Protectiveness of Alternative Guidelines in North Coast Instream Flow Policy Section A.1.8.3

Final Study Report

Prepared for:
California State Water Resources Control Board
Division of Water Rights

March 31, 2014

Prepared by:
Stetson Engineers Inc.

in cooperation with:
R2 Resource Consultants, Inc.

WATER RESOURCE PROFESSIONALS

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Prepared by:
James Reilly, Molly Palmer, Tracey Kenward
Stetson Engineers Inc.
2171 E. Francisco Blvd., Suite K
San Rafael, California 94901

in cooperation with:

Paul DeVries
R2 Resource Consultants, Inc.
15250 NE 95th Street
Redmond, Washington 98052-2518

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Acronyms and Abbreviations

abv	above
ac-ft	acre-feet
BASINS	Better Assessment Science Integrating point and Nonpoint Sources
BMI	benthic macro-invertebrates
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
Contract	Contract No. 11-130-300 between Stetson and State Water Board
Cr	creek
DFG	California Department of Fish and Game (now CDFW)
EPA	United States Environmental Protection Agency
ft	feet
ft/s	feet per second
HABTAV	habitat simulation modeling program
HSPF	Hydrologic Simulation Program – Fortran
MBF	minimum bypass flow
MCD	maximum cumulative diversion rate
mm	millimeters
NHD	National Hydrography Dataset
NMFS	United States National Marine Fisheries Service
PHABSIM	Physical Habitat Simulation Software
POD	point of diversion
POI	point of interest
Policy	State Water Resources Control Board adopted Resolution No. 2010-0021, Policy for Maintaining Instream Flows in Northern California Coastal Streams
R2	R2 Resource Consultants, Inc.
SED	Substitute Environmental Document
sq mi	square mile
State Water Board	California State Water Resources Control Board
Stetson	Stetson Engineers Inc.
Study	Volume Depletion Approach Study
SWRCB	California State Water Resources Control Board
Trib	tributary
ULA	upper limit of anadromy
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WUA	weighted usable area
XS	cross-section

1 Background and Development of North Coast Instream Flow Policy

On September 28, 2010, the State Water Resources Control Board (State Water Board or SWRCB) adopted Resolution No. 2010-0021, Policy for Maintaining Instream Flows in Northern California Coastal Streams, (Policy; SWRCB, 2010). The Policy establishes guidelines for evaluating the potential impacts of water diversion projects on stream hydrology and biological resources. The Policy area (Fig. 1-1) includes Marin and Sonoma Counties, and portions of Napa, Mendocino and Humboldt Counties.

The Policy provides guidelines for applying for new water rights within the Policy Area. Appendix A of the Policy contains two sets of approaches for evaluating the cumulative impacts of a proposed project. One of these two approaches, known as the volume depletion approach and described in Policy Section A.1.8.3, was proposed during the Policy adoption meetings in 2010. In Policy Section 10.4.1, the State Board requires that a study be completed to assess the regional protectiveness of Section A.1.8.3 within five years of the Policy adoption date. The purpose of this project is to complete the required study to assess the regional protectiveness of the alternative approach in Policy Section A.1.8.3. The work described here is known as the Volume Depletion Approach Study (Study).

1.1 Policy Terms and Definitions

A selection of key Policy terms and concepts which are relevant to the guidelines in Policy Section A.1.8.3 are defined in this section.

1.1.1 Key Terms

The following is a list of key terms from the Policy which are relevant to this Study. A full list of Policy terms may be found in the glossary in Appendix I of the Policy.

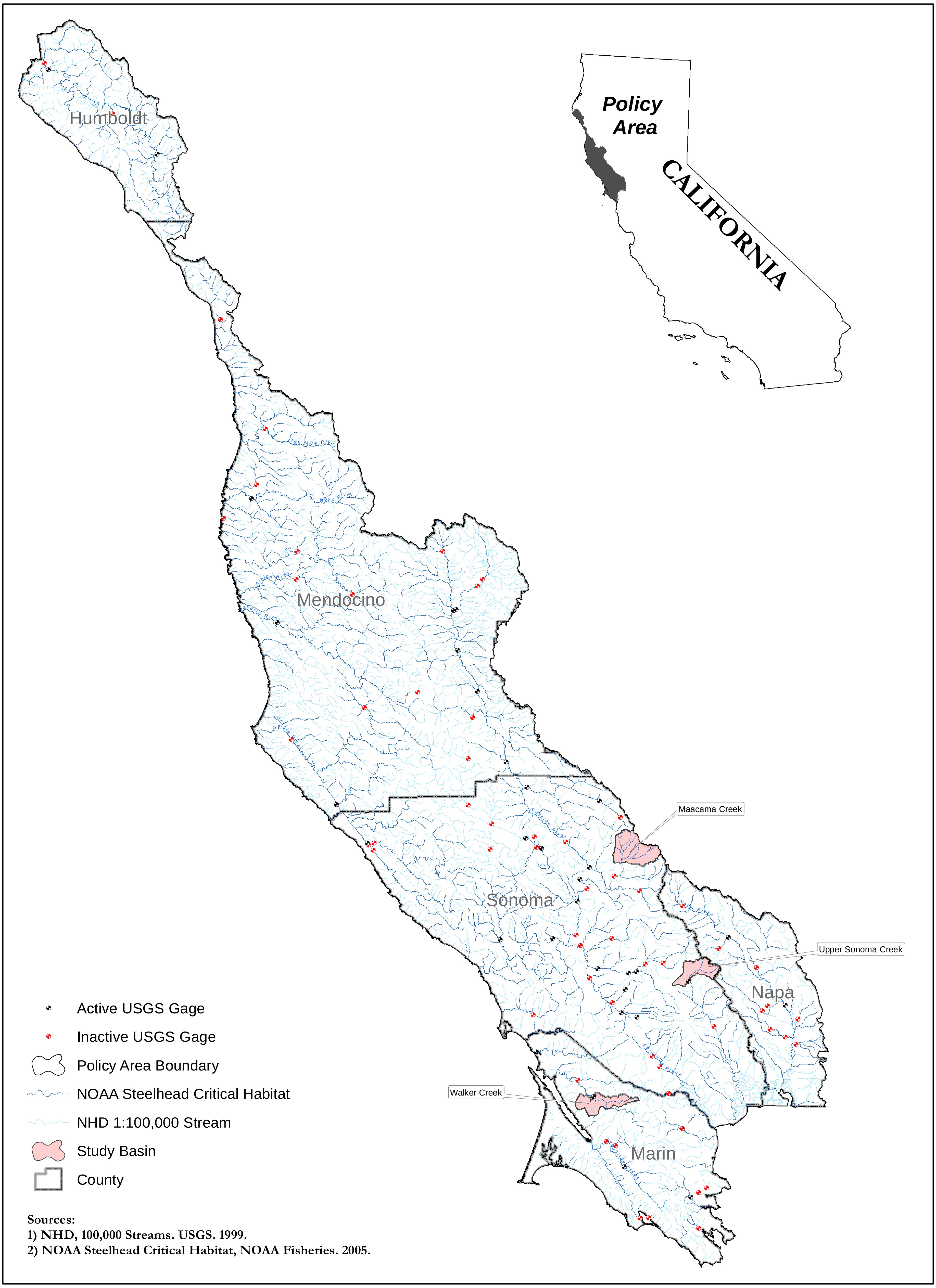
Maximum Cumulative Diversion Rate (MCD) - The sum of the rates of diversion of all diversions upstream of a specific location in the watershed.

Minimum Bypass Flow (MBF) - The minimum instantaneous flow rate of water at any location in a stream that is adequate for fish spawning, rearing, and passage. In applying the minimum bypass flow to a diversion, it is the minimum instantaneous flow rate of water that must be moving past the point of diversion before water may be diverted under a permit or license.

Point of Diversion (POD) - A location in a stream at which water is diverted.

Point of Interest (POI) - A location in a stream at which the proposed diversion's effect on instream flows for fishery resources is evaluated.

Upper Limit of Anadromy (ULA) - The upstream end of the range of anadromous fish that currently are or have been historically present year-round or seasonally, whichever extends the farthest upstream.



Sources:
1) NHD, 100,000 Streams. USGS. 1999.
2) NOAA Steelhead Critical Habitat, NOAA Fisheries. 2005.

VOLUME DEPLETION APPROACH STUDY BASINS

STETSON
ENGINEERS INC.

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FIGURE 1-1

1.1.2 Stream Classes

Section A.1.6 of the Policy defines three classes of streams:

- Class I: Fish are always or seasonally present, either currently or historically; and habitat to sustain fish exists.
- Class II: Seasonal or year-round habitat exists for aquatic non-fish vertebrates and/or aquatic benthic macroinvertebrates.
- Class III: An intermittent or ephemeral stream exists that has a defined channel with a defined bank (slope break) that shows evidence of periodic scour and sediment transport.

The Policy provides habitat indicators for classifying streams. Class I streams have fish present seasonally or year-round, either currently or historically. Class II streams do not have fish, currently or historically, but support aquatic non-fish vertebrates or aquatic benthic macroinvertebrates. Class III streams do not have fish, aquatic non-fish vertebrates or aquatic benthic macroinvertebrates. An intermittent or ephemeral stream may fall into any of the three stream classes.

1.2 Alternative Guidelines of Policy Section A.1.8.3

Policy Section A.1.8.3 contains a set of alternative guidelines for completing a cumulative diversion analysis on a Class II or III stream. A cumulative diversion analysis evaluates whether or not the proposed project, in combination with senior diversions, adversely affects instream flows needed for the protection of fishery resources. Under the alternative guidelines, any proposed project must compute the cumulative depletion due to the proposed project and all senior diversions as a percentage of the seasonal (November 1 to March 31) volume measured downstream at the upper limit of anadromy and points of interest below.

Table 1-1 summarizes the alternative guidelines for Class III and II streams in Policy Section A.1.8.3. Criteria applied to a proposed project are stipulated based on stream class and certain cumulative volume depletion thresholds. On Class III streams, if the maximum cumulative volume depletion is less than or equal to 5%, the diversion may operate without a diversion season, MBF, or maximum diversion rate. On Class II streams, if the maximum cumulative volume depletion is less than or equal to 5%, the diversion must have an MBF equal to the February median flow, but is not required to have a diversion season or maximum diversion rate.

On Class III or II streams, if the maximum cumulative volume depletion is greater than 5% but not more than 10%, the diversion may be allowed to operate with an MBF equal to the February median flow, no diversion season and no maximum diversion rate, provided the applicant pursues one of three additional options:

1. The California Department of Fish and Wildlife (CDFW[1])/National Marine Fisheries Service (NMFS) concur that the proposed diversion will not adversely affect fishery resources;
2. The applicant prepares an additional study demonstrating that the proposed diversion will not adversely affect fishery resources; or
3. The applicant agrees to additional conditions developed as part of this Study as required by Policy Section 10.4.1.

The purpose of this Study is to develop the conditions that should be applied under option number 3.

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[1] Prior to January 1, 2013, CDFW was known as the California Department of Fish and Game (DFG).

If the maximum cumulative volume depletion is found to be greater than 10%, the applicant may follow the guidelines in Sections A.1.8.1 and A.1.8.2 to complete a daily flow study (as described in Policy Appendix B), or the applicant may complete a site-specific study as described in Policy Appendix C.

Table 1-1 Summary of Guidelines in Policy Section A.1.8.3

Stream Class	Maximum Cumulative Volume Depletion	Policy Elements Required under Section A.1.8.3			
		Diversion Season	**MBF**	**Maximum Diversion Rate**	**Additional Approval or Conditions**
Class III	<=5%	None	None	None	None
	>5%, <=10%	None	February Median Unimpaired Flow	None	1. CDFW/NMFS approval; OR 2. Additional study per §A.1.8.3; OR 3. Apply conditions that result from this study, as required by §10.4.1
Class II	<=5%	None	February Median Unimpaired Flow	None	None
	>5%, <=10%	None	February Median Unimpaired Flow	None	1. CDFW/NMFS approval; OR 2. Additional study per §A.1.8.3; OR 3. Apply conditions that result from this study, as required by §10.4.1

1.3 Study Plan and Approach to Analysis

On June 11, 2012, the State Water Board and Stetson executed a contract (No. 11-130-300; Contract) to perform the Volume Depletion Approach Study. Stetson retained R2 Resource Consultants, Inc (R2), as a subcontractor to assist in the Study in the areas of fisheries science and geomorphology.

Following execution of the contract, Stetson and R2 worked in conjunction with the State Water Board to develop a study plan. The Contract and study plan proposed identifying three regionally representative study basins in which to conduct field studies, modeling and analysis of habitat. The study plan described the proposed approach for evaluating the alternative guidelines. Outlined below are the major steps described in the study plan:

- Select three regionally representative study basins
- Collect habitat and hydrology data in study basins
- Complete hydrologic models of each study basin to estimate unimpaired flows
- Perform protectiveness analysis:
    - Identify POIs in each study basin
    - Develop habitat flow curves at each POI
    - Evaluate unimpaired passage and spawning habitat at POIs
    - Evaluate unimpaired natural flow variability at POIs
    - Create impaired flow scenarios following guidelines in A.1.8.3

  - Evaluate impaired passage and spawning habitat at POIs
  - Evaluate impaired natural flow variability at POIs
  - Compare unimpaired and impaired conditions to evaluate changes in habitat and natural flow variability due to impairments

2 Study Basins

In fall 2012 and in consultation with State Water Board staff, Stetson and R2 selected three study basins to include in the Study. Field work was conducted in each study basin in winter 2012/13. Following collection of the field data, hydrologic models were prepared to simulate unimpaired flows in each study basin.

2.1 Selection of Study Basins

Study basin selection was completed in the summer and fall of 2012 in preparation for field work in the 2012/13 winter. Study basin selection was done in three steps: (1) identification of candidate basins; (2) selection of "prioritized" basins; (3) final selection of study basins. The goal of the selection process was to choose three study basins that were representative of the Policy area with regard to basin geomorphology, hydrology and fisheries habitat.

Stetson and R2, in consultation with State Water Board staff, reviewed information on basins within the Policy area in order to arrive at a list of suitable candidate basins based on the following criteria:

- Availability of existing information on anadromous fisheries habitat;
- Availability of existing information on hydrology, including a historical record of gaged flow;
- Relatively few diversions; and
- Feasible stream access.

Stetson and R2 worked to determine potential study areas within each prioritized basin. Stetson reviewed the hydrology of each basin, considering impairments, soils, topography and existing diversions, in order to determine reaches and drainage areas that would be suitable for field study and hydrologic modeling. R2 reviewed existing information on habitat to determine which areas of the basin contain suitable habitat and where potential study sites might be located. Once these reaches for potential study were identified, Stetson identified parcels along these reaches and researched owner contact information to obtain permission to access. After confirming the feasibility of obtaining access to enough study locations, three study basins were selected: Maacama Creek in Sonoma County, Sonoma Creek in Sonoma County and Walker Creek in Marin County. The locations of the three study basins within the Policy area are shown in Fig. 1-1.

Five to six study sites were selected in each study basin (Table 2-1). A schematic of a typical study basin and study sites is shown in Fig. 2-1. Each basin has two types of study sites, Class II/III streamflow gage sites and Points of Interest (POIs):

1) Class II/III sites[2]: These are locations upstream of anadromous fisheries habitat on streams which contribute flow to Class I streams. At these sites, dataloggers were installed to continuously measure and record water depth and temperature[3] throughout the field season. Flow data from these sites would be used to calibrate the hydrologic models.

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[2] Initially, Class II/III sites were placed upstream of anadromy prior to conducting habitat surveys to determine whether the locations were Class II or Class III. After conducting those surveys (see description on page 2-5 and summary in Table 2-3), it was determined that all sites were Class II.

[3] A temperature analysis has been excluded from the scope of work of this Study; however, the temperature data were collected.

2) POI (Class I) Sites: These are locations with anadromous fisheries habitat and lie downstream of the Class II/III sites, which may potentially be impacted by cumulative diversions on upstream Class II/III streams. Flow data from these sites was used to calibrate the hydrologic models and, along with water depth data, to evaluate passage and spawning opportunities in the protectiveness analysis.

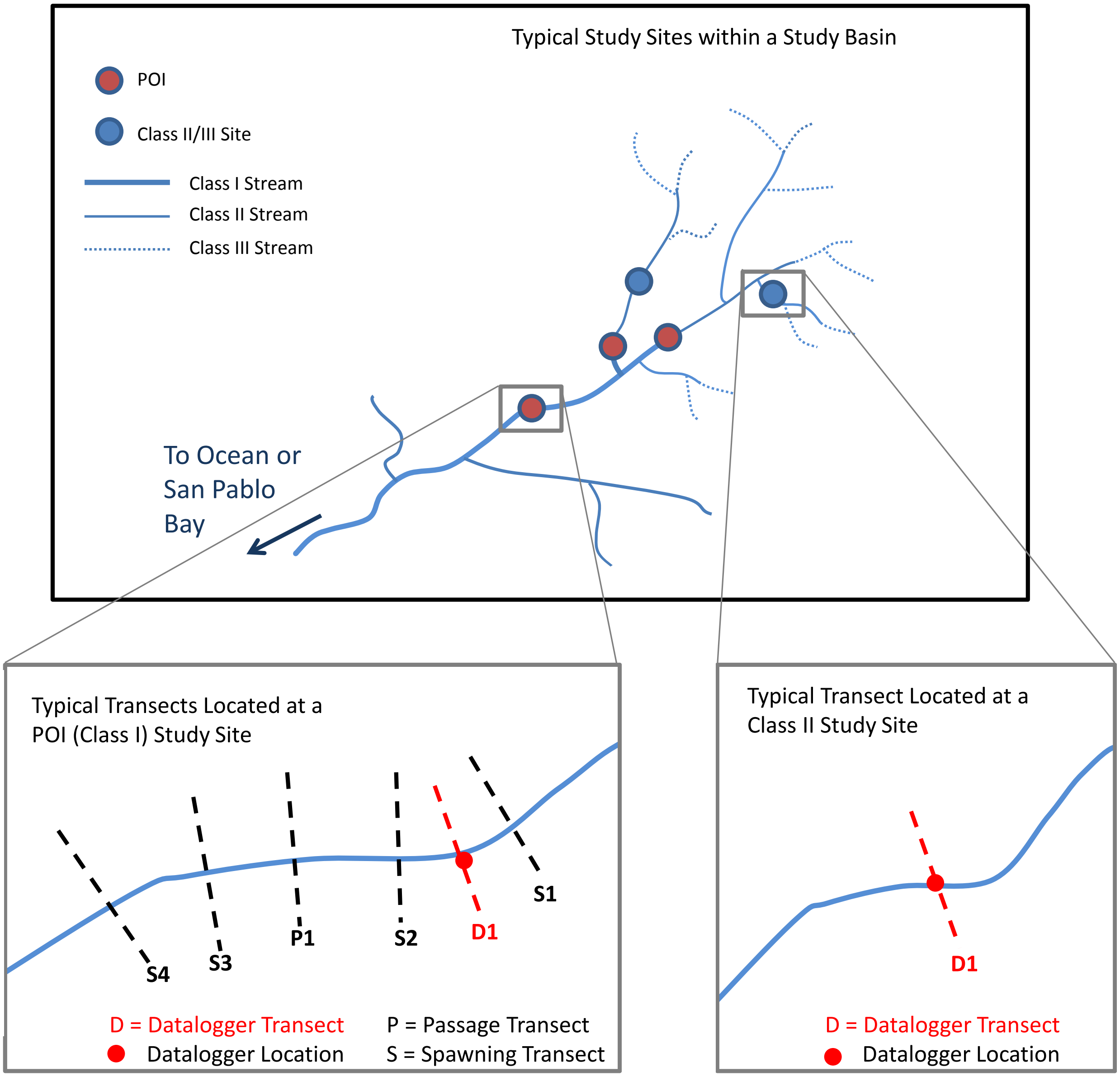


Fig. 2-1 **Schematic of Typical Study Sites within a Study Basin and Typical Transects at Study Sites**

Table 2-1 Study Sites

Study Site ID	Study Location	Drainage area (sq mi)	Streamflow gage	Habitat Survey	Stream Class[4]
Maacama Creek					
MC1	Little Ingalls Creek	0.4	X		II
MC2	Ingalls Creek	2.3	X	X	I
MC3	McDonnell Cr below Ingalls Cr	5.2	X	X	I
MC4	Briggs Cr above Maacama Cr[1]	12.4	X		I
MC5	Maacama Cr below Briggs Cr	23.5	X	X	I
Sonoma Creek					
SC1	Headwaters Sonoma Creek	0.6	X		II
SC2	Unnamed trib to Sonoma Creek	0.2	X		II
SC3	Malm Fork	0.5	X		II
SC4	Upper Sonoma Cr above Bear Cr	3.8	X	X	I
SC5	Lower Bear Cr	1.9	X	X	I
SC6	Sonoma Cr near Highway 12	8.2	X	X	I
Walker Creek					
WC1	Upper Salmon Cr	0.3	X		II
WC2	Middle Salmon Cr[2]	1.6		X	I
WC3	Unnamed trib to Walker Cr at Walker Ranch	0.2	X		II
WC4	Walker Cr[3]	12.3		X	I
WC5	Unnamed trib to Walker Cr d/s Walker	0.3	X		II
WC6	Frink Cyn, lower	3.2	X	X	I

Notes:

[1] Flow collection only; no habitat data collected.

[2] Habitat survey only; flow was measured nearby at gage WC1.

[3] Habitat survey only; flow was measured nearby at USGS gage No. 11460750

[4] Stream classification is described in Section 2.2.2.

2.2 Field Study

The three study basins are Maacama Creek in Sonoma County, Sonoma Creek in Sonoma County and Walker Creek in Marin County. The field work is described separately in the Field Study Report, included as Appendix A of this report.

2.2.1 Study Basins and Study Sites

Fig. 1-1 shows the locations of the three study basins within the Policy area and Fig. 2-2, Fig. 2-3, and Fig. 2-4 show the locations of the study sites within the three study basins. The typical arrangement of study sites within a study basin is shown in Fig. 2-1. Each study basin had three POIs and two or three Class II sites. At each Class I site, three to six habitat transects were established and habitat measurements collected at each. Table 2-2 lists the number and type of transects established at each Class I site.

Overall, the field study included 17 study sites. Dataloggers were installed to measure stream stage at 15 of these sites. Stream stage and discharge were measured in each study basin in order to provide field calibration data for hydrologic models of the study basins. In general, dataloggers were installed in October or November of 2012 and removed in May 2013, providing about one winter season of data. The dataloggers recorded pressure and temperature at 10-minute intervals. Periodically, stream discharge was measured in the field in order to relate discharge to stream stage. The raw datalogger pressure readings were corrected for barometric pressure, elevation differences and sensor shifts. Rating curves were then created using the discharge-stage measurements, and the corrected stage data were transformed into hourly time series of discharge. These hourly time series were used to calibrate the hydrologic models described in this report.

Table 2-2 Summary of Habitat Surveys for Class I Sites

Habitat Site ID	Study Location	No. of Passage Transects	No. of Spawning Transects	Spawning Habitat Morphology (Number of Cross-Sections)
Maacama Creek				
MC2	Ingalls Creek	0[1]	4	Pocket gravel (1), run (2), run tail (1)
MC3	McDonnell Cr below Ingalls Cr	0[2]	4	Riffle crest (1), pool tail (2), pocket gravel (1)
MC5	Maacama Cr below Briggs Cr	0[3]	5	Pool/run tail (2), run (2), pocket gravel (1)
Sonoma Creek				
SC4	Upper Sonoma Cr above Bear Cr	1	5	Run (2), run tail (1), pocket gravel (2)
SC5	Lower Bear Cr	0[1]	3	Pocket gravel (3)
SC6	Sonoma Cr near Highway 12	2	5	Riffle/Run (2), riffle (1), pool tail (2)
Walker Creek				
WC2	Middle Salmon Cr	1	4	Riffle (2), pool tail (2)
WC4	Walker Cr	1	5	Riffle (3), run tail (1), run (1)
WC6	Frink Canyon, lower	1	4	Riffle (2), pool tail (2)

Notes:

[1] No riffle transects limiting passage present; passage barriers distributed between mouth and site in the form of variable small leaping barriers and velocity chutes; spawning transects provide order of magnitude estimate of limiting passage flow, with highest estimate used to assess passage flow.

[2] Spawning transect S3 approximates a limiting riffle passage transect as well.

[3] Passage limited by various bedrock chutes present downstream on private property; spawning transect S1 best approximates a limiting riffle passage transect.

2.2.2 Stream Classification of Study Sites

Stream classification of the study sites was accomplished by first locating the ULA in each stream. All sites located downstream of a ULA were considered Class I. Above ULAs, benthic macroinvertebrate (BMI) surveys were performed to determine whether sites were Class II or III.

