RECLAMATION

Managing Water in the West

Windy Gap Firming Project

Aquatic Resources Technical Report

July 2008

U.S. Department of the Interior
Bureau of Reclamation
Great Plains Region

Aquatic Resources Technical Report

Windy Gap Firming Project

prepared by:

Miller Ecological Consultants, Inc.
2111 S. College Avenue, Unit D
Fort Collins, Colorado 80525

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AQUATIC RESOURCES TECHNICAL REPORT

1.0 INTRODUCTION

The Bureau of Reclamation (Reclamation) has received a proposal from the Municipal Subdistrict, Northern Colorado Water Conservancy District, acting by and through the Windy Gap Firming Project Water Activity Enterprise (Subdistrict) to improve the firm yield of the Windy Gap Project by constructing the Windy Gap Firming Project (WGFP). The proposal includes a connection of WGFP facilities to the Colorado-Big Thompson Project. For more information on the background and purpose of the WGFP see the Windy Gap Firming Project Purpose and Need Report (ERO 2005a). This technical report was prepared to identify the potential environmental effects on water resources associated with the alternatives described below and will be used in the preparation of the environmental impact statement (EIS). Separate technical reports address water resources (ERO and Boyle 2007), lake water quality (AMEC 2008), and stream water quality (ERO and AMEC 2008).

Section 2 describes the Windy Gap Firming Project alternatives that are being evaluated in the EIS. Section 3 describes the streams and reservoirs in the study area that would be affected by the Project alternatives. Section 4 describes the objectives for this report. Section 5 describes the methods used for the impact assessment. Section 6 describes the potentially affected environment. Section 7 provides an analysis of the direct effects of the WGFP alternatives on aquatic resources, and Section 8 provides an analysis of cumulative effects.

2.0 ALTERNATIVES

The Windy Gap Firming Project Alternatives Report (ERO 2005b) identified four action alternatives in addition to the No Action alternative for evaluation in the EIS. All action alternatives include development of 90,000 AF of new storage in either a single reservoir on the East Slope, or a combination of East Slope and West Slope reservoirs. The Subdistrict's Proposed Action is the construction of a 90,000 AF Chimney Hollow Reservoir with prepositioning. The alternatives are—

- Alternative 1 (No Action) – Continuation of existing operations and agreements between Reclamation and the Subdistrict for conveyance of WG water through the Colorado-Big Thompson facilities including the enlargement of Ralph Price Reservoir by the City of Longmont
- Alternative 2 (Proposed Action) – Chimney Hollow Reservoir (90,000 AF) with prepositioning
- Alternative 3 – Chimney Hollow Reservoir (70,000 AF) and Jasper East Reservoir (20,000 AF)
- Alternative 4 – Chimney Hollow Reservoir (70,000 AF) and Rockwell/Mueller Creek Reservoir (20,000 AF)

- Alternative 5 – Dry Creek Reservoir (60,000 AF) and Rockwell/Mueller Creek Reservoir (30,000 AF)

Prepositioning, under the Proposed Action, involves the storage of Colorado-Big Thompson (C-BT) water in Chimney Hollow Reservoir. Windy Gap water pumped into Granby Reservoir would then be exchanged for C-BT water stored in Chimney Hollow. Windy Gap water stored in Chimney Hollow would be delivered and allocated to the WGFP Participants. This arrangement ensures temporary space in Granby Reservoir to introduce and store Windy Gap water. Total allowable C-BT storage would not change and the existing C-BT water rights and diversions would not be expanded. To prevent the C-BT Project from expanding their diversions through prepositioning, total modeled C-BT storage in Granby Reservoir and Chimney Hollow was limited to the capacity of Granby Reservoir, which is 539,758 AF. If this capacity limitation is reached, the model forces the C-BT Project to bypass water at Granby Reservoir. This water could then be available for diversion at Windy Gap. Therefore, under prepositioning, C-BT diversions would not be expanded with respect to their current water rights and capacity limitations.

In addition to the action alternatives, a No Action alternative was identified based on what is reasonably likely to occur if Reclamation does not approve the connection of the new Windy Gap Firming Project facilities to C-BT facilities. Under this alternative, the existing contractual arrangements between Reclamation and the Subdistrict for storage and transport of Windy Gap water through the C-BT system would remain in place. All Project Participants in the near term would maximize delivery of Windy Gap water according to their demand, Windy Gap water rights, and C-BT facility capacity constraints including availability of storage space in Granby Reservoir, and the Adams Tunnel conveyance constraints. The City of Longmont would develop storage independently for firming Windy Gap water if the WGFP is not implemented. Most Participants indicate that, in the long term, they would seek other storage options, individually or jointly, to firm Windy Gap water because of their need for reliable Windy Gap deliveries and the substantial investment in existing infrastructure.

Those Participants that do not have a currently defined storage option would take delivery of Windy Gap water whenever it is available within the capacity of their existing water systems and delivery points under the terms of the existing Carriage Contract with Reclamation and the Northern Colorado Water Conservancy District (NCWCD). Participants that would operate under this scenario include Broomfield, Central Weld County Water District, Erie, Evans, Fort Lupton, Greeley, Little Thompson Water District, Louisville, Loveland, Platte River Power Authority, and Superior. The City of Lafayette anticipates that it would withdraw from participating in the WGFP and dispose of existing Windy Gap units and not pursue acquisition of future units if the Firming Project is not constructed.

The City indicates that it would develop storage facilities for Windy Gap water independently if Reclamation does not approve a connection of WGFP facilities to C-BT facilities. The City would evaluate the enlargement of the existing Ralph Price Reservoir

(Button Rock Dam) located on North St. Vrain Creek or Union Reservoir located east of the City. The enlargement of Ralph Price Reservoir by 13,000 AF would be the City's preferred option because Union Reservoir would not have sufficient capacity for Windy Gap water and conveyance, and distribution would be more efficient from a higher elevation reservoir.

Middle Park Water Conservancy District (MPWCD), under No Action, would continue to use Windy Gap water to provide augmentation flows for other water diversions in a manner similar to current operations. Through contractual agreements with the Subdistrict, MPWCD gets 3,000 AF of Windy Gap water in Granby Reservoir each year if Windy Gap water can be diverted and storage space is available. Any water stored in Granby for MPWCD is the last Windy Gap water to spill from Granby should a spill occur.

Detailed descriptions of the components and operation of the alternatives are included in the Draft Windy Gap EIS Alternatives Descriptions report (Boyle 2005).

3.0 STUDY AREAS

The aquatic resources study area ranges from the Upper Colorado River Basin on the West Slope to the tributaries of the South Platte River on the East Slope (Figure 1).

3.1 West Slope

The West Slope study area includes the three lakes complex in the upper Colorado River, Willow Creek, and the Colorado River downstream of the Blue River (Figure 2).

3.1.1 Colorado River

The study area on the Colorado River extends from Granby Reservoir downstream below the confluence with the Blue River. This reach of the Colorado would experience changes in streamflow and water quality under the alternatives. Changes in streamflow diminish below the confluence with the Blue River relative to total flow. Therefore, the Kremmling gage below the Blue River confluence was selected as the downstream study area boundary for impact analysis (Figure 2).

3.1.2 Willow Creek

Based on information in the hydrology report (ERO and Boyle 2007), Willow Creek has the potential to be affected from Willow Creek Reservoir downstream to the confluence with the Colorado River (Figure 2). Existing data for fish and instream flow on this section of Willow Creek was used to determine impacts for this section of stream.

3.1.3 Jasper East Reservoir

The Jasper East Reservoir site is located in Grand County in Sections 8, 9, 16, and 17, T2N, R76W. The average elevation at the Jasper East site is approximately 8,100 feet. A 20,000 AF reservoir is under consideration for the study site (Figure 3).

3.1.4 Rockwell/Mueller Creek Reservoir

The Rockwell/Mueller Creek Reservoir site is located in Grand County in Sections 1 and 12 of T1N, R77W near the town of Granby. Average elevation at the Rockwell/Mueller Creek site is approximately 8,100 feet. Two reservoir sizes (20,000 AF and 30,000 AF) are under consideration for the site (Figure 3).

3.2 East Slope

3.2.1 East Slope Streams

East Slope streams that may be affected include North St. Vrain Creek below Ralph Price Reservoir and St. Vrain Creek, Big Thompson River, Big Dry Creek, and Coal Creek, (Figure 4).

3.2.2 Ralph Price Reservoir

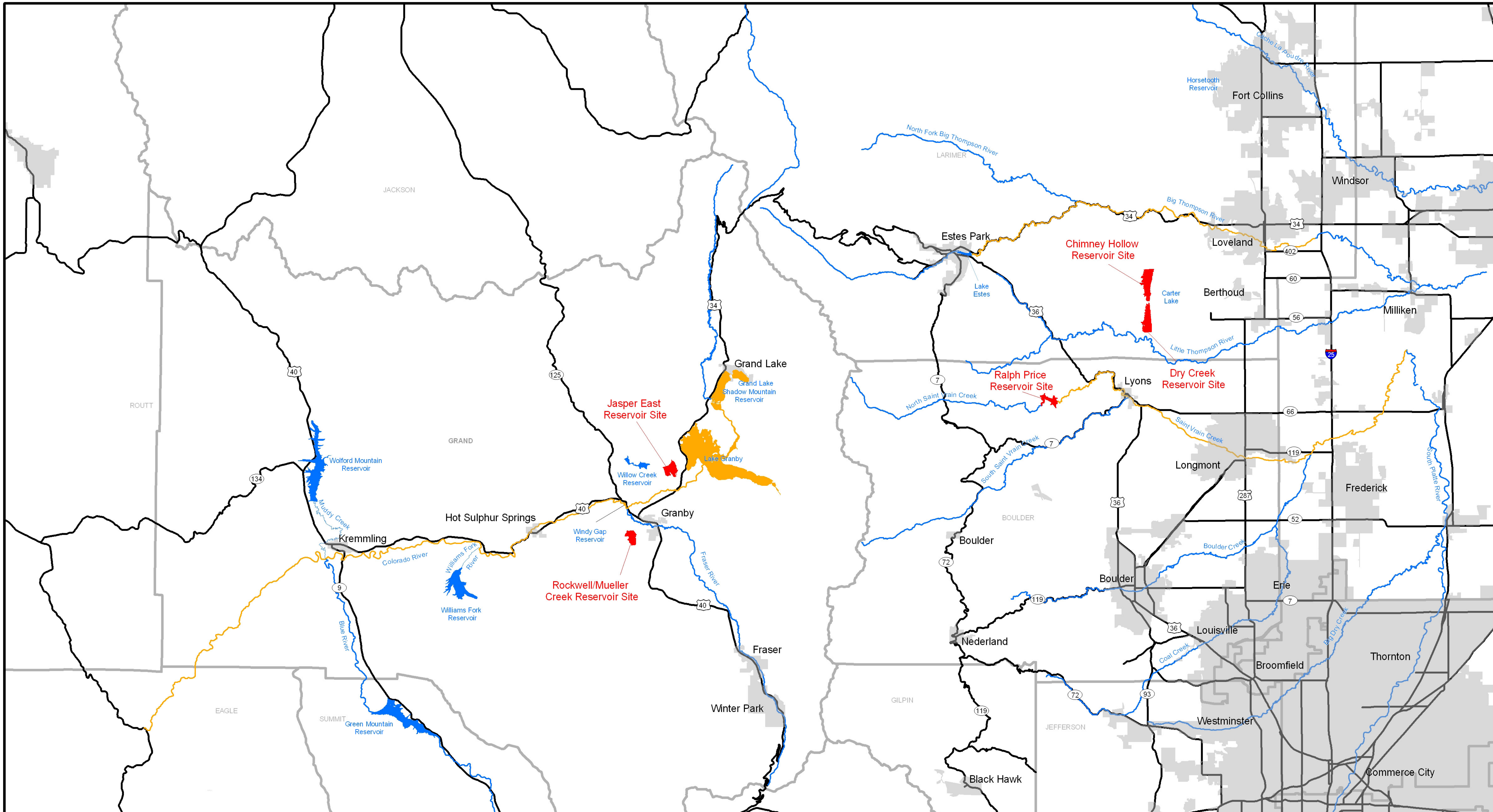
Ralph Price Reservoir (Button Rock) is located on the North St. Vrain Creek, west of the town of Lyons in Boulder County in Sections 17, 18, 19, and 20, T5N, R70W at an elevation of about 6,500 feet. Currently, the reservoir has a storage capacity of about 16,000 AF. North St. Vrain Creek, which flows into the reservoir from the west, is the primary source of water to the reservoir (Figure 4).

3.2.3 Chimney Hollow Reservoir

The Chimney Hollow Reservoir site is in Larimer County in Section 33, T5N, R70W and Sections 4, 5, and 9 of T4N, R70W. Average elevation at the Chimney Hollow Reservoir site is about 5,700 feet. Two reservoir sizes (90,000 AF and 70,000 AF) are under consideration for the site (Figure 5).

3.2.4 Dry Creek Reservoir

The Dry Creek Reservoir site is located in Sections 16, 20, 21, and 28 in Larimer County. Dry Creek is an intermittent tributary of the Little Thompson River and flows south through the valley. Average elevation of the proposed Dry Creek Reservoir is similar to the Chimney Hollow study area, approximately 5,700 feet. A 60,000 AF reservoir is under consideration for the site (Figure 5).



ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

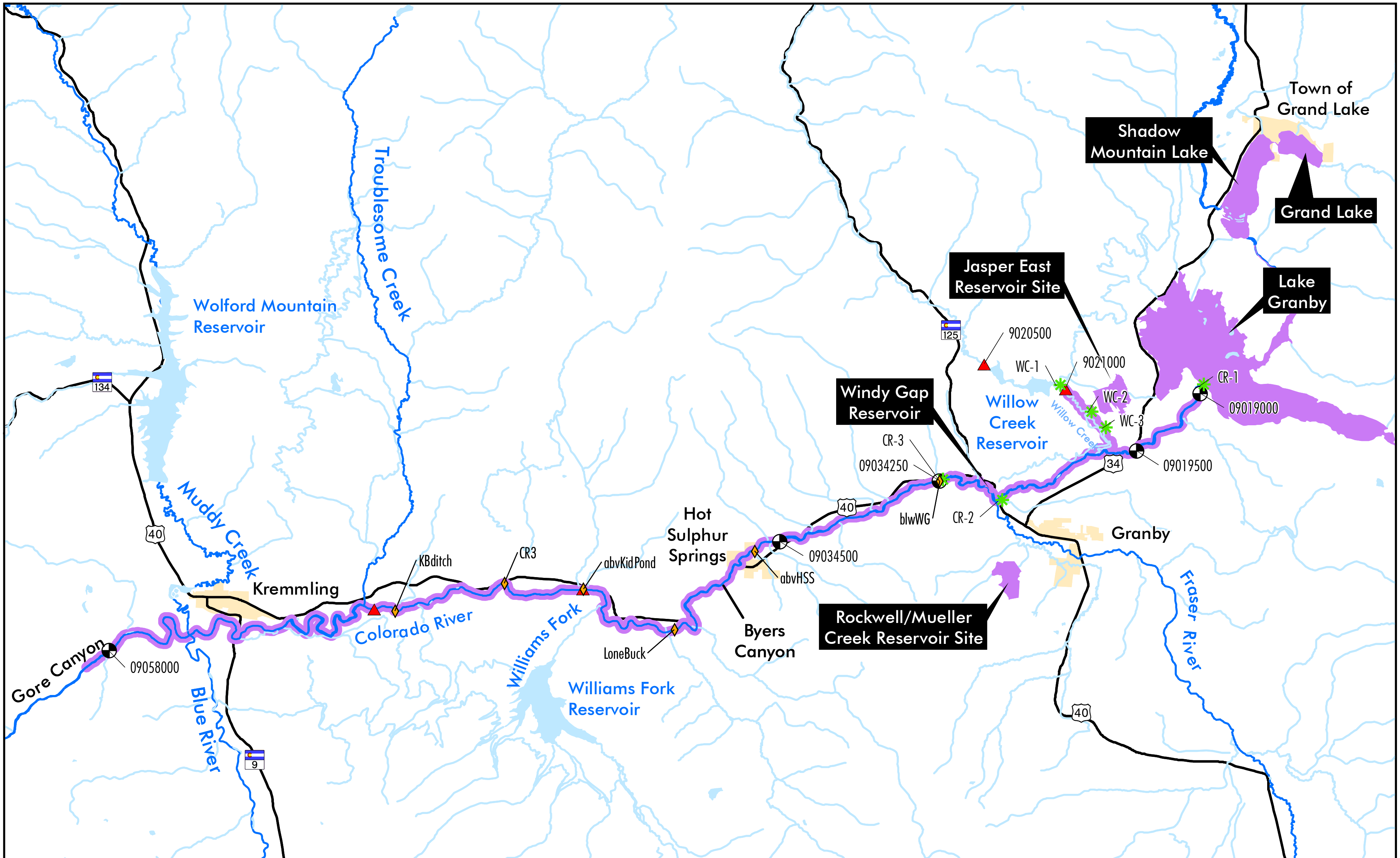
Rivers and Streams Study Area
Study Area Lakes
Potential New or Enlarged Reservoirs

0 3.5 7 Miles

N

Figure 1
Windy Gap Firming Project
Aquatic Resources
Study Area Map

Prepared for: Windy Gap Firming Project
File: Rec_Fig1_Study_Area.mxd
Date: June 2007



ERO
ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: (303) 830-1199

- NCWCD Stream Gaging Station
- USGS Stream Gaging Station and Water Quality Monitoring Location
- NCWCD Water Quality Monitoring Location
- NCWCD 2007 Stream Temperature Measurement Site
- City
- Lake or Reservoir
- Study Area Reservoir
- Study Area Stream
- Major Streams
- Minor Streams
- Highway

0 2 4 Miles

1 Inch = 4 Miles

N

Figure 2
West Slope Study Area Map

Prepared for: Windy Gap Firming Project
File: 2390 EIS\WR_WestSlopeWaterResource.mxd (JP)
November 2007

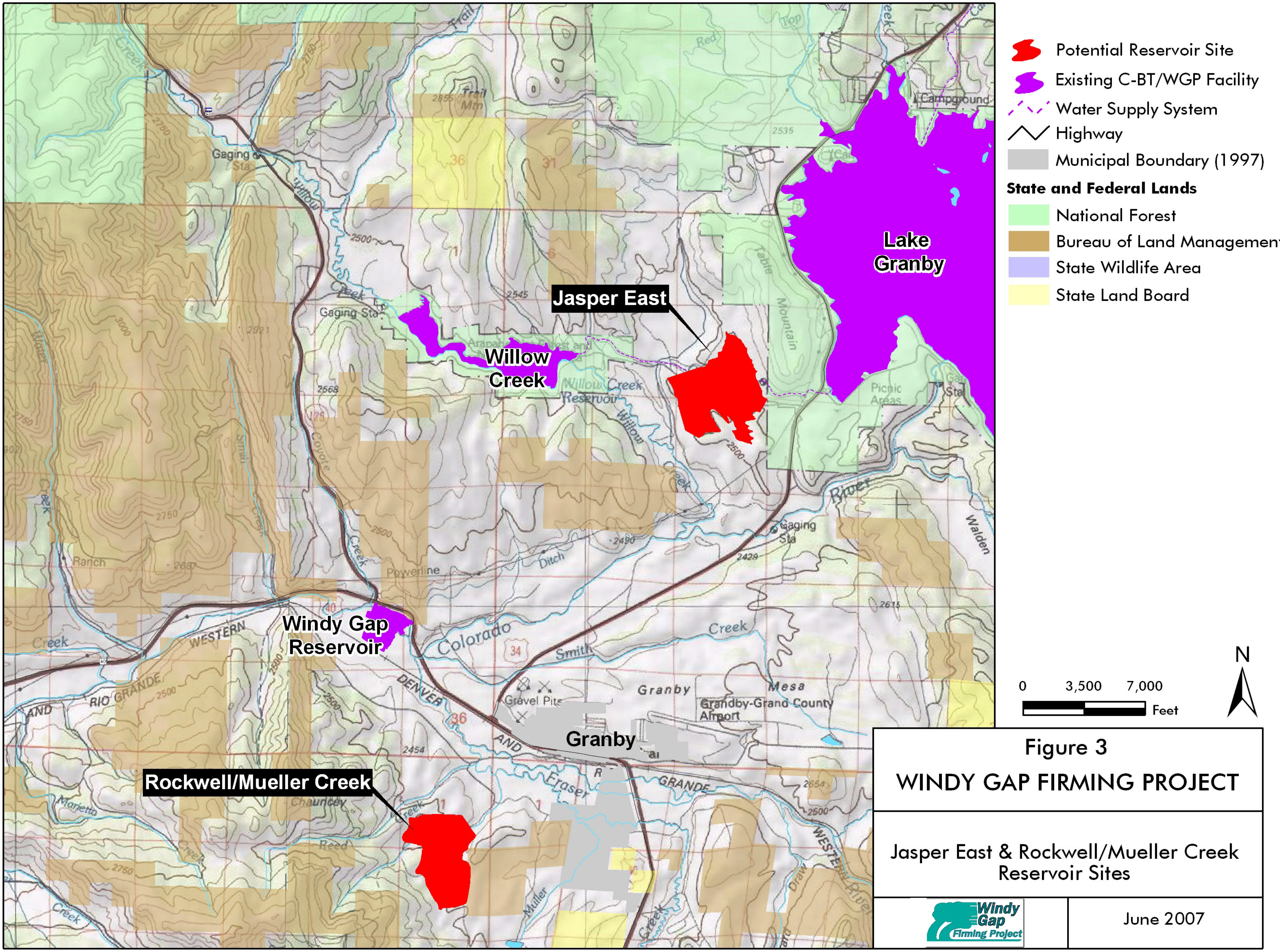


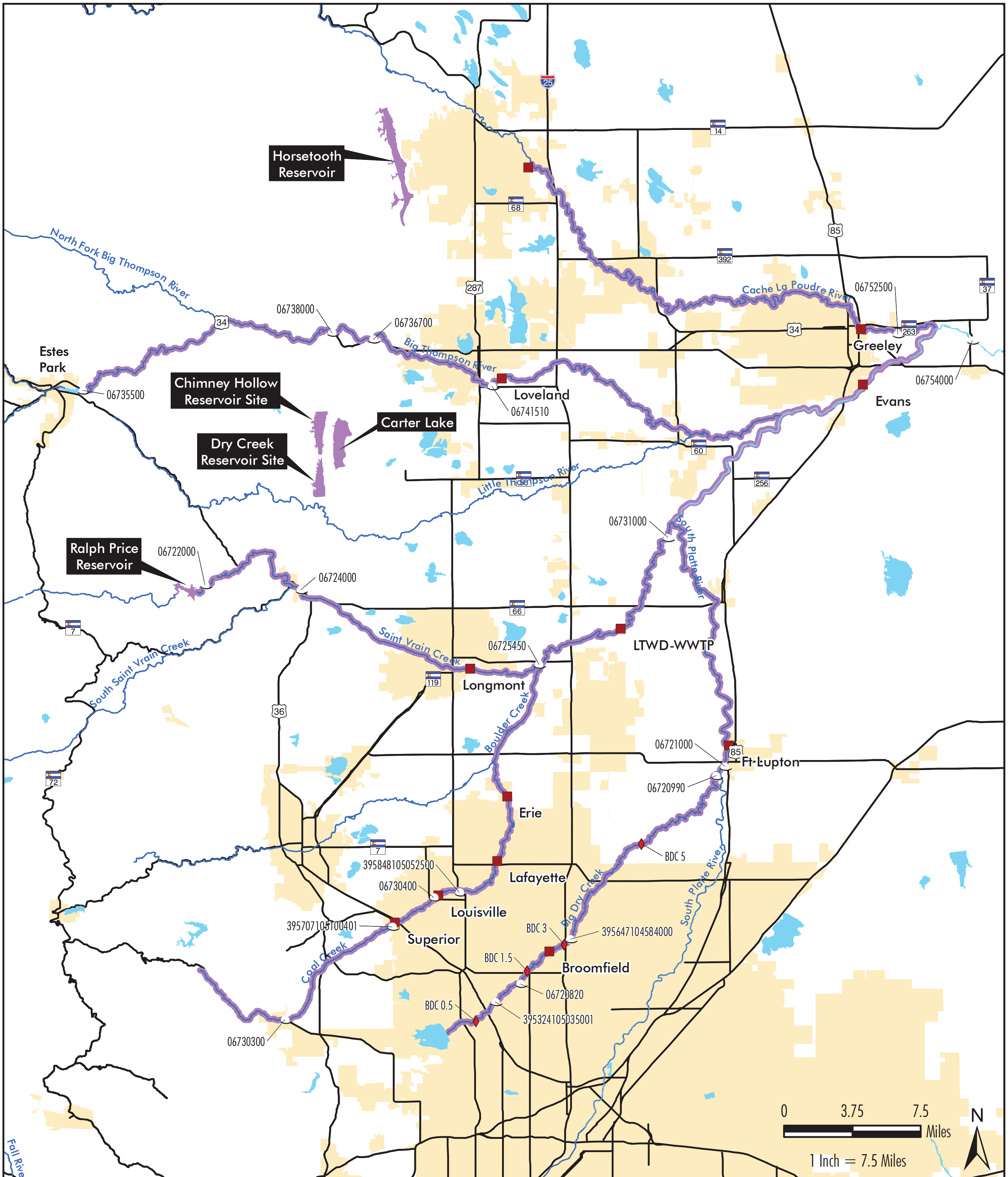
Figure 3

WINDY GAP FIRMING PROJECT

Jasper East & Rockwell/Mueller Creek Reservoir Sites

Windy Gap Firming Project

June 2007



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ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: (303) 830-1199

USGS Stream Gaging Station and Water Quality Monitoring Location

BDCWA Water Quality Monitoring Location

Waste Water Treatment Plant

Lake or Reservoir

Study Area Reservoir

Highway

Study Area Stream

Major Streams

City

Figure 4
East Slope Impacted Rivers and Creeks

Prepared for: Windy Gap Firming Project
File: 2390 EIS\WR_EastSlopeWaterResource.mxd (JP)
November 2007

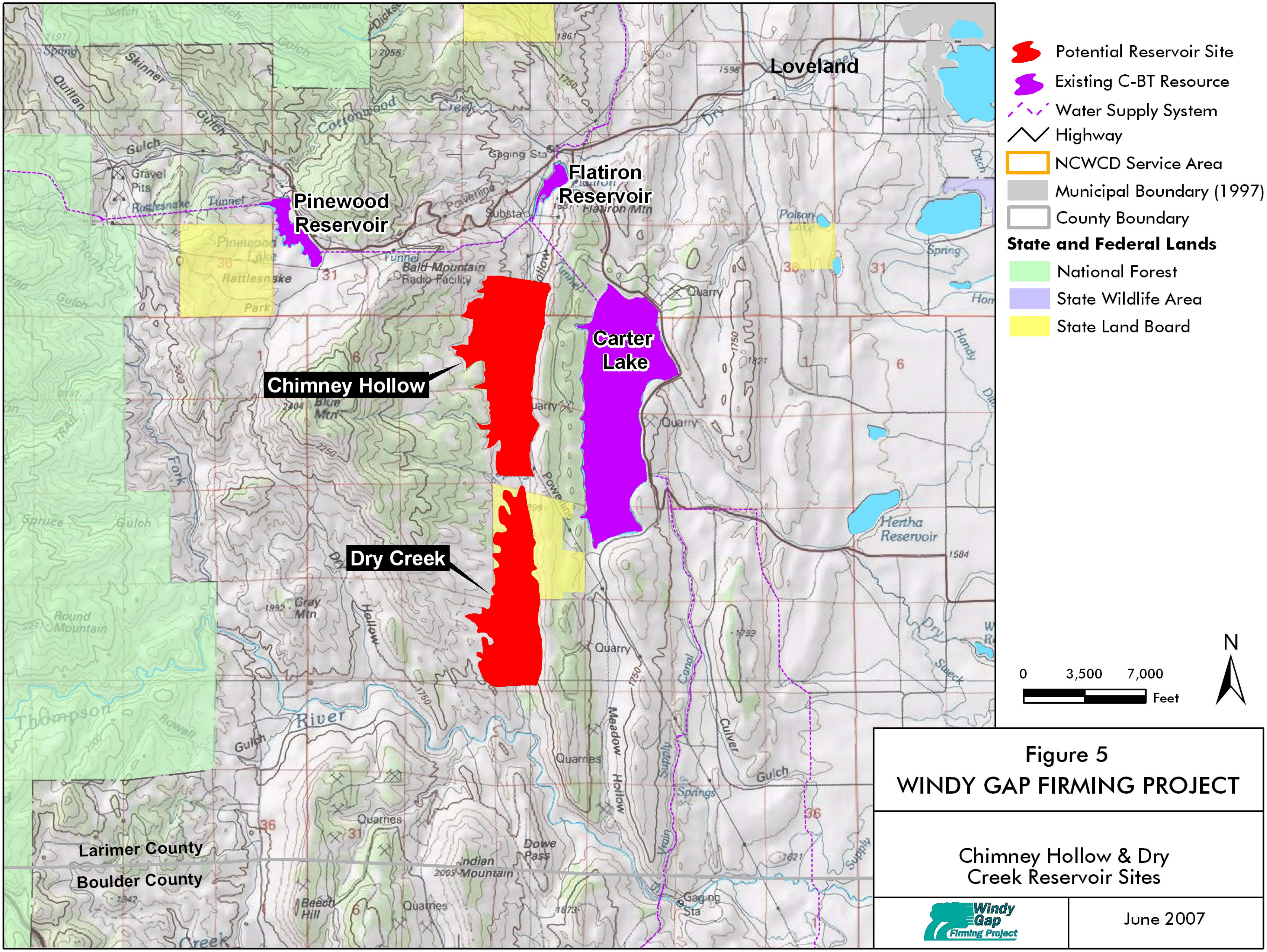


Figure 5
WINDY GAP FIRMING PROJECT

Chimney Hollow & Dry Creek Reservoir Sites

Windy Gap Firming Project

June 2007

4.0 OBJECTIVES

The purpose of this aquatic technical report is to identify potential environmental effects to aquatic resources associated with the proposed Windy Gap Firming Project alternatives. A two-dimensional hydraulic and habitat model was used to determine the relationship of habitat to flow in the Colorado River downstream of the Windy Gap project. In addition to the instream flow analysis for direct impacts, cumulative effects analysis were examined for aquatic resources that include other reasonably foreseeable projects in the project area. A third objective was to determine reservoir-related impacts for the Three Lakes (Granby Reservoir, Shadow Mountain Reservoir, and Grand Lake), Jasper East, Chimney Hollow, Dry Creek, Rockwell/Mueller Creek, Horsetooth Reservoir and Carter Lake within the Windy Gap project area. This includes impacts from assessment of changes in reservoir elevations and changes due to reservoir operations and water quality as provided by other disciplines. Stream related effects on the East Slope were assessed for direct and indirect impacts based on changes to hydrology and water quality as provided by other disciplines. Hydrologic data include information from the Water Resource Technical Report (ERO and Boyle 2007); water quality data were taken from the Lake and Reservoir Water Quality Report (AMEC 2008) and the Stream Water Quality Report (ERO and AMEC 2008).

5.0 METHODS

A variety of information sources were used to describe the Affected Environment. These sources include the Colorado Division of Wildlife (CDOW), Miller Ecological Consultants (MEC), and Northern Colorado Water Conservancy District. The type of information from these sources is listed below.

5.1 Fish Data

The fish population and fish community data within the study area is a result of fish surveys and stocking records provided by the CDOW or MEC.

5.2 Macroinvertebrates

Quantitative macroinvertebrate sampling was conducted by MEC at two sites (Lone Buck and Breeze) at the Colorado River on September 17, 2004 (see Appendix B, Figure 11). The results of macroinvertebrate analysis were used to describe benthic communities at each location. Population densities and species lists were developed for each sampling site (Appendix A). Previous studies on Willow Creek were used for a description of the macroinvertebrate community in that stream (MEC 1997). The data from macroinvertebrate sampling were used in various metrics to provide information regarding general aquatic conditions. The following metrics were used in this study:

Shannon-Weaver diversity (diversity) and evenness (evenness) values were used to detect changes in macroinvertebrate community structure. In pristine waters, diversity values typically range from near 3.0 to 4.0. In polluted waters this value is generally less than 1.0. The overall evenness value ranges between 0.0 and 1.0, with values lower than 0.3 indicative of organic pollution (Ward et al. 2002). Diversity and evenness are similar measurements because they both rely heavily on the numerical distribution of taxa, (although taxa richness also influences diversity). Both indices are designed to detect unbalance in communities (where a few species are represented by a large number of individuals). These situations are usually the result of pollution/disturbance-induced changes to the aquatic community. Diversity and evenness were used in this study to assist in the description of existing macroinvertebrate communities at each site.

The Hilsenhoff Biotic Index (HBI) is another metric that was used to measure balance in macroinvertebrate community structure. Its primary value lies in detecting organic pollution. It is derived from the proportion of taxa, and their assigned tolerance values, based on sensitivity to organic pollution (Plafkin et al. 1989). Because the structure of macroinvertebrate communities changes in different regions, the number indicating a certain water quality rating for organic pollution will vary among rivers. A comparison of the values produced within a given system provides information regarding the location and sources of potential impact from organic pollution. Values for the HBI range from 0.0 to 10.0. Lower HBI values indicate better water quality.

The Ephemeroptera, Plecoptera, Trichoptera (EPT) index was also employed to assist in the analysis of data. It is a direct measure of taxa richness among species that are generally considered to be sensitive to disturbances (Plafkin et al. 1989). Most macroinvertebrate species have specific habitat requirements. The value produced by this metric will indicate locations with preferred habitat as well as areas of disturbance or habitat modification. The EPT index is reported as the total number of distinguishable taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera found at each site. Results provided by this metric will naturally vary among river drainages, but can be valuable when describing habitat changes in a restricted area.

Taxa richness was also reported for each location in the study area. This measurement is simply reported as the total number of identifiable taxa collected from each site. It is similar to the EPT index, except that it includes all aquatic macroinvertebrate species (including those that are thought to be tolerant to disturbance). Taxa richness is useful when describing differences in habitat complexity or aquatic conditions between rivers or site locations. Taxa richness values also provide an indication of habitat preference and complexity.

A measure of macroinvertebrate standing crop at each site was determined using density and biomass. Macroinvertebrate density was reported as the mean number of macroinvertebrates/m^2 found at each location. Biomass was reported as the mean dry weight of macroinvertebrates/m^2 at each site location. Biomass values were obtained by drying macroinvertebrates from each sample in an oven at 100°C for 24 hours or until all water content had evaporated (no decrease in weight could be detected). Biomass values offer production related information in terms of quantitative weight of macroinvertebrates produced at each site. Density and biomass provide a means of measuring and comparing standing crop and provide an indication of productivity for the macroinvertebrate portion of the food web at each sampling location.

The final metric used in this study was an analysis of macroinvertebrate functional feeding groups. This process provides a measurement of macroinvertebrate community function as opposed to other metrics that measure community structure. Aquatic macroinvertebrates were categorized according to feeding strategy to determine the relative proportion of various groups. Taxa were placed into functional feeding groups based on acquisition of nutritional resources (Merritt and Cummins 1996; Ward et al. 2002). The proportion of certain functional feeding groups in the macroinvertebrate community can provide insight to various types of stress in river systems (Ward et al. 2002). In Colorado streams, the Collector-Gatherer group is usually dominant, but balanced ecosystems should provide a variety of feeding opportunities that maintain a good representation of the other functional feeding groups. Numerous variables (including habitat quality) may affect the proportions of certain functional feeding groups.

5.3 Fish Habitat Analysis

For the Colorado River, fish habitat availability was modeled for each WGFP scenario using the River2D instream-flow model (Appendix B). Two sites were selected between the Windy Gap Reservoir and the Colorado River's confluence with the Blue River. Rainbow trout and brown trout habitat availability was examined for both the juvenile and adult life stages. Daily flows for average, dry, and wet year flow conditions were modeled under the various WGFP alternatives. Daily flows were estimated by disaggregating the monthly flows based on the historical record as described in the Water Resource Technical Report (ERO and Boyle 2007).

Water quality data were obtained from other technical disciplines, in particular the water quality technical reports, for information about the existing conditions in the study area (AMEC 2008; ERO and AMEC 2008). Impacts to fish and fish habitat on both East and West slopes were also based on changes in water quality, in particular water temperature and dissolved oxygen, which would be at chronic or acute tolerance levels. Tolerance levels vary by species (Table 1). Tolerance data is not available for all species in the study area. Impacts were inferred based on data from similar species.

Potential impacts to lentic (non-flowing) fish habitat in the study area were evaluated based on the changes in trophic state, reservoir elevation, surface acreage, and water quality changes caused by the WGFP alternatives. Streamflow and water quality changes were used to qualitatively evaluate possible alterations to fish habitat from relatively minor changes in flow for East Slope streams.

Table 1. Thermal tolerance of rainbow trout, brown trout, and longnose dace.

Species	TEMPERATURE (C)																														Authors
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Rainbow Trout																																
Egg																																DeCola 1970, Danie et al 1984,
Larval												O	O	O,F	O	O	O	O	O							C						Houston 1982
Juvenile															O	O	O	O	O								C					Brown 1974,
Adult																													C			Lee and Rinne 1980
Brown Trout																																
Egg																																Brown 1974, Cherry et al 1977,
Larval																							C									Coutant 1977a, Spotila et al 1979,
Juvenile												O	O																	C		Lee and Rinne 1980, Jobling 1981,
Adult												O	O	O	O	O	O	O	O											C		Raleigh et al 1986, Carline 2001
Longnose Dace																																
Egg														O	O																	Spotila et al 1979, Brazo et al 1978
Larval																																Edwards et al. 1983
Juvenile																															C	
Adult																				O	O										C	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	

KEY:

Suitable Range	O Optimum	C Critical Maximum Temperature	F Preferred Temperature

5.4 Fish Community Analysis

Fish community analysis evaluated the potential for change in species composition at each of the potentially impacted locations. This included reservoirs, lakes, rivers, and streams. The game fish populations in these water bodies are actively managed by the CDOW for sport harvest. Management techniques include stocking and regulations to limit harvest. These management actions generally affect fish population more than environmental conditions, except for catastrophic events, such as natural or human-caused events that cause abnormally high mortality. An example of this type of event would be a winter kill under ice conditions in a reservoir or a chemical spill near a highway.

6.0 POTENTIALLY AFFECTED ENVIRONMENT

Fish populations within the study area are present in rivers, streams, lakes, and reservoirs in the upper Colorado River drainage on the West Slope and portions of the upper South Platte River drainage on the East Slope of the Rocky Mountains. Most aquatic habitats in these areas are managed as sport fisheries for salmonids (trout and/or salmon). As mentioned earlier, much of the existing data on fish populations within the study area is a product of fish surveys conducted by the CDOW. Fish species within the study area include both native and introduced species (Table 2). Prior to European settlement, Colorado River cutthroat trout was the only native trout species in the Colorado River. Rainbow and brown trout are introduced species.

6.1 West Slope Rivers and Streams

West Slope rivers and streams that may be affected by the project include the Colorado River from Granby Reservoir downstream to near Kremmling and Willow Creek. Both of these stream sections are cold water with temperatures that range between 0^{o} and 23^{o}C

(Table 3) and adequate dissolved oxygen for sustaining trout species. Discharges in the Colorado River range from a low of 43 cfs to approximately 4,300 cfs.

The historical data for dissolved oxygen and water temperature was collected at a variety of times and over a period of years. As such, the data is considered indicative of the conditions that exist at each location but is not a continuous record. While the range of the reported values has exceeded the current water quality standard, the mean values for all the data does not.

Table 2. West Slope fish species within the study area listed by water body.

West Slope Fish Species	Status N=Native I=Introduced	Colorado River	Willow Creek	Granby Reservoir	Shadow Mountain Reservoir	Grand Lake
Brown trout (*Salmo trutta*)	I	X	X	X	X	X
Rainbow trout (*Oncorhynchus mykiss*)	I	X	X	X	X	X
Lake trout (*Salvelinus namaycush*)	I			X	X	X
Kokanee (*Oncorhynchus nerka*)	I			X	X	X
Paiute sculpin (*Cottus beldingi*)	N		X			
Mottled sculpin (*Cottus bairdi*)	N	X				
Longnose dace (*Rhynichthes cataractae*)	I	X	X			
Creek Chub (*Semotilus atromaculatus*)	I	X				
Johnny darter (*Etheostoma nigrum*)	I	X				
White sucker (*Catostomus commersonii)*	I	X		X	X	X
Longnose sucker (*Catostomus catostomus*)	I	X	X	X	X	X

Table 3. Summary of stream water quality for existing conditions (ERO and AMEC 2008).

Location	Dissolved Oxygen (mg/l)		Water Temperature (C)		Discharge (cfs)
	Range	Mean	Range	Mean	Range
Colorado River below Granby	8.7-10	Na	0.5-20	9.85	13-1,520
Colorado River below Windy Gap Reservoir	4.3-12.1	9.1	3.1-17.6	7.7	43-1,162
Colorado River at Hot Sulphur Springs	7.2-13.2	9.65	0-23	7.8	48-4,310
Willow Creek	3.7-12	8.7	0-27	7.2	0.07-488
Big Thompson River at Loveland	6.1-14.2	9.6	0.5-22.5	12.4	2.3-222
St. Vrain Creek at Lyons	7.3-13.5	10	0-22	8.9	15-966

There are several flow requirements on the Colorado River. The U.S. Department of the Interior developed the Principles to Govern the Release of Water at Granby Reservoir Dam to provide Fishery Flows immediately downstream in the Colorado River. The Principles were developed "to preserve at all times that section of the Colorado River between the reservoir to be constructed near Granby Reservoir and the mouth of the Fraser River as a live stream, and also to insure an adequate supply for irrigation, for sanitary purposes, for the preservation of scenic attractions, and for the preservation of fish life." The schedule of releases from Granby Reservoir is summarized as follows: 20 cubic feet per second (cfs) from September through April; 75 cfs from May through July; and 40 cfs in August. The bypass flow requirement may be reduced from May through September when the advanced forecast of inflow to the Three Lakes system and Willow Creek Reservoir is less than 230,000 AF (Secretarial Decision Document 1961).

A Memorandum of Understanding (June 23, 1980) between the Municipal Subdistrict, NCWCD, and CDOW established instream flow requirements on the 24-mile reach of the Colorado River downstream of the WGFP to the mouth of the Blue River to support the fishery. These instream requirements include—

- From the Windy Gap Diversion Point to the mouth of the Williams Fork River: 90 cfs
- From the mouth of the Williams Fork River to the mouth of Troublesome Creek: 135 cfs
- From the mouth of Troublesome Creek to the mouth of the Blue River: 150 cfs

The Subdistrict would not be required to bypass water in excess of natural inflow to the Windy Gap diversion. In addition, the MOU includes flushing flows of 450 cfs for 50 hours during the period of April 1 through June 30 are required once every 3 years if equivalent flows do not otherwise occur.

6.1.1 Colorado River

6.1.1.1 Fish

The Colorado River between Windy Gap Reservoir and Kremmling, Colorado, is managed by the CDOW as a sport fishery for brown trout and rainbow trout. The reach from Windy Gap Reservoir to Troublesome Creek is designated as “Gold Medal” waters. Special regulations include a two-fish bag and possession limit from Granby Dam downstream to the lower boundary of Byers Canyon, and from the Troublesome Creek confluence downstream to Rifle, Colorado. The section between the lower boundary of Byers Canyon and the Troublesome Creek confluence is catch and release fishing with artificial flies and lures only. A recent fish survey (CDOW 2002 unpublished data) in the Colorado River from Windy Gap Reservoir downstream to Kremmling, Colorado, indicated that brown trout and rainbow trout were two of the dominant fish species at each sampling location (Tables 4, 5, 6, and 7). Two nonnative sucker species, white sucker and longnose sucker, were also consistently reported throughout this reach. One nonnative minnow, longnose dace (*Rhynichthes cataractae*), was found throughout the reach, while other small fish that were occasionally collected included; johnny darter (*Etheostoma nigrum*), creek chub (*Semotilus atromaculatus*), and mottled sculpin (*Cottus bairdi*). The habitat conditions are generally favorable for all the fish species collected. Brown trout populations in the Colorado River between Parshall and Sunset between 2001 and 2007 where data is available ranged from about 4,100 fish per mile to more than 11,000 fish per mile (Table 6). The trout populations are very high and comparable to the best fisheries in the western United States.

6.1.1.2 Macroinvertebrates

For baseline conditions, all metrics used in this study indicated that aquatic conditions were excellent at the Breeze and Lone Buck study locations. Diversity, evenness, and HBI values are commonly used to describe macroinvertebrate communities in western streams, and they are good indicators of pollution but not necessarily good indicators of impacts from regulated flows. These metrics indicated that aquatic conditions were excellent at both sites, with the best values for each metric occurring at the Breeze site (Table 8).

The number of individuals in the orders EPT and taxa richness also indicated that conditions were excellent at both sites. More than 40 identifiable taxa were collected at each site with over half being representatives of the EPT groups. Taxa richness and EPT are sensitive to a variety of disturbances including alterations in habitat. The thermal influence of the Williams Fork River (increased winter temperatures) at the Breeze site may be responsible for slightly elevated metric values.

Density and biomass measurements supported the findings of the other metrics applied in this study area. Values produced by these metrics indicated that numerically large benthic communities with high biomass were present at both sites. Density values were highest at the Breeze site while biomass was highest at Lone Buck. The inconsistency between these metrics can be mostly attributed to the abundance of the stonefly, *Pteronarcys californica*. Although this species is not numerically dominant, its large size makes it an important part of the biomass. The greater density of *Pteronarcys californica* at the Lone Buck site resulted in a greater overall biomass of macroinvertebrates at that site.

Table 4. Fish survey (electro-fishing) data from the Colorado River downstream of Windy Gap Reservoir from September 23-24, 2002.

Species	Hitching Post		Chimney Rock		Doucette's		Pioneer Park		Lone Buck		Parshall - Sunset	
	% of Catch	#/Mile	% of Catch	#/Mile	% of Catch	#/Mile	% of Catch	#/Mile	% of Catch	#/Mile	% of Catch	#/Mile
Johnny darter	-	-	p	p	-	-	-	-	-	-	-	-
Creek chub	-	-	-	-	<1	5	p	p	p	p	-	-
Longnose sucker	20	700	p	p	5	56	10	649	1	9	p	P
Longnose dace	P	p	p	p	p	p	p	p	p	p	p	p
Brown trout	54	1,884	86	1,209	80	938	64	3,771	87	1,157	96	10,041
Rainbow trout	15	511	13	186	15	166	13	760	12	151	2	667
Mottled sculpin	9	305	p	p	-	-	-	-	-	-	-	-
White sucker	3	102	1	11	p	p	13	747	p	p	1	318

Source: Colorado Division of Wildlife unpublished data
"p" indicates that the species was present in collections but relative abundance was not determined.
Percent of catch for Hitching Post adds to 108 percent.

Table 5. Population Estimates for brown trout greater than 6 inches in length for the Parshall to Sunset reach of the Colorado River (Ewert 2008).

Year	Fish/mile
2001	4,137
2002	9,637
2003	11,162
2004	4,782
2007	7,708

Table 6. Colorado Division of Wildlife estimates for density and biomass (numbers per hectare) of brown and rainbow trout at the Lone Buck Wildlife Area, Colorado River.

Year	Brown Trout			Rainbow Trout		
	Kg/Ha	N/Ha	N/Ha≥35 cm	N/Ha	Kg/Ha	N/Ha≥35 cm
1979	15	30	---	230	148	---
1981	14	23	10	98	31	20
1982	17	27	17	88	32	33
1983	39	63	13	80	45	21
1984	22	57	14	180	54	36
1985	8	22	2	107	44	42
1986	23	53	20	184	73	87
1988	33	51	31	543	217	250
Mean 79-88	21.4	40.8	15.3	188.8	80.5	69.9
1994	46	234	12	94	51	59
1995	14	41	12	53	24	32
1996	59	213	40	33	17	21
1997	36	210	16	33	8.6	10
1998	48	274	15	12	5.6	6
2000*	57	130	47	19	7.5	6
Mean 94-00	43.3	183.7	23.7	40.7	19.0	22.3
2001	143	485	124	30	11	12
2002	157.9	386	53	21	21.8	11

Source: Nehring and Thompson 2003
The mean values summed by pre-(1979-1988) and post-infection (1994-2000) years illustrate community response to whirling disease.
*No sampling in 1999 due to high water conditions.

Table 7. Colorado Division of Wildlife estimates for density and biomass (numbers per hectare) of brown and rainbow trout at Kemp/Breeze Ranches, Colorado River.

Year	Brown Trout			Rainbow Trout		
	Kg/ha	N/ha	N/ha≥35 cm	Kg/ha	N/ha	N/ha≥35 cm
1981	82	294	36	231	889	185
1982	48	175	53	124	410	173
1983	42	127	25	81	202	86
1984	35	150	11	78	210	78
1985	55	142	34	94	170	115
1986	44	106	33	109	277	111
Mean 81-86	51	166	32	120	360	125
1993	91	283	51	128	162	154
1994	119	428	49	53.1	67	65
1995	224	837	138	41.2	53	50
1996	190	505	164	19.9	25	24
1997	162	373	149	17.0	25	23
1998	224	632	142	15.3	31	13
1999	224	842	199	19.7	45	18
2000	232	699	248	11.5	23	17
Mean 93-00	183.3	574.9	142.5	38.2	53.9	45.5
2001	235	721	211	17.6	31	25
2002	419.4	1,682	291	58.0	118	73

Source: Nehring and Thompson 2003
The mean values summed by pre-(1981-1986) and post-infection (1993-2000) years illustrate community response to whirling disease.

Table 8. Metric values for macroinvertebrate samples collected from the Colorado River on September 17, 2004.

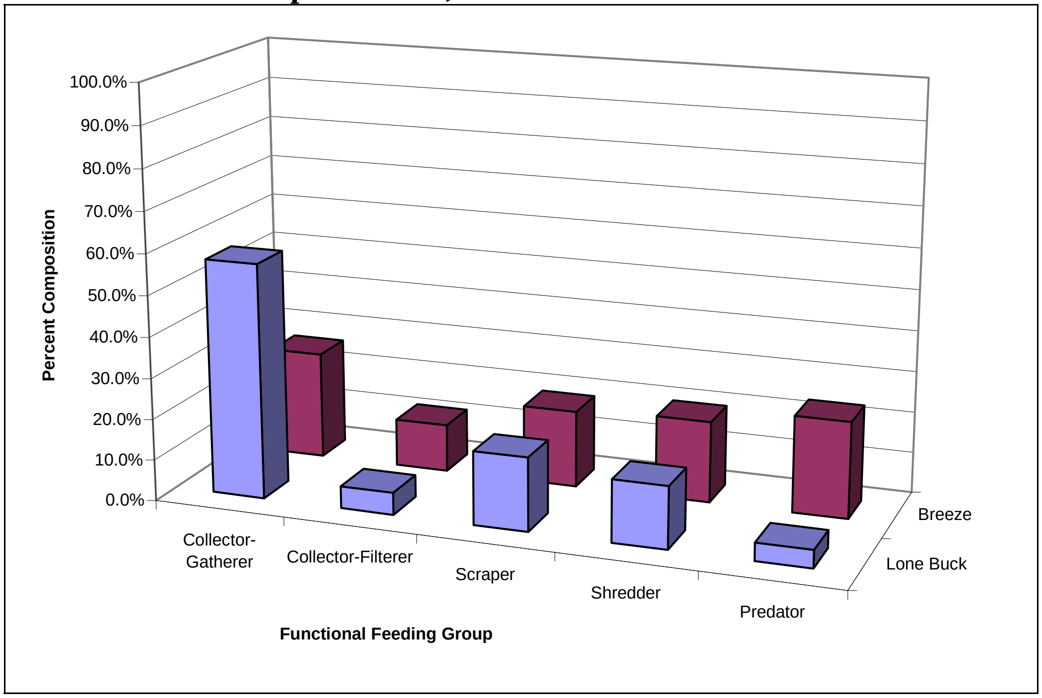
Metric	Lone Buck	Breeze
Diversity	3.90	3.68
Evenness	0.724	0.674
HBI	4.64	4.57
EPT	22	23
Taxa richness	42	44
Density (number/m^2)	7,587	26,498
Mean dry weight (g/m^2)	4.5489	3.0234

A measure of functional feeding groups is often recommended as part of benthic macroinvertebrate analysis and evaluation (Ward et al. 2002). Taxa were classified by trophic association and percent composition was calculated for each site (Table 9, Figure 6). Typically the Collector-Gatherer group is dominant in western streams, but other groups should be well represented. Some variability between sites could be observed, but the proportion of trophic groups was adequately represented at each location.

Table 9. Functional Feeding Groups for macroinvertebrate samples collected from the Colorado River on September 17, 2004.

Study Site	Collector-Gatherer	Collector-Filterer	Scrapers	Shredder	Predators
Lone Buck	57.2%	5.4%	17.9%	15.1%	4.4%
Breeze	26.2%	11.6%	18.7%	19.9%	23.6%

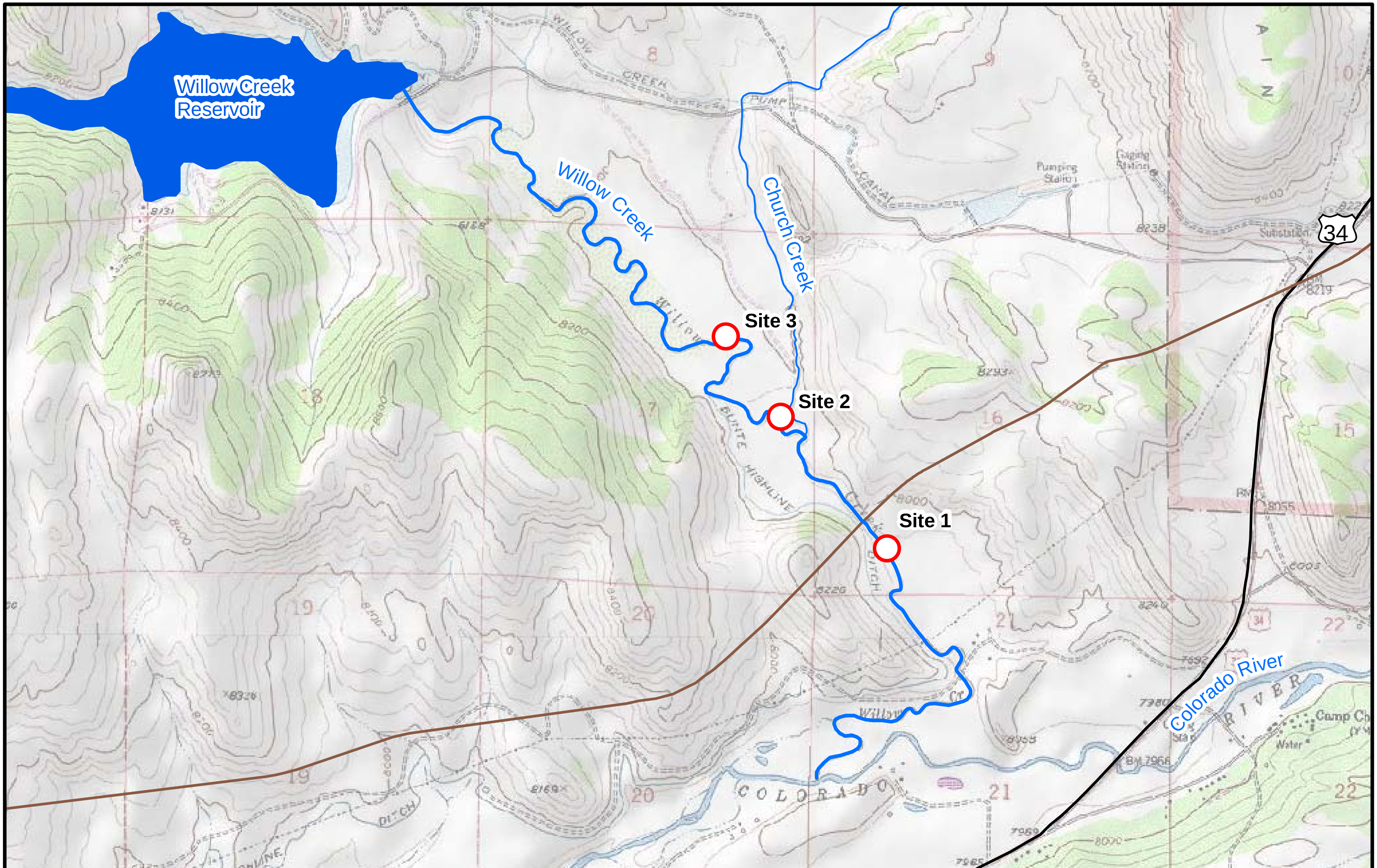
Figure 6. Functional Feeding Groups for macroinvertebrate samples collected from the Colorado River on September 17, 2004.



6.1.2 Willow Creek

6.1.2.1 Fish

Fish population data were available for three sites on Willow Creek (MEC 1998). Site 1 was immediately downstream of Church Creek; site 2 was downstream of the Bunte Highline Canal; and site 3 was upstream of the Bunte Highline Canal (Figure 7). Site 1 downstream of Church Creek had the highest number of fish of all sites. The site was dominated by brown trout (Table 10). Other fish captured at this site were longnose sucker, white sucker, and Piute sculpin. Site 2 was also dominated by brown trout (Table 10). Other species included longnose sucker at 3 percent of the total number captured and one white sucker. Site 3 had the fewest brown trout captured of all three sites (Table 10). The fish abundance is typical of small streams. All life stages of brown trout were collected in Willow Creek. Brown trout population estimates ranged from 667 fish/hectare (ha) to 1,079 fish/ha (Table 10). The habitat conditions in Willow Creek support a reproducing population of brown trout.



ERO Resources Corp.
1842 Clarkson Street
Denver, CO 80218
(303) 830-1188
Fax: 830-1199

○ **Study Site**

0 1,200 2,400 Feet

1 Inch = 2,400 Feet

N

Figure 7
Willow Creek
Study Area

Prepared for: Windy Gap Firming Project
File: Willow_Creek_Model.mxd (JP)
Date: November 2007

Table 10. Number of fish captured and relative abundance in Willow Creek.

Fish Species	Site 1			Site 2			Site 3		
	# captured	% abundance	#/ha	# captured	% abundance	#/ha	# captured	% abundance	#/ha
Brown trout (*Salmo trutta*)	202	84%	1079	171	97%	1053	113	63%	667
Longnose sucker (*Catostomus catostomus*)	31	13%	183	5	3%	30	0	0%	0
White sucker (*Catostomus commersoni*)	5	2%	25	1	1%	6	0	0%	0
Piute sculpin (*Cottus beldingii*)	3	1%	25	0	0%	0	65	36%	604
Rainbow trout (*Oncorhynchus mykiss*)	0	0%	0	0	0%	0	2	1%	12

6.1.2.2 Macroinvertebrates

Macroinvertebrate data also was collected in the previous study and used for this analysis (MEC 1997). Macroinvertebrate collections were made at the same sites as described above and concurrent with the fish collection. The standard macroinvertebrate metrics were used for the description of the existing environment. Shannon Weaver Diversity values were similar when compared among the three sites (Table 11). Diversity values ranged from 2.28 at site 3 to 2.54 at site 1. Evenness values were also similar. They ranged from 0.437 at site 2 to 0.499 at site 1. Ward and Kondratieff (1992) report that diversity values in Colorado streams generally range from near 3.0 to 4.0 with values less than 1.0 indicating polluted conditions. Evenness values are used to detect organic pollution and typically range between 0.6 and 0.8 in unpolluted streams. All of the diversity and evenness values recorded during this study indicated that aquatic conditions were less than average. However, none of the values fell into the range that suggests that the sites were heavily impacted, or polluted. The Family Biotic Index (F.B.I.) is an index used to detect organic pollution. Values range from 0 to 10 with higher numbers indicating greater stress from pollution. F.B.I. values calculated for sites at Willow Creek were in the middle of this range (4.74-5.36). The data suggests that water quality is similar among the three sites.

Table 11. A comparison of various macroinvertebrate indices calculated from quantitative samples at Willow Creek, Colorado on May 1, 1997.

Willow Creek Indices	Site 1	Site 2	Site 3
Diversity	2.54	2.29	2.28
Evenness	0.499	0.437	0.440
EPT	18	19	19
HBI	4.74	5.32	5.36
Taxa richness	34	38	36
Density (number/m^2)	956.0	888.7	667.7
Mean dry weight (g/m^2)	0.3255	0.2654	0.2851

Source: MEC 1997

All index values indicated some stress to the macroinvertebrate communities; however, the high number of individuals and taxa collected, and the presence of several pollution intolerant species suggests that pollution is not the cause of stress to invertebrate communities. It is likely that the effects of the Willow Creek Reservoir dam (less temperature fluctuation, rapid changes in discharge, etc.), or local land use create the disturbance necessary to have a slight negative effect on the index values. Rivers and streams below dams commonly support larger, but less diverse, macroinvertebrate communities.

6.1.3 Rockwell Creek

The CDOW does not have fish data for Rockwell Creek. Restricted access prohibited the collection of fish or macroinvertebrate data. Intermittent flows in this drainage are unlikely to support a substantial fishery or macroinvertebrate population.

6.1.4 Unnamed drainage at Jasper East Reservoir Site

There are no existing CDOW data for the small intermittent drainage where the Jasper East Reservoir would be located. No fish were observed in the unnamed drainage during a site visit in 2003. Short lived invertebrates, typical of intermittent streams were observed, but intermittent flows are unlikely to support a fishery.

6.2 West Slope Lakes and Reservoirs

The potentially affected lakes and reservoirs on the West Slope include Grand Lake, Shadow Mountain Reservoir, and Granby Reservoir. These water bodies all support cold water species with temperatures that range from less than 1^{o} to over $19^{o}C$. Dissolved oxygen range is from approximately 2 to 12 milligrams per liter. All these reservoirs are mesotrophic, that is, a medium productivity type reservoir environment for the fish species (Table 12).

Data were gathered from the CDOW on fish presence within the West Slope and East Slope lakes and reservoirs. The values reported in the tables are indicative of presence and relative abundance but are not necessarily an indication of fish populations. The CDOW use these data to manage reservoirs and use long-term trend data of many samplings of which these are an indication of what is present in recent sampling efforts. The numbers in the tables are for information only and are not a quantitative estimate of abundance for the entire reservoirs. It is assumed that the abundance distribution of fish captured is an approximation of species abundance.

Table 12. Existing conditions summary of trophic state, dissolved oxygen, and water temperature for existing reservoirs.

Lake/Reservoir	Trophic State	Dissolved Oxygen Range (mg/L)		Water Temperature Range (ºC)	
		epilimnion	hypolimnion	epilimnion	hypolimnion
Grand Lake	Mesotrophic	7.1-8.7	3.1-7.4	1.1-18.5	3.1-6.1
Shadow Mountain Reservoir	Mesotrophic	4.7-9.6	NA	1.1-19.7	NA
Granby Reservoir	Mesotrophic	6.2-11.9	1.1-8.8	0.4-19.2	2.4-13.5
Horsetooth Reservoir	Mesotrophic	6.8-11.3	2.0-11.8	NA	NA
Carter Lake	Mesotrophic	6.6-9.7	4.6-9.3	12.6-22.0	5.8-13.6

Source: AMEC 2008

6.2.1 Grand Lake

This lake provides recreational fishing for rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), kokanee (*Oncorhynchus nerka*), and lake trout (*Salvelinus namaycush*). Natural reproduction of lake trout in Grand Lake is self-sustaining at a level to support a reasonable fishery. Populations of brown trout in Grand Lake are at least partially maintained by natural reproduction that occurs in streams feeding into the lake. Other game fish populations are augmented through a stocking program conducted by the CDOW. Rainbow trout and kokanee are stocked annually. Lake trout were stocked on two occasions in the 1990s. Additional stocking took place in 2004 and 2007 to investigate growth rates. No extensive stocking of lake trout is anticipated in the foreseeable future (Personal communication, R. Velarde CDOW to M. DeHaven, March 12, 2008). In a July 2001 survey, rainbow trout and kokanee were not collected, but brown trout and lake trout were well represented (Table 13). The only other species that was present in collections was the longnose sucker (*Catostomus catostomus*).

Table 13. Fish survey (gill net) data for Grand Lake on July 24, 2001.

Species	Number	Percent of Catch	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Weight Range (g)
Lake trout	35	46%	323	180-889	513	45-7,031
Longnose sucker	11	14%	281	200-330	213	45-408
Brown trout	30	39%	277	165-414	231	45-635

Source: CDOW 2001

6.2.2 Shadow Mountain Reservoir

This reservoir is managed by the CDOW as a recreational fishery that provides angling opportunities for rainbow trout, brown trout, cutthroat trout (*Oncorhynchus clarkii*), kokanee, and lake trout. Natural reproduction for game fish is inadequate to support the existing level of angling recreation, , so populations are augmented through a stocking program. Rainbow trout, brown trout, and kokanee are stocked annually and cutthroat trout are stocked occasionally. Fish survey data from July 2001, provided accounts of all stocked species and two nonnative suckers (Table 14). The sucker species included the longnose sucker and white sucker (*Catostomus commersonii*). The white sucker was the dominant fish species that was collected in July of 2001.

Table 14. Fish survey (gill net) data for Shadow Mountain Reservoir on July 24, 2001.

Species	Number	Percent of Catch	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Weight Range (g)
Kokanee	2	1%	221	180-262	122	45-181
Longnose sucker	29	7%	254	23-361	213	45-544
Brown trout	38	10%	312	112-602	372	45-2,449
Rainbow trout	32	8%	236	152-310	154	45-317
Cutthroat trout	3	1%	279	264-295	227	181-272
White sucker	289	74%	328	109-434	454	45-998

Source: CDOW 2001

6.2.3 Granby Reservoir

Granby Reservoir is a recreational fishery that provides angling opportunities for lake trout, kokanee, rainbow trout, and brown trout. Fish populations are maintained through natural reproduction and a strategic stocking program that provides angling opportunities while supporting a balanced fish community. Populations of lake trout and brown trout are maintained through natural reproduction. Rainbow trout are capable of some limited natural reproduction, but populations are augmented through frequent stocking. Kokanee exhibit little or no natural reproduction and therefore populations are dependant on stocking. However, Granby Reservoir is a critical source for kokanee eggs used in the hatchery program for kokanee stocking. A recent fish survey (conducted in June 2004) provided relative abundance data for these fish and two nonnative suckers (Table 15). Results of the fish survey indicated that nonnative, nongame fish (longnose sucker and white sucker) were the most abundant fish captured (>85 percent of the total).

Balance between lake trout populations and kokanee is dependent on the water surface elevation of Granby Reservoir. During periods of low reservoir levels the two species are thermally separated since the kokanee are more tolerant of warmer surface water than lake trout. The young lake trout do not survive as well at low reservoir levels, which ultimately results in a lower number of lake trout but a better balance between fish populations. During periods of high reservoir elevations there is a greater survival rate of young lake trout and less thermal separation between lake trout and kokanee. The conditions that exist during high water elevations result in an over abundance of lake trout with greater accessibility to and predation on kokanee. This results in lower numbers of kokanee, which eventually has negative effects on lake trout numbers because there is not a sufficient prey base to support the lake trout. The CDOW attempts to keep an appropriate balance between the predatory lake trout and the kokanee upon which they prey, through stocking, management, and specific angling regulations.

Table 15. Fish survey (gill net) data for Granby Reservoir on June 29, 2004.

Species	Number	Percent of Catch	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Weight Range (g)
Kokanee	7	1%	168	140-185	50	45-55
Longnose sucker	198	37%	295	122-465	249	45-771
Brown trout	13	2%	376	180-546	513	45-1,179
Lake trout	43	8%	427	310-536	635	227-1,225
Rainbow trout	15	3%	323	117-394	404	45-635
White sucker	266	49%	363	64-500	367	3-1,542

Source: CDOW 2004

6.2.4 Windy Gap Reservoir

Windy Gap Reservoir is a private reservoir that is not stocked or managed by the CDOW, however, fish stocked in the Fraser or Colorado rivers upstream of Windy Gap would be expected to be found in the reservoir. Information on fish populations has been obtained as a result of studies that were initiated due to concerns regarding whirling disease, which has been shown to decrease the survival of juvenile trout. The CDOW conducted a fish survey in September 2001 (Table 16). Results of this survey indicated the presence of rainbow trout, brown trout, kokanee, longnose sucker, and white sucker. The white sucker was the dominant species comprising more than 85 percent of the fish that were captured.

Table 16. Fish survey (gill net) data for Windy Gap Reservoir on September 19, 2001.

Species	Number	Percent of Catch	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Weight Range (g)
Kokanee	3	2%	333	236-399	413	136-635
Longnose sucker	5	3%	224	178-335	--	--
Brown trout	14	8%	406	287-551	776	227
Rainbow trout	3	2%	427	241-574	912	136
White sucker	150	86%	312	117-490	--	--

Source: CDOW 2001

Whirling disease (WD) is caused by a parasite (*Myxobolus cerebralis*) with a complex life cycle that requires two aquatic host organisms (Nehring 2004). The two host organisms required for completion of the M. cerebralis life-cycle include an aquatic tubificid worm (*Tubifex tubifex*), and a salmonid fish (trout). Spores released by one species of host organism are designed to infect the other host organism. The spore of M. cerebralis that is produced and released from T. tubifex worms is referred to as a triactinomyxon or TAM. It has been determined that Windy Gap Reservoir in the upper Colorado River contains some of the best habitat (low-velocity water and silt or mud substrate) for T. tubifex, especially those lineages that are most susceptible to infection by M. cerebralis (Beauchamp et al. 2002). Therefore, Windy Gap Reservoir was considered a major source for TAM production in this drainage (Nehring and Thompson 2003). The earliest detection of M. cerebralis in the upper Colorado River Drainage occurred in 1988 and since that time, recruitment of wild rainbow trout has severely declined (Nehring et al. 2000). Windy Gap is no longer considered a major source of TAM in the upper Colorado River (B. Nehring 2006 personal communication to Don Carlson NCWCD).

Currently, water from Windy Gap Reservoir is released downstream into the Colorado River, and is pumped into Granby Reservoir. Once delivered and stored in Granby, Windy Gap water is available for delivery to participants from Colorado-Big Thompson project East Slope facilities. These West Slope and East Slope waters have all tested positive or are assumed to be positive for whirling disease. No new or additional aquatic routes will be used with the additional water from the WGFP; however, the quantity of water moved through this system would increase.

6.3 East Slope Rivers and Streams

East Slope rivers and streams that are potentially affected include Big Thompson River and North and mainstem St. Vrain Creeks, Big Dry Creek, and Coal Creek, as well as the intermittent tributaries for the locations of Dry Creek and Chimney Hollow Reservoirs. The foothills sections of Big Thompson River and St. Vrain drainages support trout species and have water temperatures suitable for those cold water species. In the downstream reaches of both Big Thompson and St. Vrain Creek, the water warms and supports warm water species. Temperatures range in these stream systems from near 0^{o} to over 22^{o}C.

East Slope rivers and streams are dominated by native non-game species and predominantly by small minnow-type species. Several of the species that occur in these streams are species of concern for the CDOW. No threatened or endangered species are in the Front Range streams that could be affected.

East Slope streams contain both game and non-game species (Table 17). The abundance varies by location, with cool water game species closer to the foothills transitioning to warm water species as the East Slope streams enter onto the plains. In the warmer sections of stream there are warm water game fish and also warm water non-game minnow species.

Several of the warm water non-game species are on the State Species of Special Concern List. These include Iowa Darter, Plains Topminnow, Common Shiner, Brassy Minnow, and Johnny Darter. All of these species are present in the Big Thompson and St. Vrain drainages and presence varies by location (this includes Big Dry Creek and Coal Creek). East Slope reservoirs predominantly support game fish that are managed by the CDOW (Table 18). The warm water game fish, in particular smallmouth bass, are self-sustaining though walleye in the lakes are supplemented with stocking. Chimney Hollow is an intermittent drainage that was dry during field studies; no fishery is present. Dry Creek is an intermittent drainage that is dry in the upper reaches, but the lower reach supports fathead minnows and invertebrates common to intermittent streams.

Table 17. East Slope fish species by drainage or water body.

Species	Big Thompson River	St. Vrain Creek	North St. Vrain Creek	Horsetooth	Carter	Ralph Price
Bigmouth shiner (*Notropis dorsalis*)	X	X				
Black bullhead (*Ameiurus melas*)	X					
Black crappie (*Pomoxis nigromaculatus*)	X	X				
Bluegill (*Lepomis macrochirus*)	X	X				
Brassy minnow (*Hybognathus hankinsoni*)	X	X				
Brown trout (*Salmo trutta*)	X	X	X	X	X	X
Central stoneroller (*Campostoma anomalum*)	X	X				
Common carp (*Cyprinus carpio*)	X	X				
Common shiner (*Luxilus cornutus*)	X	X				
Creek chub (*Semotilus atromaculatus*)	X	X				
Fathead minnow (*Pimephales tenellus*)	X	X				
Gizzard shad (*Dorosoma cepedianum*)	X					
Golden shiner	X					
Green sunfish (*Lepomis cyanellus*)	X	X				
Iowa darter (*Etheostoma exile*)	X	X				
Johnny darter (*Etheostoma nigrum*)	X	X				
Largemouth bass (*Micropterus salmoides*)	X	X				
Longnose dace (*Rhynichthes cataractae*)	X	X				
Longnose sucker (*Catostomus catostomus*)	X	X	X			
Plains killifish (*Fundulus zebrinus*)	X	X				
Plains topminnow (*Fundulus sciadicus*)	X	X				
Rainbow trout (*Oncorhynchus mykiss*)	X		X	X	X	X
Sand shiner (*Notropis stramineus*)	X	X				
Smallmouth bass (*Micropterus dolomieu*)	X			X		
Walleye (*Sander vitreus*)	X	X				
Western mosquitofish (*Gambusia affinis*)	X					
White bass	X					
White crappie (*Pomoxis annularis*)	X					
White sucker (*Catostomus commersonii*)	X	X				
Yellow perch (*Perca flavescens*)	X	X				

Table 18. Game and non-game fish species present in the East Slope study areas.

Species	Game	Non-game
Rainbow trout (*Oncorhynchus mykiss*)	X	
Brown trout (*Salmo trutta*)	X	
Kokanee (*Oncorhynchus nerka*)	X	
Lake trout (*Salvelinus namaycush*)	X	
Longnose sucker (*Catostomus catostomus*)		X
White sucker (*Catostomus commersonii*)		X
Longnose dace (*Rhynichthes cataractae*)		X
Johnny darter (*Etheostoma nigrum*)		X
Creek chub (*Semotilus atromaculatus*)		X
Mottled sculpin (*Cottus bairdi*)		X
Walleye (*Sander vitreus*)	X	
Yellow perch (*Perca flavescens*)	X	
Largemouth bass (*Micropterus salmoides*)	X	
Smallmouth bass (*Micropterus dolomieu*)	X	
Bigmouth shiner (*Notropis dorsalis*)		X
Black bullhead (*Ameiurus melas*)	X	
Bluegill (*Lepomis macrochirus*)	X	
Black crappie (*Pomoxis nigromaculatus*)	X	
White crappie (*Pomoxis annularis*)	X	
Brassy minnow (*Hybognathus hankinsoni*)		X
Central stoneroller (*Campostoma anomalum*)		X
Common carp (*Cyprinus carpio*)	X	
Common shiner (*Luxilus cornutus*)		X
Green sunfish (*Lepomis cyanellus*)	X	
Fathead minnow (*Pimephales tenellus*)		X
Iowa darter (*Etheostoma exile*)		X
Plains topminnow (*Fundulus sciadicus*)		X
Sand shiner *(Notropis stramineus*)		X
Plains killifish (*Fundulus zebrinus*)		X
Gizzard shad (*Dorosoma cepedianum*)		X

6.4 East Slope Lakes and Reservoirs

East Slope lakes and reservoirs potentially affected by the project include Horsetooth Reservoir, Carter Lake, and Ralph Price Reservoir. All three reservoirs support cold water species with temperatures less than 22°C for a maximum and dissolved oxygen suitable for sustaining trout (Table 12). In addition, Horsetooth Reservoir and Carter Lake support warm water species as well as the cold water species (Table 18).

6.4.1 Horsetooth Reservoir

Horsetooth Reservoir is managed for recreational fishing and species present include walleye, smallmouth bass, wiper, and trout species. Salmonid populations are managed by stocking. Warmwater species are maintained by natural reproduction.

6.4.2 Carter Lake

Carter Lake is managed for recreational fishing and includes the same species in general as Horsetooth Reservoir. Populations within the lake have the same management as Horsetooth Reservoir.

6.5 Threatened, Endangered, and Species of Concern

There are no threatened or endangered fish species within the West Slope or East Slope study areas. In the downstream reaches of the Colorado below Rifle, there is critical habitat and presence of four endangered fish species, including Colorado pikeminnow, razorback sucker, humpback chub, and bonytail chub. These species are not present within the study area. In the headwater areas of the Colorado River drainage, Colorado River cutthroat trout are present in some of the small tributary streams. These are a state species of special concern and a special management plan has been developed by the CDOW for that species. They do not occur within the study area.

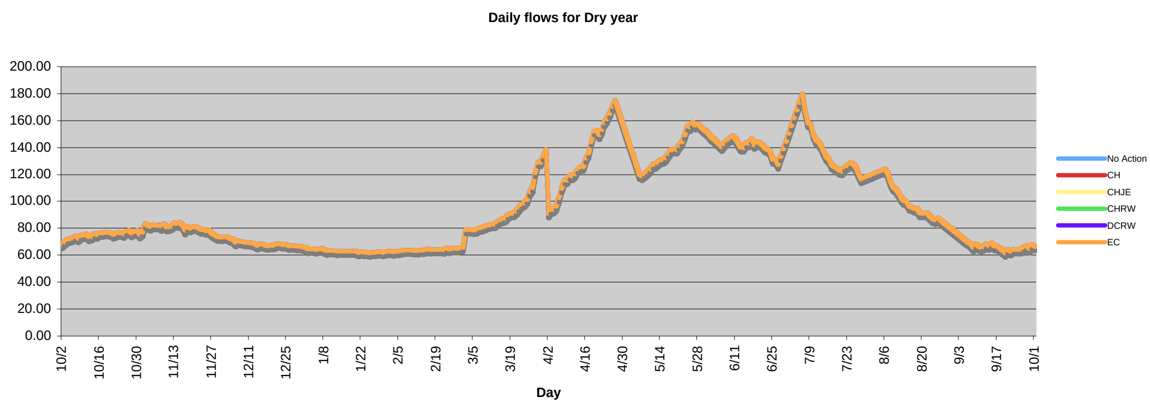
On the East Slope, one threatened species is present in Larimer County and Boulder County, the greenback cutthroat trout. Greenbacks do not occur within the study area, but are generally present in small headwater areas with isolation from other cutthroat species. In addition, there are several species of concern for the state in East Slope streams. These include brassy minnow, Iowa darter, Johnny darter, common shiner, northern redbelly dace, and stonecat. All of these species are present in the Big Thompson and St. Vrain drainages and occur at various locations from the foothills out onto the plains.

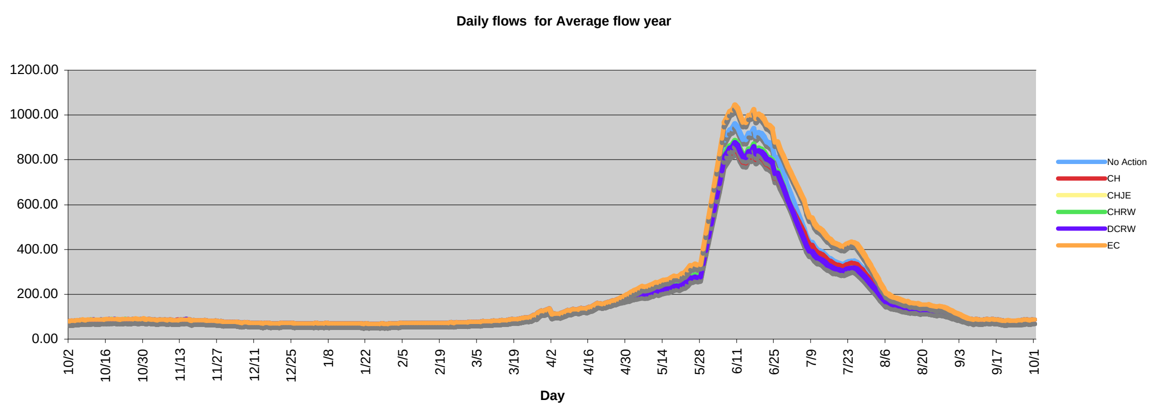
7.0 ENVIRONMENTAL EFFECTS

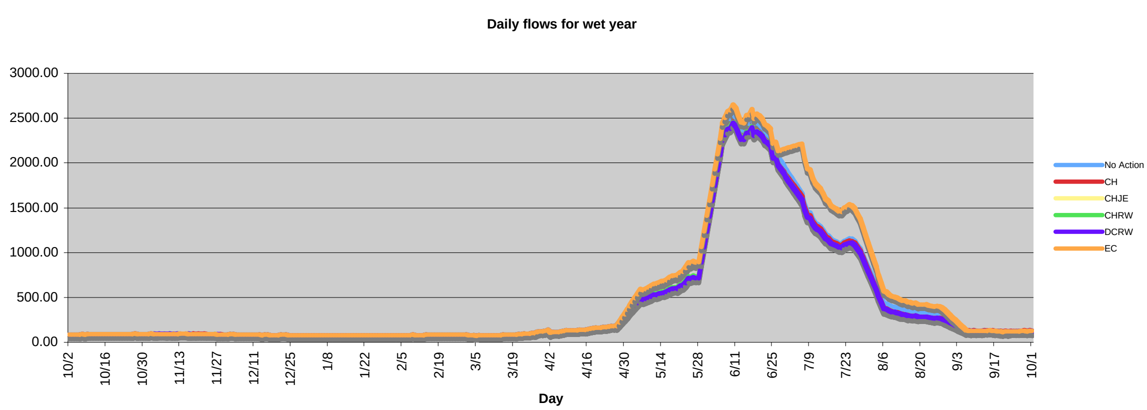
7.1 Summary of Hydrologic Effects for the Alternatives

Hydrologic changes associated with the Windy Gap Firming Project are discussed in detail in the Water Resource Technical Report (ERO and Boyle 2007). The following provides a brief summary of hydrologic changes common to all of the alternatives and those specific to each alternative. Typical hydrographs for the Colorado River at Hot Sulphur Springs are included here for reference (Figure 8). The daily flow data by year type were used in the aquatic habitat analysis.

Figure 8. Average daily flows for Colorado River at Hot Sulphur Springs by alternative and water year type. (ERO and Boyle 2007).







7.1.1 Hydrologic Changes Common to All Alternatives

All of the alternatives, including No Action, would result in additional diversions at Windy Gap Reservoir and changes in flow in the Colorado River below the diversion primarily from April to August. The majority of diversions would occur during peak runoff in May and June and extend into the descending limb of the hydrograph in some years (July and early August). Reductions in streamflow as a percent of total flow decrease downstream as tributary flows enter the Colorado River. There also would be changes in Colorado River flows below Granby Reservoir from slightly less frequent spills below Granby Reservoir. Willow Creek flows below Willow Creek Reservoir would also change due to changes in Willow Creek Feeder Canal diversions. There would be no change in reservoir elevations for Grand Lake or Shadow Mountain Reservoir for any of the alternatives. Granby Reservoir water levels would be lower under all alternatives with storage of Windy Gap water in new reservoirs and storage of C-BT Project water in Chimney Hollow Reservoir under Alternative 2.

All of the alternatives would result in an increase in Big Thompson River streamflow below Lake Estes to the Big Thompson Power Plant from the additional East Slope deliveries. No other East Slope stream or river flows will be directly impacted by the diverted water because the water will be delivered to Participants via existing canals and pipelines. There would an increase in streamflow below the Participant wastewater treatment plants on the Big Thompson River, St. Vrain Creek, Big Dry Creek, and Coal Creek. All of the alternatives would result in a decrease in storage for some months in Carter Lake and Horsetooth Reservoir, but there would be no change in reservoir storage for other East Slope C-BT Reservoirs.

7.1.1.1 Alternative 1 – No Action

Under the No Action alternative, the existing Ralph Price Reservoir on the North Fork of St. Vrain Creek would be enlarged by 13,000 AF. Windy Gap water would be exchanged upstream for storage in the reservoir, which would result in a change in flow in North St. Vrain Creek below the reservoir downstream to the St. Vrain Supply Canal on St. Vrain Creek near Lyons.

7.1.1.2 Alternative 2 – Proposed Action-Chimney Hollow Reservoir

The Proposed Action includes construction of a 90,000 AF Chimney Hollow Reservoir. This alternative includes the concept of prepositioning, which allows storage of C-BT water in Chimney Hollow Reservoir. Chimney Hollow would remain nearly full most of the time.

7.1.1.3 Alternative 3 – Chimney Hollow Reservoir/Jasper East Reservoir

Alternative 3 proposes the construction of Chimney Hollow Reservoir (70,000 AF) and Jasper East Reservoir (20,000 AF). Chimney Hollow Reservoir would fluctuate more than the Proposed Action, but elevations would remain fairly high. Storage in Jasper East Reservoir would fluctuate widely on an annual basis.

7.1.1.4 Alternative 4 – Chimney Hollow Reservoir/Rockwell Reservoir

Alternative 4 proposes the construction of Chimney Hollow Reservoir (70,000 AF) and Rockwell Reservoir (20,000 AF). Chimney Hollow Reservoir would fluctuate more than the Proposed Action, but elevations would remain fairly high. Storage in Rockwell Reservoir would fluctuate widely.

7.1.1.5 Alternative 5 – Dry Creek Reservoir/Rockwell Reservoir

Alternative 5 proposes the construction of Dry Creek Reservoir (60,000 AF) and Rockwell Reservoir (30,000 AF). Dry Creek Reservoir would fluctuate more than the Proposed Action, but elevations would remain fairly high. Storage in Rockwell Reservoir would fluctuate widely.

7.2 Methods Used to Evaluate Environmental Effects

Environmental effects were investigated for fish habitat and fish community. Fish habitat in the Colorado River and Willow Creek was evaluated using the Instream Flow Incremental Methodology (IFIM). Effects to the fish community were evaluated using estimated daily flow from the hydrologic model (ERO and Boyle 2007) and water quality modeling for streams and lakes (AMEC 2008; ERO and AMEC 2008) combined with species composition data from the affected streams.

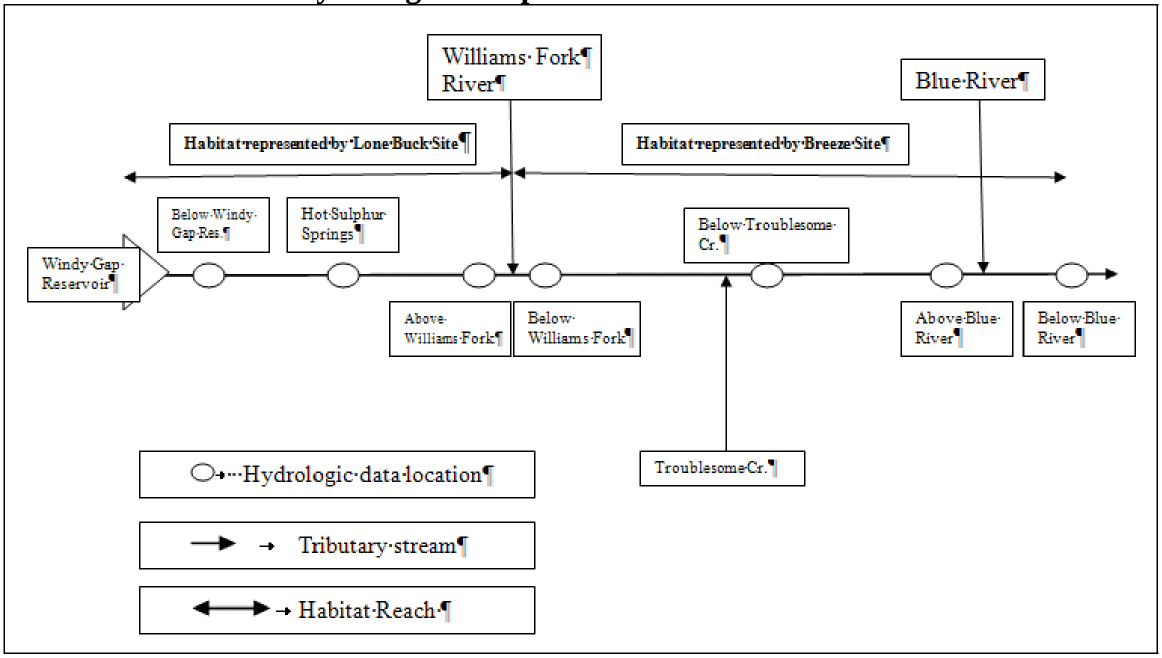
7.2.1 Fish Habitat

Fish habitat along the Colorado River was modeled using River2D for each WGFP alternative. Study site selection followed the guidelines for IFIM studies (Bovee 1982). Data collected for site selection included stream slope and discharge for gaged locations (see Appendix B). Final site location was determined during a site visit conducted by MEC and CDOW. Two study sites were selected downstream from Windy Gap, at Hot Sulphur Springs and below the William's Fork confluence. Rainbow trout and brown trout habitat availability was examined for both adult and juvenile life stages. These two sites are representative of the river from Windy Gap downstream to the Blue River.

Habitat analysis used the "representative reach" approach (Bovee 1982), which means data collected at one location (usually over 10-14 channel widths or more of river length) represent the reach. The site-specific data (width, depth, velocity, etc.) is expanded to the reach for analysis.

Hydrologic conditions at six locations from Windy Gap downstream to the Blue River were combined with the habitat data to determine changes in fish habitat for the river from Windy Gap downstream below the Blue River (Figure 9). Daily flows for average, dry, and wet year flow conditions were modeled under the various WGFP alternatives. Because of the similarity in Colorado River diversions among the action alternatives, the impacts to fish habitat are likewise similar and thus the discussion of effects is consolidated. Water diversions under the No Action alternative are less than action alternatives so impacts to fish habitat typically would be slightly less.

Figure 9. Schematic representation of how habitat study sites are expanded to a reach and location of hydrologic data points.



Appendix B provides a detailed description of the River2D model with figures displaying changes in habitat and the frequency of changes in habitat for all alternatives. Summary tables used in the discussion below indicate the range of potential effects for the alternatives, including a comparison of the percent change in habitat between the action alternatives and the No Action alternative and between the action alternatives and Existing Conditions, as well as the frequency that the impact would occur.

Effects to fish habitat in reservoirs and East Slope streams were based on hydrologic and water quality changes and the likely potential for a change in habitat. Water quality data from AMEC (2008) and ERO and AMEC (2008) were used to evaluate both stream and reservoir impacts to fish habitat and fish communities. Dissolved oxygen and water temperature were the principal stream water quality parameters used to evaluate effects to fish habitat and populations. For reservoirs, the trophic state, dissolved oxygen, water temperature, and changes in reservoir depth and area were used to determine potential effects to fish.

7.2.2 Fish Community/Population

Fish community and fish populations were assessed qualitatively based on changes in physical habitat, as well as projected water quality changes within those systems. The change was compared to the existing conditions in rivers, streams, and reservoirs to determine if there would be factors that affect fish populations at the acute or chronic level. Other factors such as fishing pressure, management and stocking can change fish populations and community structure more than physical habitat . Specific long-term field data for species occurrence by habitat type and population data by species and size are required to develop cause and affect relationships between habitat change and population levels. There are basic assumptions in IFM regarding population response to habitat. In general, more habitat is assumed to result in larger populations but the relationship may not be linear. Since detailed population data was not available (and is not available for most rivers), the qualitative approach was used for this analysis.

7.2.3 Macroinvertebrates

Macroinvertebrates were evaluated using the results of the metrics from baseline data and inferences made based on changes in stream flow and water quality. The ability to repopulate areas shortly after these areas are rewatered gives the macroinvertebrates the ability to colonize areas throughout the year. The time between low water and high water and any changes made during the summer season were used as a qualitative indicator of macroinvertebrate health.

7.3 West Slope Effects

7.3.1 Streams and Rivers

Modeling of water quality parameters for the Colorado River (ERO and AMEC 2008) predicted small changes in dissolved oxygen, a decrease of 0.1 milligram per liter, and a slight increase in water temperature of less than 1^{o}C (Table 19) for all alternatives based on average July 25 flows. July 25 was selected as a representative period when air temperatures are generally high, streamflow is lower, and Windy Gap diversions would occur in some years. Changes in stream temperature and dissolved oxygen levels would be less during May and June when the majority of Windy Gap diversions would occur because the water temperature in spring runoff and the air temperature is cooler than mid-summer. Additional analysis of potential changes in temperature and oxygen was conducted when July 25 diversions reduced Colorado River flows below Windy Gap to the minimum flow of about 90 cfs. Under these conditions, the Colorado River showed an increase in water temperature up to 4^{o}C. This results in a water temperature predicted of approximately 19^{o}C just upstream of the Williams Fork, which is within the range of water temperatures that have historically been observed in that reach. It is well below lethal and chronic levels for rainbow, cutthroat, and especially brown trout. Lower flows could increase the potential for exceedence of the weekly maximum average temperature standard for aquatic life, but is unlikely to measurably impact fish populations. This conclusion is based on the observed water temperatures, which occasionally exceed 19°C under current conditions, and the healthy fish population that is in this reach of the river. Dissolved oxygen levels could decrease up to 0.6 mg/L during diversions to minimum streamflow. Dissolved oxygen levels in the Colorado River under all modeled conditions are well above the 5.0 mg/L required for lethal effects to trout and would not impact trout in this section of the river.

Table 19. Summary of stream water quality effects from each alternative.

Location	Greatest Change in Dissolved Oxygen (mg/L) From Existing Conditions for all Alternatives	Greatest Change in Water Temperature (C) from Existing Conditions for all Alternatives
Colorado River in the study reach	-0.1 to -0.6	0.8 to 4.0
Willow Creek	No change	-0.2
St. Vrain Creek	No change	No change
North St. Vrain Creek	Decrease less than 0.5	No change
Big Thompson	No change	No change

Source: ERO and AMEC 2008

Fish habitat data is not available for the Colorado River between Granby Reservoir and Windy Gap Reservoir; however, the pattern of flow changes is similar to those shown downstream of Windy Gap Reservoir (ERO and Boyle 2007). Therefore, the changes to fish habitat and fish populations are expected to be similar to those predicted downstream of Windy Gap. Flow changes below Granby Reservoir occur in the months of May through October. Flows in May, September, and October are reduced by 5 cfs or less in average years and increase by 8 cfs or less in wet years (ERO and Boyle 2007). Maximum average monthly flow reductions of up to 20 to 30 percent in July and August of wet years; however, July flows exceed 690 cfs and August flows are 155 cfs or higher for all alternatives. This may cause some shift in habitat as a response to reduction in peak flows, but is unlikely to impact fish populations.

Peak flows are an important component for creating and maintaining in stream habitat. Peak flows affect the stream in a variety of ways. Physical components of riverine systems that affect the biota both in the riparian and instream areas include hydrology, geomorphology, and water quality. Hydrology within riverine systems, especially in systems with snowmelt-driven hydrographs, usually have spring or early summer peak flows with base flows occurring in fall through winter. The magnitude and duration of the peak flows are variable and dependent on annual snowpack and also rainfall events that occur after snowpack has subsided. These flows affect the stream morphology. Specific flow magnitude and duration are required to move sediment, initiate channel migration, create, and maintain habitat, and incorporate organic material in the form of woody debris into the system.

Research has shown that the geomorphic changes occur with peak flows of various return intervals. Hill et al. (1991) discussed the need for large flow events for channel migration and valley form influences. These events are generally large events that occur approximately 1 in 25 years or greater. More frequent flooding occurs on nearly an annual basis. These flows occur at a bankfull or slightly higher than bankfull level and are shown to rework channel features without a lot of channel migration. In general, these flows occur every 1.5 to 2 years in most stream systems (Dunne and Leopold 1978). Research has shown that flows that occur during the annual peaks do most of the in-channel reworking of bars and instream habitat to create habitat for the base flow period of the year.

By considering various physical processes that occur in river systems, particularly in alluvial systems with cobble and gravel bedforms, flow regimes can be specified that will modify channel morphology. These modifications can move from a present day condition which may be a detached floodplain and incised channel to a more connected floodplain with a less incised channel which provides function for both instream and near-channel riparian habitat (Trush et al. 2000).

The channel geometry and plan form of the channel and the biota within the channel are all affected by the volume and timing of annual discharges. Physical features of the stream channel change as a result of peak flows and the biota respond to those physical changes.

During peak runoff, two factors that affect the physical conditions within the stream are the magnitude and duration of the peak runoff. During the time of peak runoff, flows that are at or near bankfull are producing the maximum amount of work on the channel geometry including erosion on the channel banks, redistribution of sediment and transport of organic debris (large and small) downstream.

Flows that are greater than bankfull discharge expand into the floodplain and riparian areas of the stream. These inundate the floodplain, induce floodplain scour in certain locations where there are sufficient velocities to change the floodplain shape. They also mobilize organic debris in the floodplain and transport that debris to the stream channel. The amount of change in physical habitat from year to year is determined during this runoff cycle that shapes new habitats and maintains the current habitat.

The terrestrial plant community in the floodplain and riparian areas also respond to peak flows. Over bank flow prepare seed beds for plant establishment and water for initiation of plant growth. The soils become saturated, which benefits wetland and riparian plants.

Riparian corridors also include terrestrial species of plants and animals that depend on instream flows. High flows during runoff can inundate riparian areas, which promotes new vegetation growth, maintains existing vegetation, and carries organic material into the stream channel.

Biological components of riverine systems include instream biota such as primary and secondary producers (e.g., algae, periphyton, and benthic invertebrates) and consumers (e.g., invertebrates and fish). Aquatic biota has evolved to survive within the range of flows that occur under natural conditions. For example, benthic invertebrates with annual life cycles are in life stages that avoid high flows impacts. These include adult free flying life stages and egg life stages.

Fish species also have evolved to minimize impacts from detrimental flows. Spawning, hatching, and emergence for salmonids are timed to maximize success under natural flow regimes. The natural flow regimes create habitat that can be used by juvenile and adult fish to avoid detrimental effects of high flows and refuge habitat during low flows.

Aquatic biota responses to peak flows are also apparent in the various biota that inhabit the stream. Benthic macroinvertebrates in snowmelt runoff systems have generally evolved to avoid the detrimental effects of high flows. These include being in locations or in lifestages that avoid those high flow impacts. Many of the macroinvertebrates in western stream systems have evolved so that adults emerge and lay eggs prior to runoff. Therefore, the most dominant lifestages that exists in peak flow are the egg or early instars. The small size of these lifestages allows them to avoid many of the detrimental effects of peak flows.

Similarly, the large woody debris and habitat features that are formed during previous years' peak runoff provide refuge habitat for the various lifestages of fish species that inhabit streams. These types of habitat provide lower velocities during peak flow and shelters from the higher velocities normally associated with a peak runoff event.

Overall stream productivity on average in natural systems is determined by the baseflow conditions that provide for primary and secondary productivity and feeding as well as refuge habitats. Peak flows temper those populations and can influence the year class strength of salmonids if very high discharges occur when the young fish are susceptible to the peak flows. In general, the peak flow time period is the lowest amount of optimal habitat for fish species but that peak flow provides the work in the channel that shapes, creates, and maintains habitat for the majority of the year for those species.

The hydrology data for the action alternatives for the Colorado River shows little change in peak flow magnitude and recurrence intervals (ERO and Boyle 2007). These small changes in peak flow characteristics are not expected to result in substantial changes to the existing habitats that are created and maintained by the existing flow regime. Therefore, the current channel type and habitat characteristics are expected to be maintained with all alternatives.

The fish habitat model shows a consistent pattern across the WGFP alternatives at the six Colorado River hydrologic reaches and on Willow Creek (Tables 20, 21 and 22, Appendix B Figures 27-218). Tables 19 and 20 indicate the maximum modeled changes in fish habitat and the frequency of that occurrence in the study reaches for average and wet years by species and life stages. First, trout habitat availability during dry year flow conditions would not change from existing conditions for any of the alternatives or between the No Action and Action alternatives because Windy Gap diversions would not change (Table 20). Second, for each WGFP alternative, four sites (Hot Sulphur Springs, Below William's Fork, Above Troublesome Creek, and Above Blue River) exhibited no substantial changes in fish habitat availability during all flow conditions for all alternatives. Third, the Below Windy Gap site showed decreases (20-30 percent) in fish habitat availability for all WGFP alternatives during wet year flow conditions.

The effects by individual alternative and water year type are presented in Figures 27 to 410. For example, the reductions in habitat during wet conditions for brown trout juvenile at Hot Sulphur (Figure 73), shows that there is a 25 percent reduction in habitat, 10 percent of the years or 1 in 10 years. That reduction is from approximately 400,000 square feet of habitat down to 300,000 square feet of habitat (Figure 71). Average habitat for the majority of the year is approximately 150,000 square feet (Figure 63). It is more likely that the habitat condition that exists for more of the year (i.e., this lower habitat amount) is controlling the amount of space and, therefore, the upper population size than the short duration, more abundant habitat. Therefore, even though the percent reduction is large, it occurs when habitat is more available than during the majority of the year. These decreases in fish habitat would affect both trout species at the adult and juvenile life stages. However, the decrease in habitat would only occur about 10 to 20 percent of the time. Because fish habitat can be lower at high flows, diversions that reduce high flow can result in increased available habitat during runoff, but result in less habitat maintenance and creation. Habitat time series output indicates Windy Gap diversions from the Colorado River, primarily in wet years, would result in an increase in habitat at times. At the Below Windy Gap site, there would be up to a 10 percent increase in available fish habitat 90 percent of the time in wet years (Figure 50).

In general, fish habitat changes for all alternatives are very similar. The largest decrease in habitat would occur in average and wet years from Windy Gap Reservoir downstream to the Williams Fork. During times when there is a decrease in habitat, the frequency of decrease ranges from 1 year in 20 to approximately 4 years out of 10. The most frequent decrease in habitat would occur for rainbow trout adults in the reach upstream of the Williams Fork River. This section of stream would have a decrease in habitat of approximately 24 percent in 4 years out of 10 for the action alternatives. Under No Action, adult rainbow trout habitat would decrease up to 9 percent in 3 out of 10 years above Williams Fork and juvenile rainbow trout habitat would decrease up to 3 percent in 1 out of 10 years. There is a slight difference in the hydrology at the Hot Sulphur Springs site and upstream of the Williams Fork. This small difference in frequencies of occurrence of certain hydrologic values results in the differences in habitat between these two sites. All other frequencies of reduced habitat are generally less than 2 years out of 10, and in many of the wet years, the frequency of reduced habitat is 1 year out of 10.

Table 20. Summary of habitat changes (percent change from existing conditions and percent change from No Action, with frequency of occurrence in number of years out of 10) in the Colorado River and Willow Creek in dry water years for rainbow and brown trout.

	Rainbow Trout								Brown Trout							
	Juvenile				Adult				Juvenile				Adult			
	Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action	
Location/species	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**
Below Windy Gap	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10
Hot Sulphur Springs	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10
Above Williams Fork	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10
Below Williams Fork	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10
Above Troublesome Creek	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10
Above Blue River	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10
Below Blue River	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10
Willow Creek	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10	0	10/10

Table 21. Summary of habitat changes (percent change from existing conditions and percent change from No Action, with frequency of occurrence in number of years out of 10) in the Colorado River and Willow Creek in average water years for rainbow and brown trout.

	Rainbow Trout								Brown Trout							
	Juvenile				Adult				Juvenile				Adult			
	Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action	
Location/species	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**
Below Windy Gap	-6	2/10	-5	2/10	-19	2/10	-10	2/10	-8	0.5/10	-3	0.5/10	-6	2/10	-1	2/10
Hot Sulphur Springs	-6	2/10	-5	2/10	-18	2/10	-10	2/10	-7	0.5/10	-2	0.5/10	-4	2/10	-1	2/10
Above Williams Fork	-7	2/10	-5	2/10	-24	4/10	-18	4/10	-19	0.5/10	-11	0.5/10	-19	2/10	-11	2/10
Below Williams Fork	-15	1/10	-9	1/10	-15	0.5/10	-8	0.5/10	-15	0.5/10	-8	0.5/10	-15	0.5/10	-8	0.5/10
Above Troublesome Creek	-15	0.5/10	-9	0.5/10	-15	0.5/10	-9	0.5/10	-15	0.5/10	-9	0.5/10	-15	0.5/10	-9	0.5/10
Above Blue River	-13	1/10	-4	1/10	-13	1/10	-4	1/10	-13	1/10	-4	1/10	-13	1/10	-4	1/10
Below Blue River	-4	1/10	-4	0.5/10	-6	1/10	-4	0.5/10	-7	0.5/10	-4	0.5/10	-7	0.5/10	-4	0.5/10
Willow Creek	-9	2/10	-5	2/10	-19	2/10	-11	2/10	-13	2/10	-7	2/10	-21	2/10	-12	2/10

Table 22. Summary of habitat changes (percent change from existing conditions and percent change from No Action, with frequency of occurrence in number of years out of 10) in the Colorado River and Willow Creek in wet water years for rainbow and brown trout.

	Rainbow Trout								Brown Trout							
	Juvenile				Adult				Juvenile				Adult			
	Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action	
Location/species	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**
Below Windy Gap	-24	1/10	-24	1/10	-30	3/10	-30	3/10	-28	0.5/10	-28	0.5/10	-32	2/10	-32	2/10
Hot Sulphur Springs	-24	1/10	-3	1/10	-24	1/10	-3	1/10	-24	1/10	-3	1/10	-24	1/10	-3	1/10
Above Williams Fork	-25	1/10	-3	1/10	-30	3/10	-11	3/10	-29	1/10	-4	1/10	-25	1/10	-4	1/10
Below Williams Fork	-9	1/10	-6	1/10	-11	2/10	-9	2/10	-10	2/10	-8	2/10	-10	2/10	-8	2/10
Above Troublesome Creek	-13	2/10	-11	2/10	-14	2/10	-12	2/10	-13	2/10	-11	2/10	-13	2/10	-11	2/10
Above Blue River	-9	2/10	-8	2/10	-9	2/10	-8	2/10	-9	2/10	-8	2/10	-9	2/10	-8	2/10
Below Blue	-10	1/10	-6	2/10	-10	1/10	-6	2/10	-10	1/10	-6	2/10	-10	1/10	-6	2/10
Willow Creek	-6	3/10	0	-	-16	3/10	-16	3/10	-12	.5/10	0	-	-13	2/10	-10	2/10

Trout in the study area have a maximum age of approximately 6 or 7 years. Impacts to trout habitat that occur often during their life span (e.g., 4 out of 10 years) may affect populations. Impacts to trout habitat that occur less frequently (e.g., 2 out of 10 years or less) are less likely to affect populations. Trout populations would have multiple years of spawning and recruitment between the less frequent events, which is the reason these events would have less effect on the populations. In general, CDOW research on Colorado rivers has demonstrated that the greatest impact to trout populations occurs during high flows when small juvenile fish are present (especially during wet hydrologic years) (Nehring and Anderson 1993).

The predicted maximum periodic decreases in fish habitat, with the exception of potential effects to adult rainbow trout above Williams Fork, are unlikely to impact fish populations. There may be a slight impact to adult rainbow trout populations above Williams Fork from reduced flows that have a 4 year out of 10 recurrence interval. Potential effects to brown trout habitat and the frequency of the change in average and wet years would be minor and unlikely to impact current populations.

Overall, the modeled changes in fish habitat in the Colorado River for all of the alternatives indicate the greatest changes in habitat generally would occur between Windy Gap and the confluence with the Williams Fork River in wet and average years. For most of the Colorado River, the reduction in habitat would occur in 2 out of 10 years or less. For the Colorado River above the Williams Fork, the habitat is reduced in 4 out of 10 and 3 out of 10 years in average and wet years, respectively. Although wet year effects occur in up to 3 out of 10 wet years, wet years only occur about 10 percent of the time, thus the actual long-term recurrence interval is about 3 percent. Fish populations would likely not change in any location with the possible exception of upstream of the Williams Fork. The small predicted changes in water quality parameters and water temperature predicted from the water quality technical report (ERO and AMEC 2008) and therefore minimal impacts to the fish community are expected in the Colorado River downstream of Windy Gap. Overall, no changes are expected in the presence or absence of the existing species; however, there may be small changes to fish populations. The small changes in peak flow characteristics are not expected to result in substantial changes to the existing habitats that are created and maintained by the existing flow regime.

Fall spawning brown trout would not be affected by Windy Gap diversions. Rainbow trout spawning occurs from mid-April through May, with hatching in June and July. Rainbow fry emerge from the gravel in July into the first of August (Nehring and Anderson 1993). With rainbow trout spawning occurring on the lower portion of the ascending limb of the hydrograph, the redds would be covered by water through egg hatch and emergence. Since the eggs and fry would not be dewatered, an impact to these life stages is not likely for any of the alternatives.

Habitat needs of the macroinvertebrates present in the Colorado River are similar to those of the trout species. Water quality conditions are not expected to change substantially from the existing conditions. The species and distributions of macroinvertebrates are not expected to change. The abundance should remain the same as observed with the future conditions for all alternatives.

The changes to Willow Creek habitat are similar to those seen for the Colorado River with most changes in habitat less than 15 percent. The greatest change in adult habitat is during an average water year for brown trout adults with a 21 percent reduction in habitat 2 out of 10 years. All the frequency of changes would be 3 out of 10 years or less and the majority would occur 2 out of 10 years. Changes of this magnitude are unlikely to be measurable at the population level. In addition to physical habitat, the change in water quality shows that there will be a slight decrease in water temperature, which may benefit the fishery, although the slight decrease may not be measurable at the population level. Overall, the fish community is not expected to change with any of the alternatives in Willow Creek.

7.3.2 Lakes and Reservoirs

Grand Lake, Shadow Mountain Reservoir, and Granby Reservoir are currently in a mesotrophic state and are expected to remain in that trophic state for all alternatives. A maximum decrease in dissolved oxygen of 0.6 mg/L is predicted for Grand Lake for all alternatives. Granby Reservoir is expected to have a maximum dissolved oxygen decrease of 0.2 mg/L for all alternatives. The predicted changes in lake and reservoir temperatures are small and are not expected to substantially impact fish populations. Since the trophic states are expected to remain the same and the dissolved oxygen levels are going to be within the range observed under existing conditions, no change in fish population dynamics are expected due to the changes in physical environment (Table 23).

In addition, there will be a slight decrease in water surface elevation that ranges from 0 to 10 feet, depending on water year and alternative, with a corresponding maximum change in surface area of 8 percent (Table 24). These changes, like the water quality parameters, are not expected to change the dynamics of the fish population. Sequential dry years may result in multiple years with reduced surface area. It is likely several dry years in sequence would be required before any impacts to fish are shown.

There would be no change in reservoir elevation for any of the alternatives in Grand Lake, Shadow Mountain Reservoir, or Willow Creek Lake under any of the alternatives, thus there would be no effect to available fish habitat.

The new reservoirs of Jasper East and Rockwell/Mueller Creek are predicted to be oligotrophic-mesotrophic. These reservoirs likely could support a fishery with appropriate management.

Table 23. Summary of predicted trophic status and dissolved oxygen changes at existing and potential new reservoirs.

Lake/Reservoir	Predicted Trophic State (all alternatives)	Dissolved Oxygen Change (mg/L)
Grand Lake	Mesotrophic	0.4 mg/L with proposed action, 0.3 mg/L change for other alternatives
Shadow Mountain Reservoir	Mesotrophic	Decrease by 0.1 mg/L with proposed action. No change for other alternatives
Granby Reservoir	Mesotrophic	Decrease by 0.2 mg/L with proposed action. No change for other alternatives
Horsetooth Reservoir	Mesotrophic	NA
Carter Lake	Mesotrophic	NA
Jasper East Reservoir	Oligotrophic-Mesotrophic	NA
Rockwell Reservoir	Oligotrophic-Mesotrophic	NA
Chimney Hollow Reservoir	Oligotrophic	NA
Dry Creek Reservoir	Oligotrophic	NA
Ralph Price Reservoir	Oligotrophic	NA

Source: AMEC 2008

Table 24. Summary of change in water surface elevation and surface area for existing reservoirs (ERO and Boyle 2007).

Lake/Reservoir	Range of Water Surface Elevation Change (in feet) (all alternatives)			Maximum Change in Surface Area (%) all Years, all Alternatives
	Average Year	Dry Year	Wet Year	
Grand Lake	[1]	[1]	[1]	[1]
Shadow Mountain Reservoir	[1]	[1]	[1]	[1]
Granby Reservoir	-2 to -7	-2 to -6	0 to -9	-8
Horsetooth Reservoir	0 to -6	0 to -9	1 to -6	-6
Carter Lake	0 to -1	0 to -1	1 to -2	-1

[1]Water surface elevation would be limited to the current fluctuation of 1 foot.

7.4 East Slope Effects

7.4.1 Streams, Rivers, and Creeks

The No Action alternative would result in the greatest potential increase in peak streamflows on the East Slope. With the No Action alternative, the hydrological model predicts an increase in flows from April to October for Big Dry Creek, Big Thompson River, Coal Creek, and St. Vrain Creek. The Big Thompson River and St. Vrain Creek did show substantial increases in some months. There are both increases and decreases in the North St. Vrain streamflow with No Action. The lower summer flows, primarily in July, may slightly decrease fish habitat. The increases in fall and winter would be beneficial to fish. Overall, these flow changes should not measurably impact fish habitat. The slight increase in flow during the times when flows are now lowest may enhance fish habitat in all these streams. No flow changes are expected for the Cache la Poudre River and the South Platte River.

For the action alternatives, the hydrological model predicts an increase in flows from April to October for Big Dry Creek, Big Thompson River, Coal Creek, and St. Vrain Creek. These flow changes should not negatively impact fish habitat. The slight increase in flow during the times when flows are now lowest may enhance fish habitat in these streams. No flow changes are expected for the Cache la Poudre River and the South Platte River.

There would be no adverse impact to aquatic habitat in Chimney Hollow because this intermittent stream is often dry and does not support a fishery. Dam construction and inundation of Dry Creek at Dry Creek Reservoir under Alternative 5 would impact intermittent aquatic habitat supports minnows and aquatic invertebrates.

The small changes to streamflow and water quality parameters are not expected to impact the current fish or macroinvertebrate populations in East Slope streams.

7.4.2 Lakes and Reservoirs

The hydrological model-predicted changes in reservoir elevation under any of the alternatives for Carter Lake and Horsetooth Reservoir are unlikely to substantially impact the fish community (Table 24). Lower water levels would slightly reduce available habitat, but these changes would not measurably impact fish survival, reproduction, or fishing success. There would be no change in the trophic status of Carter Lake and Horsetooth Reservoir or other water quality parameters that are expected to adversely impact fish under any of the alternatives. Therefore, the habitat in these reservoirs would support fish as seen under current management by CDOW.

Ralph Price Reservoir would be enlarged under the No Action alternative and the fishery would be restored and maintained following construction. Fishery conditions would be similar to the current reservoir trophic state. It is predicted to be oligotrophic, which means productivity would be relatively low and growth for fish stocked in the lake may be slow, as is currently the case.

Chimney Hollow and Dry Creek reservoirs, as new reservoirs, would require a management plan developed by CDOW for fisheries management. The fishery would be established based on reservoir characteristics and expected outcomes for anglers. It is likely they would be similar to other Front Range reservoirs with a combination of cool water and cold water species. Both reservoirs would likely be similar to Carter Lake or Horsetooth Reservoir for species but may be less productive since they are predicted to be oligotrophic, which is less productive than the current Horsetooth Reservoir and Carter Lake.

7.5 Threatened, Endangered, and Species of Concern

Impacts to the threatened and endangered species in the Colorado River were originally addressed in the Biological Opinion (BO) for the original Windy Gap Reservoir. More recently, the future Windy Gap depletions were incorporated in the Recovery Plan for the Upper Colorado River. No effect to the threatened and endangered (T&E) fish species is expected if the steps outlined in the Recovery Plan and BO are followed.

No adverse impacts to the East Slope species of concern are expected from any of the alternatives. The slight increases in winter and fall flows may benefit these species.

8.0 CUMULATIVE EFFECTS

Several reasonably foreseeable water-based actions are expected to occur in the future on the West Slope. These actions affect the availability of water for Windy Gap diversion and also result in cumulative hydrologic effects in the Colorado River. Future water-based actions on the West Slope would also result in a change in Windy Gap water deliveries to the East Slope. Reasonably foreseeable actions expected to affect hydrologic conditions and potentially aquatic resources are described in more detail in the WGFP Water Resource Technical Report (ERO and Boyle 2007) and include—

- Denver Water Moffat Collection System Project
- Urban Growth in Summit and Grand Counties
- Reduction in Xcel Energy Shoshone Power Plant Call
- Changes in Releases from Williams Fork and Wolford Mountain Reservoirs to meet U.S. Fish and Wildlife Service Flow Recommendations for Endangered Fish in the 15-Mile Reach
- Increased Wolford Mountain Reservoir Contract Demand
- Expiration of Denver Water's Contract with Big Lake Ditch in 2013

8.1 West Slope Effects

8.1.1 Streams and Rivers

Cumulative impacts to fish habitat on the West Slope, in particular to the Colorado River and Willow Creek, are very similar to the impacts shown in the direct effects. There is a slight increase in percent of habitat lost but a slight decrease in the frequency with which that habitat is lost (Tables 25, 26, and 27). For example, Table 21 shows that there is a 15 percent decrease in juvenile rainbow trout habitat below the Williams Fork River and this decrease occurs at a frequency of 1 in 10 years. Compare that result to the result for the same location in Table 26. Table 26 shows a 19 percent decrease in juvenile rainbow trout habitat for cumulative conditions but that decrease occurs 0.5 years out of 10. Dry year impacts for cumulative conditions are higher than direct effects (Tables 20 and 25); however, since there is no effect from WGFP in dry years, all the dry year effects are due to reasonably foreseeable actions. Average year and wet year impacts are very similar with most loss occurring as was shown in the direct effects. There is additional impact downstream of the Blue River but it is small and shows that the impact to habitat occurs about 1 in 10 years.

8.1.2 Lakes and Reservoirs

Cumulative impacts to lakes and reservoirs are generally the same as those seen in the direct effects. There are small reductions expected in dissolved oxygen concentrations but no change in trophic state for any of the lakes or reservoirs. Since no change in trophic state is predicted, there is no change expected to fish for cumulative effects.

8.2 East Slope Effects

8.2.1 Streams and Rivers

There are no reasonably foreseeable water-based actions on the East Slope that add to the impacts of the Windy Gap Project. The foreseeable changes in hydrology on the East Slope are primarily related to less Windy Gap deliveries to the East Slope with the Moffat system on-line. The pattern of flows are expected to be similar to the direct effects. There are small increases to stream flow predicted to East Slope streams in April through November. These increases are generally less than 10 percent and a biological change is likely not measurable.

8.2.2 Lakes and Reservoirs

Hydrologic conditions in Horsetooth and Carter reservoirs are expected to change by approximately 1 percent with reasonably foreseeable actions. This amount of change should have no additional measurable effect on the fish populations in those reservoirs. Reasonably foreseeable changes to Ralph Price Reservoir also would be similar to the expected direct effects and no additional change to fish is expected.

8.3 Threatened, Endangered, and Species of Concern

Impacts and effects are expected to be the same as discussed in Section 7.5.

Table 25. Summary of cumulative effects habitat changes (percent change from existing conditions and percent change from No Action, with frequency of occurrence in number of years out of 10) in the Colorado River and Willow Creek in <u>dry</u> water years for rainbow and brown trout.

Location/species	Rainbow Trout								Brown Trout							
	Juvenile				Adult				Juvenile				Adult			
	Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action	
	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency
Below Windy Gap	-4	9/10	5	9/10	-16	9/10	20	9/10	-4		5	9/10	-19	9/10	23	9/10
Hot Sulphur Springs	-5	8/10	5	9/10	-16	9/10	19	9/10	-5	8/10	5	8/10	-18	9/10	22	9/10
Above Williams Fork	-7	9/10	7	9/10	-27	4/10	37	9/10	-7	9/10	7	9/10	-31	9/10	45	9/10
Below Williams Fork	-3	0.5/10	3	8/10	12	8/10	-10	8/10	-3	0.5/10	3	0.5/10	-3	0.5/10	3	0.5/10
Above Troublesome Creek	-5	9/10	6	9/10	-20	9/10	23	9/10	-5	0.5/10	-5	9/10	-13	9/10	15	9/10
Above Blue River	3	9/10	-3	9/10	9	9/10	-8	9/10	3	9/10	-3	9/10	2	9/10	-2	9/10
Below Blue River	-6	1/10	7	0.5/10	-10	2/10	14	9/10	-6	1/10	7	1/10	-6	1/10	8	2/10
Willow Creek	3	6/10	3	6/10	4	6/10	4	6/10	3	6/10	-2	2/10	4	6/10	6	2/10

Table 26. Summary of cumulative effects habitat changes (percent change from existing conditions and percent change from No Action, with frequency of occurrence in number of years out of 10) in the Colorado River and Willow Creek in average water years for rainbow and brown trout.

Location/species	Rainbow Trout								Brown Trout							
	Juvenile				Adult				Juvenile				Adult			
	Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action	
	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency
Below Windy Gap	-7	2/10	-2	2/10	-28	2/10	-12	2/10	-8	0.5/10	0	0.5/10	-6	2/10	0	2/10
Hot Sulphur Springs	-6	2/10	-10	2/10	-26	2/10	-12	2/10	-8	0.5/10	-1	0.5/10	-5	3/10	0	2/10
Above Williams Fork	-6	2/10	0	2/10	-30	4/10	-11	4/10	-7	3/10	-2	3/10	-6	4/10	-4	4/10
Below Williams Fork	-19	0.5/10	-10	1/10	-19	0.5/10	-10	0.5/10	-19	0.5/10	-10	0.5/10	-19	0.5/10	-10	0.5/10
Above Troublesome Creek	-22	0.5/10	-10	0.5/10	-22	0.5/10	-10	0.5/10	-22	0.5/10	-10	0.5/10	-22	0.5/10	-10	0.5/10
Above Blue River	-20	1/10	-2	1/10	-20	1/10	-2	1/10	-20	1/10	-2	1/10	-20	1/10	-2	1/10
Below Blue River	-20	1/10	-1	1/10	-24	1/10	-1	1/10	-24	1/10	-1	1/10	-24	1/10	-1	1/10
Willow Creek	-9	2/10	-2	2/10	-20	2/10	-4	2/10	-13	2/10	-2	2/10	-21	2/10	-12	2/10

Table 27. Summary of cumulative effects habitat changes (percent change from existing conditions and percent change from No Action, with frequency of occurrence in number of years out of 10) in the Colorado River and Willow Creek in wet water years for rainbow and brown trout.

Location/species	Rainbow Trout								Brown Trout							
	Juvenile				Adult				Juvenile				Adult			
	Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action		Maximum Change from Existing Conditions		Maximum Change from No Action	
	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency
Below Windy Gap	-29	1/10	-3	1/10	-20	2/10	0	2/10	-29	1/10	-3	1/10	-29	1/10	-3	1/10
Hot Sulphur Springs	-29	1/10	-3	1/10	-29	1/10	-3	1/10	-29	1/10	-3	1/10	-30	1/10	-4	1/10
Above Williams Fork	-30	1/10	-4	1/10	-30	1/10	-4	1/10	-30	1/10	-4	1/10	-30	1/10	-4	1/10
Below Williams Fork	-22	1/10	-3	1/10	-22	1/10	-3	1/10	-22	1/10	-3	1/10	-22	1/10	-3	1/10
Above Troublesome Creek	-22	1/10	-2	1/10	-23	1/10	-3	1/10	-23	1/10	-3	1/10	-23	1/10	-3	1/10
Above Blue River	-18	1/10	-2	1/10	-18	1/10	-2	1/10	-18	1/10	-2	1/10	-18	1/10	-2	1/10
Below Blue River	-18	1/10	-1	1/10	-18	1/10	-1	1/10	-18	1/10	-1	1/10	-18	1/10	-1	1/10
Willow Creek	-9	3/10	-2	3/10	-15	3/10	-11	3/10	-11	0.5/10	0	-	-11	2/10	-6	2/10

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10.0 APPENDIX A – MACROINVERTEBRATE DATA

10.0 APPENDIX A – MACROINVERTEBRATE SPECIES LISTS

Table 28. Macroinvertebrate data collected from the Lone Buck site on the Colorado River on September 17, 2004.

Colorado River Lone Buck September 17, 2004	Sample				Mean	Count
	1	2	3			
Acentrella insignificans	15	21	48		28.00	1
Baetis (tricaudatus)	127	138	108		124.33	1
Fallceon quilleri	31	20	9		20.00	1
Drunella grandis						
Ephemerella sp.	13	33	32		26.00	1
Serratella sp.	1				0.33	1
Epeorus (albertae)	67	81	73		73.67	1
Heptagenia sp.			1		0.33	1
Paraleptophlebia sp.	18	21	21		20.00	1
Tricorythodes minutus	2	7	5		4.67	1
Sweltsa sp.	2	2	4		2.67	1
Claassenia sabulosa						
Isoperla sp.		2			0.67	1
Pteronarcys californica	10	1	14		8.33	1
Brachycentrus americanus						
Culoptila sp.	3	24	9		12.00	1
Glossosoma sp.						
Helicopsyche borealis		2			0.67	1
Hydropsyche cockerelli	4	5	12		7.00	1
Hydropsyche (oslari)	1				0.33	1
Cheumatopsyche sp.	2	3	13		6.00	1
Agraylea multipunctata						
Hydroptila sp.			1		0.33	1
Leucotrichia pictipes	1	5	2		2.67	1
Lepidostoma sp.	25	122	45		64.00	1
Ceraclea sp.						
Oecetis sp.	2				0.67	1
Psycomyia flavida		1			0.33	1
Orthocladiinae	93	116	99		102.67	1
Tanypodinae	6	18	6		10.00	1
Tanytarsini	1		1		0.67	1
Chironomini	3	1			1.33	1
Simulium sp.	3	1	1		1.67	1

Table 25 (continued). Macroinvertebrate data collected from the Lone Buck site on the Colorado River on September 17, 2004.

Colorado River Lone Buck September 17, 2004	Sample				Mean	Count
	1	2	3			
Chelifera sp.						
Hemerodromia sp.		5	3		2.67	1
Antocha sp.						
Bezzia/Probezzia		2			0.67	1
Atherix pachypus	2		3		1.67	1
Optioservus sp.	10	42	23		25.00	1
Zaitzevia parvula	7	39	44		30.00	1
Hydracarina sp.	7	8	4		6.33	1
Gammarus sp.						
Hyalella azteca						
Asellus	2	2			1.33	1
Ancylidae sp.		4	1		1.67	1
Physa sp.		2	2		1.33	1
Planorbidae		1			0.33	1
Pisidium sp.	2	22	36		20.00	1
Dugesia sp.	4		1		1.67	1
Polycelis coronata						
Hirudinea		1			0.33	1
Oligochaeta	29	68	40		45.67	1
Nematoda	3		1		1.33	1
Totals	**496.0**	**820.0**	**662.0**		**659.33**	**42**
Shannon Weaver Diversity					3.90	
Shannon Weaver Evenness					0.72	
HBI					4.64	

Taxa in parentheses may include individuals of other closely related species that cannot be identified due to condition or life-stage.

Table 29. Macroinvertebrate data collected from the Breeze site on the Colorado River on September 17, 2004.

Colorado River Breeze September 17, 2004	Sample				Mean	Count
	1	2	3			
Acentrella insignificans	13	15	7		11.67	1
Baetis (tricaudatus)	55	139	156		116.67	1
Fallceon quilleri	11	42	16		23.00	1
Drunella grandis			1		0.33	1
Ephemerella sp.	93	202	88		127.67	1
Serratella sp.	3	1	1		1.67	1
Epeorus (albertae)	41	56	22		39.67	1
Heptagenia sp.						
Paraleptophlebia sp.	21	79	32		44.00	1
Tricorythodes minutus	12	21	6		13.00	1
Sweltsa sp.	4		19		7.67	1
Claassenia sabulosa		1	2		1.00	1
Isoperla sp.	5	12	7		8.00	1
Pteronarcys californica						
Brachycentrus americanus	21	79	31		43.67	1
Culoptila sp.	101	442	431		324.67	1
Glossosoma sp.	8	17	19		14.67	1
Helicopsyche borealis	5	7	1		4.33	1
Hydropsyche cockerelli	6	20	32		19.33	1
Hydropsyche (oslari)	11	60	45		38.67	1
Cheumatopsyche sp.		3	5		2.67	1
Agraylea multipunctata		1			0.33	1
Hydroptila sp.						
Leucotrichia pictipes						
Lepidostoma sp.	227	538	203		322.67	1
Ceraclea sp.		2	3		1.67	1
Oecetis sp.		1	2		1.00	1
Psycomyia flavida						
Orthocladiinae	268	431	327		342.00	1
Tanypodinae	3	12	14		9.67	1
Tanytarsini	3	9	8		6.67	1
Chironomini	1	2			1.00	1
Simulium sp.	40	298	65		134.33	1
Chelifera sp.	2	3	4		3.00	1
Hemerodromia sp.	3	6	1		3.33	1
Antocha sp.		3	1		1.33	1

Table 26 (continued). Macroinvertebrate data collected from the Breeze site on the Colorado River on September 17, 2004.

Colorado River Breeze September 17, 2004	Sample				Mean	Count
	1	2	3			
Bezzia/Probezzia						
Atherix pachypus			1		0.33	1
Optioservus sp.	27	61	43		43.67	1
Zaitzevia parvula	7	32	34		24.33	1
Hydracarina sp.	2	5	3		3.33	1
Gammarus sp.		5			1.67	1
Hyalella azteca			2		0.67	1
Asellus	1	9	3		4.33	1
Ancylidae sp.						
Physa sp.	2	4	2		2.67	1
Planorbidae		1	1		0.67	1
Pisidium sp.	23	33	12		22.67	1
Dugesia sp.						
Polycelis coronata	249	792	405		482.00	1
Hirudinea						
Oligochaeta	10	25	34		23.00	1
Nematoda	12	41	19		24.00	1
Totals	**1,290.0**	**3,510.0**	**2,108.0**		**2,302.67**	**44**
Shannon Weaver Diversity					3.68	
Shannon Weaver Evenness					0.67	
HBI					4.57	

Taxa in parentheses may include individuals of other closely related species that cannot be identified due to condition or life-stage.

11.0 APPENDIX B – COLORADO RIVER INSTREAM FLOW STUDY WINDY GAP RESERVOIR TO THE BLUE RIVER

11.0 APPENDIX B – COLORADO RIVER HABITAT FLOW – RELATIONSHIPS FROM WINDY GAP RESERVOIR DOWNSTREAM TO THE BLUE RIVER

Introduction

This study developed new physical habitat information for the Colorado River from Windy Gap Reservoir downstream to the Blue River. Existing habitat-flow relationships were used for Willow Creek (MEC 1997).

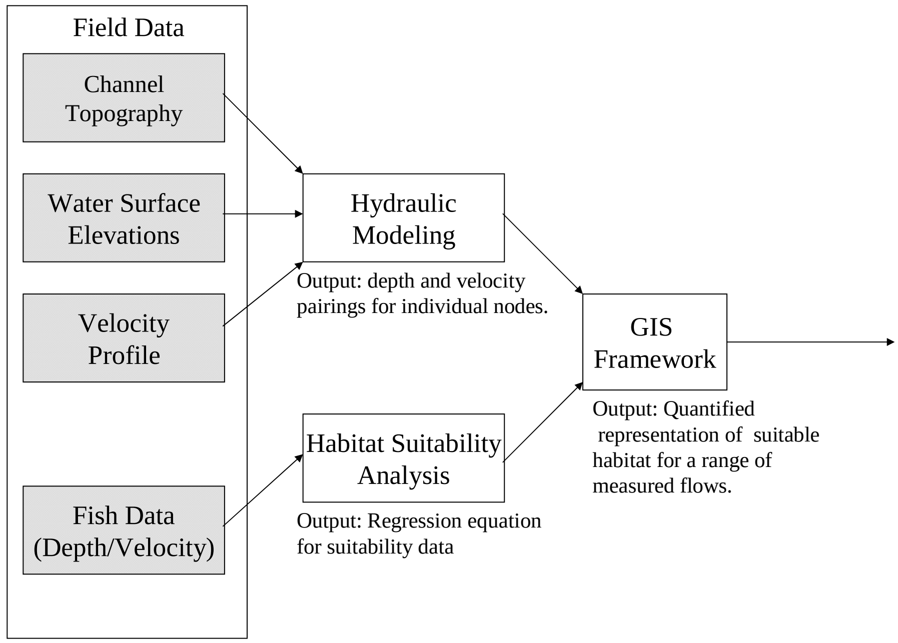
The study presented here included an analytical model that combines 2-dimensional hydraulics, a GIS habitat model and hydrologic data into a habitat time series. This approach follows the concepts of the IFIM (Bovee 1982, Bovee et al. 1998). IFIM is an analysis framework that combines stream hydraulics, habitat use criteria, and hydrology data to predict fish habitat as a function of stream flow. These components were included in the study for the Colorado River sites. Stream hydraulic conditions were measured in the field and modeled with the 2 dimensional hydraulic simulations. Existing habitat suitability data the Colorado Division of Wildlife were used for the target fish species (CDOW unpublished data). These habitat criteria were combined with the hydraulic simulations in a GIS habitat model to calculate habitat versus discharge relationships. The habitat versus discharge relationships were input to a computer spreadsheet and combined with hydrology data to calculate habitat over time. Generally, the time series analysis is the primary output from IFIM, which indicates the changes in habitat for a duration of time (Figure 10). This time series output was used to determine the change from baseline condition.

Study Area

The study area includes two sites on the Colorado River downstream from Windy Gap Reservoir. The river was divided into reaches reflecting similar conditions of flow, morphology, and habitat. The site at the Lone Buck State Wildlife Area represents the Colorado River from Windy Gap downstream to the Williams Fork River (Figure 11). The site at the Breeze State Wildlife area represents the river from the Williams Fork River downstream to the Blue River.

Objective

The objective of this study is to determine the change in habitat as a result of flow changes associated with the Windy Gap Firming project. The species of interest for the analysis were rainbow trout (*Oncorhynchus mykiss)* and brown trout (*Salmo trutta)*. The species were selected in consultation with CDOW during the site selection process.



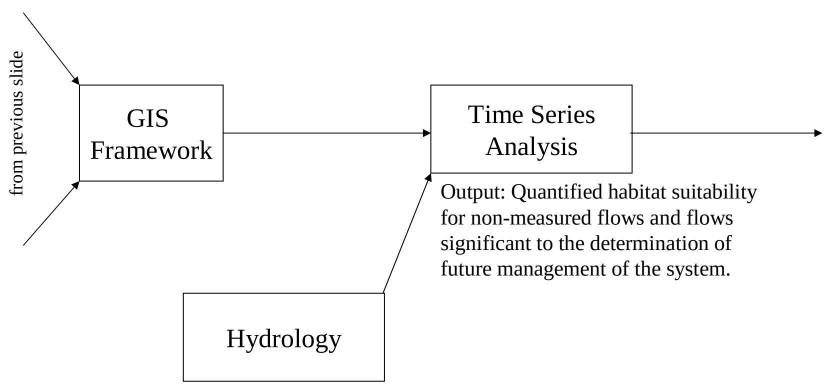


Figure 10. Flow chart of data analysis for Colorado River hydraulics and aquatic habitat.

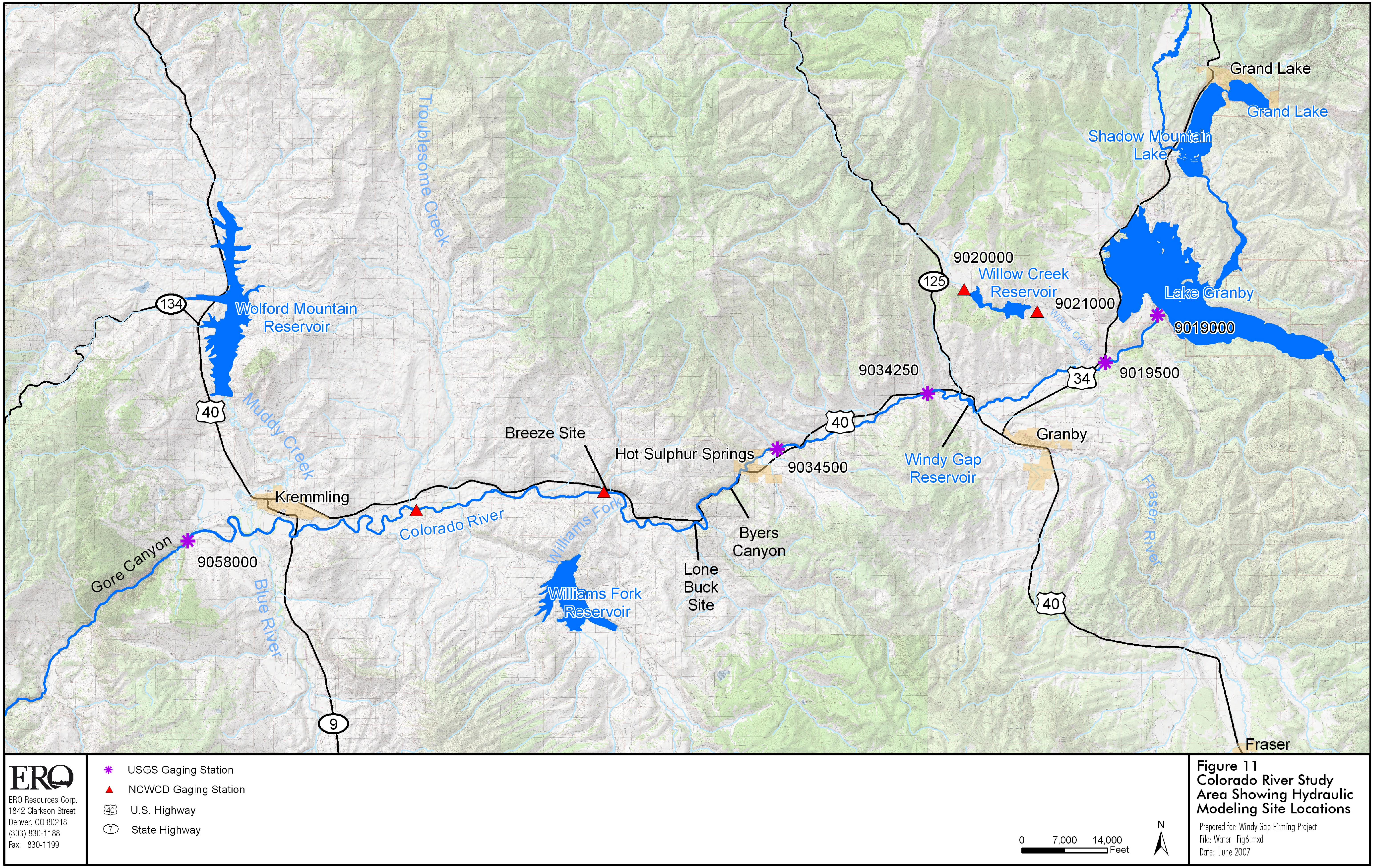


Figure 11
Colorado River Study Area Showing Hydraulic Modeling Site Locations

Prepared for: Windy Gap Firming Project
File: Water_Fig6.mxd
Date: June 2007

General Approach

The approach for assessing instream flow needs for fish utilized hydraulic analysis and habitat modeling to evaluate changes in quantity, quality, and distribution of habitat with changes in flow in the Colorado River and Willow Creek.

Hydraulic modeling begins with construction of a digital terrain map for the study area. A survey-grade Total Station was used to field map each study site, and data points so obtained were used to construct a detailed topography map (or grid) of the channel and adjacent floodplains and terraces. Multiple data sets of water-surface elevations and point velocity measurements were used to calibrate a two-dimensional hydraulic model to simulate depth and direction of flow through each site. The grid of resulting flow depths and velocities is then compared to habitat preference criteria for species of interest to determine location and quality of resulting habitat.

Habitat modeling requires information on fish utilization of certain depths and velocities of flow, in addition to utilization of certain substrate, cover, and other channel conditions. These microhabitat utilization values were compiled from existing CDOW data sets. The habitat suitability functions were then used as a filter against the grid of depth and velocity values predicted by the hydraulic model to estimate suitability of habitat in each grid cell at the site. The area of grid cells with suitable habitat were then summed to obtain total usable area for a given streamflow level.

Details of the approach for hydraulic simulation and habitat modeling are presented in the following sections.

Methods

Existing hydrology, water quality (in particular, water temperature), and fishery data were required for the study area. These data were used in conjunction with hydraulic analysis and habitat modeling to evaluate flow scenarios. The raw data from previous CDOW studies were used to develop habitat suitability curves for rainbow and brown trout.

The IFIM assumes that physical habitat is a function of streamflow level in the streams being studied (Bovee 1982). Part of the scoping process for application of IFIM involves determining the limiting factors that apply to the study streams. The factors evaluated include channel geometry, water quality, and management factors affecting fish populations. The review of existing information was used to complete the limiting factor analysis. Limiting factors reviewed were water temperature and dissolved oxygen concentrations.

In addition to habitat quantity and quality for specific life stages, factors such as water temperature, water quality, and food sources (such as benthic macroinvertebrates) may be limiting to fish populations. Macroinvertebrate sampling was conducted in each study reach to determine the diversity and abundance. Review of existing records (USGS, CDOW) was used to identify the water quality and fishery data available for the analysis.

Site Selection

The study area for the IFIM analysis included the Colorado River from Windy Gap Reservoir to the Blue River confluence. Study site selection followed the guidelines for IFIM studies (Bovee 1982). Data collected for site selection included stream slope and discharge for gaged locations (Table 29). The Colorado was divided into two stream reaches based on hydrology and habitat characteristics. Final site location was determined during a site visit conducted by MEC and CDOW. Except for the short distance of Byers Canyon, the stream slope from Windy Gap Reservoir downstream to the Williams Fork is similar and has no major tributaries to change the flow more than 10 percent (Table 29). The stream slope is consistent from the Williams Fork downstream to the Blue River. There is one major tributary, Troublesome Creek, in this river reach. The gage records show that Troublesome Creek contributes less than 10 percent to the average discharge; therefore, an additional stream study reach was not required. Byers Canyon was not modeled due to limitations of the hydraulic model to simulate the rapidly varying flow in the Canyon. Further, the canyon reach is a small percentage of the total habitat in the river, not easily accessible or fishable. Due to these factors, it was agreed during the site selection to omit this section from simulations. One study site was selected within each reach to be representative of the habitat characteristics of the reach. Two study sites were measured: 1) on the Lone Buck State Wildlife Area upstream of the Williams Fork River and, 2) downstream from the Williams Fork River on the Breeze State Wildlife Area (Figure 11). In each of these reaches, a study site of approximately ¼ mile was mapped for hydraulic analysis and habitat modeling.

In both study site reaches the stream consisted of a relatively open channel with mature riparian vegetation and trees set farther back from the streambanks that were one to two meters higher than the low flow stream channel. Within the channel at both study sites, there were three different main components: a run habitat with mid-channel bars, meander bends (Figure 12), and low gradient riffles (Figure 13). The channel at both reaches was dominated by cobble substrate as illustrated at the Lone Buck study site in Figure 14.

Table 30. Stream slope and hydrology changes for the Colorado River downstream of Windy Gap.

Location	Distance (miles)	Slope (ft/ft)
Windy Gap to Byers Canyon	7.1	0.003
Byers Canyon	2.1	0.007
Byers Canyon to William Fork River	4.1	0.004
Williams Fork River to Blue River	15.9	0.002
	Percent change in average discharge	
Colorado River at Windy Gap	--	
Colorado River downstream of Williams Fork River	45%	
Colorado River downstream of Troublesome Creek	<10%	

Figure 12. Breeze site showing mid-channel bar and river bend.

Figure 13. Example of low gradient riffle at the Breeze site.

Figure 14. Example of cobble substrate at the Lone Buck site.

Topographic Mapping

Each study site was surveyed with a survey-grade Total Station for the purpose of constructing a digital terrain model for the site. The Total Station provided local coordinates (horizontal and vertical) of each point to an accuracy of about 0.01 meter for both horizontal and vertical resolution. Horizontal stations and elevations were georeferenced to a local coordinate system at each reach. A sufficient number of points were surveyed on the ground to enable construction of a digital terrain model for the study site. In the vicinity of the channel, points were closely spaced to define channel geometry both in plan form and cross section. Channel geometry points were collected up to and above the typical high-water marks to establish ground topography for modeling flow regimes. Substrate and cover also were recorded for each surveyed point, along with field notes describing general stream and habitat conditions at the study site and reference photos for the area.

Hydraulic Data Collection

Two-dimensional hydraulic modeling requires channel geometry data, multiple water-surface elevation data sets, and multiple velocity data sets. The specific hydraulic data that were collected at each site included stream bed elevations, mean column velocity at selected locations (multiple collections at each habitat type), visual estimates of dominant and subdominant substrate size and percent embeddedness, and percent cover. All hydraulic data were georeferenced on a local coordinate system for inclusion in the digital terrain model of the site and the associated GIS data base. The following procedures were used to obtain the necessary data.

A Total Station was used to collect stream bed elevations as described above. Above-water points also were surveyed and georeferenced for linkage to GIS. At a selected number of locations within each study site, water velocity was measured for use in hydraulic model calibration. Mean column velocity was measured to the nearest 0.1 foot/second. Multiple measurements were taken in each specific habitat type for use in model calibration. Substrate composition was visually estimated at all verticals both wet and dry. Substrate was denoted for the following categories:

Aquatic vegetation
Silt
Sand
Small gravel (0.25 - 1.0 inch)
Large Gravel (>1.0 - 3.0 inch)
Cobble (>3.0 - 10.0 inch)
Boulder (>10.0 inch)
Bedrock

The substrate was categorized by dominant and subdominant size class. The substrate classification system was modified as needed to provide the information required for the habitat suitability criteria.

Cover was visually estimated by percentage. The following describes cover types:

Velocity Refuge - any instream object that provides a velocity refuge for the species of interest. This could include objects such as boulders, root wads, large woody debris or other such objects.

Visual Isolation - any object that provides visual isolation for the species of interest such as overhanging vegetation, undercut banks, or other such items.

