Giant Garter Snake

Habitat Quantification Tool

Part of the Multispecies Habitat Quantification Tool for the Central Valley Habitat Exchange

Scientific Rationale and Methods Document, Version 5
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Executive Summary

The Habitat Quantification Tools (HQT) represent a method for quantifying habitat condition for single or multiple species native to the Central Valley, California. The intent is to create a means of consistently assessing habitat condition so that high quality habitat can be managed or maintained to benefit the species. By quantifying habitat condition, the tool also allows for a range of applications that support land management, enhancement, restoration, or mitigation. Applications include comparison of relative habitat value between multiple locations, and comparison of relative habitat value for a single location over time to support quantification of improvements (“credits”) or impacts (“debits”) to habitat condition from a past or anticipated action.

Species and groups of species currently included in the Multispecies Habitat Quantification Tool (mHQT) are Chinook salmon (Oncorhynchus tshawytscha), Swainson’s hawk (Buteo swainsoni), riparian land birds, and the giant garter snake (Thamnophis gigas); more species or groups of species will be added to this current set. The mHQT has been specifically designed for use in the Central Valley Habitat Exchange (Exchange); however, it has broad applicability for use in any habitat mitigation and conservation effort for the target species in the Central Valley. The mHQT is intended to: a) provide a quantitative and effective basis for developing credits and debits based on habitat quality for one or multiple target species; b) to incentivize the development of habitat for target species in locations where it provides maximum ecological benefit; and c) to inform the suite of potential actions necessary in order to improve habitat condition and achieve maximum habitat quality.

This is the Scientific Rationale and Methods Document for the giant garter snake portion of the mHQT and the contents describe, explain, and operationalize the scientific approach to quantifying credits and debits. Habitat conditions that are important for this species are described along with methods for measuring and reporting on habitat conditions for input to the mHQT. This document includes a description and definition of the habitat attributes (important characteristics that affect habitat quality, such as emergent vegetation for giant garter snake, or flood duration for Chinook salmon, or availability of nestable trees for Swainson’s hawk), parameters measured (relevant and measurable aspects of the attributes, such as areal cover of emergent vegetation, length of time for flood duration, or number of trees of given stature within a certain area), and metrics (methods of measurement for each parameter, such as absolute percent cover emergent vegetation in delineated water body, number of days with over 10 cm water depth covering at least one acre, or number of trees over 8 m tall within the Project Area boundaries) used to assess habitat quality for each species or suite of species. This document also provides discussion illustrating why those specific attributes and methods were chosen in constructing the mHQT, as well as supporting documentation (e.g., peer-reviewed literature, gray literature, expert opinion), and methods for compiling attribute measurements into site-specific habitat quality scores.

The species or suite of species specific HQTs, the combined operation in the mHQT and the supporting Scientific Rationale and Methods Documents will undergo further scientific review and revision where necessary and as additional species are added to the mHQT.

The Central Valley Habitat Exchange’s system for quantifying habitat function is structured around a suite of core requirements. These include:

- **Science driven** – The system for quantifying habitat function must be based in the best available science about the habitat requirements of Central Valley species.
• **Addresses multiple species** – The system should be broad enough to incorporate the habitat needs of a suite of species, and define those needs based on a subset of a common suite of attributes that will facilitate comparison across species.

• **Metrics for SMART outcomes** – To support recommendations that are implementable, the Central Valley Habitat Exchange system must generate metrics that can be used to establish outcomes that are specific, measurable, attainable, relevant, and time-bound (SMART).

• **A common language for conservation objectives and permitting** – The Central Valley Habitat Exchange metrics should function as a common quantitative language capable of reconciling diverse conservation objectives, reducing the complexity of permitting, and improving the effectiveness of mitigation.

The mHQT is a multi-scaled approach for assessing environmental conditions, habitat quality and quantity, and conservation or mitigation outcomes for target native species in the Central Valley. The mHQT metrics are supported by a suite of specific methods, applied at multiple spatial scales to evaluate aquatic and terrestrial conditions related to the habitat quality and quantity for the target species. The purpose of the mHQT is to accurately quantify benefits (“credits”) or impacts (“debts”) to habitat conditions through habitat “credit” and “debit” conservation and mitigation programs.

The mHQT is designed to be applied at both the landscape scale, as a means of identifying potential priority areas for habitat restoration, enhancement, or protection, and at the Project Area scale, in which a specific parcel of land is identified and assessed as a potential area for restoration, enhancement, protection, or mitigation. Habitat-relevant attributes within the Project Area are measured and incorporated into the mHQT to assess site-specific conditions for supporting each target species or guild. The landscape condition information is combined with information on the Project Area itself to generate an assessment score of the Project Area and associated functional acres of habitat for each focal species.

Information on the needs and existing and historical distribution of the target species are used to provide spatial context at the landscape scale for a given land area in order to identify, screen, and prioritize potential Project Areas, as well as to subsequently modify scores for high priority areas to reflect changes in landscape value and changes in species landscape needs (e.g., distribution and abundance) over time. Landscape-level habitat attributes are used to develop a **Landscape Context score** for a Project Area and a target species or sets of species. Landscape Context scores include information on the known or potential occurrence and/or abundance of the species in the area and the occurrence of features in the nearby landscape that could improve upon or detract from habitat quality in area. Specific landscape scale attributes most relevant to each target species or set of species are described in the chapters that follow.

The core of the quantification approach used by the Central Valley Habitat Exchange is an assessment of a given land area for species-specific habitat attributes via metrics and the assignment of scores based on the quality and functionality of the land area across those attributes. To translate the attribute value to an attribute score, a scoring function was developed for each attribute and for each species-specific habitat type for which the attribute is relevant. This scoring function translates each attribute measurement into an attribute quality score, ranging from 0 to 1.

A Project Area can be broken out into different ‘Map Units’ that have a consistent vegetation pattern and are managed consistently and/or have the same inundation regime. Within each Map Unit, finer scale habitat units of different kinds (e.g., Riparian Units for riparian birds, and Aquatic Features for giant garter snake) can be articulated. Habitat units have consistent features, defined for each habitat unit type, and
are delineated as polygons that are <5.75 acres in size. Anywhere from zero to many habitat units can be within a Map Unit but a Map Unit does not have to have any or be completely filled with smaller habitat units. Some attributes are measured and reported at the Project Area scale, others at the Map Unit scale, and still others at the habitat unit scale. Attribute quality scores are then combined based on the frequency and spatial extent of associated conditions relevant to target species (e.g., inundation event duration and extent, crop rotation and extent). Higher habitat quality results in more favorable metrics and higher scores for the individual habitat attributes, which then are aggregated into a cumulative **Site Capacity score** for a given species within the bounds of the Project Area. The final **Project Area score** is composed of a combination of the Site Capacity score and the Landscape Context score.

Over time, the benefits (“credits”) or impacts (“debits”) of land management actions on a given Project Area can be quantified and verified by repeated assessment and scoring using the mHQT. Ultimately, the quantification approach used by the Exchange makes it possible for the user to combine habitat scores for multiple species or groups of species into a composite score for a given land area. In addition to capturing the full range of essential habitat attributes across species, composite area scoring identifies opportunities to maximize the total benefit to a given land area as the basis for enhancement recommendations by enabling comparison of attribute parameters required across species or guilds, or by enabling an effective balancing of attributes to maximize the net benefits to all species.

In summary, the core of the mHQT is a combination of: (1) the Landscape Context and Project Area habitat attributes that have been identified; (2) the scoring functions that convert parameter measurements (metrics) into an attribute quality score; and, (3) the way in which habitat attribute quality scores are combined into a single measure of functional acres—thereby reflecting habitat quality and quantity. This document describes the scientific rationale used to generate these three components of the habitat quantification tool for Giant garter snake.
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1.0 Overview of the Habitat Quantification Tool

The Multispecies Habitat Quantification Tool (mHQT) applies a multi-scaled approach to assess environmental conditions, habitat quality and quantity, and conservation or mitigation outcomes for multiple species native to the Central Valley. The mHQT has been designed for use in the Central Valley Habitat Exchange (Exchange); however, this tool could have broad applicability for use in other mitigation and conservation efforts in California's Central Valley. With its focus on the species dependent upon the river corridor and adjacent agricultural lands, this version of the mHQT targets off-channel habitat and associated uplands, much of which is privately owned in the Central Valley.

The Exchange is a new initiative taking advantage of the emerging market of habitat credits to improve habitat quality in the Central Valley by leveraging the habitat that willing landowners can provide. The Exchange will facilitate investment in conservation and restoration of vital Central Valley habitat by promoting, monitoring and assisting in the exchange of habitat credits. The Exchange will allow habitat to be traded as a commodity by creating habitat credits that willing landowners can sell to private and public investors. Potential investors include but are not limited to state agencies or private entities seeking credits for mitigation requirements or restoration mandates. Through the Exchange, landowners will be paid to “grow” habitat such as flooded fields for salmon and migratory birds, riparian forest for Swainson’s hawks and wetlands for giant garter snakes. The result will be a new funding stream that will enable landowners to earn revenue for restoring and maintaining functional habitat. The Exchange program area covers lands in the California Central Valley that extend up to 91.4 m (300 ft) elevation and downstream towards the San Francisco Bay, ending at the western extent of the Legal Delta (Figure 1).

The assessment and scoring rationale and methods described in the mHQT measure the quality and quantity of habitat. The mHQT can determine the degree to which Project Area conditions meet species habitat requirements and preferences. The mHQT scoring is designed to be responsive to changes in Project Area conditions that positively or negatively affect habitat quality and quantity and which thereby affect the amount of habitat credits and debits associated with a Project Area. Changes to habitat quality include direct and indirect effects of land and water management on the ability of the land parcel and the surrounding area to support the species. Measures of quality and quantity are combined into “functional acres”, which are units of habitat quality (“function”) over a given quantity (“acres”) relative to functional (minimum score or greater) and optimal (maximum score for a given landscape context) conditions. The Exchange Operations Manual (Exchange Manual) defines how the Exchange uses these scores to generate credits and debits.
Figure 1. Map showing extent of Central Valley Habitat Exchange Program Area, indicating three major regions within the Program Area: Sacramento Valley (pink), Delta and Central Tributaries (green), and the San Joaquin Valley (blue).

1.1 mHQT Development Process

The Exchange is a collaboration among American Rivers, Environmental Defense Fund, Point Blue Conservation Science, Trout Unlimited, California Farm Bureau Federation, Delta Conservancy, California Trout, Environmental Incentives, Stillwater Sciences, and California Department of Conservation that is
intended to lead to the development of crediting and debiting programs that help promote effective conservation and mitigation of Central Valley habitats.

The Exchange system for quantifying habitat quality and quantity is an evolving suite of technical products developed and overseen by scientists from Exchange organizations working in partnership and with input from other private organizations, NGOs, institutions, and state and federal agencies. The Exchange’s long-term success will hinge on its ability to meet the needs of a wide range of interests and stakeholders while accurately reflecting habitat conditions and performance for target species. Technical workgroup meetings occur regularly and are open to technical staff from parties interested in advancing this effort.

The Exchange is structured to accommodate habitat exchanges for multiple species, either with overlapping or spatially separate areas. To-date, HQTs have been developed for four target species or suites of species:

- Chinook salmon (including winter-run, spring-run, fall run, and late fall-run) (csHQT),
- Riparian land birds (rbHQT,
- Swainson’s hawk (shHQT),
- Giant garter snake (gsHQT)

A technical advisory committee (TAC) was created for the development of each species HQT. Each TAC is composed of species experts and key personnel from relevant agencies, including CDFW, NOAA, USFWS, DWR, and members of the Exchange science team with appropriate expertise. The tool development process has varied slightly for each species-specific tool developed thus far. In the case of the csHQT and the rbHQT, the tools were initially developed by Stillwater Sciences working under guidance of the Exchange Science Team and then improved and refined through consultation with the species or guild-specific TAC. The shHQT and gsHQTs were developed by Stillwater Sciences working with the species or guild-specific TAC from the beginning.

In all cases, the tools were developed following a similar general sequence of steps. Once the most important habitat attributes were identified for the Landscape Context score and for the Site Capacity score, information sources and/or field data collection methods were articulated along with attribute parameters and the appropriate metrics for measuring them. Habitat suitability response functions for the identified metrics were then developed to yield scores for each attribute, reported on a scale of 0 to 1.0. Areas to input relevant landscape and site-scale information were then created in an Excel-based HQT which links information entered by the user to the articulated response functions. These attribute scores are then automatically compiled into habitat quality scores for each species or guild relevant for the Project Area. Draft tools are field tested at multiple locations and with multiple users, refined based on findings from the field and input from the users, and finalized as a first version which can undergo regular
updates in order to incorporate new science into the tools. A field manual with guidance on how to collect data needed for each HQT is developed in parallel with tool development.

The HQT can thus be used to assess the effects of specific changes in Project Area conditions on habitat quality to inform the most effective management alternatives for one or several species. The components of these species HQTs are combined into a single spreadsheet tool, referred to as the multispecies HQT (mHQT). As more species or suites of species are added to the mHQT, more explanatory chapters will be available to compile into a document for the full mHQT.

1.2 Key Concepts

1.2.1 Habitat Quality and Species Performance

Habitat represents a particular combination of resources (e.g., food, shelter, and water) and environmental conditions that support a wildlife population’s vital rates—i.e., survival and reproduction (Morrison et al. 2006). Habitat can vary in quality and therefore its ability to support a population’s vital rates over time. Simply put, high quality habitat is more likely to sustain resilient populations than poor quality habitat. Improvement of habitat quality can increase carrying capacity, allowing existing habitat area to support a higher species density and greater total population size. Poor habitat quality may lead to low survival and reproduction, lower densities, and eventual extirpation of a population. Marginal habitat may support some amount of occupancy by a species, but may still result in low survival and/or reproduction, which will likely lead to population declines without high levels of immigration.

1.2.2 Water

Water is a critical component of habitat for many species, including Chinook salmon and giant garter snake. Multiple habitat attributes are combined to determine whether an area is suitable in terms of its ability to provide shelter and food resources for a given species. The California Central Valley was once dominated by vast stretches of wetlands and floodplains, flanking the Sacramento River and its tributaries to the north, the San Joaquin River and its tributaries to the south, and extending hundreds of thousands of acres across the valley floor (Figures 2 and 3A–D). As a result of this unique geography, the historical Central Valley was perhaps the most productive wetland-floodplain complex in North America, supporting a diverse and abundant spectrum of wildlife including the now-threatened Chinook salmon, giant garter snake, and riparian land birds. The winter and spring floodwaters that fed the vast emergent wetlands and created and supported extensive willow and cottonwood gallery forests that were home to many wildlife species, also washed young salmon and other native fishes out of the river channels and into the floodplains and marshes. Protected from the current of the main river and supplied with abundant food
resources, these sheltered habitats provided environmental conditions that were optimal for growth as the young salmon migrated out to the ocean. Giant garter snakes thrived in the lowland tule marshes and myriad bird species lived in the diverse and productive riparian and wetland habitats.