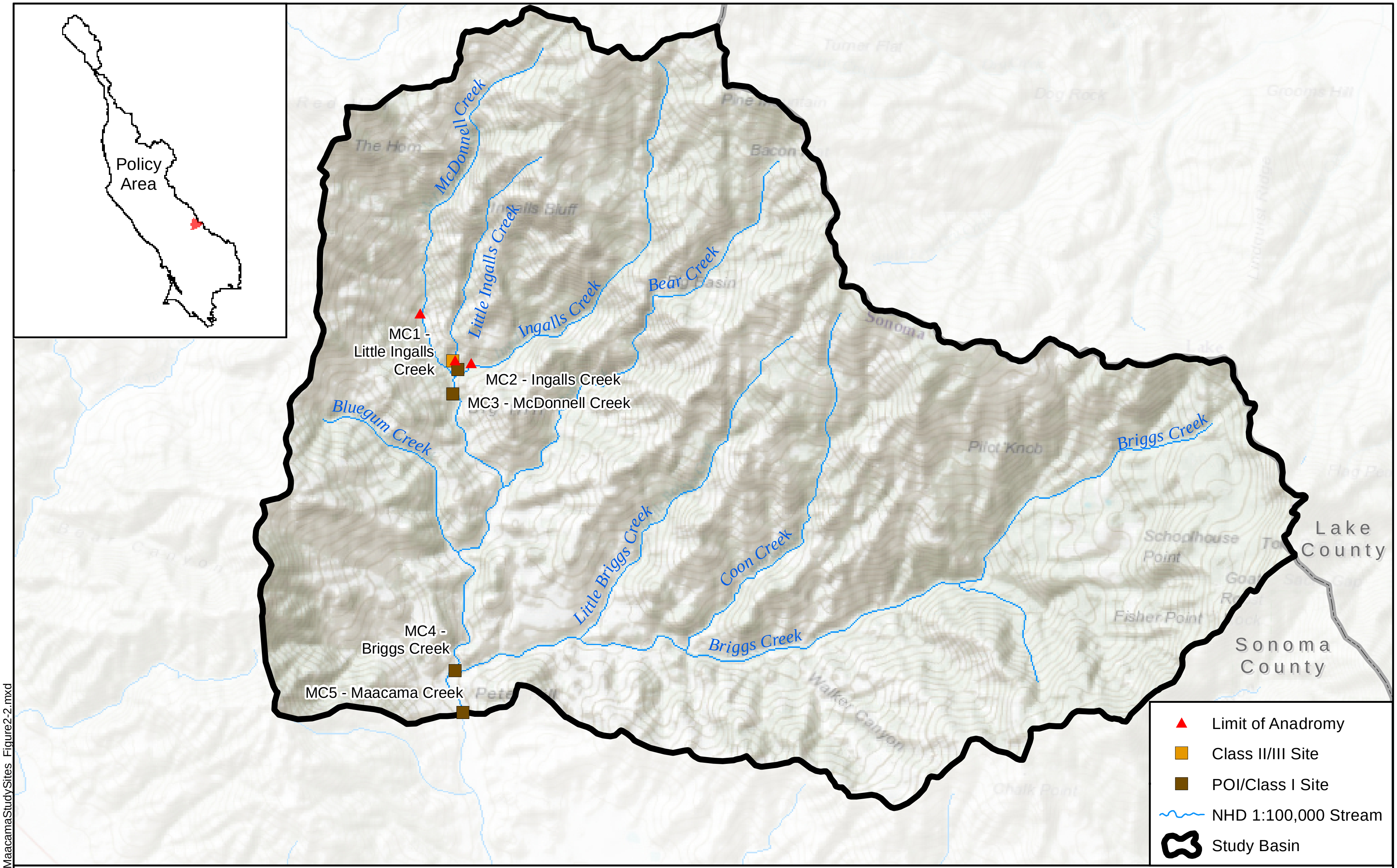
During the field study, when feasible, the upper limit of anadromy was confirmed by walking upstream from a study site until a natural passage barrier was encountered. This was the case on Ingalls Creek, McDonnell Creek, Bear Creek, and upper Sonoma Creek. The barriers were confirmed to be a relatively short distance upstream of the respective study sites. Private land and safe access restricted visual confirmation of the upper limit of anadromy in Salmon Creek and Frink Canyon, respectively. However, based on stream size, slope, locations of tributary confluences, and historic redd surveys, the upper limit was likely no more than a mile or so upstream of each study site.

BMI surveys were completed at select study sites for the purpose of assessing stream class above the limit of anadromy. The criteria used in the survey are consistent with the habitat indicators described in Section A.1.6.1 of the Policy (SWRCB, 2010). Class II sites are those above the upper limit of anadromy with BMI organisms observed. Class III streams are above the upper limit of anadromy but do not have BMI organisms. BMI surveys were completed by collecting substrate from the stream bottom and inspecting the substrate for BMIs and other aquatic organisms. All sites located upstream of anadromy were determined to have benthic macroinvertebrates. Stream classes are summarized for all sites in Table 2-3.

Table 2-3 Summary of Stream Classification at Study Sites

Study Site ID	Study Location	Anadromous (Y/N)	BMI Survey (Y/N)	Benthic Macro-Invertebrate (BMI) Survey Date	BMI Survey Results (Present/ Absent)	Stream Class
Maacama Creek						
MC1	Little Ingalls Creek	N	Y	4/4/2013	PRESENT	II
MC2	Ingalls Creek	Y	N	n/a	n/a	I
MC3	McDonnell Cr below Ingalls Cr	Y	N	n/a	n/a	I
MC4	Briggs Cr above Maacama Cr	Y	N	n/a	n/a	I
MC5	Maacama Cr below Briggs Cr	Y	N	n/a	n/a	I
Sonoma Creek						
SC1	Headwaters Sonoma Creek	N	Y	4/24/2013	PRESENT	II
SC2	Unnamed trib to Sonoma Creek	N	Y	4/24/2013	PRESENT	II
SC3	Malm Fork	N	Y	4/24/2013	PRESENT	II
SC4	Upper Sonoma Cr above Bear Cr	Y	N	n/a	n/a	I
SC5	Lower Bear Cr	Y	N	n/a	n/a	I
SC6	Sonoma Cr near Highway 12	Y	N	n/a	n/a	I
Walker Creek						
WC1	Upper Salmon Cr	N	Y	4/2/2013	PRESENT	II
WC2	Middle Salmon Cr	Y	N	n/a	n/a	I
WC3	Unnamed trib to Walker Cr at Walker	N	Y	5/8/2013	PRESENT	II
WC4	Walker Cr	Y	N	n/a	n/a	I
WC5	Unnamed trib to Walker Cr d/s Walker	N	Y	4/2/2013	PRESENT	II
WC6	Frink Cyn, lower	Y	N	n/a	n/a	I

Note:
'n/a' indicates no BMI survey was conducted because site has anadromous habitat and therefore is Class I.



MAP OF MAACAMA CREEK WATERSHED AND STUDY SITES

Source:
NHD, 100,000 Streams. USGS. 1999.

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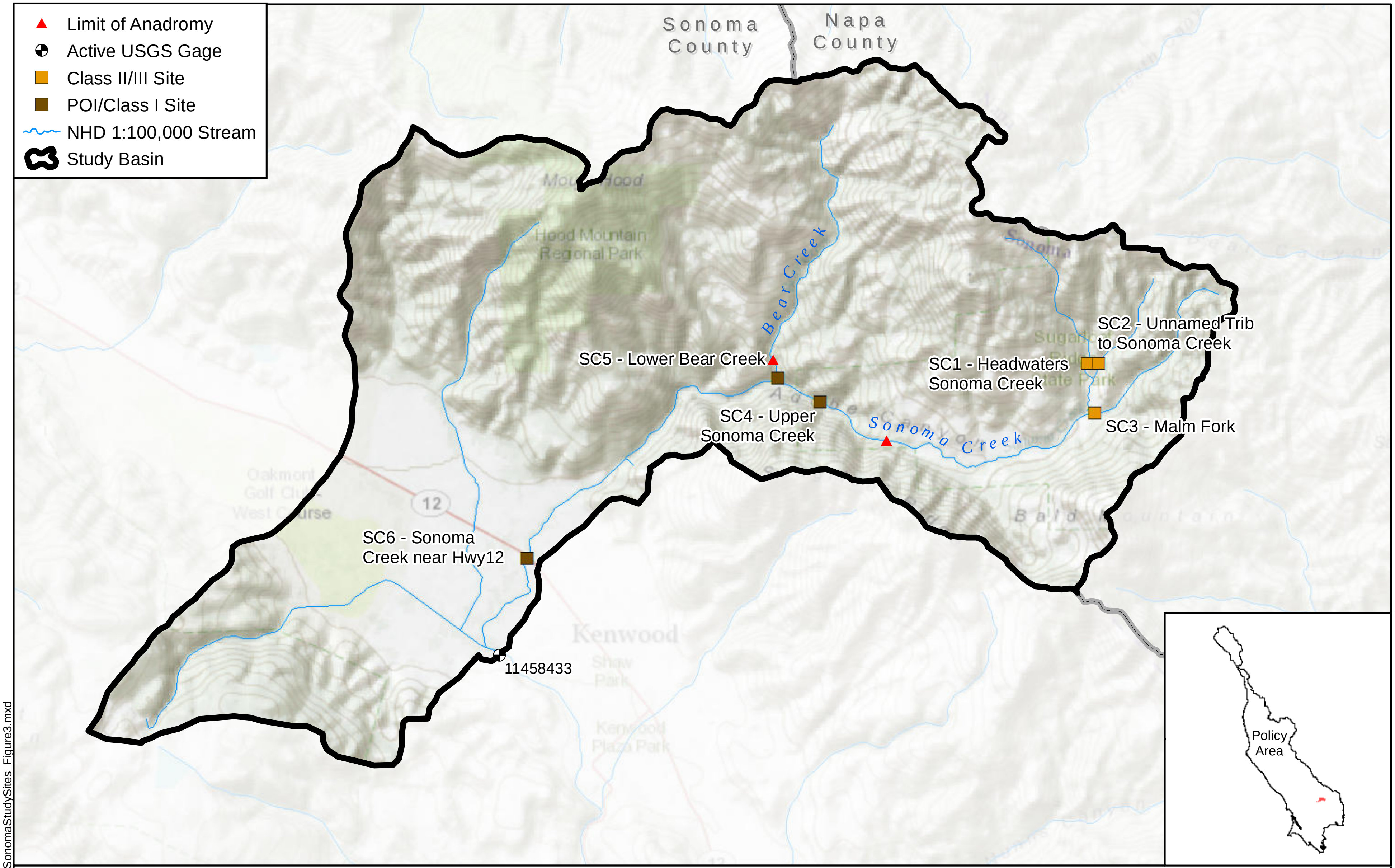
FIGURE 2-2



MAP OF SONOMA CREEK WATERSHED AND STUDY SITES

Source:
NHD, 100,000 Streams. USGS. 1999.

N

0 0.5 1 Miles

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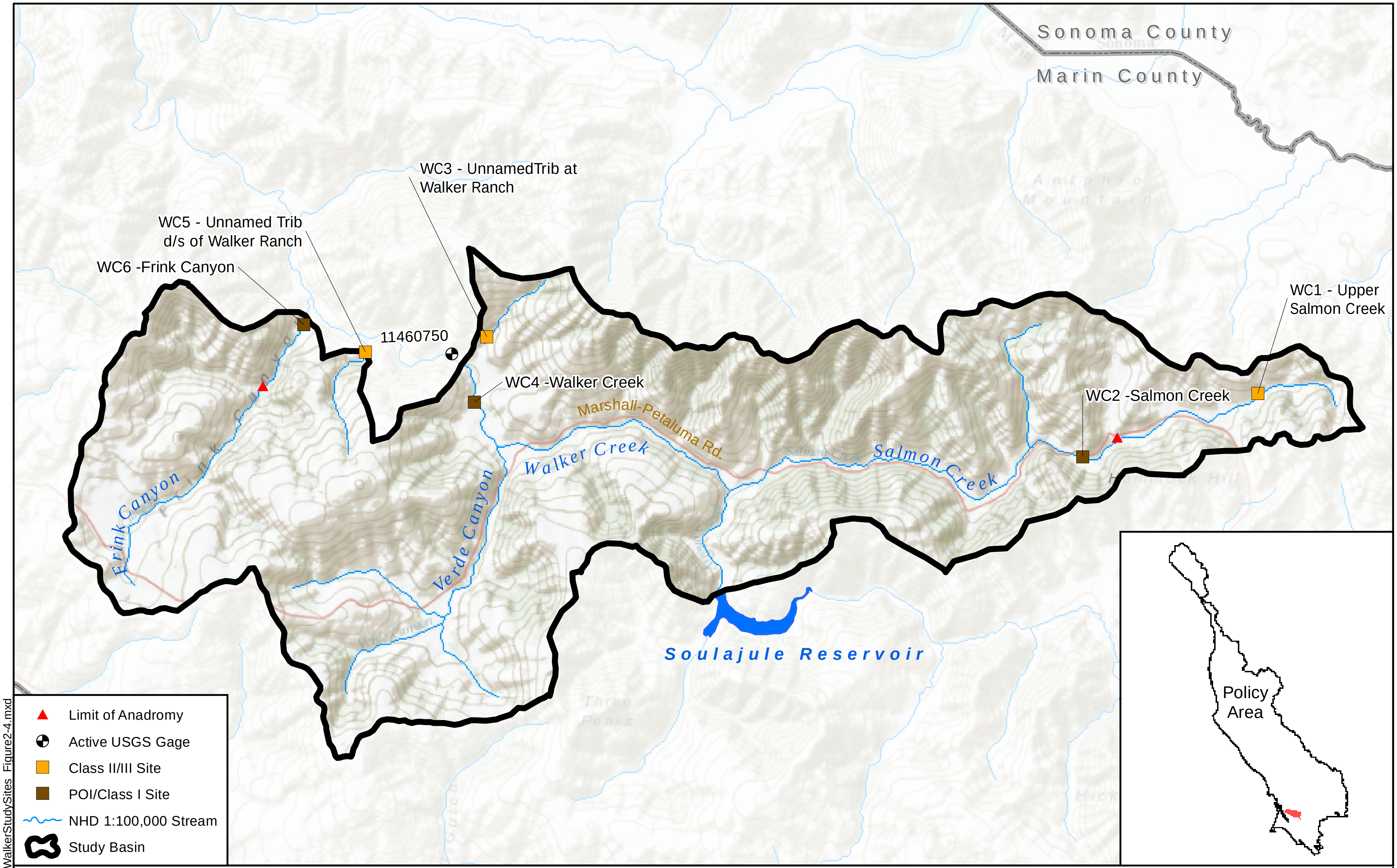
FIGURE 2-3



MAP OF WALKER CREEK WATERSHED AND STUDY SITES

Source:
NHD, 100,000 Streams. USGS. 1999.

N

0 0.5 1 Miles

FIGURE 2-4

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2.3 Hydrologic Modeling of Study Basins

Following completion of the field work, hydrologic models were prepared for the three study basins. The purpose of these models was to generate unimpaired flows at POIs and potential PODs within the study basin. The unimpaired flows are required in order to assess changes due to diversions made under Policy Section A.1.8.3. The hydrologic modeling is described in more detail in the Modeling Report, included as Appendix B of this report.

2.3.1 Model Summary

The hydrologic models of the three study basins were prepared using the Hydrologic Simulation Program - Fortran (HSPF) developed by Hydrocomp and Aquaterra and supported and distributed by the US Environmental Protection Agency (EPA) (Bicknell et al, 2001).

HSPF is a software program (model) that simulates hydrologic processes in land segments and stream channels in response to input meteorological time series. HSPF is available as part of the Better Assessment Science Integrating point and Nonpoint Sources (BASINS) software system, available via free download from the EPA (2013). Model inputs were hourly precipitation and evaporation time series and land segment and reach parameters. Model outputs were flow time series. The model simulation period was from October 1, 2003 through April 30, 2013, covering a period of nearly 10 water years.

The model setup was calibrated by adjusting land segment parameters for each of the three watersheds to provide the most accurate estimate of unimpaired flow when compared to the available gaged flows. The models were calibrated using the field data collected as part of this Study, as well as with data collected by other parties. Model calibration is described in Section 5.3 of Appendix B.

2.3.2 Unimpaired Flows

The HSPF models were calibrated using gaged flows. The selected study basins have relatively few diversions. Table 2-4 lists the existing diversions in each study basin as documented in the SWRCB eWRIMS database (2013).

- Maacama Creek: There is only one existing POD in the study area on Class II or III streams, A020901 on the McDonnell Creek headwaters. All other existing PODs are on Briggs Creek with a total max direct diversion rate of 1.85 cfs. These diversions reduce the observed streamflow at MC4, particularly in the fall when storage is filling. The downstream gage at MC5 (POI and calibration point) is also impacted.
- Sonoma Creek: There are relatively few diversions in this basin, most of which are located in the lower part of the watershed. There are three existing PODs in the study area on Class II or III streams, S000118 and S015983 on Rattlesnake Creek and A028978 on the Bear Creek headwaters.
- Walker Creek: There are relatively few diversions on Walker Creek and Salmon Creek and there are no existing PODs on Class II or III streams. There are many diversions on the Arroyo Sausal tributary upstream of the Soulajule Reservoir; however, this area is not modeled so these PODs are not included in the table.

In calibrating the models, because the existing diversions on Class II or III streams are minimal, no adjustment was made to add these diversions to the gaged flows. Because of the small quantity of existing impairments in the three study basins, the flows simulated in the HSPF models are considered reasonable estimates of unimpaired flow. The unimpaired time series are provided in the Modeling Report, which is included as Appendix B of this report.

Table 2-4 Summary of Existing Diversions in Study Basins

Basin	Stream	Gage(s) Affected	Application ID	Max Direct Diversion (cfs)	Max Storage (ac-ft)	Max Annual Use (ac-ft)
Maacama	McDonnell Cr	MC3 & MC5	A020901*	0.0006	0	0.3
Maacama	Briggs Cr	MC4 & MC5	A013578	0.670	0	485.1
Maacama	Briggs Cr	MC4 & MC5	A023098	0.225	0	156
Maacama	Briggs Cr	MC4 & MC5	D030712R	0.0007	0.5	0.9
Maacama	Briggs Cr	MC4 & MC5	D030759R	0	8	8
Maacama	Briggs Cr	MC4 & MC5	D031005R	0.008	2.5	4.1
Maacama	Briggs Cr	MC4 & MC5	S006316	0	0	0
Maacama	Briggs Cr	MC4 & MC5	S015758	0	0	0
Maacama	Briggs Cr	MC4 & MC5	S015759	0	0	0
Maacama	Briggs Cr	MC4 & MC5	S015904	0.600	0	0
Maacama	Briggs Cr	MC4 & MC5	S015905	0.225	0	0
Maacama	Coon Cr	MC4 & MC5	S014979	0.008	0	0
Maacama	Coon Cr	MC4 & MC5	S014980	0.008	0	0
Maacama	Little Briggs Cr	MC4 & MC5	S014973	0.019	0	0
Maacama	Little Briggs Cr	MC4 & MC5	S014974	0.019	0	0
Maacama	Little Briggs Cr	MC4 & MC5	S014975	0.019	0	0
Maacama	Little Briggs Cr	MC4 & MC5	S014976	0.019	0	0
Maacama	Little Briggs Cr	MC4 & MC5	S014977	0.019	0	0
Maacama	Little Briggs Cr	MC4 & MC5	S014978	0.013	0	0
Sonoma	Rattlesnake Cr	SC4, SC6 &	S000118*	0.082	0	0
Sonoma	Rattlesnake Cr	SC4, SC6 &	S015983*	0.00001	0	10
Sonoma	Bear Cr	SC5, SC6 &	A028978*	0	4.3	4.3
Sonoma	Sonoma Cr nr Hwy	SC6 & USGS	A008390	0.0019	0	0.8
Sonoma	Upper Sonoma Cr	SC6 & USGS	S014957	0.005	0	0
Sonoma	Upper Sonoma Cr	SC6 & USGS	S015600	0.013	0	0
Sonoma	Sonoma Trib abv	USGS	A005050	0.030	7	28.7
Sonoma	Sonoma Trib abv	USGS	A016192	0.150	0	32.7
Sonoma	Sonoma Trib d/s	USGS	A017938	0	4.8	4.8
Walker	Walker Ranch	WC3	S013201	0.0028	0	0
Walker	Verde Canyon	WC4 & USGS	A023829	0	45	45
Walker	Walker Trib	WC4 & USGS	A024744	0	48	48
Walker	Walker Trib	WC4 & USGS	A027728	0	18	18

*Existing POD location is on a Class II or Class III stream.

3 Anadromous Salmonid Habitat Flow Needs

The protectiveness analysis completed for this Study evaluated three key elements of anadromous habitat: upstream passage, spawning and natural flow variability. The suitability criteria for evaluating effects in this Study were the same as established for the original Policy development, and are consistent with those developed in the report titled, “North Coast Instream Flow Policy: Scientific Basis and Development of Alternatives” (Stetson and R2, 2008) and subsequently modified as a result of sensitivity analyses of effects of reducing the lower spawning depth limit (Stetson and R2, 2009). No new habitat criteria were established for this Study.

3.1 Procedure for Evaluating Anadromous Salmonid Passage and Spawning Habitat

The effects of flow diversions were evaluated in terms of reductions in upstream passage and spawning opportunities in each of the habitat sites compared with unimpaired flow conditions. Physical habitat conditions, as described by changes in depth and velocity, were used as the basis for determining impacts. These conditions were evaluated for steelhead and coho. Chinook habitat was not evaluated because the study streams are not in nor near designated critical habitat, and the effects of diversions in Class II and III streams should be minimal farther down in the channel network where Chinook spawn. It was argued during the development of the Policy MBF element that steelhead could be used as the indicator species for evaluating spawning flow needs given that, in general, they can use similar spawning habitat to Chinook (Stetson and R2, 2008). By extension, steelhead were used to evaluate effects of diversion on spawning habitat availability.

Habitat analyses were performed for upstream passage and spawning. Habitat-flow curves were generated using habitat suitability criteria specific to species and habitat attribute. Methods differed slightly for hydraulic analyses of upstream passage and spawning conditions and generally followed a similar approach as was used to develop and evaluate the original Policy elements.

3.1.1 Upstream Passage

Where feasible, at each field site, one or more limiting locations were defined along the thalweg where depth was shallowest over the low flow range, corresponding to the location where low flow upstream passage restrictions were most likely in the site. This typically corresponded to riffle crest locations (c.f. Woodard 2013). A stage-discharge rating curve was estimated for the location using measured stage and flow data, and the invert elevation identified. This was also done at each spawning cross-section. In cases when the stage of zero flow at a spawning cross-section was higher than the channel invert because of a downstream hydraulic control, the stage of zero flow at the control was used to approximate the limiting depth at the control location, assuming a similar water surface elevation at the control as at the spawning cross-section. The water surface elevation corresponding to a specified depth criterion (Table 3-1) was then determined, and the associated flow magnitude derived from the rating curve (Fig. 3-1). The site passage flow corresponded to the highest flow thus determined over all transects analyzed. This result was taken as the estimate of the minimum flow needed for upstream passage in the site. Because coho salmon are the key species in smaller channels during the fall months when the potential impacts of headwater diversions are most likely to be manifest, the depth criterion (0.6 ft) was used as the primary metric for determining upstream passage flow needs in each site. Steelhead can also pass through this depth, albeit while potentially making contact with the bottom (see Appendix G of Stetson and R2, 2008).

Table 3-1 **Minimum Upstream Passage Depth Criteria for Analyzing the Protectiveness of the Policy for Upstream Passage Needs**

Species	Minimum Passage Depth Criterion (ft)
Steelhead	0.7
Coho	0.6

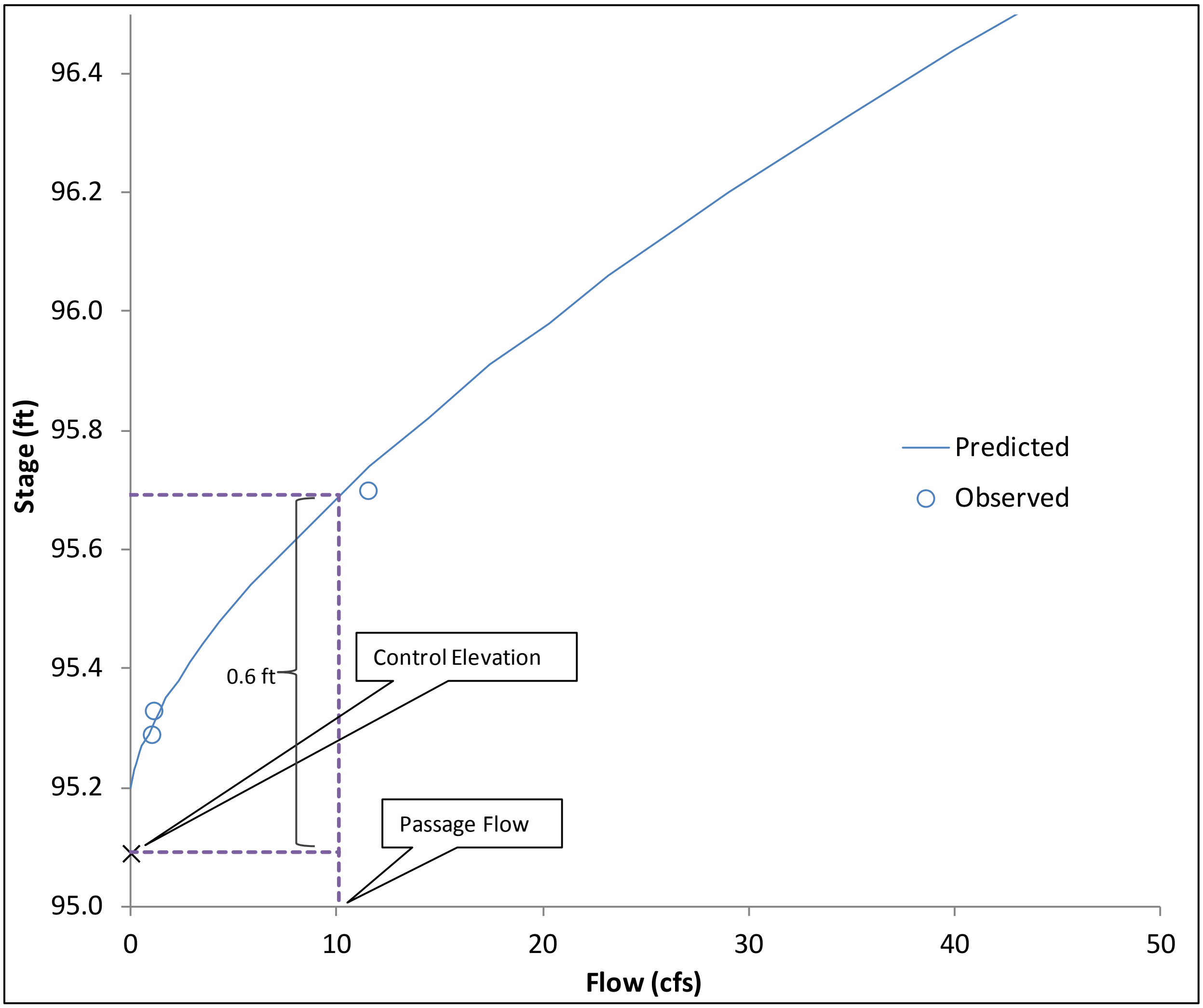

Fig. 3-1 **Example of Stage-Discharge Rating Curve at a Passage Transect, and Corresponding Limiting Upstream Passage Flow for a Depth Equal to 0.6 ft at the Passage/Hydraulic Control Location**

3.1.2 Spawning Habitat

Table 3-2 lists the minimum depth, favorable velocity, and substrate spawning criteria used for the Study. For spawning, the stage-discharge, velocity and substrate data collected at the POIs (see Appendix A) were analyzed using the U.S. Fish and Wildlife Service's (USFWS) Physical Habitat Simulation (PHABSIM) software. A 1-velocity set simulation was performed for each cross-section with the stage-discharge relationship determined via regression and the results specified as a rating table inside the IFG4 hydraulic simulation program (see Appendix A for details). Velocities were measured at flows approximating or near suitable spawning conditions.

