



Conservation Success Index: McCloud River Redband Trout

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SPECIES SUMMARY

The headwaters of the McCloud River drain the southeast slopes of Mount Shasta and its foothills in northeastern California. Tributary streams north of the mainstem McCloud infiltrate into the area's porous volcanic geology and are typically disconnected from other surface waters. The mainstem McCloud and its southern, moderate-gradient tributaries are isolated from the larger Sacramento River basin by the Upper and Middle Falls.

These natural features have isolated populations of redband trout in less than 60 miles of the Upper McCloud River system from the Sacramento River for millenia. This collection of distinct rainbow trout is generally regarded as the McCloud River redband trout *Oncorhynchus mykiss stonei*, part of a complex of Northern Sacramento River redband trout first recognized by Livingston Stone in 1885. Its distinctive coloring and form, tolerance for low-flow streams, and history of isolation make this unique subspecies a conservation interest.

Beginning in the early part of the twentieth century, stocked hatchery fish hybridized with the McCloud River redband. By the early 1970s, the distribution of pure, native fish was reduced to headwater tributaries, with the most distinct form limited to a one mile section of Sheephaven Creek. In 1972, California Trout, Shasta-Trinity National Forest, and California Department of Fish and Game initiated conservation efforts for the subspecies, beginning with transplanting Sheephaven Creek fish into Swamp Creek. Following the eradication of rainbow trout, redband were also transplanted to Trout Creek. Restoration activities continued, and by 1996 putative McCloud River redband trout existed in about 40 miles of habitat. The subspecies is designated Sensitive by the U.S. Forest Service and is a California State Species of Special Concern. The latest planning efforts culminated in the Draft Redband Trout Conservation Agreement (2007).

Hybridization with introduced rainbow trout still poses the largest threat to the McCloud River redband. Other threats include sedimentation and passage issues associated with extensive logging within the watershed, habitat alteration associated with livestock grazing, accidental harvest associated with the popular McCloud River trout fisheries downstream, and natural factors that threaten any species with a limited distribution.

Our CSI analysis incorporated data from the 2007 *Draft Redband Trout Conservation Agreement*, the 2008 *SOS: California's Native Fish Crisis* report, and additional information from Steve Bachmann, Shasta-Trinity National Forest. We are grateful for these contributions to our understanding of this species. A complete list of data sources is provided separately. This analysis for McCloud redband trout is summarized at the catchment scale (1,000 – 25,000 acres), a finer scale than the typical CSI.

Key CSI Findings

- The current distribution of McCloud River redband has been reduced to tributaries in the McCloud River headwaters.
- Multiple population groups of McCloud River redband exist, several isolated populations north of the mainstem McCloud River and a loosely connected population in the mainstem and southern tributaries. Those populations occupying the disjunct tributaries north of the mainstem have greater genetic purity and are isolated from rainbow trout.
- High population integrity scores of the “pure” redband in the tributary streams are decreased by the limited extent of those populations.
- Habitat integrity scores are degraded by an extensive road network in the riparian zone and by timber management across the ownership mosaic.
- Many other sources or indicators of low habitat integrity are absent, including urban and agricultural areas, 303(d) listed streams, and canal and dam structures.
- McCloud River redband are at low risk to the future threats of flow modification from new dams, winter flooding, or altered fire regimes.
- Stream temperature changes associated with potential climate change, resource extraction related to timber harvesting, and genetic introgression with non-native trout species represent the greatest additional future risk to this subspecies.

Our CSI analysis shows that the range-wide conditions related to species distribution are high for extant populations of McCloud River redband trout. Because of introgression levels beyond the 20% threshold commonly used to designate conservation populations, McCloud River redband are considered extirpated in Blue Heron Creek and the lower and upper portions of the McCloud River. Ongoing research by the Genomic Variation Lab at University of California-Davis will further clarify the presence of introgressed individuals across the system. Translocations have allowed the subspecies to occupy most tributary catchments that it is speculated to have historically occupied while restoration efforts allow it to occupy high order streams.

The streams in the upper McCloud support an impressive density of redband trout. These densities and isolation from rainbow trout and diseases associated with hatchery fish bolster the population integrity scores for the catchments north of the mainstem McCloud. Nonetheless, these populations persist in precariously short segments of stream; this limited population extent serves to mitigate the positive effects of isolation. Based on the Hilderbrand and Kershner criteria, the McCloud contains at least 3 populations that meet the persistence threshold – Trout Creek and possibly Dry and Bull Creeks. High scores for life history diversity reflect that there is no evidence that a life history strategy has been lost within the watershed – the mainstem McCloud is suspected to be too disconnected from its tributaries to allow for fluvial life histories, which are common in other forms of redband trout.

CSI analysis scored upstream tributary catchments high and moderate for habitat integrity and lowest in the Lower McCloud catchment. Land stewardship and the extensive road network in the Upper McCloud are the primary determinants of high and moderate scores. Public lands within the ownership mosaic in the watershed are managed by the U.S. Forest Service (Shasta-Trinity National Forest). Active timber management occurs on portions of the public and most of the private land, although public land logging has decreased in recent years and some areas of Late Successional Reserve have been set aside for lighter management. The road network was constructed to facilitate timber management; the

topography of the watershed means that many of roads follow stream courses. All but Cow and Swamp Creek catchments have between ¼ and ½ miles of road in the riparian zone for every mile of stream, which indicates that decommissioning and/or relocating roads away from riparian areas should be a high restoration priority.

Current watershed connectivity in the McCloud, always historically limited due to dry stream segments and steep gradient tributaries, is affected by the presence of many culverts and other anthropogenic barriers. Though they lower the overall watershed connectivity scores for some catchments, some barriers, such as the structure at the mouth of Moosehead Creek, function to isolate populations of McCloud redbands from rainbow trout.

The watershed is lacking many sources or indicators of stream habitat degradation, including 303(d) listed streams, extensive canal networks, and agricultural and urban areas. Only a minimal canal network and one structure – Lakin Dam, near the downstream extent of the species distribution - alter the flow regime. The CSI lacks a specific indicator for addressing one of the major stressors to the Upper McCloud, livestock grazing. As a result, some habitat integrity scores may not reflect instream conditions: the lack of acute anthropogenic stressors across the watershed may inflate the habitat integrity scores of degraded catchments in need of restoration from grazing impacts.

The CSI analysis of future security suggests the McCloud River redband is at high to moderate risk. The Upper McCloud River occurs within a mosaic of U.S. Forest Service and private ownership. Acquisition of remaining private lands along Sheephaven Creek by the U.S. Forest Service or conservation buyer are a high priority. The majority of private lands in the watershed are vulnerable to conversion from woodlands to exurban residential development due to their flat topography and proximity to existing roads. This potential threat is lessened from the Blue Heron/Whiskey Creek drainages downstream by a conservation easement held by The Pacific Forest Trust. The resource extraction threat in the system is associated with timber management on public and private lands, though large portions of several catchments are designated as Late Successional Reserves within Shasta-Trinity National Forest. The legacy of earlier introductions of rainbow and brown trout continues as an additional threat to all catchments, especially those connected to the mainstem McCloud. The extensive road network across the system may facilitate future introductions of other invasive species, including the New Zealand mud snail.

The CSI considers the effects of a + 3°C climate change scenario on the species. Our analysis suggests that the McCloud River redband is not at risk to increased winter flooding associated with rain-on-snow events or the effects of altered fire regimes associated earlier spring warming in mid-elevation zones. Although our analysis of the risks from drought suggest the subspecies is at minimal risk relative to perpetually stressed regions across the west, the persistence of McCloud redband trout in low-flow streams place them at risk to even small changes in flows associated with drought. Based on the current distribution of the species relative to air temperature, the species is at high risk to increased summer temperatures. However, the McCloud River redband may possess a resiliency to temperature stress, given its ability to persist through seasonal low-flow, higher-temperature events.

Total CSI scores are highest for the northern, disjunct tributaries with the largest isolated populations of McCloud River redband (particularly Swamp Creek) and lower in catchments with small populations (Edson Creek) or catchments connected to the mainstem McCloud (Lower McCloud). Across scoring groups, our CSI analysis suggests that continued protection and restoration efforts are warranted across the northern catchments, especially to mitigate the effects the small population size and riparian roads in Swamp, Trout, Sheephaven, and Edson Creeks. Continued restoration efforts are warranted for the

Upper McCloud River and its southern tributaries, particularly the Cow, Raccoon, and Bull Creek catchments, which score high for habitat integrity.

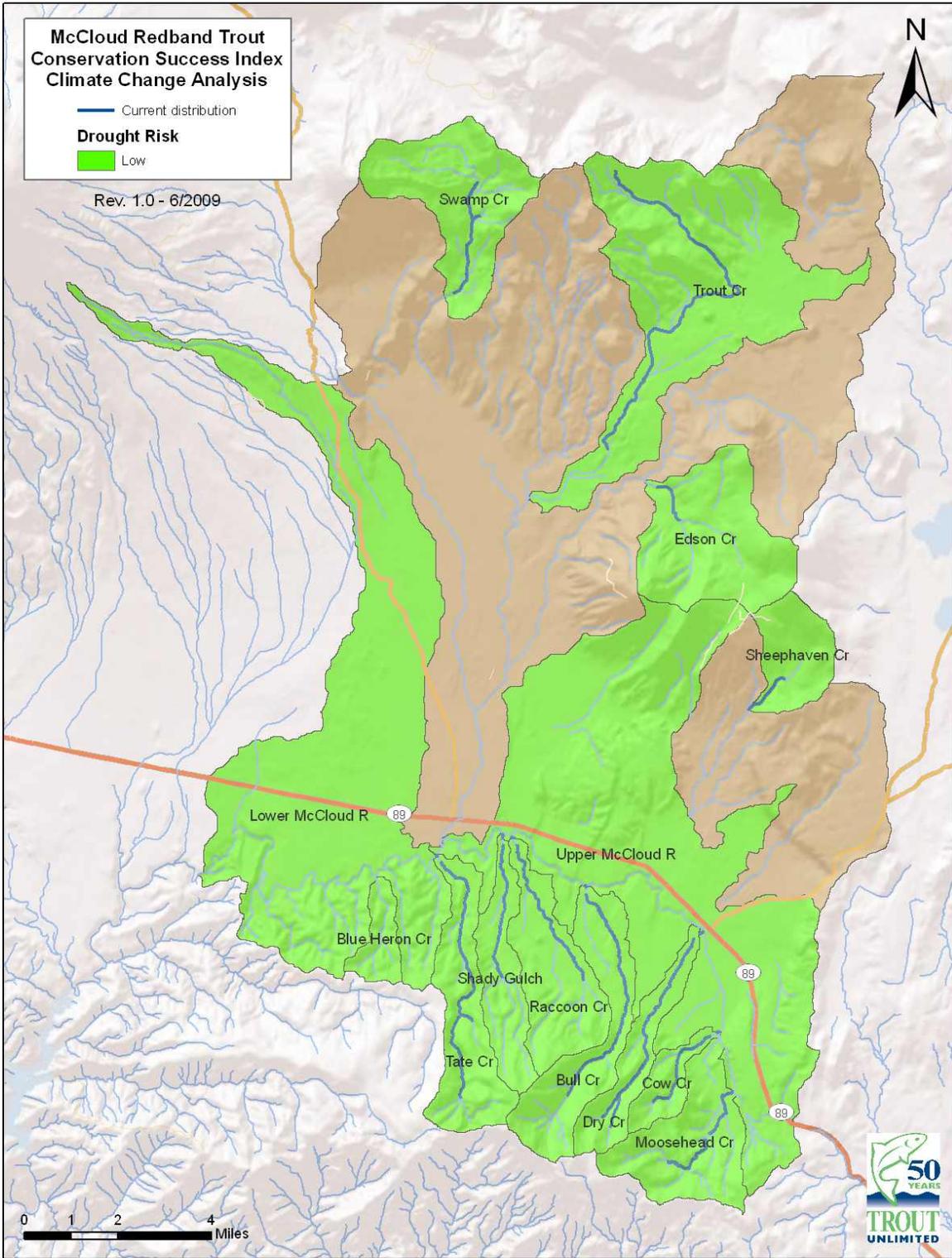
Trout Unlimited strongly supports the continued restoration efforts of California Department of Fish and Game, the U.S. Forest Service, and California Trout. These entities have made great strides in the conservation of McCloud River redband trout since coordinated efforts began in the early 1970s. Consistent with CSI findings related to habitat and population integrity, ongoing projects should address the effects of riparian roads and stream crossings while attempting to manage the connectivity of existing populations. Providing large interconnected habitats will increase the persistence of existing populations to both natural and anthropogenic disturbances, but as long as non-native rainbow trout persist in the mainstem McCloud these benefits must be weighed against the potential effects of introgression. Ongoing habitat restoration on grazing-degraded streams will also improve McCloud River redband trout habitat.

