endangered (EN)
Imperiled (N2/S2)	Vulnerable (VU)	Threatened (T)
Vulnerable (N3/S3)	Near Threatened (NT)	Special Concern (SC)
Apparently Secure (N4/S4)	Least Concern (LC)	Not At Risk (NAR)
Secure (N5/S5)	Least Concern (LC)	Not At Risk (NAR)
Unrankable (NU / SU)	Data Deficient (DD)	Data Deficient (DD)

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[1] Species ranked GXC and GHC are presumed or possibly extinct in the wild across their entire native range, but are extant in cultivation, in captivity, as a naturalized population (or populations) outside its historical native range, or as a reintroduced population not yet established. The C modifier is only used with status ranks at a global level, and not a national or subnational level. Similarly, IUCN's EW status is only used at a global level.

[2] COSEWIC status (aside from Extinct) applies only within Canada, and thus, is equivalent to the national rankings of NatureServe or the regional IUCN Red List status. See www.natureserve.org/explorer/statusca.htm.

Appendix D. Extinction Risk and Setting Conservation Priorities

Assessment of extinction risk and setting conservation priorities are two related, but different, processes. To set conservation priorities, extinction risk is considered along with other factors, including ecological and/or phylogenetic characteristics, historical and/or cultural preferences for some taxa over others, the probability of success of conservation actions, availability of funds or personnel to carry out such actions, and existing legal frameworks for conservation of at-risk taxa. For additional discussion of this topic, see Possingham et al. (2002), IUCN (2003), and Bunnell et al. (2009).

In the context of setting conservation priorities within a jurisdiction (e.g., state, province), it is critical to consider not only the status of a species or ecosystem (i.e., risk of local extinction or extirpation) within the jurisdiction, but also other factors such as the global status or risk of extinction, and the proportion of the global population or range that occurs within the jurisdiction. Because the extirpation risk of a species or ecosystem is not evenly distributed across jurisdictions, a particular species or ecosystem may be at significant risk in one jurisdiction but relatively secure in other jurisdictions. Thus, the use of conservation status alone to assign priority can result in the focus of conservation effort precisely where it is least likely to succeed (Possingham et al. 2002). In addition, conservation actions may begin too late to be effective if initial efforts are focused on the rarest species within a jurisdiction where the success of actions is least likely and most costly (Bunnell et al. 2009).

The following combinations of global and subnational conservation statuses are listed in a suggested priority sequence for conservation attention, all else being equal (jurisdiction responsibility, feasibility, etc.) (The Nature Conservancy 1988):

> G1S1, G2S1, G2S2, G3S1, G3S2, G3S3, G4S1, G5S1, G4S2,
> G5S2, G4S3, G5S3

However, "all else" is never equal; the stewardship responsibilities for a species or ecosystem will vary between the different jurisdictions in which it occurs. For example, if two species with equal global and jurisdictional conservation statuses differ such that one of the species has a large percentage of its global range in a jurisdiction, that jurisdiction bears particular responsibility for securing the future of that particular species relative to the other species that has a smaller portion of its global range in the jurisdiction. Thus, it is recommended that when reporting and publishing national or subnational statuses, a jurisdiction also include not only the global statuses, but also an estimate of the proportion (percentage) of the global population or range for the species or ecosystems that occur within that jurisdiction.

For additional discussion of this topic, see Bunnell et al. (2009), and Keinath and Beauvais (2004). In particular, Bunnell et al. (2009) describe goals for conservation that can help jurisdictions effectively allocate their resources, and also provide two tools to facilitate the process. One of these tools sorts species into practical groups for conservation action, creating groups comprised of species that require similar actions. The other tool assigns conservation priorities by ordering "species or ecosystems based on criteria governing risk (= conservation status), modified by feasibility, stewardship responsibility (as discussed above), disjunctness, and pattern of range collapse." (Bunnell et al. 2009) These tools thus enable priorities to be ordered within an action group, within a particular goal, or within an overall status rank. This system for conservation prioritization developed by Bunnell et al. (2009) can be applied to any North American jurisdiction.

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Appendix E. Changes to Status Factors with Conversions

In moving from the 2002 NatureServe conservation status factors to using the revised 2009 factors, the value choices for several factors have been expanded for better compatibility with IUCN Red List statuses. Automated conversions for the Area of Occupancy factor and those in the trends and threats categories were developed to facilitate ranking using the updated status assessment protocol and to permit use of the rank calculator. Note in the table comparing the 2002 and 2009 factors below, these automated conversions may result in the assignment of range ranks as conservation status values in many cases. Upon review of the underlying data, it should be possible to narrow these ranges or assign single status ranks, eliminating the more imprecise range ranks altogether.

Summary of Status Factors Changes between 2002 and 2009 with Conversions

2002 Factor	**2009 Factor**	Factor Change/New Rule/Conversion
Number of EOs	**Number of Occurrences**	
Z = 0 (zero)	Z = 0 (zero; presumed extinct)	Factor change? No
A = 1–5	A = 1–5	New Rule? No
B = 6–20	B = 6–20	
C = 21–80	C = 21–80	
D = 81–300	D = 81–300	
E = >300	E = >300	
U = Unknown	U = Unknown	
Number of EOs with Good Viability	**Number of Occurrences with Good Viability/Ecological Integrity**	
A = No (A- or B-ranked) occurrences with good viability	A = No occurrences with excellent or good (A or B) viability or ecological integrity	Factor Change? Yes New Rule: Along with this field, a companion field—Percent Area with Good Viability/Ecological Integrity—has been added to replace the 2002 factor Number of EOs with Good Viability. Enter a value for the number of occurrences with good viability/ecological integrity using this field ***and/or*** enter a value for the Percent Area with Good Viability/Ecological Integrity field (below). If values have been recorded for both fields, the more restrictive of the two will be used in the conservation status assessment.
B = Very few (1–3) occurrences with good viability	B = Very few (1–3) occurrences with excellent or good viability or ecological integrity	
C = Few (4–12) occurrences with good viability	C = Few (4–12) occurrences with excellent or good viability or ecological integrity	
D = Some (13–40) occurrences with good viability	D = Some (13–40) occurrences with excellent or good viability or ecological integrity	
E = Many (41–125) occurrences with good viability	E = Many (41–125) occurrences with excellent or good viability or ecological integrity	
F = Very many (>125) occurrences with good viability	F = Very many (>125) occurrences with excellent or good viability or ecological integrity	
U = Unknown	U = Unknown	

2002 Factor	2009 Factor	Factor Change/New Rule/Conversion
	Percent Area with Good Viability/Ecological Integrity	
	A = No area with excellent or good viability or integrity B = Very small percentage (<5%) of area with excellent or good viability or integrity C = Small percentage (5–10%) of area with excellent or good viability or integrity D = Moderate percentage (11–20%) of area with excellent or good viability or integrity E = Good percentage (21–40%) of area with excellent or good viability or integrity F = Excellent percentage (>40%) of area with excellent or good viability or integrity U = Unknown percentage of area with excellent or good viability or integrity	Factor change? Yes New rule: This field is an alternative replacement for the 2002 Number of EOs with Good Viability factor. Must also enter a value for Area of Occupancy.
Range Extent	**Range Extent**	
Z = Zero (no occurrences believed extant)	Z = Zero (no occurrences believed extant; presumed extinct)	Factor change? No New Rule? No
A = <100 square	A = <100 km²	
B = 100–250 km²	B = 100–250 km²	
C = 250–1,000 km²	C = 250–1,000 km²	
D = 1,000–5,000 km²	D = 1,000–5,000 km²	
E = 5,000–20,000 km²	E = 5,000–20,000 km²	
F = 20,000–200,000 km²	F = 20,000–200,000 km²	
G = 200,000–2,500,000 km²	G = 200,000–2,500,000 km²	
H = >2,500,000 km²	H = >2,500,000 km²	
U = Unknown	U = Unknown	
Population Size	**Population Size**	
Z = Zero, no individuals extant	Z = Zero, no individuals believed extant (presumed extinct)	Factor change? No New Rule? No
A = 1–50 individuals	A = 1–50 individuals	
B = 50–250 individuals	B = 50–250 individuals	
C = 250–1,000 individuals	C = 250–1,000 individuals	
D = 1,000–2,500 individuals	D = 1,000–2,500 individuals	
E = 2,500–10,000 individuals	E = 2,500–10,000 individuals	
F = 10,000–100,000 individuals	F = 10,000–100,000 individuals	
G = 100,000–1,000,000 individuals	G = 100,000–1,000,000 individuals	
H = >1,000,000 individuals	H = >1,000,000 individuals	
U = Unknown	U = Unknown	

2002 Factor		2009 Factor	Factor Change/New Rule/Conversion
Area/Linear Distance of Occupancy (Ecosystem)		**Area of Occupancy (Ecosystem)**	
Area	Linear Distance		Conversion:
Z = Zero	Z = Zero	Z = Zero (no occurrences believed extant)	
A = <0.4 km^2	A = <4 km	A = <1 km^2	
B = 0.4–4 km^2	B = 4–40 km	B = 1–4 km^2	B ≫ AB
C = 4–20 km^2	C = 40–200 km	C = 4–10 km^2	C ≫ CD
D = 20–100 km^2	D = 200–1,000 km	D = 10–20 km^2	D ≫ E
E = 100–500 km^2	E = 1,000–5,000 km	E = 20–100 km^2	E ≫ F
F = 500–2,000 km^2	F = 5,000–20,000 km	F = 100–500 km^2	F ≫ G
G= 2,000–20,000 km^2	G = 20,000–200,000 km	G = 500–2,000 km^2	G ≫ H
H = >20,000 km^2	H = >200,000 km	H = 2,000–20,000 km^2	H ≫ I
		I = >20,000 km^2	Factor change? Yes
U = Unknown	U = Unknown	U = Unknown	New rule? No

Area of Occupancy (Species)	**Area of Occupancy (Species)**[1]		
	# 4 km^2 grid cells	# 1 km^2 grid cells	Conversion:
Z = Zero	Z = 0	Z = 0	
A = <0.4 km^2	A = 1	A = 1–4	A ≫ AC
B = 0.4–4 km^2	B = 2	B = 5–10	B ≫ AD
C = 4–20 km^2	C = 3–5	C = 11–20	C ≫ DE
D = 20–100 km^2	D = 6–25	D = 21–100	D ≫ EF
E = 100–500 km^2	E = 26–125	E = 101–500	E ≫ FG
F = 500–2,000 km^2	F = 126–500	F = 501–2,000	F ≫ GH
G = 2,000–20,000 km^2	G = 501–2,500	G = 2,001–10,000	G ≫ HI
H = >20,000 km	H = 2,501–12,500	H = 10,000-50,000	H ≫ I
	I = >12,500	I = >50,000	Factor change? Yes
U = Unknown	U = Unknown	U = Unknown	New rule? No

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[1] The initial automatic conversion of Area of Occupancy for species is to 4 km^2 grid cells but in some cases (see "Estimating Area of Occupancy" on page 15), it is more appropriate to convert to a 1 km^2 grid. Although this conversion and the conversion for species Linear Area of Occupancy are both fairly generous so as to conceptually attempt to capture ≥80% of actual cases, some cases (e.g., either a particularly dispersed set of small occurrences, or a very narrowly concentrated set of occurrences) will fall outside of the converted ranges, and so these conversions should be evaluated carefully when reviewing the initial calculated rank.

2002 Factor	2009 Factor	Factor Change/New Rule/Information
Linear Distance of Occupancy (Species)	**Area of Occupancy (Species)[1]**	
	# of 1 km^2 grid cells	Conversion:
Z = Zero	Z = 0	
A = < 4 km	A = 1–4	
B = 4–40 km	B = 5–10	B ≫ BD
C = 40–200 km	C = 11–20	C ≫ DE
D = 200–1,000 km	D = 21–100	D ≫ EF
E = 1,000–5,000 km	E = 101–500	E ≫ FG
F = 5,000–20,000 km	F = 501–2,000	F ≫ GH
G = 20,000–200,000 km	G = 2,001–10,000	G ≫ HI
H = >200,000 km	H = 10,000–50,000	H ≫ I
	I = >50,000	Factor change? Yes
U = Unknown	U = Unknown	New rule? No
Environmental Specificity	**Environmental Specificity**	
A = Very narrow	A = Very narrow	Factor change? No
B = Narrow	B = Narrow	New rule: Only used if Number of Occurrences ***and*** Area of Occupancy are Unknown or Null
C = Moderate	C = Moderate	
D = Broad	D = Broad	
U = Unknown	U = Unknown	
Long-term Trend	**Long-term Trend**	
A = Very large decline (>90%)	A = Decline of >90%	Conversion:
B = Large decline (75–90%)	B = Decline of 80–90%	B ≫ BC
C = Substantial decline (50–75%)	C = Decline of 70–80%	C ≫ D
D = Moderate decline (25–50%)	D = Decline of 50–70%	D ≫ E
E = Relatively stable (+/- 25% change)	E = Decline of 30–50%	E ≫ FGH
F = Increase (>25%)	F = Decline of 10–30%	F ≫ I
	G = Relatively Stable (≤10% change)	
	H = Increase of 10–25%	Factor change? Yes
	I = Increase of >25%	New rule? No
U = Unknown	U = Unknown	
Short-term Trend	**Short-term Trend**	
		Conversion:
A = Severely declining (>70% in population, range, area occupied, and/or number or condition of occurrences)	A = Decline of >90%	A ≫ ABC
B = Very rapidly declining (50–70%)		B ≫ D
C = Rapidly declining (30–50%)	B = Decline of 80–90%	C ≫ E
D = Declining (10–30%)	C = Decline of 70–80%	D ≫ F
E = Stable (unchanged or within +/- 10% fluctuation in population, range, area occupied, and/or number or condition of occurrences)	D = Decline of 50–70%	E ≫ G
F = Increasing (>10%)	E = Decline of 30–50%	F ≫ HI
U = Unknown	F = Decline of 10–30%	
	G = Relatively Stable (≤10% change)	
	H = Increase of 10–25%	
	I = Increase of >25%	Factor change? Yes
	U = Unknown	New rule? No

2002 Factor	2009 Factor	Factor Change/New Rule/Information
Overall Threat	**Overall Threat Impact[2]**	
		Conversion:
A = Substantial, imminent threat	A = Very High	A » AB
B = Moderate and imminent threat	B = High	B » B
C = Substantial, non-imminent threat	C = Medium	C » AC
D = Moderate, non-imminent threat	D = Low	D » BC
E = Localized substantial threat	U = Unknown	E » C
F = Widespread, low-severity threat		F » C
G = Slightly threatened		G » D
H = Unthreatened		H » D
		Factor change? Yes New rule: Threat is assigned on the basis of Scope and Severity. Timing is no longer used to determine overall Threat Impact, but it still useful to record. See text for details on threat impact calculation.
Intrinsic Vulnerability	**Intrinsic Vulnerability**	
A = Highly vulnerable	A = Highly vulnerable	Factor change? No
B = Moderately vulnerable	B = Moderately vulnerable	New rule: Only used if Overall Threat Impact is Unknown or Null.
C = Not intrinsically vulnerable	C = Not intrinsically vulnerable	
Number of Protected EOs	**Number of Protected and Managed Occurrences**	
A = None. No occurrences appropriately protected and managed	A = None. No occurrences appropriately protected and managed	Factor change? No
B = Few (1–3) occurrences appropriately protected and managed	B = Few (1–3) occurrences appropriately protected and managed	New rule: Used as supplementary information only. No longer a formal rank factor.
C = Several (4–12) occurrences appropriately protected and managed	C = Several (4–12) occurrences appropriately protected and managed	
D = Many (13–40) occurrences appropriately protected and managed	D = Many (13–40) occurrences appropriately protected and managed	
E = Very many (>40) occurrences appropriately protected and managed	E = Very many (>40) occurrences appropriately protected and managed	

* * *

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Use of Superposition Models to Simulate Possible Depletion of Colorado River Water by Ground-Water Withdrawal

Scientific Investigations Report 2008–5189

U.S. Department of the Interior
U.S. Geological Survey

Use of Superposition Models to Simulate Possible Depletion of Colorado River Water by Ground-Water Withdrawal

By Stanley A. Leake, William Greer, Dennis Watt, and Paul Weghorst

Prepared in cooperation with Bureau of Reclamation

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U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

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FRONT COVER—The Lower Colorado River and adjacent farmland. Photograph from the Bureau of Reclamation.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)
	Leakance	
foot per day per foot [(ft/d)/ft]	1	meter per day per meter

Vertical coordinate information is referenced to the National Vertical Geodetic Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Elevation, as used in this report, refers to distance above the vertical datum.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Use of Superposition Models to Simulate Possible Depletion of Colorado River Water by Ground-Water Withdrawal

By Stanley A. Leake, William Greer[1], Dennis Watt[2], and Paul Weghorst[3]

Abstract

According to the “Law of the River,” wells that draw water from the Colorado River by underground pumping need an entitlement for the diversion of water from the Colorado River. Consumptive use can occur through direct diversions of surface water, as well as through withdrawal of water from the river by underground pumping. To develop methods for evaluating the need for entitlements for Colorado River water, an assessment of possible depletion of water in the Colorado River by pumping wells is needed. Possible methods include simple analytical models and complex numerical ground-water flow models. For this study, an intermediate approach was taken that uses numerical superposition models with complex horizontal geometry, simple vertical geometry, and constant aquifer properties. The six areas modeled include larger extents of the previously defined river aquifer from the Lake Mead area to the Yuma area. For the modeled areas, a low estimate of transmissivity and an average estimate of transmissivity were derived from statistical analyses of transmissivity data. Aquifer storage coefficient, or specific yield, was selected on the basis of results of a previous study in the Yuma area. The USGS program MODFLOW-2000 (Harbaugh and others, 2000) was used with uniform 0.25-mile grid spacing along rows and columns. Calculations of depletion of river water by wells were made for a time of 100 years since the onset of pumping. A computer program was set up to run the models repeatedly, each time with a well in a different location. Maps were constructed for at least two transmissivity values for each of the modeled areas. The modeling results, based on the selected transmissivities, indicate that low values of depletion in 100 years occur mainly in parts of side valleys that are more than a few tens of miles from the Colorado River.