Figure 2. Distribution of major vegetation types in the Delta under pre-European settlement conditions (from Whipple et al. 2012).

The once hydrologically dynamic central valley landscape has been significantly altered over the last century; its rivers channelized and levied, wetlands drained, and much of its native riparian habitats destroyed. Today, only five percent of the Central Valley’s historical wetland complex still exists (Figures 3C and 3D) (Bay Institute 1998, Whipple et al. 2012). Native riparian floodplain habitat has been so drastically changed that, without remediation, populations of riparian dependent species, including Chinook salmon, are on the verge of collapse (Katz et al. 2013).
Figure 3A. Historical distribution of floodplain and wetland ecosystems in the Sacramento Valley (from Bay Institute 1998).

Figure 3B. Historical distribution of floodplain and wetland ecosystems in the San Joaquin Valley (from Bay Institute 1998).
Figure 3C. Current distribution of floodplain and wetland ecosystems in the Sacramento Valley (from Bay Institute 1998).

Figure 3D. Current distribution of floodplain and wetland ecosystems in the San Joaquin Valley (from Bay Institute 1998).
1.2.3 Spatial Scale

As with many ecological processes, habitat selection occurs at multiple spatial scales, with individuals choosing to settle in a location by keying in to different features at different scales, determined in part by their ability to move among habitat gradients (Wiens et al. 1987, Morrison et al. 2006). For example, birds are highly mobile and may perceive physical vegetation structure first over a relatively large, landscape scale, then settle across the landscape according to more fine scale vegetation composition, vertical structure and other factors, such as competitors. Favorable river reaches or large floodplains attract congregations of fish capable of swimming from the Ocean coast hundreds of miles inland. Within these larger scale habitats, the distribution of individuals is often determined based upon habitat characteristics or competitive interactions at finer spatial scales. In comparison, giant garter snakes are far less mobile and dispersal is limited to active movement that occurs on the scale of hundreds of meters or relatively rare incidental and passive movement that can occur at larger scales (e.g., tens of miles) if individuals are washed downstream during large storm events.

Issues of spatial scale are incorporated into the mHQT through species or guild specific metrics and scoring functions that account for the Landscape Context and other metrics and scoring functions that operate at finer scales within the Project Area. Within the Project Area, some features, such as dominant crop cover, can be measured and reliably reported at broad scales ranging from 40 to 150 acres (e.g., the size of a farm field). Species respond to other features that occur at finer scales, and these must be reported at appropriately matching fine scales. For example, vegetation density in various vertical layers varies among vegetation types and in riparian corridors; these are most reliably observed at scales ranging from 0.5 to 5.75 acres. Thus, the spatial scale at which habitat attributes are measured and reported in the mHQT is driven by the scale at which the target species responds to that feature.

1.2.4 Time Scales

Temporal (time) scales also vary among ecological processes, and ecological responses to increasing time scales may not be linear (Wiens et al. 1987). The time required for a riverine system to respond to management practices and the time for a fish population’s vital rates to reflect such changes will vary by ecosystem, geography, area, climate, land use, and species life history. For example, salmon populations have multi-year life history patterns that result in a two- to five-year periodicity for cohort freshwater habitat use. Similarly, salmon populations often exhibit large fluctuations in abundance due to cyclical climate factors that affect marine and freshwater survival (Beamish and Bouillon 1993, Koslow et al. 2002). Swainson’s hawk roam broad areas, foraging in certain crop types depending on management practices that flush or expose abundant prey (Estep 1989). Growers rotate crop types over one to five or ten-year rotations to maintain healthy soils. Therefore, it can be difficult to distinguish the effects of specific conservation actions on a target population, especially if measurements reflect only a single
snapshot in time. The Multispecies HQT attempts to account for these issues of temporal fluctuations at different time scales by requiring reporting of conditions that change over time. For example, hydrologic modeling that combines expected future conditions (e.g., Project Area modifications and/or climate change) must be performed to estimate future time-dependent Project Area conditions for Chinook salmon. Repeated empirical measures of habitat conditions during multiple inundation events are used to assess past or existing habitat quality. Similarly, crop rotations, canal maintenance, and other associated changes in management practices that affect foraging opportunities must be reported to assess habitat quality for dependent species, such as Swainson’s hawk and giant garter snake.

1.3 Framework for Quantifying Habitat Functionality

The foundation of the Exchange system for quantifying habitat function is a science-based approach to measuring the quality and quantity of habitat, based on habitat attribute parameters and metrics, that a given area (terrestrial or aquatic) or parcel provides for target species, guilds, or groups of species. The habitat quantification tools for each species or species guild share a similar structure, easing application of the same site data for multiple species. Characteristics about the surrounding landscape inform the Landscape Context score; habitat attributes and management practices within the Project Area inform the Project Area score. For all species, the landscape conditions are combined in some way with the Project Area scores in order to develop a score for the species-specific (or guild-specific) habitat quality in the Project Area (Figure 4). The habitat quality, as a percent of the site potential, is then multiplied by the number of acres proposed in the Project Area to determine the number of functional acres. This process can be executed for each individual species or species guild, and the habitat acres reported separately, or the species-specific habitat acres can be combined using rules developed outside of the HQT as part of the Exchange Program. The components of the habitat quantification tools, including the landscape context and habitat attributes, are described below. Different applications of the mHQT, including predictive vs. retrospective, and single species vs. multiple species are also described in the following sections.
Figure 4. General overview of the structure of the Habitat Quantification Tools (HQTs) for multiple focal species.

1.3.1 Landscape Context

Within the Exchange Area (Figure 1), habitat function may be modified by contextual information that describes the regional need and/or opportunity for the target species, linkage to a larger habitat patch or significant proportion of the population, or other relevant physical and biological conditions in the surrounding watershed. Contextual information is applicable at a range of scales including: (a) Project Area location (4th order; e.g., hydrologic connectivity with floodplain, existing vegetation composition and/or structure directly surrounding the Project Area, soil type, etc.); (b) watershed or local area (3rd order; e.g., HUC 12) (meander potential, connectivity among habitat patches, surrounding land use and/or fire regime, etc.); (c) region (2nd order; e.g., channel network density, habitat fragmentation and connectivity patterns); and, (d) range (1st order; e.g., species ranges).

1.3.2 Habitat Attributes

Attributes are specific habitat characteristics or habitat-forming processes that determine the degree of habitat function (quality) for individual target species or groups of species for a Project Area. Key attributes are identified based on their relevance to species needs and tolerances.

Habitat attributes are composed of three types of information: (1) a set of measurable Habitat Parameters with known relationships to habitat quality that also include specific reportable units for measuring each parameter, referred to as metrics. Parameters are used to quantify key habitat attributes
Characteristics and processes that determine the degree of habitat function of a Project Area; (2) Attribute Timing that includes the increment(s) of time that is relevant to a given parameter and the specific timing (e.g., monthly, seasonally, annually) during which a given parameter possesses a given value, or must achieve a given threshold, in order to meet the habitat needs of the target species; and, (3) Necessary vs. Beneficial: Where “necessary” indicates that an attribute must be present for an area to be considered functional habitat; and “beneficial” indicates that the attribute can improve habitat quality but is not absolutely necessary.

1.3.3 Spatial and Temporal Scales in the HQT

Habitat attributes are observed and measured within the Project Area at the spatial scale most relevant to the target species. In the current mHQT, attributes are measured at three spatial scales: (1) Project Area, (2) Map Unit, and (3) Riparian Unit or Aquatic Feature. A Project Area is a parcel, or collection of parcels, of land identified and evaluated as a potential area for restoration, enhancement, or protection for HQT target species or suites of species (e.g., giant garter snake). A given Project Area is divided into relatively homogeneous Map Units that range from 40 to 150 acres in size for the Swainson’s hawk and Riparian land bird tools and can range up to several hundred acres in size for the giant garter snake tool. All Map Units must have consistent vegetation patterns, management actions, and flood regimes. A set of attributes are measured at the Map Unit scale. Nested within these Map Units, Riparian Units are delineated at finer scales, ranging from 0.5 to 5.75 acres, and used to report consistent areas of vegetation structure and composition. Within each Map Unit, finer scale “Aquatic Features” can also be demarcated. Each individual Aquatic Feature will have consistent habitat quality attributes such as standing or slow-moving water. While Aquatic Features will commonly be linear (e.g., canals), each will be delineated as a polygon in Geographic Information System (GIS). One or more Aquatic Features can be within a Map Unit, but a Map Unit does not have to be completely filled with smaller Aquatic Features and/or Riparian Units, or have any at all.

A rice canal or a stand of riparian forest, while delineated as an Aquatic Feature or Riparian Unit within one Map Unit, may continue into one or more adjacent Map Units. In this case, the Aquatic Feature or Riparian Unit will have different identification codes across Map Units but be linked in the HQT by bearing the same “contiguity code” (Figure 5). This information is used to calculate the extent of continuous aquatic or riparian habitat that crosses multiple Map Units. For example, a unique Aquatic Feature may be hydrologically linked to another unique Aquatic Feature, within or across Map Units; these would share the same “contiguity code” within or across Map Units. Attribute scores for Riparian Units and for Aquatic Features are rolled up per Map Unit using area-weighted averaging, and these and attributes measured at the Map Unit scale are rolled up for the Project Area also using area-weighted averaging.
Figure 5. Example Project Area for multi-species HQT, showing delineations of Map Units within the Project Area, Riparian Units within a Map Unit, and Aquatic Features within the Map Units that share connectivity codes across multiple Map Units.
Information used in the mHQT is also tailored to the time scale most relevant to species needs, including the active season(s) for the species, and, for salmon, the timing of specific inundation events. For all species, the mHQT provides scores of habitat quality for a single year. However, conditions over multiple years can be bundled to reflect a multi-year average when there are repeated or predictable patterns over time. For example, a repeating crop rotation (five-year alfalfa, two-year tomato, repeat) can be entered for Swainson’s hawk HQT (swHQT) to reflect average annual conditions, and flood events expected to occur at least every other year can be used to predict likely habitat quality for the Chinook salmon HQT (csHQT).

1.3.4 Predictive vs. Retrospective Applications of HQT

HQT scores for species with a high degree of dependence on hydrologic conditions, such as for Chinook salmon, are currently structured to accommodate two levels of data input: predictive and retrospective. Predictive data, as the name suggests, is used to estimate potential future conditions and habitat quality scores for a Project Area, as might be relevant, for example, to a location where new enhancement or management actions anticipated to change habitat condition are planned. Since this is for future conditions, there is inherent uncertainty in the input data and resulting HQT scores. For example, for a given floodplain, topographic and revegetation plans, past flow data, and quantitative hydrologic/hydraulic models can be used to describe a potential flow event. The likelihood of this event can also be calculated based upon past flow records. However, some metrics are currently not feasible to reliably predict, such as stream temperature and dissolved oxygen levels during the flow event. In contrast, retrospective application of the HQT to a Project Area using empirical observations has much greater certainty of event occurrence and conditions (although some uncertainty may remain due to the need to extrapolate some point measurements over space and time) than with predictive applications. For some metrics, retrospective applications can also be done with greater specificity than predictive applications. For example, more specific input values on flood timing, duration and extent can be provided when using observations of actual past events than from predicted likelihood of future events. These differences between predictive and retrospective information are incorporated in the csHQT at both the data input and scoring levels. For data input, the user indicates whether they are performing a predictive or a retrospective assessment, and associated data input cells become highlighted. Scoring is based upon the same principles but necessarily differs with the differences in data input. Details on how data inputs and scoring differ between the predictive and retrospective applications are provided in the csHQT chapter for the mHQT.
### 1.3.5 Habitat Quantification Toolkit

The Exchange system for quantifying habitat function for multiple species is composed of a four-part Habitat Quantification Toolkit that works synergistically to address core Exchange requirements, as outlined in Figure 6.

<table>
<thead>
<tr>
<th>Framework for Quantifying Habitat</th>
</tr>
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<tbody>
<tr>
<td>- Attributes, Parameters, and Metrics for measuring habitat utility</td>
</tr>
<tr>
<td>- Landscape context describing habitat potential in landscape</td>
</tr>
<tr>
<td>- Project Area, Map Units, Habitat Units for delineating habitat scale attributes</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Habitat Utility for Species- Information Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Attributes and parameters identified for target species and guilds</td>
</tr>
<tr>
<td>- Habitat suitability indices (bins or scoring curves for relevant parameters)</td>
</tr>
<tr>
<td>- Habitat quality Species habitat quality scores and recommendations</td>
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<table>
<thead>
<tr>
<th>Field Manual for Quantification</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Methods for measuring and/or modeling value on the ground</td>
</tr>
<tr>
<td>- Guidelines for assessment approaches to achieve assurance levels</td>
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<table>
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<tr>
<th>Spatial Analysis Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Google earth kml with relevant spatial data for landscape context assessment</td>
</tr>
<tr>
<td>- GIS ARC INFO shapefiles for landscape context assessment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Habitat Quantification Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Specifies required input information</td>
</tr>
<tr>
<td>- Automates calculations of habitat utility score</td>
</tr>
<tr>
<td>- Performs stacking to create species specific and multi-species composite scores</td>
</tr>
<tr>
<td>- Application to generate recommendations for habitat enhancements</td>
</tr>
</tbody>
</table>

*Figure 6. Generalized schematic of the Exchange Habitat Quantification Toolkit’s major components.*

The framework for quantifying habitat is provided in this chapter of the Scientific Rationale and Methods Document and the species-specific information base for each HQT is provided in the species or guild specific chapters of this document. A brief field manual with clear instructions on collecting input information for the HQT is provided as a separate document, and is thus far tailored for each species or guild tool. These Field Guidance documents also describe methods for interpretation and reporting of
HQT scores, as well as examples of applications under a range of circumstances to achieve assurance levels. Some of the landscape context information for the HQT can be obtained using either GIS or Google earth files provided with the mHQT. The HQT itself is an excel spreadsheet that includes input areas for field and office data, and output score summary tables for each species in the tool.

The multispecies HQT is designed for use by agency personnel, land owners, or third-party consultants. It is assumed that individual(s) using the HQT have a working knowledge of and access to landscape-scale information (Google Earth, Arc GIS, or aerial imagery) and Excel software. Some background in natural resources and farmland management is also essential. More intensive field and/or hydraulic modeling efforts are required for application of the Chinook salmon portion of the mHQT, as detailed in the Chinook Salmon HQT chapter of this document. It is expected that those that use the mHQT will have at least a one-day training in use of the tool and interpretation of the mHQT results.