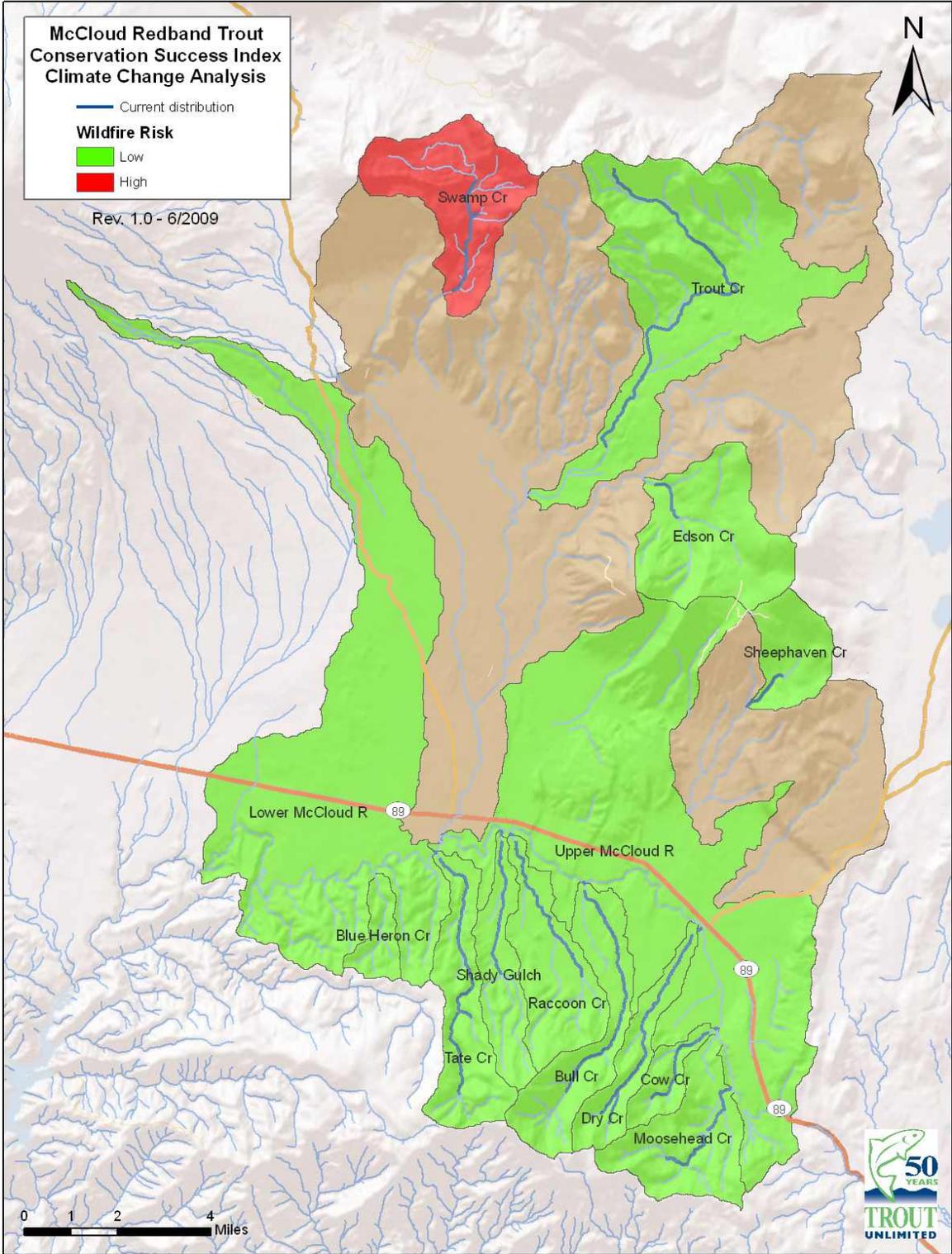
Although the redband trout in the McCloud River has not been listed under the Endangered Species Act, several government and private organizations, including Trout Unlimited, realize that its genetic identity is unique, should be conserved, and cannot be replaced with individuals outside of the McCloud River basin. Conserving the existing genetic diversity and improving populations of McCloud River redband trout should remain a future priority.

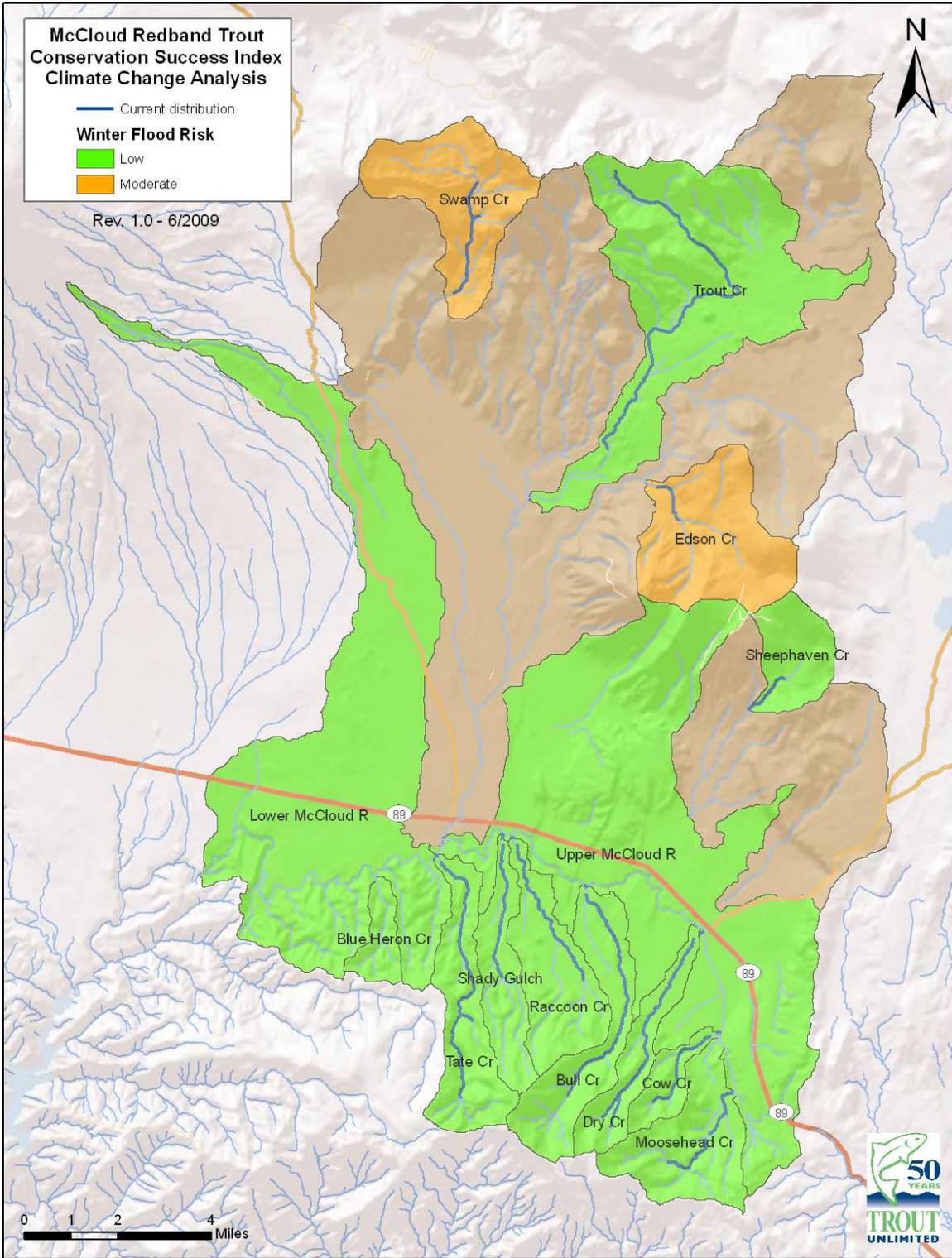
Prepared by Kurt Fesenmyer, TU, 1/27/2009

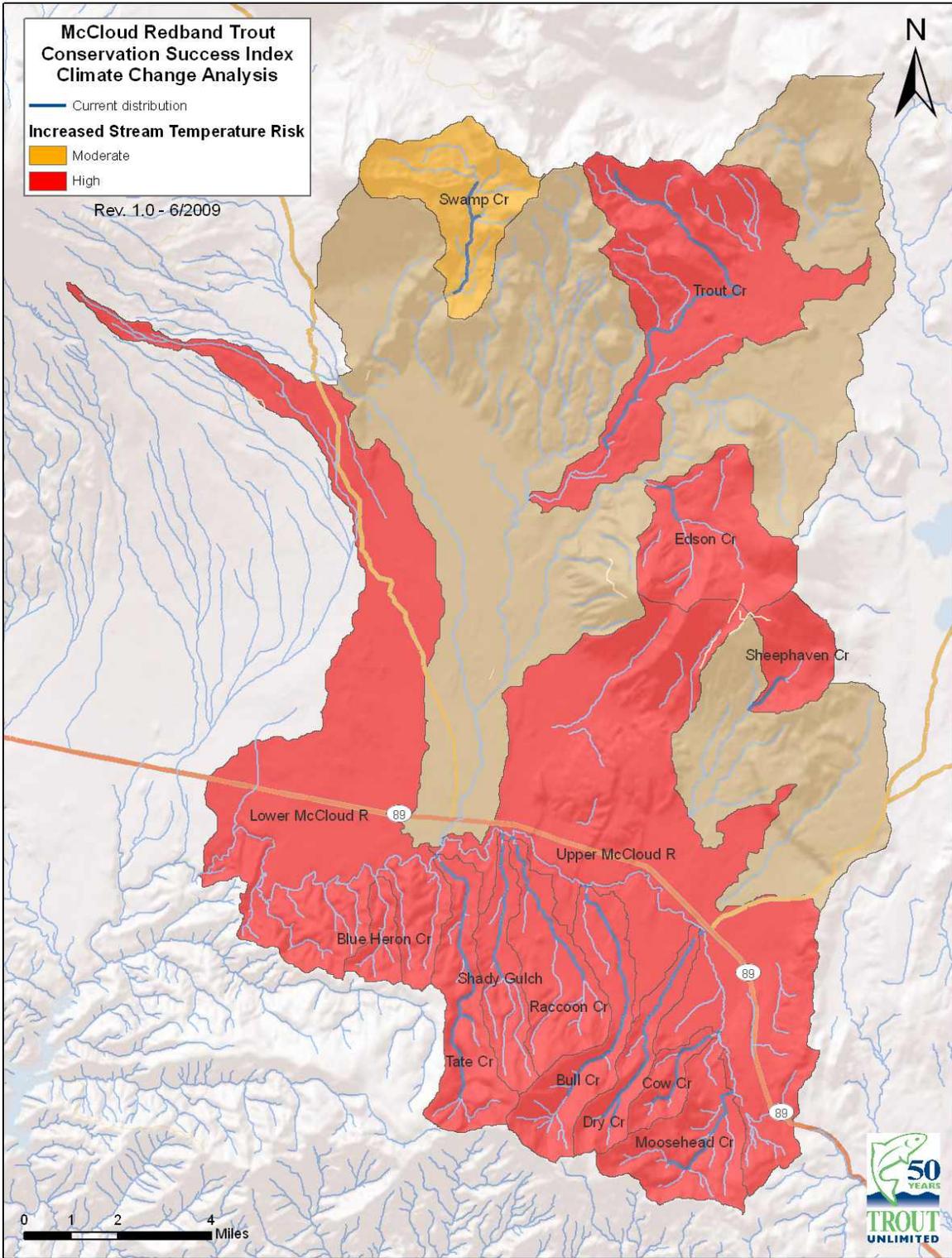
Table 1. CSI scoring results for McCloud redband trout. All indicators are scored from 1 (poorest) to 5 (best): see framework documentation for details.