The depth and velocity simulation results from IFG4 were analyzed using the HABTAV habitat simulation modeling program, which compares simulated depths and velocities obtained from the hydraulic model output files and computes a corresponding area of habitat meeting suitability criteria (Milhous et al., 1989). Predicted depths and velocities were analyzed at each point of measurement along the cross-section in HABTAV, which directly reflected the manner in which the physical data were collected. A habitat "cell" was defined as extending halfway between the measurement location and adjoining points on each side. Habitat area was represented in HABTAV as Weighted Usable Area (WUA) per unit length of stream, which was derived as the sum of the products of width and joint suitability indices calculated for each habitat cell based on the substrate and simulated depths and velocities (Bovee, 1982; Milhous et al., 1989).

Habitat suitability was defined in this Study as a step function where a cell was considered either (i) fully suitable or (ii) not at all, in terms of depth, velocity, and substrate such that the resulting WUA value reflected the width of the cross-section that was available for spawning. A cell with suitable spawning substrates was considered usable for spawning when the depth for the flow occurring on a given day equaled or exceeded a specified minimum spawning depth suitability criterion, and the velocity was between lower and upper suitability criteria (Table 3-2; also see Appendix G of the Scientific Basis report). This calculation was repeated for each flow that was simulated by IFG4, and the ultimate output of HABTAV was a WUA versus flow curve for each set of depth, velocity, and suitability index criteria defined.

Substrate suitability was modeled slightly differently than in the analyses used to develop the Policy. While the same general size range of particles was considered suitable as before, portions of the streambed with suitably sized substrates were divided into discrete patches of 3 ft width that approximated minimum steelhead redd widths (2 ft, about the width of small steelhead and coho redds, and roughly half the width of an average steelhead redd; Shapovalov and Taft 1954; similar minimum width as was evaluated for the Policy) with a buffer on each side adding up to 1 ft. Discrete patches were also defined for remnant sections (after defining other 3 ft wide patches) that were slightly narrower or wider than 3 ft, or where there was an isolated patch that was more than 2 ft and less than 4 ft wide. Each patch represented a potential redd location and was assigned a unique redd identification code in the IFG4 data deck that was carried into the habitat model. Distinctly different substrate suitability indices were defined that isolated and thus allowed simulation of habitat suitability for each distinct potential redd location so defined. In doing so, it was possible to develop habitat flow curves for each potential redd patch across a transect, and track individual redd availability as a function of flow.

Spawning was considered potentially successful for both steelhead and coho in a redd location if at least 2 ft of the 3-ft-wide segment was calculated to be suitable according to the depth and velocity criteria. The total width of usable habitat per redd (and transect) was computed by summing all usable cells. This was performed for a range of flows to generate habitat-flow relationships for each potential redd location, transect, and habitat attribute. At the same time, the results for the individual redds could then be summed to obtain a habitat-flow curve for a transect as a whole.

An additional step was taken in the analysis to account for numerical issues associated with extrapolating a measured velocity distribution to higher flows, where any irregularities in a measured cross-channel distribution become magnified at higher flows in IFG4. It was accordingly necessary to estimate a smoother velocity distribution at high flow, which is more realistic. The high flow distribution was estimated by using the flow depth and Manning's equation. The resulting two sets of velocity simulations (measured velocity distribution-based vs. depth-based) were analyzed separately using HABTAV to generate two distinct WUA-flow curves. One curve was based on velocities predicted according to the measured velocity distribution, and the other on velocities predicted based on depth distribution at high flow.

The two habitat-flow curves were then composited into a single curve that placed greater weight on the measured velocity distribution-based results over the lower simulated flow range, and greater weight on the channel average Manning's n –based results over the higher flow range.

Fig. 3-2 is an example of habitat-flow curves at six discrete segments of the bed with substrates suitable for supporting a redd. The composite curve, shown in black, was constructed from the two other lines, the curve predicted using the measured velocity distribution (red dash-dot line) and the curve predicted using the depth-based velocity distribution at a high flow (red dashed line). Specifically, the following distribution rule was applied in obtaining a composite habitat-flow curve:

- The portion of the curve based on the measured velocities was applied to all flows less than or equal to the flow at which velocities were measured
- The portion of the curve based on the depth distribution at high flow was applied to all flows greater than or equal to the high flow simulated.
- Between the two flows, the curves were weighted proportionately according to the ratio of the simulation flow to the difference between the two flows (i.e., linear weighting).

Table 3-2 Minimum Depth, Favorable Velocity, and Substrate Spawning Criteria for Analyzing the Protectiveness of the Policy for Spawning Habitat Needs

Species	Minimum Depth (ft)	Favorable Velocities (ft/s)	Usable Substrate D_{50} (mm)
Steelhead	0.7	1.0-3.0	12-46
Coho	0.7	1.0-2.6	5.4-35

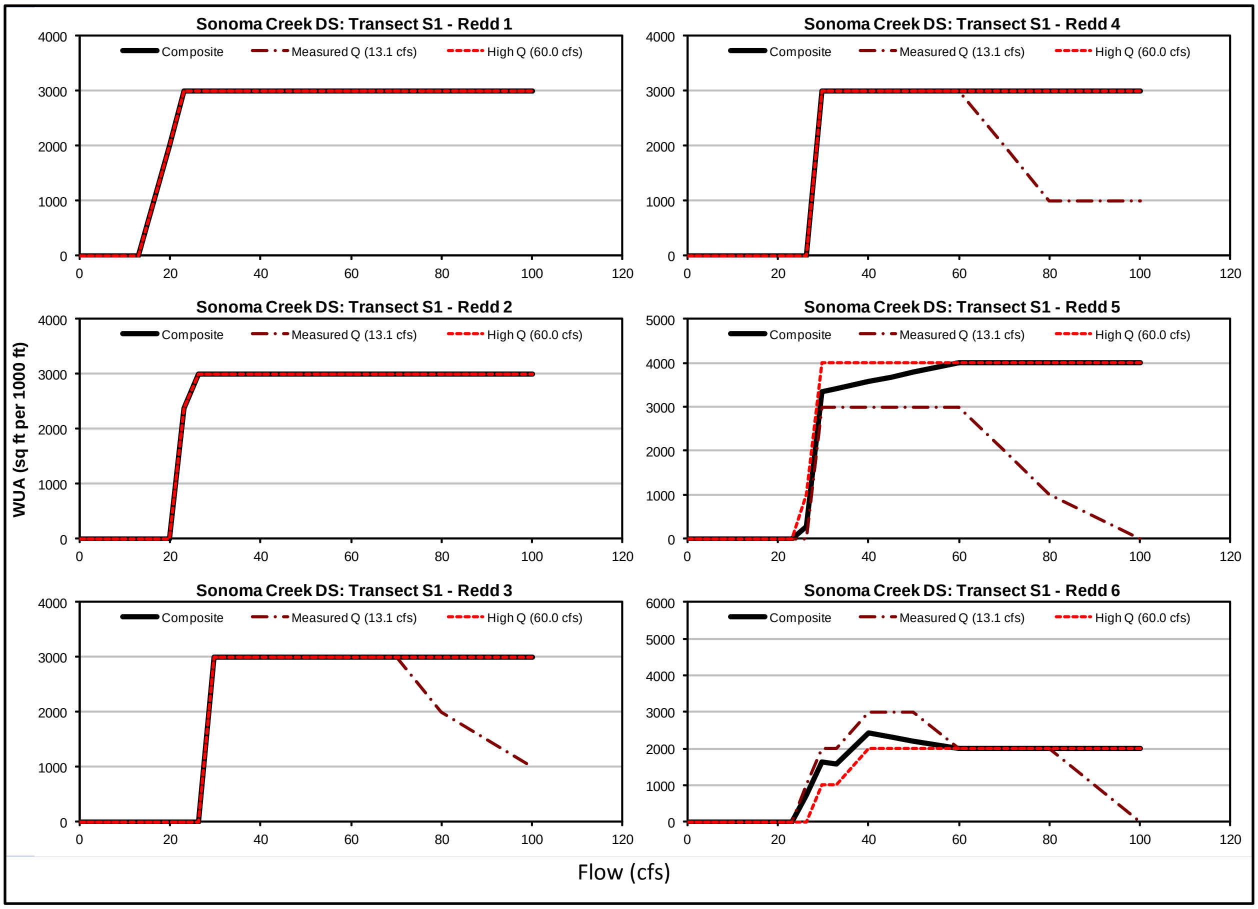

Fig. 3-2 Examples of Habitat-Flow Curves for Six Discrete Segments of the Bed with Substrates Suitable for Supporting a Redd

3.2 Critical Flows at POIs in Study Basins

Critical minimum instream flow thresholds were defined for upstream passage and spawning that could be compared against the unimpaired and impaired flow time series to assess impacts of diversions. Because a key goal of the Study is to evaluate when diversions have adverse effects on passage and spawning, it was necessary to focus only on identifying the minimum spawning flow needed, and not the maximum.

A single limiting upstream passage flow threshold was defined for each site that corresponded to the transect requiring the highest minimum flow for passage. This was taken as the estimate of the minimum flow limiting upstream passage in the site according to the depth criterion established for the Policy.

A protective minimum spawning flow was determined for each site through a series of steps. First, the composite habitat flow curves were used to define a minimum spawning flow at each redd. The minimum flow was identified on each redd-specific curve corresponding to a minimum WUA value of 2000 ft^2/1000 ft of stream (i.e., a minimum redd width of 2 ft, consistent with the original Policy development). The redd with the lowest resulting spawning flow then defined the lowest flow for each transect below which spawning habitat would disappear. As a balance towards then increasing protectiveness, the minimum spawning flow for the site was then taken to be the transect with the highest minimum spawning flow (Table 3-3). This flow represents the estimated minimum flow required to support some spawning at all transects in a site.

Table 3-3 Critical Passage, Incubation and Spawning Habitat Flows at POIs

Site ID	Drainage Area (sq mi)	XS	Limiting Flows (cfs) Incubation	Steelhead Transect Spawning Flow	Coho Passage Flow for Site	Steelhead Spawning, Incubation Flows for Site
MC2	2.3	S1	0.18	11	9.0	11, 0.18
		S2	0.15	8.8		
		S3	0.05	7.8		
		S4	0.07	7.9		
MC3	5.2	S1	0.13	26	6.7	26, 0.13
		S2	1.7	13		
		S3	0.78	22		
		S4	1.4	14		
MC5	23.5	S1	2.0	35	9.0	90, 3.8
		S2	0.05	17		
		S3	0.05	17		
		S4	0.90	20		
		S5	3.8	90		
SC4	3.8	S1	0.05	5.5	13	21, 0.12
		S2	0.05	13		
		S3	1.0	14		
		S4	0.12	21		
SC5	1.9	S1	0.05	22	3.9	35, 0.05
		S2	0.05	14		
		S3	0.05	35		
SC6	8.2	S1	1.1	20	19	51, 2.1
		S2	0.05	15		
		S3	2.1	51		
		S4	5.2	30		
		S5	0.05	20		
WC2	1.6	S1	0.05	4.6	11	12, 0.40
		S2	0.38	12		
		S3	0.05	6.0		
		S4	0.40	12		
WC4	*12.3	S1	0.05	19	22	31, 1.5
		S2	1.5	31		
		S3	4.2	18		
		S4	3.0	18		
		S5	4.0	26		
WC6	3.2	S3	0.46	14	7.5	14, 0.46
		S4	0.05	10		

*Drainage area does not include Soulajule Reservoir and its contributing drainage area.

3.3 Natural Flow Variability: Channel and Riparian Maintenance Flow Needs

As established in Appendix D of the Policy Scientific Basis Report (R2 and Stetson, 2008), winter diversions may impact many attributes of natural flow variability. This Study, as in the original Policy development, focused on channel and riparian maintenance flow needs. The 1.5-year flood magnitude was used as a surrogate for the range of high flows influencing channel form. Diversions in Class II and III streams were evaluated in terms of changes in the 1.5-year flood magnitude at the habitat sites.

Reductions in the 1.5-year flood magnitude due to diversions were used to estimate expected reduction in general channel width, depth, and substrate size. This application reflected the dominant or channel-forming discharge concept, where an intermediate frequency flood magnitude approximates the discharge associated with transporting the greatest cumulative volume of sediment (Wolman and Miller 1960). Doyle et al. (2007) compared estimates of bankfull flow and flood discharge of a given return interval against estimates of effective discharge computed using site-specific sediment transport rating curves. They found that neither flow-based metric consistently approximated the sediment-based one. However, the 1.5 to 2 year flood events were of a comparable order of magnitude to the effective discharge. In lieu of developing site-specific flow and sediment transport rating curves, this Study's analysis relied on the same representative flow-based approach as the Policy.

For this Study, changes to the unimpaired 1.5-year flood were evaluated for their potential to reduce the critical grain size in the substrate (i.e., the smallest grain size remaining stable in the bed at the prescribed flow rate). The critical grain size was calculated via algebraic rearranging of the equation for the critical dimensionless Shield's parameter, τ^*_{crit}:

$$\tau^* = \frac{\tau}{(S_s - 1)\rho g D_{50}}$$

where τ = shear stress which was estimated as a channel average property using the uniform flow approximation ρgRS, ρ = water density, g = acceleration due to gravity, R = channel hydraulic radius, S = estimate of reach friction slope, S_s = sediment specific gravity (=2.65 for quartz), and $D_{50\,crit}$ = critical median grain size. For the purpose of determining percent change in $D_{50\,crit}$, the precise value of τ^*_{crit} is unimportant because it cancels out in the calculation.

The analysis was performed at a single spawning cross-section in each site, where a pebble count was also performed over spawning gravel. The cross-section was selected in the field, at a location where a uniform flow approximation appeared reasonable and where the spawning gravel deposit was generally larger and most texturally homogeneous compared with other cross-sections. These conditions were considered to be most conducive to estimating critical grain size. As a rough check, the pebble count results were compared with the critical grain size predictions to see if they were generally comparable in magnitude, assuming a range of values for τ^*_{crit} (cf. Buffington and Montgomery, 1997).

4 Protectiveness Analysis

A protectiveness analysis was completed to compare impairments made under the Policy Section A.1.8.3 guidelines to unimpaired conditions. The habitat metrics described in Chapter 3, consistent with the original Policy development, were used to assess protectiveness. Passage and spawning days were computed for the unimpaired conditions and then for multiple diversion scenarios. Flood frequency was also compared for the unimpaired and impaired scenarios.

An increased emphasis was placed on upstream passage of adult coho salmon in this analysis compared with the development of the original Policy because the A.1.8.3 exemptions for small diversions have greatest potential for impact during the fall period when flows are low, coho salmon are migrating upstream (steelhead generally start their migration 1-2 months later; see Appendix C of the Scientific Basis report), and diversion ponds are filling.

4.1 Calculation of Passage and Spawning Days

Passage and spawning flows were evaluated for frequency of occurrence using the critical thresholds given in Table 3-3. The threshold passage and spawning flows were compared against daily flow time series for unimpaired and impaired conditions. Periodicity information was used to identify the dates between which upstream passage and spawning could occur for each species. Steelhead was the key indicator species for evaluating effects of spawning because of overlap in spawning periodicity with coho in November. Because the only difference between steelhead and coho spawning depth and velocity criteria exists in terms of the upper limit to velocity, and it is the lower flow that is of concern to protectiveness when considering effects of diversions, the results of the evaluation apply to both species. Consistent with the general development of the original Policy, upstream passage was evaluated beginning in October for coho, and spawning beginning in November for steelhead. Protectiveness was assessed in terms of changes in the number of days over ten water years that habitat opportunities existed for each impaired flow scenario, compared with unimpaired flow conditions. The methodology of comparing impaired and unimpaired passage and spawning days is consistent with the requirements of the Policy (see A.1.8.1.2; A.1.8.2.2, A.1.8.4.1 and B.5.3.4). Effects to passage were represented by changes in opportunities for coho, and effects to spawning were represented by changes in opportunities for steelhead.

4.1.1 Defining an "Upstream Passage Day"

Each POI has an associated critical passage flow (Table 3-3). Above this threshold, flow conditions at the site are conducive to upstream migration. A 'passage day' was defined as any day in which the unimpaired flow exceeded the site's critical passage flow.

4.1.2 Defining a "Spawning Day"

At each POI, there are several spawning transects, each with its own critical spawning threshold, which is a function of the individual redd locations on that transect. As described in Section 3.2, spawning flows were determined in two ways: individually at each transect, and overall at each site. The limiting spawning flow at a site was the highest spawning flow of all transects at that site. A day was considered a spawning day at a site if the unimpaired flow exceeded the site-wide limiting spawning flow, and the corresponding redd location defining the spawning flow remained wetted continuously by 0.1 ft or more of water depth over the incubation period. The duration of incubation followed the same rules as in the development of the Policy, where the respective redd locations were required to remain sufficiently wetted for 65 days total (including the spawning day) from November 1 through February 28, and 52 days after that (see Appendix G in Scientific Basis report). The corresponding minimum incubation flow for the redd location defining the minimum transect spawning flow is given in Table 3-3. Many of the incubation flow values are relatively low, reflecting the downstream hydraulic control influence of a riffle crest.

4.2 Unimpaired Flow

The basis of the protectiveness analysis is comparing unimpaired and impaired conditions to assess the impact to habitat. The first step in this analysis was to compute relevant statistics for unimpaired flows. The unimpaired flows at the nine POIs were evaluated for passage, spawning and natural flow variability.

4.2.1 Calculation of Unimpaired Passage and Spawning Days

Passage and spawning were evaluated using the critical thresholds given in Table 3-3. The unimpaired daily time series computed in the hydrologic models were evaluated using the definitions of passage and spawning days as given in Sections 4.1.1 and 4.1.2. Unimpaired passage and spawning days were counted at each POI for the 10-year flow period using the critical thresholds in Table 3-3.

4.2.2 Unimpaired Flood Frequency

Flood frequency of the unimpaired flows was assessed in order to provide a baseline for assessing changes due to potential impairments under the Policy guidelines of A.1.8.3. Flood frequency was assessed at the nine POI locations.

No annual peak flow measurements were available at any of the POI sites[4], so the hourly unimpaired flows from the hydrologic models were used for peak annual flows. To assess whether annual instantaneous peaks are similar in magnitude to hourly annual peaks, instantaneous peak flows and hourly peak flows were obtained at the two USGS gages in the study basins, Sonoma Creek at Kenwood (#11458433) and Walker Creek (#11460750). Data were obtained from the National Water Information System (NWIS; USGS, 2013a; USGS, 2013b).

Table 4-1 lists the instantaneous peak flows as reported by the USGS, as well as the average hourly discharge during the corresponding peak event. The average hourly discharge was computed as the average of the 15-minute values reported by the USGS during the hour of the instantaneous peak. The ratio of peak to hourly flow was computed for each event, showing that, on average, the instantaneous peak flow is 4% higher than the hourly flow. This shows that, in these watersheds, instantaneous peaks are not significantly higher than their corresponding hourly peaks. Therefore, for this analysis, the hourly unimpaired flows from the hydrologic models were used as estimates of the instantaneous peak flow. Though the hourly values may underestimate the instantaneous peaks slightly, the purpose of this analysis is not to determine absolute flood frequency discharge, but to assess changes in the flood frequency between unimpaired and impaired conditions. The hourly unimpaired flows are the best data available to estimate unimpaired peak flows.

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[4] The exception to this is at POI site WC4, located just upstream of USGS gage 11460750 on Walker Creek. The tributary at Walker Ranch (gaged at site WC3) enters Walker Creek between WC4 and the USGS gage. To estimate peak flows at WC4, the hourly unimpaired flows at WC3 were subtracted from the measured USGS peak flows at USGS gage 11460750.

Table 4-1 Comparison of Instantaneous and Hourly Peak Flow Data at USGS Gages in Study Basins

USGS Gage ID Number	Date of Peak	Peak Discharge[1] (cfs)	Average Hourly Discharge at Time of Peak[2] (cfs)	Ratio of Peak to Hourly	Percent Increase, Peak to Hourly
11458433	2/22/2009	439	437	1.005	0.5%
11458433	3/14/2012	835	828	1.008	0.8%
11458433	3/20/2011	1,020	986	1.034	3.4%
11458433	1/20/2010	1,170	1,140	1.026	2.6%
11460750	2/22/2009	514	502	1.023	2.3%
11460750	3/14/2012	533	522	1.021	2.1%
11460750	1/26/2008	1,310	1,293	1.014	1.4%
11460750	1/20/2010	1,690	1,563	1.082	8.2%
11460750	3/20/2011	1,880	1,603	1.173	17.3%
Average percent increase over hourly:					4.3%

Notes:

[1] Peak annual flow (USGS, 2013a)

[2] Hourly average flow as computed from USGS 15-minute data (USGS, 2013b)

At each POI, the date and value for the peak unimpaired flow for each water year of the model period from WY 2004 through 2013 were obtained. The unimpaired hourly time series from the hydrologic models were used at POIs MC2, MC3, MC5, SC4, SC5, SC6, WC2 and WC6. At POI WC4, the USGS-reported peak flows were used from the nearby gage (11460750); however, the peak values at the USGS gage were reduced by the corresponding hourly flow estimated at site WC3; the tributary gaged at WC3 enters Walker Creek between WC4 and the USGS gage, so those flows were subtracted to estimate the peaks at WC4.

The annual peak values for the 10-year period were then evaluated using the USGS program PeakFQ (USGS, 2007). The program PKFQWin v5.2.0 was used to run PeakFQ, which fits the Pearson Type III frequency to the logarithms of instantaneous annual peak flows following USGS Bulletin 17B guidelines. Flood frequency results are given in Appendix D. Table 4-2 gives the 1.5-year unimpaired flood discharge at the sites.

Table 4-2 Unimpaired 1.5-year Flood Discharge at POI Sites

POI Site	Unimpaired 1.5-year Flood Discharge (cfs)
MC2	204
MC3	376
MC5	1,591
SC4	83
SC5	61
SC6	209
WC2	62
WC4	910
WC6	191

4.3 Impaired Flow Scenarios

The purpose of the impaired flow scenarios was to determine the potential impacts to the unimpaired flow at a POI that could be caused by allowing diversions according to Policy Section A.1.8.3. Diversions were computed for a series of diversion scenarios, and the resulting impaired flows were analyzed for changes in passage and spawning days and flood frequency.

4.3.1 Diversion Scenarios

For a given watershed at a given POI, the maximum annual diversion volume allowed under A.1.8.3 is a percentage of the seasonal unimpaired flow volume at the ULA. This depletion volume can be diverted at any number of PODs. The daily volume that can be diverted at any POD is also dependent on the amount of water available on that day at that location.

Since there are an unlimited number of permutations and locations for potential PODs within a watershed, diversion scenarios were developed to include a wide range of possibilities. Four diversion scenarios were developed to estimate potential diversions in the study basins. They are illustrated schematically in Fig.4-1.

- Diversion Scenario 1 (D1): Distributed diversions in headwaters. Potential PODs are located in the headwaters on class III streams. The PODs are spread out in the headwaters with the maximum annual diversion volume divided equally among all potential PODs above a ULA.
- Diversion Scenario 2 (D2): Diversions at existing PODs. Potential PODs are located where existing or pending PODs are located. This scenario was intended to represent an actual distribution of PODs that could occur in a watershed.
- Diversion Scenario 3 (D3): Lumped diversions just upstream of ULA. Potential PODs are located just upstream of the ULA. This scenario has fewer PODs than in D1, with the entire maximum annual diversion volume above a ULA allocated to the single POD above that point.
- Diversion Scenario 4 (D4): Mixed diversions in headwaters and at ULA. Potential PODs are located just upstream of the ULA and also on class III headwaters. This scenario has the most PODs of all scenarios, with each POD having smaller diversion volumes.

Fig. 4-2, Fig. 4-3 and Fig. 4-4 show the POIs and PODs used in the diversion scenarios in each study basin. All four diversion scenarios were tested in each study basin.