The mHQT can be applied to establish pre-project baseline conditions, to estimate expected habitat quality and quantity effects of project implementation, and to objectively and consistently track and report changes in habitat quality and extent through time, following initial project implementation. The mHQT accommodates crop rotations and associated schedules for management activities that can affect species habitat conditions. Baseline conditions are established assuming the existing crop rotation, or flood regime, extend up to a 10 yr cycle. Information for each crop or flood event type within the cycle is entered into the mHQT and the scores are developed for the full cycle based on time-weighted scoring. Thus, if a field under existing, baseline conditions is managed 4 yrs for alfalfa, then 2 yrs for safflower, the existing conditions score will be based 66% on alfalfa conditions and 33% on safflower conditions. In similar fashion, these existing conditions can be compared to a different crop rotation and associated management schedule under ‘restored’ conditions.

1.4 Literature Cited in Section

Bay Institute 1998. From the Sierra to the Sea: The Ecological History of the San Francisco Bay-Delta Watershed. The Bay Institute of San Francisco. 2nd Printing.


2.0 Giant Garter Snake

2.1 Overview of Giant Garter Snake Habitat Attributes

The giant garter snake (Thamnophis gigas) Habitat Quantification Tool (HQT) assesses the value of giant garter snake habitat in a Project Area by incorporating habitat attribute information from the scale of: (1) the landscape, (2) the full Project Area; (3) a single or set of similarly managed fields, referred to as a Map Unit, and (4) sections of aquatic habitat that occur within a Map Unit, referred to as Aquatic Features. Aquatic Features are any aquatic features on a site that support active season foraging. Landscape-scale attributes include an interrelated combination of proximity to the snake’s presumed range, proximity to recent documented giant garter snake sightings, and proximity to historical tule marsh. The single measured Project Area attribute is the compiled extent of connected aquatic habitat within the Project Area. Habitat quality attributes measured at the scale of the Map Unit include: dominant vegetation or crop types, severe flooding that could limit the function of winter terrestrial habitat, connectivity to suitable aquatic habitat, and management of Aquatic Features and adjacent uplands. Aquatic Feature quality attributes include: the type and extent of each feature; the availability of water; the type, extent, and complexity of emergent wetland vegetation; the type, extent, and complexity of adjacent terrestrial vegetation (with respect to basking); and the availability of subterranean refugia (as active season retreat and non-active season brumation sites).

The giant garter snake HQT is designed to quantify the habitat quality of current site conditions and to inform restoration initiatives to improve giant garter snake habitat. The giant garter snake HQT was developed based on the best available scientific information and in partnership with a group of Central Valley giant garter snake experts that served on the Giant Garter Snake Technical Advisory Committee (see below).

It is important to consider the time of year the terrestrial vegetation data is collected. The optimal time to evaluate the extent of the terrestrial vegetation is in spring (e.g., March 15 through mid-June), since that is the time of year when snakes are coming out of brumation and preparing for the active season, hunting for food and searching for mates. Field data should be collected between May 1 and September 15 and must be collected when water is present in most Aquatic Features as an overall requirement for using the giant garter snake HQT. The time constraints on field data collection exist because water in the canals and other conveyance structures and plants used for cover are not necessarily in the same condition outside of these dates as they are during the snakes’ active season.

1 Brumation is a hibernation-like state of dormancy that reptiles enter during cold weather.
2.1.1 Habitat Quantification Tool Development Process

The goal of the HQT development is to generate a giant garter snake habitat assessment tool that is based on the best available science and has broad buy-in from a diverse group of conservation stakeholders and decision-makers. To achieve this goal, a giant garter snake TAC was created to participate in and review HQT development. Members of the TAC, each of whom has contributed to development of the HQT, are listed below:

- Brian Halstead (USGS)
- Laura Patterson (CDFW)
- Ron Melcer (formerly DWR; with Delta Stewardship Council as of February 2017)

The Technical Advisory Committee met four times throughout the course of the HQT development to build the foundation and contents, as outlined in Table 1 below. Each TAC meeting was two to four hours long and organized around a specific agenda disseminated prior to the meeting. Environmental Defense Fund and Stillwater Sciences led these meetings. The TAC meetings entailed open discussions, with key decisions marked by consensus among those present. This memo is the record of decisions and considerations made by the TAC during the development of the Giant Garter Snake HQT.

Table 1. TAC meeting details and completed steps for development of the giant garter snake HQT.

<table>
<thead>
<tr>
<th>TAC Meeting Date</th>
<th>TAC Meeting Location</th>
<th>Benchmarks for Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. April 14, 2016</td>
<td>DWR Offices, Sacramento, California</td>
<td>Agree on key attributes and potential response functions, gather information.</td>
</tr>
<tr>
<td>2. June 17, 2016</td>
<td>DWR Offices, Sacramento, California</td>
<td>Agree on field metrics, discuss response functions.</td>
</tr>
<tr>
<td>3. July 12, 2016</td>
<td>Davis Ranch, Colusa, California</td>
<td>Review first draft of HQT and field methods.</td>
</tr>
</tbody>
</table>

Follow-up communications via phone calls and emails between Stillwater Sciences and TAC members helped refine TAC determinations and fill critical information gaps. Stillwater Sciences built and is maintaining a digital library of all documents and other data sources used in the HQT. Along with other documentation, the library will be made available to all TAC members after the first version of the HQT is completed.
The gsHQT is undergoing a broader review by agency and other giant garter snake experts in 2017 and early 2018, with minor tool and memo refinements. The gsHQT was also field tested at additional locations, leading to further refinements in the tool and field guidance materials. Decisions made with the TAC during the initial formulation of the gsHQT, as well as reasoning behind minor refinements, are described in the following sections.

2.1.2 Giant Garter Snake Natural History

Identification
Giant garter snake is the largest species of garter snake. Individuals can grow up to 160 cm in length (Stebbins 2003), but average sized adults are 60–80 cm long (Wylie at al. 2010, as cited in USFWS 2015). Females tend to be slightly larger and heavier than males and weigh between 1 and 1.5 pounds (Wylie et al. 2010, USFWS 2016). They can range in dorsal color from olive green to brown or nearly black. Depending on individual, they have a cream, yellow, or orange dorsal stripe along their back, and one light-colored stripe running down each side (lateral stripes). Some individuals have a checkered pattern of dark or black spots between the dorsal and lateral stripes. Background coloration, prominence of the checkered pattern, and the three light colored stripes, are individually and geographically variable (Hansen 1980). Giant garter snakes have eight upper labial scales, where the sixth is shorter than the seventh, and their internasal scales are shorter than their prefrontal scales. Despite their relatively large size, giant garter snakes can be difficult to see in the field due to evasive behavior; one report states that upon sensing human approach, the snake typically leaves its basking site by dropping into the adjacent water and diving to the bottom to hide well before the human is within visible distance of the snake (Nafis 2016).

Status
Due to massive loss of habitat in the Central Valley, the snake is federally listed as threatened under the Endangered Species Act, and California State-listed as threatened under the California Endangered Species Act. No critical habitat has been established.

Distribution
Giant garter snake is endemic to California’s Central Valley. Historically, its distribution was throughout the Sacramento and San Joaquin Valleys from Tehama down to Kern County, with a gap in the central part of the valley. Its current range is considerably reduced and fragmented due to reclamation of wetlands for agricultural use. The current distribution is from Glenn County to the southern edge of the San Francisco Bay Delta, and from Merced County to northern Fresno County. The species remains at risk of extirpation in the southern 75 percent of its range (USFWS 2006).

Historically, there were three large giant garter snake population clusters: Sacramento Valley, Middle San Joaquin Valley, and Southern San Joaquin Valley. The population cluster in the Sacramento Valley is
thought to be relatively stable, while the Middle San Joaquin Valley population is in rapid decline (Eric Hansen, 2016 Giant Garter Snake Symposium lecture²). Much of the San Joaquin Valley population was extirpated by the late 1980s (Hansen 1988, as cited in Halstead et al. 2015a), and the historical Southern San Joaquin Valley population (south of northern Fresno County) is now extinct (Eric Hansen, 2016 Giant Garter Snake Symposium lecture; Hanson and Brode 1980).

USFWS delineates nine geographically and genetically distinct giant garter snake populations in its 2015 Recovery Plan, shown in Figure 7. These populations directly correspond to Recovery Units, defined to aid in recovery planning. Populations are defined as “a cluster of locality records in a contiguous habitat area” (USFWS 2015). The validity of these population boundaries has been confirmed by recent genetic studies that show restricted gene flow between these groups (Paquin et al. 2006, Engstrom 2010, both as cited in USFWS 2015). USFWS delineated these population boundaries by using the following sources: California Wetland and Riparian GIS database developed by Ducks Unlimited (Ducks Unlimited, Inc. 1997, as cited in USFWS 2015) for the Central Valley that identified wetlands and irrigated agriculture; California Natural Diversity Database occurrences for giant garter snakes (CNDDB 2011, as cited in USFWS 2015); the map of historical tule marsh habitat (Küchler 1977); and hydrological maps that showed tributary streams and waterways that provide potential giant garter snake habitat (USFWS 2015). Since this total area is considered by USFWS (2015) to represent the potential maximum extent of giant garter snake habitat in the Central Valley, this map will be used in the HQT as a coarse tool to guide landscape-scale habitat suitability.

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² Giant Garter Snake Symposium, hosted by The Wildlife Society Sacramento-Shasta Chapter in Elk Grove, CA on September 21, 2016

(https://drive.google.com/file/d/0B3gkF3KuVURAaGJGbDRzOVIRajA/view)
Figure 7. Population and Recovery Units for the giant garter snake, copied from USFWS 2015.
Genetics
A study done by Wood et al. in 2015 identified five genetic clusters within the distribution of giant garter snake, using 15 microsatellite loci. These clusters generally corresponded to the regional drainage basins of the Central Valley. The populations in the Delta and San Joaquin Valley populations were most geographically isolated, and thus had the greatest genetic differentiation (Wood et al. 2015). Furthermore, they found that genetic diversity was greater in populations of the northern basins than those in those of the southern basins, and that about one-half of all populations had evidence of population bottlenecks (Wood et al. 2015). Effective population sizes among the study locations, while variable, were still below recommended thresholds to avoid inbreeding (Wood et al. 2015). Wood et al. (2015) concluded that efforts focused on maintaining and enhancing existing wetlands to increase local effective population sizes and facilitate dispersal between basins may be essential for preserving these otherwise isolated populations.

Habitat
Giant garter snake is a highly aquatic snake species that inhabits wetlands, both naturally occurring and agricultural wetlands such as sloughs, irrigation canals, and rice fields. Historically, the giant garter snake inhabited tule marsh, which was distributed across much of the Central Valley. Due to conversion of habitat to other uses, mainly agriculture and urban, the giant garter snake has been extirpated from much of its original habitat. At the landscape scale, the niche for giant garter snake consists of areas in and close to rice and wetlands, with a high density of canals and a low density of streams (Halstead et al. 2010, as cited in Halstead et al. 2015a).

Essential giant garter snake habitat components include (USFWS 2015):

- aquatic features with adequate water present during the snake’s active period (generally March through October), which are used for foraging,
- emergent vegetation that allows foraging while providing cover from predators, upland habitat, for thermoregulation and summer shelter in burrows during the active period, with upland refugia for brumation/winter hibernacula during the winter inactive period.

The giant garter snake has been recognized as requiring permanent aquatic habitat in order to survive since it was first described (Fitch 1940, as cited by USFWS 2015). Especially during its active period in the summer, it uses water for feeding and aquatic vegetation for cover. Giant garter snakes spend most of their foraging time in water and feed primarily on aquatic prey, specializing on hunting small fish underwater. Historically, its diet consisted primarily of native fish, but due to the introduction and success of several non-native species into Californian waterways, the snake has adapted its food preferences to invasive species like the American bullfrog (Lithobates catesbeiana), common carp (Cyprinus carpio), and western mosquitofish (Gambusia affinis). They also take advantage of isolated pools with trapped prey, and have been observed feeding on mosquitofish several times in this way (Hansen 1980).
Natural predators of giant garter snake include various hawk species, northern harriers, egrets, bitterns, great blue herons, raccoons, skunks, opossums, foxes, and predatory fish (particularly for young giant garter snakes) (USFWS 2016). Several instances of otter predation on adult snakes have been observed, and mink are suspected of killing neonate and juvenile giant garter snakes (B. Halstead, pers. comm. 2017); these aquatic predators are likely more consequential than terrestrial mammals.

The presence of emergent vegetation allows the snake to have escape routes and cover for hunting prey. Halstead et al. 2016 found that tules (Schoenoplectus sp.) were the vegetation type most strongly selected for by giant garter snake; the structure of tules provide for excellent opportunities for thermoregulation and escape from predators. Having a good balance of vegetated aquatic feeding areas and upland basking sites is ideal for thermoregulation and feeding (Hanson and Brode 1980). While giant garter snakes are known to inhabit areas with water primrose (Ludwigia spp.) and cattails (Typha spp.), use is generally restricted to edges between these plants and open water (Hansen et al. 2010, Valcarcel 2011). At a study site in Gilsizer Slough, Sutter County, Halstead et al. (2016) found giant garter snakes to positively select for water primrose when it was present in low densities due to active management (e.g., herbicide treatment). However, the unrestricted growth of these invasive plant species can eliminate open water habitat and restrict snake movement, increasing susceptibility to predators (USFWS 2006, Hansen et al. 2010). Mechanical removal of water primrose may be an effective management practice to maintain suitable edges between open water and vegetation edges, but repeated treatments and adequate water depth are required to maintain the habitat in a suitable condition (Hansen et al. 2010). Research by Wylie et al. (2010) shows that giant garter snakes will forage in flooded rice fields after the rice plants have grown sufficiently to provide cover from predators. Seasonal wetlands managed for waterfowl do not generally provide suitable habitat for giant garter snakes since there is typically no aquatic habitat available during the active summer season (USFWS 2015).

Giant garter snakes exclusively use aquatic habitats for foraging, but also use nearby uplands for basking and retreat underground during periods of inactivity. Halstead et al. (2015b) conducted a study utilizing radio telemetry to analyze how giant garter snakes used their habitat, and found that though they spend a majority of their time near water during their active season, they also spend a considerable amount of time basking on land, and the greatest portion of their time budget is spent underground in burrows near water (Halstead et al. 2015b). Thus, during the active season, a balance of aquatic feeding habitat situated next to terrestrial basking sites is critical for high quality giant garter snake habitat.

**Life history**

Giant garter snakes typically begin emerging from winter hibernacula around April 1, but may emerge as early as March 1 in some years and in some locations (USFWS 2015). Depending on weather, activity peaks from mid- or late April to early June, and then is reduced during the mid- to late summer months (B. Halstead, pers. comm., 2017). Around October 1, snakes move underground to brumate (USWFS 2015).
During this time, they use burrows including crayfish, muskrat, or ground squirrel burrows (Hansen 1980, as cited in Halstead et al. 2015a), as well as riprap (Wylie et al. 2003, as cited by Halstead et al. 2015a) and cracks in the soil in order to avoid the low temperatures of fall and winter. Giant garter snakes prefer brumation sites near their active-season habitat, often choosing sunny aspects along south- or west-facing slopes (Halstead et al. 2015a). Through a radio telemetry study, Halstead et al. (2015b) found that giant garter snakes can spend greater than 95% of their time daily underground during brumation; most individuals spend weeks to months underground during brumation without coming to the surface (B. Halstead, pers. comm., 2017).