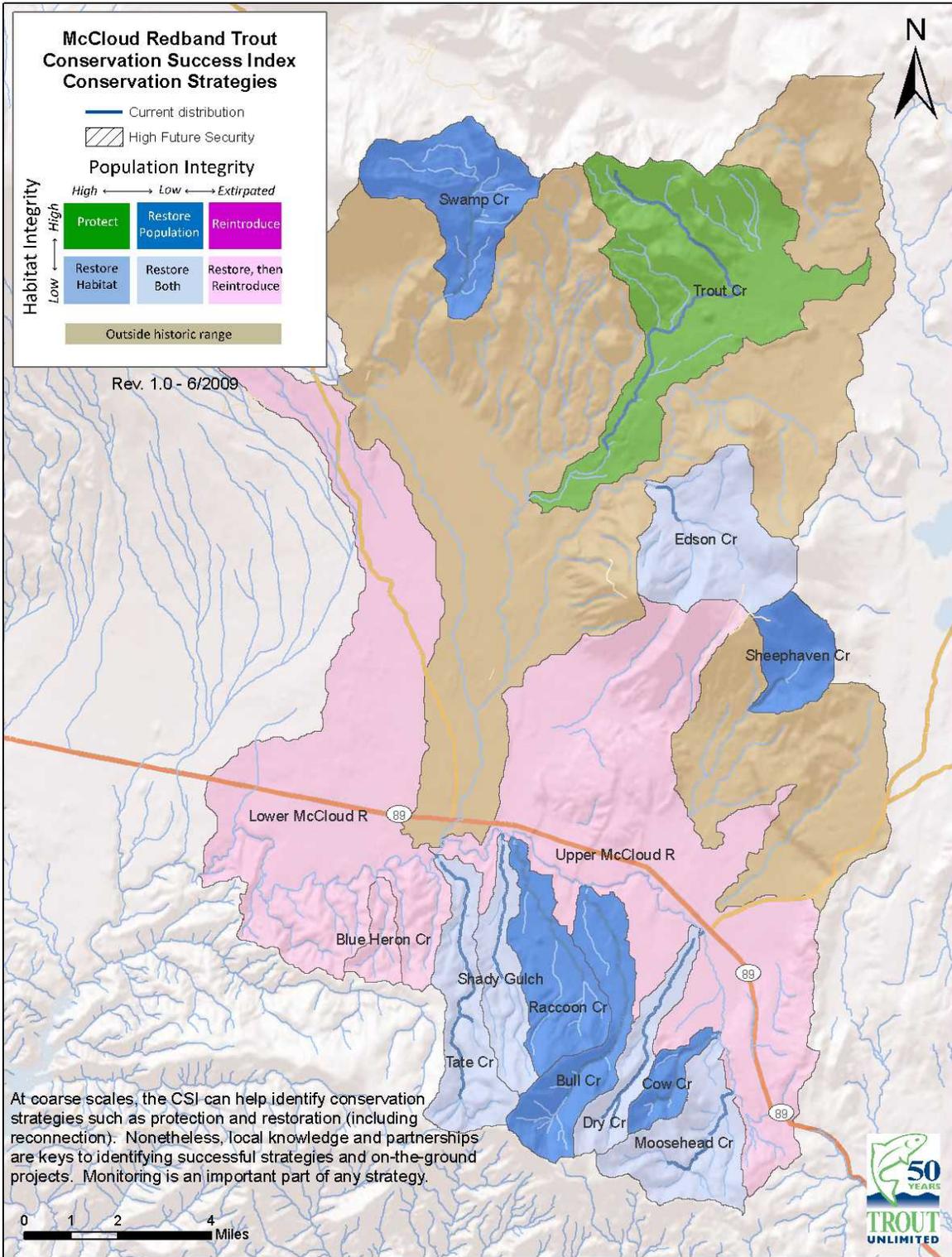
CSI Indicator	Number of Subwatersheds Receiving Scores					Total Subwatersheds Scored	
	1	2	3	4	5		
Range-wide Conditions	Percent historic stream habitat occupied	0	0	0	0	11	11
	Percent subbasins (4th) occupied	0	0	0	0	11	11
	Percent subwatersheds (6th) occupied	0	0	0	0	11	11
	Percent habitat by stream order occupied	0	0	0	0	11	11
	Percent historic lake area occupied	0	0	0	0	11	11
Population Integrity	Population Density	0	0	1	8	2	11
	Population Extent	7	3	1	0	0	11
	Genetic Purity	7	0	0	0	4	11
	Disease vulnerability	0	0	0	7	4	11
	Life history diversity	0	0	0	0	11	11
Habitat Integrity	Land Stewardship	5	1	1	0	7	14
	Watershed connectivity	0	1	0	0	13	14
	Watershed conditions	0	0	8	6	0	14
	Water quality	1	10	3	0	0	14
	Flow regime	0	0	0	1	13	14
Future Security	Land conversion	0	0	3	5	6	14
	Resource extraction	9	3	2	0	0	14
	Energy development	2	0	0	5	7	14
	Climate change	0	14	0	0	0	14
	Introduced species	10	1	3	0	0	14