Background

The Consolidated Decree of the United States Supreme Court in Arizona v. California, 547 U.S.150 (2006) recognizes that consumptive use of water from the Colorado River can occur by underground pumping. According to the “Law of the River,” users within the lower Colorado River Basin States can divert tributary inflow before it reaches the Colorado River. Once the water reaches the Colorado River, however, entitlements are required for diversions. For wells pumping in the aquifer connected to the river, determination of a tributary source of ground water pumped can be difficult. Wilson and Owen-Joyce (1994), and Owen-Joyce and others (2000) presented the “Accounting-Surface Method.” The accounting surface is defined by ground-water levels that would occur if the Colorado River were the only source and sink for water in the connected aquifer. The theory is that static (non-pumping) ground-water levels in the aquifer that are higher than the accounting surface indicate the presence of tributary water. The accounting-surface method could be used by managers to determine the need for entitlements for river water for wells pumping in the river aquifer. Wiele and others (2008) presented an updated accounting surface based on conditions in 2007–2008.

Wilson and Owen-Joyce (1994) and Owen-Joyce and others (2000) defined the “river aquifer” as the saturated ground-water system adjacent to the Colorado River, including the flood plain sediments, older alluvial sediments, and sediments in connected adjacent valleys (fig. 1). The accounting surface was defined over the area of the river aquifer beyond the Colorado River flood plain.

The accounting surface includes some parts of the river aquifer that are many tens of miles from the Colorado River. The States along the lower Colorado River have expressed interest in Federal water managers considering the timing over which wells at great distance would deplete water in the Colorado River. To further understand the temporal effects of pumping wells on the Colorado River, Reclamation subsequently set up the Non-Contract Use Modeling technical team to explore methods of assessing the timing over which wells would deplete water in the Colorado River. Team members include staff of the Bureau of Reclamation (Reclamation) and the U.S. Geological Survey (USGS). This report describes the method developed by the technical team and results for larger portions of the river aquifer along the lower Colorado River.

Acknowledgments

Ruth Thayer of Reclamation in Boulder City, Nevada, provided leadership and direction for the Non-Contract Use

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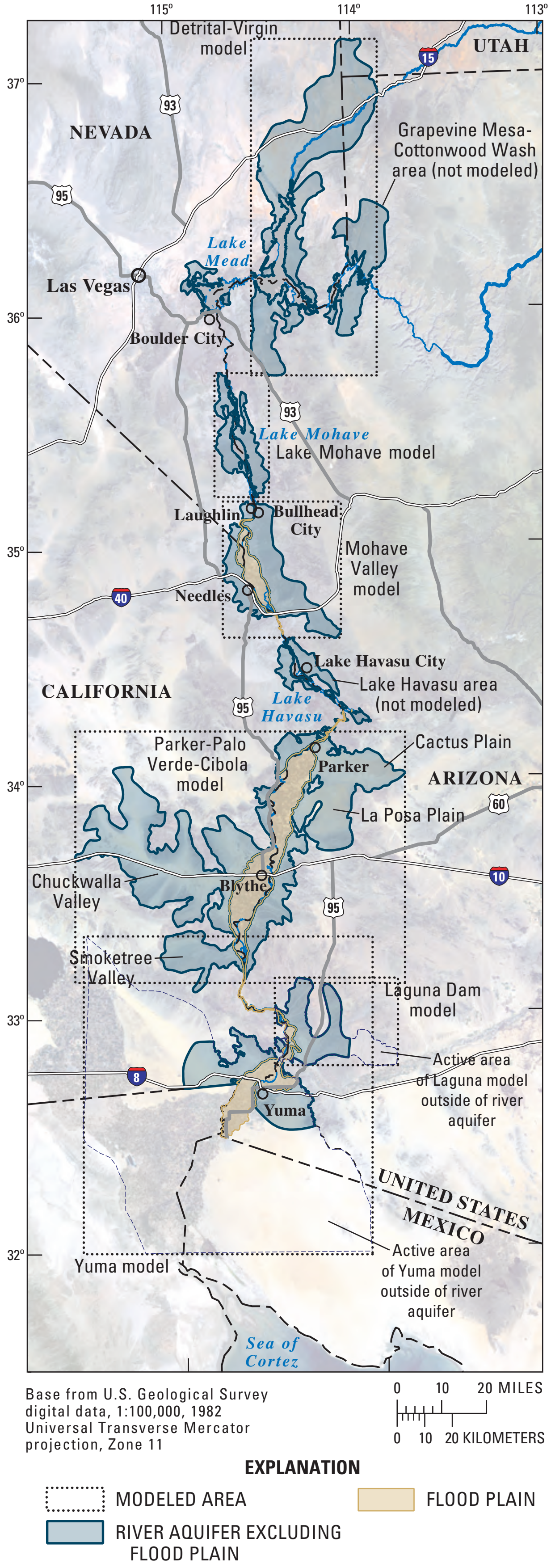
[1] Bureau of Reclamation, Yuma, Arizona

[2] Bureau of Reclamation, Boulder City, Nevada

[3] Formerly of Bureau of Reclamation, Denver, Colorado



Base from U.S. Geological Survey digital data, 1:100,000, 1982 Universal Transverse Mercator projection, Zone 11

Figure 1. Study area along the lower Colorado River.

Modeling technical team. Jeff Addiego, formerly of Reclamation in Boulder City, Nevada, helped with aspects relating to the water-accounting procedures. Carroll Brown, of the Reclamation in Yuma, Arizona, contributed advice on aspects of geology. Sandra Owen-Joyce, of the USGS in Tucson, Arizona, helped with previous work on the accounting-surface method, including the river aquifer. Steve Belew, Reclamation in Boulder City, and Jim Monical, USGS in Tucson, helped with spatial data sets needed to construct models and mapping of model results.

Approach

C.V. Theis (1940) provided the first comprehensive description of the sources of water to pumped wells. He indicated that pumped water initially comes from storage in the aquifer. With time, however, cones of depression can spread to areas of ground-water recharge and discharge, resulting in additional sources of increased inflow to the aquifer and decreased outflow from the aquifer. Along the Colorado River, the interest is in depletion of surface-water resources from ground-water pumping. The depletion can result from decreased flow from the aquifer to the river, increased flow from the river to the aquifer, or a combination of these two conditions.

An example of the progression of depletion over time for a point in a hypothetical aquifer is shown in figure 2. At time zero, when pumping starts, the source of all of the water pumped by the well is from ground-water storage. With time, however, this source decreases and the complementary source, depletion of surface water, increases. At the end of 50 years in this example, only 5 percent (a fraction of 0.05) of the pumping rate is from ground-water storage, and 95 percent is from depletion of surface water. If the well pumping was continued indefinitely, a new steady-state condition would be reached in which all of the well pumping rate would be depletion of surface water, assuming that water available in surface-water bodies is sufficient to supply the total rate of well pumping.

The time over which depletion of river water by underground pumping occurs is dependent on the river and aquifer geometry, location of the pumping, and the aquifer hydraulic diffusivity, T/S, where T is transmissivity and S is storage coefficient. It is important to note that depletion of surface water by pumping ground water is independent of the rates and directions of ground-water flow. For example, depletion can occur from decreased flow from the aquifer to the river and increased flow from the river to the aquifer. For both of these cases, the amount of water in the river is reduced and the total depletion of the flow in the river is the sum of the two quantities. If the flow system changed by means such as changing recharge amounts or locations and (or) changing river stages, the total depletion by a well would be the same as depletion by a well at the same location in the unchanged system as long as the changes to the system did not affect the aquifer diffusivity and the location of the surface-water features.

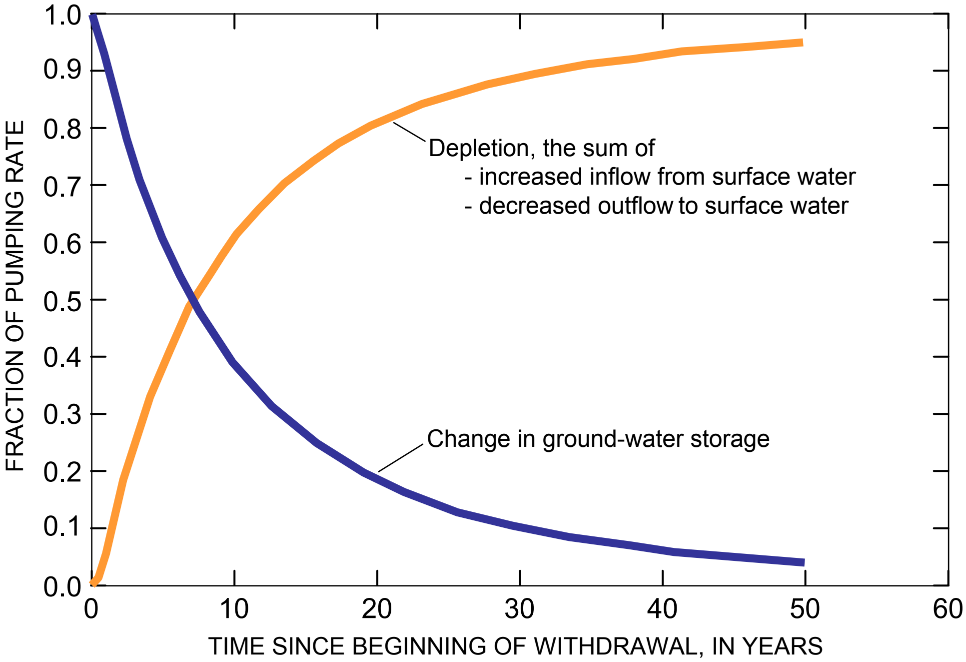


Figure 2. Sources of water to a well through time in a river-aquifer system, expressed as a fraction of the pumping rate.

If the interest is in total depletion, mathematical solution can be done using the principle of superposition in an analytical or numerical method that solves for changes in a system that is initially static. In a solution using the superposition approach, total depletion from a surface-water boundary from ground-water pumping is directly computed, and individual components of decreased flow from the aquifer to the river and increased flow from the river to the aquifer cannot be computed. The simplest approach to calculating depletion from ground-water pumping is the analytical solution by Glover and Balmer (1954). This approach assumes the river is a line source–straight and infinitely long, and fully penetrates the thickness of the aquifer, which extends an infinite distance away from the river. Using the theory of image wells, depletion in a bounded aquifer can be computed by the analytical solution, with a lateral no-flow boundary that is parallel to the river. Aquifer properties are assumed to be homogeneous. Because of the complex geometry of the Colorado River and the river aquifer (fig. 1), the analytical solution by Glover and Balmer (1954) is difficult to apply, especially in and around side valleys that are a part of the river aquifer.

A more common approach to calculating depletion is to use calibrated numerical ground-water flow models. Such models approximate the vertical and horizontal geometry of the aquifer, as well as flow patterns within the aquifer. The approach generally includes first running the model without a pumping well of interest and saving model-computed rates of ground-water flow to and from the river. The next step involves running the model again, this time with the pumping center added, again saving model-computed rates of ground-water flow to and from the river. For the two model runs, depletion is calculated as the sum of the decrease in ground-water flow to the river and increase in ground-water flow from the river.

Calibrated ground-water flow models do not exist for most parts of the lower Colorado River aquifer, and construction of such models was beyond the scope of this study. For this study, an approach was taken that is intermediate to the approaches using analytical solutions and calibrated numerical models. The intermediate approach uses numerical models that incorporate the complex horizontal geometry of the aquifer and river, but incorporate the simplifying principle of superposition, and the simple vertical geometry and homogeneity assumptions that are part of the analytical-solution approach.

Numerical superposition models for evaluating possible depletion of water in the Colorado River by ground-water pumping in the connected river aquifer were constructed for select areas along the lower Colorado River from Lake Mead to the Yuma area. The areas modeled include the river aquifer as defined by Wilson and Owen-Joyce (1994) and Owen-Joyce and others (2000). In a few of the modeled areas, the model boundaries extend beyond the defined river aquifer boundary where the defined boundary does not represent a physical no-flow boundary. Some general aspects of the modeling strategy are as follows:

1. Depletion is calculated using numerical superposition or change models. In plan view the aquifers are complexly shaped, based on the outline of the mapped river aquifer, with any mapped no-flow areas removed from the active model domain. In cross-sectional view the aquifers are simple two-dimensional horizontal slabs.

2. Models are constructed for the largest of the river-aquifer areas from Lake Mead to the Yuma area along the lower Colorado River. Smaller areas of the river aquifer are not modeled where experience with larger models indicates that computed depletion of surface water after 100 years of withdrawal for narrow sections is relatively high.

3. The models do not represent spatial variations of aquifer hydraulic properties. The models use a constant storage coefficient (specific yield), and two or more statistically derived transmissivity values. The transmissivity values are selected to simulate aquifer hydraulic diffusivity that represents (a) a conservative (or low) value that would underestimate depletion, and (b) an average value.

4. The only surface-water boundaries included in the models are the Colorado River, reservoirs along the river, and wetlands connected to the river.

5. Depletion is mapped for 100 years of withdrawal for the area of the river aquifer outside of the flood plain. The period of 100 years is commonly used as a timeframe in water management rules, such as Assured Water Supply criteria of the State of Arizona (http://www.azwater.gov/dwr/WaterManagement/Content/OAAWS/default.asp, accessed October 10, 2008).

Further details on implementation of the method are given in the following sections.

Areas Simulated

Models were constructed for six areas of the river aquifer. Starting with the most upstream reach, models included (1) Detrital-Virgin, (2) Lake Mohave, (3) Mohave Valley, (4) Parker-Palo Verde-Cibola, (5) Laguna Dam, and (6) Yuma area (fig. 1). The two largest river-aquifer areas not modeled are the Grapevine Mesa-Cottonwood Wash area and the Lake Havasu Area.

Aquifer Properties

Aquifer hydraulic diffusivity is the aquifer property that controls the rate that the depletion curve (fig. 2) progresses from zero at the start of pumping, towards 1.0 as pumping time continues. Diffusivity is T/S, where T is transmissivity and S is the storage coefficient. A lower transmissivity will result in slower propagation of drawdown and slower progression of depletion from zero to 1.0 through pumping time and a higher transmissivity will result in faster propagation of drawdown and progression of depletion through time. Conversely, a lower storage coefficient will result in faster progression of depletion and a higher storage coefficient will result in slower progression of depletion. The distribution of diffusivity, or the distributions of both transmissivity and storage coefficient over the entire river aquifer is not known, so the approach taken here calculates depletion using (a) a uniform low (or conservative from the standpoint of effects of a pumping well on the river) estimate of diffusivity and (b) a uniform average estimate of diffusivity. For this study, low and average diffusivities were computed using an estimate of the average storage coefficient and estimates of the low and average transmissivity. Methods and rationales for selecting these values are given in the following two sections.