Combination Cover - any cover that provides both velocity refuge and visual isolation. This could be any combination of the cover items listed above or a single cover object such as a downfall that provides both velocity refuge and visual isolation.

No Cover - absence of cover will also be noted.

The full set of data was recorded at one flow, including topography, depth, velocity, substrate and cover. Repeat measurements of water-surface elevations and velocities were taken throughout the fall and winter of 2004/2005 to collect data from at least two and up to three different discharge levels. During these measurements, water-surface elevations were surveyed at each study site and one discharge measured for the site.

These stage-discharge measurements provided the data necessary for model calibration and for extending the range of hydraulic simulations.

Two-Dimensional Hydraulic Modeling

Two-dimensional hydraulic modeling was accomplished using River2D hydrodynamic modeling software (Steffler et al. 2001). This model was developed to simulate two-dimensional velocity vectors in river systems, and can simulate element (i.e., grid cell) wetting and drying as flows are increased or decreased. This model operates on a grid developed from the digital terrain model for each study site, and output was linked to GIS models for analysis and display of habitat availability as a function of flow.

The 2-D model uses the georeferenced field data collected from each study site. Data inputs include site topography, substrate, and flow impediments; a stage-discharge relationship at the downstream end of the site; and calibration and validation data throughout the reach. Model calibration and validation data consist of depth and velocity measurements taken at known flow rates and locations in the study site. The survey data were used to develop a grid system to represent the stream geometry. This mesh was combined with the hydraulic data to simulate water depths and velocities for a range of flow conditions.

Habitat Suitability Curves

Species habitat-suitability criteria are required for the habitat analysis. The recommended approach is to develop site-specific criteria for each species and life stage of interest. An alternative to this is to use existing curves and literature to develop suitability criteria for species of interest. Habitat suitability criteria that accurately reflect the habitat requirements of the species of interest are essential to conducting meaningful and defensible instream flow analyses. The curves used in this study fit that criterion.

Development of habitat suitability curves requires precise information on water depths, velocities, substrates, and cover types utilized by each life stage of target species. Calculation of habitat suitability criteria for a two-dimensional hydraulic model includes use of a bivariate analysis of depth-velocity paired data to calculate fish preference for depth and velocity in the stream reach. This data is available from other Colorado stream systems for the species of interest used in this analysis. New habitat suitability criteria were calculated from the existing data.

A bivariate statistical analysis was used to develop habitat suitability criteria for each species with sufficient data (Miller 2001). This analysis first plotted bivariate histograms, then converted those to a 3-dimensional surface and finally computed a polynomial expression that replicates the 3-dimensional surface to predict suitability values. A multivariate exponential polynomial equation is developed to fit the 3-dimensional surface. The peak of the surface shape represents optimal depth and velocity for the life stage of interest (Figure 15).

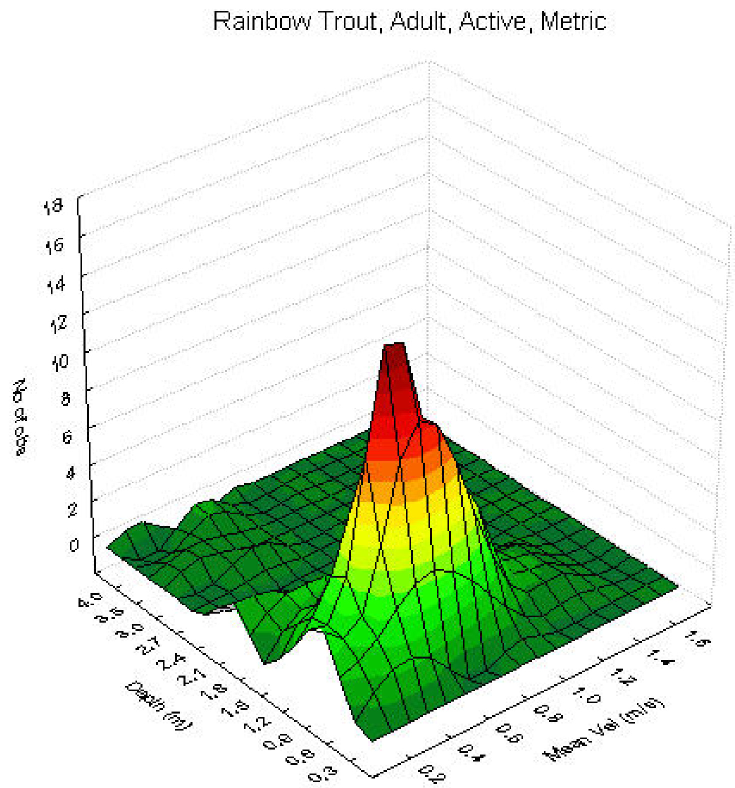


Figure 15. Example of 3-dimensional surface used to generate habitat suitability equation for adult rainbow trout.

Habitat Modeling

The habitat modeling for this analysis followed the concepts of IFIM and the computer simulation steps of the Physical Habitat Simulation System (PHABSIM). IFIM requires hydraulic data and simulations; habitat use data expressed as habitat suitability criteria; and hydrology data for a range of stream discharge conditions. The hydraulic analysis and simulations were described above.

Habitat suitability modeling for each species of interest is accomplished in an ArcView GIS analysis (Miller 2002). The ArcView instream habitat model relies on inputs from both the 2-dimensional hydraulic modeling and the habitat suitability criteria described above. These inputs are provided in the form of data layers within the GIS and parameters for spatial queries. Data layers corresponding to flow depths and velocities provided by the 2-dimensional hydraulic modeling are developed for each flow rate and overlain with data layers for substrate and cover within the study site. Specific habitat criteria developed from the suitability analyses described above are then used to conduct GIS queries. In this way, the amount of area within the study site that matches a particular species' habitat preference was determined for a specified flow rate. Multiple layers of usable habitat were generated, corresponding to each species, life stage, and flow of interest. The analysis was output as a 2-dimensional map for a visual presentation of the results. Summation of total habitat for each species and simulated flow resulted in a habitat-flow relationship by species and lifestage that becomes input for the habitat-time series analysis. The usable habitat area for each species of interest was the result of combining the hydraulic simulations for each flow with the habitat suitability function for each species and life stage. The general sequence of habitat modeling is as follows.

The 2-dimensional hydraulic simulations use a mesh to depict the stream channel. This mesh is configured to best represent each simulated flow. The result is multiple model meshes to represent the range of flow conditions. Unlike a 1-dimensional hydraulic simulation that uses multiple cross sections that remain fixed for the full range of simulation flows, each of the 2-dimensional meshes can have a different number of nodes and therefore a different surface area. The hydraulic simulation data sets contain the horizontal and vertical reference locations for each node in the model mesh. In addition, the node locations have depth and velocity data for each flow. These georeferenced data sets are combined with the habitat suitability functions in ArcView. The result of the GIS analysis is a georeferenced map of usable habitat for each species and life stage. The GIS model creates a summation file for the usable habitat for each flow. The habitat – discharge relationship for the flows simulated at each site are developed for each species and life stage.

The habitat – discharge relationships are a set of theoretical functions based on channel shape and hydraulics. The actual habitat realized by the species is a function of the discharge at the site over time. The combination of the habitat –discharge function and hydrology data is the habitat time series.

Habitat Time Series

The actual habitat experienced by the fish in any river depends on the flow regime of the river. The relative abundance of habitat conditions over a period of time is an integral part of the comparison of flow regimes. Generally, the habitat time series is the decision point in IFIM. Habitat time series produces the data needed to compare a range of flow conditions over time and to compare different flow scenarios. The habitat –discharge relationships for each study site are used as input data for the habitat time series.

The final step in the study was a comparison of flow – habitat relationships using a time series of flows for the study reach. This analysis allowed a comparison between the existing flow regime and alternate flow regimes to determine habitat available with each time series.

The daily hydrology for dry, average, and wet year types and habitat data are imported into a computer spreadsheet for the time series analysis. The spreadsheet is set up to analyze the effect of changing hydrology over time on aquatic habitat. Miller (2003) provides a detailed description of the time series analysis using a computer spreadsheet.

In general, the daily hydrology data set of interest is copied into spreadsheet columns. Any combination of flow scenarios can be analyzed with this approach. For this study, the flows from the Windy Gap hydrology analysis and monthly gage data (ERO and Boyle 2007) was used to generate a daily baseline and proposed action hydrology data sets.

Macroinvertebrates

Benthic macroinvertebrate sampling in the Colorado River during fall 2004 at each instream flow site. At each location three samples were taken in riffle habitat using a Hess Sampler with 500 μm mesh in order to provide quantitative macroinvertebrate data. An effort was made to take all samples in areas of similar size substrate and similar depth in order to avoid bias that may be directly related to habitat. Substrate within the Hess Sampler was thoroughly disturbed and individual rocks were scrubbed by hand to dislodge all benthic organisms. Benthic macroinvertebrates were preserved in 75 percent ethanol and transported to the lab where they were sorted, enumerated, and identified to the lowest practical taxonomic level (Merritt and Cummins 1996; Ward et al. 2002).

Identification to the "lowest practical taxonomic level" means that all specimens were identified down to the level that is permitted by the available morphological characteristics. Early life stages of many species lack certain anatomical characteristics that allow the specimen to be identified to the genus or species level. In these cases the "lowest practical taxonomic level" may mean only the family level; however, if the available characteristics are consistent with a species that has been previously confirmed during this study, then the individual may be included as a member of that taxa. This technique avoids the bias that would result from calculating index values using incorrectly elevated richness values.

As a means of QA/QC, each sample was inspected after sorting, and two or more qualified taxonomists reviewed approximately 20 percent of all identified taxa. Dr. Boris Kondratieff (Professor of Entomology at Colorado State University) confirmed identifications in all cases where the identification of a specimen was difficult or questionable.

Results

Limiting factor analysis

Limiting factors that may affect fish populations in addition to physical habitat include food, water temperature and water quality, in particular dissolved oxygen concentration. Existing data on water temperature and water quality was reviewed to determine if acute or chronic conditions exist within the study area. Water temperature was occasionally higher than the chronic values for trout, however, these instances were of short duration (e.g., one day)and given the high trout populations, do not appear to be limiting. No other physical or chemical limiting factors were identified. Potential biological limiting factors in the Colorado River include the presence of whirling disease and its impact on rainbow trout. The very high brown trout populations indicate that with adequate management, the conditions in the Colorado River are suitable for trout.

Hydraulic Simulations

Hydraulic models were created using River2D software to generate the mesh and hydraulic characterization for each study site. Each model was configured to represent local hydraulics based on channel topography measured during the three flow measurements at most sites. Channel hydraulics consisted of pools, riffles and runs combined with bed topography and velocities. The model software represents these in plan view to show the faster water velocities as warmer colors, reds and yellows, and slower velocities as the cooler colors of blues. The depiction of the plan view shows that model representation does match the observed condition in a general sense and further calibration was conducted to determine the accuracy of the velocity predictions. Model topography at each site was checked against photography to verify that the model was representing each of the channel configurations with sufficient detail for mid-channel as well as shoreline channel features. Mid-channel bars were depicted with relatively accurately at each of the study sites. For example, the model bed topography and velocities and depths are shown to accurately represent a mid-channel bar at the Breeze site when compared to the photography observed in the field (Figures 16 and 17).

Figure 16. Example of local hydraulics at the Breeze site.

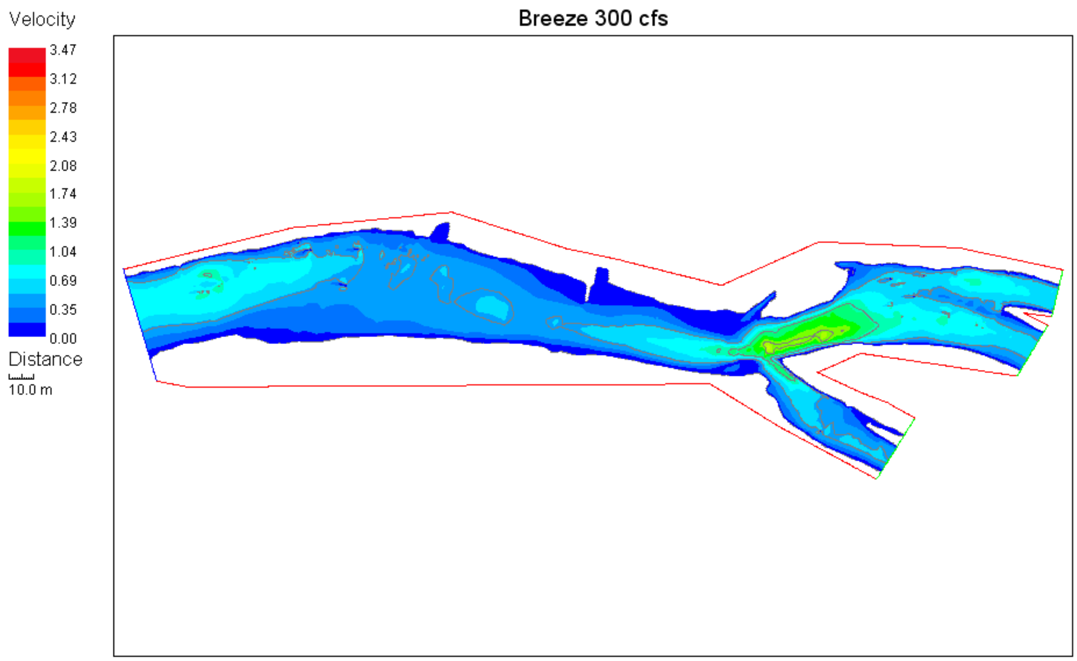


Figure 17. Depiction of the local hydraulics shown in Figure 13 placed in plan view in the hydraulic simulations.

The two-dimensional hydraulic model has the capability of not only predicting velocity magnitude but also velocity direction. During the calibration sequence, the velocity plots and vectors were reviewed to determine that eddy currents, as well as concentrated areas of higher velocities, were being represented by the model. An additional check for model calibration was distribution of observed versus modeled velocities throughout each of the study reaches. Water velocities were collected at selected points throughout each site for each measured discharge. Each of these collections resulted in a data set that was compared with a distribution of velocities selected from within the model framework. In general, the distribution of modeled velocities matched well with the distribution of measured velocities collected in the field (Figures 18 and 19). The majority of the modeled and measured velocities were in the same range.

The hydraulic model requires a stage discharge relationship at the downstream end of the model site to estimate the stage (water surface elevation) relative to discharge for the modeling solutions. Stage-discharge relationships were developed from measured water surface elevations using a regression to fit a range of discharges to measured water surface elevations.

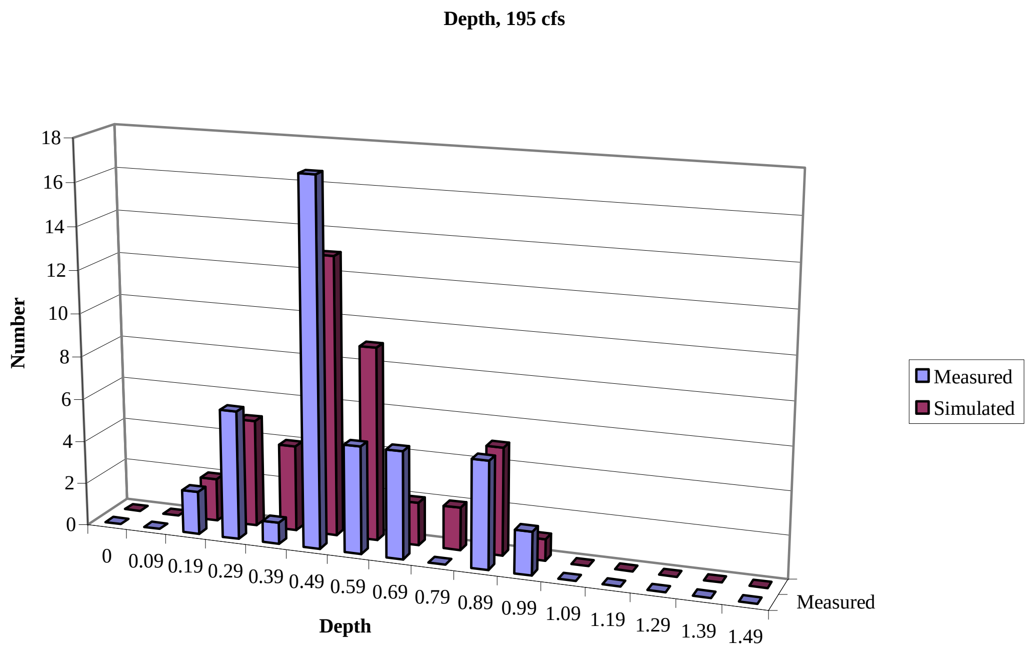


Figure 18. Depth calibration histogram, Breeze site, 195 cfs.

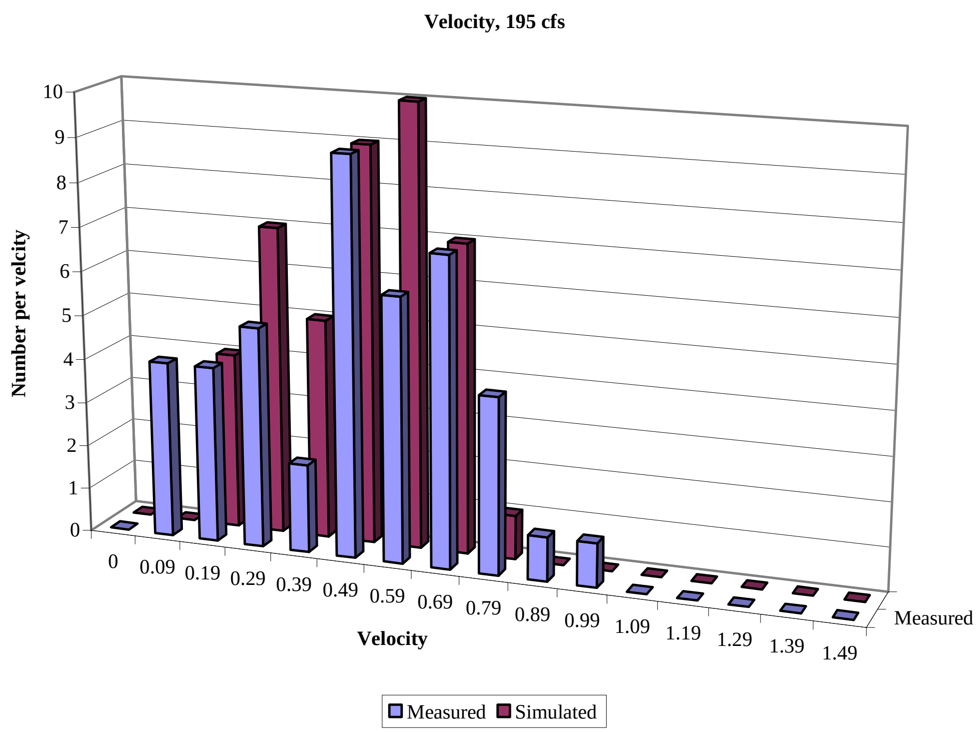


Figure 19. Velocity calibration histogram, Breeze site, 195 cfs.

Model Simulations

A range of flows were simulated for each study site to develop the hydraulics to be analyzed for the habitat simulation. Hydraulic output (depth, velocity) was transferred from River2D to Excel spreadsheets with the georeferenced x, y and z bed location for each simulated flow. These data were then transferred to the GIS model for habitat simulation.

Habitat Time Series

Habitat time series analysis was used to assess the impact of the WGFP on the aquatic habitat in the Colorado River. The development of habitat conditions over a period of time is an integral part of the comparison of flow regimes. For this study, both daily hydrology and daily habitat time series analysis were conducted for the study reaches.

The habitat time series was the result of combining the respective daily flow regimes and the weighted usable area (WUA) discharge relationships for each life stage to produce habitat as a function of time. These habitat over time data sets were analyzed using standard duration techniques. The exceedence values were calculated for hydrology and habitat time series data. The exceedence represents the percent of time a hydrology or habitat value is equaled or exceeded. For example, flow or habitat values at the 50 percent exceedence level are equaled or exceeded 50 percent of the time.

Periodicity of the life stages was considered when developing the time series data. Year round flows were used for adult and juvenile life stages.

Habitat for both species at both sites peaks between 400 and 500 cfs (Figures 20 through 23). These habitat versus discharge functions were combined with hydrology in the habitat time series to predict habitat over time for each alternative. One factor that is not evident with the habitat time series is spatial changes of habitat with flow. The River2D model can illustrate those for particular flows of interest. Figures 24 through 26 show the location of key habitat (darker blue color within the channel) at flow ranges from approximately 100 cfs to 750 cfs ().

The habitat exceedence values were calculated for all alternatives and are displayed in Figures 27 to 410. The IFIM time series analysis indicates the changes in habitat and the duration of changes in habitat for each of the alternatives at seven locations on the Colorado River and on Willow Creek for both adult and juvenile rainbow and brown trout. The analysis was conducted for average, dry, and wet years. As indicated by the dry year figures, there would be no change in existing available habitat for any of the alternatives. The change in habitat exceedence were generally less than 5 percent in average years and up to about 30 percent in wet years for some alternatives.

Habitat exceedence values were calculated for direct and cumulative effects at the locations indicated below. Topographic and hydraulic data from the two study sites

(Lone Buck—Above Williams Fork and Breeze—Below Williams Fork) were extrapolated to calculate habitat values at other locations using hydrologic data specific to each location.

<u>Direct Effects</u>

Below Windy Gap	Figure 27 to Figure 50
Hot Sulphur Springs	Figure 51 to Figure 74
Above Williams Fork	Figure 75 to Figure 98
Below Williams Fork	Figure 99 to Figure 122
Above Troublesome Creek	Figure 123 to Figure 146
Above Blue River	Figure 147 to Figure 170
Below Blue River	Figure 171 to Figure 194
Willow Creek	Figure 195 to Figure 218

<u>Cumulative Effects</u>

Below Windy Gap	Figure 219 to Figure 242
Hot Sulphur Springs	Figure 243 to Figure 266
Above Williams Fork	Figure 267 to Figure 290
Below Williams Fork	Figure 291 to Figure 314
Above Troublesome Creek	Figure 315 to Figure 338
Above Blue River	Figure 339 to Figure 362
Below Blue River	Figure 363 to Figure 386
Willow Creek	Figure 387 to Figure 410

Figures for each of the locations include two types of graphs indicating changes in habitat over time. The habitat exceedence graphs indicate the amount time that the area of habitat (in sq. feet) is greater than a given percentage. For example, in Figure 35 for the Below Windy Gap location during wet years for juvenile rainbow trout indicates that about 15 percent of the time habitat under existing conditions (EC) exceeds about 350,000 sq. feet. Under all the alternatives, 15 percent of the time habitat would exceed about 275,000 sq. feet or habitat would exceed 350,000 sq. feet about 10 percent of the time. Thus in this case, there is a reduction in available habitat under the alternatives or put another way, 350,000 sq. feet of habitat would be available less often. Another way to interpret this graph is that about 75 percent of time there would be no change in available habitat from existing conditions during wet years for any of the alternatives.

Figure 37 for the same location, species, and wet year indicates the percent changes in exceedence. On this graph the left axis indicates the percent change in habitat from existing conditions, where the 0 line is existing conditions. Values above the 0 line indicate an increase in habitat from existing conditions and values below the 0 line indicate a decrease in habitat. The bottom axis indicates the percent of time (i.e., days) that habitat changes. Thus, in this example, about 10 percent of the time (bottom axis) habitat under the alternatives decreases about 25 percent (left axis). Small differences in alternatives are indicated by the different color lines. About 50 percent of the time there is little to no change between the alternatives and existing conditions in this example. Figure 51 indicates an increase in habitat of up to 10 percent for the Chimney Hollow

Alternative from existing conditions about 90 percent of the time in wet years. This occurs because fish habitat can be reduced at high flows and diversions that reduce flow increase available habitat.

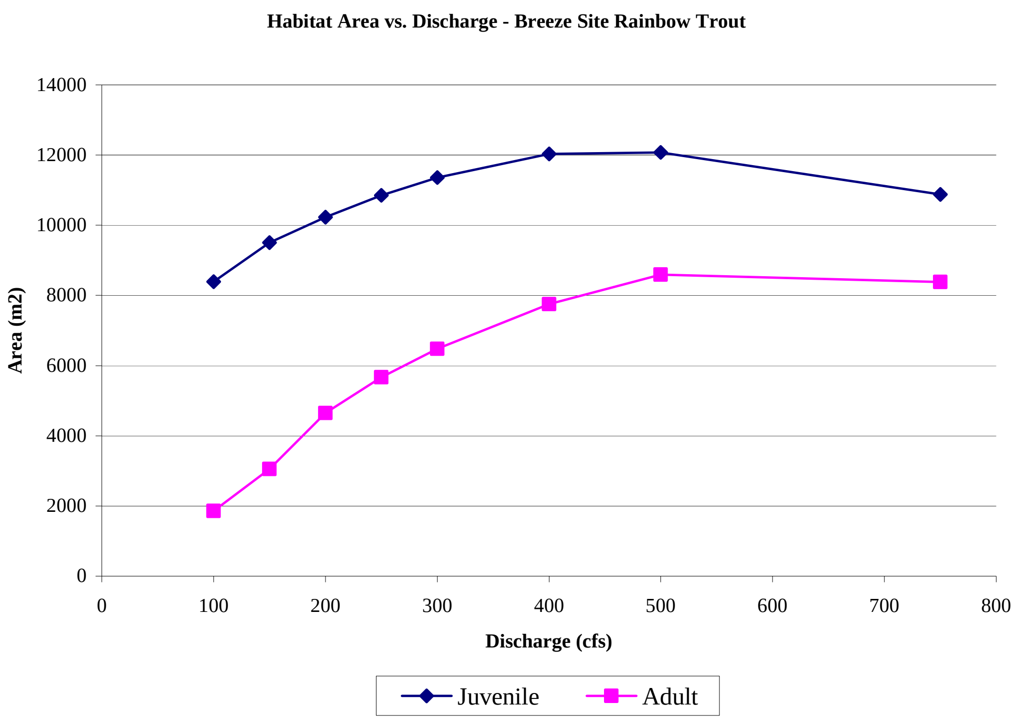


Figure 20. Habitat area versus discharge – Breeze site rainbow trout.

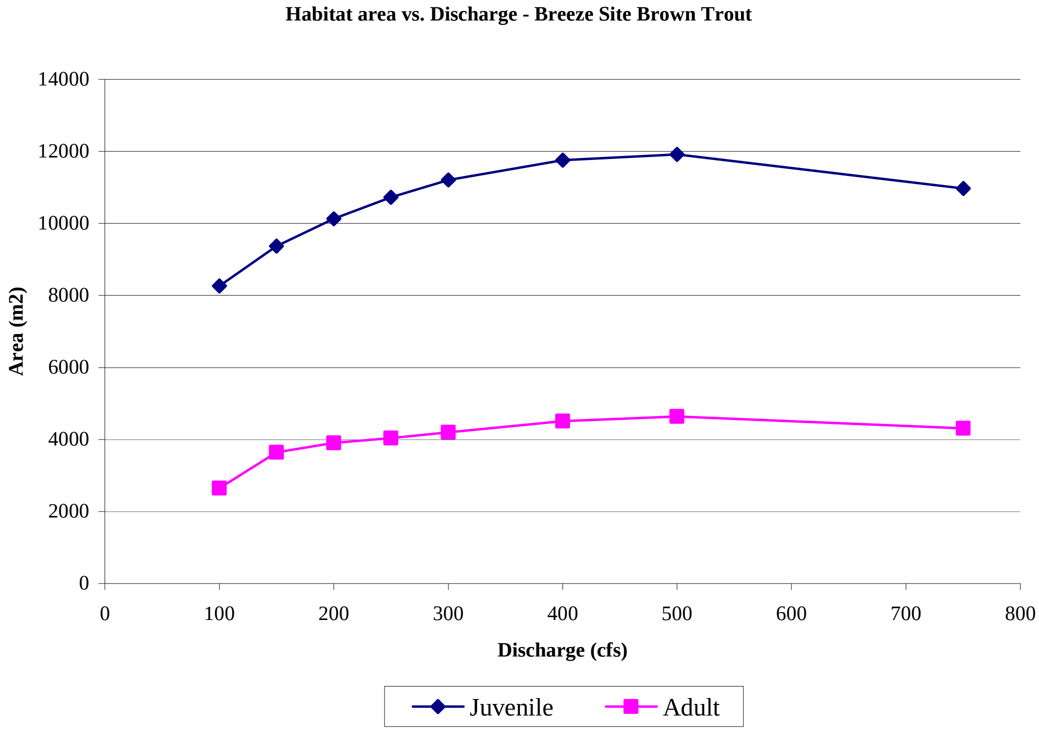


Figure 21. Habitat area versus discharge – Breeze site brown trout.

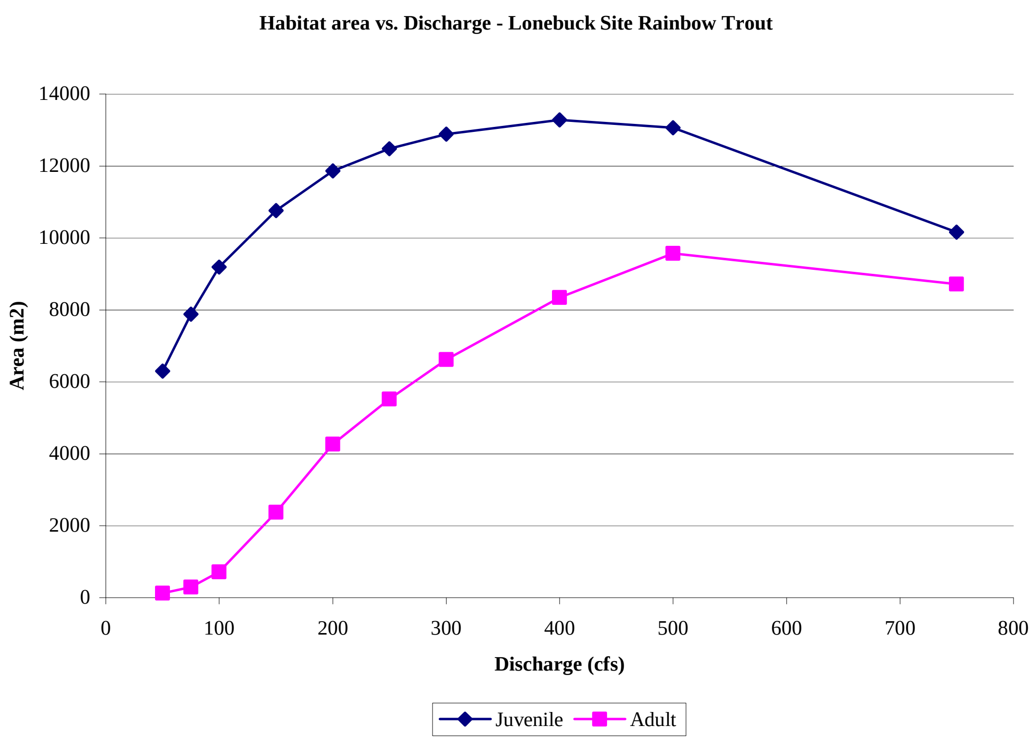


Figure 22. Habitat area versus discharge – Lonebuck site rainbow trout.

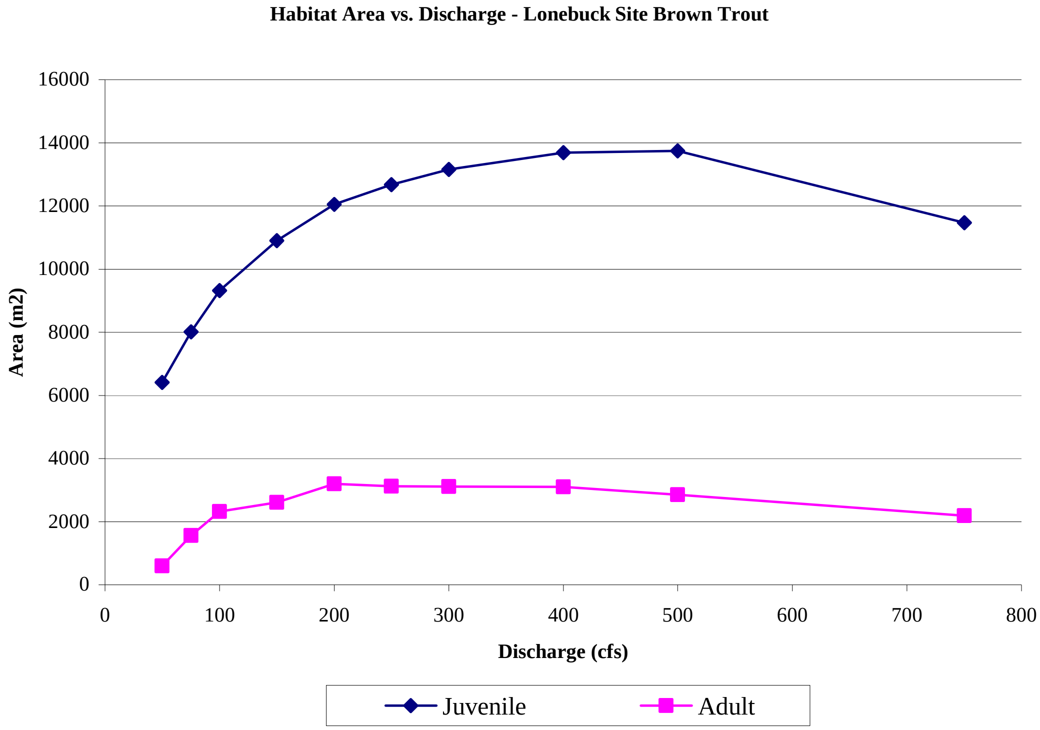


Figure 23. Habitat area versus discharge – Lonebuck site brown trout.

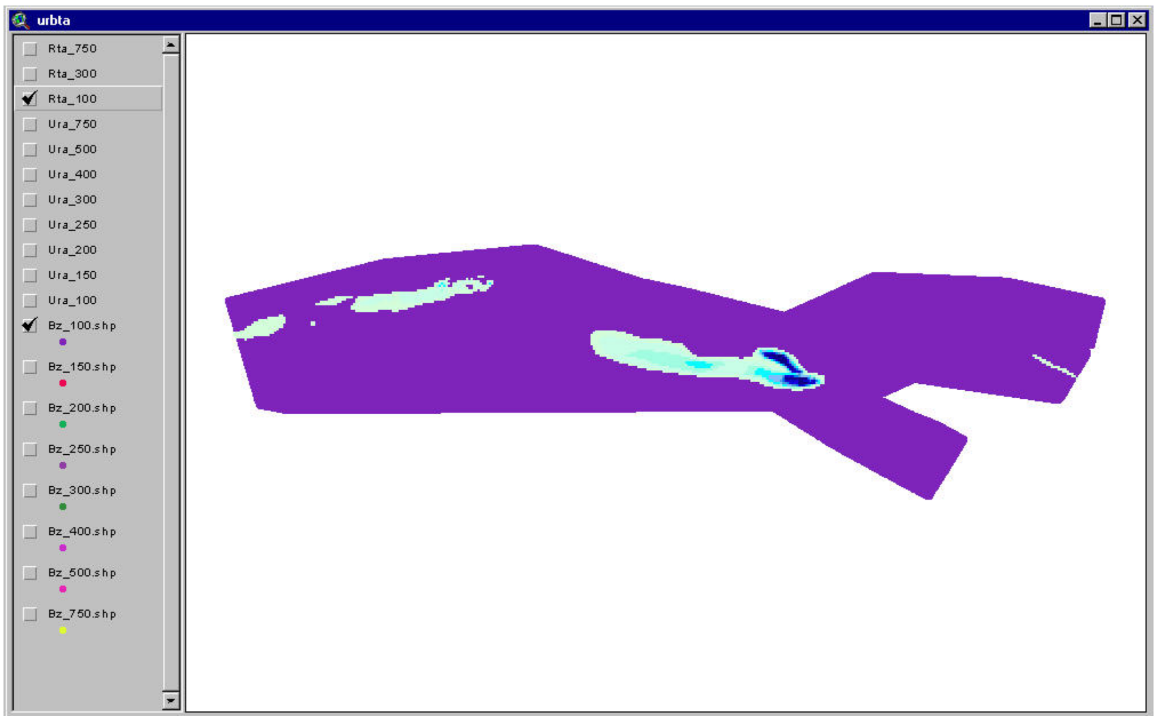


Figure 24. Plan view of rainbow trout adult habitat at 100 cfs.

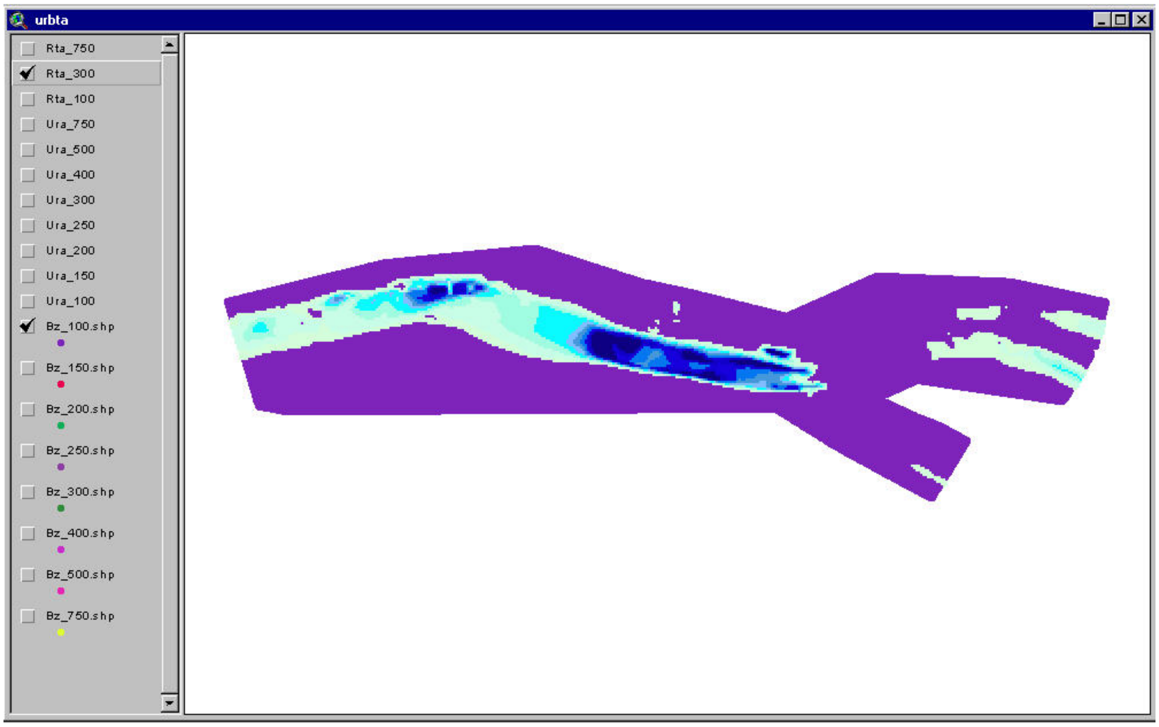


Figure 25. Plan view of rainbow trout adult habitat at 300 cfs.

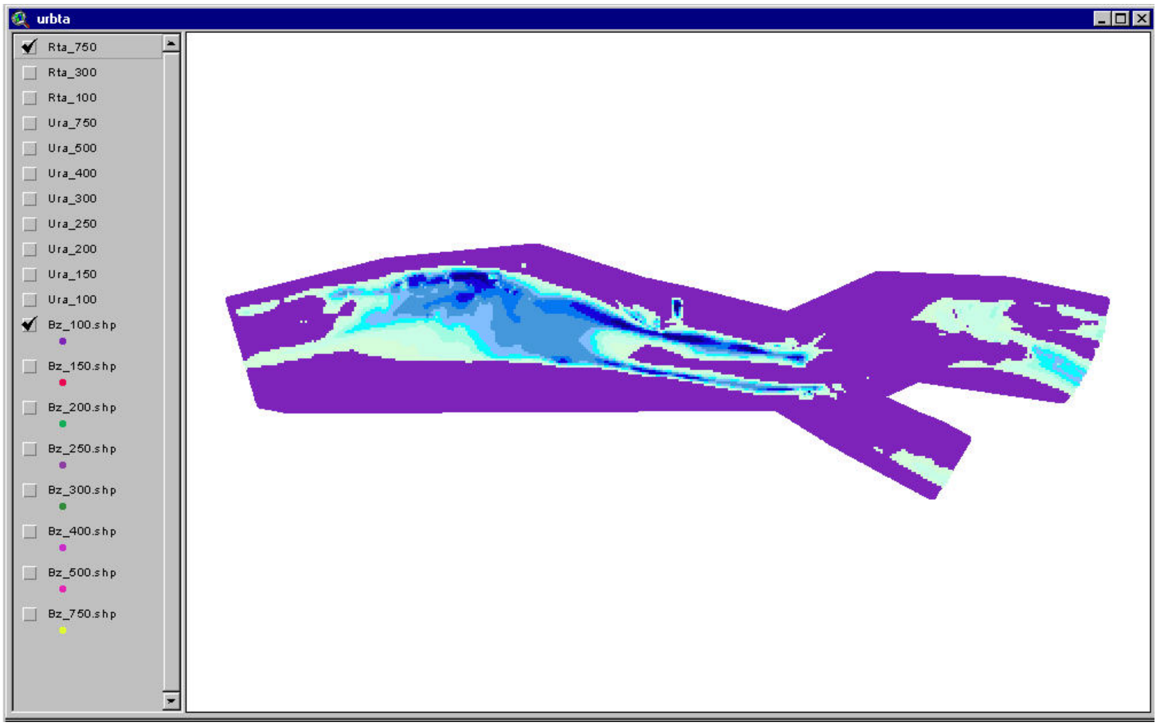


Figure 26. Plan view of rainbow trout adult habitat at 750 cfs.

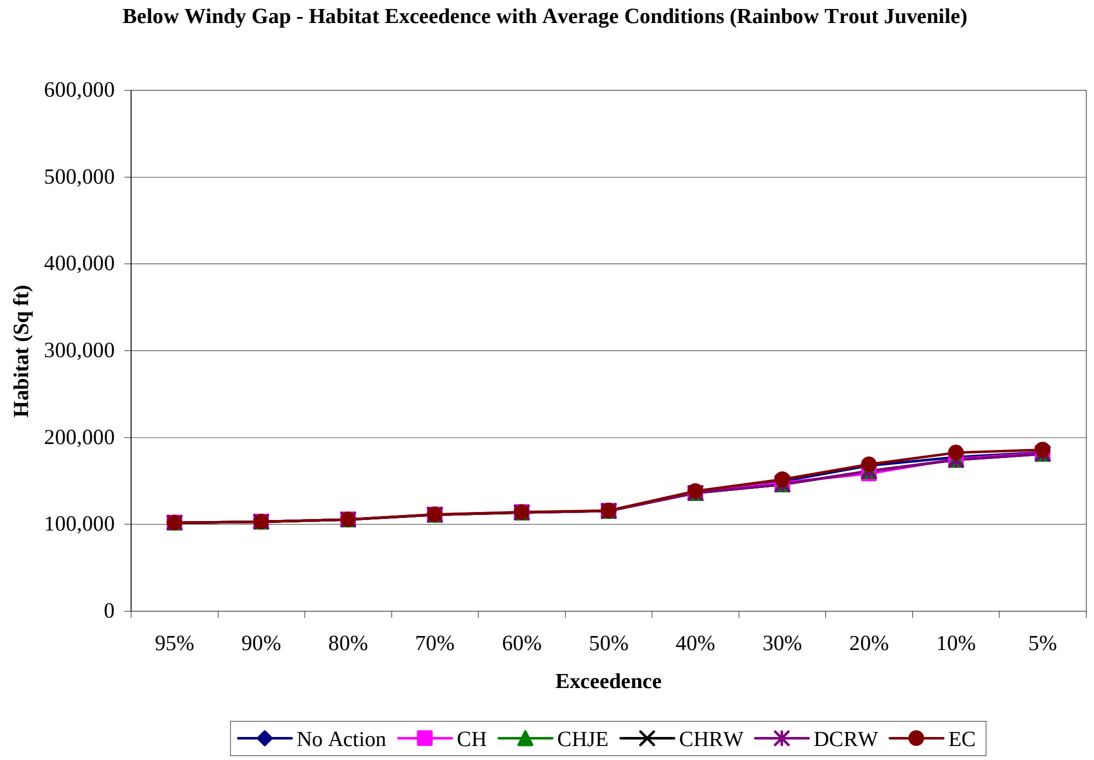


Figure 27. Below Windy Gap – habitat exceedence with average conditions (rainbow trout juvenile).

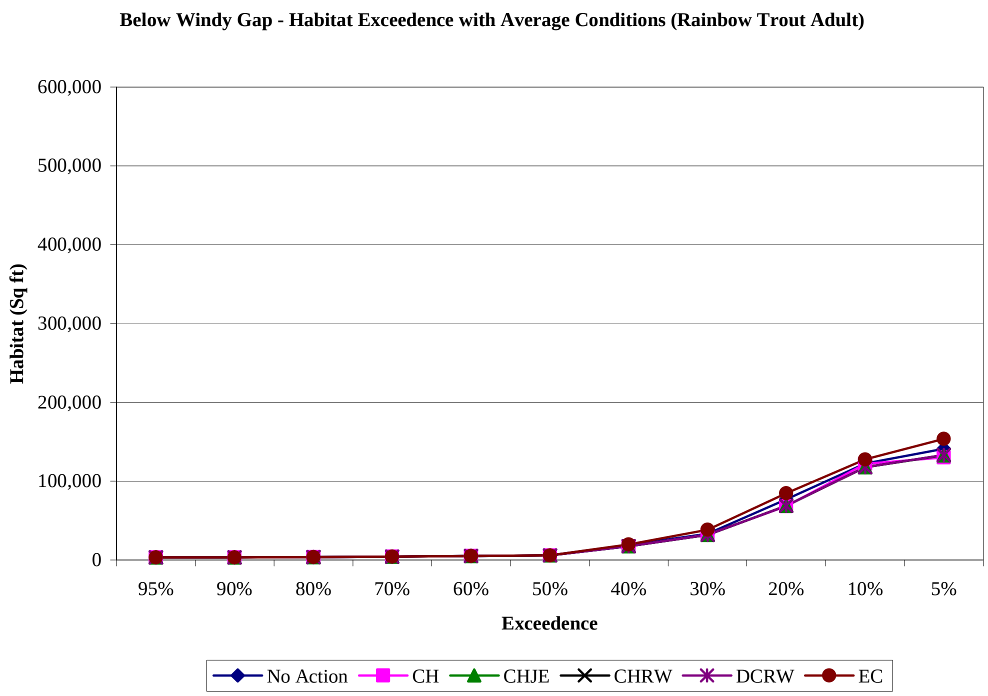


Figure 28. Below Windy Gap – habitat exceedence with average conditions (rainbow trout adult).

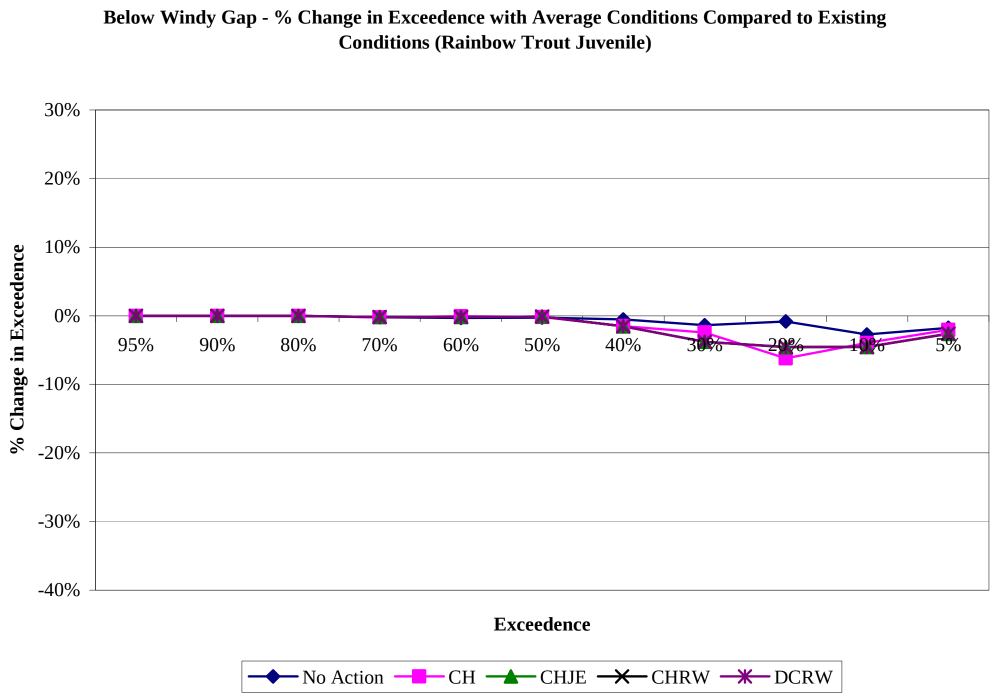


Figure 29. Below Windy Gap – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile).

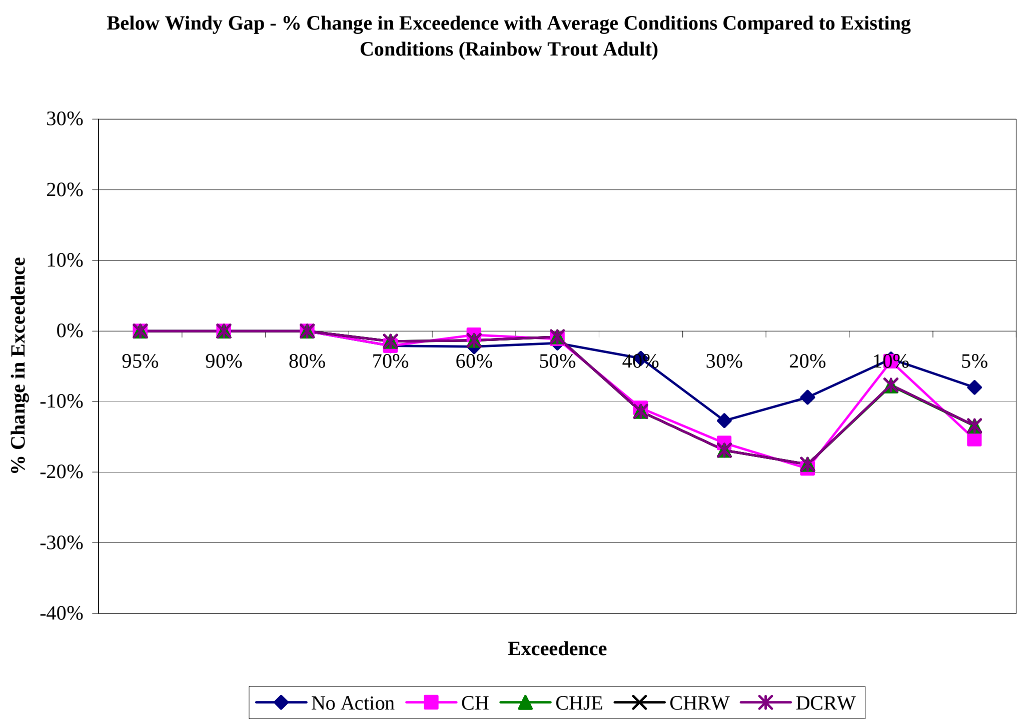


Figure 30. Below Windy Gap – percent change in exceedence with <u>average</u> conditions (rainbow trout adult).

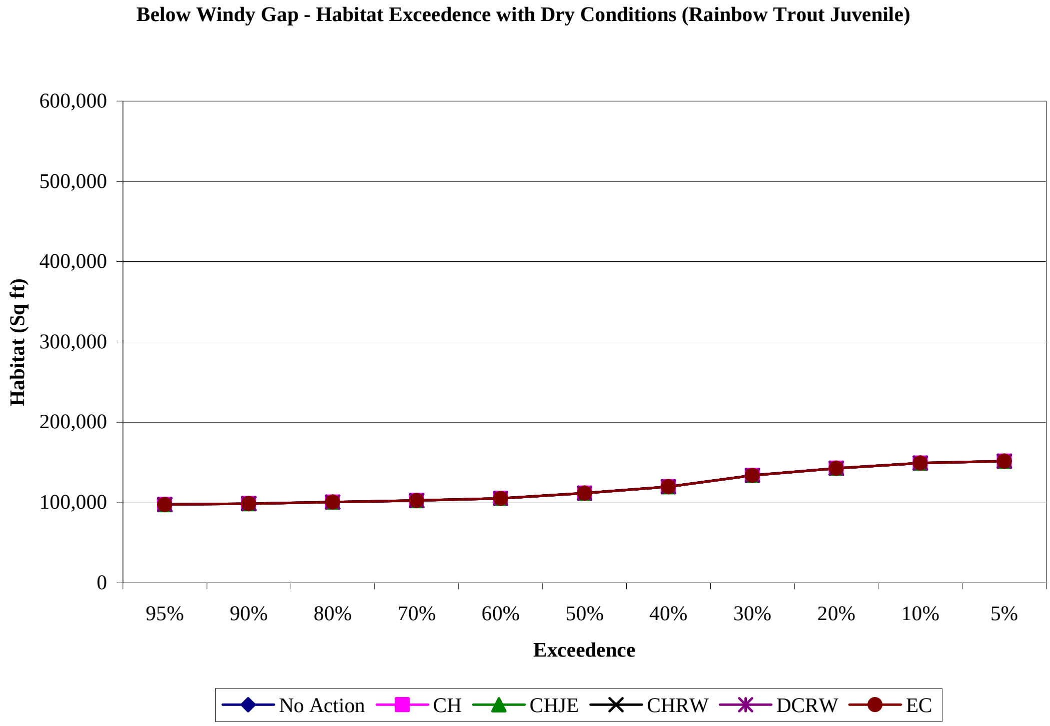


Figure 31. Below Windy Gap – habitat exceedence with dry conditions (rainbow trout juvenile).

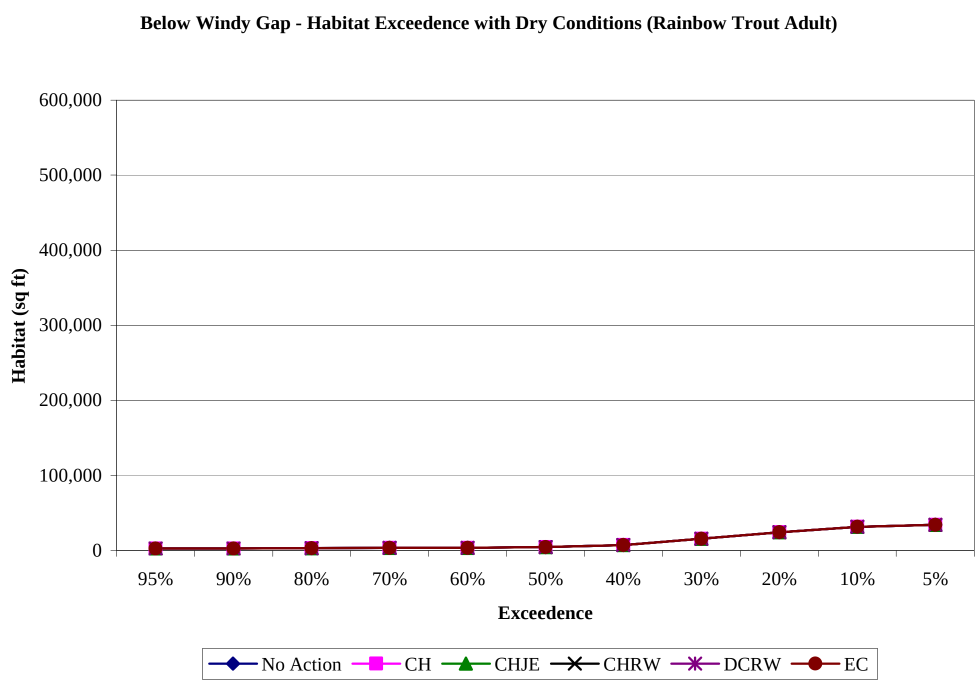


Figure 32. Below Windy Gap – habitat exceedence with dry conditions (rainbow trout adult).

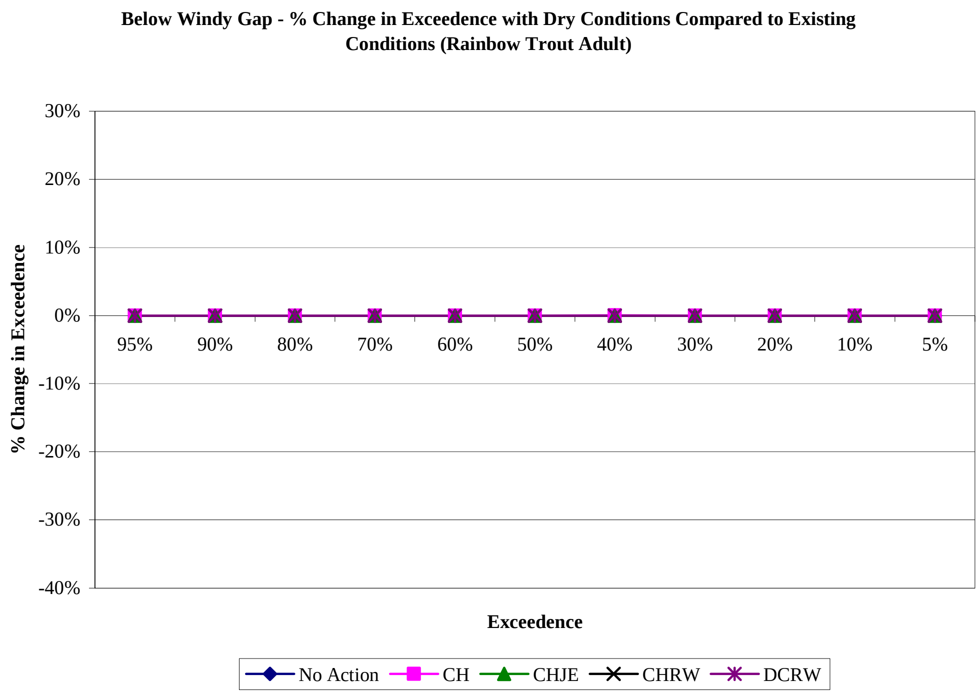


Figure 33. Below Windy Gap – percent change in exceedence with dry conditions (rainbow trout juvenile).

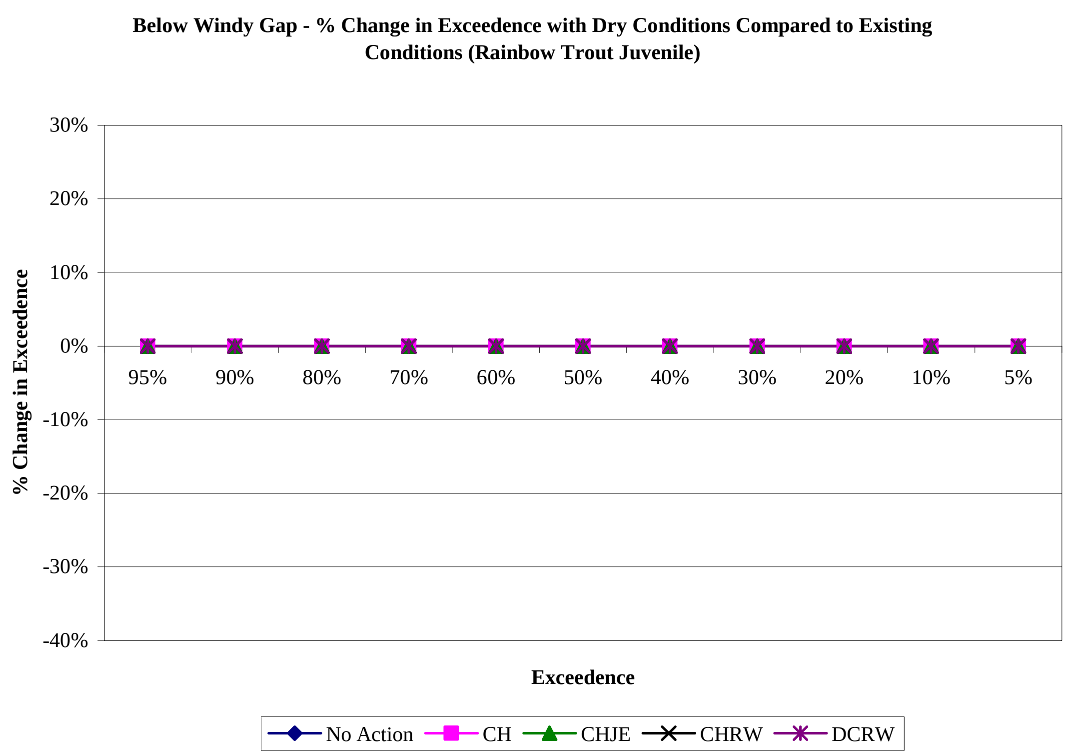


Figure 34. Below Windy Gap – percent exceedence with dry conditions (rainbow trout adult).

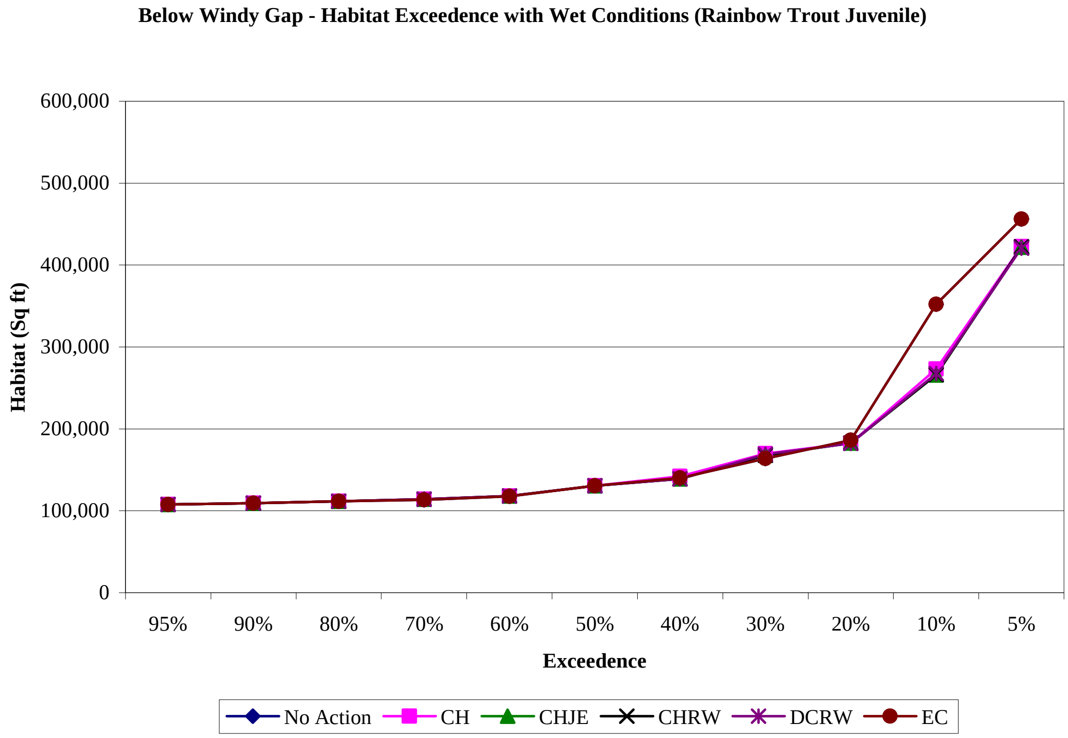


Figure 35. Below Windy Gap – habitat exceedence with <u>wet</u> conditions (rainbow trout juvenile).

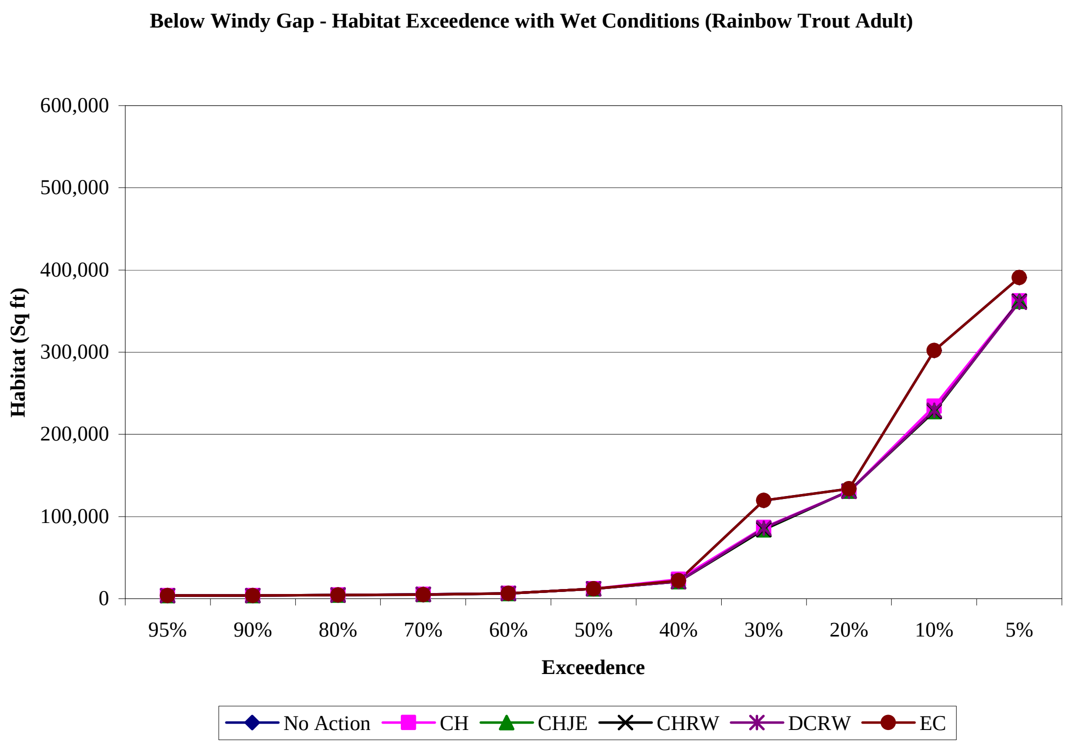


Figure 36. Below Windy Gap – habitat exceedence with <u>wet</u> conditions (rainbow trout adult).

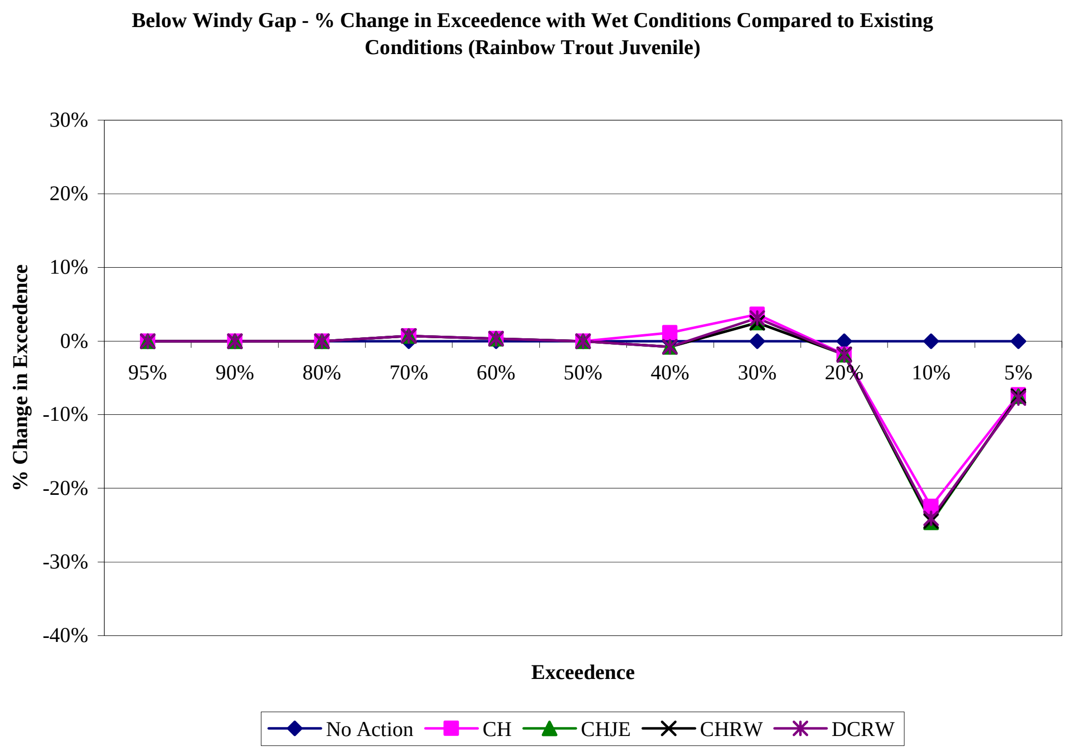


Figure 37. Below Windy Gap – percent change in exceedence with wet conditions (rainbow trout juvenile).

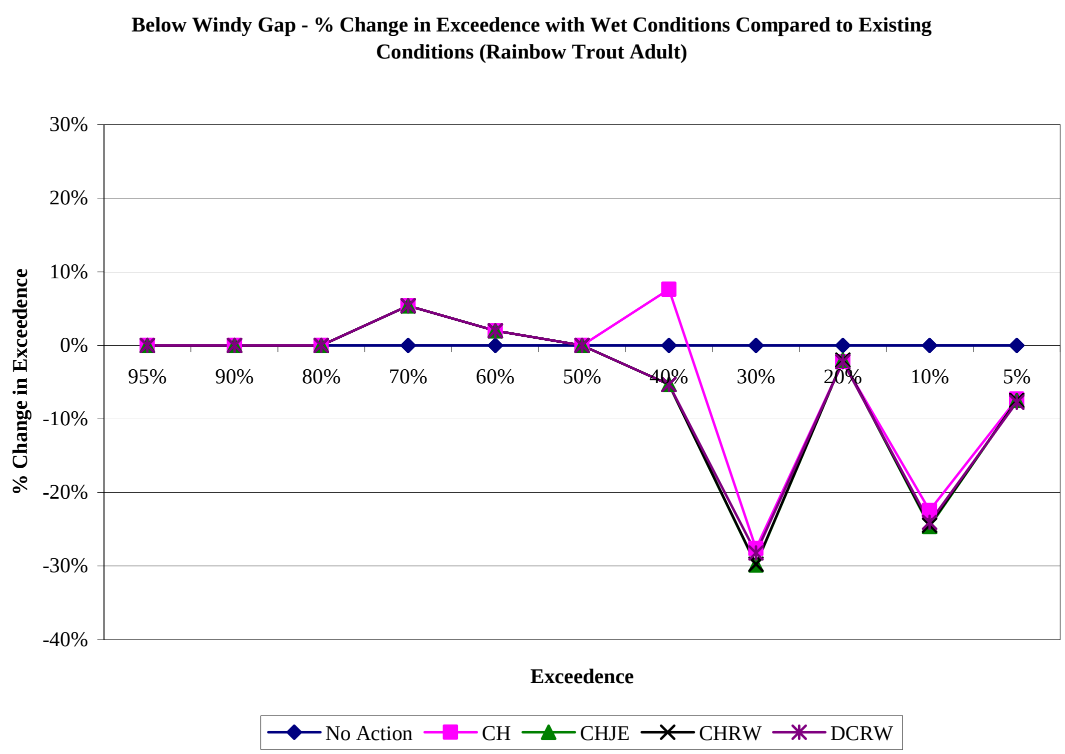


Figure 38. Below Windy Gap – percent change in exceedence with wet conditions (rainbow trout adult).

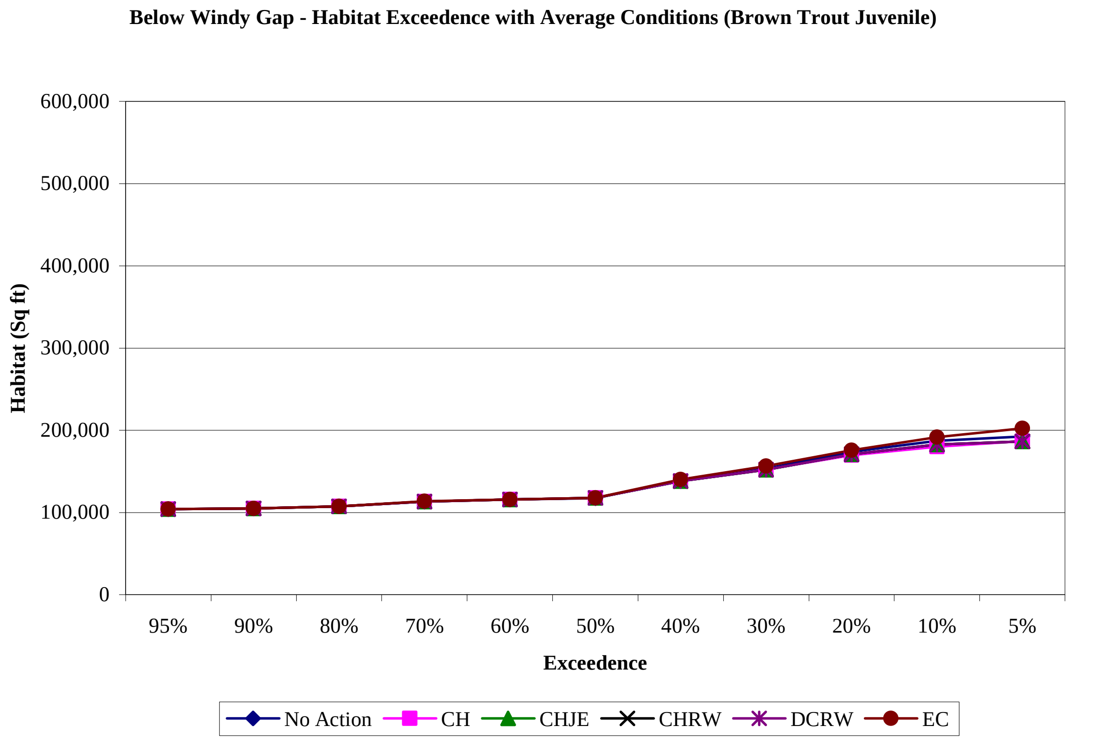


Figure 39. Below Windy Gap – habitat exceedence with <u>average</u> conditions (brown trout juvenile).

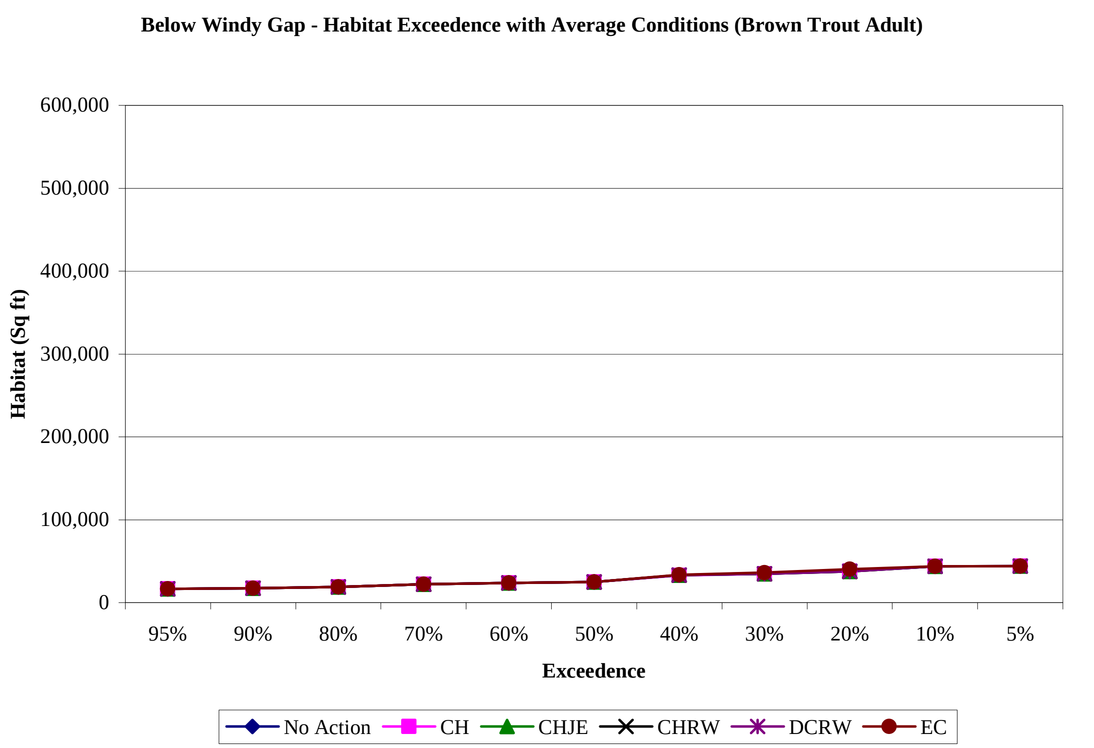


Figure 40. Below Windy Gap – habitat exceedence with <u>average</u> conditions (brown trout adult).

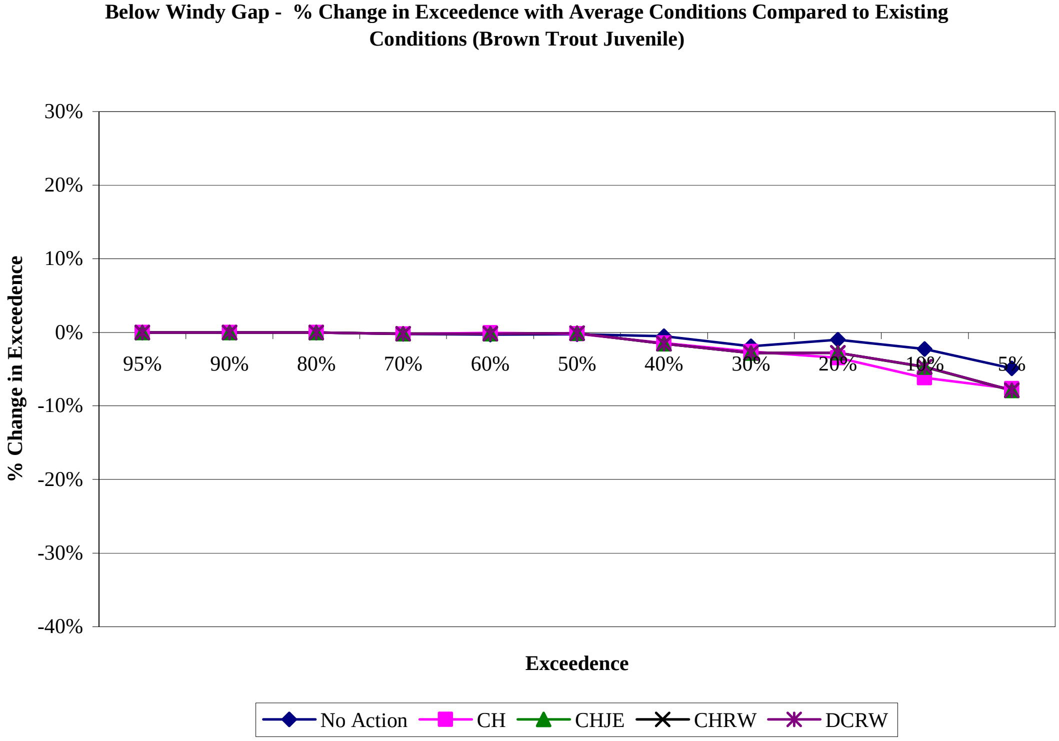


Figure 41. Below Windy Gap – percent change in exceedence with <u>average</u> conditions (brown trout juvenile).

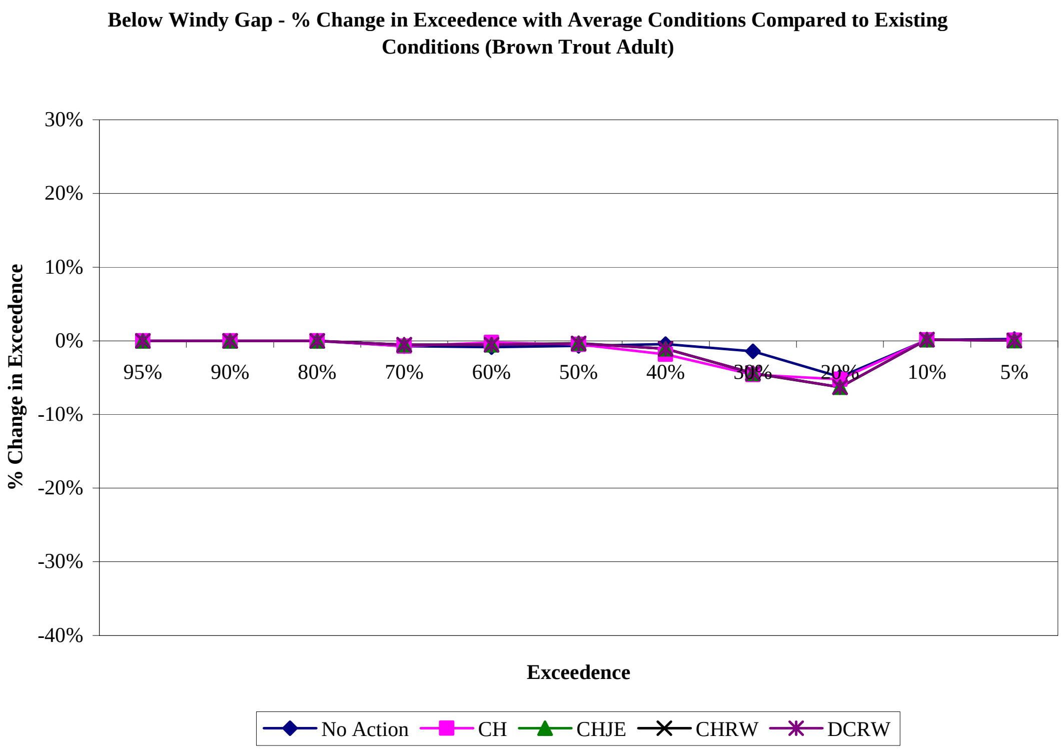


Figure 42. Below Windy Gap – percent change in exceedence with average conditions (brown trout adult).

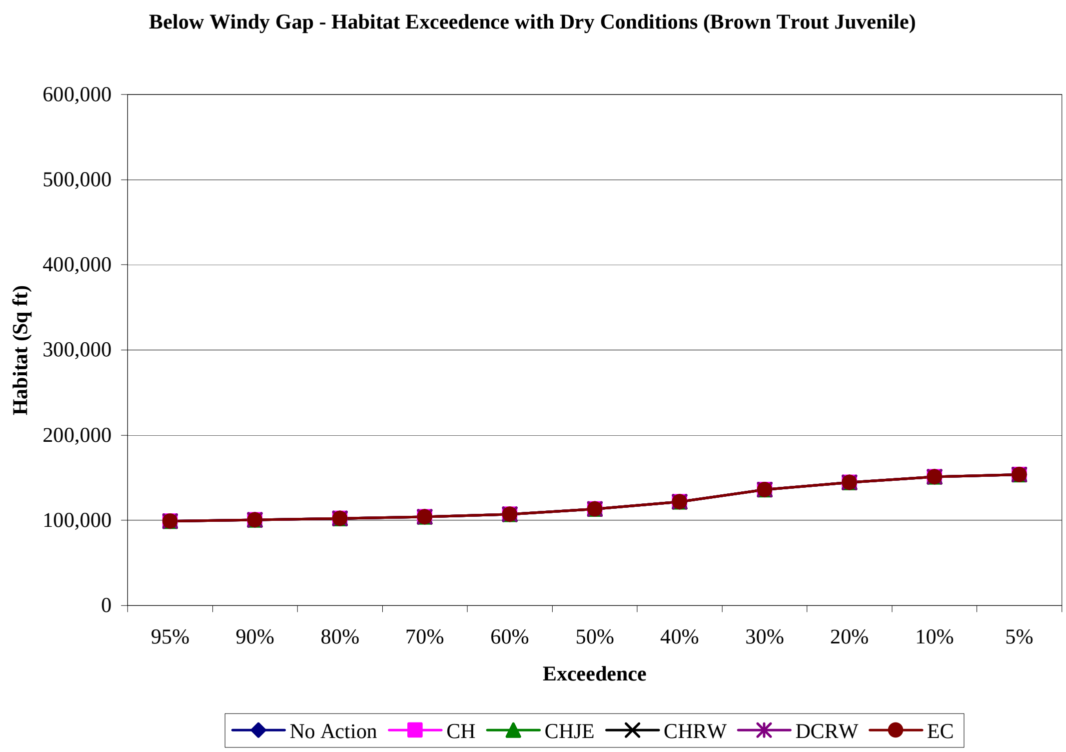


Figure 43. Below Windy Gap – habitat exceedence with dry conditions (brown trout juvenile).

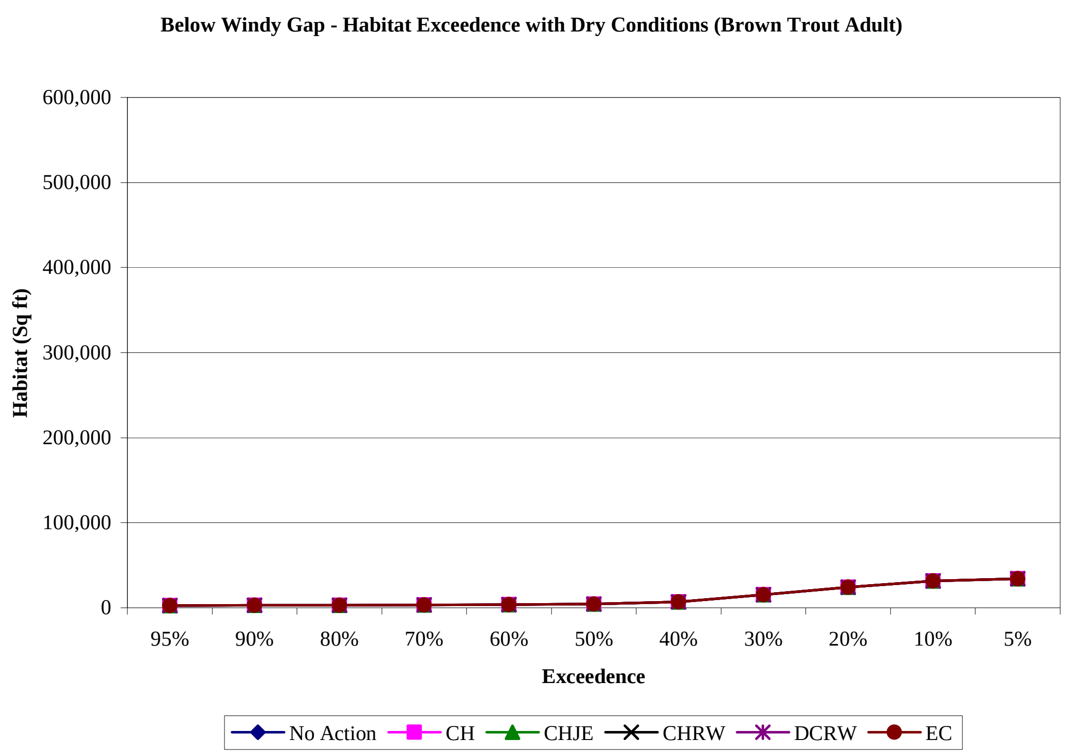


Figure 44. Below Windy Gap – percent change in exceedence with dry conditions (brown trout juvenile).

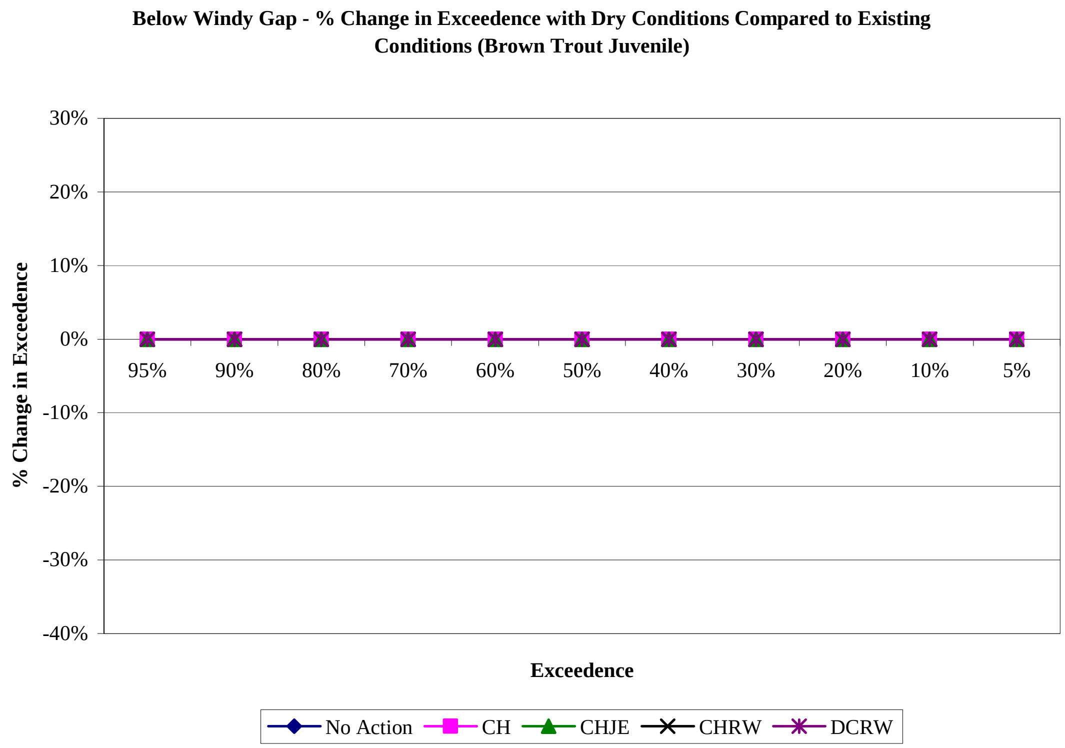


Figure 45. Below Windy Gap – habitat exceedence with dry conditions (brown trout adult).

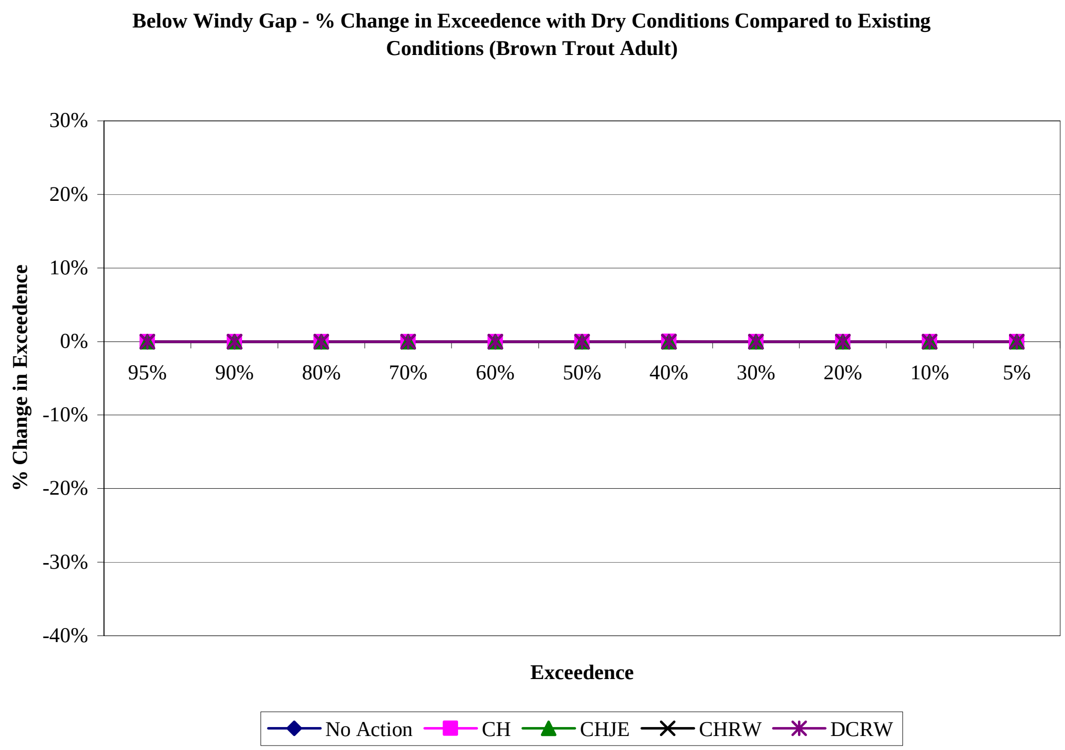


Figure 46. Below Windy Gap – percent change in exceedence with dry conditions (brown trout adult).

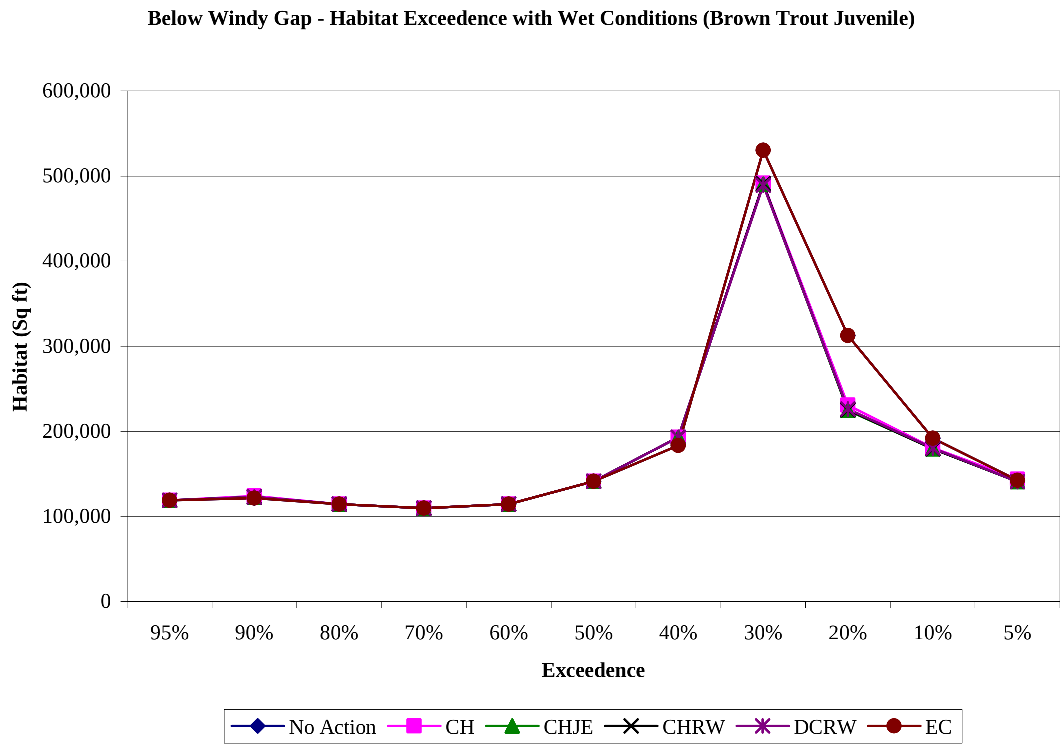


Figure 47. Below Windy Gap – habitat exceedence with wet conditions (brown trout juvenile).

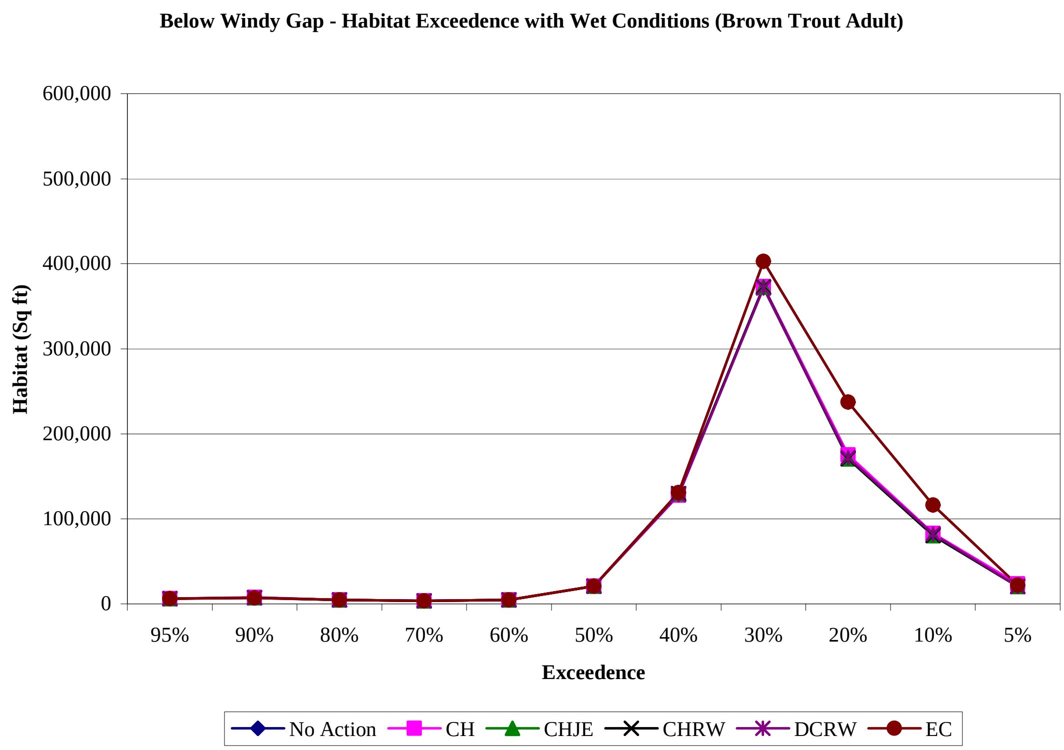


Figure 48. Below Windy Gap – habitat exceedence with wet conditions (brown trout adult).

Figure 49. Below Windy Gap – percent change in exceedence with wet conditions (brown trout juvenile).

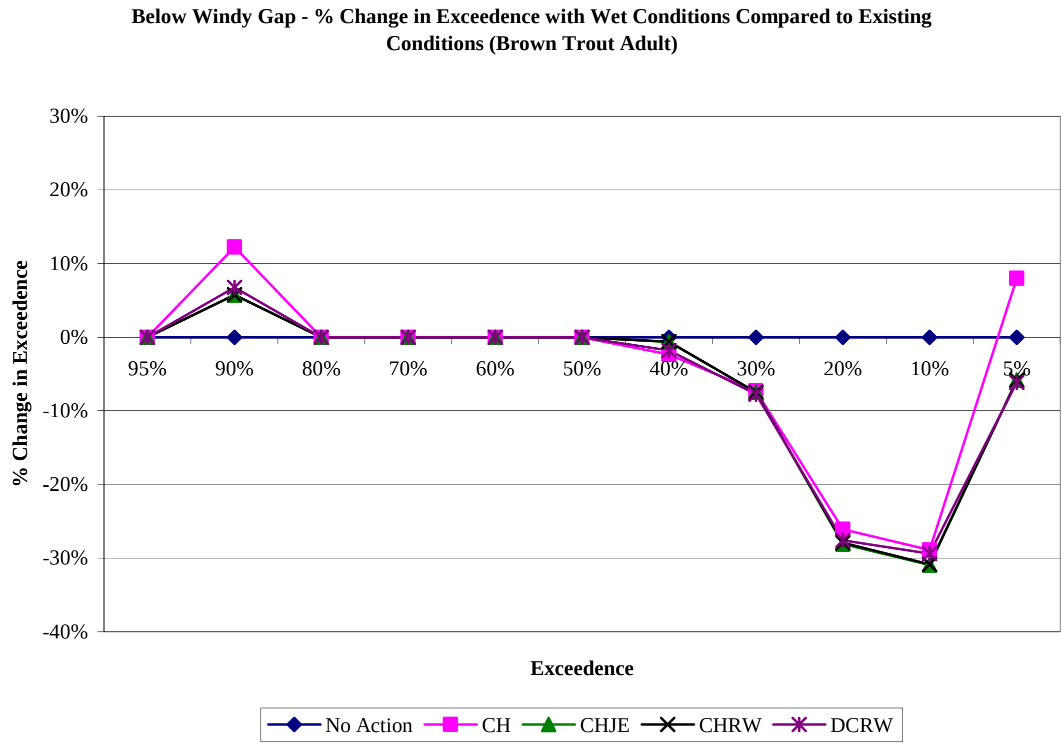


Figure 50. Below Windy Gap – percent change in exceedence with wet conditions (brown trout adult).

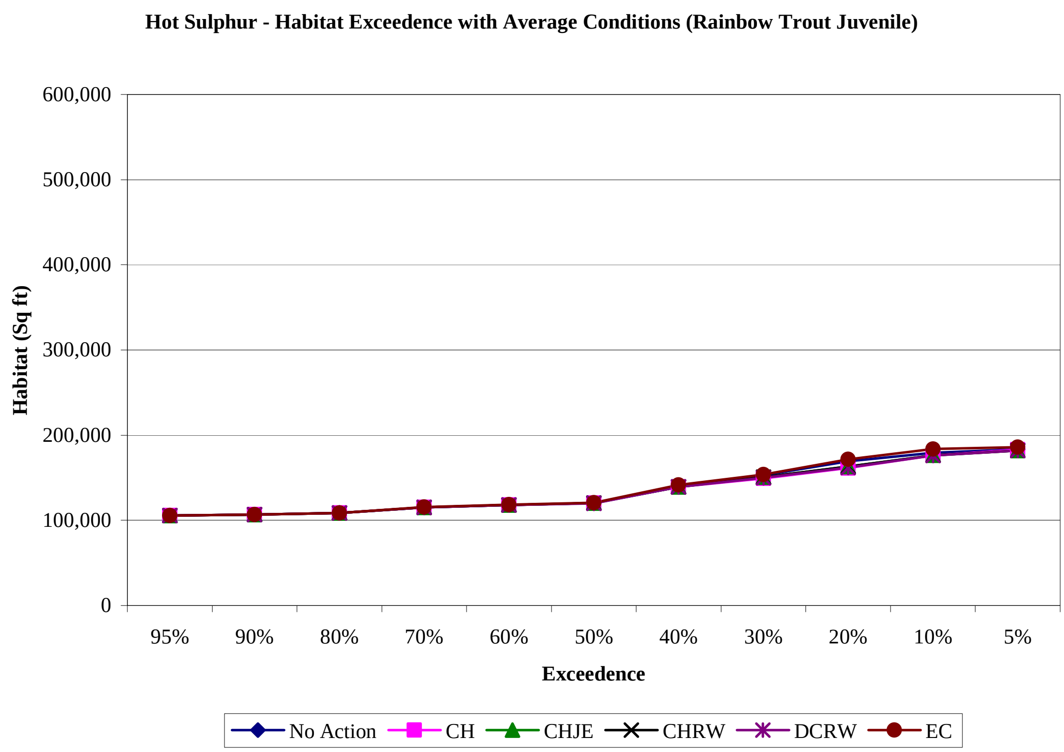


Figure 51. Hot Sulphur – habitat exceedence with average conditions (rainbow trout juvenile).

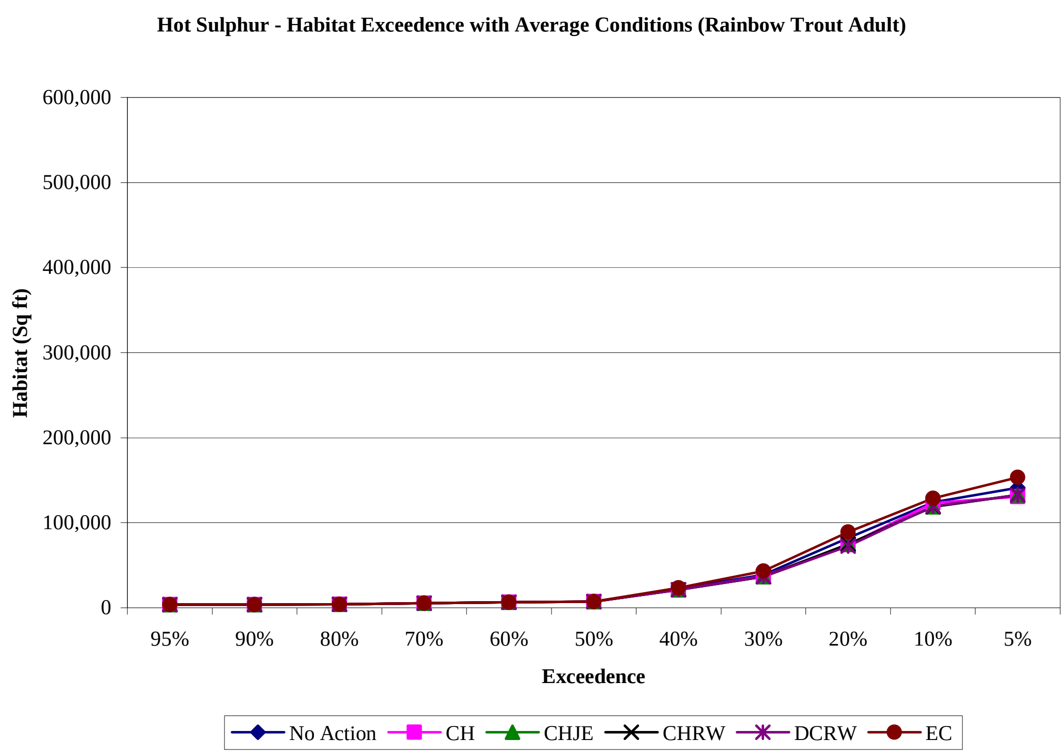


Figure 52. Hot Sulphur – habitat exceedence with average conditions (rainbow trout adult).

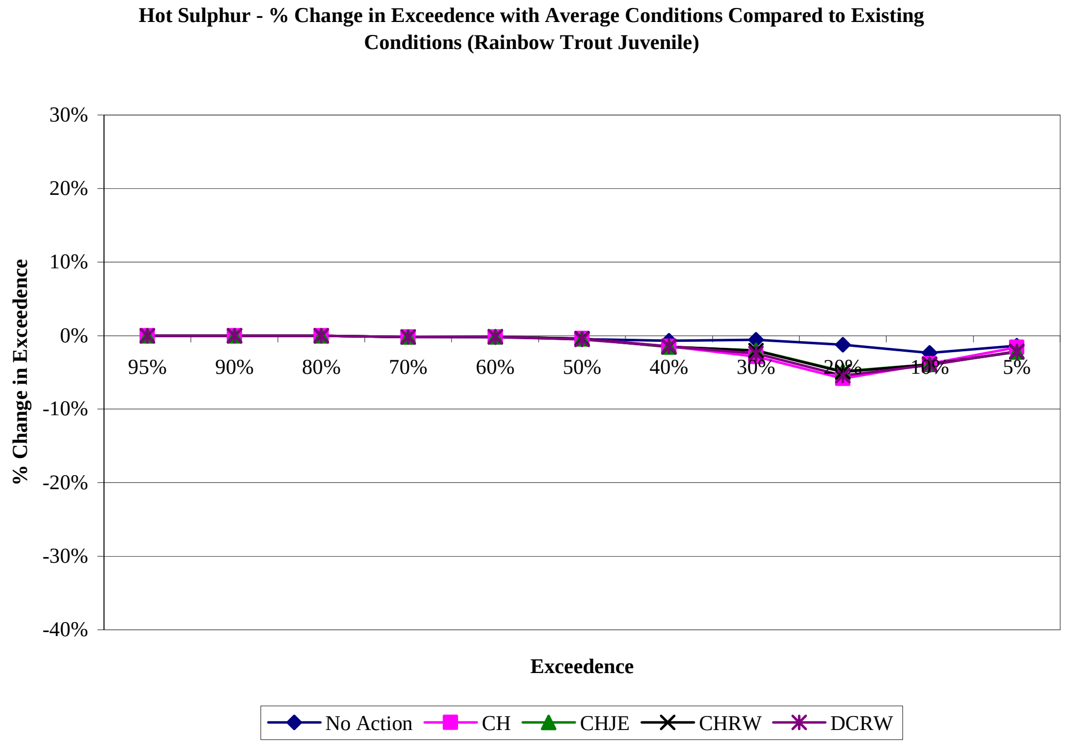


Figure 53. Hot Sulphur – percent change in exceedence with average conditions (rainbow trout juvenile).

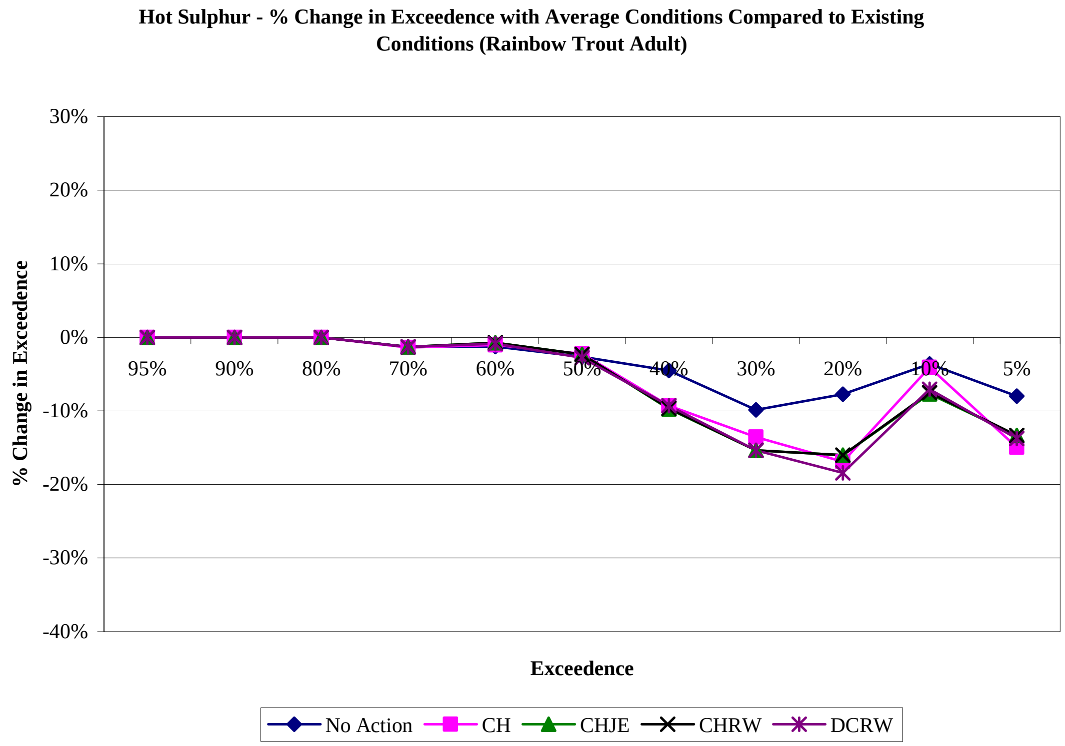


Figure 54. Hot Sulphur – percent change in exceedence with average conditions (rainbow trout adult).

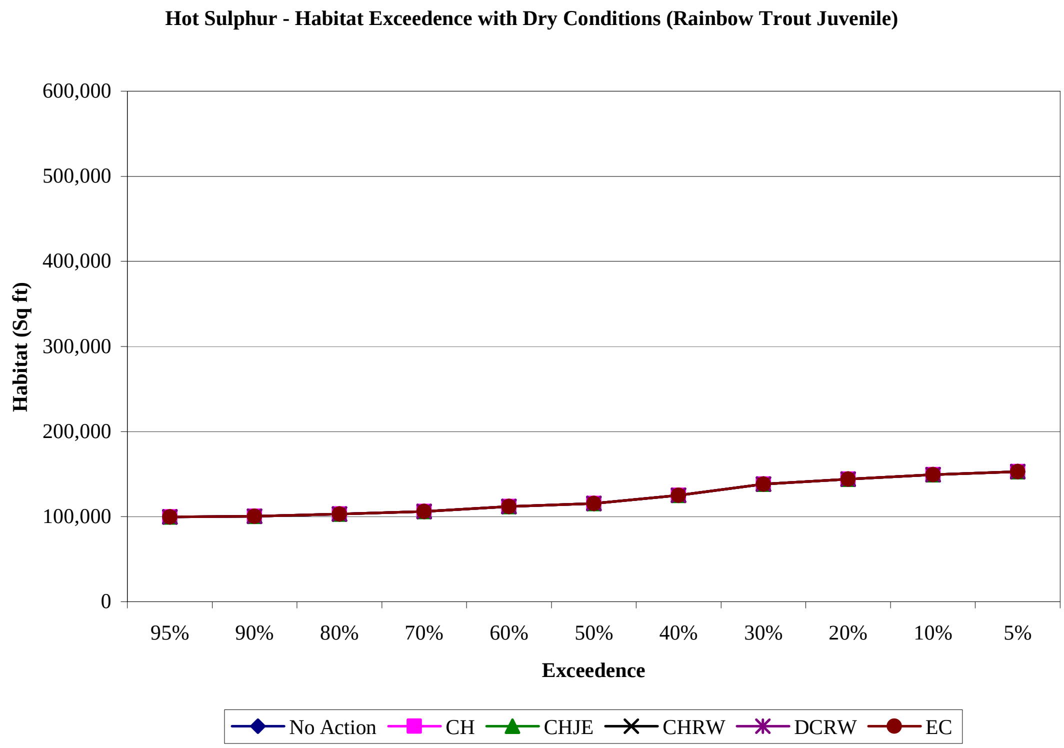


Figure 55. Hot Sulphur – habitat exceedence with dry conditions (rainbow trout juvenile).

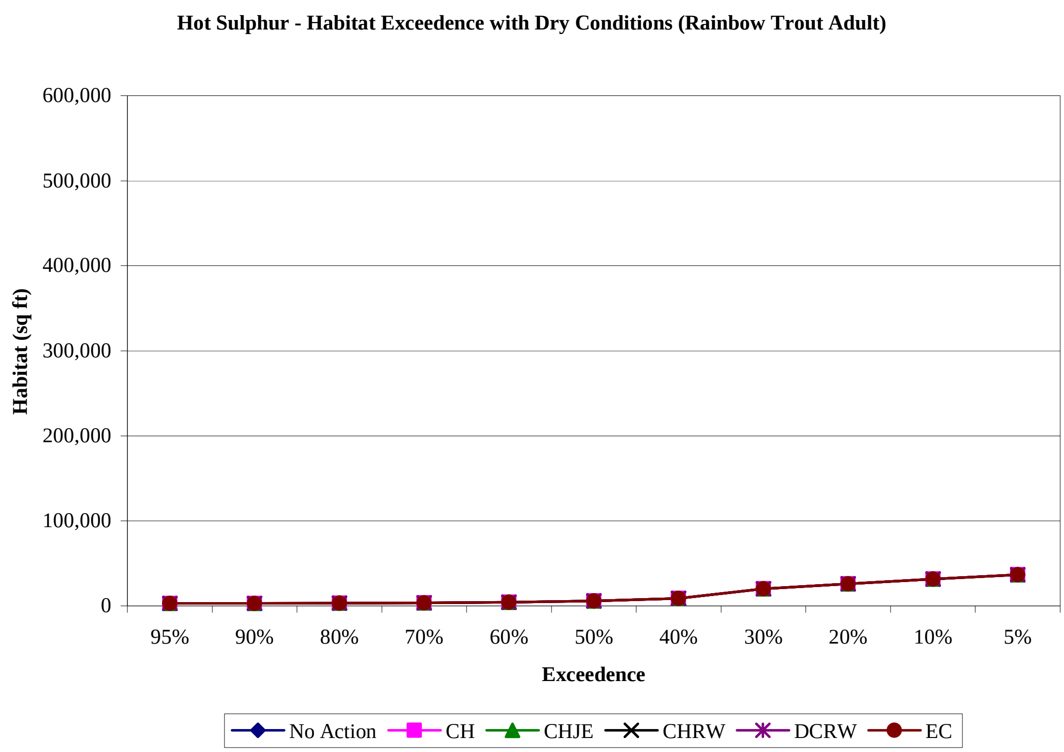


Figure 56. Hot Sulphur – habitat exceedence with dry conditions (rainbow trout adult).

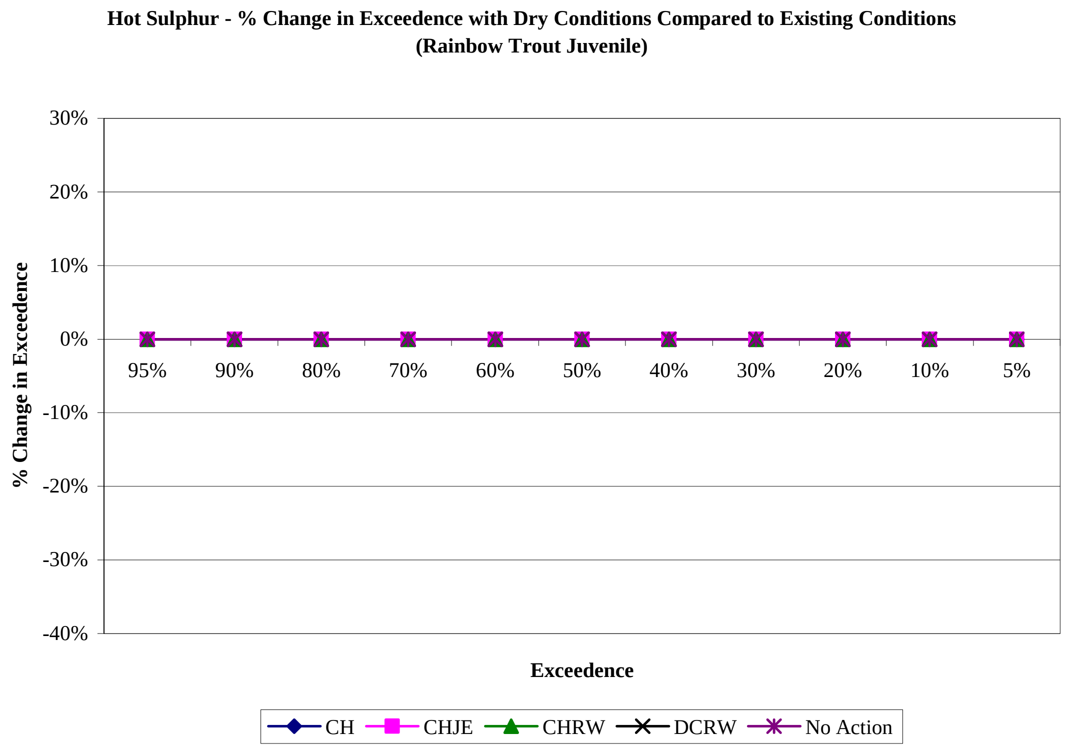


Figure 57. Hot Sulphur – percent change in exceedence with dry conditions (rainbow trout juvenile).

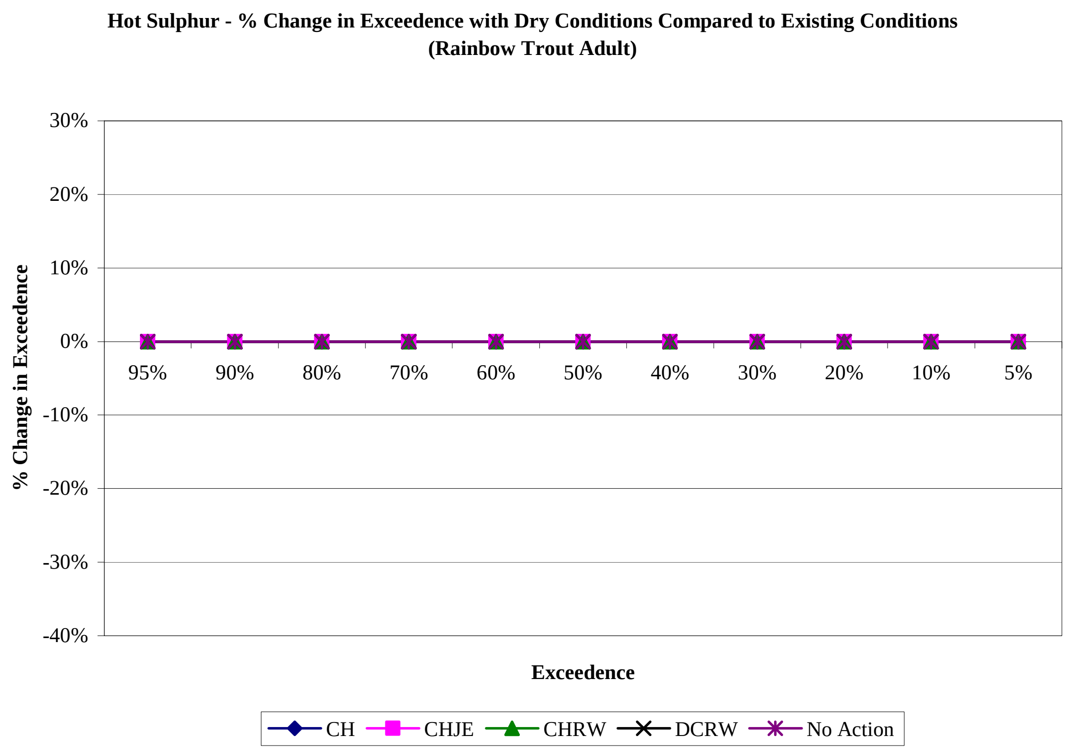


Figure 58. Hot Sulphur – percent change in exceedence with dry conditions (rainbow trout adult).

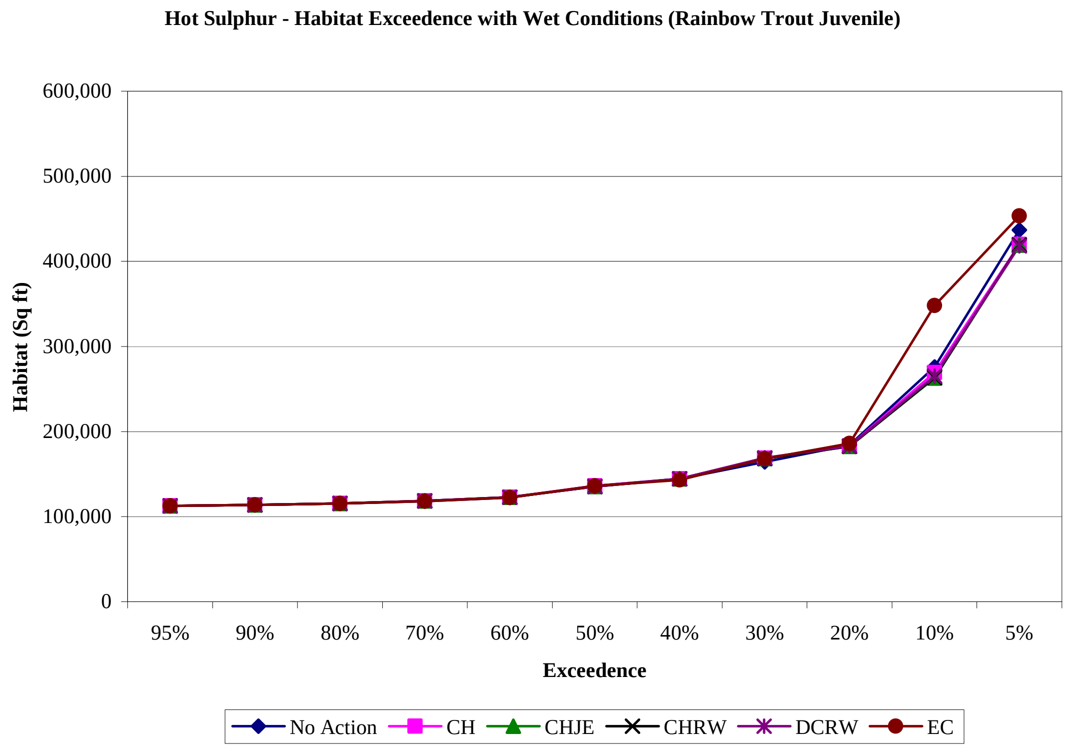


Figure 59. Hot Sulphur – habitat exceedence with wet conditions (rainbow trout juvenile).

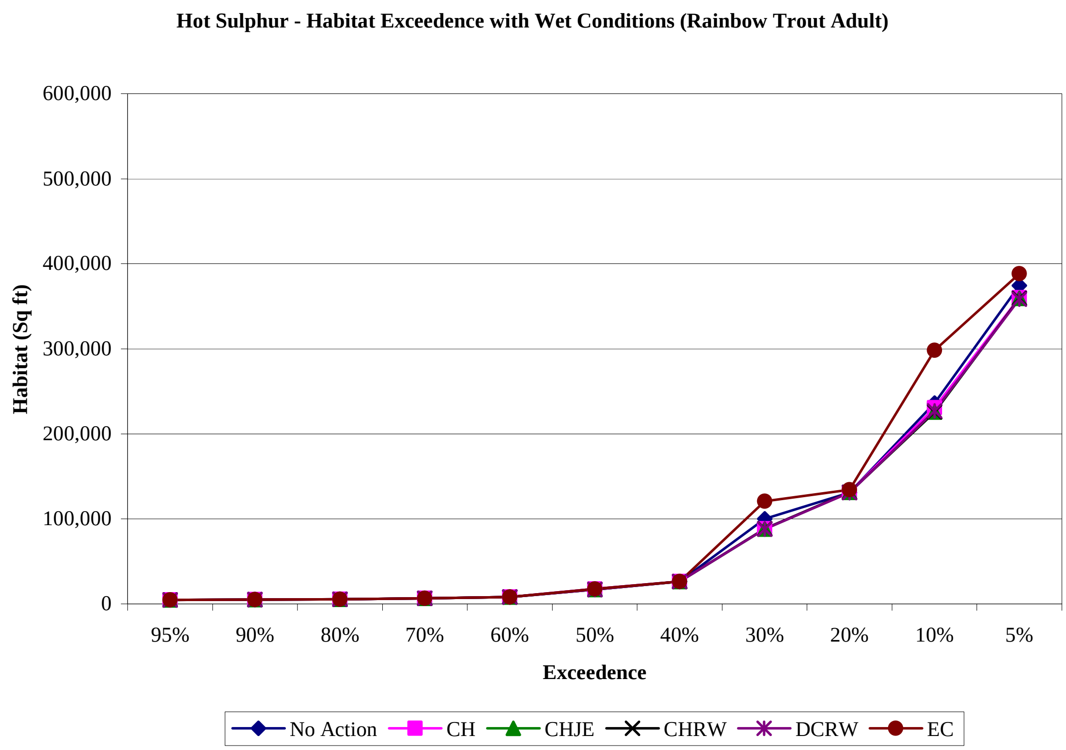


Figure 60. Hot Sulphur – habitat exceedence with wet conditions (rainbow trout adult).

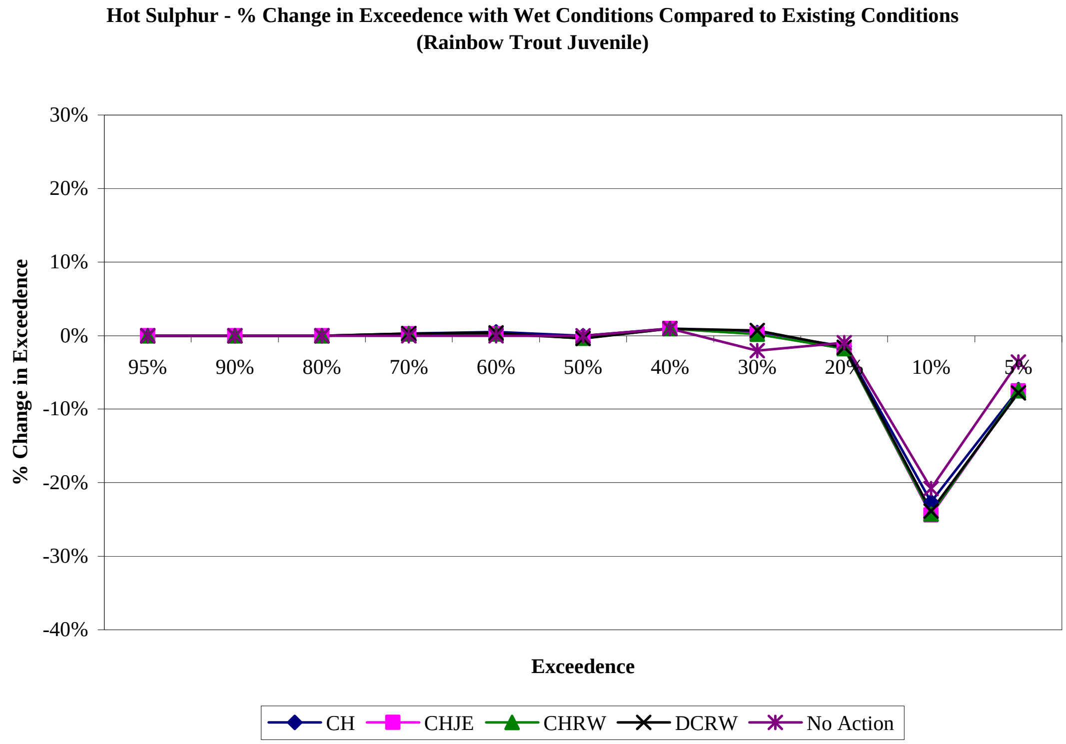


Figure 61. Hot Sulphur – percent change in exceedence with wet conditions (rainbow trout juvenile).

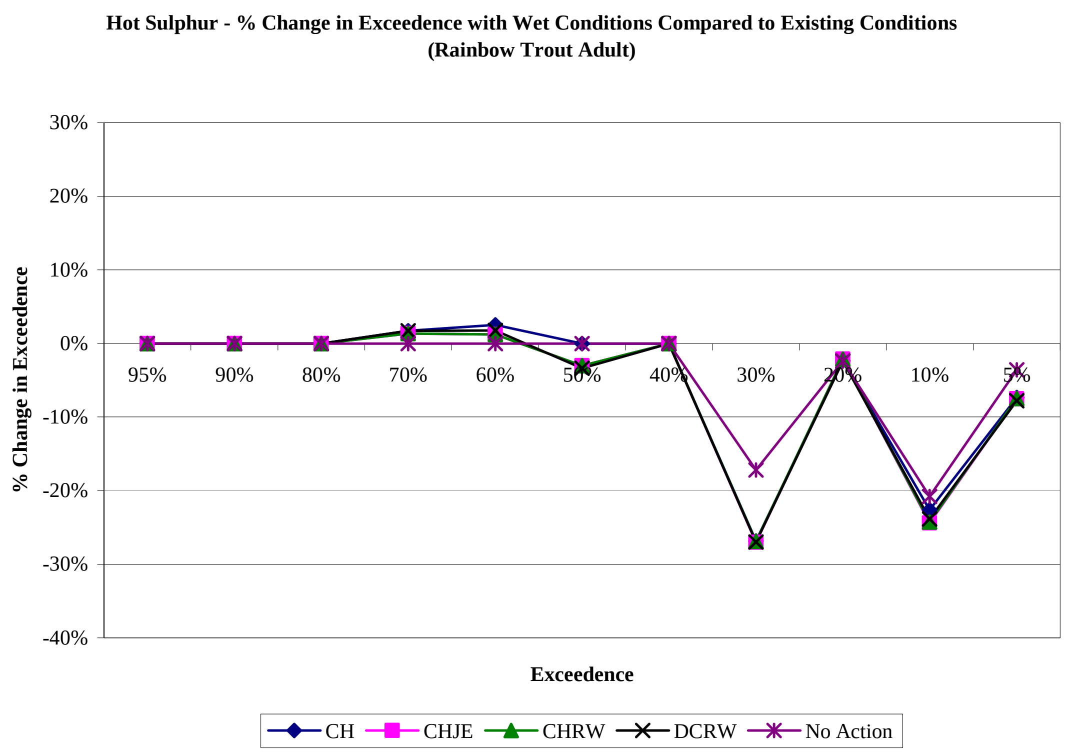


Figure 62. Hot Sulphur – percent change in exceedence with wet conditions (rainbow trout adult).

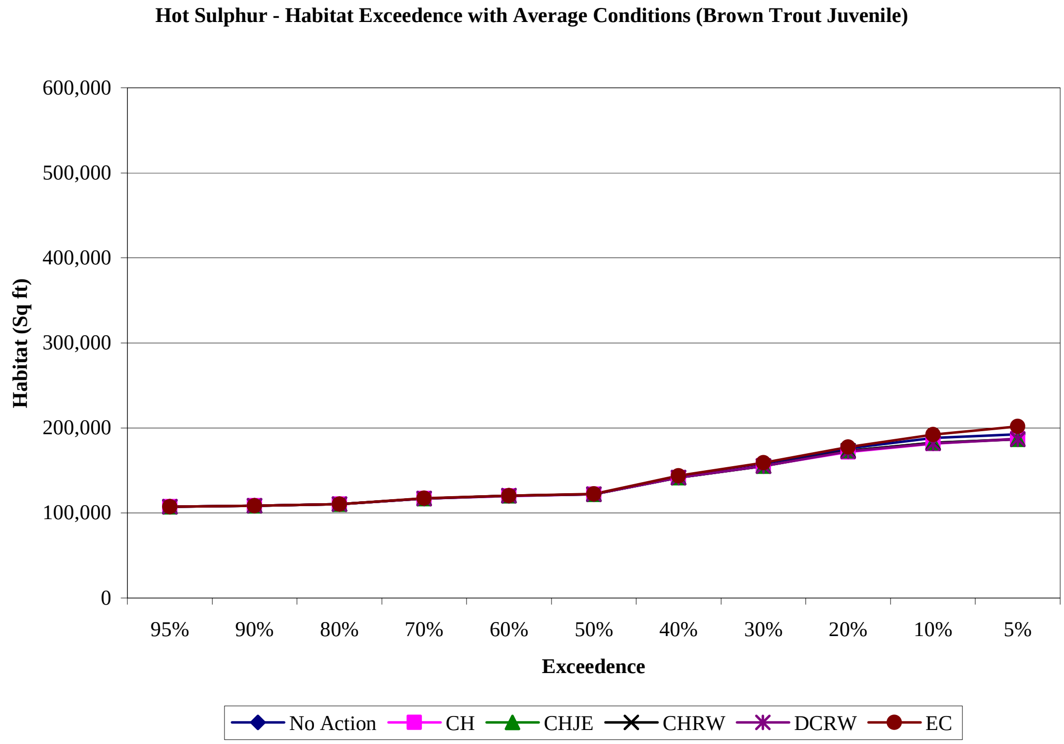


Figure 63. Hot Sulphur – habitat exceedence with average conditions (brown trout juvenile).

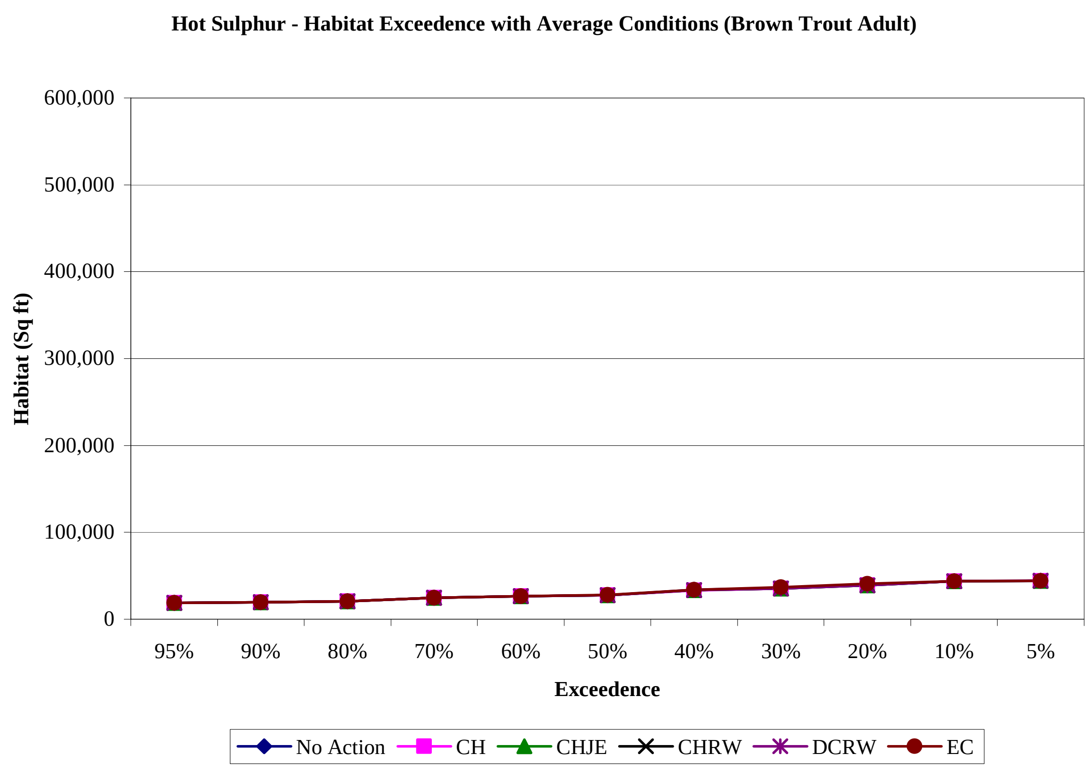


Figure 64. Hot Sulphur – habitat exceedence with average conditions (brown trout adult).

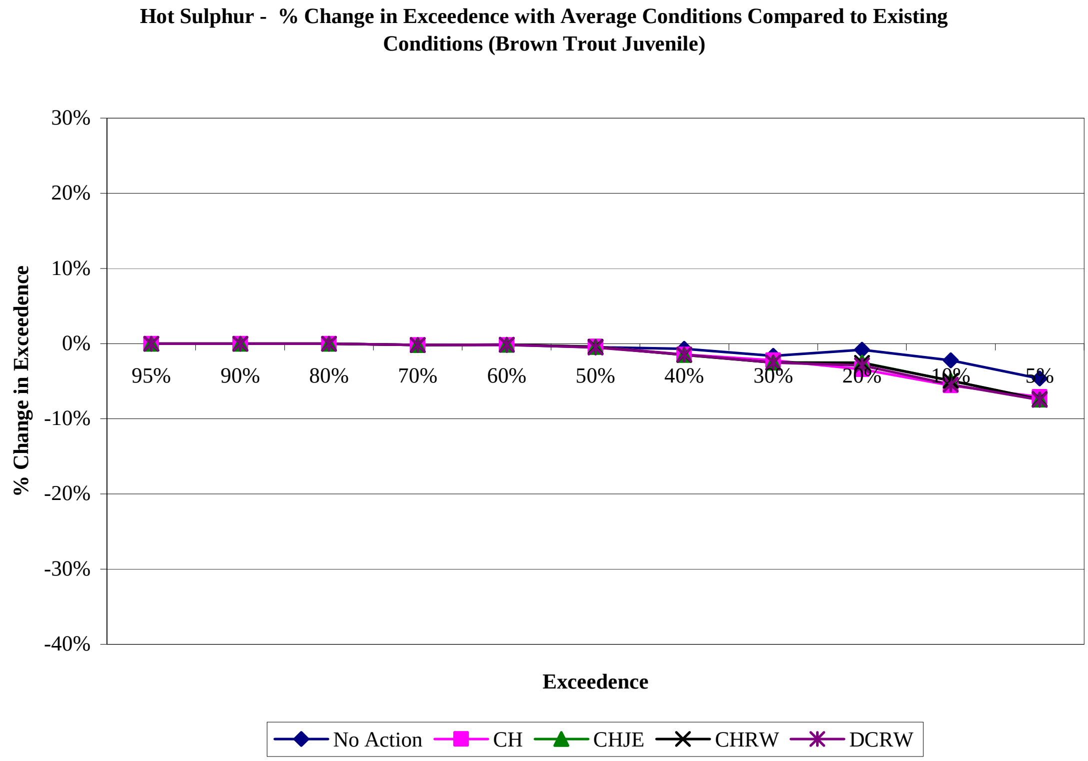


Figure 65. Hot Sulphur – percent change in exceedence with average conditions (brown trout juvenile).

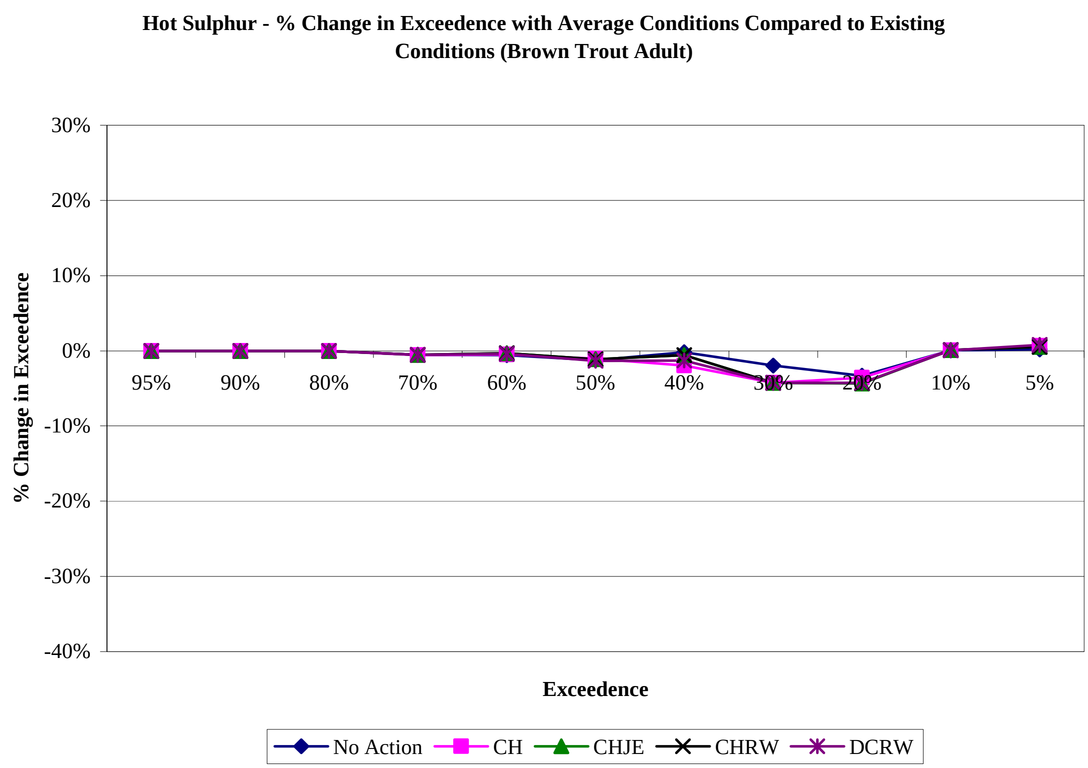


Figure 66. Hot Sulphur – percent change in exceedence with average conditions (brown trout adult).

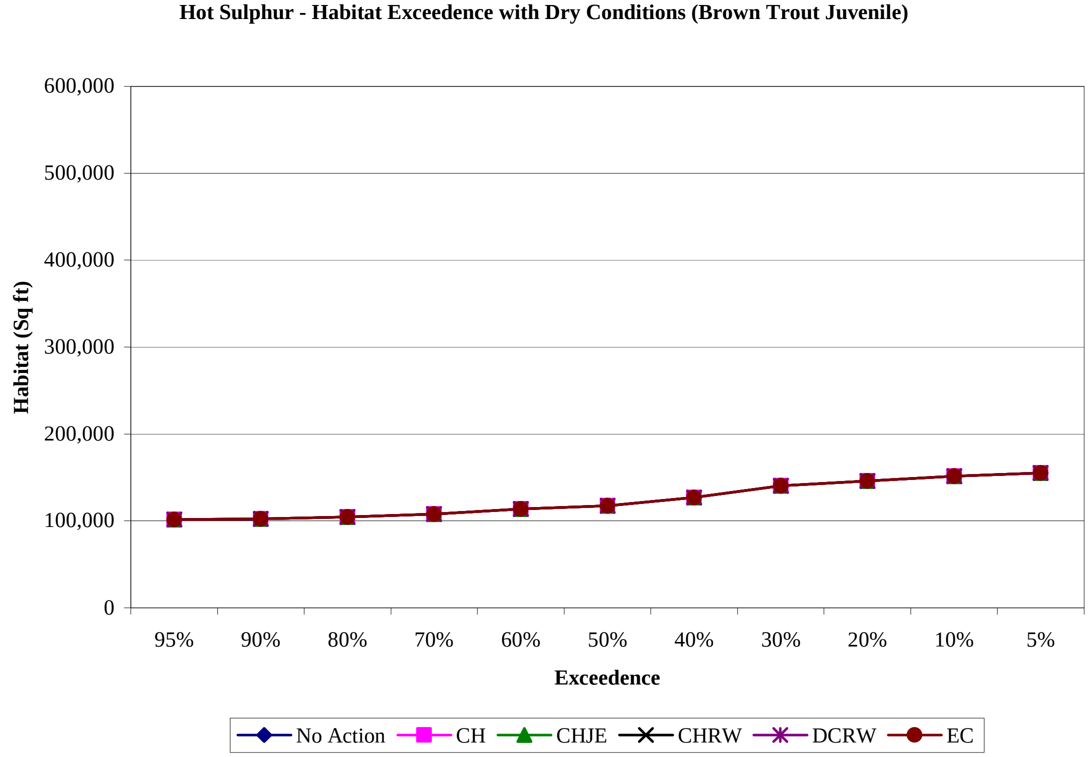


Figure 67. Hot Sulphur – habitat exceedence with dry conditions (brown trout juvenile).