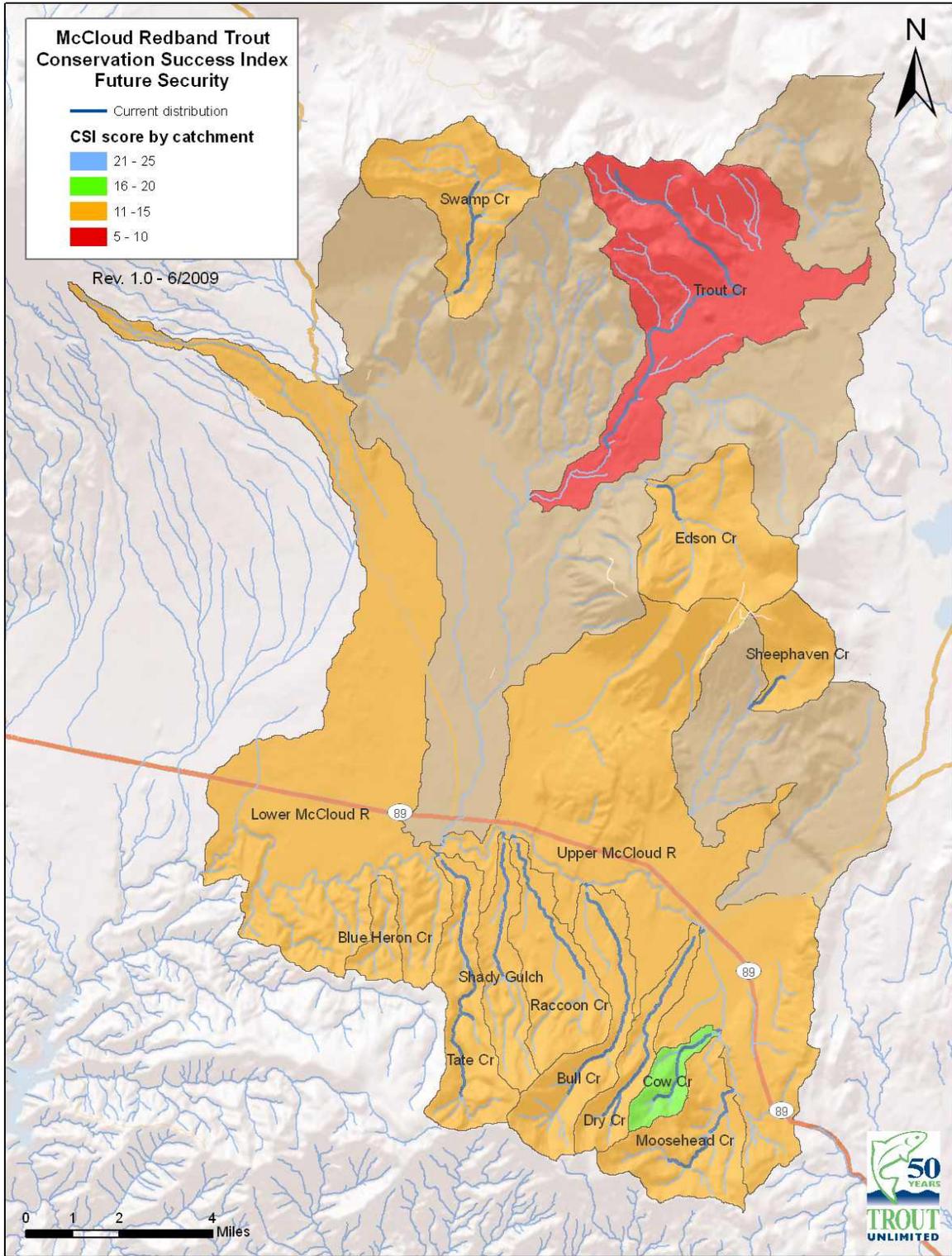


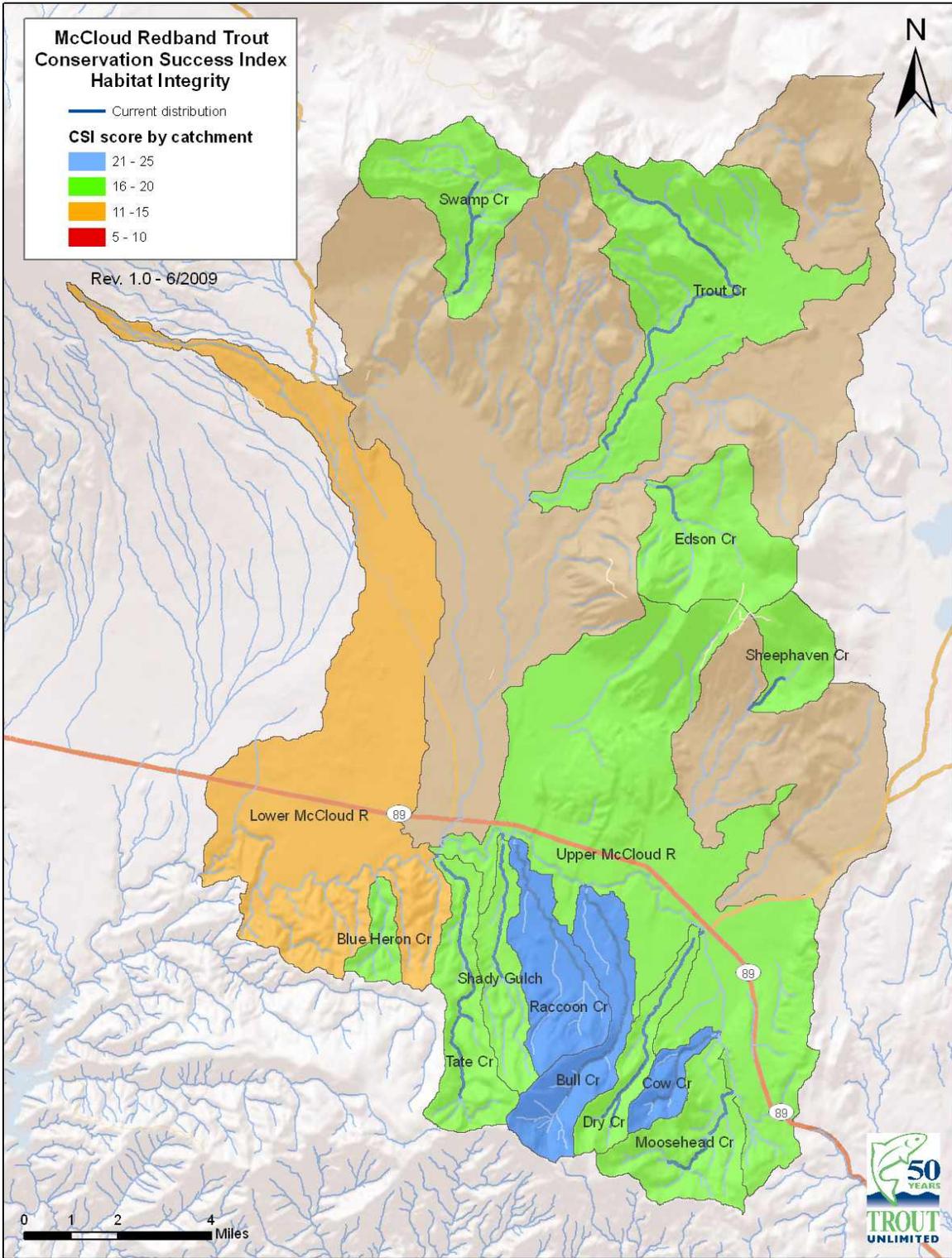


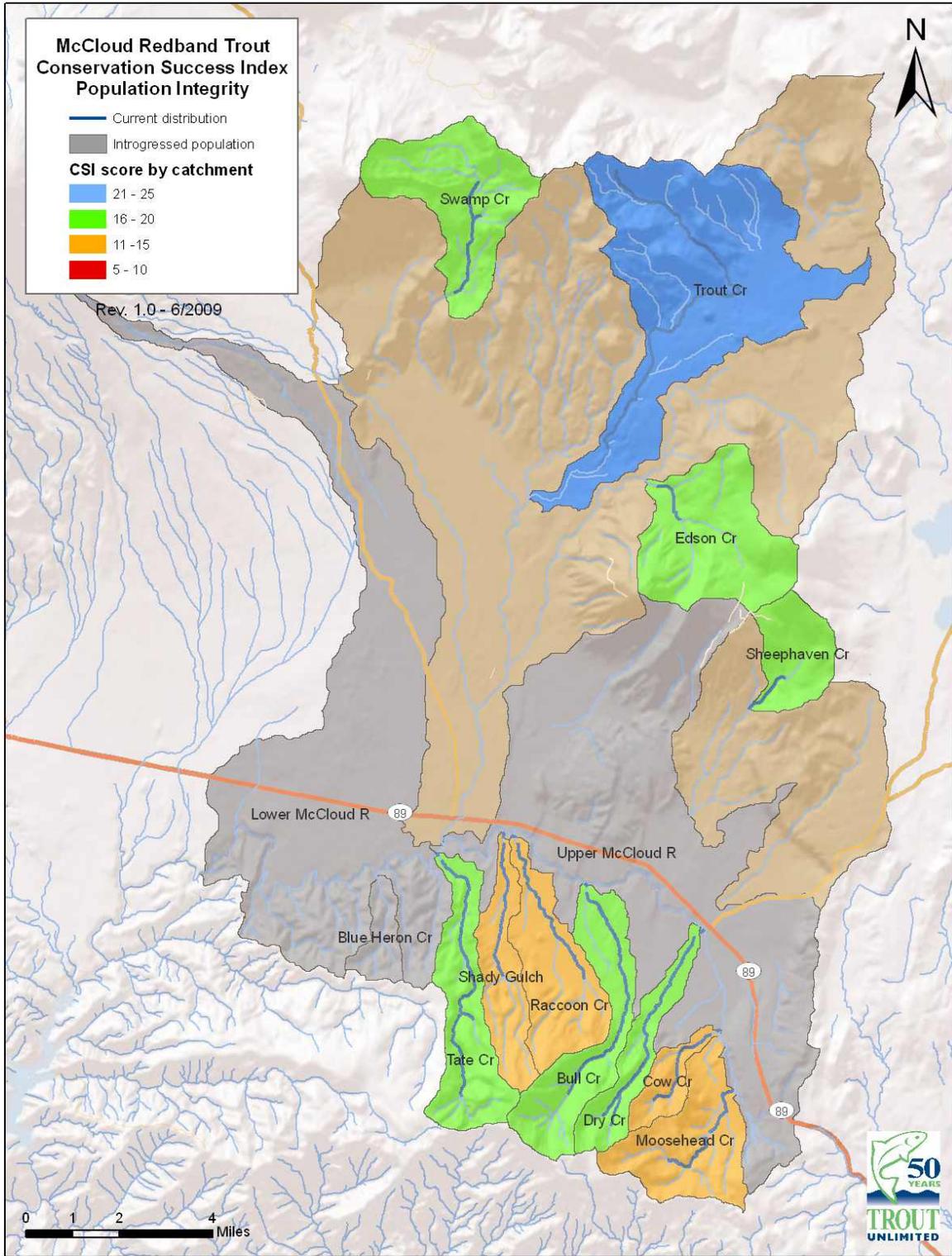


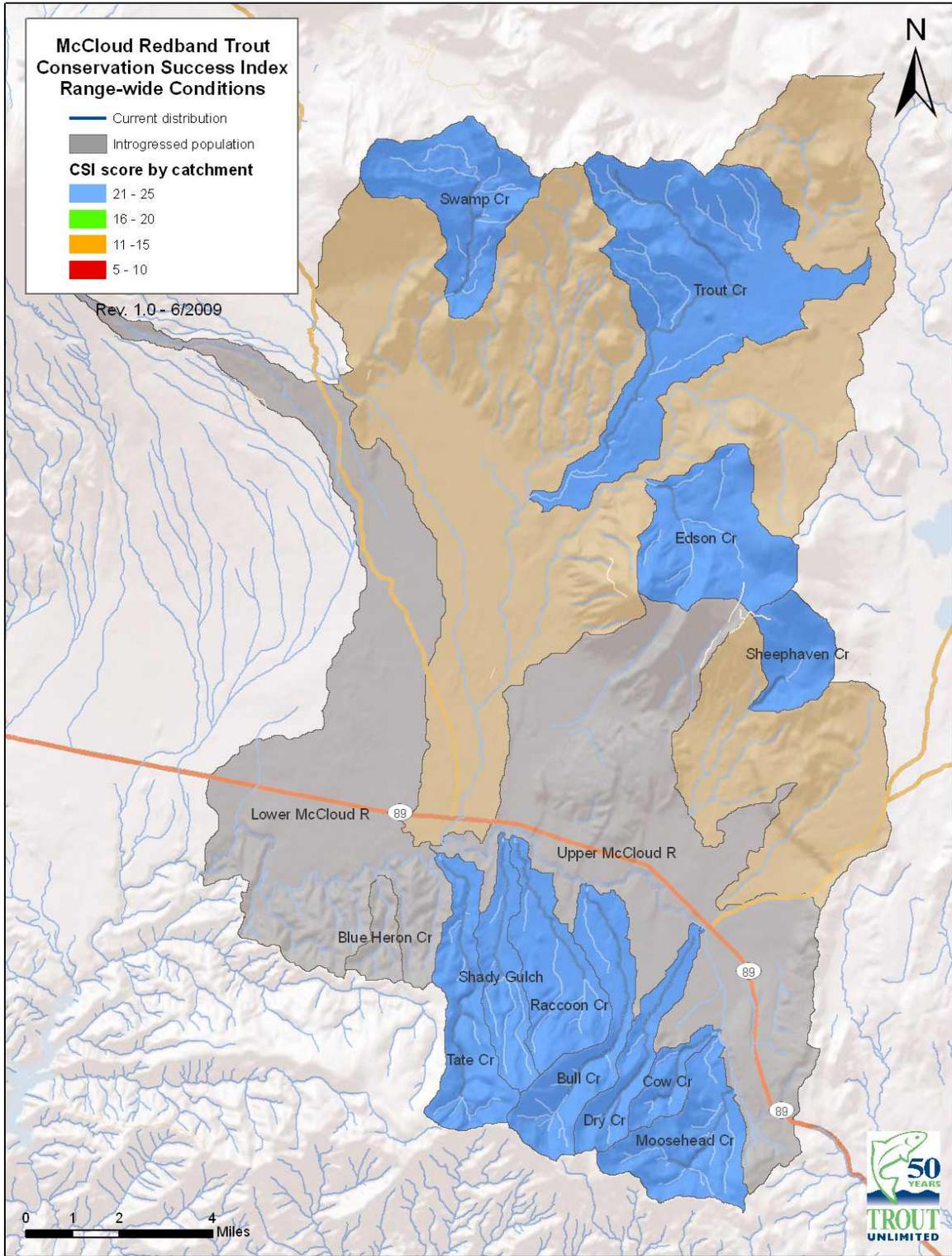


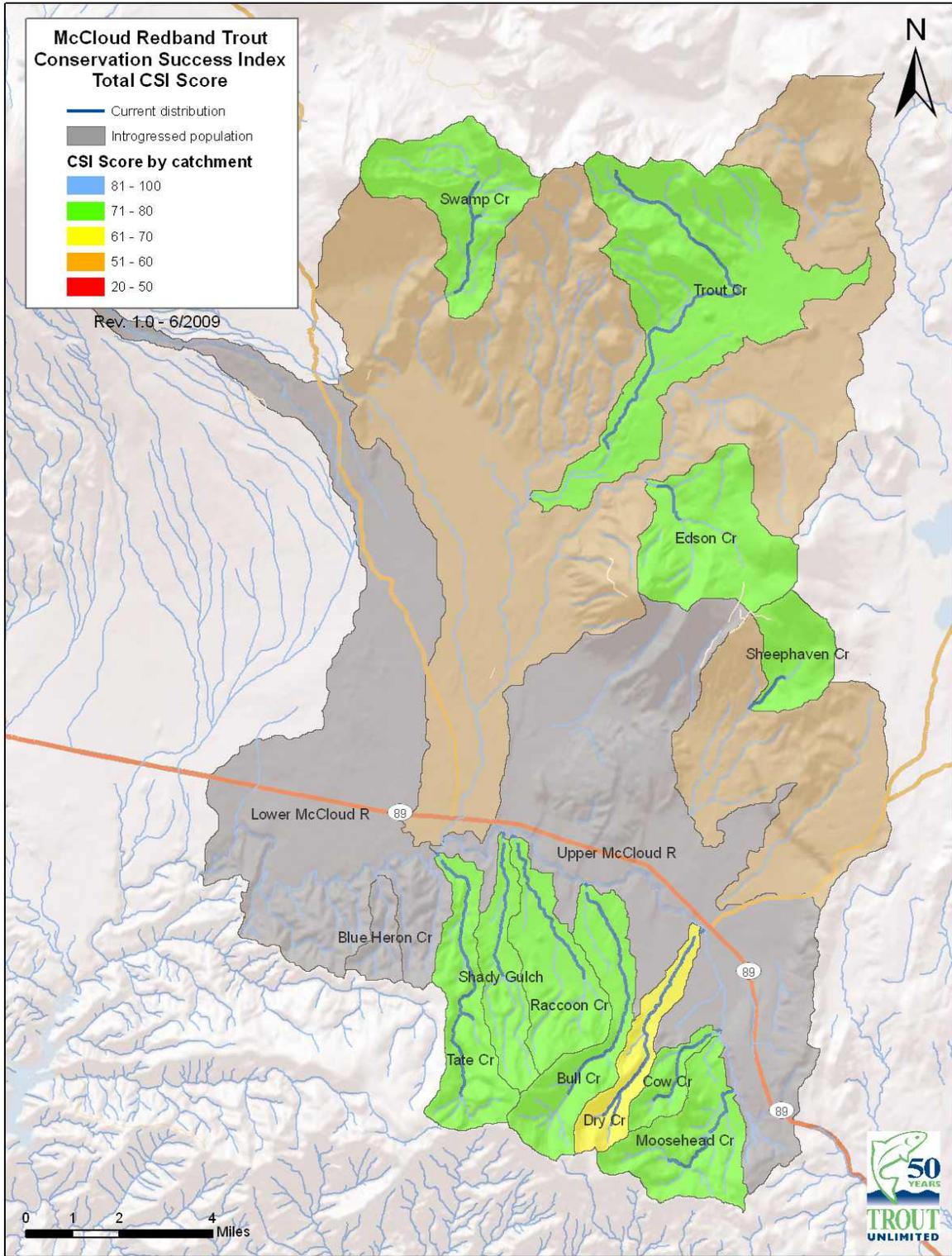












Conservation Success Index: California Native Trout: McCloud Redband Trout, Goose Lake Redband Trout, Paiute Cutthroat Trout and Eagle Lake Rainbow Trout Subwatershed Scoring and Rule Set

Introduction:

The CSI is an aggregate index comprised of four different component groups: Range-wide Condition; Population Integrity; Habitat Integrity; and Future Security. Each CSI group has five indicators that describe a specific component of each group. Each indicator is scored from 1 to 5 for each subwatershed or catchment, with a score of 1 indicating poor condition and a score of 5 indicating good condition. Indicator scores are then added to obtain the subwatershed or catchment condition for a Group, and Group scores are added for a CSI score for a subwatershed or catchment (Figure 1). CSI scores can then be summarized to obtain the general range of conditions within the historical or current distribution of the species.

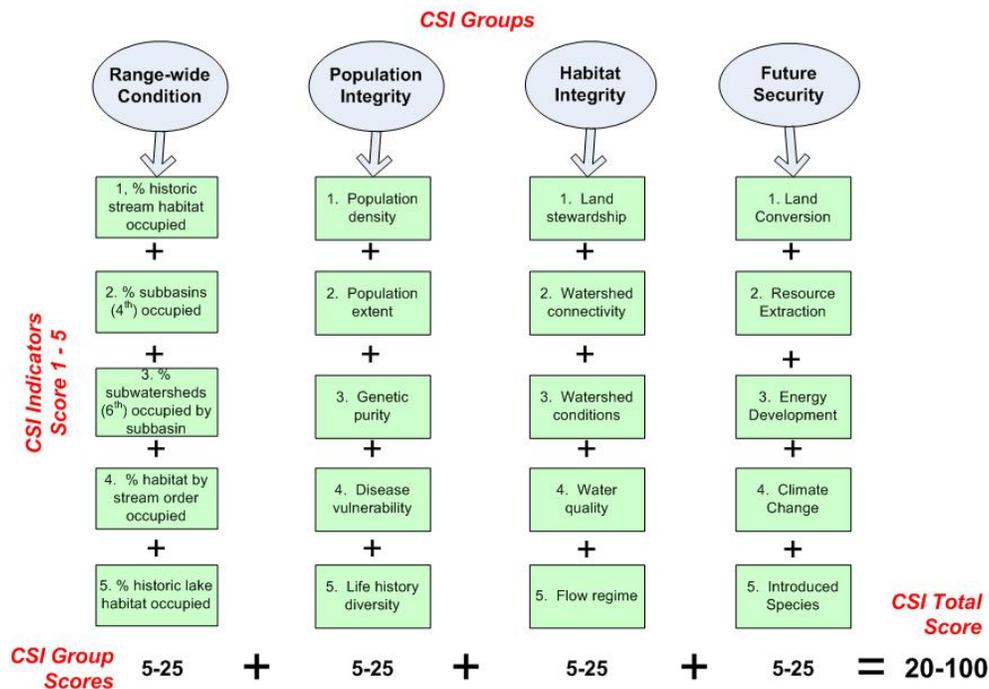


Figure 1. Each subwatershed or catchment is scored from 1 to 5 using 20 indicators within four main groups. Indicator scores are added per group to obtain an overall group score. Group scores are then added to obtain a composite CSI score for each subwatershed or catchment.

CSI Groups and Indicators

The CSI consists of four main groups of indicators:

1. Range-wide condition
2. Population integrity
3. Habitat integrity
4. Future Security

Below is an overview of each CSI group and the indicators within each group. Each section contains an overview of the group indicators

Range-wide Condition: *Indicators for range-wide condition:*

Overview:

1. Percent of historical stream habitat occupied.
2. Percent of subbasins occupied by populations.
3. Percent of subwatersheds (6th level HUC) or catchments occupied within subbasin.
4. Percent of habitat by stream order occupied.
5. Percent of lake or by surface area occupied.

Indicator: 1. Percent of historic streams occupied by populations

Indicator Scoring:

Occupied stream habitat	CSI Score
0 – 9%	1
10 – 19%	2
20 – 34%	3
35 – 49%	4
50 – 100%	5

Explanation: The percentage of streams currently occupied by the species, based on sampling data.

Rationale: Populations occupying a larger extent of habitat will have an increased likelihood of persistence.

Data Sources: The current and historical distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;¹ current and historical distribution of Paiute cutthroat trout from USFWS;^{2,3} current and historical distribution of Eagle Lake rainbow trout from Pine Creek RMPG;⁴ current distribution of Goose Lake redband from Oregon DFW⁵ and Modoc National Forest,⁶ historic distribution assumed to be all perennial streams in the upper Pit/Goose Lake system, excluding the mainstem North and South Fork Pit and mainstem Pit below Alturas; subwatersheds based on NRCS data⁷ (for Goose Lake Redband Trout); catchments based on NHD Plus⁸ (all other species).

Indicator: 2. Percent subbasins occupied.

Indicator Scoring:

Subbasins occupied	CSI Score
1-49%	1
50-69%	2
70-79%	3
80-89%	4
90-100%	5

Explanation: The percentage of historically occupied subbasins that are currently occupied by the species. The same percentage is applied to all subwatersheds or catchments scored.

Rationale: Larger river basins often contain populations functioning as distinct populations.

Data Sources: The current and historical distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;¹ current and historical distribution of Paiute cutthroat trout from USFWS;^{2;3} current and historical distribution of Eagle Lake rainbow trout from Pine Creek RMPG;⁴ current distribution of Goose Lake redband from Oregon DFW⁵ and Modoc National Forest,⁶ historic distribution assumed to be all perennial streams in the Upper Pit/Goose Lake system; subbasins based on NRCS data⁷