Transmissivity

Although detailed distributions of transmissivities for the river aquifer are not known, many estimates of transmissivity for sediments in the river aquifer were published by Metzger and Loeltz (1973, table 2), Metzger and others, (1973, table 5), and Olmstead and others, (1973, table 7). The best of these estimates were used to develop log-normal distributions of transmissivity for several subreaches of the river aquifer. From those log-normal distributions, low and average transmissivity values were selected.

The best values of transmissivity were selected from Metzger and Loeltz (1973, table 2), Metzger and others, (1973, table 5), and Olmstead and others, (1973, table 7) using the following two criteria:

1. Only transmissivity values from tests in the younger and older alluvium of the lower Colorado River are used.

2. Test results are listed in the source reports as being fair, good, or excellent, in terms of conformance to theoretical values and reliability of the estimate.

Published values were available for Mohave Valley, Parker-Palo Verde-Cibola, and Yuma areas. The first two of these areas are above Laguna Dam, and the Yuma area is below Laguna Dam. Published values of transmissivity that meet the criteria are generally higher in the Yuma area than in the areas above Laguna Dam. For this reason, separate log-normal distributions of transmissivity were developed for reaches above and below Laguna Dam. Transmissivity values used are given in tables 1 and 2. In some cases, the source documents listed multiple estimates for an individual well. Where these estimates met the criteria for inclusion in the analysis, multiple values for the same well were included.

The statistical analyses used 25 estimates of transmissivity upstream of Laguna Dam (table 1) and 58 estimates downstream of Laguna Dam (table 2). Best-fit log-normal distributions to these data are shown in figures 3*A* and 3*B*. The low estimate of transmissivity was selected as the value for which probability is 0.05 (5 percent) that transmissivity is less than or equal to the value. The average estimate of transmissivity was selected as the value for which probability is 0.5 (50 percent) that transmissivity is less than or equal to the value. The low and average estimates of transmissivity for areas upstream of Laguna Dam are 6,300 ft^2/day (47,000 gal/day/ft), and 26,200 ft^2/day (196,000 gal/day/ft), respectively (fig. 3*A*). The low and average estimates of transmissivity for

Table 1. Transmissivity values above Laguna Dam used for statistical analysis.
[Type of test: D, drawdown; R, recovery; S, specific capacity; numbers in square brackets are range interval tested, in depth below land surface, in feet]

Well Name	Other Identifier	Transmissivity, in gallons per day per foot	Transmissivity, in feet squared per day	Method of analysis
Mohave Valley (Metzger and Loeltz, 1973, table 2)				
(B-18-22)15aab	D. Hulet	240,000	32,100	R
(B-18-22)27bbc	G. McKellip	600,000	80,200	D
(B-18-22)27bbc	G. McKellip	900,000	120,300	R
(B-18-22)27bbc	G. McKellip	240,000	32,100	S
9N/23E-29F1	City of Needles	600,000	80,200	R
9N/23E-29F1	City of Needles	300,000	40,100	S
9N/23E-32K1	City of Needles	450,000	60,200	R
9N/23E-32K1	City of Needles	70,000	9,400	S
11N/21E-36G2	Soto Brothers	94,000	12,600	R
11N/21E-36G2	Soto Brothers	75,000	10,000	S
11N/21E-36Q1	W. Riddle	160,000	21,400	D
11N/21E-36Q1	W. Riddle	170,000	22,700	R
11N/21E-36Q1	W. Riddle	140,000	18,700	S
Parker Valley (Metzger and others, 1973, table 5)				
(B-7-21)14dcd	USBIA No.8	460,000	61,500	R
(B-9-20)11dbc	USBIA No.2	400,000	53,500	R
(B-9-19)5ddd	USGS LCRP-15	300,000	40,100	R [175-199]
(B-7-21)14acd	USBIA No.7	75,000	10,000	R
(B-7-21)23acd	USBIA No.9	120,000	16,000	D,R
(B-7-21)23dcd	USBIA No.10	40,000	5,300	D,R
Palo Verde Valley (Metzger and others, 1973, table 5)				
5S/22E-28C2	U.S. Citrus Corp	64,000	8,600	R
6S/22E-11H1	H. M. Neighbor	700,000	93,600	R
6S/22E-15Q1	E. Weeks	290,000	38,800	R
6S/22E-35R2	Southern Counties Gas Co	150,000	20,100	R
8S/21E-13A1	USGS LCRP-16	63,000	8,400	D
8S/21E-13A1	USGS LCRP-16	170,000	22,700	R

areas downstream of Laguna Dam are 15,500 ft^2/day (116,000 gal/day/ft) and 45,900 ft^2/day (343,000 gal/day/ft), respectively (fig. 3*B*).

Storage coefficient

In aquifers such as the river aquifer along the lower Colorado River, the storage coefficient accounts for processes including (a) draining and filling of pore spaces at the water table, (b) contraction and expansion of the aquifer skeleton, and (c) decompression and compression of water in the pore spaces. The property that accounts for the first of these processes is designated as the aquifer specific yield. The property that accounts for the remaining two of these processes is the elastic aquifer storage coefficient. In the river aquifer along the lower Colorado River, the specific yield accounts for the dominant mechanism of storage change. Specific yield in the river aquifer is several orders of magnitude larger than the elastic storage coefficient, and therefore is used to define low and average diffusivity. The best estimate of specific yield in the area is from Loeltz and Leake (1983). They published estimates of specific yield from neutron-probe studies along both sides of the Colorado River at 18 cross sections, spaced at approximate 1-mile intervals. The average specific-yield value from these studies was about 0.2, and this value is used in this study of depletion along the lower Colorado River.

Table 2. Transmissivity values below Laguna Dam used for statistical analysis; all transmissivity values are from Olmstead and others (1973, table 7).

[Type of test: D, drawdown; R, recovery; LA, leaky artesian analysis with observation wells; numbers in square brackets are interval tested, in depth below land surface, in feet]

Well Name	Other Identifier	Transmissivity, in gallons per day per foot	Transmissivity, in feet squared per day	Type of test
16S/22E-29Gca2	USGS LCRP-26	570,000	76,200	R
16S/23E-8Ecc	USBR CH5	340,000	45,500	D
16S/23E-8Ecc	USBR CH5	750,000	100,300	R
16S/23E-22Fdc	H. Mitchell	440,000	58,800	R
16S/23E-9Naa	M. E. Spencer	300,000	40,100	R
16S/23E-8Ecc	USGS LCRP-23	240,000	32,100	R
16S/23E-10Rcc	Dover and Webb	420,000	56,100	R
(C-7-22)14bcd	USGS LCRP-14	110,000	14,700	R
(C-8-21)19dad	F. J. Hartman	230,000	30,700	R
(C-8-21)30cdc	F. J. Hartman	1,800,000	240,600	R
(C-8-22)13bdd2	S. Sturges	65,000	8,700	R
(C-8-22)18cbd	Powers	610,000	81,600	R
(C-8-22)18ddd	Powers	800,000	107,000	R
(C-8-22)19ccc	USBR CH702	68,000	9,100	R
(C-8-22)21ddd	B. Church	390,000	52,100	R
(C-8-22)22caa	B. Church	430,000	57,500	R
(C-8-22)22cda1	B. Church	320,000	42,800	R
(C-8-22)22cda2	B. Church	380,000	50,800	R
(C-8-22)25bad	F. J. Hartman	400,000	53,500	R
(C-8-22)26adb	S & W	290,000	38,800	R
(C-8-22)28aaa	B. Church	350,000	46,800	R
(C-8-22)30cab	C. Lord	380,000	50,800	R
(C-8-22)30ddd	C. Lord	360,000	48,100	R
(C-8-22)34aaa	W. R. Whitman	960,000	128,300	R
(C-9-23)20cdd	YCWUA 5	250,000	33,400	D
(C-9-23)29adb	Yuma Mesa Fruit Growers	600,000	80,200	D
(C-9-23)30cba2	YCWUA 6	200,000	26,700	D
(C-9-24)13cdd	USBR CH3	300,000	40,100	D
(C-9-24)13cdd	USBR CH3	300,000	40,100	R
(C-9-24)36aaa	McDaniel & Sons, Inc.	160,000	21,400	R
(C-10-23)12aba1	J. F. Nutt	210,000	28,100	D
(C-10-23)12aba1	J. F. Nutt	260,000	34,800	R
(C-10-23)12bda	J. F. Nutt	500,000	66,800	R
(C-10-23)15aab	J. F. Nutt	270,000	36,100	R
(C-10-23)31bbb1	USGS LCRP-1	280,000	37,400	LA
(C-10-24)12bcc2	YCWUA 8	260,000	34,800	R
(C-10-24)13bbd1	YCWUA 9	540,000	72,200	R
(C-10-25)1bba	P. R. Sibley	443,000	59,200	R
(C-10-24)2cda	F. Jeffries	460,000	61,500	R
(C-10-24)35cab	J. F. Barkley	600,000	80,200	R
(C-11-23)34bbc	USGS LCRP-30	1,300,000	173,800	R
(C-11-24)2abd	J. F. Nutt	1,100,000	147,100	D and R
(C-11-24)23bcb	USGS LCRP 10	740,000	98,900	R
(C-11-25)3dac	E. Hughes	730,000	97,600	R
(C-9-23)17abc1	YCWUA 3	230,000	30,700	D
(C-8-22)34add	USBR CH750	150,000	20,100	R

Table 2. Transmissivity values below Laguna Dam used for statistical analysis; all transmissivity values are from Olmstead and others (1973, table 7)—Continued.

[Type of test: D, drawdown; R, recovery; LA, leaky artesian analysis with observation wells; numbers in square brackets are interval tested, in depth below land surface, in feet]

Well Name	Other Identifier	Transmissivity, in gallons per day per foot	Transmissivity, in feet squared per day	Type of test
(C-8-22)35caa1	USBR CH704	340,000	45,500	R [435-570]
(C-8-22)35caa1	USBR CH704	1,100,000	147,100	R [99-170]
(C-8-22)35caa2	USBR CH751	190,000	25,400	R
(C-8-22)35cca	Az. Western College	230,000	30,700	R
(C-8-22)35cad	USBR CH752	200,000	26,700	R
(C-8-23)25acb	Gunther and Shirley	260,000	34,800	R
(C-8-23)25dab	Gunther and Shirley	300,000	40,100	R
(C-8-23)26bac	G. Ogram	180,000	24,100	R
(C-8-23)27ada	USBR CH701	330,000	44,100	D
(C-8-23)27ada	USBR CH701	230,000	30,700	R
(C-8-23)27ddd1	Carter	120,000	16,000	R
(C-8-24)22ccd	McLaren Produce Co.	300,000	40,100	D

Characteristics of Models

All models were constructed and implemented in the same way, with the major differences being the geometry of the domain and surface-water features simulated and the transmissivity values tested. Simulations were carried out with the USGS model program MODFLOW-2000 (Harbaugh and others, 2000). Common characteristics of the models are as follows:

1. Each model domain represents a major contiguous area of saturated alluvium and adjacent saturated older alluvium along the lower Colorado River. The lateral boundaries of the active model domain were determined by the outermost position of (a) the “river aquifer” as mapped by Wilson and Owen-Joyce (1994) or (b) the Colorado River alluvium upstream and downstream boundaries of each model where no adjacent river aquifer was mapped. The areas modeled are shown in figure 1. Coordinates for perimeters of the active model domains were prepared in the coordinate system defined by Universal Transverse Mercator Zone 11, 1927 North American Datum. In some areas, the model perimeters were smoothed to remove unnecessary details in the river aquifer boundaries.
2. Units of length in the models are feet. As discussed in following sections, however, some computations used coordinates in meters to construct model data sets. Units of time in the models are days.

Model grids were oriented with rows in an east-west direction and columns in a north-south direction. The origin of each model is the northwest corner of the domain, so that model rows increment in a southerly direction and model columns increment in an easterly direction (fig. 4). The lateral grid spacing was 0.25 mile (402.3 m) along rows and columns.

The number of rows in each model, N_{row}, was computed as

$$N_{row} = INT\left[\frac{(Y_{\max} - Y_{\min})}{\Delta} + 0.49999\right],$$

where

INT is a function that converts a real number to an integer by truncating digits to the right of the decimal place,

$Y_{\max}$ is the maximum of all UTM easting coordinates (in meters) along the model perimeter,

$Y_{\min}$ is the minimum of all UTM easting coordinates (in meters) along the model perimeter, and

Δ is the grid spacing (402.3 m).

Similarly, the number of columns in each model, N_{col}, was computed as

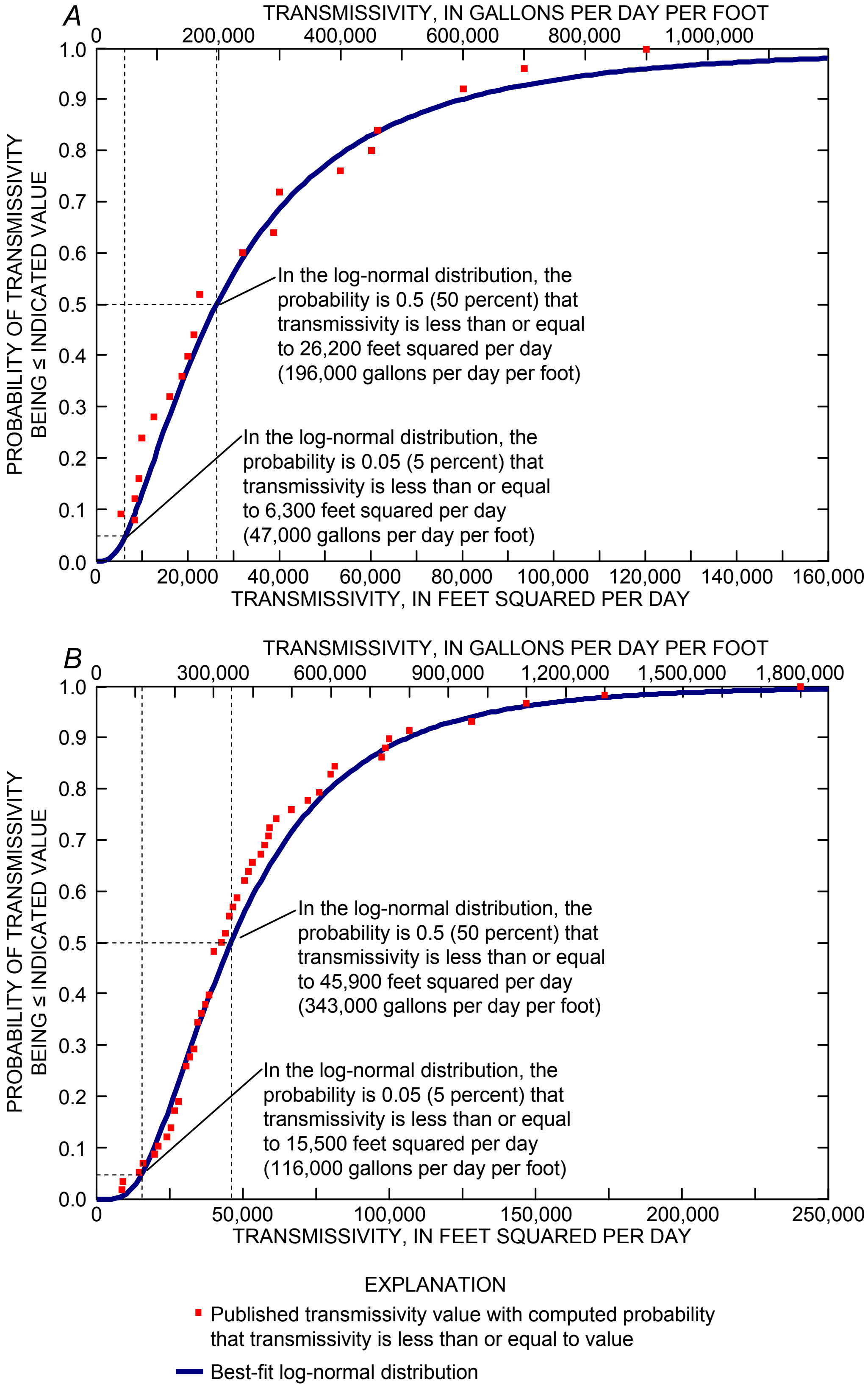
$$N_{col} = INT\left[\frac{(X_{\max} - X_{\min})}{\Delta} + 0.49999\right],$$

where

$X_{\max}$ is the maximum of all UTM northing coordinates (in meters) along the model perimeter,

$X_{\min}$ is the minimum of all UTM northing coordinates (in meters) along the model perimeter.