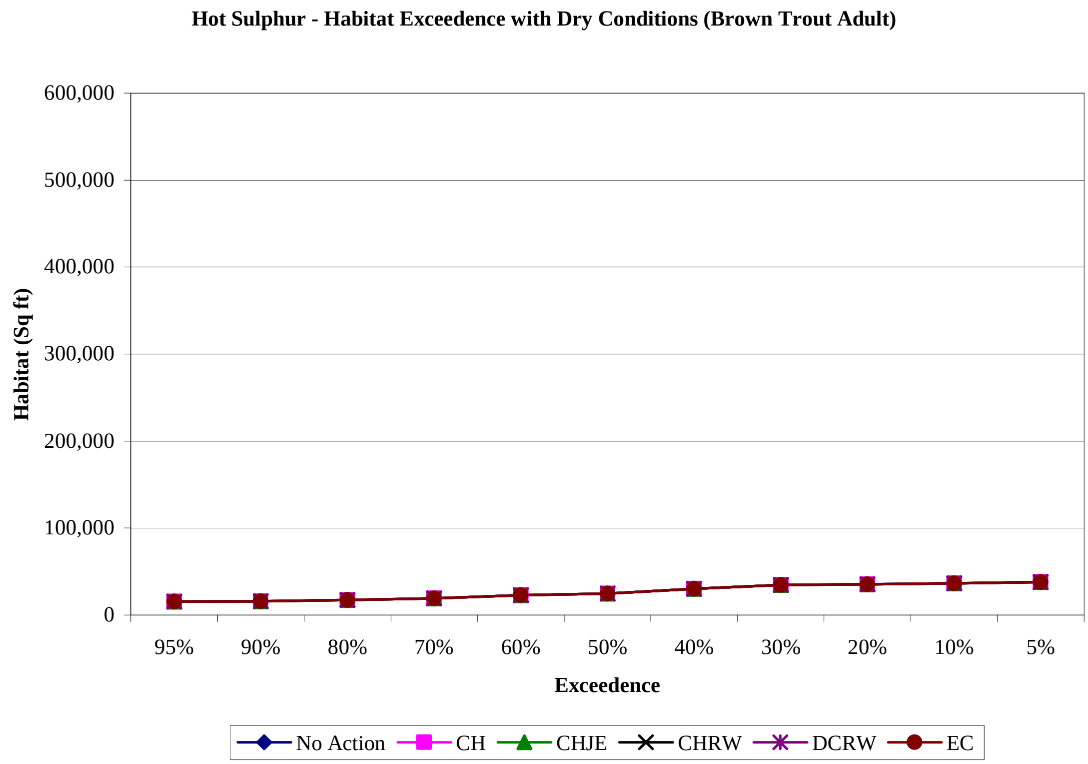


Figure 68. Hot Sulphur – habitat exceedence with dry conditions (brown trout adult).

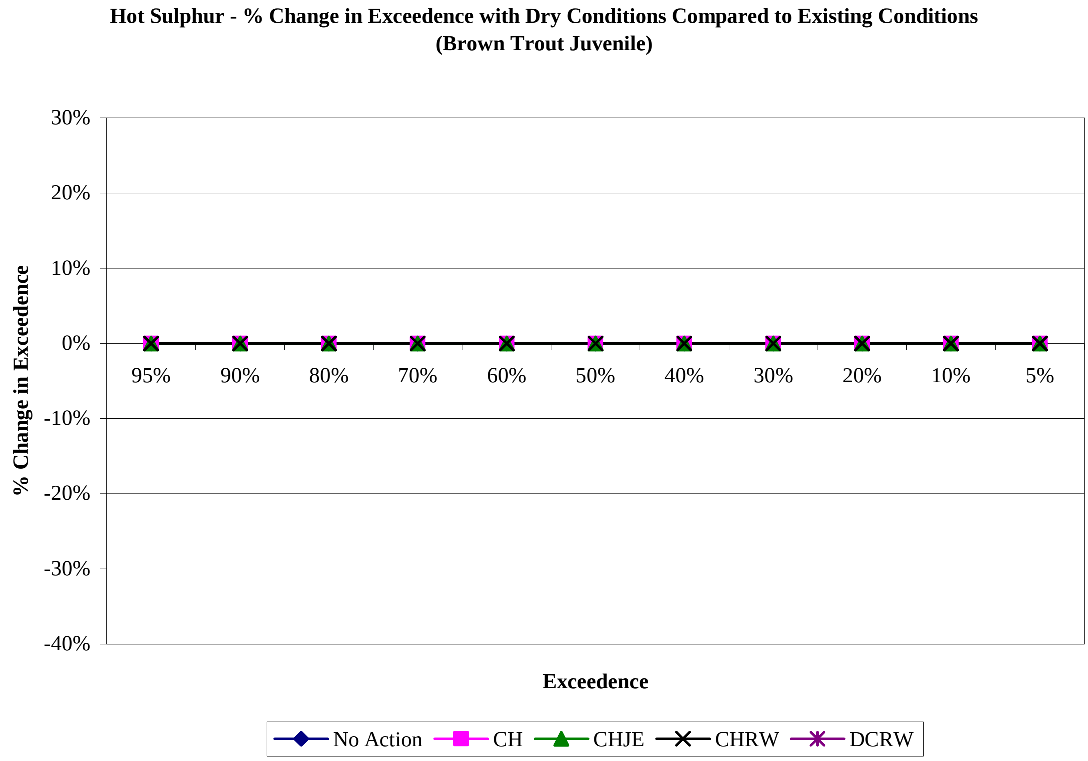


Figure 69. Hot Sulphur – percent change in exceedence with dry conditions (brown trout juvenile).

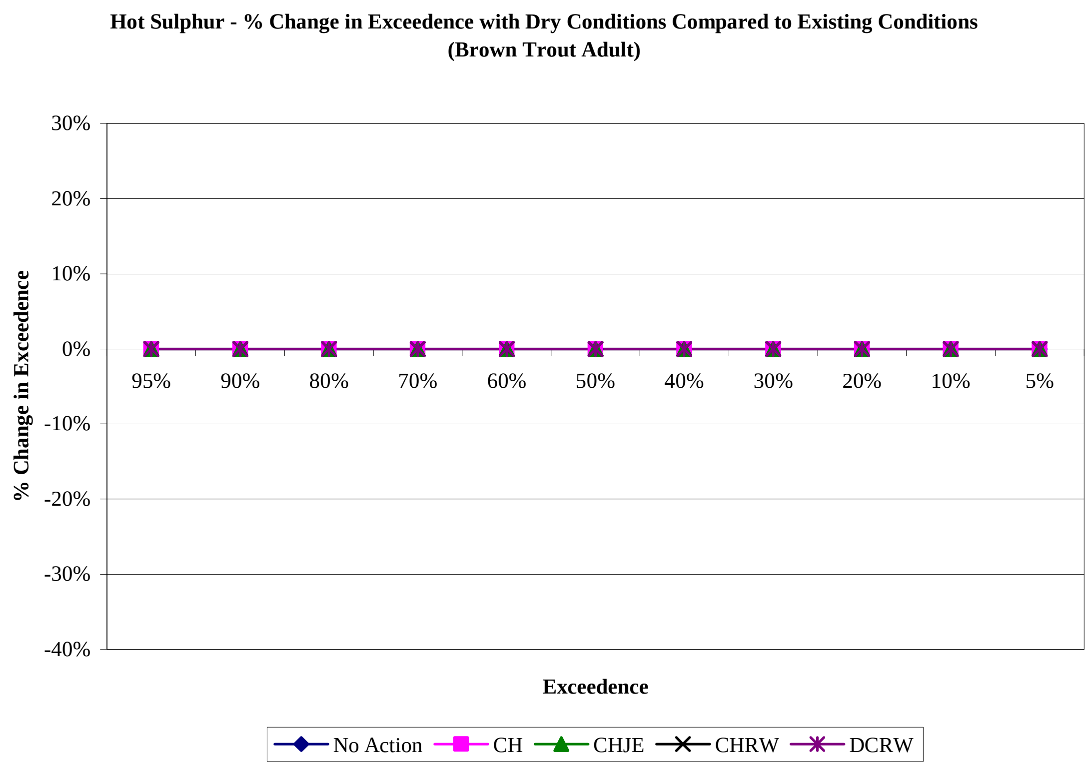


Figure 70. Hot Sulphur – percent change in exceedence with dry conditions (brown trout adult).

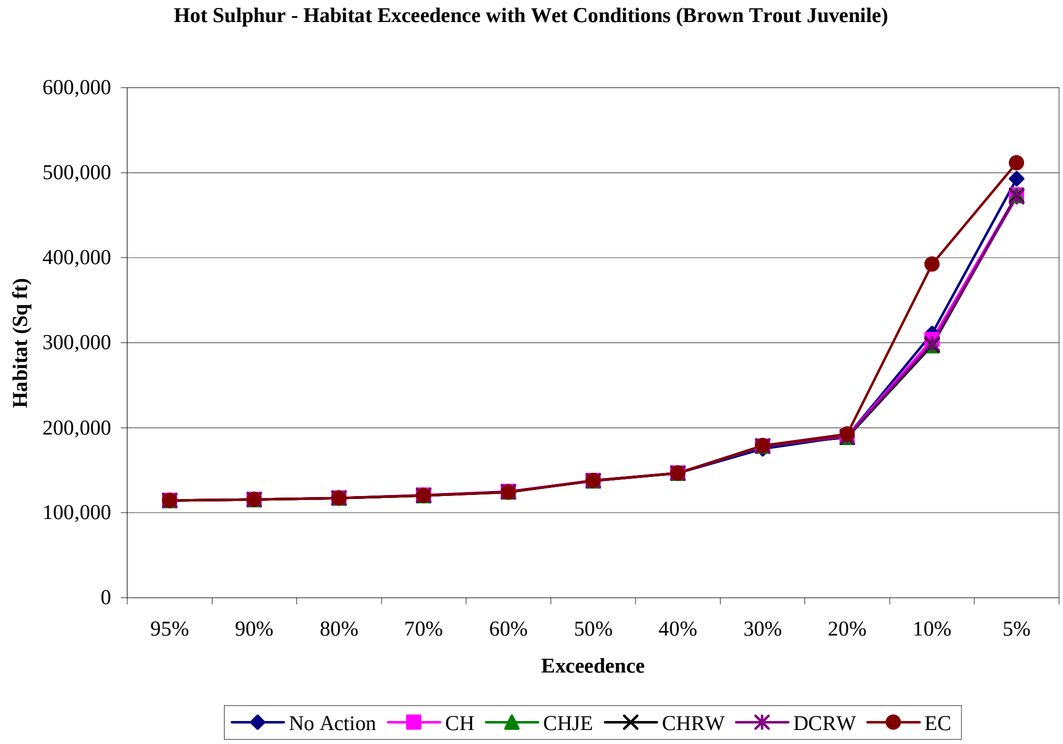


Figure 71. Hot Sulphur – habitat exceedence with wet conditions (brown trout juvenile).

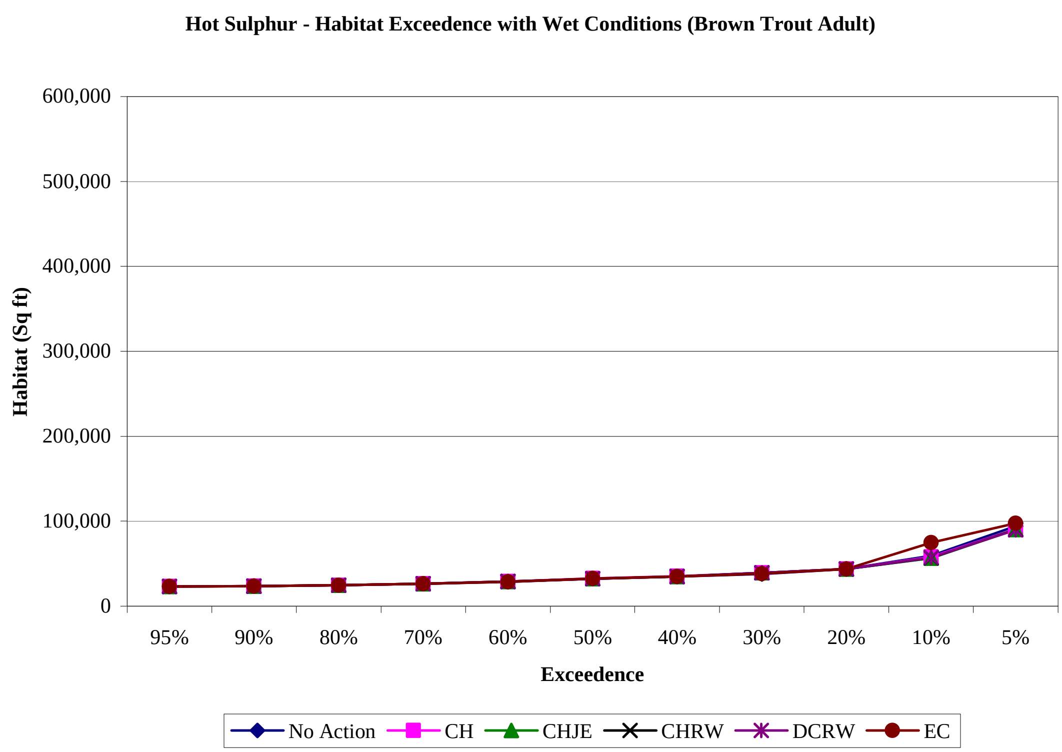


Figure 72. Hot Sulphur – habitat exceedence with wet conditions (brown trout adult).

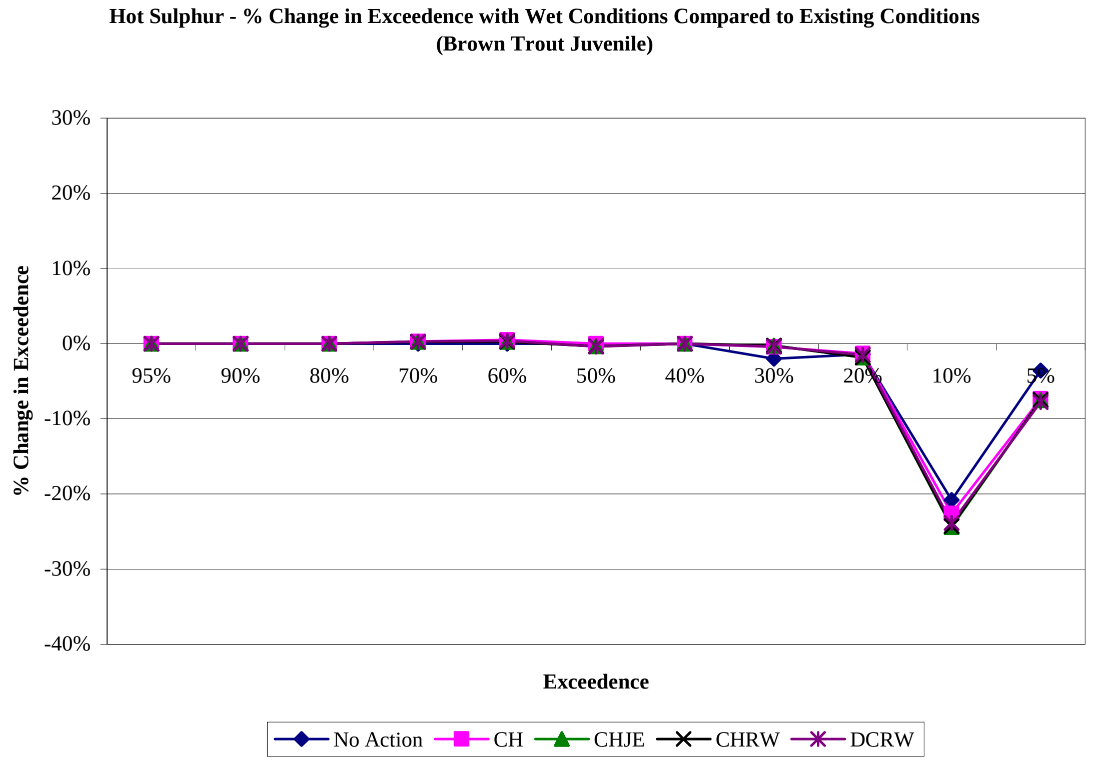


Figure 73. Hot Sulphur – percent change in exceedence with wet conditions (brown trout juvenile).

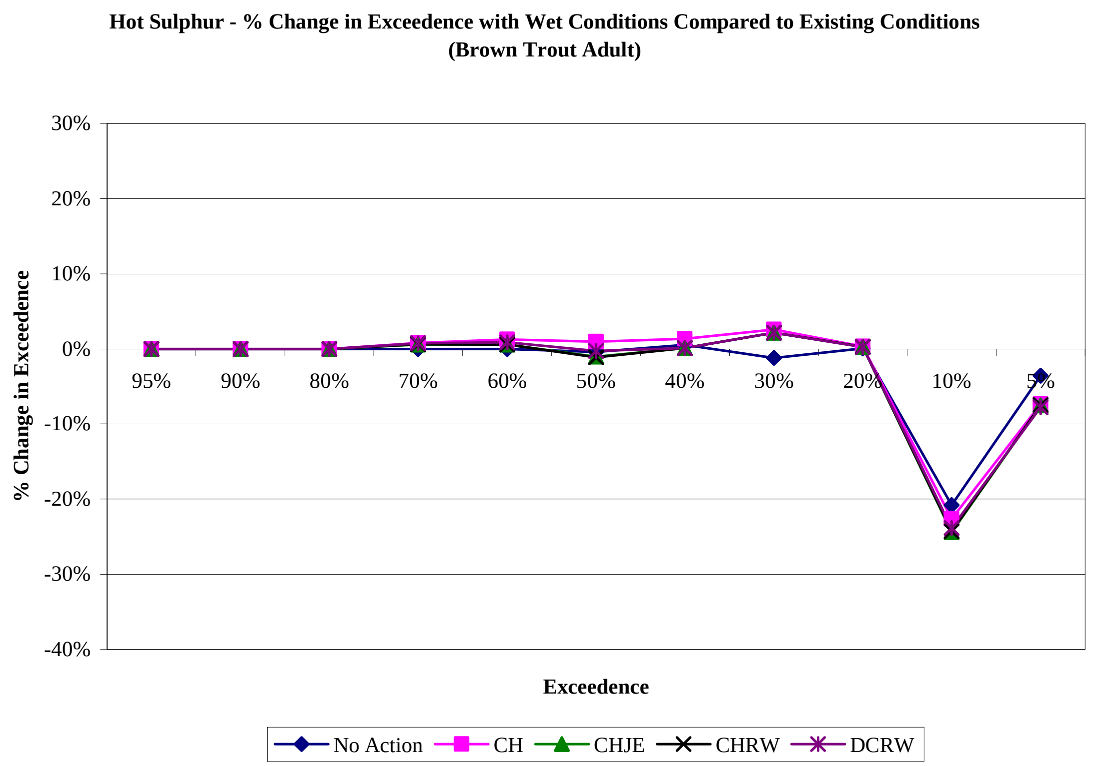


Figure 74. Hot Sulphur – percent change in exceedence with wet conditions (brown trout adult).

Figure 75. Above William's Fork – habitat exceedence with average conditions (rainbow trout juvenile).

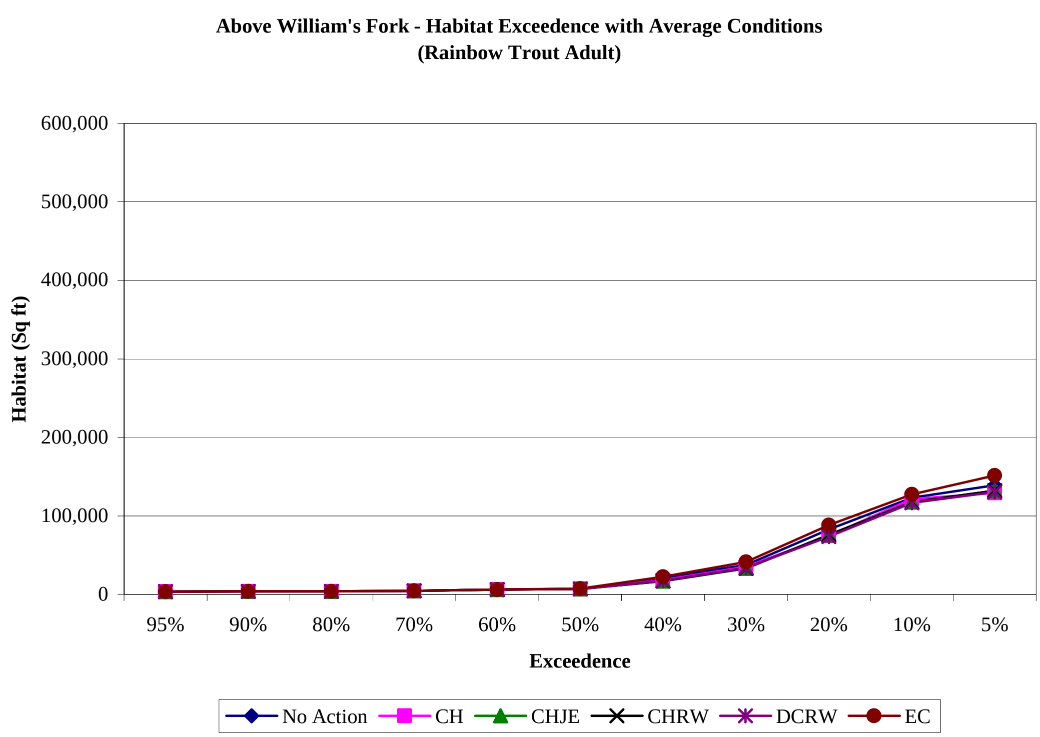


Figure 76. Above William's Fork – habitat exceedence with average conditions (rainbow trout adult).

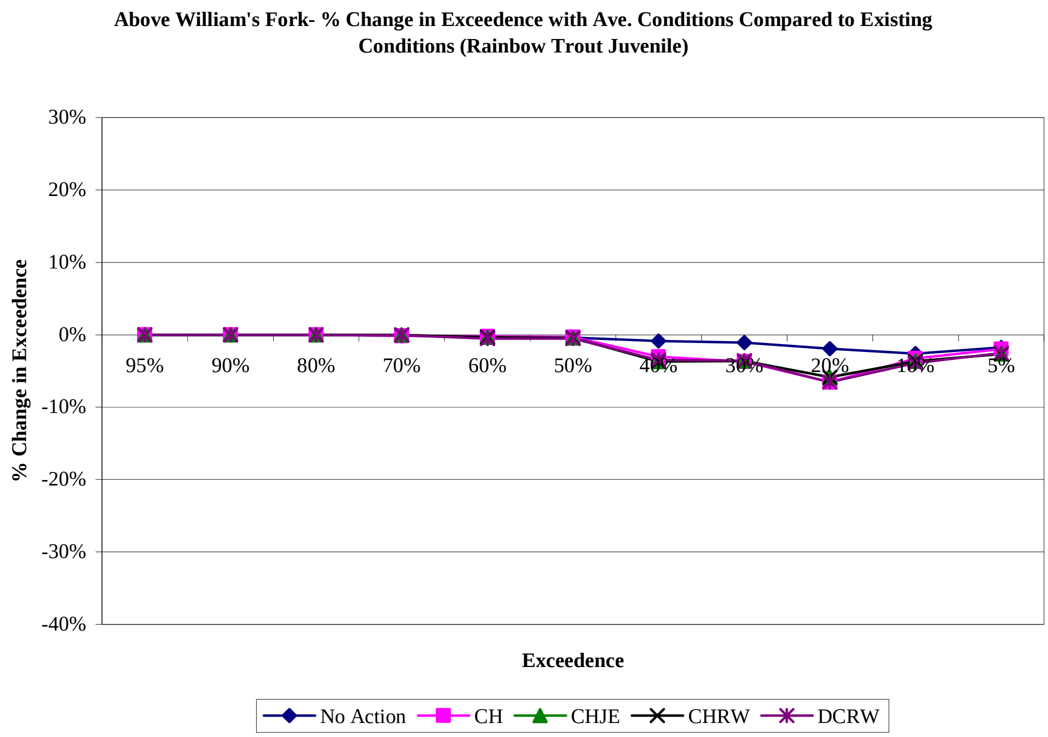


Figure 77. Above William's Fork – percent change in exceedence with average conditions (rainbow trout juvenile).

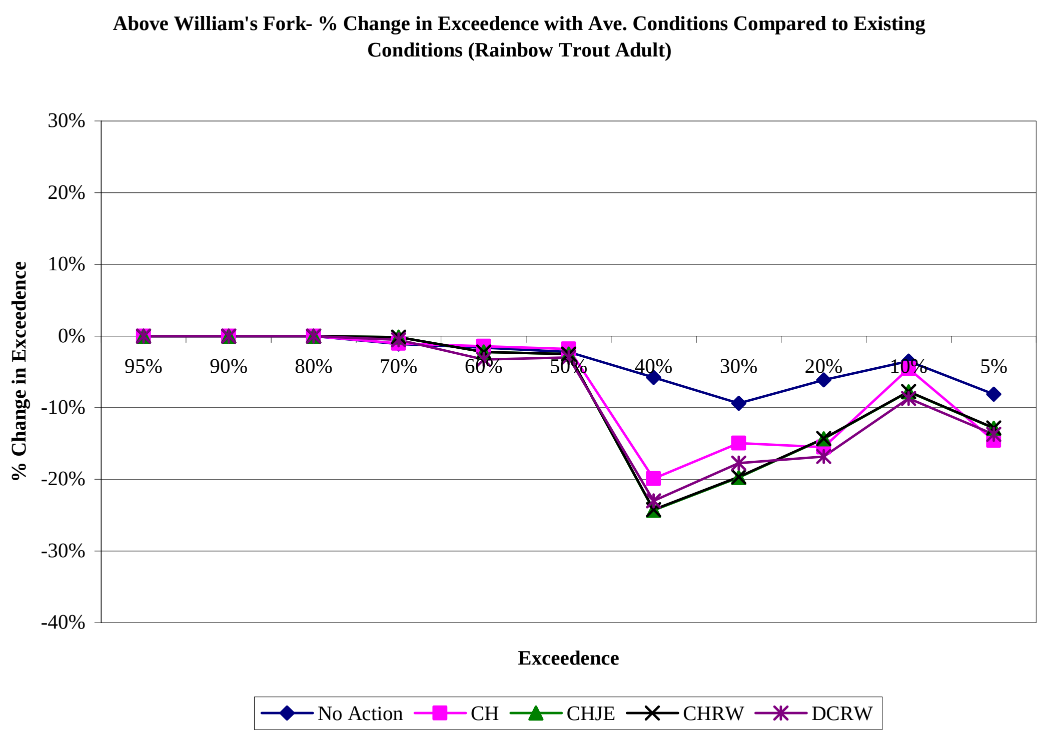


Figure 78. Above William's Fork – percent change in exceedence with average conditions (rainbow trout adult).

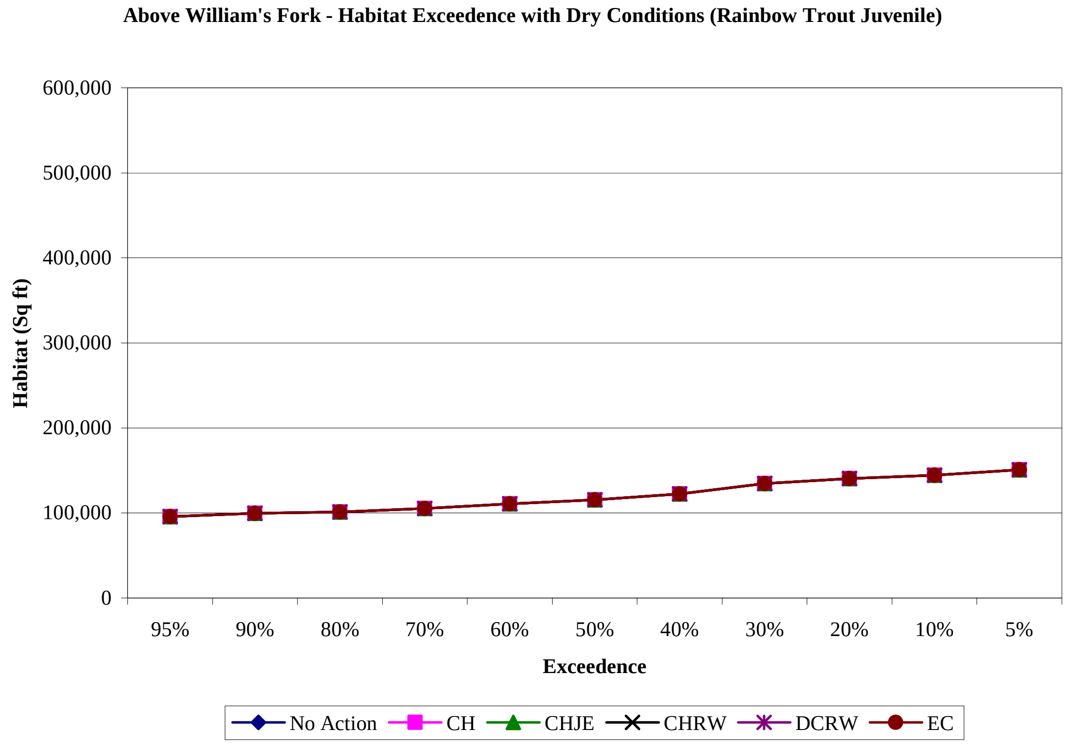


Figure 79. Above William's Fork – habitat exceedence with dry conditions (rainbow trout juvenile).

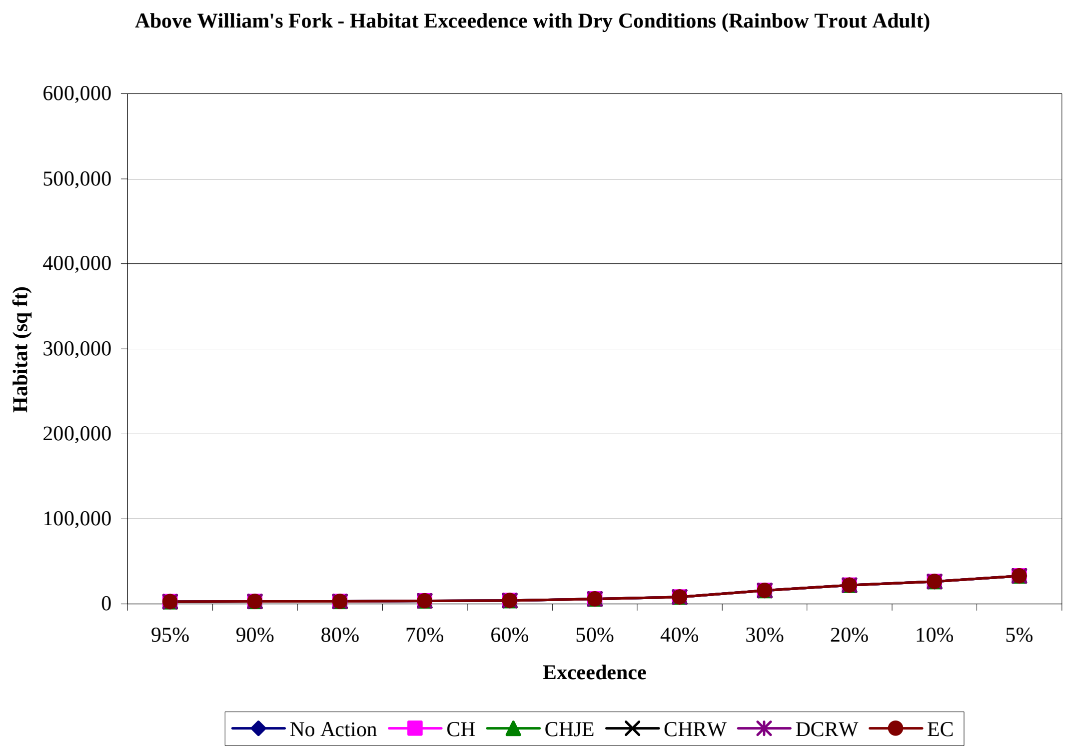


Figure 80. Above William's Fork – habitat exceedence with dry conditions (rainbow trout adult).

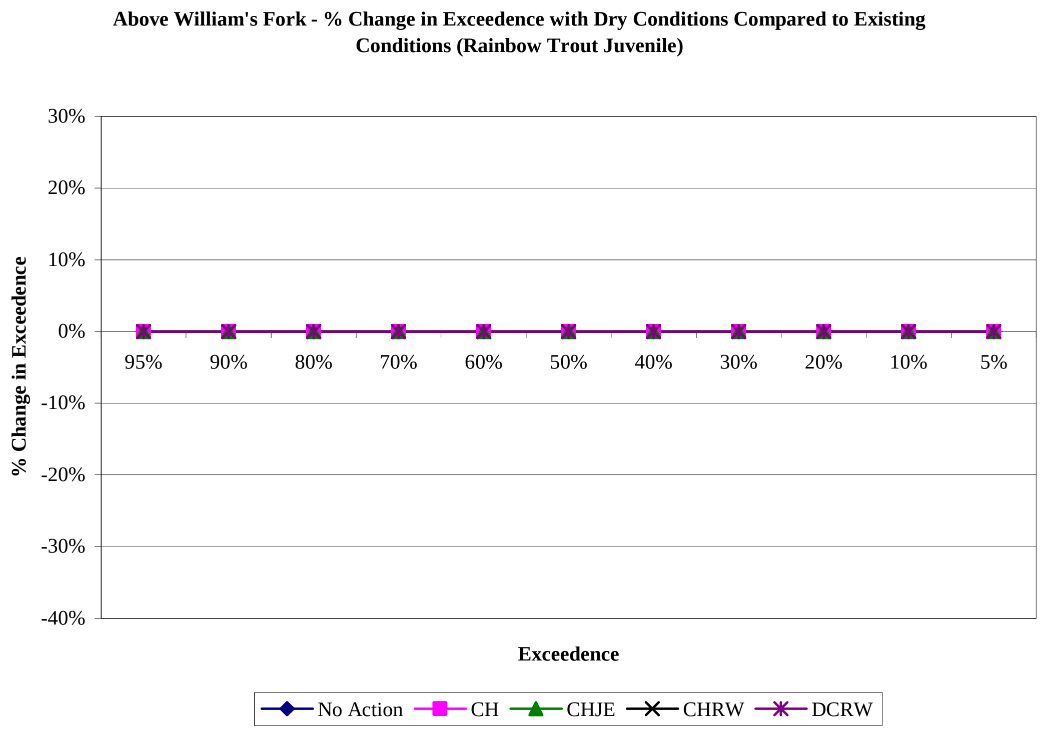


Figure 81. Above William's Fork – percent change in exceedence with dry conditions (rainbow trout juvenile).

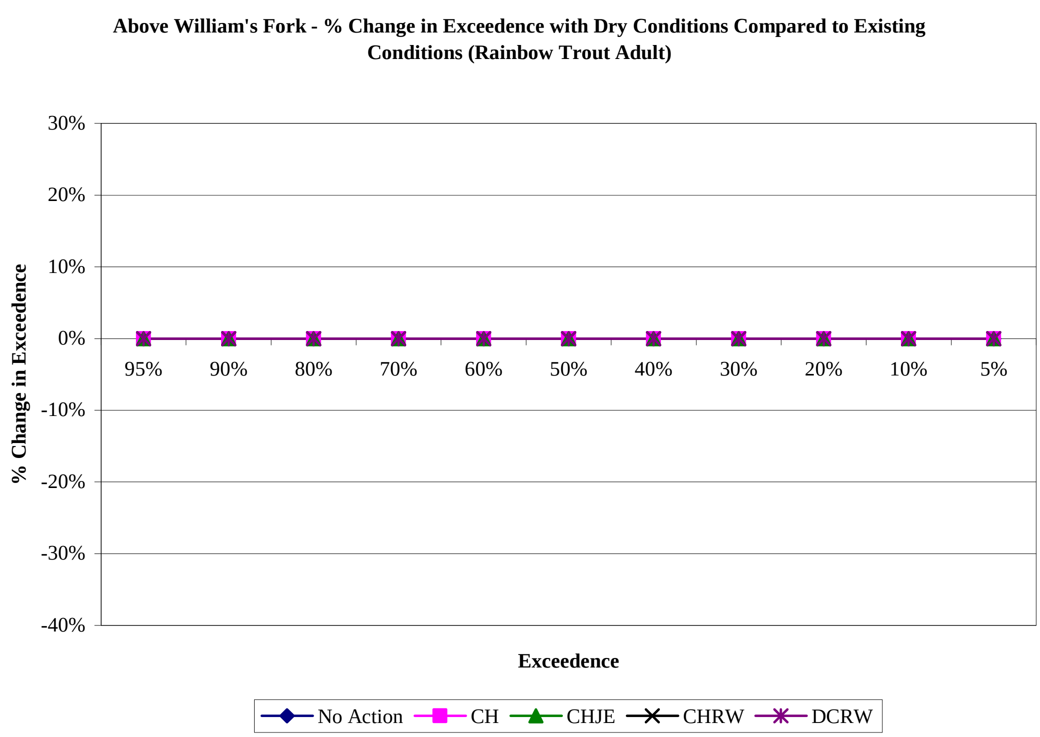


Figure 82. Above William's Fork – percent change in exceedence with dry conditions (rainbow trout adult).

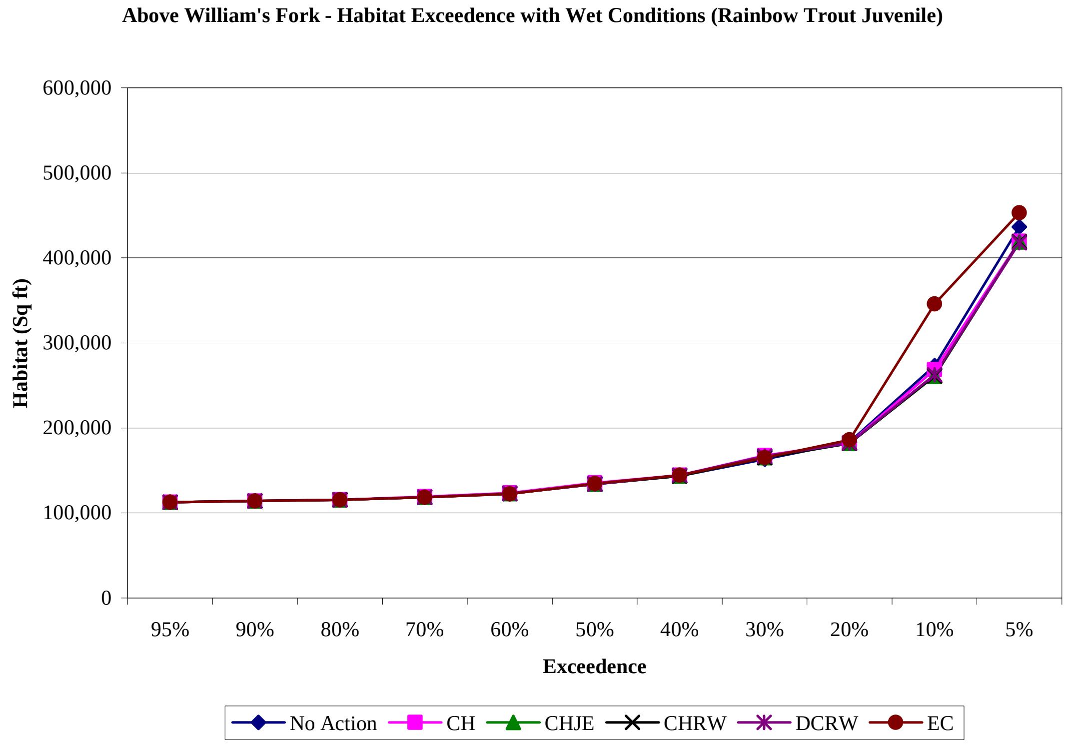


Figure 83. Above Williams Fork – habitat exceedence with wet conditions (rainbow trout juvenile).

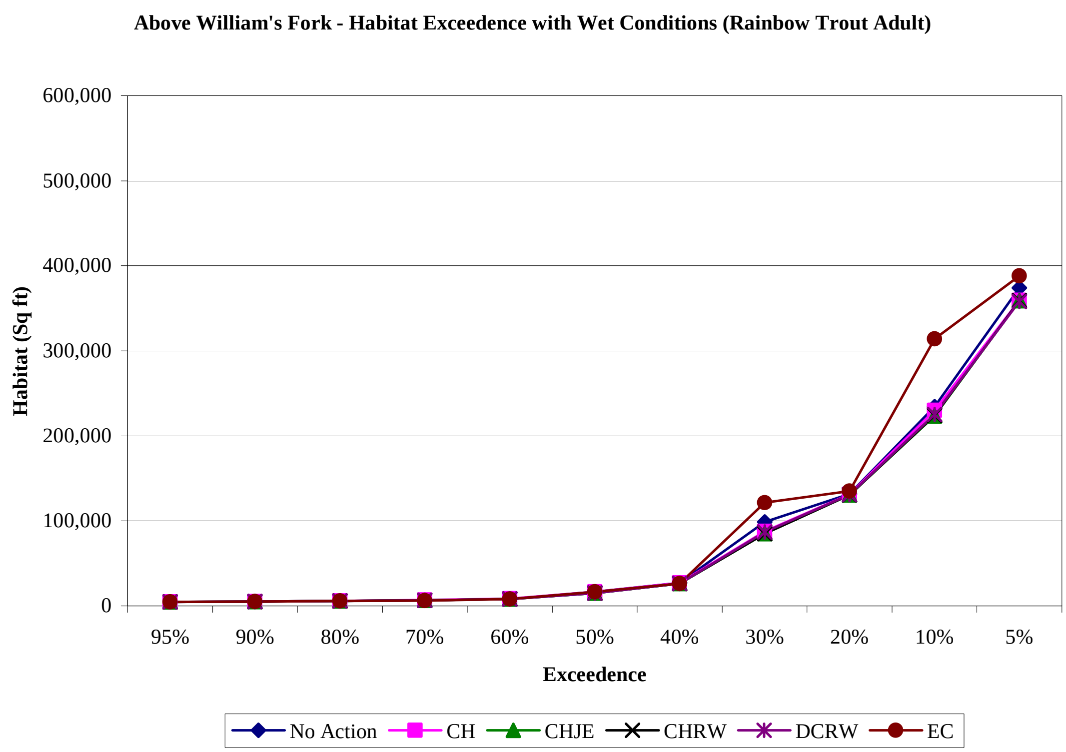


Figure 84. Above William's Fork – habitat exceedence with wet conditions (rainbow trout adult).

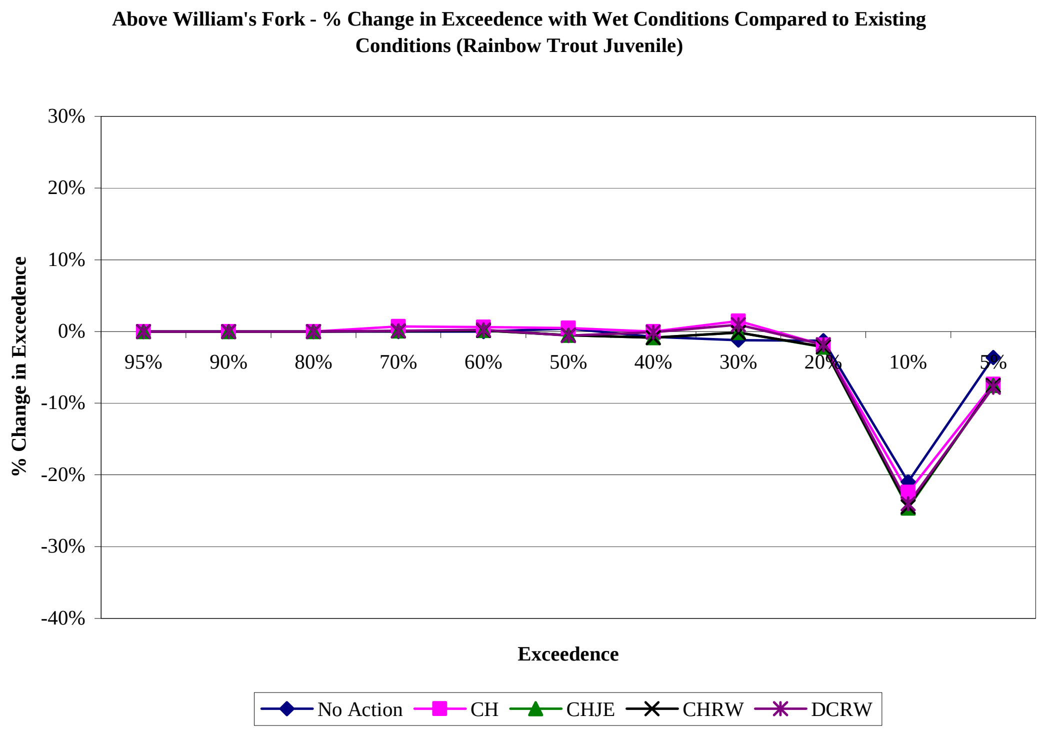


Figure 85. Above William's Fork – percent change in exceedence with wet conditions (rainbow trout juvenile).

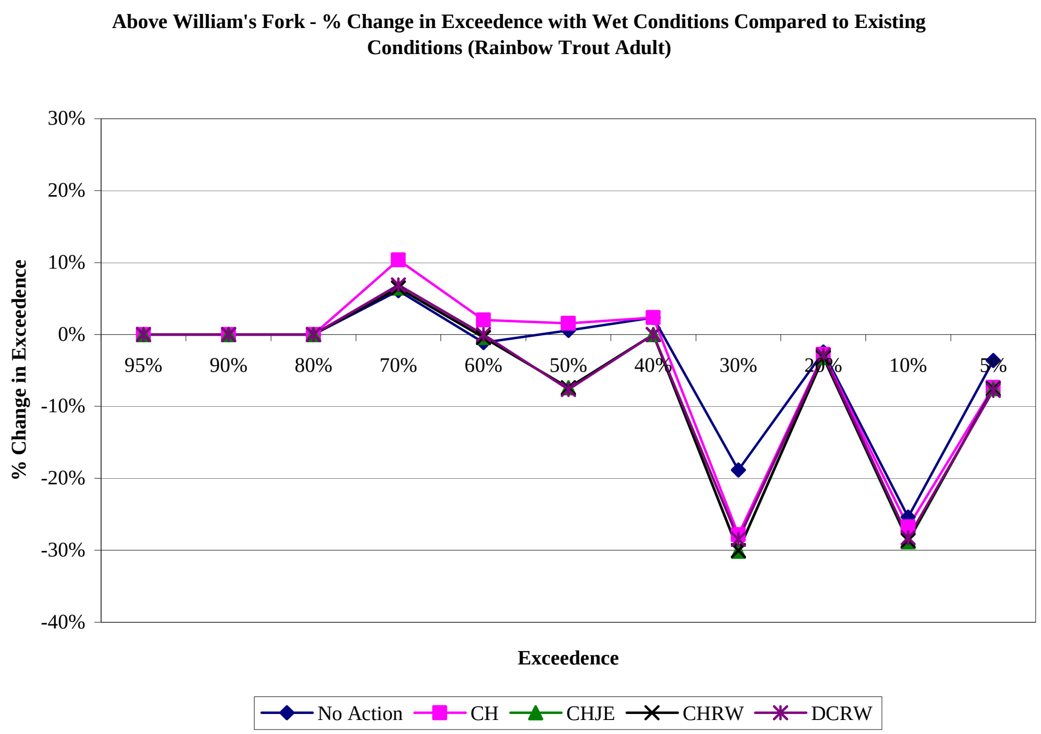


Figure 86. Above William's Fork – percent change in exceedence with wet conditions (rainbow trout adult).

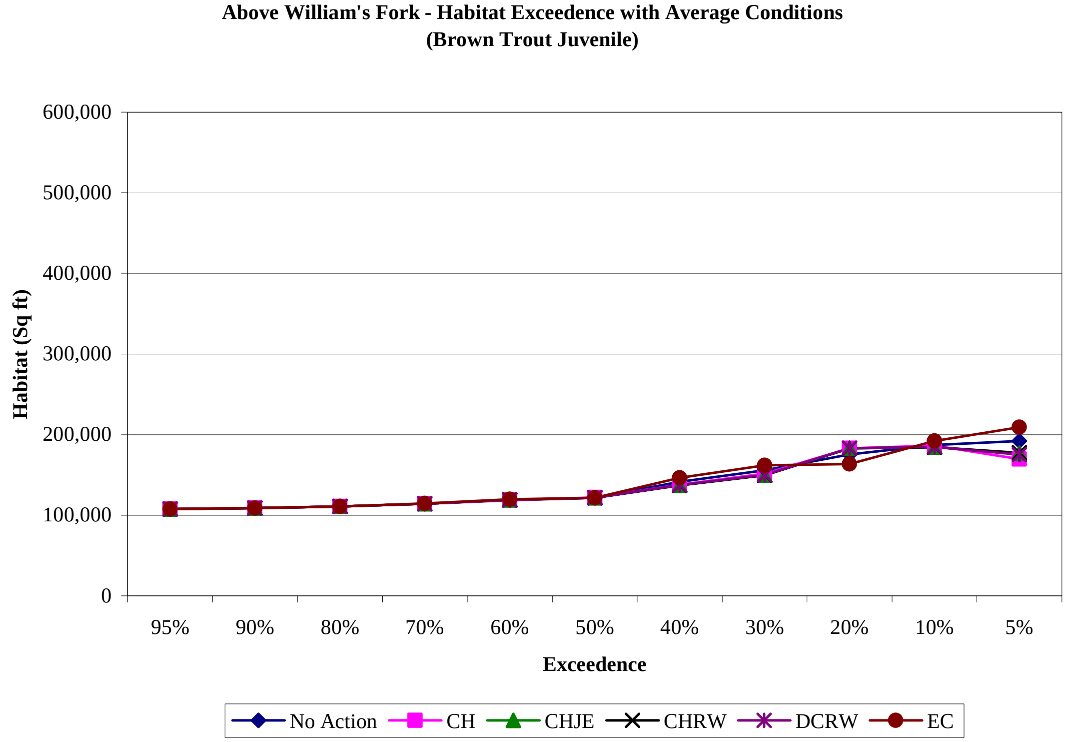


Figure 87. Above William's Fork – habitat exceedence with average conditions (brown trout juvenile).

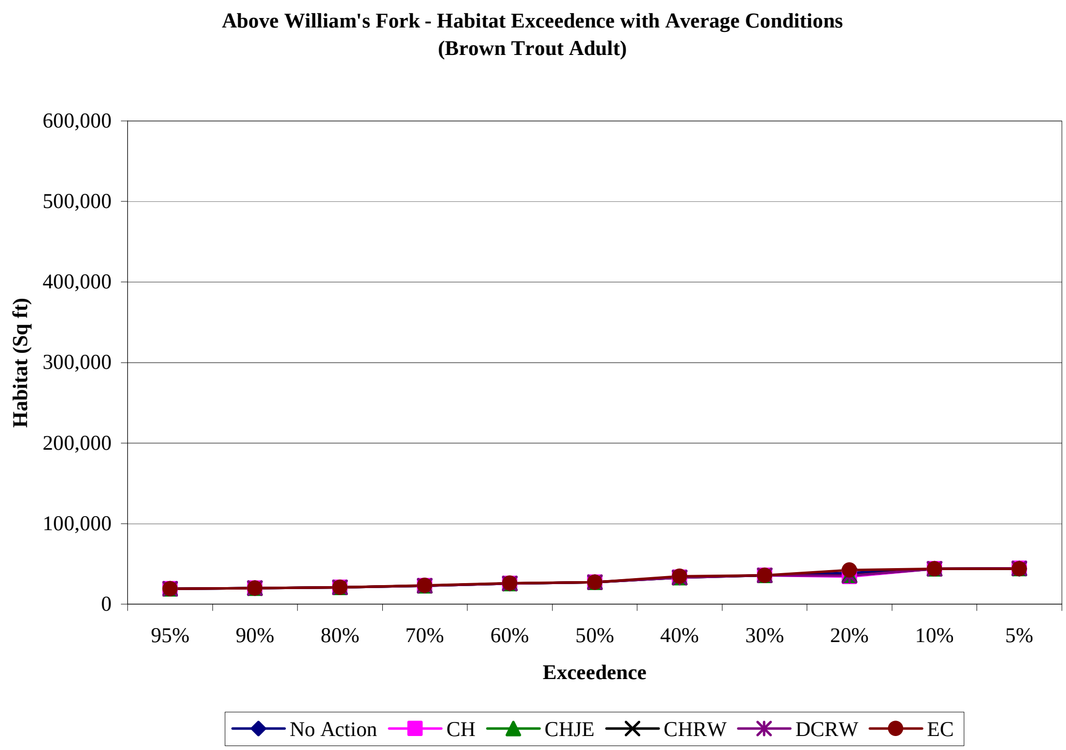


Figure 88. Above William's Fork – habitat exceedence with average conditions (brown trout adult).

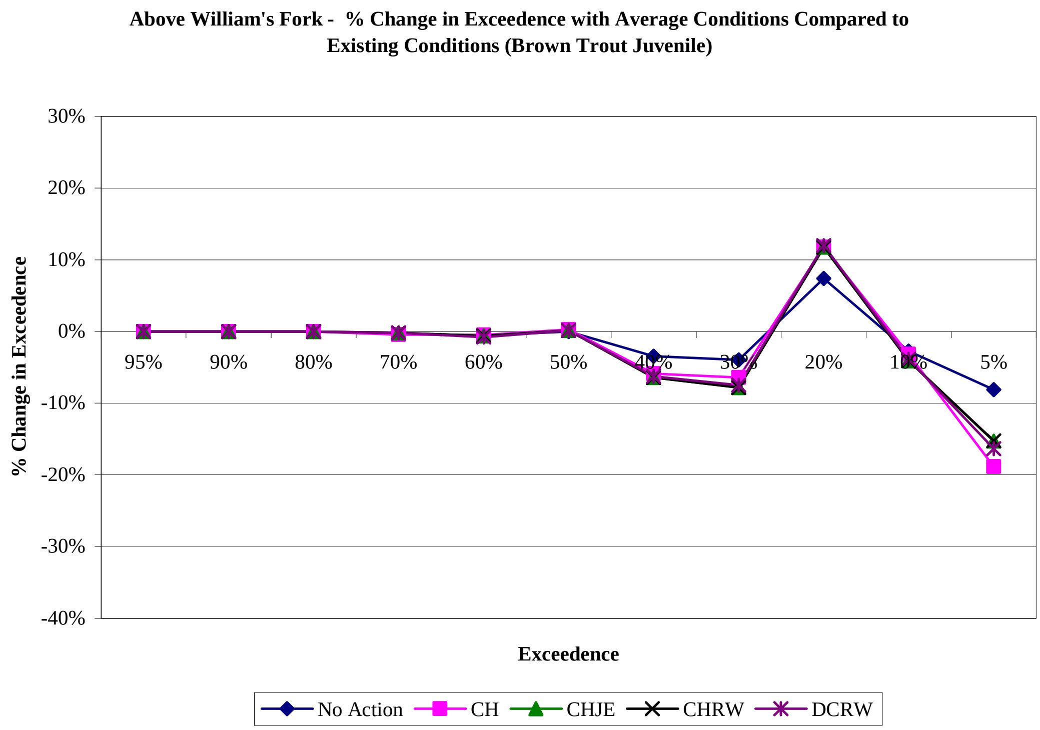


Figure 89. Above William's Fork – percent change in exceedence with average conditions (brown trout juvenile).

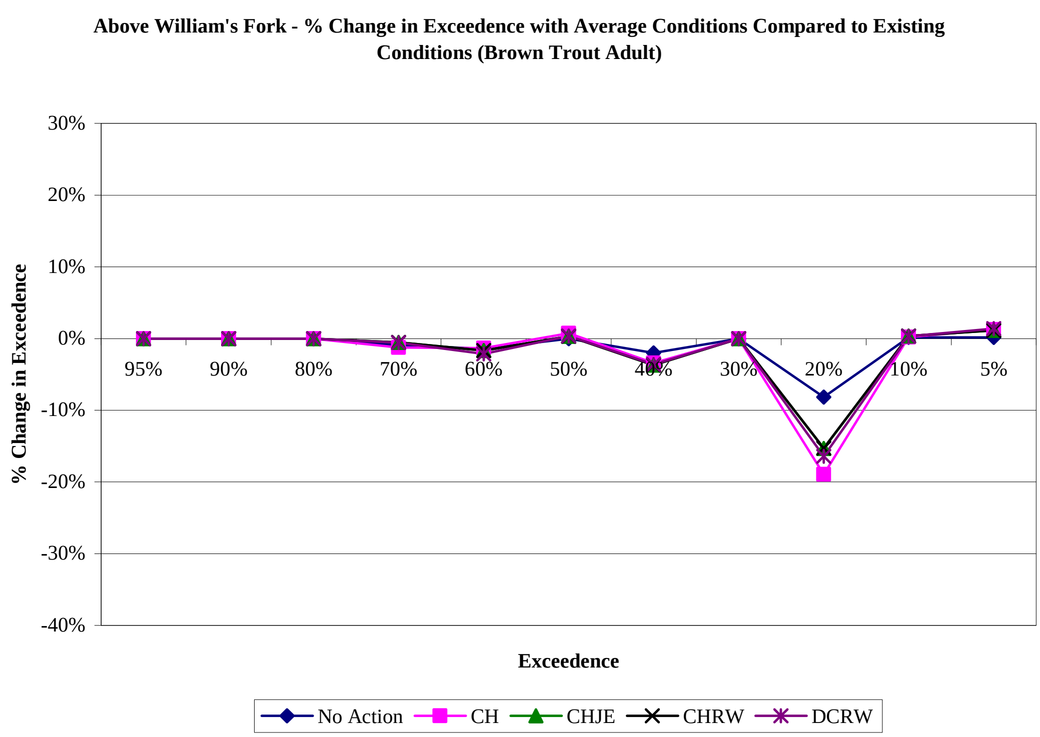


Figure 90. Above William's Fork – percent change in exceedence with average conditions (brown trout adult).

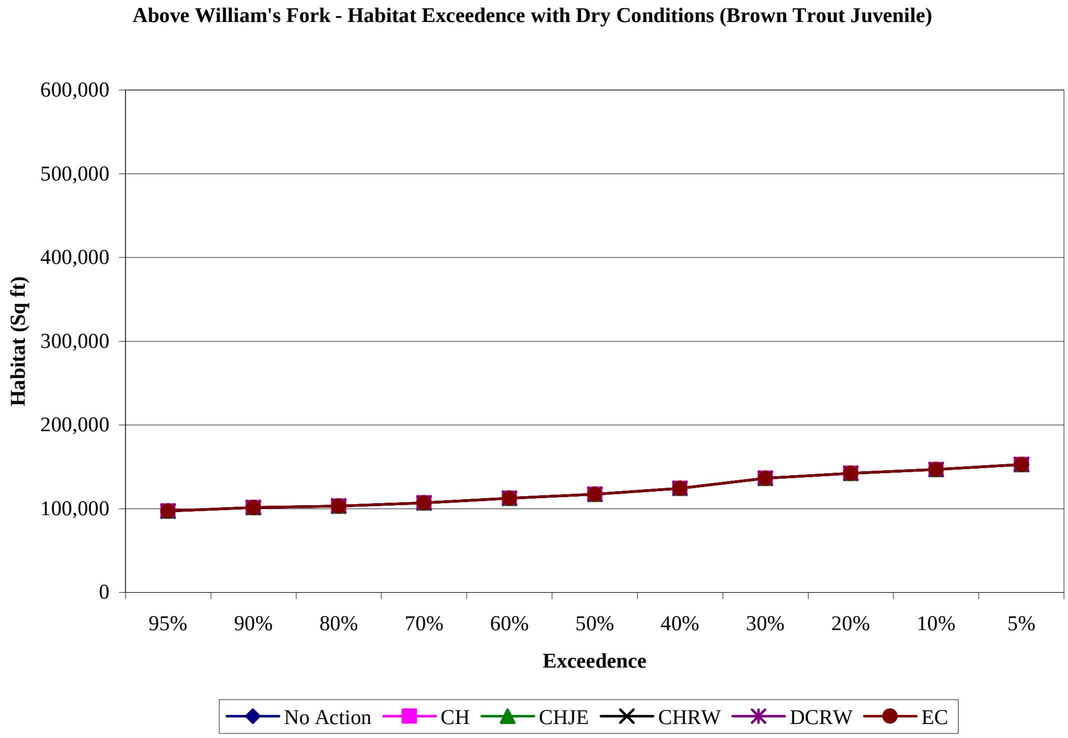


Figure 91. Above William's Fork – habitat exceedence with dry conditions (brown trout juvenile).

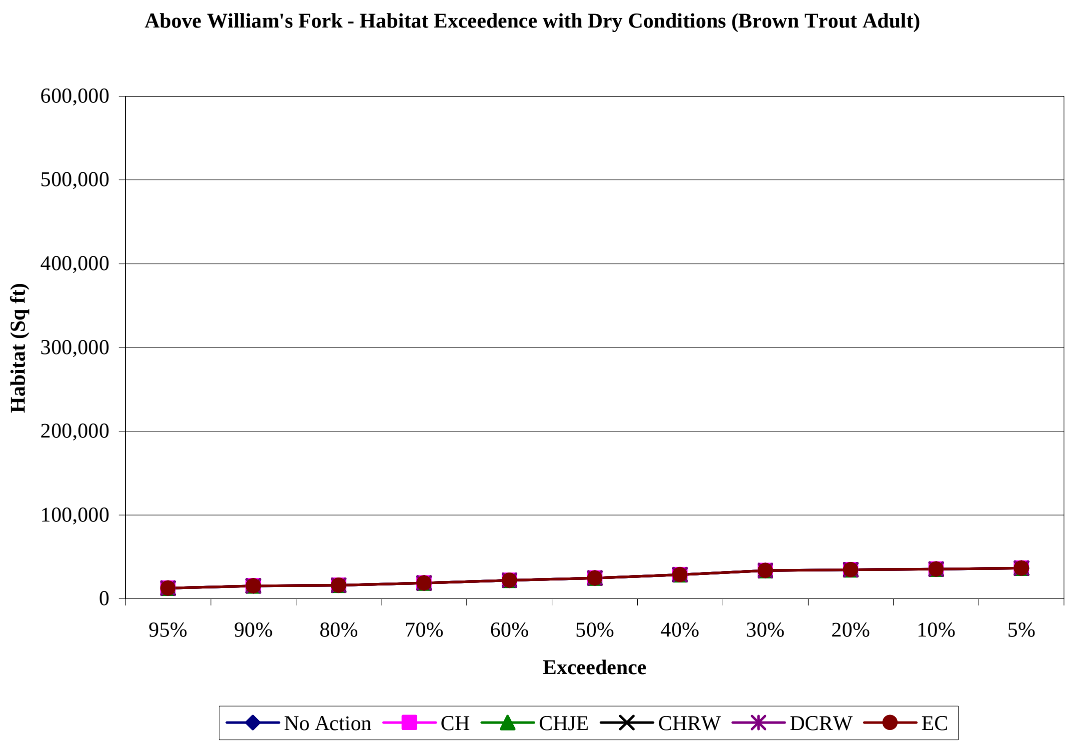


Figure 92. Above William's Fork – habitat exceedence with dry conditions (brown trout adult).

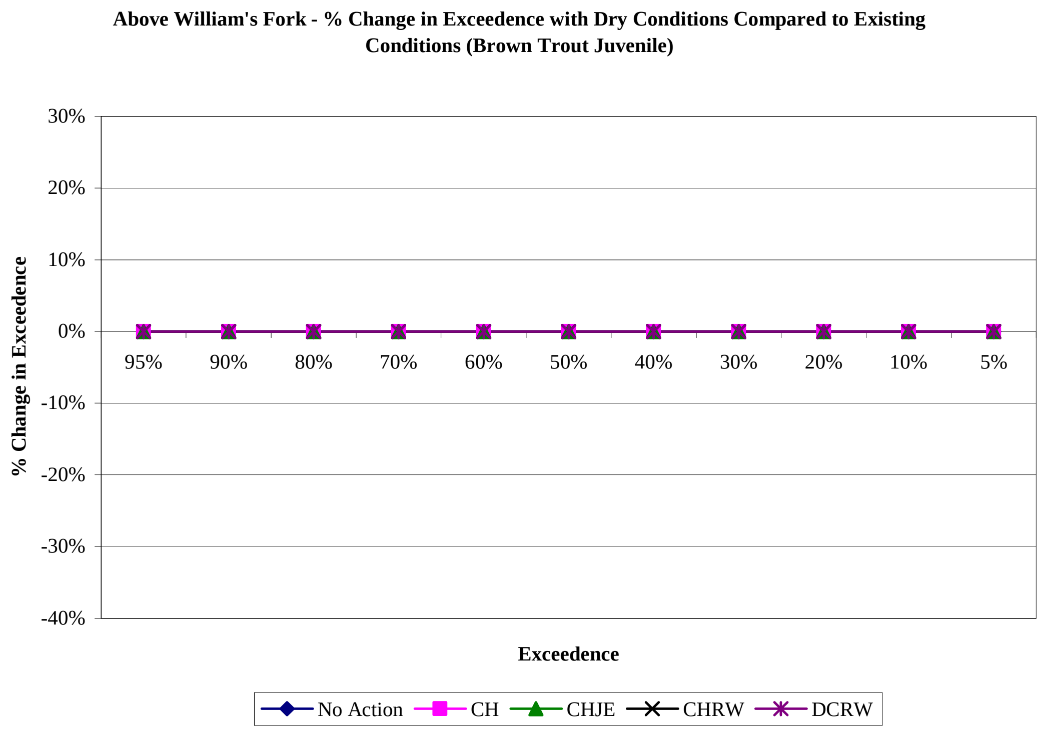


Figure 93. Above William's Fork – percent change in exceedence with dry conditions (brown trout juvenile).

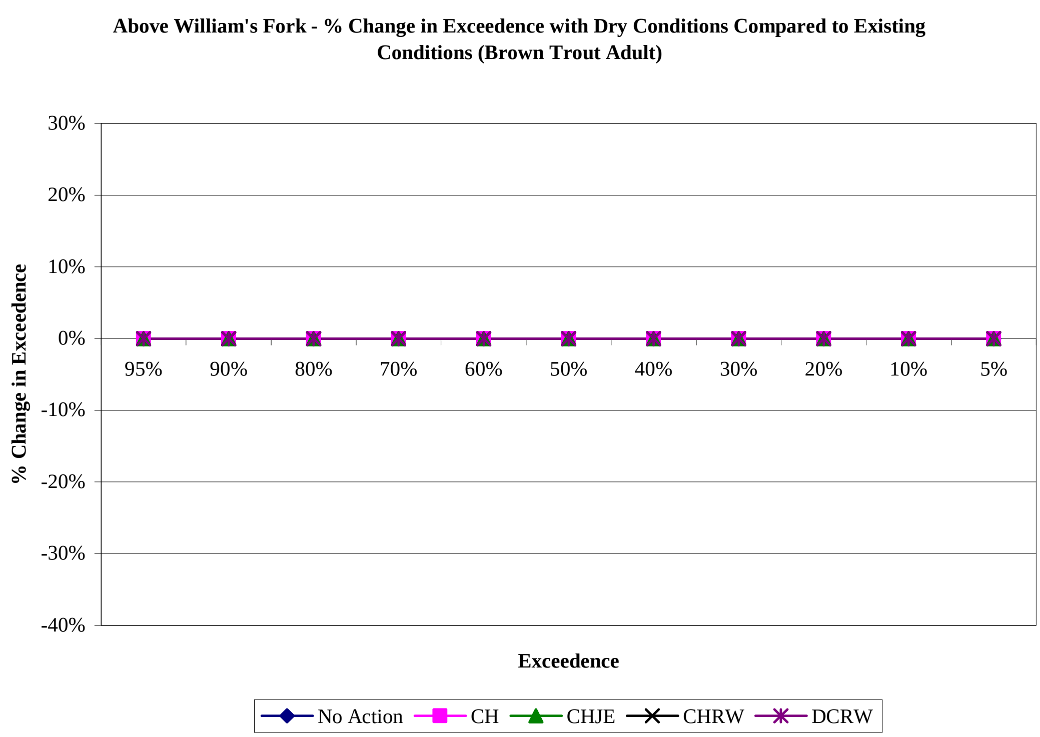


Figure 94. Above William's Fork – percent change in exceedence with dry conditions (brown trout adult).

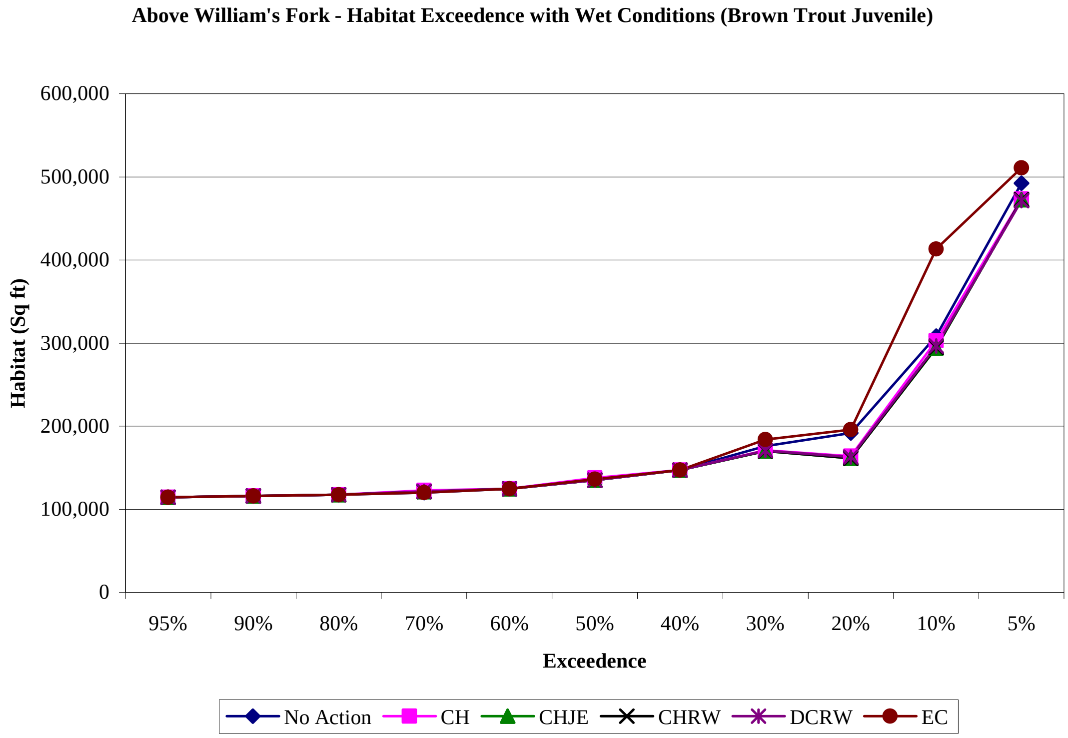


Figure 95. Above William's Fork – habitat exceedence with wet conditions (brown trout juvenile).

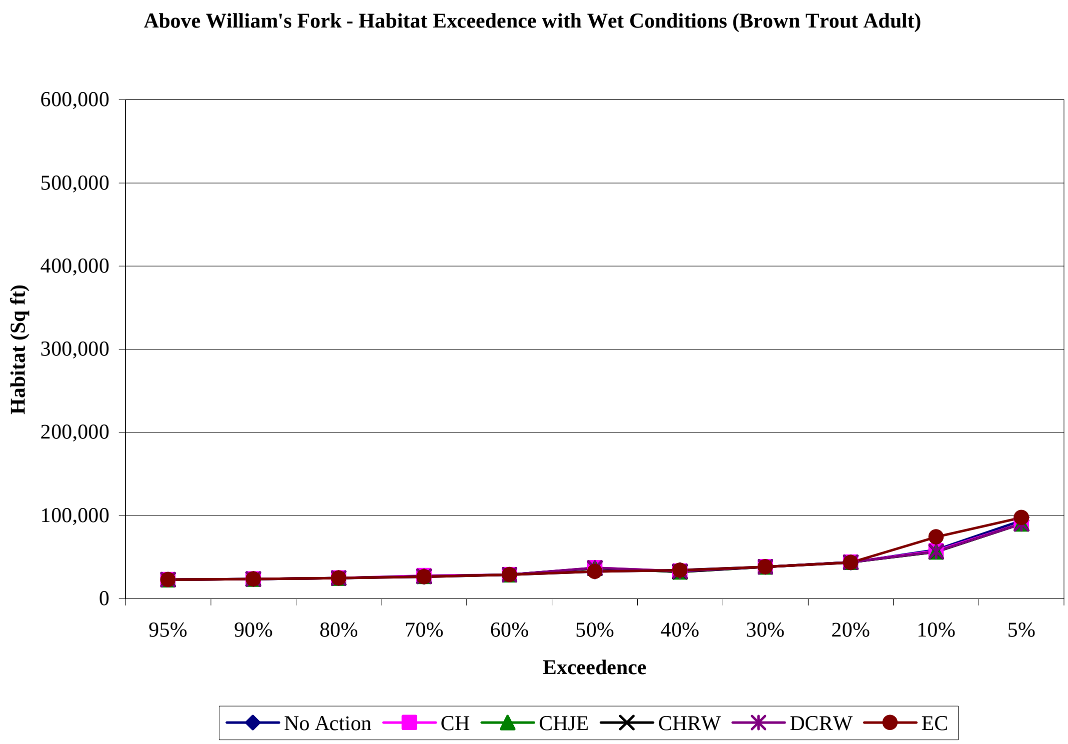


Figure 96. Above William's Fork – habitat exceedence with wet conditions (brown trout adult).

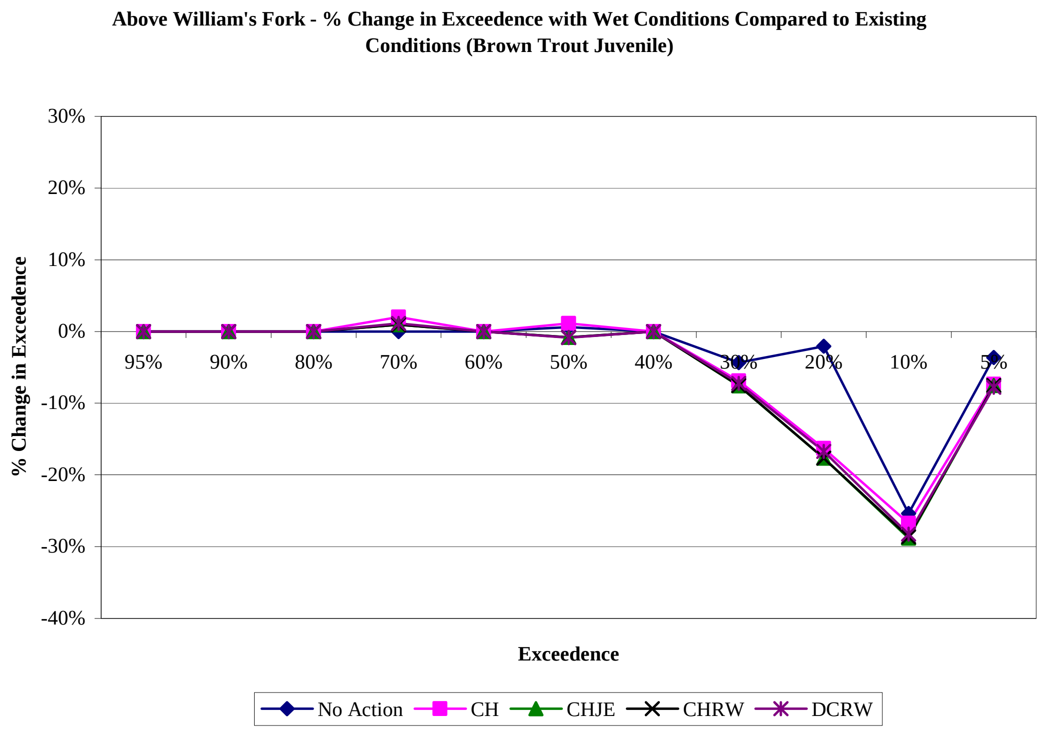


Figure 97. Above William's Fork – percent change in exceedence with <u>wet</u> conditions (brown trout juvenile).

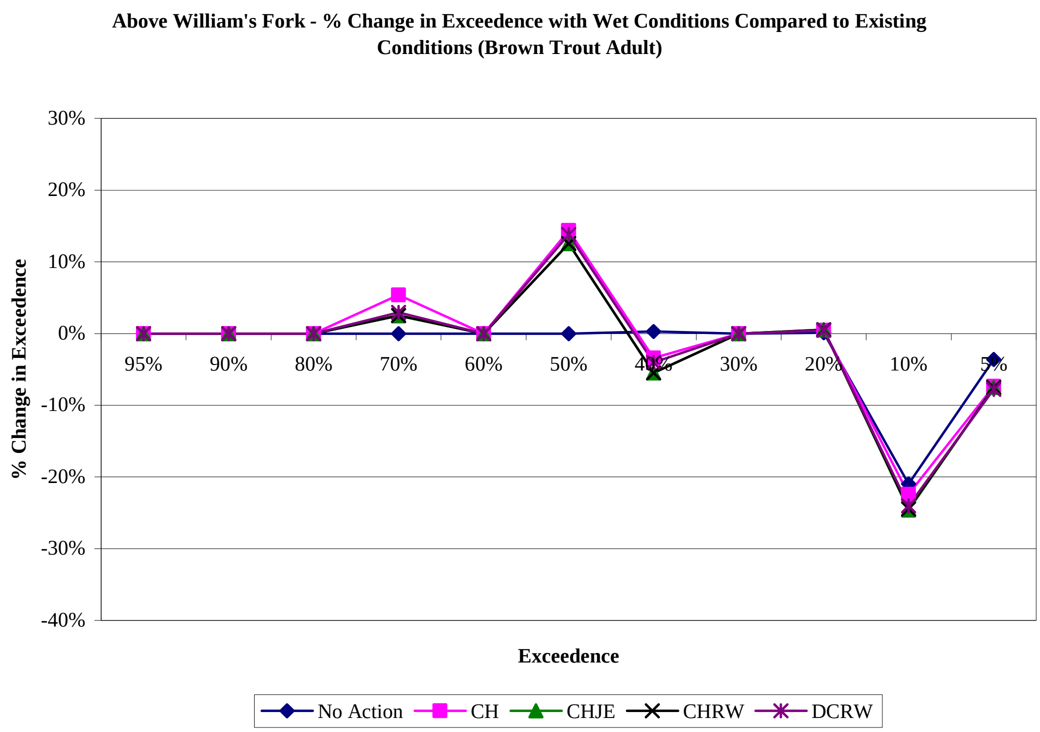


Figure 98. Above William's Fork – percent change in exceedence with <u>wet</u> conditions (brown trout adult).

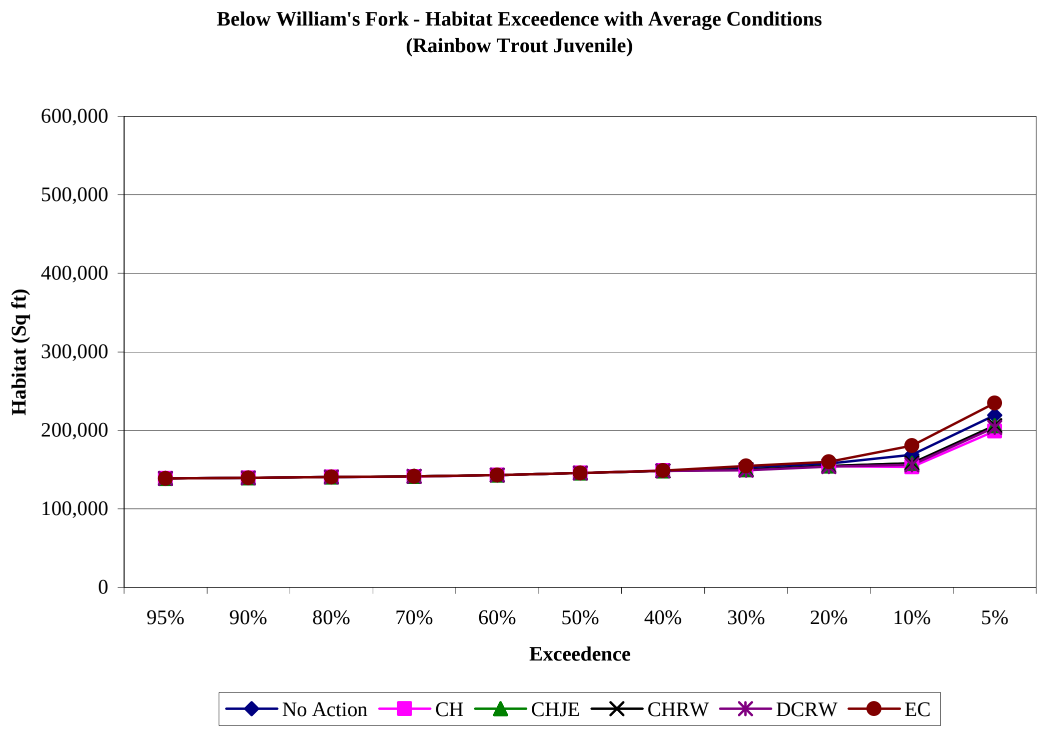


Figure 99. Below William's Fork – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile).

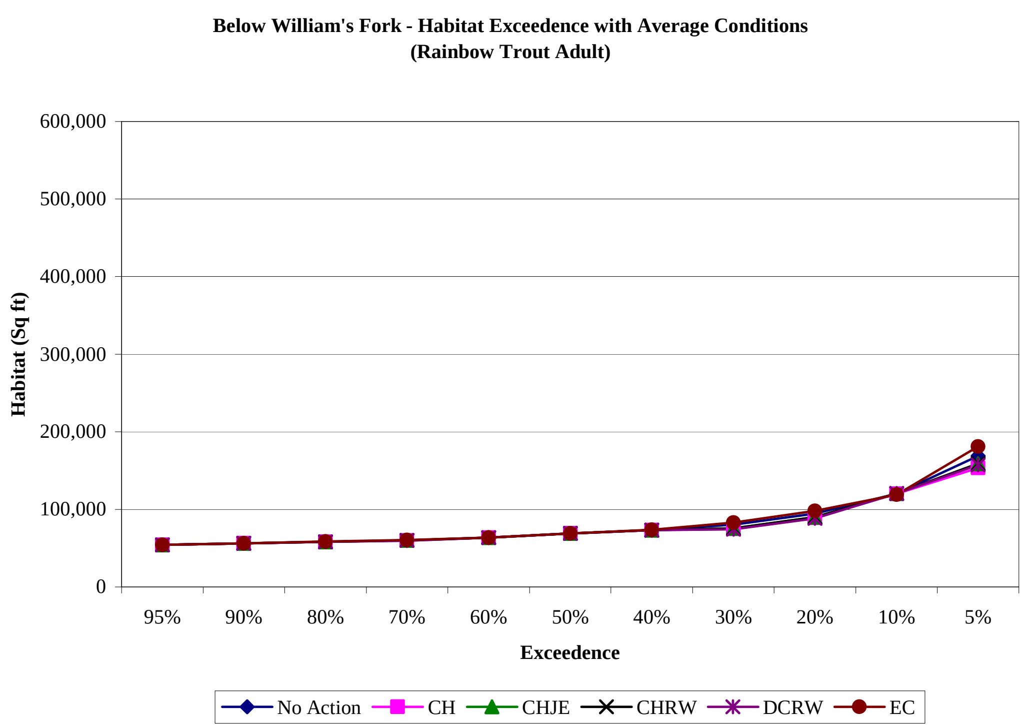


Figure 100. Below William's Fork – habitat exceedence with <u>average</u> conditions (rainbow trout adult).

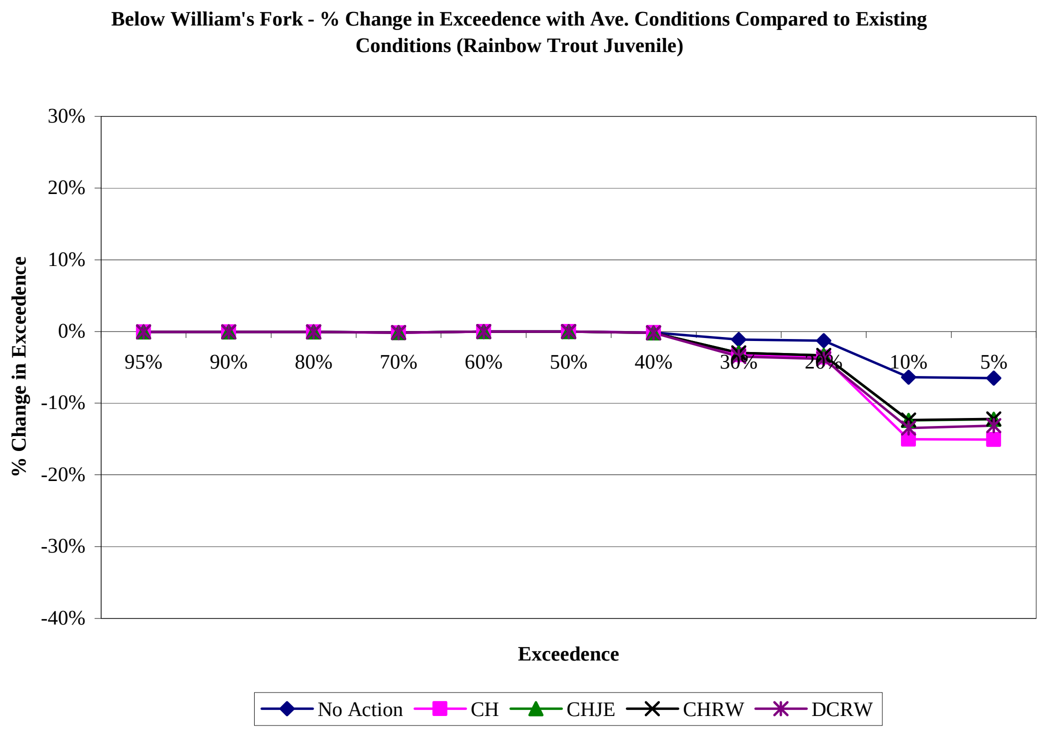


Figure 101. Below William's Fork – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile).

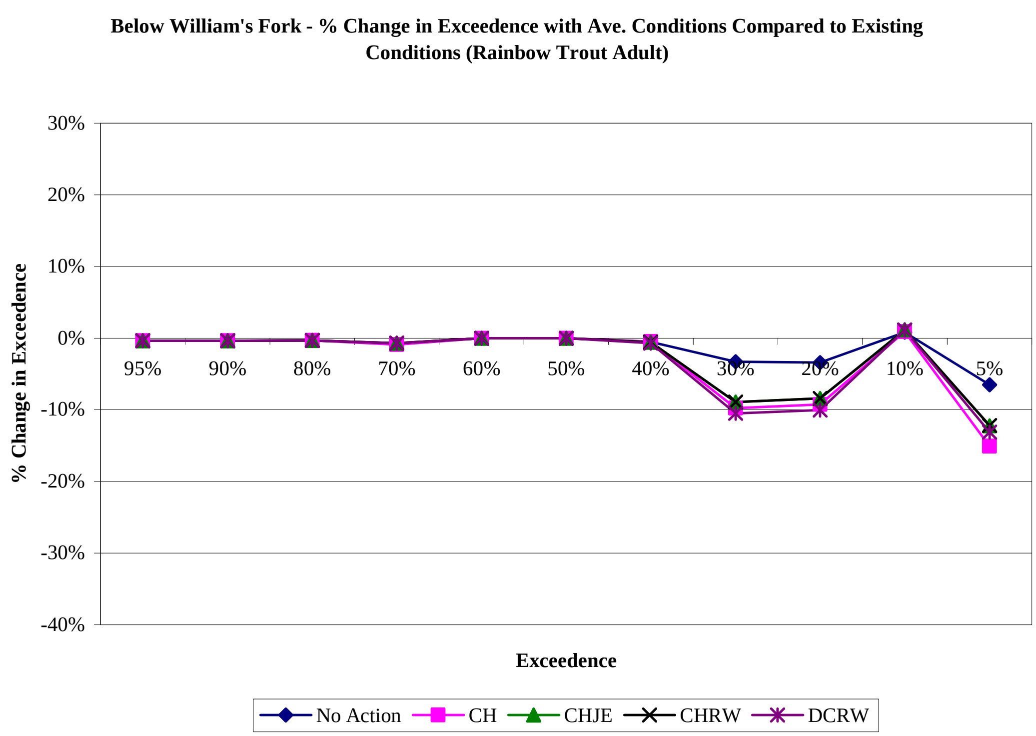


Figure 102. Below William's Fork – percent change in exceedence with <u>average</u> conditions (rainbow trout adult).

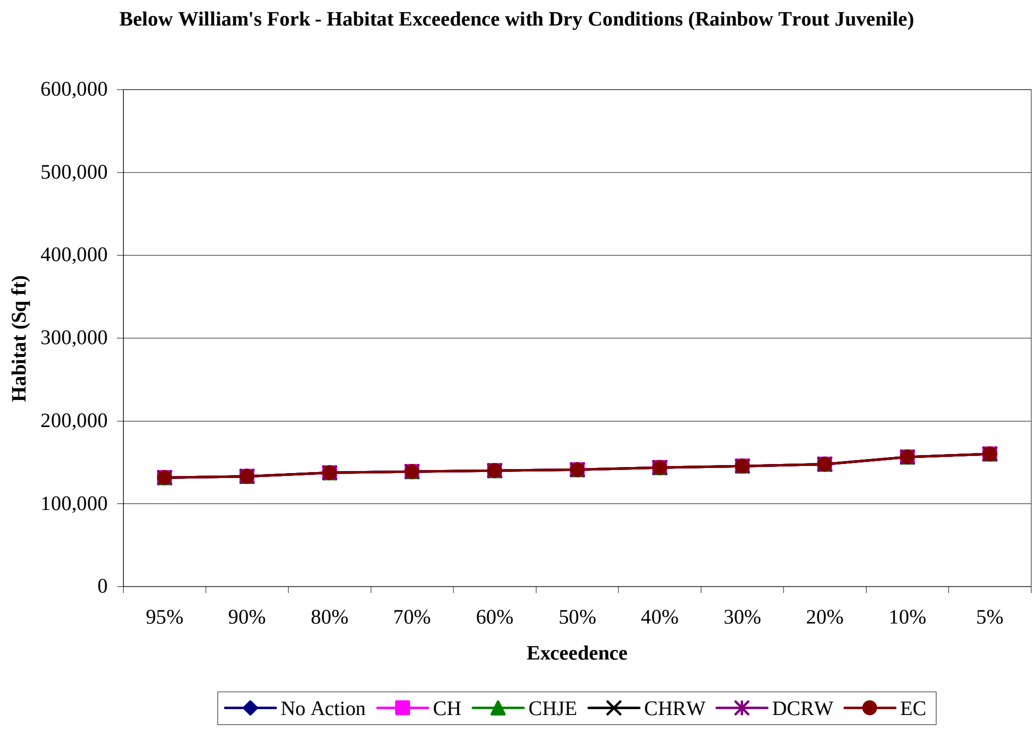


Figure 103. Below William's Fork – habitat exceedence with dry conditions (rainbow trout juvenile).

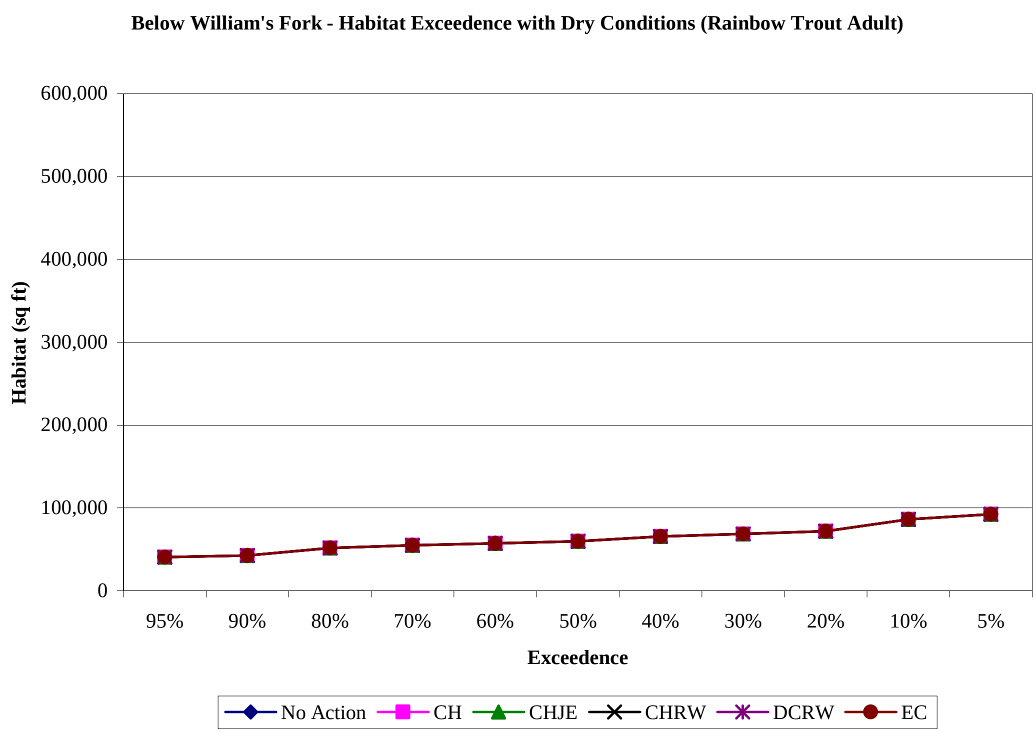


Figure 104. Below William's Fork – habitat exceedence with dry conditions (rainbow trout adult).

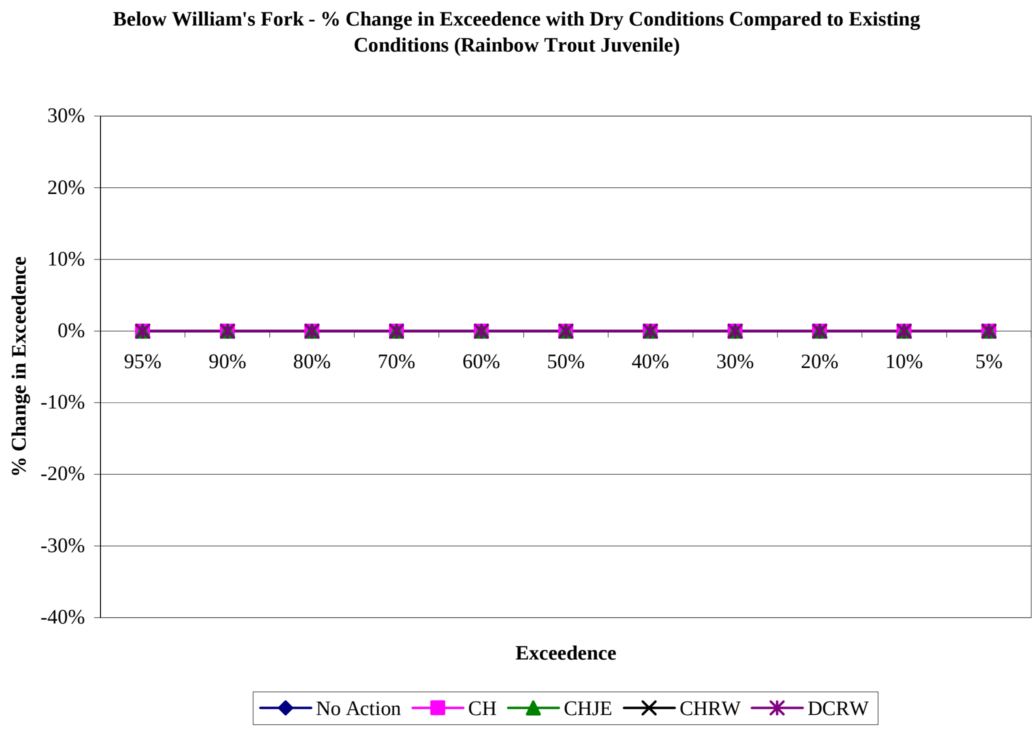


Figure 105. Below William's Fork – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile).

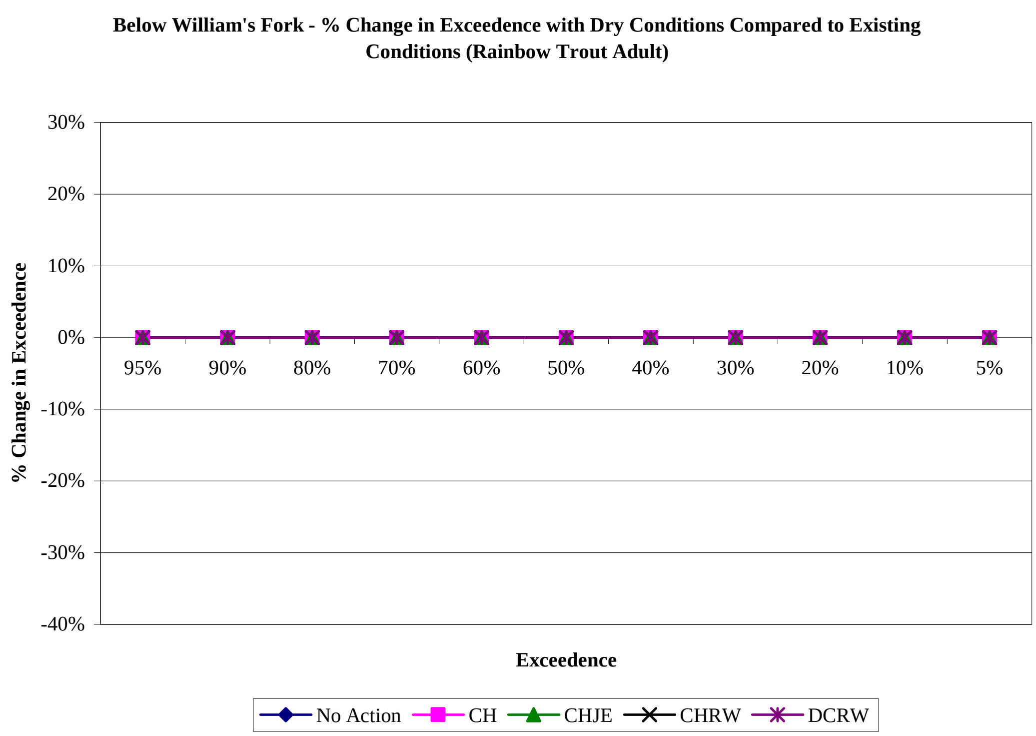


Figure 106. Below William's Fork – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult).

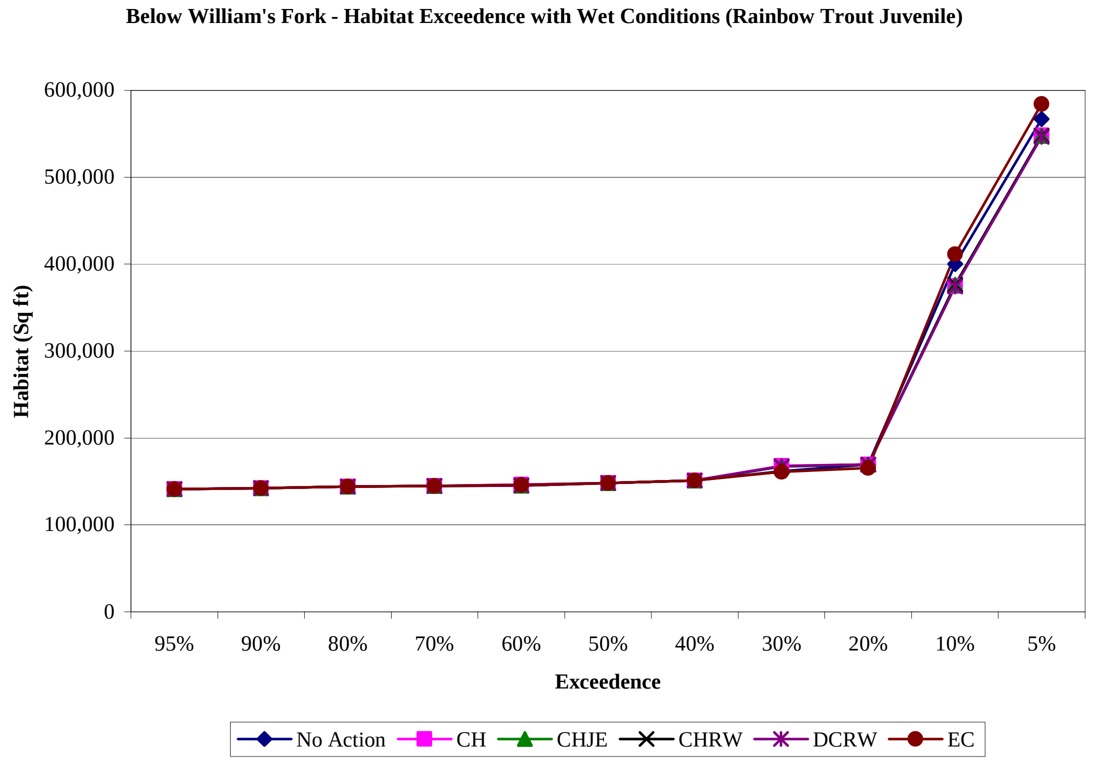


Figure 107. Below William's Fork – habitat exceedence with wet conditions (rainbow trout juvenile).

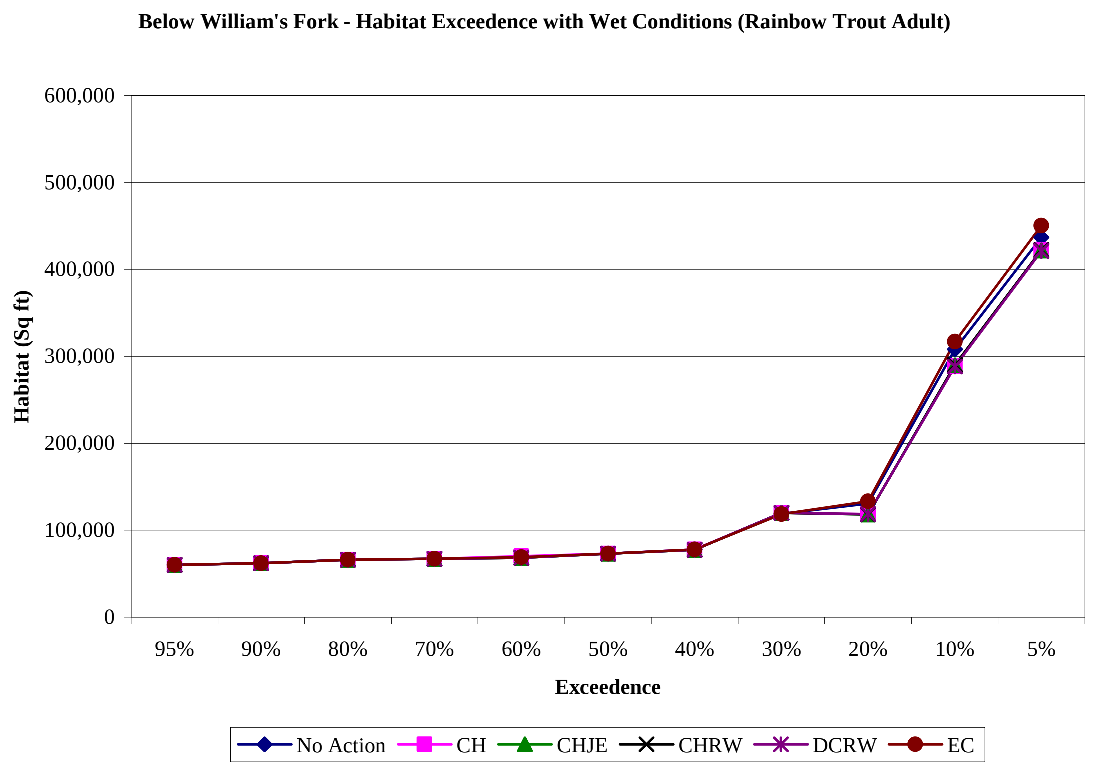


Figure 108. Below William's Fork – habitat exceedence with wet conditions (rainbow trout adult).

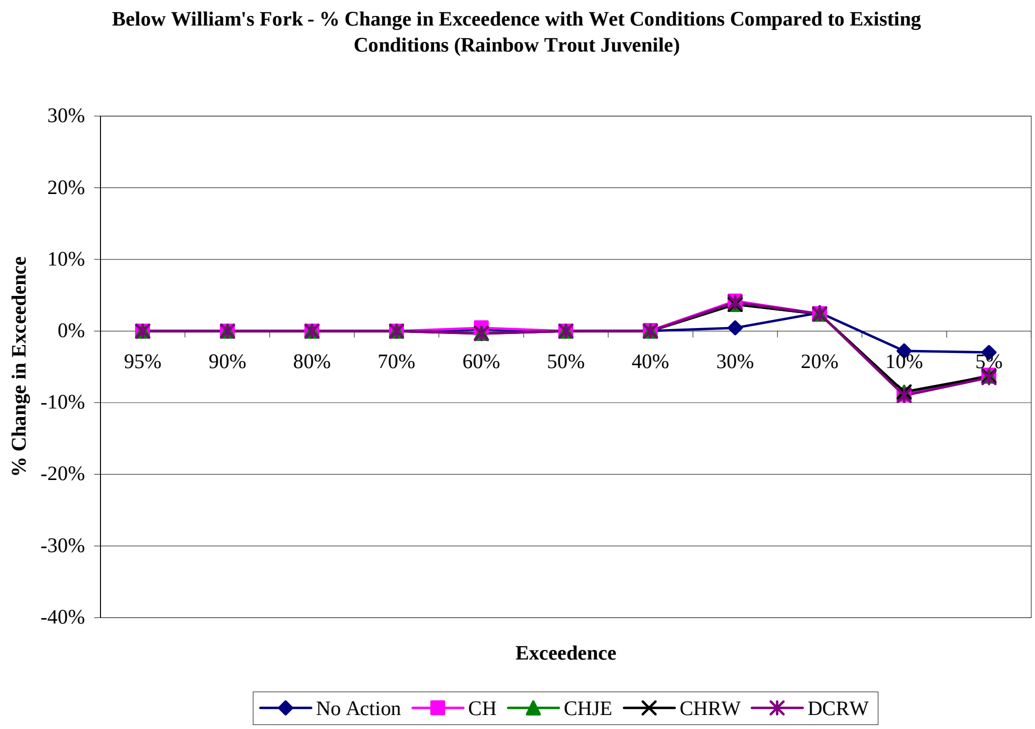


Figure 109. Below William's Fork – percent change in exceedence with <u>wet</u> conditions (rainbow trout juvenile).

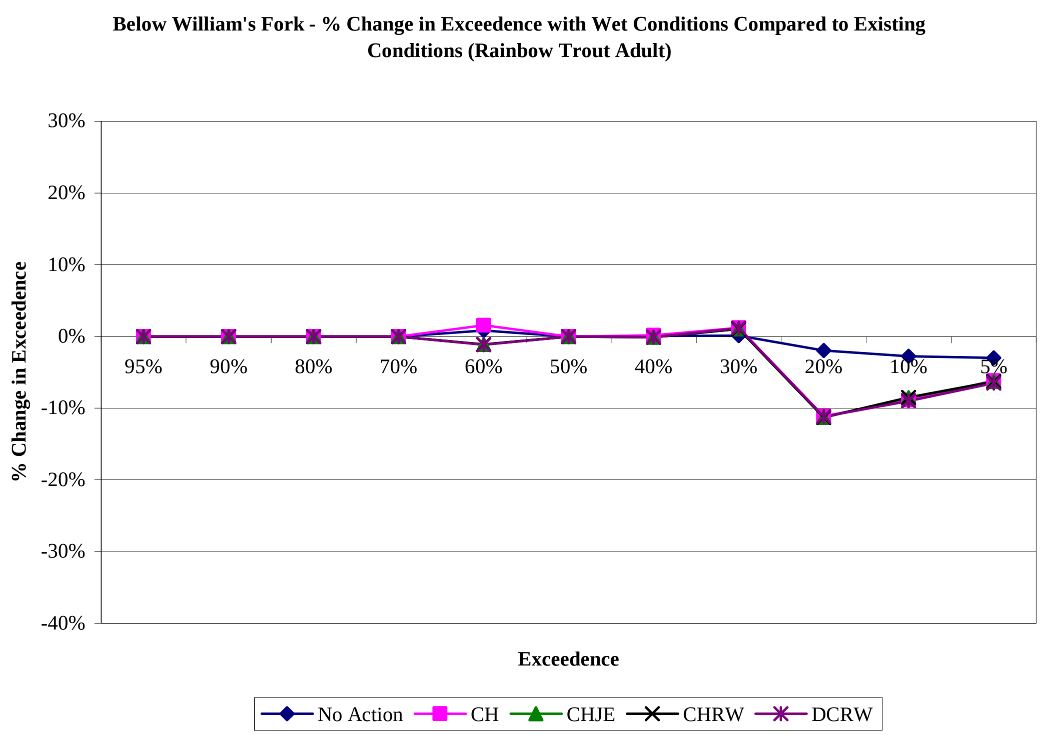


Figure 110. Below William's Fork – percent change in exceedence with <u>wet</u> conditions (rainbow trout adult).

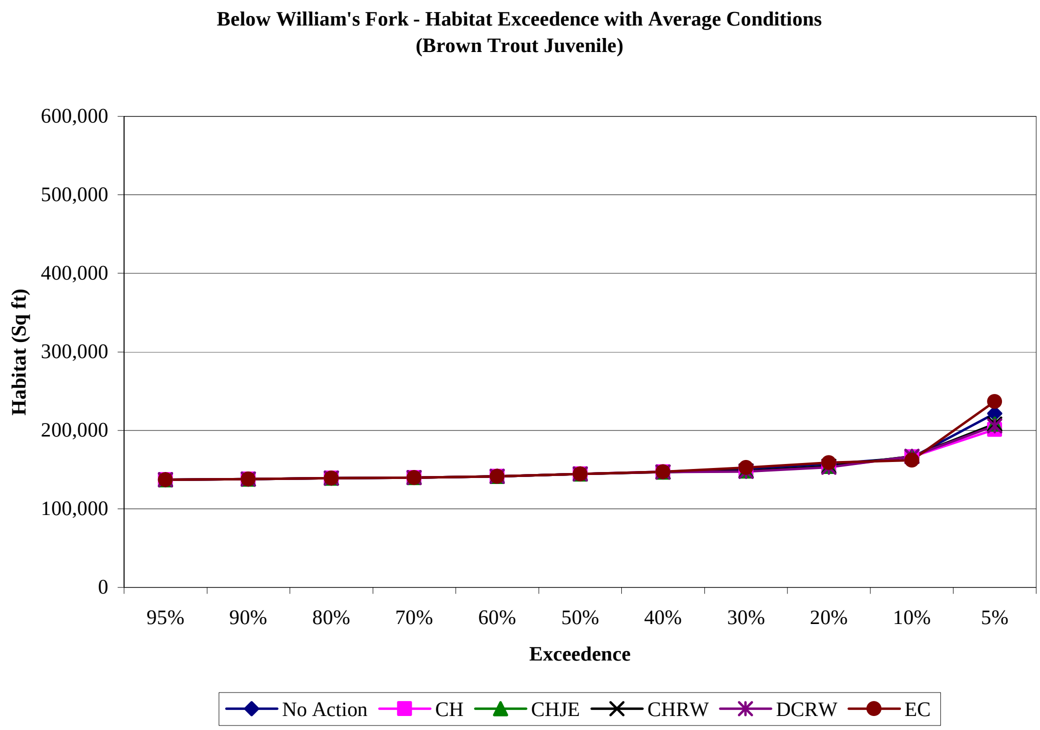


Figure 111. Below William's Fork – habitat exceedence with average conditions (brown trout juvenile).

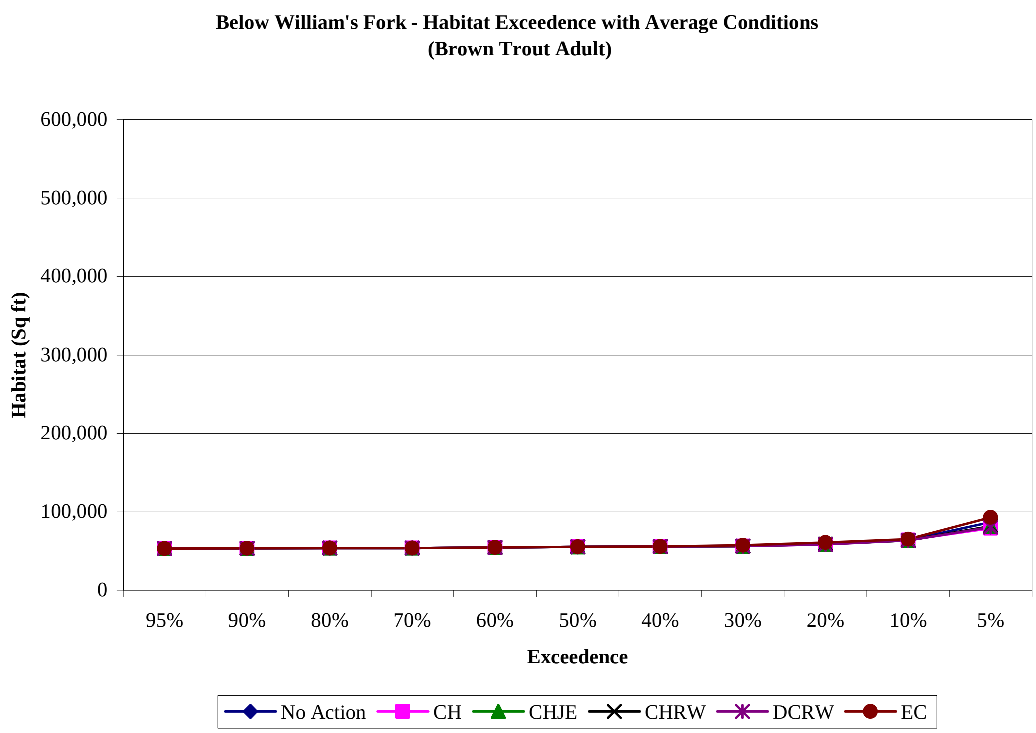


Figure 112. Below William's Fork – habitat exceedence with average conditions (brown trout adult).

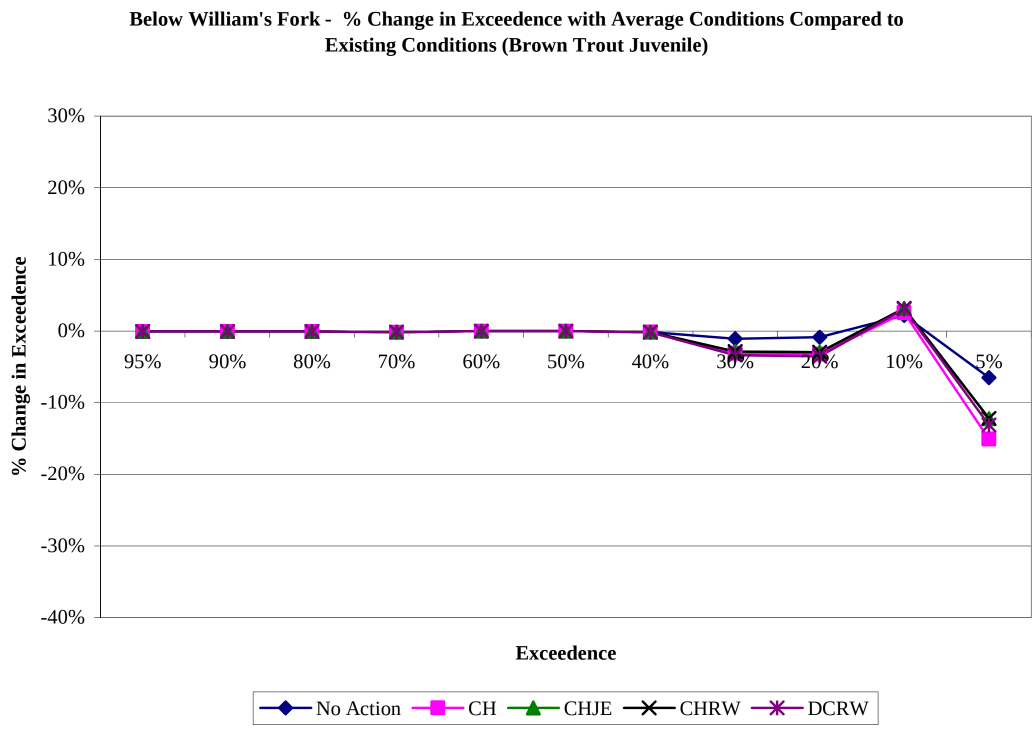


Figure 113. Below William's Fork – percent change in exceedence with <u>average</u> conditions (brown trout juvenile).

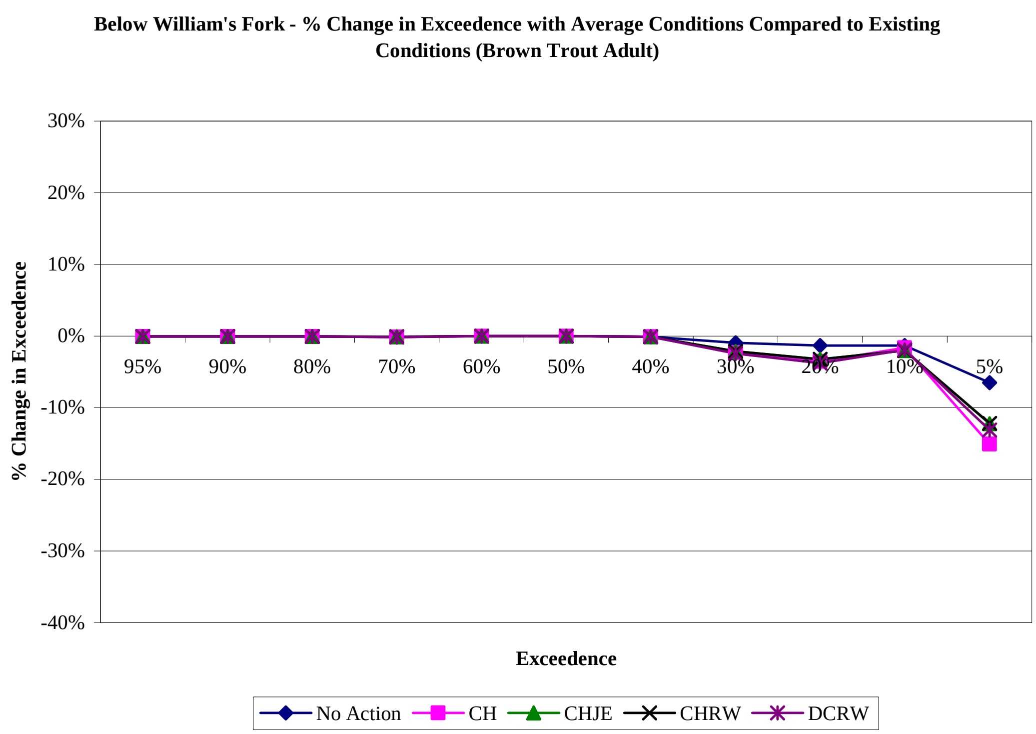


Figure 114. Below William's Fork – percent change in exceedence with <u>average</u> conditions (brown trout adult).

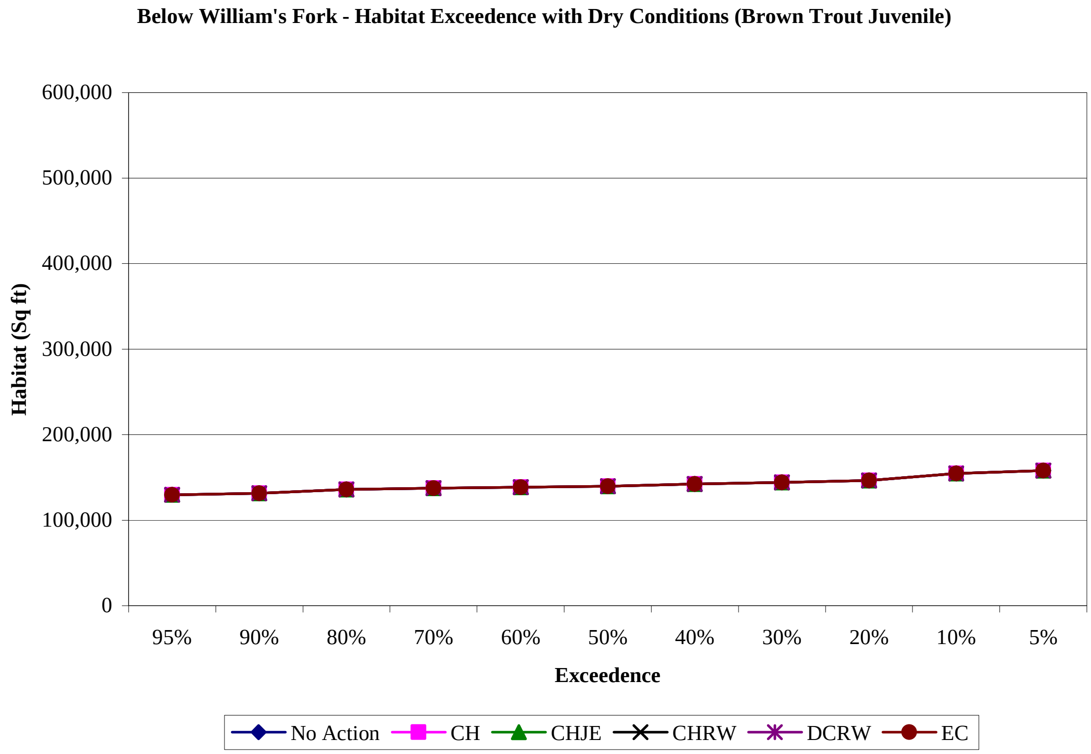


Figure 115. Below William's Fork – habitat exceedence with dry conditions (brown trout juvenile).

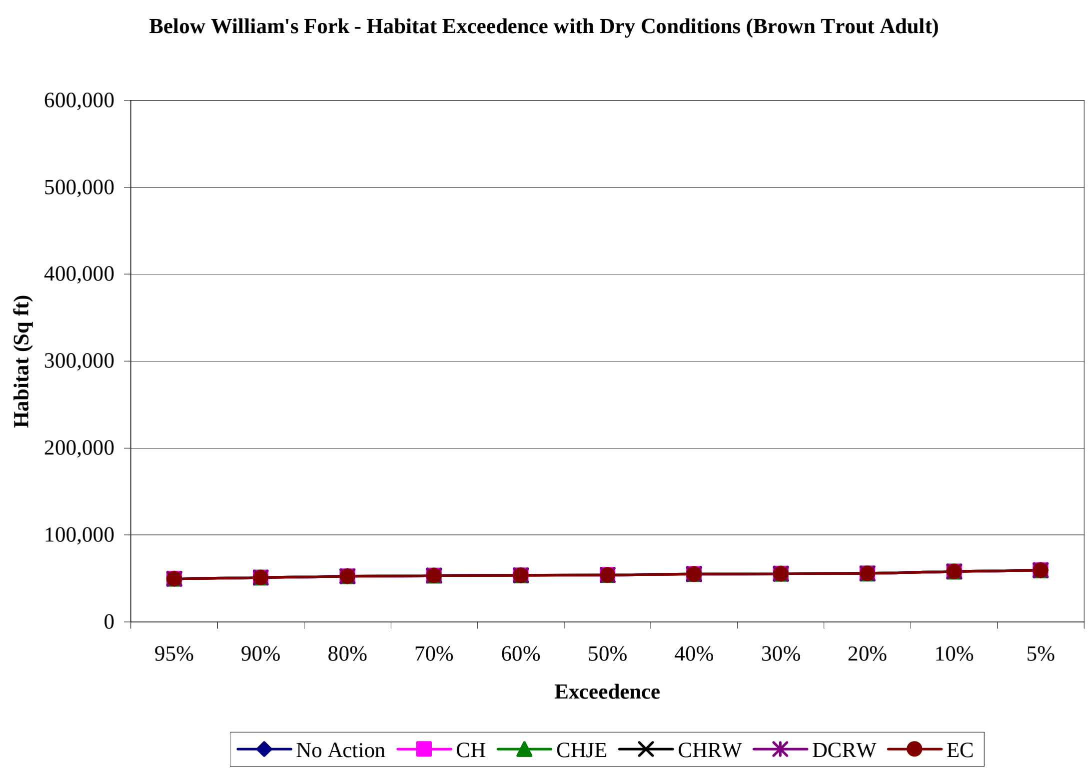


Figure 116. Below William's Fork – habitat exceedence with dry conditions (brown trout adult).

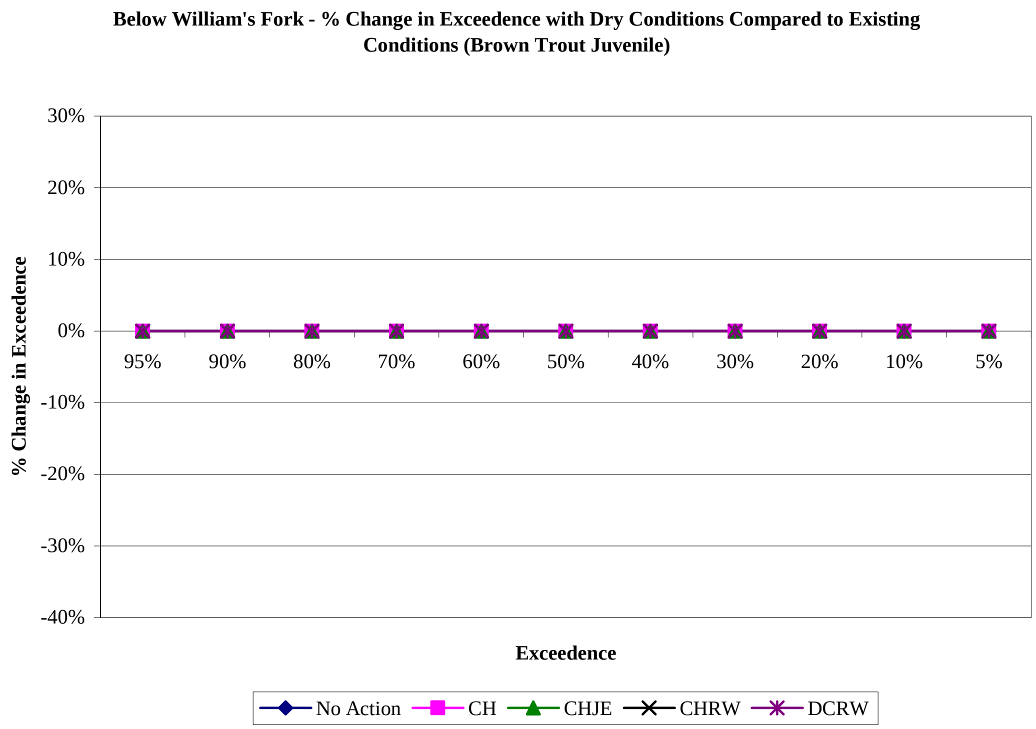


Figure 117. Below William's Fork – percent change in exceedence with dry conditions (brown trout juvenile).

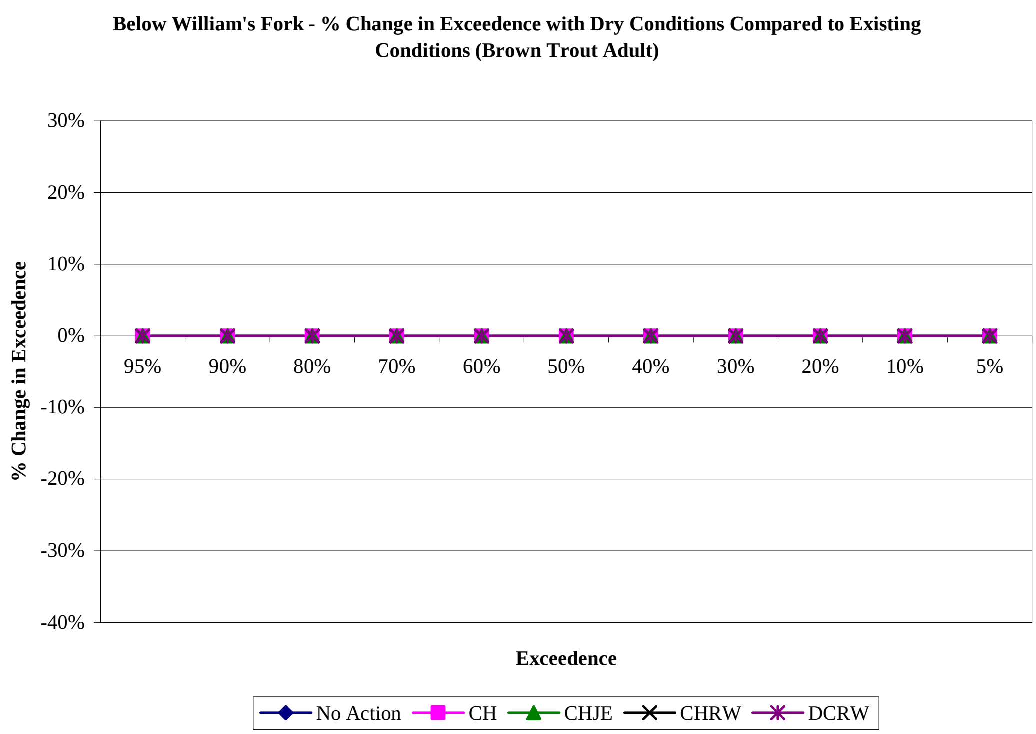


Figure 118. Below William's Fork – percent change in exceedence with dry conditions (brown trout adult).

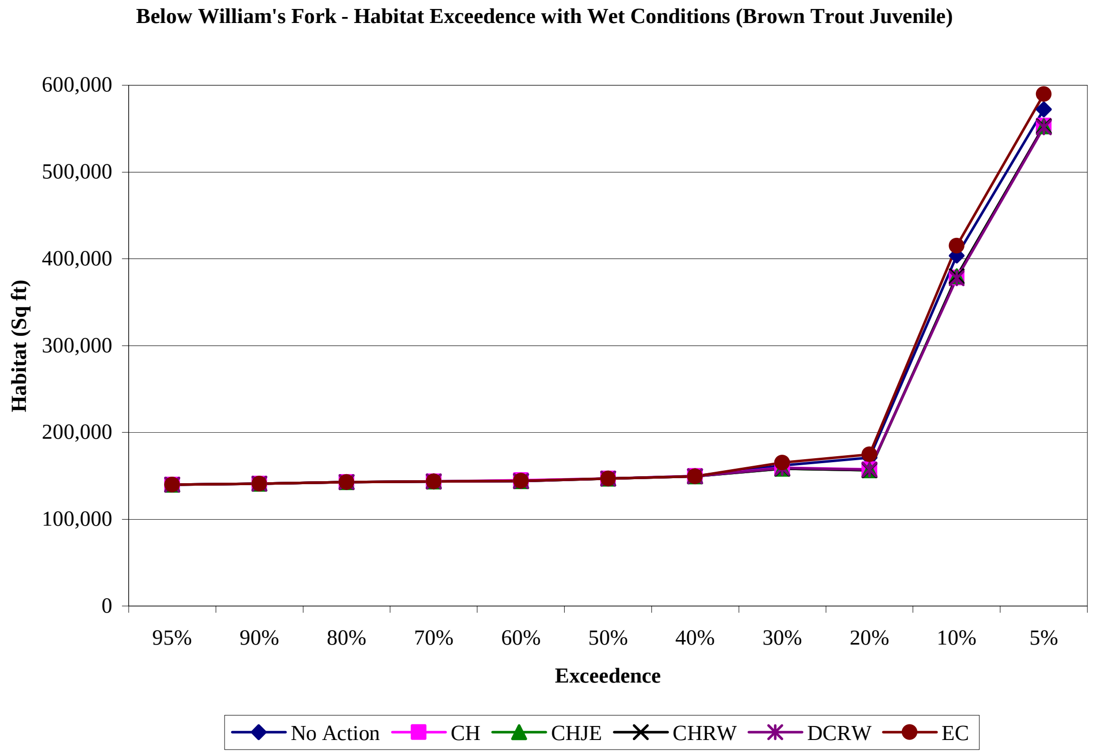


Figure 119. Below William's Fork – habitat exceedence with wet conditions (brown trout juvenile).

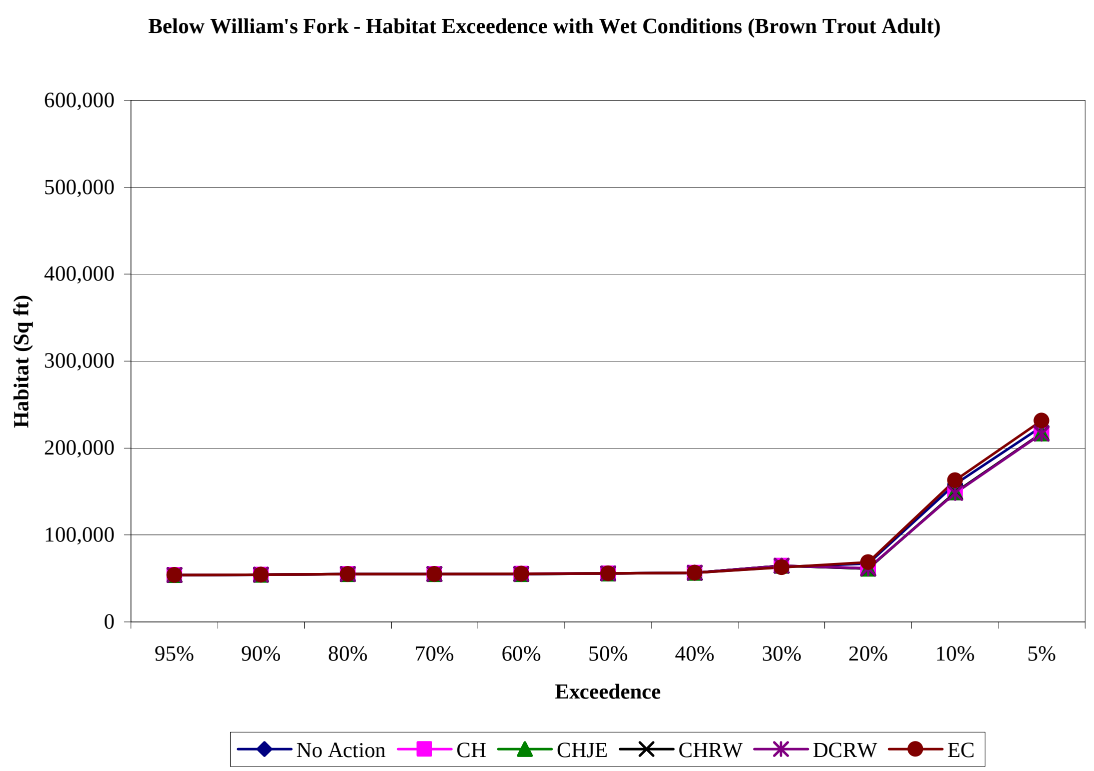


Figure 120. Below William's Fork – habitat exceedence with wet conditions (brown trout adult).

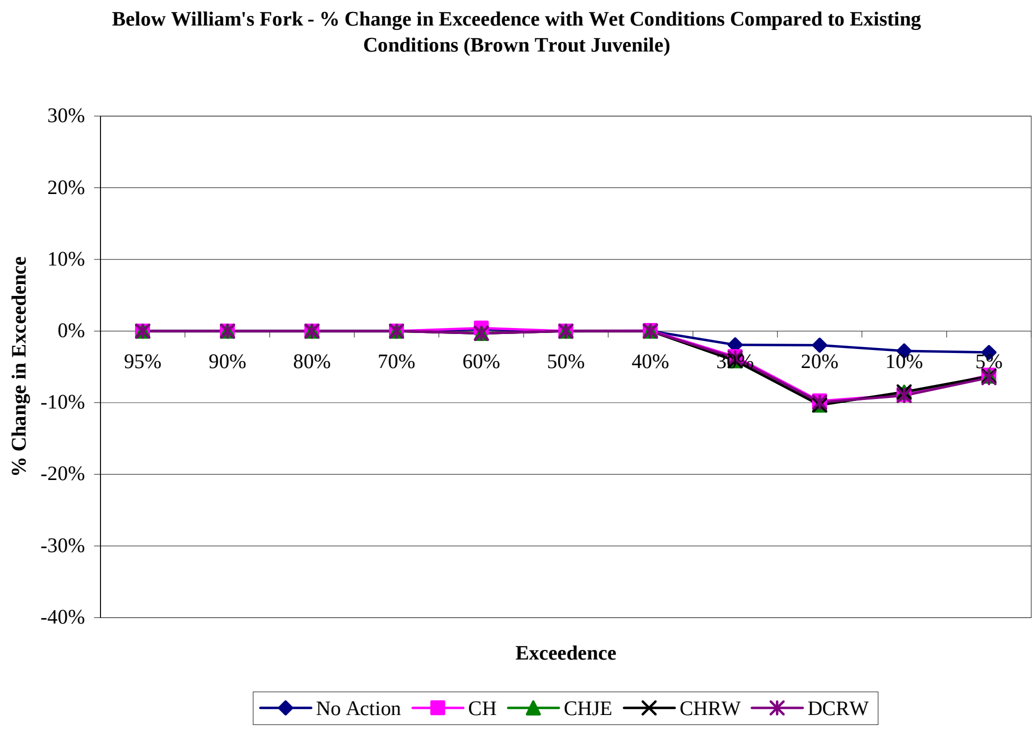


Figure 121. Below William's Fork – percent change in exceedence with wet conditions (brown trout juvenile).

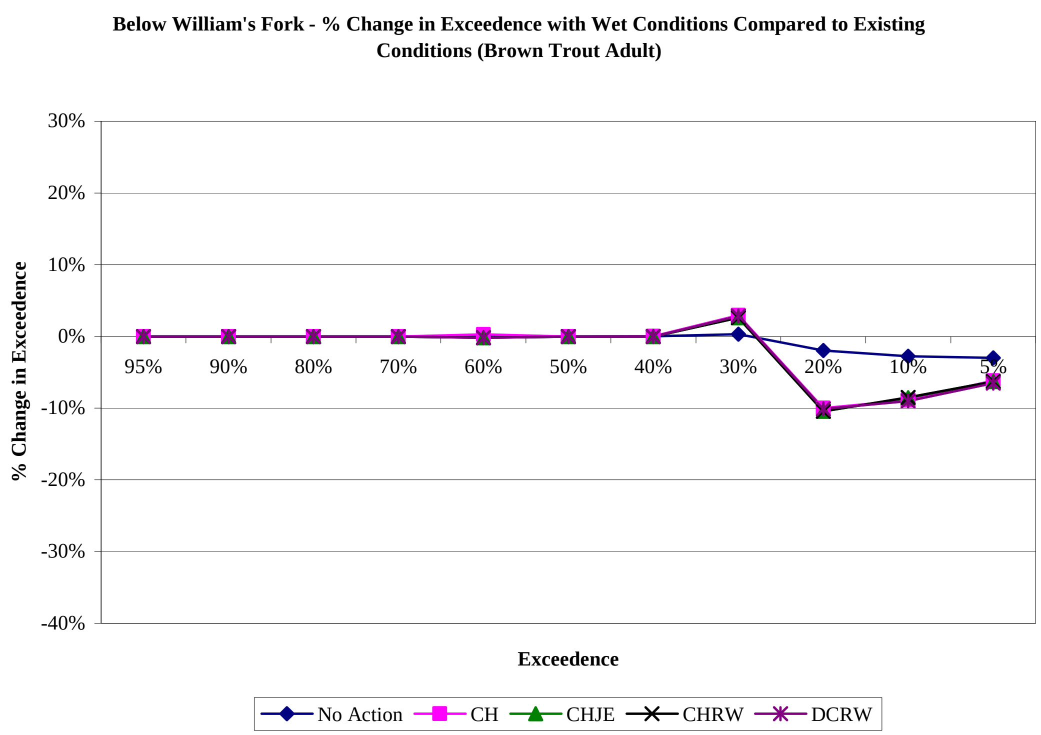


Figure 122. Below William's Fork – percent change in exceedence with wet conditions (brown trout adult).

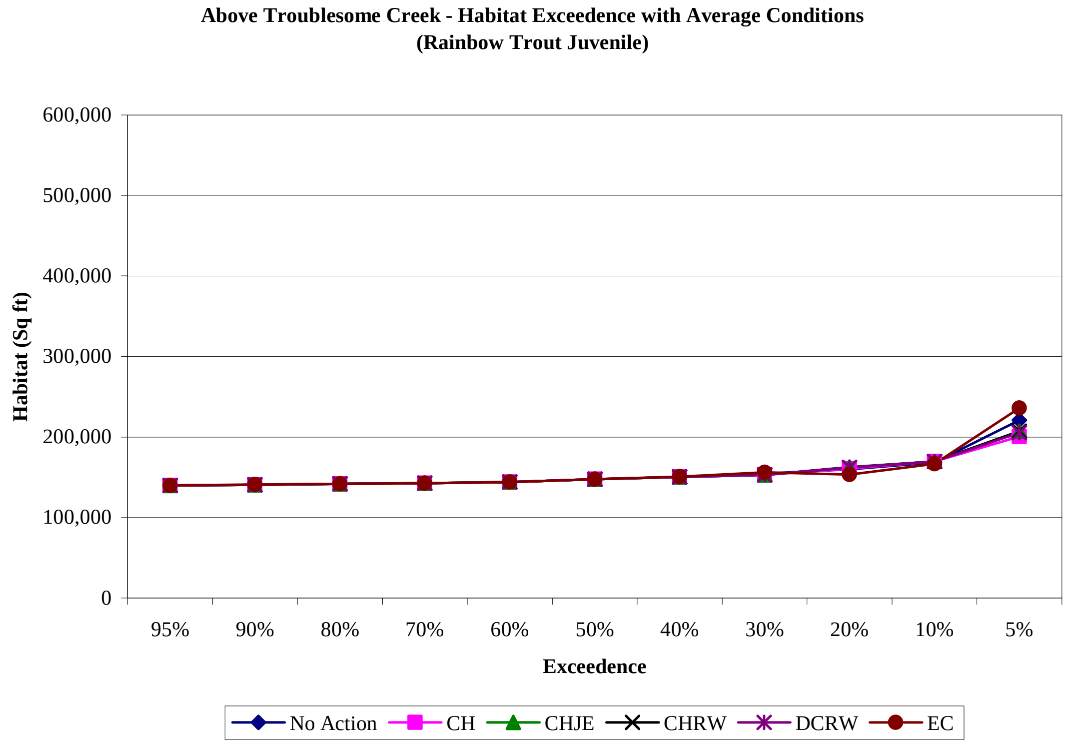


Figure 123. Above Troublesome Creek – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile).

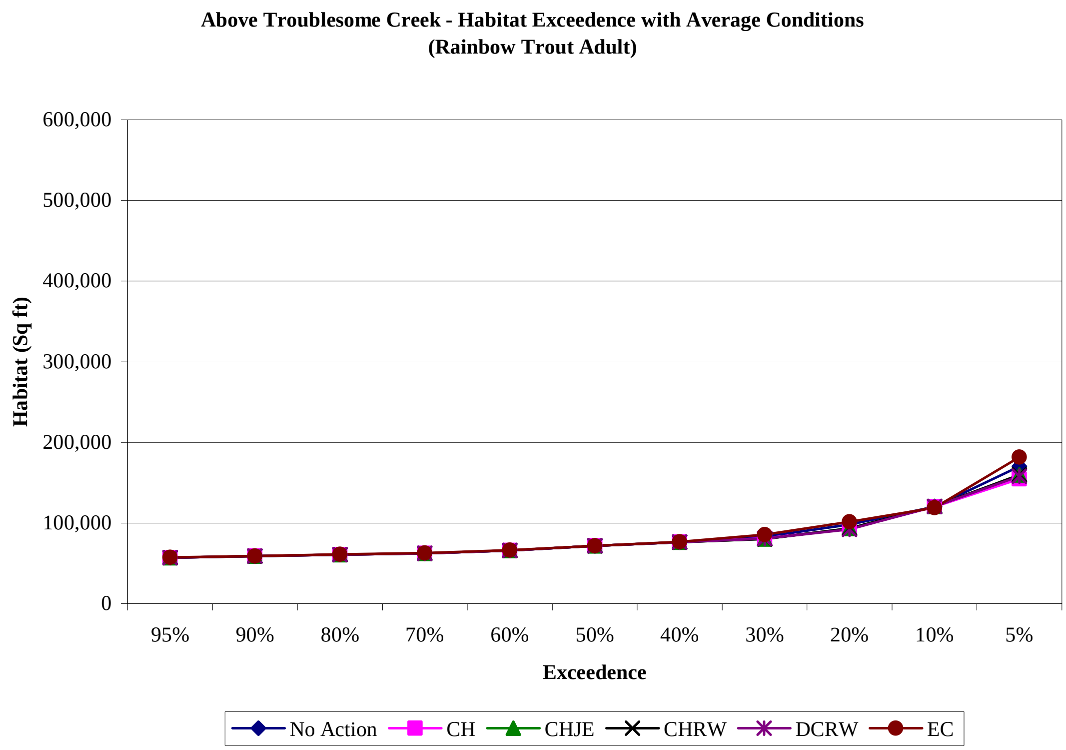


Figure 124. Above Troublesome Creek – habitat exceedence with <u>average</u> conditions (rainbow trout adult).

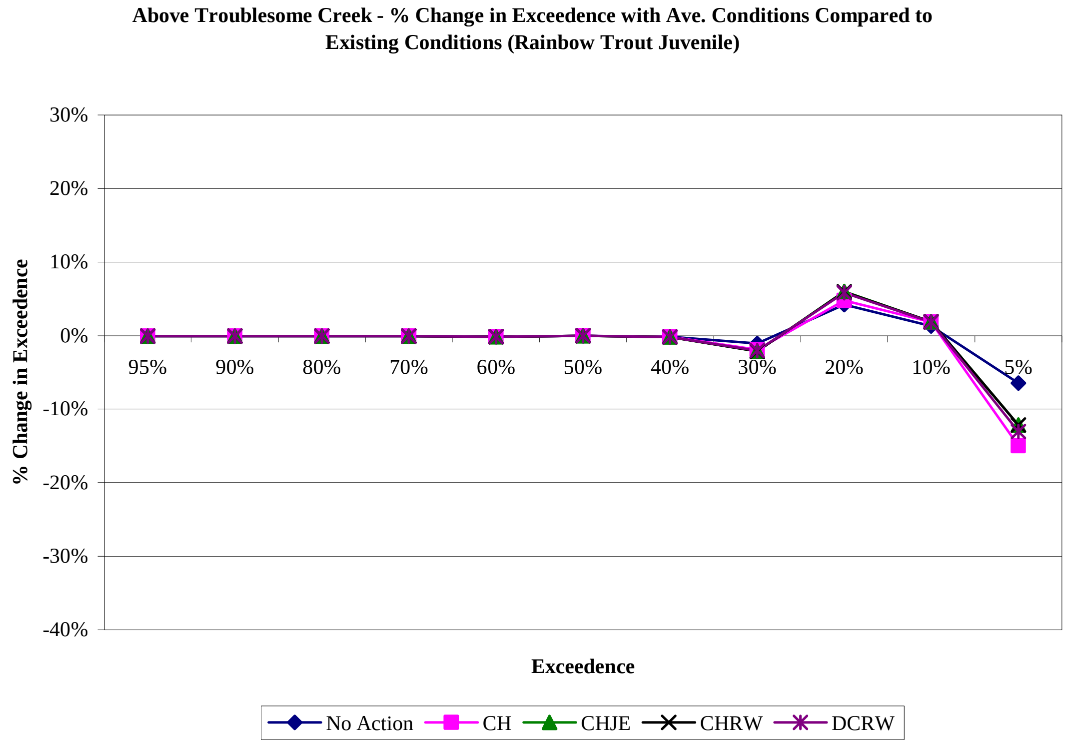


Figure 125. Above Troublesome Creek – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile).