During their active period between mid-March and October, male giant garter snakes spend 96% of their time within 10 m of water (Halstead et al. 2015b). Courtship and breeding begins following spring emergence, with males searching for a mate immediately after brumation. Mating generally occurs from March through May (USFWS 1993); some mating might also occur in the autumn (USFWS 1999). Giant garter snakes are ovoviviparous, and females give birth to 10–46 live young between June and October after a 2- to 3-month gestation period (Halstead et al. 2011). Upon hatching, the young scatter into adjacent cover and use their yolk sacs for nutrition as they transition to foraging on their own (USFWS 2016). Young giant garter snakes generally double in size during their first year (USFWS 2016), although growth rates are dependent on precipitation and prey availability (Rose et al. 2018). Sexual maturity is determined more by approaching asymptotic size than age. An average female can reach the size of sexual maturity at two years of age and bear offspring for the first time at age three (Rose et al. 2018). Fewer data exist for sexual maturity in males. Using the figure of 79% of mean body length of males at sexual maturity for other genera without male-male combat (Shine 1994) as a guide, male giant garter snakes reach such a percent length—and therefore expected sexual maturity—at two years old on average and therefore would reproduce for the first time at age three (Rose et al. 2018). The maximum life span of giant garter snakes, while uncertain, is thought to be greater than 10 years (Halstead et al. 2015a).

Threats
The giant garter snake’s population decline in its former range due to historical agricultural reclamation of wetlands is an example of dramatic critical habitat loss (Hanson and Brode 1980). The current primary threat to giant garter snakes is habitat loss and fragmentation due to urbanization and shifts in the distribution and extent of rice production (USFWS 2015). Other current threats associated with land and water management include changes in water availability, levee and canal maintenance, water management practices that are not compatible with giant garter snake, flooding, and water transfers (USFWS 2015). Levee and canal maintenance can result in habitat loss or direct mortality (USFWS 2006). Flooding may also kill individuals and possibly result in the extirpation of populations (Halstead et al. 2015a). Dredging waterways for sediment and/or vegetation removal can result in direct mortality and in some cases habitat loss (USFWS 1993, as cited in Halstead et al 2015a). Mowing can result in direct
mortality and reduce protection from predators and temperature extremes (Halstead et al. 2015a). Disking
and other mechanical disturbances of the soil are even more damaging than mowing since these
practices, in addition to direct mortality, may additionally disrupt burrows and soil cracks in the soil, which
are important for summer shelter or winter hibernacula. Repeated deep, high-flow flooding is also thought
to be incompatible with giant garter snake occurrence (Wylie et al. 2005; USFWS 2006, as cited in
Halstead et al. 2015a).

2.1.3 Giant Garter Snake Timing Windows

Giant garter snakes, on average, emerge from brumation in mid-to-late March and remain active until
early October (Rossman et al. 1996, Wylie et al. 2009, both as cited in Halstead et al. 2015a). However,
the timing of annual cycles varies with climatic conditions. For the giant garter snake HQT, the TAC
decided upon March 15 through October 1 as the “active period” and October 2 through March 14 as the
“inactive period”.

2.2 Landscape-Scale Habitat Attributes

The Landscape Context score summarizes the landscape habitat attributes that contribute to the habitat
quality of a Project Area and the likelihood that a Project Area will support a viable population of giant
garter snake. There are four landscape scale attributes in the HQT; however, these are not all used to
develop the landscape context score. Some are used to guide response functions associated with Site-
Capacity attributes.

2.2.1 Proximity to Presumed Range

Rationale

The existing information on giant garter snake populations and distribution is limited. Detection of giant
garter snakes is challenging due to a number of variables including trap reliability, location accessibility,
and heterogeneity in trapping and detection techniques (Halstead et al. 2015a). Multiple studies have
reported negative results for surveys performed in areas expected to support giant garter snake
populations; however, these results must be interpreted with caution because many detection challenges
exist that could result in false negatives. In addition to detection challenges, there is no distinct habitat
indicator, although a set of attributes based upon current and historical information does help inform
distribution (Halstead et al. 2015c).

The historical and current distribution of giant garter snake is described above in Section 2.1.2 (Natural
History of Giant Garter Snakes). In the HQT, habitat credit will be given for areas that fall within USFWS-
delineated Recovery Units (Figure 7). This map should be used only as a means to help inform whether a
property falls within the generalized projected range of giant garter snake, and should not be construed to represent definitive giant garter snake distribution.

**Metrics**
This attribute is measured for the Project Area as “yes” in range or “no” out of range based upon the giant garter snake Recovery Units in the Central Valley in Figure 5. Spatial data in Figure 5 is available for those using the tool to locate a project site through either Google Earth (as a kml) or using ARC INFO (shapefile), as described under Section 1.3.5 Habitat Quantification Toolkit.

**Scoring functions**
This attribute is reported as either a “yes” or “no” response and is a necessary attribute. In order for habitat credit to be assigned, this attribute must be a “yes.”

### 2.2.2 Proximity to Historical Tule Marsh

**Rationale**
The recently published article by Halstead et al. (2015c) indicates that proximity to historical tule marsh may be an important variable for predicting the probability of occurrence of giant garter snakes at sampled sites in the Sacramento Valley. Despite the conversion of nearly all natural marshes to other land uses in the past century, the occurrence of rice agriculture and its supporting network of irrigation and drainage canals and the restoration of marsh habitats provide much suitable habitat throughout the Sacramento Valley (Halstead et al. 2010). The research of Halstead et al. (2015c) indicates, however, that giant garter snakes have not been able to disperse into all suitable habitats, and are largely restricted to areas where they likely were historically abundant. A possible explanation is the disinclination or inability for individuals of the species to disperse widely from their original location, particularly due to lack of hydrologic connectivity across the landscape.

Based on the conclusions of Halstead et al. (2015c), the TAC determined that including proximity to historical tule marsh could be a modest predictor of the likelihood of an area to support currently, or to support in the future, giant garter snake. Because distance to historical tule marsh was found to be a modest predictor of giant garter snake occurrence by Halstead et al. (2015c), this attribute will be re-examined as new information on snake occurrence in relation to landscape factors becomes available.

Some discussion amongst TAC members ensued regarding the best sources of information on the distribution of historical tule marsh, with the group considering Küchler (1977) and/or the Sacramento-San Joaquin Delta Historical Ecology Study (Whipple et al. 2012) as potential sources; Küchler (1977) was used since it was the dataset included in the analysis by Halstead et al. (2015c). Figure 8 shows the potential extent of historical tule marsh as approximated by Küchler (1977) overlaid with documented giant garter snake captures from CNDDB (from USFWS 2015); note that there are many reported giant
garter snake occurrences that are outside of the historical tule marsh area, but all reported observations included are within 50 km. The TAC decided to use the simplest representation as a direct linear relationship between proximity to historical tule marsh up to 50 km (reported as distance from the Project Area to the closest recorded historical tule marsh boundary, and the attribute score [Figure 9]). Beyond 50 km (31 mi), an area will not be assigned giant garter snake habitat credit.
Figure 8. Distribution of historic tule marsh (lime green; Küchler 1977) and giant garter snake captures (CNDDB); figure copied from USFWS 2015. CNBBD data may be from as early as 1908, but is presumed to generally from between 1974 to current. Note giant garter snake locations at the northern extent of the range, but within 50 km of the mapped historic tule marsh.


**Figure 9.** Scoring response function for site distance from historical tule marsh, as measured in kilometers.

### Metrics

Measure the distance from the Project Area to the closest boundary of mapped historical tule marsh (0–50 km) using a Google Earth map (kml file) that has been created for the giant garter snake HQT using boundaries published by Küchler (1977).

### Scoring functions

To get credit for giant garter snake habitat, an area must be within 50 km of historical tule marsh. Within 50 km, the scoring response is linear, where the score is inversely related to distance from the Project Area to the nearest mapped boundary of historical tule marsh up to 50 km based upon Küchler (1977) (see Google Earth file associated with giant garter snake HQT, Figure 8). The linear scoring response is assumed based on preliminary data from Halstead et al. (2015c) and the TAC recommendations. As further data becomes available, this scoring response will be updated to reflect the new information.

### 2.2.3 Proximity to Recently Reported Occurrences

#### Rationale

Well-documented reports from recent sightings within 20 km (12.4 mi) can be used to indicate the potential of a Project Area to support giant garter snakes. Sources may include the California Natural Diversity Database (CNDDB), published literature, reported sightings from giant garter snake biologists, and vetted/confirmed reports with photo documentation from citizen science sources such as [www.inaturalist.org](http://www.inaturalist.org). It is important to note that no snake sightings in a given area does not indicate absence; many areas may have either never been surveyed, or if it has, survey conditions (e.g., number...
of traps, survey timing, date) may affect detection probabilities. Occurrence data from more than 20 years ago are not included because these offer too much uncertainty that the snake population observed is still present in the area. As currently conceived, credit for this attribute is only assigned for sightings that occur within 20 km (12.4 mi) of the Project Area; beyond that, the score for this beneficial attribute will be “0.” These thresholds were generated based upon the minimal data that exists and TAC discussions. While a single snake is not expected to traverse 20 km, TAC members estimated that multiple generations could, in rare cases, cross that distance within the 20 yr reporting window. This is based very high overlap in territory extent from one year to the next as well as professional judgement from the TAC (Reyes et al. 2017). Linear scoring response is applied because there is no information to support an alternative or more nuanced approach. Similarly, too little information on population size, density and distribution within the species range exists to include this level of information as an attribute for the gsHQT.

Metrics
This attribute is measured from the closest boundary of an Aquatic Feature within the Project Area to the reported occurrence in kilometers.

Scoring functions
Within 20 km, the scoring response is linear, where the score is inversely related to distance to the closest reported sighting within 20 years (Figure 10).

![Figure 10. Scoring response function for site distance to recently reported giant garter snake sighting, as measured in kilometers.](image-url)
2.2.4 **Region within Program Area**

**Rationale**
The historical and current distribution of giant garter snake is categorized into three areas: the Sacramento River Valley (including recovery units Colusa Basin, Butte Basin, Sutter Basin, American Basin, Yolo Basin, and Cosumnes-Mokelumne Basin), the Delta (including recovery unit Delta Basin), and the San Joaquin River Valley (including recovery units San Joaquin Basin, and Tulare Basin). As described in USFWS 2015, these areas are individually necessary to “conserve genetic distinctiveness, demographic robustness, important life history stages, or other features necessary for the long-term sustainability of the entire listed species.” Recovery Unit boundaries may be subject to updates as new research becomes available and new populations are discovered and defined. The TAC discussed likely differences in specific habitat needs for giant garter snakes residing in these three regions (that include one to multiple Recovery Units). Although definitive information is not yet available on different needs for the populations in these regions, delineation of which region a Project Area is in will enable inclusion of different response functions once that information is available.

**Metrics**
The metric is the location of the Project Area within one of the three delineated Regional Units, as depicted in Figure 11. The Regional Unit in which the Project Area is located will be identified using the associated CVHE HQT Google Earth file or GIS ARC INFO shapefile (see Section 1.3.5 Habitat Quantification Toolkit), with a pop-up window that provides the Project Area polygon number. When this number is entered into the mHQT, it will indicate what Regional Unit the Project Area is in and trigger the appropriate response functions in other parts of the mHQT.

**Scoring Functions**
Categorization of location will not directly affect the attribute score, but will enable development of Region-specific response functions once those are determined. At this writing (February 2017), response functions are based predominantly on observation from the Sacramento Valley.
Figure 11. The three giant garter snake Regional Units; these can be used to direct region-specific response functions in future version of the gsHQT.
2.3  Project Area-Scale Habitat Quality Attributes

Only one attribute is assessed at the Project Area scale: extent of connected aquatic habitat.

2.3.1 Extent of Connected Aquatic Habitat within Project Area

Rationale
This attribute is intended to recognize the value of large vs. small stretches of connected, protected aquatic habitat that cross over multiple Map Units within a Project Area. Project Areas that have more extensive connected aquatic habitat can support a greater number of snakes and offer more diversity in foraging areas for those individuals. Thus, up to 100 acres, habitat quality increases with increased extent of connected aquatic habitat.

For the gsHQT, aquatic habitat is defined as:

- standing or slow-moving water of at least 1-m wetted width that is inundated (with a continuous line of water over 10 cm deep) throughout the majority of the snake’s active period (e.g., at least May 1–September 15), with still or slow-moving water, earthen banks, and with at least 5% cover of emergent wetland plants.

These criteria were selected based upon professional judgement from the TAC on snake habitat needs. The 100-acre connected habitat area threshold is based upon professional judgement and the approximate area of the single known isolated giant garter snake population located along the Cosumnes River at Snake Marsh prior to the drought (roughly 53 acres; Hansen et al. 2010). Another aspect of the logic behind this attribute includes recognition that the off-site lands are not necessarily protected and therefore offer no guaranteed future habitat for the snake, no matter how suitable, thus the extent of protected within Project Area habitat is important. From three Pilot Site sites surveyed thus far, the Aquatic Feature acreage has represented from approximately 5% to 8% of the total farmed land, so that a rice operation of 5,000 to 10,000 acres might have 100 acres that could qualify as giant garter snake habitat. Thus, a maximum threshold of 100 acres will encourage landowners to manage these features for giant garter snake and to ensure that the features are connected to help reach this threshold.

Further refinement on these thresholds (e.g., criteria for size of connected, suitable aquatic habitat [100 acres]; and criteria defining aquatic habitat [10 cm depth, earthen banks, and 5% cover]) will be revisited as new information becomes available.

Metrics
This attribute is measured as the sum of connected aquatic habitat areas in the Project Area, delineated within each Map Unit, that have also been observed to have direct connections to one another either within or between Map Units. Connected aquatic habitat is defined as aquatic habitat that has either less...
than 1000 m length open water aquatic connection, and/or an overland connection that is less than 50 m length. Hydrologic connections must be open water, rather than through submerged pipes for example, and include slow moving or stagnant water ways with at least 10 cm deep and continuous water along the full length of the connecting structure. Overland connections are also important and must be areas with low or no traffic (a laneway or farm road is okay) and must be passable by the snake (e.g., vertical walls are not). More detail on how these aquatic habitat connections are defined is provided in Section 2.4.3. Connectivity to Suitable Off-Site Aquatic Habitat.

**Scoring functions**

Increased credit is assigned as the extent of connected aquatic habitat increases from 0 to 100 acres within a Project Area (Figure 12). Once the extent of connected aquatic habitat in a Project Area reaches 100 acres, it is assumed that no additional increase in habitat quality per acre occurs. Therefore, the attribute score does not increase over 100 acres of connected aquatic habitat.