The active part of the model grid was determined in a two-step process using the model perimeter polygon and polygons denoting areas of no flow within the model perimeter (fig. 4). Areas of no flow can occur where low permeability rocks are surrounded by the river aquifer. For the first step,



In the log-normal distribution, the probability is 0.5 (50 percent) that transmissivity is less than or equal to 26,200 feet squared per day (196,000 gallons per day per foot)

In the log-normal distribution, the probability is 0.05 (5 percent) that transmissivity is less than or equal to 6,300 feet squared per day (47,000 gallons per day per foot)

In the log-normal distribution, the probability is 0.5 (50 percent) that transmissivity is less than or equal to 45,900 feet squared per day (343,000 gallons per day per foot)

In the log-normal distribution, the probability is 0.05 (5 percent) that transmissivity is less than or equal to 15,500 feet squared per day (116,000 gallons per day per foot)

Figure 3. Cumulative distribution functions for best-fit log-normal distributions of transmissivity along the Lower Colorado River. *A*, Distribution function for data north of the Yuma area. *B*, Distribution function for data in the Yuma area.

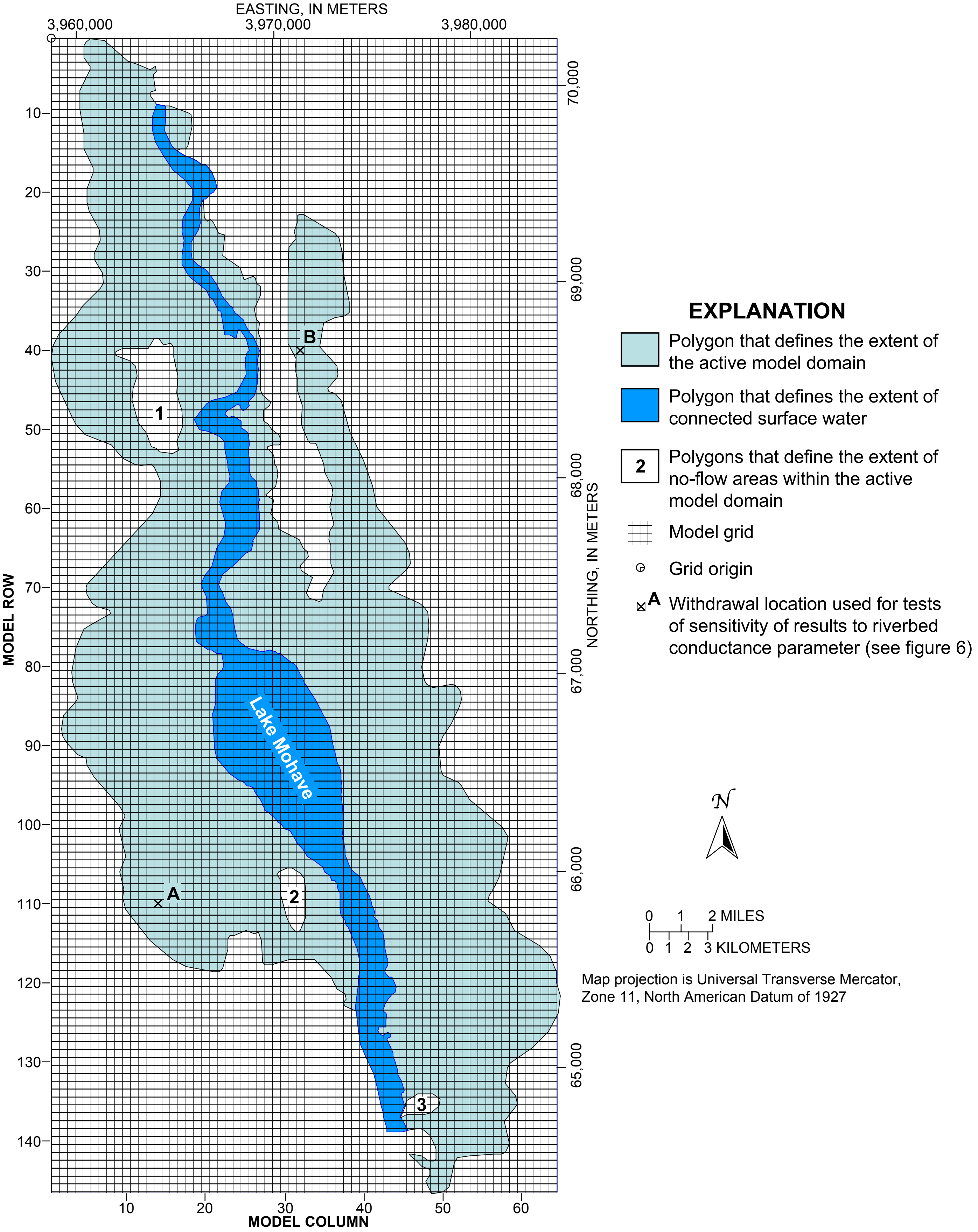


Figure 4. Model grid and features of the Lake Mohave ground-water superposition model.

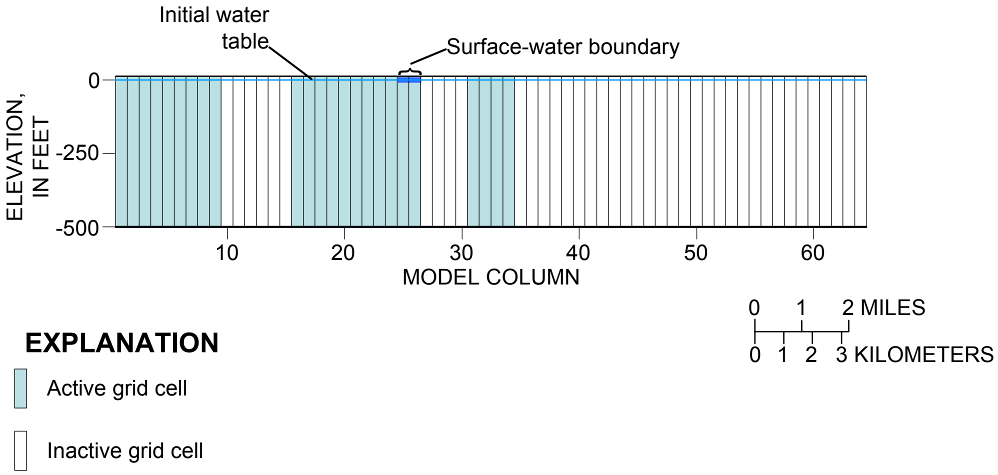


Figure 5. Vertical section along row 40 of the Lake Mohave ground-water superposition model.

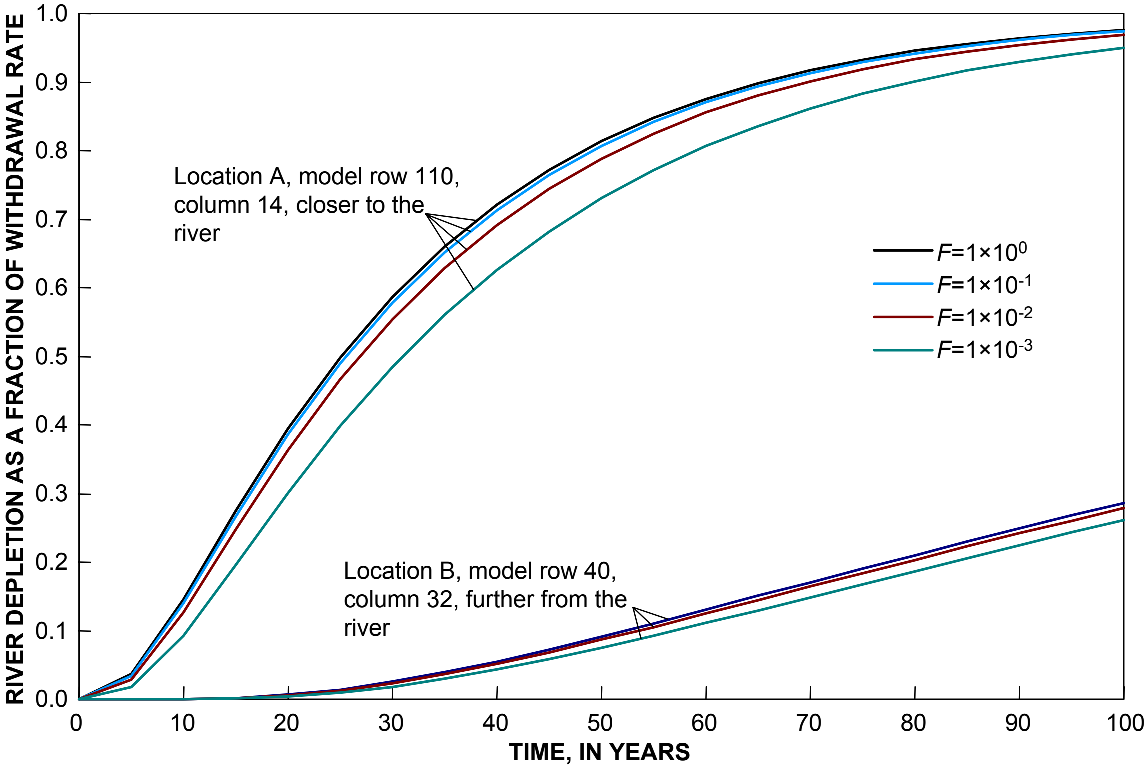


Figure 6. Results from sensitivity tests of the riverbed conductance parameter in the Lake Mohave ground-water superposition model for two withdrawal locations (see fig. 4). Multiple depletion curves were generated by multiplying all conductance values by the parameter *F*.

Table 3. Characteristics of superposition models constructed for parts of the flood plain and river aquifer adjacent to the lower Colorado River.
[Transmissivity values run: Yes, depletion analysis was completed for value; No, depletion analysis was not completed for value.]

Model name	UTM Easting of west edge of grid, meters[1]	UTM Northing of north edge of grid, meters[1]	Number of model rows	Number of model columns	Number of active model cells	Transmissivity values run, feet squared per day (gallons per day per foot)				
						980 (7,300)	6,300 (47,000)	15,500 (116,000)	26,200 (196,000)	45,900 (343,000)
Detrital-Virgin	719593.75	4116963.00	396	148	21,025	Yes	Yes	No	Yes	No
Lake Mohave	702348.12	3958695.50	146	64	4,103	No	Yes	No	Yes	No
Mohave Valley	706260.69	3897829.00	160	139	8,976	No	Yes	No	Yes	No
Parker-Palo Verde-Cibola	636450.00	3789000.00	296	388	40,292	No	Yes	No	Yes	No
Laguna Dam	730897.38	3672455.25	103	145	6,302	No	Yes	No	Yes	No
Yuma	640414.62	3691950.25	374	340	59,645[2]	No	Yes	Yes	Yes	Yes

[1] Coordinates are UTM Zone 11, North American Datum of 1927.

[2] For the model in the Yuma area, depletion was not calculated for active model cells in Mexico and areas in USA west of the area of the accounting surface published by Owen-Joyce and others (2000). A total of 16,147 simulations were made for each of four transmissivity values.

all cells that were more than 50 percent within the model perimeter were denoted as active, and all cells that were 50 percent or less within the model perimeter were denoted as inactive. Second, all cells that were more than 50 percent within any area of no flow were denoted as inactive.

3. Each model consists of one layer of cells with a bottom elevation of –500 ft and an initial head elevation of 0 ft for each active cell (fig. 5). This results in a uniform starting saturated thickness of 500 ft. The top elevation of the model was set at a uniform elevation of 10 ft.
4. Connected surface-water features were simulated using the River Package of MODFLOW-2000. For all models, river stages were set to an elevation of zero, thereby allowing computation of change in flow to or from surface-water features that result from change in head in connected cells. In the River Package, the degree of connection between the surface water and a connected cell is controlled by the riverbed conductance term, C_{riv} , which is defined as

$$C_{riv} = K_{rb} A / b_{rb},$$

where

K_{rb} is the vertical hydraulic conductivity of the riverbed,

A is the area of the river in the cell, and

b_{rb} is the thickness of the riverbed.

Large riverbed conductance values were specified so that simulated surface-water features are hydraulically well connected to underlying model cells. This approach approximates a specified-head boundary at the location of surface-water feature. For the Parker-Palo Verde-Cibola model the River Package data set was constructed using the program RIVGRID (Leake and Claar, 1999), using an approximate river centerline, an assumed river width of 100 ft, an assumed K_{rb} of 50 ft/day, and an assumed b_{rb} of 5 ft. The area, A , used to compute the riverbed conductance, C_{riv} is computed by program RIVGRID as the product of the length of the river traversed in a cell by the centerline and the assumed river width. The average value of C_{riv} for the Parker-Palo Verde-Cibola model was 2.3×10^5 ft^2/day. For all other models A was computed as the area of intersection of a polygon representing the Colorado River and (or) reservoirs (fig. 4) and the model cell. The quantity was set at 0.929 day^{-1}, therefore the maximum conductance (for the case of a cell entirely within the river/reservoir polygon) is about 1.62×10^6 ft^2/day. The average riverbed conductance for the Mohave Valley model is 7.3×10^5 ft^2/day. For the Lake Mohave model (fig. 4) the average riverbed conductance was 1.3×10^6 ft^2/day reflecting a wider surface-water body than is present in the Mohave Valley model.

The sensitivity of model results to the value of riverbed conductance was tested using the Lake Mohave model. Depletion curves were computed by the model for withdrawal at two locations. For the first point, labeled “A” on figure 4, depletion can occur when effects of withdrawal propagate about 4.5 miles northeastward to the edge of Lake Mohave. For the second point, labeled “B” on figure 4, depletion can occur when effects of withdrawal propagate about 14 miles along a side valley and then southwestward to the edge of Lake Mohave. Because of the shorter distance to surface water, depletion occurs more rapidly from withdrawals at point A than at point B. For each location, depletion curves were computed using a multiplication factor, *F*, of 1×10^{-1}, 1×10^{-2}, and 1×10^{-3}, for all riverbed conductance values (fig. 6). Curves shown for $F=1\times10^0$ use the original riverbed conductance values. As can be seen on figure 6, differences in depletion calculated with the original riverbed conductance values and with values that are three orders of magnitude lower are relatively minor, with the greatest differences occurring at location A. This observation along with the fact that thick, low-permeability riverbed sediments are not known to occur along the lower Colorado River leads to the conclusion that the strategy of using relatively high riverbed conductance values is reasonable.

A summary of characteristics of the six superposition models is given in table 3. The Laguna and Yuma models included parts of the model domain that extend beyond the mapped area of the river aquifer (fig. 1). The Laguna model was extended to the east because of uncertainty in where the river aquifer ends. An extension of the model domain such as this tends to slow down the progression of simulated depletion through time in comparison to that simulated in a model that includes a no-flow boundary. The Yuma model was extended southward and westward into the delta region of the Colorado River to reflect the continuous nature of the ground-water flow system thought to exist there.

Estimates of depletion in all models were made using the low and average transmissivity values from data upstream of Laguna Dam, 6,300 ft^2/day (47,000 gal/day/ft) and 26,200 ft^2/day (196,000 gal/day/ft), respectively. In addition, for the Yuma area, estimates of transmissivity were made using low and average transmissivity values derived from data downstream from Laguna Dam. Finally, for the Detrital-Virgin model, depletion also was calculated using a lower estimate of transmissivity, 980 ft^2/day (7,300 gal/day/ft). This was done because there were no published estimates of transmissivity in this area in the sources of data used in the statistical analyses. Transmissivity from one location in the Virgin Valley was inferred to be about 980 ft^2/day (7,300 gal/day/ft) from hydraulic conductivity and thickness estimates in a report by Las Vegas Water District (1992).

Procedure for Computing and Displaying Areal Representation of Depletion

A computer program was written to run each superposition model repeatedly to calculate depletion at 100 years for every active model grid cell. The program required that most MODFLOW data sets for the model be constructed prior to running the program. Steps taken by the program to calculate depletion for each active cell in the model grid are as follows:

1. Calculate the northing and easting of the cell center in Universal Transverse Mercator Zone 11 coordinates.
2. Construct a MODFLOW-2000 Well Package data set for a single well at the row and column location of the cell using the flow rate of -1.431×10^5 ft^3/day (a withdrawal of 1,200 acre-ft/year). The final results are independent of this rate because the system responds linearly to withdrawal (Leake and Reeves, 2008). The superposition model only considers the effects of the well being added, not effects of other wells that may exist in the real system.
3. Run the model.
4. Open the listing file from the model run and read the induced flow from the river in the volumetric mass balance for a simulation time of 100 years.
5. Divide the induced flow rate by the withdrawal rate to get the fraction of withdrawal rate that is accounted for as depletion at 100 years.
6. Save information including row and column location, northing and easting, and depletion fraction at 100 years.