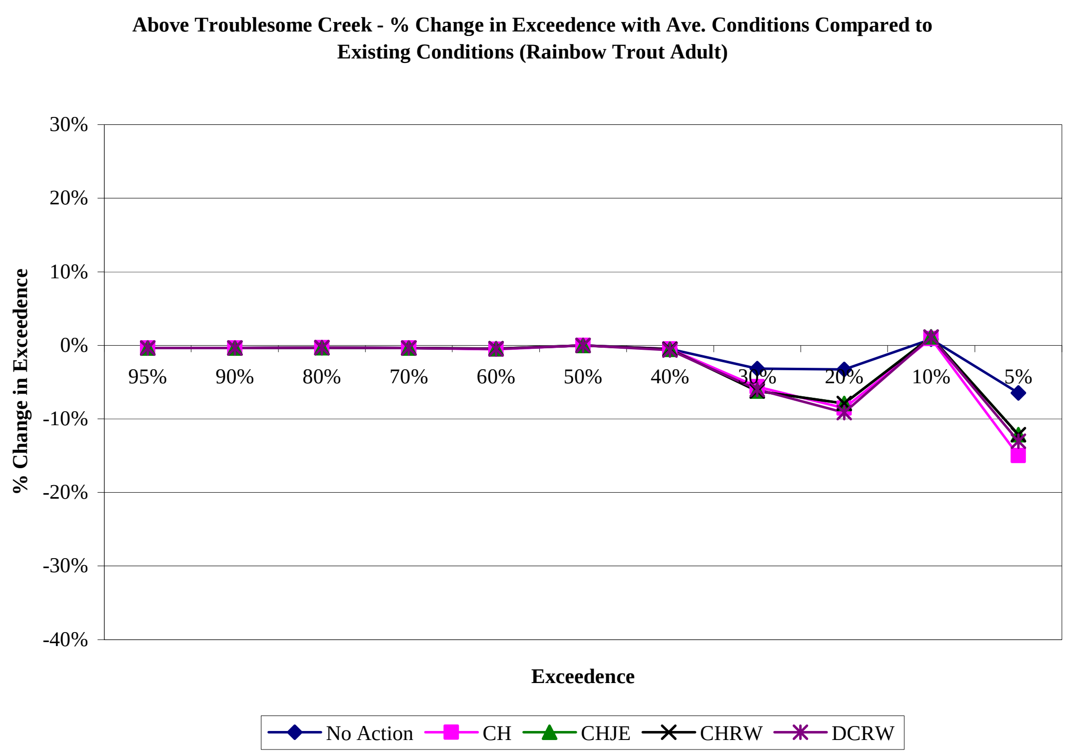


Figure 126. Above Troublesome Creek – percent change in exceedence with <u>average</u> conditions (rainbow trout adult).

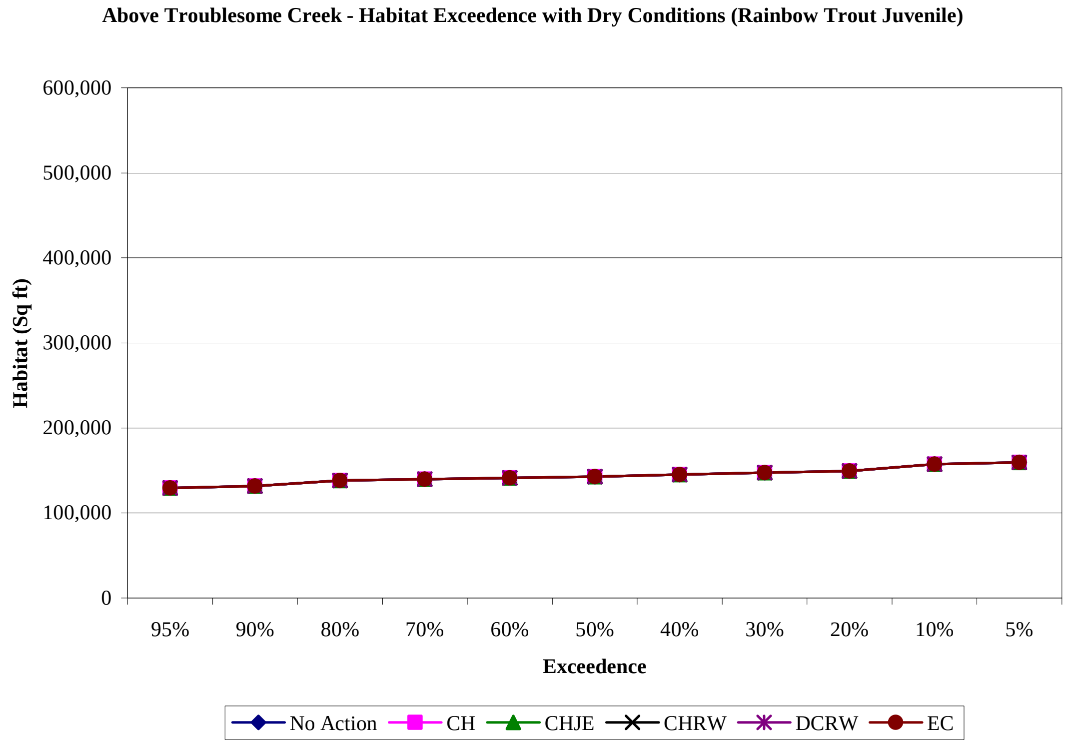


Figure 127. Above Troublesome Creek – habitat exceedence with dry conditions (rainbow trout juvenile).

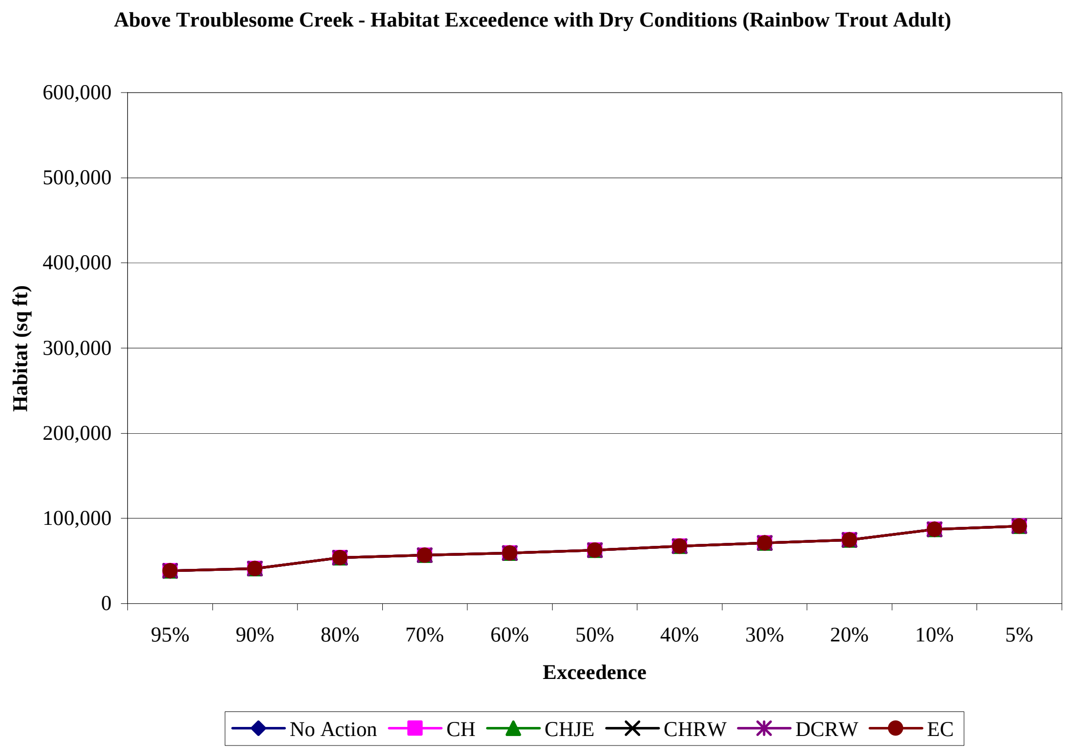


Figure 128. Above Troublesome Creek – habitat exceedence with dry conditions (rainbow trout adult).

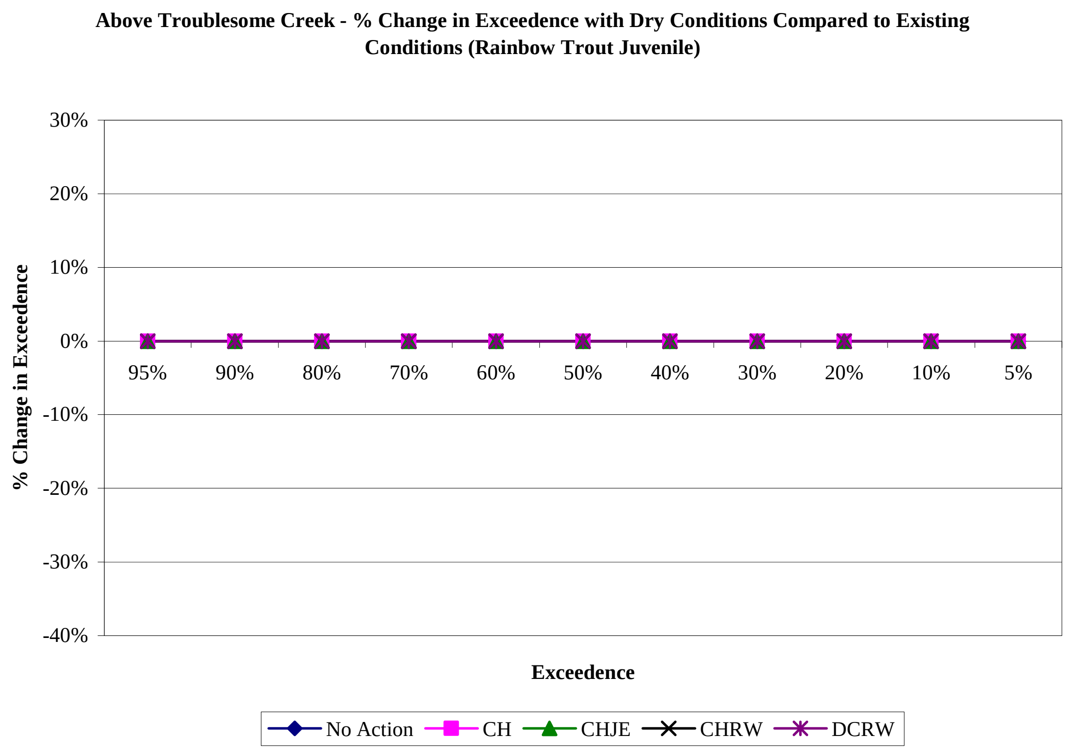


Figure 129. Above Troublesome Creek – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile).

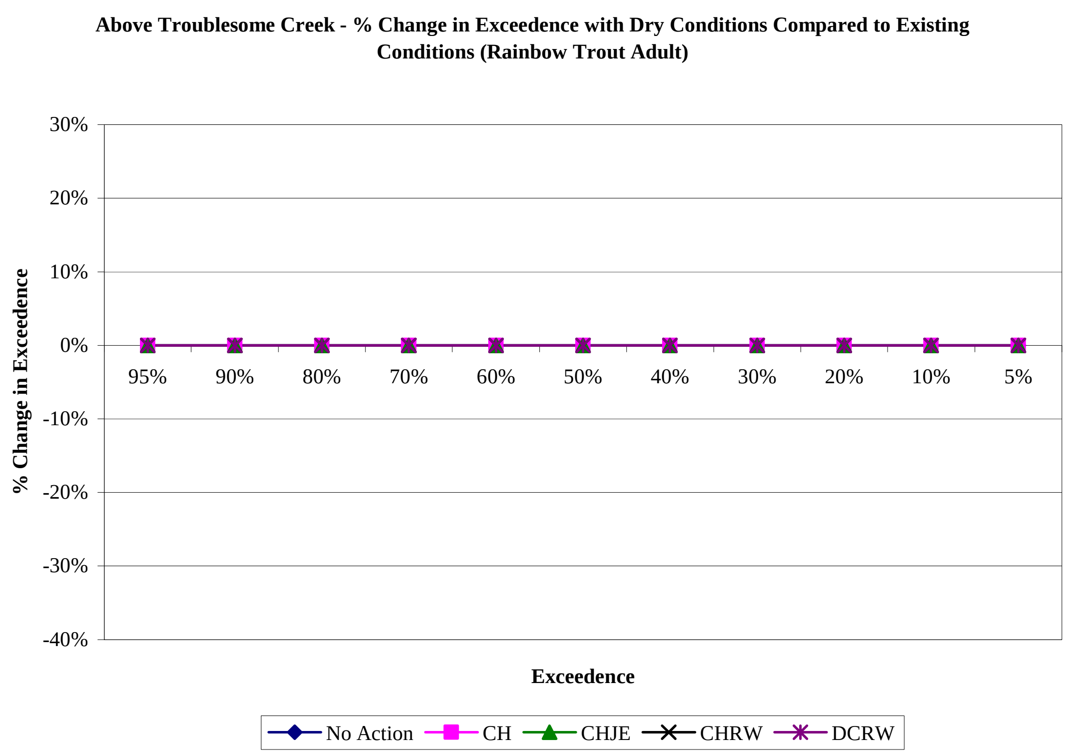


Figure 130. Above Troublesome Creek – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult).

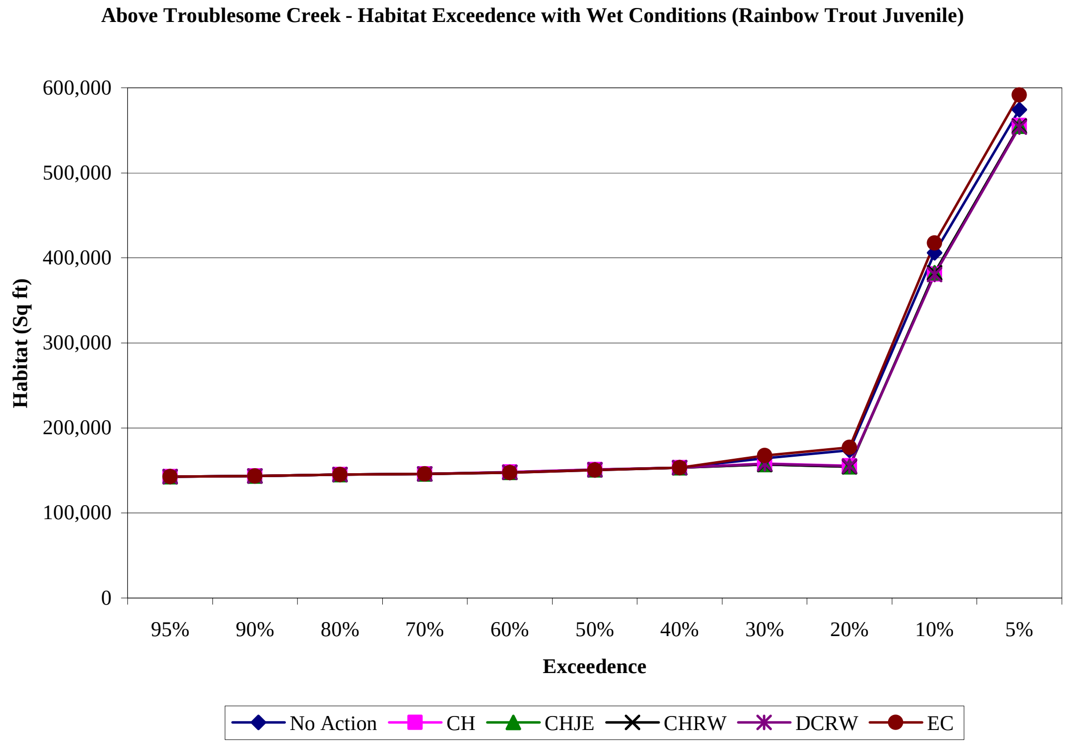


Figure 131. Above Troublesome Creek – habitat exceedence with wet conditions (rainbow trout juvenile).

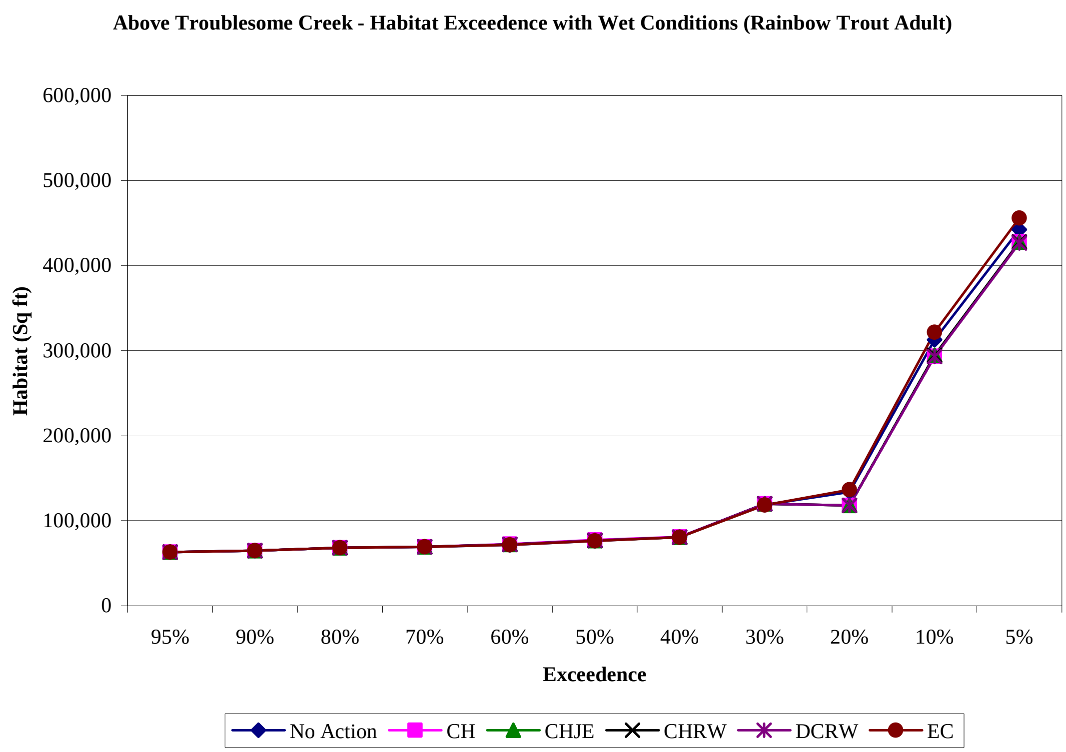


Figure 132. Above Troublesome Creek – habitat exceedence with wet conditions (rainbow trout adult).

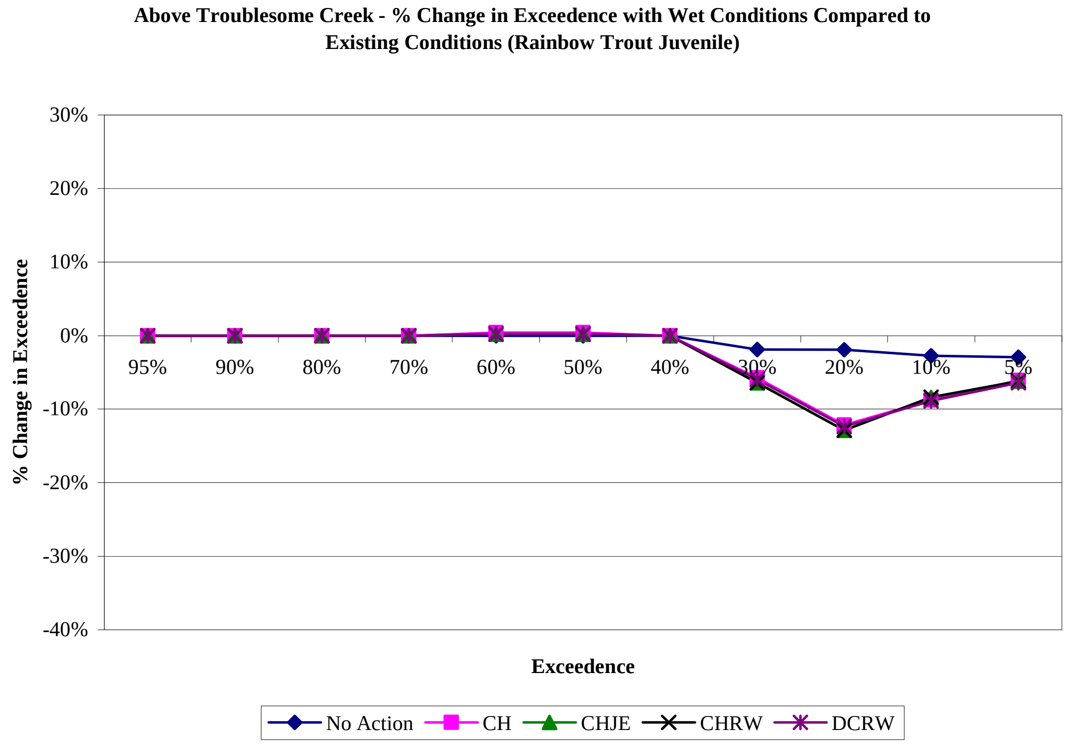


Figure 133. Above Troublesome Creek – percent change in exceedence with <u>wet</u> conditions (rainbow trout juvenile).

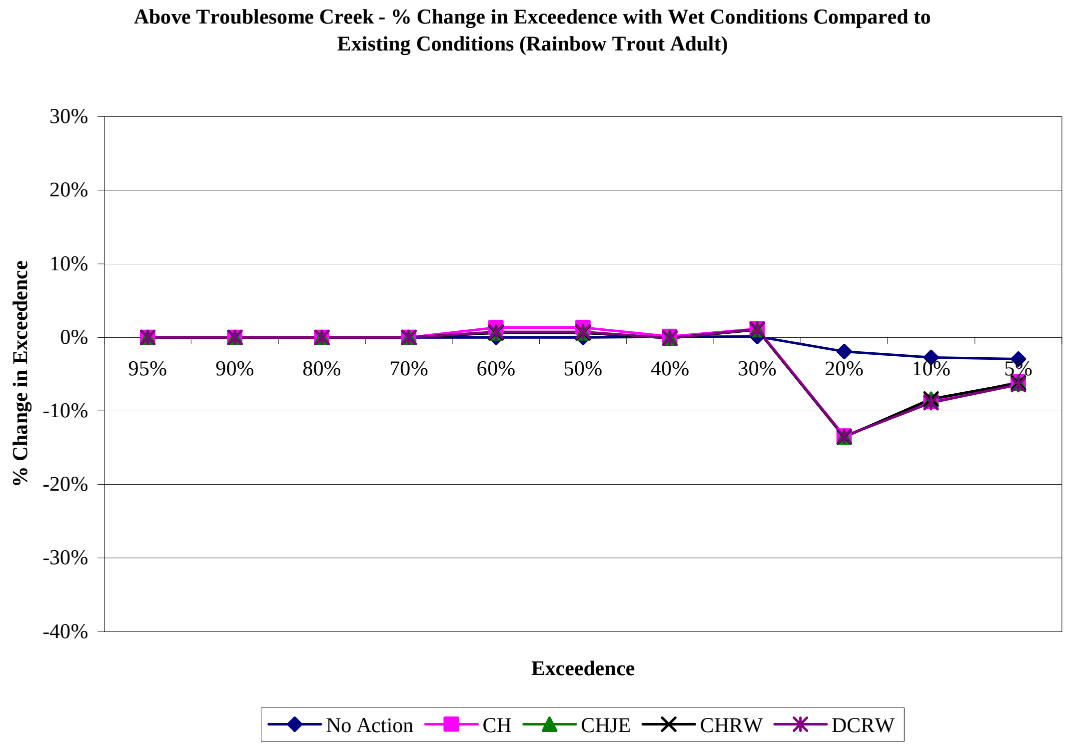


Figure 134. Above Troublesome Creek – percent change in exceedence with <u>wet</u> conditions (rainbow trout adult).

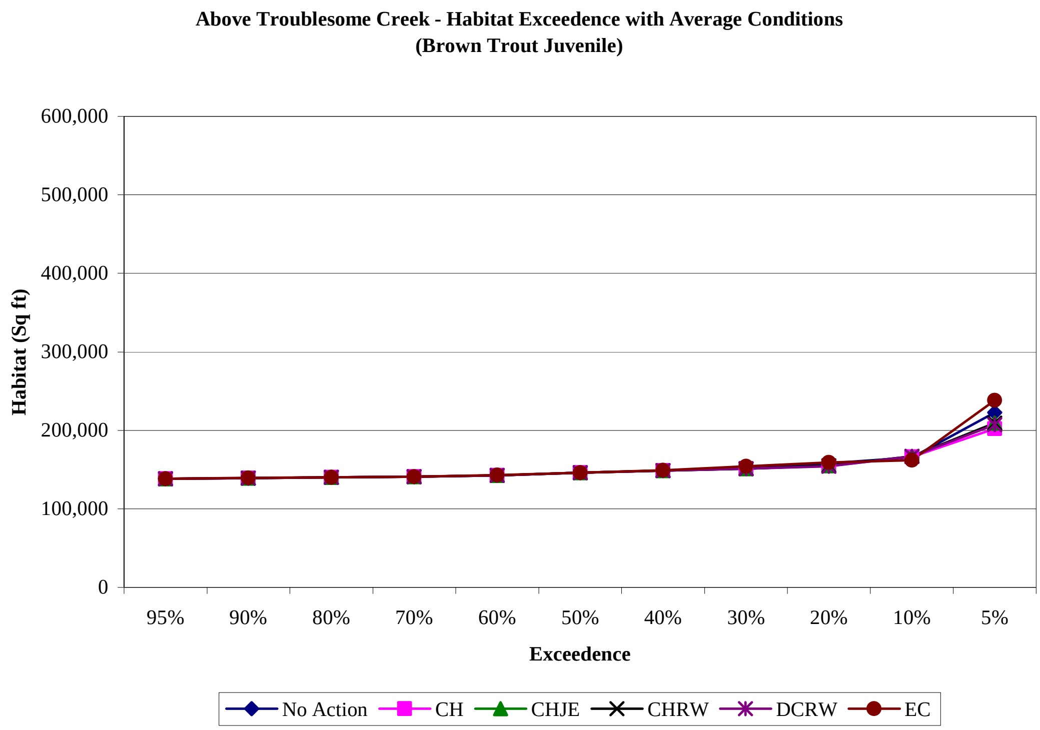


Figure 135. Above Troublesome Creek – habitat exceedence with <u>average</u> conditions (brown trout juvenile).

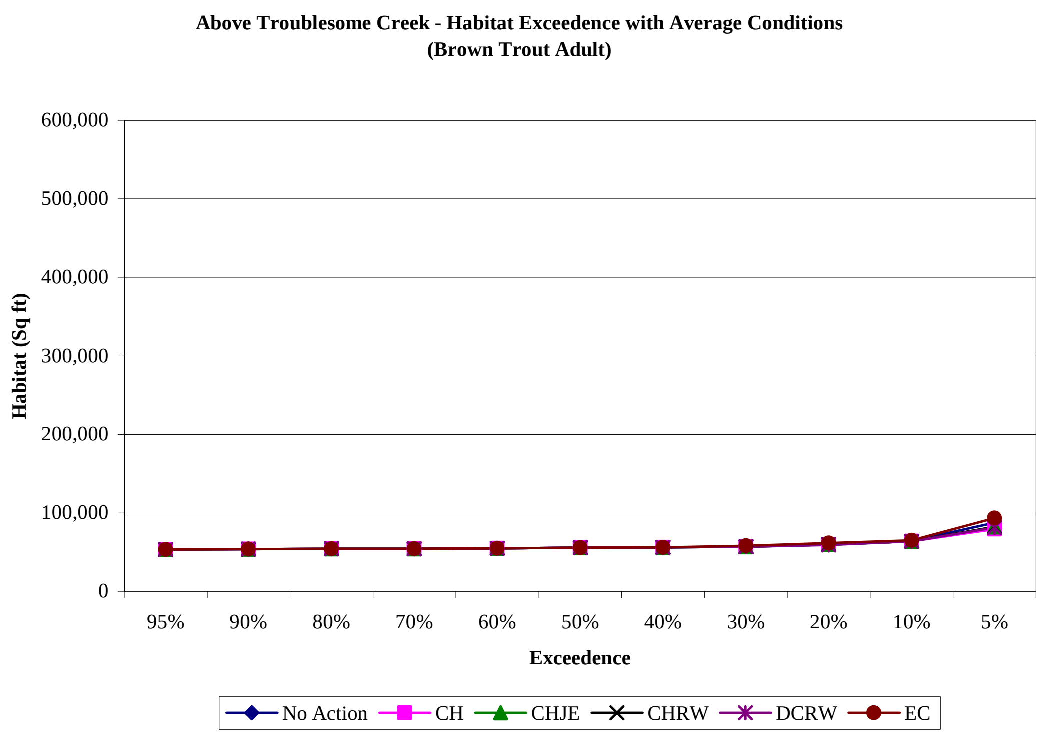


Figure 136. Above Troublesome Creek – habitat exceedence with <u>average</u> conditions (brown trout adult).

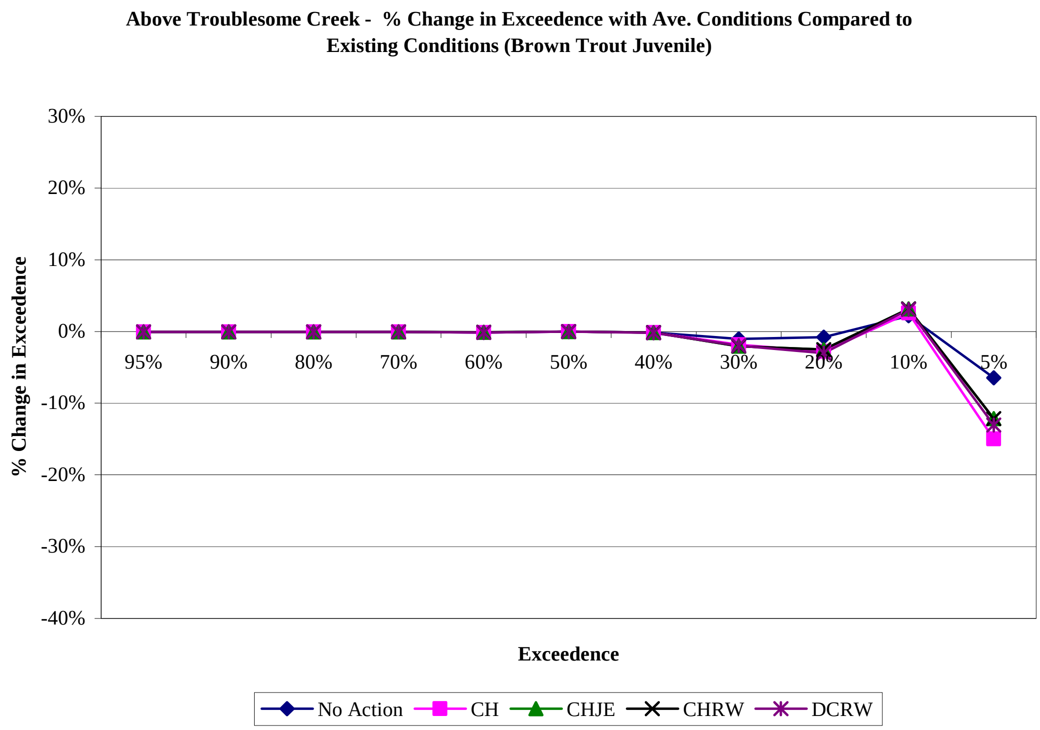


Figure 137. Above Troublesome Creek – percent change in exceedence with <u>average</u> conditions (brown trout juvenile).

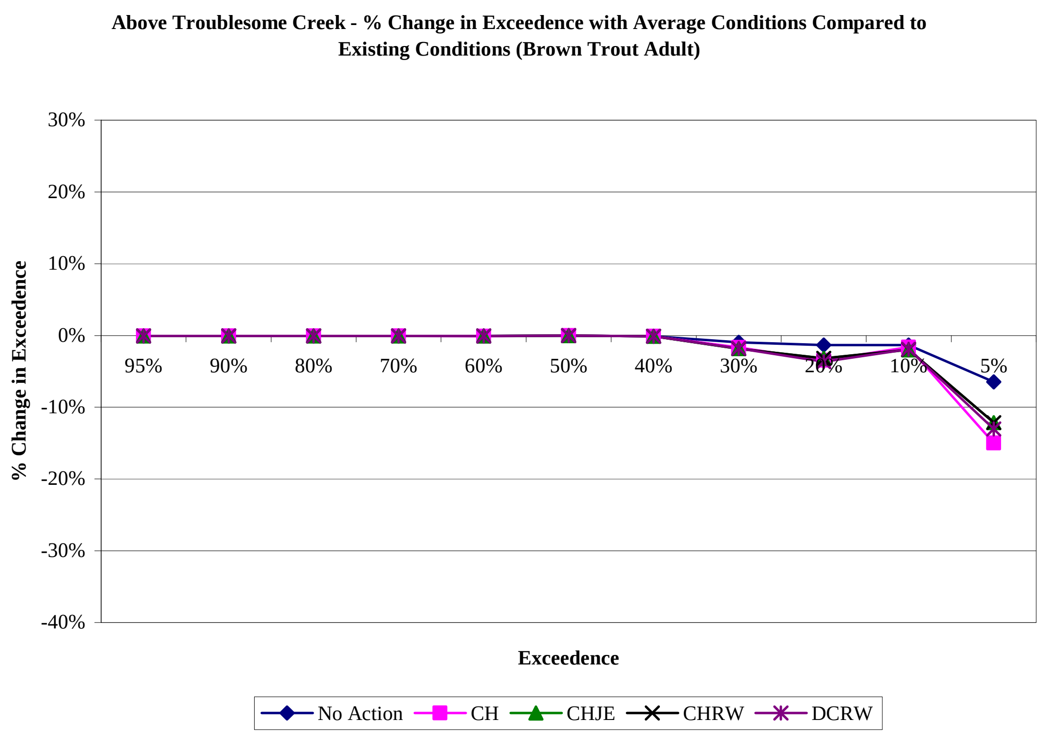


Figure 138. Above Troublesome Creek – percent change in exceedence with <u>average</u> conditions (brown trout adult).

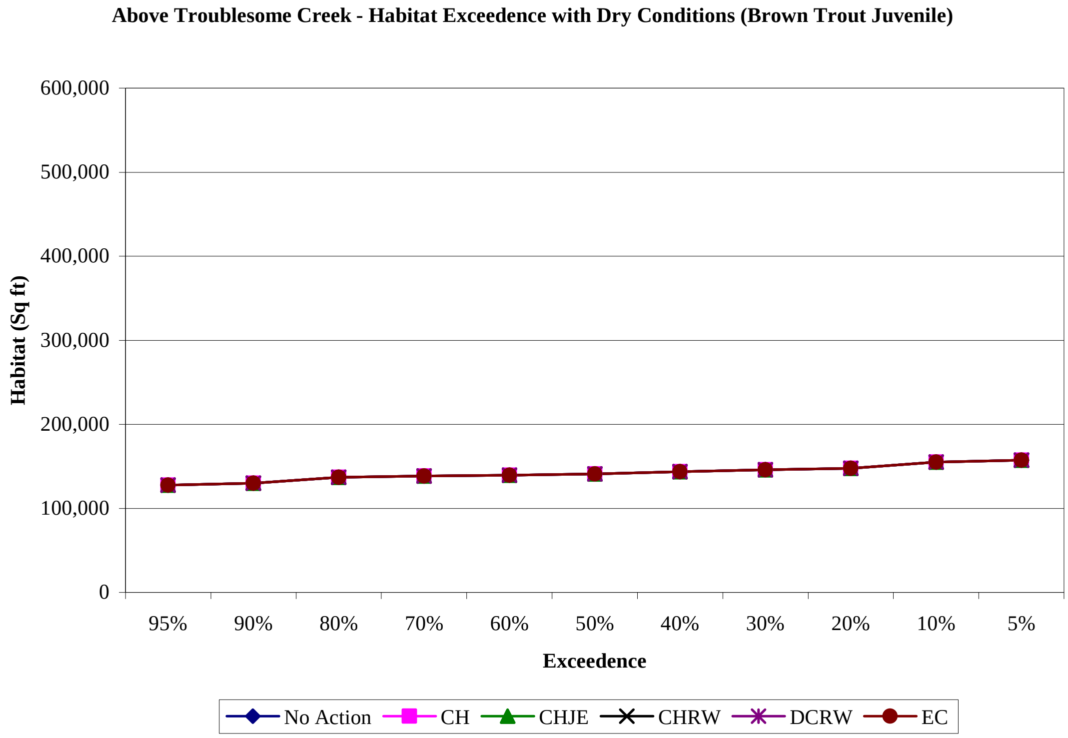


Figure 139. Above Troublesome Creek – habitat exceedence with dry conditions (brown trout juvenile).

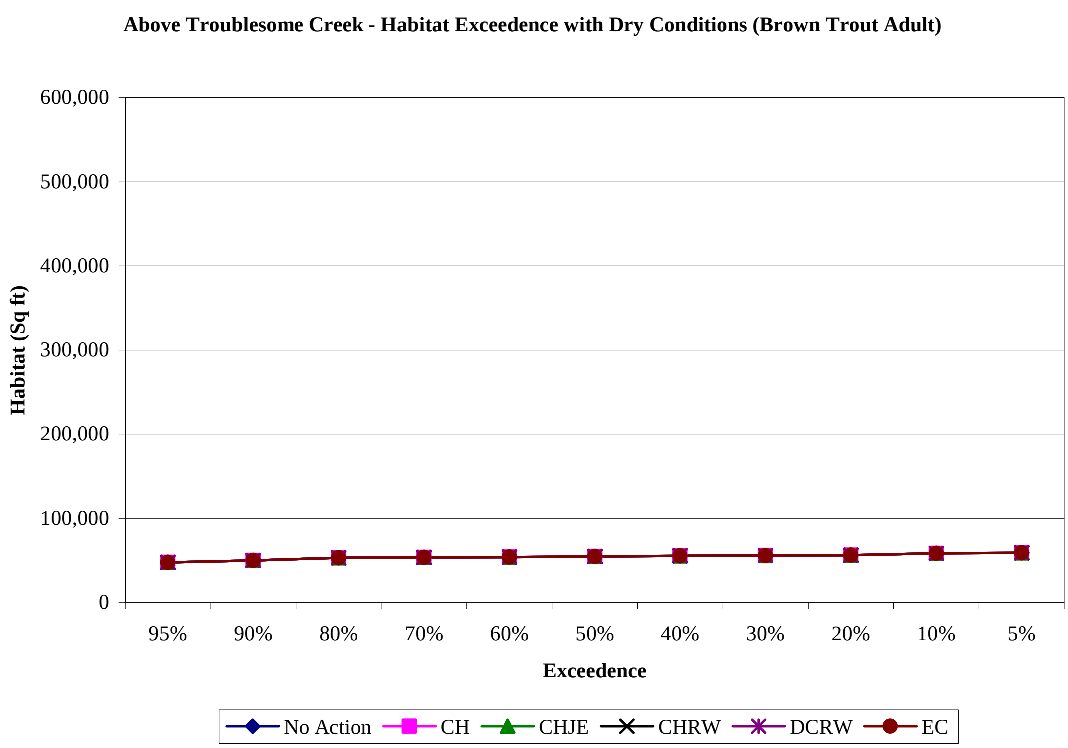


Figure 140. Above Troublesome Creek – habitat exceedence with dry conditions (brown trout adult).

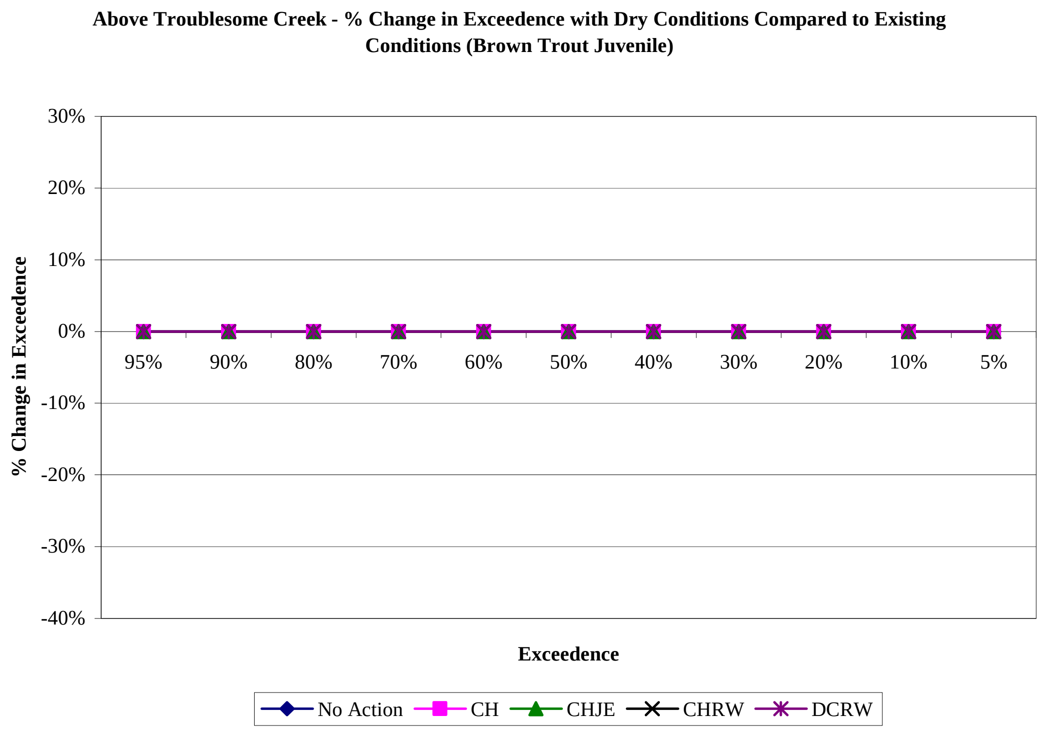


Figure 141. Above Troublesome Creek – percent change in exceedence with <u>dry</u> conditions (brown trout juvenile).

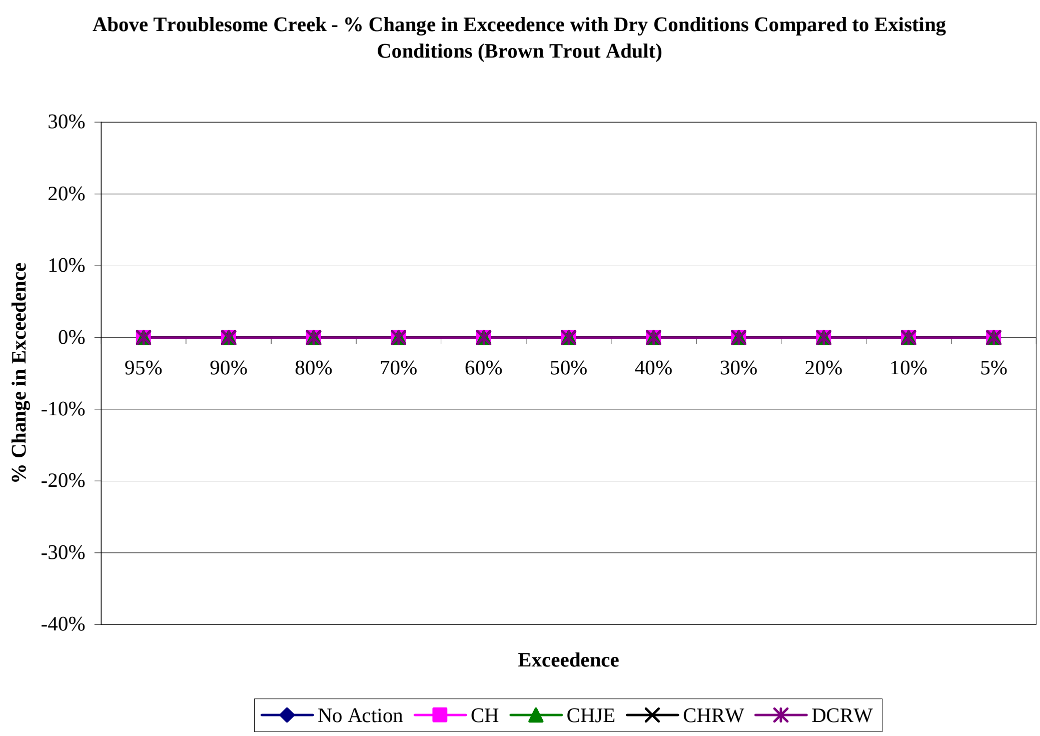


Figure 142. Above Troublesome Creek – percent change in exceedence with <u>dry</u> conditions (brown trout adult).

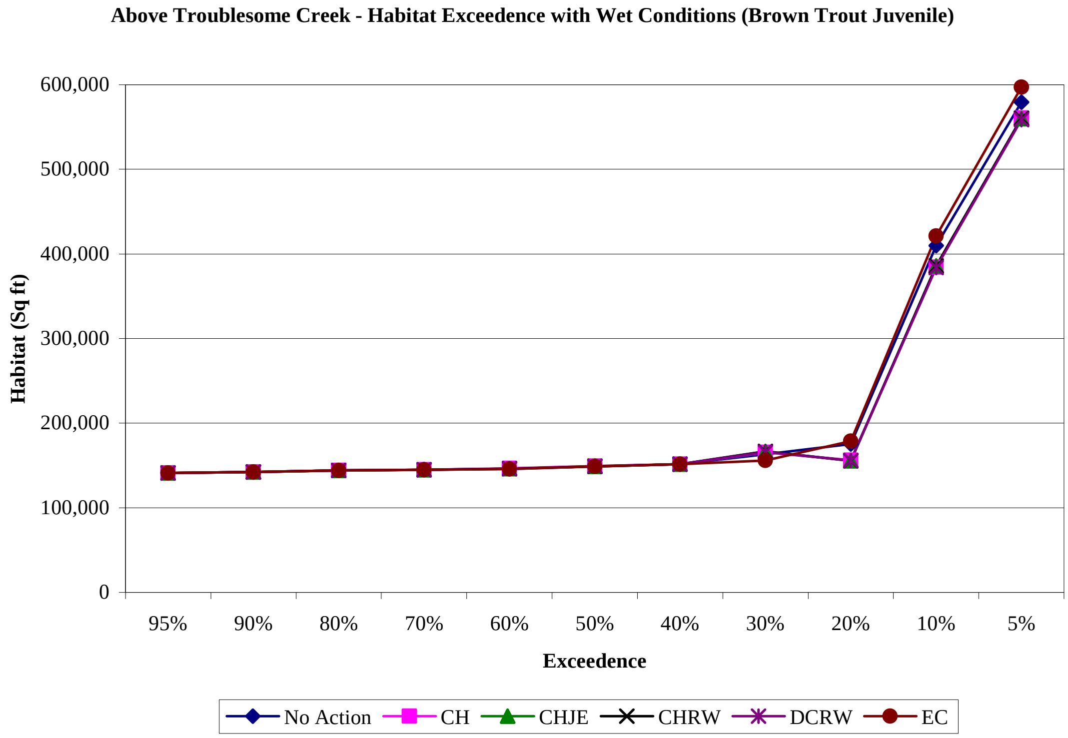


Figure 143. Above Troublesome Creek – habitat exceedence with wet conditions (brown trout juvenile).

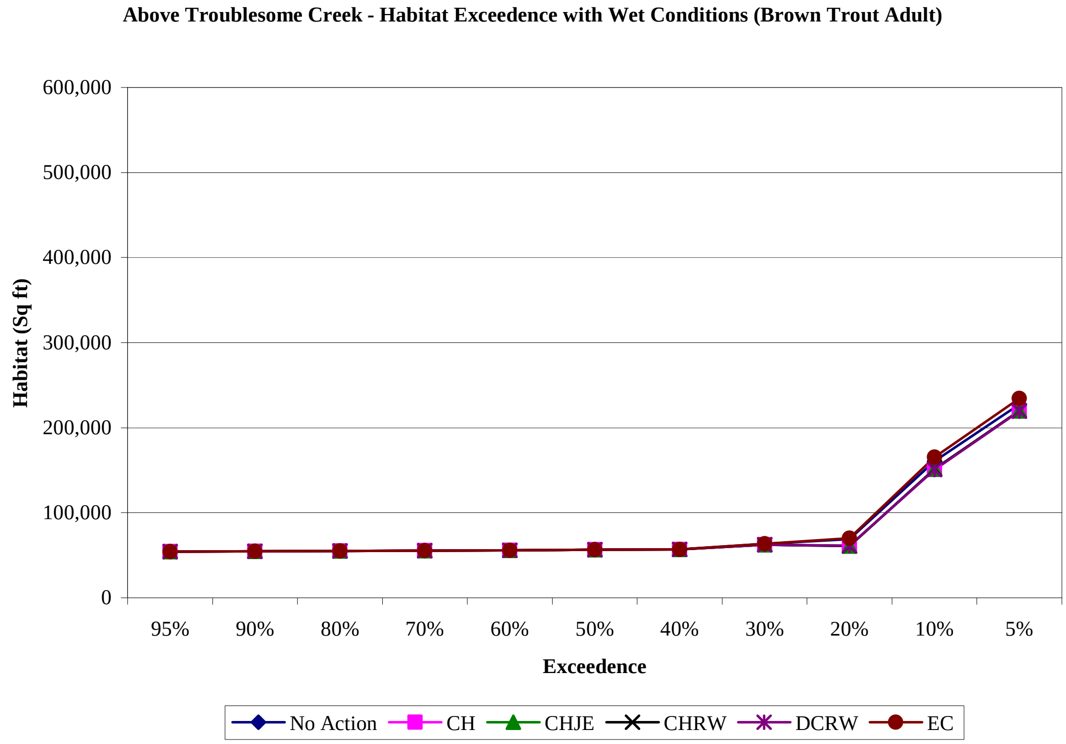


Figure 144. Above Troublesome Creek – habitat exceedence with wet conditions (brown trout adult).

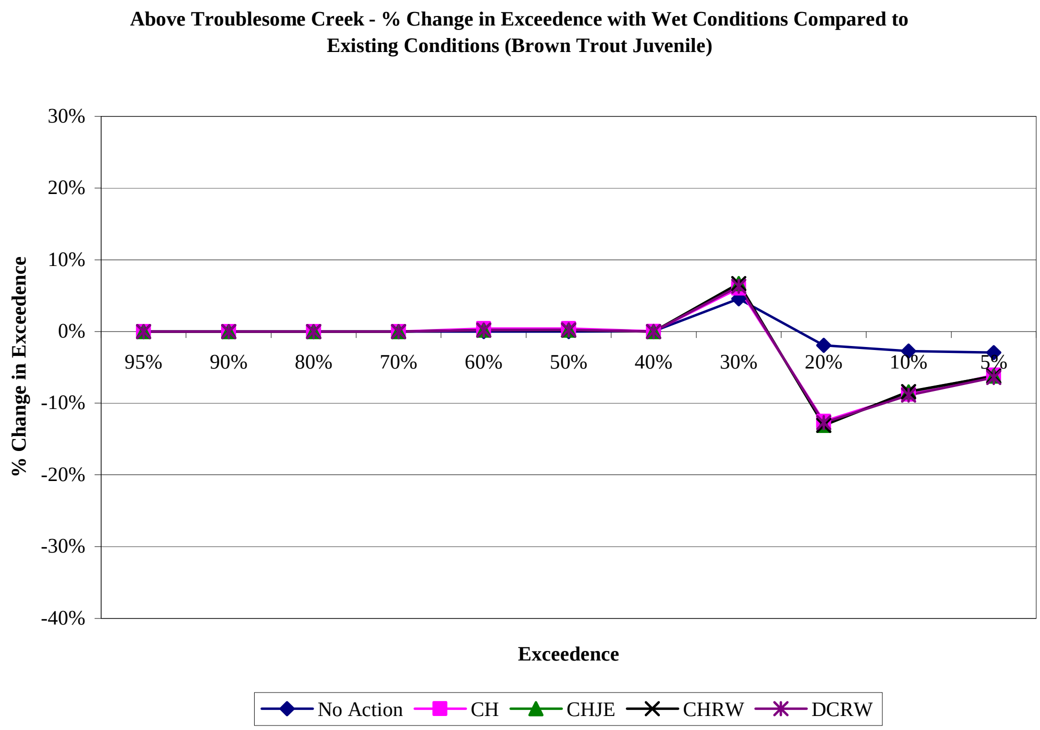


Figure 145. Above Troublesome Creek – percent change in exceedence with wet conditions (brown trout juvenile).

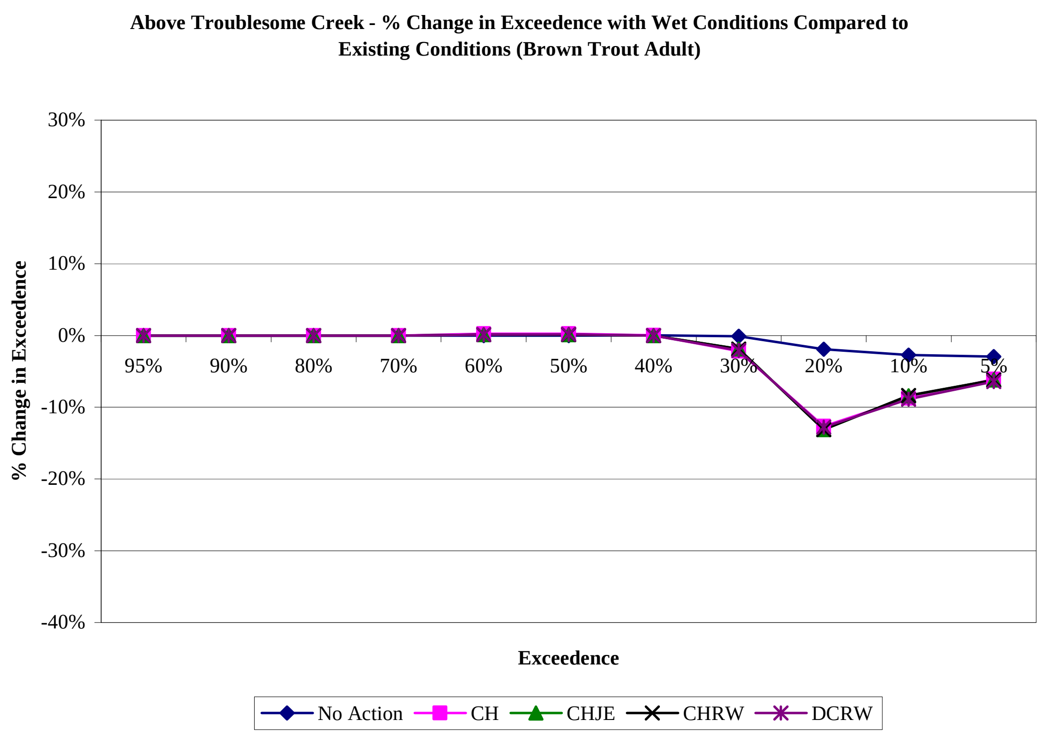


Figure 146. Above Troublesome Creek – percent change in exceedence with wet conditions (brown trout adult).

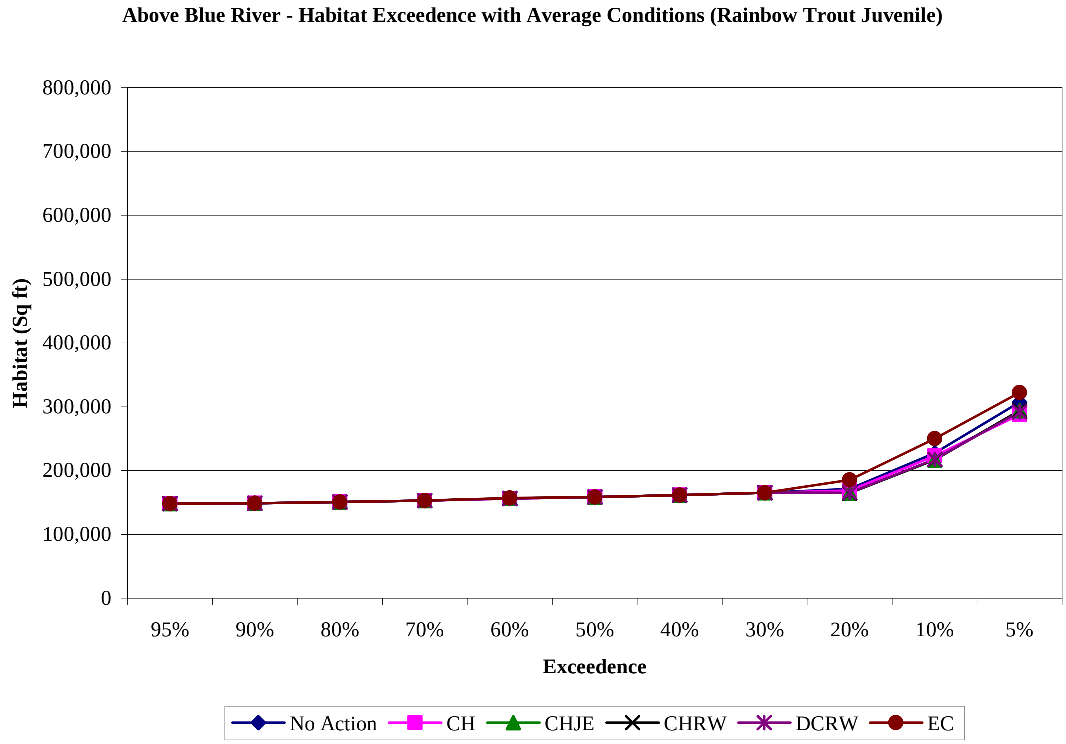


Figure 147. Above Blue River – habitat exceedence with average conditions (rainbow trout juvenile).

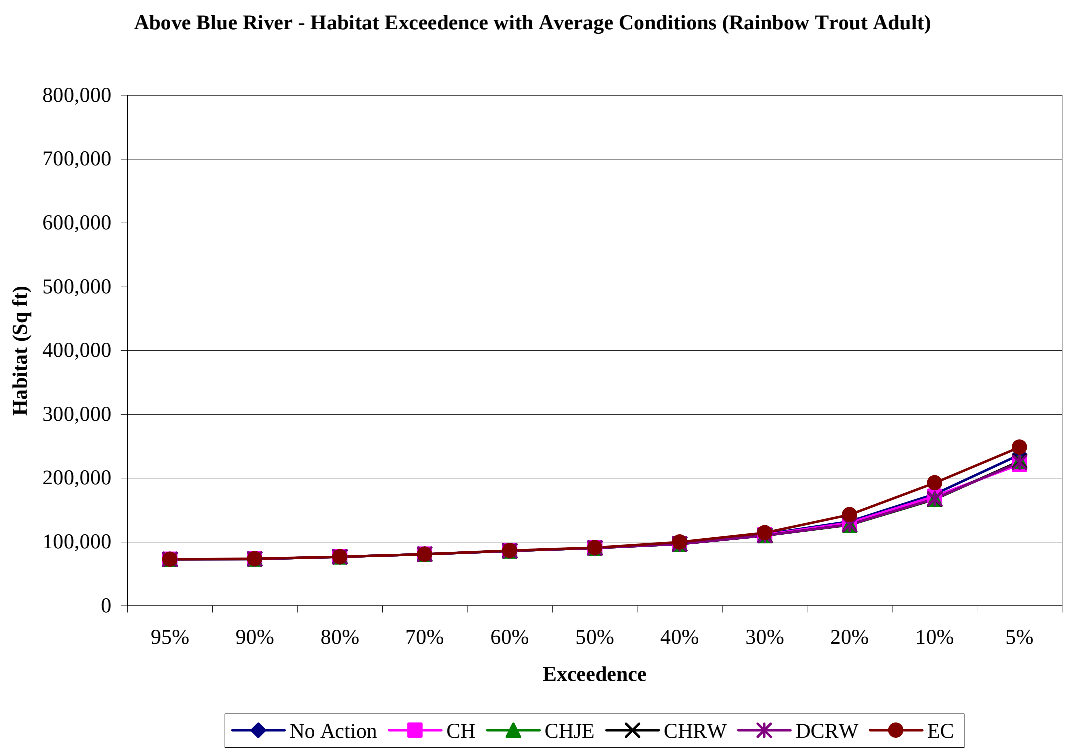


Figure 148. Above Blue River – habitat exceedence with average conditions (rainbow trout adult).

Figure 149. Above Blue River – percent change in exceedence with average conditions (rainbow trout juvenile).

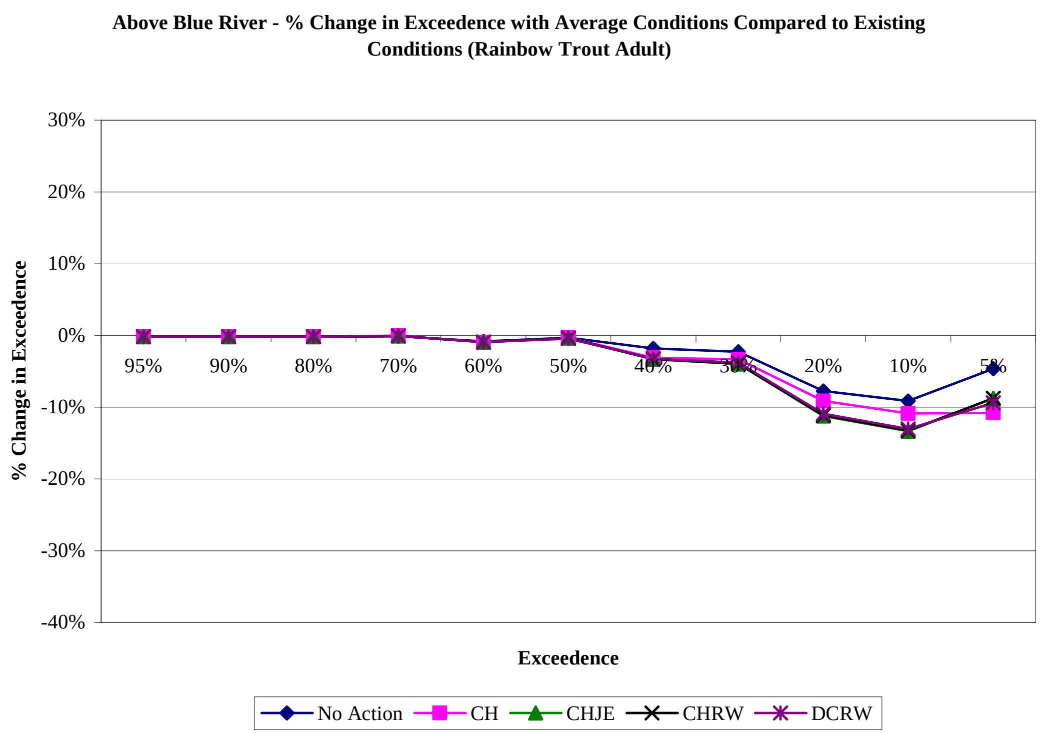


Figure 150. Above Blue River – percent change in exceedence with average conditions (rainbow trout adult).

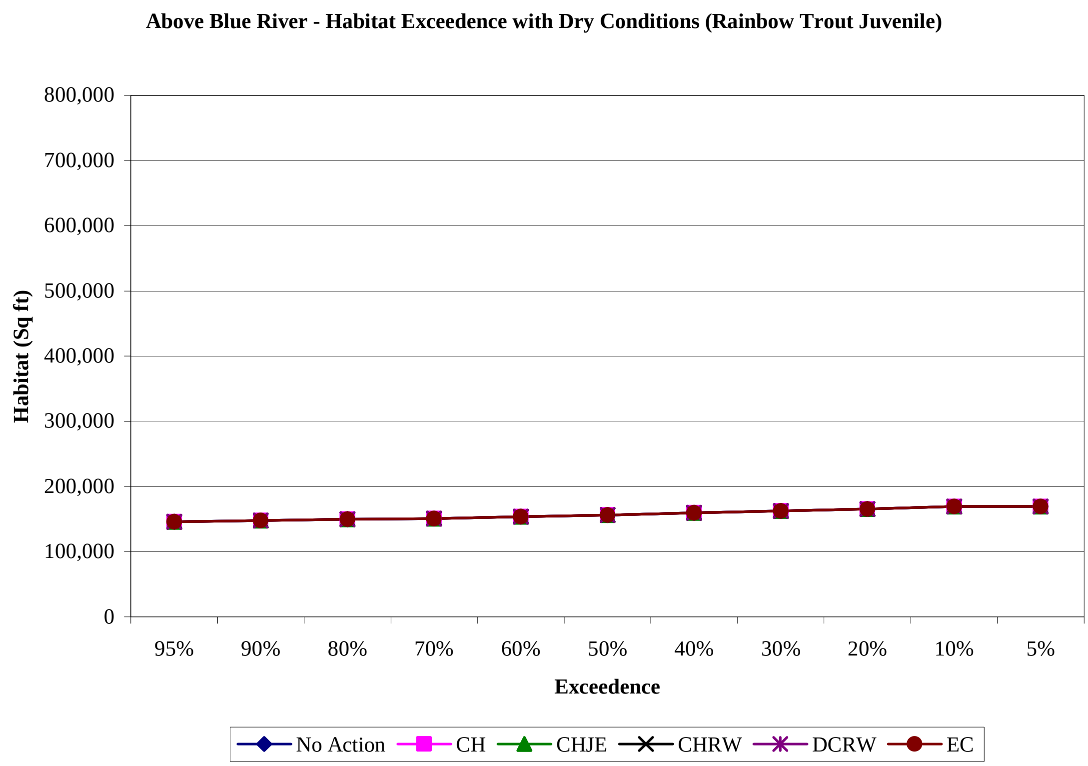


Figure 151. Above Blue River – habitat exceedence with dry conditions (rainbow trout juvenile).

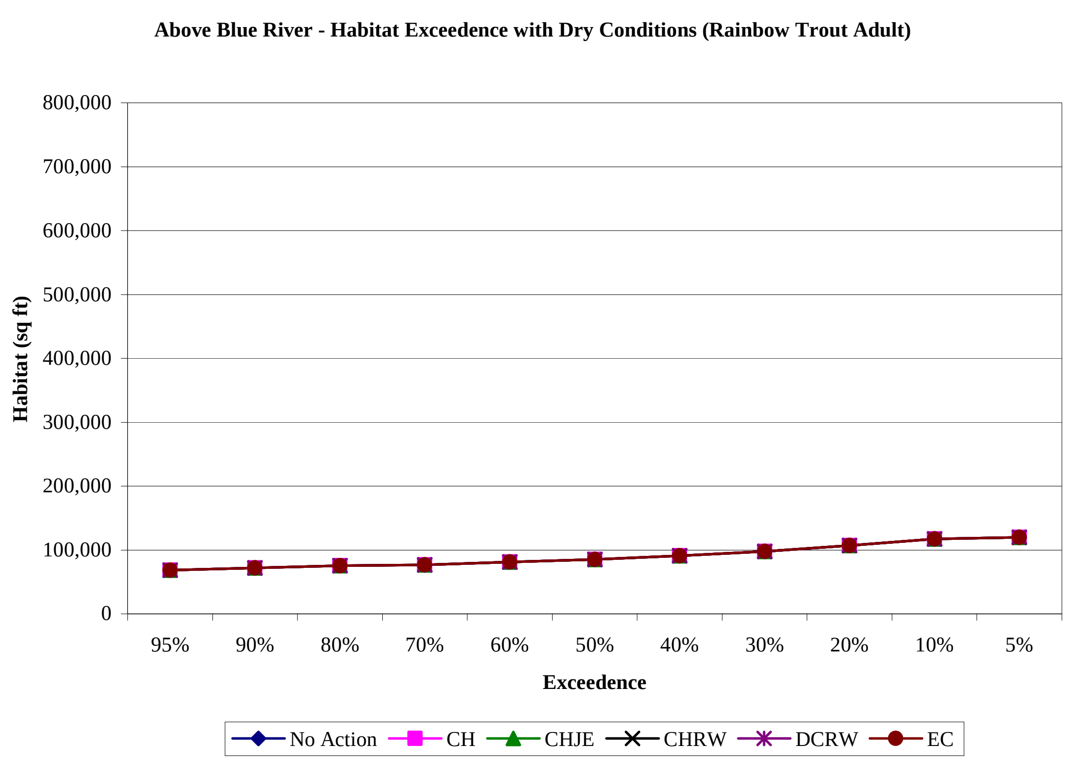


Figure 152. Above Blue River – habitat exceedence with dry conditions (rainbow trout adult).

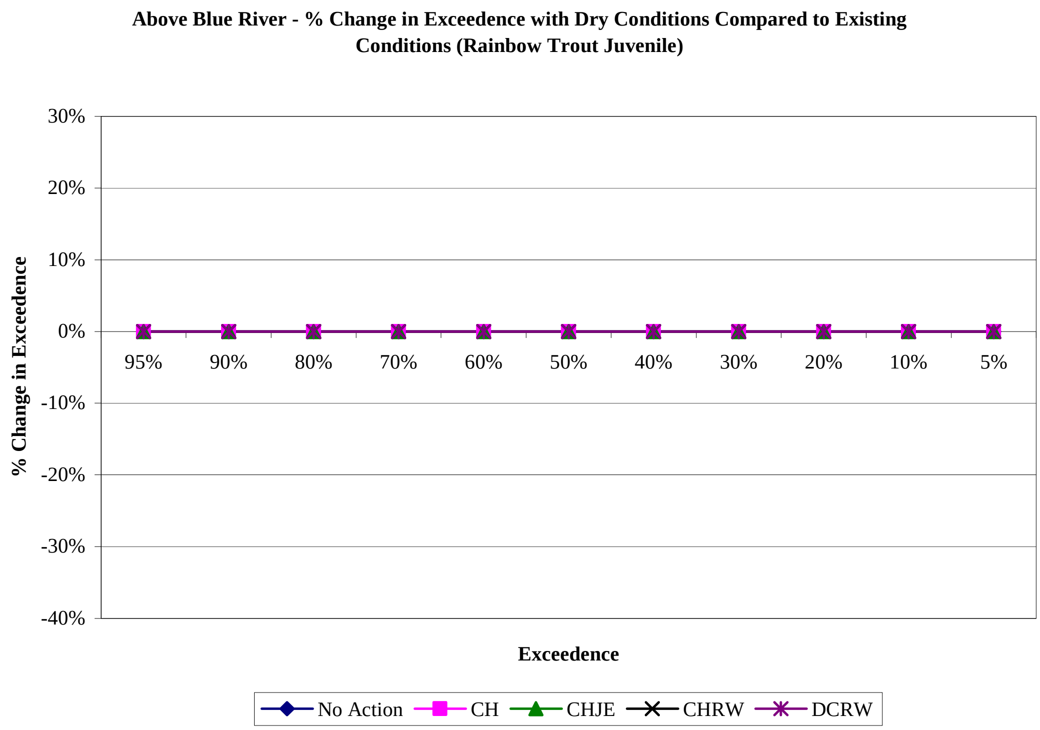


Figure 153. Above Blue River – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile).

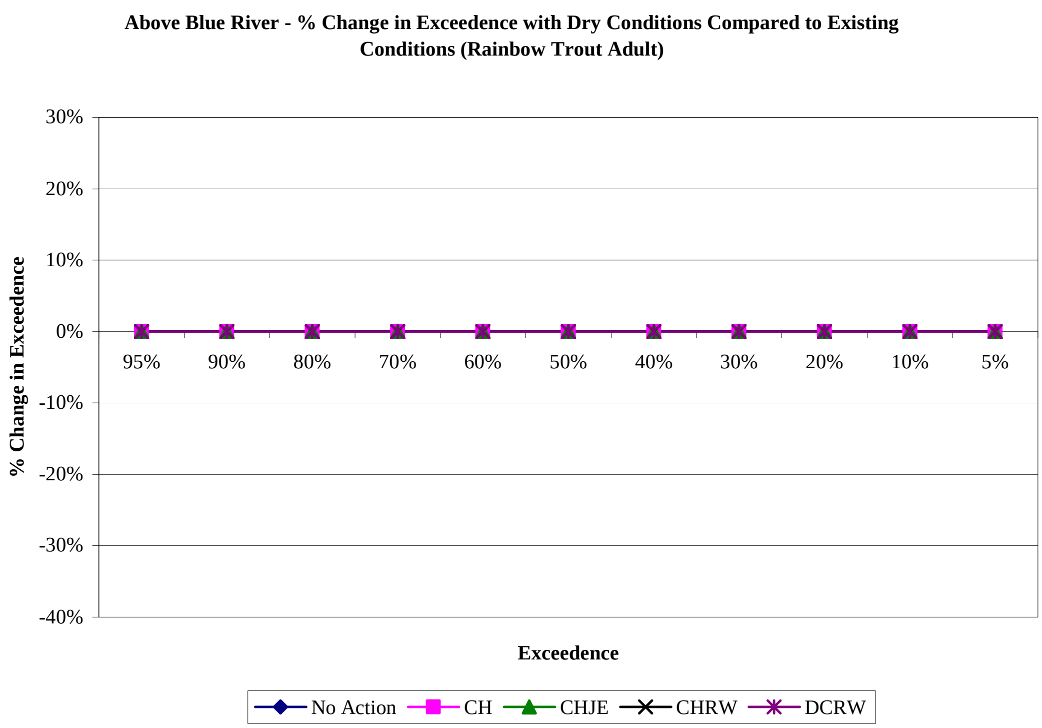


Figure 154. Above Blue River – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult).

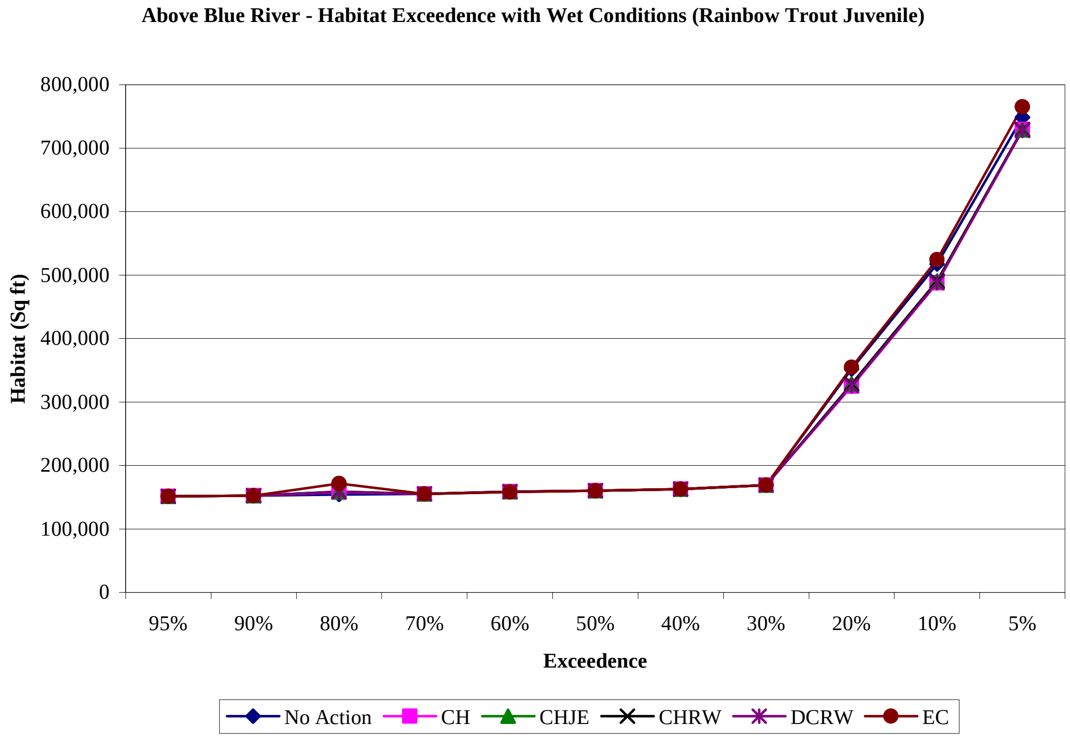


Figure 155. Above Blue River – habitat exceedence with wet conditions (rainbow trout juvenile).

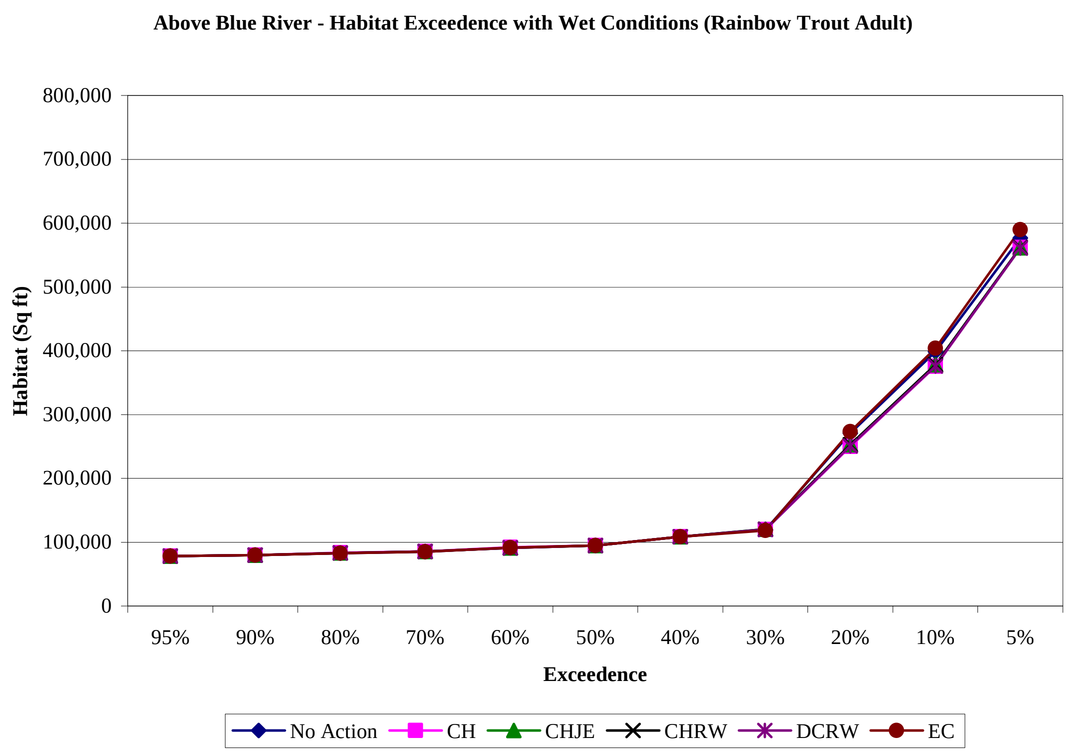


Figure 156. Above Blue River – habitat exceedence with wet conditions (rainbow trout adult).

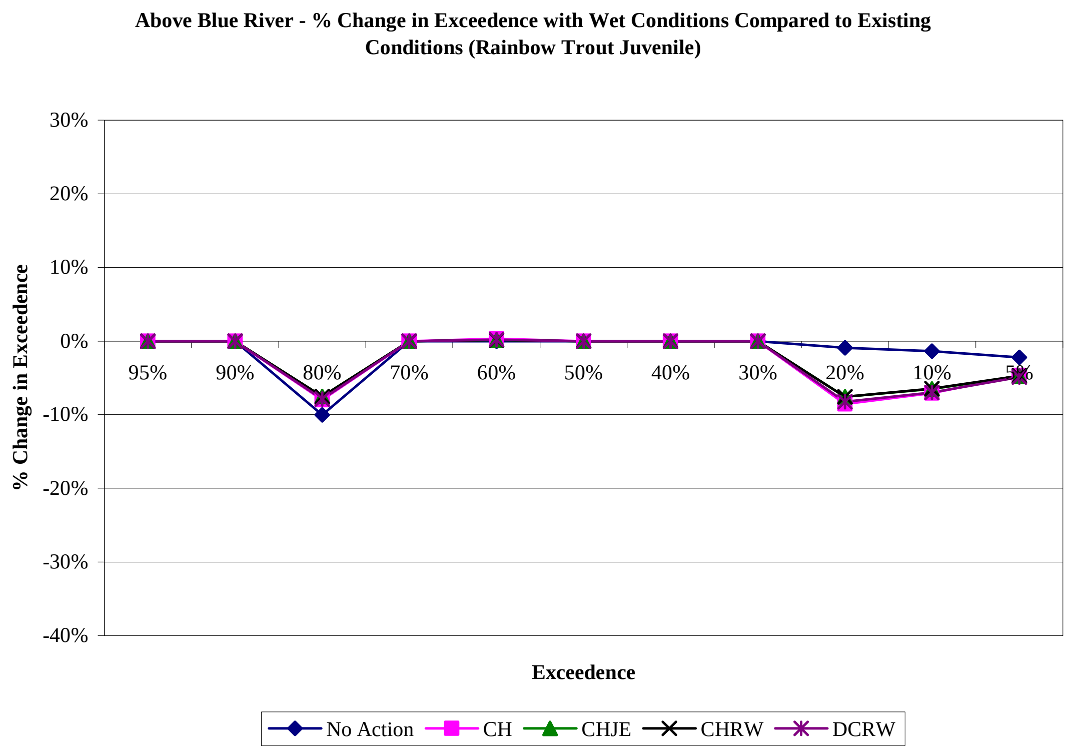


Figure 157. Above Blue River – percent change in exceedence with wet conditions (rainbow trout juvenile).

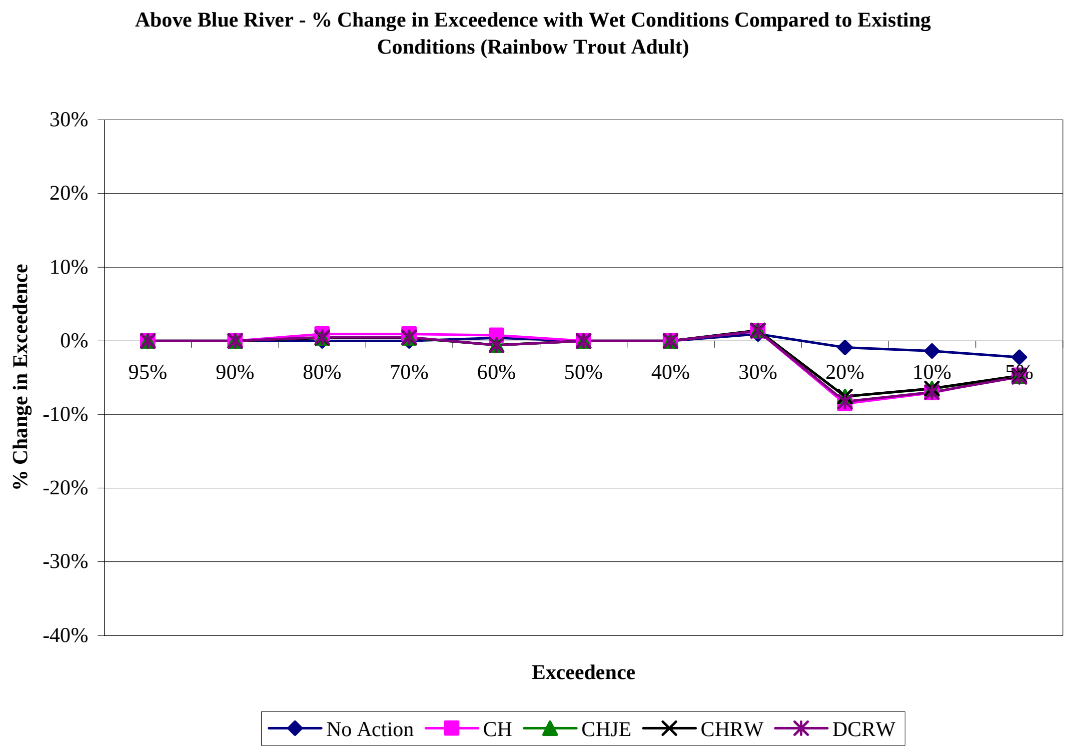


Figure 158. Above Blue River – percent change in exceedence with wet conditions (rainbow trout adult).

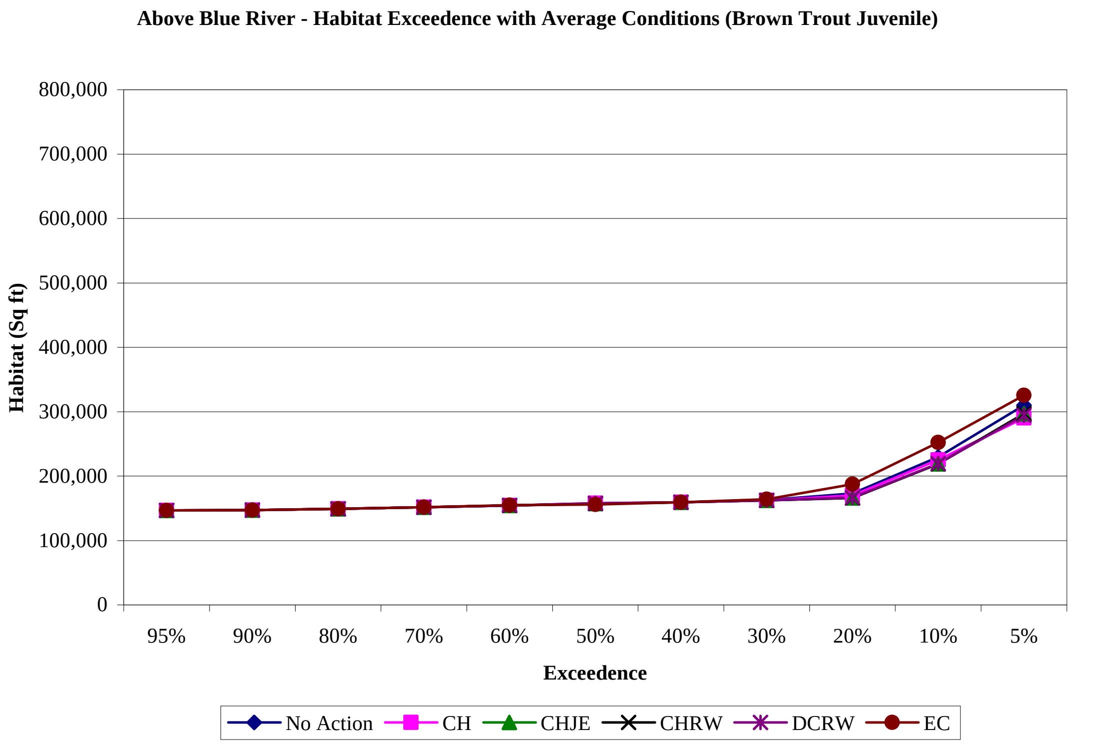


Figure 159. Above Blue River – habitat exceedence with <u>average</u> conditions (brown trout juvenile).

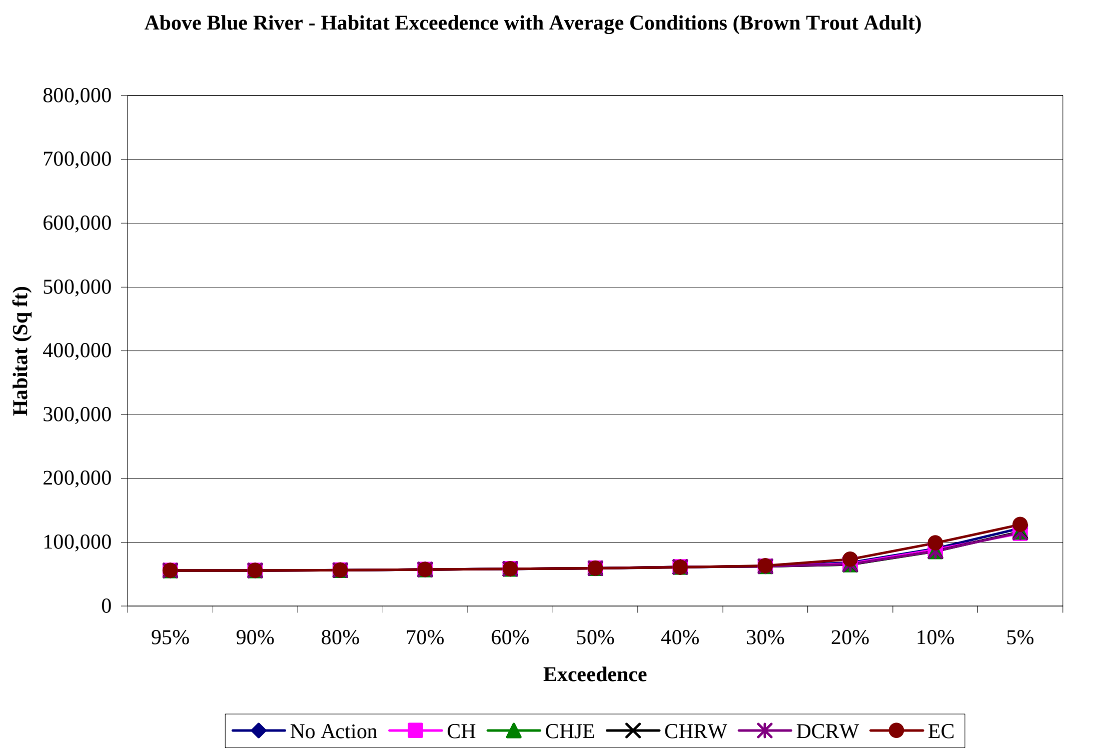


Figure 160. Above Blue River – habitat exceedence with <u>average</u> conditions (brown trout adult).

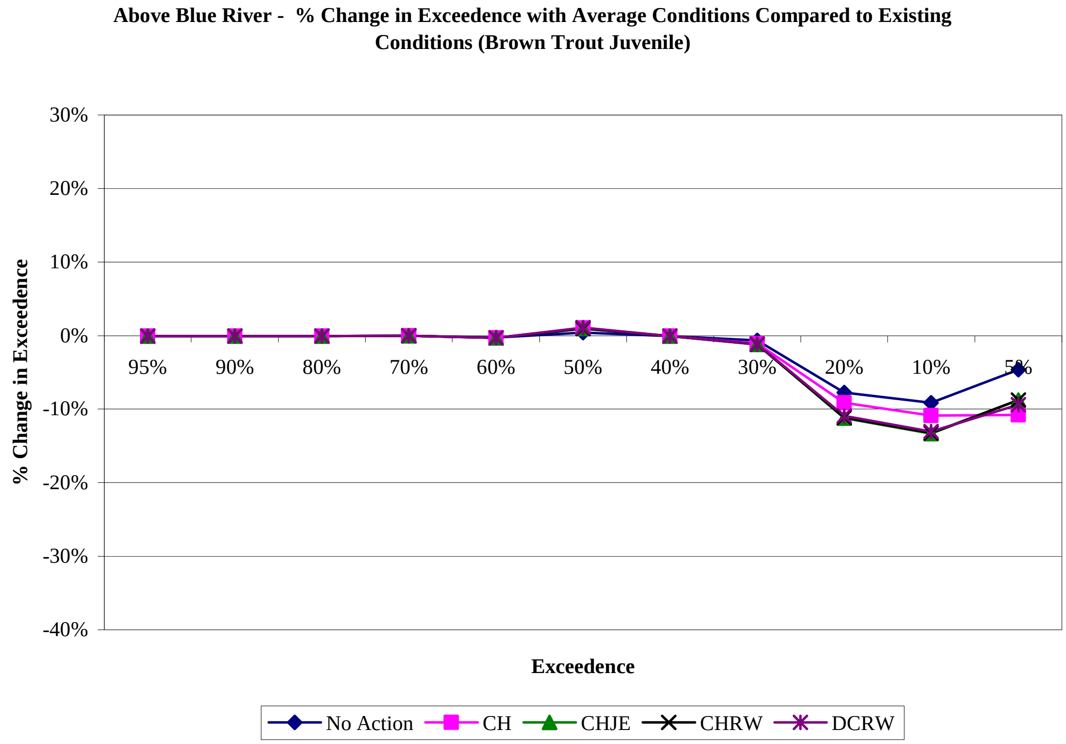


Figure 161. Above Blue River – percent change in exceedence with <u>average</u> conditions (brown trout juvenile).

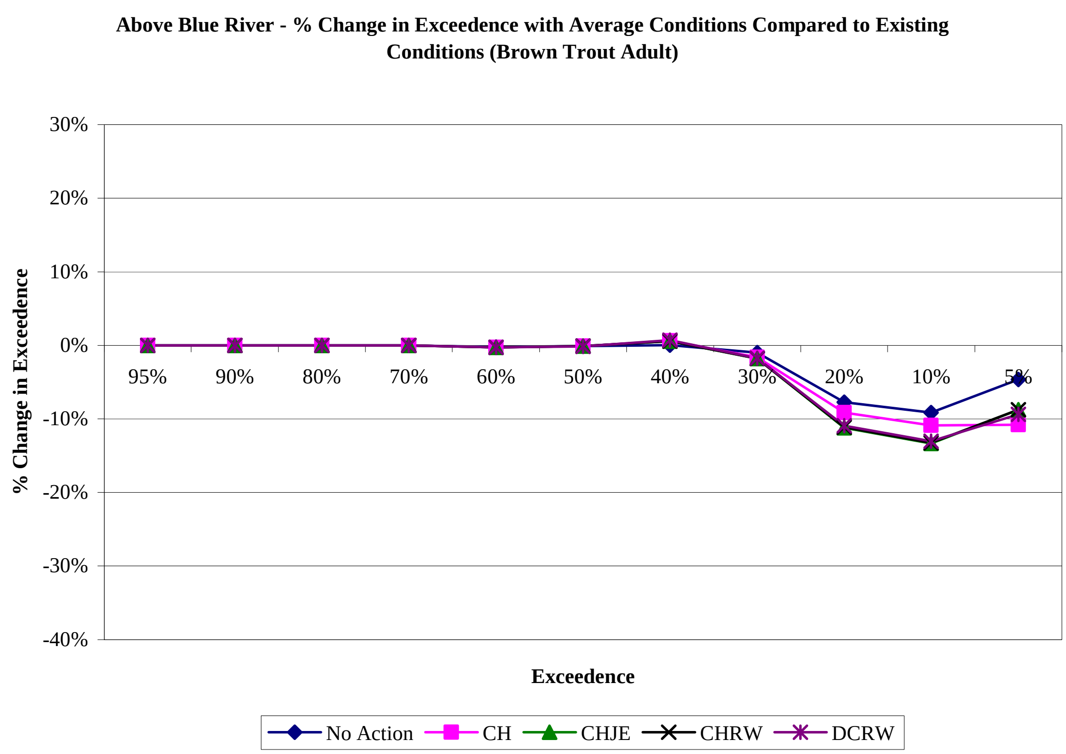


Figure 162. Above Blue River – percent change in exceedence with <u>average</u> conditions (brown trout adult).

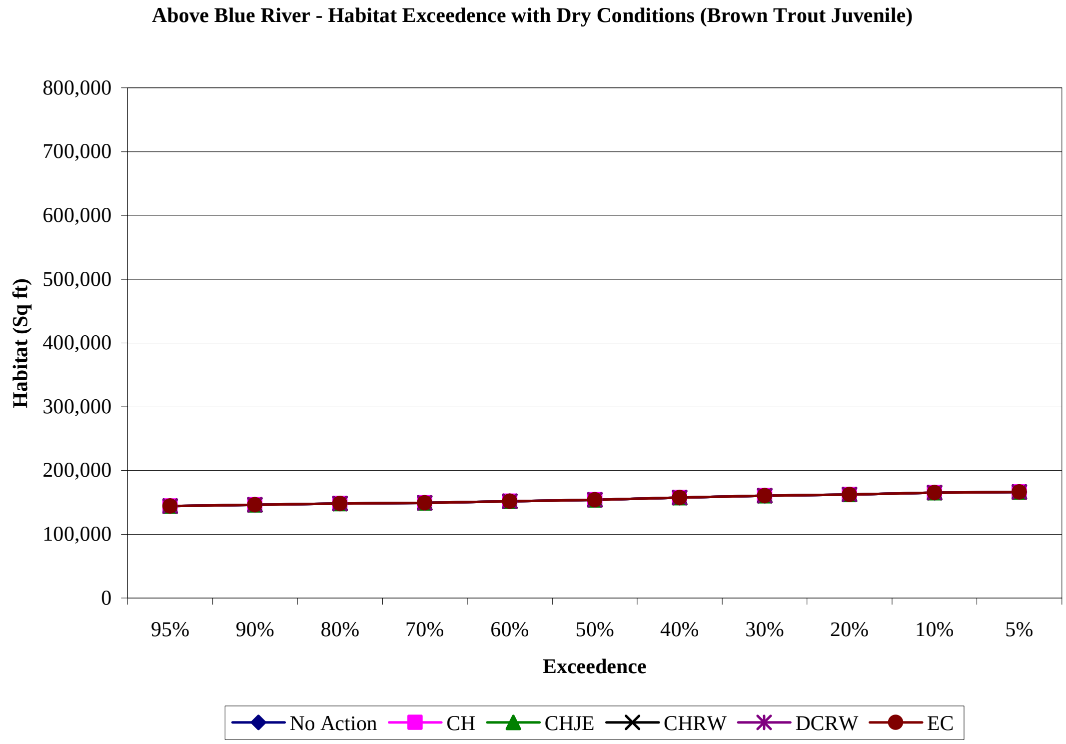


Figure 163. Above Blue River – habitat exceedence with <u>dry</u> conditions (brown trout juvenile).

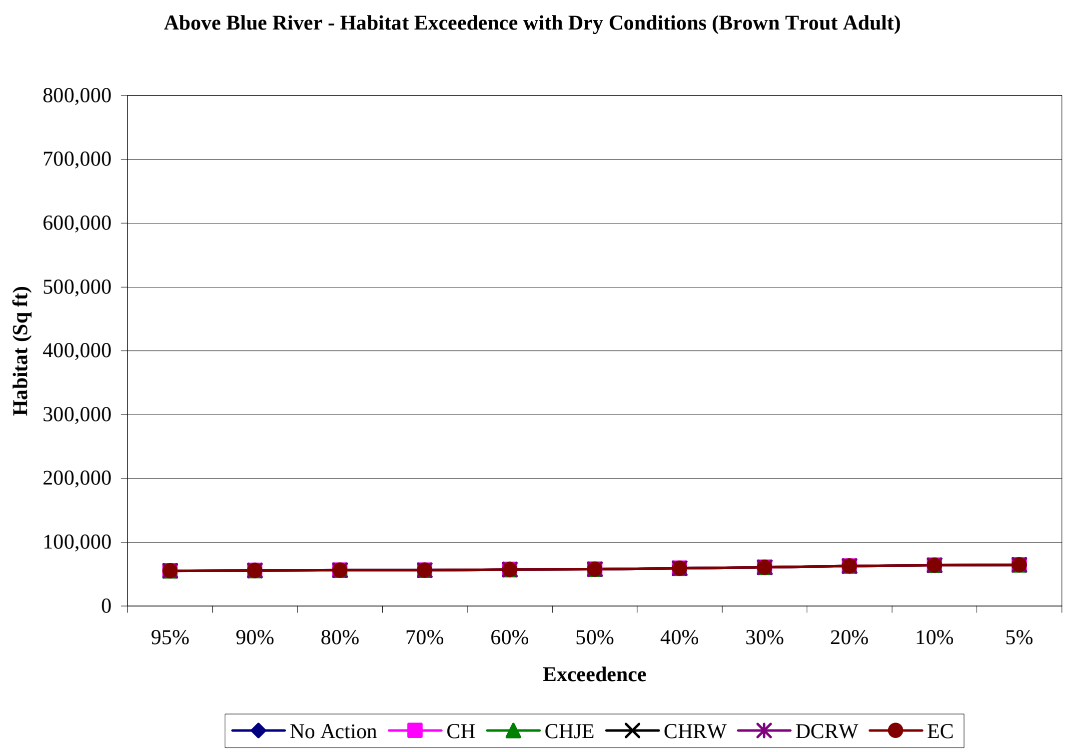


Figure 164. Above Blue River – habitat exceedence with <u>dry</u> conditions (brown trout adult).

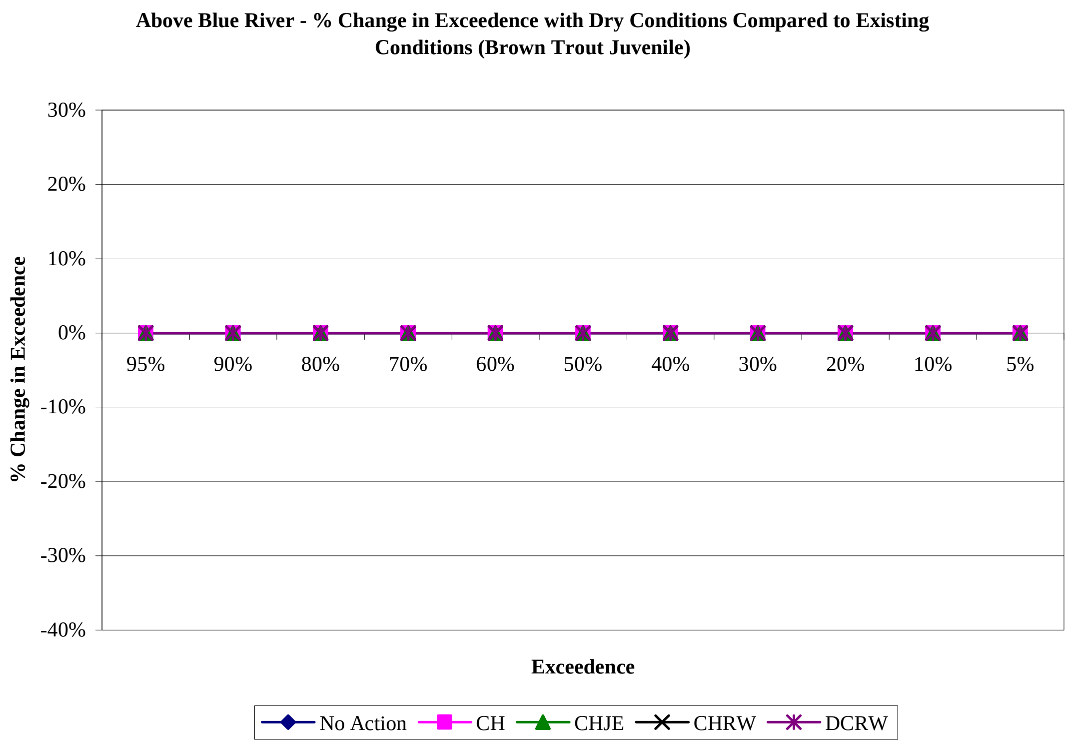


Figure 165. Above Blue River – percent change in exceedence with dry conditions (brown trout juvenile).

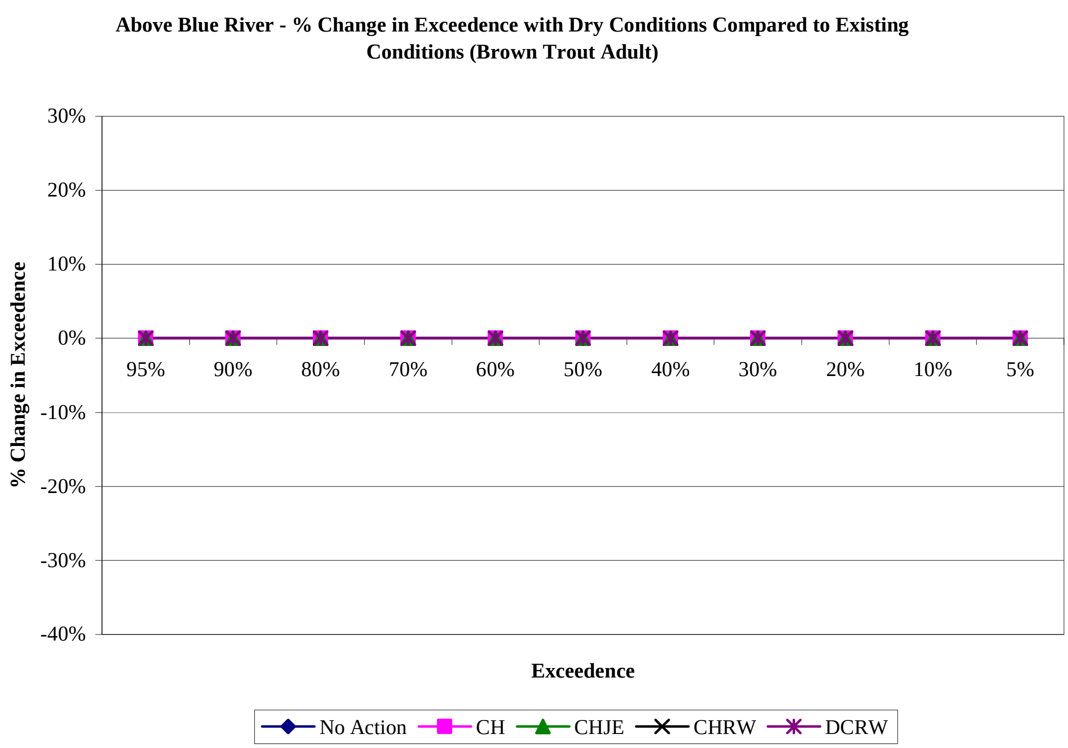


Figure 166. Above Blue River – percent change in exceedence with dry conditions (brown trout adult).

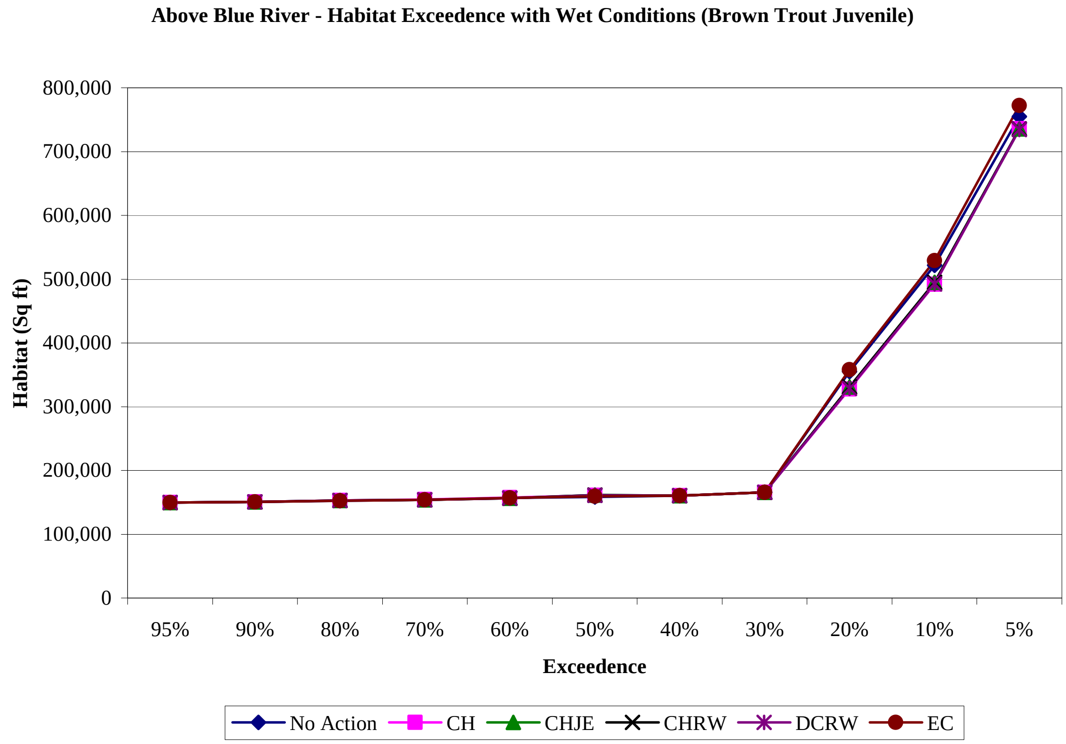


Figure 167. Above Blue River – habitat exceedence with wet conditions (brown trout juvenile).

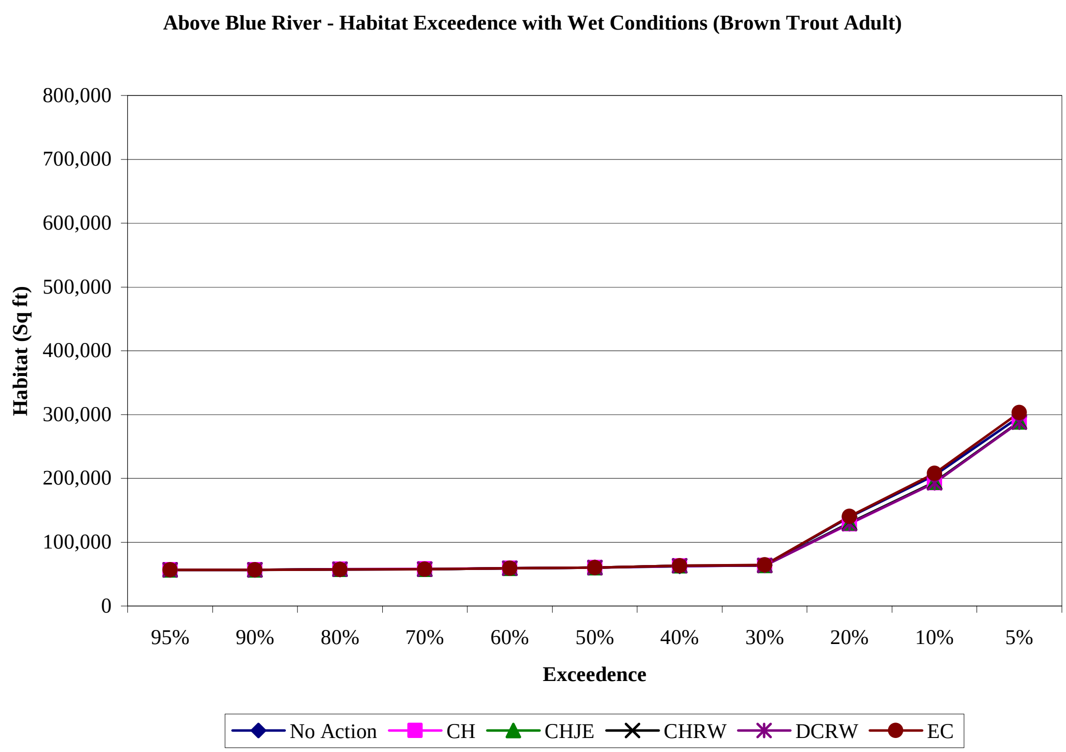


Figure 168. Above Blue River – habitat exceedence with wet conditions (brown trout adult).

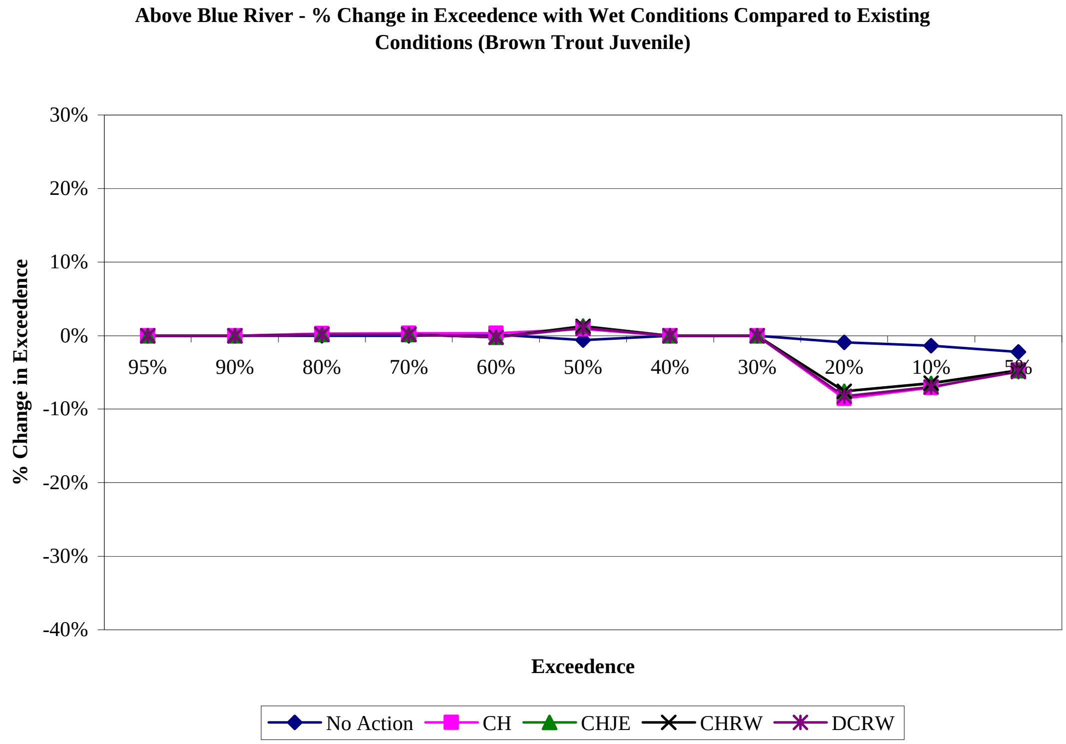


Figure 169. Above Blue River – percent change in exceedence with <u>wet</u> conditions (brown trout juvenile).

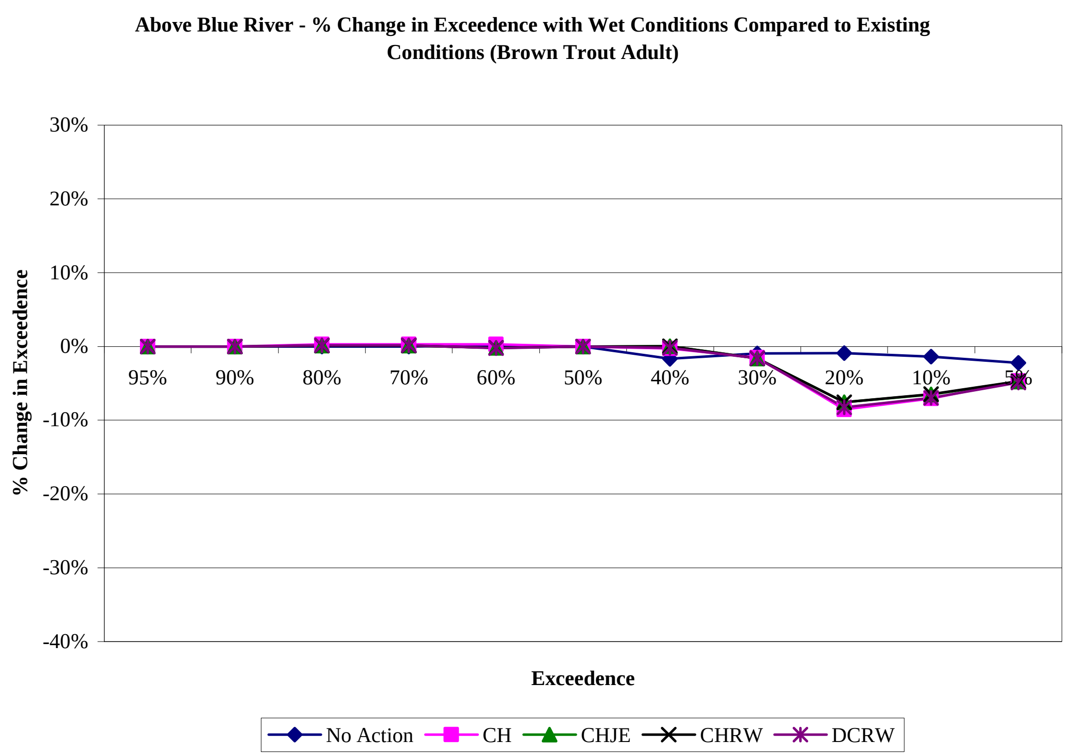


Figure 170. Above Blue River – percent change in exceedence with <u>wet</u> conditions (brown trout adult).

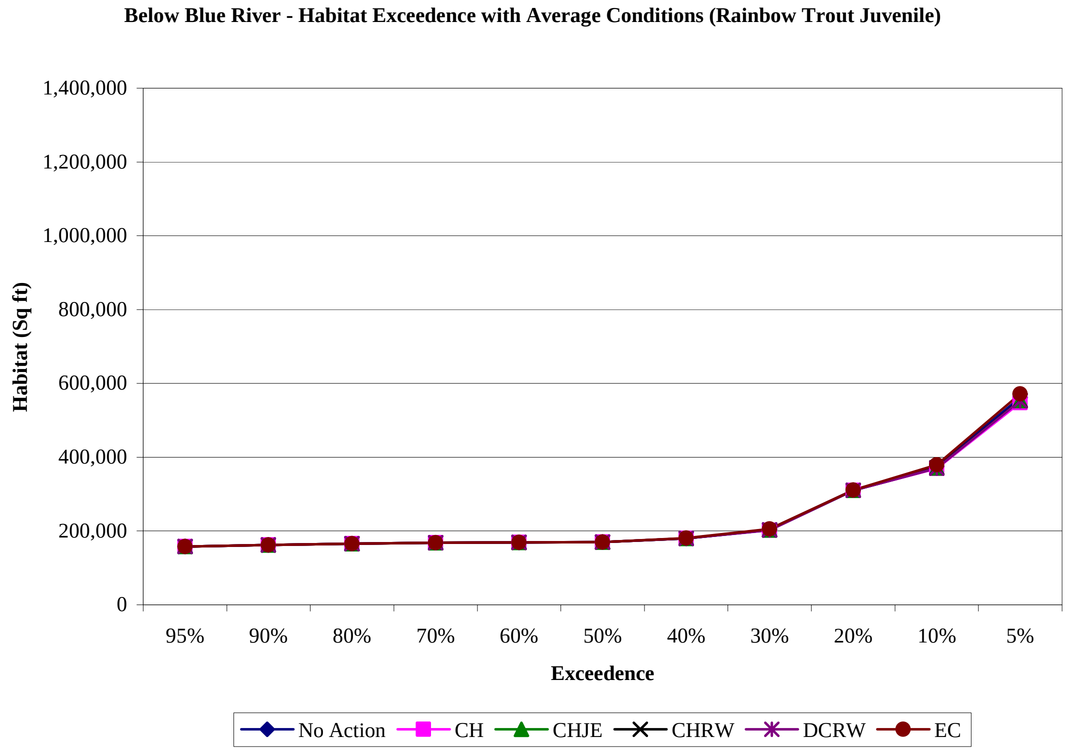


Figure 171. Below Blue River – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile).

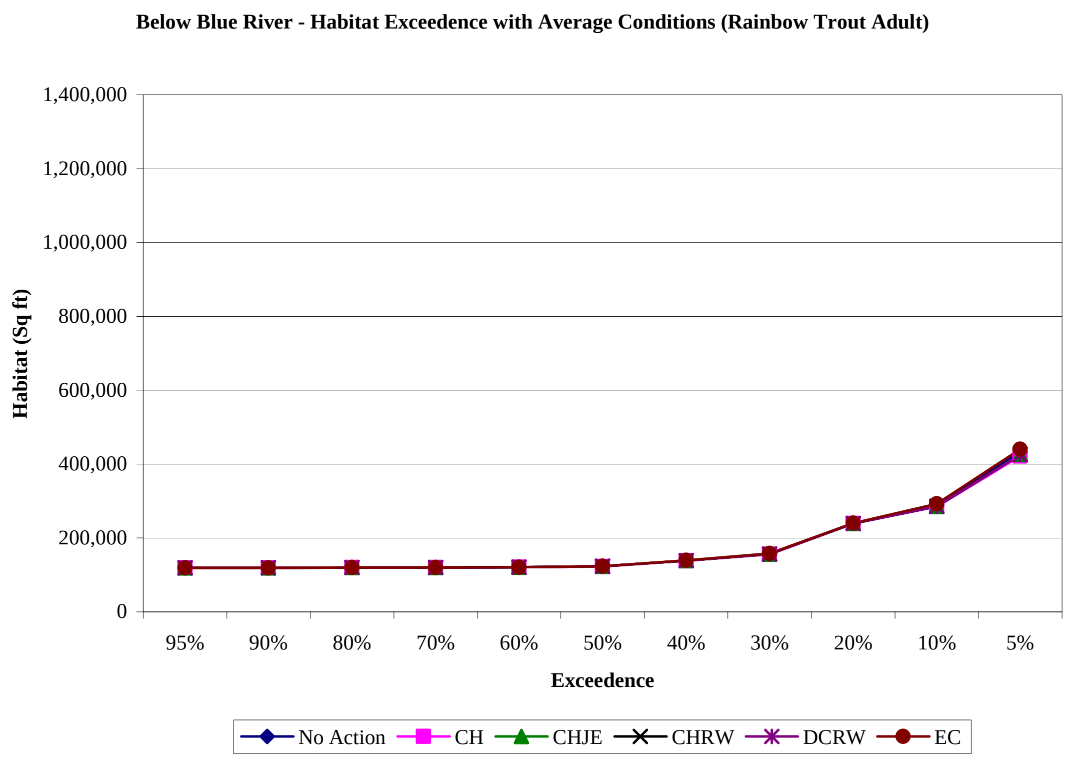


Figure 172. Below Blue River – habitat exceedence with <u>average</u> conditions (rainbow trout adult).

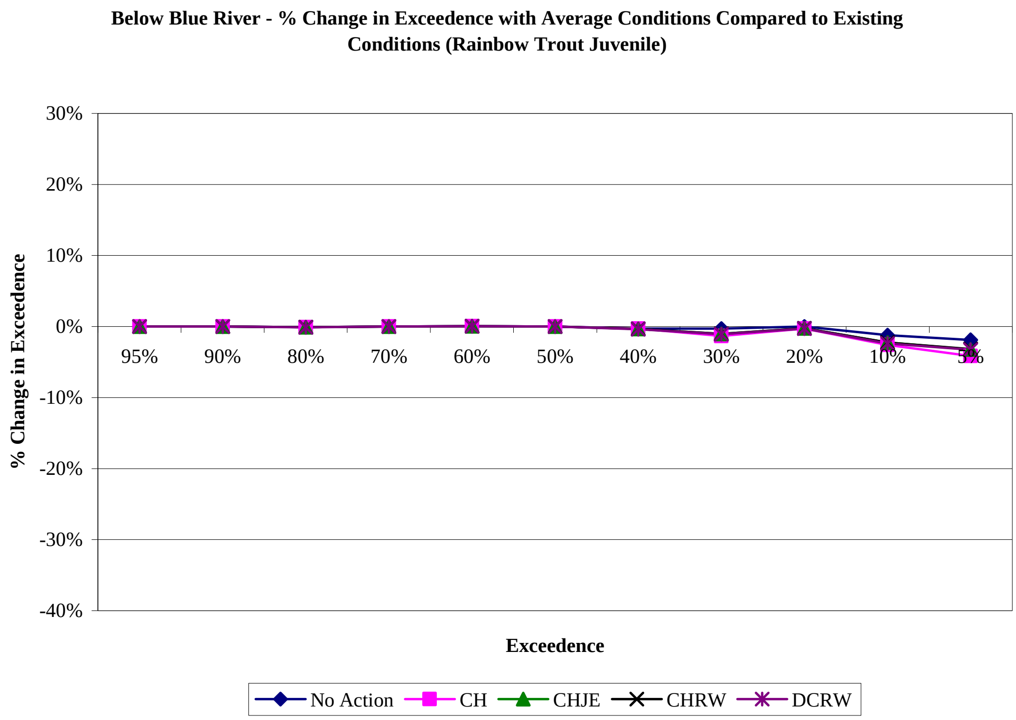


Figure 173. Below Blue River – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile).

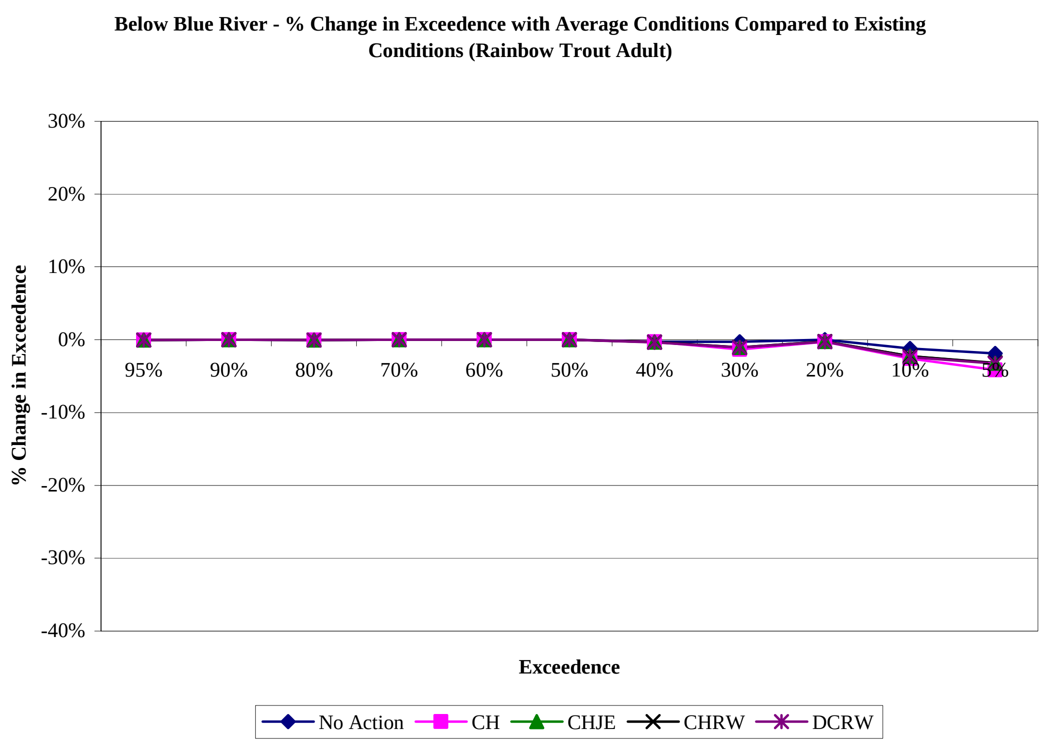


Figure 174. Below Blue River – percent change in exceedence with <u>average</u> conditions (rainbow trout adult).

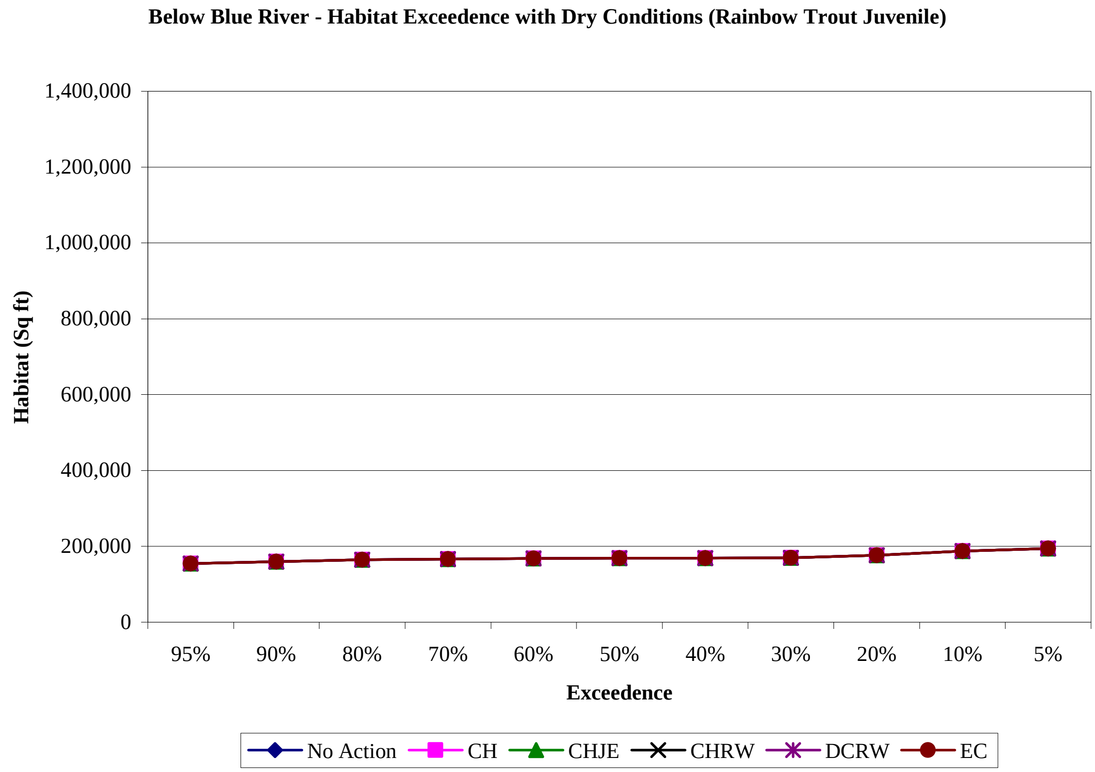


Figure 175. Below Blue River – habitat exceedence with dry conditions (rainbow trout juvenile).

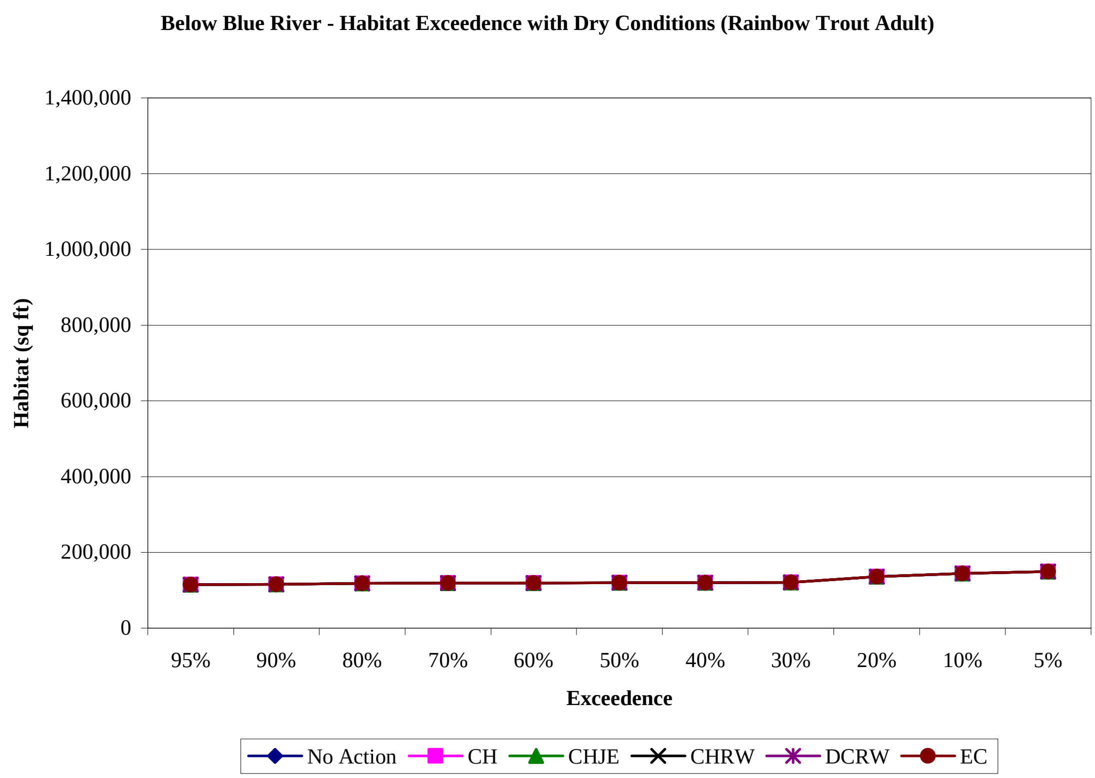


Figure 176. Below Blue River – habitat exceedence with dry conditions (rainbow trout adult).

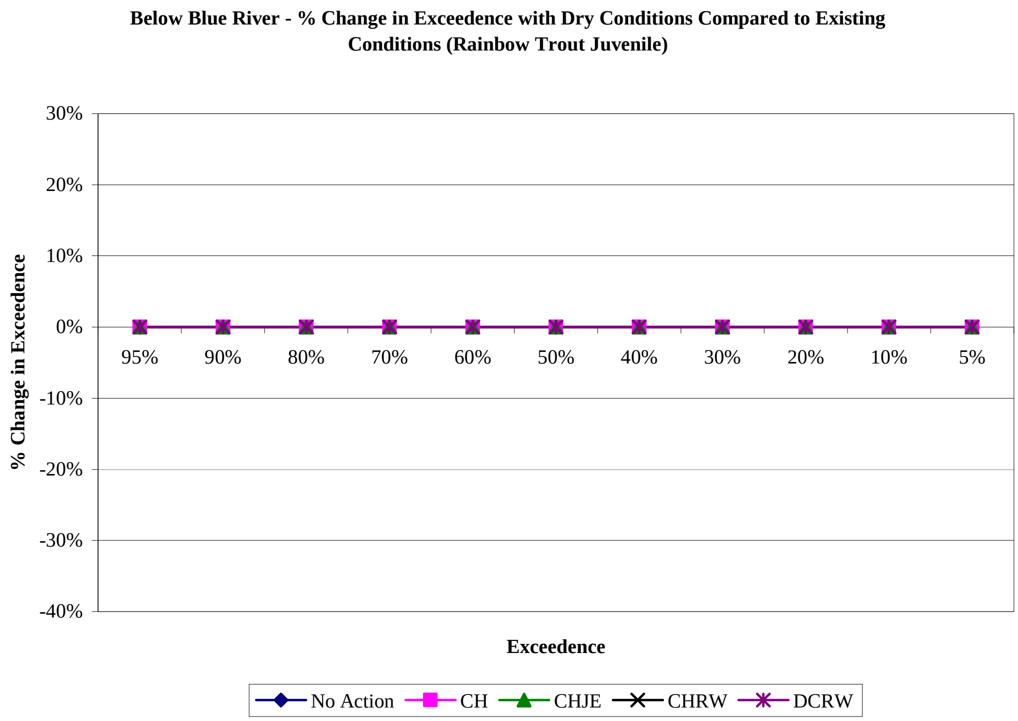


Figure 177. Below Blue River – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile).

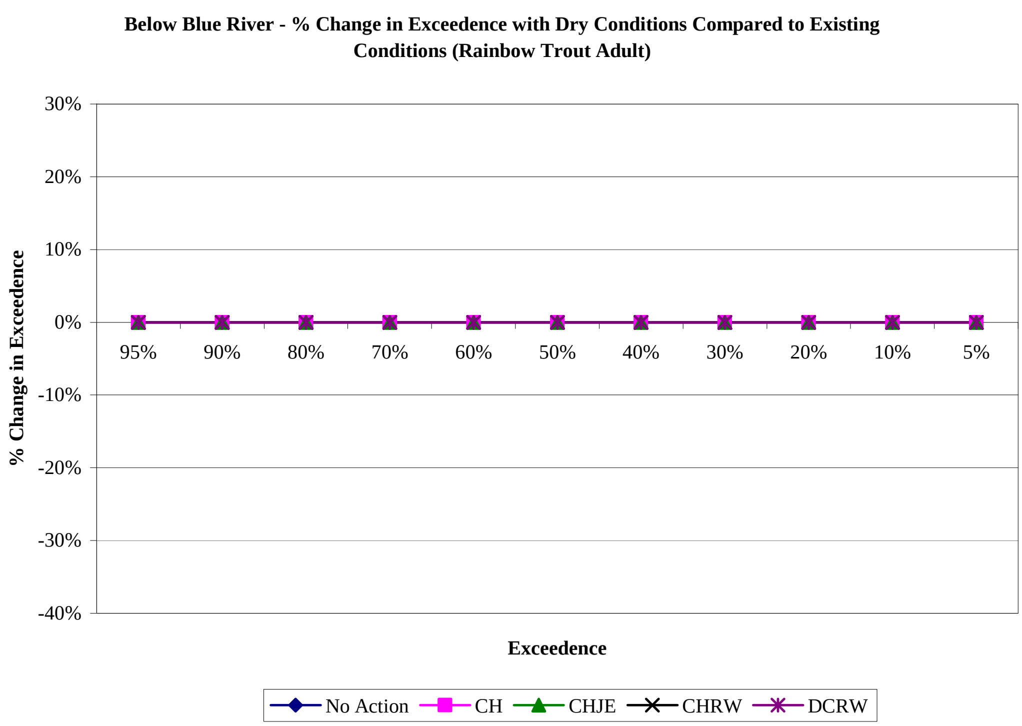


Figure 178. Below Blue River – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult).

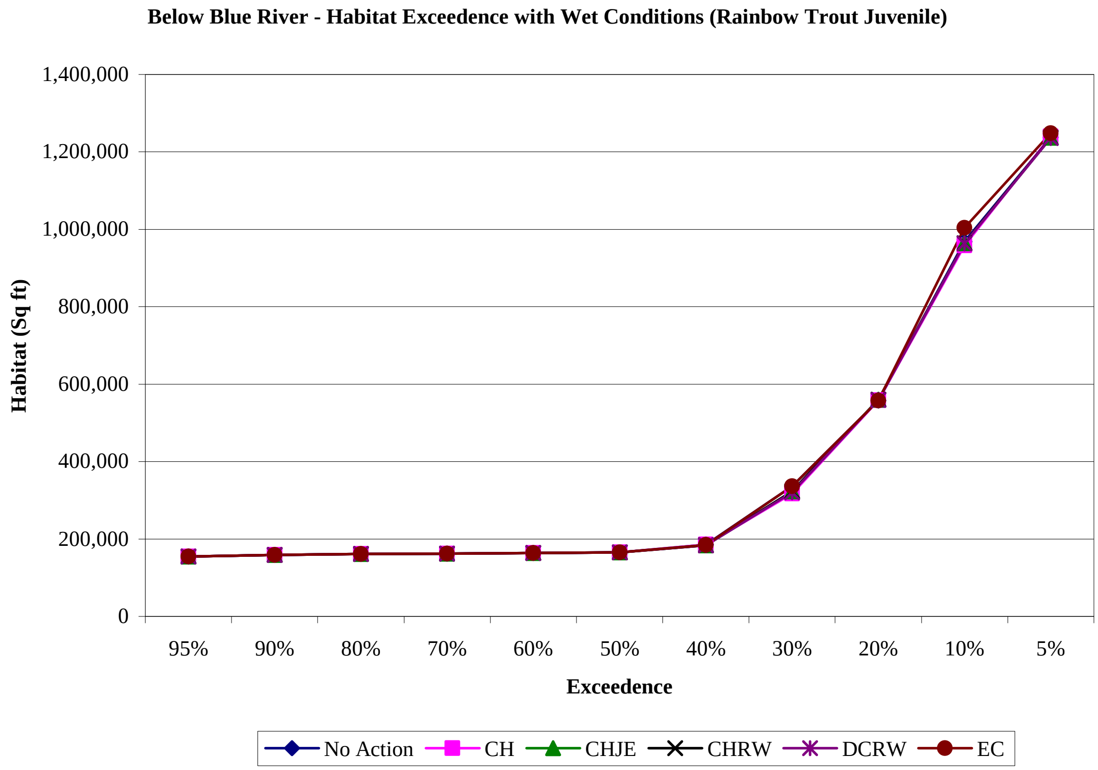


Figure 179. Below Blue River – habitat exceedence with wet conditions (rainbow trout juvenile).

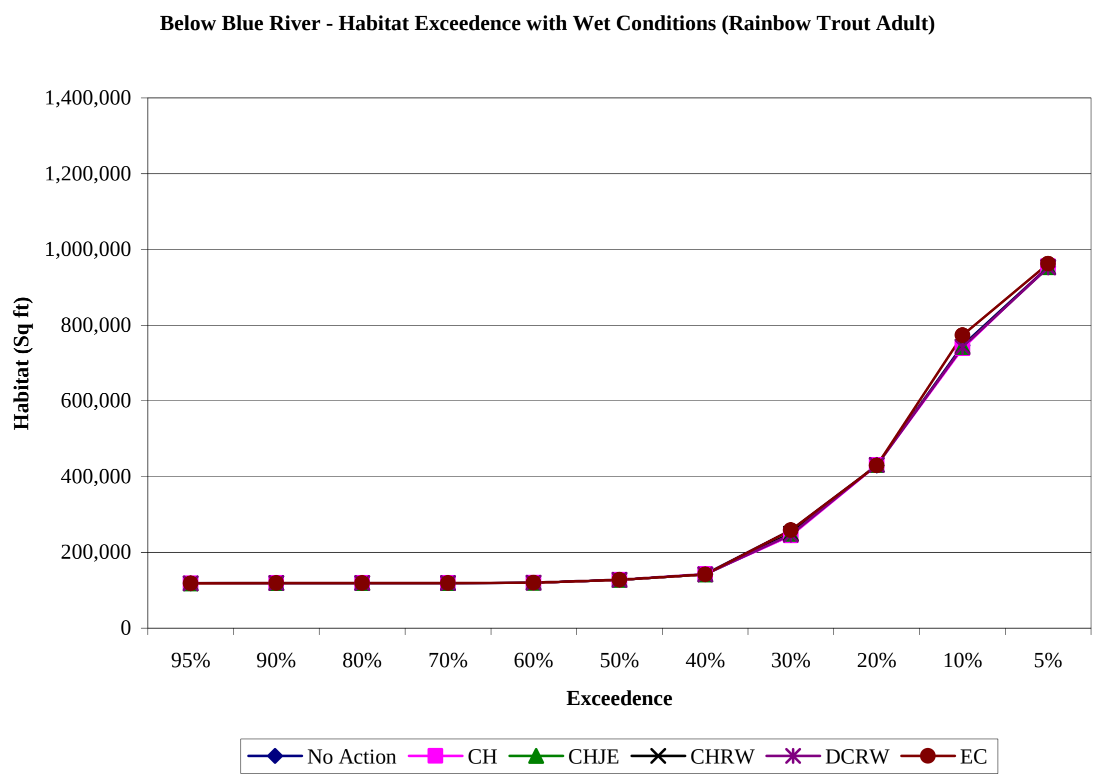


Figure 180. Below Blue River – habitat exceedence with wet conditions (rainbow trout adult).

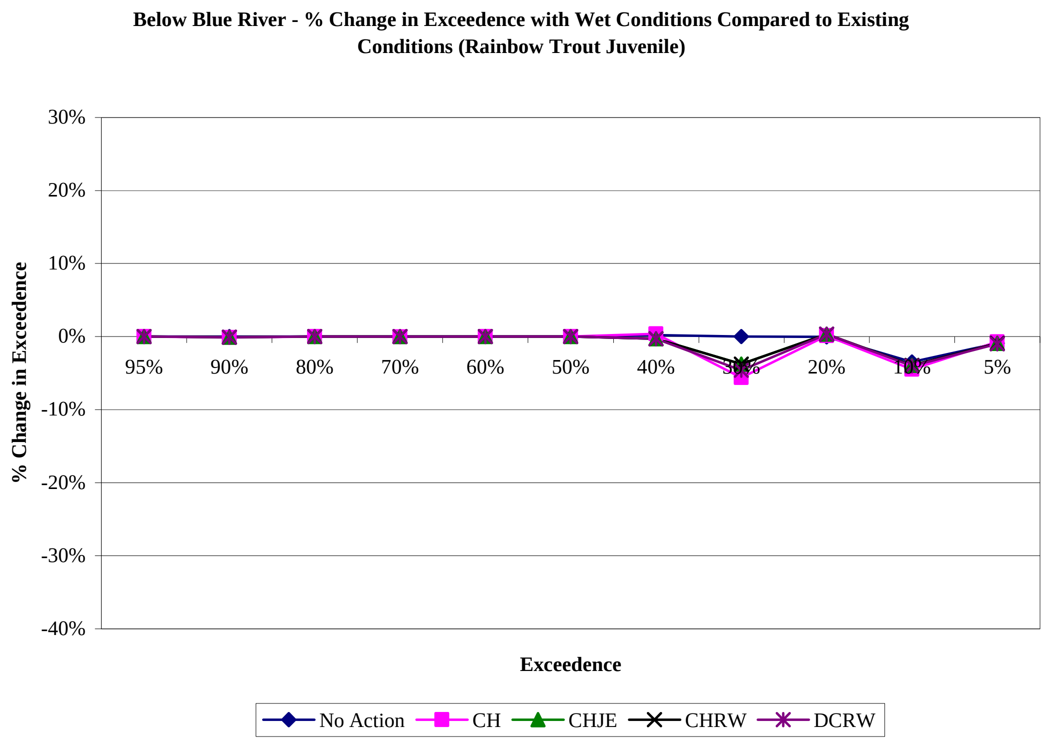


Figure 181. Below Blue River – percent change in exceedence with wet conditions (rainbow trout juvenile).

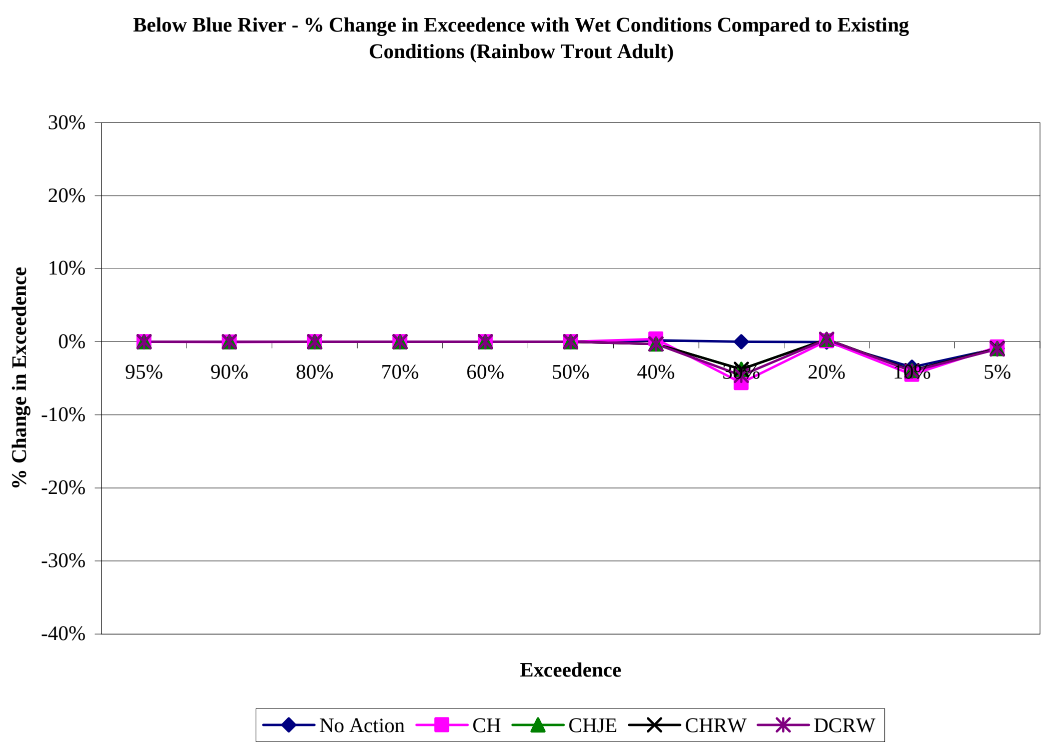


Figure 182. Below Blue River – percent change in exceedence with wet conditions (rainbow trout adult).