Indicator: 3. Percent subwatersheds or catchments occupied within subbasin.

Indicator Scoring:

Subwatersheds or catchments occupied by subbasin	CSI Score
1 – 20%	1
21-40%	2
41-60%	3
61-80%	4
81-100%	5

Explanation: The percentage of historically occupied subwatersheds or catchments that are currently occupied by the species within each subbasin. The percentage is the same for all subwatersheds within a subbasin.

Rationale: Species that occupy a larger percentage of subwatersheds or catchments are likely to be more broadly distributed and have an increased likelihood of persistence.

Data Sources: The current and historical distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;¹ current and historical distribution of Paiute cutthroat trout from USFWS;^{2;3} current and historical distribution of Eagle Lake rainbow trout from Pine Creek RMPG;⁴ current distribution of Goose Lake redband from Oregon DFW⁵ and Modoc National Forest,⁶ historic distribution assumed as all perennial streams in the Upper Pit/Goose Lake system, excluding the mainstem North and South Fork Pit and mainstem Pit below Alturas; subwatersheds based on NRCS data⁷ (for Goose Lake Redband Trout); catchments based on NHD Plus⁸ (all other species).

Indicator: 4. Habitat by stream order occupied.

Indicator Scoring:

Occupied 2 nd order streams and higher	CSI Score
0 – 9%	1
10 – 14%	2
15 – 19%	3
20 – 24%	4
25 – 100%	5

Explanation: The percentage of currently occupied habitat that is first order streams.

Rationale: Species that occupy a broader range of stream sizes will have an increased likelihood of persistence. This is especially true because small, first order streams tend to have more variable environmental conditions and smaller populations than larger streams.⁹

Data Sources: The current distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;¹ current distribution of Paiute cutthroat trout from USFWS;^{2;3} current distribution of Eagle Lake rainbow trout from Pine Creek RMPG;⁴ subwatersheds based on NRCS data⁷ (for Goose Lake Redband Trout); current distribution of Goose Lake redband from Oregon DFW⁵ and Modoc National Forest;⁶ catchments based on NHD Plus⁸ (all other species); stream order was determined using the NHD Plus.⁸

Indicator: 5. Lake habitat occupied.

Indicator Scoring:

Occupied lake habitat	CSI Score
0 – 9%	1
10 – 19%	2
20 – 34%	3
35 – 49%	4
50 – 100%	5

Explanation: Percentage of natural and artificial lakes that contain populations of wild trout.

Rationale: Lakes often harbor unique life histories and large populations that are important to long-term persistence of the species.¹⁰

Data Sources: The current distribution of McCloud Redband Trout provided by Shasta-Trinity National Forest;¹¹ current distribution of Paiute cutthroat trout from USFWS;^{2;3} current distribution of Eagle Lake rainbow trout from Pine Creek RMPG;⁴ current distribution of Goose Lake redband from Oregon DFW⁵ and Modoc National Forest⁶, subwatersheds based on NRCS data⁷ (for Goose Lake Redband Trout); catchments based on NHD Plus⁸ (all other species); lakes from the National Hydrography Dataset.¹²

Population Integrity: *Indicators for the integrity of populations.*

Overview:

1. Population density
2. Population extent
3. Genetic integrity
4. Disease vulnerability
5. Life history diversity

Indicator: 1. Population density.

Indicator Scoring:

Fish / mile	CSI Score
1 – 50 (total pop < 500)	1
1 – 50 (total pop ≥ 500)	2
51 - 150	3
151 - 400	4
>400	5

Explanation: Population density within each subwatershed or catchment. When multiple populations were present within a subwatershed or catchment, population density was calculated as a weighted average with the length of each stream occupied by a population as the weight.