When these steps are completed for each active cell in the model grid, the program is terminated. The northing and easting coordinates and depletion values then can be mapped using a geographic information system or other contouring program. The grid spacing of 0.25 mile results in a dense network of points for mapping over the area of the river aquifer.

Note that the method as implemented requires one simulation (model run) for each cell in the model grid for each transmissivity value used. For example, the Parker-Palo Verde model has 40,292 active model cells, requiring a total of 80,584 simulations for two uniform values of transmissivity. For the Yuma model, the active area is much larger than the area over which Owen-Joyce and others (2000) mapped the accounting surface. The mapped depletion, however, was restricted to a subarea of the model domain, requiring a total of 64,588 simulations for four uniform transmissivity values.

Results

Distributions of simulated depletion in the six model areas are shown on maps in figures 7–17. The maps show the simulated depletion at 100 years for one pumping well, as a function of the position of that well. Values shown are depletion as a percentage of the well pumping rate, expressed as colored areas in ten intervals ranging from 0–10 to 90–100. Supplemental contours showing 1 percent and 5 percent depletion are shown where values in this range were computed. Depletion percentages are not shown for areas within the flood plain of the Colorado River or areas underlying surface water. In the following discussions of results for the six areas modeled, particular focus is on any areas where depletion is 5 percent or less in 100 years.

Detrital-Virgin Area

This area includes Detrital Valley south of Lake Mead and the much larger Virgin Valley north of Lake Mead. With the lowest transmissivity value tested, 980 ft^2/day (7,300 gal/d/ft), the 5 percent depletion contour is within 5–10 miles of Lake Mead (fig. 7). Results for the two higher transmissivity values shown in figures 8 and 9, increased depletion can be seen by the increasing distance of the 5 percent contour from Lake Mead. For the highest value tested, 26,200 ft^2/day (196,000 gal/d/ft), depletion is greater than 5 percent in all of Detrital Valley and in all but the uppermost part of Virgin Valley.

Lake Mohave Area

This area was the smallest among the six areas modeled. For the two transmissivity values tested, 6,300 and 26,200 ft^2/day (47,000 and 196,000 gal/d/ft), no areas of depletion less than 10 percent were simulated (fig. 10). The lowest values of depletion are in a narrow north-south trending side valley on the east side of the river.

Mohave Valley Area

In this area, depletion simulated using the higher transmissivity value tested, 26,200 ft^2/day (196,000 gal/d/ft), is higher than 50 percent over the entire model domain (fig. 11). Using the lower value tested, 6,300 ft^2/day (47,000 gal/d/ft), a small area of depletion less than 5 percent was simulated in a side valley in the southeast part of the model domain.

Parker-Palo Verde-Cibola Area

This area is the largest river-aquifer area modeled and is the most complex in terms of horizontal geometry. Side valleys in the river aquifer include Chuckwalla and Smoketree Valleys in the west-central and southwest part of the area, and Cactus and La Posa Plains in the northeast part of the area. Using the lower transmissivity value tested, 6,300 ft^2/day (47,000 gal/d/ft), 5 and 1 percent simulated depletion contours can be seen in each of these side valleys (fig. 12). With the higher transmissivity value tested, 26,200 ft^2/day (196,000 gal/d/ft), only Chuckwalla Valley has simulated depletion values less than 10 percent (fig. 13).

Laguna Dam Area

This area includes the part of the river aquifer that is immediately above Laguna Dam. Much of this part of the river aquifer is east of the river. Using the lower transmissivity value tested, 6,300 ft^2/day (47,000 gal/d/ft), 5 and 1 percent simulated depletion contours can be seen around Castle Dome Plain (fig. 14). With the higher transmissivity value tested, 26,200 ft^2/day (196,000 gal/d/ft), simulated depletion is greater than 10 percent for the entire area (fig. 15).

Yuma Area

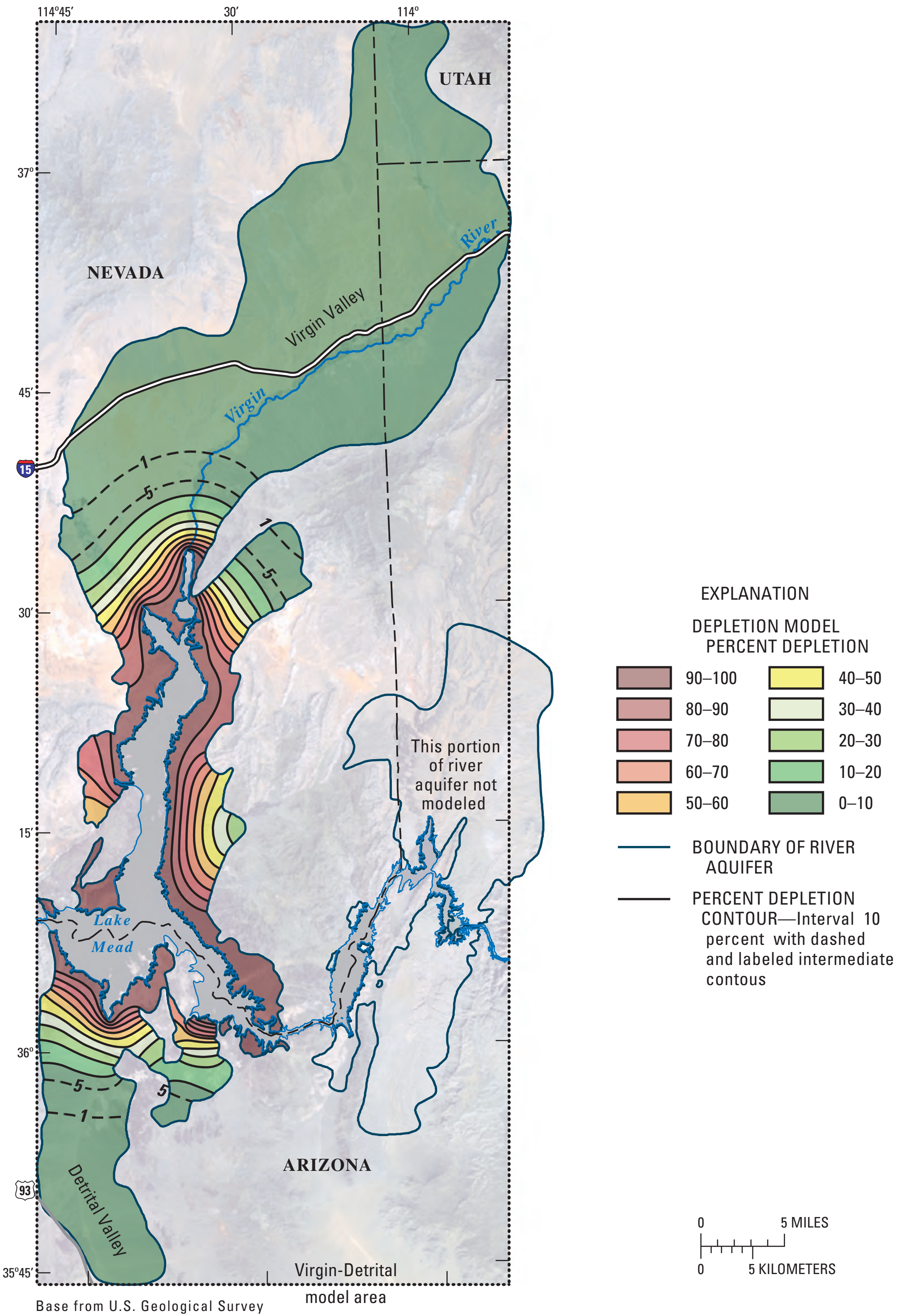
For the Yuma area, depletion was simulated for the area of the accounting surface mapped by Owen-Joyce and others (2000). For the two transmissivity values used in models upstream from Laguna Dam, 6,300 and 26,200 ft^2/day (47,000 and 196,000 gal/d/ft), areas of depletion of 5 percent or less were simulated with the lower of these values (fig. 14), but no areas of depletion of 10 percent or less were simulated with the higher value (fig. 15). Depletion also was simulated using two additional transmissivity values, 15,500 and 45,900 ft^2/day (116,000 and 343,000 gal/d/ft). For the lower transmissivity, a small area of depletion less than 10 percent was simulated on the west side of the mapped area in southeastern Imperial Valley (fig. 16). For the higher transmissivity, simulated depletion is greater than 20 percent throughout the model domain (fig. 17).

Summary and Conclusions

The Accounting-Surface Method was developed (Wilson and Owen-Joyce, 1994; Owen-Joyce and others, 2000; Wiele and others, 2008) to provide water managers with a possible tool help evaluate the need for entitlements by wells pumping in the river aquifer. To further understand temporal effects of pumping wells on the Colorado River, Reclamation set up a technical team to assess timing over which wells at great distance would deplete water in the Colorado River. Possible methods for calculating depletion of surface water from ground-water pumping range from simple analytical solutions to complex numerical ground-water flow models. For this study, an intermediate approach was taken, using numerical superposition models with complex horizontal geometry and simple vertical geometry. Six areas of the river aquifer along the lower Colorado River were modeled. Published transmissivity values were analyzed to determine low and average transmissivity values. A value of 0.2 was used for the aquifer specific yield (or storage coefficient) in all models. All model grids consisted of one layer of cells, with model rows and columns oriented in east-west and north-south directions, respectively.

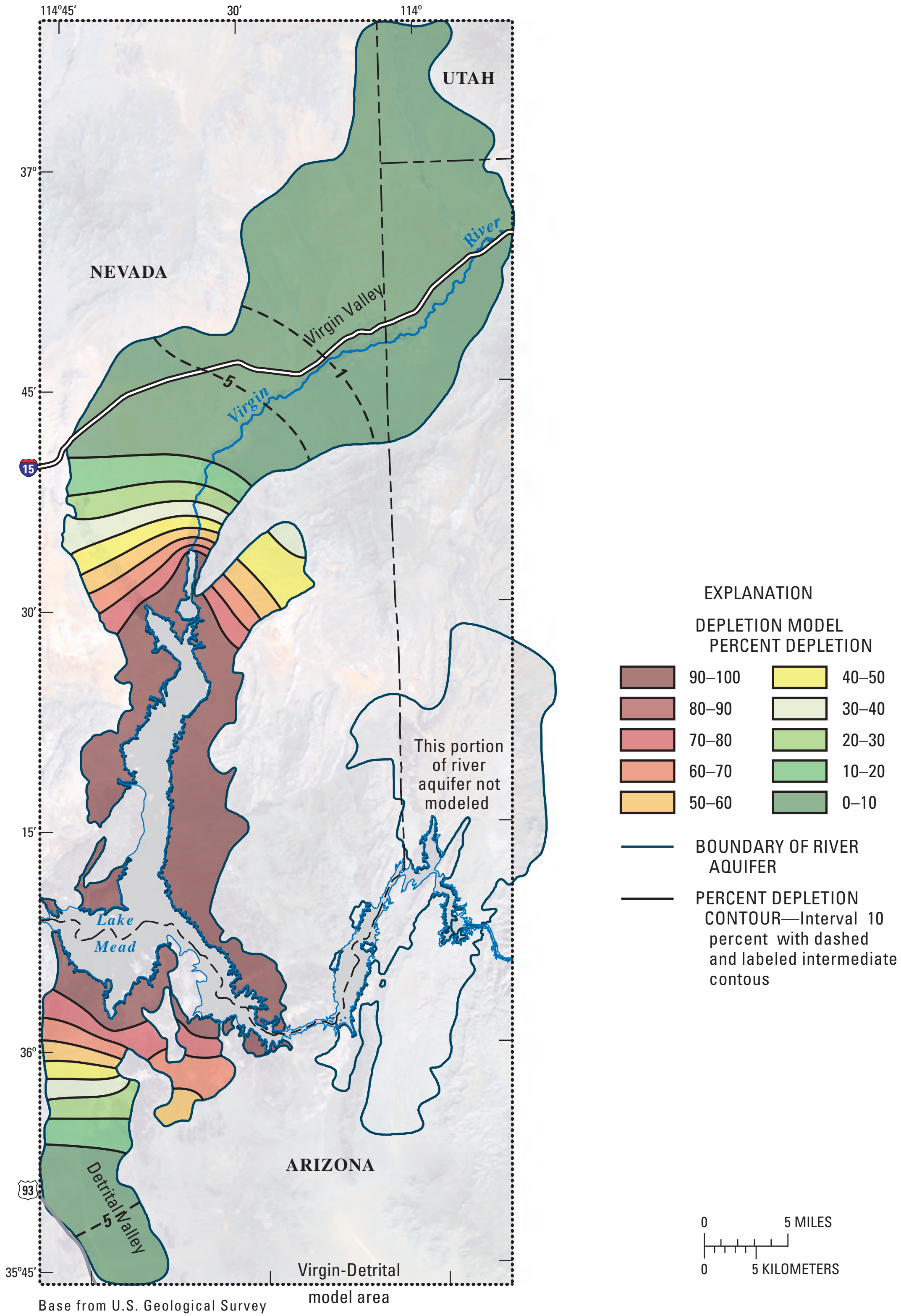
Distribution of depletion was simulated using MODFLOW-2000. One simulation was done for each active cell in the model grid for each transmissivity value tested. Maps were prepared to show the simulated depletion at 100 years for one pumping well, as a function of the position of that well.

Areas in which simulated depletion at 100 years was less than or equal to 5 percent generally occurred only in side valleys with the lower or more conservative transmissivity values tested. For the smaller areas modeled, and for the river aquifer within the river valley adjacent to the flood plain in all models, simulated depletion at 100 years was generally in the range of 10–100 percent of the pumping rate.



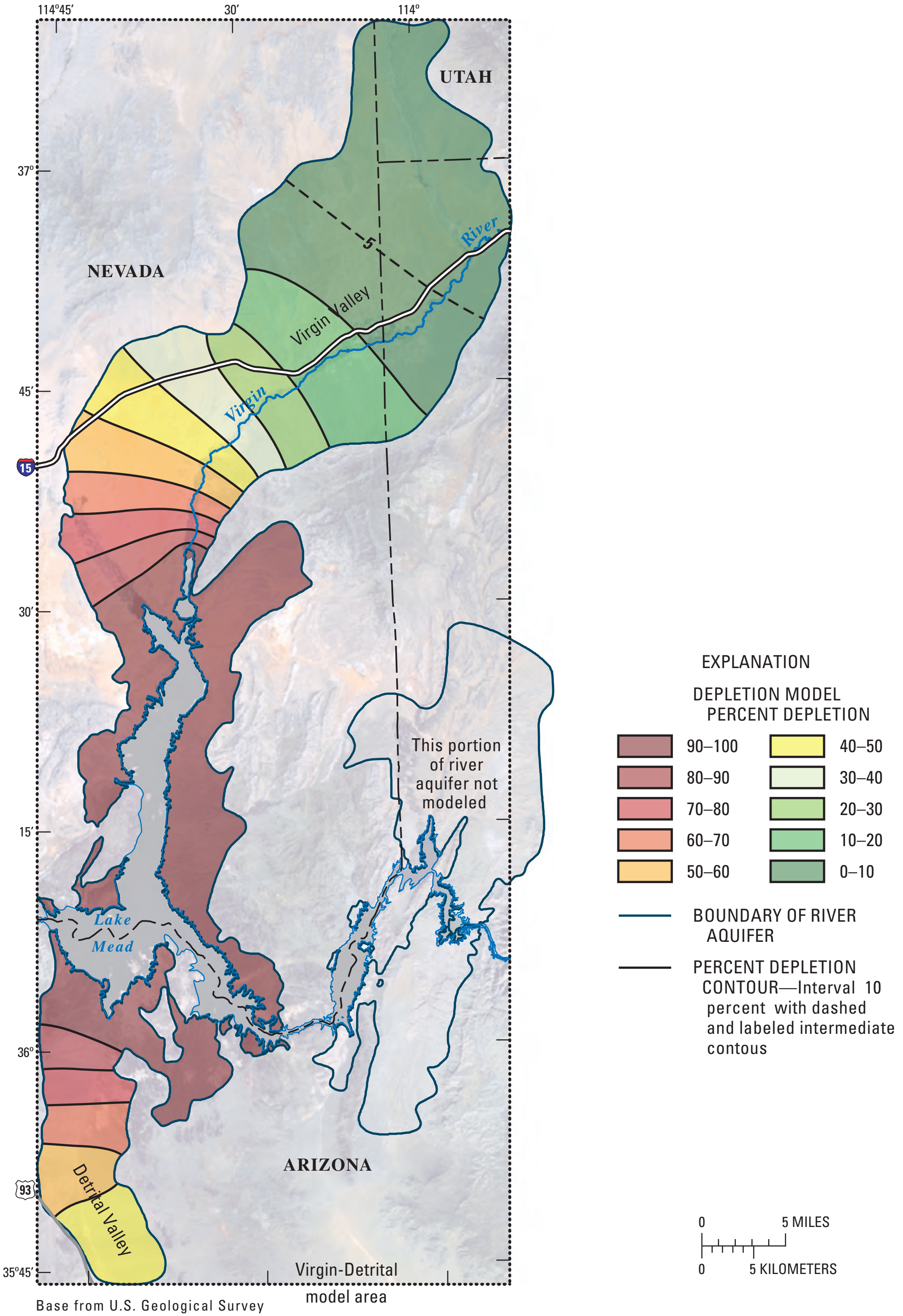
Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 7. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 980 feet squared per day (7,300 gallons per day per foot).



