

BEFORE THE SECRETARY OF INTERIOR



Photo Credit: Patrick Donnelly/Center for Biological Diversity

**PETITION TO LIST THE DIXIE VALLEY TOAD (*BUFO (ANAXYRUS) WILLIAMSI*) AS A THREATENED OR ENDANGERED SPECIES UNDER THE
ENDANGERED SPECIES ACT**

September 18, 2017

CENTER FOR BIOLOGICAL DIVERSITY

NOTICE OF PETITION

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Submitted this 18th of September, 2017

Pursuant to Section 4(b) of the Endangered Species Act (ESA), 16 U.S.C. § 1533(b); section 553(e) of the Administrative Procedure Act (APA), 5 U.S.C. § 553(e); and 50 C.F.R. § 424.14(a), the Center for Biological Diversity, Jenny Loda and Patrick Donnelly hereby petition the Secretary of the Interior, through the U.S. Fish and Wildlife Service (FWS or Service), to protect the Dixie Valley toad (*Bufo (Anaxyrus) williamsi*) as a threatened or endangered species.

Petitioners request emergency listing of the Dixie Valley toad at the soonest possible time, in light of the impending threat of geothermal energy production in its range. The Service has the authority to promulgate an emergency listing rule for any species when an emergency exists that poses a significant risk to the species. 16 U.S.C. §1533(b)(7).

FWS has jurisdiction over this petition. This petition sets in motion a specific process, placing definite response requirements on FWS. Specifically, the Service must issue an initial finding as to whether the petition “presents substantial scientific or commercial information indicating that the petitioned action may be warranted.” 16 U.S.C. § 1533(b)(3)(A). FWS must make this initial finding “[t]o the maximum extent practicable, within 90 days after receiving the petition.” *Id.*

The Center for Biological Diversity (“Center”) is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center is supported by more than 1.5 million members and online activists throughout the United States. The Center and its members are concerned with the conservation of endangered species and the effective implementation of the Endangered Species Act.

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EXECUTIVE SUMMARY

The Dixie Valley toad (*Bufo (Anaxyrus) williamsi*) is a small toad found only in the Dixie Valley in the Great Basin of northern Nevada. This endemic amphibian was recently described as a unique species, and is thought to have become isolated from all other toad populations in the Pleistocene. This toad is restricted to just four spring-fed wetlands across a range of only 6 km², where it is immediately and severely threatened by the proposed construction and operation of a geothermal plant. The toad is also threatened by the disease chytridiomycosis, which has been devastating frog and toad populations around the world, climate change, and invasive species, including bullfrogs and weeds like Russian olive and tamarisk. Its vulnerability to these threats is further compounded by its limited range and inability to disperse across the surrounding inhospitable environment.

The Dixie Valley toad warrants listing as a threatened or endangered species. The Endangered Species Act states that a species shall be determined to be endangered or threatened based on any one of five factors (16 U.S.C. § 1533 (a)(1)). The toad is threatened by four of these factors – the modification or curtailment of habitat or range, disease, the inadequacy of existing regulatory mechanisms to ensure its survival, and other factors including invasive species, climate change, and its limited range.

The most immediate risk to the Dixie Valley toad's survival is the construction and operation of a proposed geothermal energy project in its range. The biggest risk of geothermal energy production is the impact on hydrology in the area, which is likely to include a reduction or elimination of the spring flow into the wetlands that provide essential habitat for the toads, as well as potential changes in water temperature and chemistry.

The Dixie Valley toad's survival is also threatened by disease, including the deadly chytridiomycosis which has caused mass die offs and declines of amphibians throughout the world, including some of the toad's closest relatives. The chytrid fungus has been detected in nearby populations of bullfrogs, which can act as vectors for the pathogen due to their resistance to the fungus. Bullfrogs are an invasive species that likely also poses a threat to the toad, as bullfrogs commonly prey on and outcompete other frog species. The Dixie Valley toad is also threatened by climate change, as the significant increase in warming expected in the Great Basin will likely increase evaporation, resulting in the reduction of the toad's wetland habitat.

I. INTRODUCTION

The Dixie Valley toad (*Bufo (Anaxyrus) williamsi*) is a small toad species in the Great Basin region of northern Nevada, distinct from other toad species categorized in the *Bufo boreas* complex. Government agencies and others have recognized it as a unique population of toads for a number of years, leading to discussions about a Candidate Conservation Agreement that began in 2008, out of concern for the toad's survival; however, this process was abandoned several years ago and an Agreement was never completed. The Dixie Valley toad was recently formally described as a unique species (Gordon et al. 2017). The toad lives only on the western edge of the Dixie Valley Playa in Dixie Valley, Nevada, restricted to four wetlands fed by geothermal springs.

The Dixie Valley toad lives in the harsh environment of a cold desert valley in Northern Nevada, where its wetland habitat is warmed by a flow of heated water from geothermal springs. It is the smallest toad and has one of the smallest ranges among its related species in the western United States.

The Dixie Valley toad is threatened by restricted range, habitat degradation, invasive species, disease, and climate change. The most immediate threat to the toad's survival is the proposed expansion of geothermal energy production in the Dixie Valley, which is likely to reduce or eliminate the flow of springs to the toad's wetland habitat. Without Endangered Species Act protection, extinction looms for this endemic toad.

Scientists estimate that about 25 percent of the United States' amphibians and reptiles are at risk of extinction, yet less than 70 of the approximately 1,400 U.S. species protected under the Endangered Species Act are amphibians and reptiles. Nearly half of amphibian species worldwide are now considered to be experiencing population declines, at the most rapid rates among all vertebrates (Stuart et al. 2004, p. 1783). In the United States 31.7% of amphibian species are in decline and overall occupancy of amphibians in the U.S. declined 3.7% annually from 2002-2011 (Adams et al. 2013, pp. 1-2). Despite being one of the most imperiled vertebrate groups, most at-risk amphibians are not currently protected under the Endangered Species Act (Walls et al. 2016, p. 156).

Frogs are a particularly sensitive taxon. Alroy (2015) found that extinction rates for frogs are now four orders of magnitude higher than background levels, with a conservative estimate that we have lost about 200 species of frogs since the 1970s (p. 13004-05). We have already lost at least 3% of frog species and that we are on pace to lose another 7% within the next century, even with no acceleration in the growth of environmental threats (Ibid.).

II. NATURAL HISTORY

A. Taxonomy and Description

The Dixie Valley toad, *Bufo williamsi*, is an anuran species that is part of the broader species complex of western toads (*Bufo boreas*). For a number of years the toad has been regarded as a likely unique species or a subspecies of *B. boreas*, and at minimum it has been recognized as a unique population (Forrest et al. 2017, p. 162; Rose et al. 2015, p. 529). However, it has recently been formally described as a discrete species, *B. williamsi* (Gordon et al. 2017).

The determination that the Dixie Valley toad is a full species is based on a combination of diagnostic morphological characters and genetic evidence differentiating it from other species within the *B. boreas* species complex, and localized distribution (Ibid.).

Gordon et al. highlight numerous distinctive morphological characteristics of the Dixie Valley toad, when compared to the broader *B. boreas* species complex, including but not limited to: a small adult size, a shorter, narrower head combined with a longer relative snout length; larger, closely set eyes and larger tympanum; shorter parotoids; significantly shorter hind legs; and distinctive coloration: "[t]he dorsal ground color consists of olive shades that contain minute

black flecks, rust colored warts are bordered by fine, black halos, and prominent parotoid glands are pale tan and black specked” (Ibid. at 129-32). Statistical analyses detected significant differences for 14 morphological characters evaluated at the species level among all species within the *B. boreas* species complex (Ibid. at 131).

The Dixie Valley toad is the smallest toad within the *B. boreas* species complex, with a snout-vent length (“SVL”) more than 25 mm smaller than *B. boreas* (Ibid. at 127). Sampling efforts by Gordon et al. revealed a mean snout-vent length of 54.8 mm for adult Dixie Valley toads, with a range of 44.01-69.97 mm (Ibid. at 125). Forrest et al. reported a mean SVL of 52.1 mm for adult Dixie Valley toads, including a mean SVL of 51.6 mm for adult males and 54.3 mm for adult females (2017, p. 167). The Dixie Valley toad’s relatively large, closely set eyes large tympanum, and its unique coloration distinguish this species from all other taxa within the *B. boreas* species complex (Gordon et al. 2017 at 129).