Rationale: Small populations, particularly those below an effective size of 500 individuals, are more vulnerable to extirpation.^{13;14}

Data Sources: Density of McCloud Redband trout from the Draft McCloud Redband Conservation Agreement;¹⁵ density of Paiute cutthroat trout from USFWS;^{2;3} abundance data for Goose Lake redband from Oregon DFW^{16;17} and personal communication with Claude Singleton (BLM), Stewart Reid (Western Fishes), and Marty Yamagiwa (USFS); subwatersheds based on NRCS data⁷ (for Goose Lake Redband Trout); catchments based on NHD Plus⁸ (all other

species). Because of incomplete data, some subwatersheds/catchments were scored based on expert opinion considering the landscape context. Scoring rules were based, in part, on May and Albeke¹⁴ and Williams et al.¹⁸

Indicator: 2. Population extent.

Indicator Scoring:

Connectivity	CSI Score
< 6.2 mi (<10 km) connected habitat	1
6.2 – 12.4 mi (10-20 km) connected habitat	2
12.4 – 18.6 mi (20-30 km) connected habitat	3
18.6 – 31.1 mi (30-50 km) connected habitat	4
> 31.1 mi (>50 km) connected habitat	5

Explanation: Population connectivity is the amount of connected perennial streams available to the population.

Rationale: Populations with less available habitat are more vulnerable to extirpation¹⁹ as a result of small, localized disturbances.

Data Sources: Score based on extent of connected habitat for the contiguous populations using populations identified for population density (see above). McCloud barriers data from Steve Bachmann, USFS (personal communication). Paiute cutthroat barriers data from USFWS;^{2,3} Eagle Lake rainbow trout barriers described in Pine Creek RMPG;⁴ Goose Lake redband barriers from Oregon DFW²⁰ and personal communication with Claude Singleton (BLM), Stewart Reid (Western Fishes), and Marty Yamagiwa (USFS). Natural barriers from National Hydrography Dataset.²¹ Scoring rules were based, in part, on May and Albeke¹⁴ and Williams et al.¹⁸

Indicator: 3. Genetic integrity.

Indicator Scoring:

Genetic purity	CSI Score
< 80%	1
80 – 89 %	2
	3
90 – 98 %	4
99 - 100 %	5

Explanation: Genetic integrity represents the genetic purity of the population.

Rationale: McCloud Redband trout genetics from the Draft McCloud Redband Conservation Agreement;¹⁵ Paiute cutthroat genetics from UC-Davis;²² Eagle Lake rainbows are not

hybridized, but history of hatchery selection for fish size and reproduction timing degrade genetic integrity by 1 point; Goose Lake redband hybridization estimations from ODFW,²³ Claude Singleton (BLM), Stewart Reid (Western Fishes), and Marty Yamagiwa (USFS) (personal communication); subwatersheds based on NRCS data⁷ (for Goose Lake Redband Trout); catchments based on NHD Plus⁸ (all other species). Because of incomplete data, some subwatersheds/catchments were scored based on expert opinion considering the landscape context. Scoring rules were based, in part, on May and Albeke¹⁴ and Williams et al.¹⁸

Indicator: 4. Disease vulnerability

Indicator Scoring:

Disease Risk	CSI Score
Disease/pathogens present in target species	1
Disease/pathogens in habitat but not target fish	2
None present but proximity < 6.2 mi (10 km)	3
None present but proximity > 6.2 mi (10 km)	4
No diseases/pathogens present	5

Explanation: The risk of each population to disease.

Rationale: Non-native pathogens and parasites, including the myxozoan parasite that causes whirling disease, can infect native trout and reduce their populations.

Data Sources: Stocking hatchery fish contributes to the 1 point degradation of the mainstem and tributaries of the Upper McCloud. The proximity of the popular Silver King Creek fishery contributes to the 1 point degradation to the otherwise isolated populations of Paiute cutthroat. Hatchery dependent Eagle Lake rainbows = 3. Goose Lake redband considers the presence of active stocking of non-native salmonids.²³

Indicator: 5. Life history diversity.

Indicator Scoring:

Life History Diversity	CSI Score
One life history form present: resident only	1
One historical life history was lost	3
All historical life history forms present	5

Explanation: The number of life histories present in the population: resident, fluvial, adfluvial.

Rationale: Loss of life history forms, particularly migratory forms, increases the risk of extirpation and may reduce genetic diversity.^{19;24;25}

Data Sources: Life History Diversity of McCloud Redband trout based on data from the Draft McCloud Conservation Agreement²⁶ and personal communication with Steve Bachmann, USFS,

and Curtis Knight, Caltrout. Paiute cutthroat trout from USFWS.^{2,3} Eagle Lake rainbow trout from Pine Creek RMPG;⁴ Goose Lake redband from ODFW^{16,17} and Modoc National Forest. Scoring rules were based, in part, on May and Albeke¹⁴ and Williams et al.¹⁸

Habitat Integrity: Indicators for the integrity of aquatic habitats.

Overview:

1. Land stewardship
2. Watershed connectivity
3. Watershed conditions
4. Water quality
5. Flow regime

Indicator: 1. Land stewardship.

Indicator Scoring:

Protected occupied habitat*	Subwatershed protection	CSI Score
none	any	1
1 – 9%	<25%	1
1 – 9%	≥25%	2
10 – 19%	<25%	2
10 – 19%	≥25%	3
20 – 29%	<50%	4
20 – 29%	≥50%	5
≥30%	any	5

* If subwatershed only contains currently unoccupied habitat then scores are based only on subwatershed protection: <25% =1; 25 – 50%=2; >50%=5.

Explanation: The percent of occupied stream habitat AND percent subwatershed that is protected lands. Protected lands are federal or state lands with regulatory or congressionally-established protections, such as: federal or state parks and monuments, national wildlife refuges, wild and scenic river designations, designated wilderness areas, inventoried roadless areas on federal lands, Research Natural Areas, Areas of Critical Environmental Concern, others areas of special protective designations, or private ownership designated for conservation purposes.

Rationale: Stream habitat and subwatersheds with higher proportions of protected lands typically support higher quality habitat than do other lands.

Data Sources: Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas²⁷ and the U.S. Department of Agriculture, Forest Service’s National Inventoried Roadless Areas dataset.²⁸ McCloud Redband also considers areas designated as Late Successional Reserves by the Northwest Forest Plan.²⁹

Indicator: 2. Watershed connectivity.

Indicator Scoring:

Number of stream/canal intersections	Current/historical connectivity subwatershed or catchment	CSI Score
GE 12	LT 50%	1
8 – 11	50 – 74%	2
5 – 7	75 – 89%	3
1 – 4	90 – 94%	4
0	95 – 100%	5

Current/historical connectivity 4th:

- >90%: +1
 - <50%: -1
- Score for worst case

Explanation: The number of stream-canal intersections and reduction in perennial stream connectivity in the subwatershed and subbasin. Connectivity is measured by determining the longest continuous section of stream habitat uninterrupted by man-made structures impassable by fish in the subwatershed and dividing that by the longest continuous section of connected perennial stream habitat. Connectivity is also computed for the subbasin. Man-made barriers may include dams, water diversion structures, or human-caused dewatered stream segments that impede fish movement.

Rationale: Increased hydrologic connectivity provides more habitat area and better supports multiple life histories, which increases the likelihood of persistence.¹⁹ Diversions, when they do not directly inhibit fish passage, can represent false movement corridors, cause fish entrainment, and act as population sinks.^{30;31}

Data Sources: McCloud barriers data from Steve Bachmann, USFS (personal communication). Paiute cutthroat barriers data from USFWS;^{2;3} Eagle Lake rainbow trout barriers described in Pine Creek RMPG;⁴ Goose Lake redband barriers from Oregon DFW²⁰ and personal communication with Claude Singleton (BLM), Stewart Reid (Western Fishes), and Marty Yamagiwa (USFS). Stream data and additional natural barriers from National Hydrography Dataset.²¹

Indicator: 3. Watershed condition.

Indicator Scoring:

Land conversion	CSI Score
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≥30%	1
20 – 29%	2
10 – 19%	3
5 – 9%	4
0 - 4%	5

CSI score is downgraded 1 point if road density is ≥ 1.7 and < 4.7 mi/square mile.
If road density is ≥ 4.7 mi/square mile it is downgraded 2 points.

Explanation: The percentage of converted lands in the subwatershed or catchment and the density of roads.

Rationale: Habitat conditions are the primary determinant of persistence for most populations.³² Converted lands are known to degrade aquatic habitats.^{33;34} Road density is computed for the subwatershed; roads are known to cause sediment-related impacts to stream habitat.³⁵⁻³⁷ Lee et al.³⁶ recognized 6 road density classifications as they related to aquatic habitat integrity and noted densities of 1.7 and 4.7 mi/mi² as important thresholds.

Data Sources: Converted lands were determined using the National Land Cover Database,³⁸ with all Developed, Pasture/Hay, and Cultivated Crops land cover types considered to be converted lands. Road density was determined using TIGER Census,³⁹ National Forest roads data,⁴⁰⁻⁴² and Oregon BLM data.⁴³

Indicator: 4. Water quality.

Indicator Scoring:

Miles 303(d) Streams	Agricultural Land	Number Active Mines	Active oil and gas wells	Road mi/ Stream mi	CSI Score
>0	58-100%	≥10	≥ 400	0.5 – 1.0	1
	28-57%	7-9	300 – 399	0.25 – 0.49	2
	16-27%	4-6	200 – 299	0.24 - 0.10	3
	6-15%	1-3	50 – 199	0.05 – 0.09	4
	0-5%	0	0 - 49	0 – 0.04	5

Score for worst case.

Explanation: The presence of 303(d) impaired streams, percentage agricultural land, number of active mines and oil and gas wells, and miles of road within 150 ft of all perennial, intermittent, and ephemeral streams in the subwatershed.

Rationale: Decreases in water quality, including reduced dissolved oxygen, increased turbidity, increased temperature, and the presence of pollutants, reduces habitat suitability for salmonids. Agricultural land can impact aquatic habitats by contributing nutrients and fine sediments, and deplete dissolved oxygen. Mining activity can deteriorate water quality through leachates and sediments. Oil and gas development is associated with road building, water withdrawals, and

saline water discharge.^{7:28} Roads along streams can also contribute large amounts of fine sediments that smother benthic invertebrates, embed spawning substrates, and increase turbidity.^{44:45}

Data Sources: 303(d) impaired streams from USEPA.⁴⁶ The National Land Cover Database³⁸ was used to identify agricultural lands; Hay/Pasture and Cultivated Crops were defined as agricultural land. Active mines were identified by using the Mineral Resources Data System.⁴⁷ Oil and gas wells from USGS. Road density within a 150 ft buffer was computed using TIGER Census,³⁹ National Forest roads data,⁴⁰⁻⁴² and Oregon BLM data⁴³ and the National Hydrography Dataset.²¹

Indicator: 5. Flow regime.

Indicator Scoring:

Number of dams	Miles of canals	Storage (acre-ft)/stream mile	CSI Score
≥5	≥20	≥2,500	1
3 – 4	10 – 19.9	1,000 – 2,499	2
2	5 – 9.9	250 – 999	3
1	1 – 4.9	1- 249	4
0	0 – 0.9	0	5

Explanation: Number of dams, miles of canals, and acre-feet of reservoir storage per perennial and intermittent stream mile.