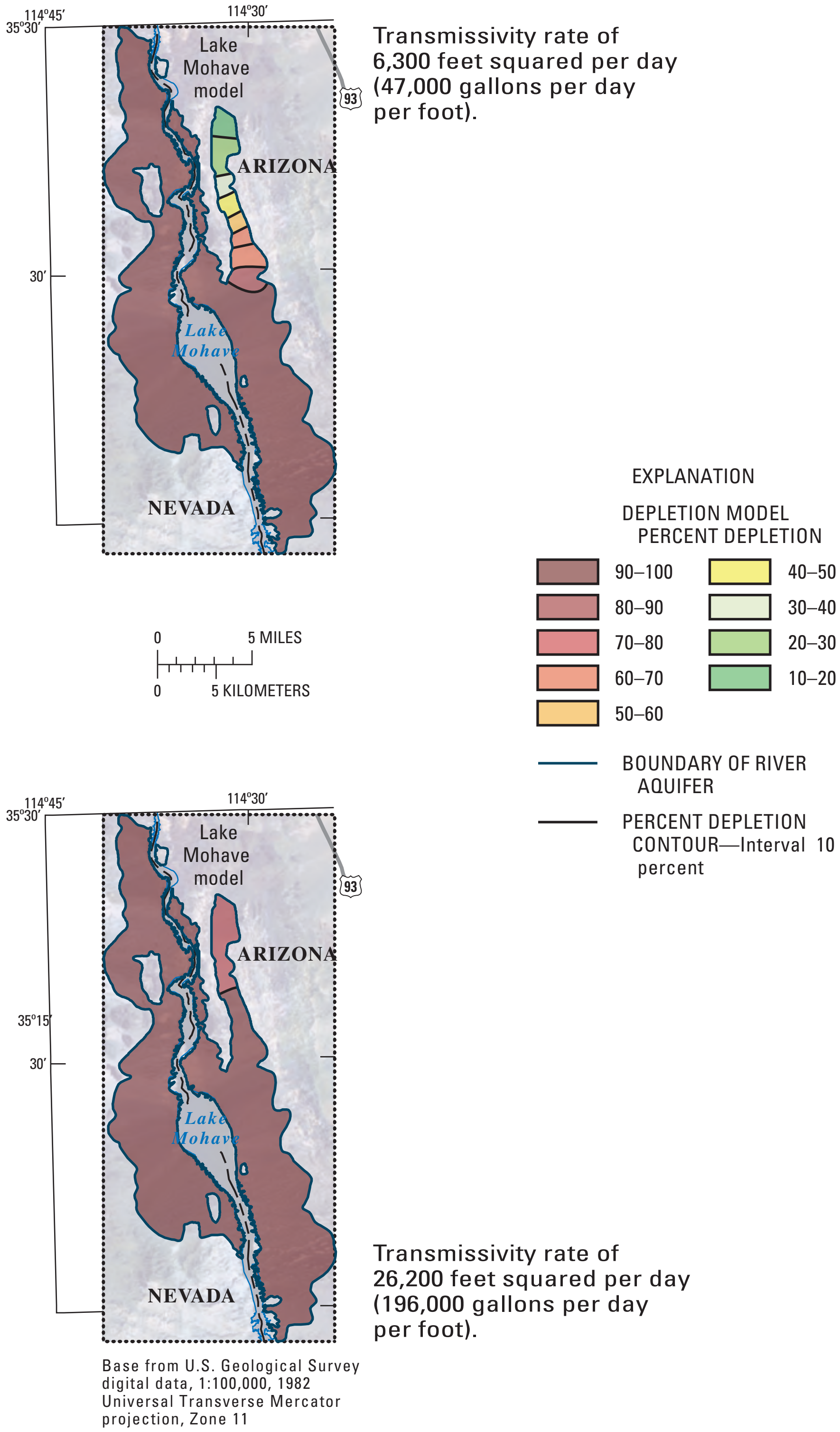
Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 8. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day (47,000 gallons per day per foot).



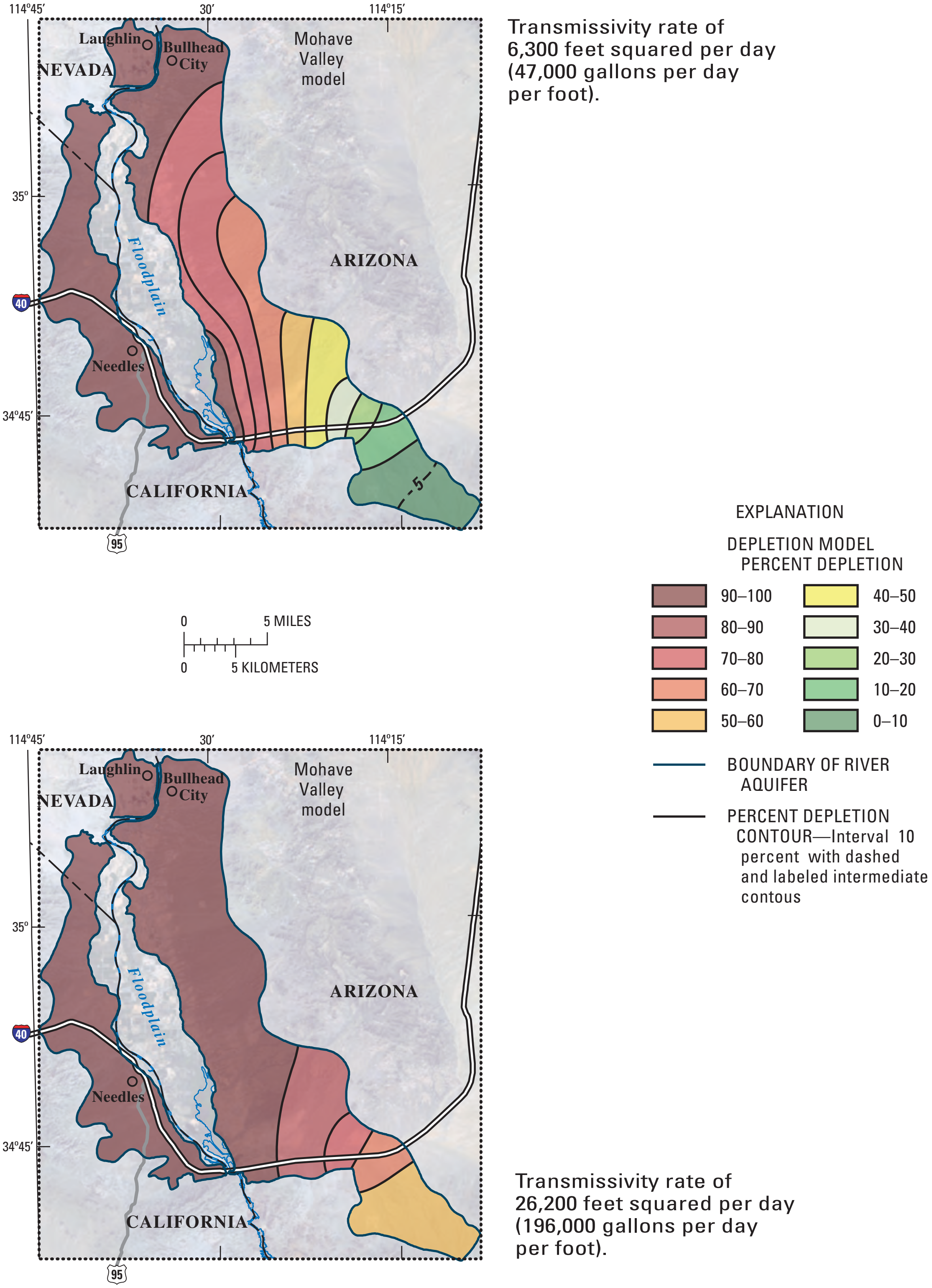
Base from U.S. Geological Survey digital data, 1:100,000, 1982
Universal Transverse Mercator projection, Zone 11

Figure 9. Percent depletion in 100 years by pumping wells within the Virgin-Detrital model area of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day (196,000 gallons per day per foot).



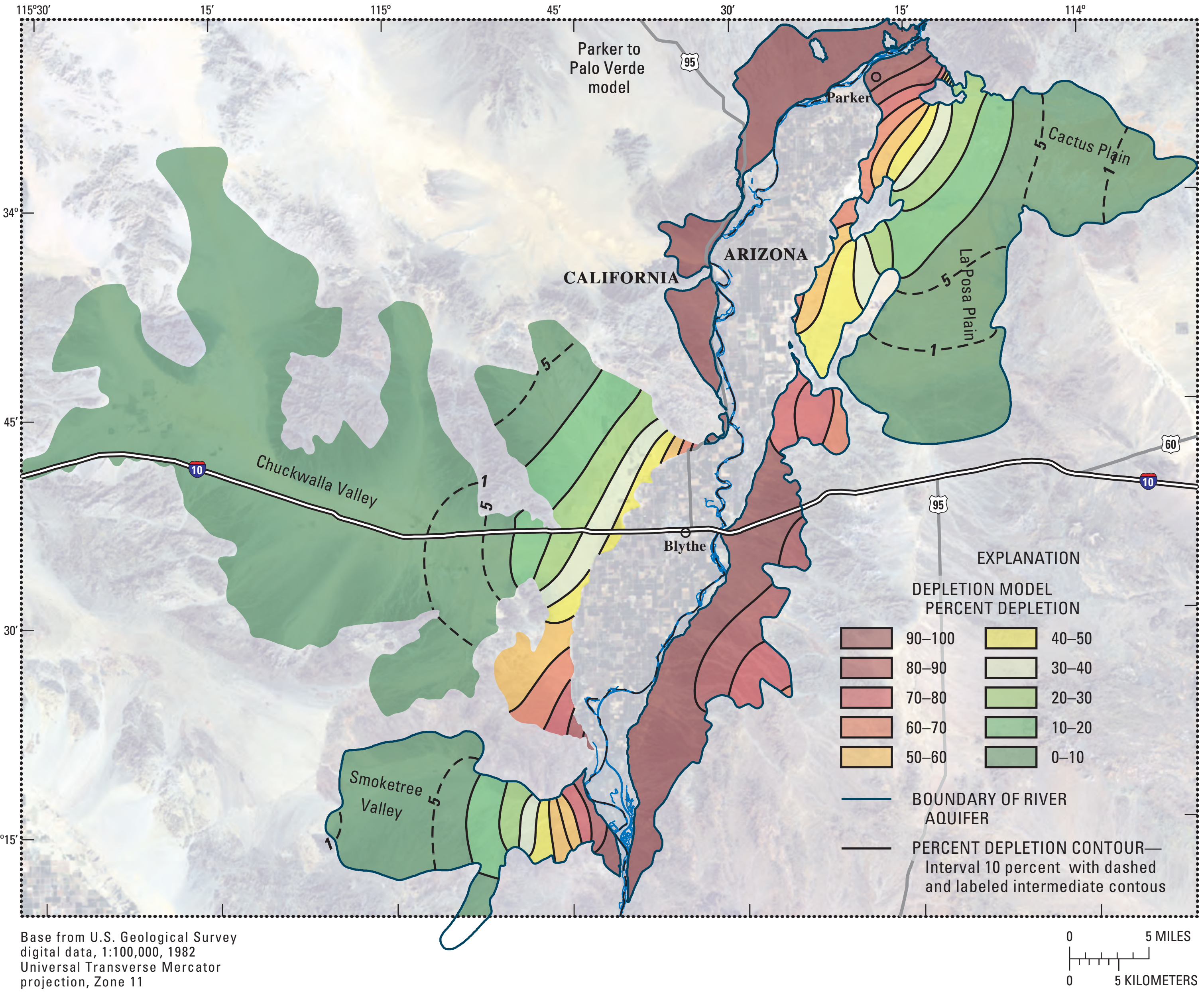
Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 10. Percent depletion in 100 years by pumping wells within the Lake Mohave model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 and 26,200 feet squared per day (47,000 and 196,000 gallons per day per foot).



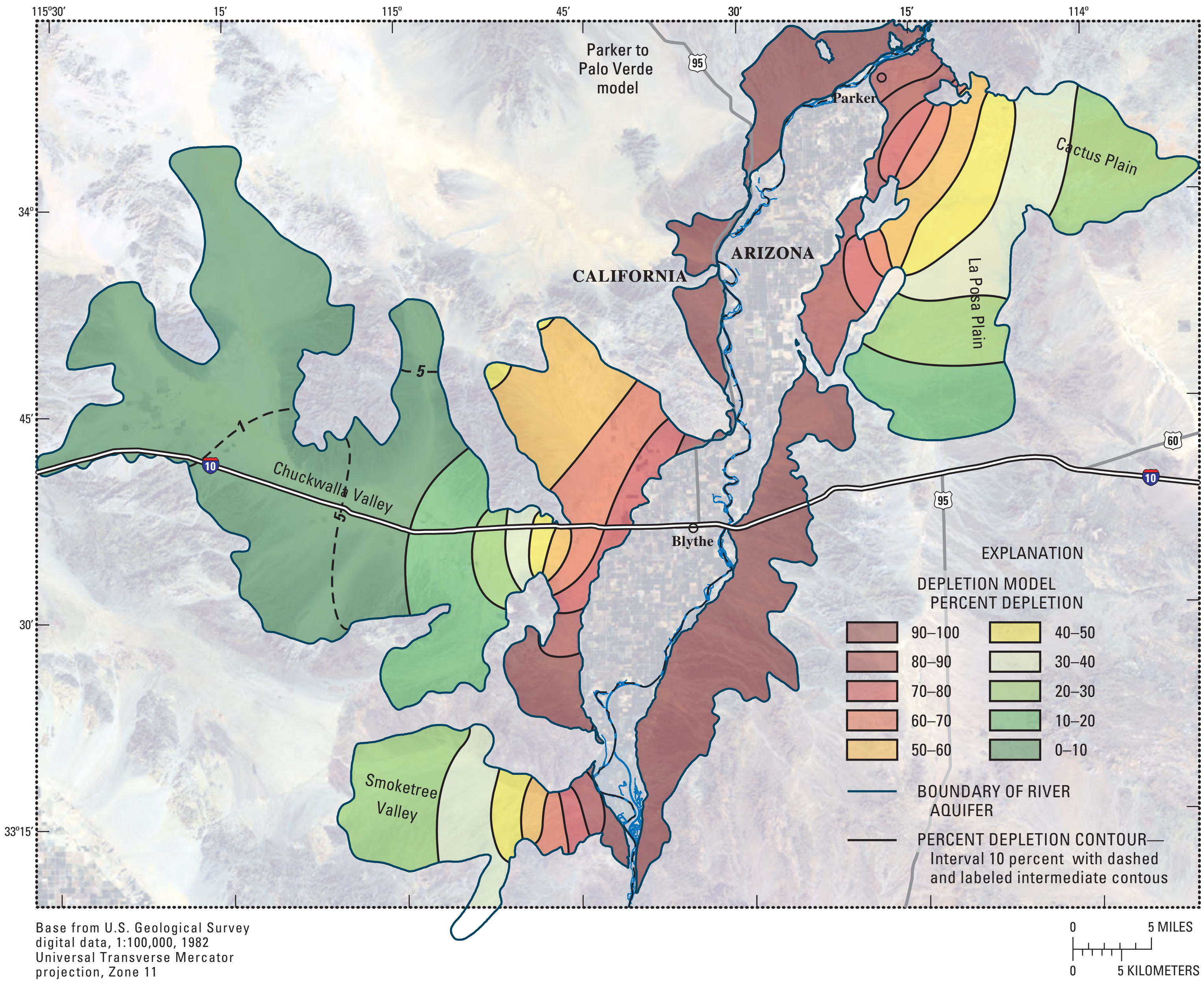
Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 11. Percent depletion in 100 years by pumping wells within the Mohave Valley model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 and 26,200 feet squared per day (47,000 and 196,000 gallons per day per foot).



Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 12. Percent depletion in 100 years by pumping wells within the Parker-Palo Verde-Cibola model area of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day (47,000 gallons per day per foot).



Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 13. Percent depletion in 100 years by pumping wells within the Parker-Palo Verde-Cibola model area of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day (196,000 gallons per day per foot).

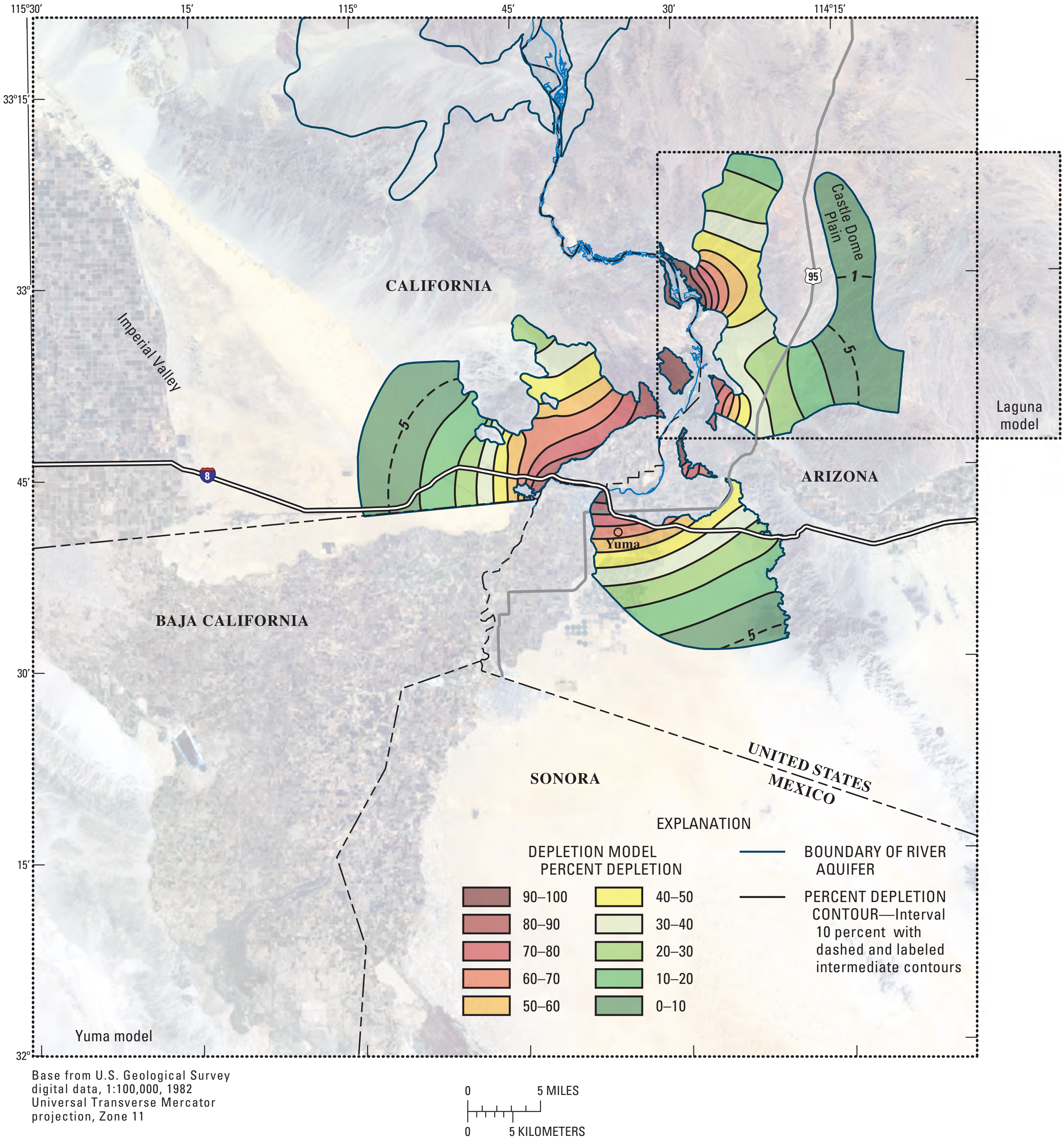
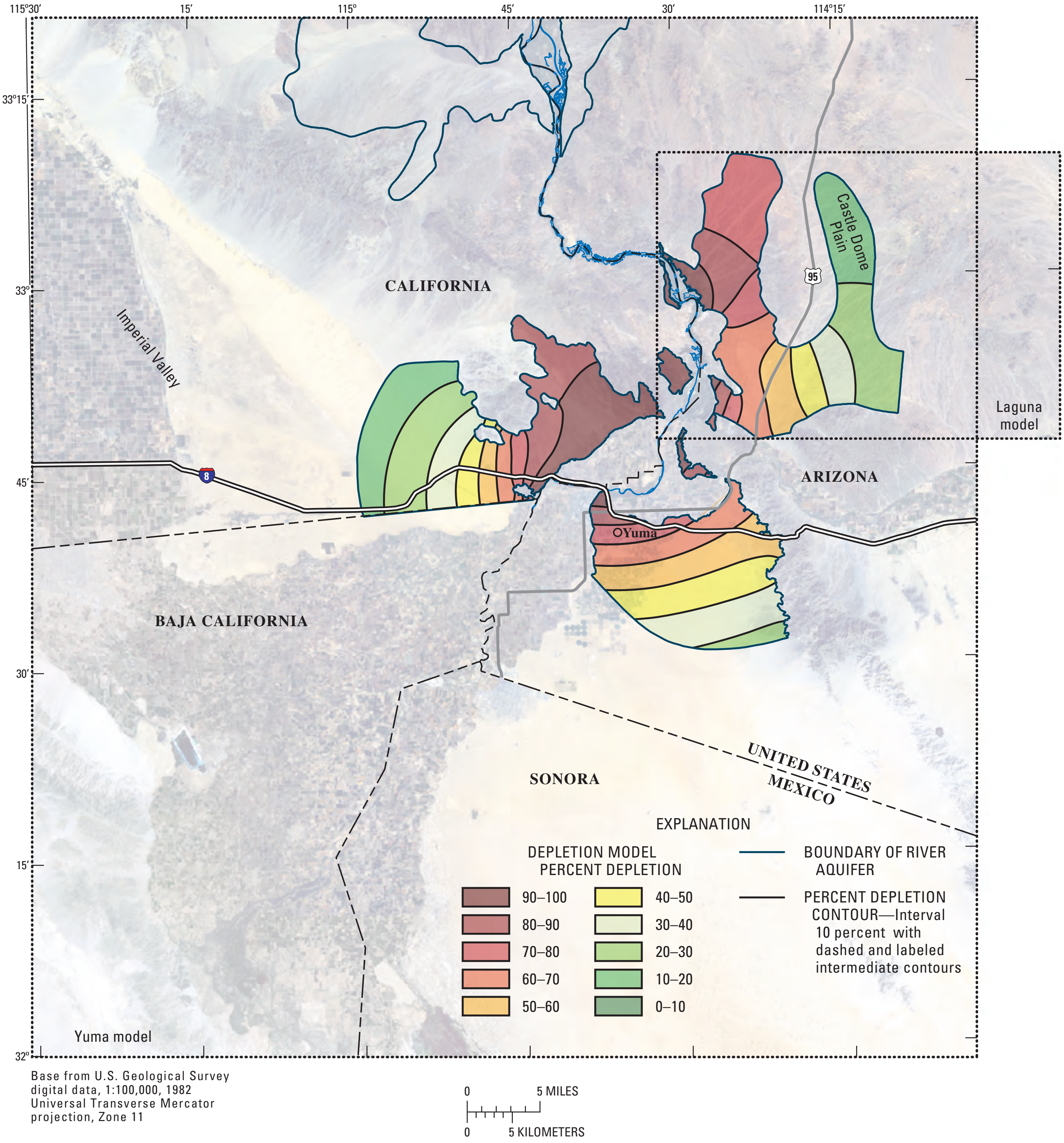
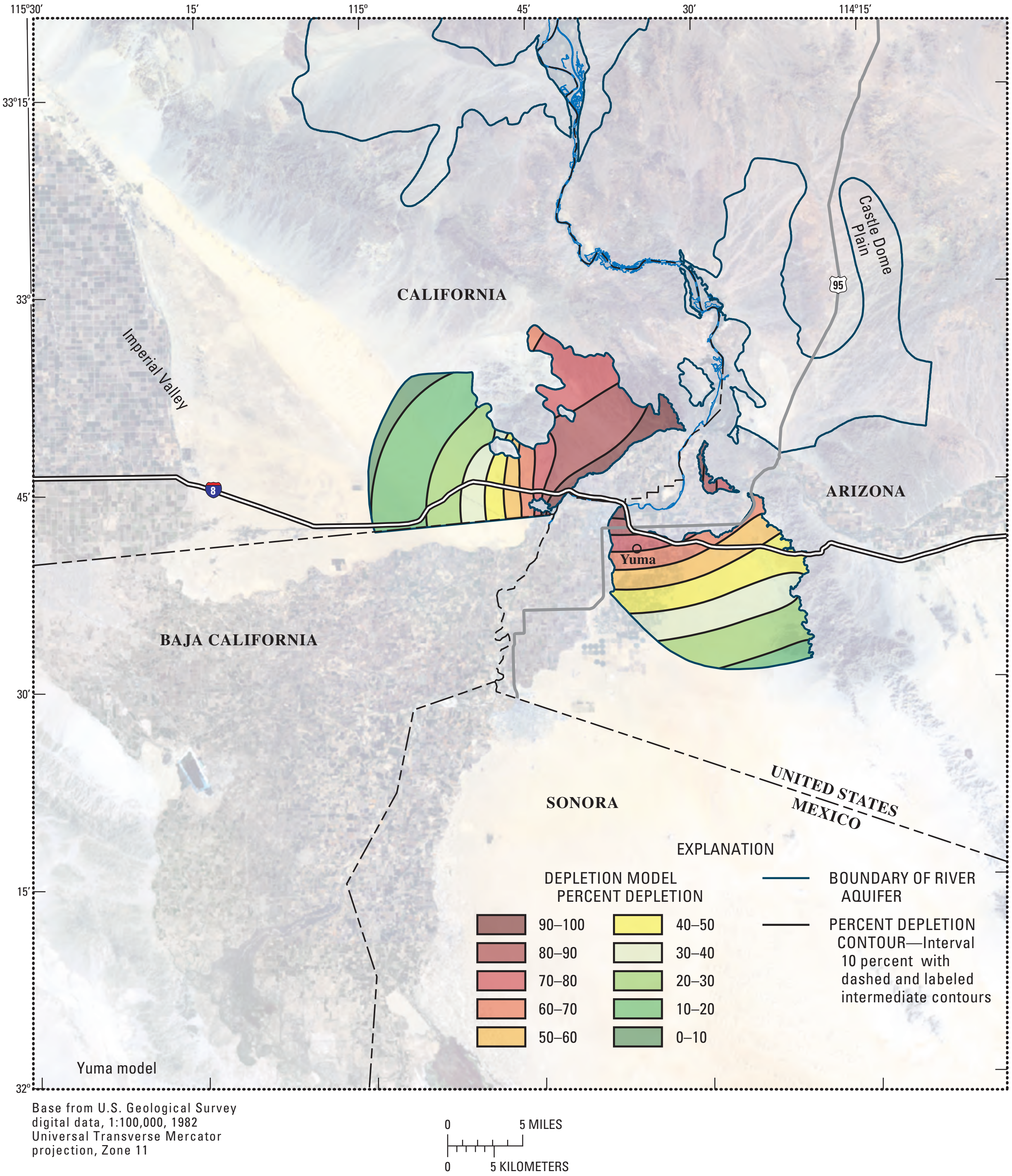


Figure 14. Percent depletion in 100 years by pumping wells within the Yuma and Laguna model areas of the Colorado River aquifer assuming a transmissivity rate of 6,300 feet squared per day (47,000 gallons per day per foot).



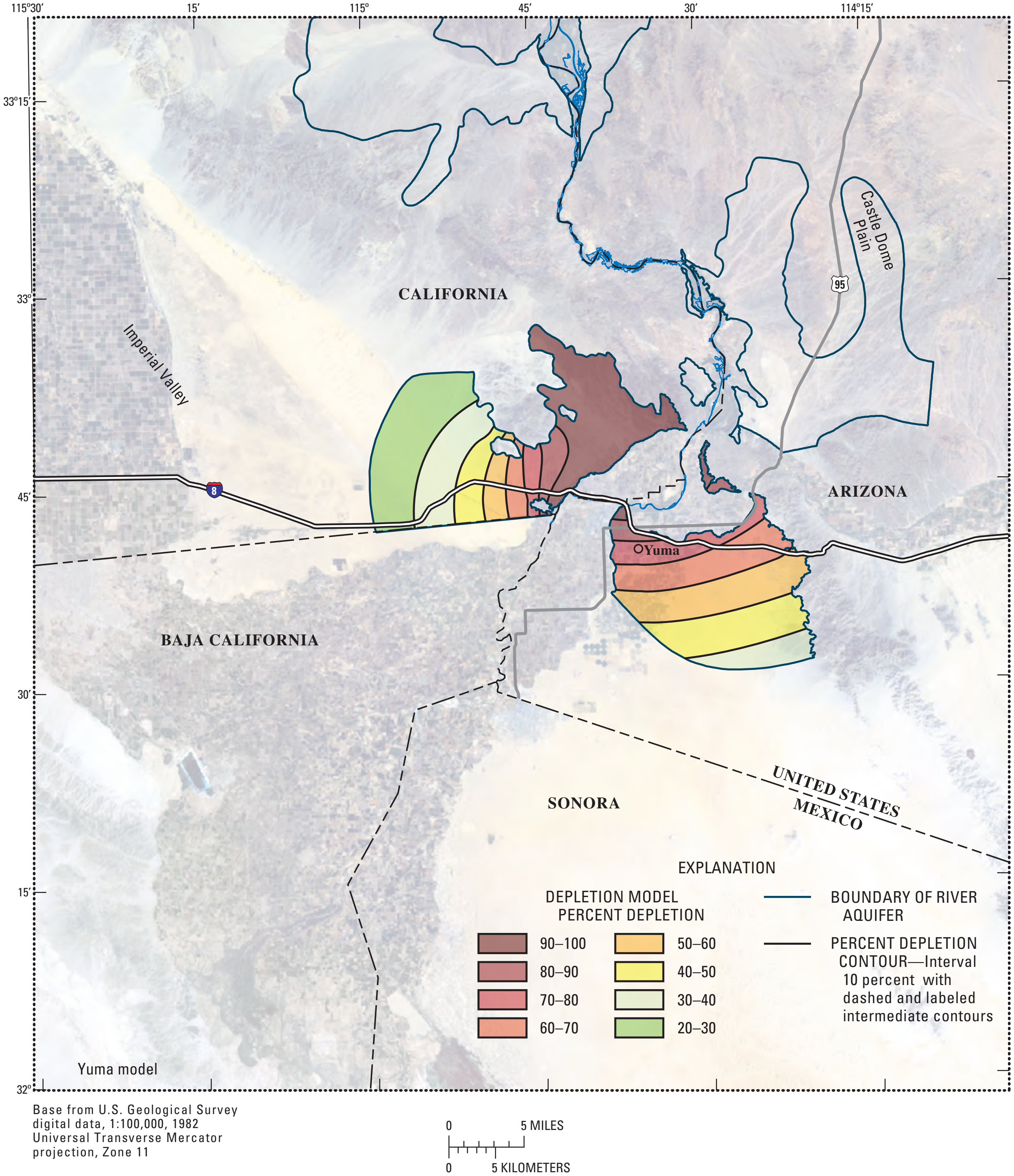
Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 15. Percent depletion in 100 years by pumping wells within the Yuma and Laguna model areas of the Colorado River aquifer assuming a transmissivity rate of 26,200 feet squared per day (196,000 gallons per day per foot).



Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 16. Percent depletion in 100 years by pumping wells within the Yuma model area of the Colorado River aquifer assuming a transmissivity rate of 15,500 feet squared per day (116,000 gallons per day per foot).



Base from U.S. Geological Survey
digital data, 1:100,000, 1982
Universal Transverse Mercator
projection, Zone 11

Figure 17. Percent depletion in 100 years by pumping wells within the Yuma model area of the Colorado River aquifer assuming a transmissivity rate of 45,900 feet squared per day (343,000 gallons per day per foot).

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Report 2008–5189

Playas, which are shallow, centrally located basins in which water gathers after a rain and quickly evaporates are not present in the Palo Verde Mesa and Palo Verde Valley as the surface topography generally slopes eastward towards the Colorado River along the east side of the Palo Verde Valley. The closest playa to the BSPP site is Ford Dry Lake, which is about 8 to 9 miles west of the site in Chuckwalla Valley. Ford Dry Lake is not located Palo Verde Mesa Groundwater Basin and is hydraulically up-gradient from Palo Verde Valley. Moreover, the McCoy Mountains separate Ford Dry Lake from the BSPP site. As a result, Ford Dry Lake will not be affected by groundwater extraction from the BSPP site.

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DR-S&W-179

Information Required:

> Please conduct a more thorough analysis of the groundwater recharge/discharge that is likely occurring in the Palo Verde Mesa Groundwater basin. Please provide a table with estimates either by reference or by actual calculations of the estimated amount of recharge/discharge that is occurring. Anticipated recharge can be calculated using a procedure described in Hely & Peck (1964). The analysis should use isohyetal maps of average annual precipitation overlaid on the basin boundaries. Several factors (2, 5, & 10%) should be applied to the calculated volume to give a range of anticipated recharge.

Response:

Recharge from Runoff

Methods to estimate runoff proposed by Hely and Peck (Hely and Peck, 1964) were used to estimate mean annual runoff in the Palo Verde Mesa Groundwater Basin. Hely and Peck (1964) found that "a large part of the runoff generated by precipitation within the area is absorbed in the alluvium of the valleys and plains" and proposed to estimate runoff based on precipitation data, rainfall-runoff relations and observed characteristics of the terrain. Project hydrogeologists reviewed topographic and geological data to generate Figure DR-S&W-179-1 that divided the Palo Verde Mesa Groundwater Basin into localities that approximated the localities as described by Hely and Peck (i.e. mountains, hills, alluvium-steep slope or alluvium-shallow slope – see their Figure 10). The hydrogeologists then calculated the area for each locality. Figure 10 in Hely and Peck (1964) was used to select an average runoff curve number for each locality assuming an average of all soil types which roughly corresponded to a median of the soil type "B" as defined by the US Bureau of Reclamation. For example, an average runoff number of 74 was selected for alluvium-steep slope. Hely and Peck (1964) developed a relationship between the runoff curve number and the runoff as a percentage of the precipitation (see Hely and Peck, 1964 Figure 9). Using this relationship, the annual volume of runoff from each locality was calculated by multiplying the area of each locality times the mean annual precipitation times the percentage of runoff estimated for the runoff curve number. The mean annual precipitation was approximated for each locality by overlaying the mean annual runoff from small tracts information (Plate 3, Hely & Peck, 1964) with Figure DR-S&W-179-1 of localities for the Chuckwalla/Palo Verde basins.

From the estimated total runoff for the Chuckwalla/Palo Verde basin, simple percentages of 3 percent 5 percent and 10 percent were applied to the estimated total runoff to generate a total annual infiltration volume (acre-feet) for the basin. Table DR-S&W-179-1 presents the estimate of total annual infiltration for the Palo Verde Mesa Groundwater Basin.

Metzger et al. (1973) and Owens-Joyce et al. (1987) followed the approach outlined by Hely and Peck (1964) reporting that recharge from runoff through the McCoy Wash was about 800 acre-ft/year and runoff from the Palo Verde Mountains was 1,200 acre-feet/year. The value assuming 10% of runoff infiltrates and recharges the groundwater best matches the value reported by Metzger et al. (1973) for the McCoy Wash, but in general the values estimated as noted above are lower than reported by previous investigations.

Recharge from underflow from the Colorado River

As provided in the August 2009 BSPP AFC, geochemical and water level data indicate that groundwater from outside the basin is flowing into the area as flux from the Colorado River. The USBR in their analysis of the accounting surface has concluded that groundwater below the Project site is in communication with the Colorado River. Geochemical data show that there is a gradual mixing of water from the river to the west and into the Project site as TDS concentrations progressively increase away from the River. An estimate of groundwater flux from the River into the Palo Verde Mesa Groundwater Basin was made using a simple underflow calculation and Darcian flow across a cross sectional area at the upper portion of the basin (see AFC Figure 5.17-7). The aquifer was assumed to extend a distance of 19,000 feet perpendicular to flow and at a depth of 600 feet below the water table at this location. Using the average transmissivity of 26,000 ft^2/day from Leake et al. (2008) and a groundwater gradient of 0.0003 ft/ft from measurements taken in 2000 (AFC Figure 5.17-7), the groundwater flux across this area is approximated at 1,241 acre-feet per year.

Recharge from Return from Irrigation

Recharge from applied irrigation water diverted from the Colorado River through the Palo Verde Irrigation District is unknown, although it could be significant given that 375,000 acre-feet were provided in 2007. Under an assumption that 10 percent of the applied water infiltrates and recharges the groundwater basin, an estimated 37,500 acre-feet per year recharges the Palo Verde Valley, which includes a portion of the Palo Verde Mesa Groundwater Basin. Adjusting for the areal distribution of the basin relative to the extent of agricultural land within the valley yields a recharge of about 15,750 acre-feet/year.

Discharge

An estimate of discharge from the Palo Verde Mesa could not be completed. Information on groundwater supply well pumping and history could not be established although inquiries were made for these data of the Palo Verde Irrigation District. The USGS NWIS database, while having well information to a certain extent, does not have the pumping history for most of the wells in the database.

As noted in the AFC, while the discharge from the Palo Verde Mesa Groundwater Basin is not known, it is reasonable to assume that the discharge for agriculture use has in the past exceeded the recharge from sources other than the Colorado River. The absence of significant changes in water level data in the Palo Verde Mesa Groundwater Basin over time suggest a buffering affect from another source of recharge, which is presumed to be the Colorado River.

Water Balance

Without a certain understanding of discharge from the Palo Verde Mesa Groundwater Basin, it is not possible to construct a reasonable water balance. Table DR-S&W-179-2 summarizes the information above including a variation of recharge to the basin from assumptions of differential infiltration. As noted, in the AFC and in this DR response, the significant recharge from the Colorado River underflow is the primary mechanism for recharge to the basin along with inflow and agricultural return. Recent historic water level data indicate relative stability within the basin, and published reports suggest that the shallow aquifer discharges to surface water returning water to the River. Given the proposed amount of water usage, and the buffering effect of the River, the proposed Project water use is not significant and would not significantly impact storage within the Palo Verde Mesa Groundwater Basin.

References

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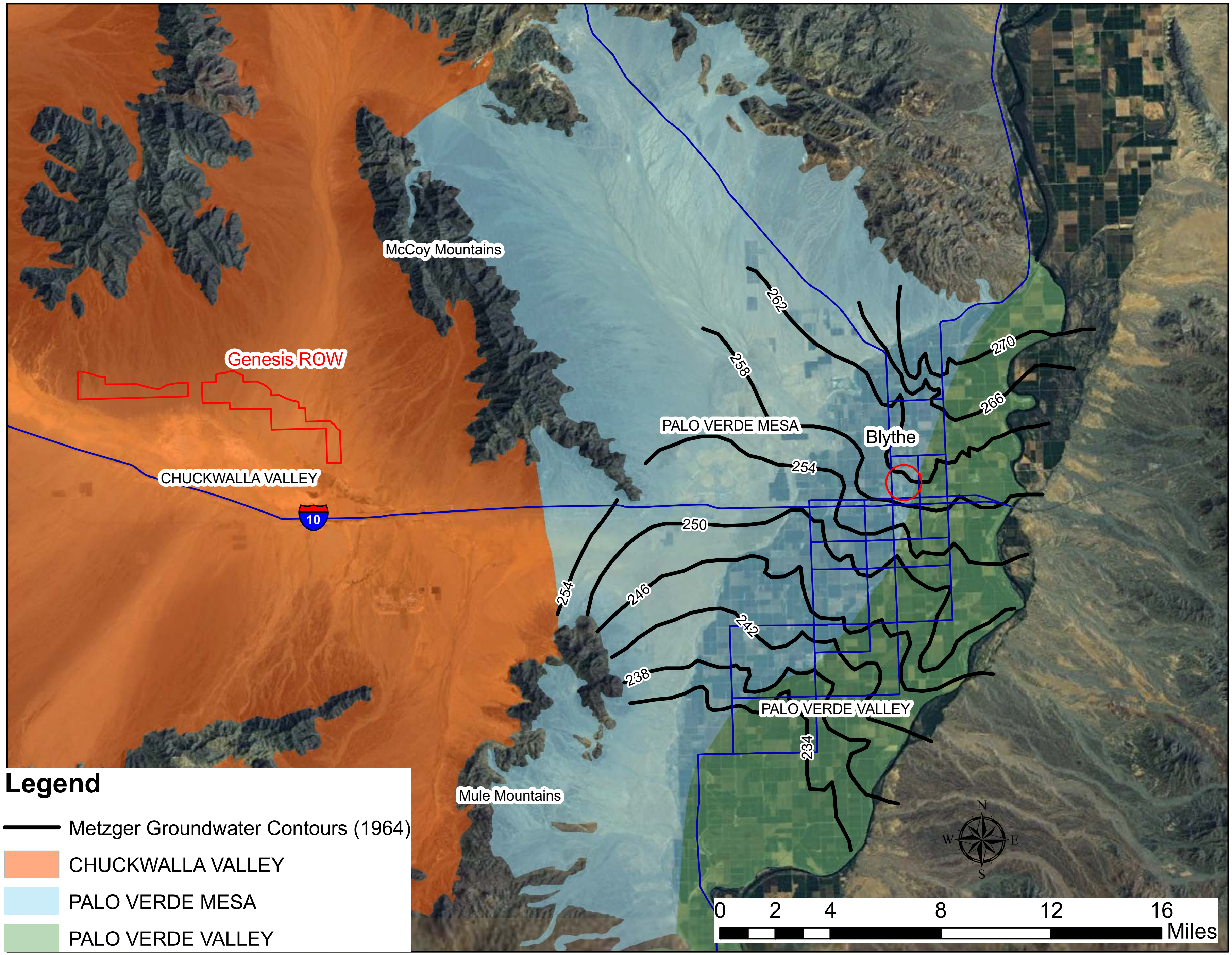
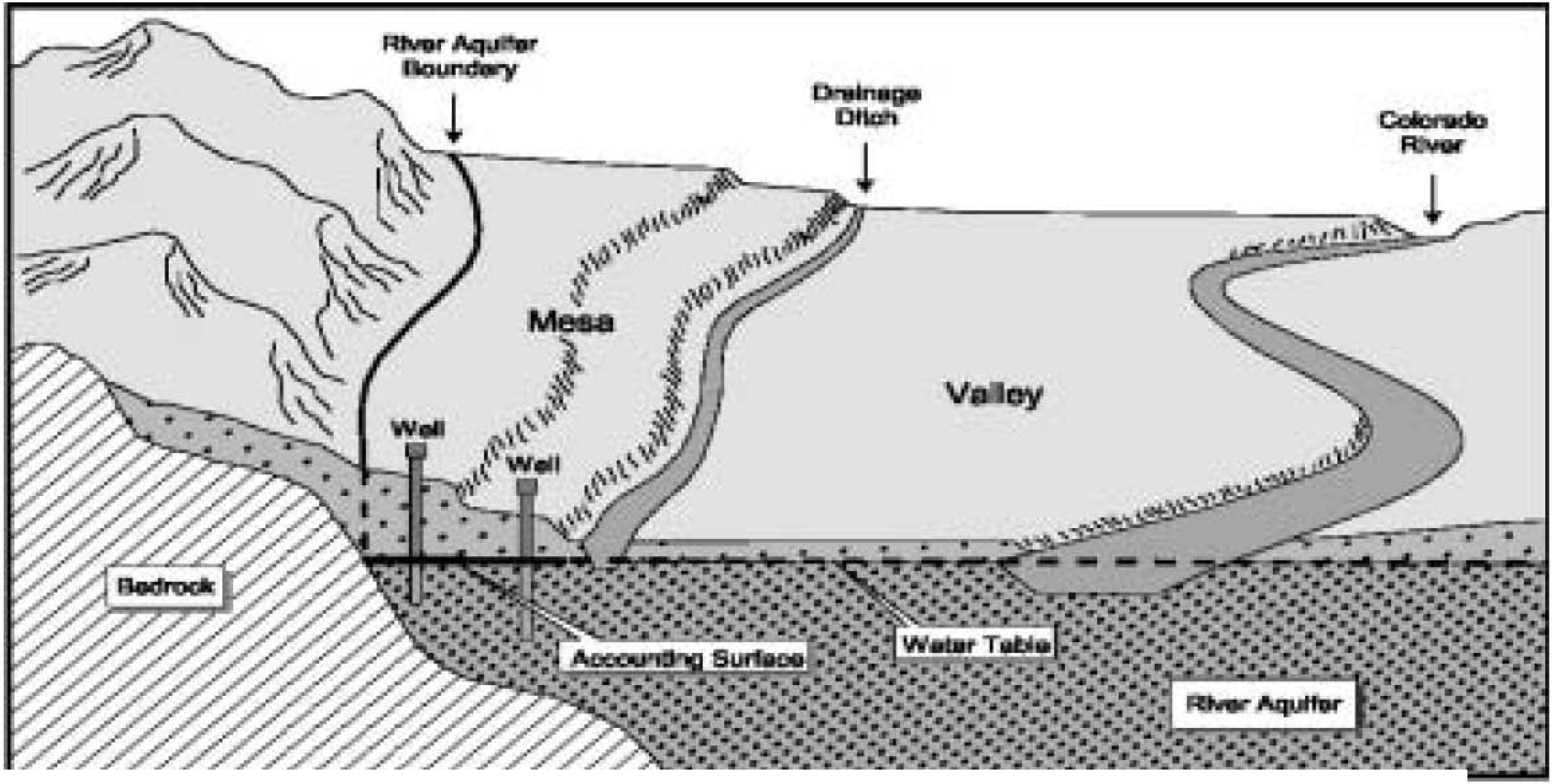
Table DR-S&W-179-1 Estimates Of Runoff And Infiltration Palo Verde Mesa Groundwater Basin

Layer See Figure DR-S&W-179-1	Area (acres)	Mean Annual Precipitation (inches)	Total Volume of Rainwater from Mean Annual Precip (AcFt)	Runoff Curve Classification	Runoff Curve Number	Runoff (% of precip)	Total Annual Volume of Runoff (AcFt)	Total Annual Volume of Infiltration (AcFt) Based on 3%	Total Annual Volume of Infiltration (AcFt) Based on 5%	Total Annual Volume of Infiltration (AcFt) Based on 10%
unit1-pvm	23,695	4	7,898	Alluvium, Steep Slope	74	3.5%	276	8	14	28
bedrock-pvm	5,624	4	1,875	Mountains	93	29.1%	546	16	27	55
bedrock-pvm	16,819	6	8,409	Mountains	93	29.1%	2,447	73	122	245
bedrock-pvm	13,571	4	4,524	Mountains	93	29.1%	1,316	39	66	132
bedrock-pvm	18,298	4	6,099	Hills	83	10%	610	18	30	61
unit1-pvm	79,574	5	33,156	Alluvium, Steep Slope	74	3.5%	1,160	35	58	116
unit2-pvm	382	4	127	Hills	83	10%	13	0	1	1
unit2-pvm	122,370	4	40,790	Alluvium, Flat Slope	69	2%	816	24	41	82
Totals	**280,332**		**102,878**				**7,184**	**216**	**359**	**718**



GROUNDWATER BASINS IN THE BLYTHE AREA

SOIL AND WATER RESOURCES Figure 1*
Schematic Diagram Showing the River Aquifer and Accounting Surface



Mesa wells that have a static water-level elevation equal to or below the accounting surface are presumed to yield water that will be replaced by water from the Colorado River.