Molecular phylogenetic analyses of toad populations sampled throughout the Great Basin region provided additional support to classify the Dixie Valley toad as a distinct species. Gordon et al. used the mitochondrial control region as the genetic marker, a rapidly evolving region of mtDNA that has been used in previous phylogenetic studies of *B. boreas* (Ibid. at 126). Phylogenetic hypothesis were tested with multiple methods to compare tree reconstructions highlighting relationships between taxa of the *B. boreas* species complex. DNA analyses and a condensed phylogeny of the *B. boreas* species complex supported the conclusion that *B. williamsi* is a unique species, with a recent divergence from *B. boreas*, similar to others within the species complex (Ibid. at 134). Aquatic isolation of Dixie Valley is estimated to have occurred approximately 650 thousand years ago (Ibid. at 136).

B. Biology

The Dixie Valley toad is typically nocturnal and emerges at dusk, similar to other toads in the *B. boreas* complex (Ibid. at 135). The toad can be found in moist vegetation or in still, shallow water with little vegetation cover (Ibid.). The toad’s breeding season occurs from approximately March to June, with sexually mature males congregating around the perimeter of wetland vegetation (Ibid.). Male Dixie Valley toads develop distinct nuptial pads on the dorsal side of the thumb, similar to many other bufonids (Ibid. at 129). The species does not have an advertisement call, but males emit a release call when they come into contact with one another (Ibid.). Egg masses are laid and develop in still, shallow water on the edges of the marsh habitat and toadlets are likely fully metamorphosed in approximately 10 weeks (Ibid. at 135; Forrest et al. 2013, pp. 76-77).

Little is known about the Dixie Valley toad’s non-breeding behavior or dispersal, but it is likely that the toad retreats to burrows to hibernate in the fall and emerges to breed in the spring (Gordon et al. 2017, p. 135).

The Dixie Valley toad stores bufotoxin in paratoid glands which are conspicuous in shape and color, possibly triggering a warning to potential predators (Ibid.). The toad also has additional stores of bufotoxin in large, conspicuous tibial glands (Ibid.). In addition, the coloring of the toad makes it very cryptic and difficult to detect when within wetland vegetation (Ibid.).

C. Habitat

The Dixie Valley toad is found in spring-fed wetlands and surrounding upland habitat on the western edge of the Dixie Valley Playa (Ibid. at 134). The habitat separating the four spring discharge sites and their downstream marsh habitat consists of sagebrush steppe dominated by big sagebrush (*Artemisia tridentata* ssp. *tridentata*), greasewood (*Sarcobatus vermiculatus*), rubber rabbitbrush (*Ericameria nauseosa*) and saltbush (*Atriplex* spp.) (Ibid. at 134-35). The spring-fed wetlands relied upon by the toad typically contain spikerush (*Eleocharis* spp.), three-square bulrush (*Schoenoplectus* sp.), knotweed (*Polygonum* spp.), canarygrass (*Phalaris* spp.), duckweed (*Lemna* sp.), various species of rush (*Juncus* sp.), common reed (*Phragmites australis*), and cattail (*Typha* spp.) (Ibid. at 135).

Dixie Valley is a cold-desert ecosystem, experiencing extreme temperature fluctuations between daytime and nighttime temperatures, with daily fluctuations often exceeding 20 °C, as well as seasonal extremes, ranging from <0 °C in winter to >0 °C in summer (Ibid.; Forrest et al. 2017, p. 164).

The Dixie Valley toad relies on only four wetlands fed by geothermal springs, which are the only perennial sources of habitable freshwater in the toad's native habitat. The soils in the surrounding areas contain very dry, alkaline playa deposits covered with salt crusts, which likely serves as an impassible barrier for the toads (Forrest et al. 2017, p. 164).

III. RANGE AND STATUS

The Dixie Valley toad is only found in Churchill County, Nevada, where it is restricted to the western edge of the Dixie Valley Playa, east of the Stillwater Range in Dixie Valley (Gordon et al. 2017, p. 134). Figure 1 shows the location of the Dixie Valley toad's range, as compared to the broader range of the *B. boreas* species complex and the separation from the narrow ranges of other localized, endemic toads found within this complex (Ibid. at 127). The Dixie Valley toad's entire estimated range is approximately 6 km² (600 hectares) (Ibid. at 134).¹ The entire species depends on just four wetlands fed by geothermal springs, the only perennial source of freshwater in its habitat (Forrest et al. 2017, p. 164).

The soils in the area surrounding the Dixie Valley toad's range are primarily very dry, alkaline playa deposits covered with salt crusts that likely act as an impassible barrier for the toad (Ibid.). In addition, the Dixie Valley is a closed drainage basin surrounded by mountains and has been hydrologically isolated since the Pleistocene (Ibid.).

There are no current estimates of the Dixie Valley toad's population abundance and structure; however, given its narrow range and restriction to four wetlands the toad's population is likely small (Gordon et al. 2017, p. 135; Forrest et al. 2013, p.79). Other populations and species found within the *B. boreas* species complex have experienced declines across their range in the western

¹ Some of the other toad species within the *B. boreas* species complex have similarly small ranges; however, these species are also considered to be vulnerable. The Amargosa toad's (*B. nelson*) range is limited to about a 16 km stretch of the Amargosa River and nearby spring systems and the black toad (*B. exsul*) occupies a range of about 15 hectares in the Deep Springs Valley of eastern Inyo County (Goebel et al. 2005, p. 429; Fellers 2005, p. 406).

U.S. and the three other localized, endemic toads in this complex (*B. canorus*, *B. exsul*, *B. nelsoni*) are classified as vulnerable or endangered (Gordon et al, 2017, p. 136; IUCN 2017). The Yosemite toad (*B. canorus*) is also listed as threatened under the Endangered Species Act.

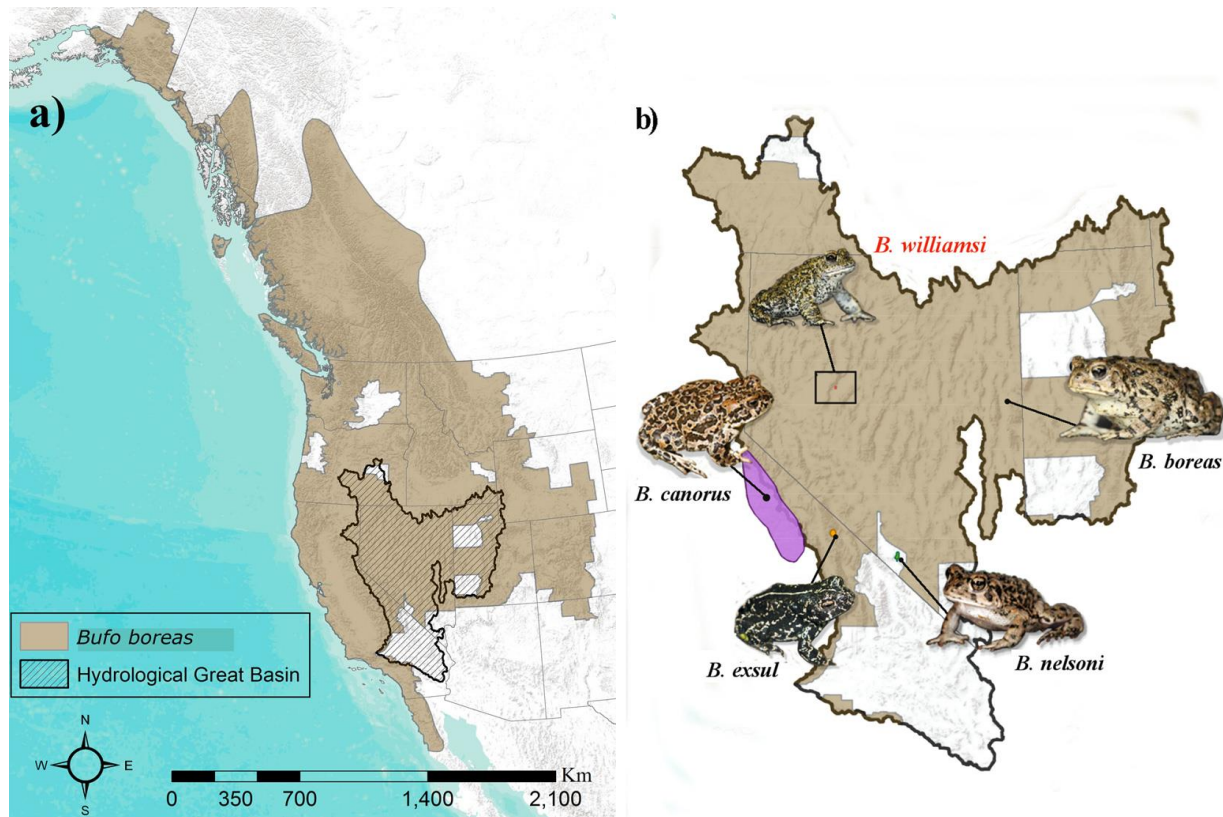


Figure 1. *Bufo (Anaxyrus) boreas* species complex distribution. a) *Bufo (Anaxyrus) boreas* distribution (shown in brown) across the Western United States with hydrological Great Basin shown with black outline and hash mark interior; b) *Bufo (Anaxyrus) boreas* species complex and ranges for toads including new species, illustrating the narrow distribution of localized endemics. Spatial data for all toads except *B. williamsi* provided by IUCN (2015). Images taken by M.R. Gordon except *B. canorus* with photo credit to G. Nafis. (Gordon et al. 2017, p. 127, Figure 2).