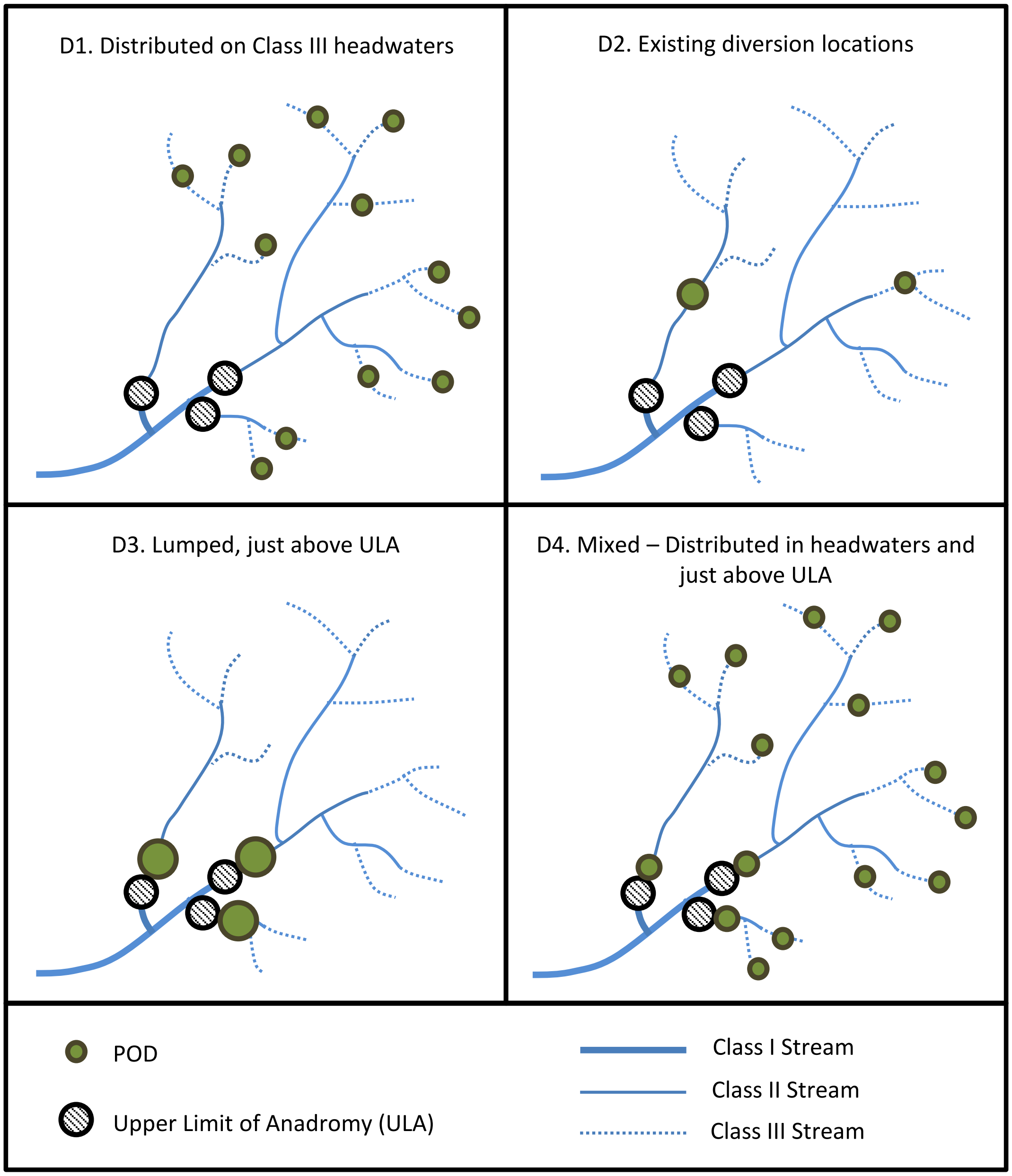

Fig. 4-1 **Schematics of POD Locations for Four Diversion Scenarios**

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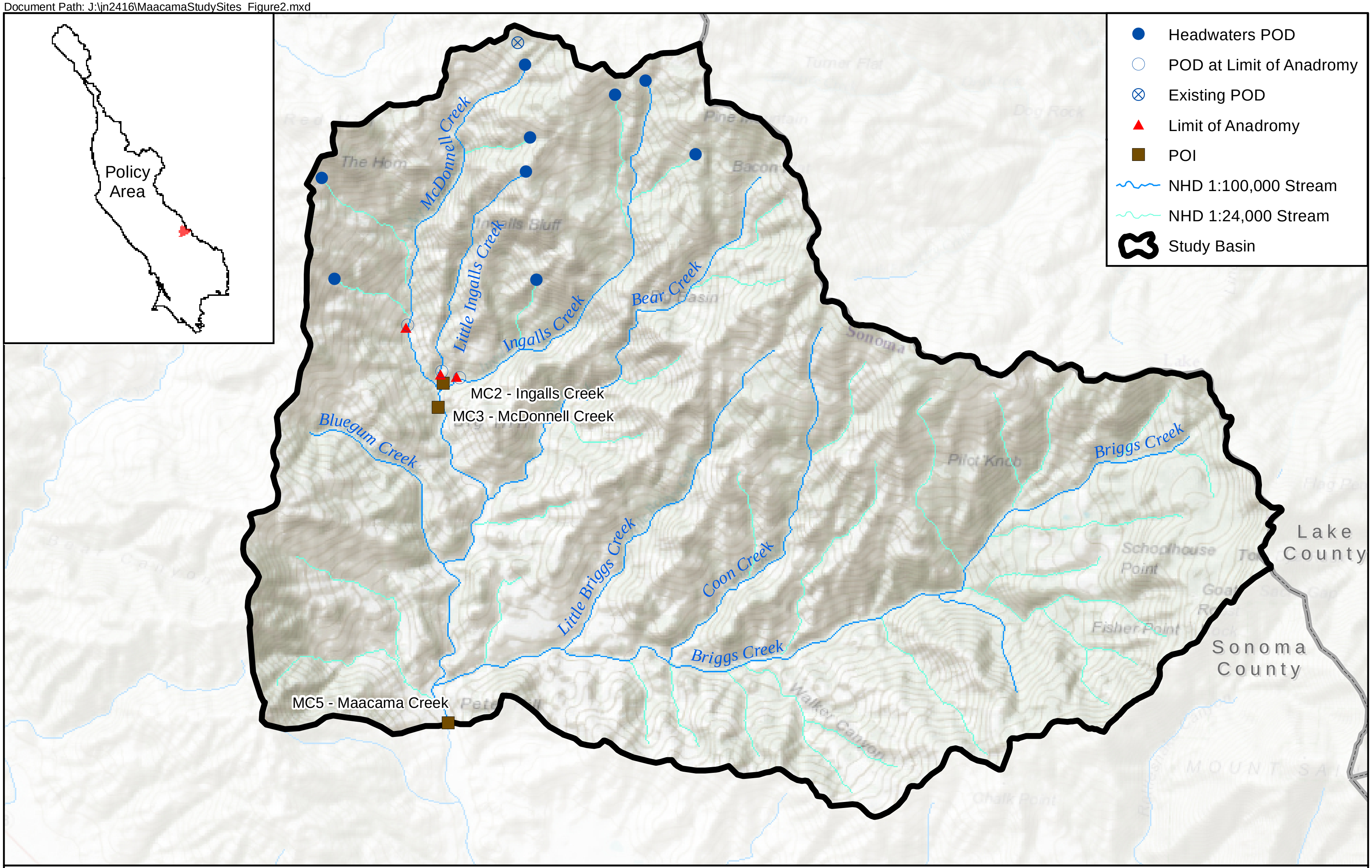


STETSON ENGINEERS INC.

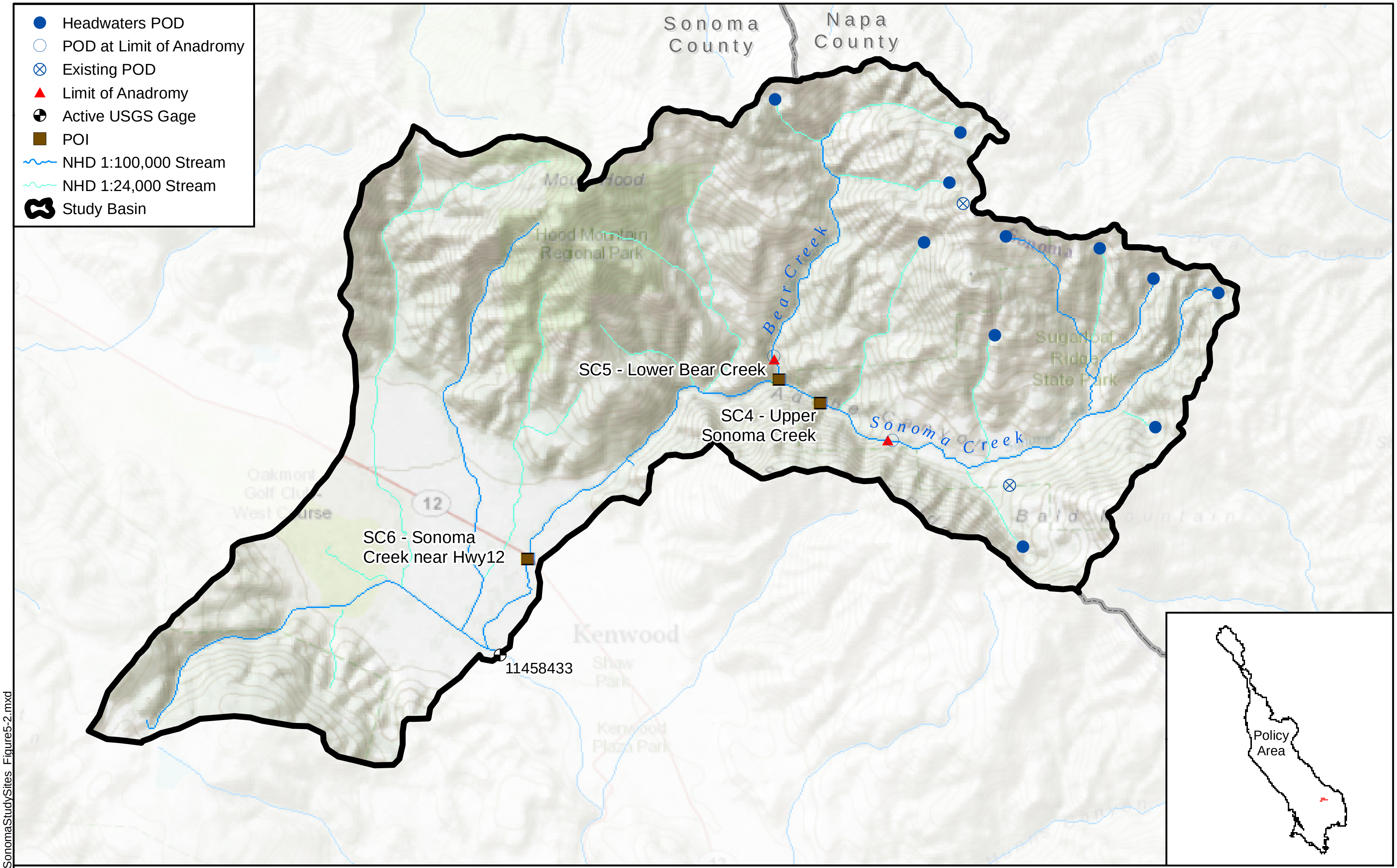
MAACAMA CREEK WATERSHED
POINTS OF DIVERSION FOR IMPAIRED FLOW ANALYSIS

Source:
NHD, 1:100,000/1:24,000 Streams. USGS. 1999.

N

0 0.5 1 Miles

FIGURE 4-2



STETSON ENGINEERS INC.

SONOMA CREEK WATERSHED
POINTS OF DIVERSION FOR IMPAIRED FLOW ANALYSIS

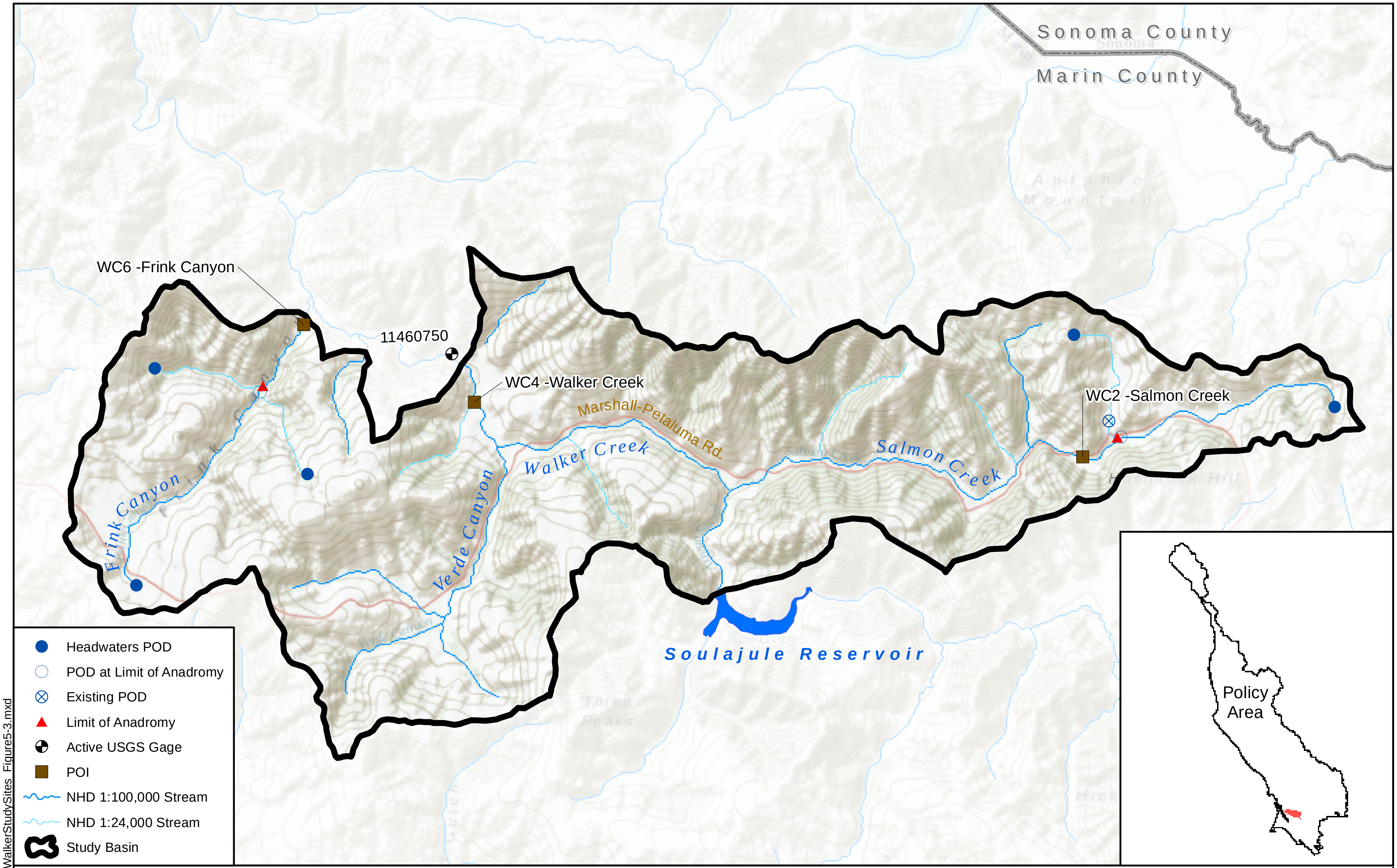
Source:
NHD, 1:100,000/1:24,000 Streams. USGS. 1999.

N

0 0.5 1 Miles

Document Path: J:\jn2416\SonomaStudySites_Figure5-2.mxd

FIGURE 4-3



WALKER CREEK WATERSHED
POINTS OF DIVERSION FOR IMPAIRED FLOW ANALYSIS

STETSON ENGINEERS INC.

Source:
NHD, 1:100,000/1:24,000 Streams. USGS. 1999.

N

0 0.5 1 Miles

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FIGURE 4-4

4.3.2 Flow Impairment Scenarios

The analysis of impaired flows considered four scenarios, one for each diversion distribution. Based on the stream class of the PODs in each scenario, other policy elements were applied appropriately. Table 4-3 lists the four scenarios and applicable Policy elements. The February median unimpaired flow MBF applies to all scenarios with PODs on Class II streams. Scenarios with Class III PODs have a February median flow MBF only when the maximum cumulative volume depletion exceeds 5%. The February median flow MBF applies only to a fraction of the diversions equal to the fraction of the maximum cumulative volume depletion that exceeds 5%. Following the A.1.8.3 guidelines, no scenarios have a diversion season or an MCD.

Table 4-3 Scenarios used in Flow Impairment Analysis

Policy Element	Scenario D1	Scenario D2	Scenario D3	Scenario D4
Diversions	Distributed	Existing PODs	Lumped	Mixed
Div Season	None	None	None	None
MBF	Feb Median[1]	Feb Median[1]	Feb Median	Feb Median[1]
MCD	None	None	None	None

Note:

[1] For any Class III PODs in scenario, February median unimpaired flow MBF applies only if maximum cumulative volume depletion is greater than 5%; otherwise, there is no MBF at Class III PODs. Class II PODs have a February median unimpaired flow MBF in all cases.

4.3.3 Calculating Diversions

Under the alternative guidelines of Policy Section A.1.8.3, any proposed project must compute the cumulative depletion due to the proposed project and all senior diversions as a percentage of the seasonal (November 1 to March 31) volume measured downstream at the ULA and downstream POIs. For this Study, the seasonal unimpaired flow volumes were computed at each ULA (Table 4-4). In all three study basins, the seasonal unimpaired flow at ULAs was the limiting flow, as the seasonal volume at downstream POIs was always greater than at the ULA.

Table 4-4 Seasonal Unimpaired Flow Volume at Upper Limits of Anadromy in Study Basins

Study Basin	Location	Average Annual Seasonal (Nov 1 - Mar 31) Unimpaired Flow Volume (ac-ft)
Maacama	ULA on Little Ingalls Creek	200
Maacama	ULA on Ingalls Creek	1,535
Maacama	ULA on McDonnell Creek	740
Sonoma	ULA on Sonoma Creek	760
Sonoma	ULA on Bear Creek	690
Walker	ULA on Salmon Creek	340
Walker	ULA on Frink Canyon	1,180

For each of the four diversion scenarios described in Section 4.3.1, the maximum annual diversion volume at each POD was determined as a function of the maximum cumulative volume depletion[5]. First, for a given maximum cumulative volume depletion, the maximum annual diversion volume above each ULA was computed. For example, if the maximum cumulative volume depletion was set at 10%, the maximum annual diversion volume above the ULA on McDonnell Creek would be 10% of the 740 ac-ft of seasonal flow, or 74 ac-ft. The maximum annual diversion volume above each ULA was then distributed to the upstream PODs to determine the maximum annual diversion volume at each POD. For the distributed (D1), existing POD (D2), and lumped diversion scenarios (D3), the maximum annual diversion volume was divided equally among all upstream PODs. For the mixed scenario (D4), the maximum annual diversion volume was distributed with 50% of the volume assigned to the Class II diversion at the ULA, and 50% divided equally among all the Class III diversions in the headwaters.

The calculated diversions [6] at each POD for each diversion scenario were computed daily for the period of October 1, 2003 through April 30, 2013 using the daily unimpaired flow results from the hydrologic models. Spreadsheet models were created to simulate the daily diversions in each study basin. Guidelines in A.1.8.3 were applied, including applying an MBF at PODs on Class II streams in all cases, and applying an MBF at PODs on Class III streams when the maximum cumulative volume depletion exceeded 5% at the ULA. No diversion season was imposed, as the A.1.8.3 guidelines do not require it. Diversions were first computed at the most upstream PODs in the model.

At Class III PODs, if the maximum cumulative volume depletion exceeded 5%, an MBF was imposed only on a fraction of the diversions equal to the fraction of the maximum cumulative volume depletion in excess of the 5% threshold. This represents the intended implementation of A.1.8.3, in which diversions up to 5% would be allowed without an MBF, but any applicants in excess of a maximum cumulative volume depletion of 5% would be subject to an MBF. In the distributed (D1) and mixed (D4) scenarios, this was implemented by splitting each Class III POD into two effective diversions, one subject to an MBF, and one without an MBF[7]. This setup was used in order to maintain scenarios representative of highly distributed diversions in Class III streams.

For each day in the nearly 10-year period, the calculated diversion was computed using the available unimpaired flow, the maximum annual diversion volume at that POD and the MBF (if applicable). Calculated diversions were then subtracted from the available flow at all points downstream. No adjustments were made to the streamflow routing to account for the increase in travel time associated with the reduced flows due to diversions, since in these relatively small study areas, the travel time between points is less than a day. Calculated diversions were computed at successively downstream PODs, with the available unimpaired flow at each location reduced by any upstream diversions. Finally, the calculated daily diversions upstream of each POI were summed and then subtracted from the unimpaired flow at each POI to create impaired flow time series.

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[5] In this Study, 'maximum cumulative volume depletion' refers to the maximum allowable percentage depletion above a ULA, expressed as a percentage of the seasonal unimpaired flow at that ULA.

[6] In this Study, 'calculated diversion' refers to the diversion volume that is available for diversion at a POD at a given time, based on the availability of unimpaired flow at the POD, the maximum annual diversion volume at that POD, and any MBF, MCD or diversion season which applies at that POD.

[7] At these dual-POD locations, the available water for each POD was divided according to the ratio of the maximum cumulative volume depletion and the 5% threshold that separates the no-MBF/MBF rule. For example, if the maximum cumulative volume depletion for a scenario was 6%, five-sixths of the unimpaired flow at the POD was available for diversion without an MBF, while one-sixth of the unimpaired flow at the POD was available for diversion with an MBF.

4.3.4 Limiting Diversion Scenario

In each diversion scenario, the total volume of calculated diversions is a function of the location of the PODs, the diversion rules at those PODs, and the unimpaired water availability. The calculated diversions may be less than the maximum cumulative volume depletion allowed, due to limiting water availability. The results of the impaired flow calculations described in Section 4.3.2 indicate which arrangement of PODs has the largest calculated diversion volume and is therefore likely to have the highest potential impact on habitat.

For each of the four scenarios described in Section 4.3.1, calculated diversions were computed following the guidelines in Policy Section A.1.8.3 with a maximum cumulative depletion volume of 10%. Fig. 4-5 shows the average annual calculated diversion volume upstream of each POI for each of the four diversion scenarios. Table 4-5 gives the calculated diversions by month. At most sites, the existing PODs scenario (D2) represents the smallest calculated diversion. The lumped scenario (D3) has the largest diversions. The distributed (D1) and mixed (D4) generally have calculated diversions that fall in between those for D2 and D3.

Results of these diversion calculations were used to identify the limiting scenarios for the protectiveness analysis. The scenario with the highest calculated diversion volume is the lumped scenario (D3). Since the PODs in this scenario are placed just upstream of the ULAs, this diversion scenario represents the maximum diversion that could be taken under any of the four diversion scenarios. The calculated diversion volume in this scenario is equal to the maximum cumulative volume depletion. For example, at the ULA at Ingalls Creek, the seasonal unimpaired flow volume is 1,535 ac-ft. With a 10% maximum cumulative volume depletion, the maximum annual diversion allowed upstream of that POI is 154 ac-ft. The results in Table 4-5 show that the under scenario D3, the average annual calculated diversion is 154 ac-ft.

Though the lumped scenario (D3) has the highest calculated diversions, it does not assess the effects of any Class III diversions. Because of that, the distributed scenario (D1) was also tested in the protectiveness analysis in order to assess how diversions on Class III streams impact habitat at POIs. As explained in Section 4.3.1 and shown in Figs. 4-2, 4-3 and 4-4, the scenario D1 PODs were placed on all headwaters streams shown in the 1:24,000 National Hydrography Dataset (NHD) coverage. The diversions in this scenario estimate the highest calculated diversion that may be expected on Class III streams in each study basin.

In this Study, protectiveness has been assessed using the lumped (D3) and distributed (D1) scenarios. The guidelines in Policy Section A.1.8.3 that pertain to Class II streams were tested with the lumped diversion scenario, while the Class III guidelines were tested with the distributed diversion scenario.