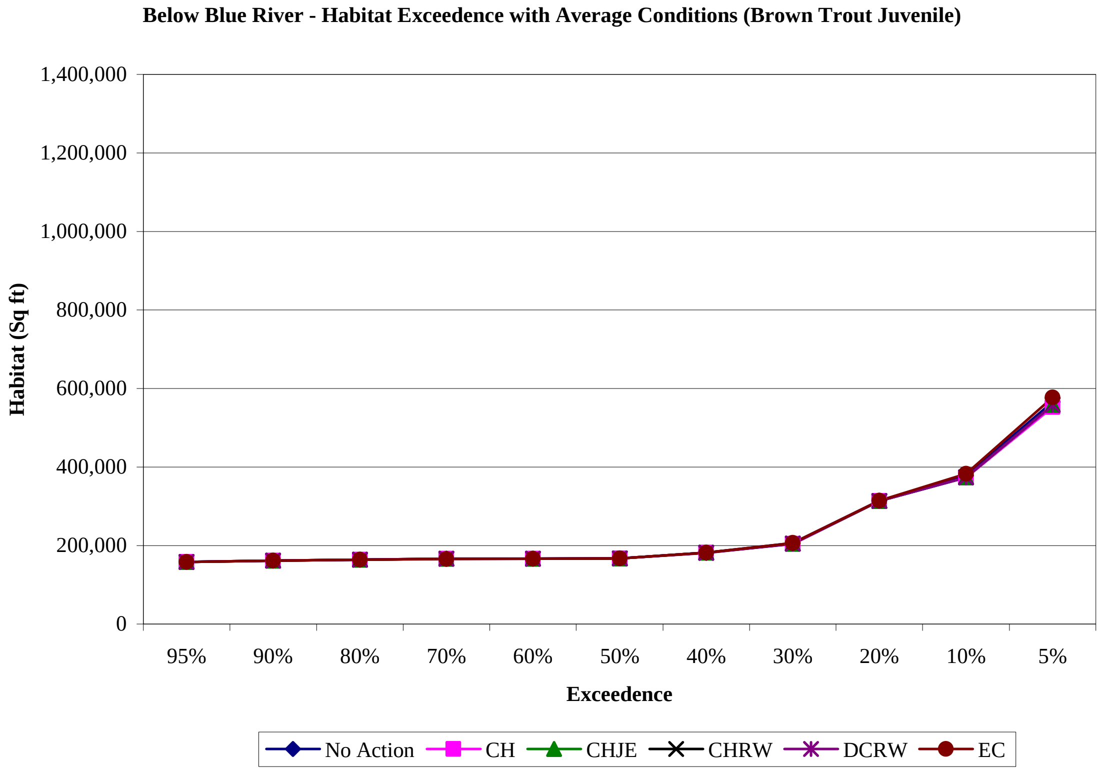


Figure 183. Below Blue River – habitat exceedence with average conditions (brown trout juvenile).

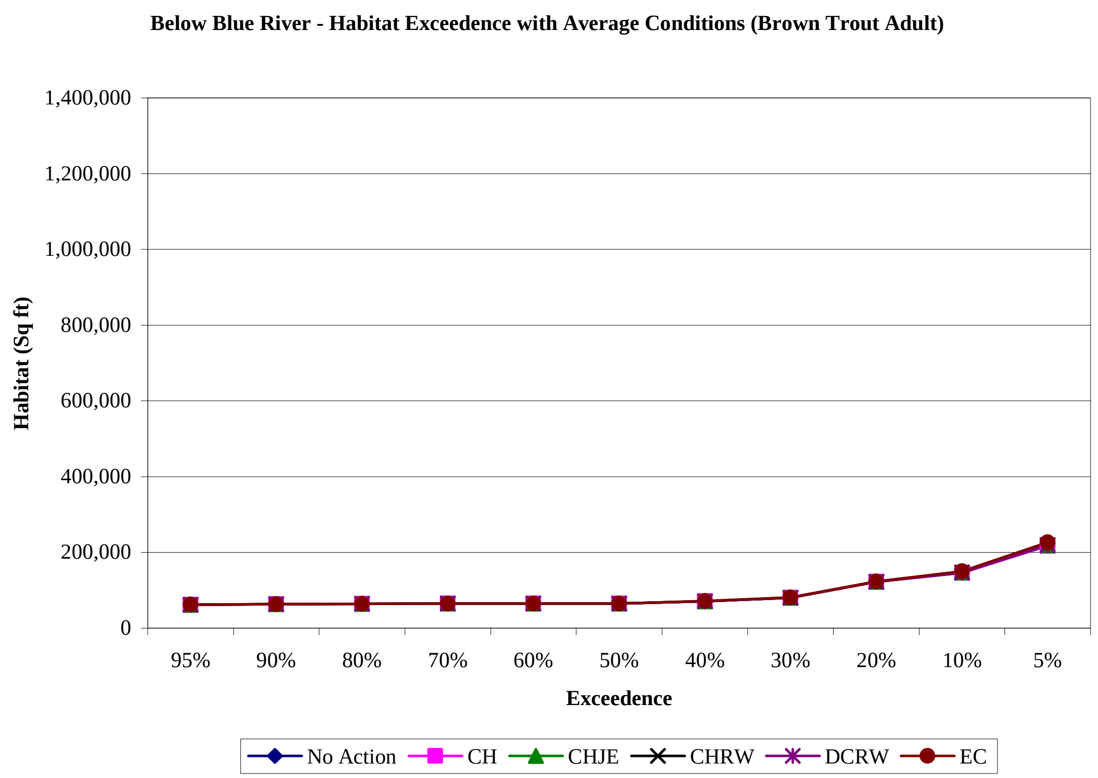


Figure 184. Below Blue River – habitat exceedence with average conditions (brown trout adult).

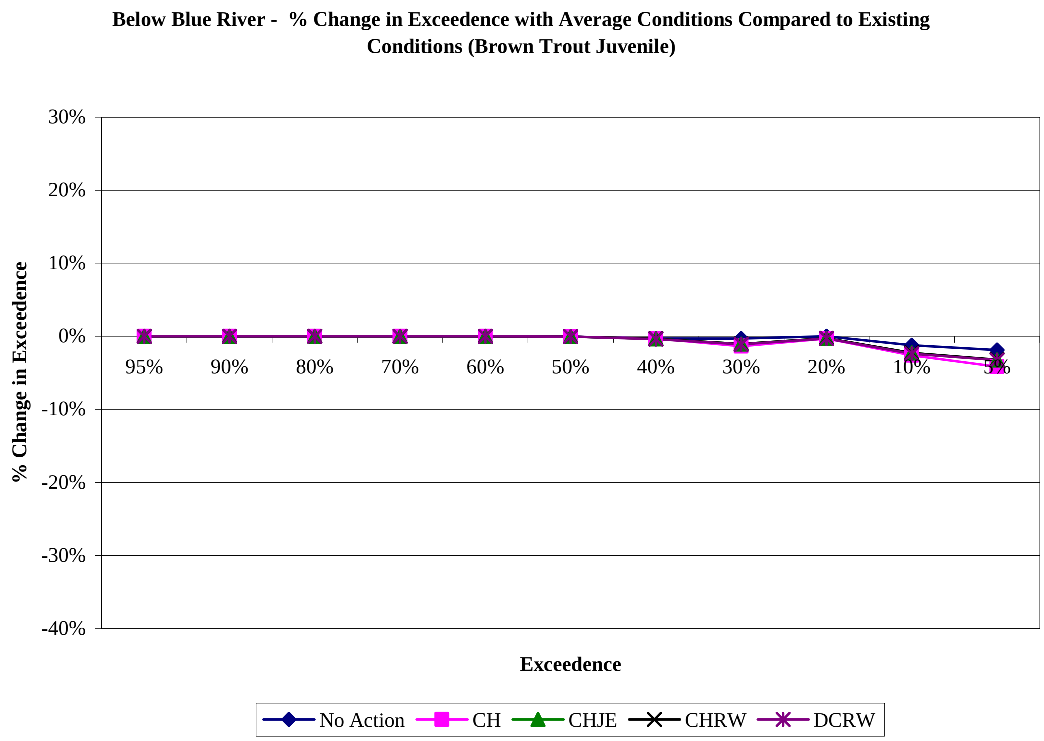


Figure 185. Below Blue River – percent change in exceedence with <u>average</u> conditions (brown trout juvenile).

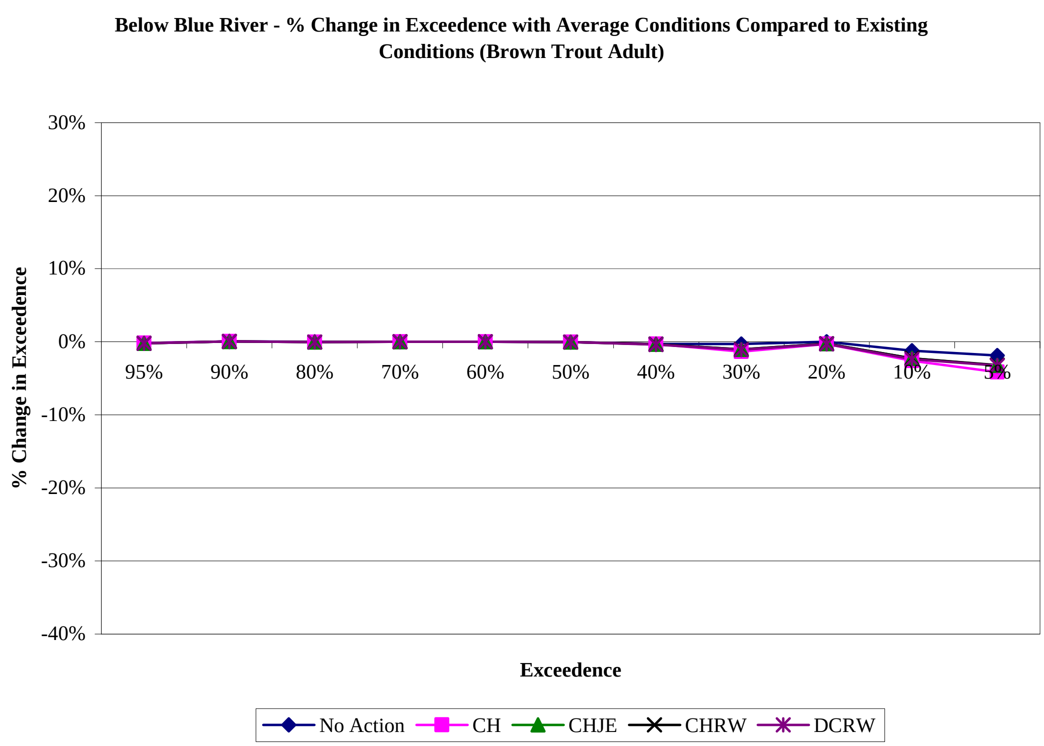


Figure 186. Below Blue River – percent change in exceedence with <u>average</u> conditions (brown trout adult).

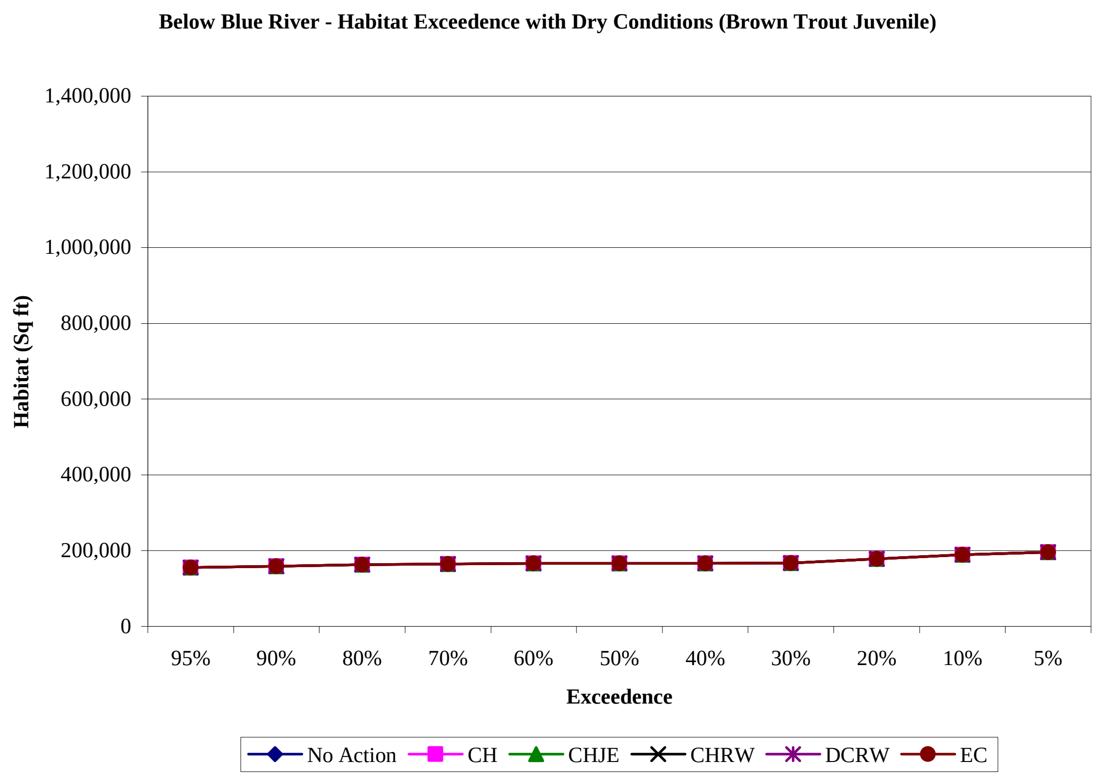


Figure 187. Below Blue River – habitat exceedence with <u>dry</u> conditions (brown trout juvenile).

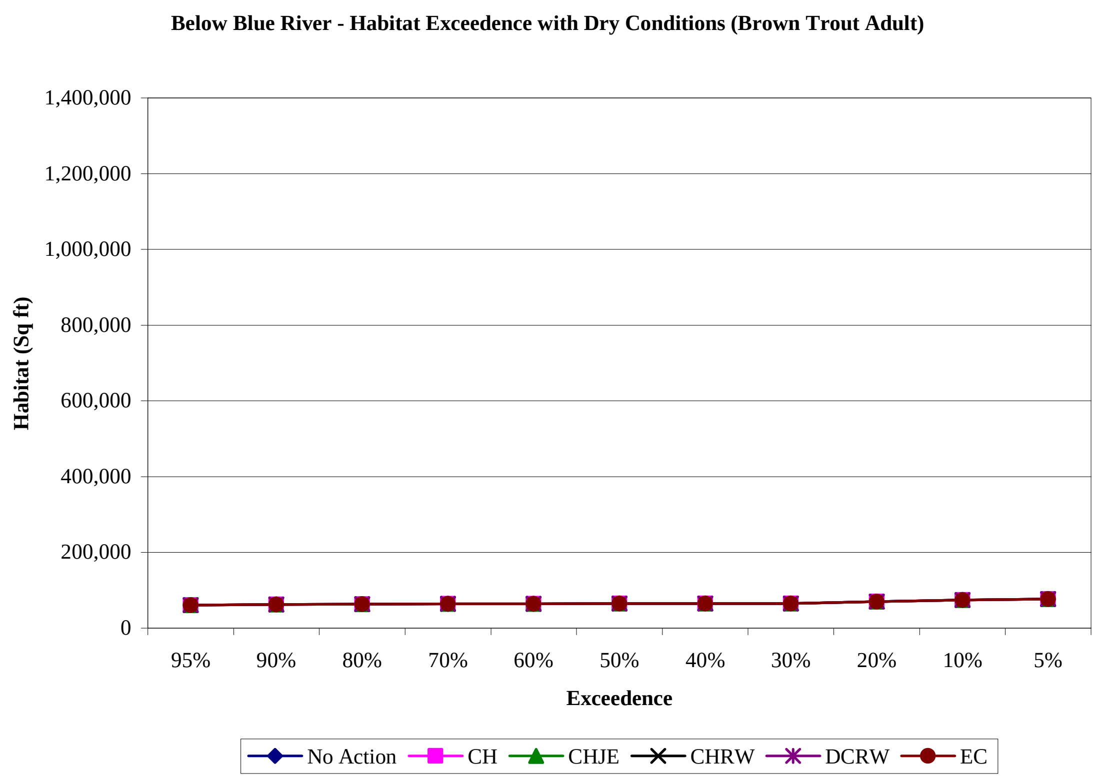


Figure 188. Below Blue River – habitat exceedence with <u>dry</u> conditions (brown trout adult).

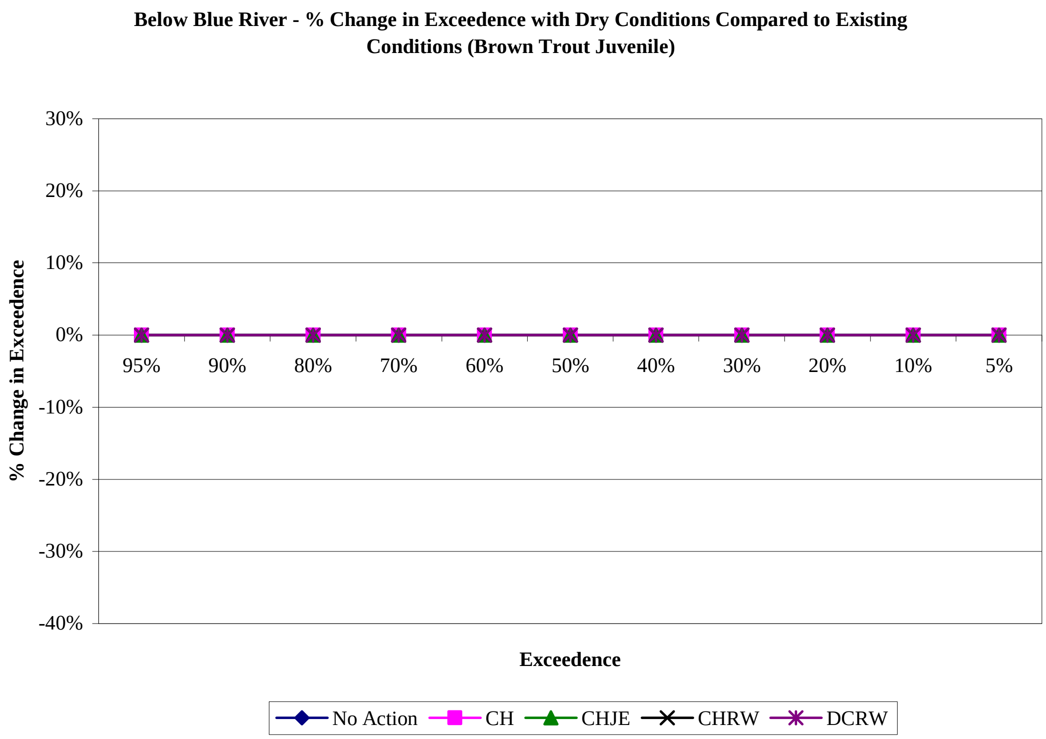


Figure 189. Below Blue River – percent change in exceedence with <u>dry</u> conditions (brown trout juvenile).

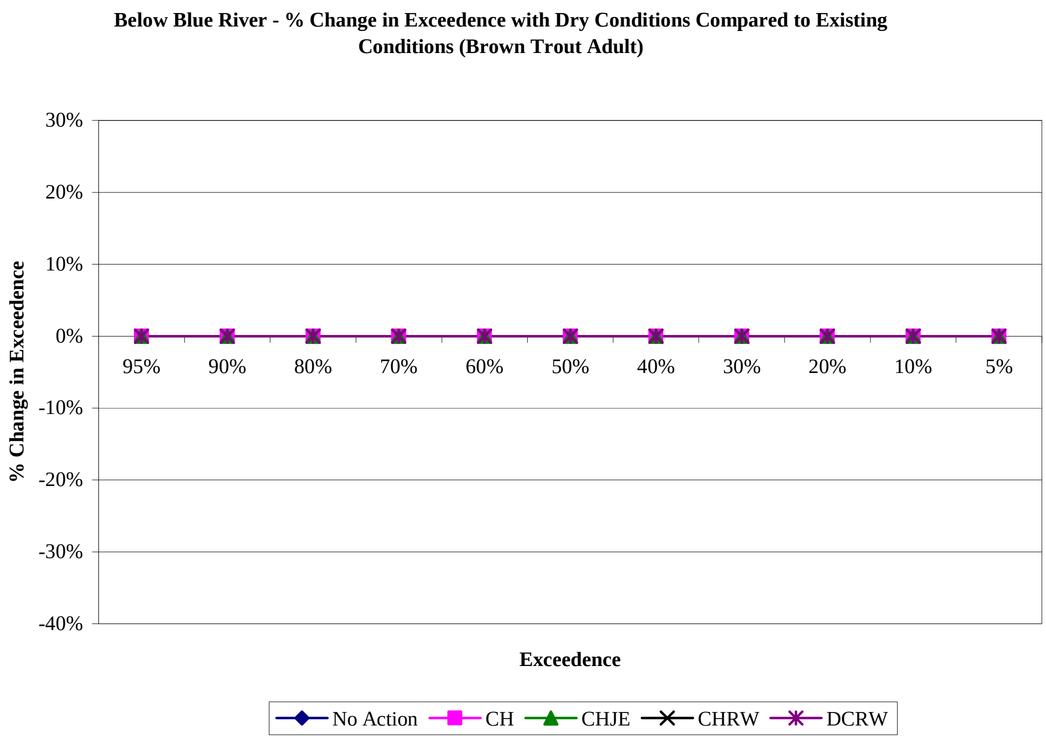


Figure 190. Below Blue River – percent change in exceedence with <u>dry</u> conditions (brown trout adult).

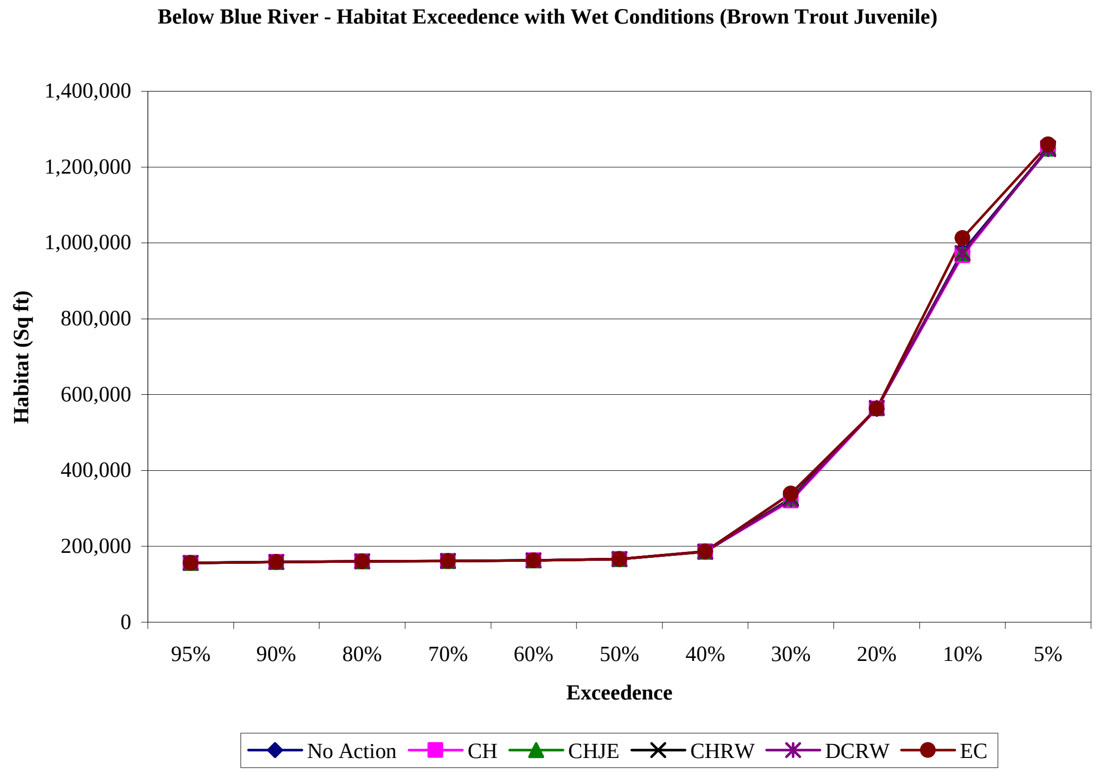


Figure 191. Below Blue River – habitat exceedence with wet conditions (brown trout juvenile).

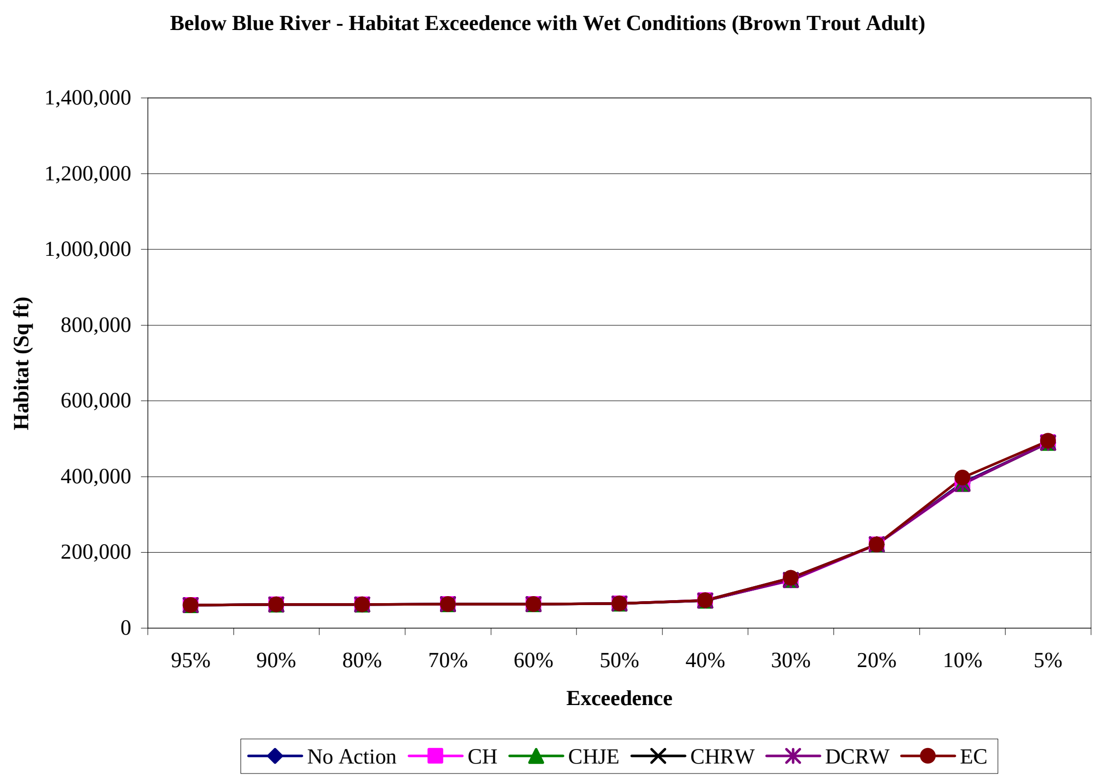


Figure 192. Below Blue River – habitat exceedence with wet conditions (brown trout adult).

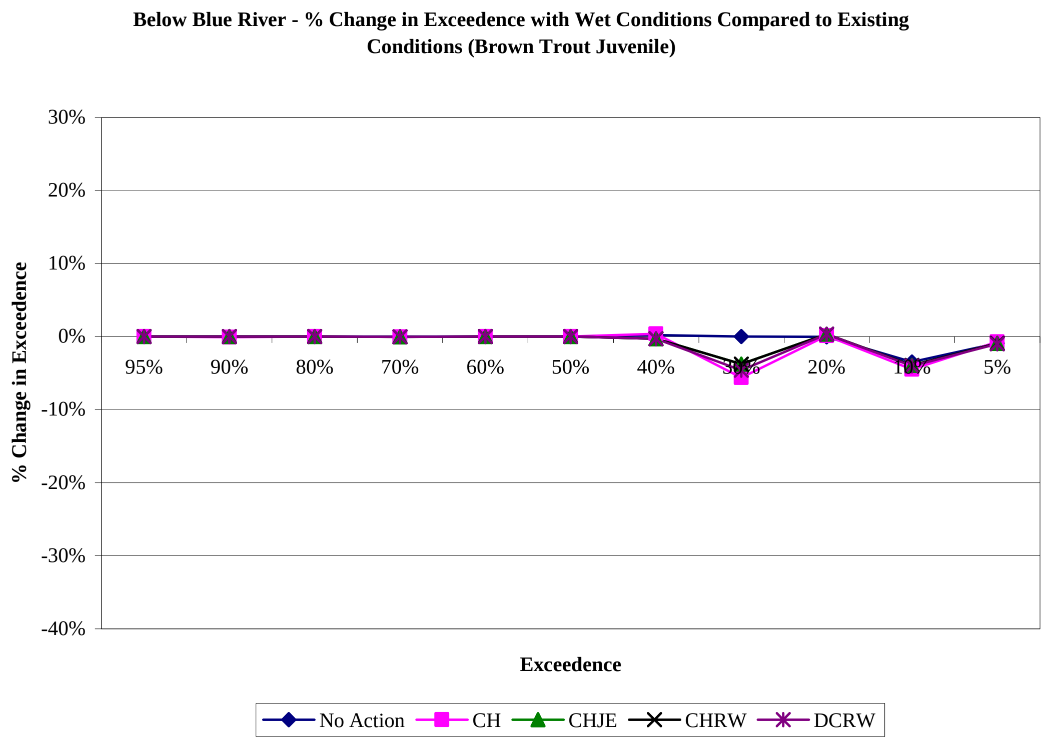


Figure 193. Below Blue River – percent change in exceedence with wet conditions (brown trout juvenile).

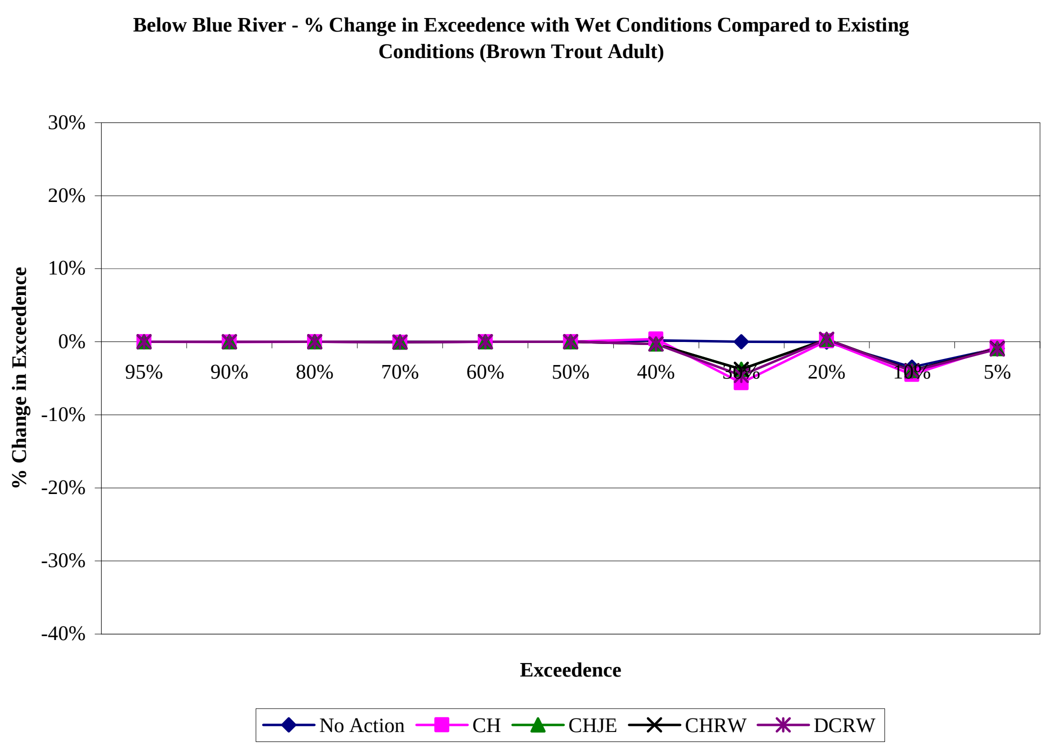


Figure 194. Below Blue River – percent change in exceedence with wet conditions (brown trout adult).

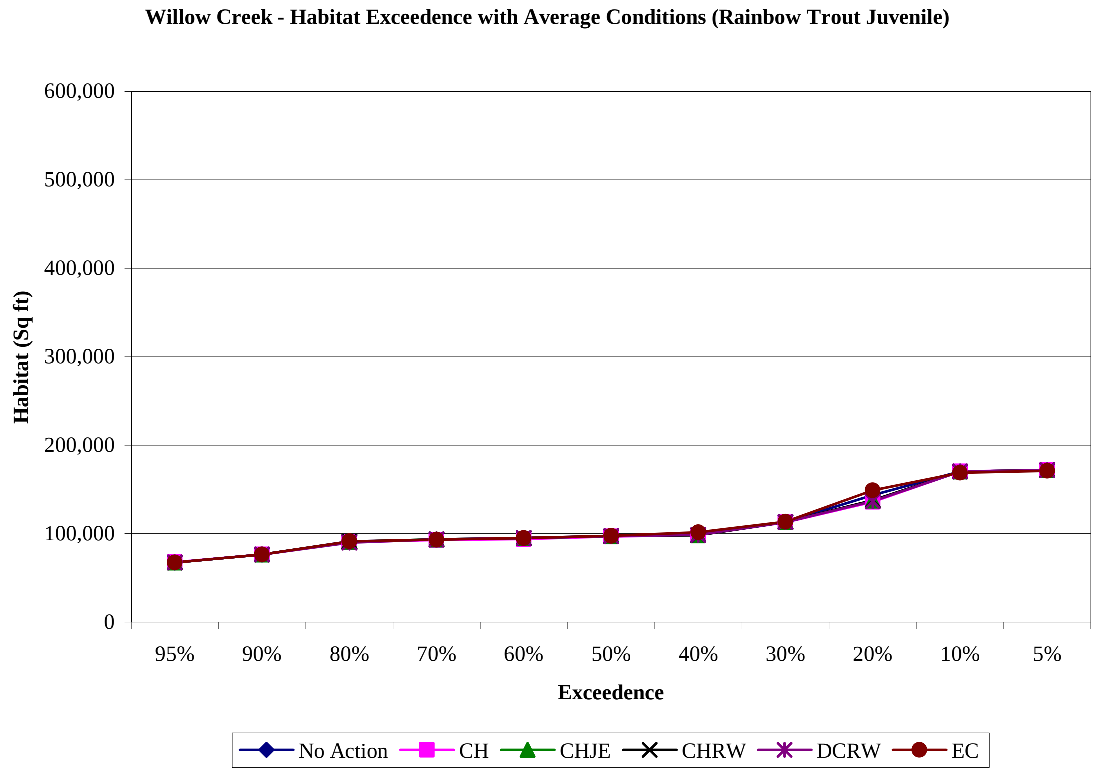


Figure 195. Willow Creek- habitat exceedence with <u>average</u> conditions (rainbow trout juvenile).

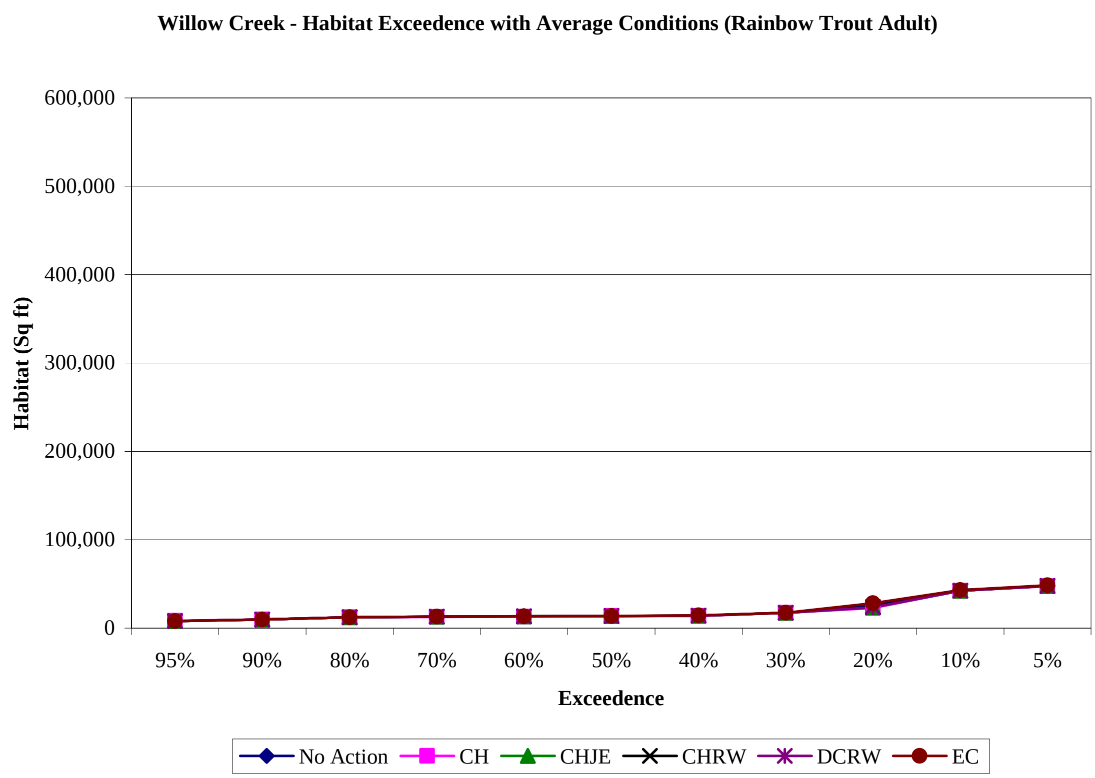


Figure 196. Willow Creek – habitat exceedence with <u>average</u> conditions (rainbow trout adult).

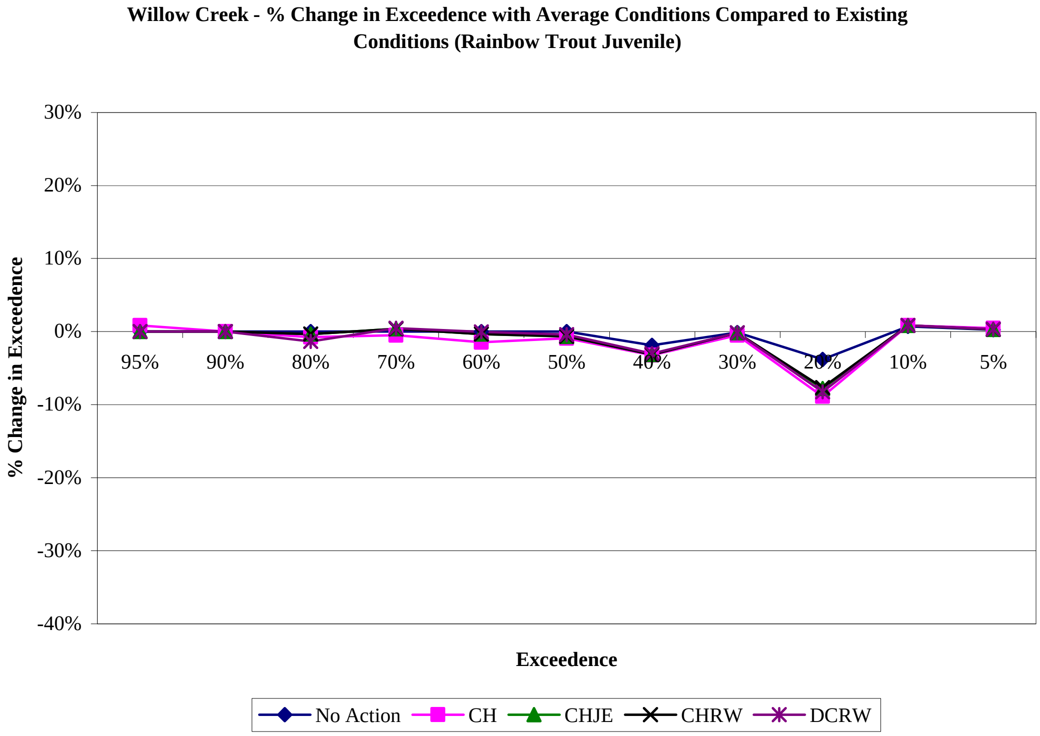


Figure 197. Willow Creek – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile).

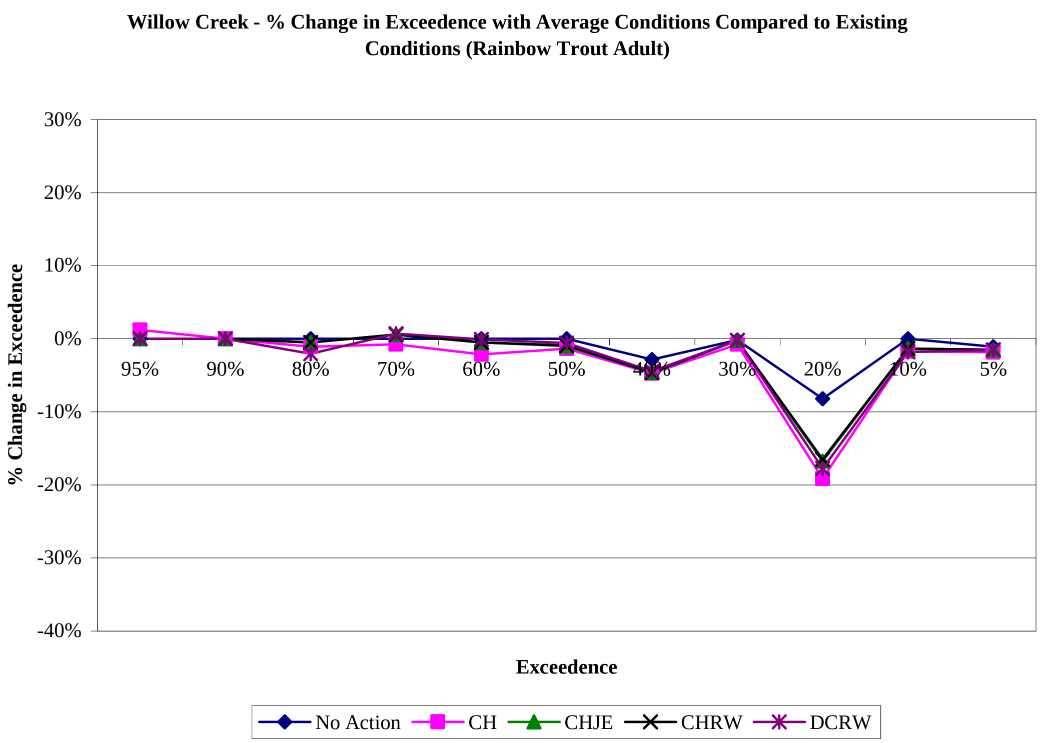


Figure 198. Willow Creek – percent change in exceedence with <u>average</u> conditions (rainbow trout adult).

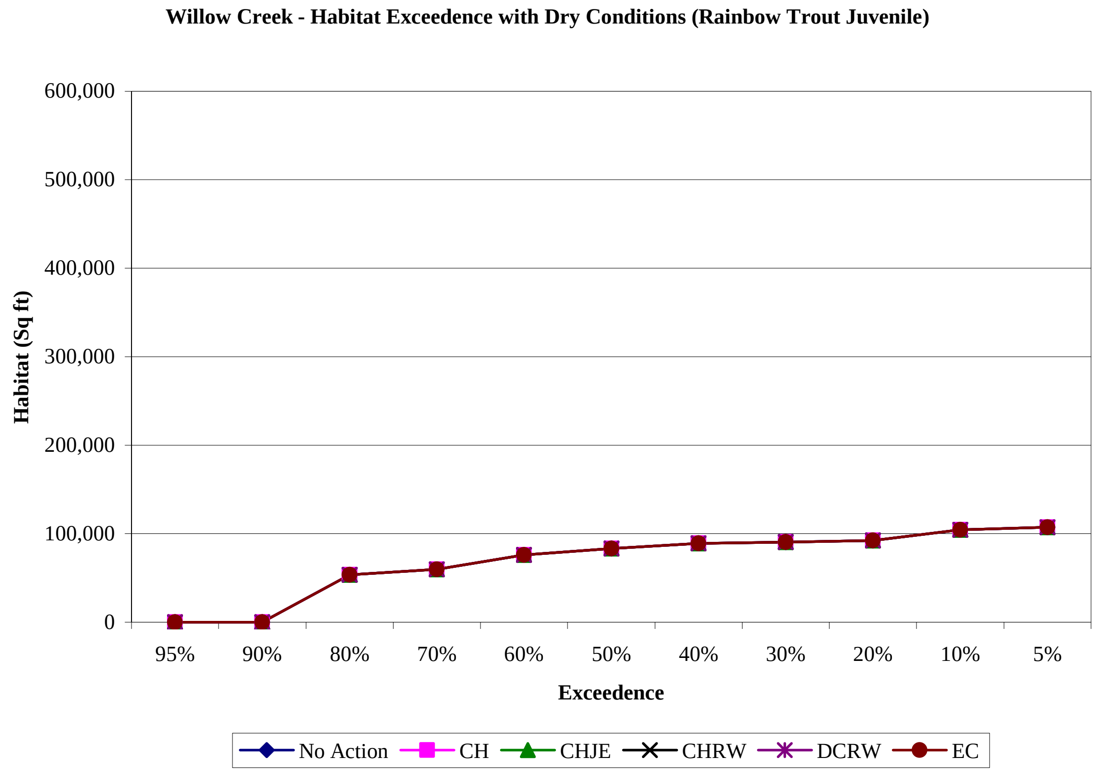


Figure 199. Willow Creek – habitat exceedence with dry conditions (rainbow trout juvenile).

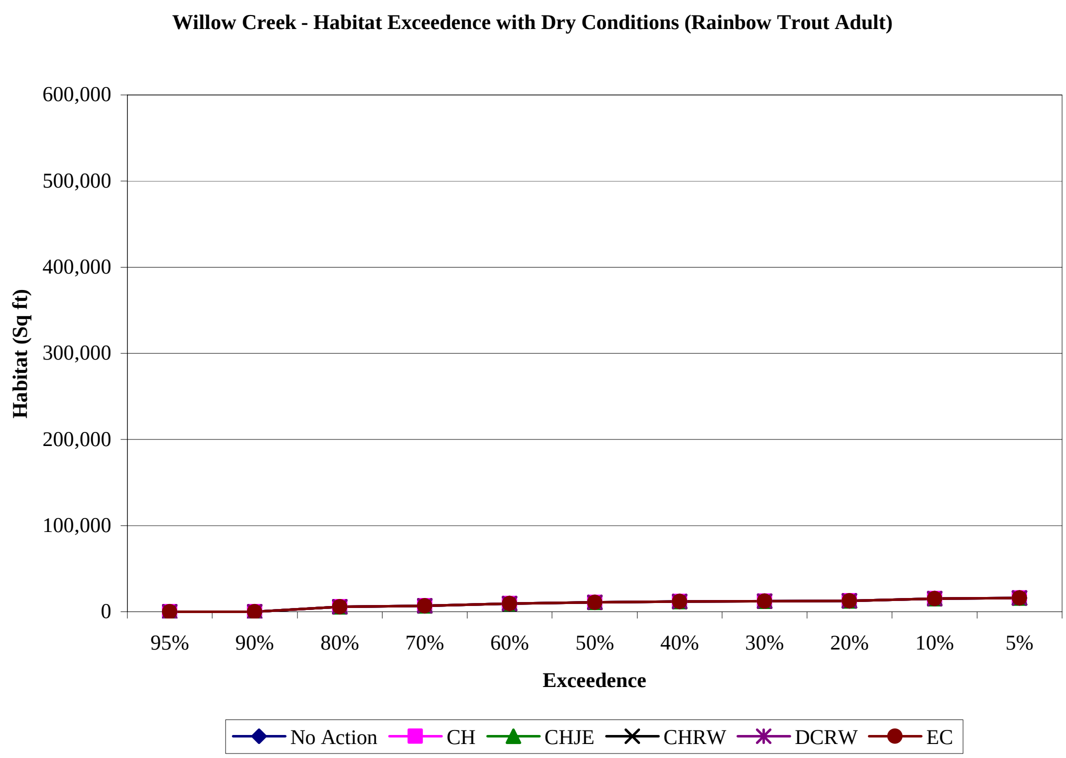


Figure 200. Willow Creek – habitat exceedence with dry conditions (rainbow trout adult).

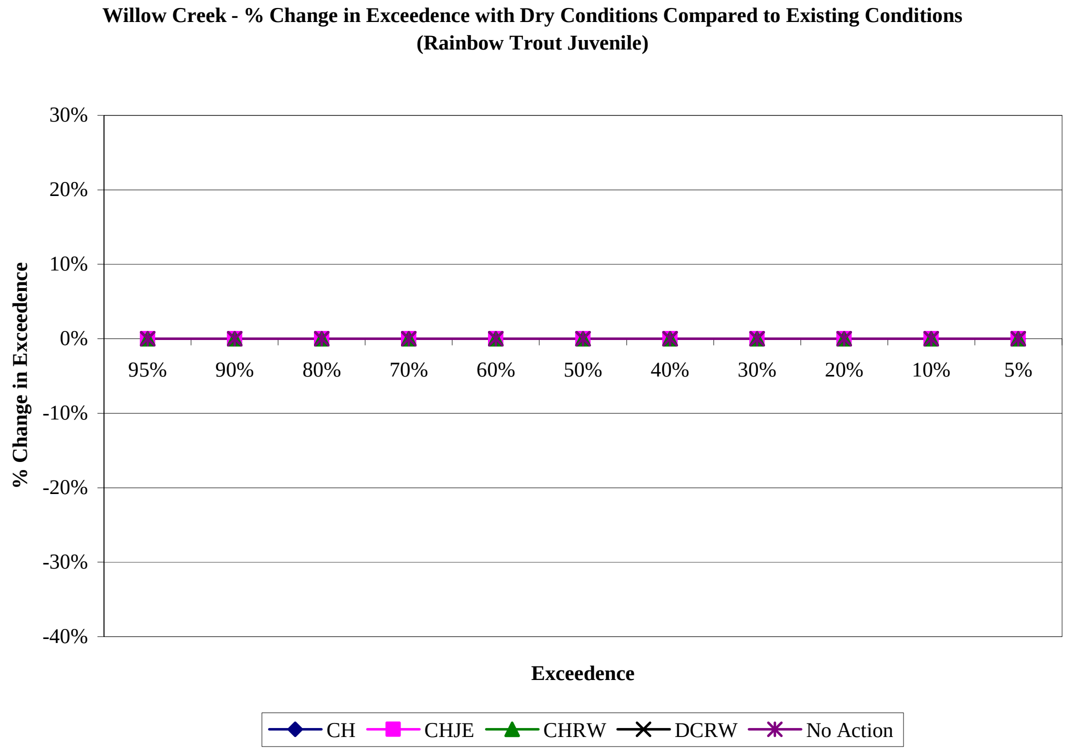


Figure 201. Willow Creek – percent change in exceedence with dry conditions (rainbow trout juvenile).

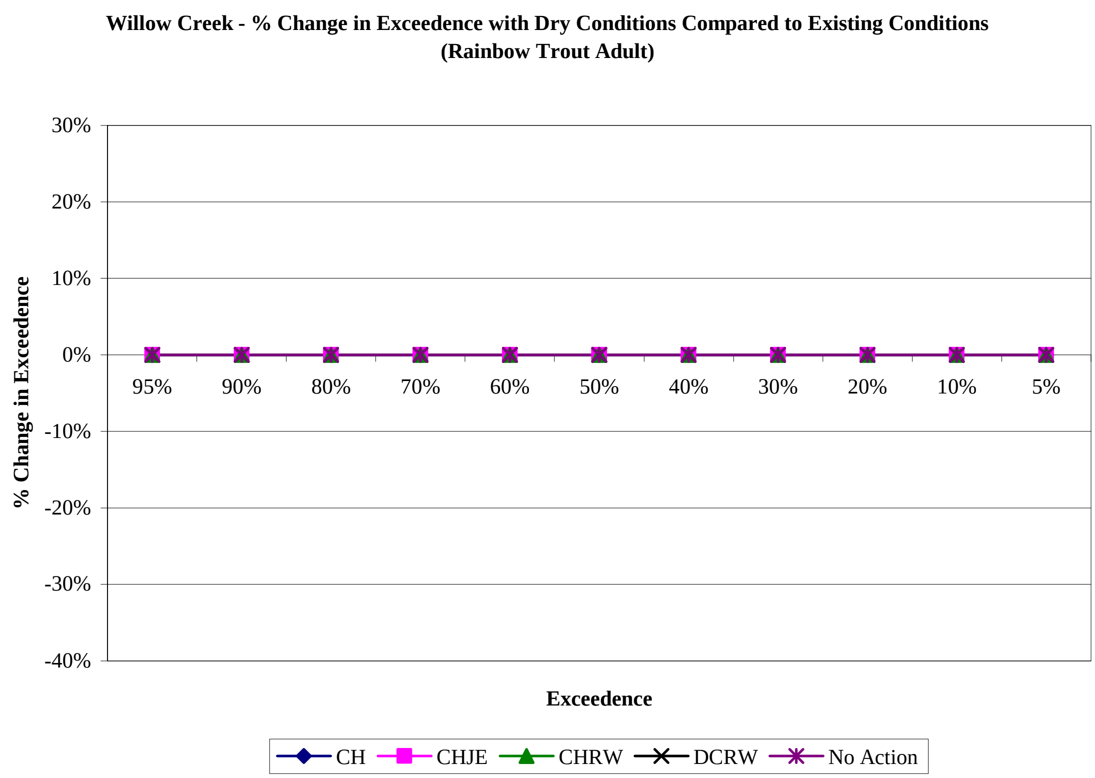


Figure 202. Willow Creek – percent change in exceedence with dry conditions (rainbow trout adult).

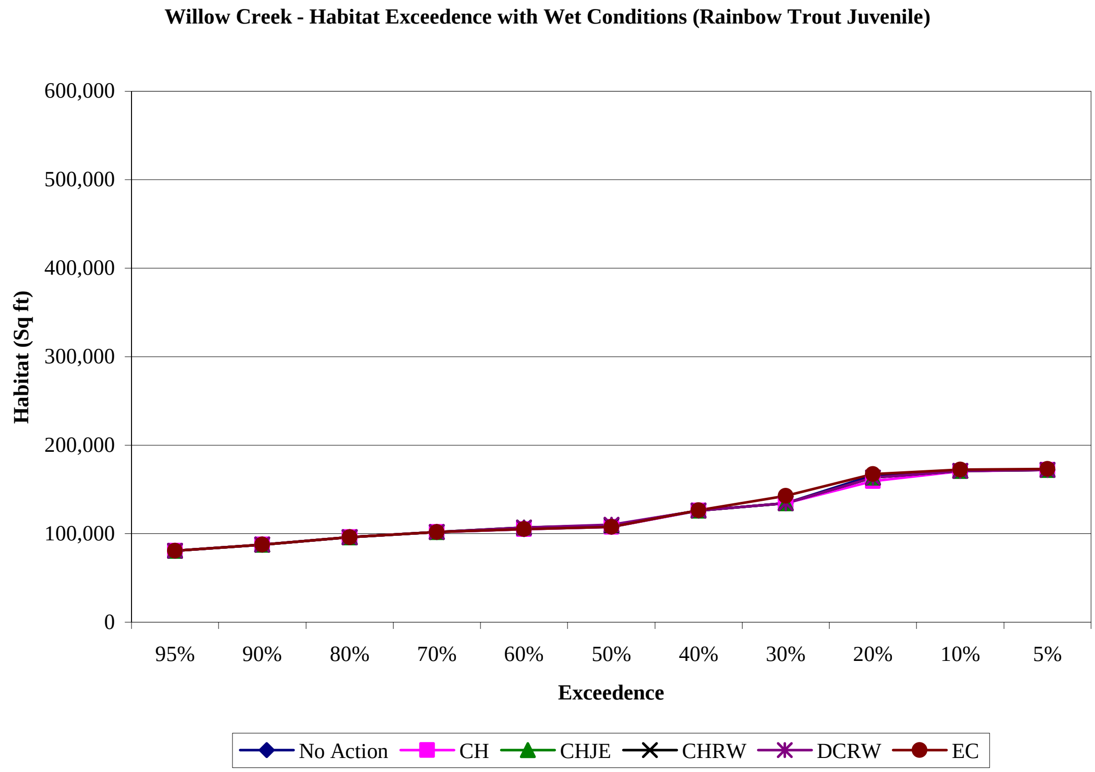


Figure 203. Willow Creek – habitat exceedence with <u>wet</u> conditions (rainbow trout juvenile).

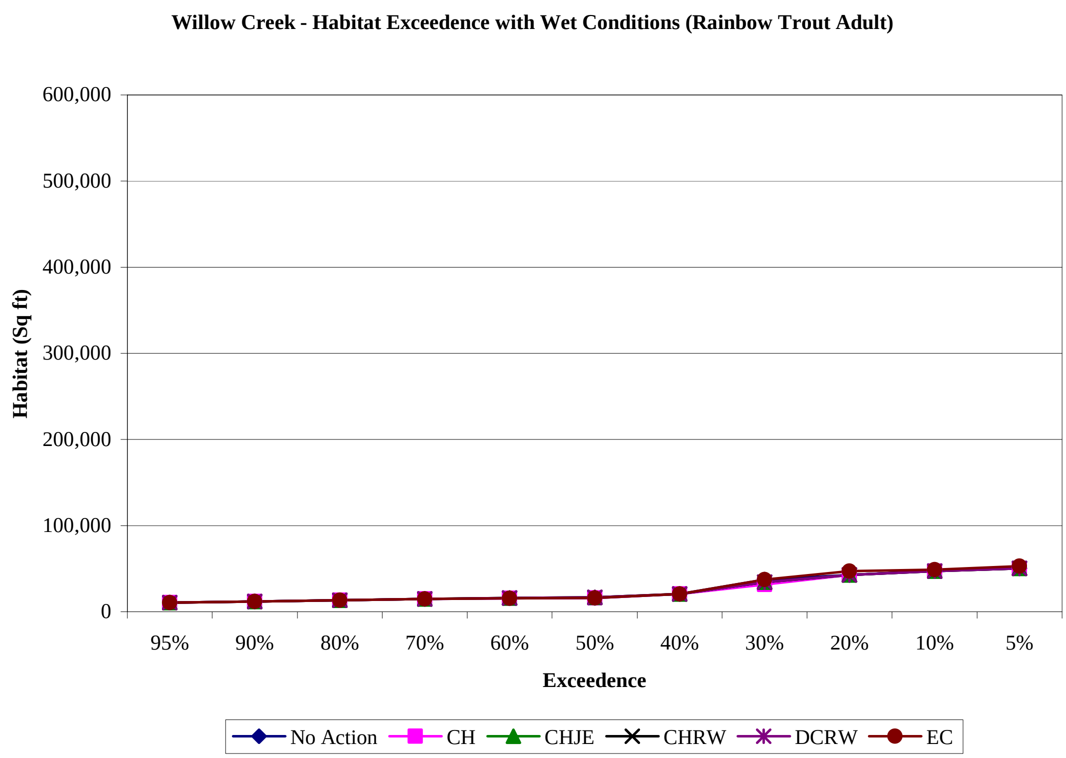


Figure 204. Willow Creek – habitat exceedence with <u>wet</u> conditions (rainbow trout adult).

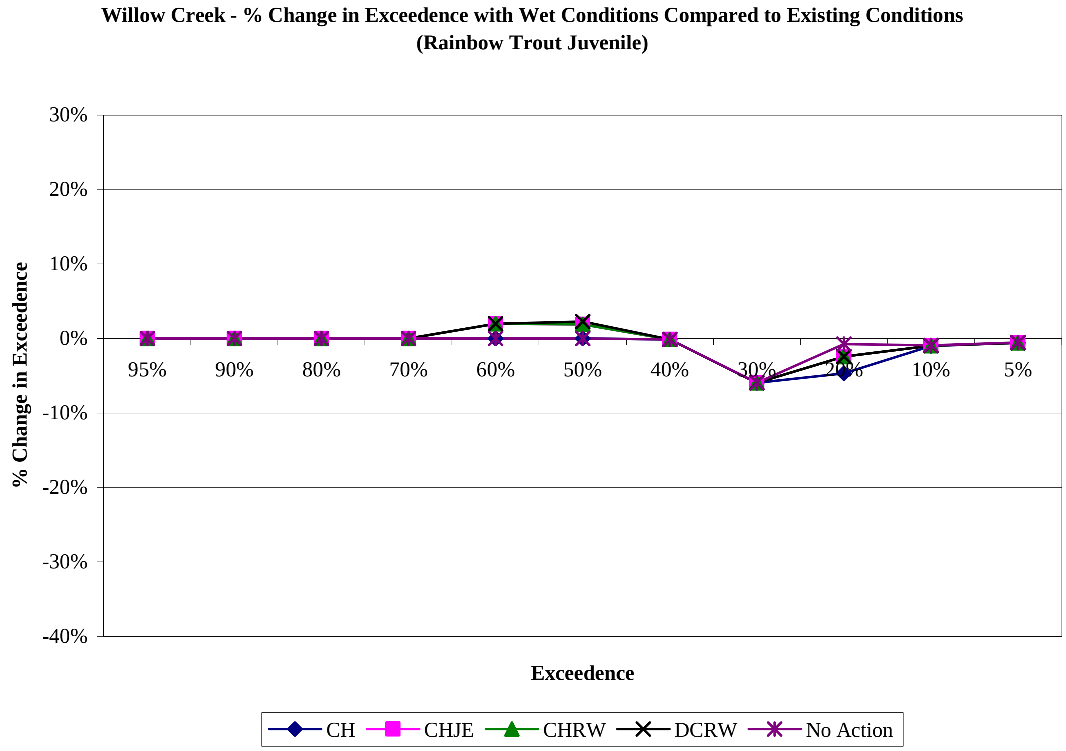


Figure 205. Willow Creek – percent change in exceedence with wet conditions (rainbow trout juvenile).

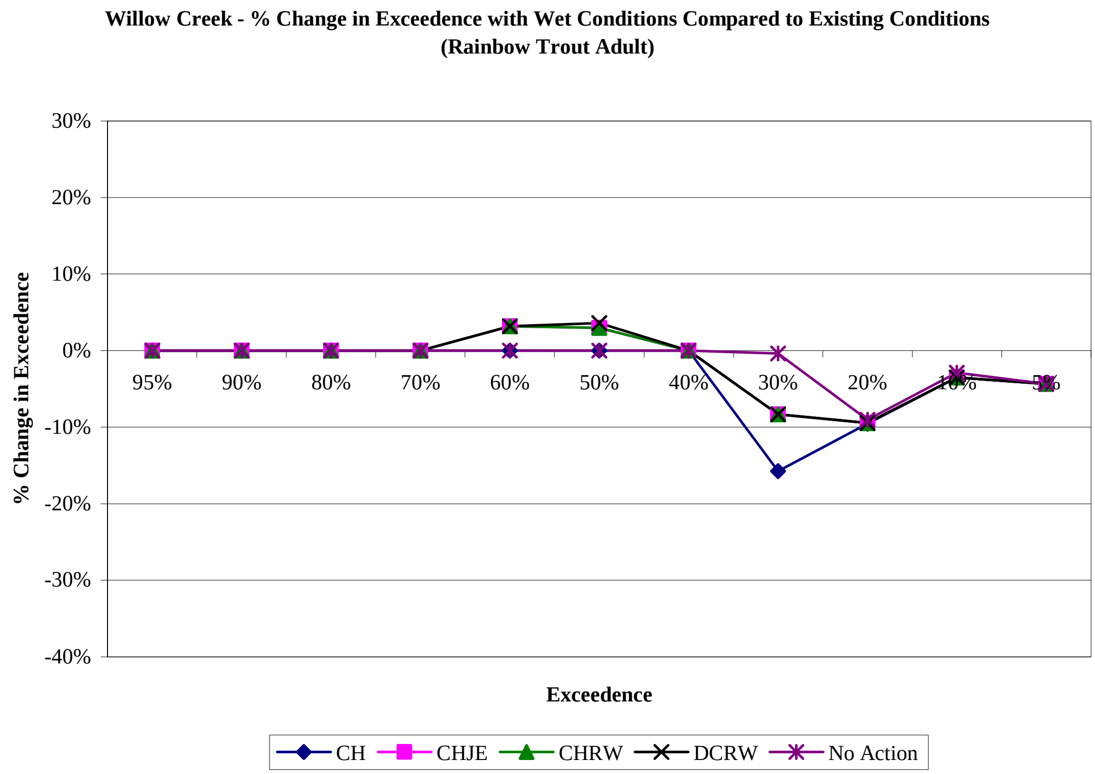


Figure 206. Willow Creek – percent change in exceedence with wet conditions (rainbow trout adult).

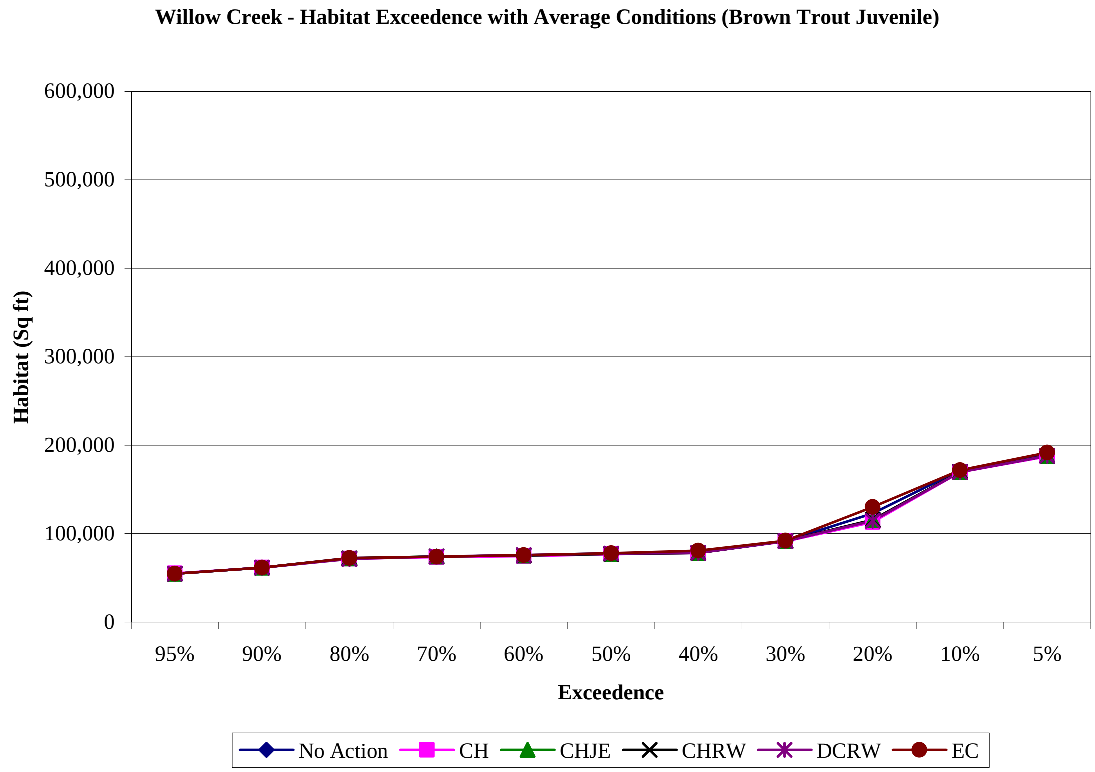


Figure 207. Willow Creek – habitat exceedence with <u>average</u> conditions (brown trout juvenile).

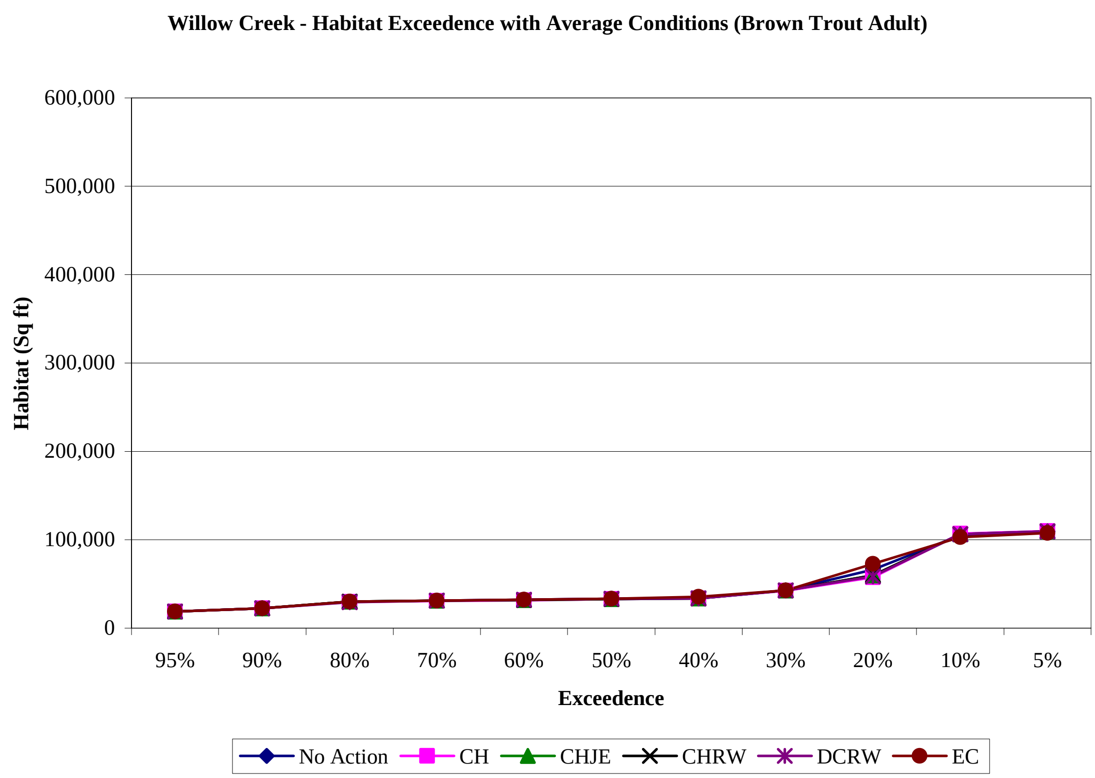


Figure 208. Willow Creek – habitat exceedence with <u>average</u> conditions (brown trout adult).

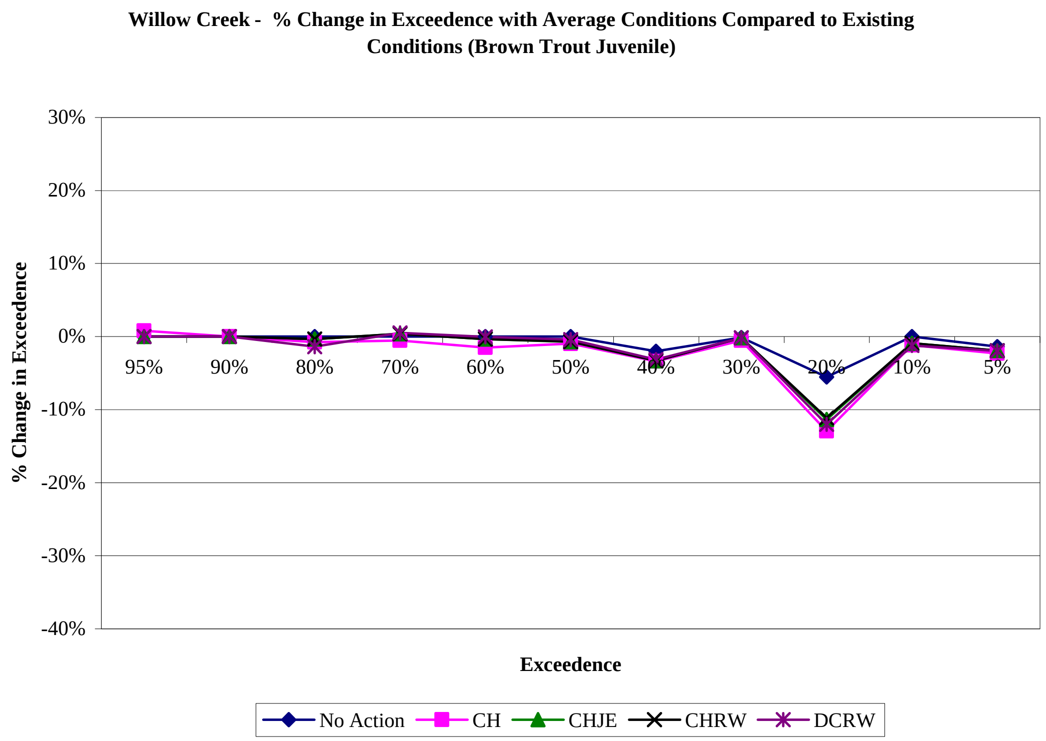


Figure 209. Willow Creek – percent change in exceedence with <u>average</u> conditions (brown trout juvenile).

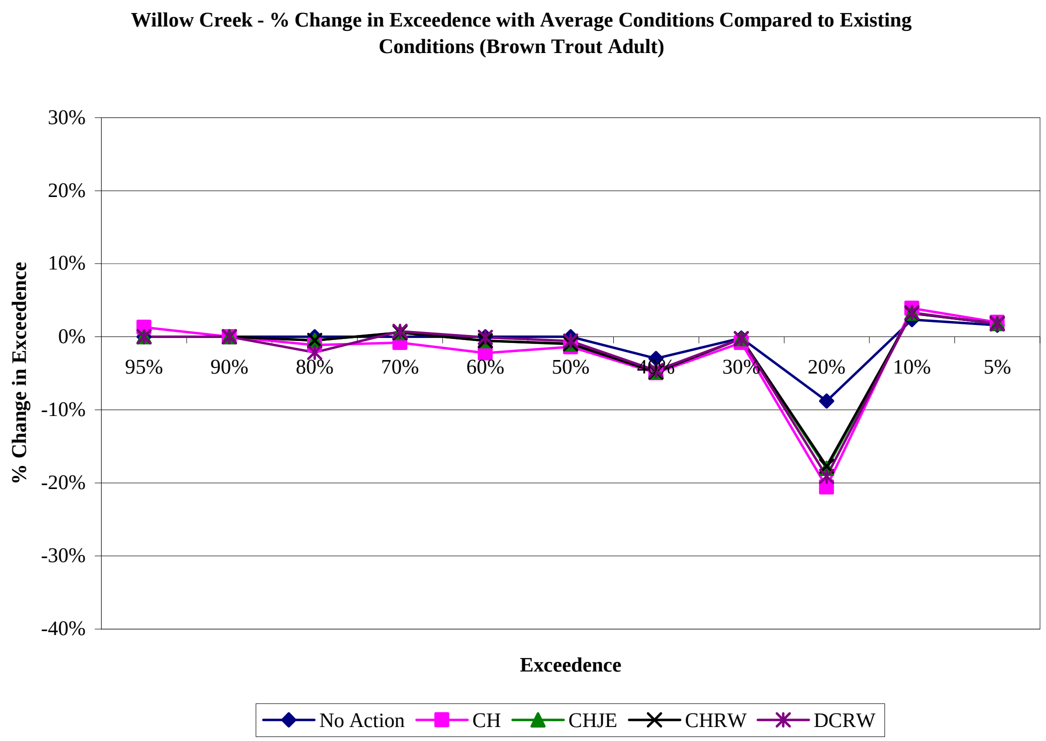


Figure 210. Willow Creek – percent change in exceedence with <u>average</u> conditions (brown trout adult).

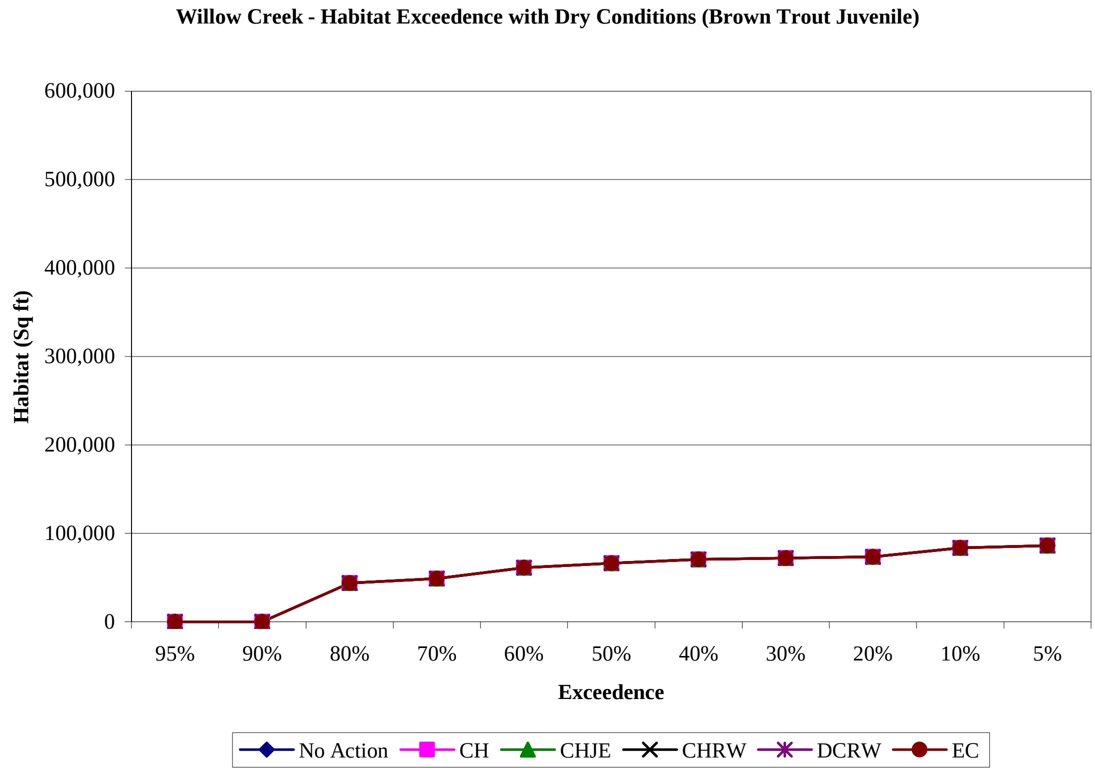


Figure 211. Willow Creek – habitat exceedence with dry conditions (brown trout juvenile).

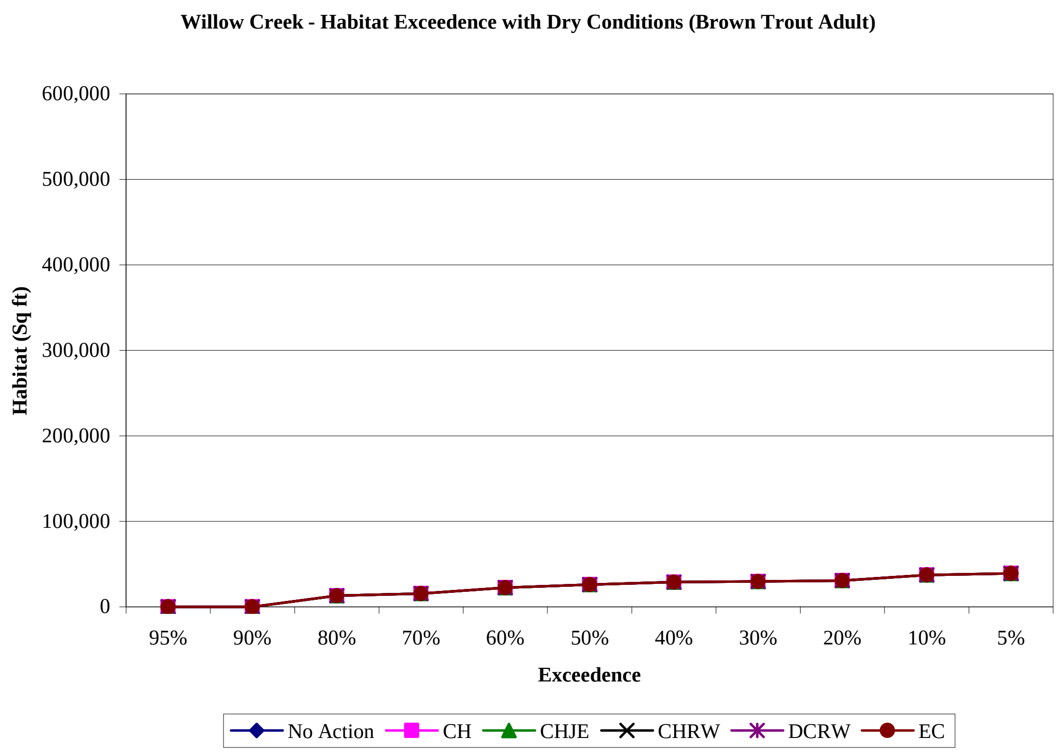


Figure 212. Willow Creek – habitat exceedence with dry conditions (brown trout adult).

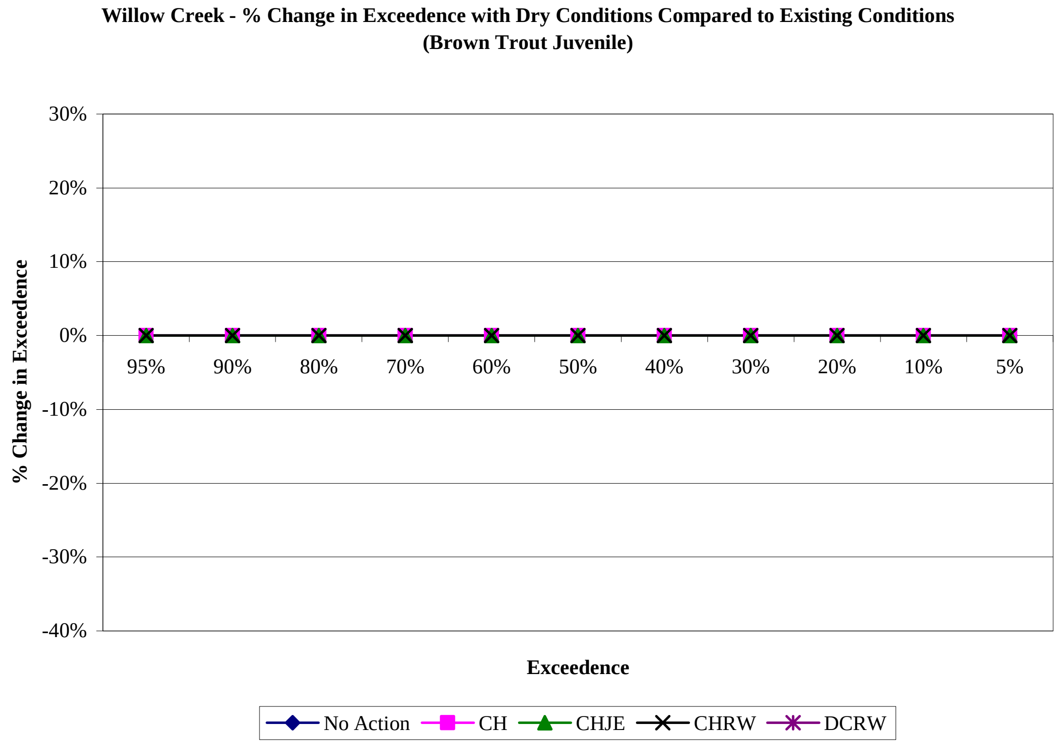


Figure 213. Willow Creek – percent change in exceedence with dry conditions (brown trout juvenile).

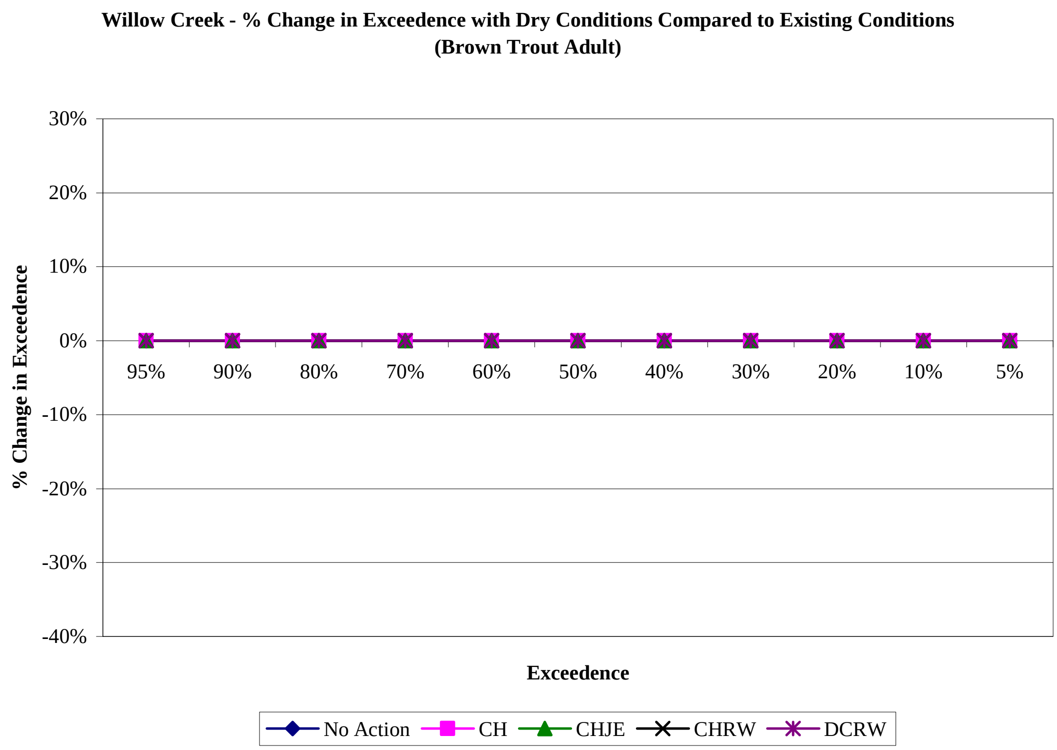


Figure 214. Willow Creek – percent change in exceedence with dry conditions (brown trout adult).

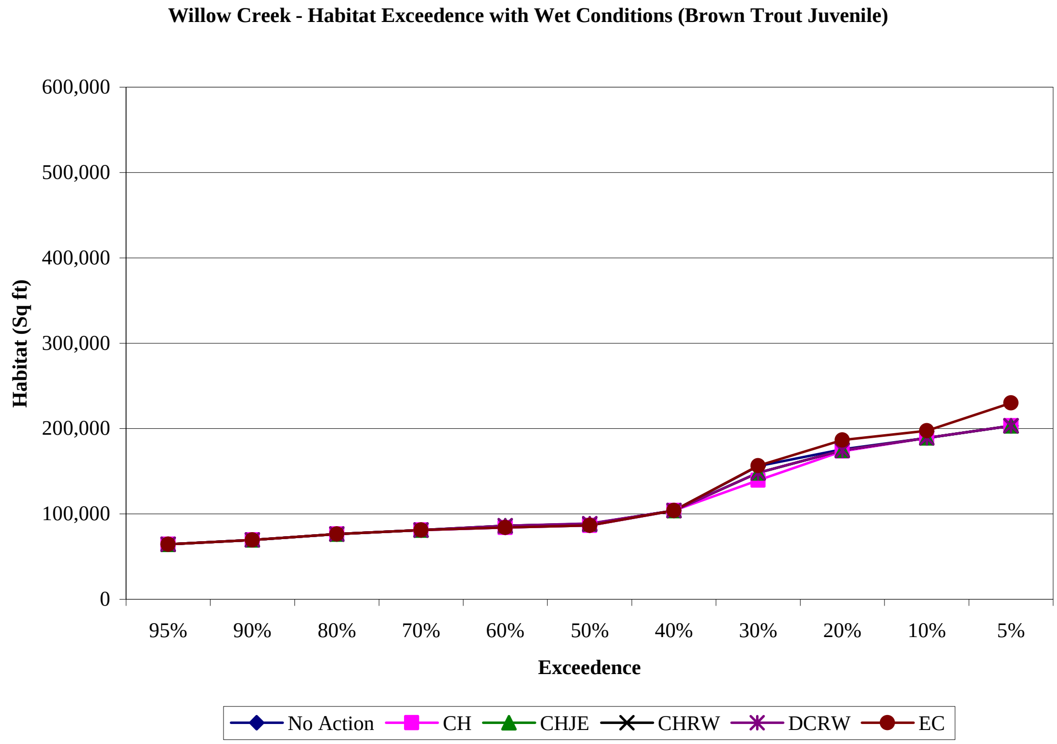


Figure 215. Willow Creek – habitat exceedence with wet conditions (brown trout juvenile).

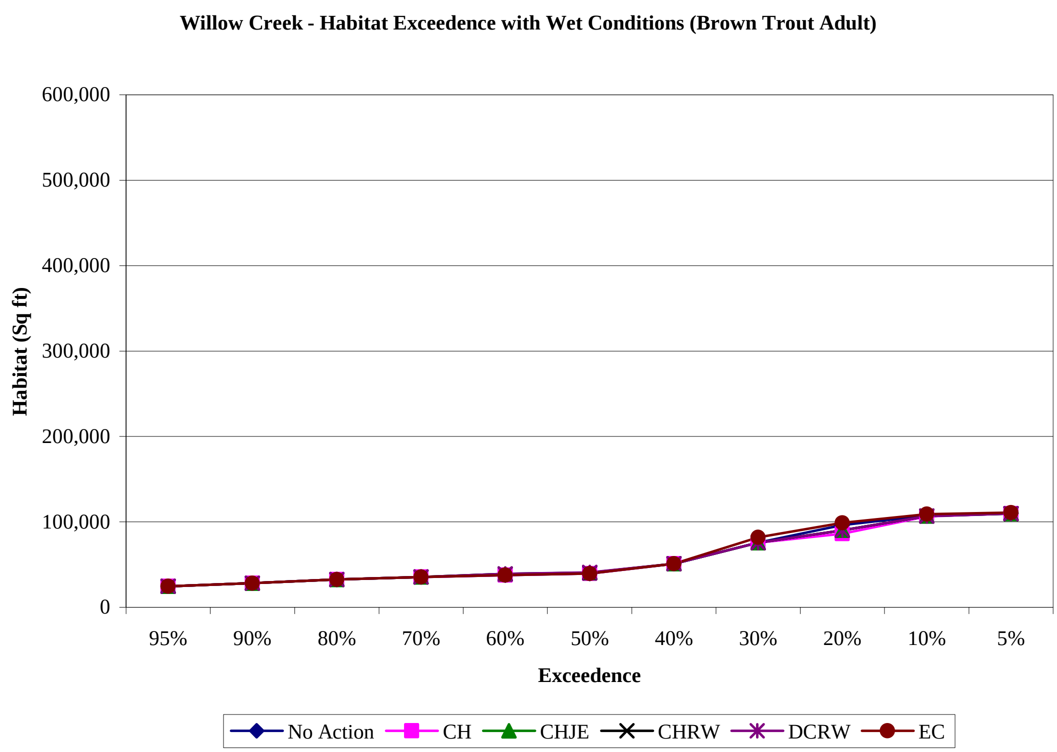


Figure 216. Willow Creek – habitat exceedence with wet conditions (brown trout adult).

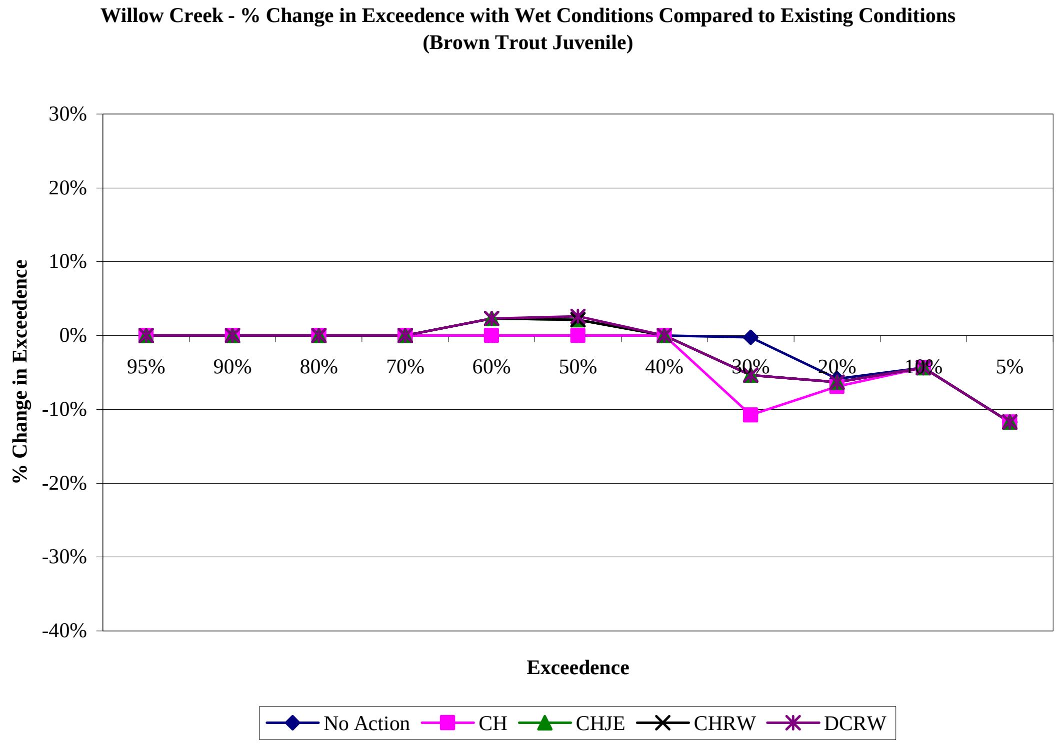


Figure 217. Willow Creek – percent change in exceedence with wet conditions (brown trout juvenile).

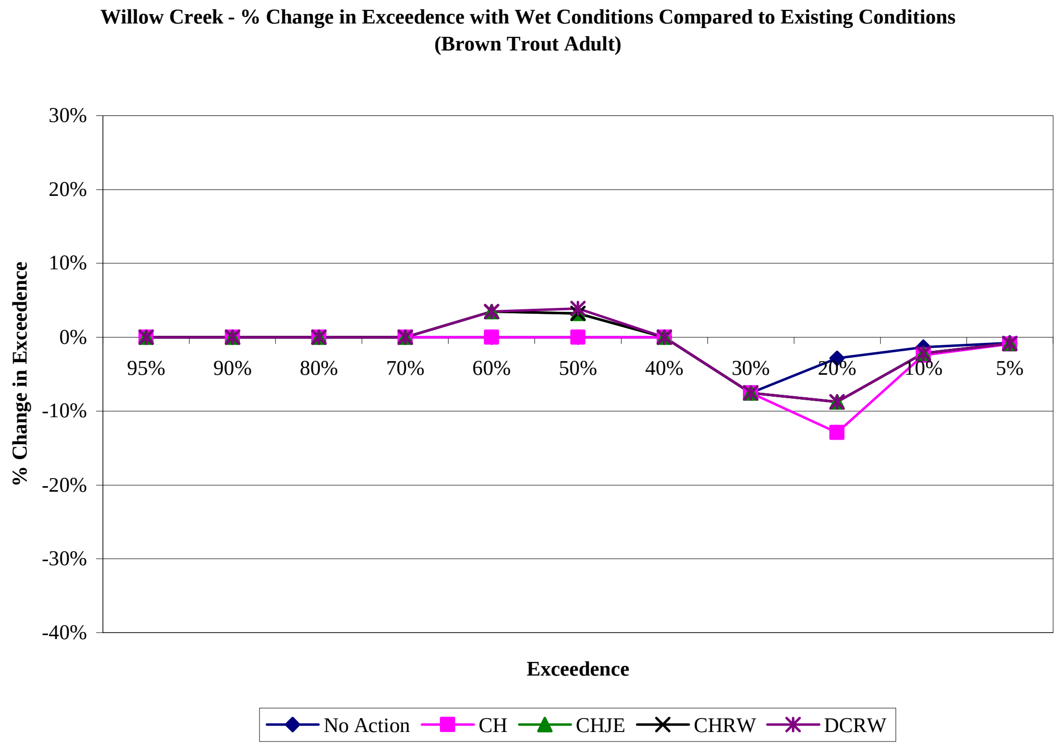


Figure 218. Willow Creek – percent change in exceedence with wet conditions (brown trout adult).

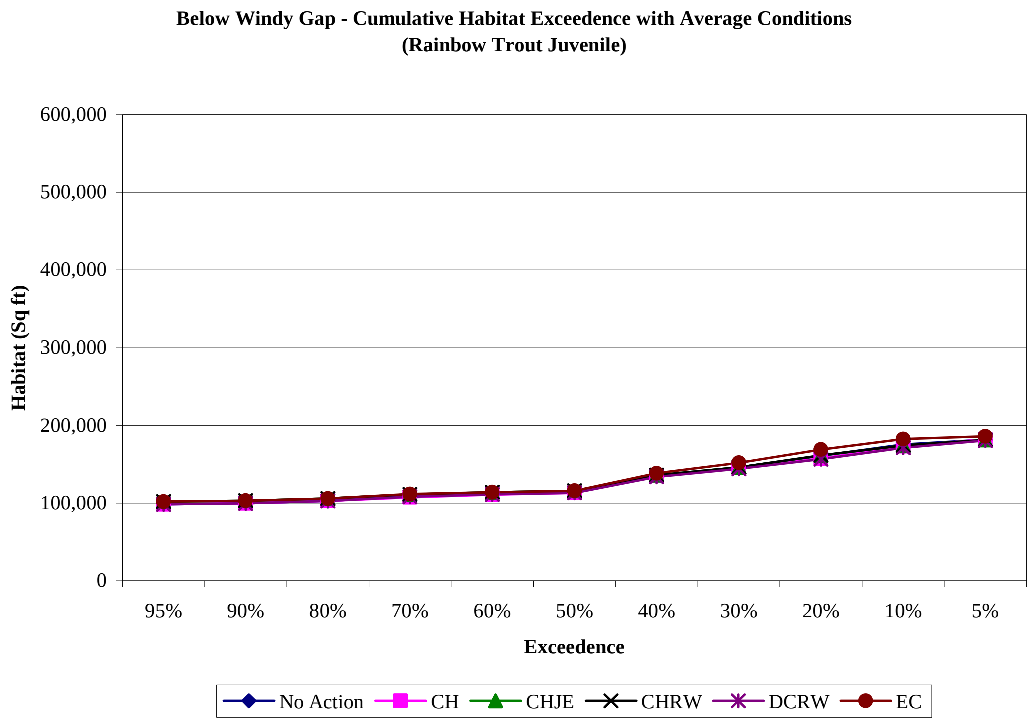


Figure 219. Below Windy Gap – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

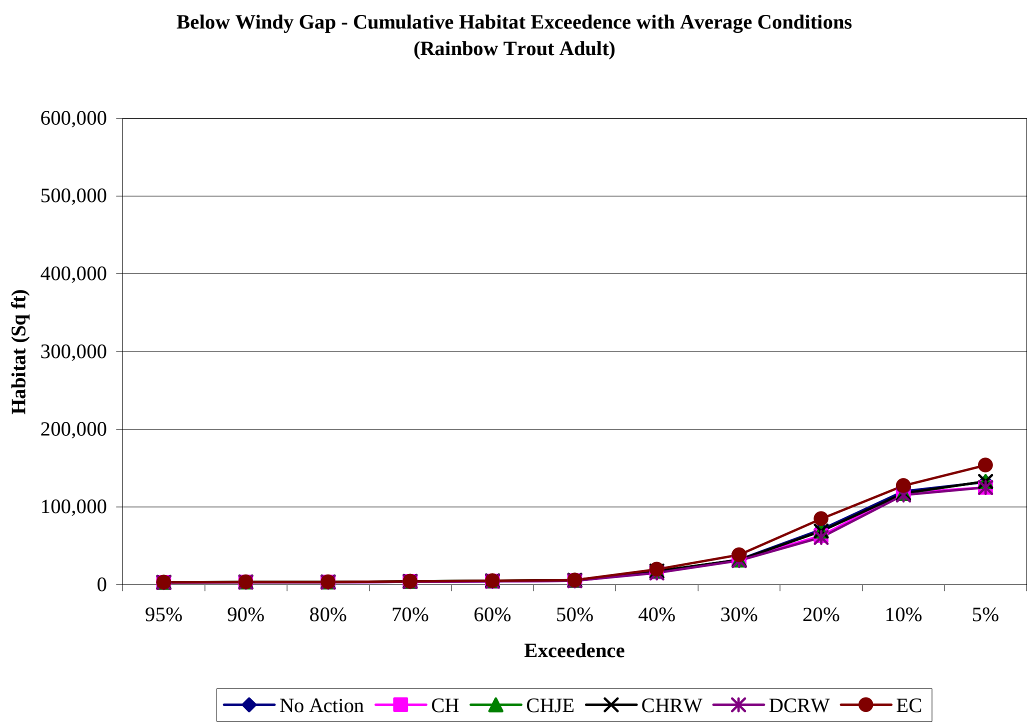


Figure 220. Below Windy Gap – habitat exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

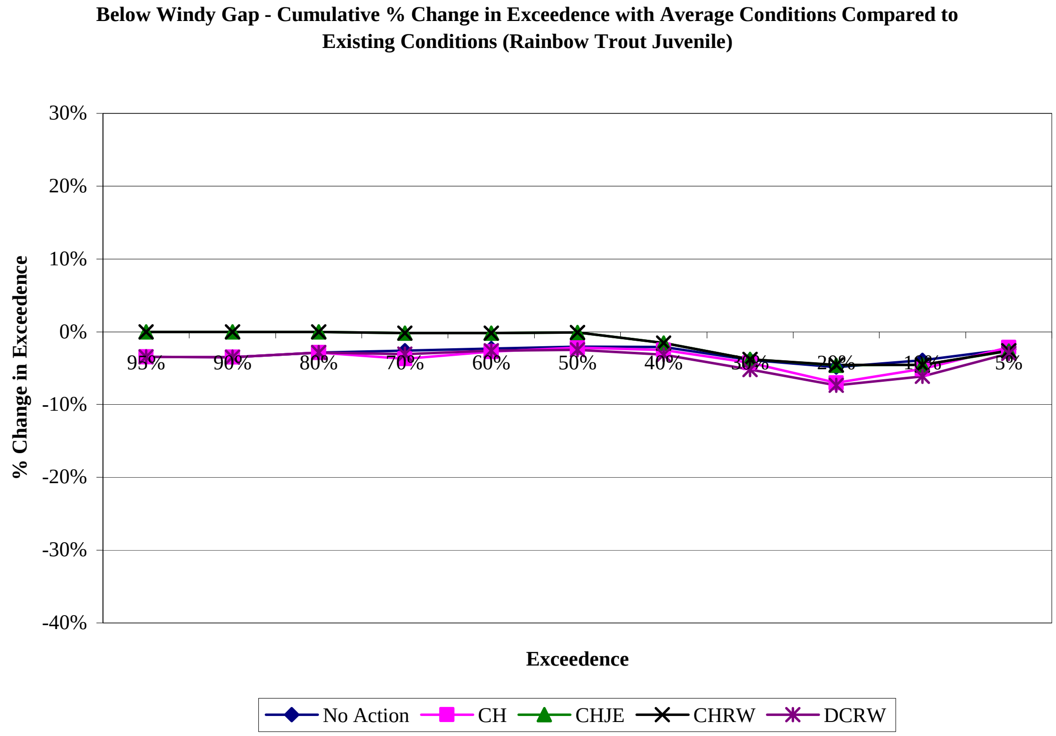


Figure 221. Below Windy Gap – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects .

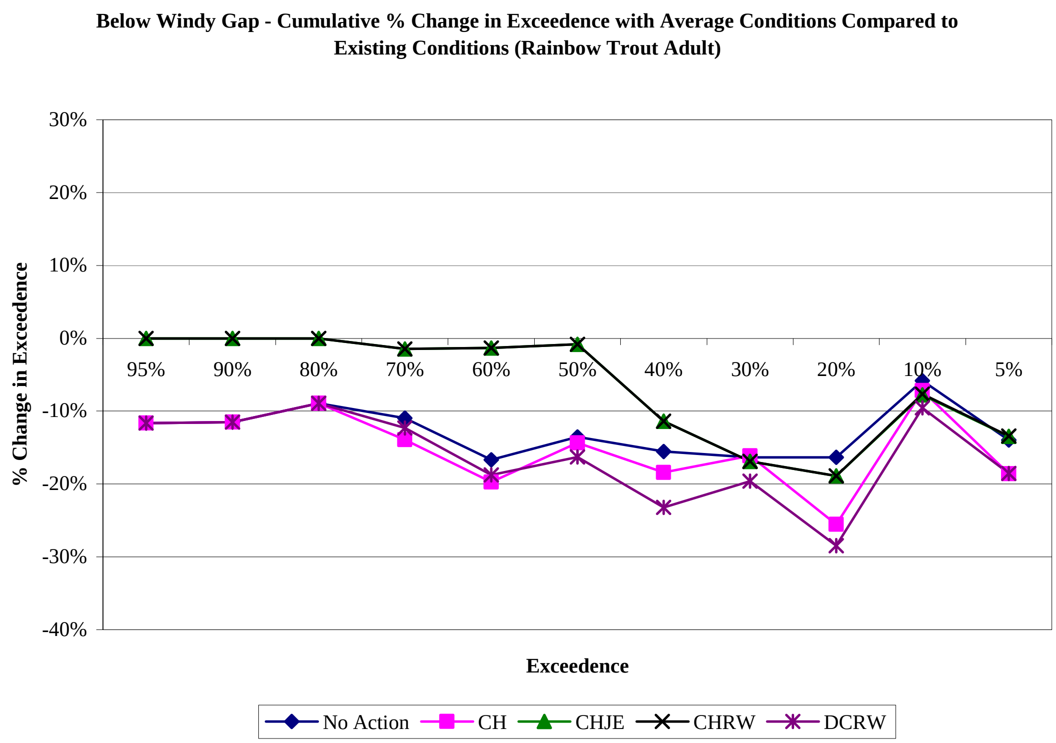


Figure 222. Below Windy Gap – percent change in exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects .

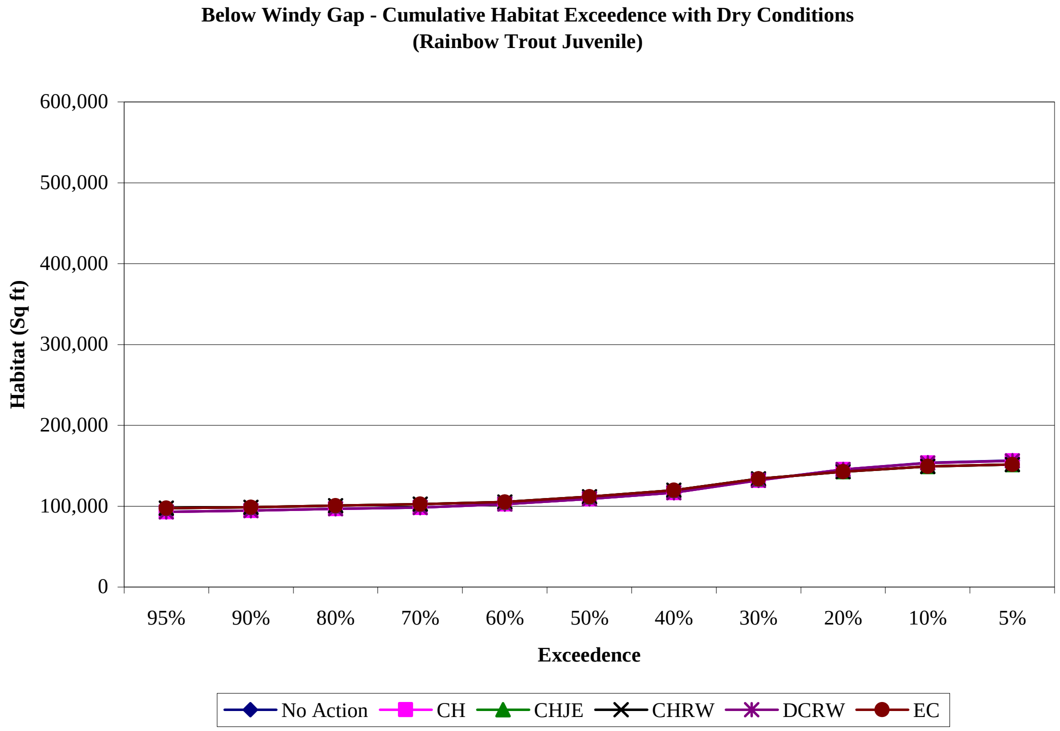


Figure 223. Below Windy Gap – habitat exceedence with dry conditions (rainbow trout juvenile) cumulative effects.

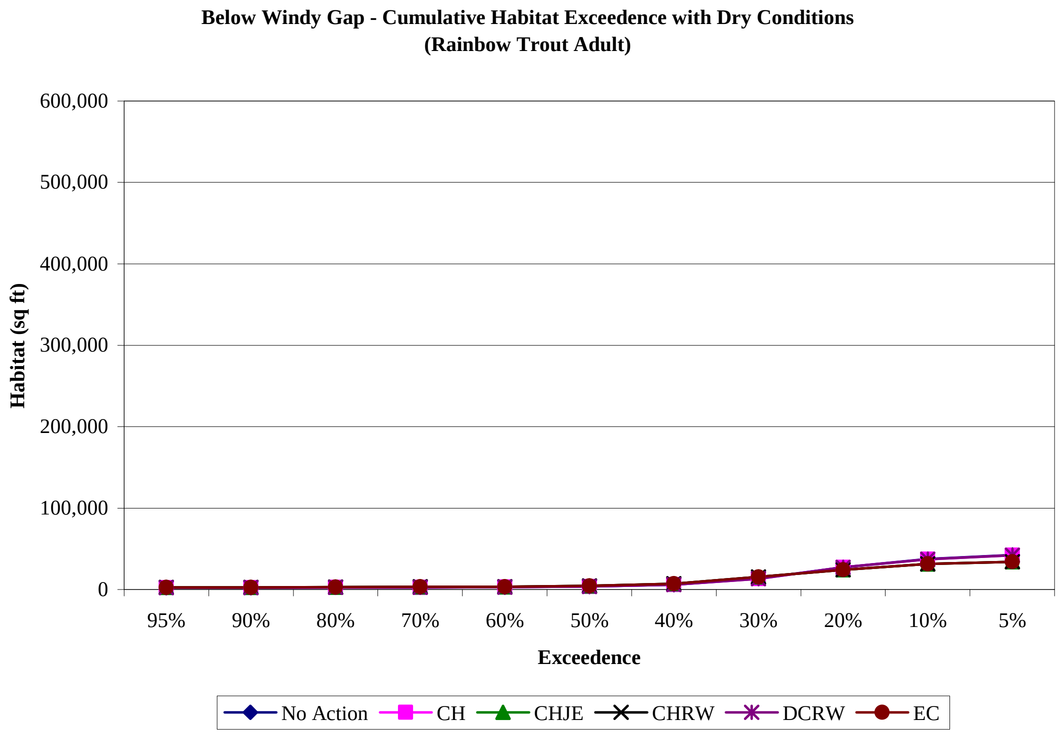


Figure 224. Below Windy Gap – habitat exceedence with dry conditions (rainbow trout adult) cumulative effects.

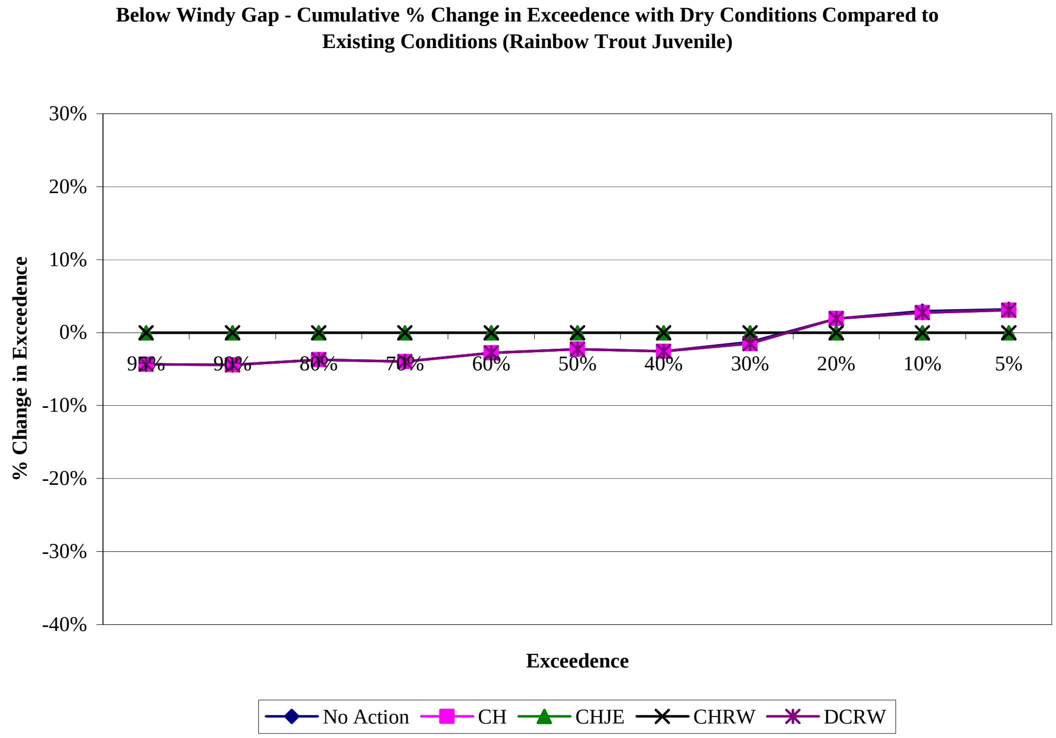


Figure 225. Below Windy Gap – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile) cumulative effects.

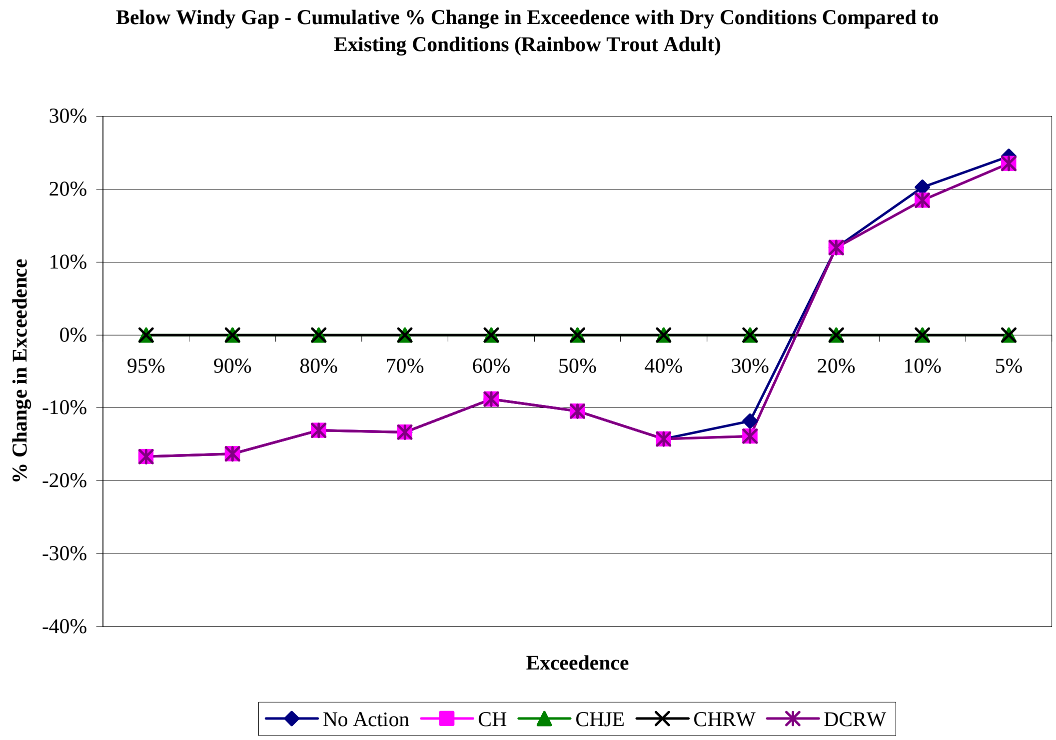


Figure 226. Below Windy Gap – percent exceedence with <u>dry</u> conditions (rainbow trout adult) cumulative effects.

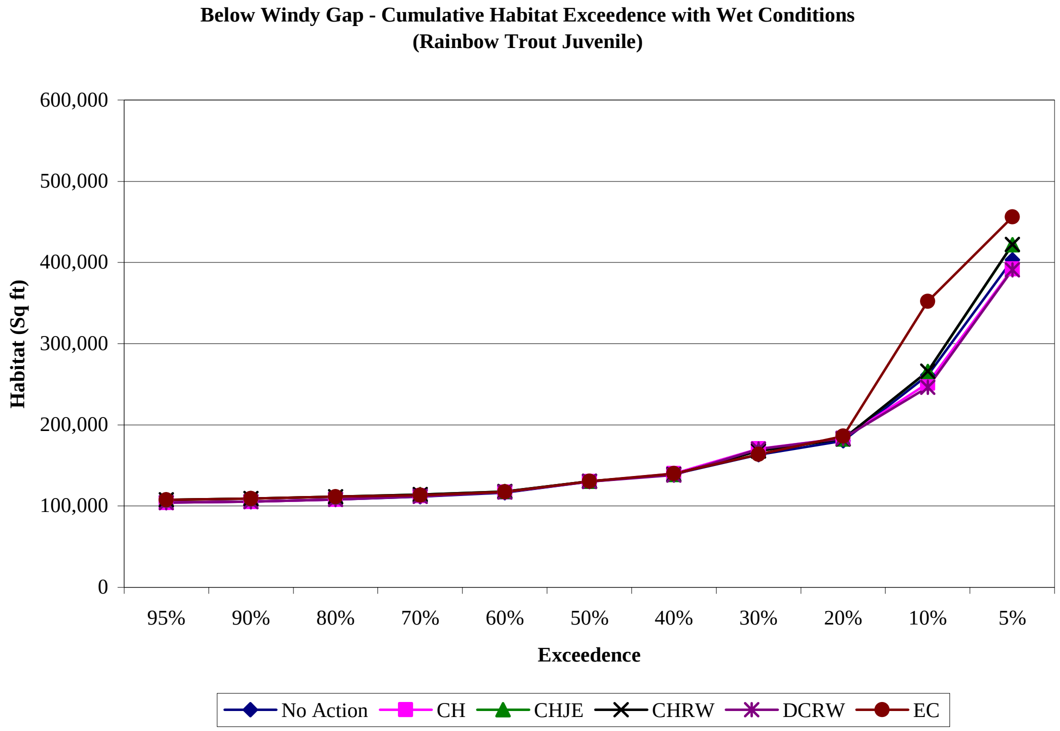


Figure 227. Below Windy Gap – habitat exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

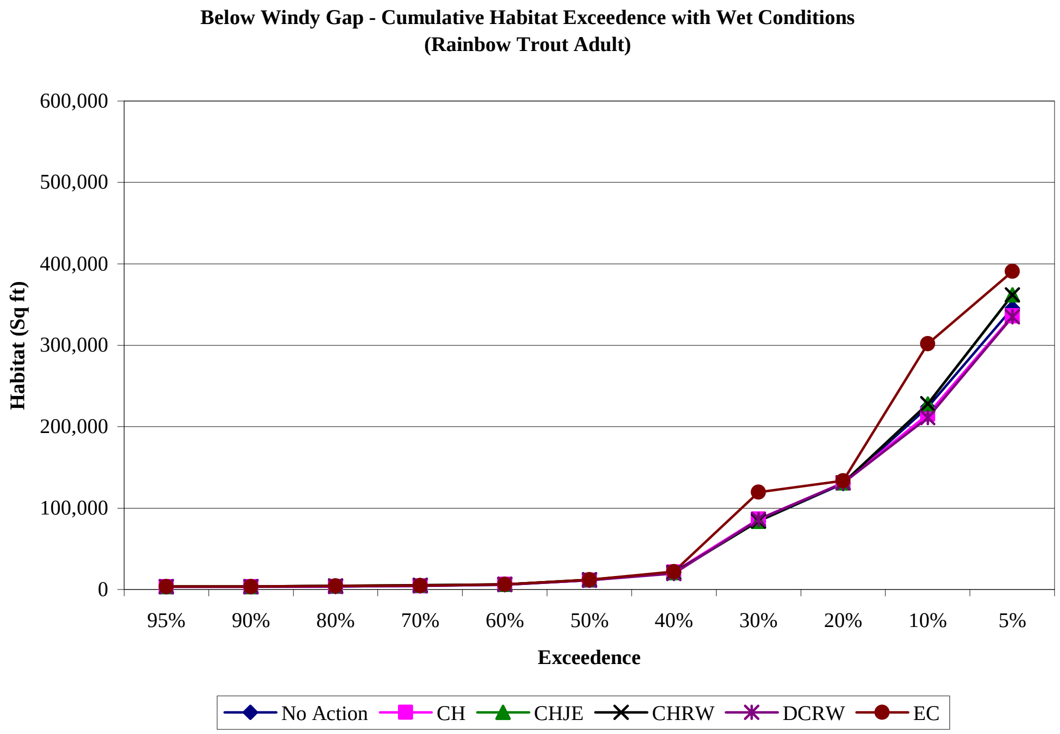


Figure 228. Below Windy Gap – habitat exceedence with wet conditions (rainbow trout adult) cumulative effects.

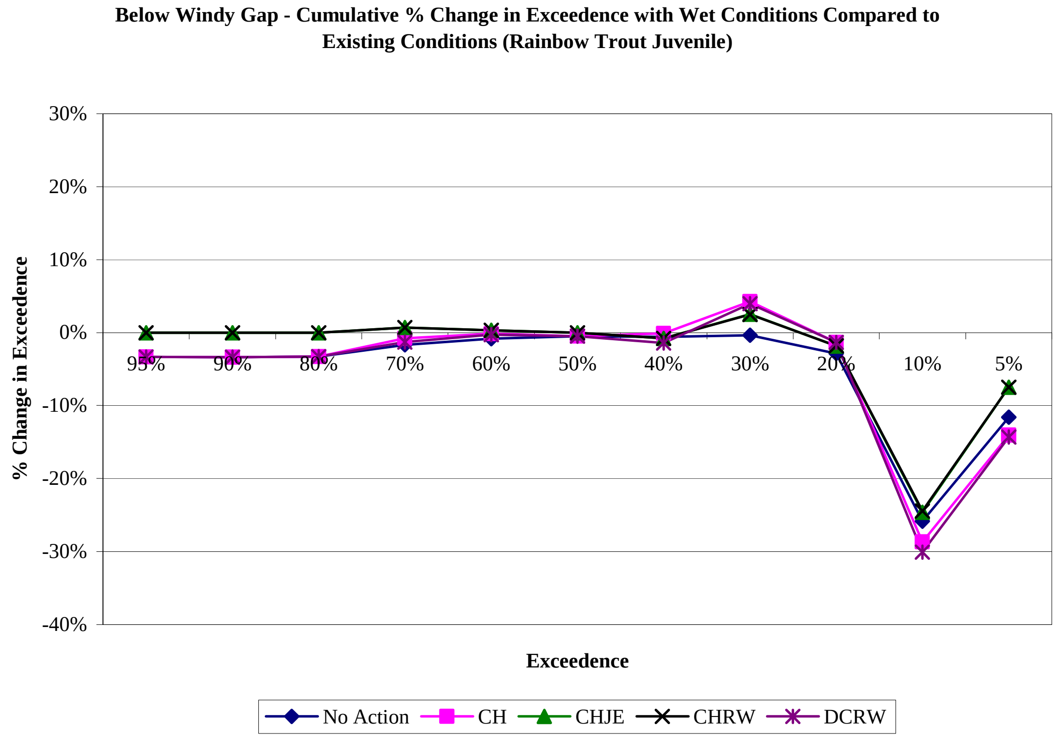


Figure 229. Below Windy Gap – percent change in exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

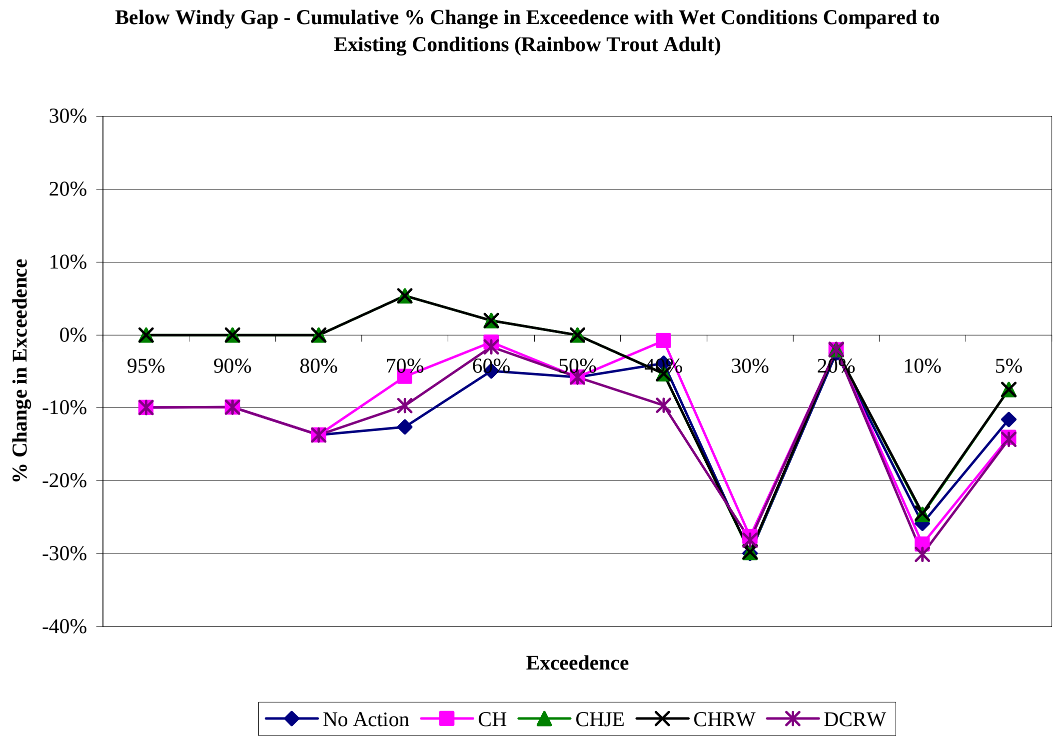


Figure 230. Below Windy Gap – percent change in exceedence with wet conditions (rainbow trout adult) cumulative effects.

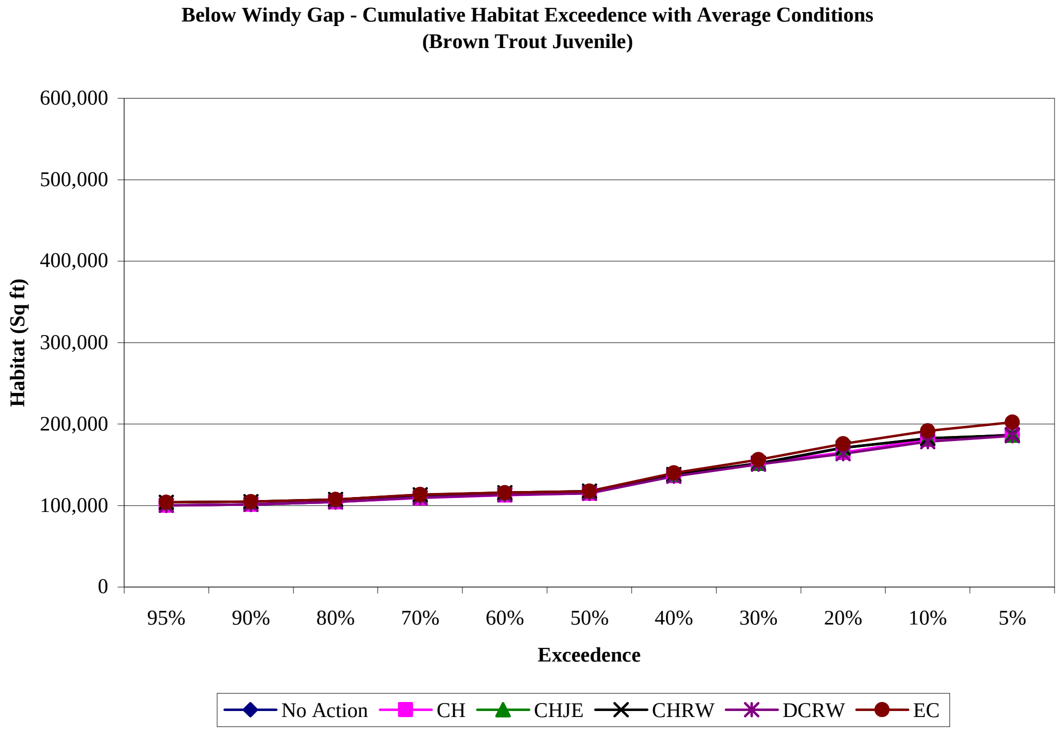


Figure 231. Below Windy Gap – habitat exceedence with average conditions (brown trout juvenile) cumulative effects.

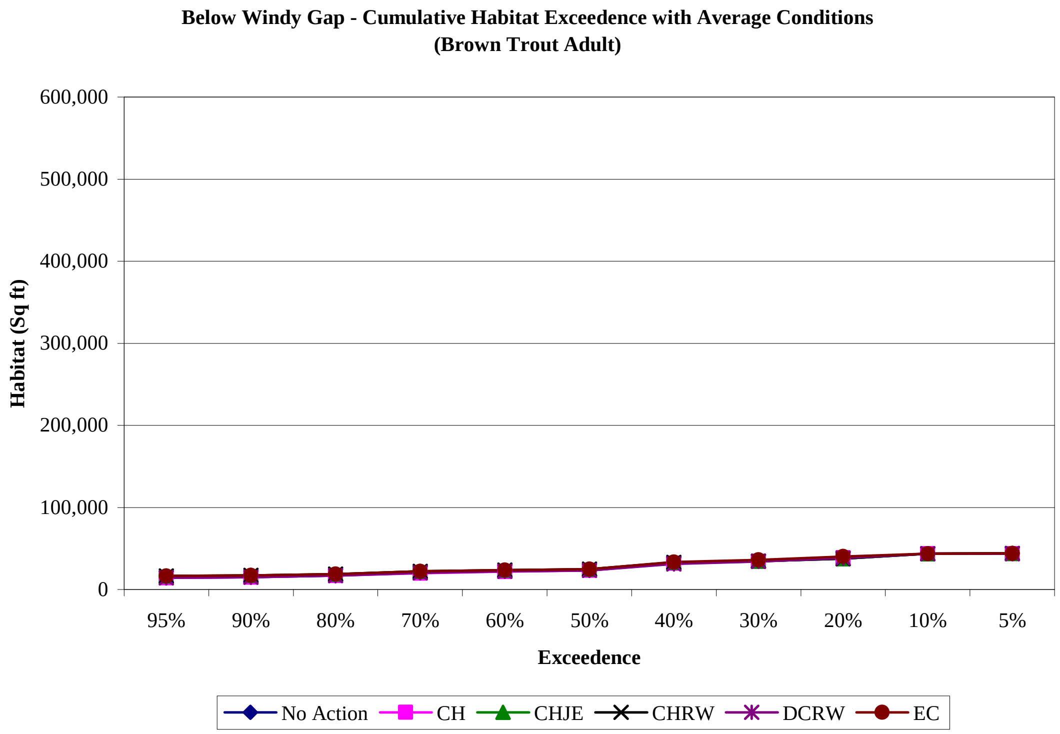


Figure 232. Below Windy Gap – habitat exceedence with average conditions (brown trout adult) cumulative effects.

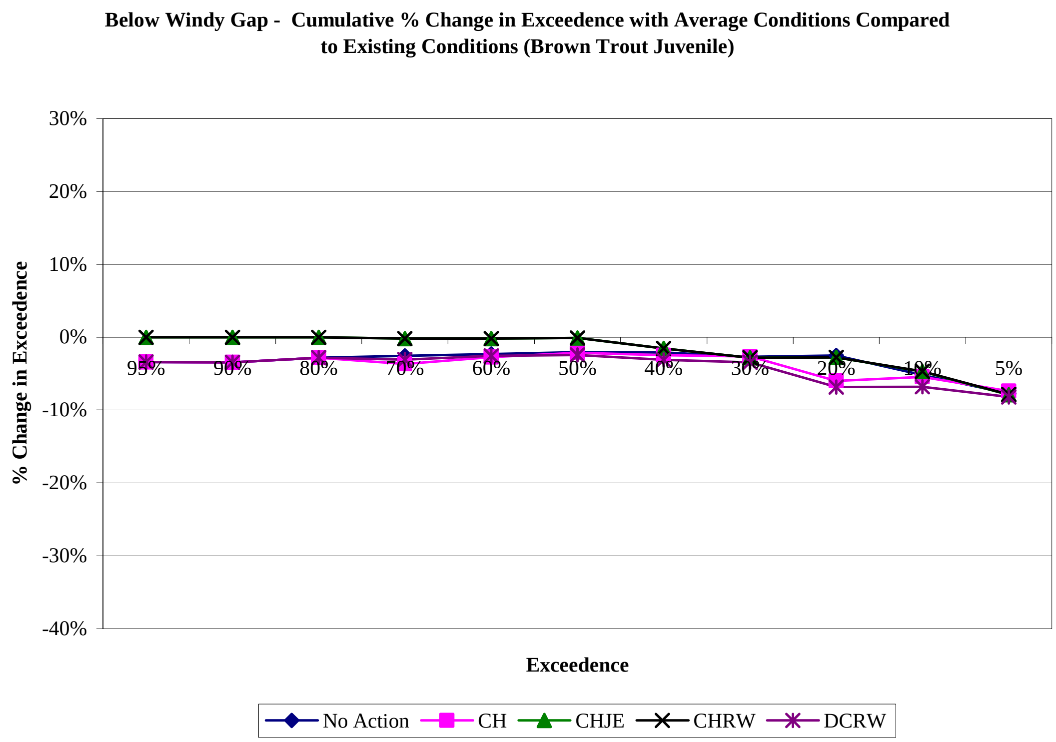


Figure 233. Below Windy Gap – percent change in exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

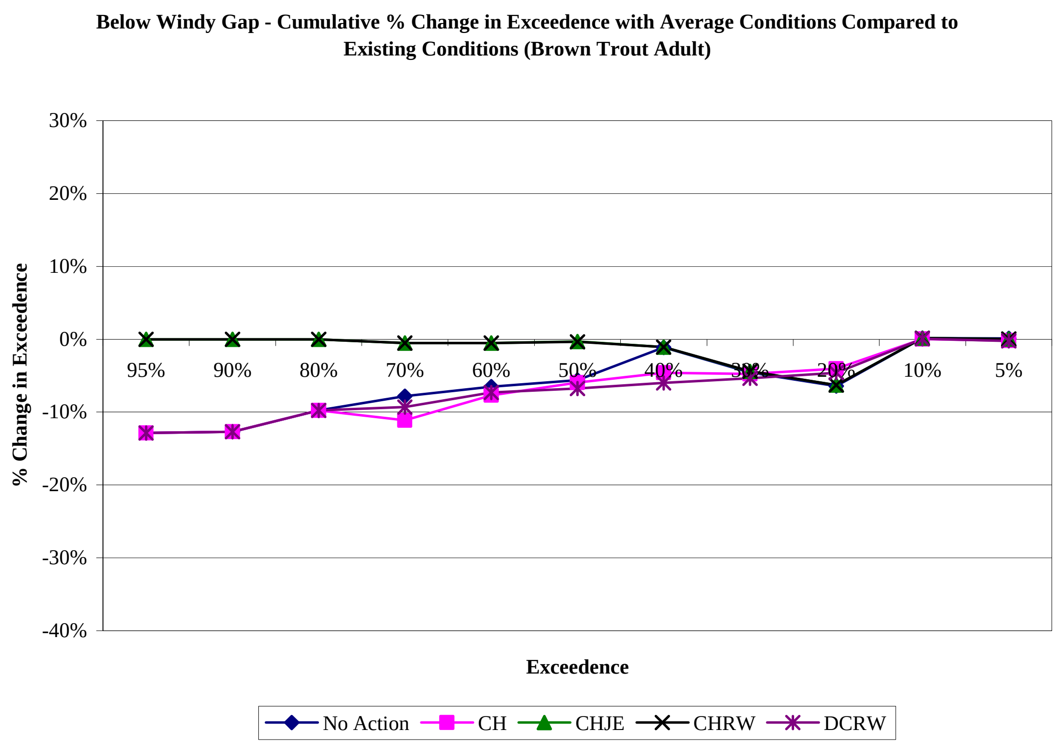


Figure 234. Below Windy Gap – percent change in exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

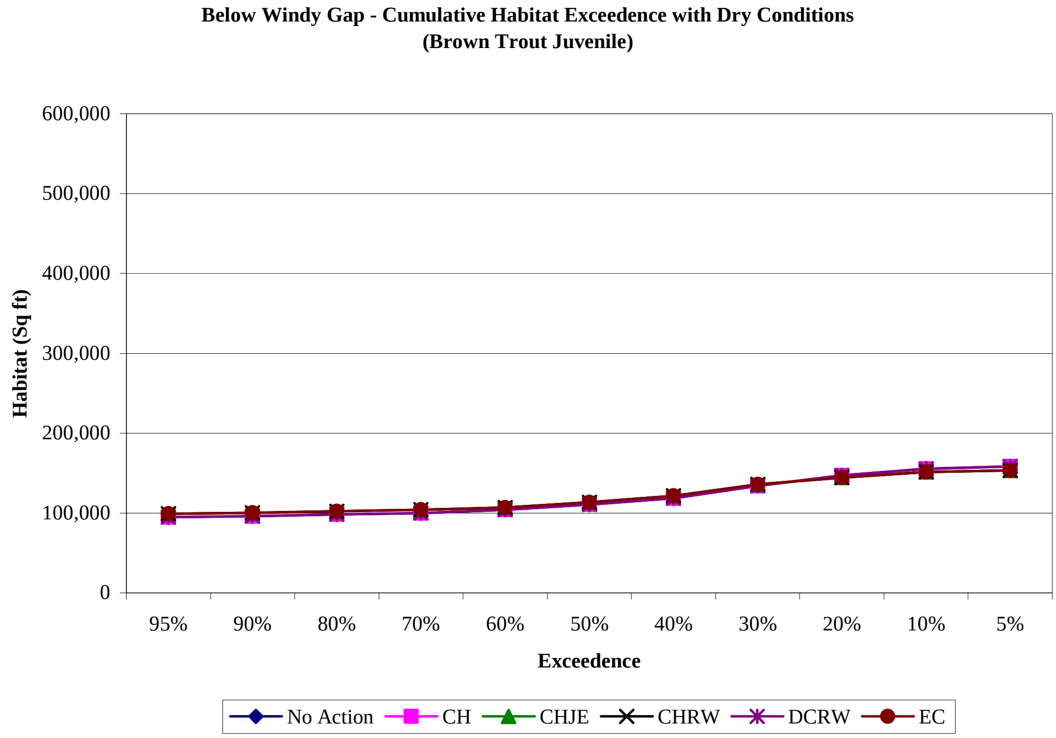


Figure 235. Below Windy Gap – habitat exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

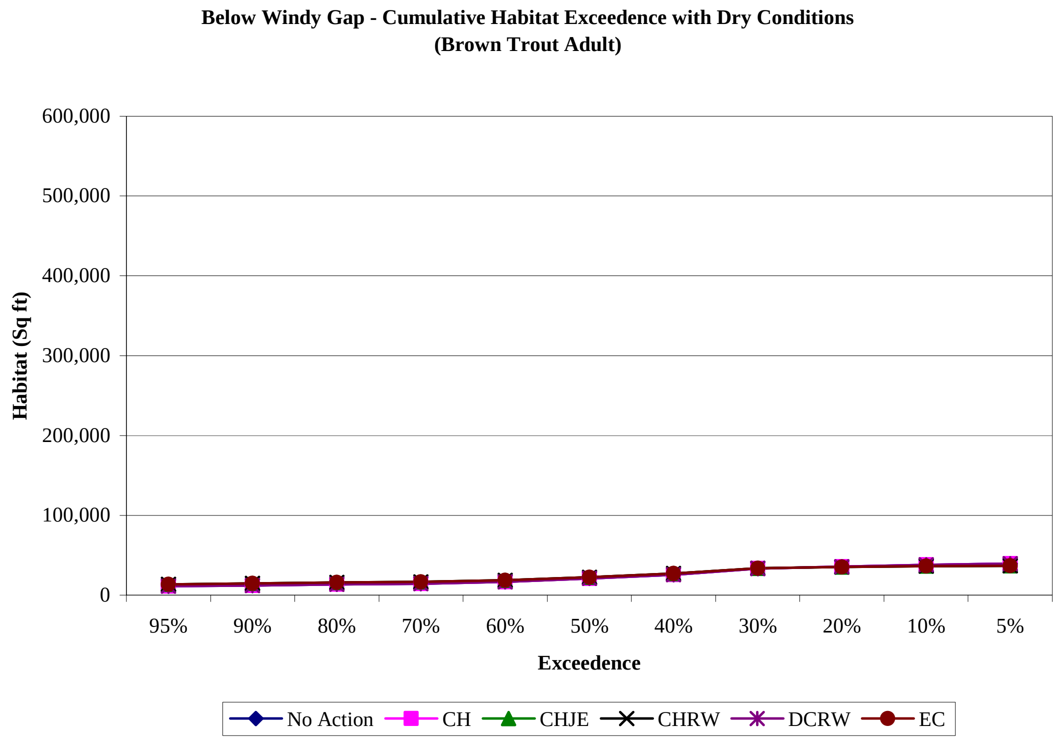


Figure 236. Below Windy Gap – habitat exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

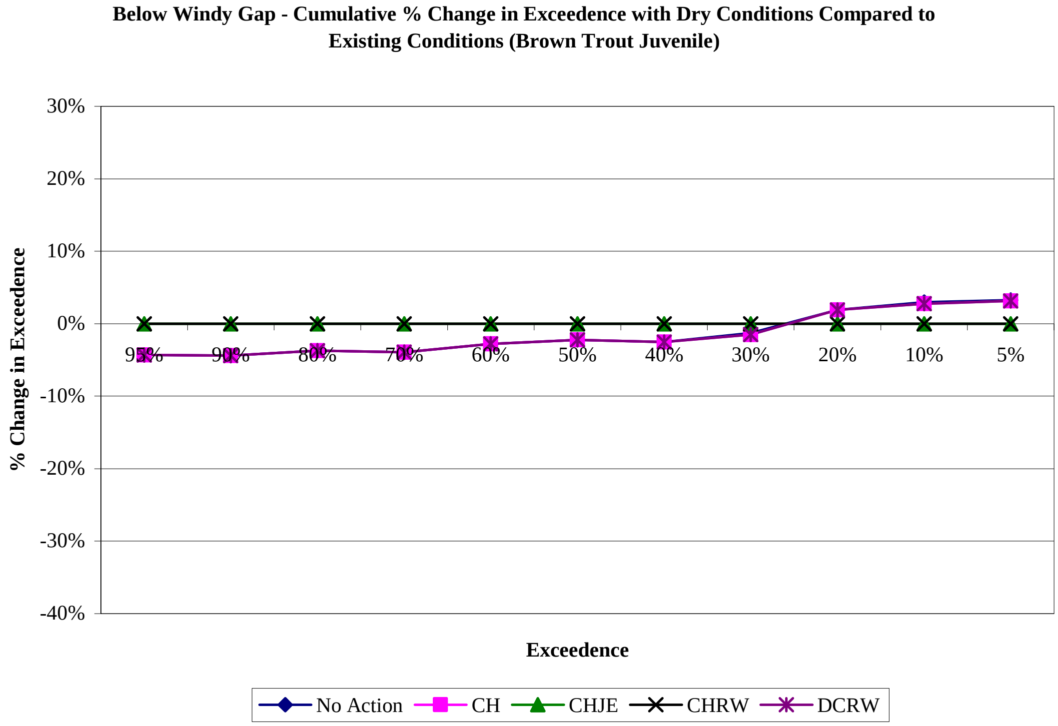


Figure 237. Below Windy Gap – percent change in exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

Figure 238. Below Windy Gap – percent change in exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

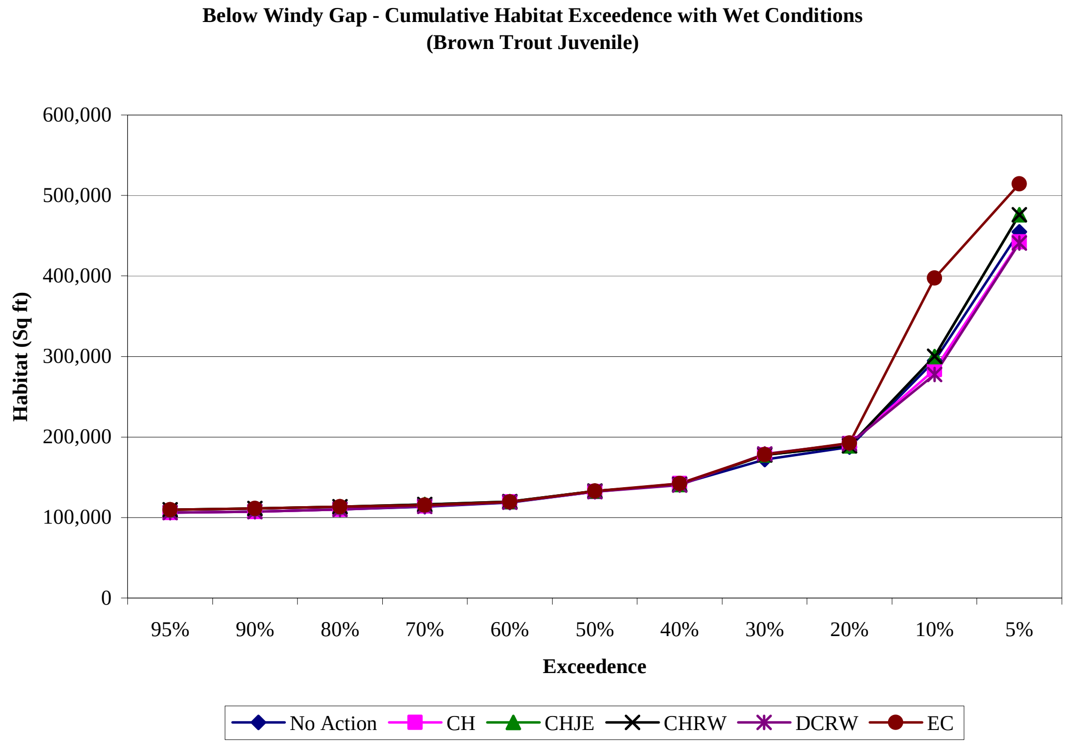


Figure 239. Below Windy Gap – habitat exceedence with wet conditions (brown trout juvenile) cumulative effects.