IV. THREATS

A. Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Exploitation of geothermal energy, including extensive use of groundwater, is the primary imminent threat to the Dixie Valley toad's habitat. Livestock grazing may also be a threat to the Dixie Valley toad.

1. Geothermal Energy

The development of the geothermal energy proximal to Dixie Meadows presents an immediate threat to the Dixie Valley toad (Forrest et al. 2017, p. 172; Gordon et al, 2017, p.136). Dixie Valley is the hottest and one of the largest geothermal systems in the Basin and Range province and is already home to one of Nevada's largest geothermal energy plants (Blackwell et al. 2007, p. 1-2). Development of geothermal energy production in the Dixie Valley could cause numerous impacts, including a direct loss of habitat and habitat fragmentation through construction of new facilities, roads, and utility lines. The biggest risk of geothermal energy production to the toad's survival is the impact on hydrology in the area, which is likely to include a reduction or elimination of the spring flow into the wetlands that provide essential habitat for the toads, as well as potential changes in water temperature and chemistry.

The Bureau of Land Management approved two geothermal exploration projects within Dixie Valley in 2010 and 2012 (BLM 2017, p 1-4). Both the leases and the permits for exploration are now owned by Ormat and together make up the Combined Dixie Meadows Geothermal Unit Area (Ibid.). Combined, these permitted exploration projects authorize up to 34 well pads (with multiple wells on each pad), 205.6 acres of surface disturbance on BLM-administered lands, 4 acres of surface disturbance on the US Navy's Lamb Mineral Interests, and two groundwater wells (Ibid.). Ormat has since completed several exploratory wells under this authorization and drilling is ongoing to continue evaluating the geothermal resource in the area (Ibid., p. 2-4).

The BLM recently released a draft Environmental Assessment to consider the proposed Dixie Meadows Geothermal Utilization Project in Dixie Valley on behalf of ORNI 32, LLC, a subsidiary of Ormat (BLM 2017). The proposed project would include the development and operation of geothermal power plants and related wells and pipelines and the construction and operation of an associated generation-tie (gen-tie) line to bring electricity to market (Ibid. at 1-1). The proposed project would occur on BLM and Navy lands. As can be seen in Figure 2 below, the proposed Dixie Meadows Geothermal Utilization Project is in close proximity to known occurrences of the Dixie Valley toad, and the Dixie Meadows thermal springs that provide essential habitat for the toad.

As outlined below, geothermal energy production necessarily entails changes to surface thermal water features—it is inherent in the technology. Any such changes would have significant deleterious effects on the toad's population and vigor, up to and including the complete die-off of Dixie Meadows and the extinction of the toad. There are no acceptable mitigation methods to prevent this outcome.

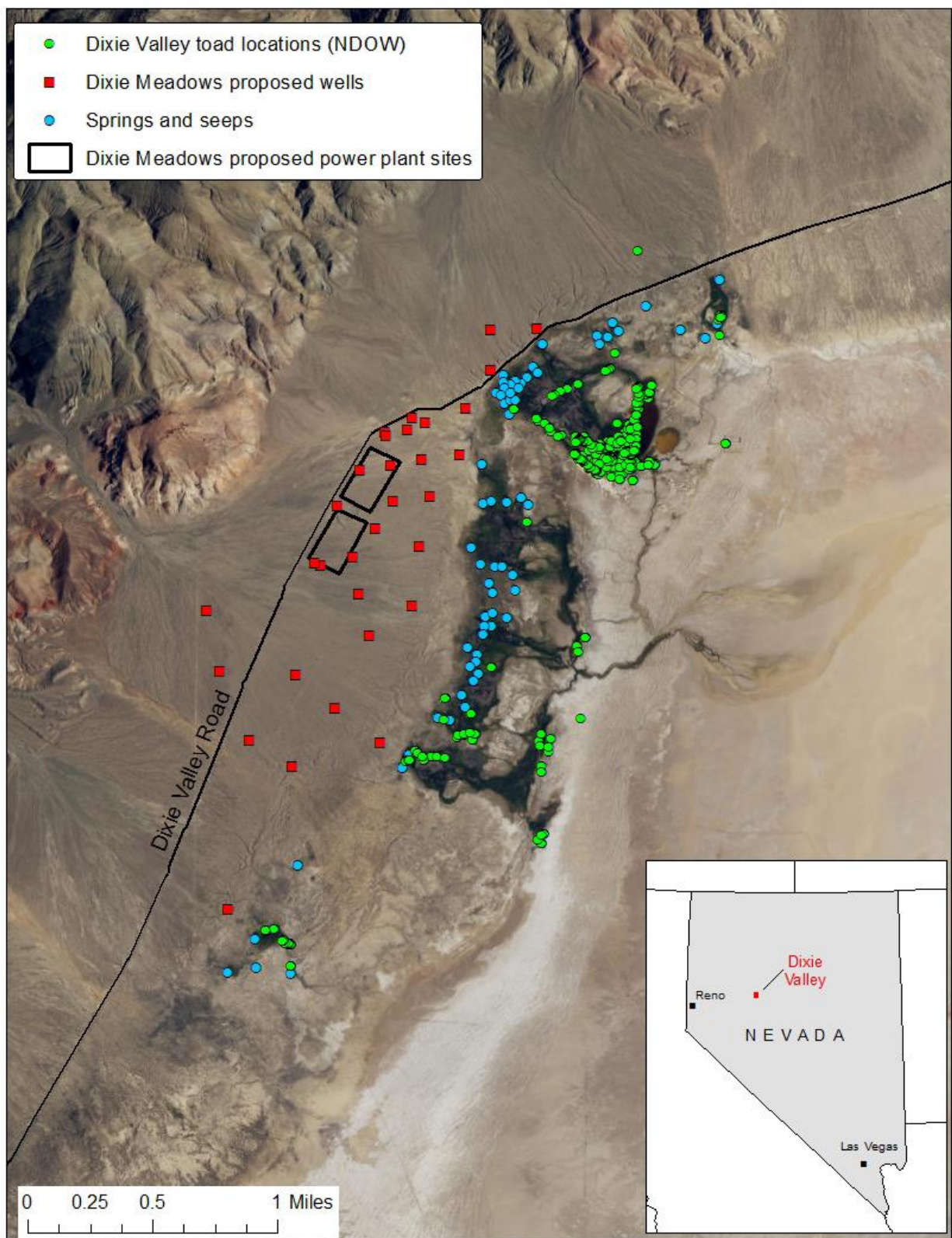


Figure 2. Map of the Dixie Valley toad's restricted range, showing documented sightings of the toads (green circles) provided to petitioners by the Nevada Department of Wildlife (2017). The

map also shows the close proximity of the proposed wells (red squares) and proposed power plant sites to the springs and seeps (blue circles) that feed into the toad's essential habitat.

Impacts from Closed-Loop Pumping and Reinjection

Most modern geothermal facilities are closed-loop and dry-cooled. A closed-loop geothermal facility is one which pumps groundwater from the geothermal reservoir, extracts heat from the water, and then reinjects the cooled water into the geothermal reservoir. A dry-cooled facility uses air in its cooling towers, rather than water. These two features mean that most geothermal facilities do not directly consume groundwater. Thus, they are generally exempt from needing to obtain certain water permits, for example certificated water rights.