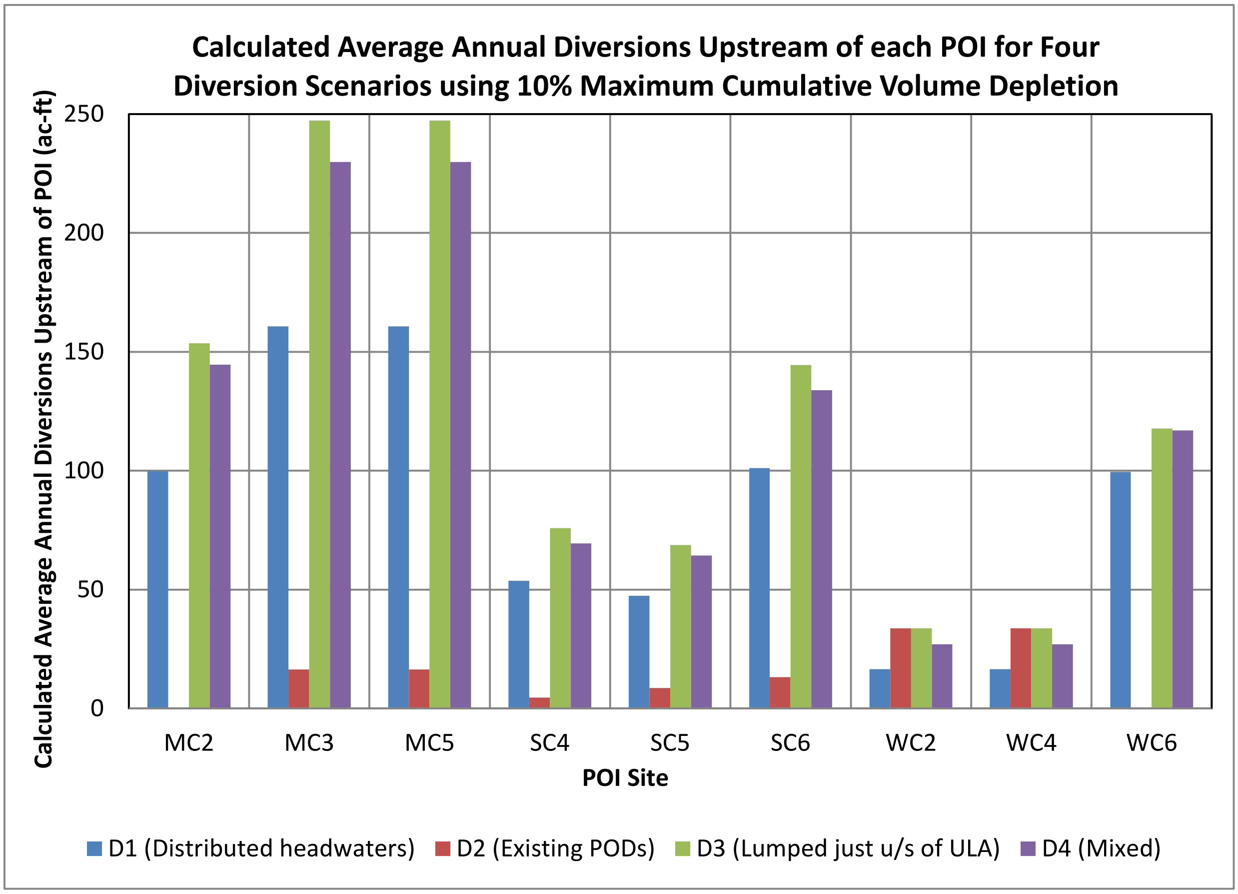

Fig. 4-5 Average Annual Diversions Upstream of Each POI for Four Diversion Scenarios

Table 4-5 Calculated Average Monthly Diversions Upstream of Each POI for Four Diversion Scenarios using 10% Maximum Cumulative Volume Depletion

Table 4-5.a Diversions upstream of MC2

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	3	0	31	25
Nov	4	0	21	17
Dec	29	0	70	60
Jan	20	0	22	20
Feb	19	0	9	14
Mar	15	0	0	7
Apr	5	0	0	1
May	3	0	0	1
Jun	1	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	100	0	154	145

Table 4-5.b Diversions upstream of MC3

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	5	0	44	35
Nov	7	0	31	25
Dec	50	4	112	95
Jan	34	3	44	38
Feb	30	3	17	23
Mar	22	3	0	10
Apr	7	1	0	2
May	4	1	0	1
Jun	1	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	161	16	247	230

Table 4-5.c Diversions upstream of MC5

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	5	0	44	35
Nov	7	0	31	25
Dec	50	4	112	95
Jan	34	3	44	38
Feb	30	3	17	23
Mar	22	3	0	10
Apr	7	1	0	2
May	4	1	0	1
Jun	1	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	161	16	247	230

Table 4-5.d Diversions upstream of SC4

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	2	0	10	10
Nov	3	0	9	7
Dec	19	2	26	25
Jan	14	1	18	15
Feb	8	1	13	10
Mar	5	1	0	2
Apr	1	0	0	0
May	1	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	54	5	76	69

Table 4-5.e Diversions upstream of SC5

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	1	0	12	9
Nov	1	0	7	5
Dec	15	2	26	24
Jan	11	2	15	13
Feb	10	2	8	9
Mar	6	2	0	3
Apr	2	1	0	1
May	1	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	47	9	69	64

Table 4-5.f Diversions upstream of SC6

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	3	0	22	19
Nov	5	0	16	12
Dec	34	4	53	49
Jan	24	3	33	28
Feb	18	3	20	19
Mar	12	2	0	5
Apr	3	1	0	1
May	1	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	101	13	144	134

Table 4-5.g Diversions upstream of WC2

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	0	0	0	0
Nov	0	1	3	2
Dec	6	19	18	13
Jan	5	8	10	7
Feb	4	4	3	3
Mar	2	2	0	1
Apr	0	0	0	0
May	0	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	17	34	34	27

Table 4-5.h Diversions upstream of WC4

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	0	0	0	0
Nov	0	1	3	2
Dec	6	19	18	13
Jan	5	8	10	7
Feb	4	4	3	3
Mar	2	2	0	1
Apr	0	0	0	0
May	0	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	17	34	34	27

Table 4-5.i Diversions upstream of WC6

	Calculated Avg. Monthly Diversions (ac-ft)			
Month	D1	D2	D3	D4
Oct	2	0	13	14
Nov	2	0	15	13
Dec	34	0	56	52
Jan	27	0	22	21
Feb	22	0	12	15
Mar	11	0	0	3
Apr	1	0	0	0
May	0	0	0	0
Jun	0	0	0	0
Jul	0	0	0	0
Aug	0	0	0	0
Sep	0	0	0	0
Total	99	0	118	117

Calculated diversions for all scenarios computed using 10% maximum cumulative volume depletion; Diversion scenarios are:

D1 = Distributed diversions in headwaters

D2 = Diversions at existing PODs

D3 = Lumped Diversions just upstream of Upper Limit of Anadromy (ULA)

D4 = Mixed Diversions at headwaters and just upstream of ULA

4.3.5 Calculation of Impaired Passage and Spawning Days

After the daily impaired time series were generated following the procedures in Section 4.3.3, impaired passage and spawning days were computed. The procedures were identical to those described in Section 4.2.1 except the impaired daily time series were used rather than the unimpaired daily time series. The limiting flows used (see Table 3-3) were the same as for the unimpaired analysis.

4.3.6 Impaired Flood Frequency

Flood frequency was evaluated at the 5% and 10% levels of maximum cumulative volume depletion. The impaired flood frequency was computed for the distributed scenario (D1) and the lumped scenario (D3). Impaired flood frequency was not computed for diversion scenarios D2 or D4, since the lumped scenario (D3) is likely to be more limiting. PODs in D3 are located near the ULAs, which results in the highest flow availability at the POD and lowest tributary flow between the PODs and the POIs; therefore the diversion rates in this scenario are likely to be the highest and will have the greatest impact on flood frequency.

Additional steps were needed to estimate the hourly impaired flows, which were used as a surrogate for instantaneous peak flows (see explanation in Section 4.2.2).

4.3.6.1 Impaired Hourly Flows for Distributed Scenario (D1)

For the distributed scenario (D1), the calibrated HSPF hydrologic models were used to explicitly calculate impaired hourly flows at the POIs given the hourly diversions at the PODs. This was necessary because travel times for the flows from the D1 PODs in the headwaters to the POI could be greater than one hour and must be considered for peak flow calculations.

Hourly calculated diversions were computed for the entire 10-year simulation period using the simulated unimpaired hourly flows, the MBF, and the maximum annual diversion volume at each headwater POD using the same methods described in Section 4.3.3 but on an hourly time step instead of daily. These hourly diversions were then used as times series input to HSPF and were subtracted from the inflow entering the reach downstream of each headwater to give impaired inflow.

HSPF results at the POIs provide the impaired hourly time series required for the flood frequency analysis. The impaired annual peaks were determined by identifying the highest hourly flow in each water year in the impaired hourly time series.

4.3.6.2 Impaired Hourly Flows for Lumped Scenario (D3)

The procedures to estimate impaired peak flows from the impaired daily flows for the lumped scenario (D3) are similar to those used in the Scientific Basis Report for the Cumulative Flow Impairment Index (CFII) flow alternative (Stetson and R2, 2008; see Section 4.3.5 and Appendix Section F.3).[8]

First, for each water year at each POI, the date of the unimpaired peak was compared to the date of the last diversion in that diversion scenario. If the unimpaired peak occurred after the last diversion, then the impaired peak is equal to the unimpaired peak and there was no change for that year.

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[8] The methods used to compute peak annual impaired flows for Scenario D1 (Section 4.3.6.1) were also used to verify the flood frequency methodology used for the lumped Scenario D3 (Section 4.3.6.2). Hourly diversions were computed and modeled in HPSF for the lumped scenario with 10% maximum cumulative volume depletion in the Maacama Creek study basin. Peak annual flows at the POIs were compared for the two methods and were consistent.

If the unimpaired peak occurred during the diversion period (meaning, the unimpaired peak was reduced by diversions), then the impaired daily flow time series for that year was evaluated to determine the impaired average daily peak and corresponding date. In some years of the analysis, diversions occurred on the date of the peak impaired daily flow. In these cases, the following methods were used to determine the hourly peak:

- For POIs located just below the ULA, the bypass flow at the ULA was known from the diversion analysis described in Section 4.3.3. Hourly diversion rates were then computed using the total calculated diversion volume on that day, the bypass flow, and the unimpaired hourly flow. Impaired hourly flows were computed by subtracting the hourly diversions from the unimpaired hourly flows. The peak flow was estimated as the highest hourly flow on that date.
- For POIs located downstream of the ULA, the hourly diversion rates were computed for the POIs located upstream. The sum of the upstream hourly diversions was subtracted from the hourly unimpaired flow to estimate the hourly impaired flow at the POI.
- At site WC4, one impaired peak occurred in WY 2007 during a period when unimpaired hourly flows were not available[9]. At this site, a ratio was computed for each event in which the instantaneous and average daily unimpaired peaks were known. The ratio is the instantaneous peak flow divided by the corresponding daily peak flow. At site WC4, this ratio ranged from 1.4 to 3.8. For the impaired peak in WY 2007, the impaired daily flow was multiplied by 1.4 in order to estimate the impaired instantaneous peak. The minimum value of the ratio range was used in order to be conservative and simulate a larger reduction in impaired peak flow.

4.3.6.3 Impaired 1.5-year Flood Magnitudes

Once the annual impaired peaks were estimated for the distributed and lumped impaired time series, flood frequency was estimated at the 5% and 10% levels of maximum cumulative volume depletion using the same procedures as described in Section 4.2.2. PeakFQ was used to compute the impaired flood frequency for Scenarios D1 and D3. Results for the 5% and 10% maximum cumulative volume depletions are in Table 4-6 and Table 4-7, respectively. At four of the sites (SC4, SC5, SC6 and WC4), the low or high outlier threshold was manually adjusted in PeakFQ to ensure that the impaired flood frequency was calculated using the same number of values as the unimpaired flow. This is necessary for a valid comparison between the two frequency curves.

The impaired flood frequency results are given in Appendix D.

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[9] At site WC4, rather than modeling the WC4 flows using the HSPF model, the WC4 flow was calculated by subtracting the simulated flow at WC3 from the observed flow at the USGS gage. See Section 5.2 of Appendix B for explanation. For the period from WY 2004 - 2007, only daily USGS flows were available. Therefore, at siteWC4, hourly flows are available only for WY 2008-2013. At all other sites, unimpaired hourly flows are available for the entire 10-year simulation period.

Table 4-6 Impaired 1.5-year Flood Discharge at POI Sites with 5% Maximum Cumulative Volume Depletion

	Impaired 1.5-year Flood Discharge (cfs)	
POI Site	Distributed Scenario (D1)	Lumped Scenario (D3)
MC2	197	150
MC3	367	284
MC5	1,580	1,411
SC4	80	73
SC5	59	57
SC6	205	197
WC2	60	58
WC4	n/a	910
WC6	182	134

Table 4-7 Impaired 1.5-year Flood Discharge at POI Sites with 10% Maximum Cumulative Volume Depletion

	Impaired 1.5-year Flood Discharge (cfs)	
POI Site	Distributed Scenario (D1)	Lumped Scenario (D3)
MC2	196	150
MC3	363	282
MC5	1,578	1,380
SC4	80	68
SC5	58	56
SC6	201	189
WC2	60	53
WC4	n/a	863
WC6	179	134

5 Protectiveness of Guidelines in Policy Section A.1.8.3

This chapter describes the results of the protectiveness analysis of Policy Section A.1.8.3. The diversion guidelines were evaluated as written, without any modifications to the policy elements.

5.1 Passage and Spawning Habitat

The provisions of Policy Section A.1.8.3 were evaluated for the range of maximum cumulative volume depletions from 0% to 10%. The two limiting diversion scenarios described in Section 4.3.4 were tested for the range of depletions: the lumped diversion scenario (D3) tests the protectiveness of the A.1.8.3 guidelines for Class II streams, while the distributed scenario (D1) tests the protectiveness of the guidelines for Class III streams. Table 5-1 gives the two scenarios and associated Policy elements used to evaluate the protectiveness of the A.1.8.3 guidelines.

Table 5-1 Scenarios used to Assess Protectiveness of A.1.8.3 Guidelines

Policy Element	Scenario D1	Scenario D3
Diversions	Distributed	Lumped
Diversion Season	None	None
MBF	Feb Median[1]	Feb Median
MCD	None	None

Note:

[1] For Class III PODs, February median unimpaired flow MBF applies if maximum cumulative volume depletion is greater than 5%; otherwise, there is no MBF at Class III PODs.

For each scenario, the maximum cumulative volume depletion was varied from 0% to 10%, in increments of 1%. Diversions at the PODs were computed following the procedures in Section 4.3.3. An impaired time series was created for each maximum cumulative volume depletion percentage. Then, impaired passage and spawning days were computed as described in Section 4.3.5. At each site, for each maximum cumulative volume depletion percentage, the number of impaired passage and spawning days were compared to the number of unimpaired passage and spawning days. The Policy has established that a loss in passage and spawning days no greater than 10% per month is expected to be protective (see Policy Sections A.1.8.1.2, A.1.8.2.1, A.1.8.4.1 and B.5.3.4).

The results for Scenarios D1 and D3 are described below. Graphs of the critical results are presented in this chapter; full tables of the results and graphs for each month are in Appendix E.

5.1.1 Loss of Passage and Spawning Days for Distributed Scenario (D1)

The distributed scenario is an estimate of the highest amount of water that could be diverted if PODs were located only on Class III streams. This impaired flow scenario tests the guidelines in Table 1-1 that apply to Class III streams.

Fig. 5-1, Fig. 5-2, and Fig. 5-3 show the percent[10] of passage days lost during the months of October, November and December, respectively, for each percentage maximum cumulative volume depletion for

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[10] The number of unimpaired passage days for each site which the percent is computed from may be found in the legends of Figs. 5-1, 5-2, and 5-3, as well as in the full tables in Appendix E.

the distributed scenario, based on the sum of days over the entire 10-year analysis period. For example, to compute the percent of passage days lost in October, the percent of passage days was computed for each maximum cumulative volume depletion percentage as follows: the total impaired passage days in every October of the model period[11] were subtracted from the total unimpaired passage days in every October; this number of days was then divided by the total unimpaired passage days in October. Similar calculations were done for November through March[12]. Fig. 5-4, Fig. 5-5 and Fig. 5-6 give the results for spawning days lost in October, November and December, respectively.

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[11] The model duration is 10 years, so the monthly totals of passage and spawning days are based on 10 of each month per model period.

[12] Results for October through December are included in this chapter; full results through March are included in Appendix E.

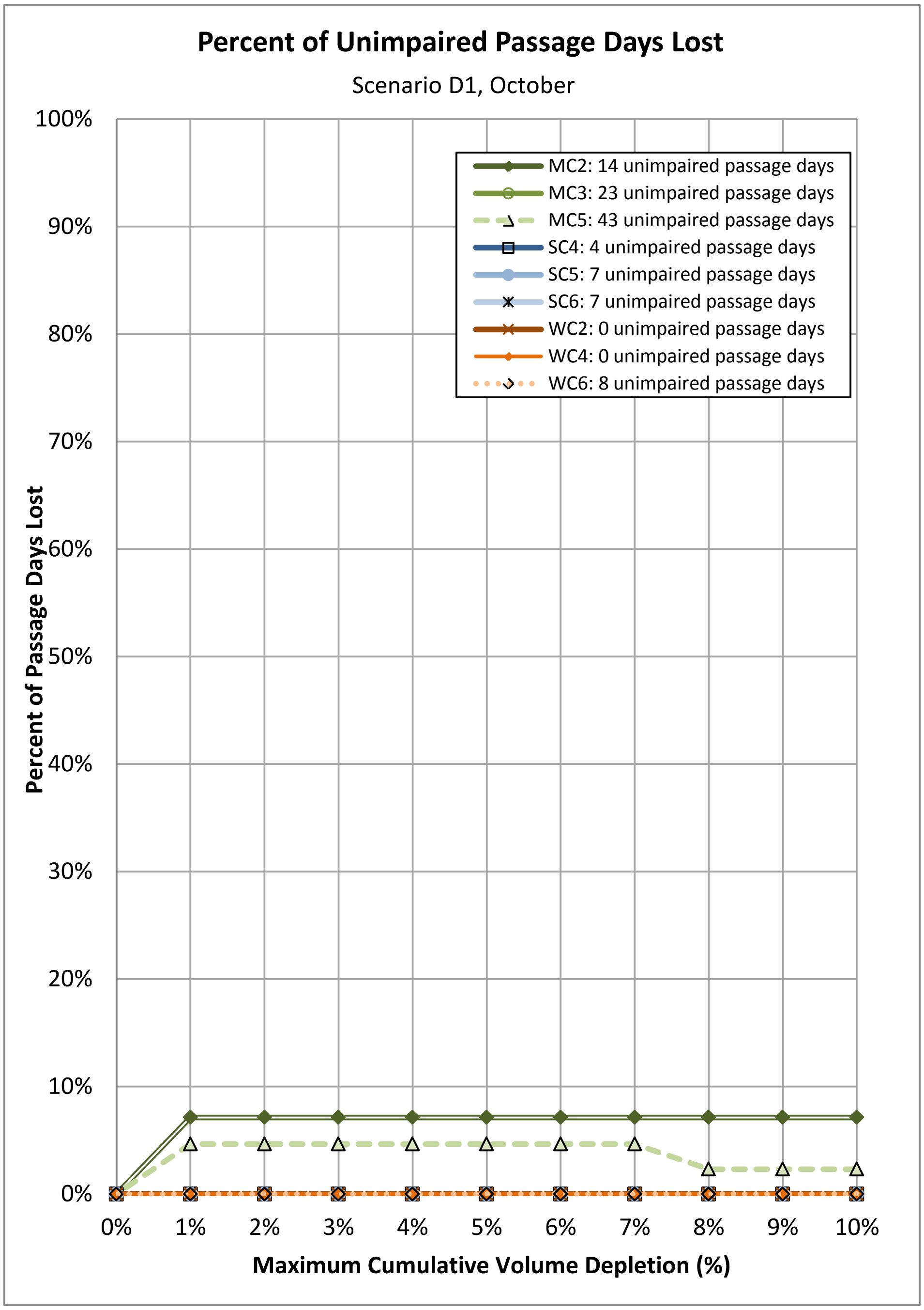

Fig. 5-1 **Distributed Scenario (D1): Percent of Unimpaired Passage Days Lost in October**

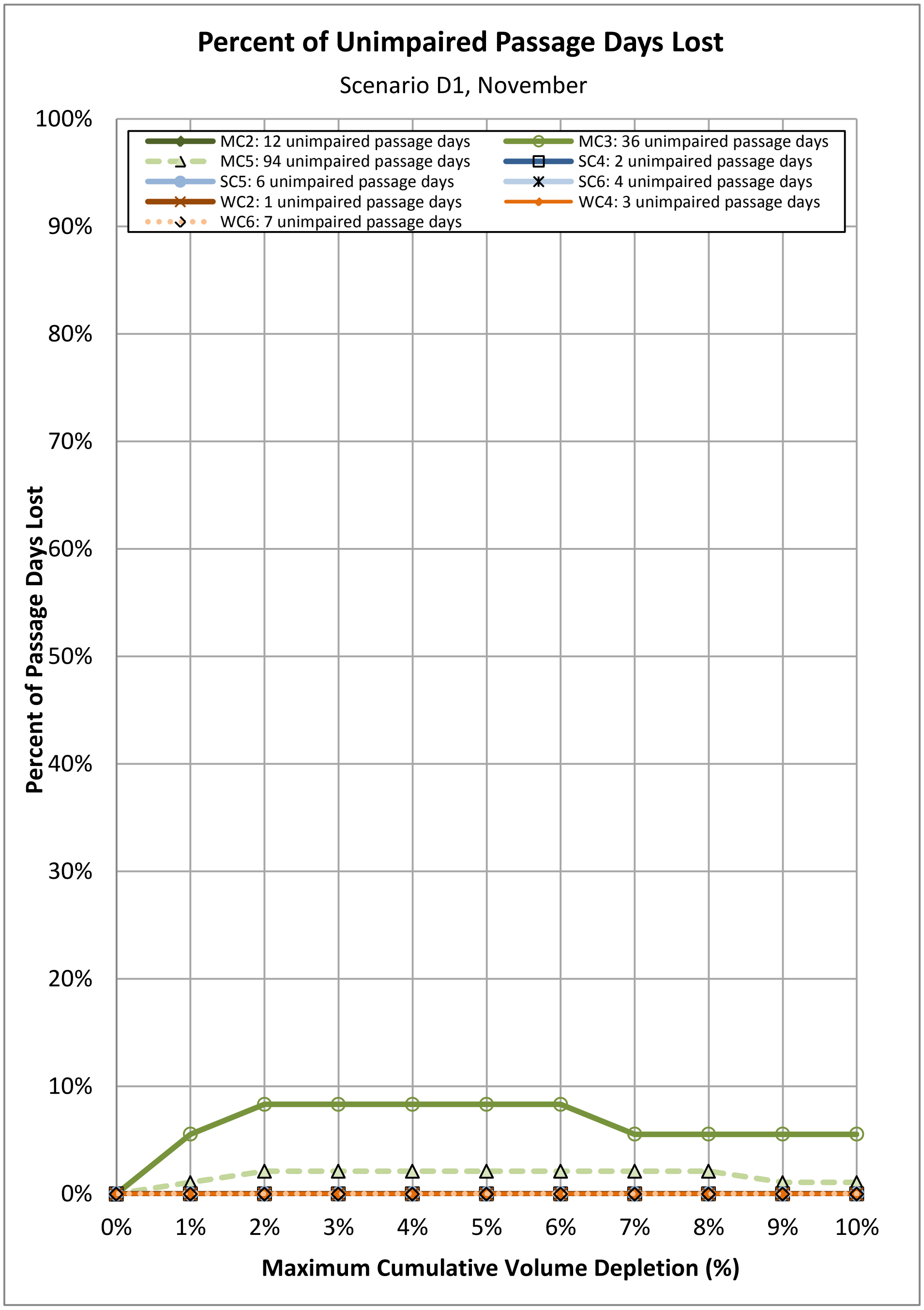

Fig. 5-2 Distributed Scenario (D1): Percent of Unimpaired Passage Days Lost in November

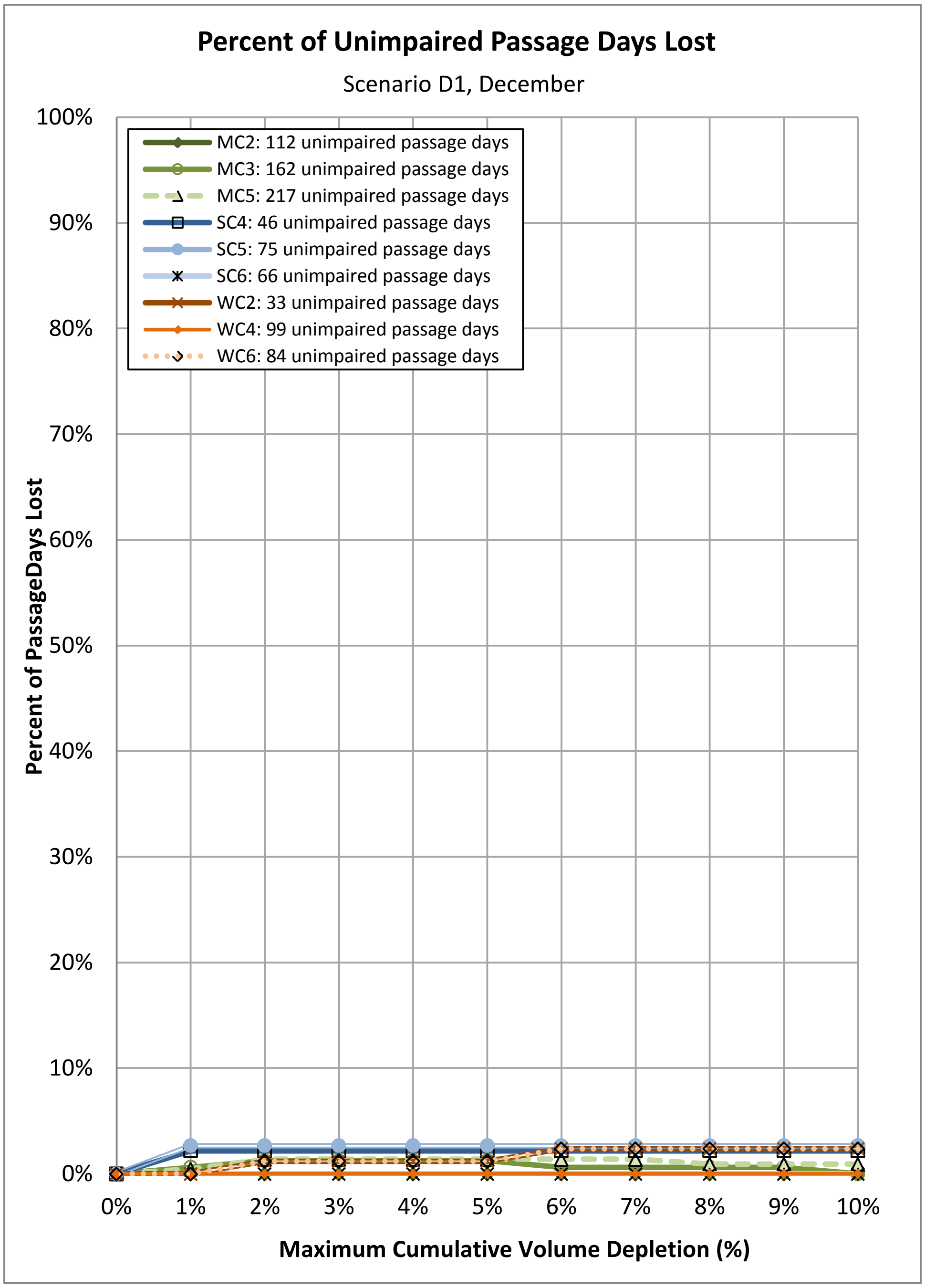

Fig. 5-3 **Distributed Scenario (D1): Percent of Unimpaired Passage Days Lost in December**