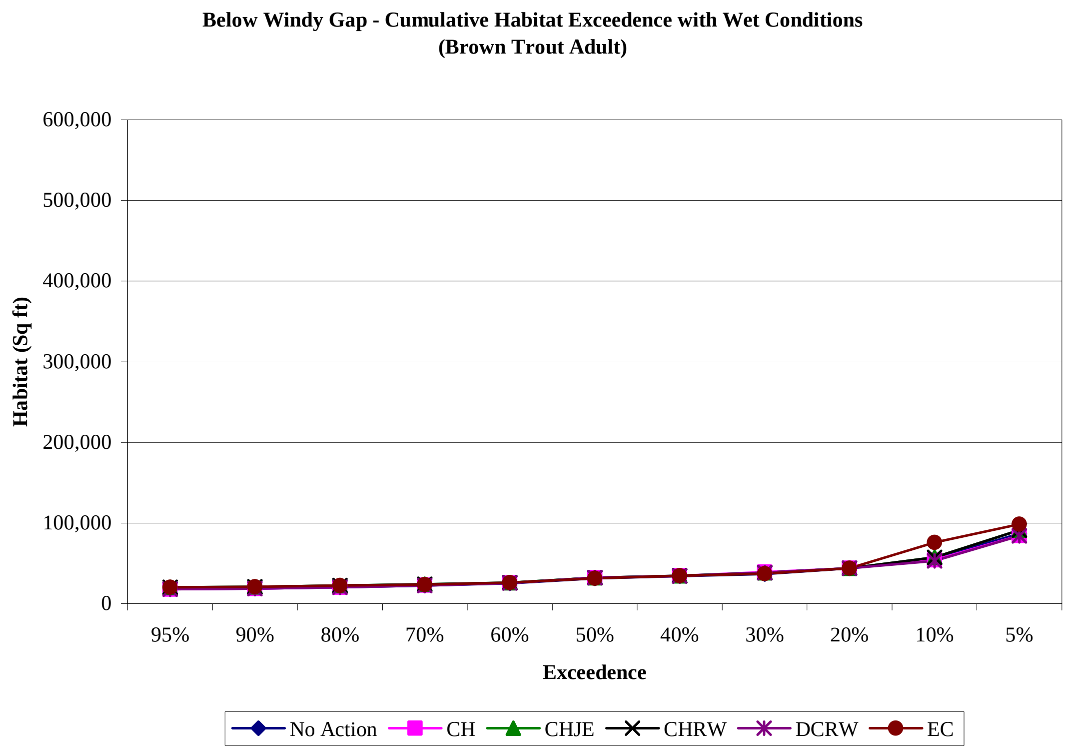


Figure 240. Below Windy Gap – habitat exceedence with wet conditions (brown trout adult) cumulative effects.

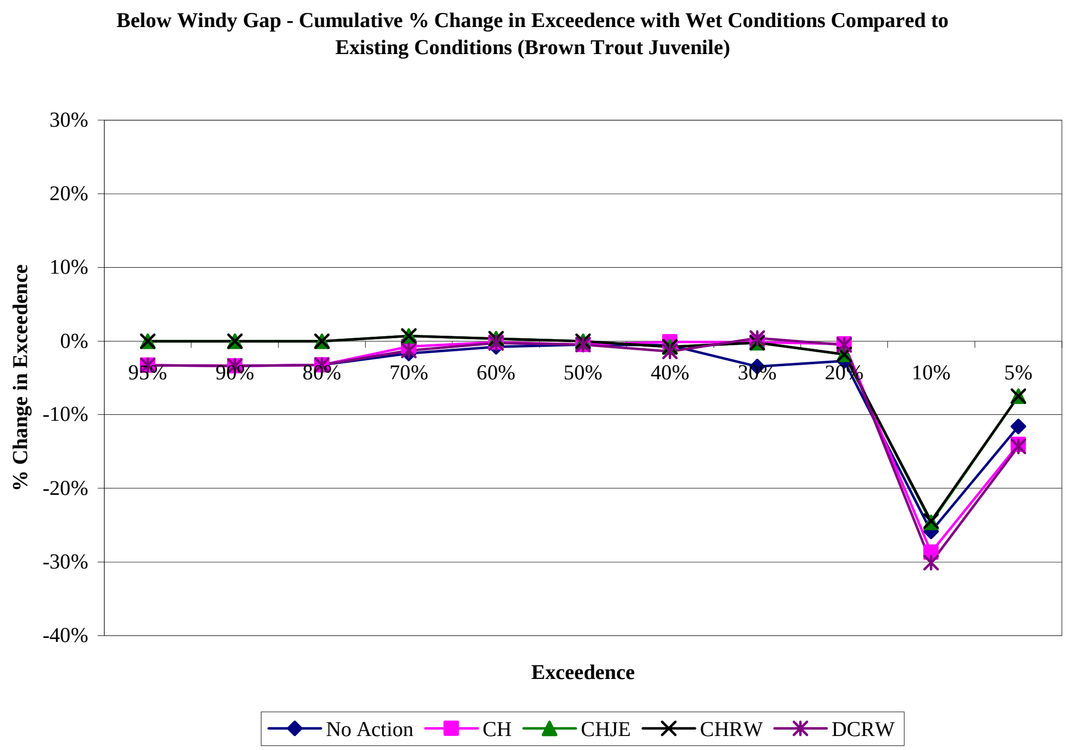


Figure 241. Below Windy Gap – percent change in exceedence with wet conditions (brown trout juvenile) cumulative effects.

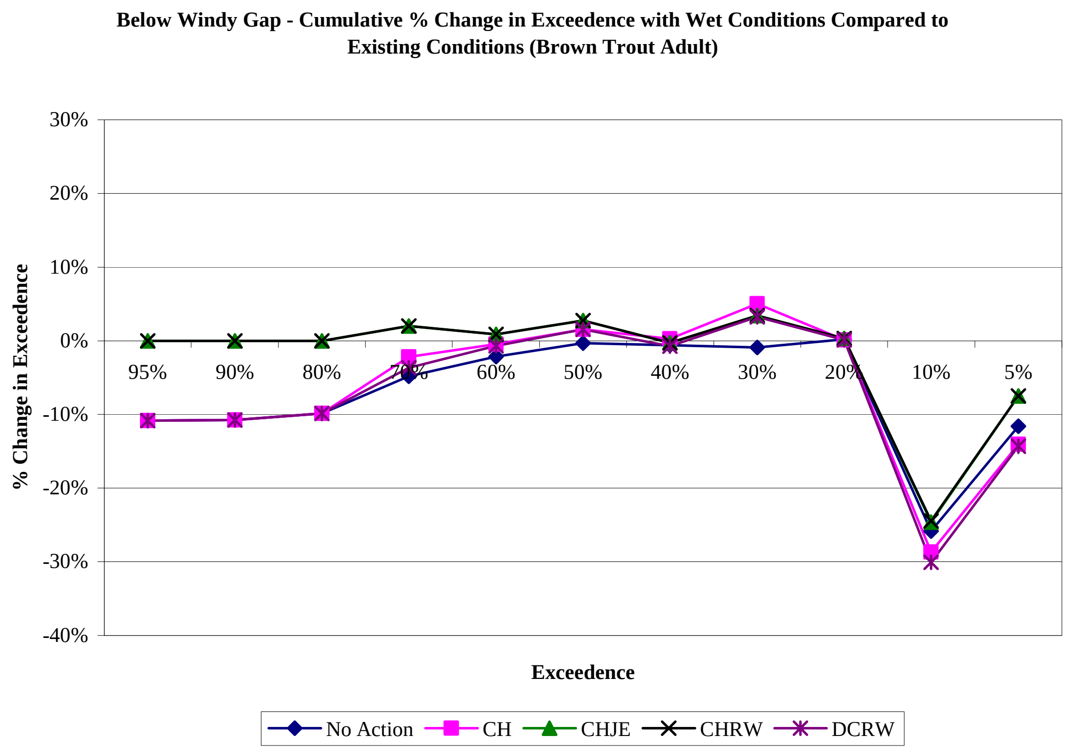


Figure 242. Below Windy Gap – percent change in exceedence with wet conditions (brown trout adult) cumulative effects.

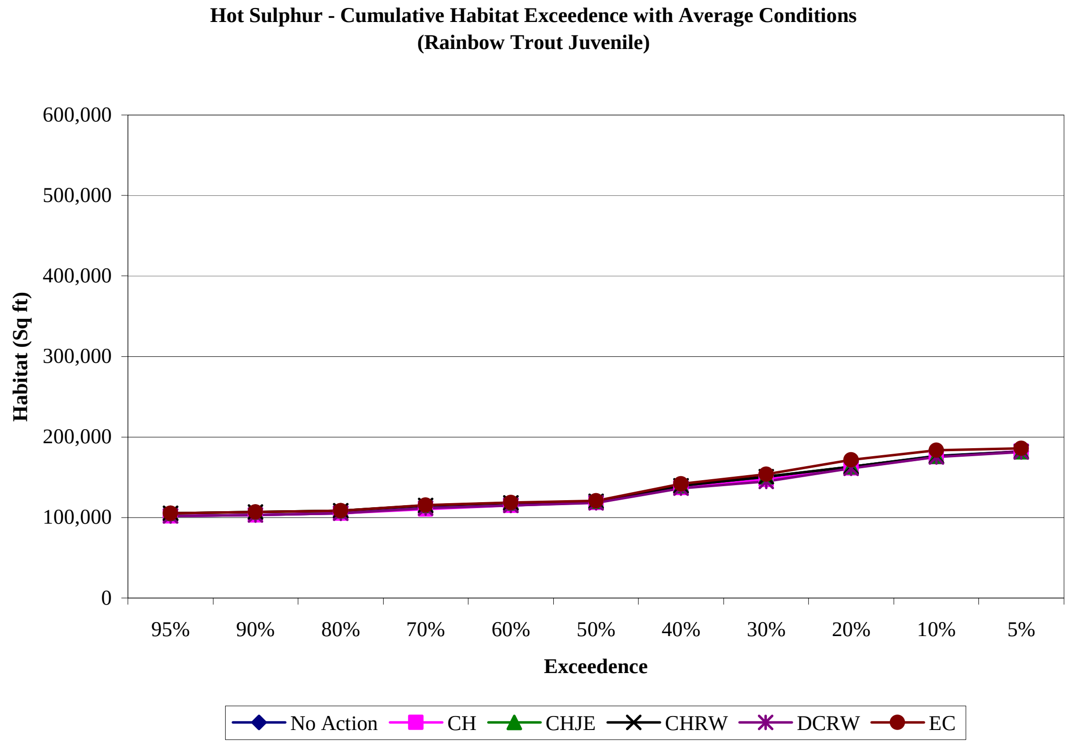


Figure 243. Hot Sulphur – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

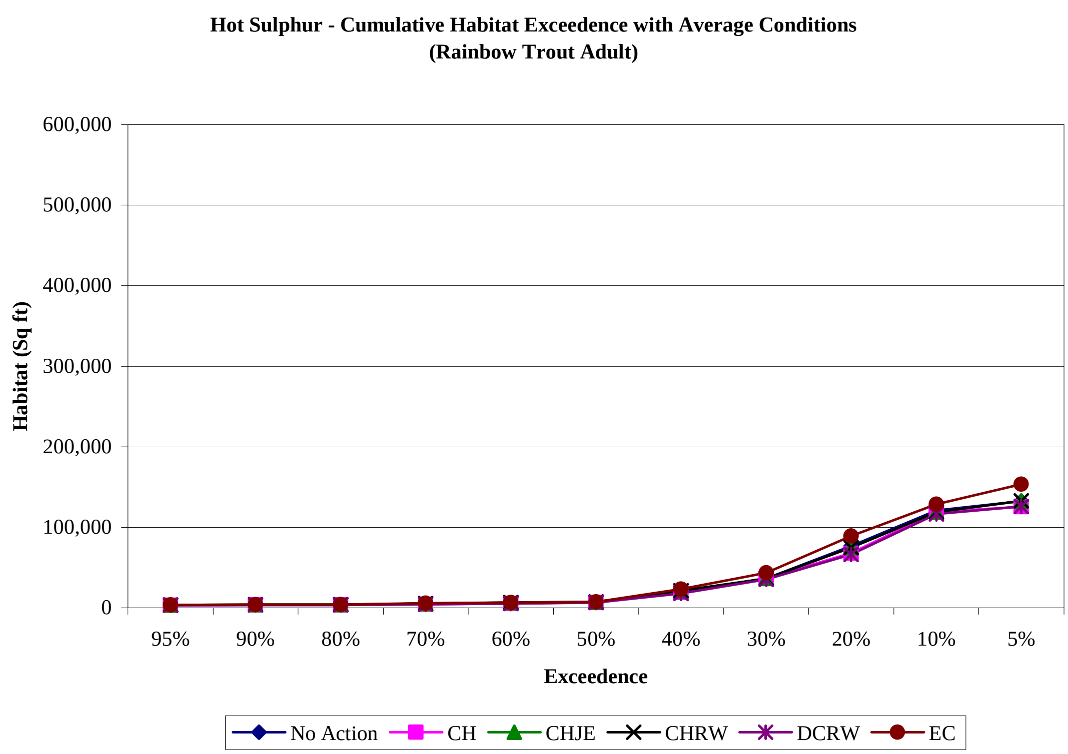


Figure 244. Hot Sulphur – habitat exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

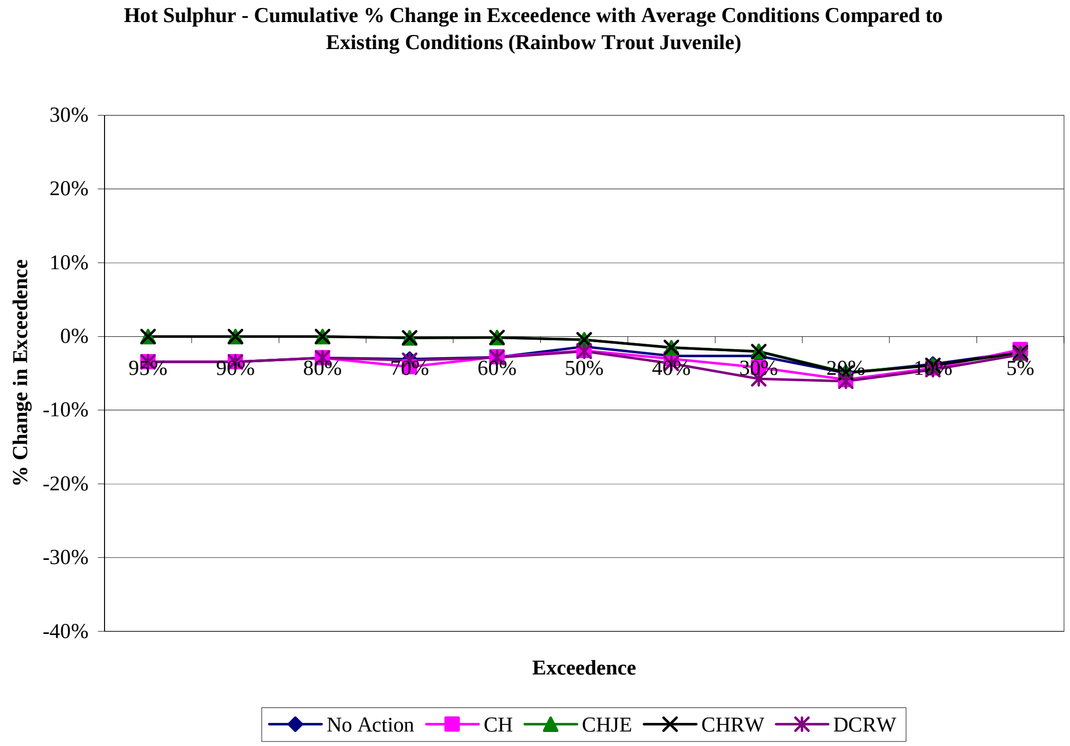


Figure 245. Hot Sulphur – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

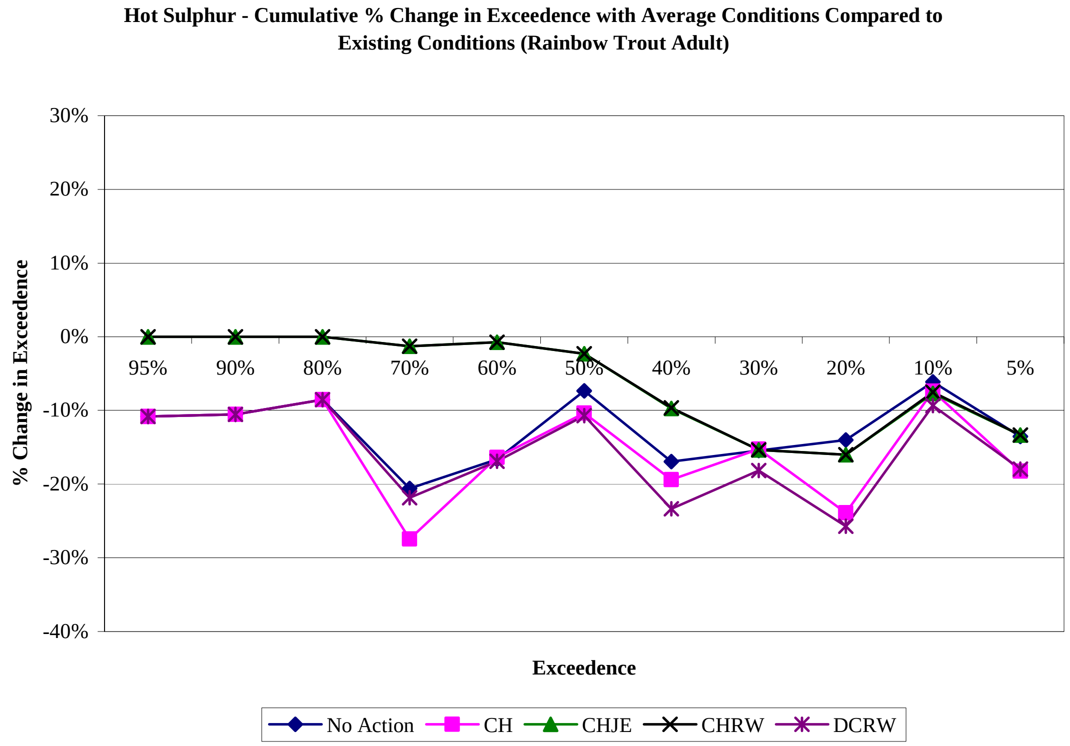


Figure 246. Hot Sulphur – percent change in exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

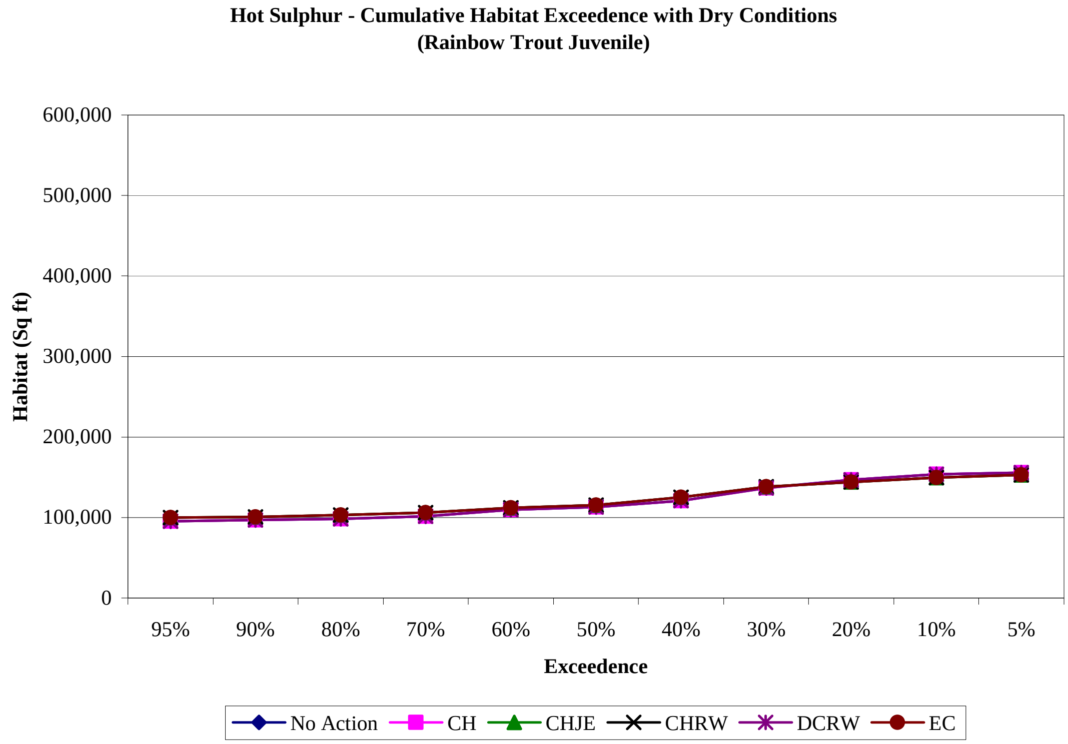


Figure 247. Hot Sulphur – habitat exceedence with dry conditions (rainbow trout juvenile) cumulative effects.

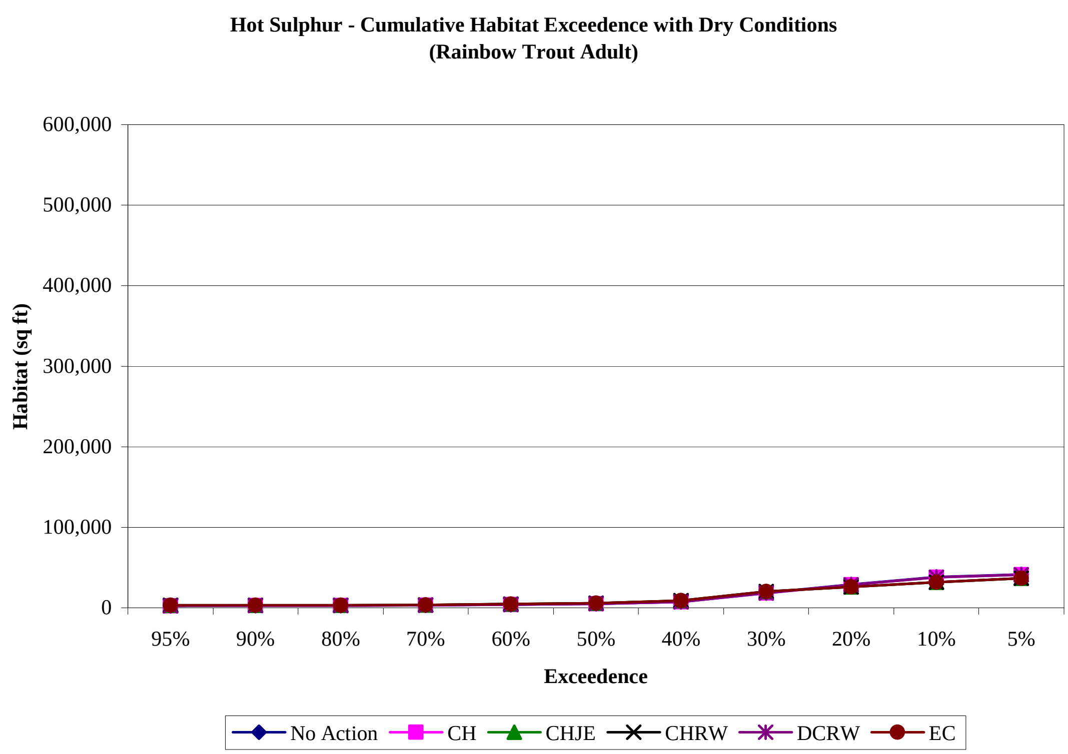


Figure 248. Hot Sulphur – habitat exceedence with dry conditions (rainbow trout adult) cumulative effects.

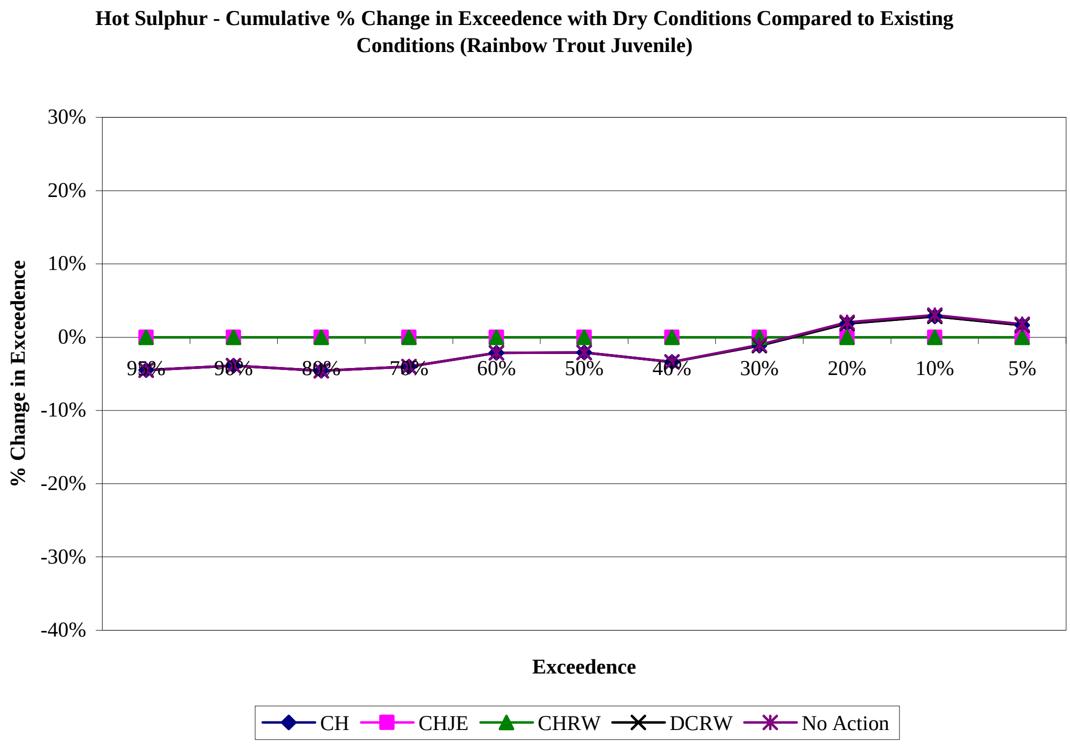


Figure 249. Hot Sulphur – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile) cumulative effects.

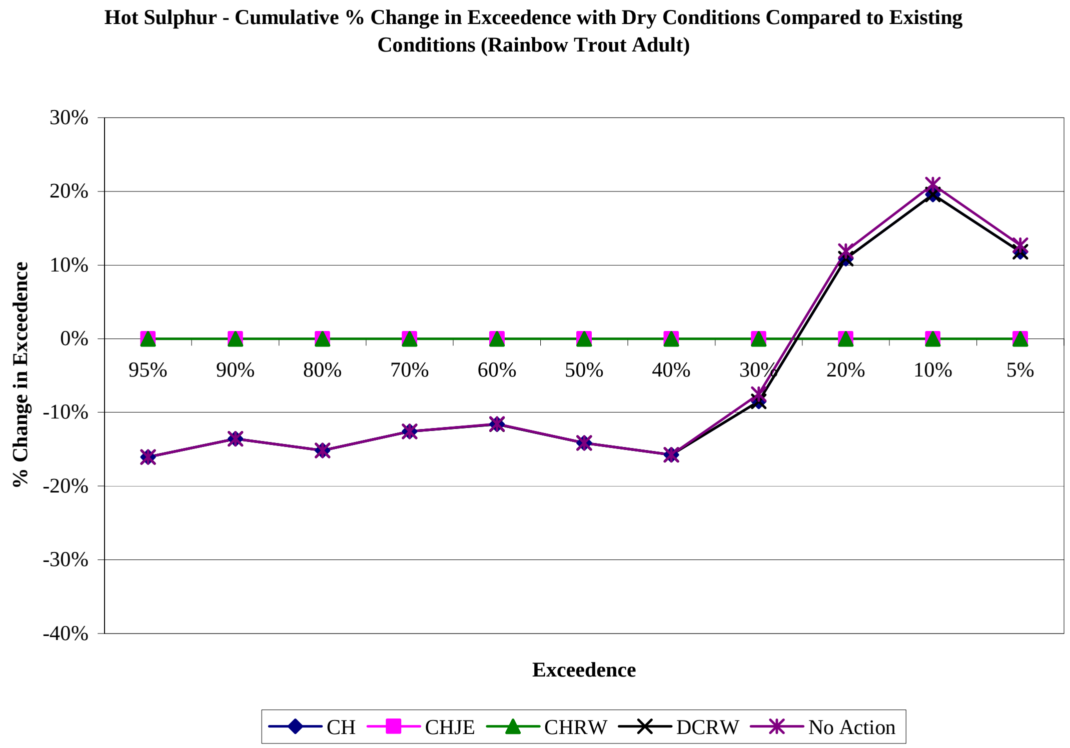


Figure 250. Hot Sulphur – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult) cumulative effects.

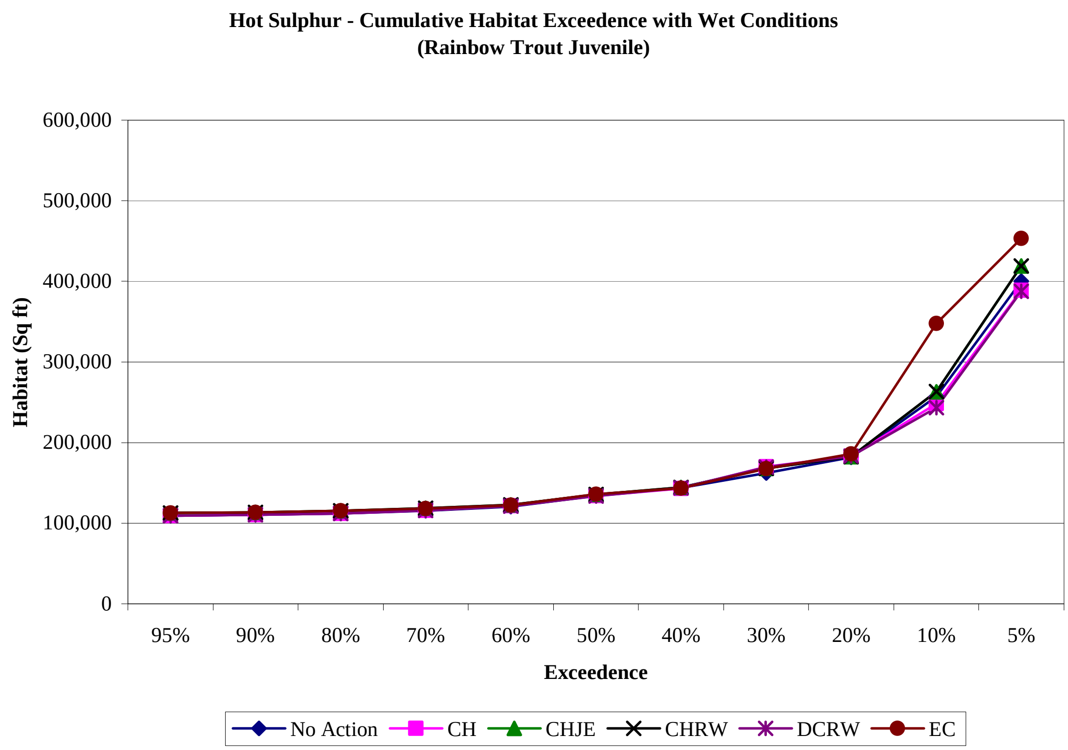


Figure 251. Hot Sulphur – habitat exceedence with <u>wet</u> conditions (rainbow trout juvenile) cumulative effects.

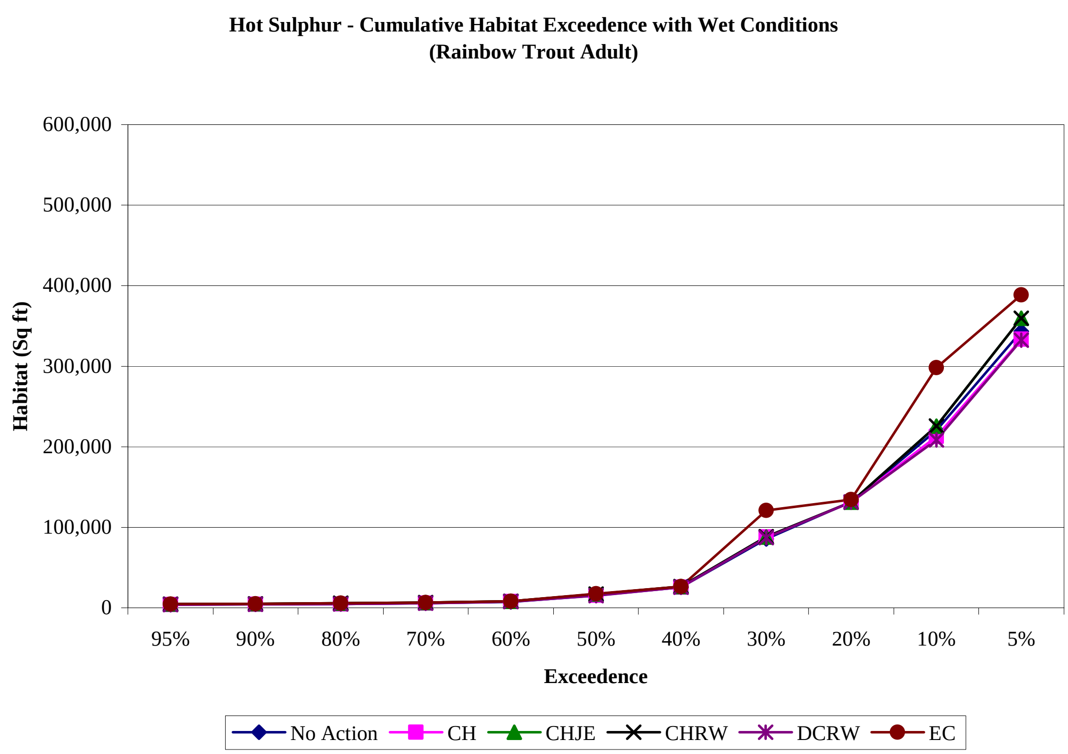


Figure 252. Hot Sulphur – habitat exceedence with <u>wet</u> conditions (rainbow trout adult) cumulative effects.

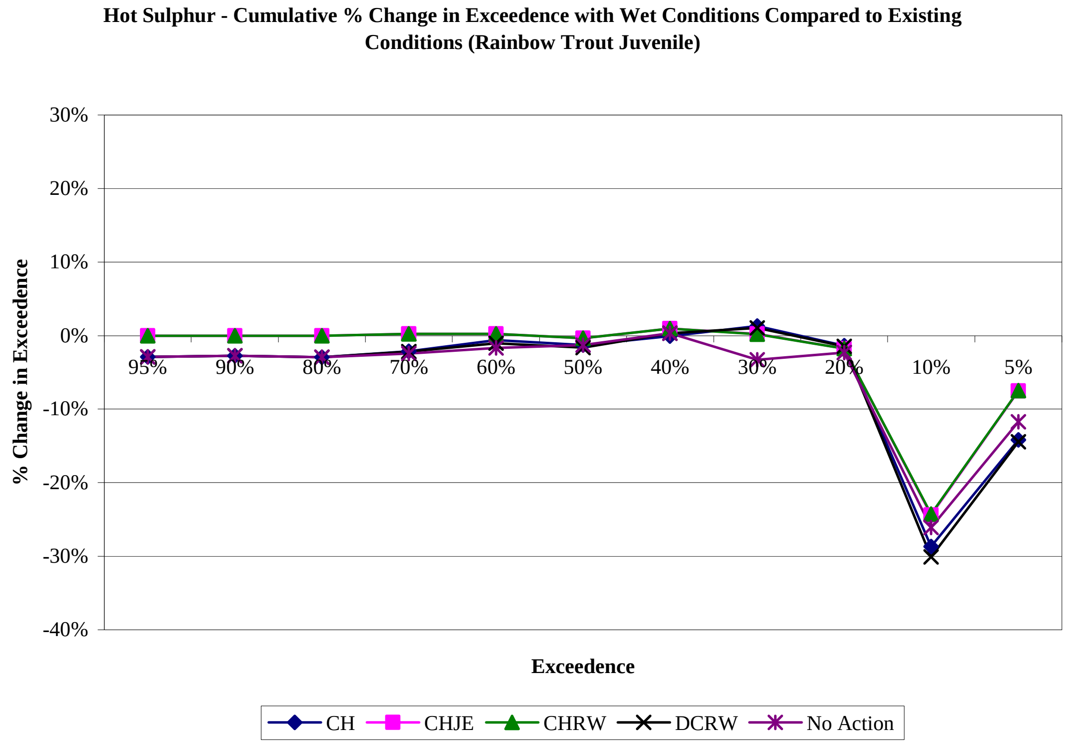


Figure 253. Hot Sulphur – percent change in exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

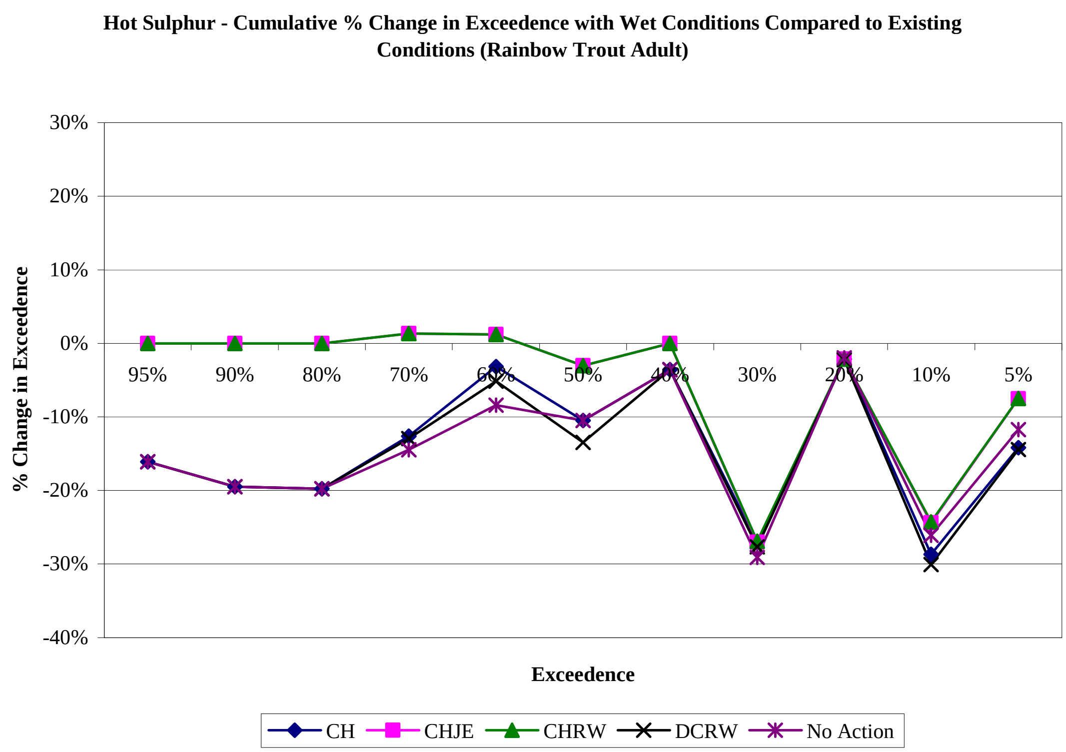


Figure 254. Hot Sulphur – percent change in exceedence with wet conditions (rainbow trout adult) cumulative effects.

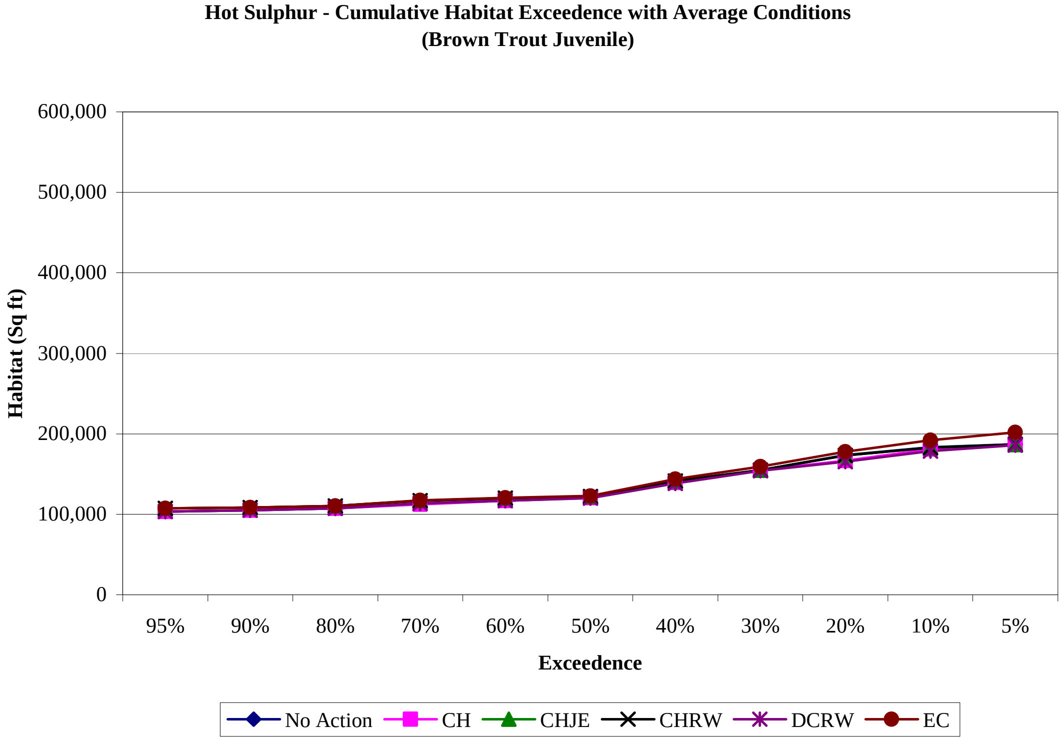


Figure 255. Hot Sulphur – habitat exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

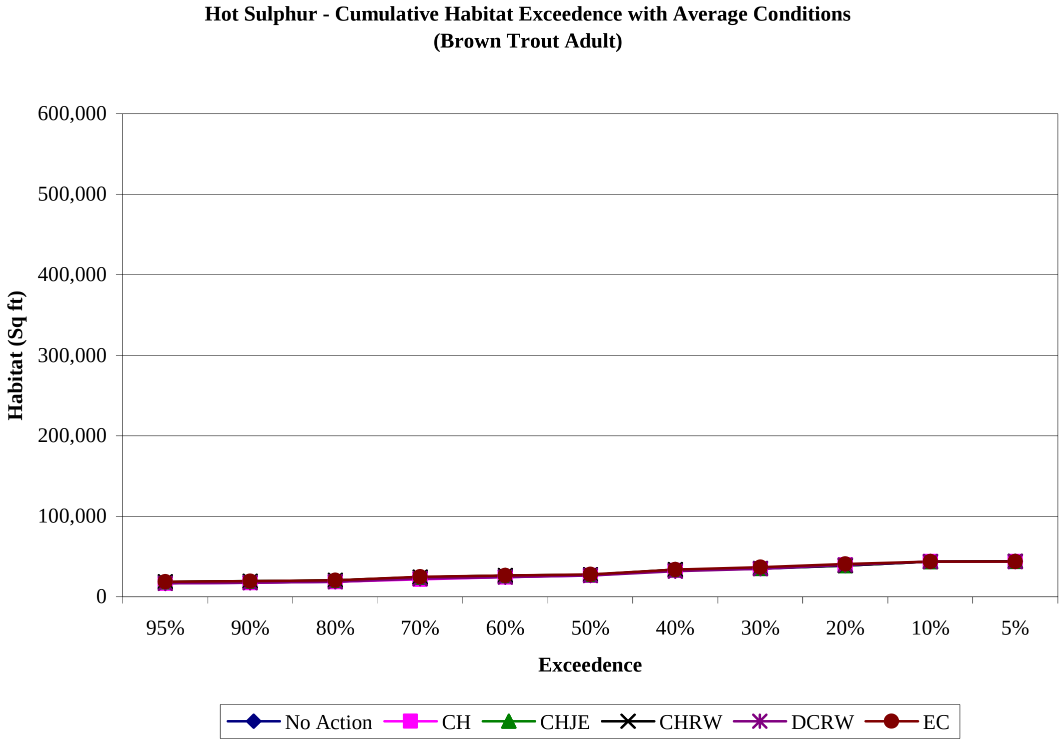


Figure 256. Hot Sulphur – habitat exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

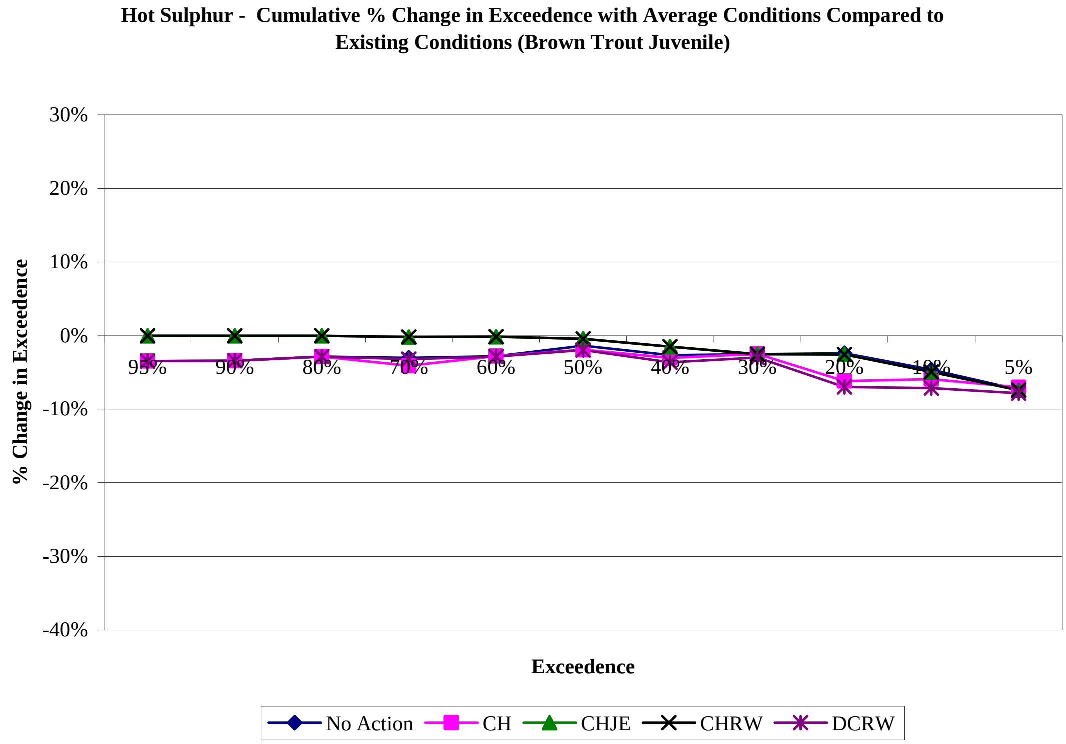


Figure 257. Hot Sulphur – percent change in exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

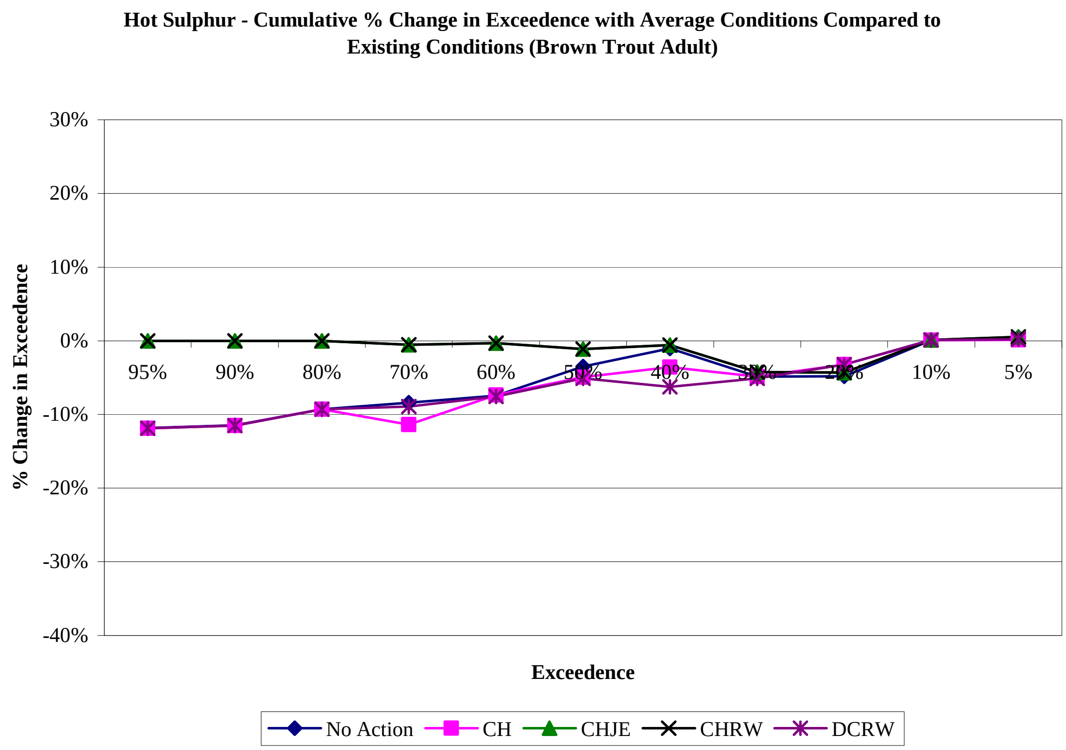


Figure 258. Hot Sulphur – percent change in exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

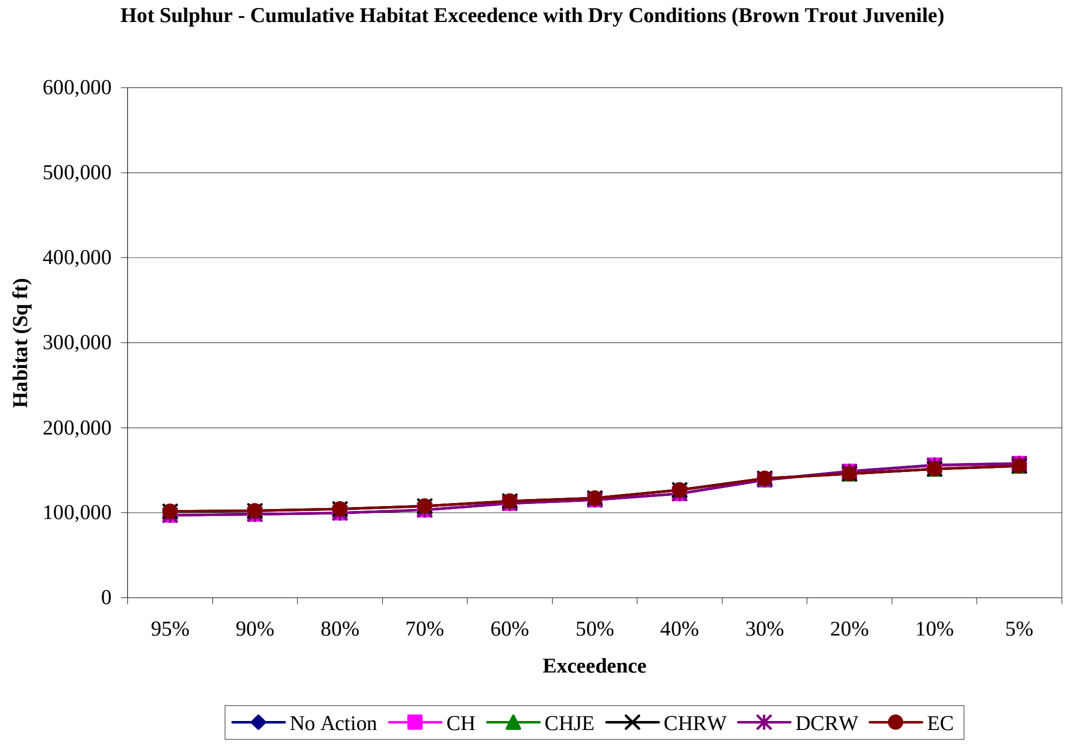


Figure 259. Hot Sulphur – habitat exceedence with dry conditions (brown trout juvenile) cumulative effects.

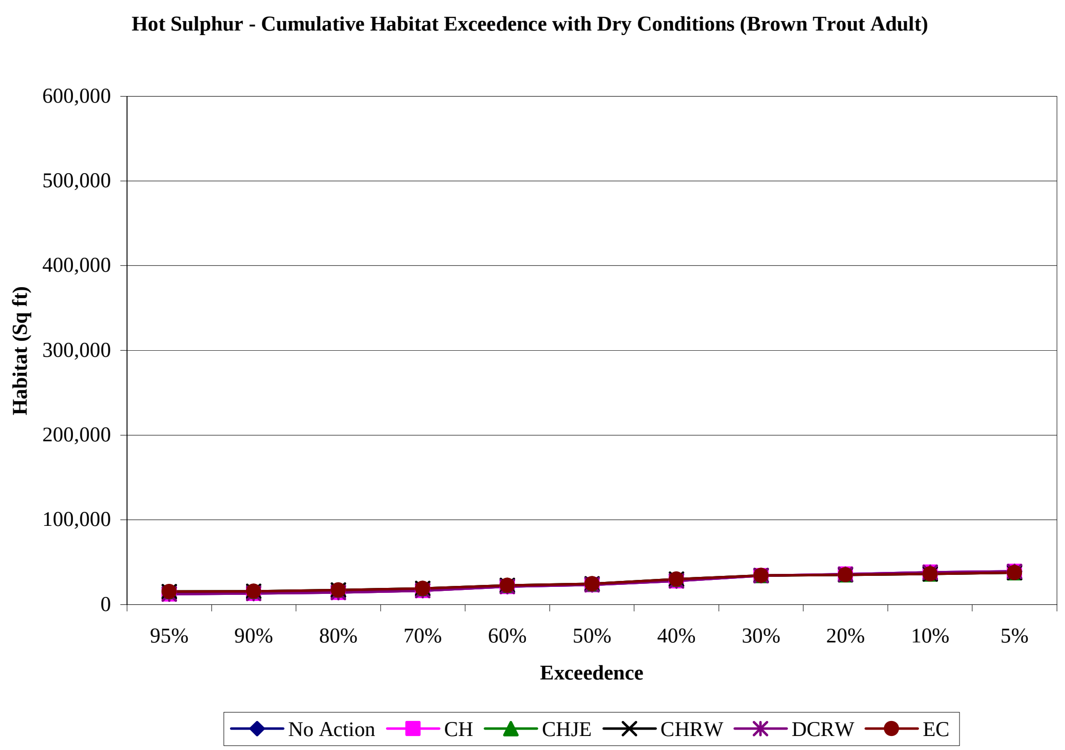


Figure 260. Hot Sulphur – habitat exceedence with dry conditions (brown trout adult) cumulative effects.

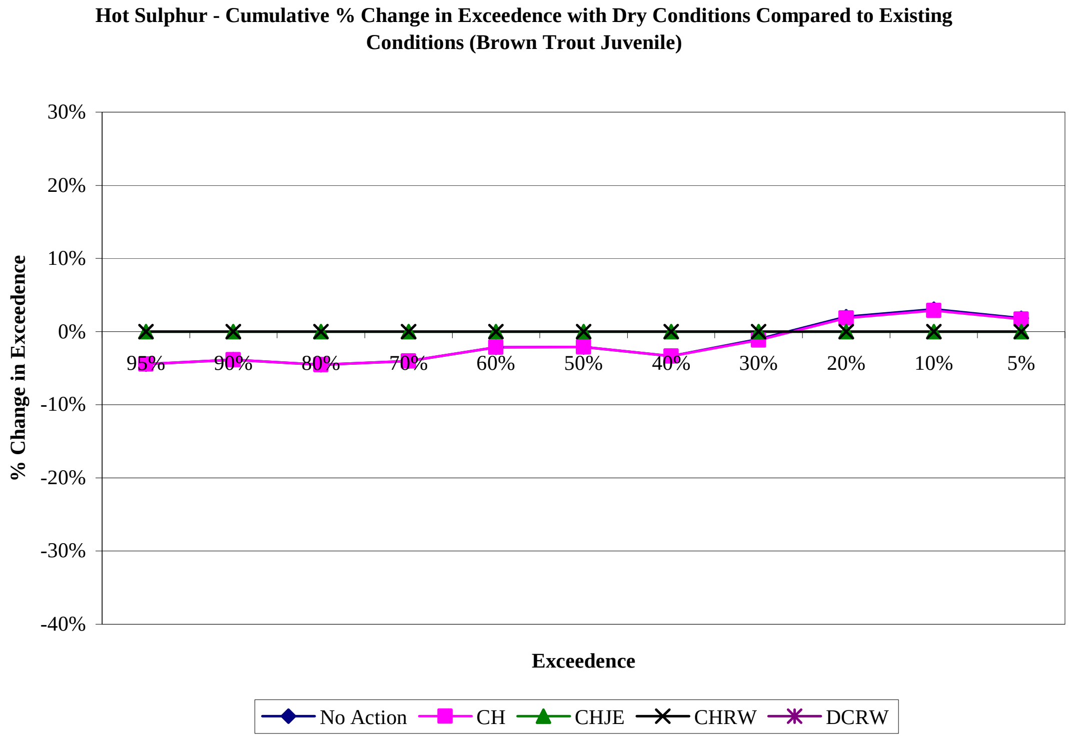


Figure 261. Hot Sulphur – percent change in exceedence with dry conditions (brown trout juvenile) cumulative effects.

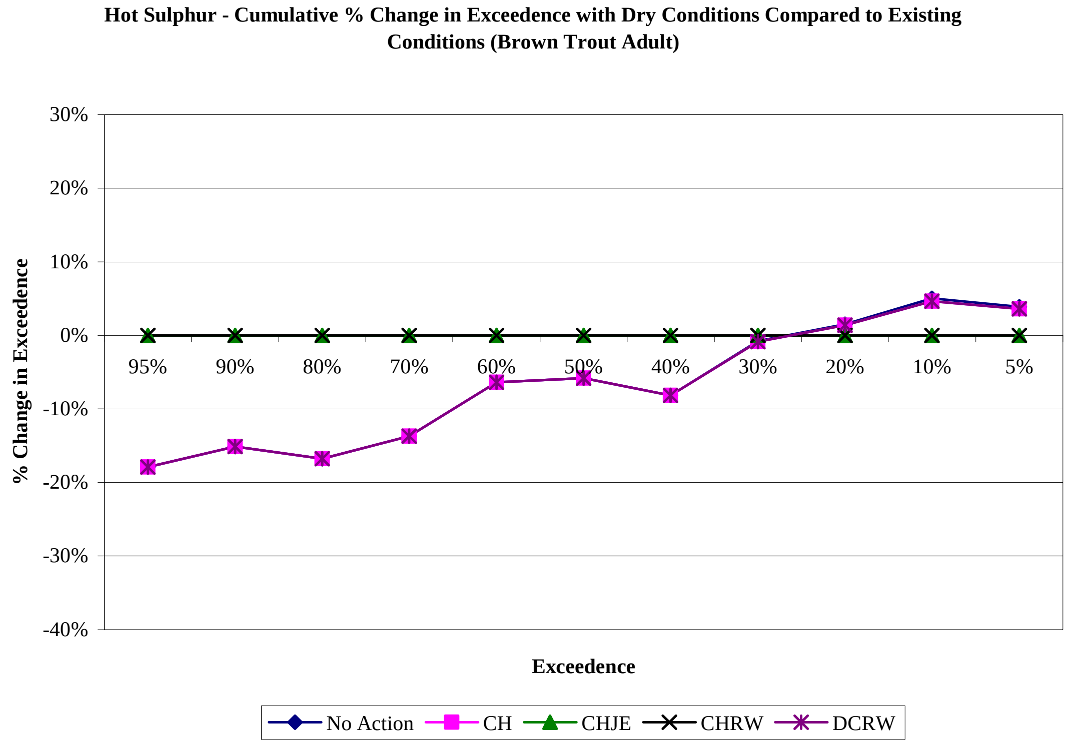


Figure 262. Hot Sulphur – percent change in exceedence with dry conditions (brown trout adult) cumulative effects.

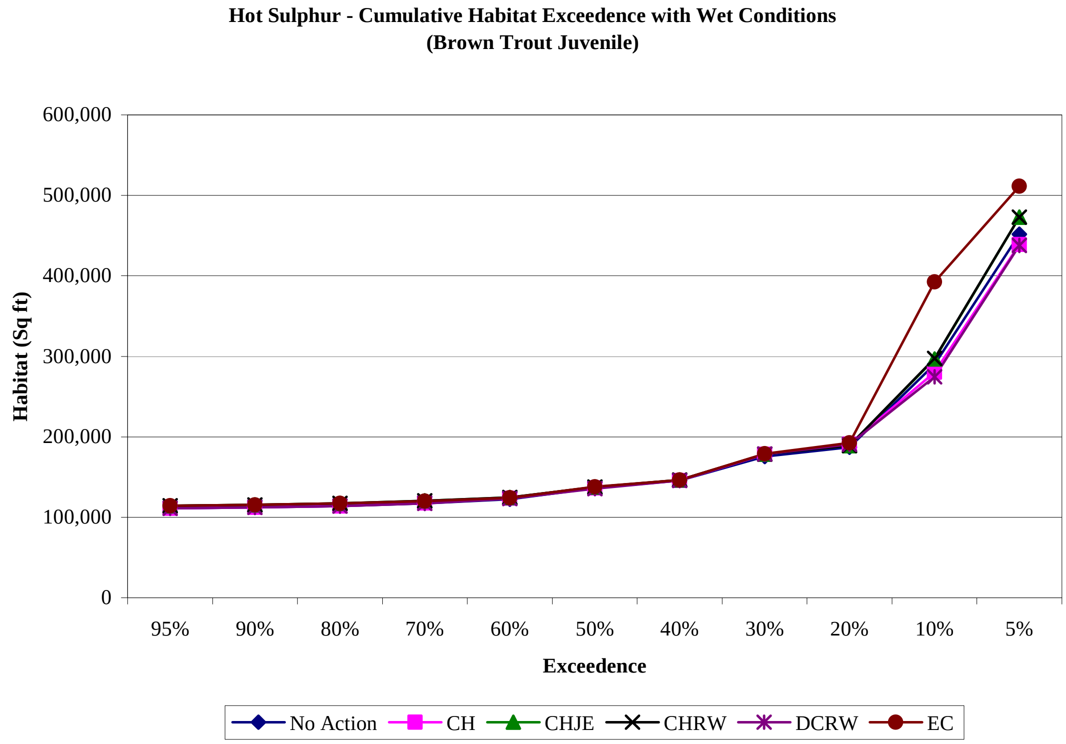


Figure 263. Hot Sulphur – habitat exceedence with wet conditions (brown trout juvenile) cumulative effects.

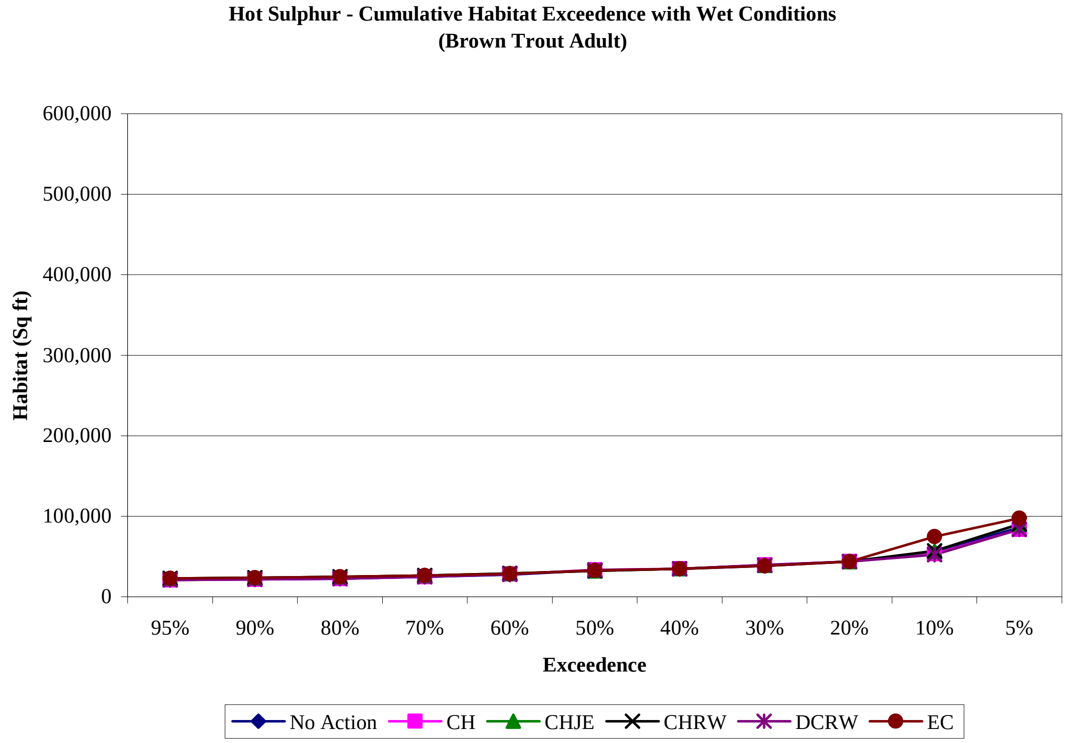


Figure 264. Hot Sulphur – habitat exceedence with wet conditions (brown trout adult) cumulative effects.

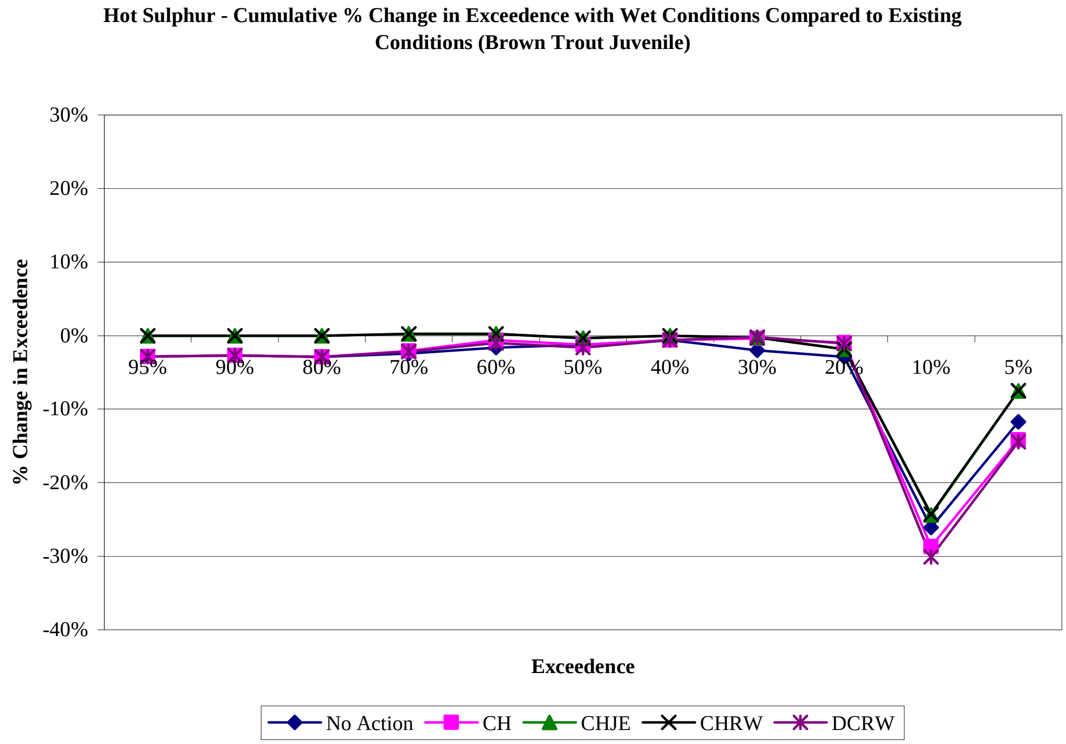


Figure 265. Hot Sulphur – percent change in exceedence with <u>wet</u> conditions (brown trout juvenile) cumulative effects.

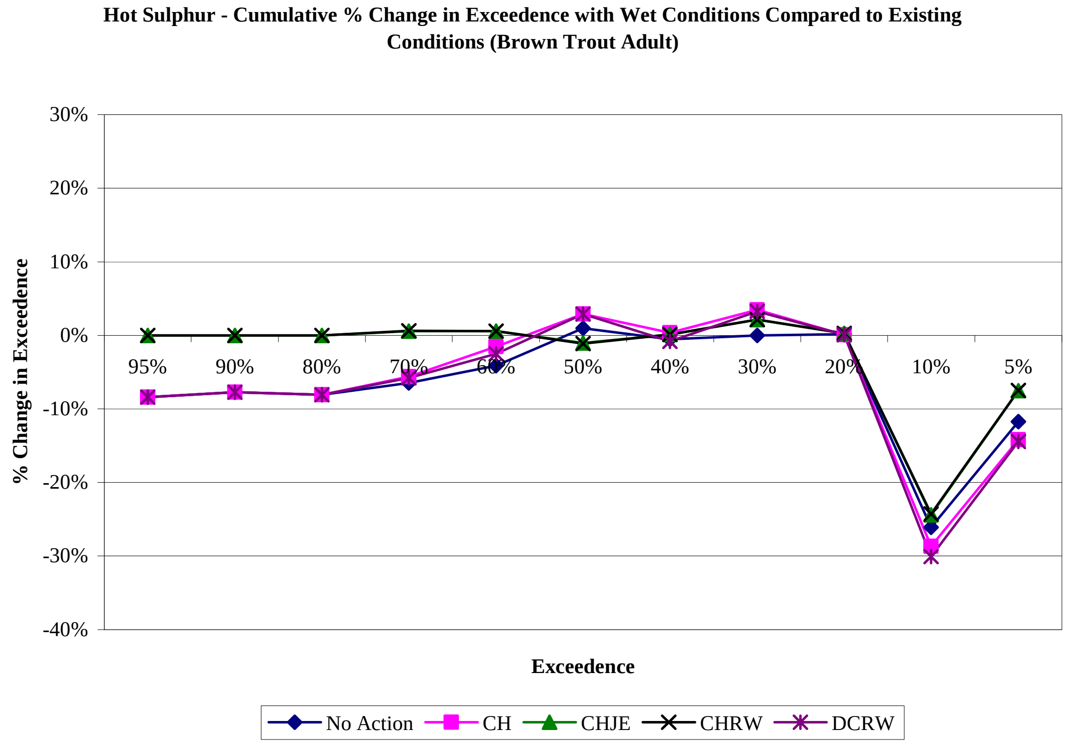


Figure 266. Hot Sulphur – percent change in exceedence with <u>wet</u> conditions (brown trout adult) cumulative effects.

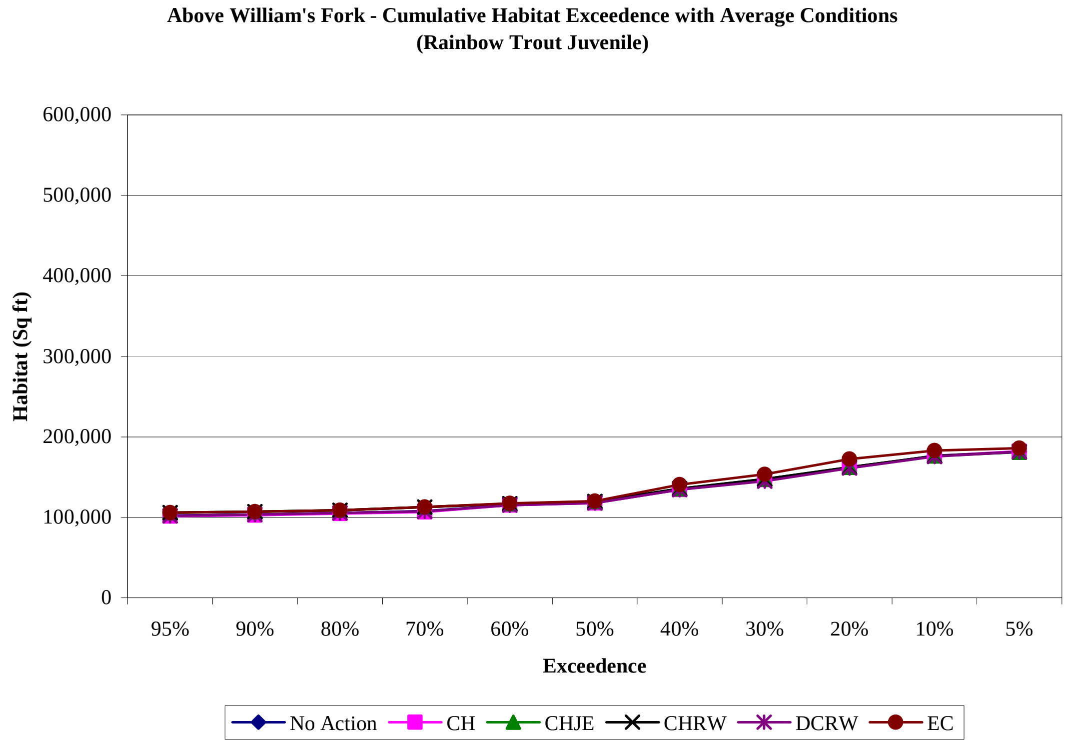


Figure 267. Above William's Fork – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

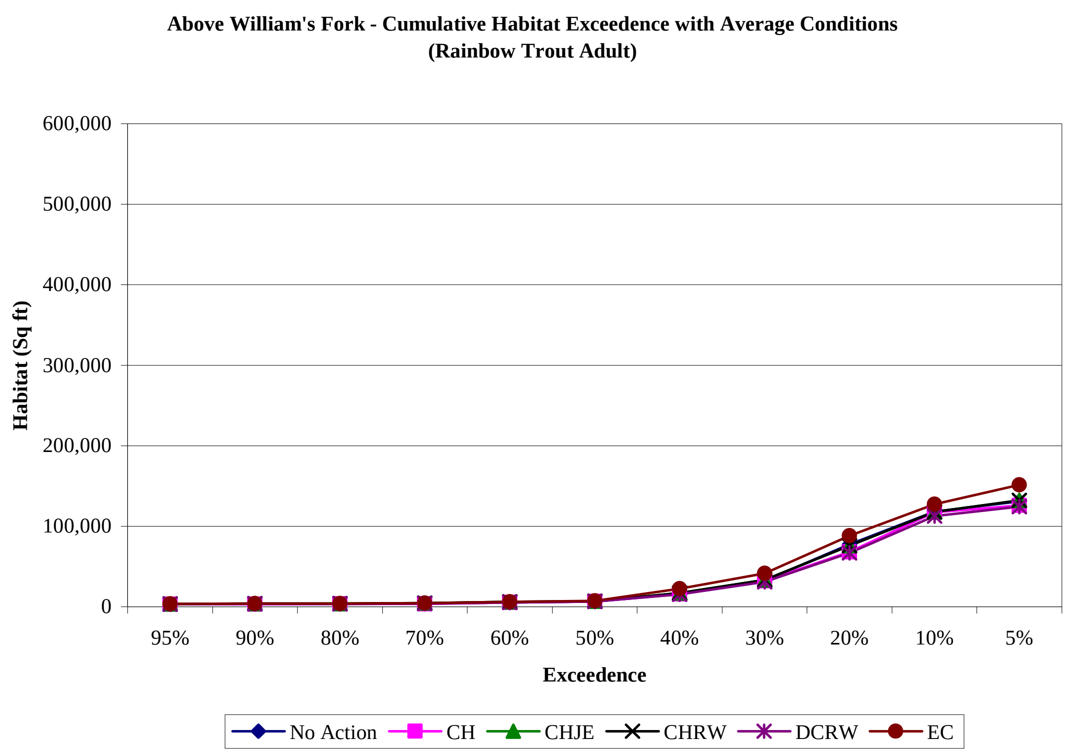


Figure 268. Above William's Fork – habitat exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

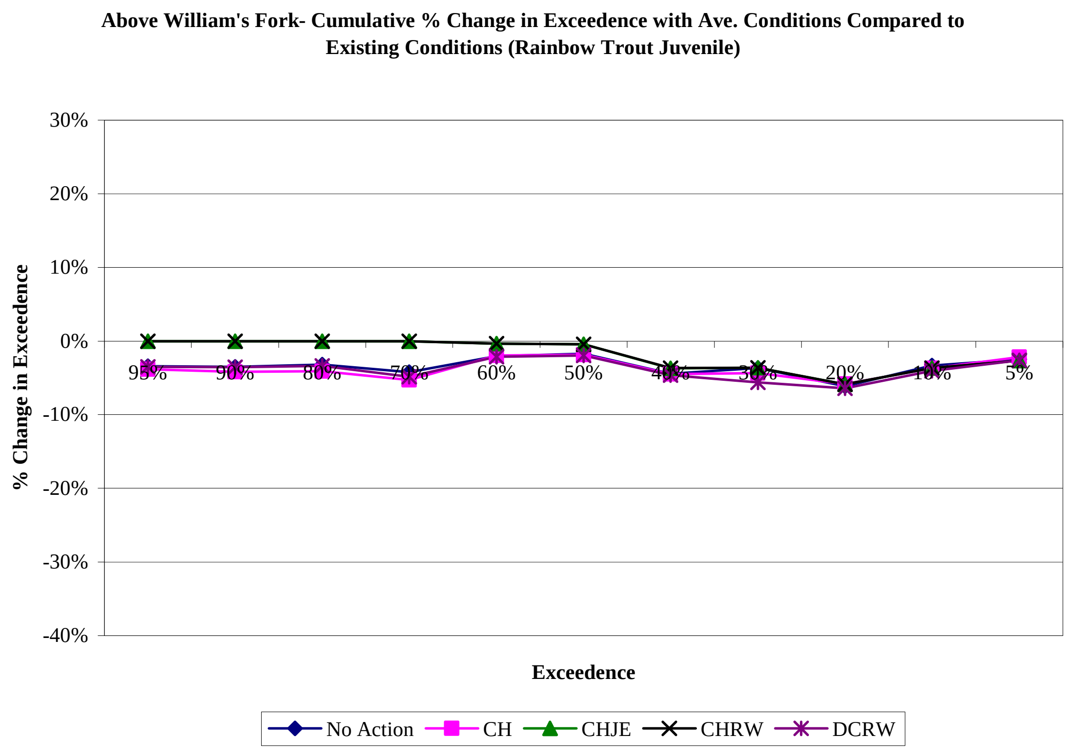


Figure 269. Above William's Fork – percent change in exceedence with average conditions (rainbow trout juvenile) cumulative effects.

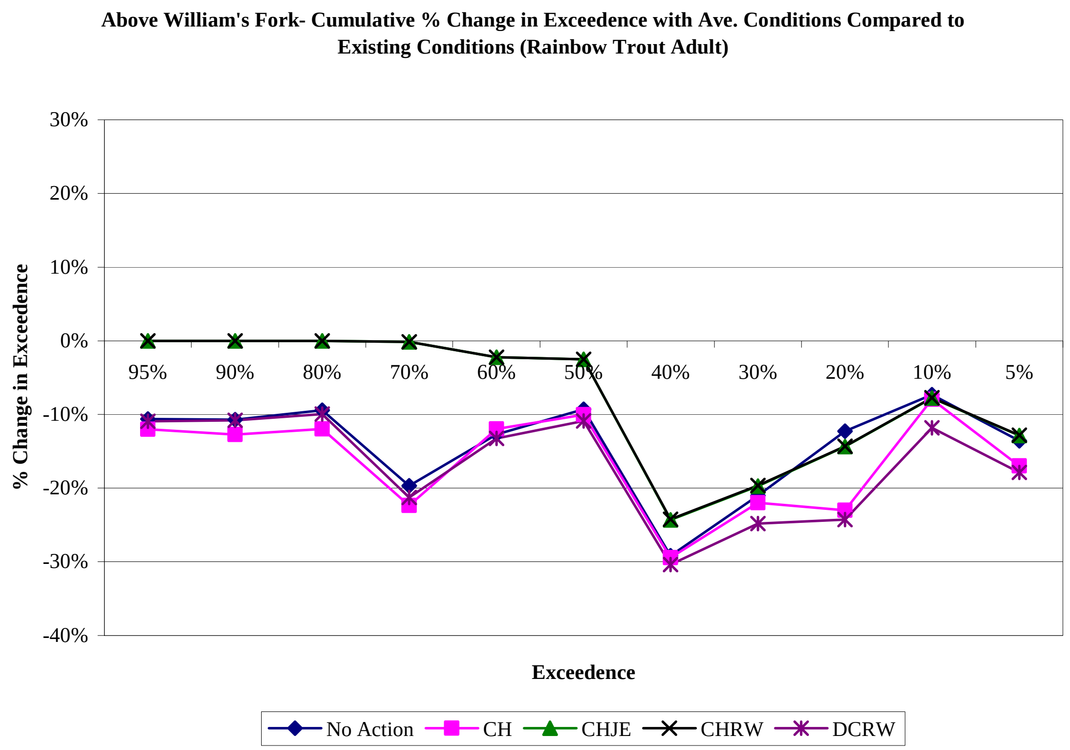


Figure 270. Above William's Fork – percent change in exceedence with average conditions (rainbow trout adult) cumulative effects.

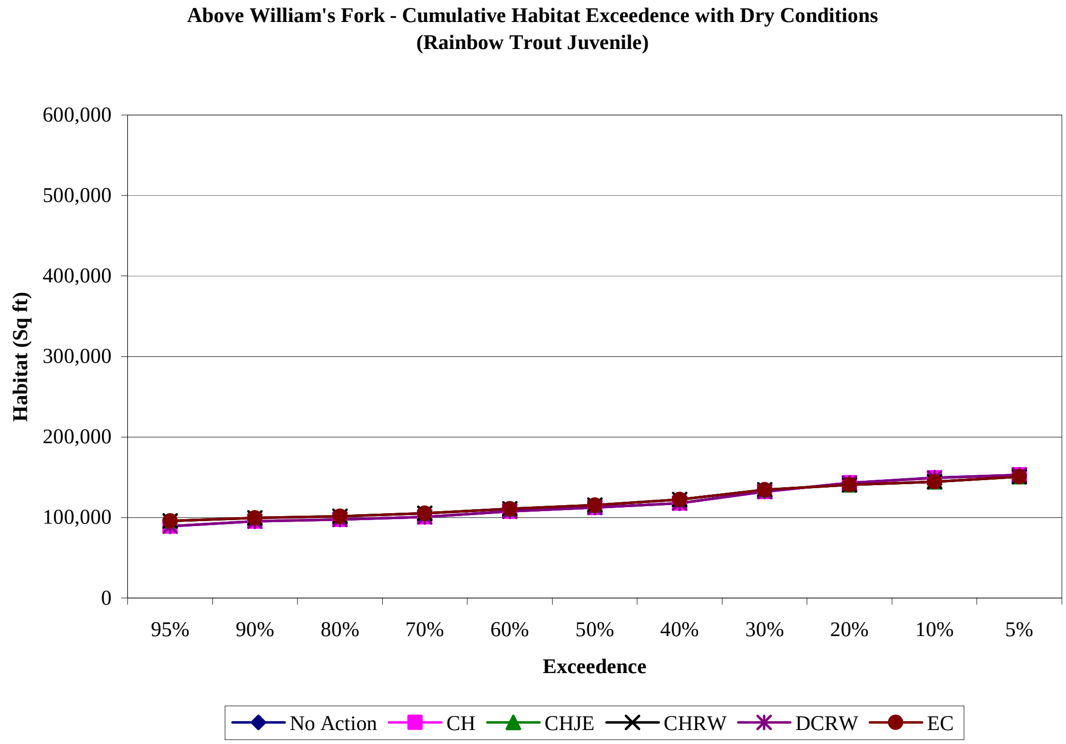


Figure 271. Above William's Fork – habitat exceedence with <u>dry</u> conditions (rainbow trout juvenile) cumulative effects.

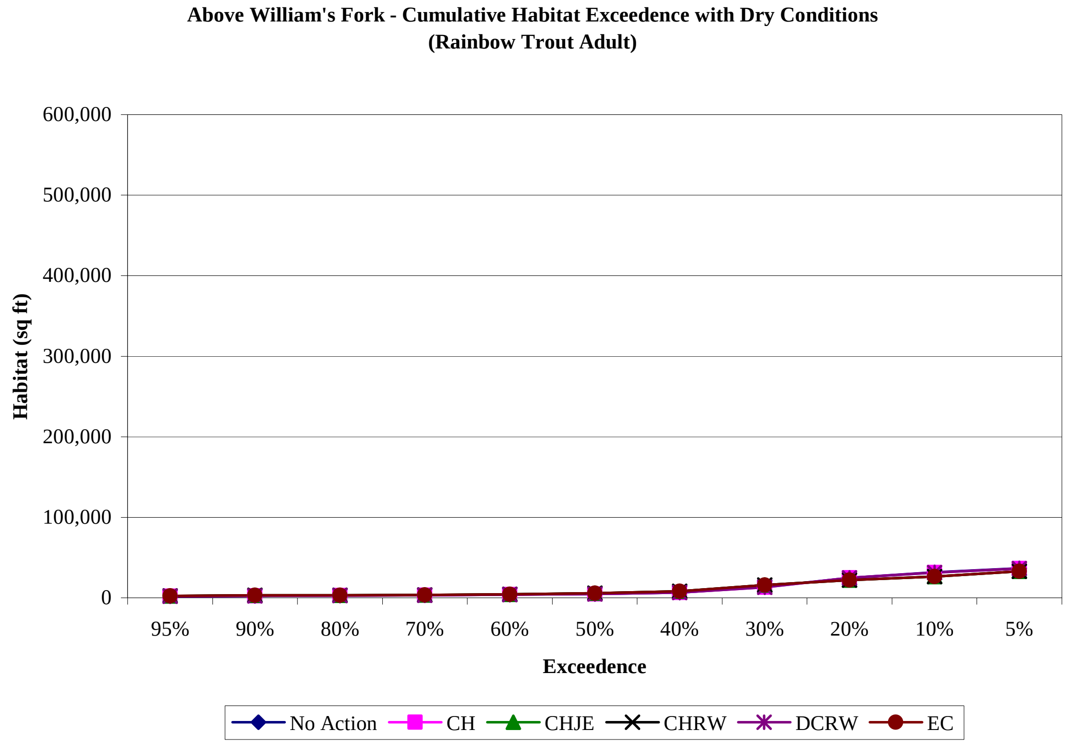


Figure 272. Above William's Fork – habitat exceedence with <u>dry</u> conditions (rainbow trout adult) cumulative effects.

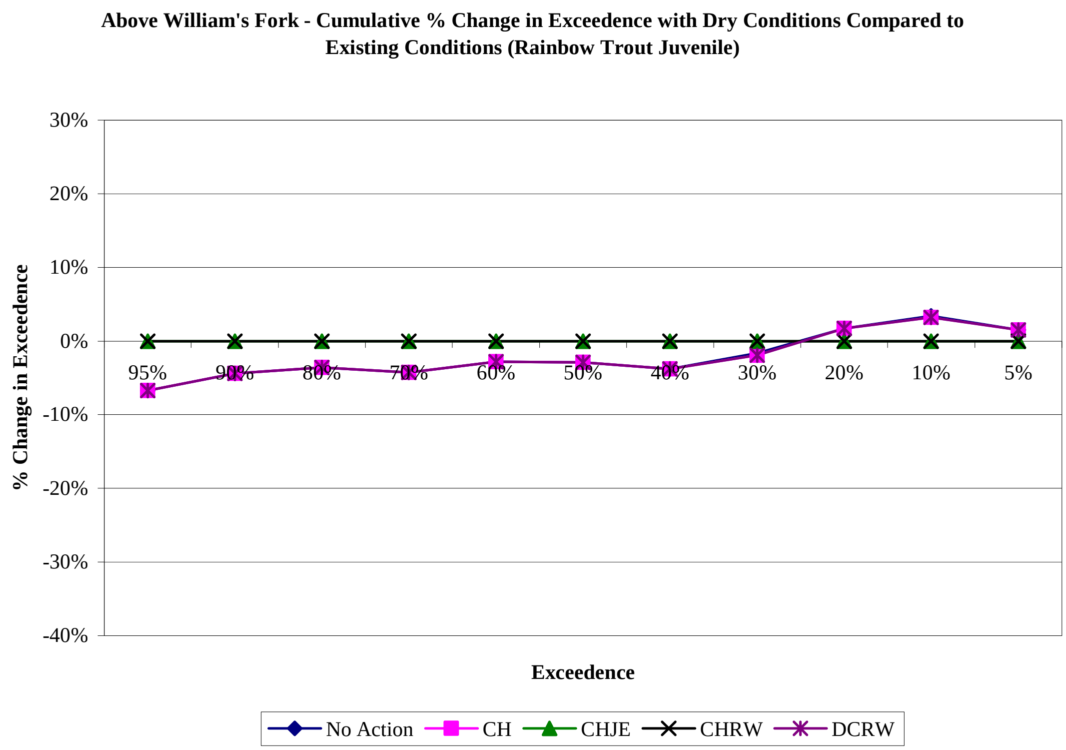


Figure 273. Above William's Fork – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile) cumulative effects.

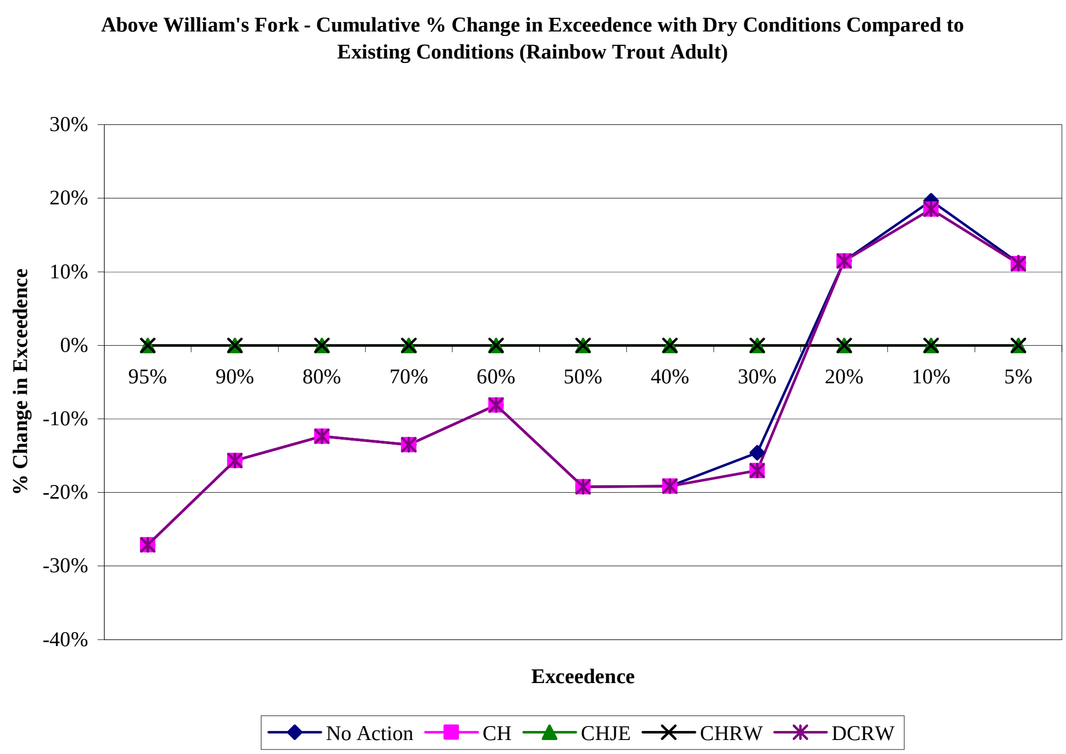


Figure 274. Above William's Fork – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult) cumulative effects.

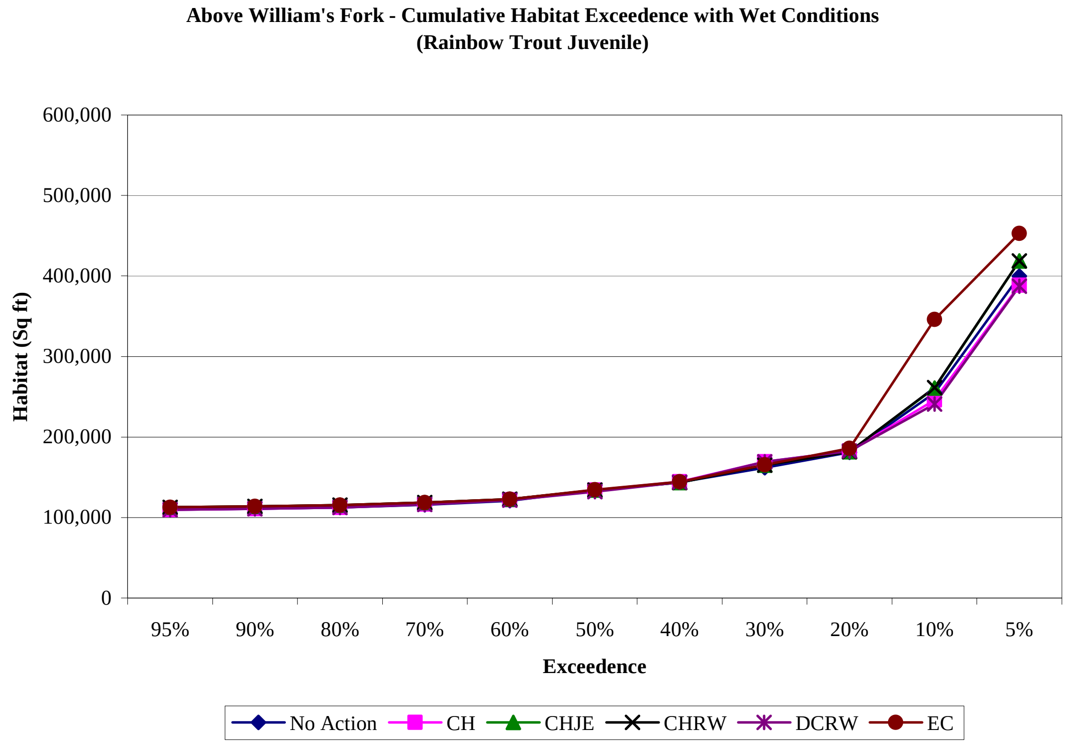


Figure 275. Above Williams Fork – habitat exceedence with <u>wet</u> conditions (rainbow trout juvenile) cumulative effects.

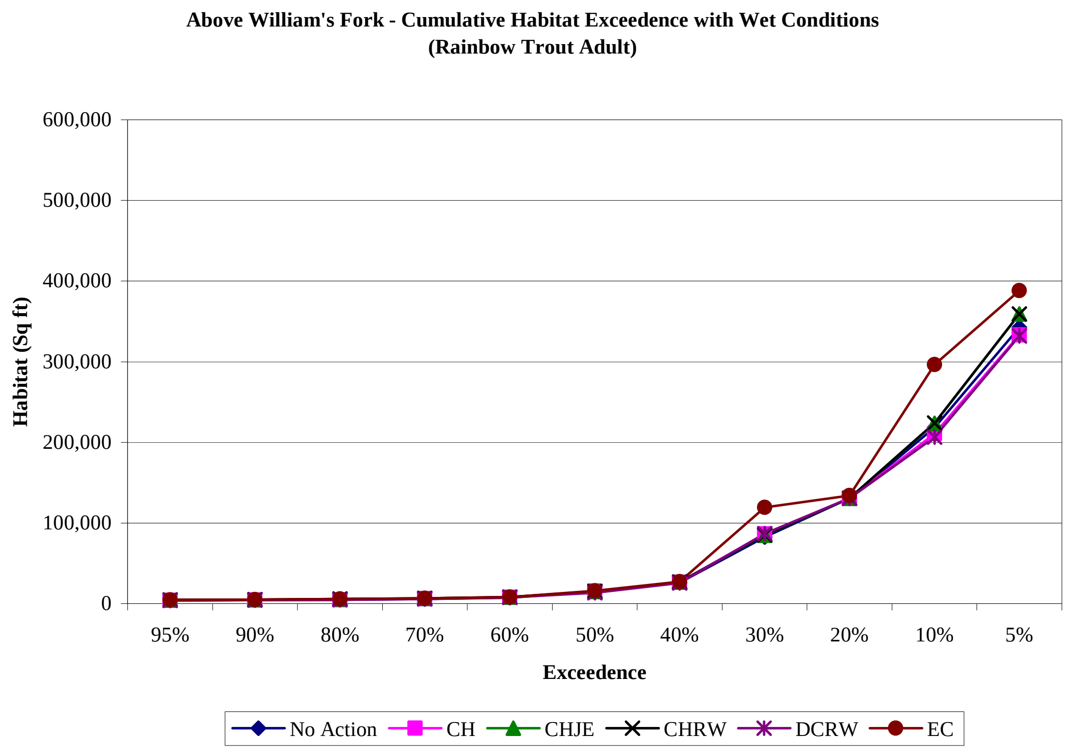


Figure 276. Above William's Fork – habitat exceedence with <u>wet</u> conditions (rainbow trout adult) cumulative effects.

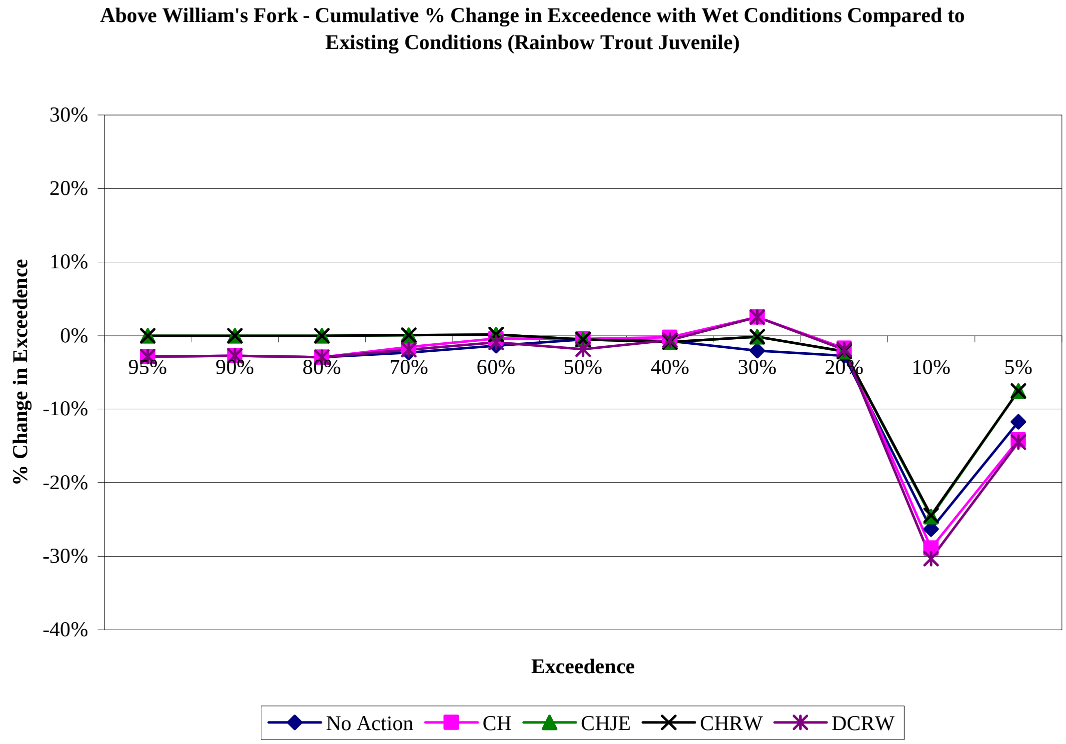


Figure 277. Above William's Fork – percent change in exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

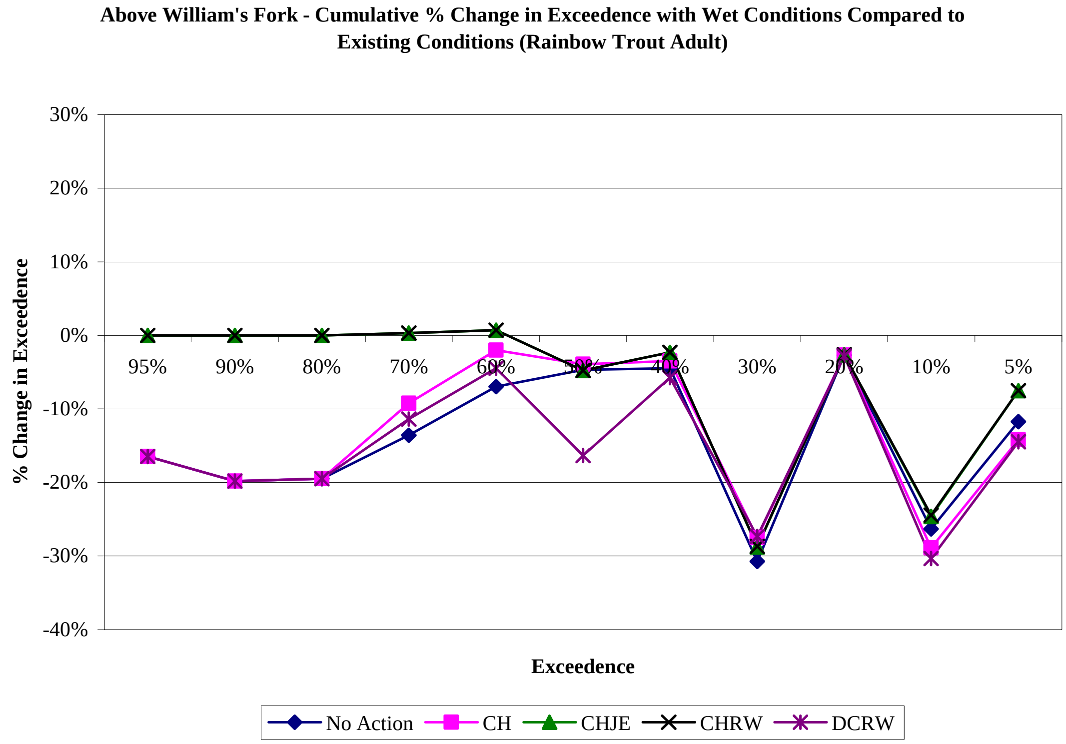


Figure 278. Above William's Fork – percent change in exceedence with wet conditions (rainbow trout adult) cumulative effects.

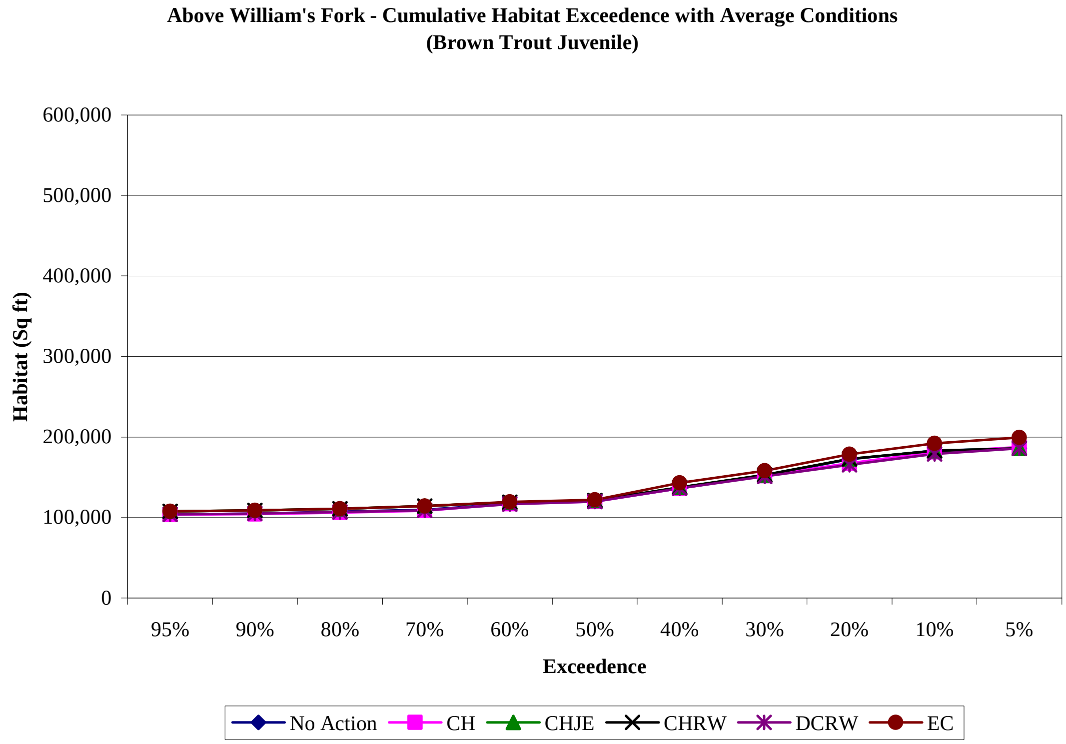


Figure 279. Above William's Fork – habitat exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

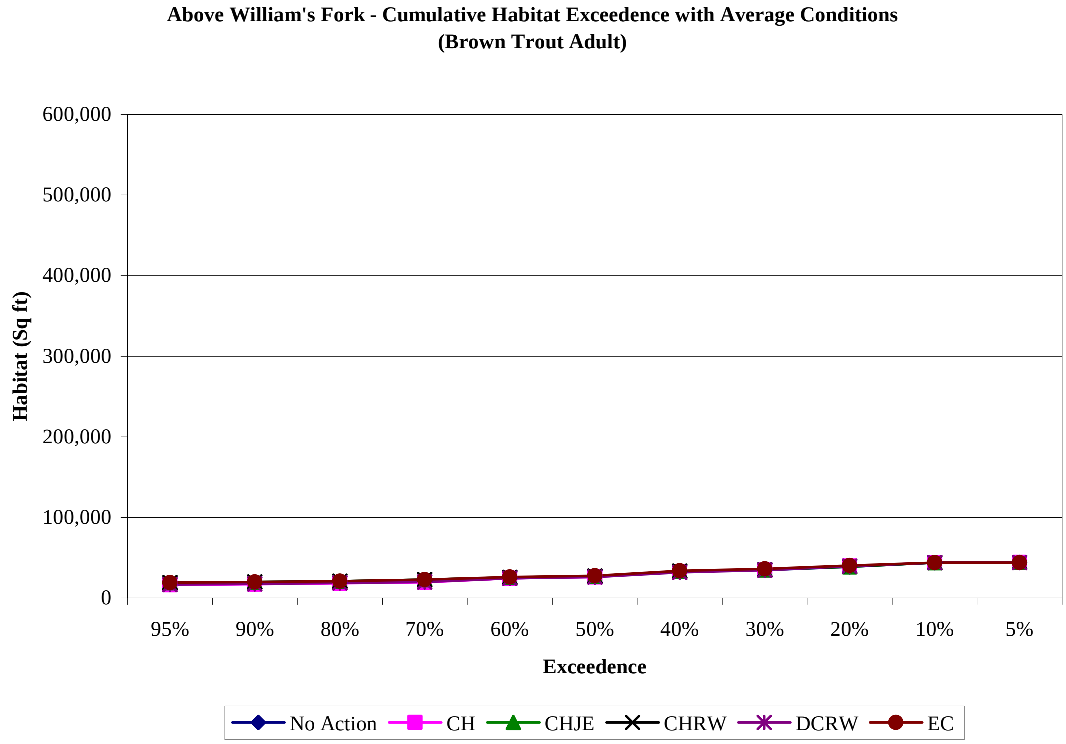


Figure 280. Above William's Fork – habitat exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

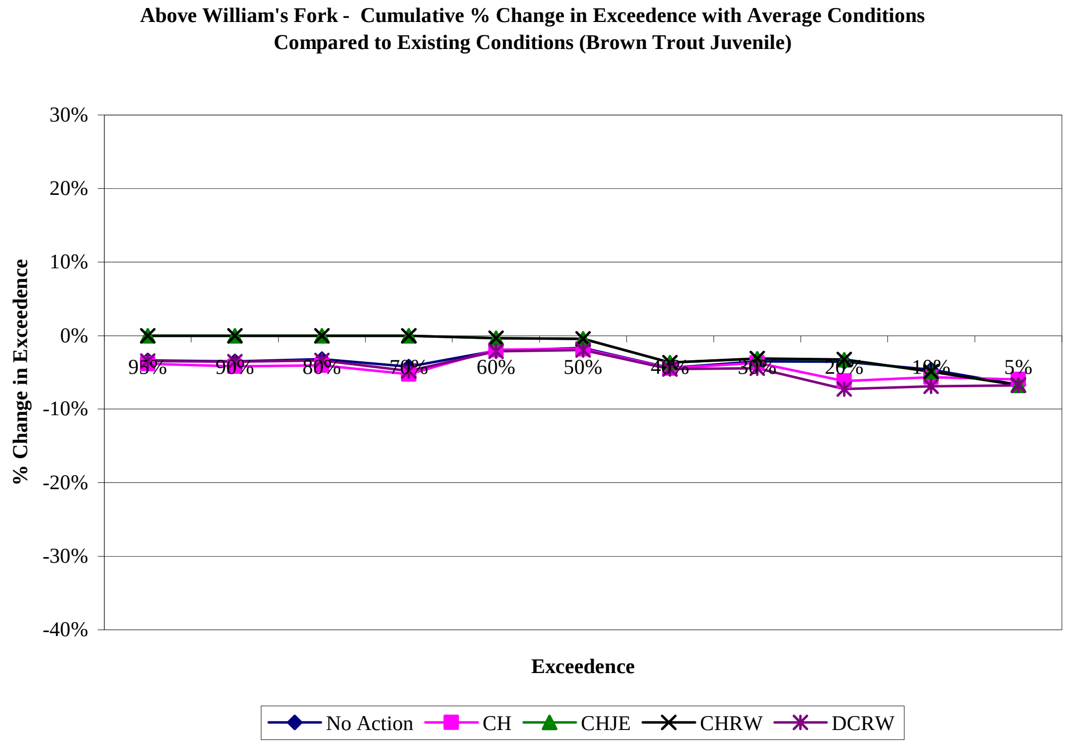


Figure 281. Above William's Fork – percent change in exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

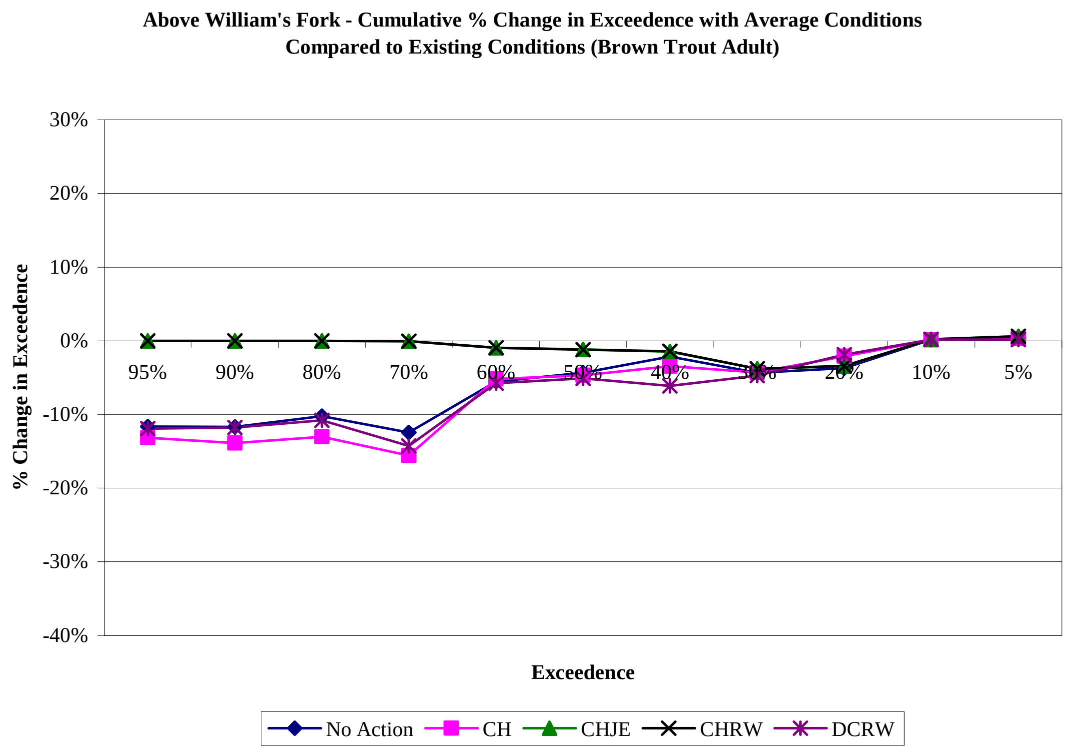


Figure 282. Above William's Fork – percent change in exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

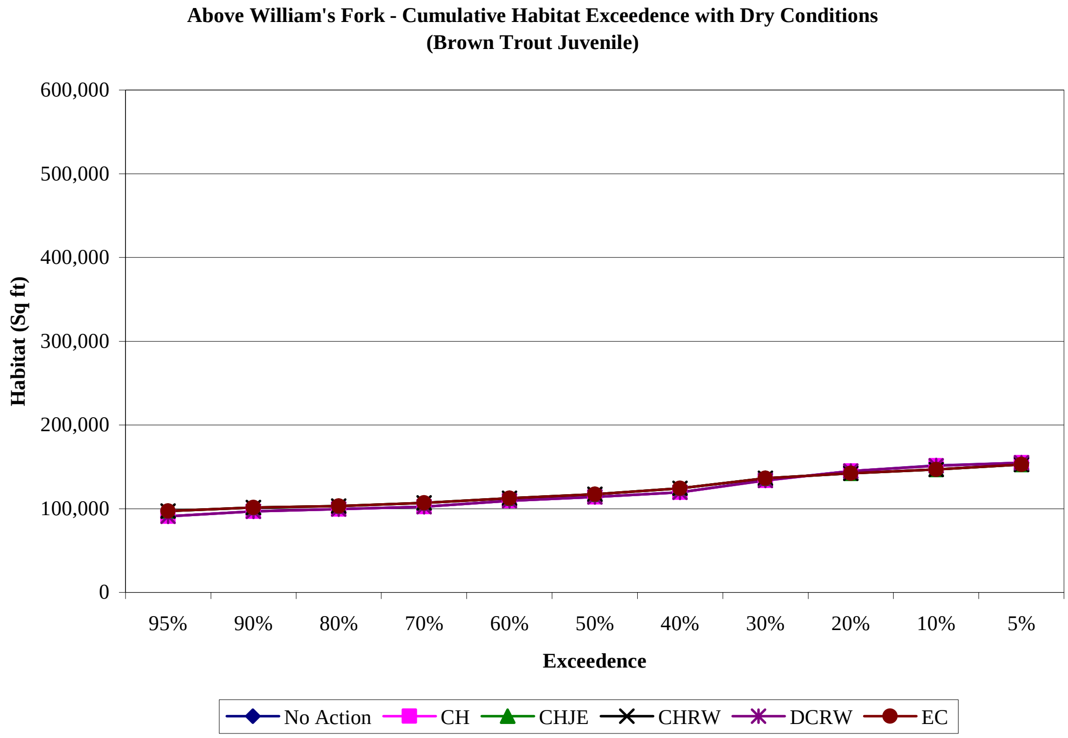


Figure 283. Above William's Fork – habitat exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

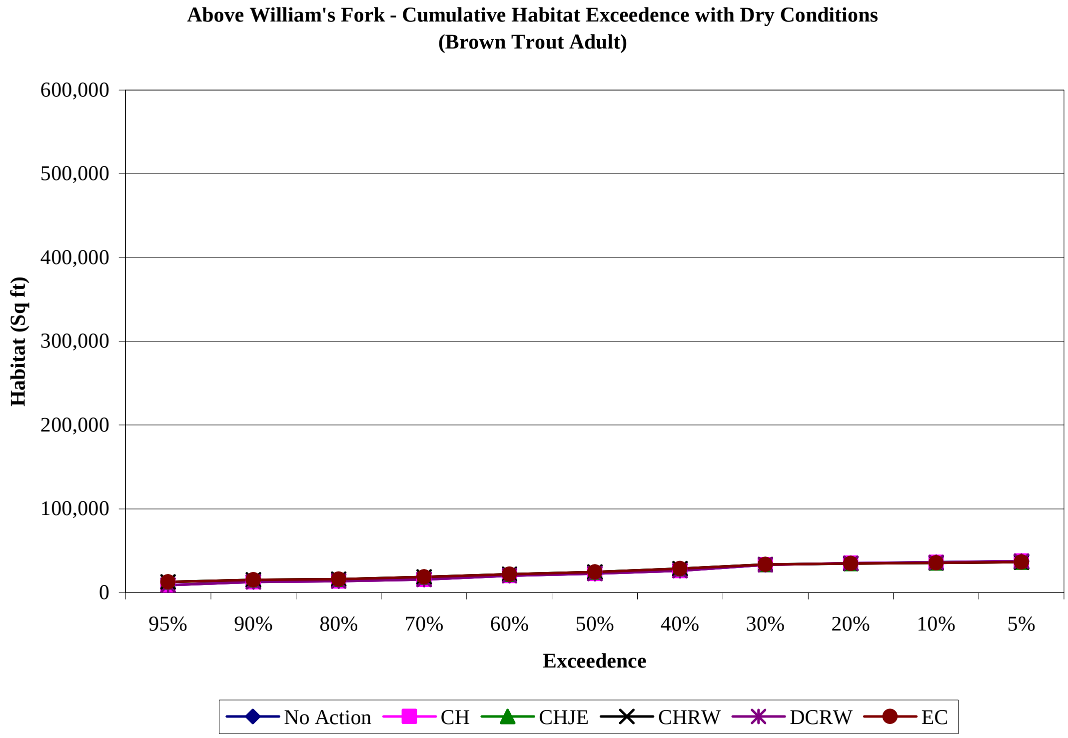


Figure 284. Above William's Fork – habitat exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

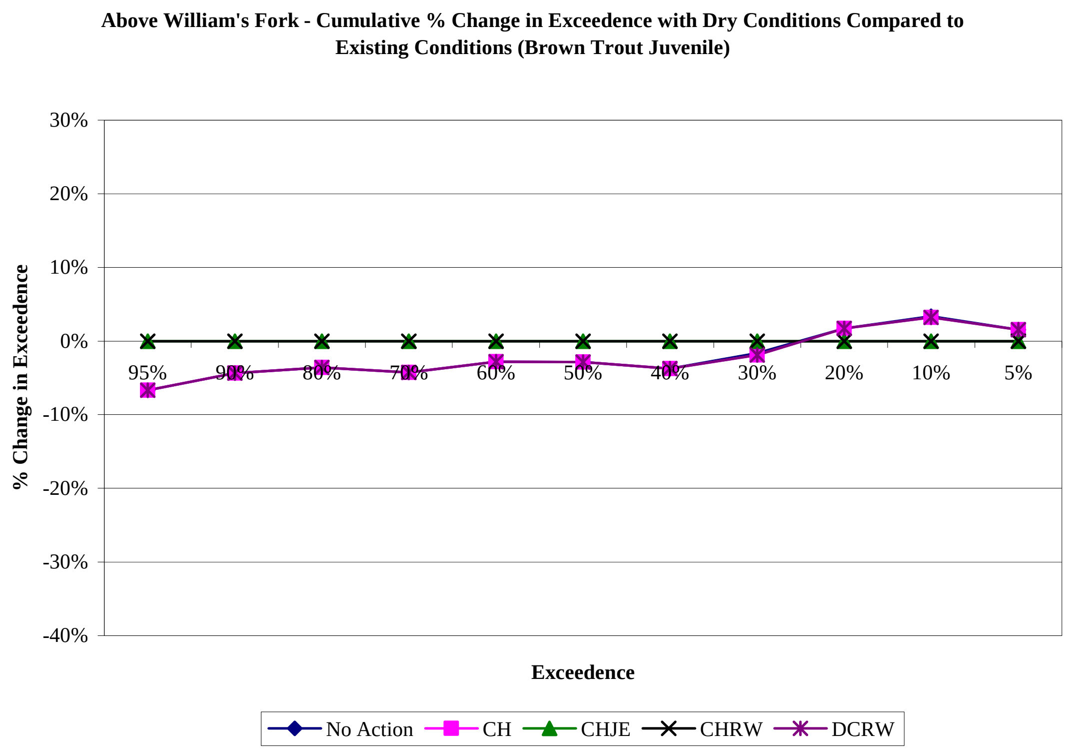


Figure 285. Above William's Fork – percent change in exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

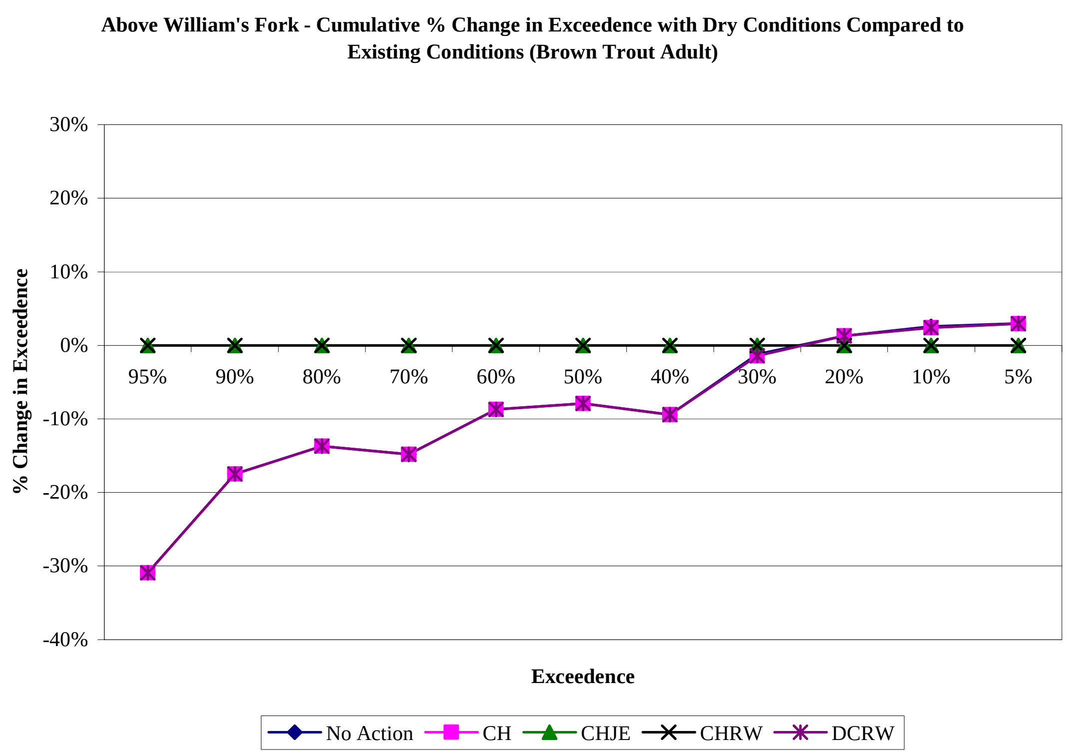


Figure 286. Above William's Fork – percent change in exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

Figure 287. Above William's Fork – habitat exceedence with wet conditions (brown trout juvenile) cumulative effects.

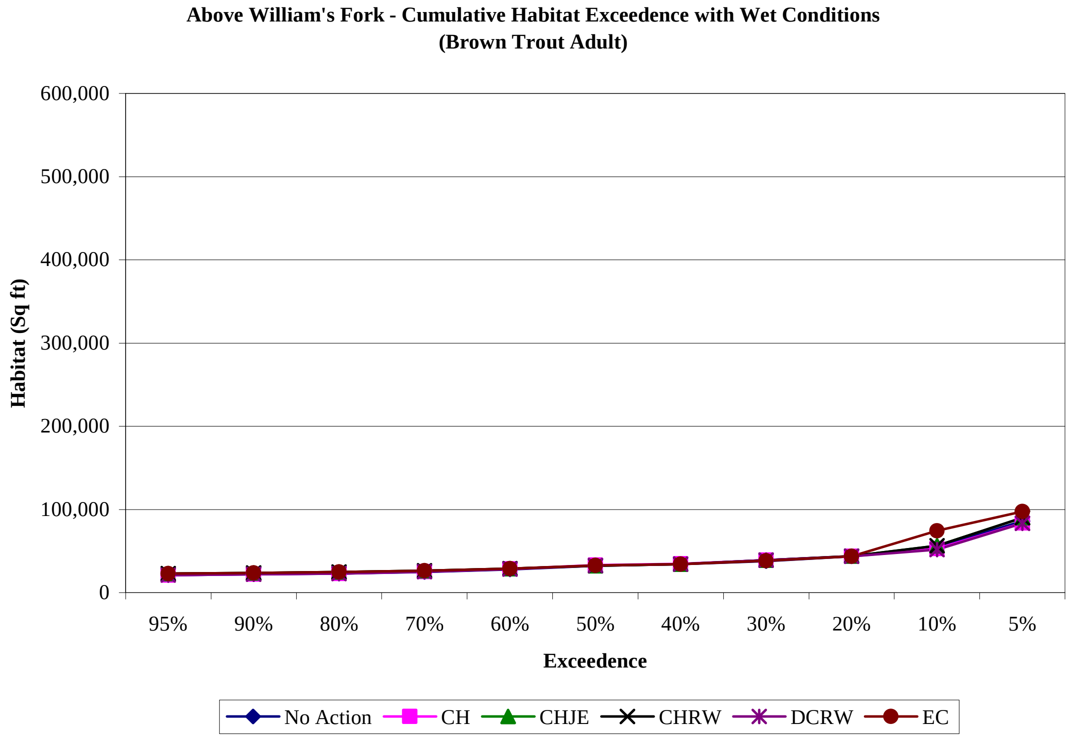


Figure 288. Above William's Fork – habitat exceedence with wet conditions (brown trout adult) cumulative effects.

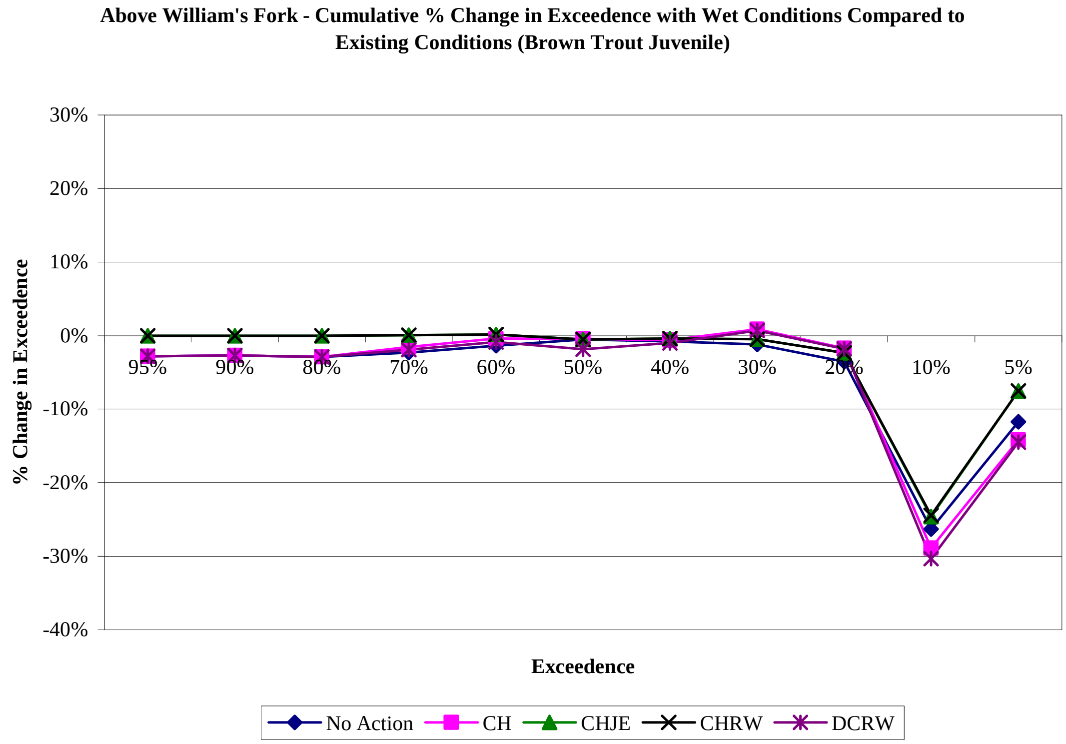


Figure 289. Above William's Fork – percent change in exceedence with wet conditions (brown trout juvenile) cumulative effects.

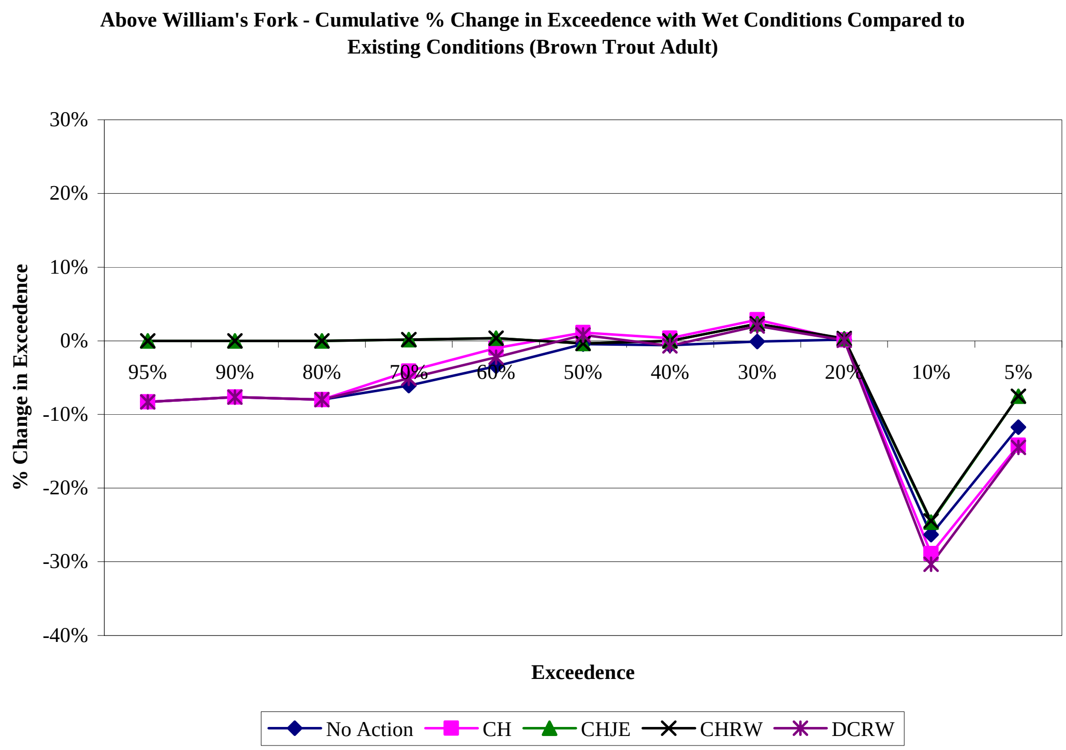


Figure 290. Above William's Fork – percent change in exceedence with wet conditions (brown trout adult) cumulative effects.

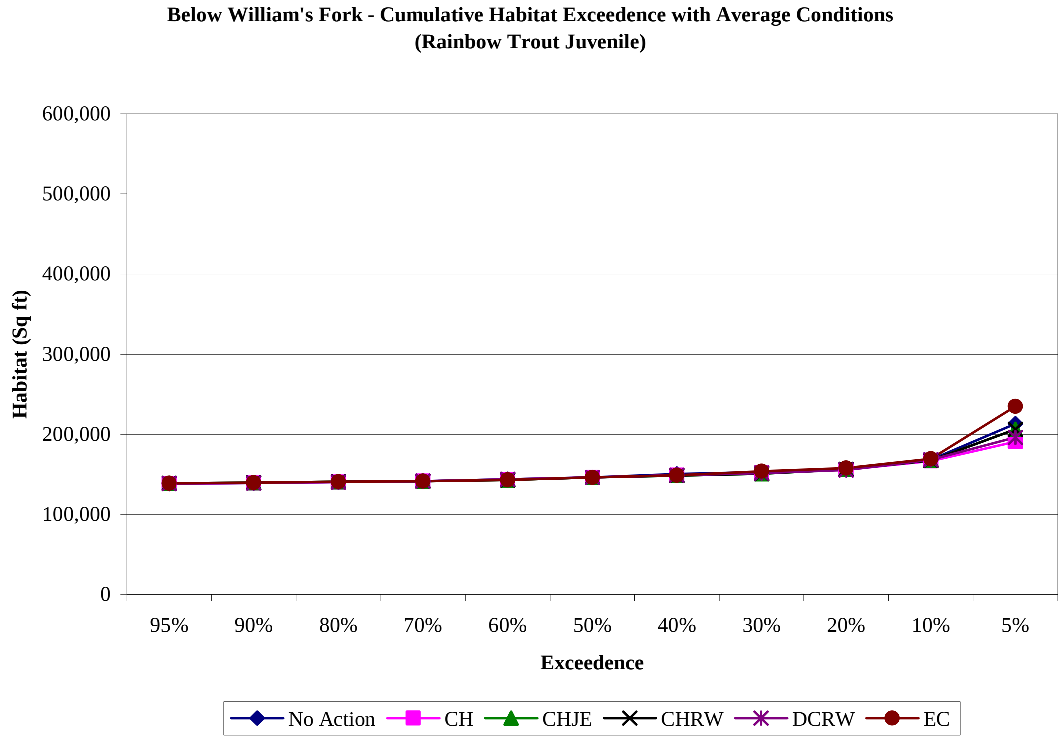


Figure 291. Below William's Fork – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

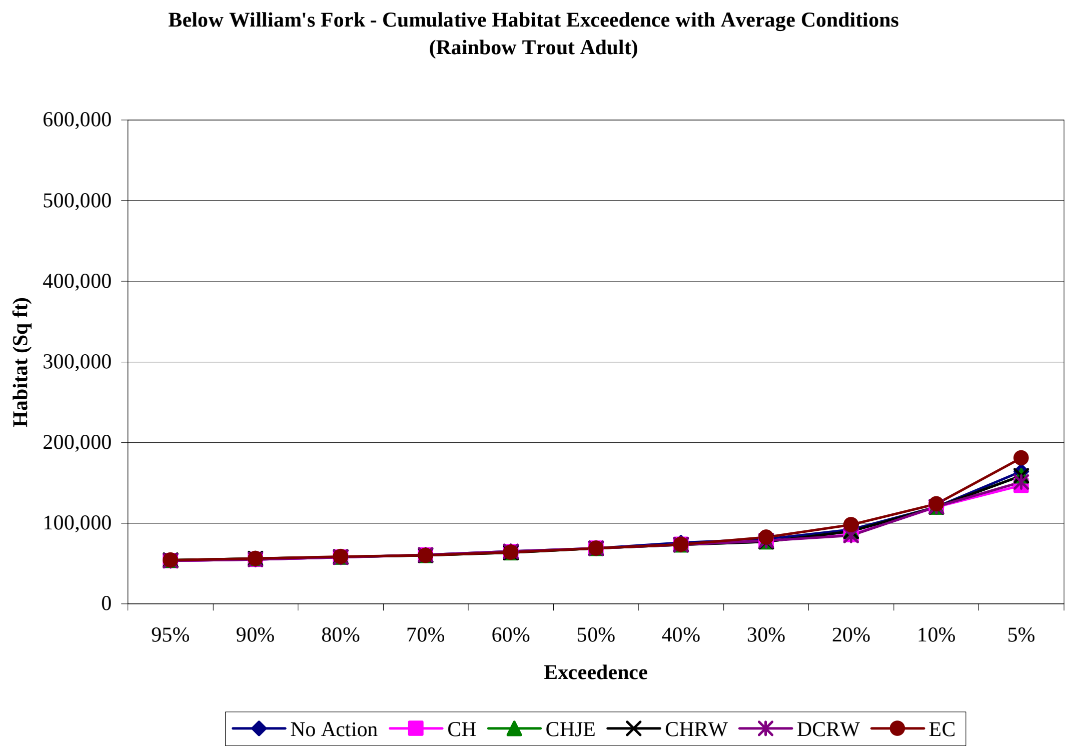


Figure 292. Below William's Fork – habitat exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

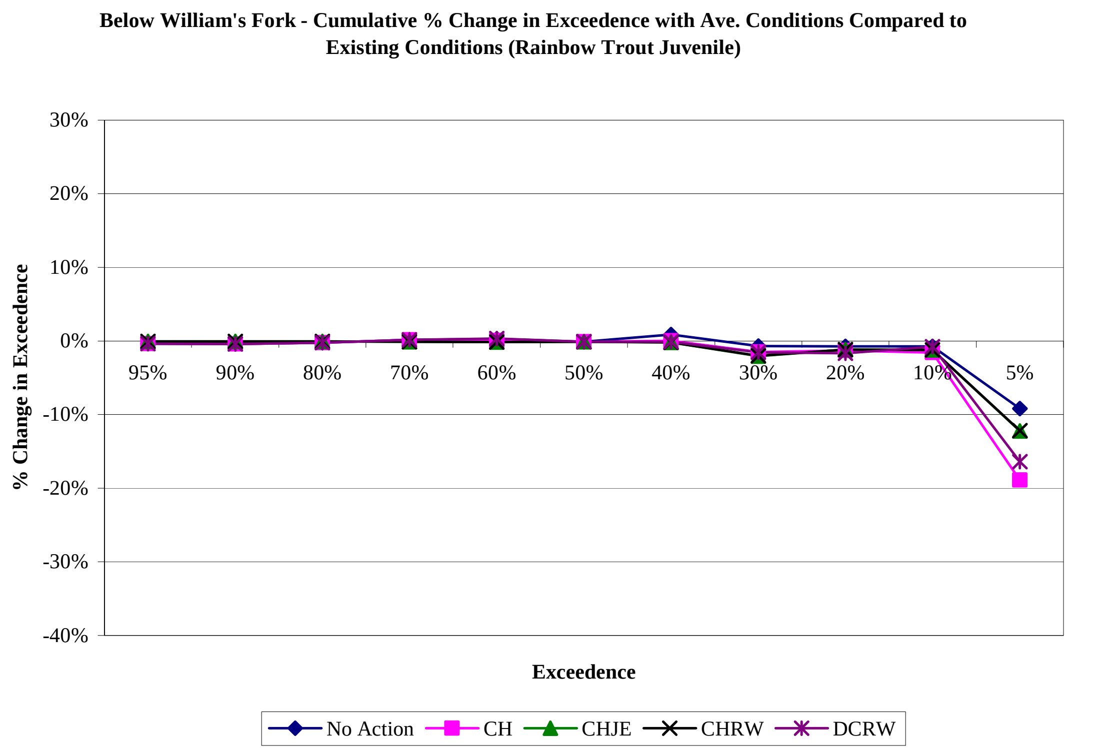


Figure 293. Below William's Fork – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

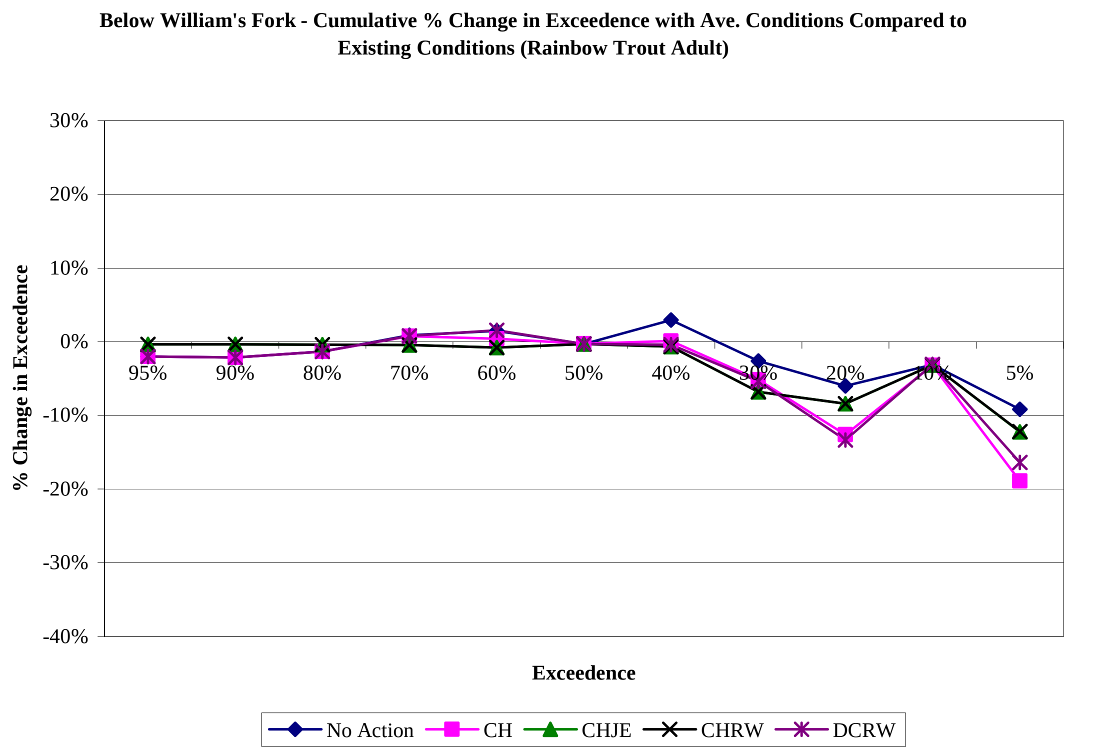


Figure 294. Below William's Fork – percent change in exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

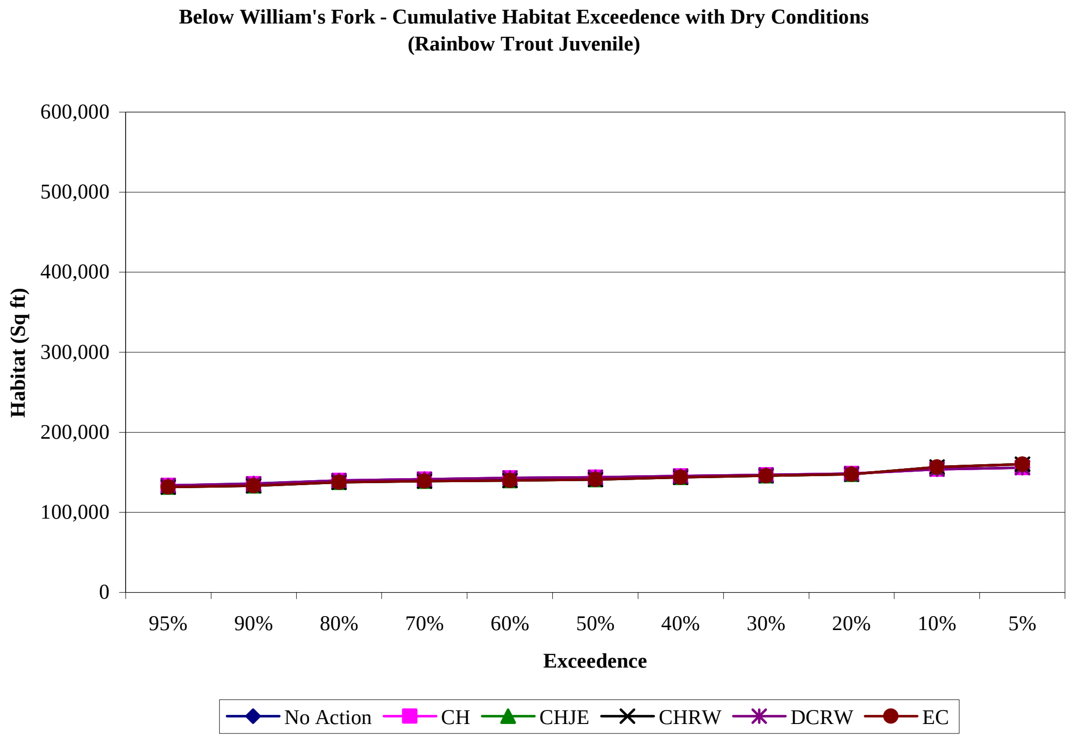


Figure 295. Below William's Fork – habitat exceedence with dry conditions (rainbow trout juvenile) cumulative effects.

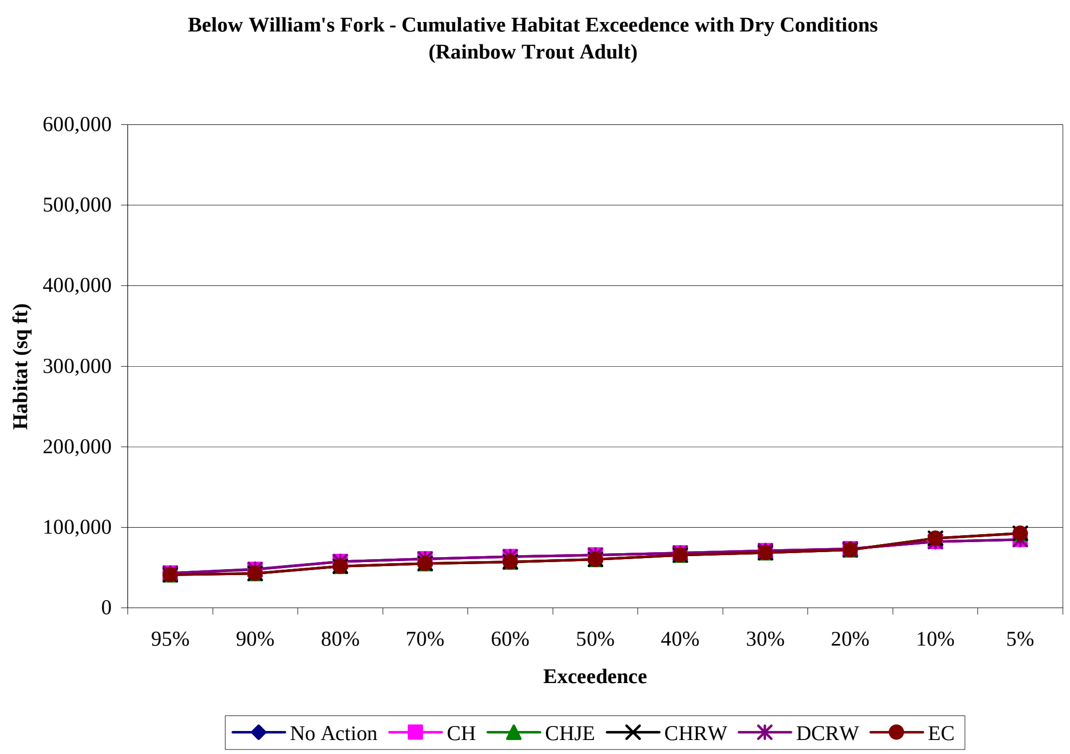


Figure 296. Below William's Fork – habitat exceedence with dry conditions (rainbow trout adult) cumulative effects.