However, this does not mean they do not cause impacts to surface expression of groundwater. Indeed, numerous analyses of the environmental impacts of geothermal energy have cited changes to surface manifestations of geothermal waters as inherent in geothermal energy production technology (Kristmannsdottir & Armannsson, H. 2003, Bayer et al. 2015, p.374; Maochang 2001, p. 99). "Historical evidence shows that natural thermal features have been affected, often severely, during the development and initial production stages of most high-temperature geothermal systems" (Hunt 2001, p. 99). "Changes in surficial features and land elevations accompanying geothermal development should be viewed as the rule, rather than the exception" (Sorey 2000, p. 708).

There are three changes of primary concern: changes to quantity of spring discharge, and changes to the temperature and chemical composition of spring discharge.

Decreases in Spring Discharge

In a memorandum prepared for this petition, hydrologist Tom Myers describes the hydrogeologic setting of Dixie Meadows, presents a conceptual flow model for the geothermal waters being discharged from the springs there, and presents several scenarios under which closed-loop pumping and reinjection at Dixie Meadows could negatively impact spring discharge (Myers 2017). He provides several mechanisms by which geothermal development may impact spring discharge.

First, overall discharge in the system is quite small (~50-200gpm) relative to the amount of water being proposed for pumping and reinjection (~14,000 gpm). Simply based on the pumping rates, the geothermal development could overwhelm the natural system.

Second, the pumping and reinjection wells would alter the natural pressure gradients in the aquifer- some places would pull water from natural discharge zones as they depressurize, while other areas near injection wells would experience very high pressure. This high pressure could force water into fractures, or create new fractures, thereby significantly altering flowpaths and likely affecting spring discharge.

Third, it is highly unlikely that reinjection wells would replace water in the same exact locales that it was pumped from. Due to the heterogeneity of the substrate, there is no certainty that

permeable fractures in the injection wells would intersect the permeable fractures in the collection wells. This would cause reinjected water to be lost to the circulation, especially if reinjection reaches fractures that are transverse to the general fracture trend found in the fault system.

Examples of Decreases in Spring Discharge from Geothermal Energy Utilization

In addition to the site-specific analysis presented here, there are numerous examples of geothermal energy facilities causing impacts to adjacent thermal water features, up to and including complete drying of the features. It is unclear whether development of further geothermal in the Dixie Valley will result in complete drying of the springs, as in the below examples, but it is in the range of possibilities and for this reason, this development presents a serious threat to the survival of the toad.

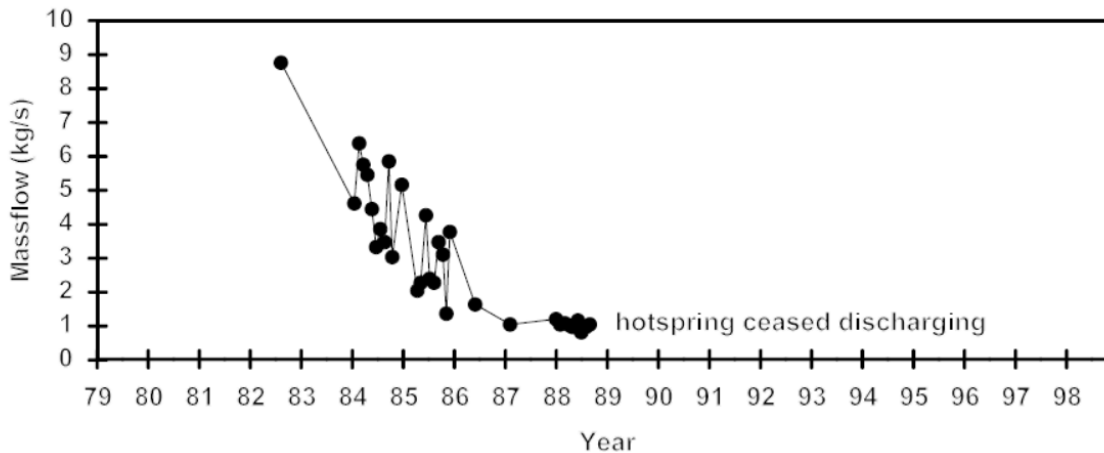
One infamous example is at Brady's Hot Springs, Nevada, where thermal hot springs sufficient to host a resort and spa (at a minimum flow of 21 gallons per minute) completely dried up upon the drilling and pumping of geothermal wells (Lund 1982, p. 14). Unfortunately the drilling there began in the 1950s, so there is a paucity of data on the pre-development conditions there.

Another well-known example from Nevada is at the Steamboat Springs hot springs and geyser complex near Reno. In this case, the drying up of springs is well-studied. And while the USGS found that the primary driver of the springs decline was groundwater pumping in the Truckee Meadows, it attributed declines in the water table of 1-3 to pumping and reinjection at the Caithness Power Incorporated geothermal energy facility nearby (Sorey & Colvard 1992, p. 101).

Like Nevada, New Zealand is a place where the impacts of geothermal energy development to surface waters have been readily apparent. Even with a complete reinjection regime, thermal features and pools still dried up at the Ohaaki hydrothermal field in New Zealand (Rissman et al. 2012, p. 224). Specific data show that, as discharge began declining, "the overflow rate and water level at the Ohaaki pool were strongly influenced by the operation of nearby bores," showing a near one-to-one ratio of increased well production to decreased surface water discharge (Hunt 2001, p. 32).

At the Wairakei geothermal field, numerous hot springs and pools went dry over a period of two years after geothermal pumping began (Ibid. p. 24). At the Rotorua geothermal field, a quite comprehensive set of time-series data is quite revealing: when geothermal utilization began in the sixties, geysers ceased erupting and spring discharges decreased dramatically (Ibid. p. 43). However in 1987 the government abruptly began reducing pumping activity, in an effort to save the geysers, and within two years flows had increased and geyser eruptions resumed at some sources.

This experience is mirrored in the Philippines at the Bao-Banati thermal springs, where the opening of the Tongonan 1 power plant in 1983 coincided with a significant decline in spring activity and a near complete end to geyser activity (Bolanos & Parrilla 2000, p. 46). Time-series data shows Hot Spring 16 declining to zero flow over a period of six years:



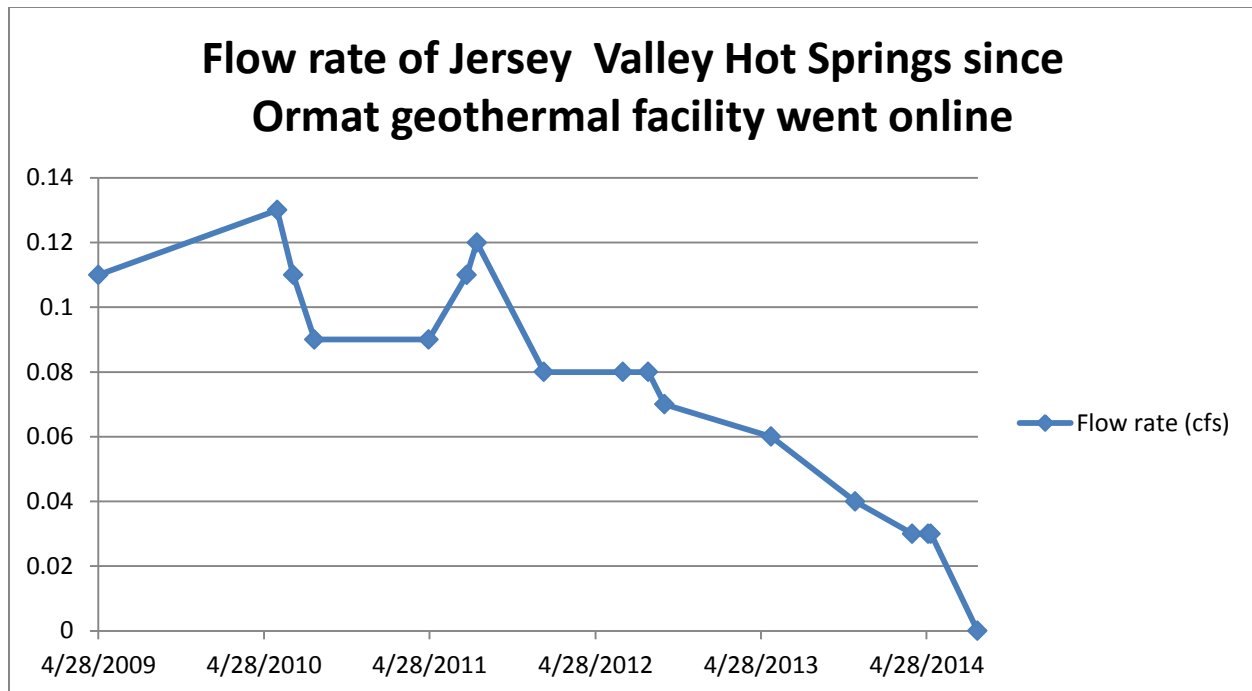
Good data exists on the surface thermal water features of the Long Valley caldera, near Mammoth, California. Monitoring of such features subsequent to the development of Casa Diablo, a geothermal facility, has shown “a cessation of spring flow at Colton Spring, 2 km east of Casa Diablo”; “declines in water level in Hot Bubbling Pool, 5 km east of Casa Diablo... of 1.2m”; and a 30-40% reduction in thermal water content in the springs at Hot Creek Fish Hatchery (Sorey 2000, p. 706). This reveals that impacts from geothermal development may extend beyond a hyper-localized reach, which has important implications for Dixie Valley. Even if the geothermal facility were moved several kilometers away from Dixie Meadows, the threat to the toad would remain.