Rationale: Natural flow regimes are critical to proper aquatic ecosystem function.⁴⁸ Dams, reservoirs, and canals alter flow regimes.⁴⁹ Reduced or altered flows reduce the capability of watersheds to support native biodiversity and salmonid populations.

Data Sources: The National Inventory of Dams⁵⁰ provided data on dams and their storage capacity and supplemented with additional information for Lakin Dam on the McCloud River. Data on canals were obtained from the National Hydrography Dataset²¹ Perennial and intermittent streams were obtained from the National Hydrography Dataset.²¹

Future Security Indicators for the future security of populations and aquatic habitats.

Overview:

1. Land conversion
2. Resource extraction
3. Energy development
4. Climate change
5. Invasive Species

Indicator: 1. Land conversion.

Indicator Scoring:

Land Vulnerable to Conversion	CSI Score
81 – 100%	1
61 – 80%	2
41 - 60%	3
21 - 40%	4
0 – 20%	5

Explanation: The potential for future land conversion is modeled as a function of slope, land ownership, roads, and urban areas. Land is considered vulnerable to conversion if the slope is less than 15%, it is in private ownership and not already converted, it is within 0.5 miles of a road, and within 5 miles of an urban center. Lands encumbered by conservation easements are not available for conversion.

Rationale: Conversion of land from its natural condition will reduce aquatic habitat quality and availability.⁵¹

Data Sources: Slope was computed from the National Elevation Dataset.⁵² Land cover was determined from the National Land Cover Database,³⁸ and all land cover classes except developed areas and cultivated crops cover types were considered for potential conversion. Urban areas were determined using 2000 TIGER Census data,⁵³ roads from TIGER Census³⁹ and National Forest data,^{40;41} and land ownership using Public, Conservation, and Trust Lands v05.2.⁵⁴ Conservation easement data from The Pacific Forest Trust and the California Protected Areas Database.⁵⁵ Stephen’s Meadow easement manually added for Eagle Lake rainbow trout.

Indicator: 2. Resource extraction.

Indicator Scoring:

Forest management	Hard Metal Mine Claims	CSI Score
51-100%	51 -100%	1
26 – 50%	26-50%	2
11 – 25%	11-25%	3
1 – 10%	1 – 10%	4
0%	0%	5

Score for worst case.

Explanation: Percentage of subwatershed or catchment available industrial timber production and the percent of subwatershed with hard metal mining claims (assuming an average of 20 acres per claim) outside of protected areas. Protected lands include: federal or state parks and

monuments, national wildlife refuges, wild and scenic river designations, designated wilderness areas, inventoried roadless areas on federal lands, Research Natural Areas, Areas of Critical Environmental Concern, others areas of special protective designations, or private ownership designated for conservation purposes.

Rationale: Increased resource development will increase road densities, modify natural hydrology, and increase the likelihood of pollution to aquatic systems. If lands are protected then the watersheds will be less likely to be developed.

Data Sources: The number of mining claims was determined using Bureau of Land Management data,⁵⁶ and each claim was assumed to potentially impact 20 acres. Timber management potential identifies productive forest types from the existing vegetation type in Landfire⁵⁷ without formal protection as protected areas or Late Successional Reserves under the Northwest Forest Plan.⁵⁸ Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas,²⁷ and the U.S. Department of Agriculture, Forest Service’s National Inventoried Roadless Areas dataset.²⁸

Indicator: 3. Energy Development.

Indicator Scoring:

Leases or reserves	New Dams		CSI Score
	4 th	6 th	
51-100%	≥0	≥1	1
26 – 50%	3		2
11 – 25%	2		3
1 – 10%	1		4
0%	0		5

Score for worst case

Explanation: The acreage of oil, gas, and coal reserves; geothermal or wind development areas; and the number of dam sites located for potential development outside of protected areas within each subbasin and subwatershed or catchment.

Rationale: Increased resource development will increase road densities, modify natural hydrology, and increase the likelihood of pollution to aquatic systems. Changes in natural flow regimes are likely to reduce habitat suitability for native salmonids and increase the likelihood of invasion by non-native species.⁵⁹ If lands are protected then the watersheds will be less likely to be developed.

Data Sources: Wind resources (“Good” and better) from Wind Powering America/National Renewable Energy Lab (NREL).⁶⁰ Coal leases are mineable types from the Coal Fields of the United States dataset.⁶¹ Geothermal known and closed lease areas and oil and gas leases and agreements from BLM Geocommunicator.⁶² Potential dam sites are based on Idaho National

* Several geospatial data types are available from Geocommunicator, and they have the following definitions:

Laboratory (INL) hydropower potential data.⁶³ Protected areas data were compiled from the ESRI, Tele Atlas North American / Geographic Data Technology dataset on protected areas²⁷ and the U.S. Department of Agriculture, Forest Service’s National Inventoried Roadless Areas dataset.²⁸ Goose Lake redband trout also reports miles of proposed energy transmission corridor by subwatershed.⁶⁴ This value is not considered in the scoring.

Indicator: 4. Climate change.

Indicator Scoring:

TU Climate Change Analysis	
Climate Risk Factors	CSI Score
High, High, Any., Any	1
High, Any, Any, Any	2
Mod., Mod., Mod, (Mod or Low)	3
Mod, Mod, Low, Low	4
Low, Low, Low, (Mod or Low)	5

Explanation: Climate change is based on TU Climate Change analysis, which focuses on 4 identified risk factors related to climate change:

- a. Increased Summer Temperature: loss of lower-elevation (higher-stream order) habitat impacts temperature sensitive species
- b. Uncharacteristic Winter Flooding: rain-on-snow events lead to more and larger floods
- c. Uncharacteristic Wildfire: earlier spring snowmelt coupled with warmer temperatures results in drier fuels and longer burning, more intense wildfire
- d. Drought

Lease: Parcel leased for oil and gas production.

Agreement: An ‘agreement’ between operator and host (private or public) to evaluate geological, logistic, geophysical, etc issues involving a concession. The agreement essentially allows a technical evaluation of lease feasibility.

Unit Agreements: Multiple entities go in collectively on an agreement. Implied: there are limits to the number of agreements that one individual entity can have outstanding, and a unit agreement allows them to get around the limit.

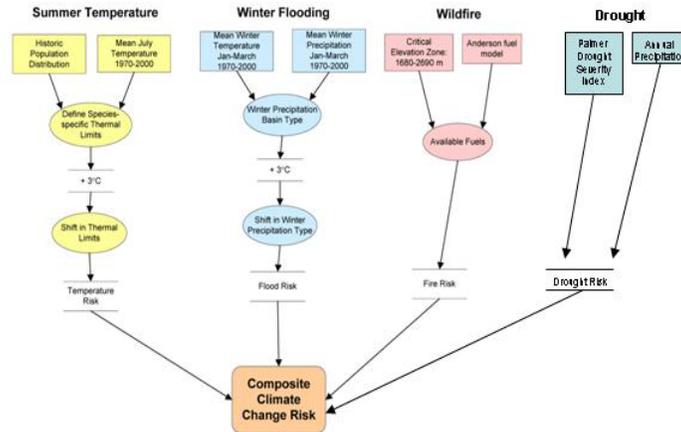
Communitization: Combining smaller federal tracts to meet the necessary minimum acreage required by the BLM (for spacing purposes).

Authorized: Bid on and sold lease or authorization, ready for production.

Lease Sale Parcel: Parcel slated for auction but not yet sold.

Closed: Not retired, just expired and may become available and open to resubmittal.

Other Agreements: Catch-all for other agreement types.



Each of the four factors is ranked as low, moderate, or high. Increased summer temperature due to climate change was modeled as a 3°C increase. Uncharacteristic winter flooding can result from basins transitioning from snow dominated to rain-on-snow dominated with increased winter flooding. Uncharacteristic wildfires result from changes in climate and fire fuels. Droughts occur as a result of increases in water-loss from higher temperatures and less precipitation.

Rationale: Climate change is likely to threaten most salmonid populations because of warmer water temperatures, changes in peak flows, and increased frequency and intensity of disturbances such as floods and wildfires.^{65;66} A 3°C increase in summer temperature has the potential to impact coldwater species occupying habitat at the edge of their thermal tolerance. Increased winter flooding can cause local populations to be extirpated. Wildfire can change aquatic habitats, flow regimes, temperatures, and wood inputs that are important to salmonids.⁶⁷ These risks are further discussed by Williams et al.⁶⁵

Data Sources: Temperature and precipitation data were obtained from the PRISM Group.⁶⁸ Elevation data were obtained from the National Elevation Dataset⁵², and LANDFIRE data for the Anderson Fire Behavior Fuel Model 13⁵⁷ was used as input for wildfire risk. McCloud redband thresholds: low < 19 C, high > 21 C. Paiute cutthroat threshold: low < 18 C. Eagle Lake rainbow: low < 20 C, high > 22 C. Goose Lake redband: low < 20 C, high > 22 C.

Indicator: 5. Introduced species.

Indicator Scoring:

Present in basin	Present in catchment/subwatershed	Road Density	CSI Score
Yes	Yes	Any	1
Yes	No	> 4.7	2
Yes	No	1.7 – 4.7	3
Yes	No	< 1.7	4
No	No	Any	5

Explanation: The presence of introduced, injurious species in a subbasin and subwatershed or catchment and road density. Road density is the length of road per subwatershed, and represents the potential for future introduction of species not native to the basin.

Rationale: Introduced species are likely to reduce native salmonid populations through predation, competition, hybridization, and the introduction of non-native parasites and pathogens.⁶⁹ In the absence of data on presence of non-native species, road density can be used as a surrogate for risk of non-native fish introductions by purpotrators.⁷⁰

Data Sources: Information on McCloud introduced species from the Draft Conservation Agreement;²⁶ Paiute cutthroat trout from USFWS;^{2;3} Eagle Lake rainbow trout from Pine Creek RMPG;⁴ and Goose Lake from ODFW²³ and Upper Pit River Watershed Assessment.⁷¹ Road density calculated for the Watershed Conditions indicator also informs the introduced species indicator.

Reference List

1. USFS. "McCloud Redband Trout distribution". 2007. USFS (internal). Contact: Jonna Cooper, jecooper@fs.fed.us.
2. US Fish and Wildlife Service, "Paiute Cutthroat Trout 5-Year Review: Summary and Evaluation" (2007).
3. US Fish and Wildlife Service, "Revised Recovery Plan for the Paiute Cutthroat Trout" (2004).
4. Teresa Pustejovsky, "A Conservation Plan for Pine Creek and Eagle Lake Rainbow Trout" (Lassen County Resource Advisory Council, 2007).
5. Flitcroft, R. L. and Dambacher, J. "Great Basin redband trout stream distribution map". 2001. Corvallis, OR, Oregon Department of Fish and Wildlife, Aquatic Inventory Project.
6. Modoc National Forest. "Threatened Endangered Species: Fish". 2007. Alturas, CA, USFS.
7. NRCS, USGS, and USEPA. "Watershed Boundary Dataset". Natural Resources Conservation Service, U.S. Geological Survey, and U.S. Environmental Protection Agency. 2008. Coordinated effort between the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA). The Watershed Boundary Dataset (WBD) was created from a variety of sources from each state and aggregated into a standard national layer for use in strategic planning and accountability. <http://datagateway.nrcs.usda.gov> [Accessed DD/MM/YYYY].
8. USEPA and USGS. "National Hydrography Dataset Plus - NHDPlus (1:100,000 scale)". 2005. Sioux Falls, South Dakota, U.S. Environmental Protection Agency and U.S. Geological Survey. <http://www.horizon-systems.com/nhdplus/>.
9. D. P. Peterson, B. E. Rieman, J. B. Dunham, K. D. Fausch, M. K. Young, "Analysis of trade-offs between threats of invasion by nonnative brook trout (*Salvelinus fontinalis*) and intentional isolation for native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*)", *Can.J.Fish.Aquat.Sci.* 65, 557-573 (2008).
10. M. K. Young, "Conservation assessment for inland cutthroat trout" *Report No. General Technical Report RM-GTR-256* (U.S. Forest Service, Fort Collins, Colorado, 1995).
11. USFS. "McCloud Redband Trout distribution". 2007. USFS (internal). Contact: Jonna Cooper, jecooper@fs.fed.us.
12. USGS and USEPA, "National Hydrography Dataset (1:24,000)" (1999).
13. M. E. Soule, *Where do we go from here? Viable populations for conservation* (Cambridge University Press, Cambridge, England, 1987).