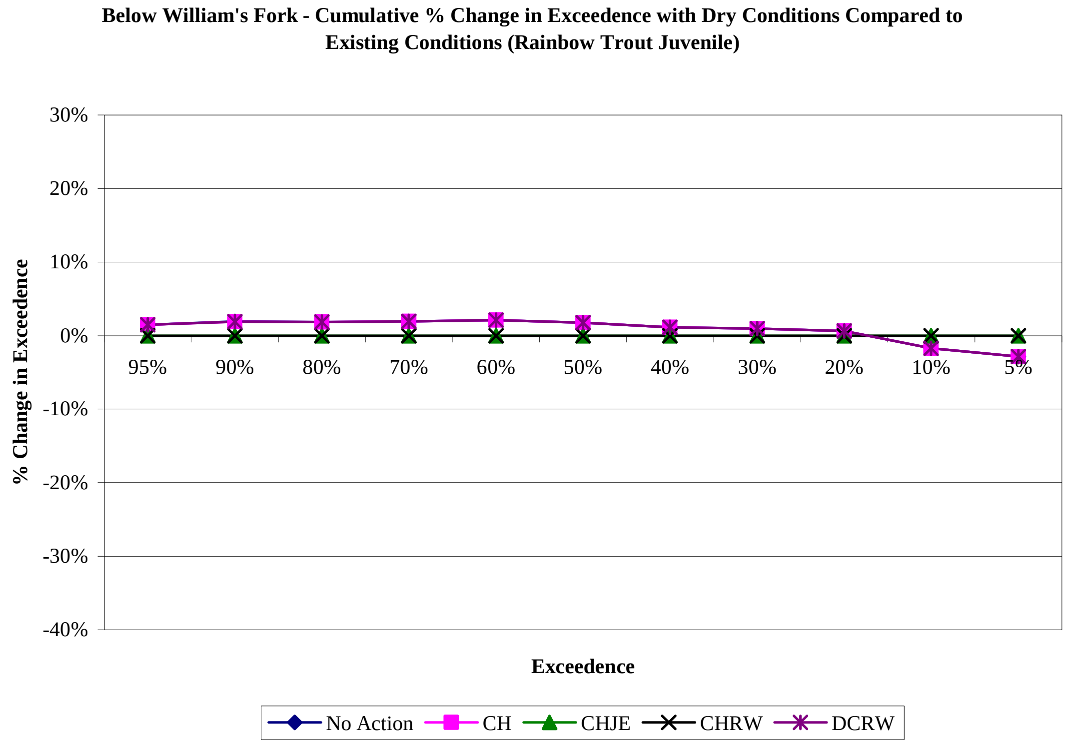


Figure 297. Below William's Fork – percent change in exceedence with dry conditions (rainbow trout juvenile) cumulative effects.

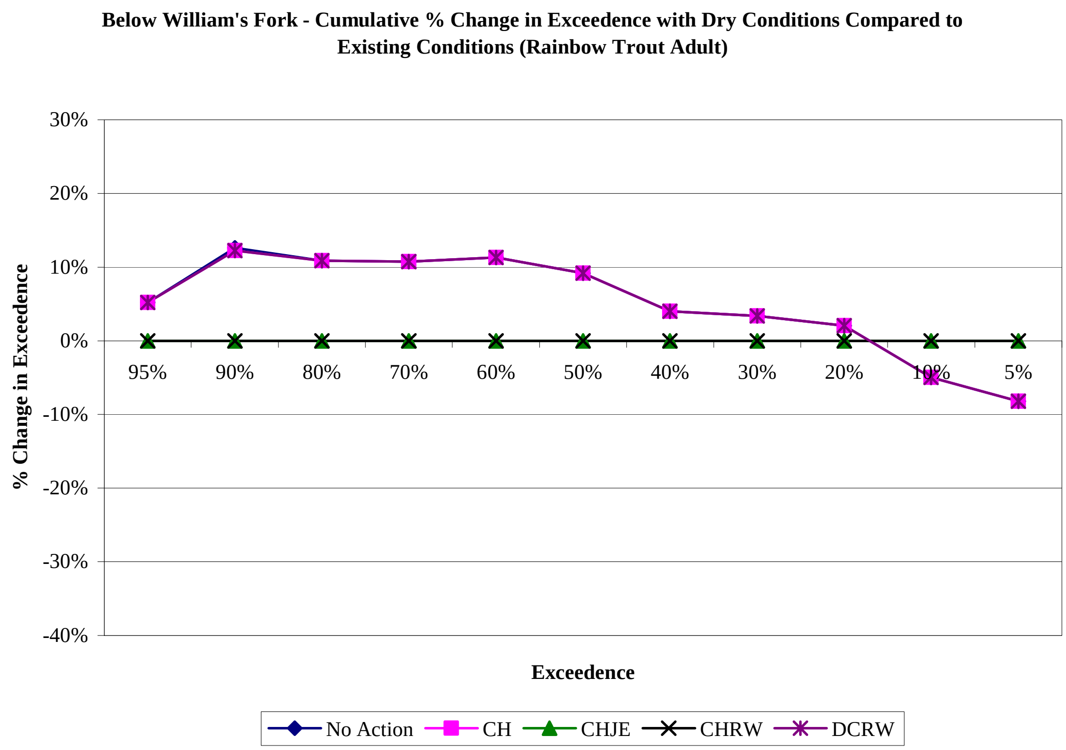


Figure 298. Below William's Fork – percent change in exceedence with dry conditions (rainbow trout adult) cumulative effects.

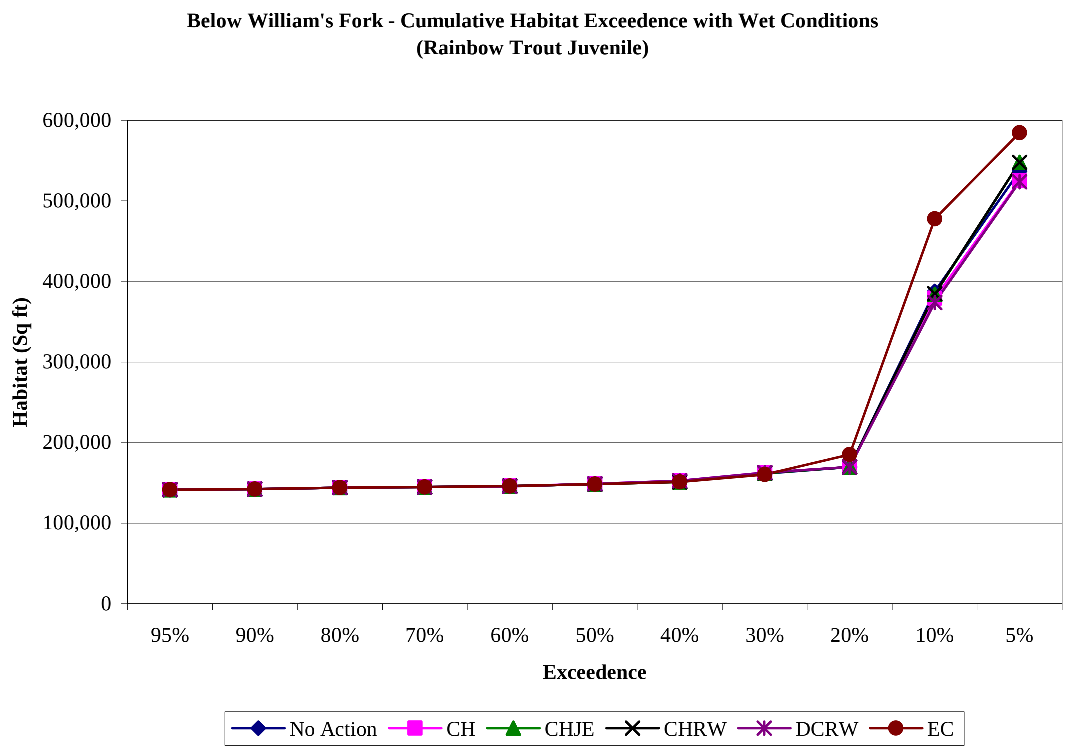


Figure 299. Below William's Fork – habitat exceedence with <u>wet</u> conditions (rainbow trout juvenile) cumulative effects.

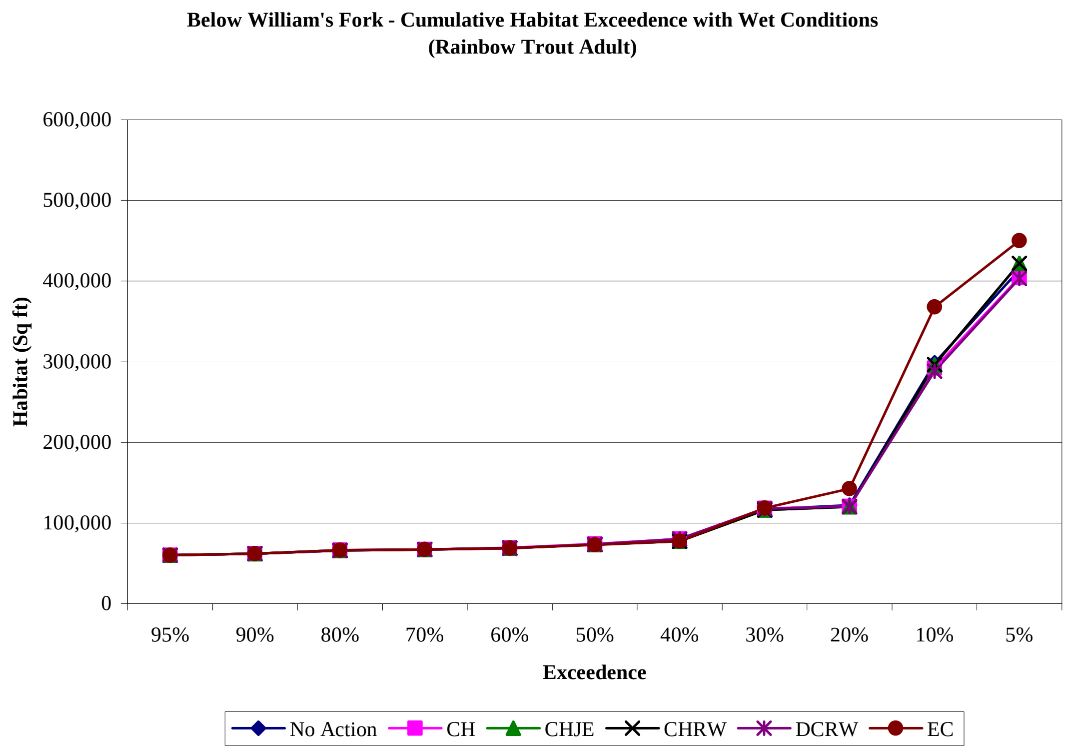


Figure 300. Below William's Fork – habitat exceedence with <u>wet</u> conditions (rainbow trout adult) cumulative effects.

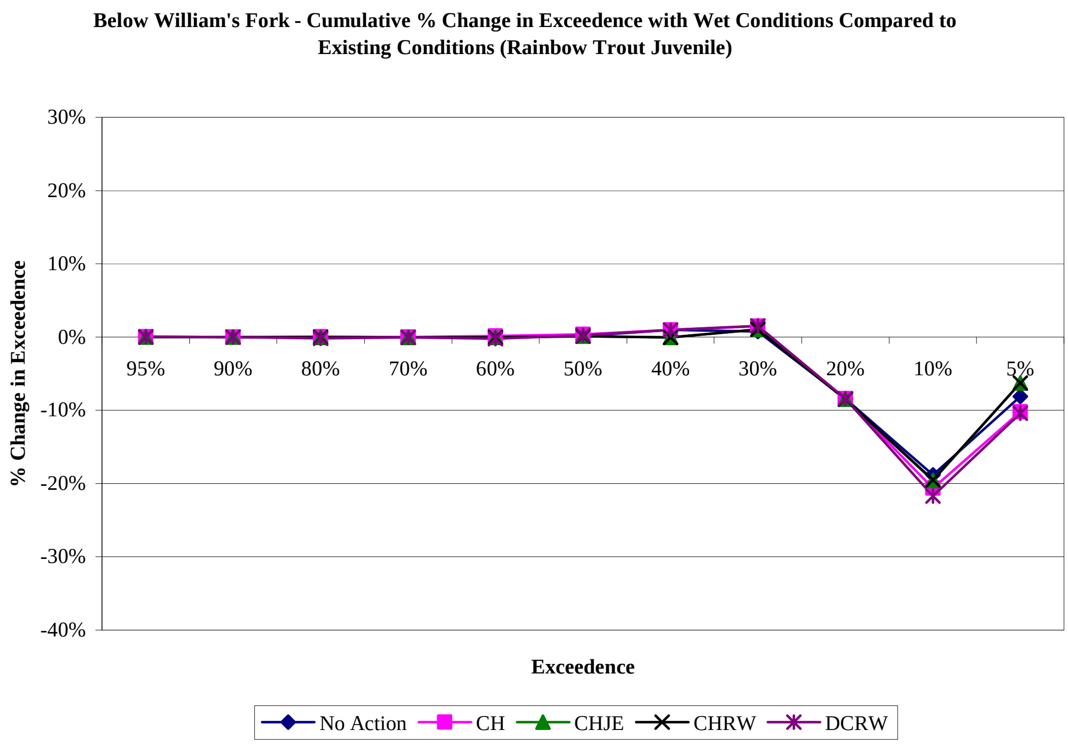


Figure 301. Below William's Fork – percent change in exceedence with <u>wet</u> conditions (rainbow trout juvenile) cumulative effects.

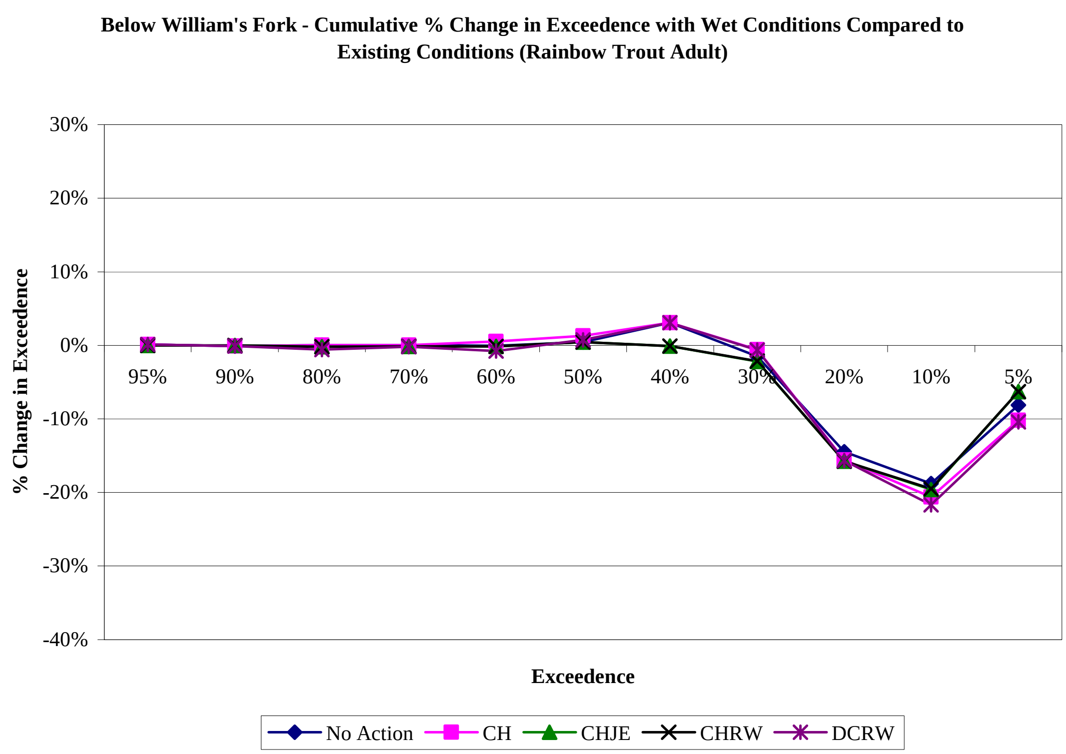


Figure 302. Below William's Fork – percent change in exceedence with <u>wet</u> conditions (rainbow trout adult) cumulative effects.

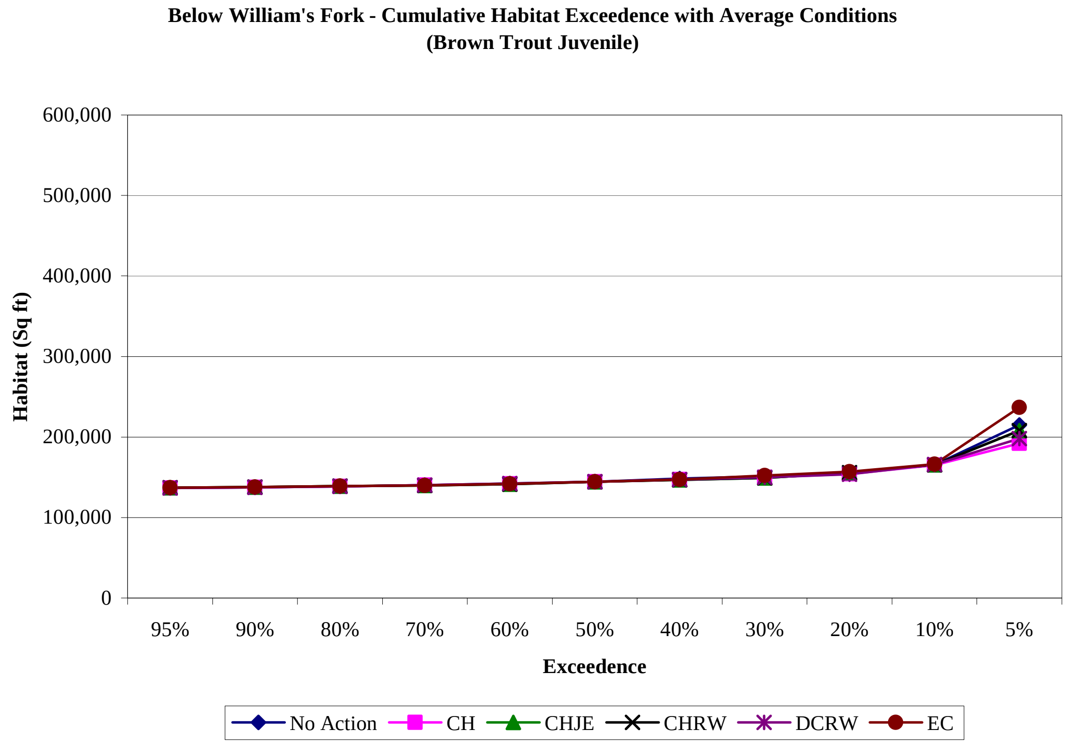


Figure 303. Below William's Fork – habitat exceedence with average conditions (brown trout juvenile) cumulative effects.

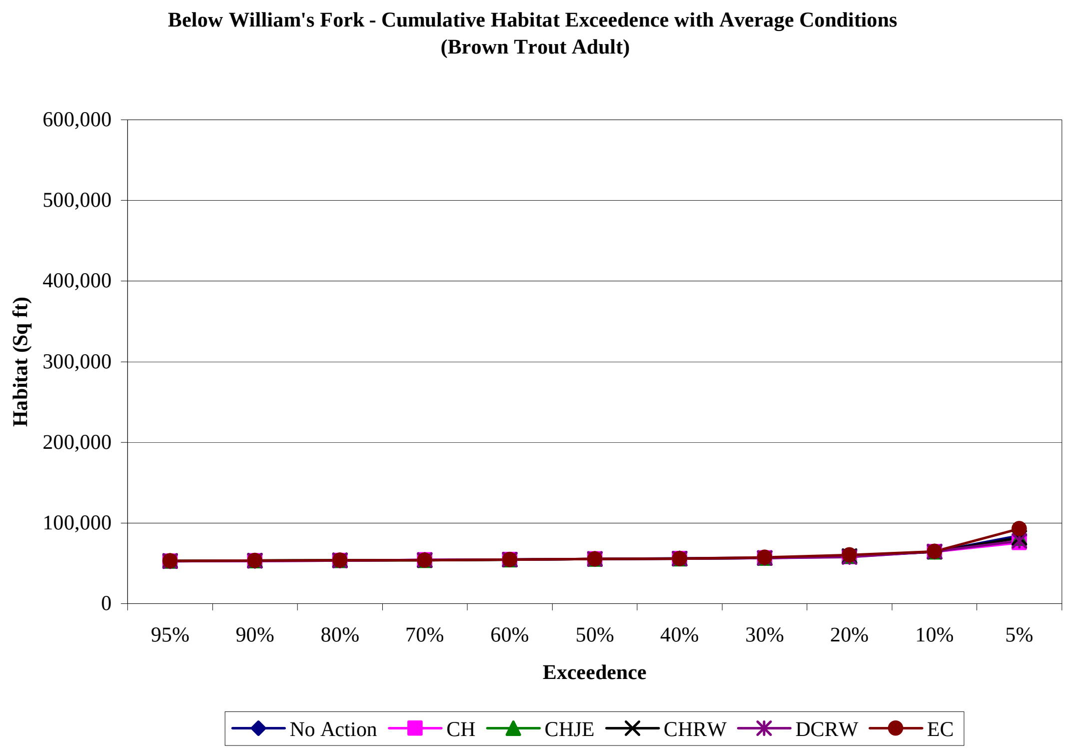


Figure 304. Below William's Fork – habitat exceedence with average conditions (brown trout adult) cumulative effects.

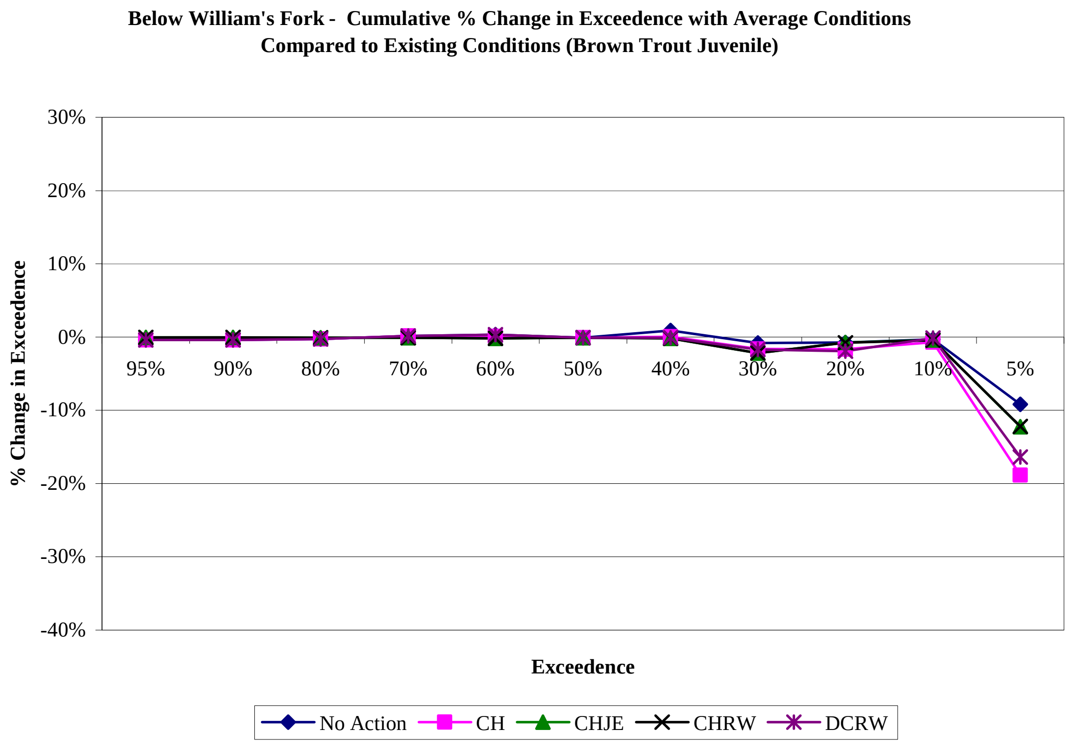


Figure 305. Below William's Fork – percent change in exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

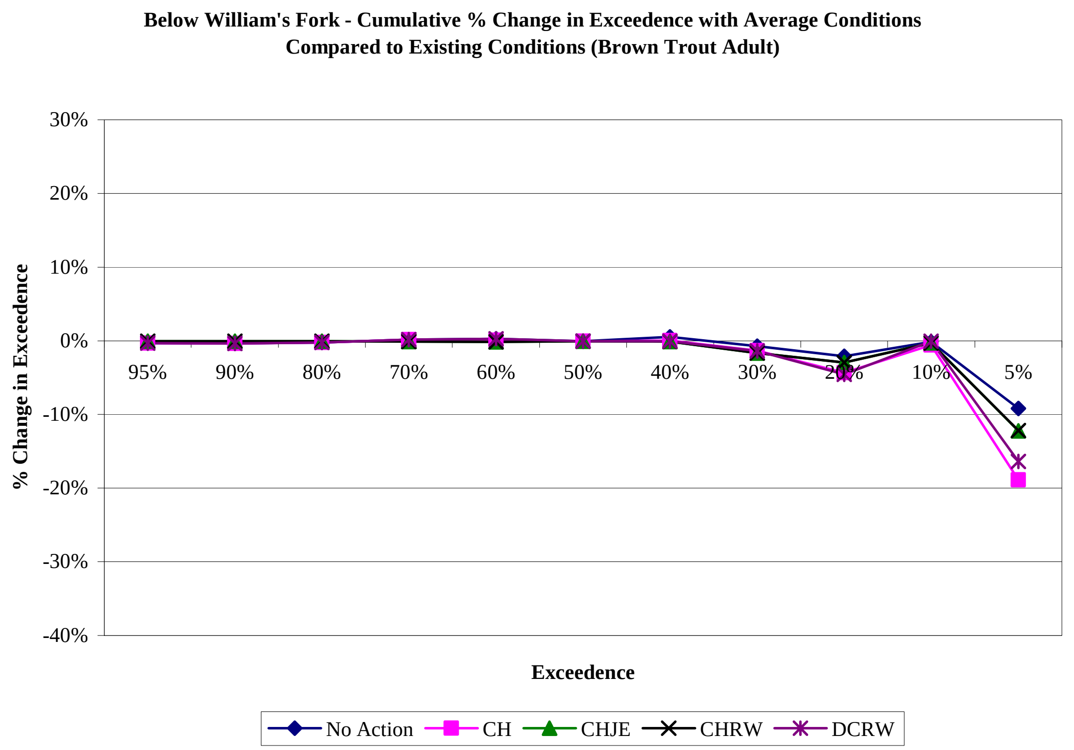


Figure 306. Below William's Fork – percent change in exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

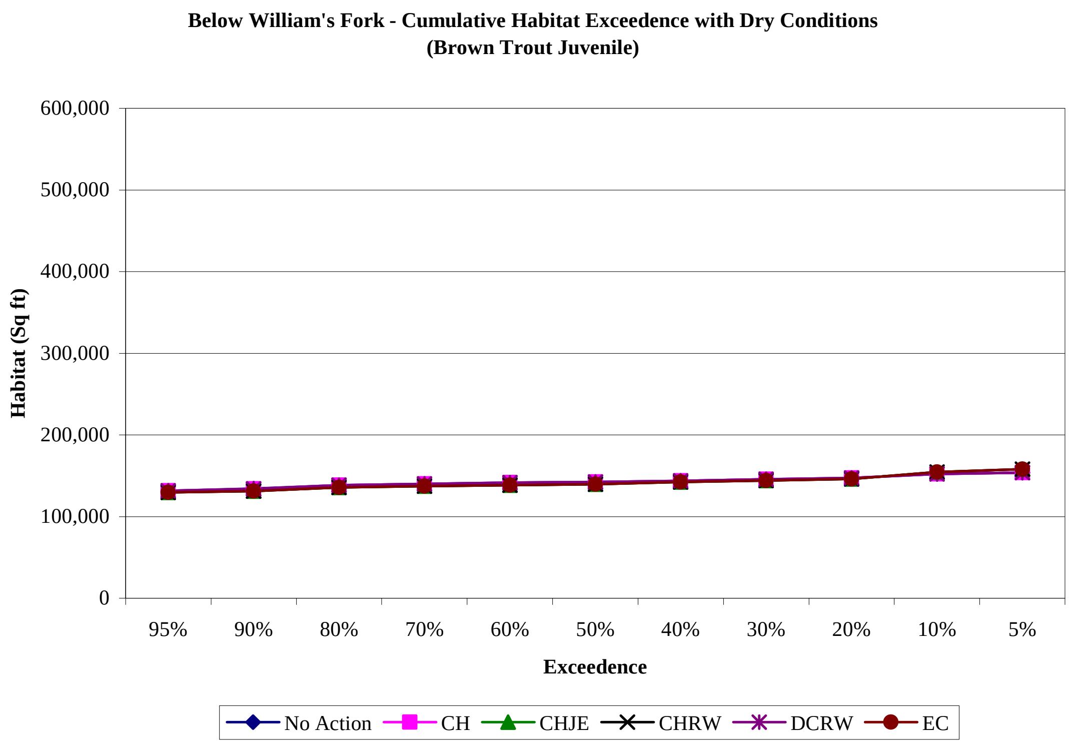


Figure 307. Below William's Fork – habitat exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

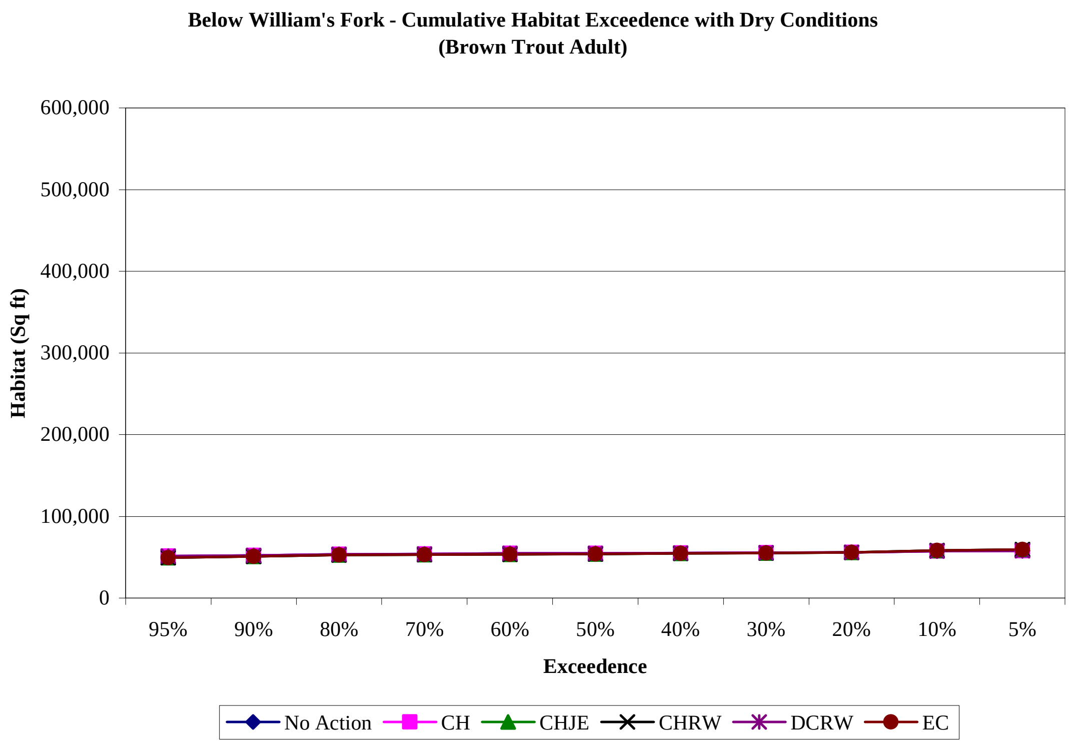


Figure 308. Below William's Fork – habitat exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

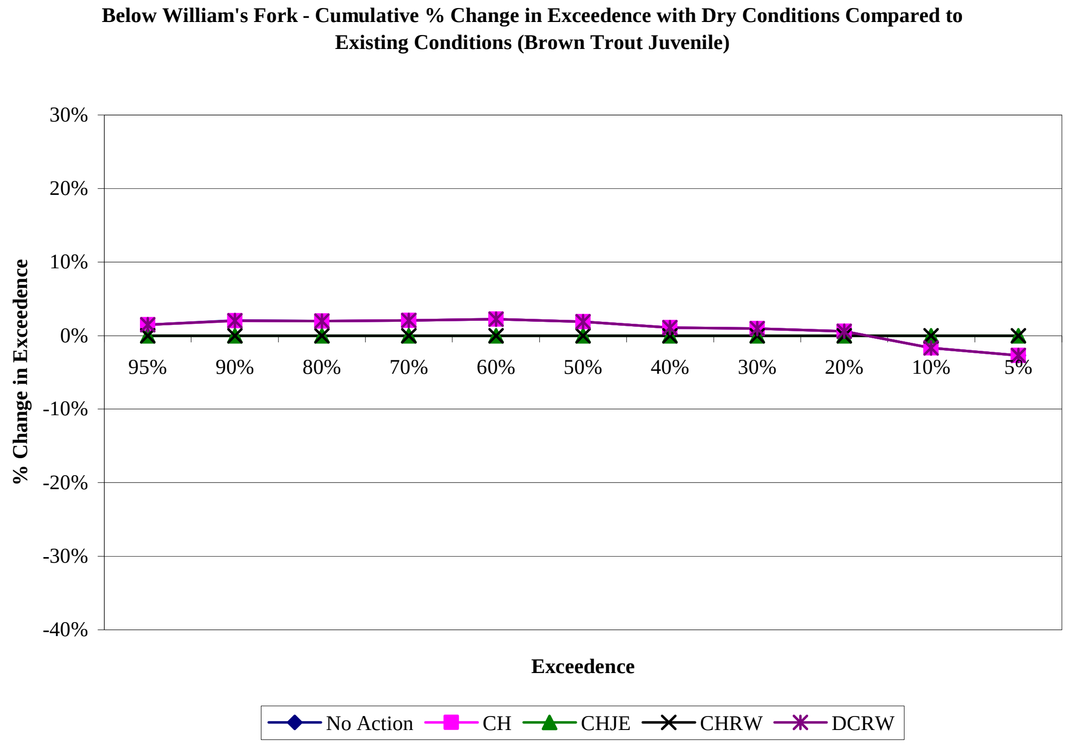


Figure 309. Below William's Fork – percent change in exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

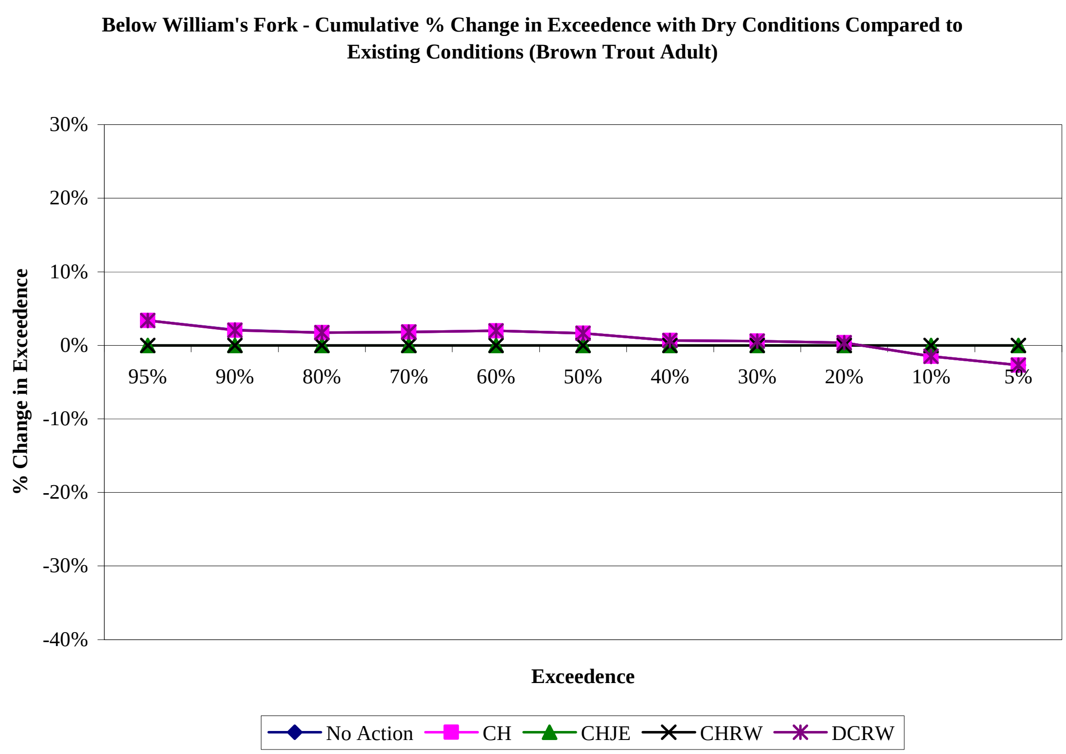


Figure 310. Below William's Fork – percent change in exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

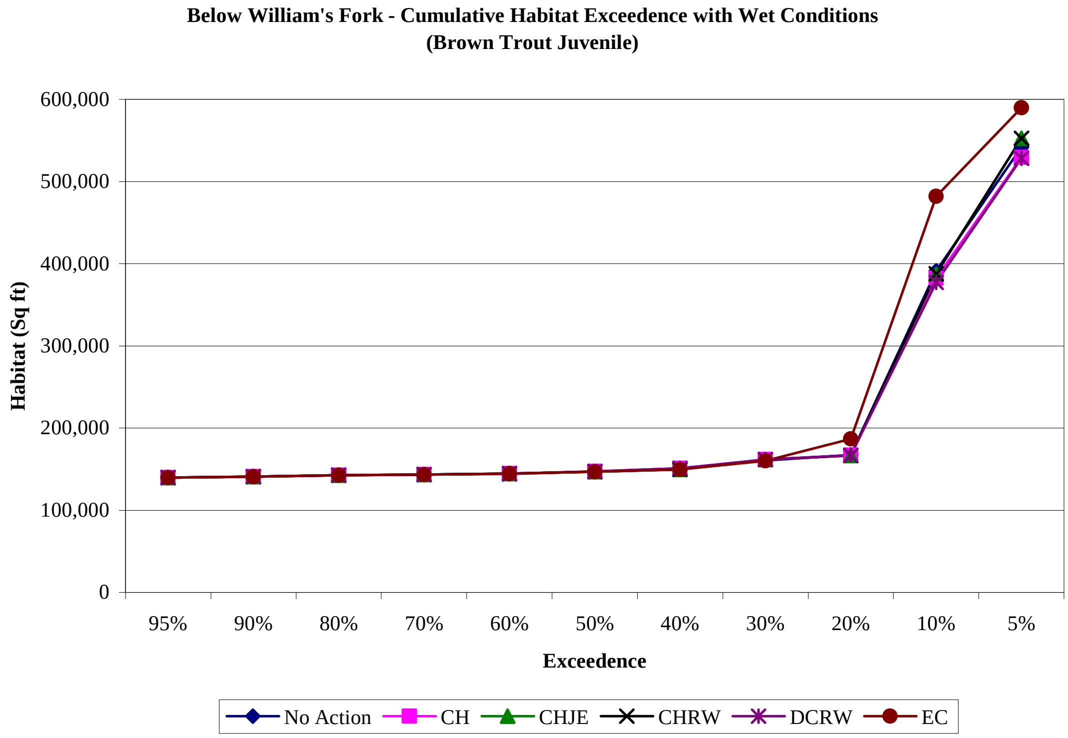


Figure 311. Below William's Fork – habitat exceedence with wet conditions (brown trout juvenile) cumulative effects.

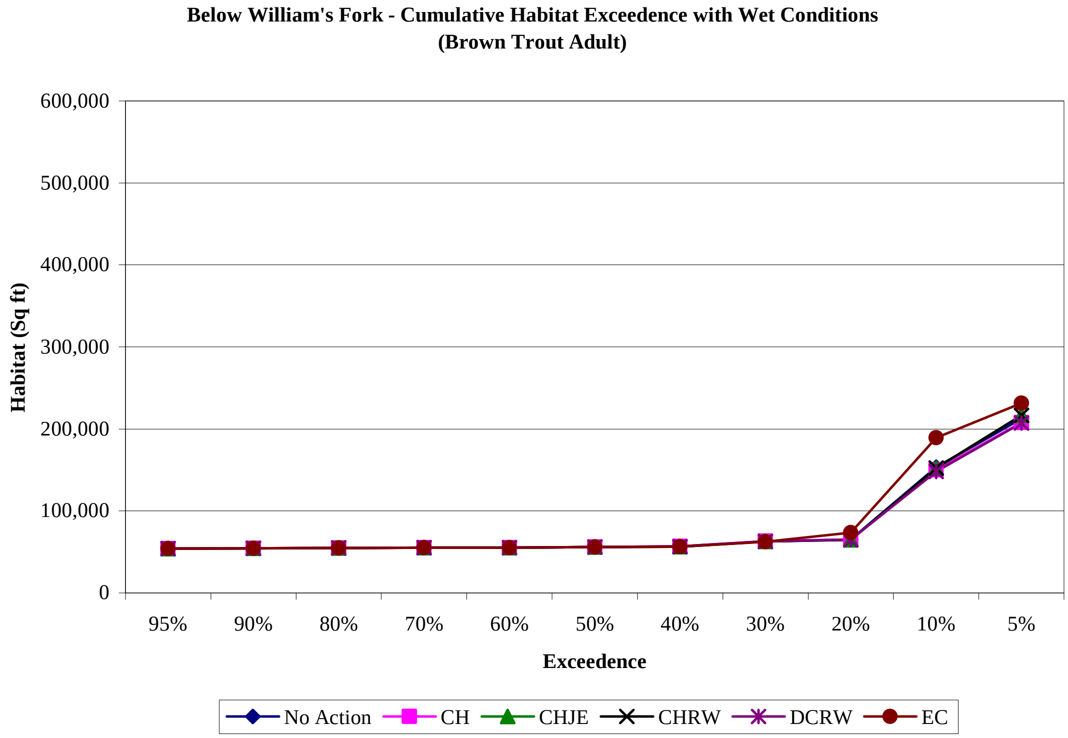


Figure 312. Below William's Fork – habitat exceedence with wet conditions (brown trout adult) cumulative effects.

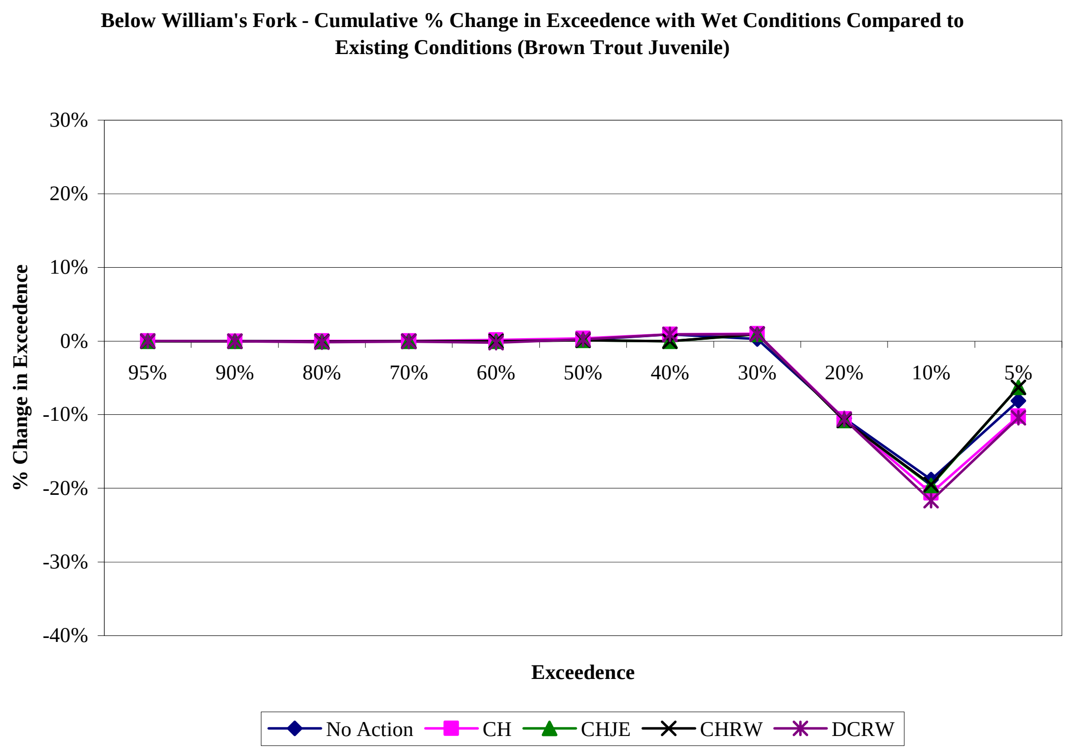


Figure 313. Below William's Fork – percent change in exceedence with wet conditions (brown trout juvenile) cumulative effects.

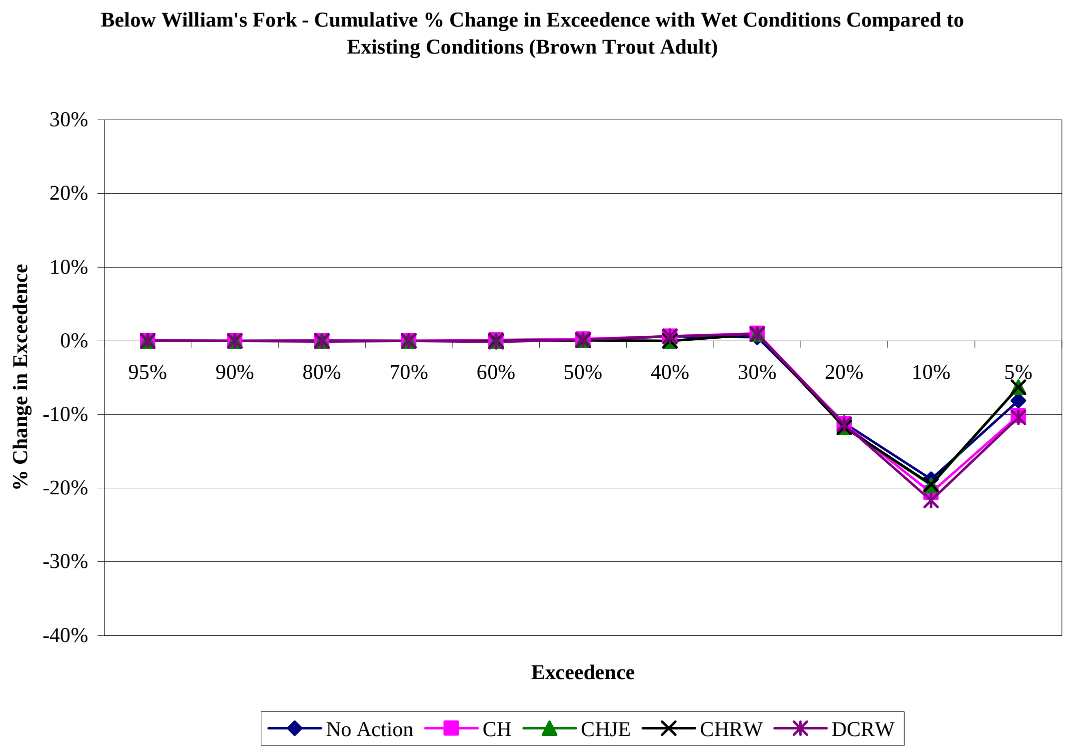


Figure 314. Below William's Fork – percent change in exceedence with wet conditions (brown trout adult) cumulative effects.

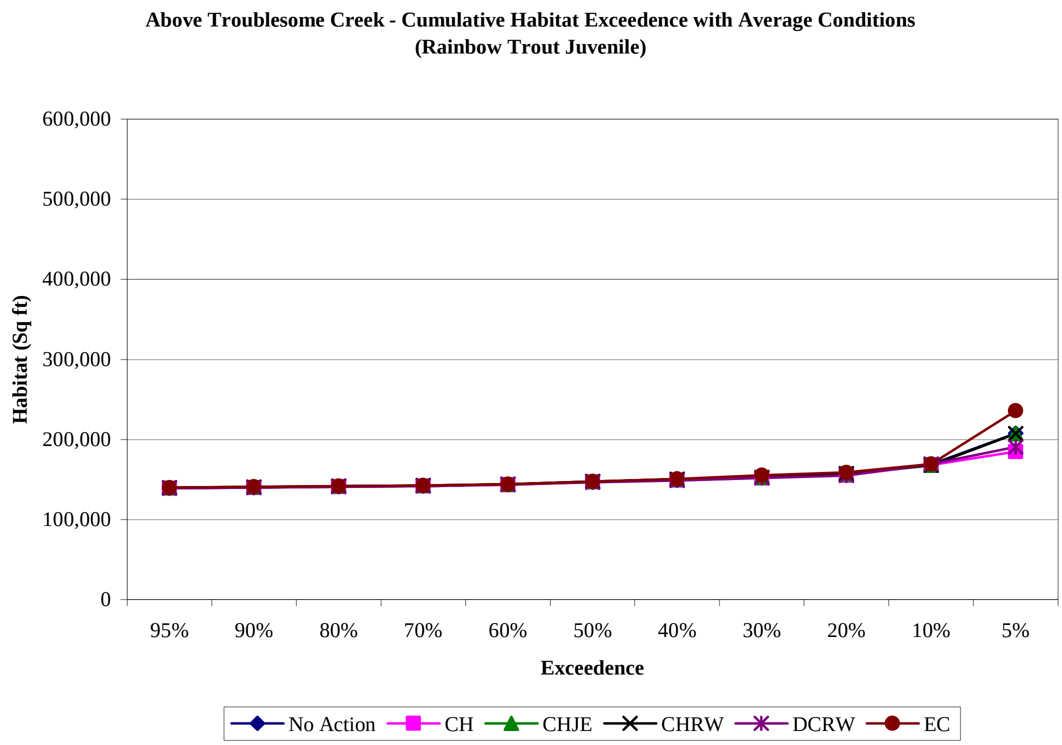


Figure 315. Above Troublesome Creek – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

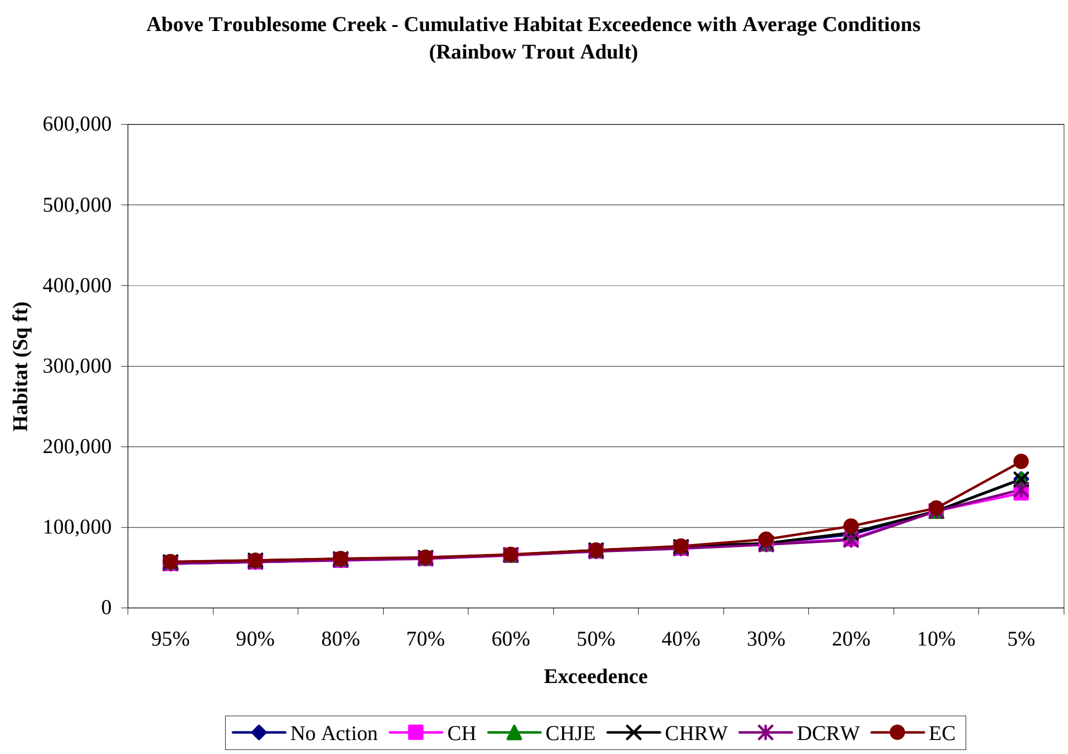


Figure 316 Above Troublesome Creek – habitat exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

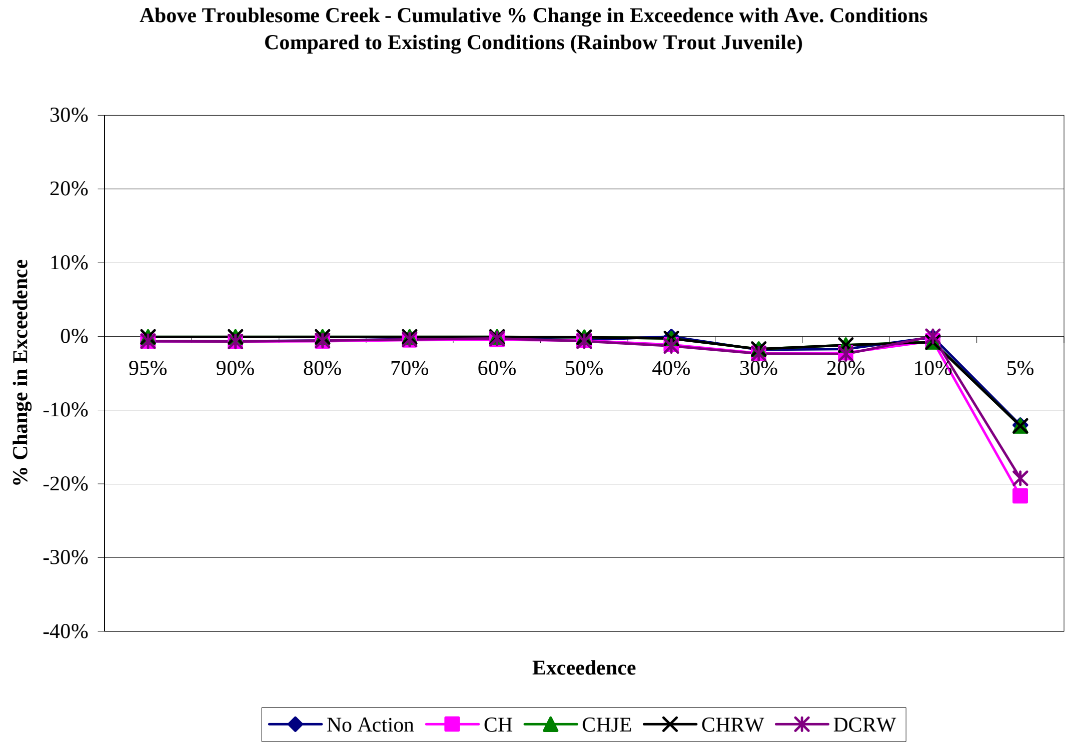


Figure 317. Above Troublesome Creek – percent change in exceedence with average conditions (rainbow trout juvenile) cumulative effects.

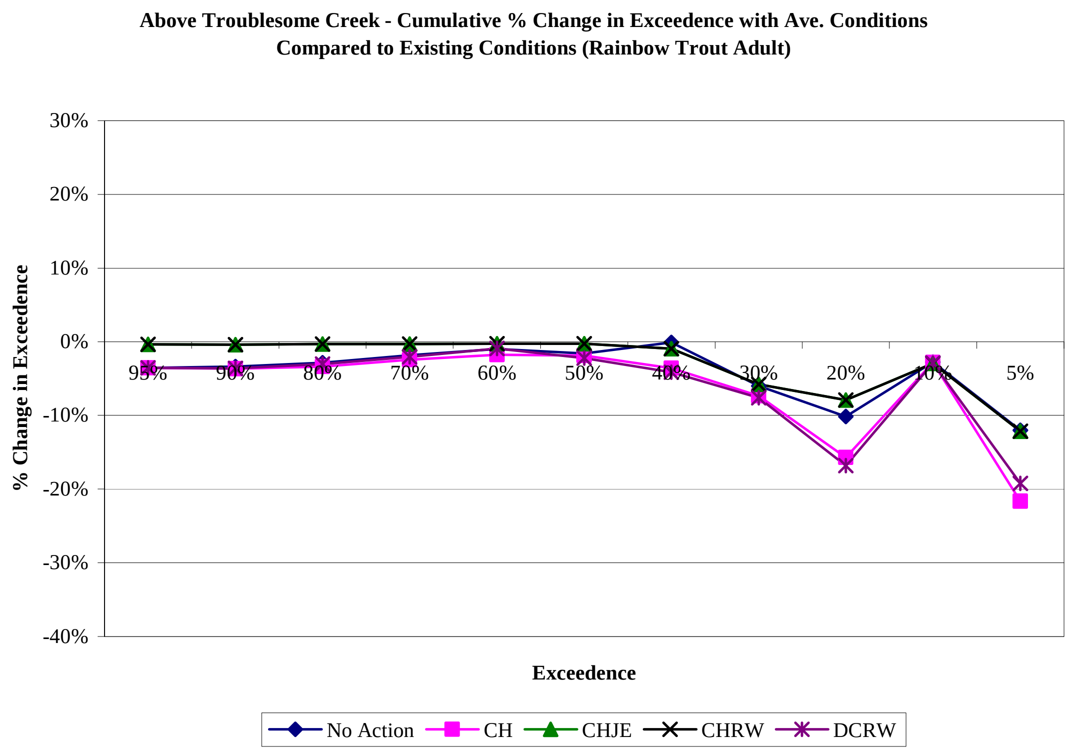


Figure 318. Above Troublesome Creek – percent change in exceedence with average conditions (rainbow trout adult) cumulative effects.

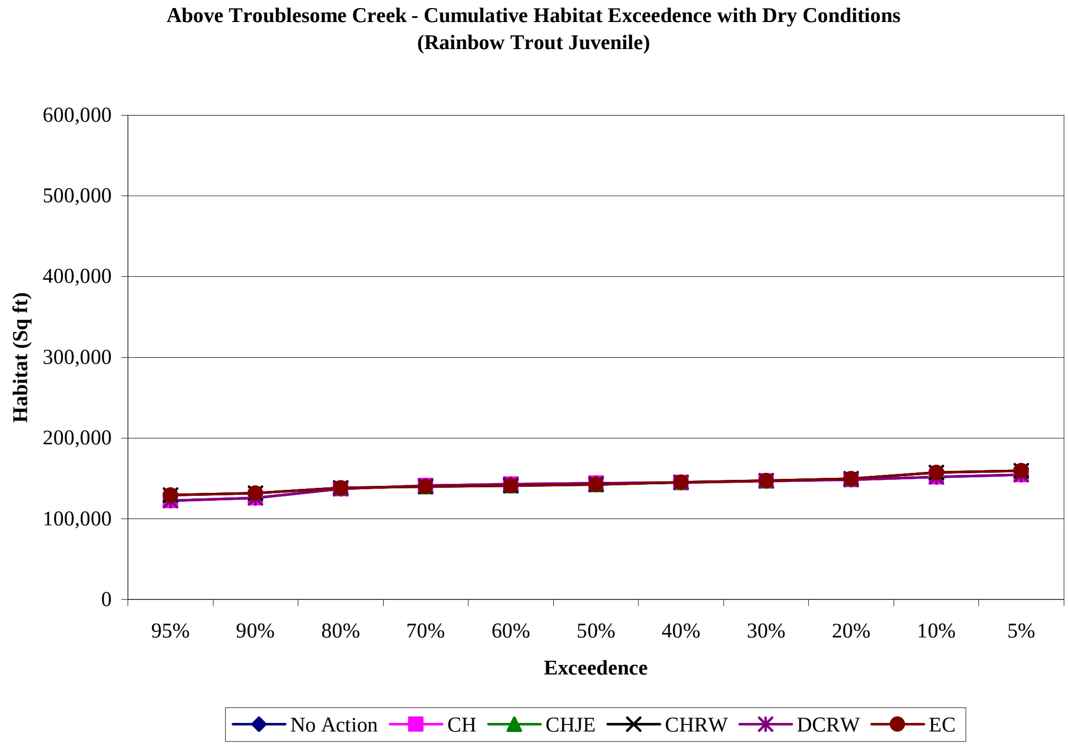


Figure 319. Above Troublesome Creek – habitat exceedence with dry conditions (rainbow trout juvenile) cumulative effects.

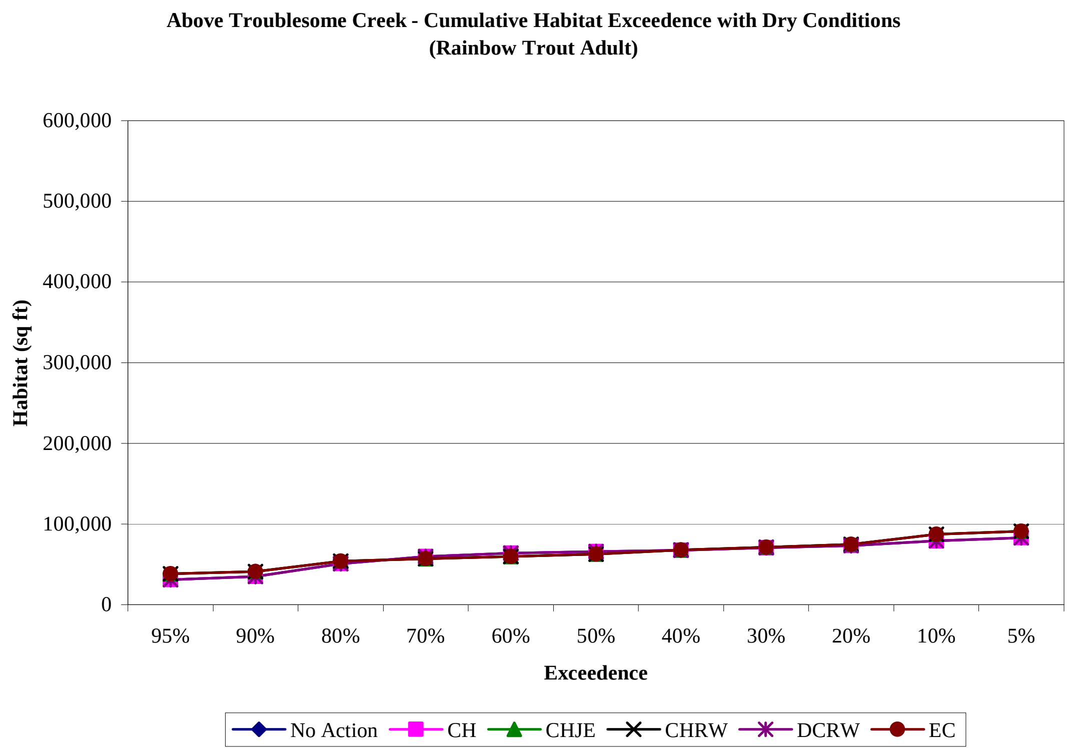


Figure 320. Above Troublesome Creek – habitat exceedence with dry conditions (rainbow trout adult) cumulative effects.

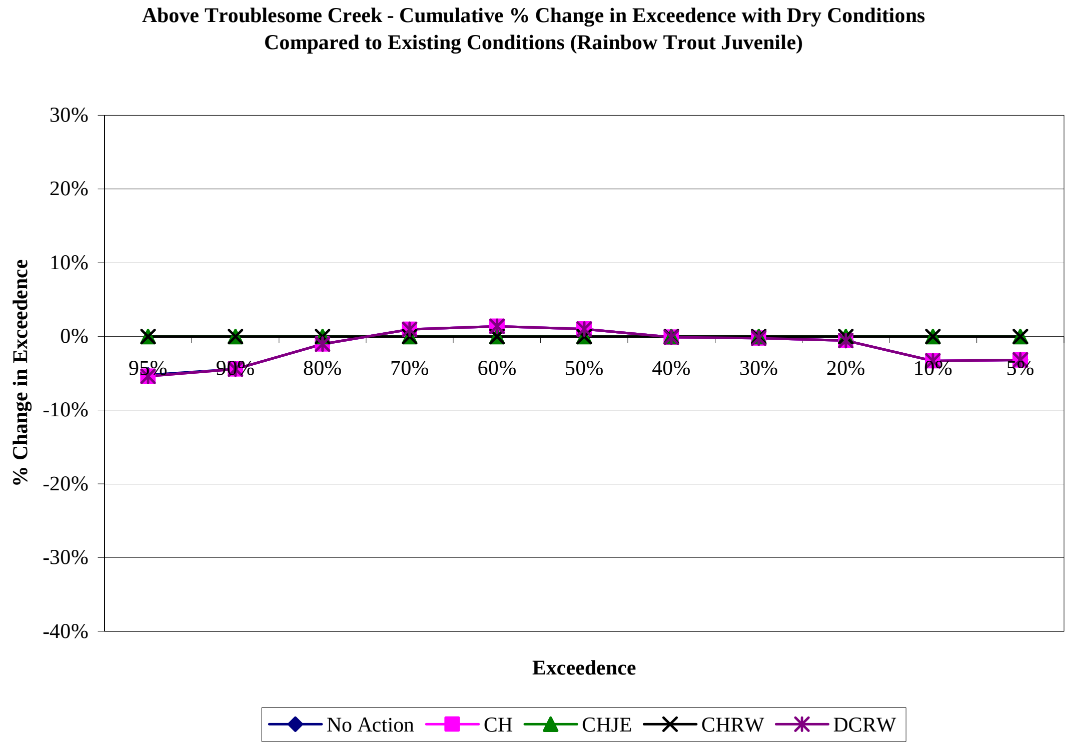


Figure 321. Above Troublesome Creek – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile) cumulative effects.

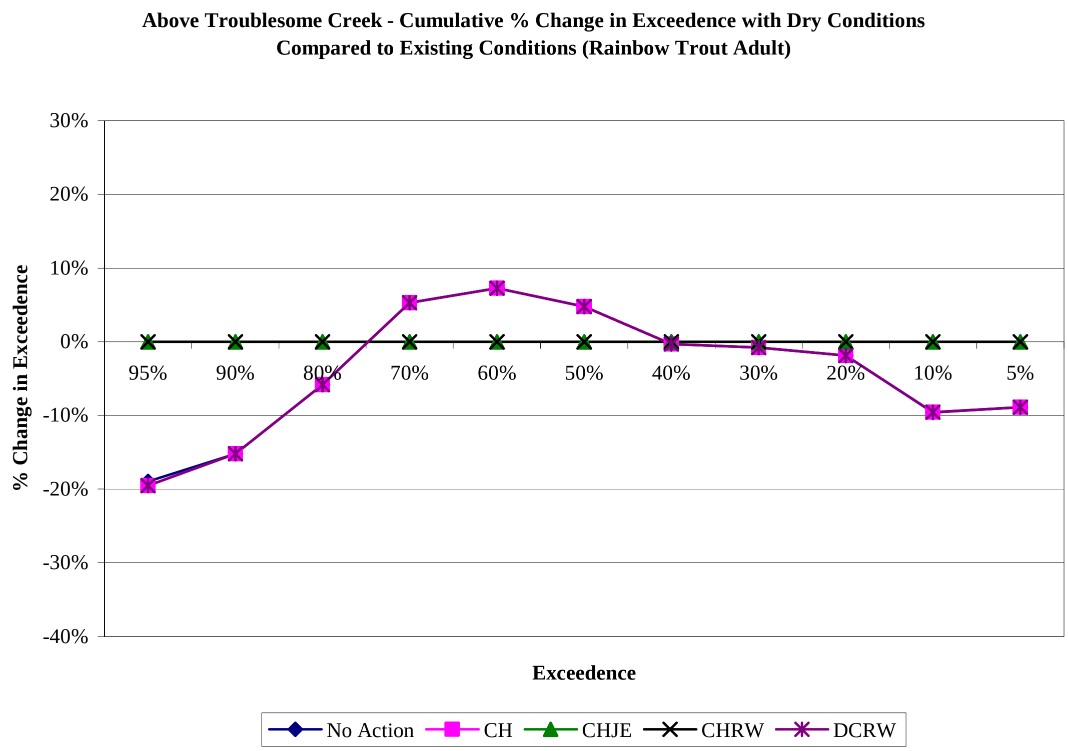


Figure 322. Above Troublesome Creek – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult) cumulative effects.

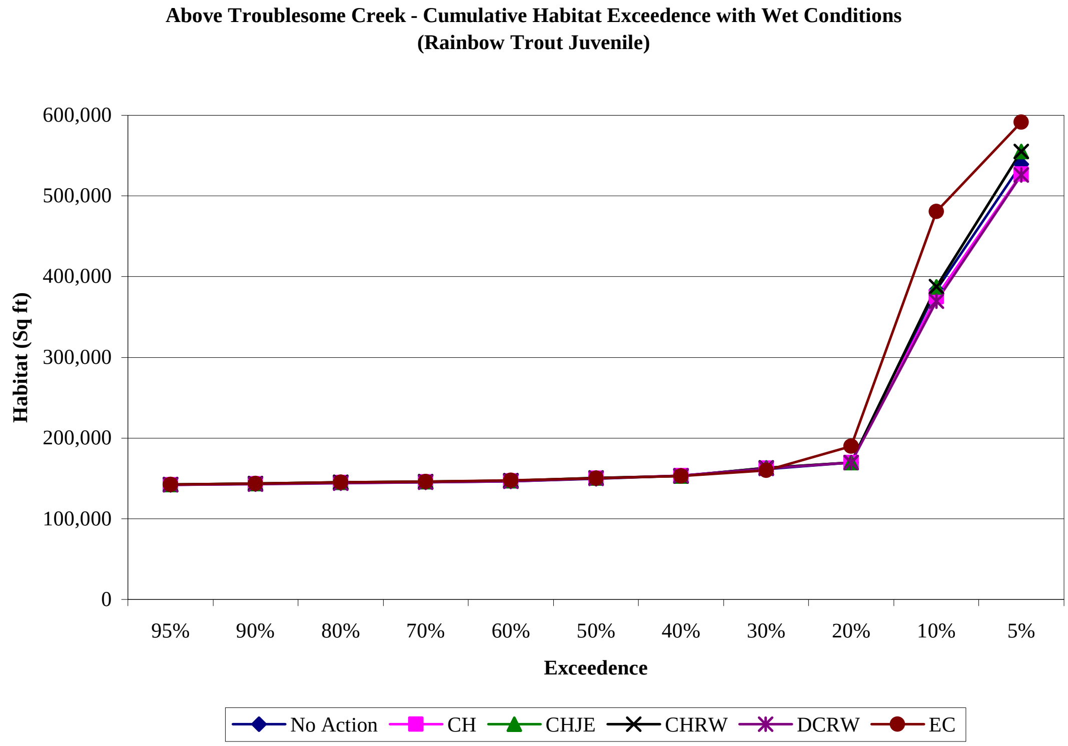


Figure 323. Above Troublesome Creek – habitat exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

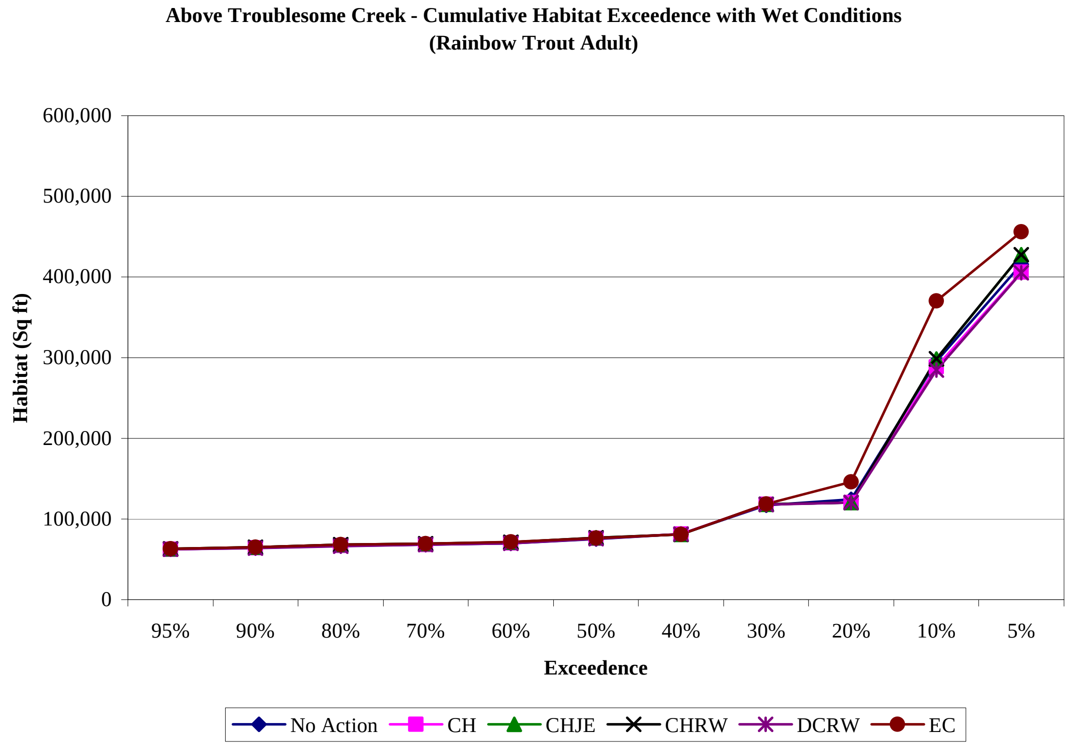


Figure 324. Above Troublesome Creek – habitat exceedence with wet conditions (rainbow trout adult) cumulative effects.

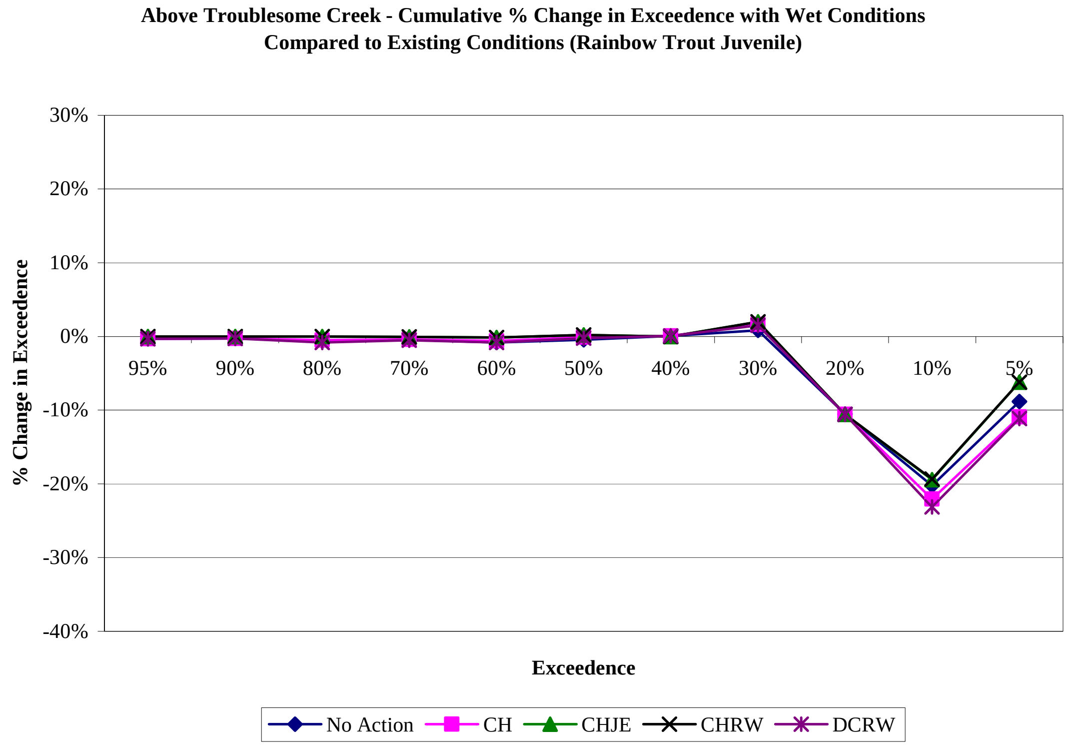


Figure 325. Above Troublesome Creek – percent change in exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

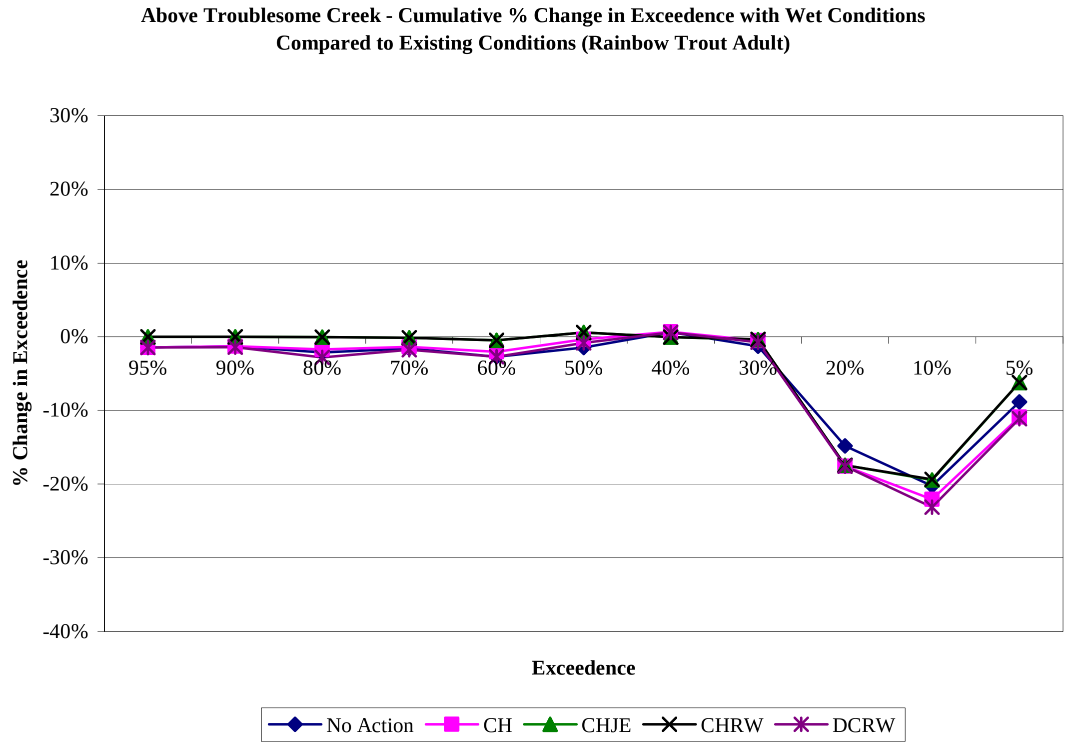


Figure 326. Above Troublesome Creek – percent change in exceedence with wet conditions (rainbow trout adult) cumulative effects.

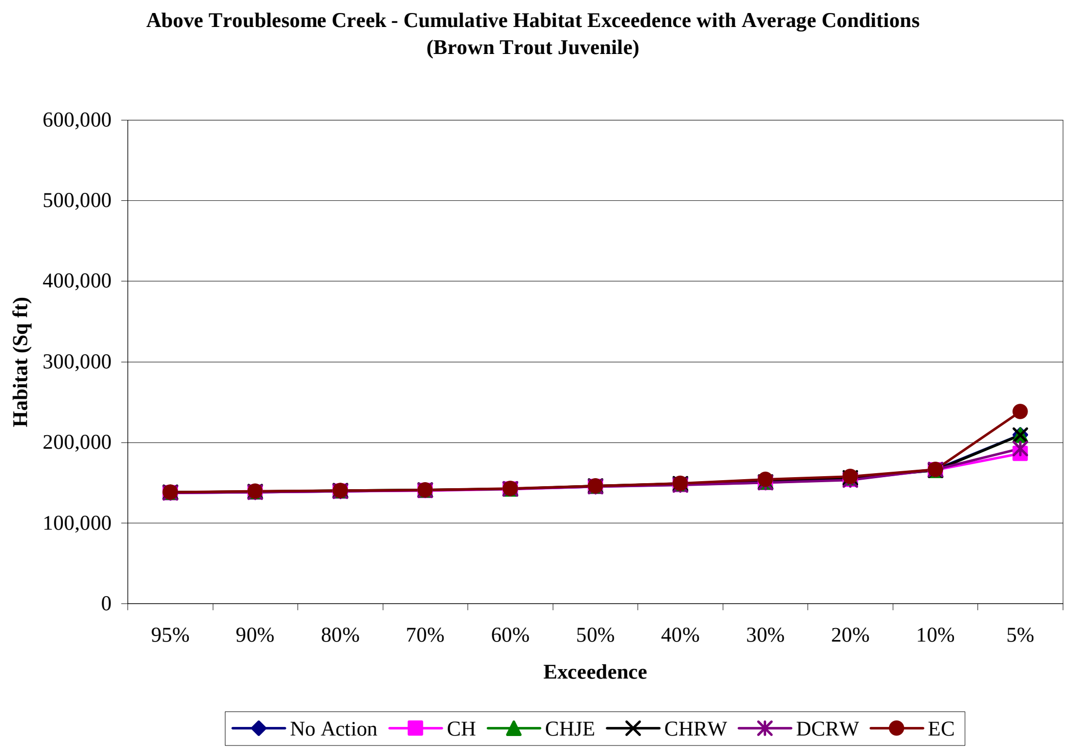


Figure 327. Above Troublesome Creek – habitat exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

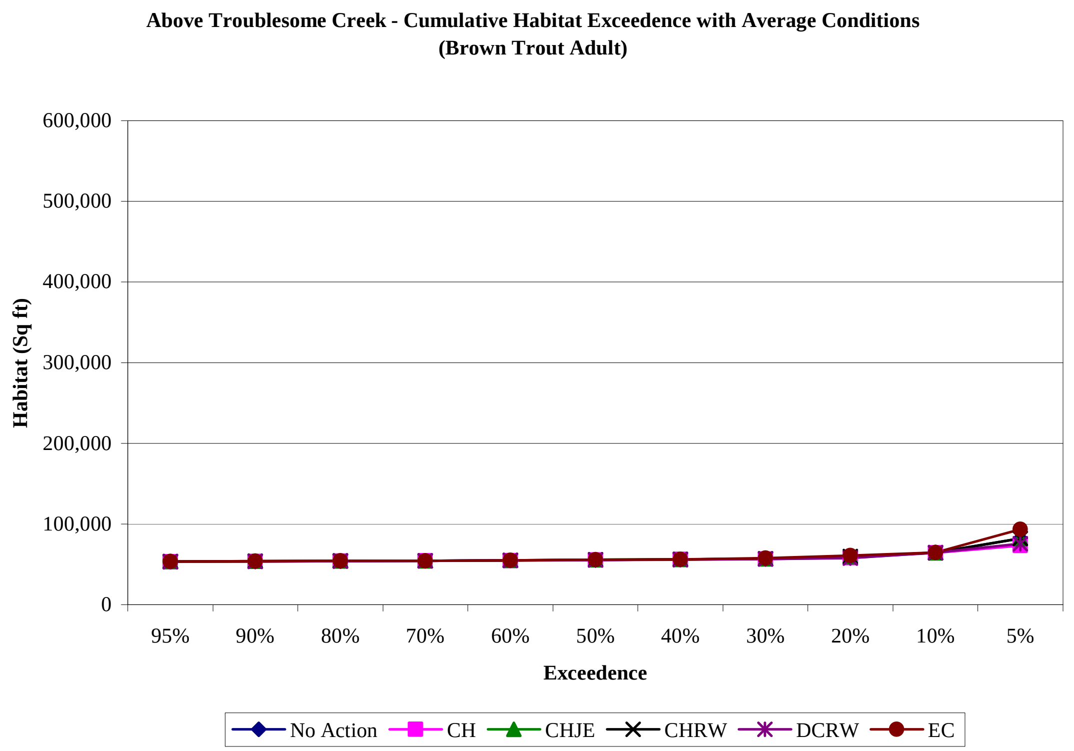


Figure 328. Above Troublesome Creek – habitat exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

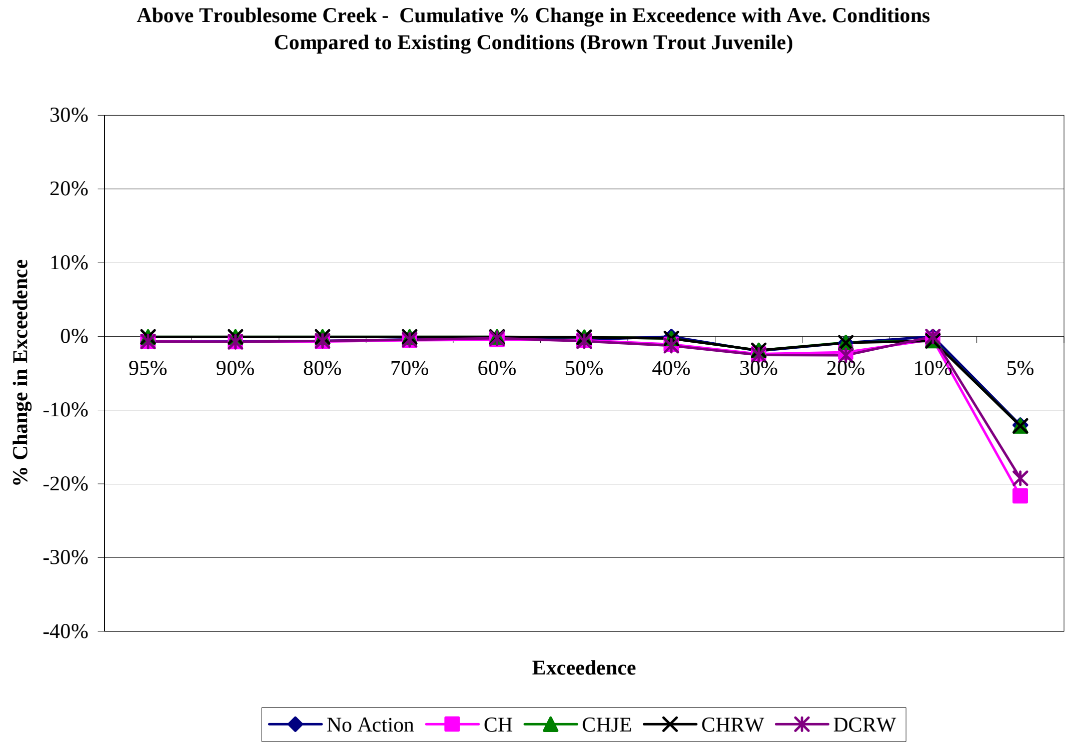


Figure 329. Above Troublesome Creek – percent change in exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

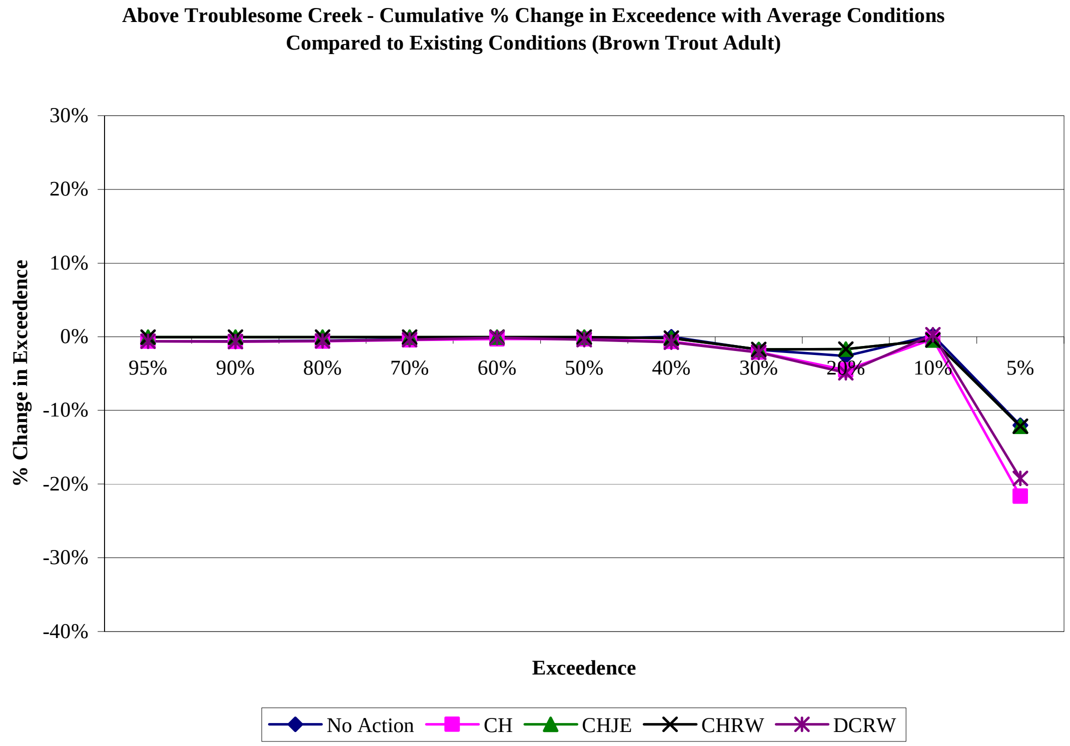


Figure 330. Above Troublesome Creek – percent change in exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

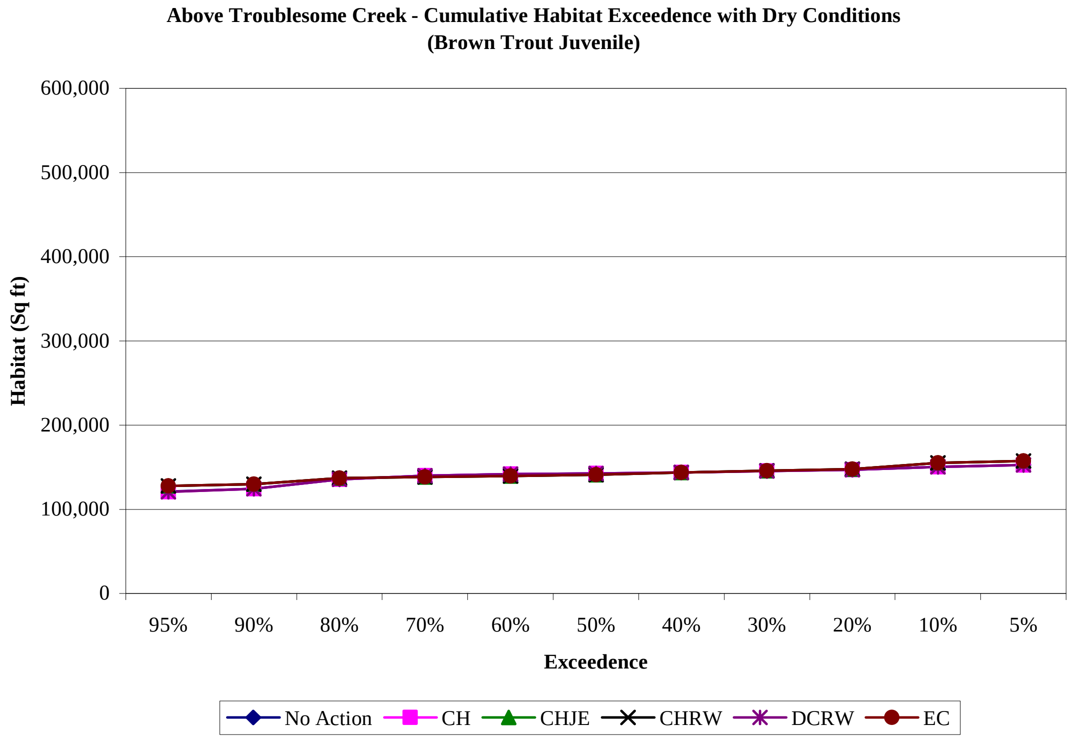


Figure 331. Above Troublesome Creek – habitat exceedence with dry conditions (brown trout juvenile) cumulative effects.

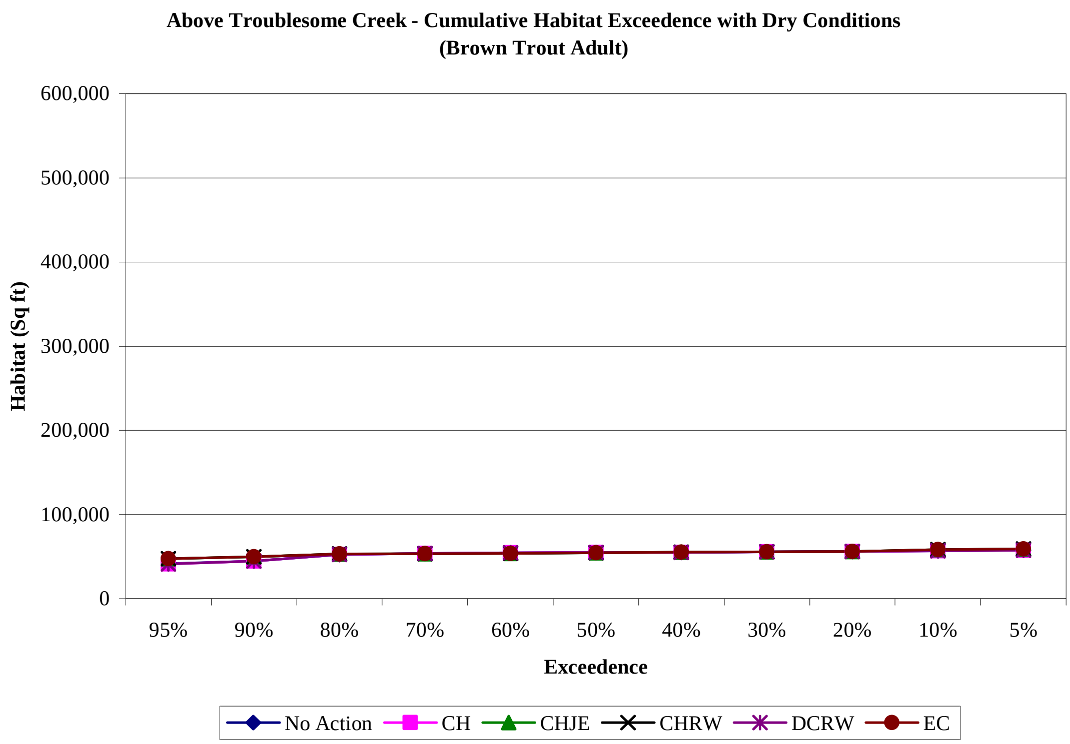


Figure 332. Above Troublesome Creek – habitat exceedence with dry conditions (brown trout adult) cumulative effects.

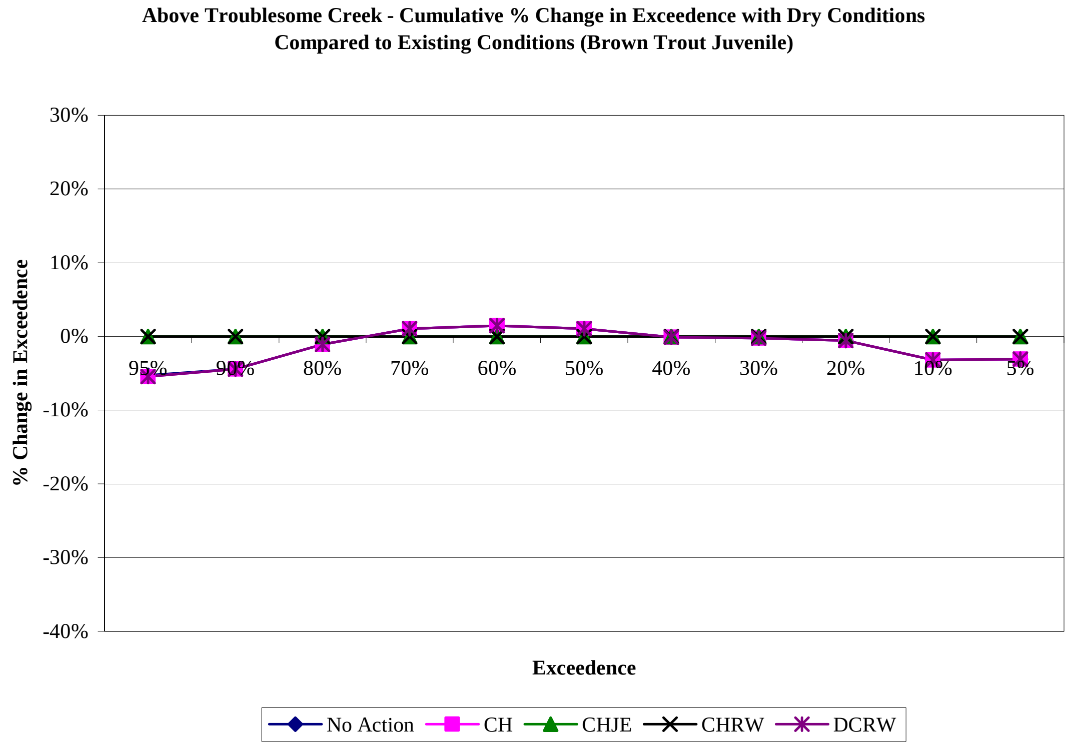


Figure 333. Above Troublesome Creek – percent change in exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

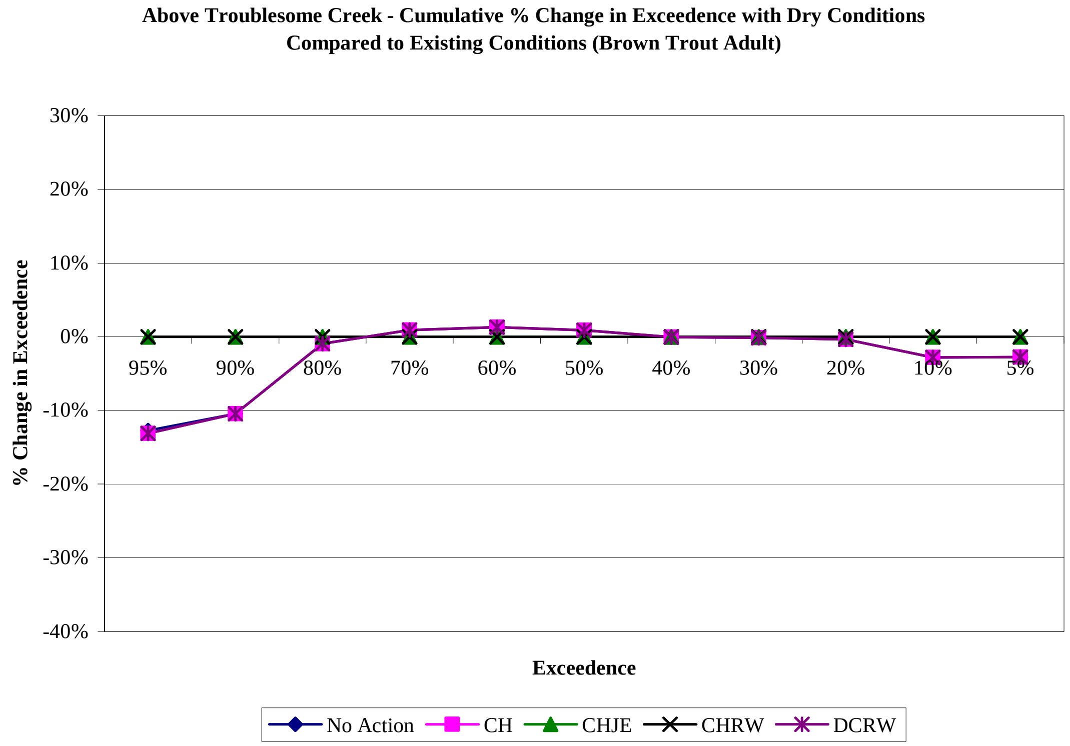


Figure 334. Above Troublesome Creek – percent change in exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

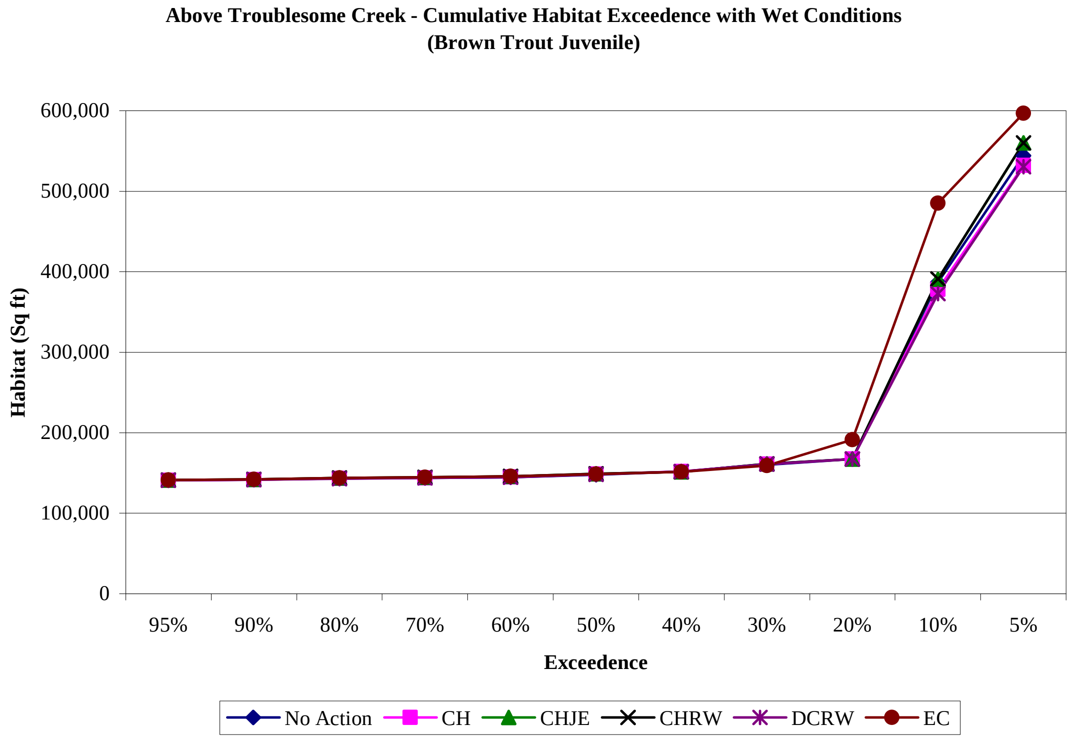


Figure 335. Above Troublesome Creek – habitat exceedence with <u>wet</u> conditions (brown trout juvenile) cumulative effects.

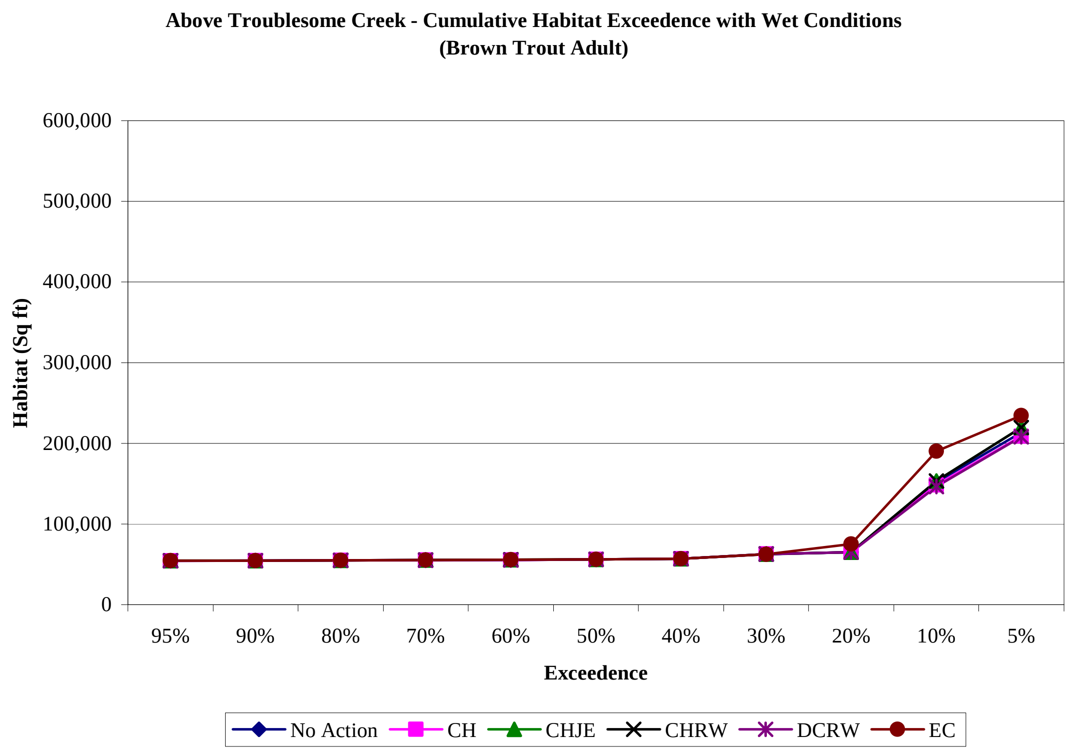


Figure 336 Above Troublesome Creek – habitat exceedence with <u>wet</u> conditions (brown trout adult) cumulative effects.

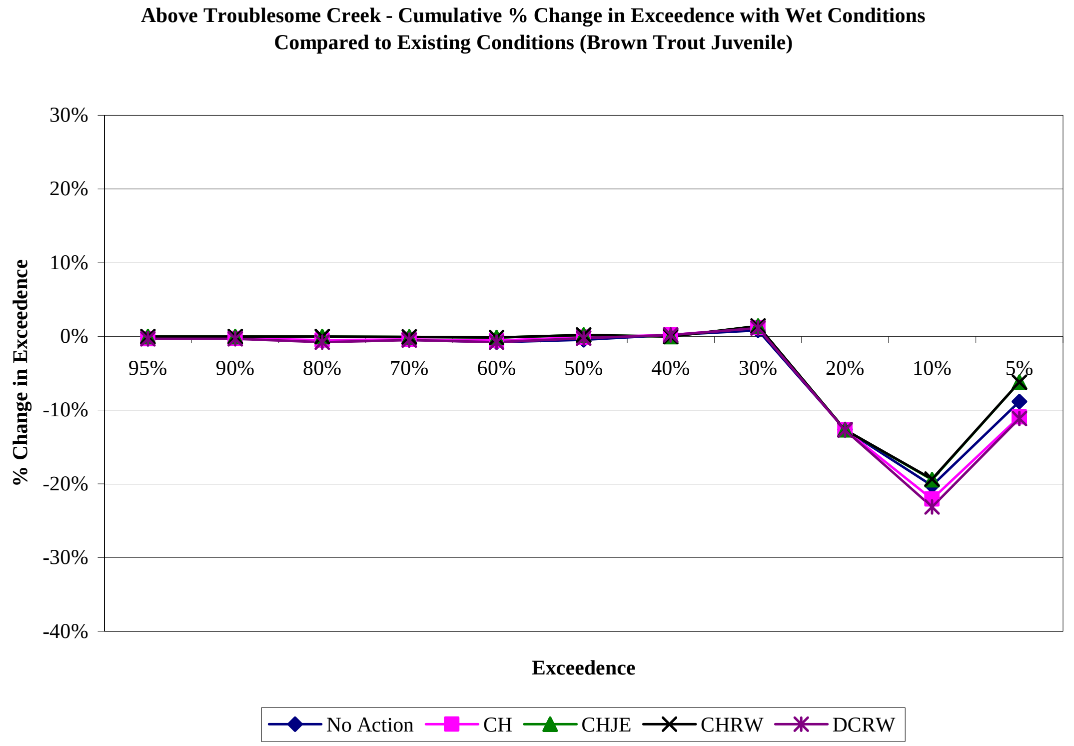


Figure 337. Above Troublesome Creek – percent change in exceedence with <u>wet</u> conditions (brown trout juvenile) cumulative effects.

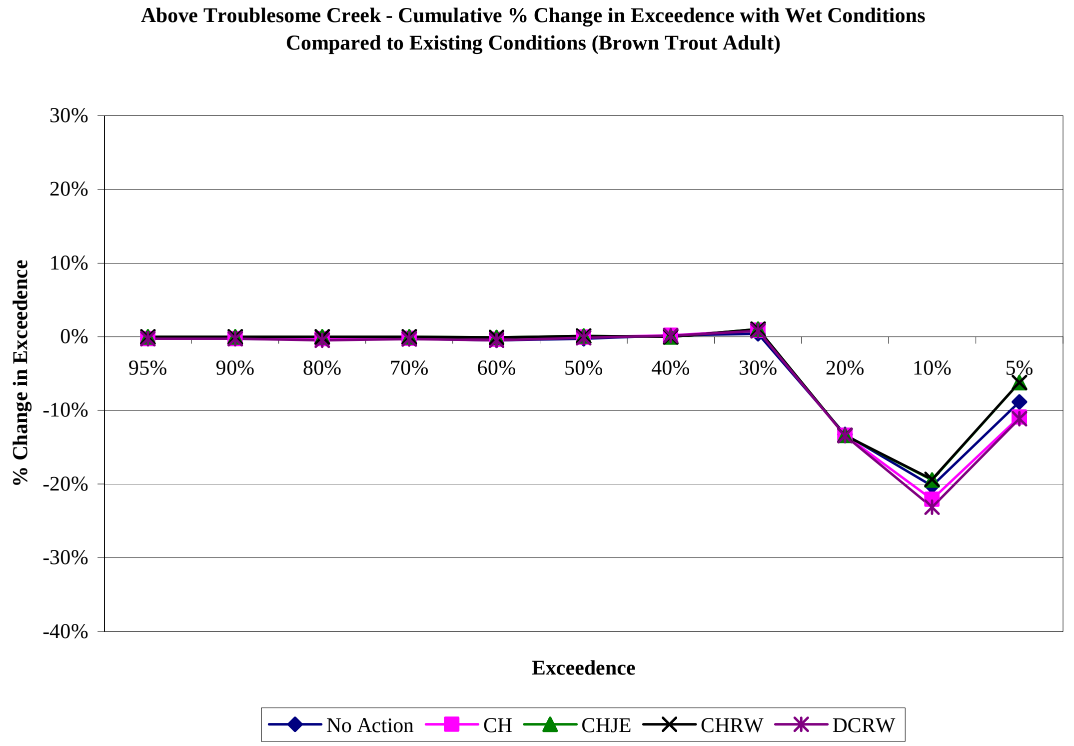


Figure 338. Above Troublesome Creek – percent change in exceedence with <u>wet</u> conditions (brown trout adult) cumulative effects.

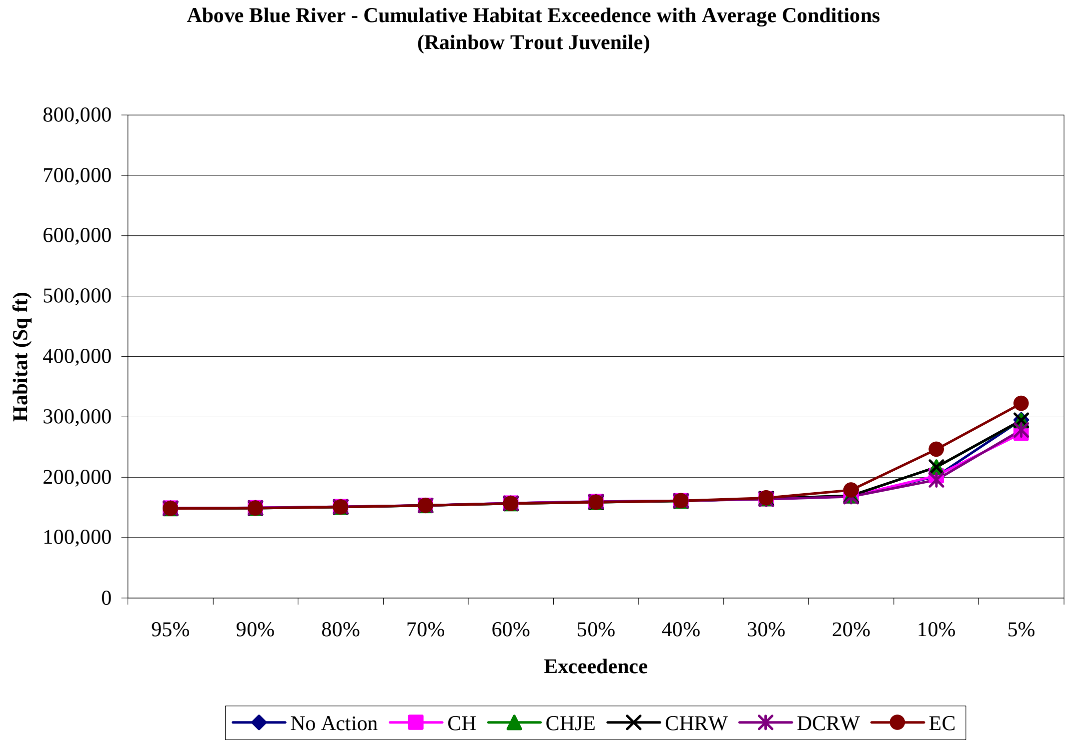


Figure 339. Above Blue River – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

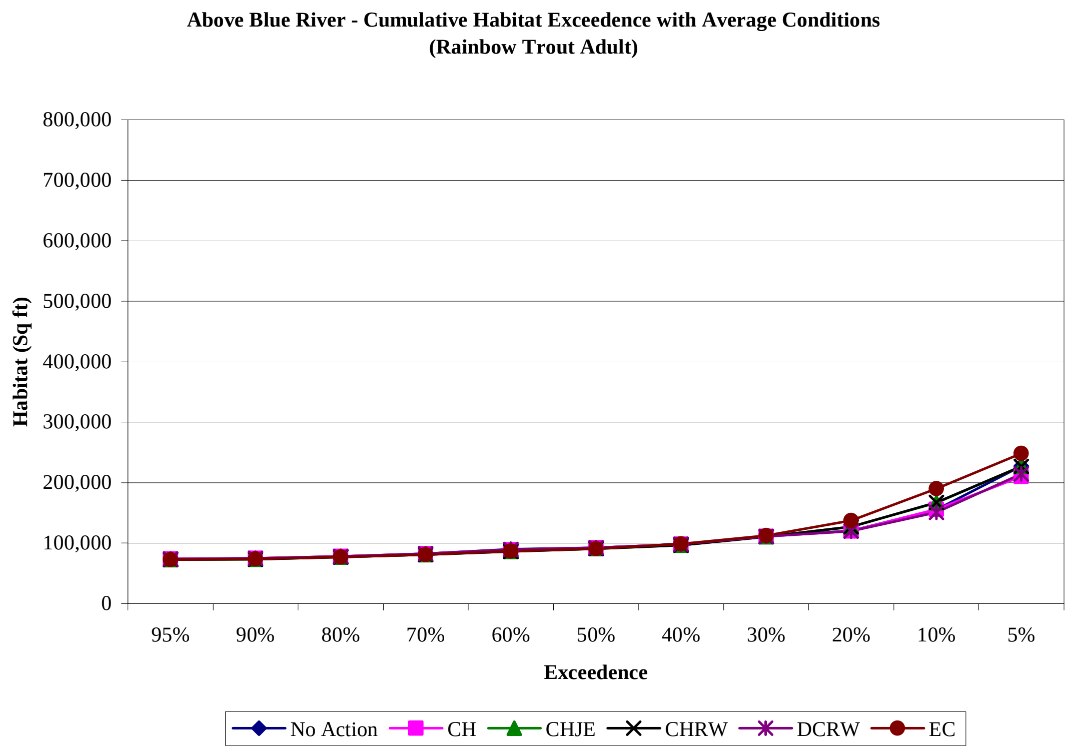


Figure 340. Above Blue River – habitat exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

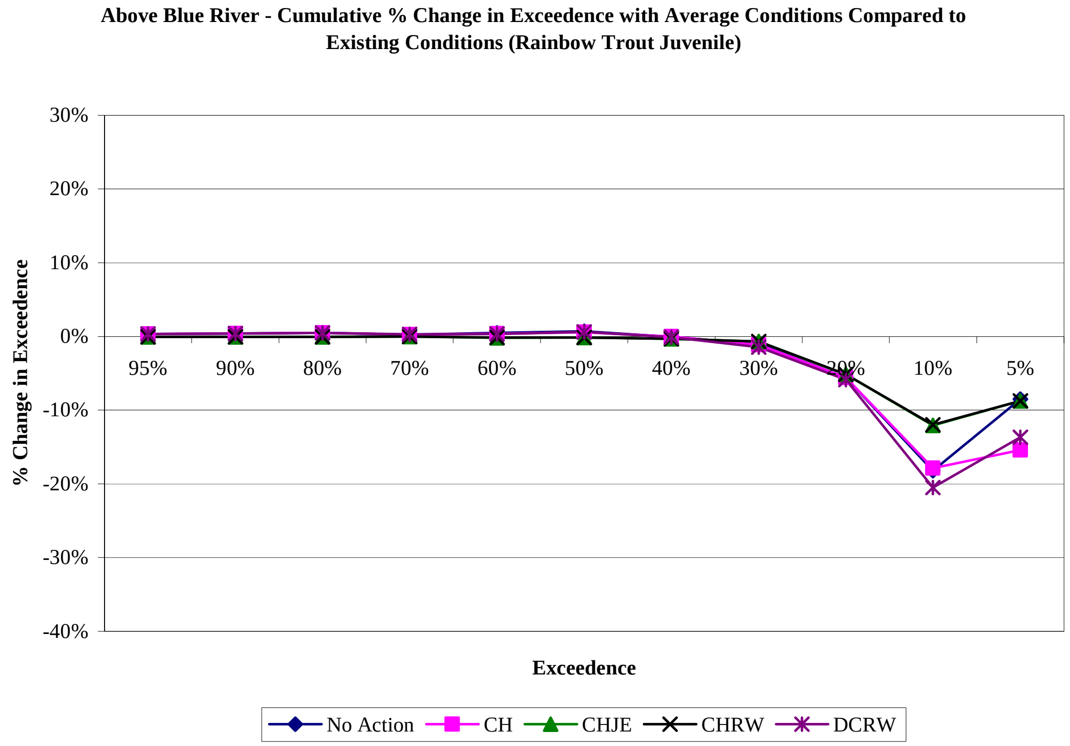


Figure 341. Above Blue River – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

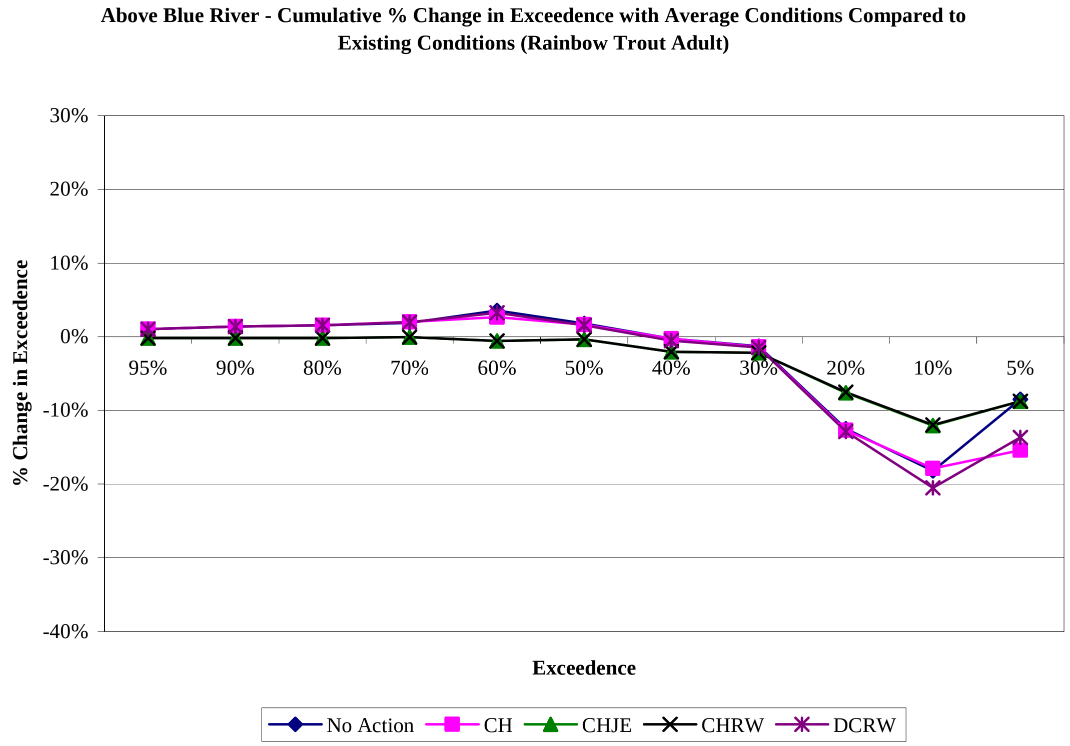


Figure 342. Above Blue River – percent change in exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

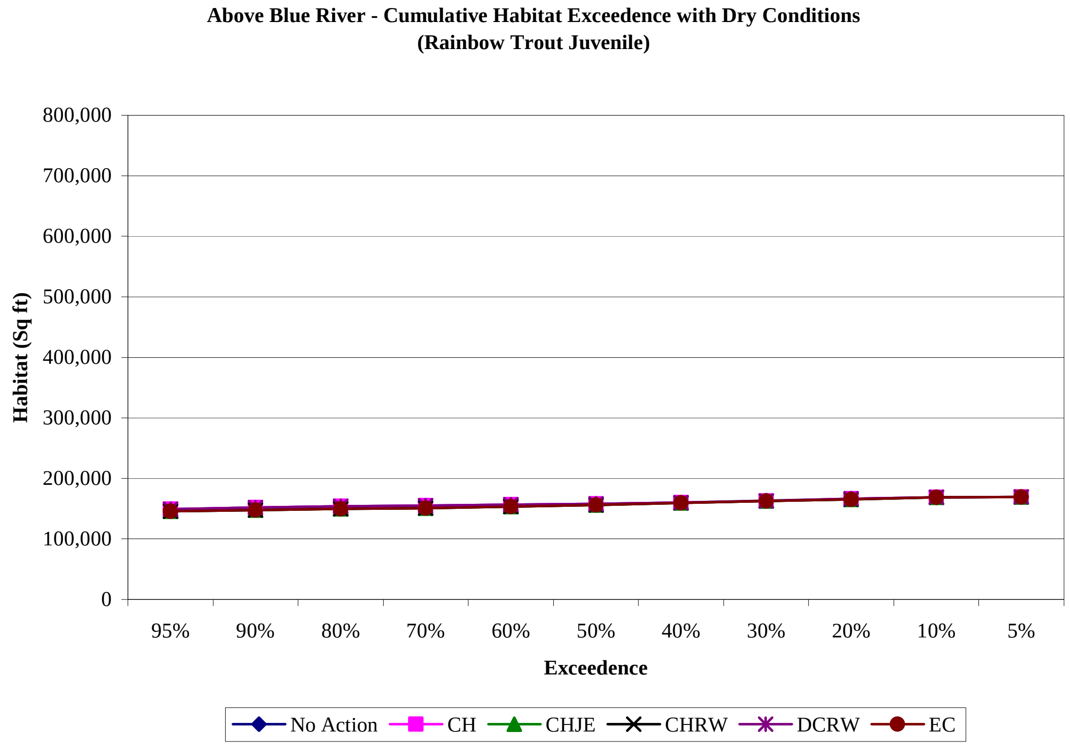


Figure 343. Above Blue River – habitat exceedence with <u>dry</u> conditions (rainbow trout juvenile) cumulative effects.

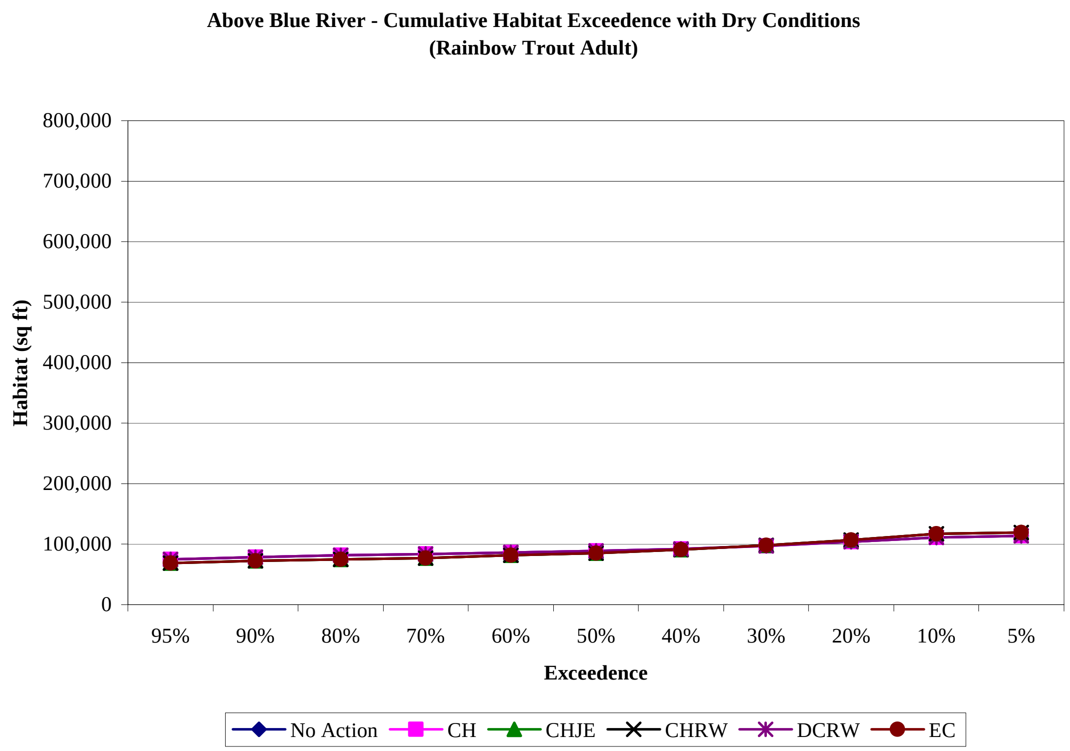


Figure 344. Above Blue River – habitat exceedence with <u>dry</u> conditions (rainbow trout adult) cumulative effects.

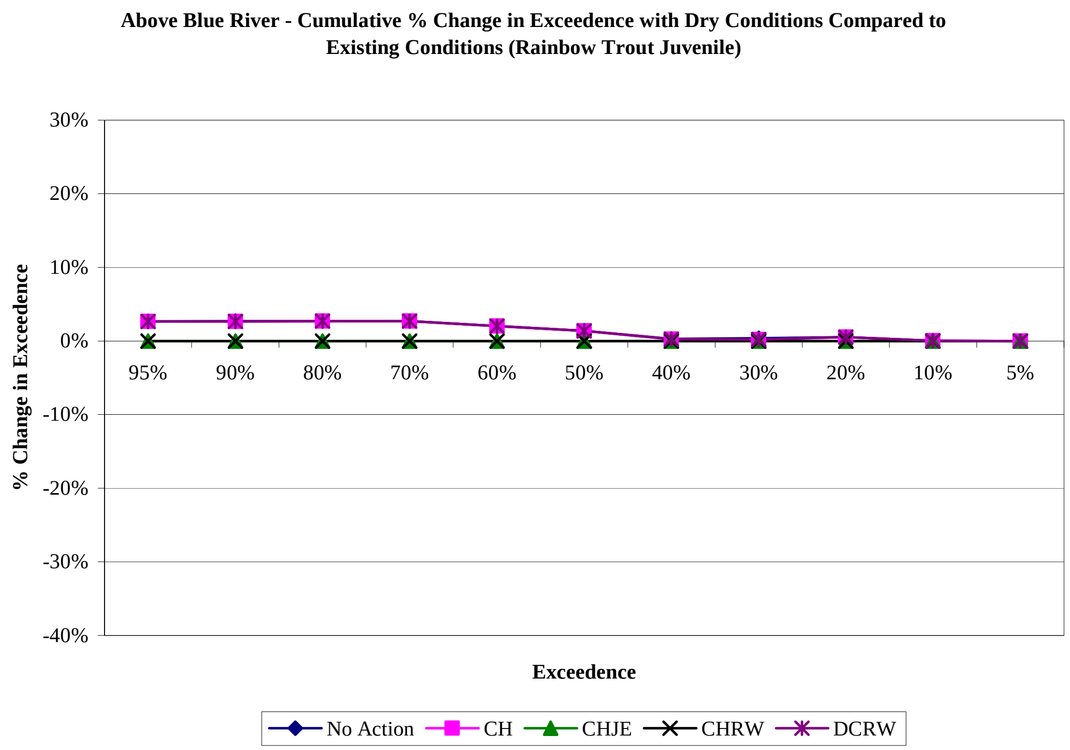


Figure 345. Above Blue River – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile) cumulative effects.

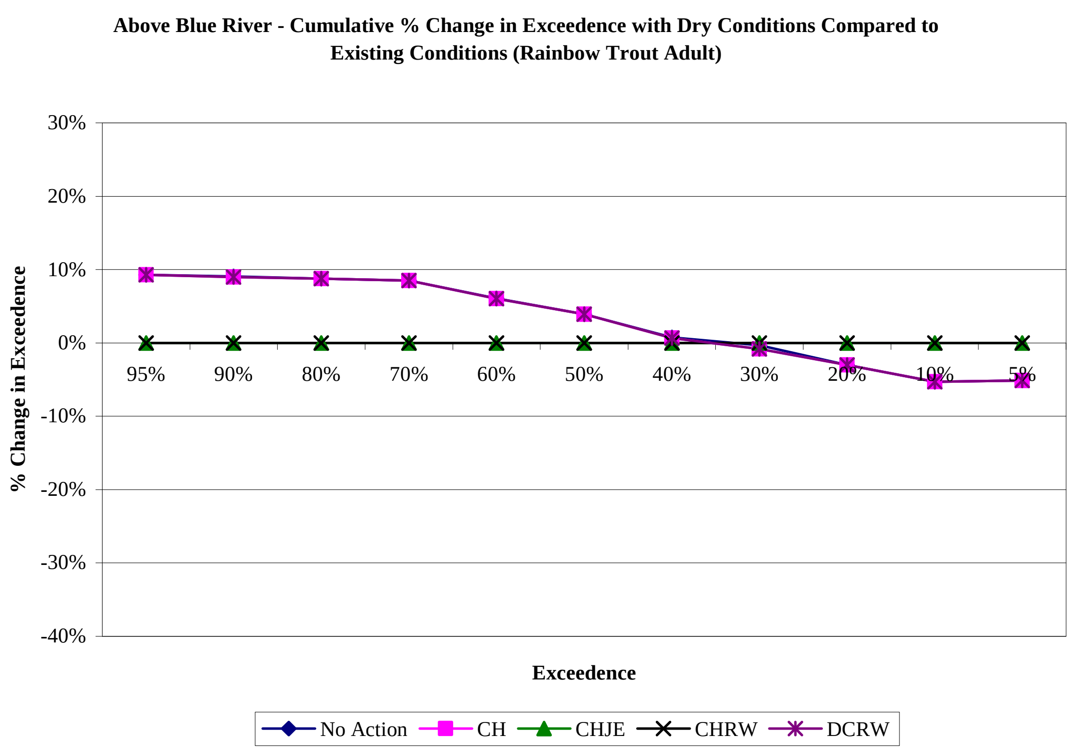


Figure 346. Above Blue River – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult) cumulative effects.

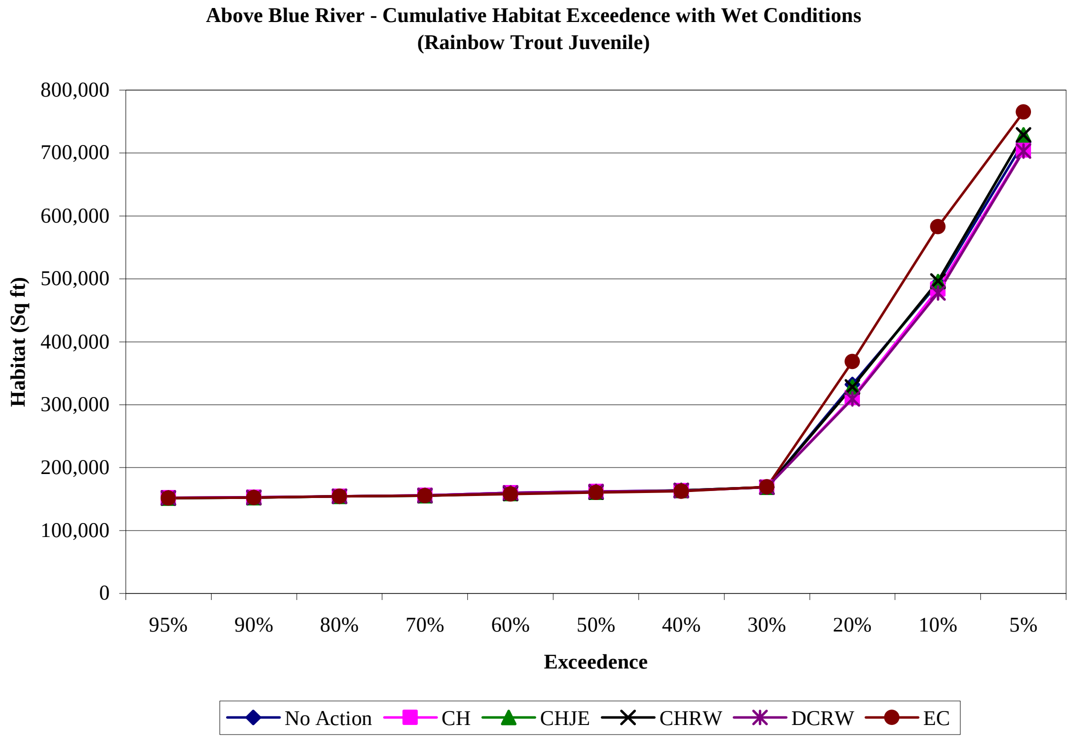


Figure 347. Above Blue River – habitat exceedence with <u>wet</u> conditions (rainbow trout juvenile) cumulative effects.

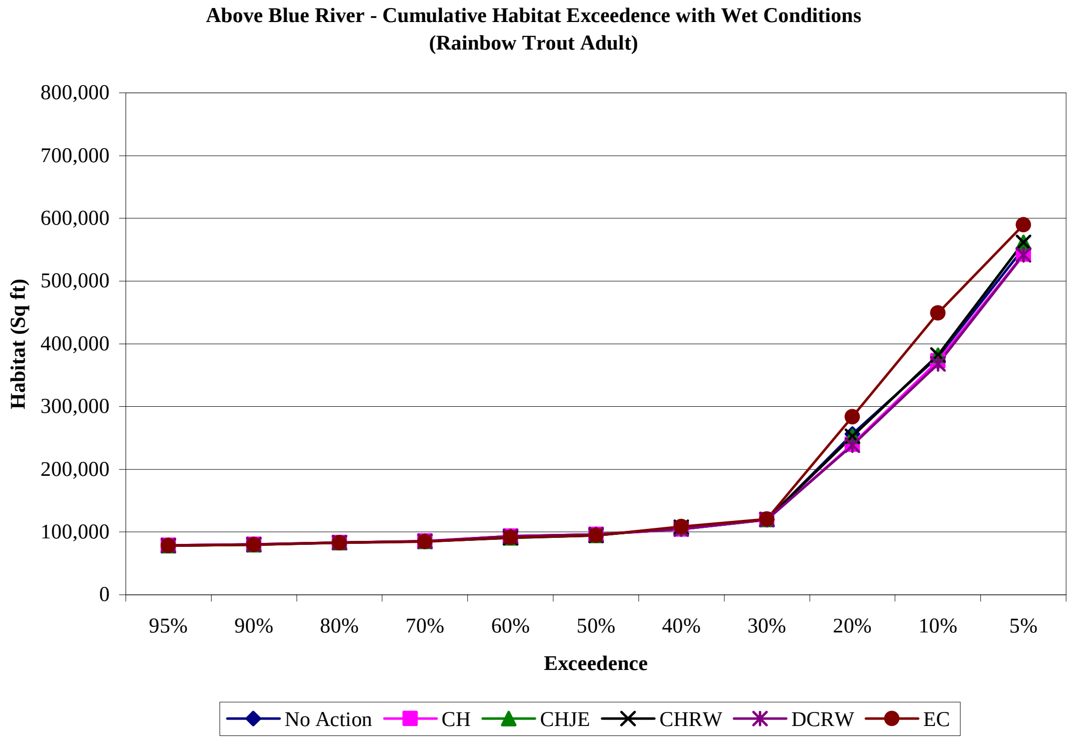


Figure 348. Above Blue River – habitat exceedence with <u>wet</u> conditions (rainbow trout adult) cumulative effects.

Figure 349. Above Blue River – percent change in exceedence with <u>wet</u> conditions (rainbow trout juvenile) cumulative effects.

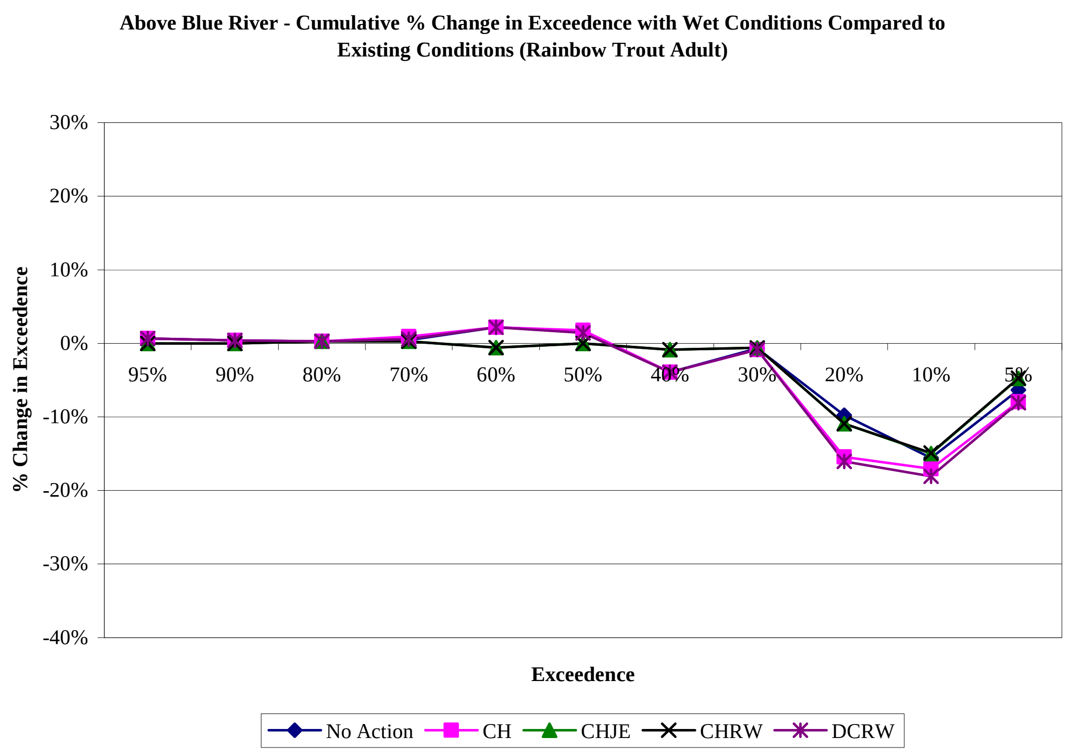


Figure 350. Above Blue River – percent change in exceedence with <u>wet</u> conditions (rainbow trout adult) cumulative effects.