Finally, and closest to home, is the example of Jersey Valley, just forty miles northeast of Dixie Meadows. On June 4, 2010, BLM approved EA DOI-BLM-NV-063-EAO8-091, for the Jersey Valley Geothermal Project (“JVGP”). JVGP was developed by Ormat, who are the proponents of the Project under evaluation here. There are several pertinent similarities between the Project and JVGP: both are dry-cooled and closed-loop facilities, meaning there is ostensibly no consumption of geothermal water; and both are located directly adjacent to an important thermal spring resource—in the case of JVGP, the Jersey Hot Springs.

According to Ormat’s website,² JVGP went online in the first quarter of 2011, with full operation anticipated in the second quarter of 2011. Fortunately, as opposed to the situation at Dixie Meadows, there is reliable time-series data available for discharge from Jersey Hot Springs from the NDWR.³ The available data are presented here in chart form:

² <http://www.ormat.com/news/latest-items/ormat-technologies-brings-only-geothermal-power-plant-online-us-2010>

³ No direct URL. Obtain data at <http://water.nv.gov> → Mapping and Data → Spring and Stream Flow → View Spring, Stream Flow, and Site Data → Basin 132 Jersey Valley → Site Name: “132 N27 E40 29DDDB1”. Data presented here captured at 10:45AM on June 29, 2017.



One can see a clear declining trend in flows since the JVGP went online in 2011. From 2009-2011, the average flow rate was 0.109 cfs (48.5 gpm, 78.2 afy). In 2012 the average flow rate was 0.0775 cfs (34.8 gpm, 56.1 afy); in 2013 it was 0.05 cfs (22.4 gpm, 36.2 afy); and in 2014 it was 0.0225 cfs (10.1 gpm, 16.3 afy), with the final reading showing zero flow.

While there is no data available to demonstrate a causal relationship between the initiation of operations at JVGP and the drying up of Jersey Valley Hot Springs, the correlation is extremely strong. Indeed, Joe Moskowitz from the BLM Mt. Lewis Field Office states, “BLM acknowledges that there is a reduction in flows at Jersey Hot Springs, and we think it is likely the result of pumping and reinjection at the Jersey Valley Geothermal Project” (Personal communication 2017). Given the strong correlation, and the anecdotal determination that there is a causal relationship, there is sufficient reason to think that this is a potential outcome of geothermal development at Dixie Meadows.

The Dixie Valley toad’s life cycle is entirely reliant on dependable flows from the springs at Dixie Meadows. These springs give rise to an enormous marsh ecosystem, where the toad spends the vast majority of its life. Additionally, the springs provide the standing water critical for the toad’s reproductive cycle. The successful production of a new generation of toads can require sufficient standing water for the better part of a year.

The toads require a stable water supply for breeding and egg laying. While unknown specifically for this species, close congeners typically complete breeding within a few weeks. However, embryonic development within the eggs and the subsequent development of the tadpoles can be extended and depends upon several environmental variables. Typically this process takes about three months in closely related species. Finally, the newly emerged toadlets require very stable moist habitats to survive. Their small body size leaves them extremely vulnerable to desiccation until they reach a larger body size. While their growth rate is dependent on environmental

conditions and food supply, many months would be needed before toads would be large enough to forage in any but the wettest areas.

Thus if the springs were to decrease in flow it would reduce the amount of habitat available to the toad, potentially reducing the viability of breeding habitat and possibly resulting in the loss of one or more generations of toads. If the springs were to dry up altogether, even for just a short period of time, it would almost certainly spell extinction for the toad, as it would have no habitat and nowhere to complete its reproductive cycle.

Changes in Discharge Temperature and Chemistry

The ecosystem of Dixie Meadows is in a finely tuned balance, and two critical components of that balance are the temperature and chemistry of the water discharged by the springs there. It should be noted for this discussion that the waters emerging at the Dixie Meadows springs are a mixture of deep geothermal and shallow alluvial aquifer waters. Huntington et al. (2014) describe three methods for determining this. First, discharge at some of the Dixie Meadows springs vents is at a temperature greater than 50°C, much hotter than any possible warming of basin-fill water along deep faulting. This implies that at least a portion of Dixie Meadows springs' discharge gets heated to those much higher temperatures from a geothermal source. Second, discharge at Dixie Meadows springs has a very low magnesium to lithium ratio (between 4.6×10^{-4} and 5.6×10^{-4}), with lithium concentrations of between 306 and 420 µg/L. High levels of dissolved lithium suggest that water has had extensive contact with hot rocks, implying geothermal content to the waters at Dixie Meadows springs. By comparison, cold alluvial-fill springs have a magnesium-to-lithium ratio of about 1:1. Finally, using geothermometry, a more exact level of mixing could be detected. The hottest spring at Dixie Meadows springs has an estimated geothermal mixing quotient of 25.6%, making it one of the highest levels of surface expression of geothermal water in all of the Dixie Valley.

Some reduction in overall temperature of the geothermal reservoir is inherent in the technology of closed-loop pumping and reinjection. Simple application of the laws of thermodynamics tells us that reinjecting cooled water (hot geothermal water which has passed through a heat exchanger) into the hot geothermal water reservoir will incrementally cool off the reservoir. In its comments on the Dixie Meadows Geothermal Utilization Project EA, the U.S. Fish and Wildlife Service states that this difference in temperature, "...may significantly influence any changes in the temperature of the Dixie Meadows thermal springs..." (2017, p. 3).

Emplacement of the reinjection wells can be a critical factor in determining how much a pumping and reinjection scheme will affect surface discharge. Reinjection is a crucial component of a closed-loop system, and is necessary to maintain reservoir pressure. "However, there is a fundamental tension between [the] beneficial pressure maintenance effect [of reinjection] and thermal breakthrough (when the cool injected water reaches the production wells). In some fields, particularly those with a few large faults, thermal breakthrough has occurred rapidly and injection has been moved further out" (Kaya et al. 2011, p. 48).

Thus for our purposes here, we could see geothermal development in Dixie Meadows having to choose between in-field reinjection, reinjecting the spent geothermal water in the original well

location, maintaining pressure but reducing temperature; or out-field reinjection, reinjecting the spent geothermal water further afield, potentially reducing pressure (and therein spring discharge) while maintaining the temperature.

One of the key factors to consider when evaluating the potential for changes to temperature and chemistry is changes to flowpaths which might alter the mixing ratio of geothermal to shallow alluvial waters discharging from the springs at Dixie Meadows. In particular, a reduction in pressure of the geothermal reservoir can cause cold downflow, wherein colder water from the shallow alluvial aquifer flows downward due to a pressure gradient (Bayer et al. 2015, p. 374). This would also have the effect of reducing shallow groundwater levels at the surface. Reinjection can also cause deformation and shattering of substrate, potentially offering new pathways for gas and water circulation and therein altering the hydrology of adjacent surface features (Rissman et al. 2012, p. 232).

In his memorandum, Myers notes, “[r]einjection of water would locally increase the pressure. If the pressure increase is near one of the pathways upward to the springs, it could increase the amount of geothermal water in the mix of shallow and geothermal water discharging to the surface. This discharge could therefore have higher temperatures or more briny water due to a higher proportion of geothermal water” (Myers 2017, p. 8).

In a memorandum prepared for the Fallon Paiute-Shoshone Tribe regarding the Dixie Meadows geothermal project, hydrologists from Dyer Engineering Consultants also caution about opening new flowpaths: “...however changes in aquifer pressures from well injection can introduce new travel paths for the geothermal water to mix. The pressures can open new flow paths between the shallow aquifer and the un-mixed hot springs. Once these paths are created they could potentially be irreparable” (Dyer Engineering Consultants, Inc. 2017, p. 2).