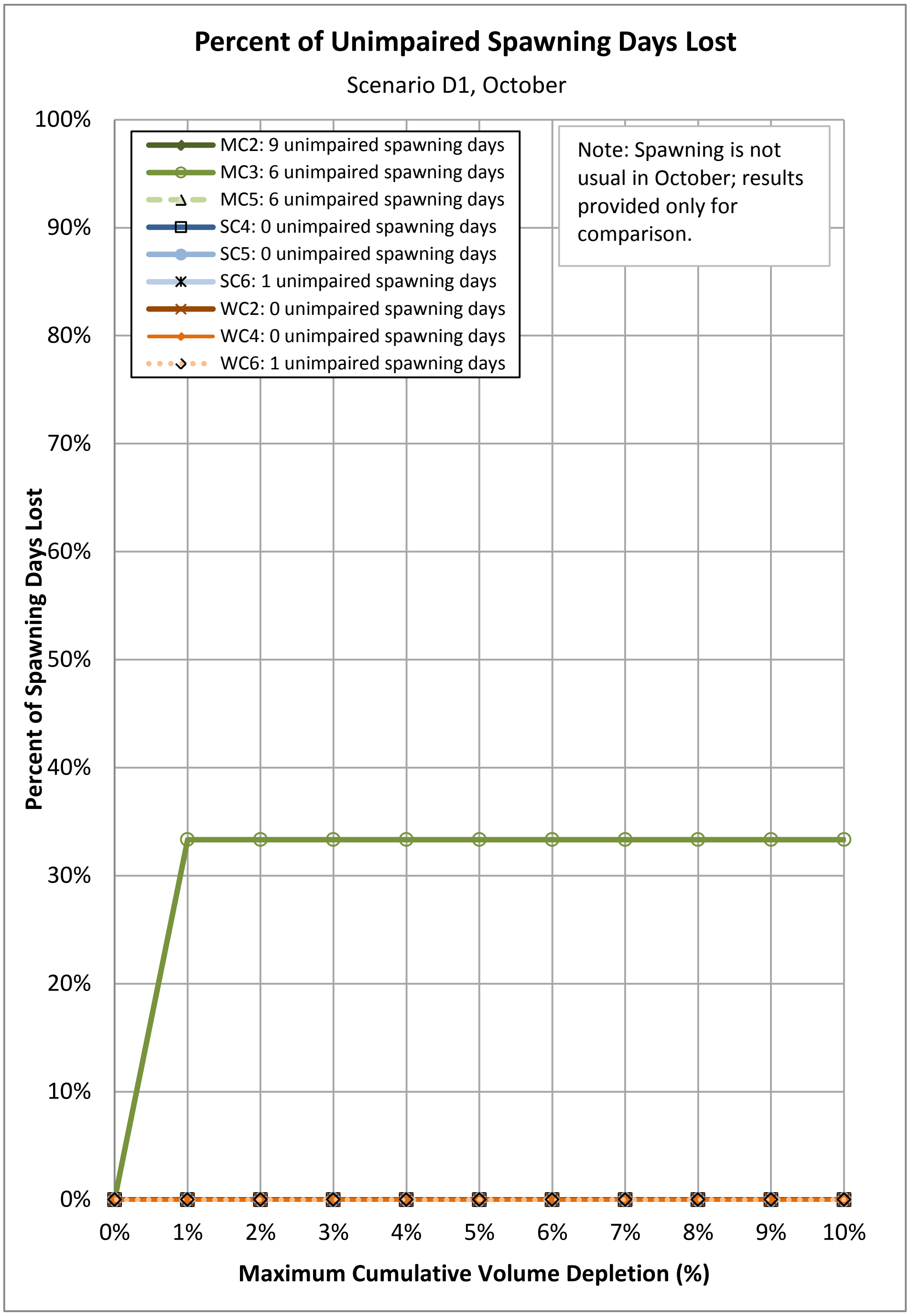

Fig. 5-4 **Distributed Scenario (D1): Percent of Unimpaired Spawning Days Lost in October**

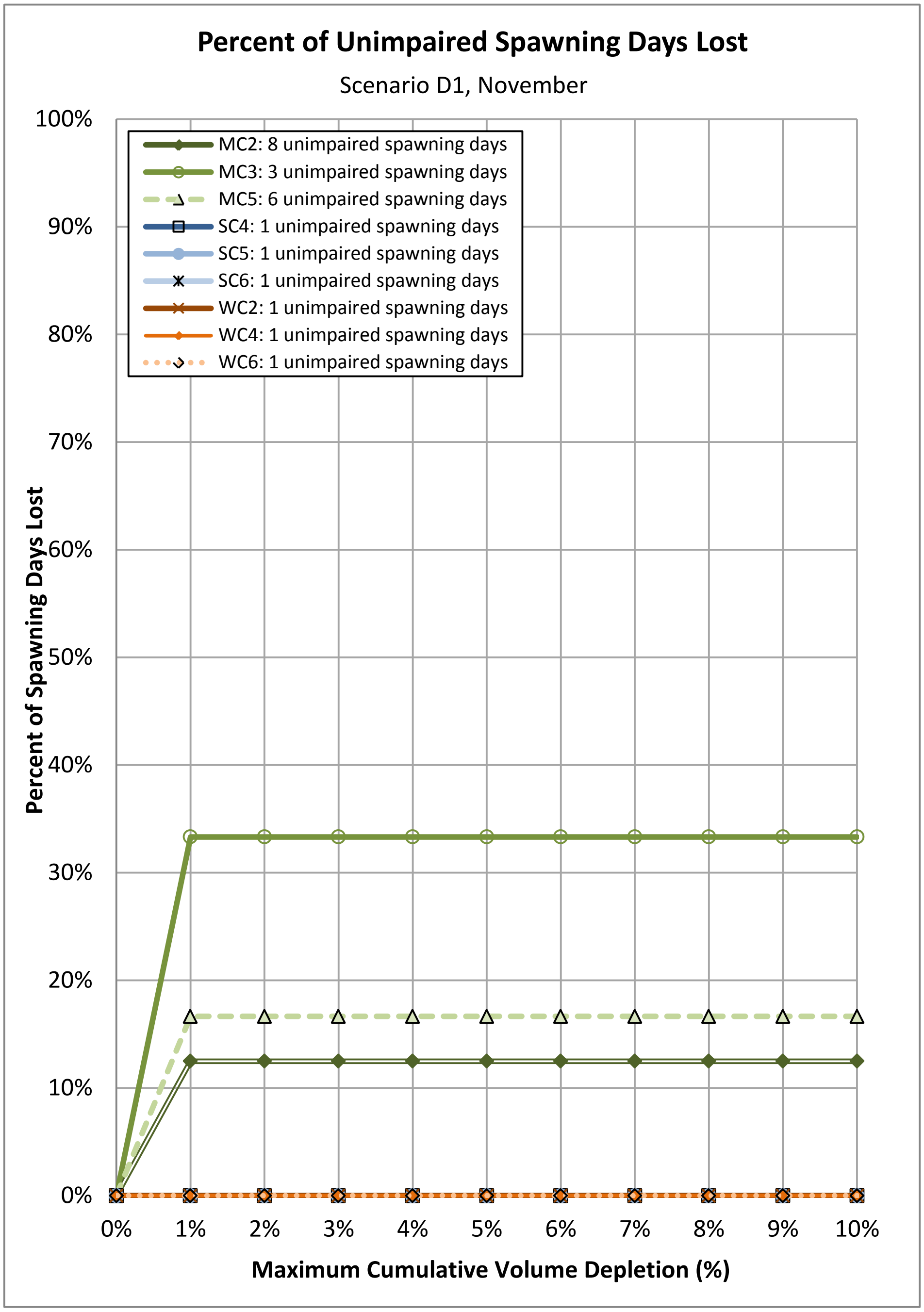

Fig. 5-5 Distributed Scenario (D1): Percent of Unimpaired Spawning Days Lost in November

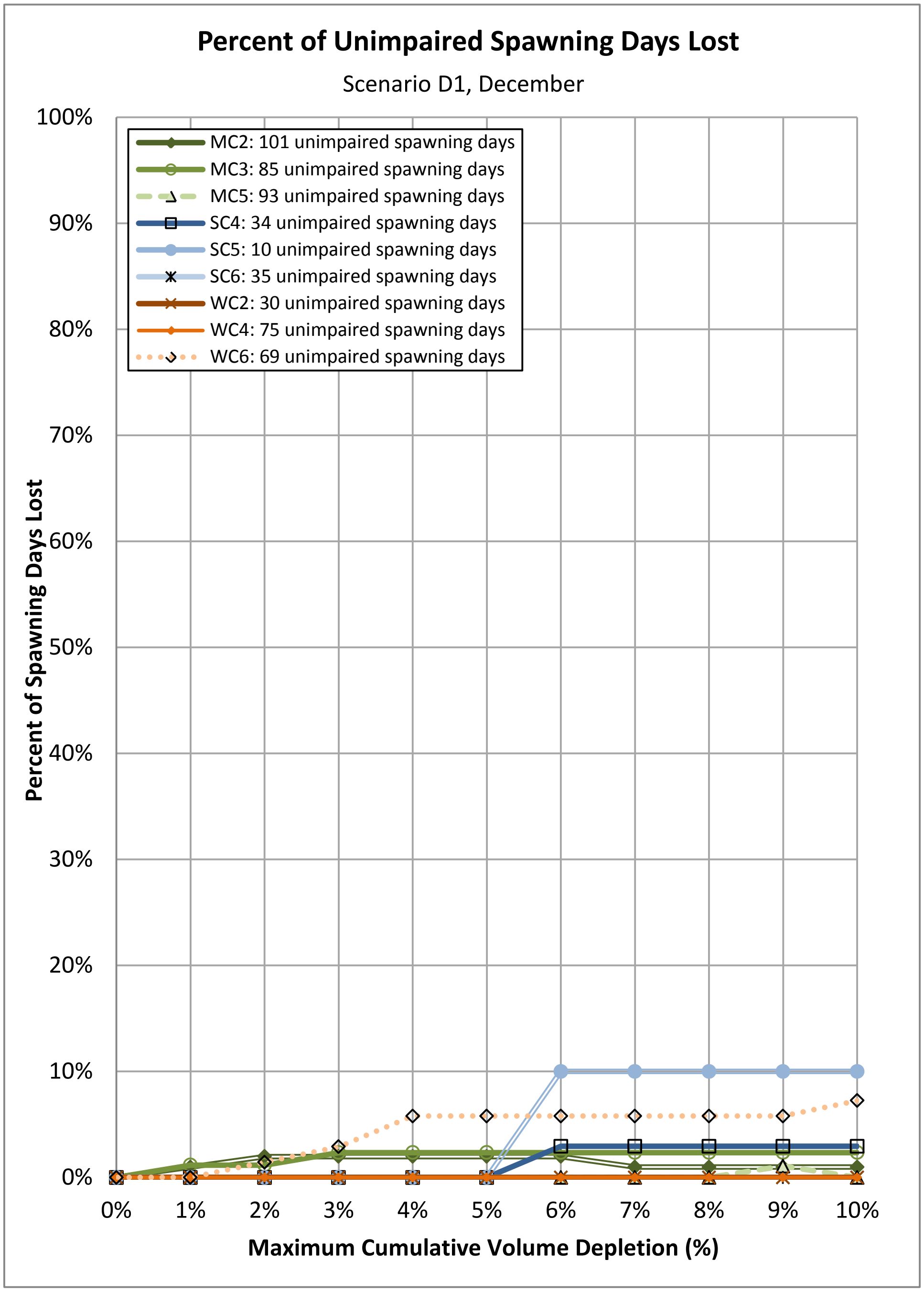

Fig. 5-6 **Distributed Scenario (D1): Percent of Unimpaired Spawning Days Lost in December**

5.1.2 Loss of Passage and Spawning Days for Lumped Scenario (D3)

The lumped scenario represents the highest calculated diversion that occurs under the Policy guidelines in A.1.8.3. Diversions are located just upstream of the ULAs, where the highest water availability occurs. Results from the lumped scenario represent the highest calculated diversions made under the Class II guidelines in Table 1-1.

Fig. 5-7, Fig. 5-8 and Fig. 5-9 show the percent of passage days lost during the months of October, November and December, respectively, for each percentage maximum cumulative volume depletion for the lumped scenario, based on the sum of days over the entire 10-year analysis period. Fig. 5-10, Fig. 5-11 and Fig. 5-12 show the percent of spawning days lost for each percentage maximum cumulative volume depletion for the lumped scenario during October, November and December, respectively. The percentage of passage and spawning days lost was computed in the same manner as described for the distributed results in Section 5.1.1. Results for subsequent months indicate lesser impacts (Appendix E), which are expected given that the simulated reservoirs fill during the October-December period, after which flows are bypassed.[13] The results show that most of the smaller streams are associated with reductions in spawning and passage days in excess of 10 percent during the period when reservoirs are filling. At most sites when the maximum cumulative depletion level is approximately 5% or higher, it is not until December that the loss of spawning and passage opportunities becomes relatively minor (Table 5-2). The impact appears to be minor to negligible in the three larger channels (Walker, Maacama, and lower Sonoma creeks).

These results show that, under the guidelines of Policy Section A.1.8.3, both passage and spawning days are impacted in streams near the upper limits of anadromy under the lumped diversion scenario (D3) during October and November especially. Throughout the development of the Policy, this low flow period was recognized to be critical in smaller streams for coho salmon and early migrating steelhead (SWRCB 1997; DFG-NMFS, 2000; DFG-NMFS, 2002) draft guidelines. Hence, the criteria of Policy Section A.1.8.3 for Class II streams appear to not be sufficiently protective as written because of impacts to passage and spawning opportunities during these early months. Potential solutions for reducing these impacts are discussed in Chapter 6.

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[13] This is consistent with findings in the original Policy development, in which the most severe impacts were expected during the period when reservoirs were filling (SWRCB, 1997;DFG-NMFS, 2000; DFG-NMFS, 2002).

Table 5-2 Lumped Diversion Scenario: Maximum Cumulative Volume Depletion Percentages above Which the Number of Impaired Spawning and Passage Days Lost Exceeds 10% of the Unimpaired Spawning and Passage Days, by Month from October through January

Site ID	Maximum Cumulative Volume Depletion At Which 10% Loss in Spawning Days Occurs (%)				Maximum Cumulative Volume Depletion At Which 10% Loss in Passage Days Occurs (%)			
	Oct[1,2]	Nov	Dec	Jan	Oct[2]	Nov	Dec	Jan
MC2	*1*	1	7	>10	1	1	6	>10
MC3	*1*	2	8	>10	>10	>10	>10	>10
MC5	*>10*	1	>10	>10	>10	>10	>10	>10
SC4	*n/a*	>10	>10	8	2	2	10	>10
SC5	*n/a*	>10	7	4	2	1	4	>10
SC6	*2*	>10	>10	>10	1	7	>10	>10
WC2	*n/a*	6	7	9	n/a	7	7	>10
WC4	*n/a*	>10	>10	>10	n/a	>10	>10	>10
WC6	*1*	7	9	>10	1	1	7	>10

Notes:

[1] Spawning is not usual in October; results provided only for comparison.

[2] n/a indicates no unimpaired passage or spawning days during that month.

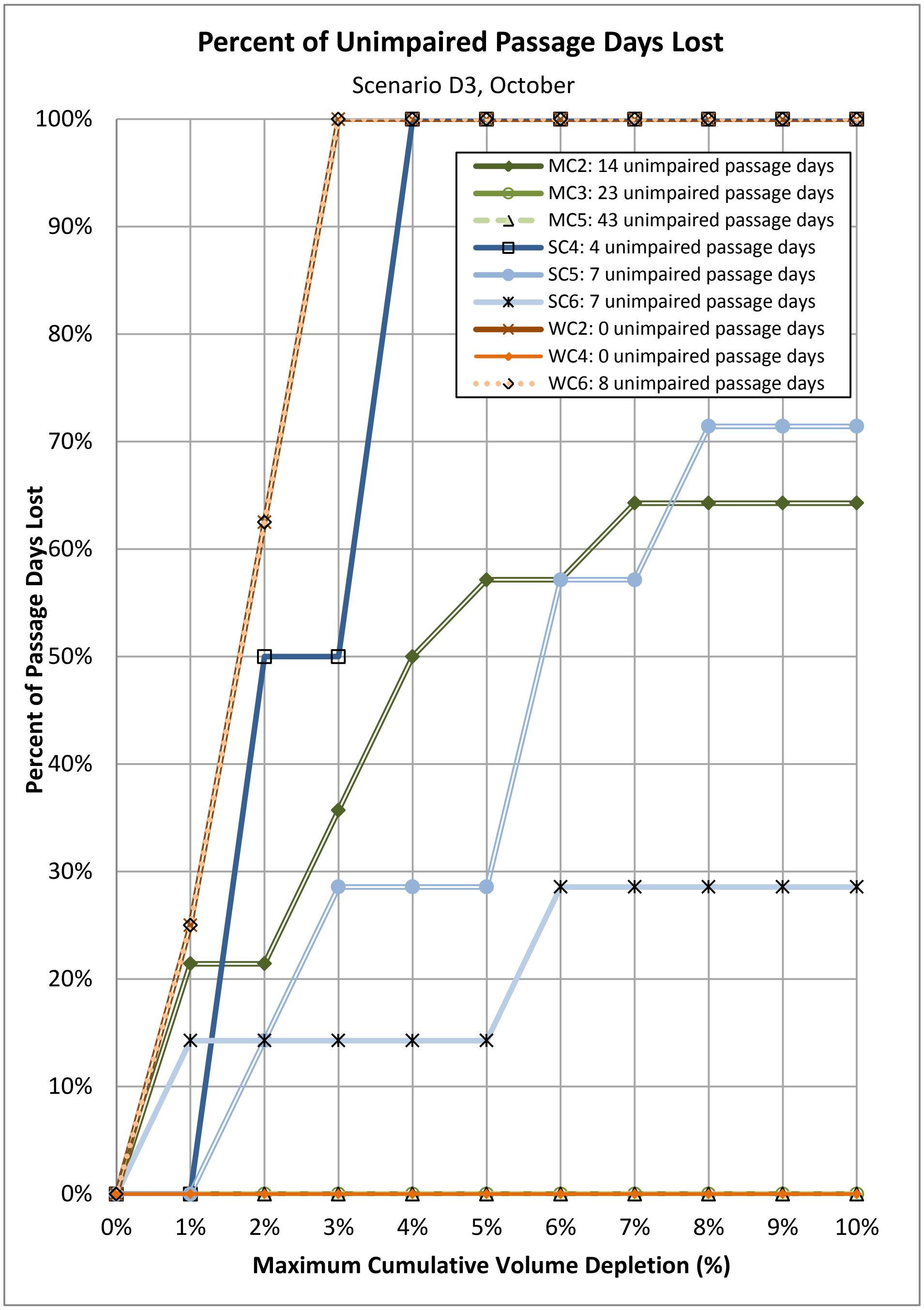

Fig. 5-7 **Lumped Scenario (D3): Percent of Unimpaired Passage Days Lost in October**

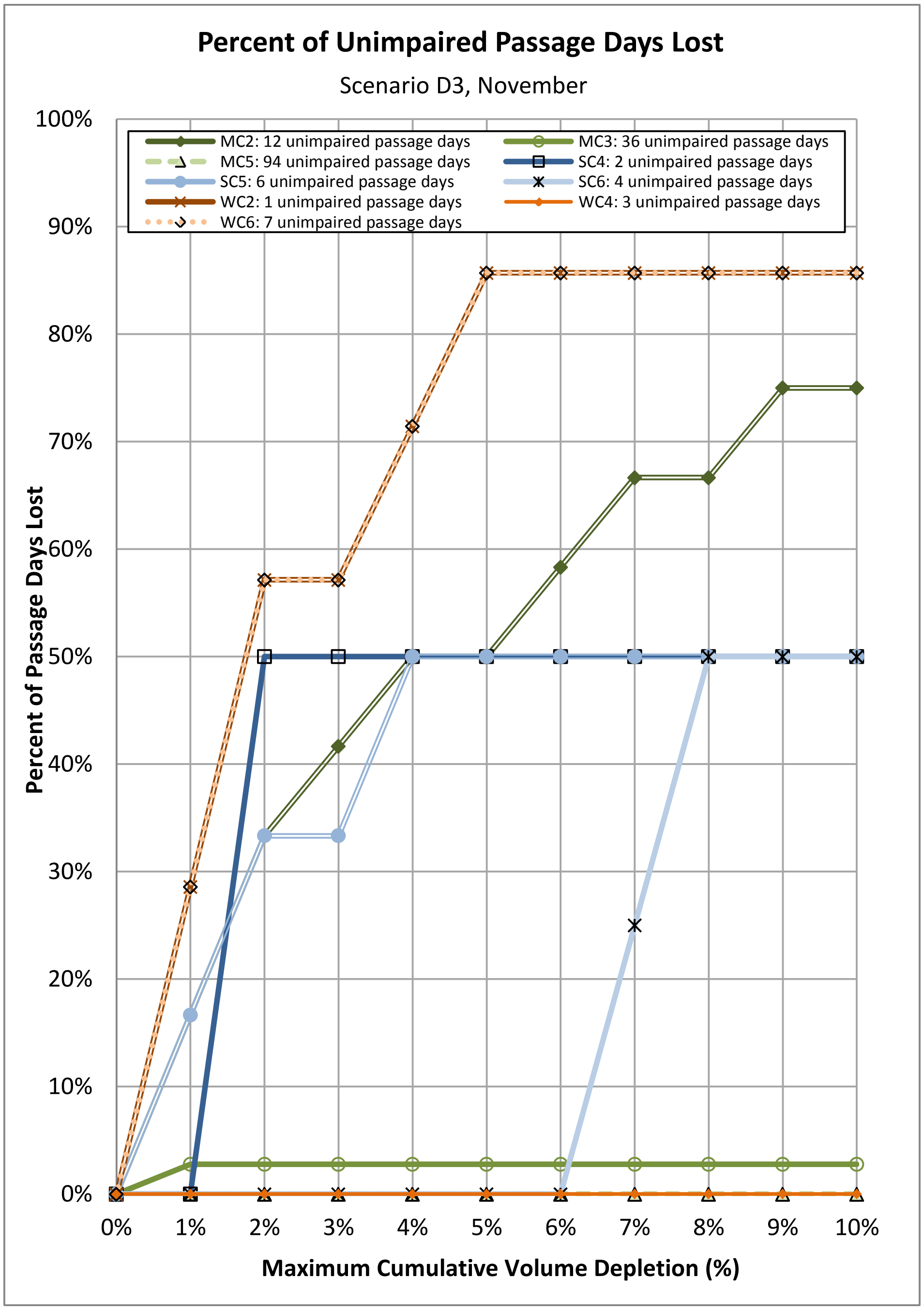

Fig. 5-8 **Lumped Scenario (D3): Percent of Unimpaired Passage Days Lost in November**

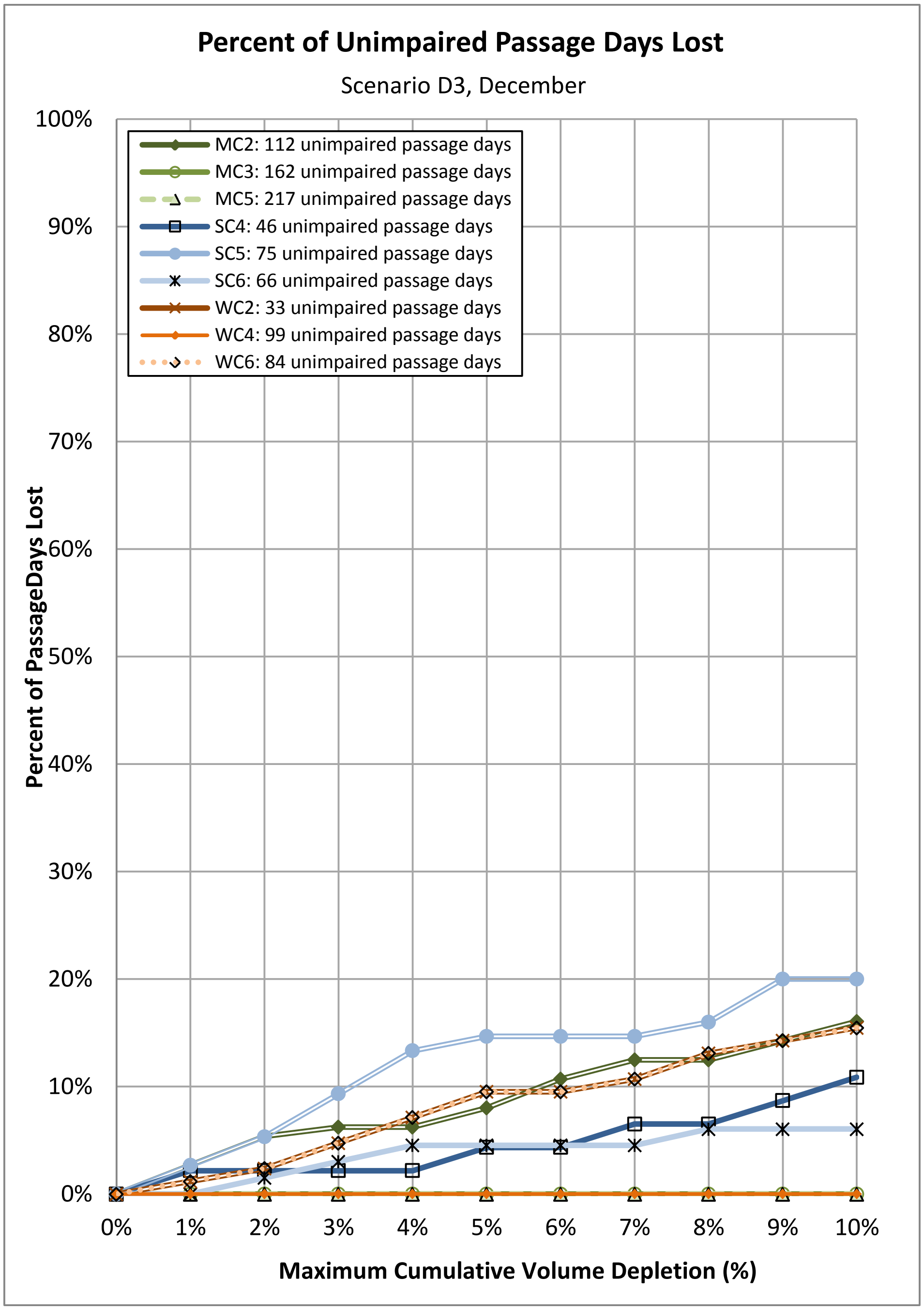

Fig. 5-9 **Lumped Scenario (D3): Percent of Unimpaired Passage Days Lost in December**