![Graph showing attribute score increase with extent up to 100 acres.](image)

**Figure 12.** Increased connected aquatic habitat within a Project Area provides greater habitat quality and so the attribute score increases with extent up to 100 acres.

### 2.4 Map Unit-Scale Habitat Quality Attributes

Several attributes are most conveniently and accurately measured at the Map Unit Scale. These include attributes related to land and Aquatic Feature management, connectivity to habitat outside of the Project Area, and likelihood of severe or sudden winter-time flooding. In all, there are five attributes reported at the Map Unit scale.
2.4.1 Dominant Vegetation Type

Rationale
If the Map Unit is entirely occupied by permanent wetland, then the entire Map Unit area is reported to support Freshwater Emergent Wetland and the entire Map Unit is also delineated as an Aquatic Feature. All questions concerning Aquatic Features, described under Section 2.5 Aquatic Feature Habitat Attributes, are addressed for that Map Unit-Aquatic Feature. Overall, giant garter snakes have higher survival rates in natural wetlands compared to linear water conveyance structures (Reyes et al. 2017). Therefore, the gsHQT scores these natural or restored unmanaged wetlands higher than rice or other water canals and conveyance structures, even if the acreages of emergent vegetation and all other characteristics are the same in an Aquatic Feature associated with a crop field as a natural or restored emergent wetland.

For Map Units that are not themselves wetlands, Aquatic Features associated with an upland or crop cover type are affected by this cover type on a year-by-year basis as well as over the long-term. Characterizing the dominant vegetation type in each Map Unit that is itself not a permanent wetland provides context for analyzing the suitability of Aquatic Features within the Map Unit. Giant garter snakes are most commonly associated with emergent wetlands and rice agriculture. Irrigation canals associated with rice agriculture provide marsh-like habitat, as well as consistent hydrologic patterns that support the giant garter snakes’ summer foraging requirements. Other crops (e.g., corn, tomatoes, alfalfa, and wheat) and orchards do not have the reliable and continuous hydrological patterns that are required for the snake, and are therefore usually much less suitable. “Seasonal wetlands” are typically flooded in the winter and dry in the summer to manage for waterfowl, and are therefore not suitable for giant garter snakes (USFWS 2015). Forested areas along aquatic features are not used by giant garter snake: the trees and overhanging vegetation provide roosts for snake predators and limit basking opportunities.

Metrics
This attribute is characterized as freshwater emergent wetland, rice, irrigated non-woody crop types, and developed, forested, orchard, or vineyard, as selected from a list.

Scoring functions
The vegetation type 'Freshwater Emergent Wetland' is entered as a Vegetation Cover Type for Map Units that are themselves wetlands, and is considered optimal habitat for the giant garter snake, so receives the highest score for this attribute. Rice is scored with the second highest rank (0.80) since giant garter snakes are strongly associated with rice water conveyance features (Halstead et al. 2010), although they do not show a preference for foraging in the rice fields themselves (Reyes et al. 2017). Other crop types, grasslands, and shrublands are categorized in the “Other” category, which receive a low score (0.25). Developed, forested, orchard, and vineyard areas receive a score of “0” (Figure 13). Note also that where
Map Units are themselves permanent wetlands, information for the entire Map Unit is also entered and scored as an Aquatic Feature, as described below in Section 2.5 Aquatic Feature Habitat Attributes.

![Figure 13. Scoring response functions for Map Unit vegetation types.](image)

### 2.4.2 Severe Flooding during Winter Dormancy

**Rationale**

During its inactive/brumation period (between early October and as early as March), giant garter snakes retreat underground in upland terrestrial habitats above prevailing flood elevations. If their winter hibernacula are located below flood levels, brumating snakes may be killed or injured by being flushed downstream during rapid flood events. According to the Natomas Basin HCP, flooding can damage brumation refugia by saturating and thereby liquifying fine clay-silt substrates resulting in collapse of refugia; saturating shrink-swell clay substrates and thereby causing refugia exit routes to swell shut; exposing brumation refugia surfaces to wave erosion; and deposition of silt that could block refugia access cracks or channels (City of Sacramento et al. 2003). Such situations can occur in some areas of bypasses where rapid flooding occurs in otherwise supportive habitat. However, giant garter snakes may be able to withstand mild or moderate floods with low velocities and depths, where they can survive under water for several weeks, possibly due in part to low metabolic rates associated with brumation or partial emergence from brumation (B. Halstead, pers. comm., 2016). While giant garter snakes might be able to
Survive such disturbances, the disturbances are not advantageous to the individuals or population and therefore not a reasonable part of the type of highly supportive habitat credited through the gsHQT.

**Metrics**

Historical information is used to determine whether the Map Unit has a greater than 10% chance of rapid flooding between October 2 and March 15 in any given year, where the majority of terrestrial habitat can become fully inundated within 1 day. This question is primarily intended to exclude areas that are within a bypass; however other areas that regularly experience very abrupt and fast-moving floods should be excluded as well. Quantitative documentation on the flood frequency and type of flood for the area can have some degree of uncertainty (e.g., +/- 10%) or be based on flood types and extents over the past 20 to 30 yrs. Potential sources of information include local hydrograph records, historical imagery, and past flood information from flood maintenance districts and/or the landowner.

**Scoring functions**

This attribute is scored as a “yes” if the Project Area has a greater than 10% chance of rapid flooding in any given year, as described above (0), or “no” if the Project Area is not located in an area that has a greater than 10% chance of rapid flooding (1.0). This is a necessary attribute: in order for habitat credit to be assigned to a Map Unit, this attribute must be a “no” (1.0).

**2.4.3 Connectivity to Suitable Off-site Aquatic Habitat**

**Rationale**

Connectivity to suitable off-site habitat (typically wetlands, rice fields, or large, permanent water conveyances such as sloughs or regional drains) is important for sustainability of the on-site population and to support genetic mixing among on-site and off-site populations. “On-site” refers to areas within the Project Area, including other Map Units that are under consideration as protected giant garter snake habitat for the Exchange. “Off-site” refers to waters and lands outside of the Project Area (and therefore Map Units). Connectivity among Map Units within the same Project Area, described under Section 2.3.1. Extent of Connected Aquatic Habitat within Project Area, are recognized through the contiguity code and do not represent linkages to off-site habitat and populations.

Since giant garter snakes move most easily and the greatest distances by water, hydrological connections with off-site habitat are considered more important than overland (terrestrial) connections. An overland connection with off-site habitat is also beneficial, although the maximum distance is far less than for hydrologic connections due to the short distances giant garter snakes are known to typically travel across land. There are some barriers to movement, primarily large rivers and large highways. Large rivers are known as barriers to giant garter snake movement as demonstrated by the genetic division between populations east versus west of the Sacramento River (Wood et al. 2015). Large highways also act as barriers both because snakes are exposed to predators as they cross the highway and because cars...
often cause fatality among snakes. A short hydrologic connection between on-site habitat and off-site habitat without any barriers to movement is scored highest in the HQT while overland connections and connections of longer distances are scored lower.

A “corridor” is defined in the 2015 USFWS revised draft recovery plan as a “canal, waterway, slough, channel, or creek that connects two or more areas known to support giant garter snakes”. The revised plan also states that the corridor must have the necessary habitat components to provide suitable giant garter snake habitat (i.e., aquatic, upland, and upland refugia components) in order to function as a viable dispersal and movement corridor. Sub-optimal aquatic habitat (e.g., water conveyances lined with woody riparian vegetation) is included in the tool as having the potential to provide connective corridors between areas of more stable or suitable habitat, as long as the three basic necessary habitat components are present.

The TAC discussed what could be best used to represent the greatest distance an “average” giant garter snake could travel by water and by land between on-site and off-site areas. No known hard data exist on average distances traveled by water versus land. However, Reyes et al. (2017) found that average core areas—where snakes spend half of the active season—are less than 6,500 m² and that average annual home ranges are 40,000 m². If one assumes a habitat width of 20 m centered on a canal (Reyes et al. 2017), these figures translate to 325–2000 m lengths of aquatic travel. Based on these estimates using the best known available data, the TAC agreed upon interim estimates of 1,000 m maximum distance for hydrologic connections and 50 m for overland connections. These values are used in the HQT as maximum distances and the connections are scored using direct linear relationships with 0 m distance yielding a score of 1.0.

For the giant garter snake HQT, “off-site suitable aquatic habitat” is defined as being a collective group of inter-connected Aquatic Features at least 100 acres in size and inundated (with a continuous line of water over 10 cm deep) throughout the majority of the snake’s active period (e.g., at least May 1–September 15), with still or slow-moving water, earthen banks, and with at least 5% cover of emergent wetland plants. This aquatic connection must link to a larger area or continuously linked series of smaller areas that can include emergent wetlands, rice fields or extensive slow-moving water ways that add up to at least 100 acres in extent. These criteria were selected based upon professional judgement from the TAC on snake habitat needs and to ensure that the linkages are to areas capable of supporting viable giant garter snake populations. The 100-acre habitat area threshold is based upon professional judgement and the approximate area of the single known isolated giant garter snake population located along the Cosumnes River at Snake Marsh prior to the drought (roughly 53 acres; Hansen et al. 2010), and will be refined as new information becomes available. Further refinement on the thresholds (e.g., criteria for size of connected, off-site suitable aquatic habitat [100 acres]; and criteria defining an Aquatic Feature [10 cm depth, earthen banks, and 5% cover]) will be revisited as new information becomes available.
Metrics
A hydrologic connection for this attribute consists of an Aquatic Feature within a Map Unit(s) that connects to off-site suitable aquatic habitat that is outside of the Project Area (Figure 14). A hydrologic connection is also characterized as being easily accessed by giant garter snakes and does not include a large river (e.g., Sacramento River or tributaries, San Joaquin River, other large river with fast-moving water), or large, open bypasses. Hydrologic connections must be continuous open water connections, since giant garter snakes are not known to readily swim through underwater submerged pipes or culverts. Thus, although snakes might swim through a short, submerged culvert, conditions are not ideal and connectivity credit can be assigned as a short over land connection. Similarly, structures such as floodgates that could interfere with snake movement from one Aquatic Feature to another during active season must be considered, and if such features obstruct movement, then the connection should be deemed non-existent (Figure 14). Where connections are unobstructed by either physical barriers or large, fast-moving water bodies, the length of the connection is measured in meters up to a maximum threshold of 1,000 m. Any length greater than 1,000 may be entered as 1,001 m (and is considered in the HQT as no linkage). Furthermore, this aquatic connection must link to a larger area or continuously linked series of small areas that can include emergent wetlands, rice fields, or extensive slow-moving water ways that add up to at least 100 acres in extent.

For off-site aquatic connections, but not for within-site aquatic connections, slow moving streams or water conveyances that are lined with woody riparian vegetation may offer a linkage between the on-site and off-site populations, particularly for the more ‘adventurous’ dispersers. However, this feature would need to have at least a continuous strip of habitat (water or adjacent upland) open to the sky, as can be observed via Google Earth, during the active giant garter snake period. Such woody vegetation-lined aquatic features do not count as within Project Area connections because the ‘average snake’ is not expected to use them and therefore the within-Project Area habitats could not be considered continuous for the majority of individuals.

An overland (terrestrial) connection consists of any land that does not include a major highway (i.e., Highway 5 or 99) between the on-site aquatic habitat and off-site suitable aquatic habitat. The length of the overland connection is measured in meters up to a maximum threshold of 50 m. Any distance greater than 50 m may be entered as 51 m (and is considered in the HQT as no linkage).

An example of aquatic and overland connections to off-site habitat is shown in Figure 14, in which these connections were evaluated during a site visit to confirm that giant garter snakes could access the off-site habitat through the water ways and over the levee. It was determined that there was no aquatic connection to the large canal to the south due to physical barriers running under the levee road (indicated with red “no symbol” in Figure 14). Other types of aquatic barriers that have been encountered are completely submerged culverts.
Figure 14. Aquatic and overland connections between an Aquatic Feature within a Map Unit and off-site suitable aquatic habitat, indicated with red arrows. Connectivity barriers indicated with red “no symbol”
Scoring functions
The attribute is reported as either a “yes,” there is a hydrological connection or “no,” there is not a hydrological connection. If yes, the attribute is then reported by length of connection or distance to off-site suitable aquatic habitat with a 1,000-m-maximum threshold (a linear decrease from 0 m [1.0 score] to 1,000 m [0.0 score]) (Figure 15). The length of a hydrological connection is considered a beneficial attribute.

![Scoring response function for the hydrologic distance between the Map Unit suitable aquatic habitat outside of the Project Area (meters).](image)

\[ y = -0.001x + 1 \]

**Figure 15.** Scoring response function for the hydrologic distance between the Map Unit suitable aquatic habitat outside of the Project Area (meters).

If there is no hydrologic connection to off-site suitable aquatic habitat, then the attribute for an overland connection is reported as either “yes,” there is an overland connection to off-site suitable aquatic habitat or “no,” there is not an overland connection to off-site suitable aquatic habitat. If yes, the attribute is then reported by distance overland to an off-site aquatic habitat with a 50-m maximum threshold and the distance is included as a beneficial attribute (Figure 16). If no, then no connection is reported.
2.4.4 Maintenance of Water Conveyances

Rationale
Management of water conveyances\(^3\) (typically agricultural irrigation canals) may have sudden and drastic impacts on giant garter snakes, either via significant habitat alteration or direct mortality (USFWS 2006). Canal maintenance activities with the most potential to impact giant garter snakes include canal grading to excavate and reslope ditches or channels, and deposition of ditch and canal spoils material on adjacent upland habitat. Sediment scraping from canal edges destroys emergent vegetation habitat concentrated there and can cause direct mortality to foraging snakes. Sediment removal from the canal bottom rather than the sides is usually less invasive or dangerous to the giant garter snake since the center of the canal is least likely to support emergent vegetation (the preferred giant garter snake foraging habitat), and therefore dredging only the center line can reduce direct mortality and enable the snake to escape to either side compared to dredging along canal sides.

Halstead et al. 2015b reported that “under most conditions, we found giant garter snakes to be within 10m of water at 95% of observations. For females during brumation and individuals that we found underground, however, the average individual had a 10% probability of being located > 20 m from water.”

Piling sediment debris collected from canal grading activities on non-road locations adjacent to the canal

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\(^3\) The terms “water conveyance,” “canal,” and “channel,” are sometimes used interchangeably in the following sections.
can cause large scale mortality if this occurs during brumation, since snakes in underground burrows or cracks in the soil can be entombed. For these reasons, Aquatic Features for which canal spoils are removed from the site, or where there are no dredge spoils, receive the highest score. The soil under private access roads and public roads are compacted and offer few if any locations for refugia; therefore, placing dredge spoils on existing roads is less likely to harm or kill giant garter snakes. Thus, as dredge spoils are placed farther from an Aquatic Feature, the habitat functionality increases. Dredge spoils placed farther from the Aquatic Feature, and during the active rather than the inactive season, are assumed to have less detrimental effect on the snake and therefore receive higher scores for this particular attribute.