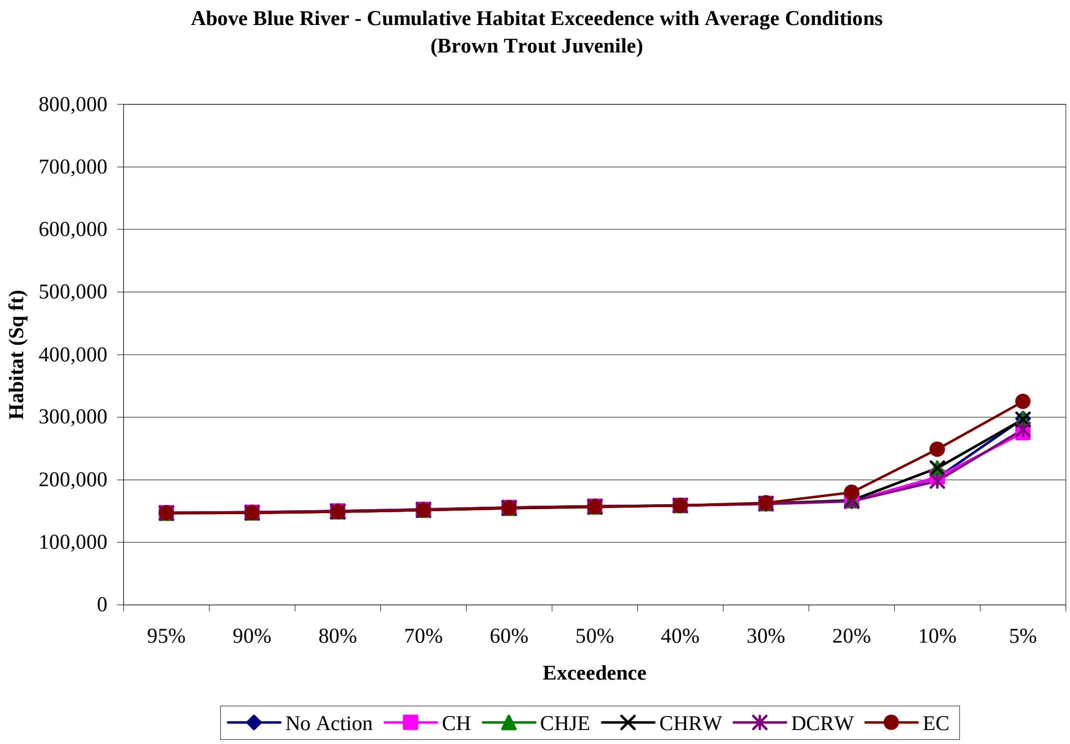


Figure 351. Above Blue River – habitat exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

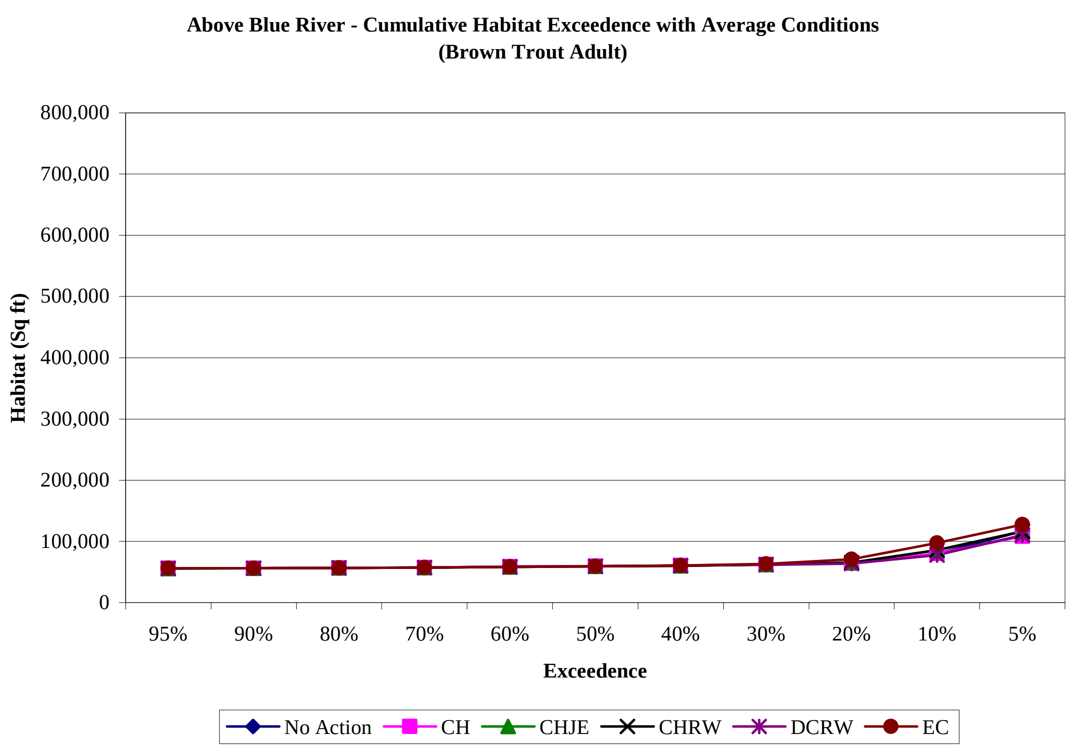


Figure 352. Above Blue River – habitat exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

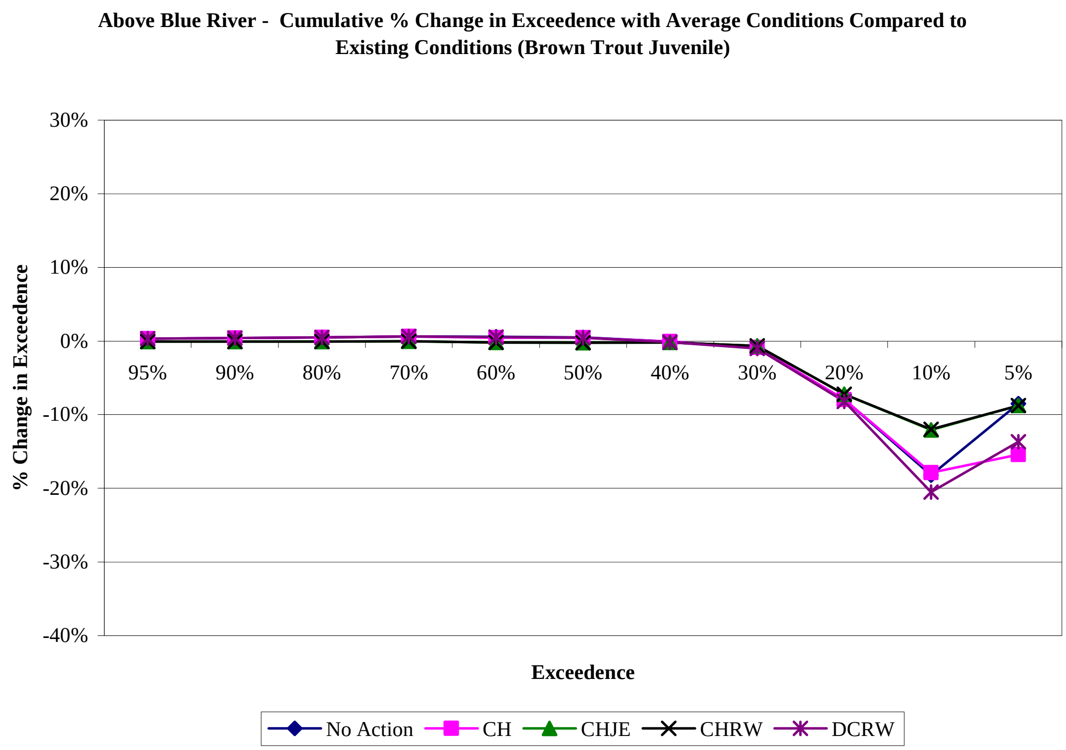


Figure 353. Above Blue River – percent change in exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

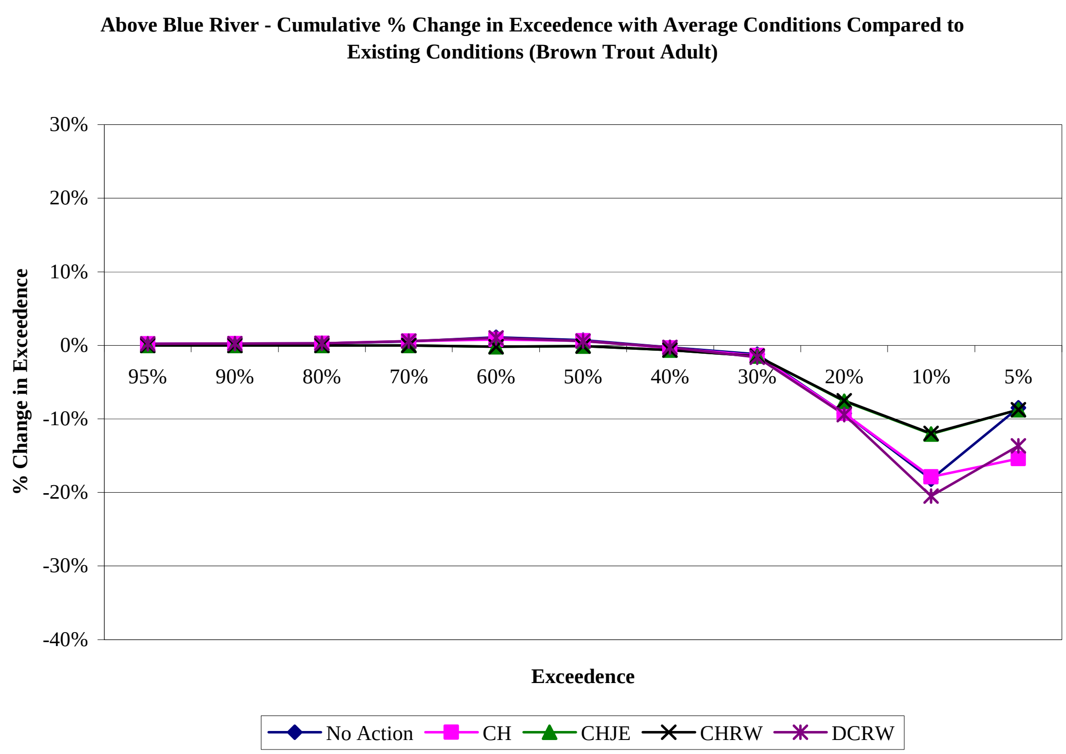


Figure 354. Above Blue River – percent change in exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

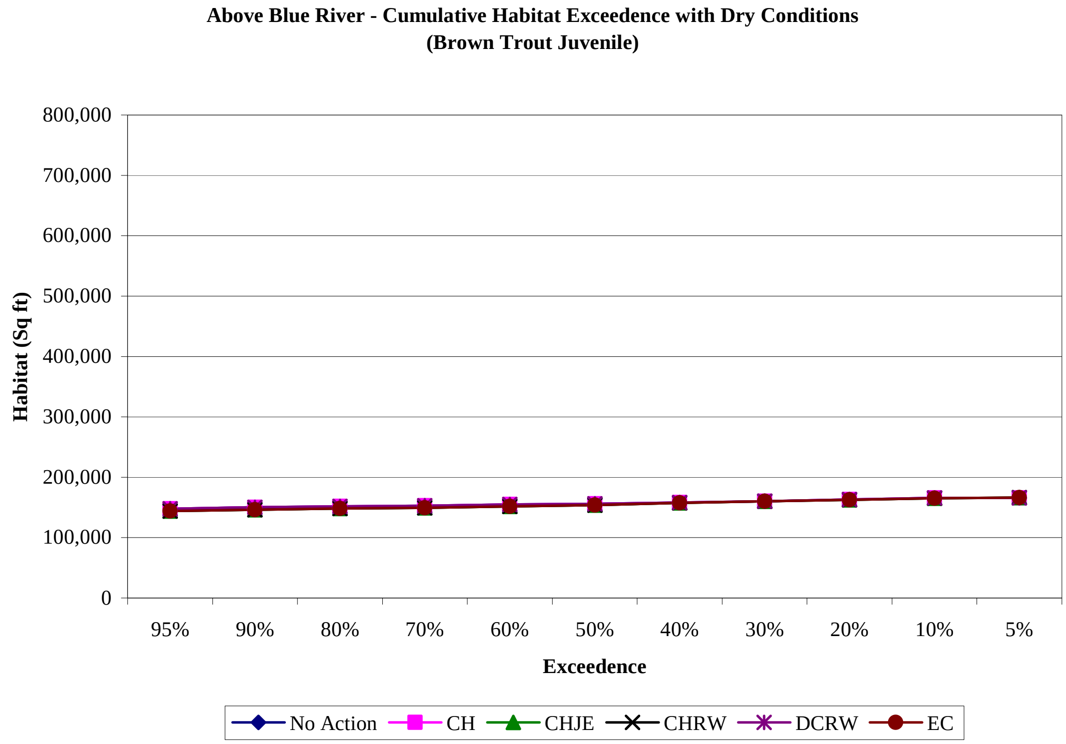


Figure 355. Above Blue River – habitat exceedence with dry conditions (brown trout juvenile) cumulative effects.

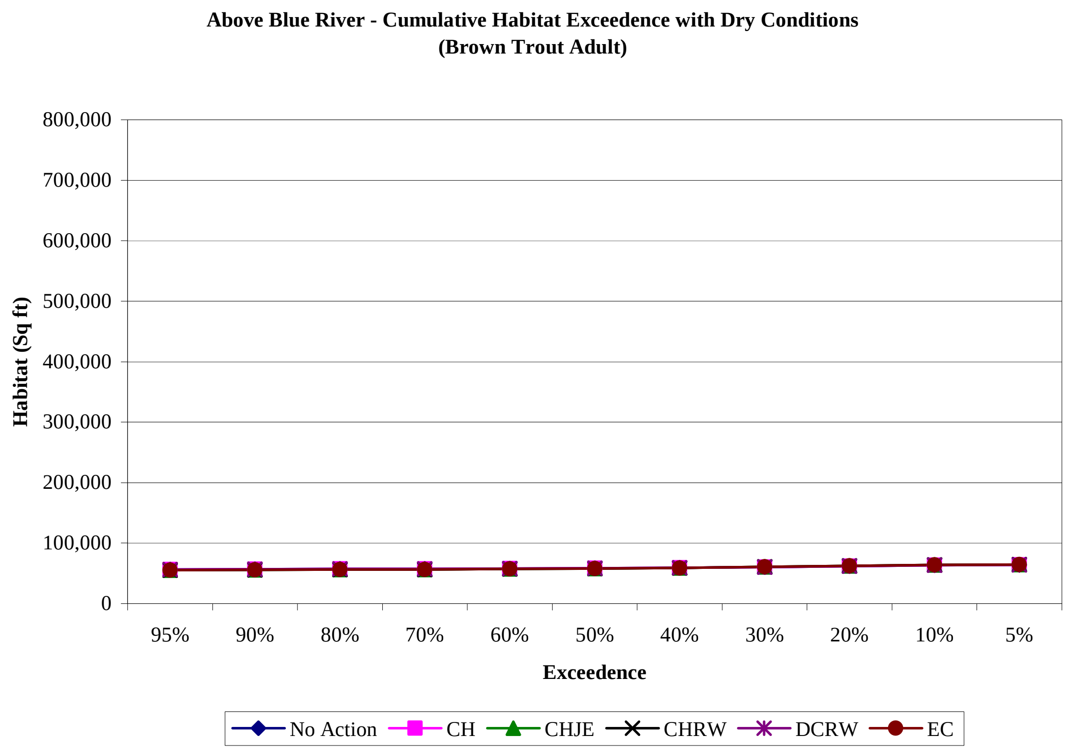


Figure 356. Above Blue River – habitat exceedence with dry conditions (brown trout adult) cumulative effects.

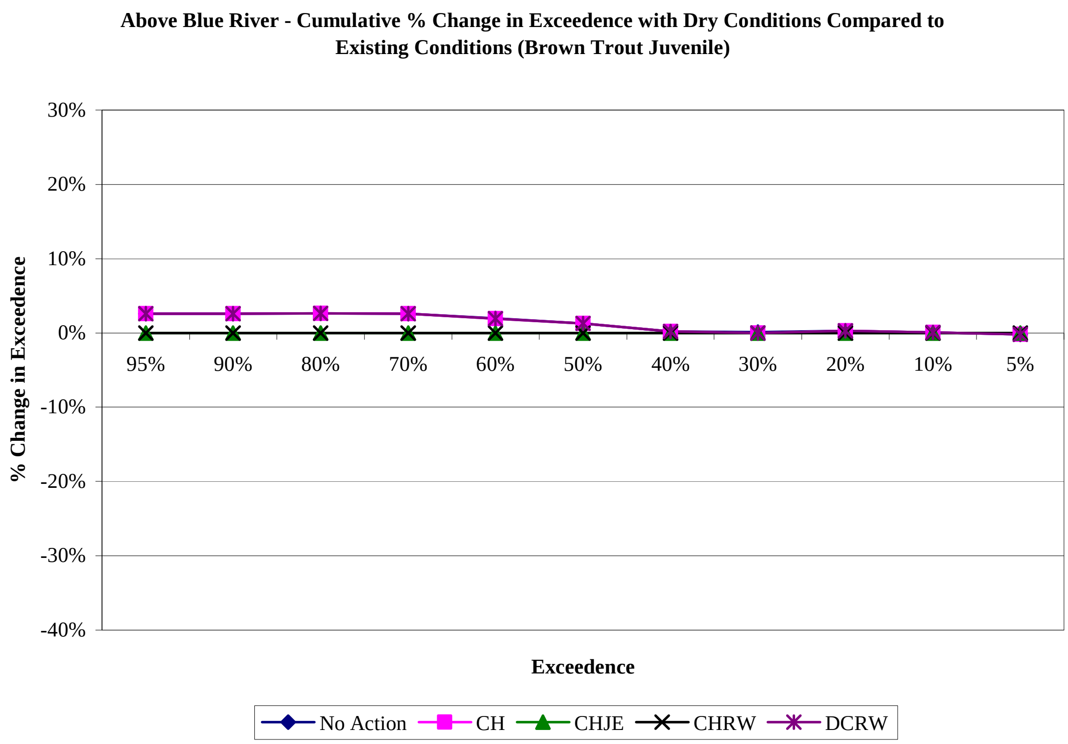


Figure 357. Above Blue River – percent change in exceedence with dry conditions (brown trout juvenile) cumulative effects.

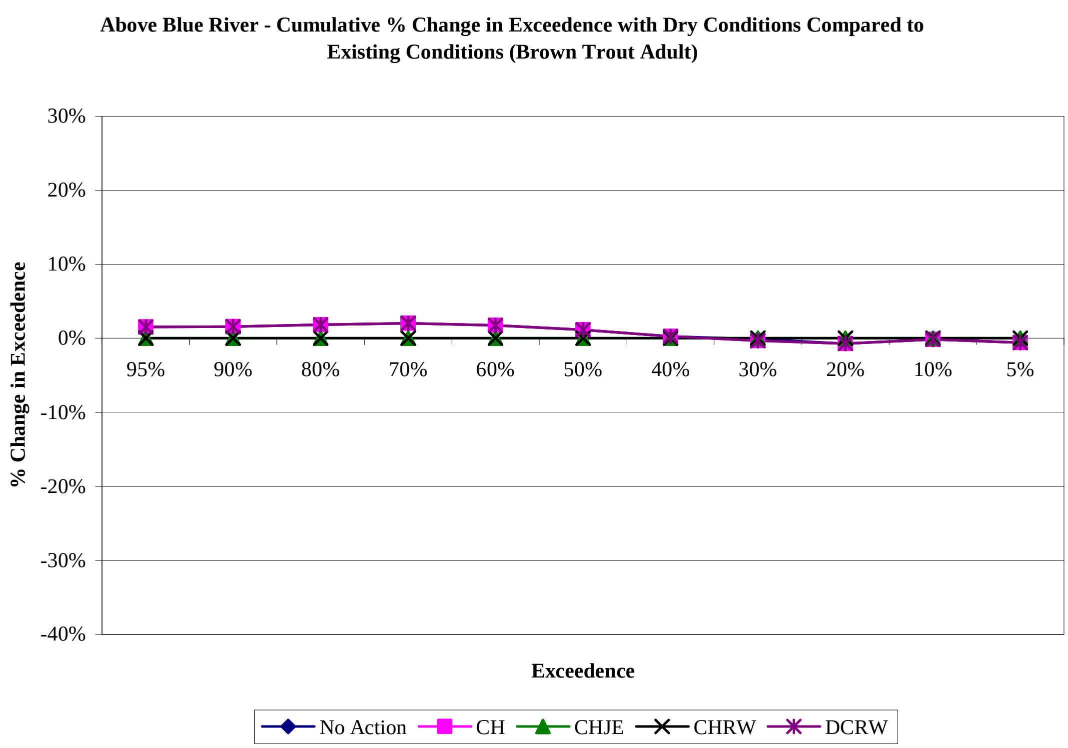


Figure 358. Above Blue River – percent change in exceedence with dry conditions (brown trout adult) cumulative effects.

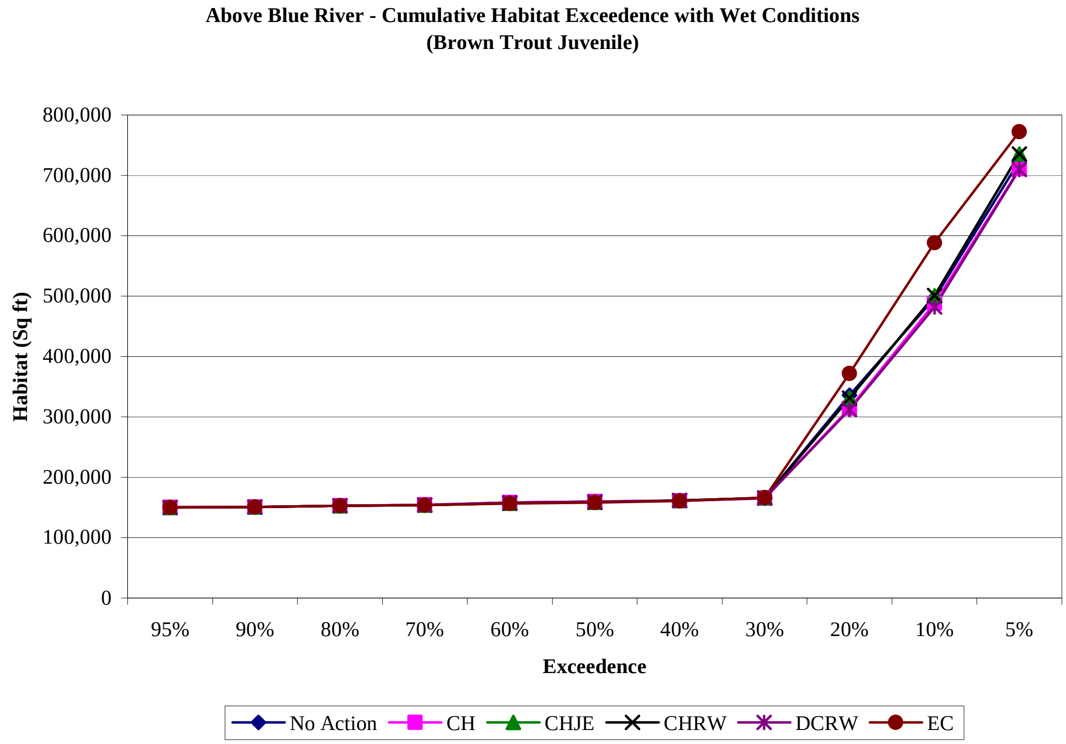


Figure 359. Above Blue River – habitat exceedence with wet conditions (brown trout juvenile) cumulative effects.

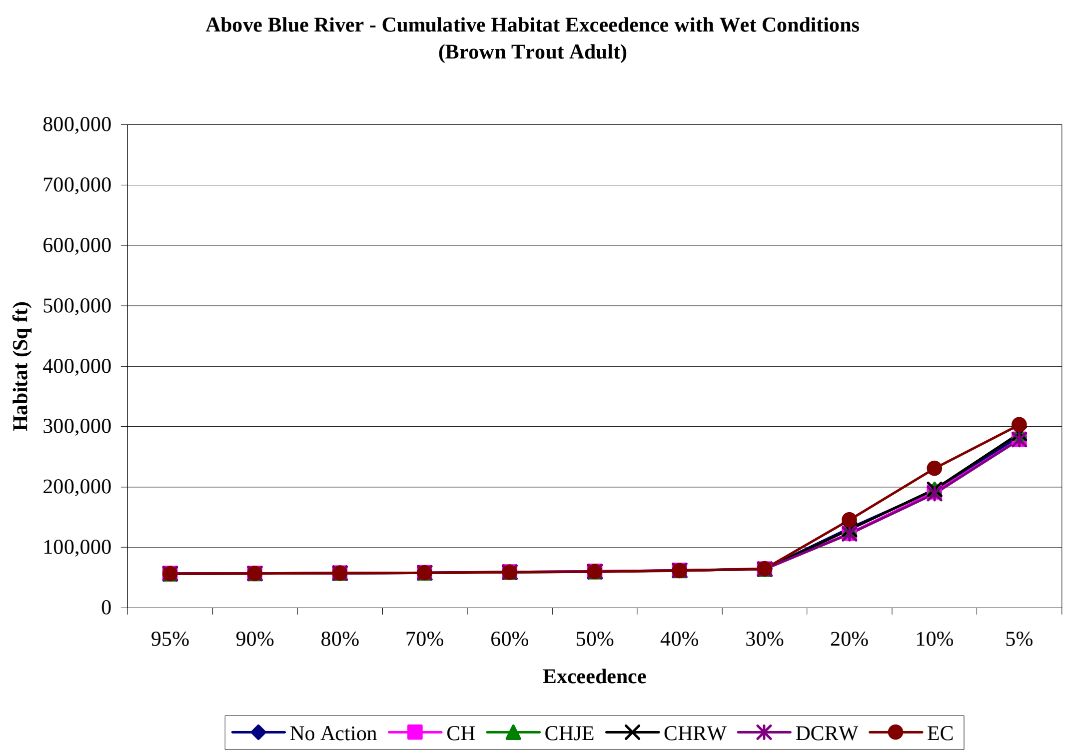


Figure 360. Above Blue River – habitat exceedence with wet conditions (brown trout adult) cumulative effects.

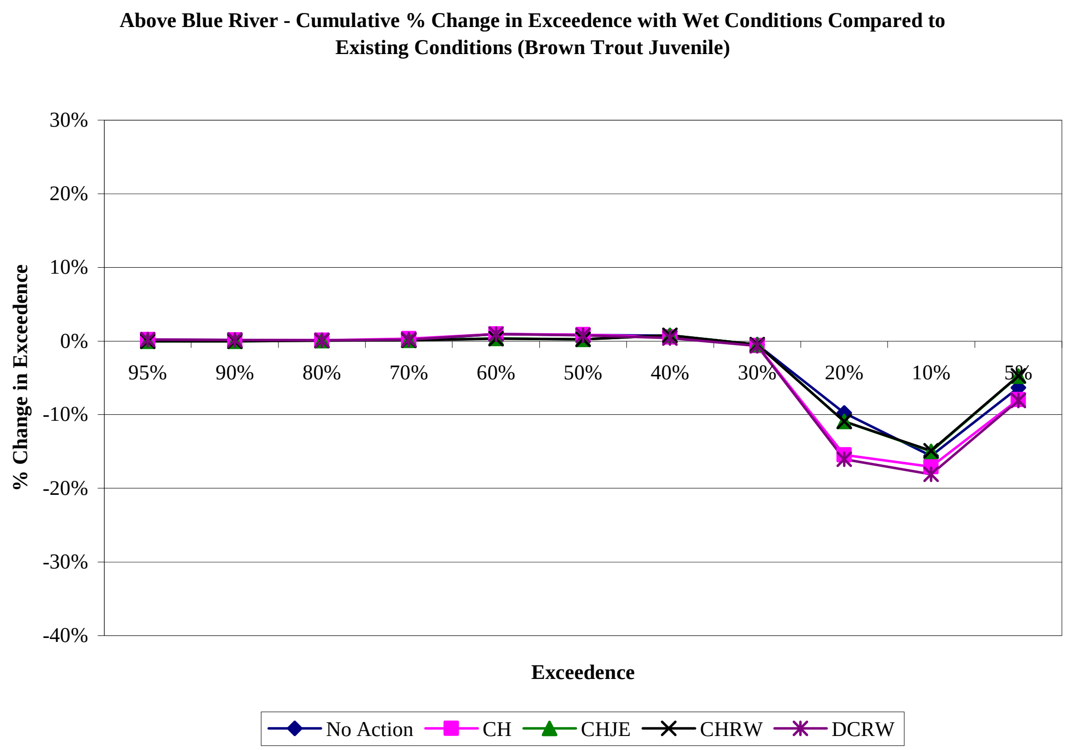


Figure 361. Above Blue River – percent change in exceedence with <u>wet</u> conditions (brown trout juvenile) cumulative effects.

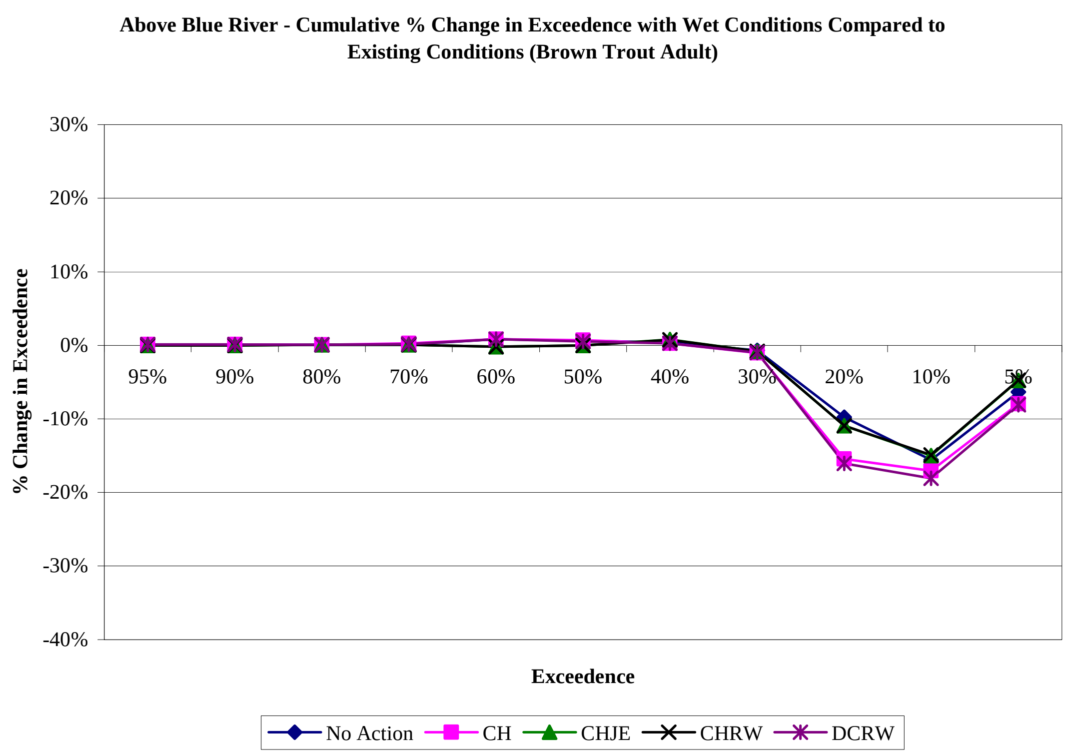


Figure 362. Above Blue River – percent change in exceedence with <u>wet</u> conditions (brown trout adult) cumulative effects.

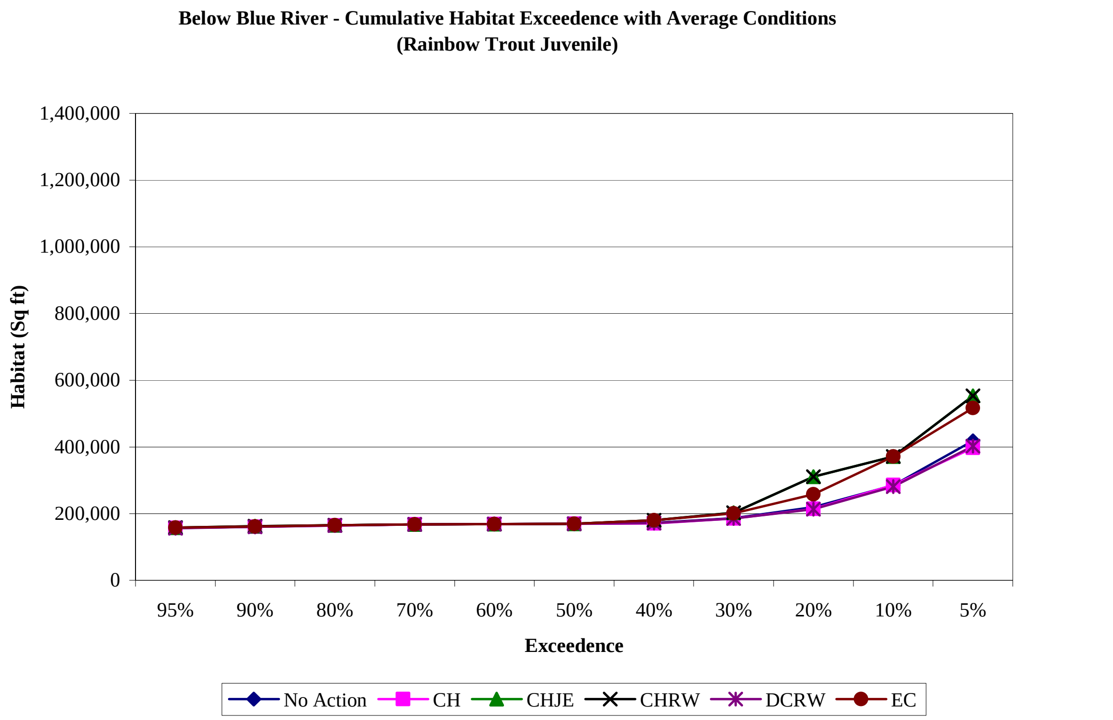


Figure 363. Below Blue River – habitat exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

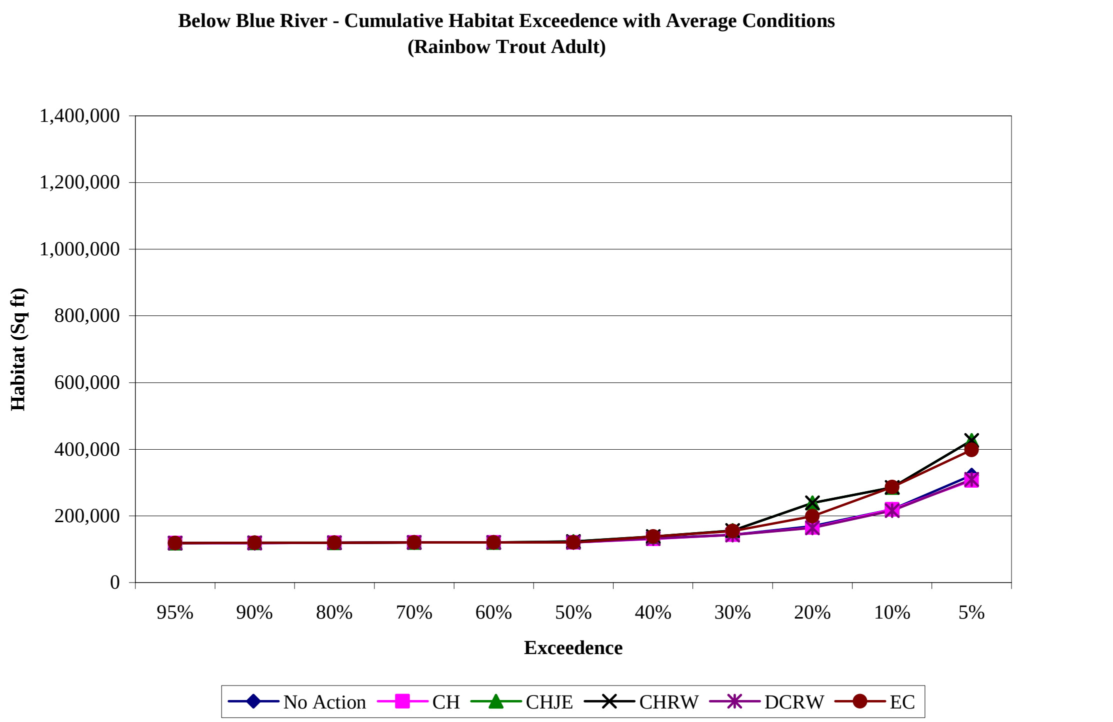


Figure 364. Below Blue River – habitat exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

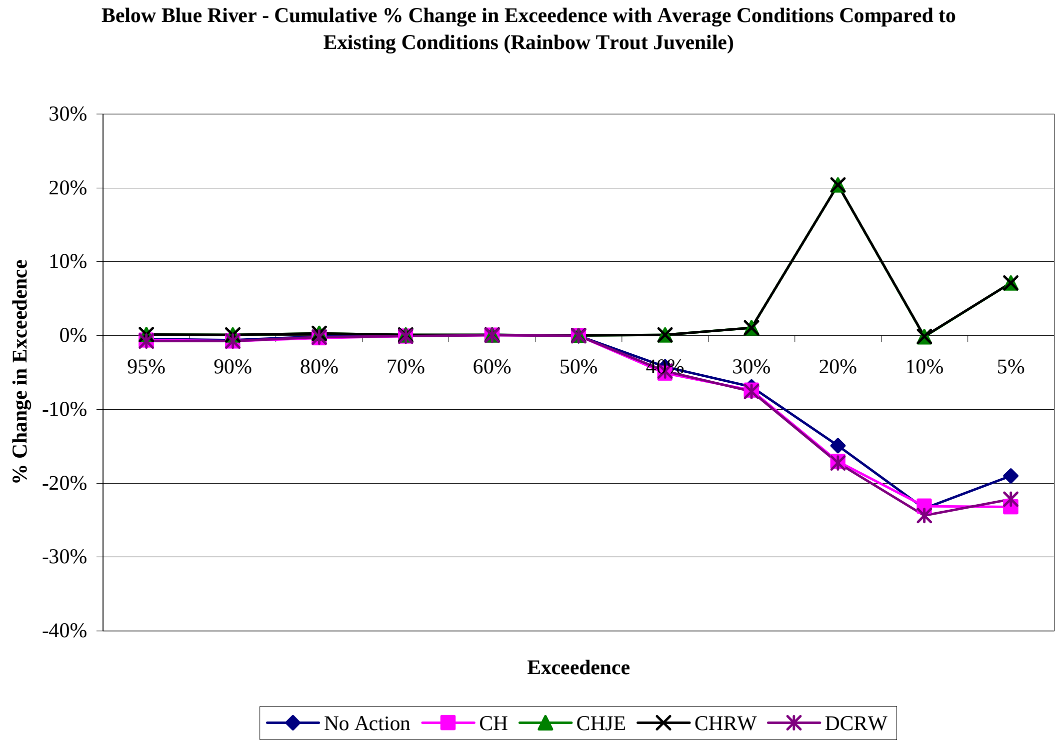


Figure 365. Below Blue River – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

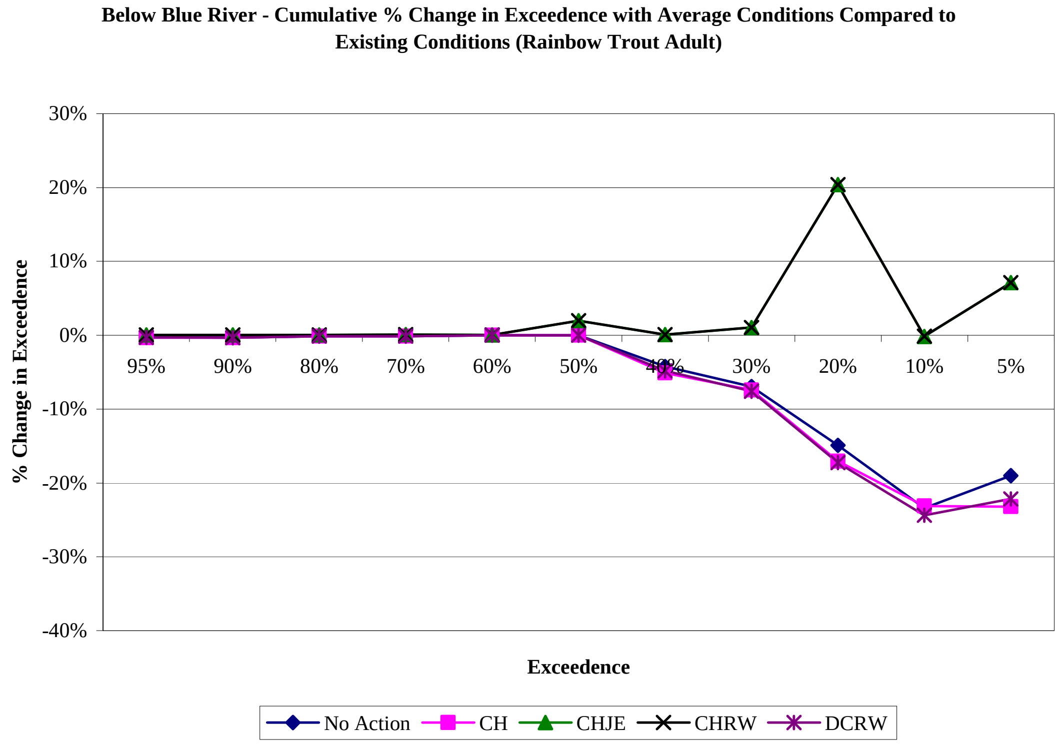


Figure 366. Below Blue River – percent change in exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

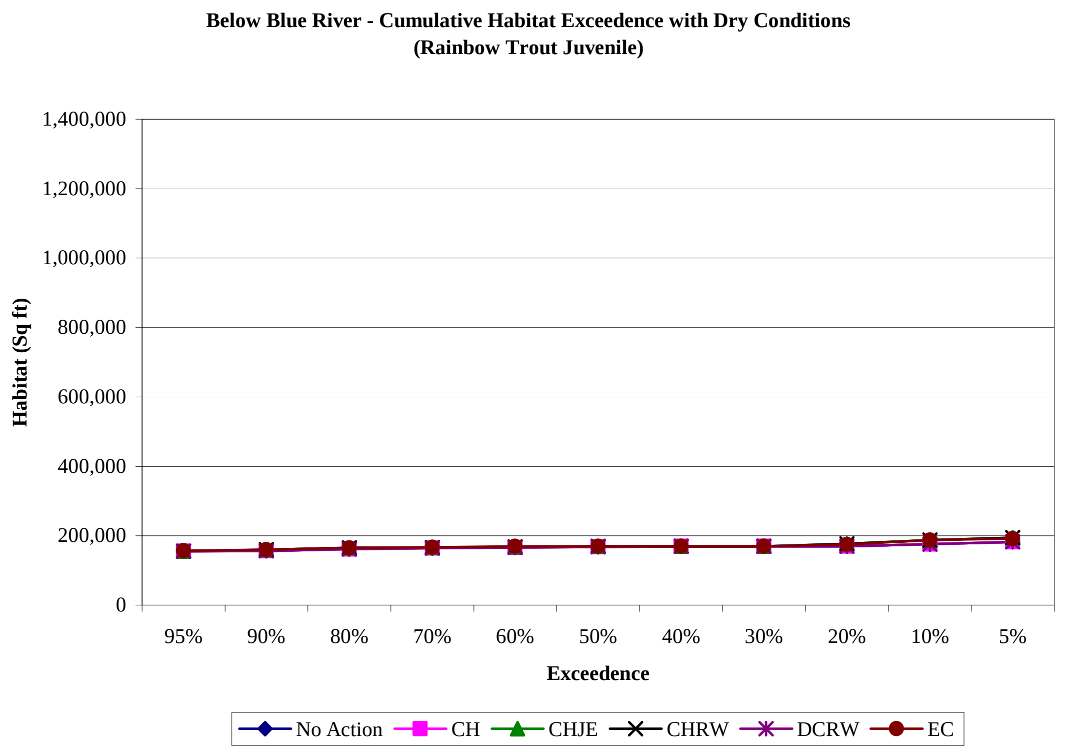


Figure 367. Below Blue River – habitat exceedence with dry conditions (rainbow trout juvenile) cumulative effects.

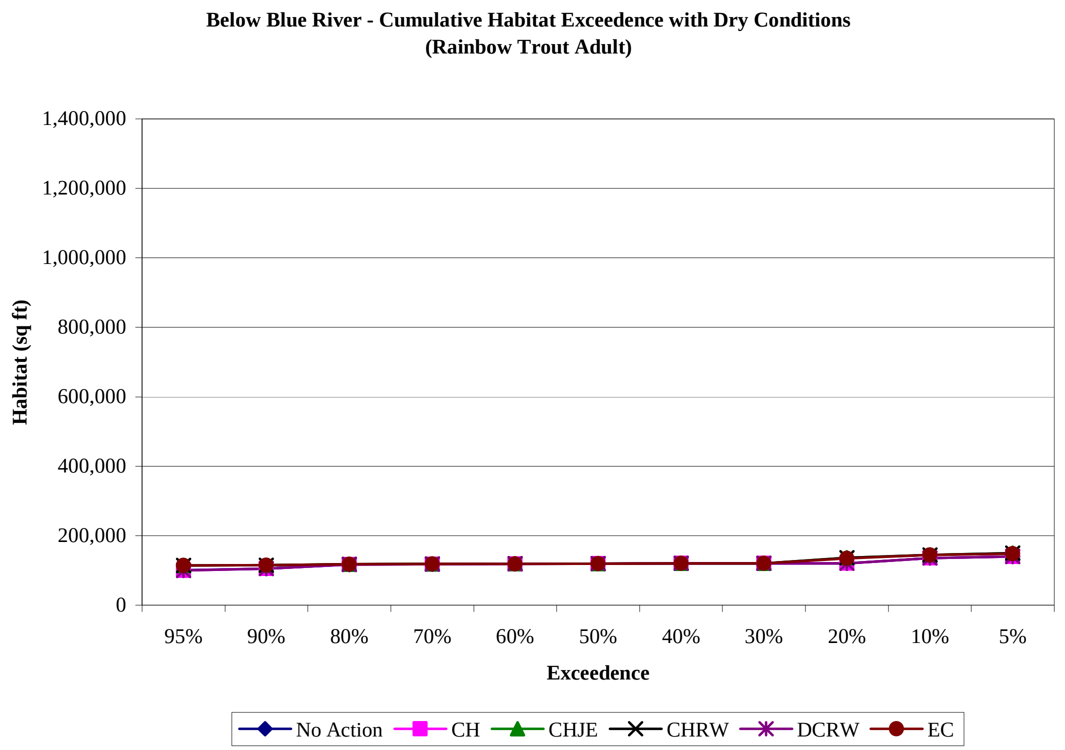


Figure 368. Below Blue River – habitat exceedence with dry conditions (rainbow trout adult) cumulative effects.

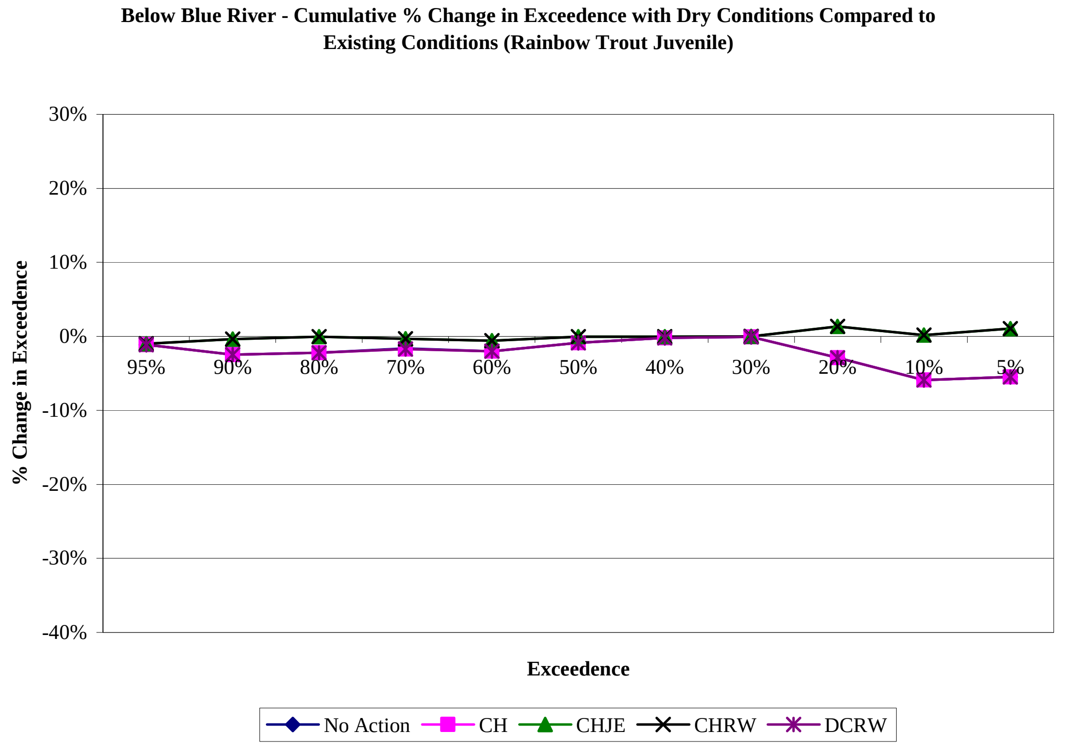


Figure 369. Below Blue River – percent change in exceedence with <u>dry</u> conditions (rainbow trout juvenile) cumulative effects.

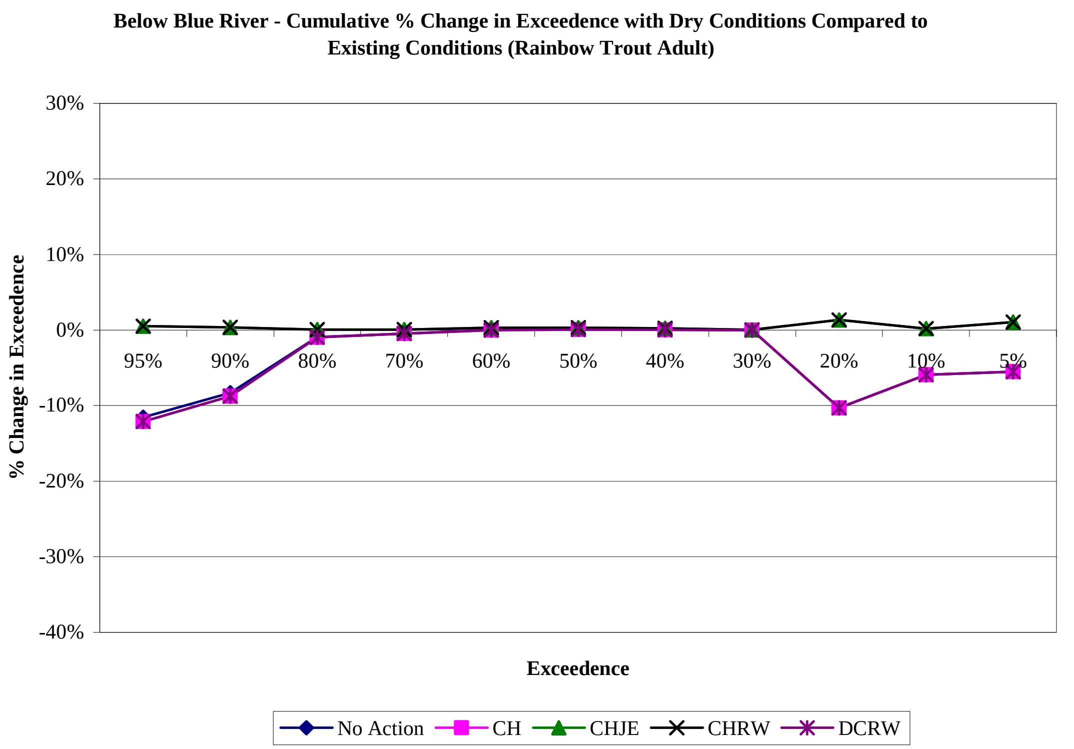


Figure 370. Below Blue River – percent change in exceedence with <u>dry</u> conditions (rainbow trout adult) cumulative effects.

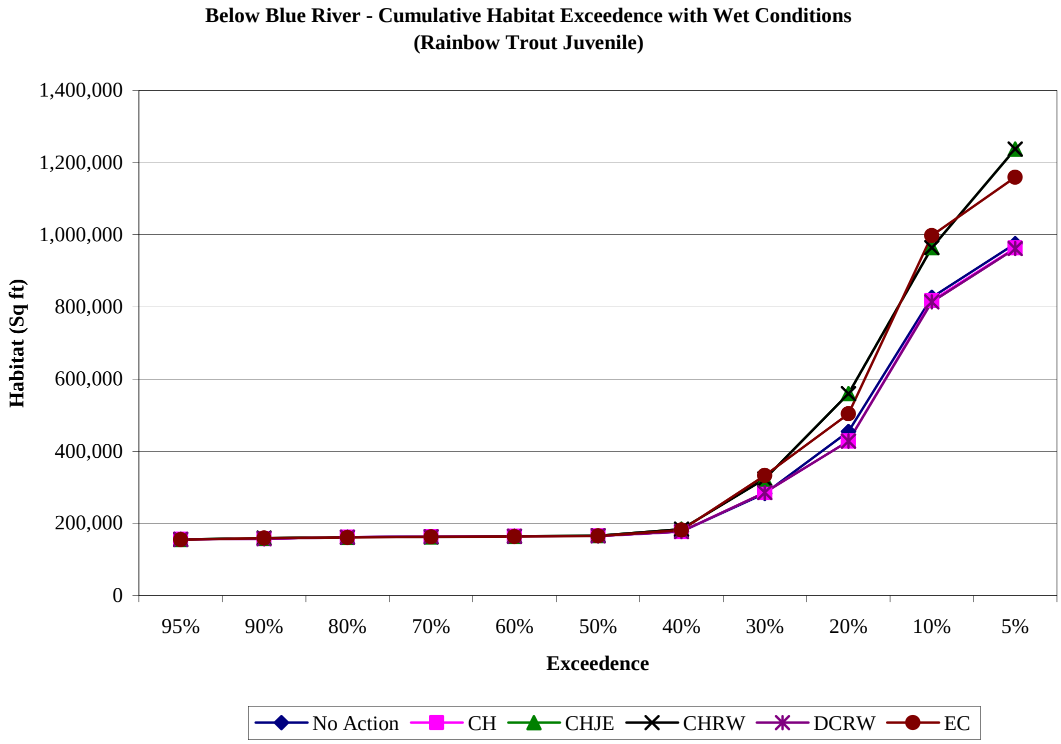


Figure 371. Below Blue River – habitat exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

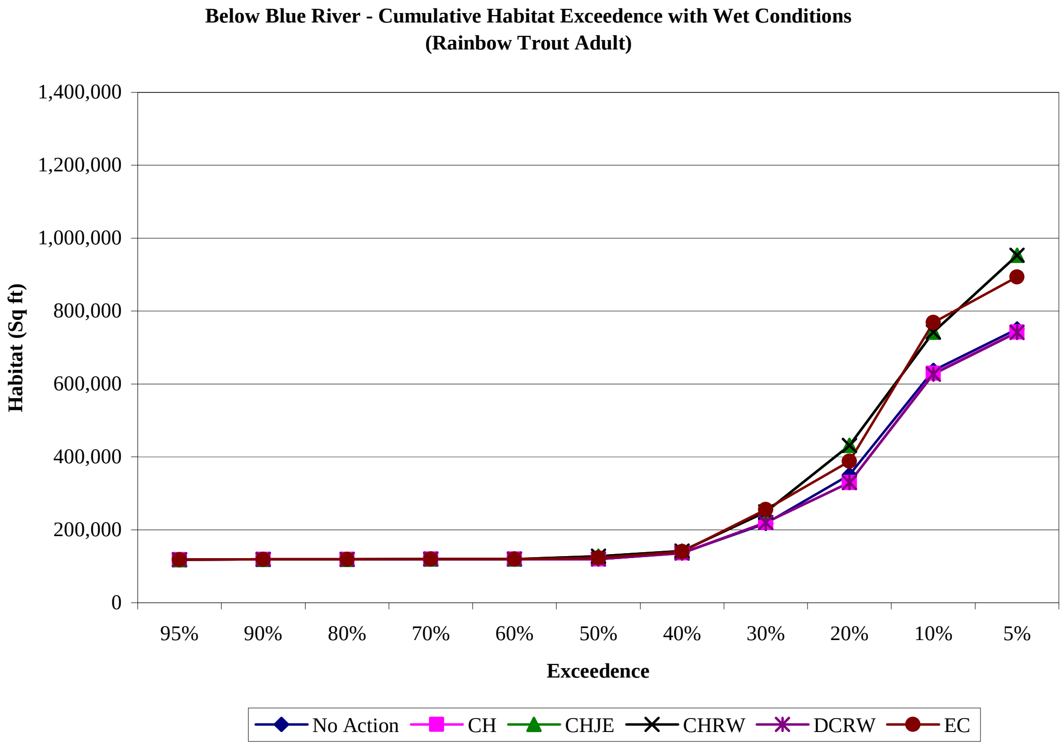


Figure 372. Below Blue River – habitat exceedence with wet conditions (rainbow trout adult) cumulative effects.

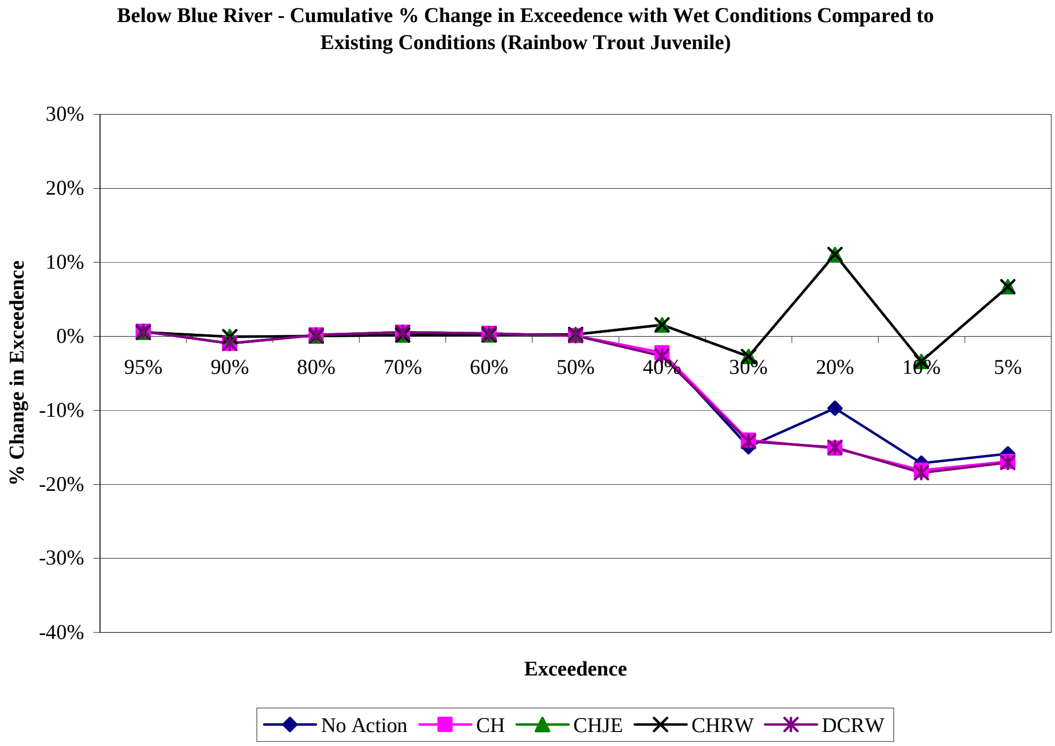


Figure 373. Below Blue River – percent change in exceedence with <u>wet</u> conditions (rainbow trout juvenile) cumulative effects.

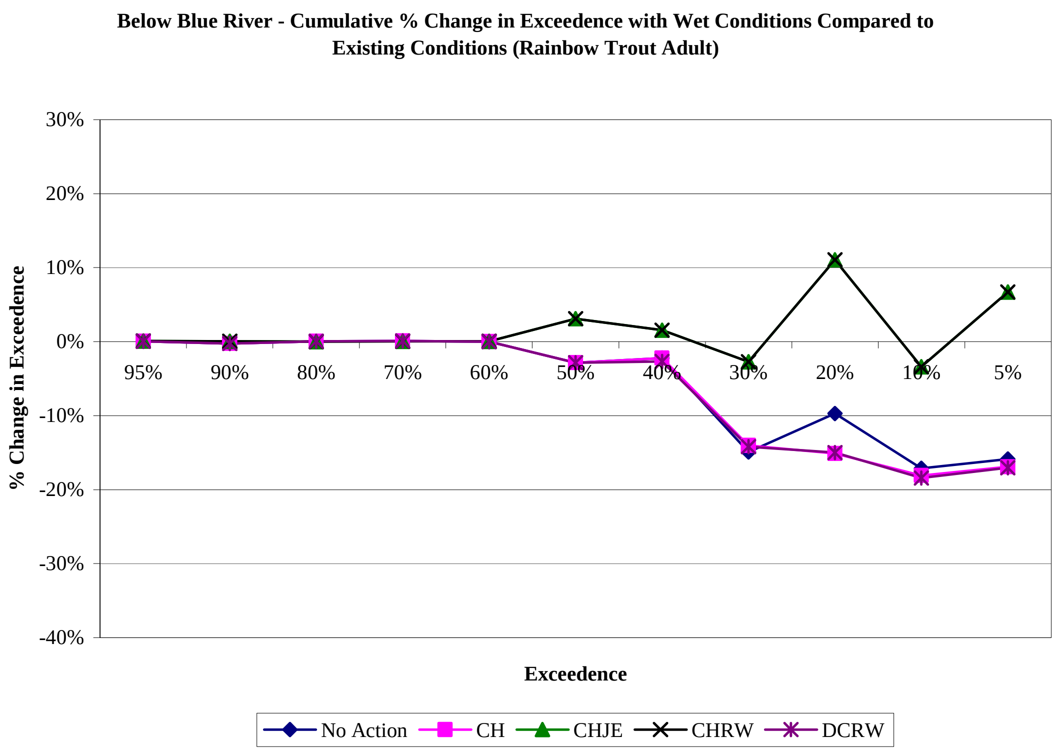


Figure 374. Below Blue River – percent change in exceedence with <u>wet</u> conditions (rainbow trout adult) cumulative effects.

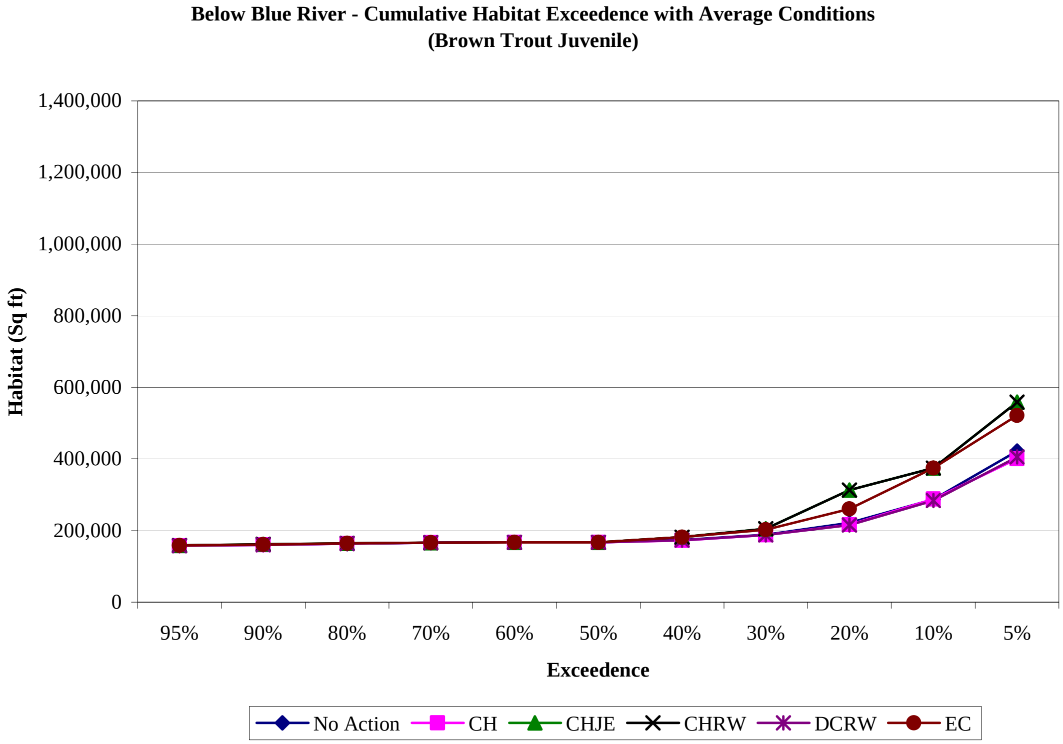


Figure 375. Below Blue River – habitat exceedence with average conditions (brown trout juvenile) cumulative effects.

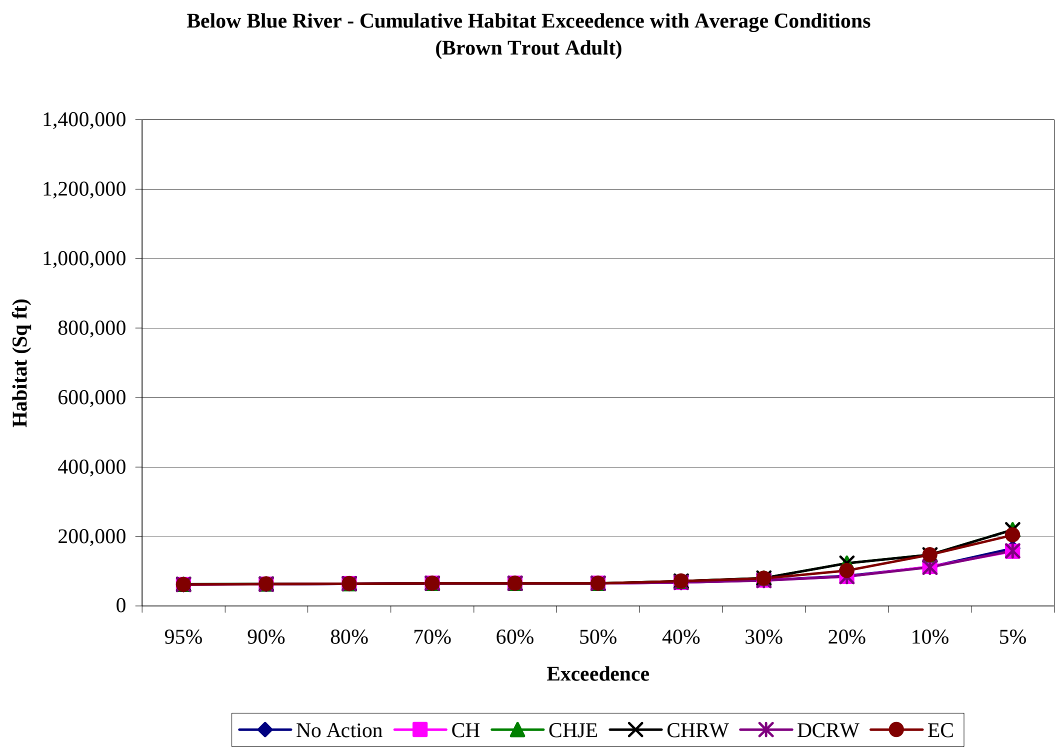


Figure 376. Below Blue River – habitat exceedence with average conditions (brown trout adult) cumulative effects.

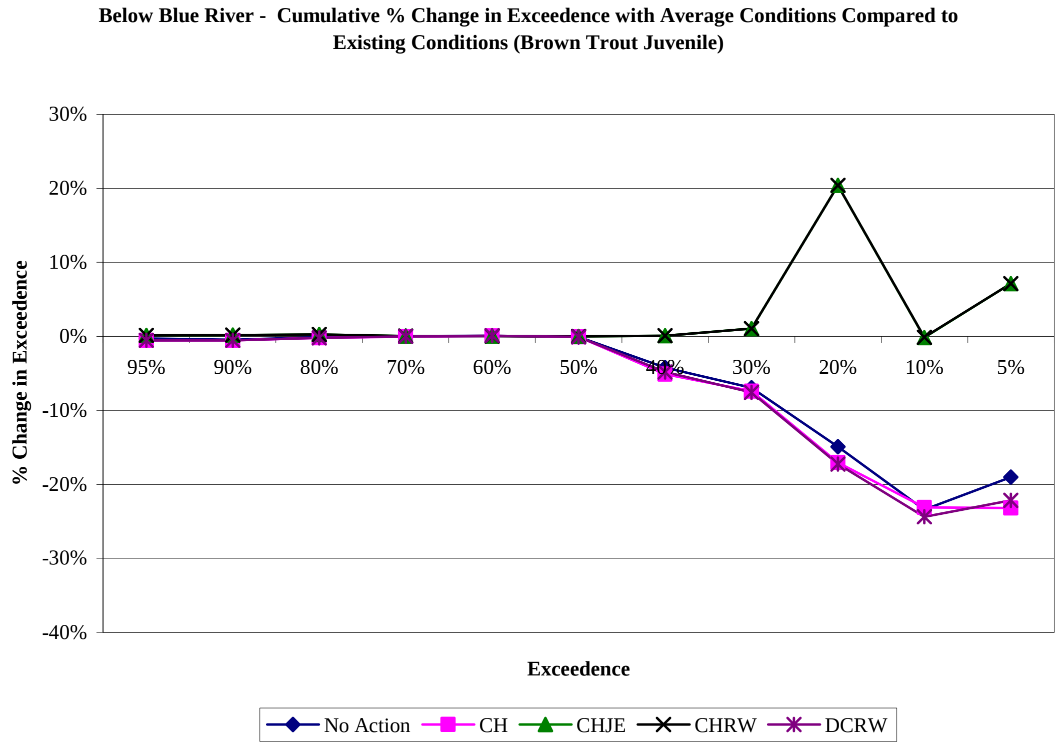


Figure 377. Below Blue River – percent change in exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

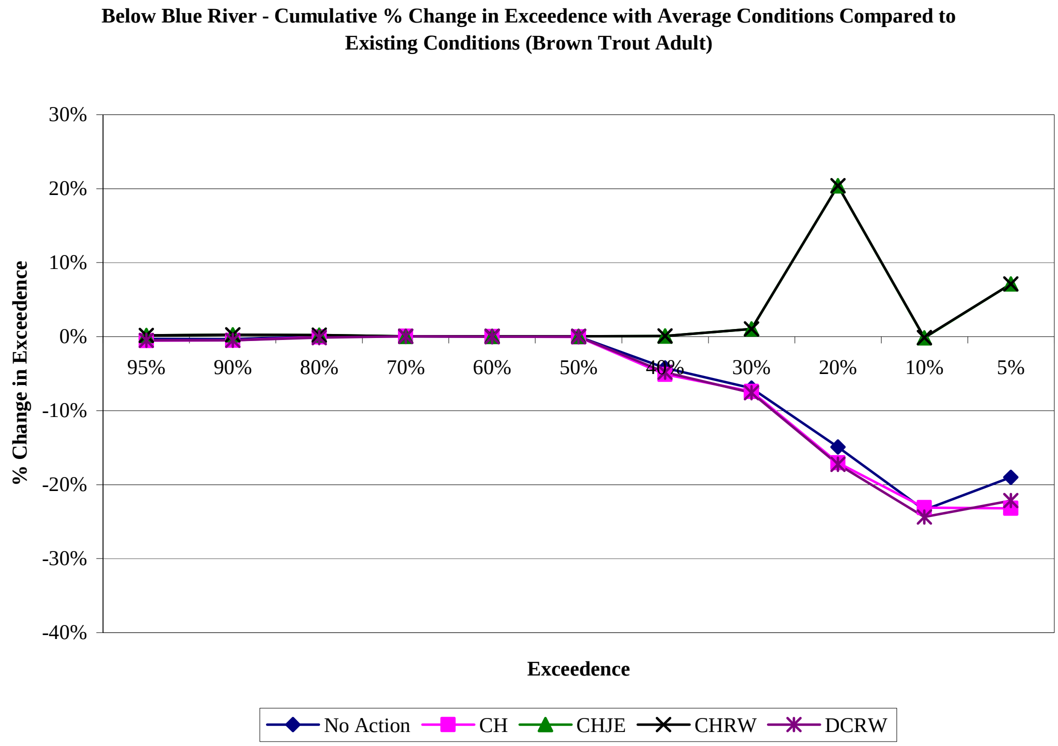


Figure 378. Below Blue River – percent change in exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

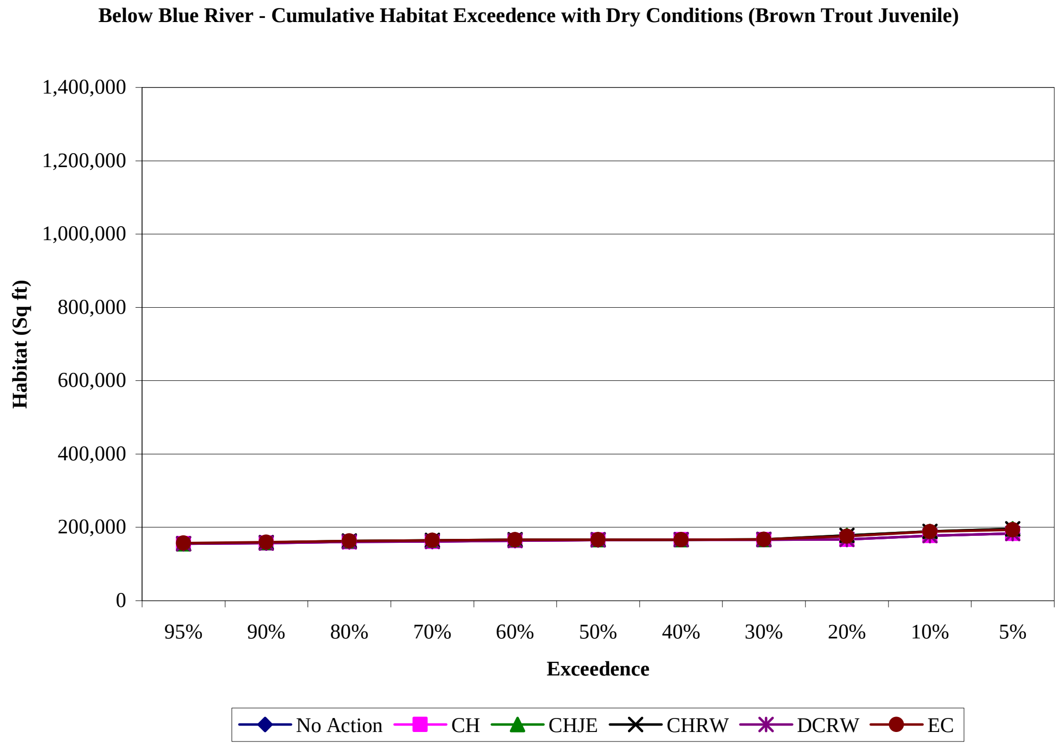


Figure 379. Below Blue River – habitat exceedence with dry conditions (brown trout juvenile) cumulative effects.

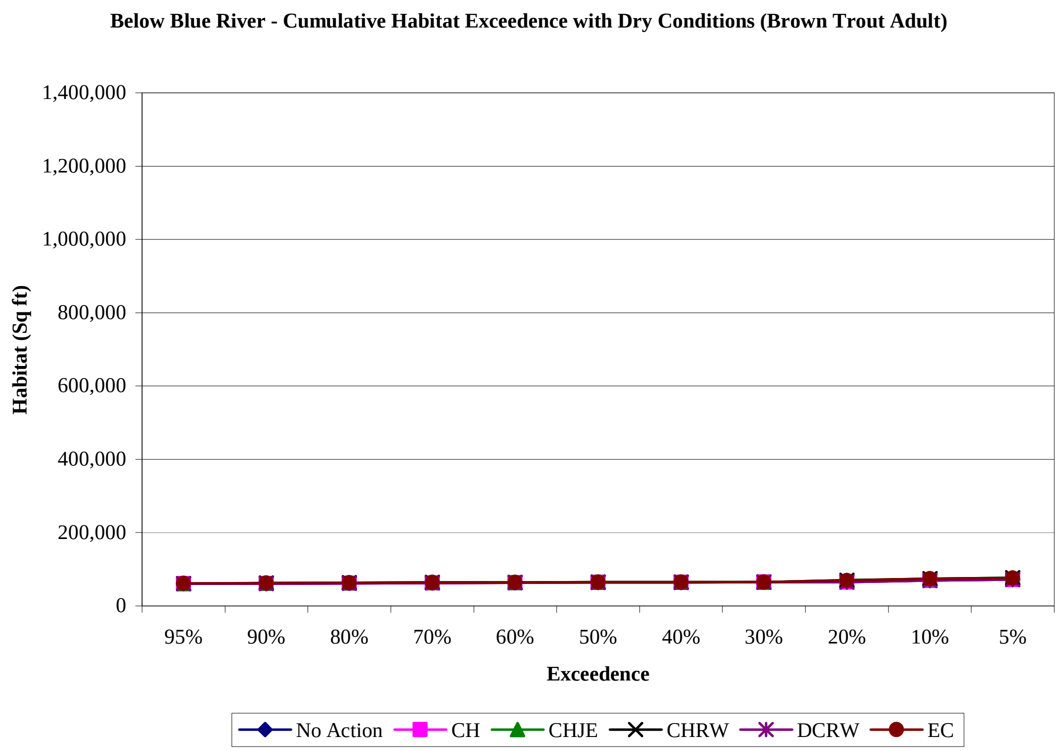


Figure 380. Below Blue River – habitat exceedence with dry conditions (brown trout adult) cumulative effects.

Figure 381. Below Blue River – percent change in exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

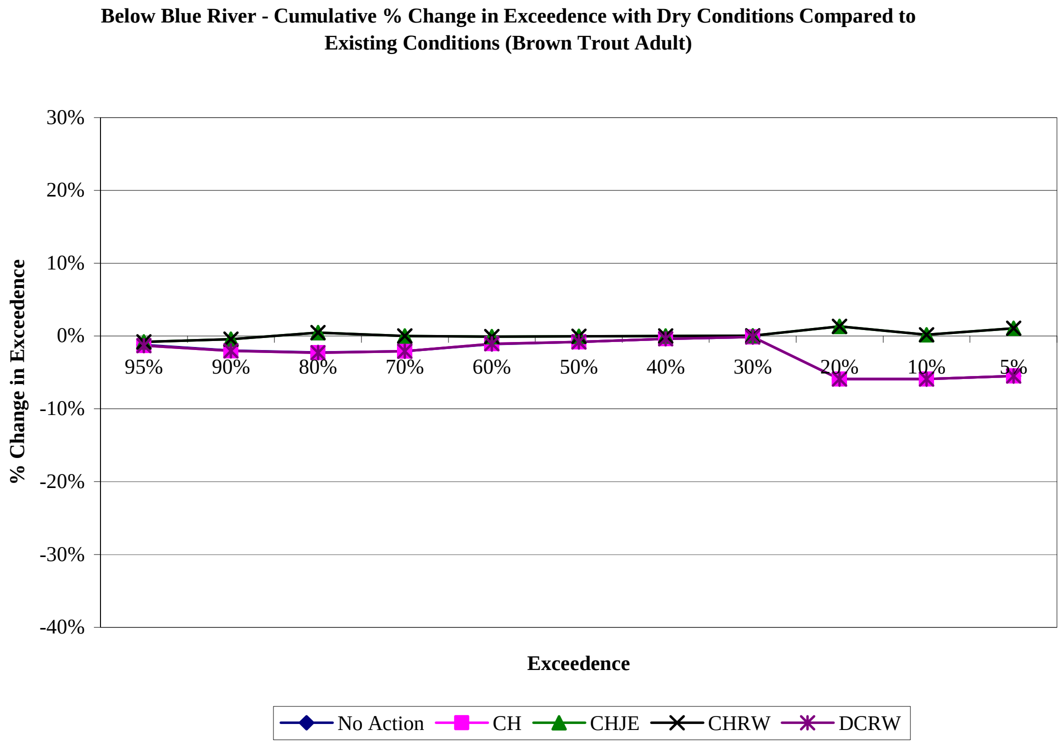


Figure 382. Below Blue River – percent change in exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

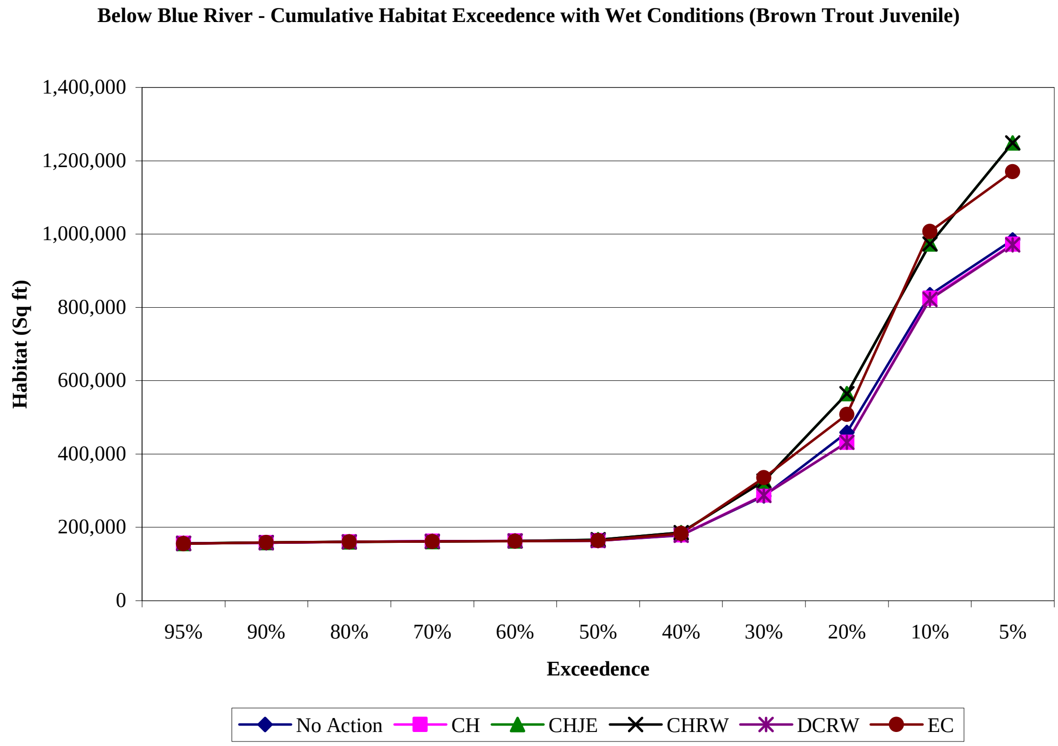


Figure 383. Below Blue River – habitat exceedence with wet conditions (brown trout juvenile) cumulative effects.

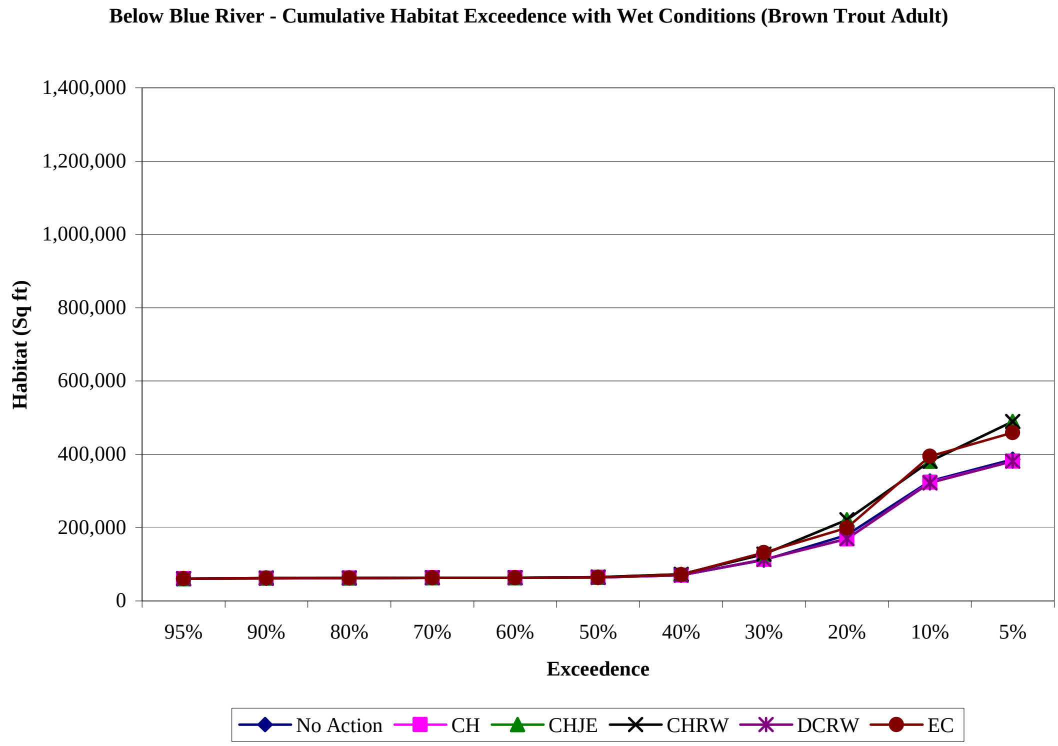


Figure 384. Below Blue River – habitat exceedence with wet conditions (brown trout adult) cumulative effects.

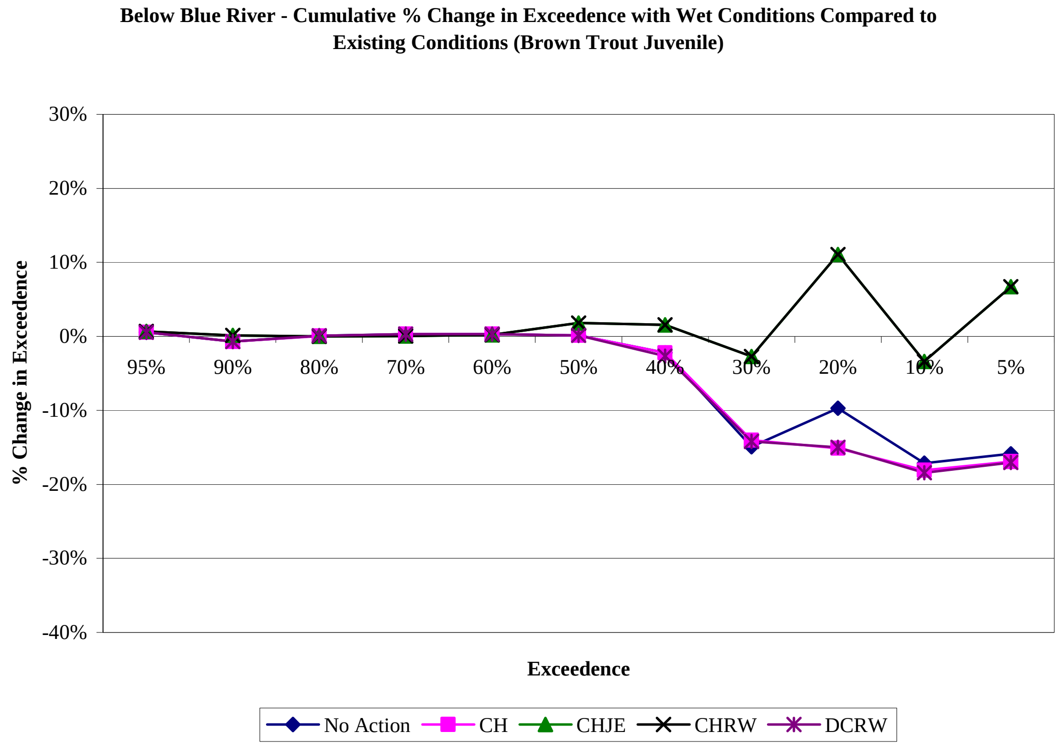


Figure 385. Below Blue River – percent change in exceedence with wet conditions (brown trout juvenile) cumulative effects.

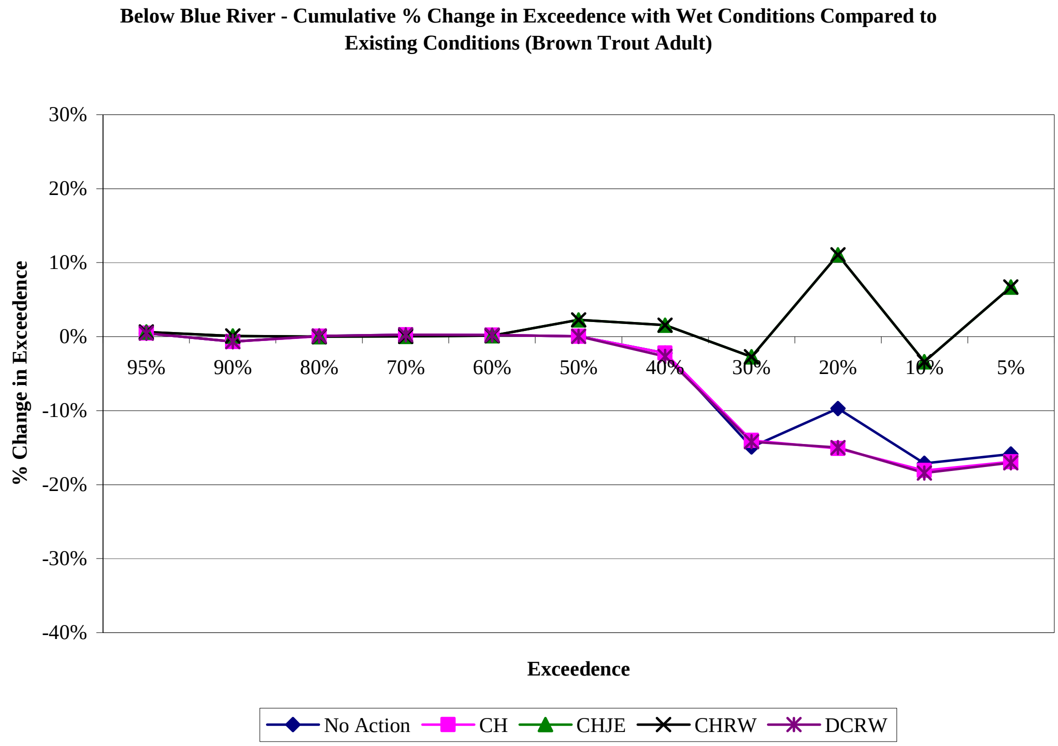


Figure 386. Below Blue River – percent change in exceedence with wet conditions (brown trout adult) cumulative effects.

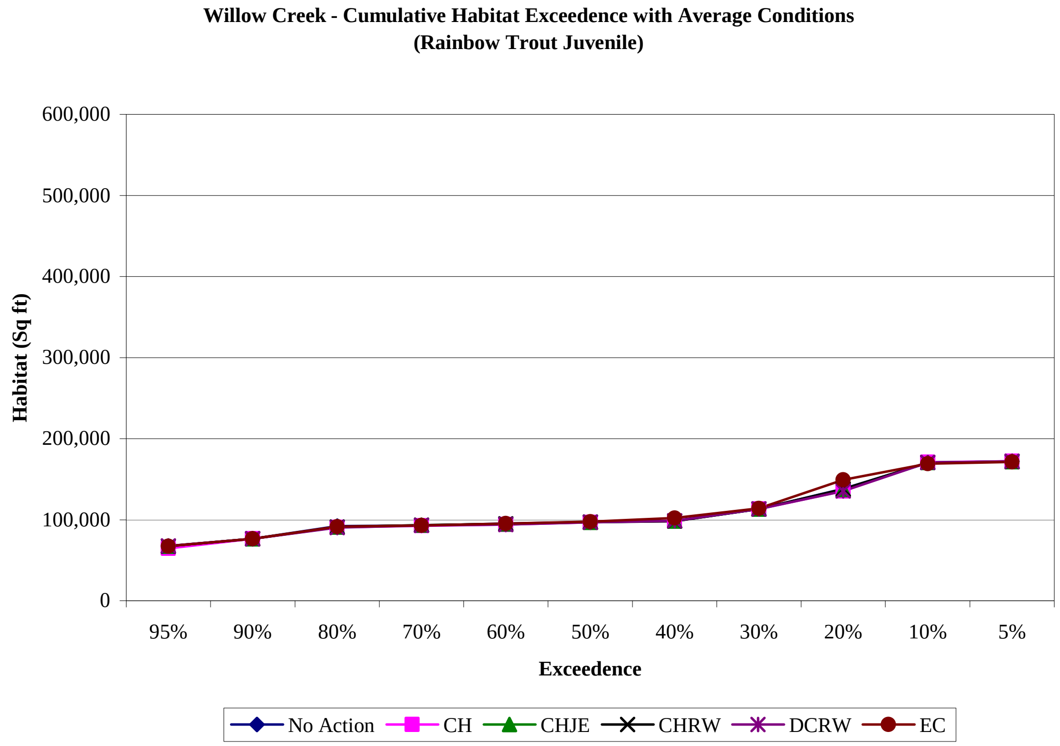


Figure 387. Willow Creek- habitat exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

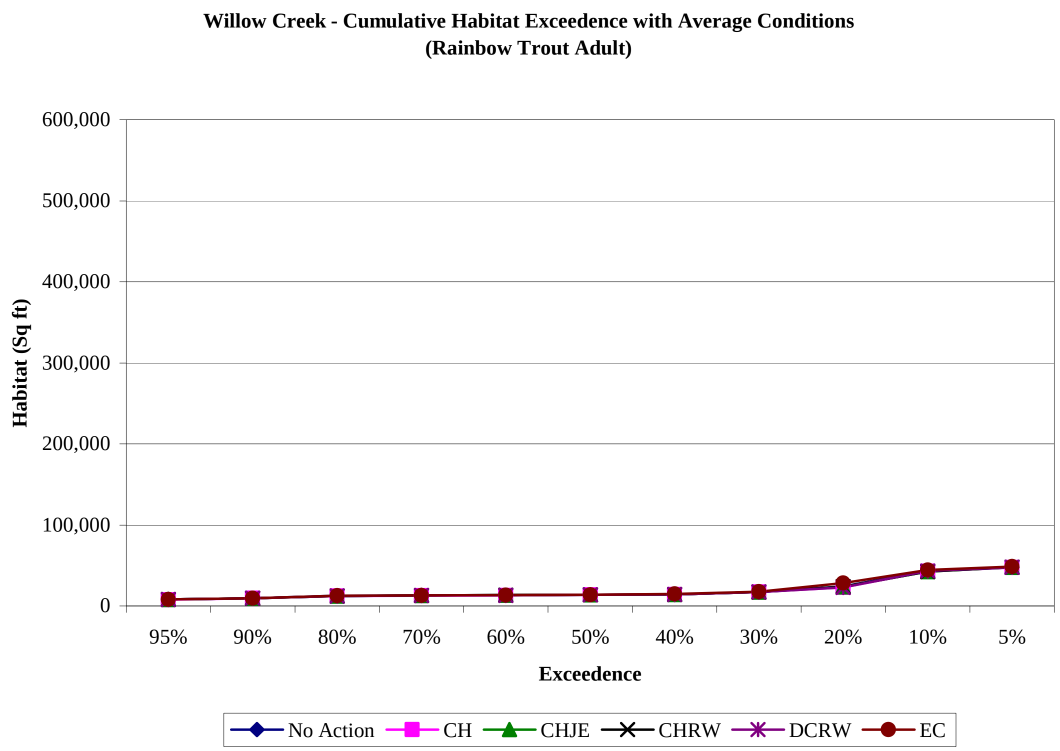


Figure 388. Willow Creek – habitat exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

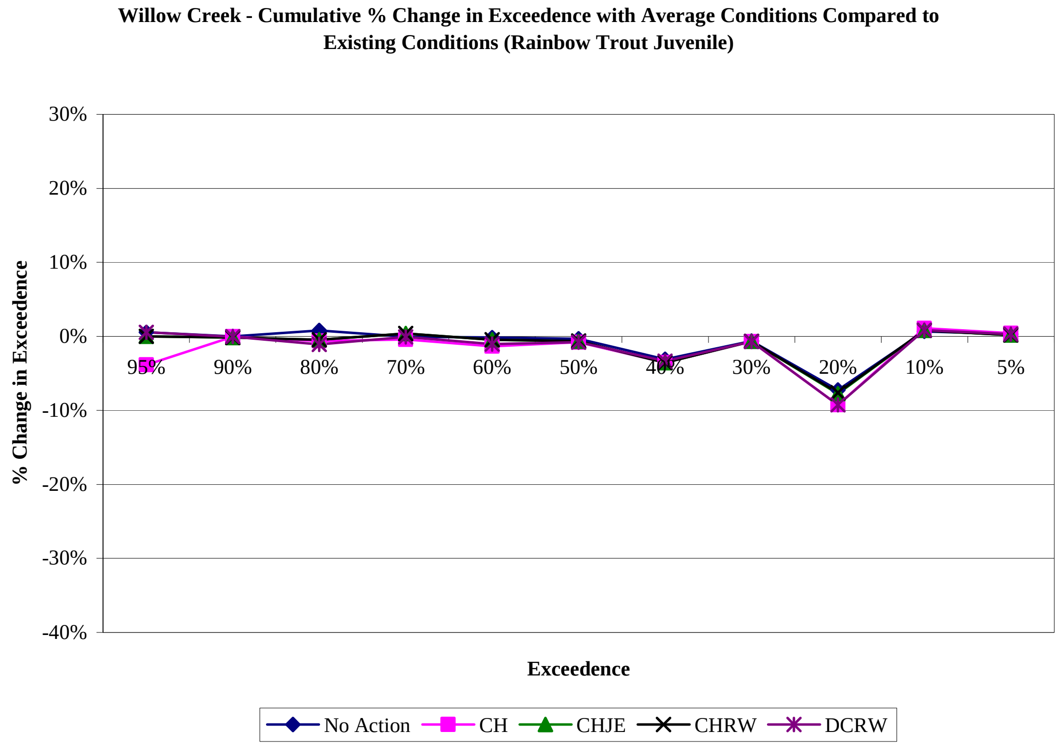


Figure 389. Willow Creek – percent change in exceedence with <u>average</u> conditions (rainbow trout juvenile) cumulative effects.

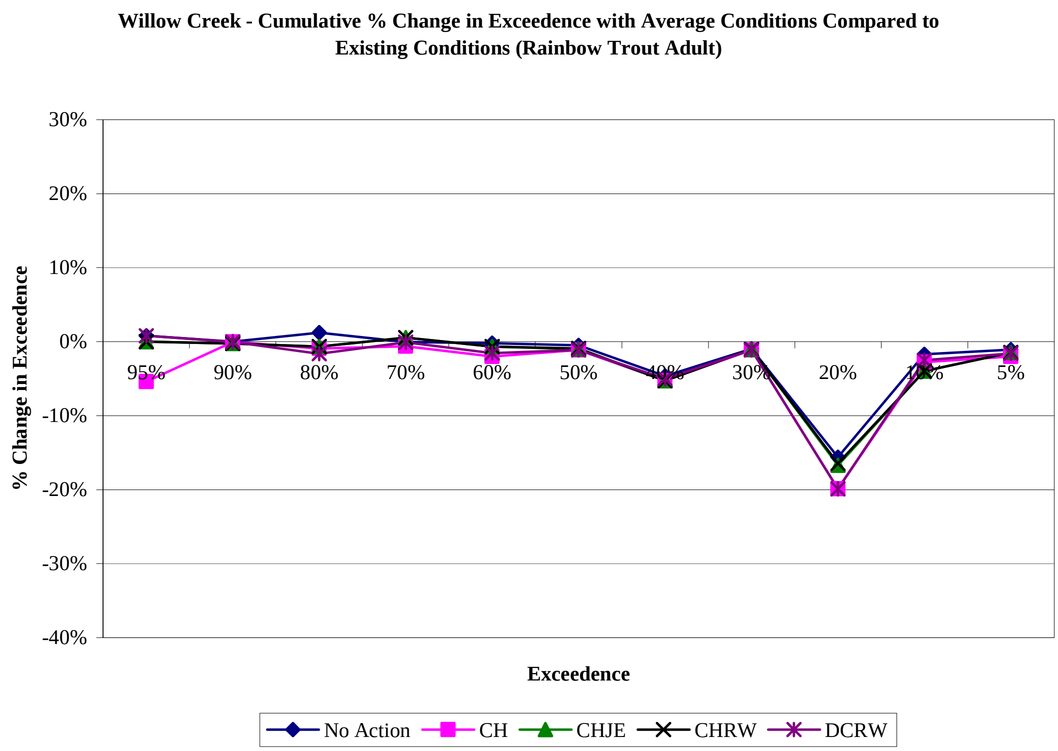


Figure 390. Willow Creek – percent change in exceedence with <u>average</u> conditions (rainbow trout adult) cumulative effects.

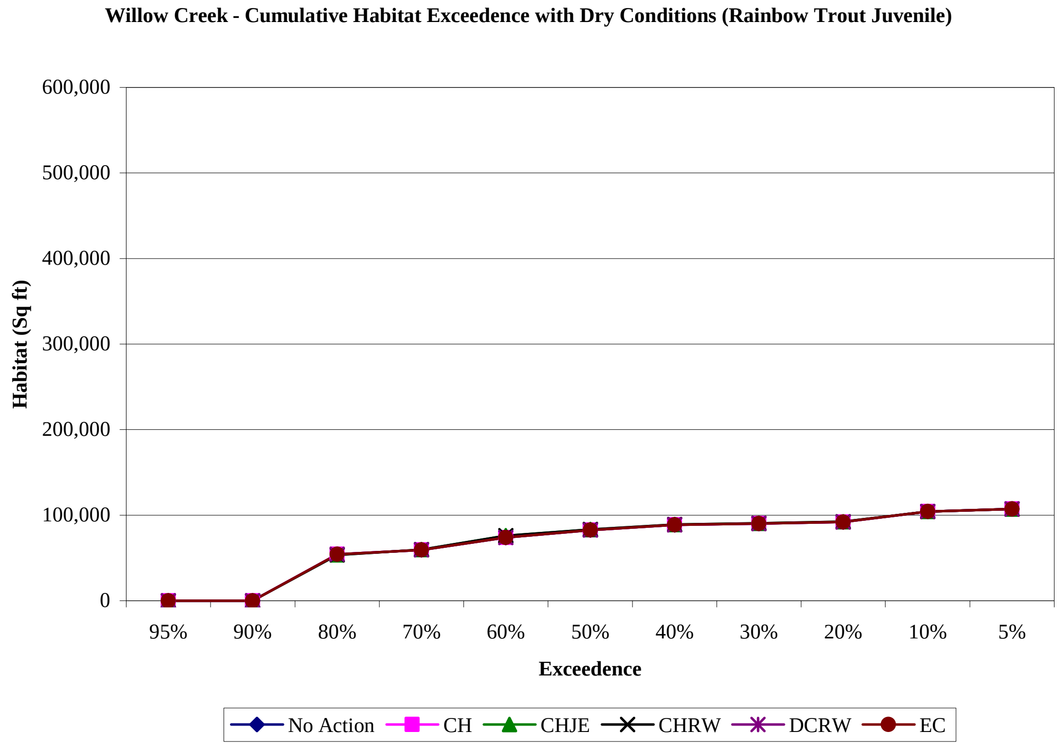


Figure 391. Willow Creek – habitat exceedence with dry conditions (rainbow trout juvenile) cumulative effects.

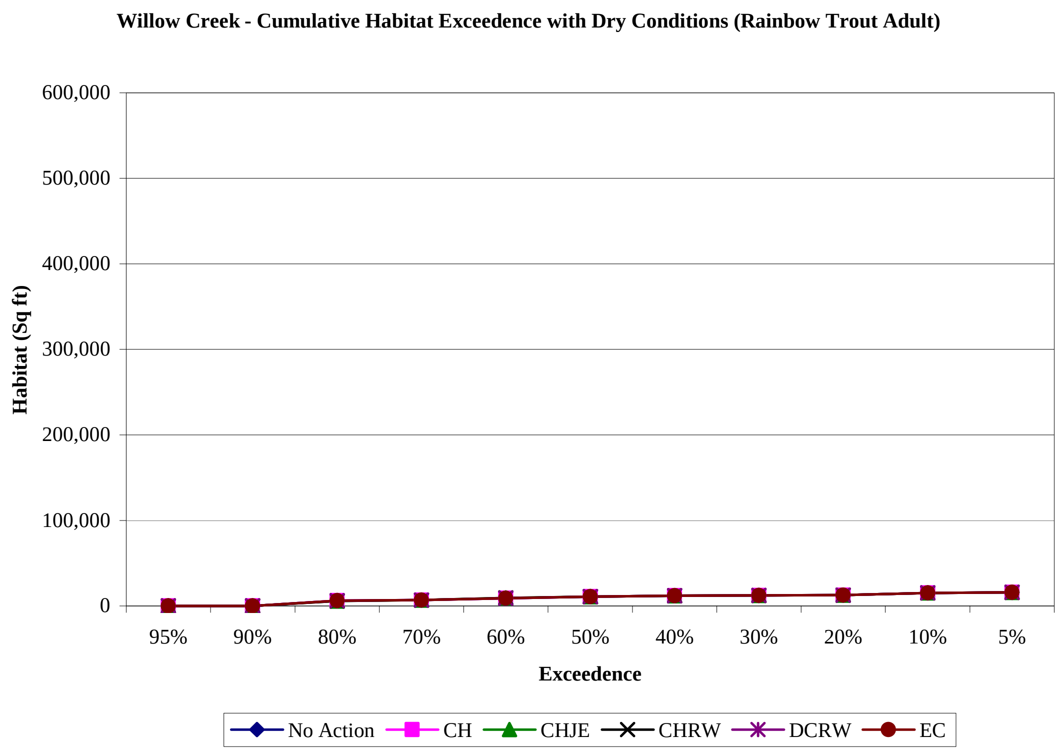


Figure 392. Willow Creek – habitat exceedence with dry conditions (rainbow trout adult) cumulative effects.

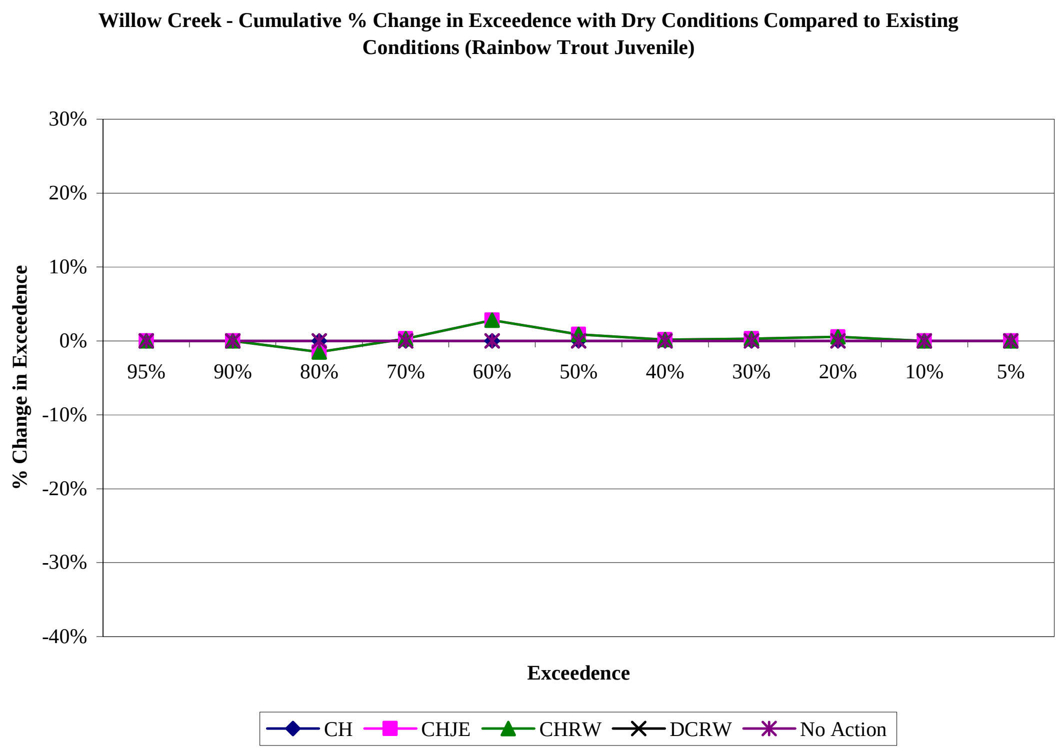


Figure 393. Willow Creek – percent change in exceedence with dry conditions (rainbow trout juvenile) cumulative effects.

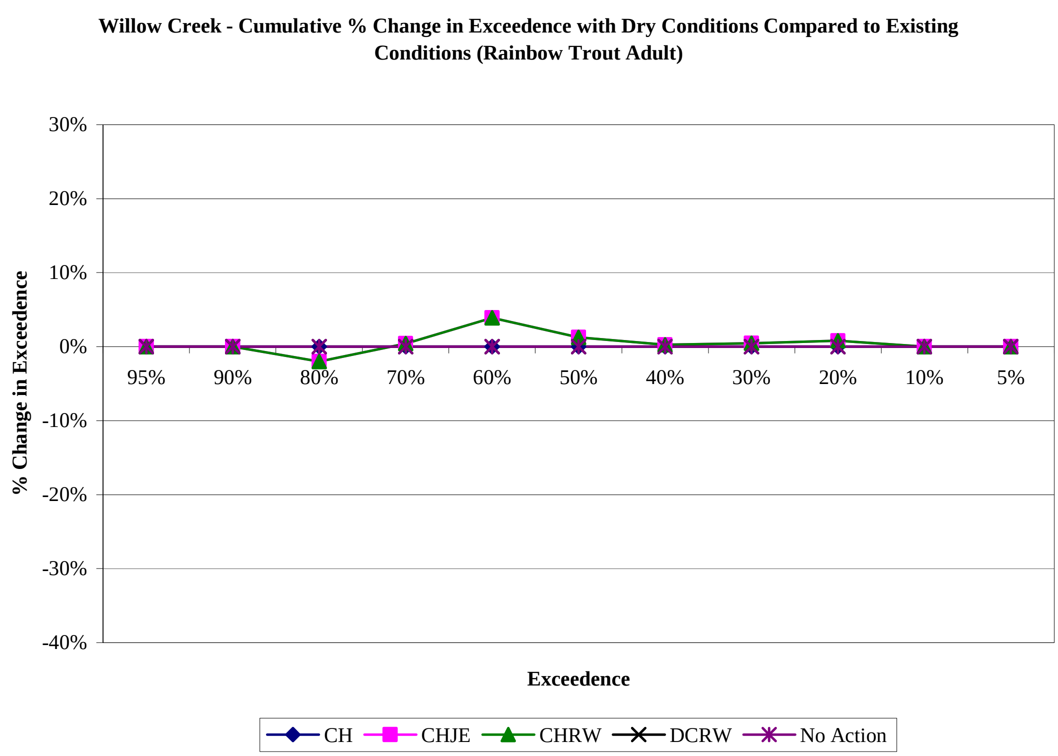


Figure 394. Willow Creek – percent change in exceedence with dry conditions (rainbow trout adult) cumulative effects.

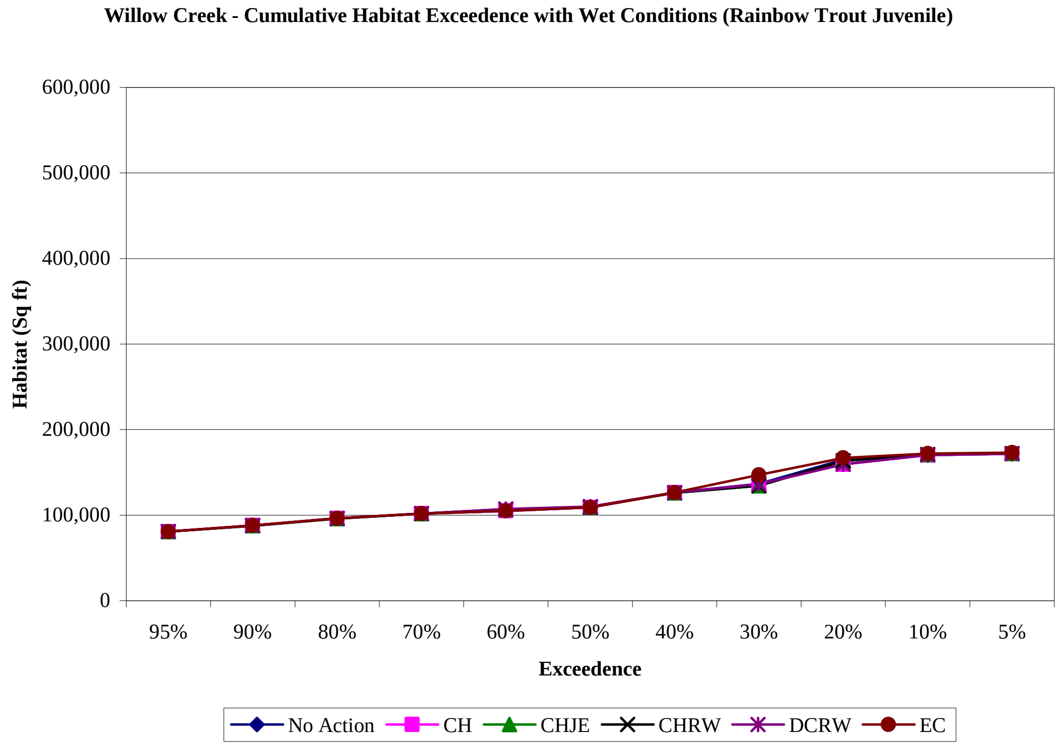


Figure 395. Willow Creek – habitat exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

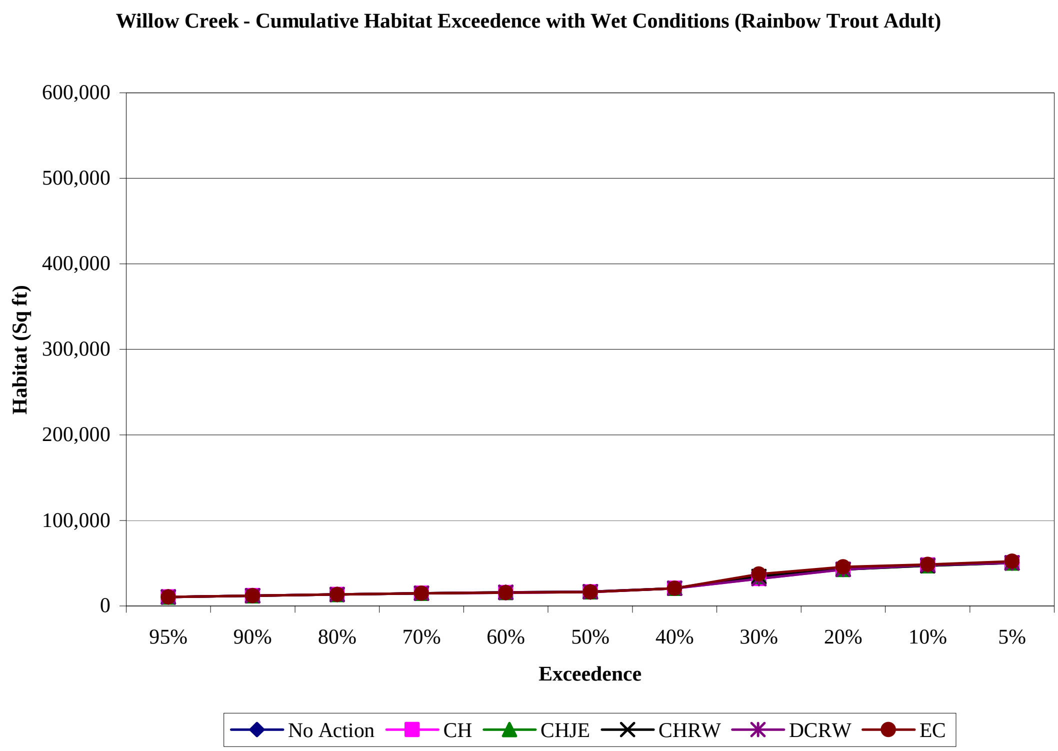


Figure 396. Willow Creek – habitat exceedence with wet conditions (rainbow trout adult) cumulative effects.

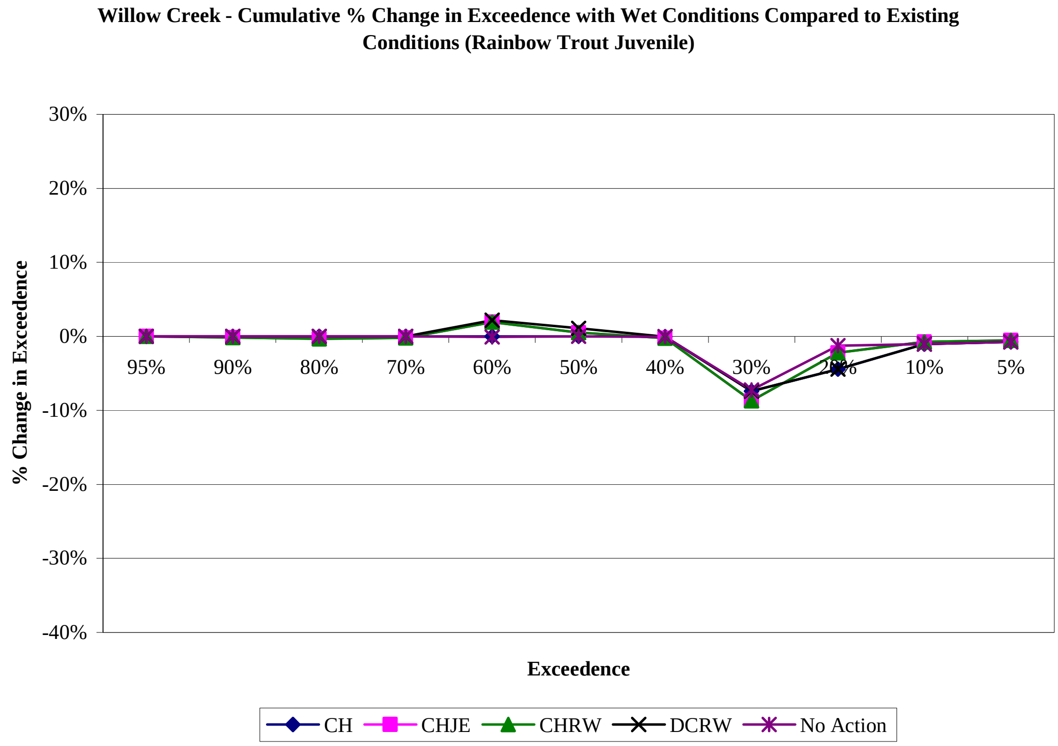


Figure 397. Willow Creek – percent change in exceedence with wet conditions (rainbow trout juvenile) cumulative effects.

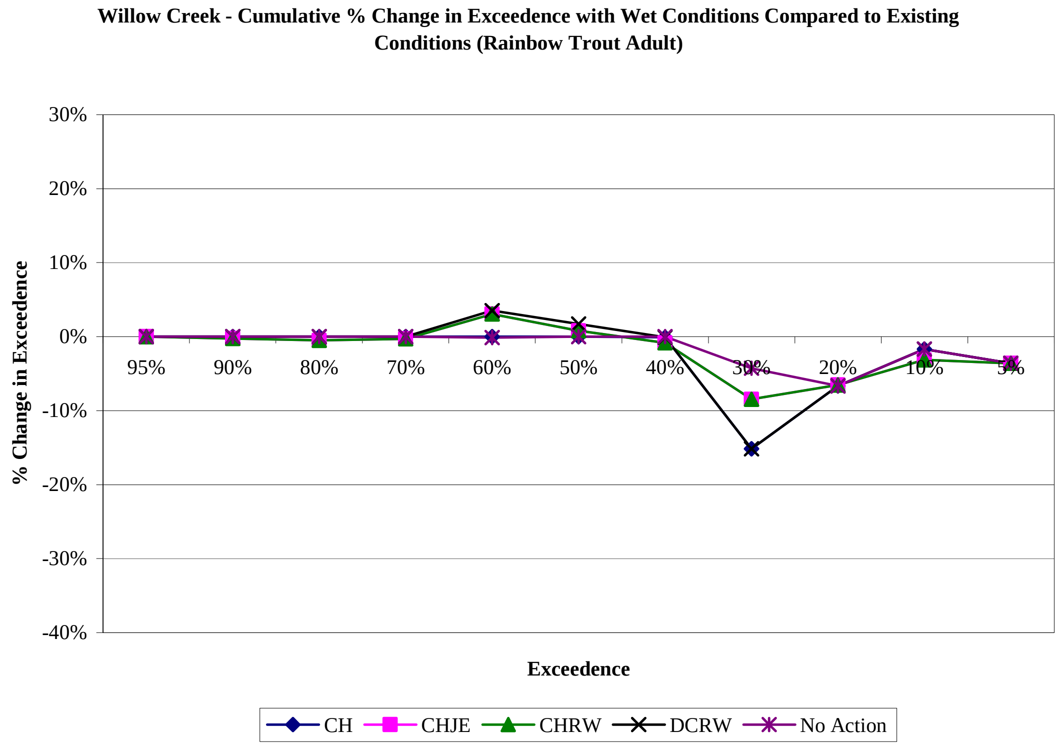


Figure 398. Willow Creek – percent change in exceedence with wet conditions (rainbow trout adult) cumulative effects.

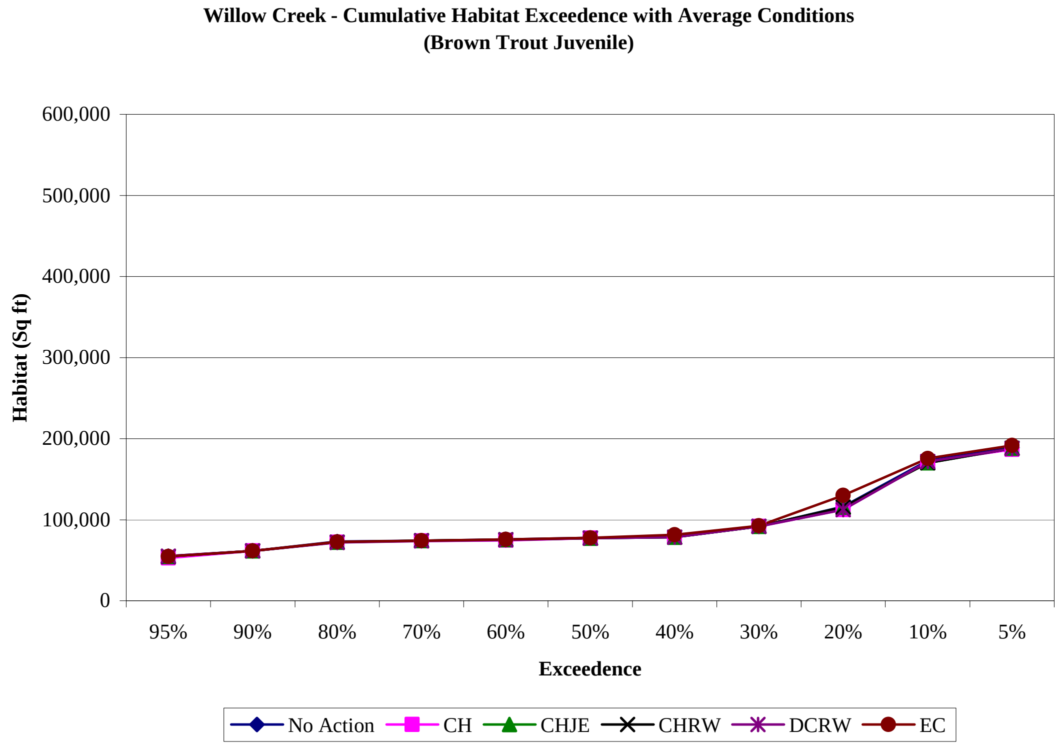


Figure 399. Willow Creek – habitat exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

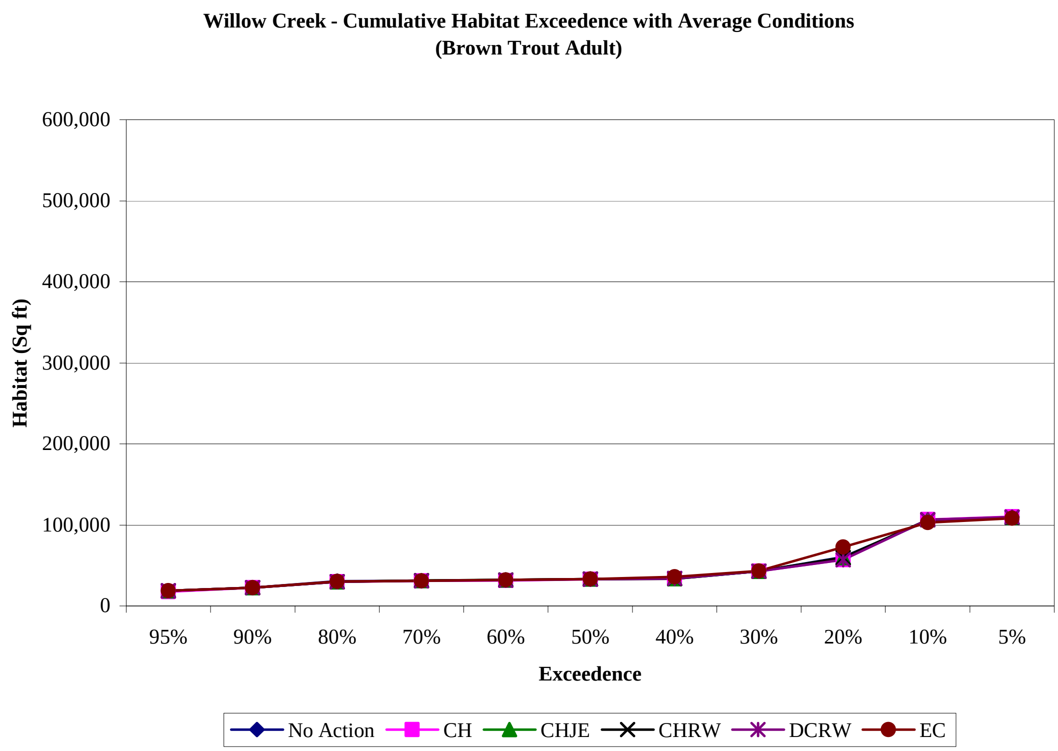


Figure 400. Willow Creek – habitat exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

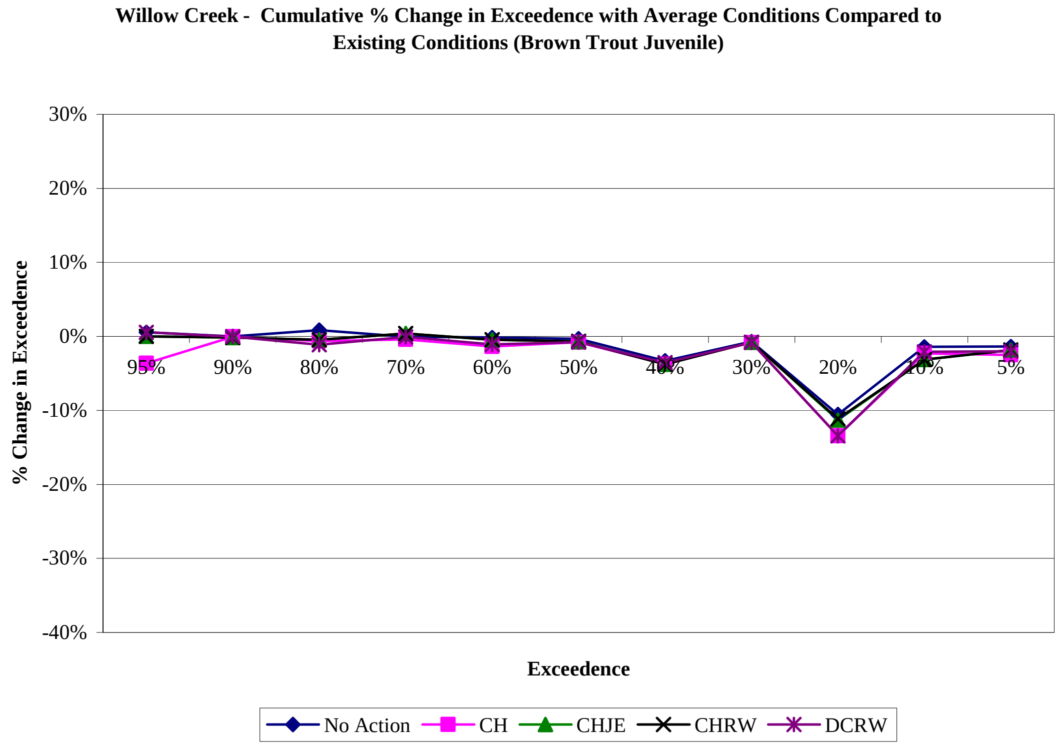


Figure 401. Willow Creek – percent change in exceedence with <u>average</u> conditions (brown trout juvenile) cumulative effects.

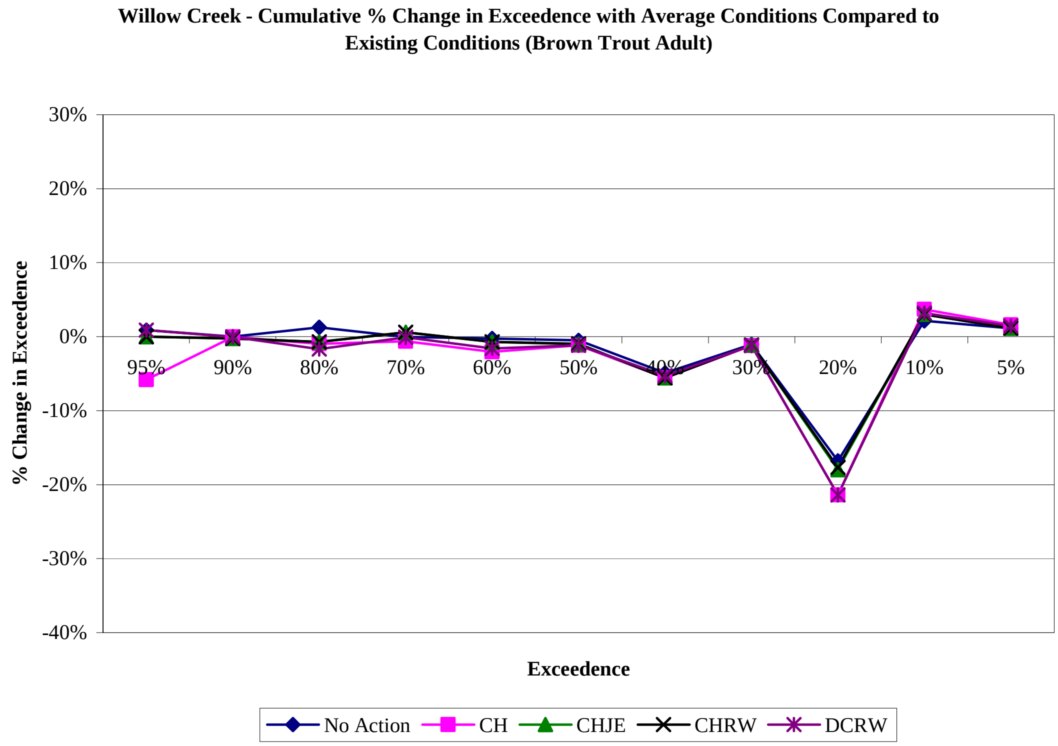


Figure 402. Willow Creek – percent change in exceedence with <u>average</u> conditions (brown trout adult) cumulative effects.

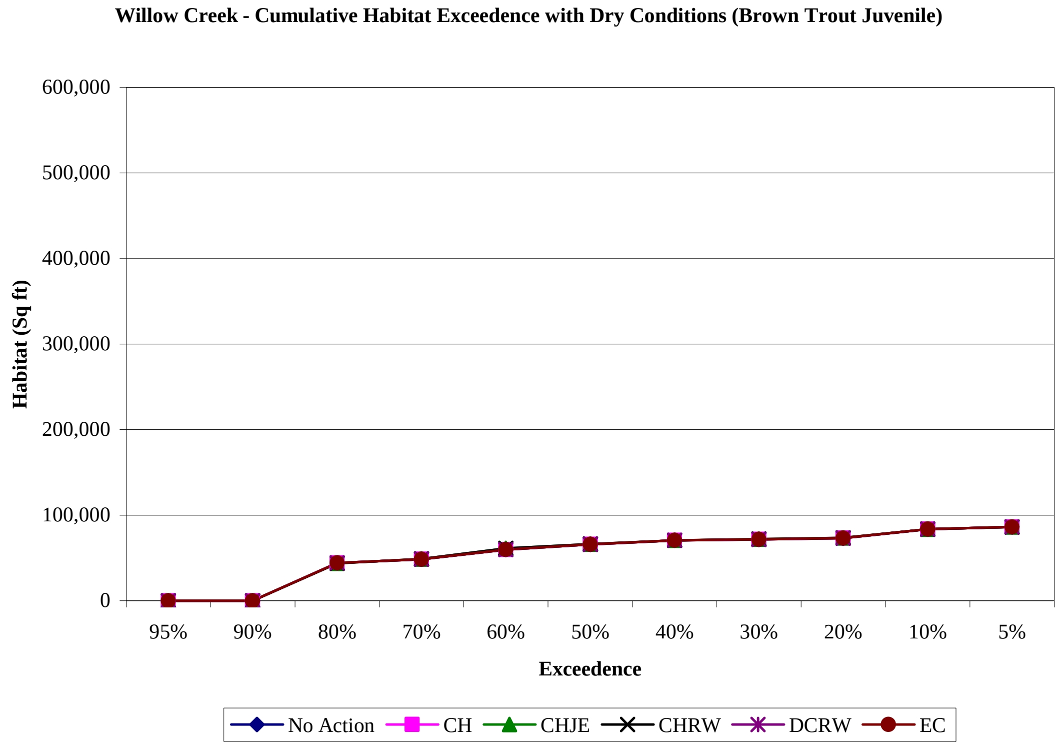


Figure 403. Willow Creek – habitat exceedence with dry conditions (brown trout juvenile) cumulative effects.

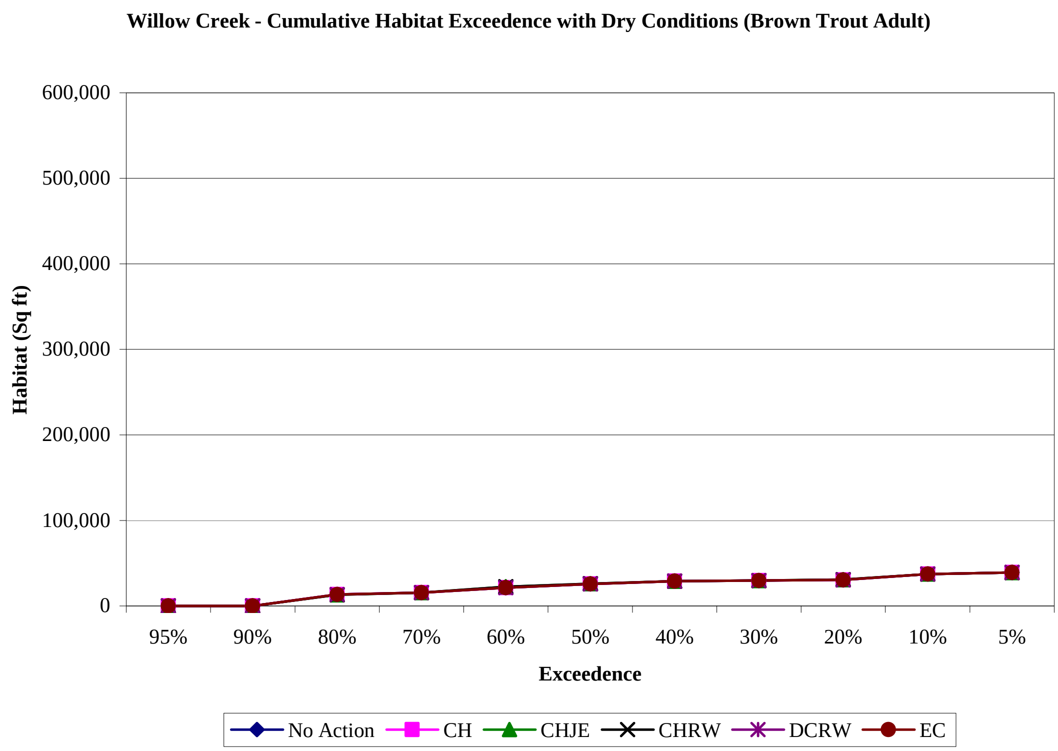


Figure 404. Willow Creek – habitat exceedence with dry conditions (brown trout adult) cumulative effects.

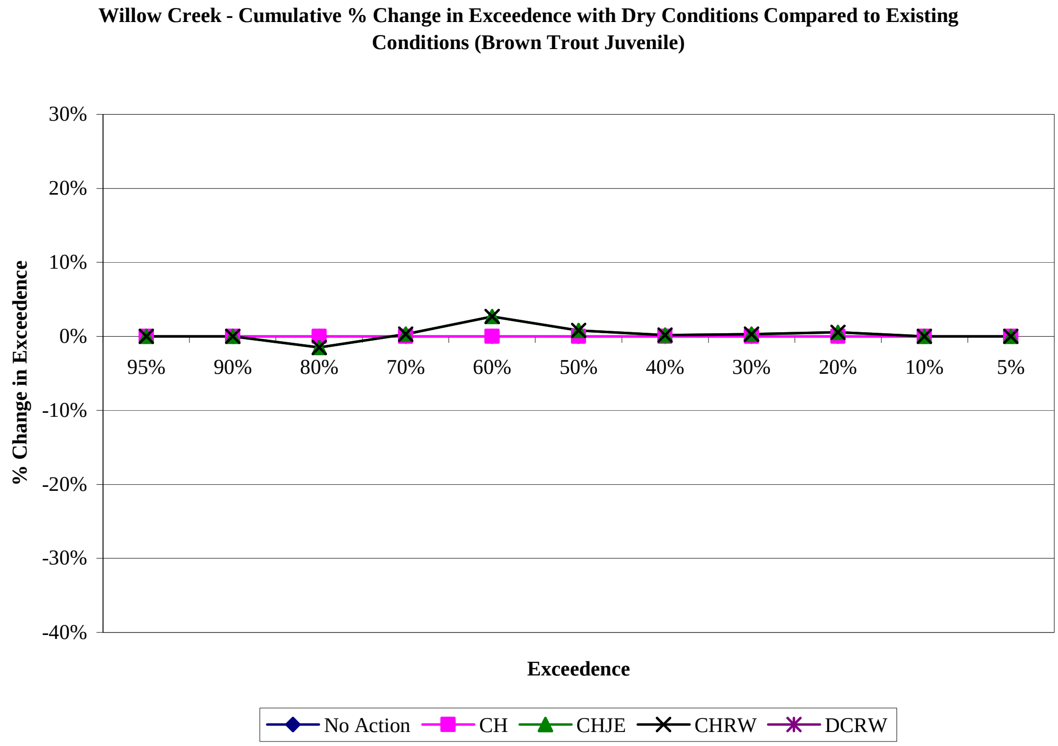


Figure 405. Willow Creek – percent change in exceedence with <u>dry</u> conditions (brown trout juvenile) cumulative effects.

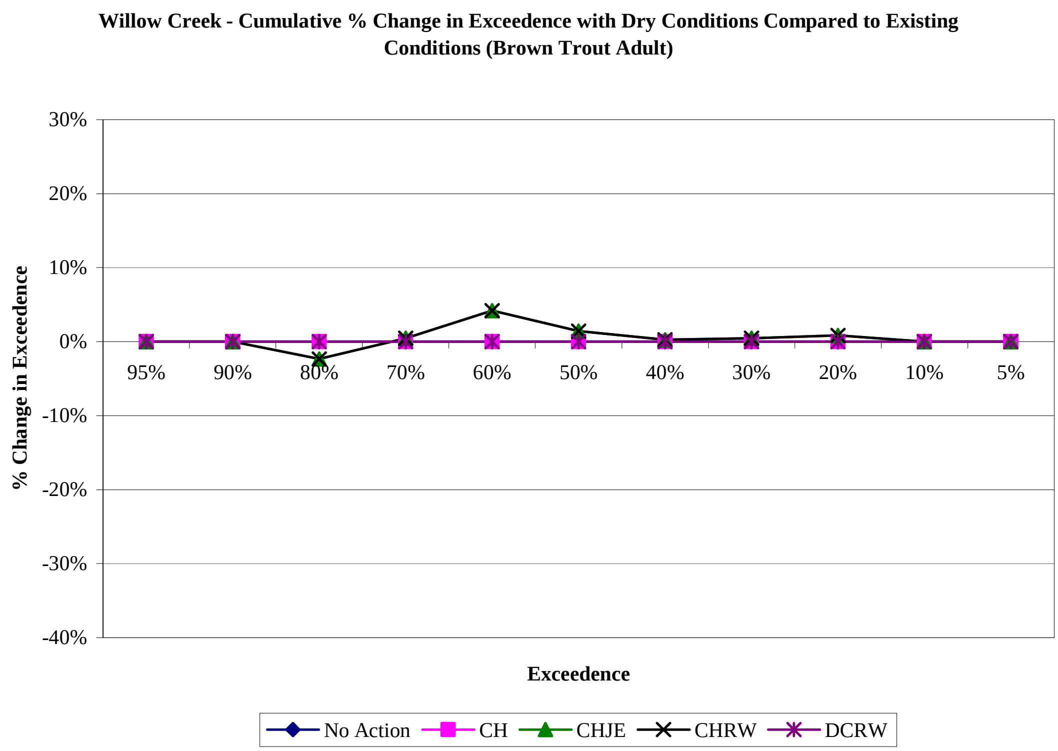


Figure 406. Willow Creek – percent change in exceedence with <u>dry</u> conditions (brown trout adult) cumulative effects.

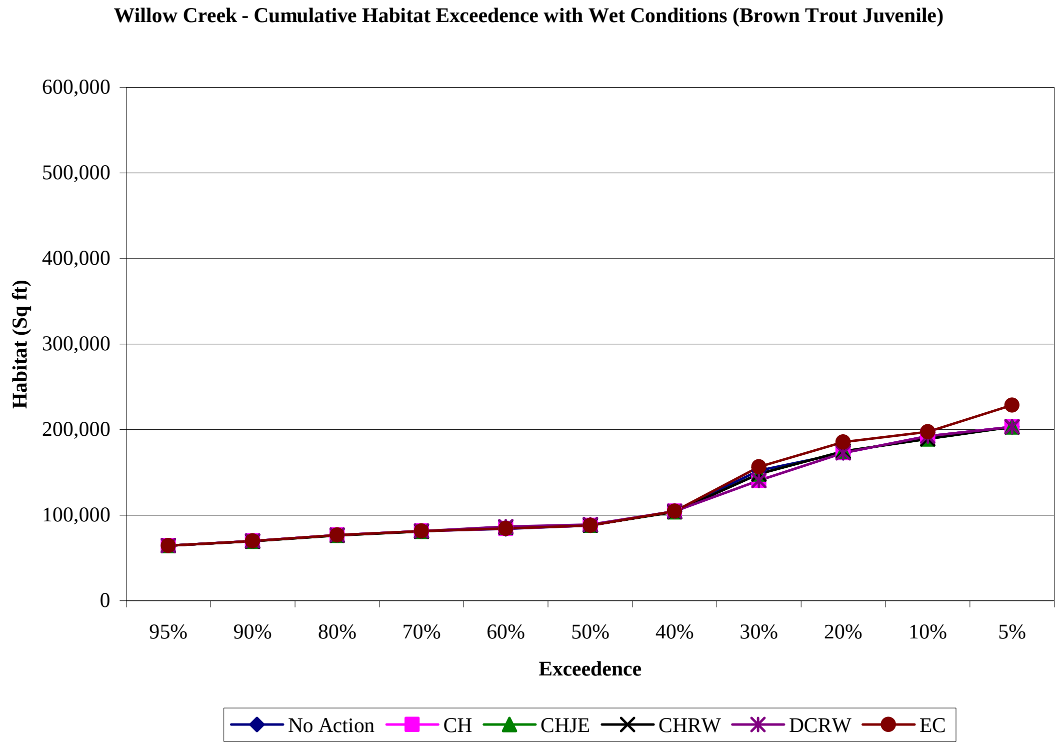


Figure 407. Willow Creek – habitat exceedence with wet conditions (brown trout juvenile) cumulative effects.

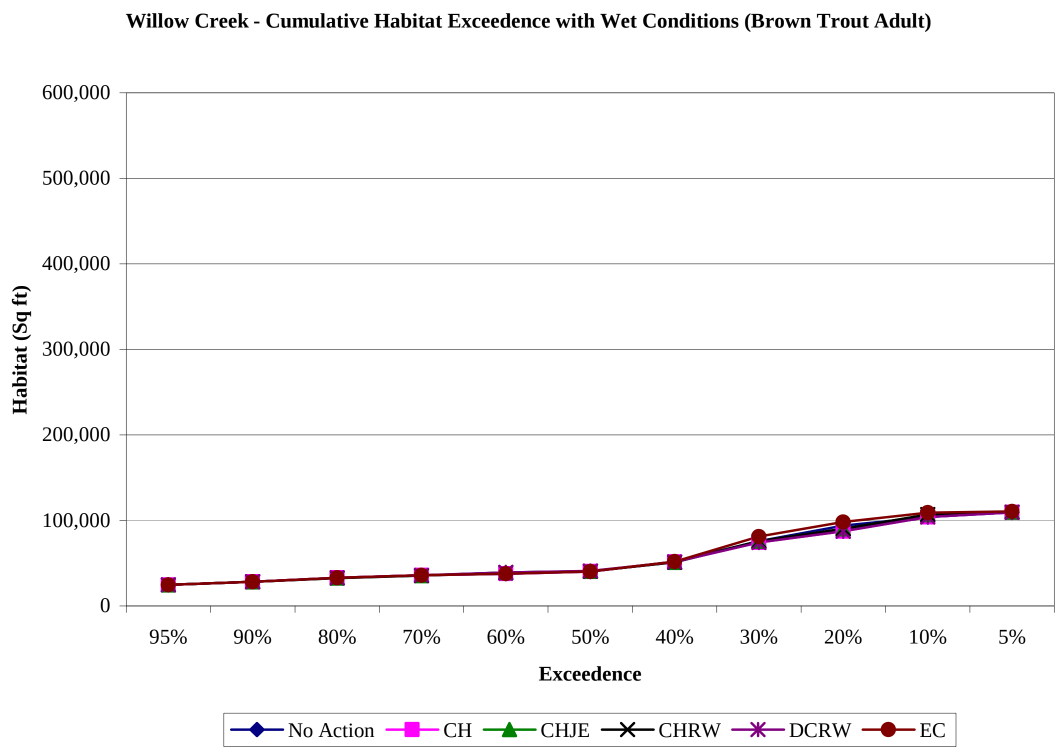


Figure 408. Willow Creek – habitat exceedence with wet conditions (brown trout adult) cumulative effects.

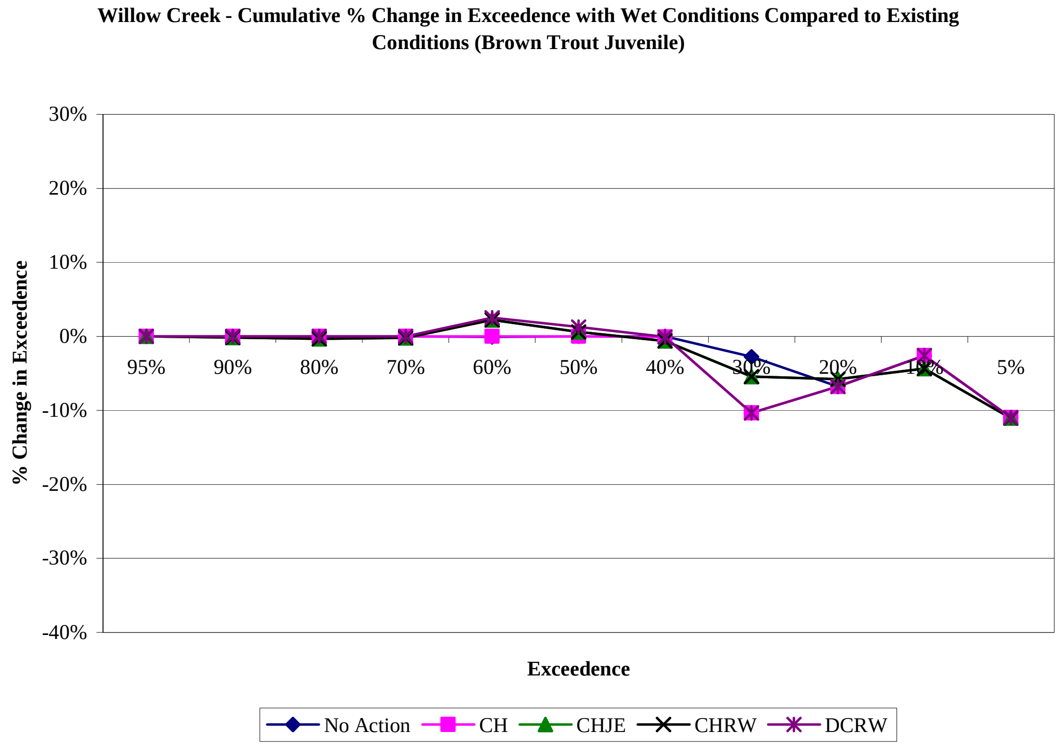


Figure 409. Willow Creek – percent change in exceedence with wet conditions (brown trout juvenile) cumulative effects.

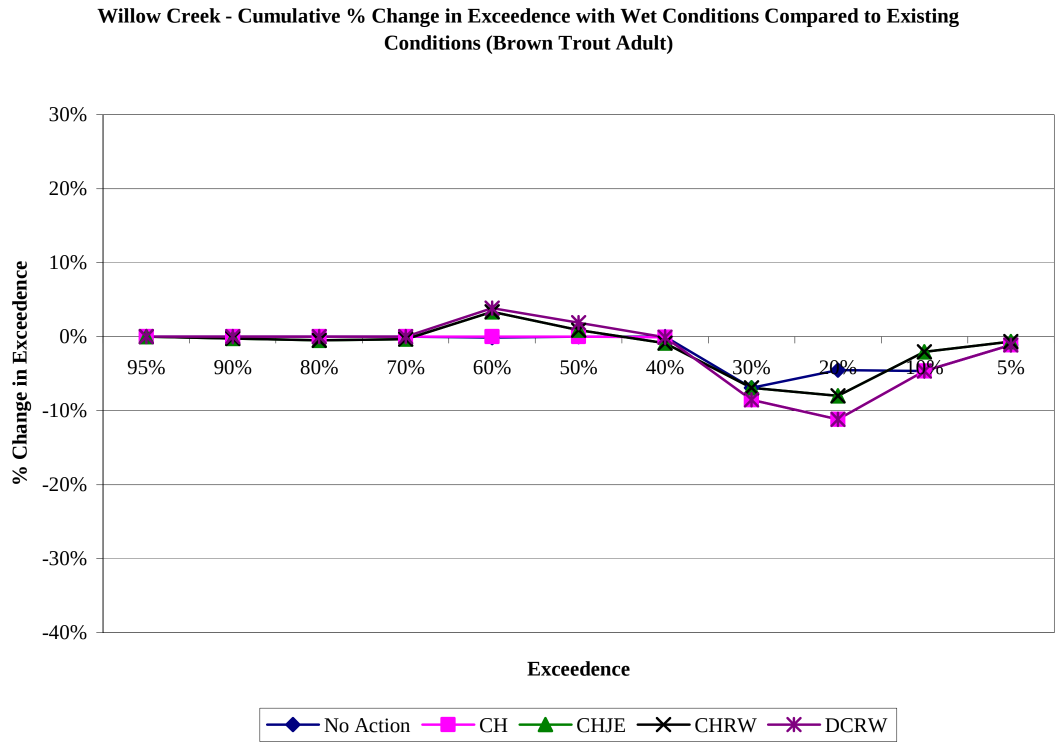


Figure 410. Willow Creek – percent change in exceedence with wet conditions (brown trout adult) cumulative effects.