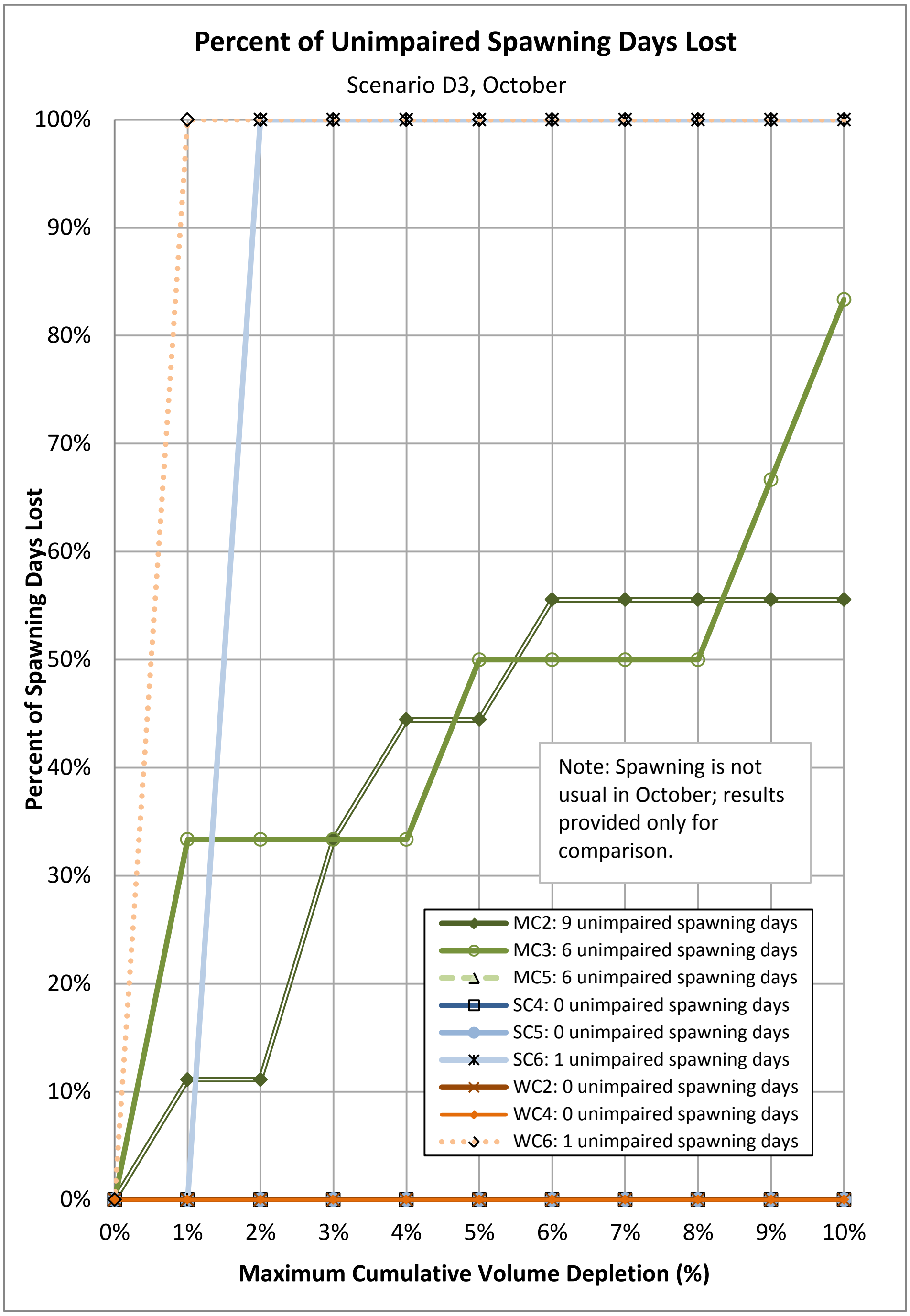

Fig. 5-10 Lumped Scenario (D3): Percent of Unimpaired Spawning Days Lost in October

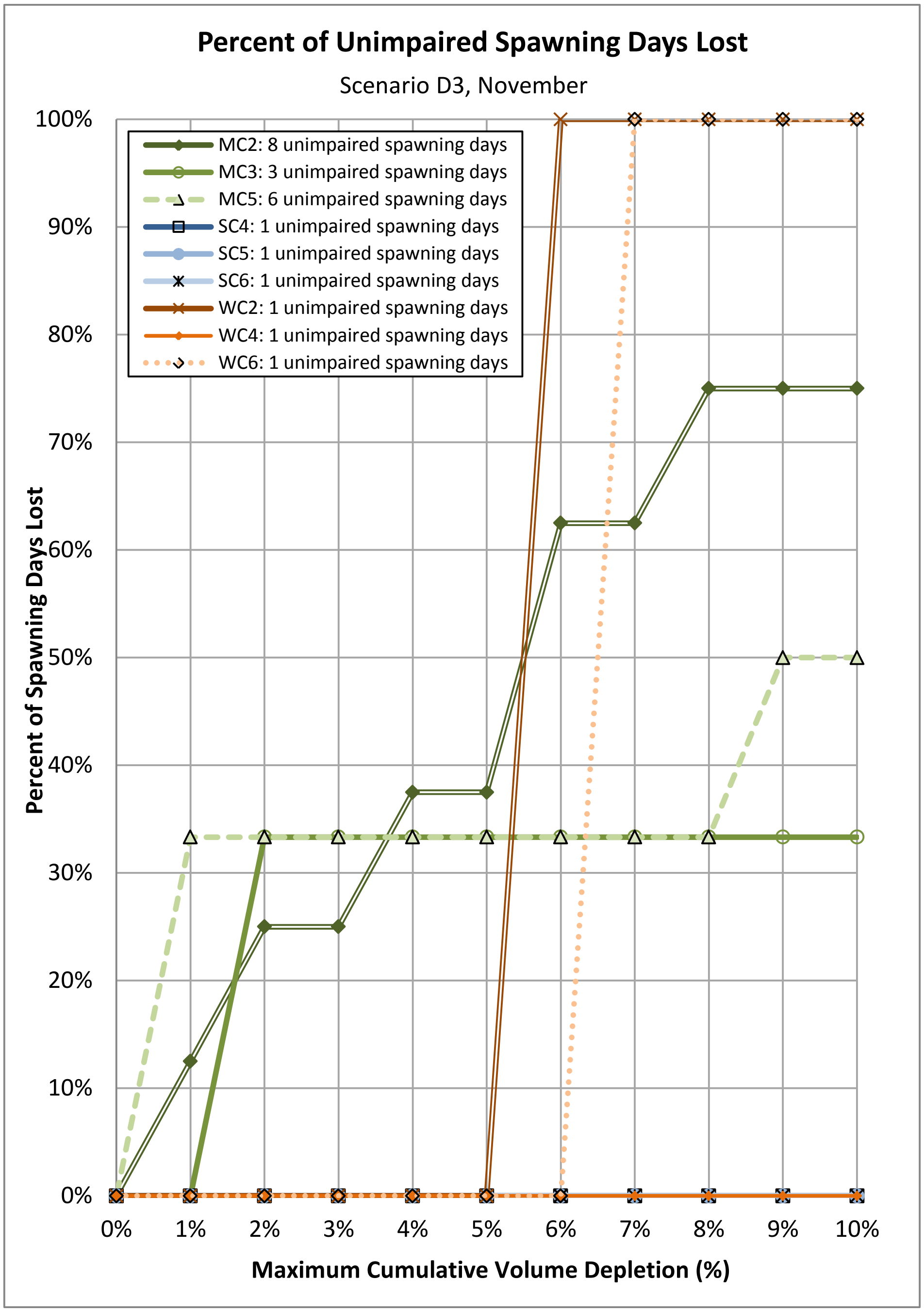

Fig. 5-11 Lumped Scenario (D3): Percent of Unimpaired Spawning Days Lost in November

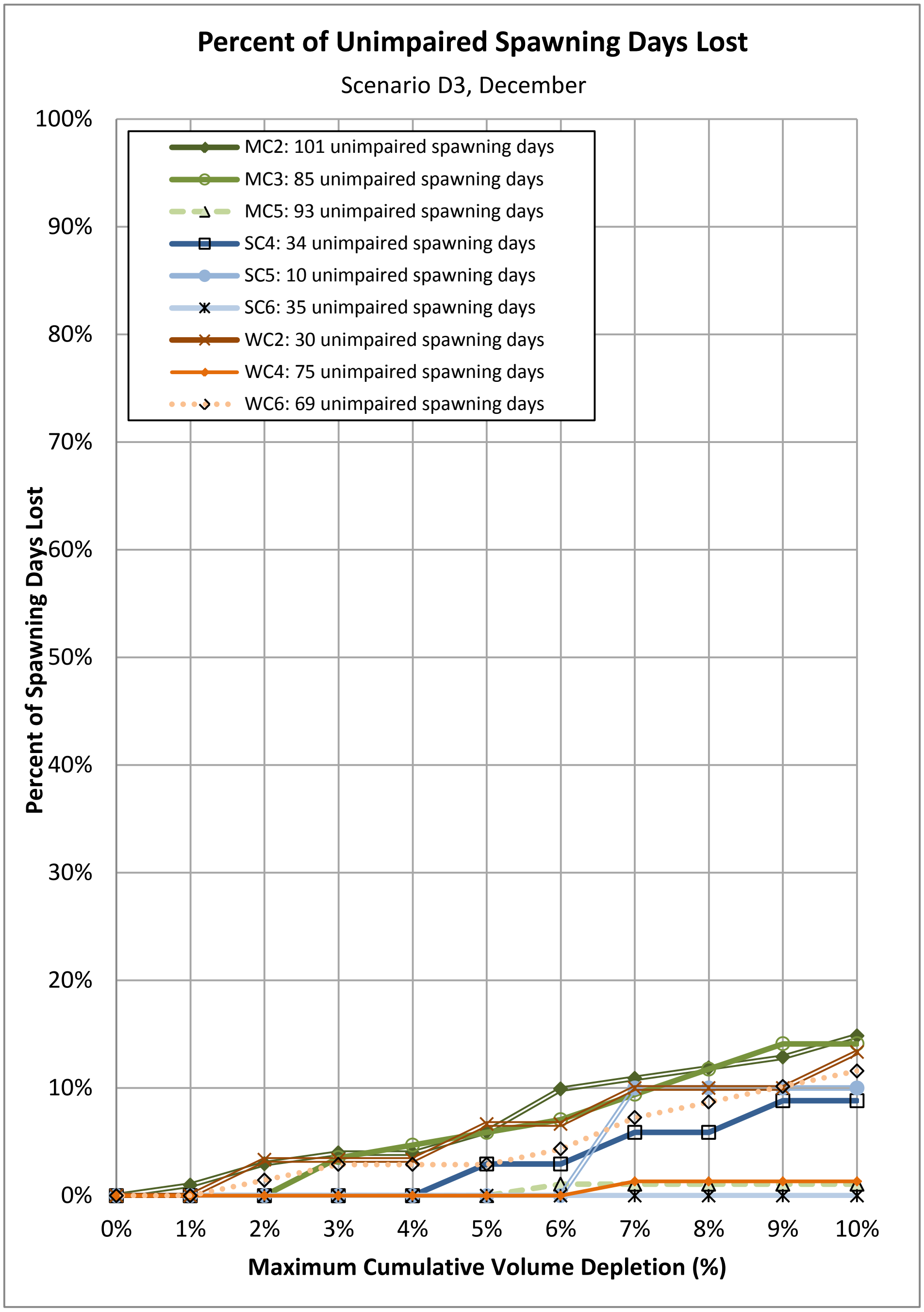

Fig. 5-12 **Lumped Scenario (D3): Percent of Unimpaired Spawning Days Lost in December**

5.2 Natural Flow Variability

The change in the 1.5-year flood magnitude was evaluated for the distributed diversion scenario (D1) and the lumped diversion scenario (D3) using the results from Section 4.3.6. At a 5% maximum cumulative volume depletion, Scenario D1 has an average reduction in 1.5-year flood magnitude of 2.8% and D3 has an average reduction of 14% (Table 5-3). At a 10% maximum cumulative volume depletion, the average reduction in 1.5-year flood magnitude increases to 3.8% for D1 and 17% for D3 (Table 5-4). The Policy established that a 5% reduction in 1.5-year flood magnitude is expected to be protective of natural flow variability (see Policy Sections A.1.8.1.3b, A.1.8.2 and A.1.8.4.2b).

Table 5-3 Percent Reduction in 1.5-year Flood Magnitude at 5% Maximum Cumulative Volume Depletion

Site	Percent Reduction in 1.5-year Flood Magnitude	
	Distributed Scenario (D1)	**Lumped Scenario (D3)**
MC2	3.2%	26%
MC3	2.4%	25%
MC5	0.7%	11%
SC4	3.5%	13%
SC5	3.3%	7%
SC6	2.2%	6%
WC2	2.6%	6%
WC4	<2.6%	0%
WC6	4.7%	30%
Average	**2.8%**	**14%**

Table 5-4 Percent Reduction in 1.5-year Flood Magnitude at 10% Maximum Cumulative Volume Depletion

Site	**Percent Reduction in 1.5-year Flood Magnitude**	
	Distributed Scenario (D1)	**Lumped Scenario (D3)**
MC2	3.9%	26%
MC3	3.4%	25%
MC5	0.8%	13%
SC4	5.0%	18%
SC5	4.8%	8%
SC6	3.6%	10%
WC2	2.9%	15%
WC4	<3%	5%
WC6	6.2%	30%
Average	**3.8%**	**17%**

As discussed in Appendix D of the Scientific Basis Report (R2 and Stetson, 2008), excessive diversions will, over the long term, result in channel adjustments toward establishment of a smaller channel, and thus reduced habitat area. In addition, the grain size distribution of bedload should also decrease in terms of the substrate median particle size (D_{50}). The analyses and literature reviewed suggested that a reduction in peak flow magnitudes associated with up to 5% of the 1.5-year flood magnitude should be protective of channel maintenance flows, and that changes in channel size and spawning habitat quality should be relatively small. At that level of reduction, changes in streambed slope should be negligible, and bankfull width and depth should change gradually. The grain size distribution may change most rapidly because the bed armor layer grain size distribution will reflect substrate mobility as influenced by the last few floods. Thus, as described in the Scientific Basis report, reductions in peak flow magnitudes associated with fill and spill reservoirs are likely to result in some degree of fining (i.e. a, general reduction in overall particle sizes) of the streambed surface armor layer in the near term (order of magnitude approximately <10 years), followed by a more gradual reduction in stream size as reflected by bankfull widths and depths (order of magnitude approximately 10-100 years, reflecting riparian zone adjustments as well).

A predictive relationship was developed for the Policy based on hydraulic geometry relations analyzed by Parker et al. (2003) and developed from empirical data collected in a multitude of streams. The relationship described the predicted average reduction in bankfull depth and width, and in substrate D_{50} in response to a reduction in the bankfull flow. The 1.5-year flood was argued to be a reasonable regional surrogate metric for bankfull flow. No acceptable threshold for diversion volume could be defined because in general, impacts to channel morphology are predicted to change commensurately with changes in bankfull flow over the likely range of diversion rates that would be permitted under the Policy. The data collected for this Study corroborated both the general form and magnitude of the relation for substrate size, as well as the absence of a clearly defined threshold level of diversion above which reductions in grain size occur at a greater rate (Fig. 5-13). The reduction in critical grain size was calculated relative to the size estimated for the unimpaired flood (Table 5-5; see also Section 3.3). The predicted change in critical grain size is generally consistent with the empirically-based relationship evaluated during development of the Policy. Accordingly, the relationship to predict reduction in grain size has been used to assess impacts due to reduction in 1.5-year flood magnitude for the distributed and lumped scenarios, as evaluated in Sections 5.2.1 and 5.2.2, respectively.

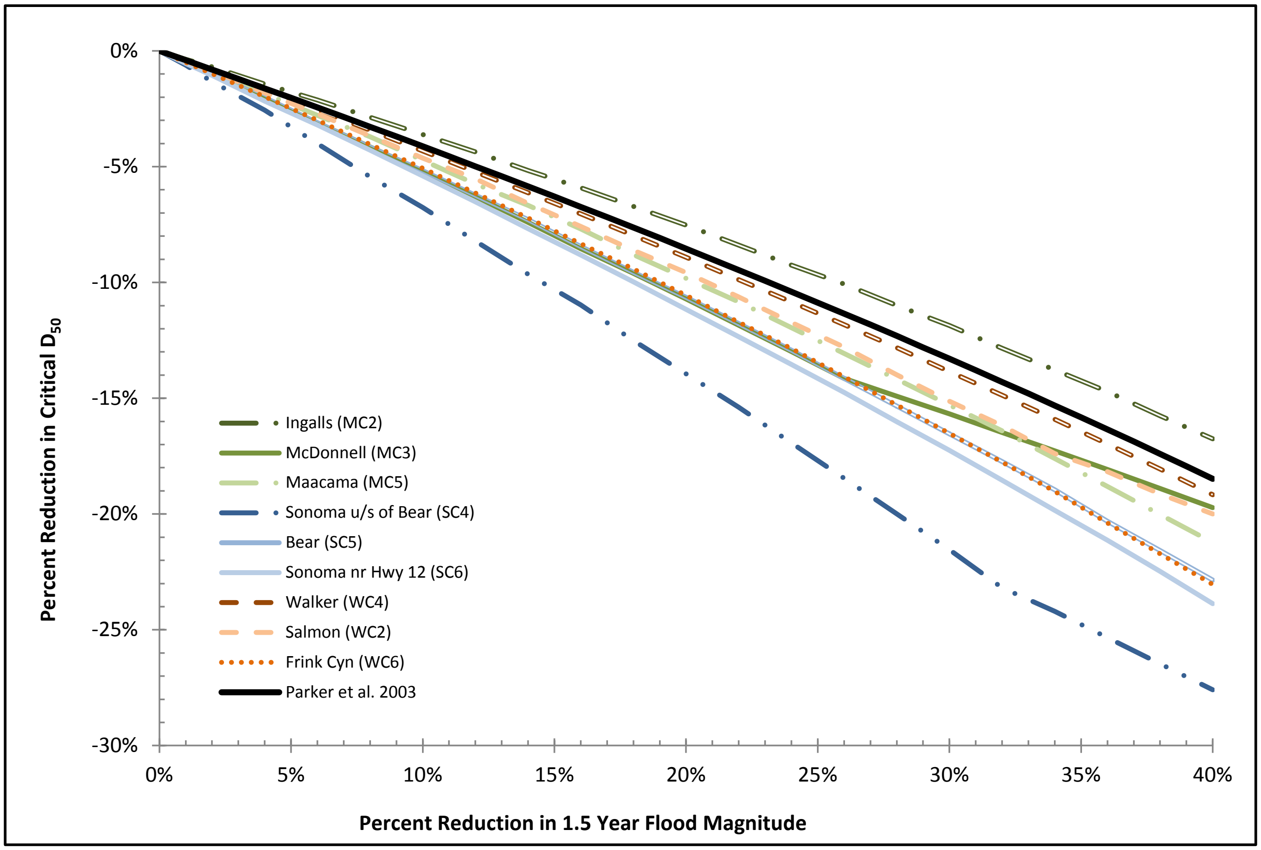

Fig. 5-13 **Predicted Reduction in Grain Size at Selected Spawning Transects with Predicted Reduction in the 1.5-year Flood Magnitude, and Comparison with Empirically Derived Relation (thick black line) Following Parker et al. (2003).**

Table 5-5 **Calculated Values of D_{50crit} in Spawning Gravel Deposits Sampled at Selected Spawning Transects for the Unimpaired 1.5-year Flood Magnitude**

Site	1.5-year Flood (cfs)	Transect	Slope	R (m)	D_{50crit} (mm)
MC2	204	S1	0.0520	0.37	247
MC3	376	S4	0.0094	0.72	86
MC5	1,591	S3	0.0005	1.67	11
SC4	83	S1	0.0016	0.47	10
SC5	61	S1	0.0055	0.50	35
SC6	209	S2	0.0061	0.58	46
WC2	62	S2	0.0070	0.32	29
WC4	910	S1	0.0040	1.08	56
WC6	191	S4	0.0084	0.61	66

Note:

Grain sizes were calculated assuming $\tau^*crit = 0.047$

5.2.1 Natural Flow Variability in Distributed Scenario (D1)

Under Scenario D1, which reflects distributed diversions on Class III streams, the average reduction in 1.5-year flood magnitude is less than 5% at all nine sites (Table 5-3). At a 10% maximum cumulative volume depletion, the reduction in 1.5-year flood averages less than 5% at the nine sites, but exceeds 5% at one site, WC6 (Table 5-4).

The estimated reductions in the 1.5-year flood magnitude associated with Scenario D1 appear to pose a minor to negligible risk of impacting channel maintenance processes. The reasoning for this conclusion is as follows:

- As shown in Table 5-6, the predicted reductions in the 1.5-year flood magnitude translated to small reductions in critical grain size. If it is assumed that the change in critical grain size scales comparably to the actual grain size of the spawning gravel deposit sampled in the field at the same location, then any reduction in future D_{50} of pebble counts would similarly be expected to be small. In all nine sites, the corresponding reduction in grain size is about 1 mm or less.
- The present spawning gravel deposit D_{50} values (Table 5-6) are within the central range of suitable spawning gravel sizes for steelhead and coho (Table 3-2), and thus the reduction of 1 mm and less at all sites is taken to mean that any effects of the distributed scenario (D1) on spawning habitat quality will be negligible.
- Given that the site-specific results depicted in Fig. 5-13 corroborate the Policy's basis for relating channel maintenance processes in terms of grain size, and the inter-related nature of grain size and channel size predicted by Parker et al. (2003), we infer that significant reductions in channel size would also not be expected.

The guidelines in A.1.8.3 for Class III streams with maximum cumulative volume depletion no greater than 5% are protective of natural flow variability. For Class III streams with a maximum cumulative volume depletion greater than 5% but no more than 10%, the guidelines in A.1.8.3 are also protective and no additional conditions are necessary to protect natural flow variability.

Table 5-6 Predicted Reduction in Median grain size (D_{50}) of Sampled Spawning Deposits Based on Percent Reduction in Critical Grain Size Associated with Scenario D1 Diversions

Site	Percent Reduction in 1.5-year Flood Magnitude		Spawning Gravel Deposit Pebble Count D_{50} (mm)	Percent Reduction in D_{50crit}, Spawning Gravel D_{50}		Predicted Long Term Spawning Gravel D_{50} (mm)	
	5% max cumulative vol depl.	10% max cumulative vol depl.		5% max cumulative vol depl.	10% max cumulative vol depl.	5% max cumulative vol depl.	10% max cumulative vol depl.
MC2	3.2%	3.9%	17	1.1%	1.4%	17	17
MC3	2.4%	3.4%	18	1.4%	1.8%	18	18
MC5	0.7%	0.8%	34	0.4%	0.4%	34	34
SC4	3.5%	5.0%	18	2.3%	3.3%	18	17
SC5	3.3%	4.8%	16	1.7%	2.4%	16	16
SC6	2.2%	3.6%	26	1.2%	2.0%	26	25
WC2	2.6%	2.9%	21	1.1%	1.3%	21	21
WC4	<2.6%	<3%	20	1.1%	1.3%	20	20
WC6	4.7%	6.2%	25	2.4%	3.1%	24	24

5.2.2 Natural Flow Variability in Lumped Scenario (D3)

Under Scenario D3, which has diversions just upstream of the ULAs on Class II streams, the reduction in 1.5-year flood magnitude averages 14% for a 5% maximum cumulative volume depletion and 17% for a 10% maximum cumulative volume depletion, with a range of 5%-30% at the 10% volume depletion level (Table 5-3). This magnitude of reduction in flood frequency is not considered to be protective of natural flow variability under the Policy.

The resulting changes in grain size predicted based on hydraulic measurements and analysis are relatively large (Table 5-7). The changes are not negligible in most of the smaller streams, and it may be expected that commensurate reductions in channel size would be expected as well based on the corroboration depicted in Fig. 5-13. Because of this, Class II streams under Policy Section A.1.8.3 appear to require additional conditions to be protective of natural flow variability.

Table 5-7 Predicted Reduction in Median grain size (D_{50}) of Sampled Spawning Deposits Based on Percent Reduction in Critical Grain Size Associated with Scenario D3 Diversions

Site	Percent Reduction in 1.5-year Flood Magnitude		Spawning Gravel Deposit Pebble Count D_{50} (mm)	Percent Reduction in D_{50crit}, Spawning Gravel D_{50}		Predicted Long Term Spawning Gravel D_{50} (mm)	
	5% max cumulative vol depl.	10% max cumulative vol depl.		5% max cumulative vol depl.	10% max cumulative vol depl.	5% max cumulative vol depl.	10% max cumulative vol depl.
MC2	26%	26%	17	10%	10%	15	15
MC3	24%	25%	18	13%	14%	16	15
MC5	11%	13%	34	5.2%	6.2%	32	32
SC4	12%	18%	18	8.2%	13%	17	16
SC5	6.6%	8.2%	16	3.4%	4.3%	15	15
SC6	5.7%	9.6%	26	3.1%	5.2%	25	25
WC2	6.5%	15%	21	3.0%	7.1%	20	20
WC4	0.0%	5.2%	20	0.0%	2.2%	20	20
WC6	30%	30%	25	17%	17%	21	21

5.3 Dewatering of Class II Streams

The guidelines in Policy Section A.1.8.3 allow for some diversions on Class III streams without a season of diversion, MBF, or maximum diversion rate. As summarized in Table 1-1, PODs on Class III streams are permitted to divert water without any restrictions if the maximum cumulative volume depletion is less than or equal to 5%. Dewatering of Class II streams due to these unrestricted diversions on Class III streams was considered as a potential impact of the alternative guidelines.[14]

Due to their locations in the headwaters, Class III streams have small drainage areas which provide only limited flows. The results of the hydrologic models prepared for this Study show that flow at the ULA,

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[14] Note that for all Class II diversions and for Class III diversions with a maximum cumulative volume depletion greater than 5%, the A.1.8.3 guidelines require an MBF. These bypassed flows are protective of dewatering on Class II streams. Accordingly, the evaluation in Section 5.3 only considers the case when an MBF is not required (Class III streams with maximum cumulative volume depletion less than or equal to 5%).

which is generally the downstream limit of Class II streams, is primarily composed of runoff to the Class II stream with relatively small flow contribution from upstream Class III streams. For example, the McDonnell Creek tributary in the Maacama Creek study basin has four headwaters PODs (see Fig. 4-2). The total average annual unimpaired flow at those four headwaters PODs is about 150 ac-ft per year. At the ULA located on McDonnell Creek downstream of those headwaters PODs, the average annual unimpaired flow is 1,850 ac-ft per year. The contribution from the headwaters represents only about 8% of the annual flow at the ULA. Local inflow to the Class II stream is the most significant component of streamflow on the Class II stream.