In practice, we assume that land managers maintain canals of similar size and crop type association consistently throughout a Project Area. Therefore, Aquatic Features are categorized as “large” or “small to medium” sized water conveyance structures within a given Map Unit, to align information gathering for the HQT with common management practices. A third category for Aquatic Features, “Other,” can include natural emergent wetlands, isolated water bodies, or water ways that are not actively managed for water conveyance.

HQT response functions for water conveyance maintenance activities are based upon several relative principles, rather than direct empirical data on management action frequency and type and snake fatalities. Since canal grading during the active period can result in fatalities (USFWS 2006), less frequent canal grading during the active period is scored as more protective of giant garter snakes, and no grading is scored as optimal. If grading is necessary, then operating equipment along the center of the canal is most protective, grading along one side only is next best, and grading along both sides is least protective. Similarly, grading timing is best if it occurs during the time when the snake is most active, May 1 through September 15, so snakes may actively move out of harm’s way (many snakes are inactive in March and April, as well as the last two weeks in September). During the winter dormancy period, from October 1 through March 1, snakes are below ground and effectively inactive and most vulnerable to direct mortality or internment.

**Metrics**

The frequency, intensity, timing, and spoils placement of grading activities for both “large” (greater than 3 m wide) and “small to medium” (less than 3 m wide) water conveyance structures, using the categories for each outlined under Scoring Functions, below. Grading activities are presumed to be primarily for vegetation removal/control or sediment removal.
Scoring functions

Metrics associated with water conveyance maintenance activities are beneficial rather than required for giant garter snake habitat.

Scores for water conveyance grading frequency decrease linearly with increased frequency over a 10-year period, with a score of “0” for two-year frequency (i.e., five times in 10 years) since that frequency offers little time for the local population to recover from considerable maintenance-associated mortality incidents (Figure 17).

Giant garter snake habitat quality provided by a water conveyance structure is degraded with increasing proportion of the structure that is graded at once, with greatest reduction in quality occurring when both sides supporting emergent vegetation are scraped. Thus, scoring for water conveyance grading intensity is as follows:

- No maintenance (1.0)
- Bottom only (0.9)
- One side at a time (0.75)
- Two sides simultaneously (0)

These relationships are depicted in Figure 18.

**Figure 17.** Scoring response function for number of times canals are graded within a 10-year period—scores drop to “0” for 5 or more grading actions within a 10-yr period

**Figure 18.** Scoring response function for the number of canal sides graded at a time.
Canal dredging and scraping that occurs during the snake’s active season, particularly during the warm period of the day when the snake metabolism is higher and therefore the animals are more mobile, is the least impactful time to perform these maintenance activities. Dredging and scraping canal sides during inactive season is most likely to cause fatalities by entombment and/or direct crushing of the animals. Therefore, activities performed during the inactive fall and winter season lowers the habitat quality score for that Aquatic Feature. Bottom only dredging during the inactive season is less likely to entomb or disturb snakes since the snakes occupy subterranean refugia along canal banks and adjacent uplands rather than along the bottom of a canal or wetland. Therefore, while this combination of timing and grading location is not ideal (no grading is ideal), this combination of management action and timing receives higher habitat scores than scraping one or both sides during the inactive season.

Scoring for water conveyance maintenance timing (if such maintenance occurs) is as follows:

- No dredging or grading (1.0)
- May 1 through September 15 (0.75)
- September 16 through April 30 (0.25)
- September 16 through April 30, if Bottom only (0.5)

These relationships are depicted in Figure 19.

As discussed above, and as cited in Halsted et al 2015b, snakes are most likely found close to the aquatic feature. Spoils placement can endanger individuals, and thus placing spoils further from the canal creates a more functional habitat. Scoring for dredge material placement if grading occurs is as follows:

- There are no dredge spoils (1)
- Dredge spoils are deposited off-site (1)
- Dredge spoils are deposited greater than 10 m from water’s edge or on existing access roads (0.67)
• Dredge spoils are deposited between 3-10m from water’s edge or on existing access roads (0.33)
• Dredge spoils are deposited within 10 m of water’s edge (0)

These relationships are depicted in Figure 20.

![Figure 20](image)

**Figure 20.** Scoring response function for disposal location of canal dredge spoils.

### 2.4.5 Maintenance of Uplands Along Water Conveyances

**Rationale**

Upland vegetation along water conveyances is often managed by mowing, burning, or disking. These management activities may injure and/or kill giant garter snakes (USFWS 2006) and reduce protection from predators and temperature extremes (Halstead et al. 2015a). Disking and other mechanical disturbances of the soil are even more damaging than mowing since these practices, in addition to direct mortality, may disrupt burrows and soil cracks in the soil, which are important for summer shelter or winter hibernacula. Upland vegetation mowing or burning are least harmful to the snake when completed during the brumation period, generally October 1 through March 14. During this time, snakes are underground and will not be impacted by above-ground vegetation maintenance. If above-ground upland vegetation management is completed during the active period, snakes may be impacted by the drastic alteration of their habitat in addition to potential injuries or fatalities from the maintenance machinery. Upland maintenance activities during this period are more harmful if done more frequently.

**Metrics**

Describe the type of upland vegetation maintenance activity performed directly adjacent to the Aquatic Feature (e.g., not in associated crop field) by selecting one of the following options: mowing, burning, light to moderate grazing, heavy grazing, and disking or plowing.
Also, describe the timing of the upland maintenance activity performed by selecting one of the following options:

- Never
- October 2 through March 14
- March 15 through October 1

Scoring functions

Scores for each upland vegetation maintenance activity type are categorical and based upon the degree of potential damage to the snakes directly, or to their basking, retreat, and brumation habitat (Figure 21).

Figure 21. Scoring response function for the type of vegetation maintenance performed adjacent to an Aquatic Feature (L–M graze = light to moderate grazing, H graze = heavy grazing).

Scoring also differs depending on the timing of vegetation management, with 0.75 score assigned for above-ground activity (i.e., mowing, burning, or grazing) during the dormant period, while a 0.25 score is assigned for the same above ground management activities performed during the active period (Table 2). Disking or plowing results in assignment of 0 habitat for that set of Aquatic Features, regardless of timing since snakes can be in below ground refugia at any time of year and thus such ground disturbing activities could result large scale mortality.
Table 2. Scoring the timing of different upland vegetation maintenance activities

<table>
<thead>
<tr>
<th>Timing</th>
<th>Mow/Graze/Burn</th>
<th>Disk/Plow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Oct 2–Mar 14</td>
<td>0.75</td>
<td>0</td>
</tr>
<tr>
<td>Mar 15–Oct 1</td>
<td>0.25</td>
<td>0</td>
</tr>
</tbody>
</table>

2.5 Aquatic Feature Habitat Attributes

As described in Section 1.3.3 (Spatial and Temporal Scales within a Project Area), Aquatic Features are areas with standing or slow-moving water of at least 1 m wetted width and can commonly be linear (e.g., canals), or non-linear (ponds, natural wetlands), as permanently or seasonally wet features in the Project Area that are delineated within each Map Unit. Since Aquatic Features provide essential habitat for the giant garter snake, and variation in aquatic habitat can occur at sub-Map Unit scales, there are many important habitat attributes that must be reported for each Aquatic Feature within Map Units of a Project Area. These include the type and size of the Aquatic Feature; the permanence of water during the snake’s active period; the type, extent, and complexity of emergent vegetation; and the availability and complexity of adjacent basking habitat and refugia. Altogether, there are ten attributes, with one to several metrics each, that are reported for each Aquatic Feature within a Map Unit. These Aquatic Feature attributes are clustered into four sets: Feature type and inundation timing, emergent vegetation characteristics, basking habitat, and refugia. If the habitat scores for any of the first three of these attributes are “0”, then the Aquatic Feature is not credited as giant garter snake habitat. This is based on the principle that the HQT is designed to provide credit for highly supportive, rather than adequate, habitat.

2.5.1 Aquatic Feature Extent & Connectivity

Rationale

There are two aspects of this attribute: (1) actual acres of Aquatic Features that provide the basis for assigning giant garter snake habitat acres; and (2) increased quality of habitat per acre associated with increased extent of connected aquatic habitat associated with aquatic habitat within the Map Unit. The first aspect, extent of Aquatic Feature habitat within a Map Unit, is directly proportional to the amount of potential foraging habitat available to giant garter snakes. When using habitat associated with rice fields, giant garter snakes typically spend most of their foraging time in the canals and substantially less time foraging directly in the rice fields; additionally, rice fields are only used for foraging when the rice plants are emergent (B. Halstead, pers. comm., 2016). Therefore, measurements of the extent of aquatic habitat
do not include the entire area of the rice field, but rather are delineated by the water’s edge of the Aquatic Feature during the active period.

The second aspect of this attribute, extent of connected aquatic habitat associated with a Map Unit, only applies for Map Units that have connections to off-site habitat. In these cases, increased extent of connected aquatic habitat that is protected within the Project Area has a positive effect on the quality of habitat in the Map Unit, up to 100 acres, beyond which we assume increased connected extent no longer adds increased quality per unit area. Part of this logic is based in the discussion provided in “Section 2.4.3 Connectivity to Suitable Off-site Aquatic Habitat” regarding habitat acreage needed to support an independent viable population. This beneficial attribute on extent of connected aquatic habitat associated with a Map Unit reflects the increased value of “well connected” Map Units and habitat compared to those that are less well connected to Aquatic habitat within the Project Area. Thus, rice fields and associated canals that are adjacent to or include emergent wetlands are recognized as higher quality habitat than those without nested emergent wetlands.

Metrics
For each Map Unit, Aquatic Features are delineated to the water’s edge during the giant garter snake active period and assigned unique identification codes (e.g., AF-1). If the same feature spans two Map Units, it is assigned a different unique identification code for each Map Unit, but the sections of that feature share the same ‘connectivity code’, indicating a continuous connection between the two. Different Aquatic Features might occur in one Map Unit, such as a small irrigation ditch and a large canal; these are assigned unique identification codes and if connected, then a shared connectivity code. The acreage for each Aquatic Feature within each Map Unit is measured in Google Earth or GIS and then field checked, or measured directly in the field.

To count as part of a connected extent of aquatic habitat, the Aquatic Feature must have standing or slow-moving water between May 1 and September 15 and cannot be cement-lined. The maximum value of connected aquatic habitat associated with each Map Unit is reported. Thus, consider the following:

- set 1 of connected irrigation canals in Map Units 1 and 2, total 12 acres;
- set 2 of connected canals in Map Units 1 and 2, not connected with the 1st set, total 20 acres
- set 3 of connected canals in Map Units 2 and 3, total 22 acres.

In this case, the value of 20 acres will be included for Map Unit 1, and the value of 22 acres will be reported for Map Units 2 and 3. This attribute is intended to reflect greater habitat value for Map Units with Aquatic Features that are linked to large connected areas of aquatic habitat within the Project Area. This attribute is similar to the Project Area scale attribute, in which the extent, up to 100 acres, of the largest connected aquatic habitat in the Project Area is scored. The difference between these two attributes is the scale at which they are measured (Map Unit versus Project Area), and the intended effect.
of rewarding increased connectivity among Map Units in a Project Area (Map Unit attribute), and rewarding increased overall extent of connected aquatic habitat in a Project Area (Project Area attribute).

**Scoring functions**

Acres of Aquatic Feature habitat within each Map Unit is used in developing the Site Capacity Score through area-weighted averaging of Aquatic Feature attribute scores within a Map Unit, such that the attribute scores for the largest feature will account for the greatest proportion of its Map Unit score.

Increased habitat quality conferred by increased extent only applies to Map Units with a connection to off-site suitable habitat. If there is a connection to off-site suitable habitat, then increased extent of connected aquatic habitat within the Project Area, associated with this Map Unit, is beneficial up to 100 acres. Scoring is based upon direct linear relationships between the score (0 to 1.0) and the maximum area threshold set for increased habitat quality benefit associated with qualifying aquatic habitat (Figure 22).

![Figure 22. Scoring function for effect of within Project Area connected habitat extent on habitat quality where there is a connection to off-site habitat.](image)

**2.5.2 Aquatic Feature Type**

**Rationale**

Giant garter snakes spend the active period foraging in aquatic vegetation along the edges of slow-moving or stagnant water. These aquatic features support a prey base for the snakes and provide enough structural complexity to both protect the snakes from predators and to sometimes create opportunities for
basking. The historical habitat for giant garter snakes is tule marsh. These marshes often have many pockets of emergent vegetation providing hiding areas for hunting as well as protection from predators. In these tule marshes, high habitat heterogeneity occurs at fine scales: there are pockets of open water interspersed with areas of emergent vegetation and areas of upland terrestrial habitat. This heterogeneity is beneficial for giant garter snake because it provides structural complexity and supports the prey on which the snake depends.

The complexity of the tule marsh and human-created habitat depends on land use as well as the layout of the aquatic feature. Tule marsh is the native habitat of the giant garter snake and its current preferred habitat. Since much of the historical tule marsh has been destroyed or converted to other land uses, giant garter snakes have adapted to rice fields and agricultural canals as well as to wetlands. When the rice becomes emergent, giant garter snake will actively use it for foraging. However, giant garter snakes more often utilize the canals associated with rice rather than the rice fields themselves. Runoff from rice into the associated water conveyance structures can increase productivity of invertebrates for giant garter snake prey. Moreover, rice fields warm the water draining back into the Aquatic Feature, which supports active giant garter snakes (B. Halstead, pers. comm., 2016). Finally, there is also usually continuous flow between large rice canals and rice fields during the giant garter snake’s active season, such that the snake can utilize the greater habitat extent of the rice field for foraging during the flooded time period. Small rice canals often have very low and sometimes discontinuous water once rice has been flooded up during the GGS active season. Similarly, large irrigation ditches that service non-rice row crops, such as tomatoes, corn, or wheat, can be have periods with very low or discontinuous water during the GGS active season; therefore, these Aquatic Feature types are scored much lower than emergent wetlands, permanent conveyances, and large rice canals. Small non-rice irrigation ditches and isolated water bodies can offer some habitat for GGS but are not as high-quality due to non-hydrologic connectivity and less reliable water coverage during the GGS active season. Therefore, these types receive just 0.10 out of 1.0 attribute scores for Aquatic Feature type.

**Metrics**

Identify which type of Aquatic Feature is present based on the categories described under scoring functions below.

**Scoring functions**

This attribute is necessary. To receive giant garter snake credit, a Map Unit must include at least one Aquatic Feature that can support the giant garter snake. One Aquatic Feature type, concrete lined water bodies, does not qualify as giant garter snake habitat; but differences among the other types can be beneficial, as summarized in Figure 23. If the Map Unit and Aquatic Feature are one and the same, as would occur if the entire Map Unit was an emergent wetland, then the Map Unit Cover Type is designated as “Emergent Vegetation” and an Aquatic Feature is also created within that Map Unit that has the same...
number of acres and is indicated as an “Emergent wetland” type of Aquatic Feature. For the purposes of the tool, “bank” is defined as the area along the canal where the land slopes down towards the water line.