14. B. E. May and S. Albeke, "Range-wide status of Bonneville cutthroat trout (*Oncorhynchus clarki utah*): 2004" *Report No. Bonneville Cutthroat Trout Status Update Interagency Coordination Workgroup, Publication Number 05-02* (Utah Division of Wildlife Resources, Salt Lake City, Utah, 2005).
15. USFS, "Draft McCloud Redband Trout Conservation Agreement" (USDA Forest Service R5 California, 2007).
16. Oregon Department of Fish and Wildlife. "Great Basin Redband Trout 2008 distribution and abundance". 2008. Corvallis, OR, Oregon Department of Fish and Wildlife, Native Fish Investigation Project.
17. Oregon Department of Fish and Wildlife. "Great Basin Redband Trout 2007 distribution and abundance". 2007. Corvallis, OR, Oregon Department of Fish and Wildlife, Native Fish Investigation Project.
18. J. E. Williams, A. L. Haak, N. G. Gillespie, W. T. Colyer, "The Conservation Success Index: synthesizing and communicating salmonid condition and management needs", *Fisheries* 32, 477-492 (2007).
19. W. T. Colyer, J. L. Kershner, R. H. Hilderbrand, "Movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho-Wyoming", *N.Am.J.Fish.Manage.* 25, 954-963 (2005).
20. Oregon Department of Fish and Wildlife. "Oregon Fish Passage Barriers". 2009. Salem, OR, Oregon Department of Fish and Wildlife.
21. USGS and USEPA. "National Hydrography Dataset (1:24,000)". 1999.
22. J. F. Cordes, J. A. Israel, B. May, "Conservation of Paiute Cutthroat Trout: The Genetic Legacy of Population Transplants in an Endemic California Salmonid", *California Fish and Game* 90, 101-118 (2004).
23. Oregon Department of Fish and Wildlife, "2005 Oregon Native Fish Status Report" (Oregon Department of Fish and Wildlife, Fish Division, Salem, OR, 2005).
24. J. Bascompte, H. Possingham, J. Roughgarden, "Patchy populations in stochastic environments: critical number of patches for persistence", *The American Naturalist* 159, 128-137 (2002).
25. B. E. Rieman, D. C. Lee, J. D. McIntyre, K. Overton, R. Thurow, "Consideration of extinction risks for salmonids" *Report No. Fish habitat relationships technical bulletin, Number 14* (US Department of Agriculture, Forest Service, Logan, Utah, 1993).
26. USFS, "Draft McCloud Redband Trout Conservation Agreement" (USDA Forest Service R5 California, 2007).

27. ESRI. "Protected areas (1:100,000)". 2004. Redlands, California, U.S. Tele Atlas North America, Inc. / Geographic Data Technology, Inc., ESRI.
28. USDA Forest Service. "National inventoried roadless areas (IRAs)". 2008. Salt Lake City, Utah, Geospatial Service and Technology Center, U.S. Department of Agriculture, Forest Service. http://fsgeodata.fs.fed.us/clearinghouse/other_fs/other_fs.html.
29. USFS, "Late-Successional Reserves and Managed Late Successional Areas within NWFP in California" *Accessed Dec 2008*, (USDA Forest Service - Region 5 - Remote Sensing Lab, 2006).
30. A. J. Schrank and F. J. Rahel, "Movement patterns in inland cutthroat trout (*Oncorhynchus clarki utah*): management and conservation implications", *Can.J.Fish.Aquat.Sci.* 61, 1528-1537 (2004).
31. J. J. Roberts and F. J. Rahel, "Irrigation canals as sink habitat for trout and other fishes in a Wyoming drainage", *Trans.Amer.Fish.Soc.* 137, 951-961 (2008).
32. A. L. Harig, K. D. Fausch, M. K. Young, "Factors influencing success of greenback cutthroat trout translocations", *N.Am.J.Fish.Manage.* 20, 994-1004 (2000).
33. B. B. Shepard, R. Spoon, L. Nelson, "A native westslope cutthroat trout population responds positively after brook trout removal and habitat restoration", *Intermount.J.Sci.* 8, 191-211 (2002).
34. S. M. White and F. J. Rahel, "Complementation of habitats for Bonneville cutthroat trout in watersheds influenced by beavers, livestock, and drought", *Trans.Amer.Fish.Soc.* 137, 881-894 (2008).
35. G. S. Eaglin and W. A. Hubert, "Effects of logging and roads on substrate and trout in streams of the Medicine Bow National Forest, Wyoming", *N.Am.J.Fish.Manage.* 13, 844-846 (1993).
36. D. C. Lee, J. R. Sedell, B. E. Rieman, R. F. Thurow, J. E. Williams, "Broadscale assessment of aquatic species and habitats" in *An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins: Volume III*, T. M. Quigley and S. J. Arbelbide, Eds. (USDA Forest Service, General Technical Report PNW-GTR-405, Portland, Oregon, 1997).
37. T. F. Waters, *Sediment in streams: sources, biological effects, and control* (American Fisheries Society Monograph 7, Bethesda, Maryland, 1995).
38. USGS. "National Land Cover Database". 2001. Sioux Falls, South Dakota, U.S. Geological Survey.
39. USGS. "All Roads in the Western United States (2000 TIGER) (1:100,000)". 2008. <http://sagemap.wr.usgs.gov/HumanFootprint.aspx>.

40. USFS, "California NWFP Transportation" *Accessed Dec 2008; 1:24,000*, (USDA Forest Service Pacific Southwest Region Remote Sensing Lab, 2008).
41. USFS. "Lassen National Forest Transportation". 10-1-2008. USFS.
42. Modoc National Forest. "Modoc National Forest Transportation". 2007. US Forest Service Region 5.
43. US Bureau of Land Management. "Ground Transportation Roads - Oregon and Washington". 2009. Oregon BLM State Office. Continually updated, accessed December 2008.
44. D. S. Lloyd, "Turbidity as a water quality standard for salmonid habitats in Alaska", *N.Am.J.Fish.Manage.* 7, 34-45 (1987).
45. R. J. Davies-Colley and D. G. Smith, "Turbidity, suspended sediment, and water clarity: a review", *J.Am.Water Resour.Assoc.* 37, 1085-1101 (2001).
46. USEPA. "303(d) listed waters". (2002). 2002. Washington, DC, U.S. Environmental Protection Agency.
47. USGS. "Mineral Resources Data System (MRDS) (Active)". (2005). 2008. Reston, Virginia, U.S. Geological Survey. <http://tin.er.usgs.gov/mrds/>.
48. N. L. Poff et al., "The natural flow regime", *BioScience* 47, 769-784 (1997).
49. A. C. Benke, "A perspective on America's vanishing streams", *J.N.Am.Benthol.Soc.* 9, 77-88 (1990).
50. USACE. "National Inventory of Dams". 2008. U.S. Army Corps of Engineers. <http://crunch.tec.army.mil/nidpublic/webpages/nid.cfm>.
51. S. E. Stephens et al., "Predicting risk of habitat conversion in native temperate grasslands", *Conserv.Biol.* 22, 1320-1330 (2008).
52. USGS. "National Elevation Dataset (30m) (1:24,000)". 2008. Sioux Falls, SD, USGS EROS Data Center. <http://ned.usgs.gov/>.
53. ESRI. "US MapData Places (2000 TIGER)". (1998 - 2002). 2005. Redlands, CA, ESRI.
54. California Resources Agency Legacy Project, "Public, Conservation, and Trust Lands v05.2" *1:100,000 scale*, (1-20-0007).
55. Greeninfo Network, "California Protected Areas Database (CPAD) Fee and Easement" *Draft as of Dec 2008*, (2008).
56. Hyndman, P. C. and Campbell, H. W. "BLM mining claim recordation system: mining claim density". 1996. Fort Collins, Colorado, Open-File Report 99-325. Natural Resource Ecology Laboratory, U.S. Geological Survey.

57. USFS. "LANDFIRE". (Rapid Refresh). 2008. Wildland Fire Leadership Council and U.S. Forest Service. <http://www.landfire.gov/>.
58. USFS, "Late-Successional Reserves and Managed Late Successional Areas within NWFP in California" *Accessed Dec 2008*, (USDA Forest Service - Region 5 - Remote Sensing Lab, 2006).
59. K. D. Fausch, "A paradox of trout invasions in North America", *Biol.Invasions* 10, 685-701 (2008).
60. Wind Powering America and National Renewable Energy Laboratory. "Wind Resource Potential". 2003. National Renewable Energy Laboratory, USDOE.
61. USGS. "Coal Fields of the United States". 2009. Reston, VA, USGS Eastern Energy Team, National Atlas of the United States.
62. USBLM. "Geocommunicator". 2008. USBLM and USFS. <http://www.geocommunicator.gov/GeoComm/index.shtm>.
63. INL. "Hydropower Resource Assessment". 2004. Idaho Falls, Idaho, Idaho National Laboratory.
64. Argonne National Laboratory. "West-wide energy corridor centerlines, final Programmatic EIS". 2008. Argonne National Laboratory.
65. J. E. Williams, A. L. Haak, H. M. Neville, W. T. Colyer, "Potential consequences of climate change to persistence of cutthroat trout populations", *N.Am.J.Fish.Manage.* 29, 533-548 (2009).
66. J. E. Williams, A. L. Haak, H. M. Neville, W. T. Colyer, N. G. Gillespie, "Climate change and western trout: strategies for restoring resistance and resilience in native populations" in *Wild Trout IX: Sustaining wild trout in a changing world*, R. F. Carline and C. LoSapio, Eds. (Wild Trout Symposium, Bozeman, Montana, 2007).
67. J. B. Dunham, M. K. Young, R. E. Gresswell, B. E. Rieman, "Effects of fire on fish populations: landscape perspectives on persistence of native fishes and nonnative fish invasions", *Forest Ecology and Management* 178, 183-196 (2003).
68. PRISM Group. "PRISM 800m Normals (1971 - 2000)". (1972 - 2000). 2008. Corvallis, Oregon, Oregon State University. <http://www.prism.oregonstate.edu/>.
69. K. D. Fausch, B. E. Rieman, M. K. Young, J. B. Dunham, "Strategies for conserving native salmonid populations at risk from nonnative fish invasions: tradeoffs in using barriers to upstream movement" *Report No. General Technical Report RMRS-GTR-174* (U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, 2006).
70. F. J. Rahel, "Unauthorized fish introductions: fisheries management of the people, for the people, or by the people" in *Propagated fish in resource management*, M. J. Nickum, P. M.

Mazik, J. G. Nickum, D. D. MacKinlay, Eds. (American Fisheries Society Symposium 44, Bethesda, Maryland, 2004).

71. Vestra Resources, "Upper Pit River Watershed Assessment" Redding, CA, 2004).