Amphibians are especially vulnerable to changes in water chemistry because they have semi-permeable skin and their eggs and tadpoles develop in the water. As cold-blooded animals they can also be especially sensitive to changes in temperature.

The expected decrease in water temperature from proposed geothermal energy production is a threat to the persistence of the Dixie Valley toad, as this species depends on the existing thermal properties of these springs. A reduction in the current warm temperatures of the Dixie Valley toad’s wetland habitat may shorten the length of the toad’s breeding season and will likely also impact the timing of the development of the toad’s eggs and tadpoles.

As explained further below in the discussion of disease threats, water temperatures also influence where the chytrid fungus (Bd) can become established and the susceptibility of the Dixie Valley toad and other amphibians to Bd. Lower water temperatures are likely to increase the ability of Bd to become established and persist in the Dixie Valley toad’s habitat

Examples of Changes in Discharge Temperature and Chemistry from Geothermal Energy Utilization

An example of the “fundamental tension” concept referred to above is well illustrated at Brady Hot Springs in Nevada. The geothermal project there experienced a 24°C drop in produced geothermal fluid temperature after just three years of operation (Krieger & Sponsler 2002, p. 735). In order to resolve this issue, several new reinjection wells were sunk several miles away. While this helped stanch the decline in produced fluid temperature, it resulted in a significant drop in reservoir pressure.

The Long Valley caldera of California has seen significant geothermal utilization, and could be thought of as the “poster child” for how closed-loop pumping and reinjection can affect surface thermal water features, including their temperature and chemistry. Geothermal production there has caused an overall decrease in temperature in the geothermal reservoir of 10-15°C, with localized reductions of up to 80°C, and concomitant impact on surficial expression of these waters (Sorey 2000, p. 706).

The aforementioned Wairakei geothermal field had the chloride content of discharge from numerous springs decrease subsequent to geothermal well development- some by as much as 70% or more- over a period of several years (Hunt 2001, p. 25). Concomitantly the springs saw temperature decreases of as much as 30°C. Important to note is that these changes were greatly exacerbated in springs with lower amounts of discharge. This could be critical to the analysis in Dixie Meadows: while the main Dixie Hot Spring gives rise to a significant portion of the toad’s habitat, numerous smaller vents create many smaller marshes where the toad resides, and these could have the potential to be more severely impacted.

The aforementioned Ohaaki pool saw a decrease of 30-50°C after several years of geothermal utilization nearby—data reveals that there are significant fluctuations in the temperature of surface discharge based on the quantity and temperature of fluids being reinjected (Ibid. p 43). Interestingly, the chloride content of the discharge at Ohaaki pool has varied dramatically since geothermal utilization began – at times somewhat lower than initial conditions, but at other times as much as double the initial level, based on the amount of content of reinjected water. Other thermal features such as mud pots were noted to have decreased in temperature by as much as 38°C.

Similarly at the Bao-Banati thermal springs, declines in both temperature and chloride concentrations in spring discharge have been observed (Ibid. p. 47). As at Ohaaki, the numbers have tended to swing wildly around due to changes in amount, timing, and location of reinjected water. But the downward trend over time has been clear.

Kaya et al. (2011) examined nearly every significant geothermal reinjection project in the world (pp. 55-56). Their paper is attached here, as it is an exhaustive look at the topic, and one can only draw one conclusion from a survey of the data contained therein: that pumping and reinjection is an iterative process, involving many changes and fine-tuning to even approach achieving desired results. And in the meantime, temperatures and discharge levels can vary widely, implying significant disturbances to surface conditions. As a non-comprehensive list of examples:

- Oromesa Power Plants in California reinject 100% of produced fluid, but are experiencing a 1°F annual cooling;
- Heber field has experienced “ground inflation” due to reinjection;
- In addition to having dried up surface features as reported above, Steamboat Springs is experiencing a 1°C annual cooling of the geothermal reservoir.

Impossibility of Effective Mitigation

While there is no disputing the impacts to surface water from geothermal energy utilization described here, they are typically dealt with from a land manager’s context by implementing a “monitoring and mitigation” program. The ostensible point of such a program is to detect impacts to surface water as they are occurring, and to change parameters of a project to attempt to ameliorate those impacts.

Geothermal production at Dixie Meadows is an existential threat to the toad because *there is no way to mitigate the potential impacts*.

First, monitoring of impacts may be elusive. Since the exact pathways connecting the geothermal reservoir to the surface are not known, no monitoring regime could possibly be sufficient to detect impacts (Myers 2017, p. 9). There are numerous ways that surface water is expressed at Dixie Meadows, which includes spring discharge but also includes evapotranspiration and seepage, two factors which are far less readily measurable than straight spring discharge. It is essentially impossible to monitor evapotranspiration or seepage in real-time—the only feasible monitoring of spring discharge would be at the main Dixie Hot Spring vent. Even piezometers or other shallow wells would not be sufficient monitoring devices, as discharge at the spring complex is the result of complex interactions of deep and shallow groundwater flowing along fractured and faulted zones. The point is that there is no feasible way to have a monitoring program comprehensive enough to detect impacts to the springs in real-time.

Second, even if it were feasible to detect impacts, by the time those impacts are detected, it may be too late to mitigate them. “Hydrologic systems require time to recover from stresses, meaning that drawdown continues to expand at a distance from the source of the stress. The impacts would likely become worse before they become better” (Ibid.).

It is highly unlikely that, after a multi-million dollar capital investment in developing a geothermal power plant, a project developer would be compelled to completely shut off operations. There would be too much economic and political momentum wrapped up in the project, and it is more likely that other, less substantial, mitigation methods would be chosen.

But even should the most extreme mitigation measure of a temporary cessation of pumping and reinjection be selected as mitigation, it is not clear that this would prevent impacts. It can take years or even decades for aquifers to recover from depletion or significant perturbation. Since the Dixie Valley toad is entirely reliant on standing water in the marsh-wetland for its reproductive cycle, even one season of reduced spring flows could result in catastrophic population declines

for the toad. This is unacceptable- there is simply no way to mitigate for reduced or zero spring flow from DMSC.

The US Fish and Wildlife Service (2017) concurred with this assessment in their comments on the Dixie Meadows EA: “due to the proximity of the proposed geothermal production (pumping) and cooled geothermal fluid injection to the Dixie Meadows thermal springs, we believe early detection is not possible and timely implementation of measures to avoid and minimize or otherwise mitigate impacts to aquatic resources ... particularly Dixie Valley Toad, will not be feasible” (p. 4).

And indeed, this has been evaluated on a conceptual level with regard to geothermal energy utilization by Hunt (2001): “The decline in thermal features is associated with the decline in reservoir pressure. The only way to prevent or minimize the decline of thermal features is therefore to minimize reduction in reservoir pressures. At present there are no viable techniques available to do this without severely curtailing production” (p. 16). Thus, as he states, there is no realistic mitigation for impacts to thermal features—such impacts are inherent in the technology.

Bredehoeft and Durbin (2009) discuss the infeasibility of groundwater monitoring and mitigation plans, and reach similar conclusions, in particular with respect to time (p. 8). They find that there is a temporal “lag” between the onset of impacts and the ability to detect them; and then another temporal lag between potential mitigation measures and when they actually begin to ameliorate negative impacts. While their paper is focused on large-scale interbasin groundwater export, and thus is dealing in distances much larger than those being discussed here, the points they make still hold. Given that the toad will go extinct if the springs at Dixie Meadows dry up even briefly, no amount of time lag between impacts onset, impacts detection, impacts mitigation, and impacts amelioration would be acceptable.

One mitigation measure warrants a special comment, and that is the use of “mitigation water.” Piping water that a geothermal facility is already pumping to the surface back into springs in order to compensate for reduced or zero spring discharge would mean that Dixie Meadows, and the Dixie Valley toad, would forever be dependent on the continued operation of the geothermal facility. As soon as the facility was decommissioned, the springs could be dry, Dixie Meadows could die-off, and the toad could go extinct. Additionally, provided mitigation water is unlikely to exactly match the temperature and chemistry parameters that the water discharged into Dixie Meadows currently has (Myers 2017, p. 9). The toad needs sustained and natural flows from DMSC for its continued survival. Substituting piped in water for such flows puts the toad on the slow road to extinction.