- **Emergent wetland** that is part of permanently wet natural (typically non-human made) feature (regardless of adjacent crop type)
- **Large permanent water conveyance**—a large canal or other form of water conveyance with earthen sides that holds standing or slow-moving water throughout the year and is at least 5 m wide. This category includes canals that direct the flow from a larger body of water (river, reservoir) to agricultural fields, as well as regional drains that direct flow from agricultural fields downstream to rivers.
- **Large rice canal**—an irrigation and/or drainage canal with earthen sides that holds standing or slow-moving water *year-round*, is at least 2 m wide at water’s edge, and is associated with rice fields.
- **Small- to medium-size rice canal**—an irrigation and/or drainage canal that holds standing or slow-moving water during the rice growing season (at least May 1 through September 15), has earthen sides, is at least 1 m wide, and is associated with rice fields.
- **Large irrigation ditch** or water conveyance that is at least 2-m wide, has earthen sides, and is associated with agricultural crops other than rice or non-agricultural lands.
- **Small to medium-size irrigation ditch** or water conveyance at least 1-m wide, has earthen sides, and is associated with agricultural crops other than rice or non-agricultural lands.
- **Isolated body of open standing water** with earthen sides and natural borders (e.g., stock pond)
- **Cement-lined water body**—water body of any size that has concrete sides.

**Figure 23.** Scoring response function for the type of Aquatic Feature.
2.5.3 Presence of Water During the Active Period

Rationale
Giant garter snakes are highly aquatic and need a continuously available water source during the snake’s active period between March and October. Sufficient water during the snake’s active season supplies food such as small fish and amphibians. If an Aquatic Feature is dry prior to the snakes’ spring emergence or during the active foraging season, then there may not be an established prey base, thus permanently flooded features provide the highest quality habitat for giant garter snake.

Presence of water in canals and irrigation ditches is seasonally dependent on crop type. The TAC acknowledges that rice agriculture, which provides important habitat, is often managed such that water may not be present after September 15, despite the snake typically beginning brumation around early October; this water management regime is still generally compatible with the snake’s needs and has been included in the metrics as a fall cut-off date for presence of water during the snake’s active period. Extending water presence through October 1 extends the period of foraging to a time point closer to the beginning of brumation, and the gsHQT assigns slightly more credit to Aquatic Features that are inundated through October 1 versus those that are dry by September 15.

Metrics
Identify months during which each Aquatic Feature is flooded (defined as having continuous water along the entire bottom of the feature), based on the following categories: Note that this attribute should represent the general trend of the Aquatic Feature. If an Aquatic Feature is permanently flooded over a ten-year period except for one year when water levels were very low and it was dry from August-November, “Permanent” is still the appropriate choice.

- Permanent (all year, year after year)
- March 15 through October 1
- May 1 through September 15
- Winter only
- Shorter time or never

Scoring functions
This attribute is necessary from at least May 1 through September 15 to provide giant garter snake habitat. Beyond that time window, the attribute becomes beneficial. Having water present permanently is ideal, while inundation that extends from March 15 through October 1 provides additional foraging habitat to the permanently flooded areas, and delayed inundation until May 1 is also valuable (Figure 24).
2.5.4 Emergent Wetland Vegetation Types

Rationale
Giant garter snakes spend much of their time in the emergent vegetation within aquatic features. Different types of emergent vegetation have very different characteristics and therefore provide varying habitat quality. Giant garter snakes prefer tules (Halstead et al. 2016). Tules provide unique habitat structure that best supports giant garter snake foraging and basking habits. Tules grow such that single stalks of the rush emerge from the water, unlike cattails, which grow in bunches. The tule architecture allows the giant garter snake to forage between each stalk, and provides complexity in the water surface and underwater habitat in which the snake hunts, and escapes predators. Tules also may bend over, creating mat-like structures above the water (Figure 25). This phenomenon provides basking opportunities for the giant garter snake in the middle of the aquatic feature where the snakes are protected from terrestrial predators and can escape into the water easily if threatened, unlike basking sites in upland habitats which may be further from the safety of water (Halstead et al. 2016) (Figure 25). Cattail and water primrose can provide cover and habitat complexity in the aquatic feature, and cattails can also create mat like structures for basking, but the architecture of these species is less amenable to hunting and hiding for giant garter snake (Halstead et al. 2016), and the basking opportunities on the downed cattails are smaller and less abundant than those provided by tules.
Figure 25. Giant garter snake basking on tule mat over water (Photo from Figure 1 in Halstead et al. 2016; U.S. Geological Survey photo by Matt Meshriy).

**Metrics**
Emergent vegetation type within the Aquatic Feature is measured by category, where the dominant species, representing at least 50% of all the emergent vegetation, is: tules, cattails, water primrose, or other.

**Scoring functions**
This attribute is beneficial. The scoring response function is categorical with tules providing full credit (1.0 score), cattails and water primrose providing half credit (0.5 score), and other vegetation types providing no additional credit (Figure 26).
2.5.5 Emergent Wetland Vegetation Percent Cover

Rationale
Emergent wetland vegetation provides hiding areas for hunting as well as protection from predators. Too little emergent vegetation provides too little protection and too few hunting areas; while too much vegetation limits the open water habitat available for foraging and constrains movement for escape from predation. The emergent wetland vegetation type most commonly selected for by giant garter snakes is tules (Halstead et al. 2016). Cattails and water-primrose can also provide habitat if management of these species prevents the formation of monocultures (Halstead et al. 2016); floating vegetation is appropriate only if there is enough space in between the plants to allow for a snake to maneuver through (e.g., gaps of at least 20 cm are most common, such as with low-density water primrose). Scoring for this attribute is based on this optimal, moderate level of emergent vegetation cover. Percent cover is estimated for the three species of aquatic vegetation that support giant garter snake: tules, cattails, and water-primrose. Other emergent or floating aquatic vegetation, such as Phragmites or duckweed, are not included in estimates of emergent vegetation cover.

Tules lining banks of an Aquatic Feature often form matted patches on which giant garter snakes can rest and bask in a relatively protected location (B. Halstead, pers. comm., 2016). Therefore, the TAC determined that for Aquatic Features in which the emergent vegetation is dominated by tules AND in which the wetland vegetation percent cover 50% or greater, basking habitat can be considered present and of high quality so that attributes on terrestrial vegetation extent and complexity are less important. This shift in importance between upland and emergent vegetation for basking is reflected in the HQT scoring, such that with tule dominated emergent vegetation with a percent cover of 50% or greater,
attribute weighting is shifted away from upland vegetation and towards emergent vegetation. Thus, where tule cover is at least 50%, the importance of upland vegetation as basking habitat is greatly diminished in the gsHQT scoring. Where tule cover is less than 50%, upland vegetation as basking habitat is weighted as the primary basking habitat area (see Section 2.5 Scoring for more details on score weighting).

**Metrics**

Percent cover of tules, cattails, and water-primrose within the Aquatic Feature is estimated and placed in one of five percent cover bins: <5%, 26%–50%, 51–75%, 76–95%, and >95%.

**Scoring functions**

This attribute is beneficial. The scoring response function is a bell curve, with approximately 26–75% emergent vegetation as optimal, 6–25% and 76–95% as moderate, and very little (<5%) or very dense (>95%) emergent vegetation as least desirable (Figure 27).

![Figure 27](image)

*Figure 27. Scoring response function for the percent cover of emergent vegetation within the Aquatic Feature.*

### 2.5.6 Emergent Wetland Vegetation Complexity

**Rationale**

The more complex the distribution of emergent vegetation (e.g., tules, cattails, and/or water-primrose), the greater the access to both open water and cover from any given spot within the Aquatic Feature and the more opportunities for giant garter snakes to find cover and hide from prey as well as from predators and to move quickly to capture prey or escape predation.
Metrics

The complexity of the emergent vegetation pattern within the Aquatic Feature is classified using the drawings in Figure 28 below.

Figure 28. Example patterns of complexity for dominant emergent vegetation cover in an Aquatic Feature (blue is open water and green is emergent vegetation). Attribute scores associated with each type of pattern are listed below each diagram. *The 0.5 score applies to Tules and Cattails only. Primrose is scored as a 0 at complexity level “g” due to the dense mats of vegetation which limit foraging opportunities for the snake.

Scoring functions

This attribute is beneficial. Scoring is categorical, such that more complex distribution of emergent aquatic vegetation is scored higher than less complex structure. Note that complete lack of emergent vegetation and 100% cover of emergent vegetation are both valued at 0 in Figure 29.
2.5.7 Terrestrial Vegetation Type

Rationale
Terrestrial habitats directly adjacent to Aquatic Features affect the aquatic habitat, offer basking opportunities, and provide refugia for retreat and brumation for giant garter snake. Giant garter snakes can use herbaceous vegetation types for basking since these areas can offer a patchwork of shade and sunny areas while simultaneously helping the snakes hide from predators. Tall, woody vegetation (e.g., riparian forest or dense scrub-shrub) is typically too dense and provides too much shade to create basking habitat for giant garter snakes; in addition, it can provide perches for avian predators, such as Swainson’s hawk and red-tailed hawk, that prey upon giant garter snakes. For these reasons, Aquatic Features with heavily forested uplands along the banks are not good giant garter snake habitat. Aquatic Features lined with occasional small trees and shrubs are moderately suitable since they can have some open and sunny areas with perches that are not common for predatory raptors, and Aquatic Features with grass-forb covered banks and adjacent uplands can provide excellent habitat.

Metrics
Classify the adjacent upland vegetation cover type directly adjacent to the Aquatic Feature as having one of the following: tall trees (>5 m in height) with over 50% absolute cover including the area adjacent to both banks; over 50% small tree or shrub absolute cover including the area adjacent to both banks; or over 50% graminoid and forb absolute cover including the area adjacent to both banks.

Scoring functions
This attribute is necessary, where Aquatic Features with over 50% tree cover or shrub cover directly adjacent to the water’s edge are not given habitat credit (attribute score = 0), and herbaceous cover is given full credit (attribute score = 1).
2.5.8 Terrestrial Vegetation Width along Aquatic Feature

Rationale
Giant garter snakes use terrestrial habitats adjacent to Aquatic Features to thermoregulate by basking in the sun to warm up or by entering the water to cool down. Terrestrial vegetation in these areas also provides opportunities for giant garter snakes to hide from predators while basking. Giant garter snakes can travel alongside an Aquatic Feature and are likely to use the area to bask while being hidden from predators. Thus, a low and patchy layer of vegetation that extends from the water’s edge several meters inland is important for providing basking habitat. Very narrow strips of vegetation, less than 1 to 1.5 m, do not provide good cover and are too narrow a band for the snakes to move easily along the channel without slipping into the open. Therefore, wider strips of vegetation cover, up to 5 meters with at least 10% vegetation cover, provide better basking and upland habitat for Giant garter snakes. This attribute addresses just the width of vegetation cover along an Aquatic Feature. The type and pattern of vegetation cover within that strip are addressed through other attributes.

Metrics
The width of land, from the waterline along the Aquatic Feature to the road, that supports at least 10% herbaceous vegetation cover between March 15 and October 1 is reported, in meters. A road is defined as a frequently used vehicular path. This attribute must be recorded during the active season, but ideally between April 15 and July 1.

Scoring functions
This attribute is beneficial. Figure 30 shows the different bins for width of vegetated surface adjacent to the water’s edge, and associated attribute scores.

![Figure 30. Scoring response function for upland percent of ground exposed to sunlight.](image)
2.5.9 Terrestrial Vegetation Complexity

Rationale
Terrestrial vegetation complexity can affect the ability of giant garter snakes to heat up when migrating out of the water after aquatic foraging. Ideally, there is a combination of relatively low-lying vegetation with canopy openings that offer solar exposure at the square meter scale. Short grasses, especially perennial (clumped) grasses, are an example of good terrestrial cover for giant garter snakes. Under optimal conditions, thermoregulation opportunities include ample sun exposure while simultaneously offering the snake options for hiding from predators. Patterns of sun-penetration-to-ground-level are evaluated such that the snake can bask while being afforded some cover from overhead vegetation or other objects. The length of the snake, from 0.5 to 1 m, determines the scale at which the complexity works best to simultaneously offer both basking opportunity and cover from predators. The height of the snake off the ground, from 1 to 3 cm, governs the height at which sun exposure is relevant.

Metrics
This is based upon an ocular estimate of the percent of upland area, adjacent to and alongside the entire Aquatic Feature, that includes a mix of sun exposure and cover per square meter, from the Aquatic Feature waterline to the road or to 5 m upland (whichever is closest).

Scoring functions
This attribute is beneficial (a–c in Figure 31). Scoring is based on the area that provides a mix of sun exposure and cover per square meter across the uplands directly adjacent to the aquatic habitat. Three broad bins of percent cover categories are used to assign scores for this attribute (Figure 31).

![Figure 31. Scoring response function for upland areas that includes a mix of exposed and covered ground surface per square meter.](image-url)
2.5.10 Subterranean Refugia

Rationale
Giant garter snakes use a variety of subterranean refugia for retreat during overly warm or cold weather, as well as for retreat during the long brumation period from October through March. Refugia is provided by any structure that enables the snakes to hide from predators. Examples of subterranean refugia include mammal burrows (e.g., ground squirrel, muskrat, or beaver), rip-rap, concrete, brush piles, cracks in soil, coarse/clumpy soil, crayfish burrows, etc. More of these features provide more opportunities for resting as well as protection from predators. Rip-rap lined with geotextile fabric is not included as suitable subterranean refugia since access through the fabric is limited. Areas having no apparent refugia but other positive habitat conditions for giant garter snake can provide habitat but of lower quality than areas with visible refugia present. Thus, the TAC determined that this attribute is beneficial rather than necessary. Three coarse categories of refugia abundance are identified since refugia can be difficult to accurately tally and the snakes can make use of many different types of refugia.

Refugia occur in upland areas near the aquatic feature under assessment. When collecting data, refugia should be located within 5 meters of the aquatic feature which is generally, but not always, at the waterline (Figure 32).

Figure 32. Example of an aquatic feature where the waterline may be near the blue dashed line, but the refugia should be located upland of the red line (edge of the aquatic feature).
Metrics
The abundance of subterranean refugia opportunities is estimated for the area along the Aquatic Feature using the following categories:

- Abundant (seeing them without having to search for them)
- Sparse to Moderate
- None (can see that it has been recently graded)

Note that many times you can more easily find burrows on the non-road or non-managed side of the ditch/canal. This attribute is beneficial.

Scoring functions
This beneficial attribute is scored to recognize different degrees of benefit for the giant garter snake based upon whether or not there is abundant, little to moderate, or no apparent refugia present (Figure 33).