Finally, it is unclear that mitigation measures would even be adhered to, should the project go forward. A monitoring and mitigation plan was developed as a part of the JVGP, and yet Jersey Hot Spring still went dry. While BLM, Ormat, and the existing rights holders in Jersey Valley are in negotiations to utilize mitigation water to satisfy the concerns of the existing rights holders, this in no way provides protection for the wildlife and other resources dependent on Jersey Hot Springs for their existence. The monitoring and mitigation plan developed for JVGP was inadequate, has not been followed, and has failed to prevent catastrophic impacts. There is no reason to believe that the result would be any different in Dixie Meadows. BLM has not

proven itself to be a trustworthy partner in protecting wildlife resources adjacent to geothermal energy development.

2. *Groundwater Extraction*

The toad's habitat is also threatened by the possibility of groundwater extraction in the Dixie Valley (Forrest et al. 2017, p. 172). Demand for water is increasing in the arid southwest due to population increases, and Nevada is one of the driest states (Huntington et al. 2014, p. 2). In order to support continued growth in the nearby Fallon urban area of the Carson Desert, Churchill County is considering importing water from the Dixie Valley (Ibid.). Exploitation of the Dixie Valley's groundwater resources could reduce or completely eliminate the springs flowing to the wetlands that are essential to the Dixie Valley toad's survival (Forrest et al. 2017, p. 172).

3. *Livestock Grazing*

Livestock grazing is one of the most widespread land management practices in western North America and it has been associated with a wide range of negative impacts on habitat and vertebrate taxa, including amphibians (Fleischner 1994; Dickman 1968; Corn and Fogelman 1984). Grazing can negatively affect riparian and aquatic systems through changes in hydrologic functioning, nutrient cycling, and herbaceous biomass productivity, soil compaction, vegetation removal, and nutrient redistribution (Brown et al. 2015, p.46). Trampling by livestock may also be a significant source of mortality for all amphibian life stages, especially for tadpoles and metamorphs that lack mobility and congregate near water margins (Hogrefe et al. 2005, p. 15).

Livestock grazing currently occurs in the Dixie Meadows, but there appears to be no specific information available on how current management of grazing in this area impacts Dixie Valley toads. Droughts, which are likely to occur more frequently with climate change, typically magnify grazing impacts.

However, grazing is a known threat to other toads in the *B. boreas* species complex. The U.S. Fish and Wildlife Service identified livestock grazing as a factor contributing to degradation of the Yosemite toad's (*Bufo canorus*) habitat within the Sierra Nevada in its final rule listing the toad as threatened under the Endangered Species Act (USFWS 2014, p. 24289). Grazing is considered to be a prevalent threat to the Yosemite toad and a potential limiting factor in the range-wide population recovery of the Yosemite toad (Ibid. at 24291). The boreal toad (*Bufo boreas boreas*) is also threatened by direct and indirect impacts of livestock grazing. Bartelt (1998) observed that hundreds of toads had been directly killed by livestock trampling and hundreds more died afterward as a result of desiccation because the vegetation they had been using for cover was trampled to the point that it no longer provided moist microhabitats (Bartelt 1998, p. 96).

B. Overutilization

There is no information available regarding the collection of the Dixie Valley toad and overutilization is not likely a current threat; however, its recent description as a unique species and subsequent press coverage may lead collectors to seek out this unique species.

C. Disease

The disease chytridiomycosis has been documented to lead to mass die offs, declines, and even complete extinctions of amphibian populations in many parts of the world (Stuart et al. 2004; Kilpatrick et al., 2010). Chytridiomycosis is a disease caused by the fungal pathogen *Batrachochytrium dendrobatidis* (Bd) and infections with Bd can lead to mortalities in some amphibian species. Green et al. (2002) classified Bd as a leading candidate for many population declines in the United States.

Bd is implicated in declines of other members of the *B. boreas* species complex, indicating that the Dixie Valley toad may also be susceptible to this deadly fungus. Chytridiomycosis has devastated boreal toad populations in the southern Rocky Mountains and has also been detected in Utah (Pilliod et al. 2010; Keinath and McGee 2005, p. 36; National Wildlife Health Center 2001, p.1). Populations of boreal toads infected with chytrid fungus have declined to near extinction within one year, and there are no documented cases of an infected population recovering following infection. Bd is also a threat to the threatened Yosemite toad (*Bufo canorus*) and there is evidence related to Bd's role in historical die-offs in Yosemite toads (USFWS 2014, pp. 24296-98).

While Bd has historically not been considered as a substantial threat to the Amargosa toad (*Bufo nelsoni*) in past assessments and conservation efforts, chytridiomycosis was identified as the cause of death in captive *A. nelsoni* (Forrest et al. 2015, p. 918). Sampling done in 2011 and 2012 revealed overall high rates of Bd infections in wild Amargosa toads in the Oasis Valley (Ibid. at 920). Clinical signs of the disease chytridiomycosis were not detected in the Amargosa toads sampled, the reason for this is unclear and this study alone is insufficient to determine the susceptibility of the Amargosa toad to the disease (Ibid. at 922).

Forrest et al. (2013) tested Dixie Valley toads from Dixie Meadows and American bullfrogs from the nearby Turley Pond for Bd in 2011 and 2012 (p.74). Although Bd was not detected on the Dixie Valley toads sampled in 2011 (n = 39 toads) and in 2012 (n = 56 toads), Bd was detected on bullfrogs in both years and the prevalence of Bd infections was significantly higher in bullfrogs in 2012 (Ibid. at 77). The negative tests for Bd on the toads is not conclusive evidence that Bd is not present among this species as the sample sizes used were not sufficient to detect low levels of prevalence in the population.

Bd infections appear to have little to no effect on bullfrogs and bullfrogs are known to be vectors of this pathogen (Daszak et al. 2014; Hanselmann et al. 2004). While the highly alkaline soil between Turley Pond and the main Dixie Meadows habitat may generally act as a barrier for the bullfrogs, these ponds could periodically become connected hydrologically if heavy precipitation resulted in flooding (Forrest et al. 2013, p. 82). In addition, Dixie Valley toads and bullfrogs are

both found in the pond associated with the cold spring and Bd testing has not occurred at this site (Ibid.).

Although susceptibility to Bd appears to be species-specific, this can also be impacted by environmental factors. Bd prevalence and virulence are particularly influenced by temperature (Forrest & Schlaepfer 2011, p. 1). Both field and laboratory studies have shown that Bd prevalence is correlated with cooler temperature and Bd growth may cease when it gets too hot (> 28°C in lab studies) (Ibid.).

Forrest and Schlaepfer (2011) examined the impacts of temperature variations on Bd prevalence in lowland leopard frogs (*Rana yavapaensis*) in the wild in Arizona, including seven sites influenced by geothermal springs and five that were not (p. 7). A strong inverse correlation was found between Bd infection status and water temperatures, as well as between the water temperature where the frogs were captured and Bd prevalence (Ibid. at 4). Forrest and Schlaepfer (2011) concluded that habitats with water temperatures exceeding 30°C could provide lowland leopard frogs with significant protection from Bd. These results, along with previous research on temperature effects on Bd, suggests that the likely changes in water temperature from proposed geothermal energy production may impact the prevalence of Bd in the Dixie Valley toad and other amphibians in the area.

Disease likely works synergistically with other threats to amphibians (Fellers et al. 2001, Kiesecker et al. 2001). Thus, other stressors to the toad such as drought or changes in hydrology, water temperature and chemistry caused by geothermal energy development or groundwater extraction may increase the toad's susceptibility to Bd or other pathogens.

Listing the Dixie Valley toad could help ensure monitoring for Bd and speed efforts to ensure infected bull frogs do not infect the toad.

D. Inadequacy of Existing Regulatory Mechanisms

The Dixie Valley toad occurs on both US Navy and BLM-administered lands in the Dixie Meadows. The toad is on the Bureau of Land Management's sensitive species list for Nevada (as *Bufo boreas* spp.) But sensitive species designations afford little protection, requiring only that the impacts be considered but not preventing actions that would harm the Dixie Valley toad. Thus, the BLM can conclude in a Biological Evaluation that individuals or populations will be harmed or destroyed by an action, but still carry out this action.

The Carson City District of the BLM recommended in 2013 that 413 acres of Dixie Valley toad habitat on BLM land be considered as a potential Area of Critical Environmental Concern (ACEC) because it contains essential habitat for the toad (BLM, Carson City District 2013, p. 13). However, this ACEC has not been designated and petitioners are unaware of any commitments to create this ACEC.⁴

⁴ In fact, designating an ACEC in this area appears to be in conflict with the proposed geothermal energy project currently under consideration, and it is unclear how the BLM could resolve this conflict.

The toad is also listed as an at-risk species by Nevada's Natural Heritage Program (as *Anaxyrus sp. 1*). However, species included on the At-Risk Plant and Animal Tracking List are not provided any additional protections by the state (Nevada Natural Heritage Program 2017). The At-Risk List simply directs the data acquisition priorities of the Natural Heritage Program and provides current information on the status of these taxa.

The U.S. Fish and Wildlife Service, BLM, the Nevada Department of Wildlife, the Fallon Naval Air Station, and other cooperators began discussions in 2008 about developing a Candidate Conservation Agreement (CCA) for the Dixie Valley toad, which included at least an early draft CCA for the toad and Dixie Valley chub from 2009. However, petitioners' current understanding is that the agreement was never completed and has been abandoned and sitting idle for several years.

No existing regulations currently protect the toad from geothermal development. Indeed, the BLM appears set to approve permits for the facility, necessitating listing of the toad.

E. Other Factors

Factors such as a small restricted range, climate change, and invasive species are among the threats to the survival of the Dixie Valley toad. Each of these is discussed below.

1. Climate Change

Amphibians and reptiles are considered to be highly sensitive to anthropogenic climate change (Corn 2005, Blaustein et al. 2010, Mitchell and Janzen 2010, Li et al. 2013). As ectothermic animals, all aspects of their life history are strongly influenced by the external environment, particularly temperature and moisture. In northwestern North America, for example, amphibians and reptiles were ranked as the most sensitive group to climate change out of 195 plant and animal species assessed (Case et al. 2015). Their high sensitivity was attributed to their dependency on habitats that are projected to be significantly altered by climate change such as seasonal wetlands and streams (90% of the amphibians and reptiles were identified as having at least one highly sensitive habitat upon which they depended). Amphibians were also determined to be vulnerable to climate change due to their physiological sensitivity (e.g., highly water-permeable skin).

Climate change is expected to affect amphibians and reptiles at the individual and population levels through a number of pathways including shifts in phenology and range; habitat alterations including changes in hydrology, vegetation, and soil; changes in pathogen-host dynamics, predator-prey relationships and competitive interactions which can alter community structure; and interactions with other stressors such as UV-B radiation and contaminants, all of which can affect survival, growth, reproduction and dispersal capabilities (Corn 2005, Blaustein et al. 2010, Mitchell and Janzen 2010, Li et al. 2013).

For amphibians, water availability is a key resource that affects survival, reproduction, activity levels, and dispersal, while temperature can affect timing of breeding, hibernation, and the ability to find food (Corn 2005, Blaustein et al. 2010, Lawler et al. 2010). Climate change is driving

greater variability in precipitation, increasing the frequency of extreme weather events, and increasing surface water temperatures (Melillo et al. 2014). As a result, climate changes-related changes in hydrological regimes (i.e., alterations in stream flow, lake depth, amount and duration and winter snow pack, pond hydroperiods, soil moisture) and warming temperatures are predicted to have largely negative effects on amphibian breeding success and survival, dispersal, and habitat suitability (Blaustein et al. 2010, Walls et al. 2013).

Numerous studies have documented climate-associated shifts in amphibian phenology, range, and pathogen-host interactions (Corn 2005, Blaustein et al. 2010, Li et al. 2013) with emerging evidence for climate change-related declines (i.e., Lowe 2012, Rohr and Palmer 2013). Li et al. (2013) reported the results of 14 long-term studies of the effects of climate change on amphibian timing of breeding in the temperate zone of the US and Europe. This meta-analysis indicated that more than half of studied populations (28 of 44 populations of 31 species) showed earlier breeding dates, while 13 showed no change, and 3 populations showed later breeding dates, where spring-breeding species tended to breed earlier and autumn-breeding species tended to breed later. Several studies indicate that shifts in timing of breeding can have fitness and population-level consequences. For example, amphibians that emerge earlier in the spring can be vulnerable to winter freeze events or desiccation if they arrive at breeding sites prior to spring rains (Li et al. 2013).

Climate-associated shifts in amphibian ranges can be particularly problematic for restricted range and high-elevation species that have specific habitat requirements and limited options for movement (Li et al. 2013). As greenhouse gas emissions continue to grow, studies project high turnover of amphibian species as habitats become climatically unsuitable. For example, Lawler et al. (2010) projected 50% or greater climate-induced turnover of amphibian species in many regions of the US by the later part of the century (see Figure 3 of Lawler).

Climate change has also been implicated in stimulating the emergence of infectious amphibian diseases at the local and global scale. Increases in climate variability and extreme weather events resulting from climate change appear to provide an advantage to pathogens, such as chytridiomycosis (chytrid fungus) which is driving amphibian declines worldwide (Rohr and Raffel 2010, Li et al. 2013, Raffel et al. 2013). Raffel et al. (2013) found a causal link between increased temperature variability and chytrid-induced mortality in frogs, which in the context of other studies linking chytrid outbreaks to temperature shifts, provides compelling evidence for a climate-change role in amphibian mortality from chytrid fungus (Li et al. 2013). Several recent studies indicate a role of climate change in amphibian population declines, in combination with other stressors (i.e., Lowe 2012, Rohr and Palmer 2013).

Climate scenarios suggest that there will be significant warming across the Southwest, with more warming projected for the Great Basin than southern deserts (Abatzoglou and Kolden 2011, p. 474). Warming across the Great Basin is likely to be amplified during the summer (Ibid.). In the Dixie Valley, this expected warming trend is likely to increase in the evaporation and decrease the surface water residence time in the Dixie Meadows, leading to a reduction in the toad's wetland habitat. Models predict the Great Basin will get more rain, more frequent rain events and more severe rain events in the winter, including frequent anomalously wet winters occurring 60% more often across the northern Great Basin by the mid-21st century (Ibid.). While an

increase in precipitation may appear to have some positive consequences for the Dixie Valley toad, it may also cause changes to the Dixie Valley's ecosystem that could be detrimental to the toad. In addition, severe rain events could lead to flooding which could cause Turley Pond to become hydrologically connected with the main Dixie Meadows habitat, exposing the toads to bullfrogs that carry Bd and that are likely to prey on the toads (Forrest et al. 2013, p. 82).

2. *Invasive Species*

Bullfrogs (*Rana catesbeiana*) are a nonindigenous species that have been implicated as a cause of amphibian declines throughout the western United States (McGee & Keinath 2005, p.39; Kats and Ferrer 2003, p.100). Bullfrogs are often important competitors with native amphibians (Kats and Ferrer 2003, p. 100). Bullfrogs are also voracious, opportunistic predators, consuming a wide variety of prey dominated by invertebrates and small vertebrates. All life history stages of amphibians may be vulnerable to predation from adult bullfrogs and eggs and larvae may be preyed upon by bullfrog tadpoles (McGee & Keinath 2005, p. 39).

Bullfrogs are present at the southern end of the Dixie Valley toad's range (Gordon et al, 2017, p. 136). Bullfrogs are much larger than Dixie Valley toads and even bullfrog metamorphs are larger than the adult toads, thus bullfrogs are likely to predate the toads (Ibid.).

Introduced species can spread pathogens to Dixie Valley toads, and as discussed in the disease section above, bullfrogs can serve as a reservoir for the chytrid fungus and are recognized as a vector for the transmission of this pathogen.

Invasive noxious weeds may also negatively affect the Dixie Valley toad. Invasive weed species, such as Russian olive (*Elaeagnus angustifolia*) and saltcedar, or tamarisk (*Tamarix* spp.), can outcompete native vegetation, interfere with nutrient cycling, and interfere with natural aquatic systems.

V. CONCLUSION

The Dixie Valley toad is a recently described species, increasing the regional diversity of the *Bufo boreas* species complex to five species. The fortunate discovery of this unique toad provides the opportunity to ensure that this unique piece of our national freshwater heritage survives for future generations. The toad only persists within a range of 6 km² in the Dixie Valley of Churchill County, Nevada, where it relies on four spring-fed wetlands. This small toad is threatened by exploitation of geothermal energy and groundwater resources, the disease chytridiomycosis, climate change, invasive species, and limited range. It is not adequately protected by any state or federal laws. The toad's survival is most imminently at risk from the proposed expansion of geothermal energy production in the Dixie Valley, which is likely to reduce or eliminate the flow of springs to the toad's wetland habitat. Based on the best available scientific information, the Dixie Valley toad is in danger of extinction and qualifies for protection under the Endangered Species Act.

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