![Figure 33. Scoring response function for abundance of upland subterranean refugia.](image)

2.6 Scoring

2.6.1 Overview of Scoring Approach
We have designed the HQT so that existing habitat attributes are scored based upon the habitat needs and preferences of the giant garter snake. Habitat attributes scores are combined based upon (1) if they are required for habitat to exist, in which case attribute scores are either a “1” or a “0” and multiplied by
the rest of the site score (necessary attributes); or (2) if they are beneficial for the snake, in which case the attribute scores are assigned a percent weight which is then added to the total Project Area score. Attribute scoring weights are based upon the relative importance of each attribute for giant garter snake habitat. Figure 34 provides a summary of how the attribute scores are combined into an overall Project Area score for giant garter snake.

Overall the weights assigned to each set of attributes were distributed based upon professional judgement and interpretation of available scientific literature regarding habitat characteristics. Some of the initial weightings were refined based on observations and circumstances encountered at five pilot sites where we applied the draft gsHQT to conditions ranging from traditional rice fields, to wetlands created by collection canals, to natural and restored emergent wetlands. A quantitative comparison of observed vs. site scores has yet to be done for giant garter snake, but is planned as more empirical information associated with assessment sites become available. More details on the score structure and logic behind the ggsHQT scoring are provided in the sections below.
2.6.2 Landscape Context Scoring

The first major split in the gsHQT, as illustrated in Figure 34, is between Landscape Context and Site Capacity Scores. The score weighting is heavily skewed towards the Site Capacity, with a 90:10 split, Site Capacity: Landscape Context. The logic behind this distribution is that the most important Landscape Context attributes are necessary, and therefore not part of the weighted score. For example, location of the Project Area within the designated species range is a necessary attribute and not included in the weighted score. Similarly, connectivity to 100+ acres of off-site habitat or a minimum of 100 acres of on-site habitat is a necessary attribute reported within the Site Capacity Score. Thus, the essential needs for being located within the species range and having sufficient gene flow with off-site populations or existence of on-site habitat large enough to support a self-sustaining population, must be met before any score greater than “0%” is assigned to a Project Area. Moreover, snake individuals are not known to travel large distances under natural conditions and therefore on-site habitat conditions must cover most if not all of their natural history needs.

The two non-necessary Landscape Context attributes are beneficial, so that higher scores increase the overall functional habitat score for a Project Area but a Project Area has the potential to provide functional habitat even if neither of these two attributes are present. These non-necessary landscape attributes,
distance to recent sightings and distance to historical tule marsh, are not definitive evidence of the likelihood of giant garter snake to occupy an area. Due to the snake’s elusive nature and the limited number of surveys reported for private lands, there is significant uncertainty regarding current population extent. Moreover, the relationship between current population occurrence and the extent of historical tule marsh is indirect. Thus, while these attributes can increase our confidence that a project area can be occupied by giant garter snake, they are not definitive. Scoring for these beneficial landscape attributes, distance to recent sightings and distance to historical tule marsh, are weighted 60%/40%, such that the distance to recent sighting score is multiplied by 0.6 and the distance to historical tule marsh score is multiplied by 0.4. Greater weight is placed on recent sightings since this offers more definitive evidence of an area supporting giant garter snake than proximity to historical habitat (tule marsh). However, since sightings of this species most often require trained looking, no sightings do not indicate absence. The proximity to historical tule marsh provides an alternative, but less certain and therefore with slightly lower weight, means of estimating likelihood that the area supports current populations. These two products are summed and multiplied by 1 if the area is within giant garter snake range and by 0 if the site is outside of the species range (Figure 34).

### 2.6.3 Site Capacity Scoring

Attributes measured within a Project Area are combined into a Site Capacity Score by rolling up attribute scores at three nested scales: Project Area, Map Unit, and Aquatic Feature. There is one Project Area wide attribute, which comprises 4% of the full Site Capacity Score. The maximum Map Unit attribute scores sum up to 0.06, and therefore comprise 6% of the Site Capacity score (Figure 34). The maximum Aquatic Feature scores sum up to 0.80 and therefore comprise 80% of the Site Capacity score (Figure 34). Both the Map Unit and Aquatic Feature scales include one attribute considered necessary for assigning habitat: if not met, the Map Unit or Aquatic Feature will not be assigned any credit as giant garter snake habitat.

#### Project Area Attribute Scoring

Within the Site Capacity Score, the broader scale Project Area and Map Unit attributes address the quality of connectivity and habitat extent. Thus, once the required attributes for connectivity or self-sustainability are satisfied, the quality of the connection to off-site habitat and the extent of connected on-site habitat can increase the quality of on-site conditions. These are important but not core benefits and so are assigned a relatively small weight of 4% apiece.
Map Unit Scoring

All Map Unit scores, which include the scores for Aquatic Features within each Map Unit, are rolled up into area-weighted average scores for all Map Units that occur within a Project Area. Functional habitat will only be assigned to a Map Unit if that Map Unit is not subject to rapid flooding, a necessary attribute. A Map Unit will also only receive giant garter snake habitat credit if there are Aquatic Features within the Map Unit that meet the four Aquatic habitat quality requirements described above under Aquatic Features. Where these minimum qualifying thresholds are met, the degree of connectivity (measured as the inverse of the connection length) between on-site Aquatic Features and off-site wetlands or rice fields is scored for each Map Unit and included as 4% of the Map Unit score.

Finally, vegetative cover type associated with each Map Unit is scored based upon habitat quality effects for giant garter snake. The vegetation type, assigned at the Map Unit scale and averaged for multiple vegetation types, or crops, within a rotation, has a small weight of 2% of the overall habitat score. Many of the benefits associated with vegetation types, particularly irrigation needs, are already incorporated in other attributes. However, snakes are known to use irrigation canals associated with rice fields and recent studies indicate that snakes living in areas with a high cover of rice fields have higher survival rates than those that live in areas with a lower cover of rice (comparison to snakes living in large emergent wetlands are not included; Reyes et al. 2017). Aquatic Features associated with rice receive higher scores than Aquatic Features associated with other, non-wetland, vegetation cover types. Thus, 2% of the habitat score reflects these difference between wetlands, rice, other irrigated non-woody crops, and upland vegetation types, all other things being equal for the structure and management of associated Aquatic Features. The vegetation type and connectivity scores for each Map Unit are combined as an area-weighted average for the Project Area, and make up 6% of the overall score.

Aquatic Feature Scoring

The vast majority of the habitat score weight, 80%, is placed on conditions that directly affect an individual snake and where it lives, as addressed within the Aquatic Features score. Thus, conditions associated with Aquatic Features and the directly adjacent uplands describe where the snake forages, basks, reproduces, and resides during its seasonal brumation. Aquatic Feature scores are rolled up into area-weighted average scores for all of the Aquatic Features that occur within each Map Unit. Within the Aquatic Feature attributes, we split the management actions that affect habitat conditions from physical characteristics of the Aquatic Features themselves. The physical conditions of an Aquatic Feature affect the survival as well as reproduction rates of local individuals throughout the entire year and/or either their active or inactive periods. Therefore 60% out of 80% of the scoring for Aquatic Features, is placed on the Aquatic Feature characteristics compared to Aquatic Feature management, which is assigned 20% out of the 80% overall Aquatic Feature weight. Those management actions that can result in large scale mortality events, such as tilling basking and brumation habitat adjacent to an Aquatic Feature, result in a habitat score of “0” for that set of features. Other management actions can improve or degrade habitat
conditions but are not expected to have large mortality effects and are therefore scored as more or less beneficial.

Within the Aquatic Feature conditions, we placed half of the weight on the basic characteristics of the Aquatic Feature; type, size, and duration of flooding. Duration of flooding is given the greatest weight among these three attributes, based on expert opinion from TAC members that permanence of water is of paramount importance for giant garter snake habitat (B. Halstead, pers. comm., 2017) and that successful giant garter snake trapping efforts are in permanent water bodies. Other aspects of an Aquatic Feature, including emergent vegetation characteristics and basking habitat quality, are given a much smaller portion than the Aquatic Feature flood duration, since these are less fundamental elements of the habitat structure. The weights among attributes describing emergent vegetation and basking habitat are nearly evenly distributed.

Finally, Aquatic Feature management attributes are weighted at 20%, or one-third the weight of the Aquatic Feature physical characteristics. Since canal grading is expected to cause more fatalities either directly or through entombment (B. Halstead, pers. comm., 2016) than most upland management actions (possibly except tilling directly adjacent to the Aquatic Feature), canal grading attributes are given ¾ of the overall management weight compared to the upland management actions.

An Aquatic Feature is considered functional habitat if it provides the fundamental structural conditions needed for giant garter snake habitat, and if there are no management actions that are known to cause multiple, rather than single and incidental, fatalities. Thus, functional habitat will only be assigned to Aquatic Features where the following six conditions are met:

1. The feature holds still or slow-moving water from at least May 1 through September 15.
2. The features either has an aquatic or terrestrial connection (under 2,000 m or 50 m, respectively) to off-site or to on-site (within the Project Area) aquatic habitat at least 100 ac in size.
3. The feature is earthen, rather than cement-lined.
4. The upland vegetation along the feature banks is dominated by herbaceous rather than woody vegetation.
5. No diskimg or plowing is done on uplands directly adjacent to the Aquatic Feature.

The habitat quality provided by each qualifying Aquatic Feature is then determined by scoring beneficial attributes, within a range of 0 to 1.0, and multiplying these scores by attribute weights. Weights for eight structural beneficial attributes, and seven necessary or informational attributes associated with each Aquatic Feature are listed in Table 3, and weights for six beneficial management attributes are listed in Table 4.
The Aquatic Feature attribute weighting changes slightly depending upon the presence and amount of tules in the Aquatic Feature. If the emergent vegetation cover is over 50% and the dominant emergent vegetation types is tules, then it is assumed that the giant garter snake can use senescent tule mats within the Aquatic Feature for basking and thermoregulation, and therefore the scoring shifts some of the weight for terrestrial basking habitat over to the attributes for emergent vegetation extent and distribution. This shift in scoring weight is indicated by the weights for Attributes 10, 11, 12 and 14 in Table 3, in which the first number reflects the weight with less than 50% tule cover, and the second reflects the weight with over 50% tule cover. Some weighting is kept on the upland basking habitat to support maintenance of alternative basking habitat even in the presence of tule cover. The attribute score times weight products are then summed to create the score for each Aquatic Feature, which also ranges from 0 to 1.0.
Table 3. Habitat attributes that address the structure of Aquatic Features and their scoring weights in the giant garter snake HQT.

<table>
<thead>
<tr>
<th>No.</th>
<th>Aquatic Feature Structure Attributes</th>
<th>Percent Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Map Unit ID</td>
<td>Information</td>
</tr>
<tr>
<td>2</td>
<td>Aquatic feature unique ID</td>
<td>Information</td>
</tr>
<tr>
<td>3</td>
<td>How big is the Aquatic Feature (acres)? (This is used to calculate the area-weighted average Aquatic Feature score for each Map Unit.)</td>
<td>Multiply</td>
</tr>
<tr>
<td>4</td>
<td>What type of aquatic feature is it?</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>What is the contiguity code for this feature?</td>
<td>Information</td>
</tr>
<tr>
<td>6</td>
<td>What is the extent of connected giant garter snake aquatic habitat associated with this feature? (ac)</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Is this a small to medium or a large canal or managed water conveyance, or neither?</td>
<td>Information</td>
</tr>
<tr>
<td>8</td>
<td>During what months is the aquatic feature flooded?</td>
<td>20</td>
</tr>
<tr>
<td>9</td>
<td>What is the dominant type of emergent vegetation?</td>
<td>Multiply by 10 and 11</td>
</tr>
<tr>
<td>10</td>
<td>Within the aquatic feature, what is the percent cover of emergent vegetation?</td>
<td>5/8</td>
</tr>
<tr>
<td>11</td>
<td>What is the complexity of the emergent vegetation within the aquatic feature?</td>
<td>5/8</td>
</tr>
<tr>
<td>12</td>
<td>From the waterline toward the road, how far does vegetation of at least 10% cover extend (m)?</td>
<td>6/3</td>
</tr>
<tr>
<td>13</td>
<td>What is the upland vegetation on banks of Aquatic Feature (0 to 10 m from waterline) (only herbaceous counts)</td>
<td>Necessary</td>
</tr>
<tr>
<td>14</td>
<td>What percent of the area is composed of 1 square meter patches that contain a mix of exposed and covered ground surface, such that a snake can bask without being exposed to predation? (0 to 5 m from waterline or to road (whichever is closest)</td>
<td>6/3</td>
</tr>
<tr>
<td>15</td>
<td>From the waterline to the road or 5 m (whichever is closest), what is the abundance of subterranean refugia opportunities?</td>
<td>6</td>
</tr>
</tbody>
</table>

**Aquatic Feature Structure Subtotal**

|   | 60 |
Table 4. Habitat attributes that address management of Aquatic Features and their scoring weights in the giant garter snake HQT.

<table>
<thead>
<tr>
<th>No.</th>
<th>Aquatic Feature Management Attribute</th>
<th>Percent Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of times canals are graded in 10-year period</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Number of sides graded at a time (0, 1, or 2 sides, bottom only)</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Dates that grading occurs</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Location where grading spoils are deposited</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td><strong>Canal grading score</strong></td>
<td><strong>15</strong></td>
</tr>
<tr>
<td>5</td>
<td>Type of maintenance performed on adjacent uplands</td>
<td>2.5</td>
</tr>
<tr>
<td>6</td>
<td>Dates when maintenance occurs on adjacent uplands</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td><strong>Upland maintenance score (average 5-6)</strong></td>
<td><strong>5</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Aquatic Feature Management Subtotal</strong></td>
<td><strong>20</strong></td>
</tr>
</tbody>
</table>

**Combined Landscape and Site Capacity Score**

The Site Capacity Score is combined with the Landscape Context Score at a 90%/10% weighting for giant garter snake. This is done by taking the sum of the Landscape Context score and the sum of the Site Capacity score (Figure 34). Many of the most important Landscape Context attributes are considered necessary and so are not a part of the score itself. Thus, the two remaining Landscape Context attributes, distance to historical tule marsh and distance to documented occurrence, are beneficial and assigned 4% and 6%, respectively, of the overall Project Area score. This leaves 90% of the remaining weight on Site Capacity. The high proportion of the score placed on the Site Capacity Score reflects the smaller scale at which giant garter snakes live and move compared to other CVHE species such as Swainson’s hawk and Chinook salmon. A detailed diagram of the scoring weights is provided in Figure 35. This figure shows those aspects of the score that could be controlled by the land manager, assuming that water feature type and flood duration are immutable.
Figure 35. Detailed diagram of attributes and attribute weighting in the GGS Habitat Quantification Tool. Blue text indicates attributes that can be controlled by the land manager without changing water management timing.
2.7 Literature Cited in Section