In addition, results from the distributed flow scenario (D1) show that as the maximum cumulative volume depletion increases, calculated diversions on Class III streams are limited by the water availability. Therefore, even if a high maximum cumulative volume depletion were permitted on the Class III stream, the water is not available at the Class III PODs to satisfy the desired level of diversion, which further limits the impact of these diversions. For example, if 10% maximum cumulative volume depletion were permitted at the four headwaters PODs in the McDonnell Creek tributary in the Maacama Creek study basin, the allowable maximum volume depletion is 74 ac-ft per year, but the calculated diversions average 56 ac-ft per year during the 10-year study period. The calculated diversions are 76% of the maximum cumulative volume depletion, demonstrating that the water is limited at those PODs.

The highest potential for dewatering a Class II stream would occur if the entire maximum cumulative volume depletion with no MBF requirement were permitted at a single Class III POD immediately upstream of the Class II/III stream boundary. At times when the Class III reservoir is filling, diversions at this POD could dewater the reach directly downstream of the POD. However, inflow to the Class II stream downstream of the POD will limit the distance of the reach over which this occurs. Therefore, model predictions suggest that dewatering of a Class II stream could only occur under the guidelines in Policy Section A.1.8.3 under a highly specific and unlikely diversion scenario, with potential dewatering occurring over a short time period and limited reach length. Because of this, potential impacts related to stream dewatering are not significant.

5.4 Re-filling of Reservoirs for Frost Protection

The model scenarios described in the previous sections all assume a single filling of each reservoir during each water year. That is, each reservoir is filled starting October 1 using the first available water, and once filled, no additional diversions are taken. However, some permits within the Policy Area allow for re-filling of a reservoir in order to provide water for frost protection in March, April and May. Some future applications for water within the Policy area are also expected to request diversions for frost protection.

For frost protection, reservoirs are primarily re-filled during March, April and May. During these months, passage and spawning[15] are not critical; rather, water temperature and downstream migration flow pulses are important habitat attributes for juvenile salmon and steelhead. As was discussed in the Scientific Basis report (R2 and Stetson, 2008), regional criteria for temperature and downstream migration are not readily established. Instead, criteria for temperature are highly specific to particular

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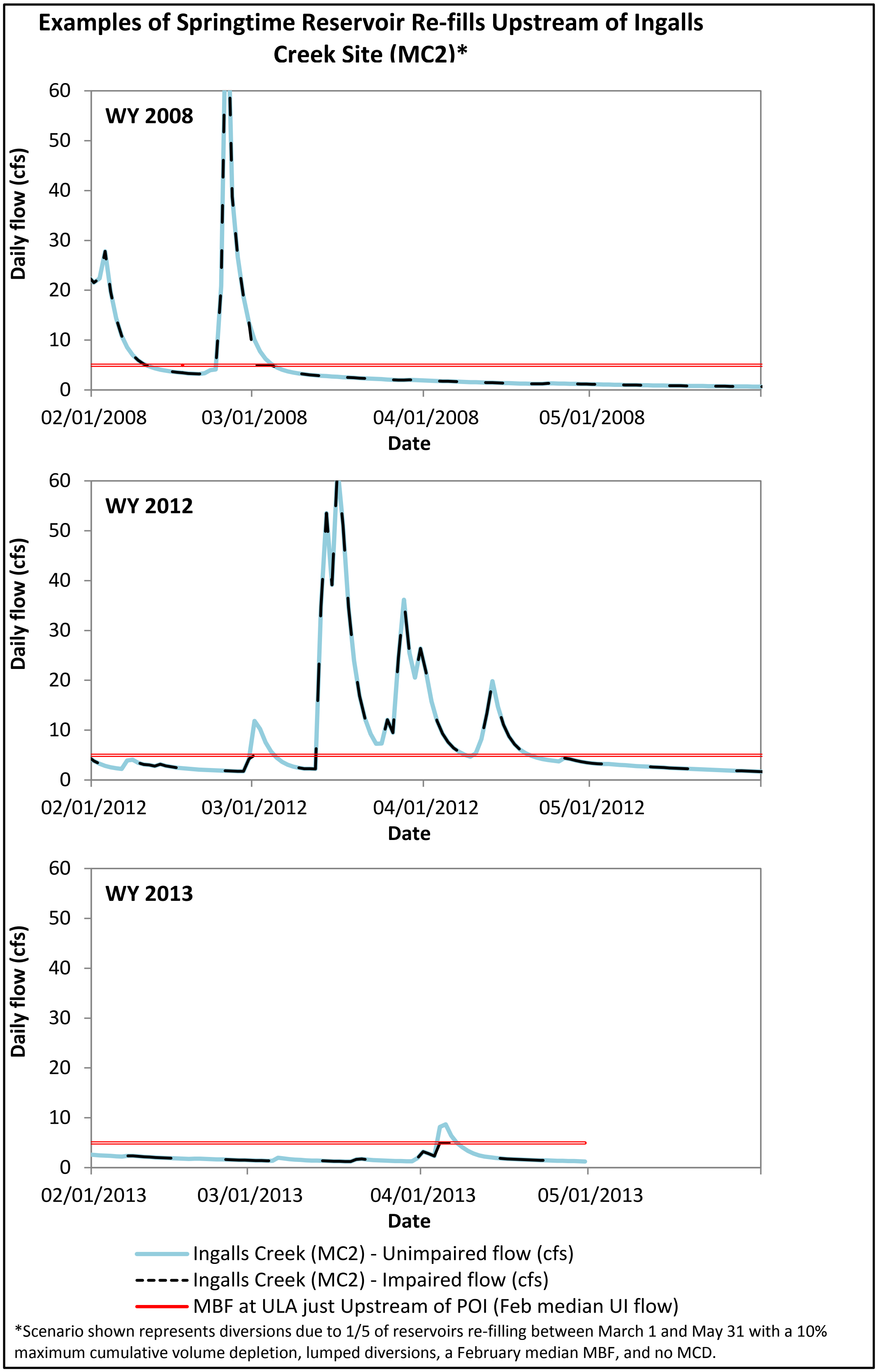
[15] Even though passage and spawning are not critical in March, April and May, an analysis was performed to verify that re-filling of reservoirs during these months would not cause significant impacts to flows. Following the procedures described in Section 4.3, a model scenario was created to re-fill 20% of the reservoirs (PODs) during March, April and May using the lumped diversion scenario. Results were computed for the range of volume depletions from 0% to 10%. At each site, reduction in passage and spawning days did not exceed 10% in any of the three months.

habitat sites based on channel size, physiography, hydrology, riparian vegetation, and microclimate. Criteria for downstream migration flow pulses are also difficult to define (e.g., see Appendix D in Stetson and R2, 2008).

The key attribute of flow during this period appears to be the occurrence of a relatively rapid, definable increase over base flow during outmigration months (peak period is March through May for steelhead, coho and Chinook; see Appendix C of Stetson and R2 2008), but criteria are not easily established in terms of how much the increase should be and for how long. Another complicating factor is that the timing of when pulses occur will vary depending on the hydrologic year type and precipitation patterns. For example, the pulses may occur in March but not later, throughout April and May, or not at all specific to particular habitat sites. Fig. 5-14 shows examples of three water years of flow in March, April and May at one of the study sites. The figure also shows when diversions for re-filling for frost protection might occur. The three panels illustrate the differences in timing and patterns of flow which occur during the frost protection season. It is clear that in 'drier' years, re-filling can have a significant impact on the occurrence of pulse flows in any of these months.

A suitable criterion for frost protection diversions cannot be developed readily for the policy area without significant additional study and analysis. Given the various sources of uncertainty that influence the definition of an appropriate regional pulse flow criterion, whatever criterion is ultimately specified should be conservative. Because water temperature problems are most likely to be observed during base flow periods between springtime pulses (e.g., Fig. 5-15), it appears that a higher MBF would be needed for the March 31-May 31 period than is presently prescribed under the Policy.


Examples of Springtime Reservoir Re-fills Upstream of Ingalls Creek Site (MC2)*

*Scenario shown represents diversions due to 1/5 of reservoirs re-filling between March 1 and May 31 with a 10% maximum cumulative volume depletion, lumped diversions, a February median MBF, and no MCD.

Fig. 5-14 **Examples of Temporal and Annual Variability of Timing of Flow Pulses during the Outmigration Period of Juvenile Steelhead and Salmon**

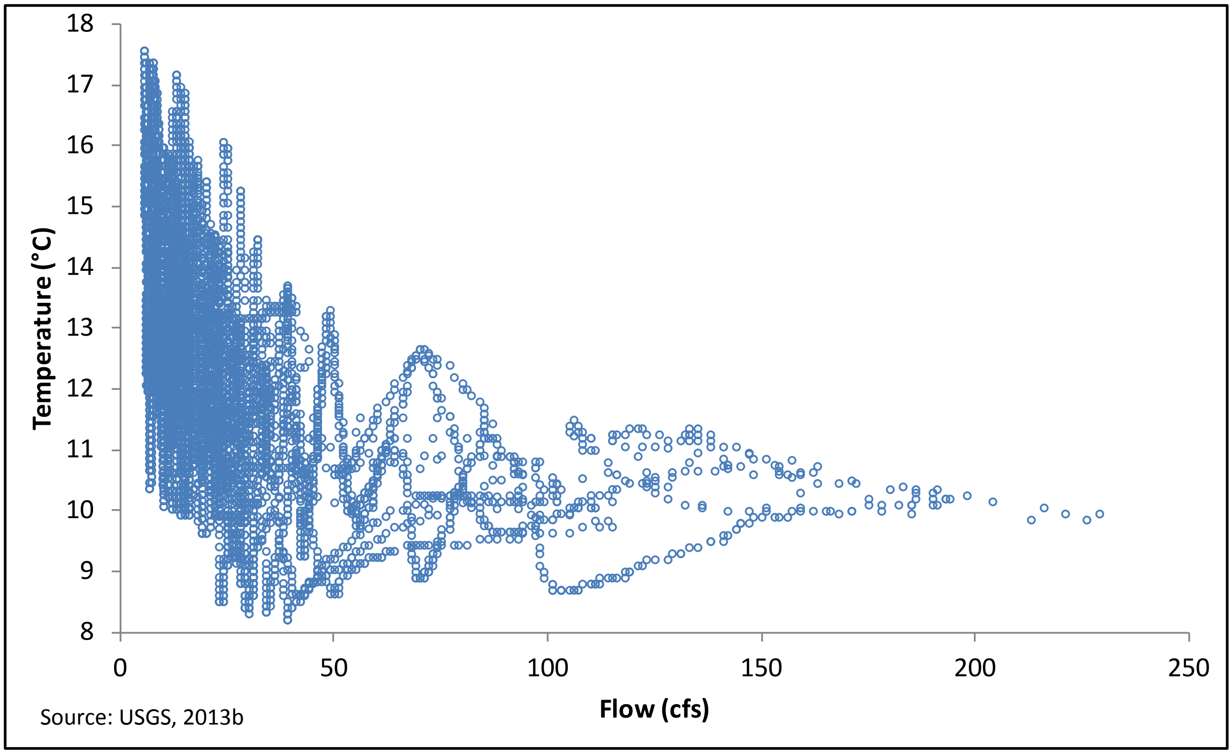


Fig. 5-15 **Example of Springtime Relationship between Flow and Water Temperature, March 1 – June 1, 2010 at USGS gage # 11458433 (Sonoma Creek at Kenwood).**

5.5 Protectiveness of A.1.8.3 Guidelines - Summary

5.5.1 Class III Streams

The A.1.8.3 guidelines for Class III streams were tested in this analysis using the distributed diversion scenario (D1). The results for passage and spawning days (Section 5.1.1) show that limited impacts to spawning are predicted to occur in November (Fig. 5-5) at three sites. For all other months, the reduction in passage and spawning days is equal to or less than 10% at all sites for maximum cumulative volume depletions of 10% or less. These results indicate that the Class III guidelines are likely to be regionally protective of passage and spawning.

The flood frequency analysis for Scenario D1 (Section 5.2.1) shows that, up to a maximum cumulative volume depletion of 10%, the reduction in 1.5-year flood magnitude averages less than 5%. Results of the Scenario D1 analysis indicate that the A.1.8.3 guidelines are protective of natural flow variability. Dewatering of Class II streams was also assessed to be a negligible impact.

In conclusion, the A.1.8.3 guidelines are protective for maximum cumulative volume depletion up to 5%. For maximum cumulative volume depletion greater than 5% but no more than 10%, the A.1.8.3 guidelines are also protective and no additional conditions are recommended for implementation under option 3 of the A.1.8.3 requirements for Class III streams.

5.5.2 Class II Streams

The A.1.8.3 guidelines for Class II streams were tested in this analysis using the lumped diversion scenario (D3). The results for passage and spawning days (Section 5.1.2) show that significant percentages (>10%) of passage and spawning days are lost in October and November due to diversions on Class II streams (see, for example, Fig. 5-7, Fig. 5-8 and Fig. 5-11 in which percent of days lost exceeds 10% at most sites). In fact, the results show that significant impacts occur at maximum cumulative volume depletions as low as 1 to 2%. These results indicate that the A.1.8.3 rules for Class II streams would not be protective of passage and spawning without additional conditions.

In addition, the flood frequency results show that, under Scenario D3, the reduction in 1.5-year flood magnitude would be on the order of 15% on average for all study sites, significantly higher than the 5% threshold permitted in the Policy. Therefore, the A.1.8.3 guidelines for Class II streams would not be protective of natural flow variability without additional conditions.

Overall, the A.1.8.3 guidelines as written for Class II streams appear not protective for maximum cumulative volume depletions from 0 to 10%.[16] Chapter 6 outlines additional scenarios, including additional Policy elements, which were evaluated to determine additional protective conditions for Class II streams.

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[16] Even though significant impacts were observed for Scenario D3 at maximum cumulative volume depletion equal or less than 5% or less, the additional conditions developed in this Study per Policy Section A.1.8.3 (option 3 under Class II streams) only apply to cases with maximum cumulative volume depletions of greater than 5% but no more than 10%. Any additional conditions recommended for maximum cumulative volume depletions equal to or less than 5% would have to be implemented through a revision to the Policy.

6 Protective Conditions for Class III and II Streams

The purpose of this Study is to evaluate the regional protectiveness of the volume depletion approach outlined in Policy Section A.1.8.3. In particular, Policy Sections 10.4.1 and A.1.8.3 state that this Study will develop any additional conditions necessary to protect fishery resources affected by diversions on Class II and Class III streams in cases in which the maximum cumulative volume depletion is greater than 5% but no more than 10%. Upon completion of this Study, as per Policy Sections 10.4.1 and A.1.8.3, the additional conditions recommended in this Study will be available to applicants under the A.1.8.3 guidelines as an option for obtaining a permit or license.

For cases in which the maximum cumulative volume depletion is less than 5%, the guidelines in Policy Section A.1.8.3 will remain in effect regardless of the findings of this Study. Additional conditions have been recommended and the State Water Board may consider adding these conditions when they consider revising the Policy at a later time.

Table 6-1 summarizes the findings on protectiveness for each stream class and level of maximum cumulative volume depletion. For Class III streams, the A.1.8.3 guidelines appear to be regionally protective for maximum cumulative volume depletions ranging from 0% to 10%. No additional conditions are required for Class III streams.

On Class II streams, the A.1.8.3 guidelines were found not protective for all cases. Recommendations for additional conditions have been developed for maximum cumulative volume depletions equal or less than 5% and the State Water Board may consider adding these criteria when they consider revising the Policy at a later time. Per Option 3 for Class II streams in Policy Section A.1.8.3, additional conditions have been developed for Class II streams in which the maximum cumulative volume depletion is greater than 5% but no more than 10%.

The remainder of this chapter focuses on the additional conditions that should be used for Class II streams with maximum cumulative volume depletion greater than 5% but no more than 10%.

Table 6-1 Findings on Protectiveness of Policy Elements in Policy Section A.1.8.3

Stream Class	Maximum Cumulative Volume Depletion	Policy Elements Required under Section A.1.8.3			Findings on Protectiveness of Policy Elements
		Diversion Season	MBF	MCD	
Class III	<=5%	None	None	None	Regionally protective of passage, spawning and natural flow variability
	>5%, <=10%	None	February Median Unimpaired Flow	None	Regionally protective of passage, spawning and natural flow variability
Class II	<=5%	None	February Median Unimpaired Flow	None	Not regionally protective; additional conditions recommended.[1]
	>5%, <=10%	None	February Median Unimpaired Flow	None	Not regionally protective; additional conditions required.[2]

Notes:

[1] Recommendations only; additional criteria may only be applied through a revision of the Policy.

[2] Per Option 3 for Class II streams in Section A.1.8.3, these additional conditions become effective upon completion of this Study.

6.1 Protective Conditions for Class III Streams

The results in Chapter 5 show that for Class III streams, the A.1.8.3 guidelines as written are expected to be protective of passage, spawning, natural flow variability and dewatering of Class II streams. No additional conditions are required. For Class III streams with maximum cumulative volume depletion greater than 5% but no more than 10%, the following policy elements apply:

- No diversion season
- February median unimpaired flow MBF
- No MCD

6.2 Protective Conditions for Class II Streams

For Class II streams, the A.1.8.3 guidelines as written are not protective and additional conditions were investigated.

6.2.1 Additional Policy Elements Investigated

Under the A.1.8.3 guidelines as written, the only Policy element related to diversion restriction applied to Class II streams is the February median unimpaired flow MBF. Scenarios were developed to investigate Policy elements in addition to the February median MBF. The Policy elements investigated were:

- Diversion season: The diversion season tested was December 15 through March 31. This season is used in the main Policy and was tested during the original Policy development. Though this diversion season was used, the season used to compute the volume for the maximum cumulative volume depletion remained unchanged at November 1 through March 31.
- Higher MBF: In this Study, the February median unimpaired flows were generally lower than the site-specific passage and spawning flows developed for each POI; as such, for Class II streams, the February median MBF was not protective of passage and spawning flows in October and November. A potential solution for this is to use a higher MBF. The main Policy uses a regionally protective MBF criterion, given in Section 2.2.1.2. The regionally protective MBF and the February median unimpaired flow are compared at the nine POIs in Table 6-2. At these POIs, the regionally protective MBF is higher than the February median MBF on average by a factor of 4. Regionally protective MBFs are also higher than February median flows at the PODs where diversions were simulated in the impairment scenarios. The regionally protective MBF in Policy Section 2.2.1.2 was investigated as an additional Policy element.
- MCD: The maximum cumulative diversion rate is also used in the main Policy and is equal to 5% of the 1.5-year flood magnitude. Because the 1.5-year flood magnitude can be difficult to calculate in small headwaters stream that may be upstream of gage data, a surrogate was developed for this Study. At the nine POIs, 5% of the 1.5-year flood magnitude was compared to the February median unimpaired flow. 5% of the 1.5-year flood magnitude was found to be about 1 to 2 times the February median unimpaired flow (see values in Table 6-2). For the MCD Policy element, the February median flow was tested as the MCD as an approximation of 5% of the 1.5-year flood magnitude on a regional basis.

Table 6-2 Comparison of February Median MBF and Regionally Protective MBF at POIs

Site ID	Drainage Area (sq mi)	Mean Annual Unimpaired Flow (cfs)	5% of the 1.5-year Unimpaired Peak Flood Magnitude (cfs)	Site-specific Criteria at POIs		MBF Options	
				Coho Passage Flow for Site (cfs)	Steelhead Spawning Flow for Site (cfs)	February Median Unimpaired Flow (cfs)	Regionally Protective MBF Computed from Equations in Policy §2.2.1.2 (cfs)
MC2	2.3	5.6	10	9.0	11	5.0	33
MC3	5.2	9.5	19	6.7	26	8.5	38
MC5	23.5	36.2	80	9.0	90	30.0	73
SC4	3.8	3.6	4	13	21	4.7	17
SC5	1.9	2.4	3	3.9	35	2.6	16
SC6	8.2	8.2	10	19	51	9.1	27
WC2	1.6	1.6	3	11	12	1.9	12
WC4	*12.3	34.3	46	22	31	30.6	93
WC6	3.2	4.4	10	7.5	14	4.4	22

*Drainage area does not include Soulajule Reservoir and its contributing drainage area.

6.2.2 Additional Scenarios to Evaluate Class II Conditions

To develop protective Class II conditions, additional scenarios were created. First, each new Policy element described above was added individually; then, after examining results of those scenarios, three additional scenarios were created to combine modified Policy elements. Table 6-3 summarizes the five additional scenarios used to evaluate Class II diversions.

Table 6-3 Additional Scenarios Used to Develop Conditions for Class II Streams

Policy Element	Additional Policy Elements Added Individually			Combinations of Policy Elements	
	Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5
Diversions	Lumped	Lumped	Lumped	Lumped	Lumped
Div Season	***Dec 15-Mar 31***	None	None	***Dec 15-Mar 31***	None
MBF	Feb Median	***Regional Eqn in Policy §2.2.1.2***	Feb Median	Feb Median	***Regional Eqn in Policy §2.2.1.2***
MCD	None	None	***Feb Median***	***Feb Median***	***Feb Median***

Note:
Italicized items are Policy elements that differ from or are in addition to the guidelines as written in A.1.8.3.

6.2.3 Results for Adding Individual Policy Elements (Scenarios A1, A2 and A3)

Scenarios A1, A2 and A3 were created to test the protectiveness of additional policy elements for Class II streams. To evaluate passage, spawning and natural flow variability, the same procedures described in Section 4.3 were used to impair the flows and compute flood frequency.

To compare the scenarios with each other and with the original A.1.8.3 guidelines using a single metric representing all sites, the percent loss of passage and spawning days was averaged for all nine POIs. The average values for the three scenarios are compared in Fig. 6-2 and Fig. 6-3. Full results by site and by month for each scenario are given in Appendix E.

The reduction in the 1.5-year flood magnitude is given for a 5% maximum cumulative volume depletion (Table 6-4) and for a 10% maximum cumulative volume depletion (Table 6-5). These results, combined with the passage and spawning results illustrated in Fig. 6-2 and Fig. 6-3, were used to assess protectiveness of the scenarios.

The results show that adding a diversion season policy element (Scenario A1) protects sensitive passage and spawning in October and November and shifts the impacts to December and January when there are substantially more days with flow conditions conducive to each habitat need. Intuitively, this outcome is protective of early migrants, which is important for maintaining biological diversity. Run timing diversity is important for population resilience and viability under shifting environmental conditions (McElhany et al. 2000; Schindler et al. 2010). In Pacific salmon populations at the northern end of their distribution, variability in timing of spawn migrations corresponds with differential spawning habitat use, and variability in habitat use appears to contribute to population diversity (Boatright et al. 2004; Doctor and Quinn 2004; Quinn et al. 2000). Early spawning runs in many small streams along the California coast are blocked at the delta by sandbars that form during the low-discharge period in summer. Initial runs of adult salmon and steelhead rely on increased fall and winter stream discharge, tidal events, or winds to breach the sandbars, which then enable access to freshwater spawning habitats (Shapovalov and Taft 1954; Brown et al. 1994; DFG 2002; Bond et al. 2008). Once in freshwater, stream discharge also determines the amount of habitat area available for holding and spawning, and increased flows during the fall improve upstream passage, holding capacity, and spawning habitat conditions during that relatively dry period. CDFW has suggested that steelhead population viability is reliant on the timing of sandbar breaching, concurrent increased discharge, and quality of corresponding spawning habitat (DFG, 1996). Thus, the timing and magnitude of stream discharge, especially for adults that enter the stream early, may be critical in accommodating reproductive success in these populations. Allowing diversion without regard to the temporal nature of the natural flow regime, and the temporal distribution of the adult run could result in disproportionate negative effects on accessibility, in-stream fish passage, and quality and quantity of spawning habitat on the early portions of the spawning run for both coho and steelhead in October and November.

Shifting the impact of diversion to later in the winter when there are more days with flows suitable for spawning will impact the main part of the run when there are more fish present, especially in the case of steelhead. Hence, there is a trade-off associated with implementing the Policy diversion season element, where maintaining biological diversity is balanced against ensuring spawning opportunities for more fish. Escapement data compiled by Shapovalov and Taft (1954) for the central and north coast of California indicate that roughly 3% and 36% of the steelhead and coho runs, respectively, occurred prior to December 15, and over 90% and 64%, respectively, during the Policy diversion season of December 15-March 31. The unimpaired flow hydrology predicted for the six smaller study sites was associated with an average of 1 spawning day every four years in October and November, and around 4-5 days/year for each month from December through March. Comparing proportion of run size with average annual spawning opportunities in the six smallest streams[17] where impacts are most likely indicates that spawning opportunities are critical in November and December for most of the coho salmon run, and in January through March for a significant proportion of the steelhead run. Fig. 6-1 shows a comparison of run count data compiled by Shapovalov and Taft (1954) for coho salmon and steelhead trout in coastal California streams and availability of spawning habitat by month. The bar height represents the ratio of the percent of the total run in a month divided by the average number of spawning days for that month under unimpaired flows in the six smaller study sites. December appears relatively less important for steelhead than January, and moderately important for coho. Therefore, it appears that shifting impacts to the last two weeks in December and early January may be a reasonable compromise between preserving biological diversity and maximizing spawning opportunities for the bulk of the runs of both species.

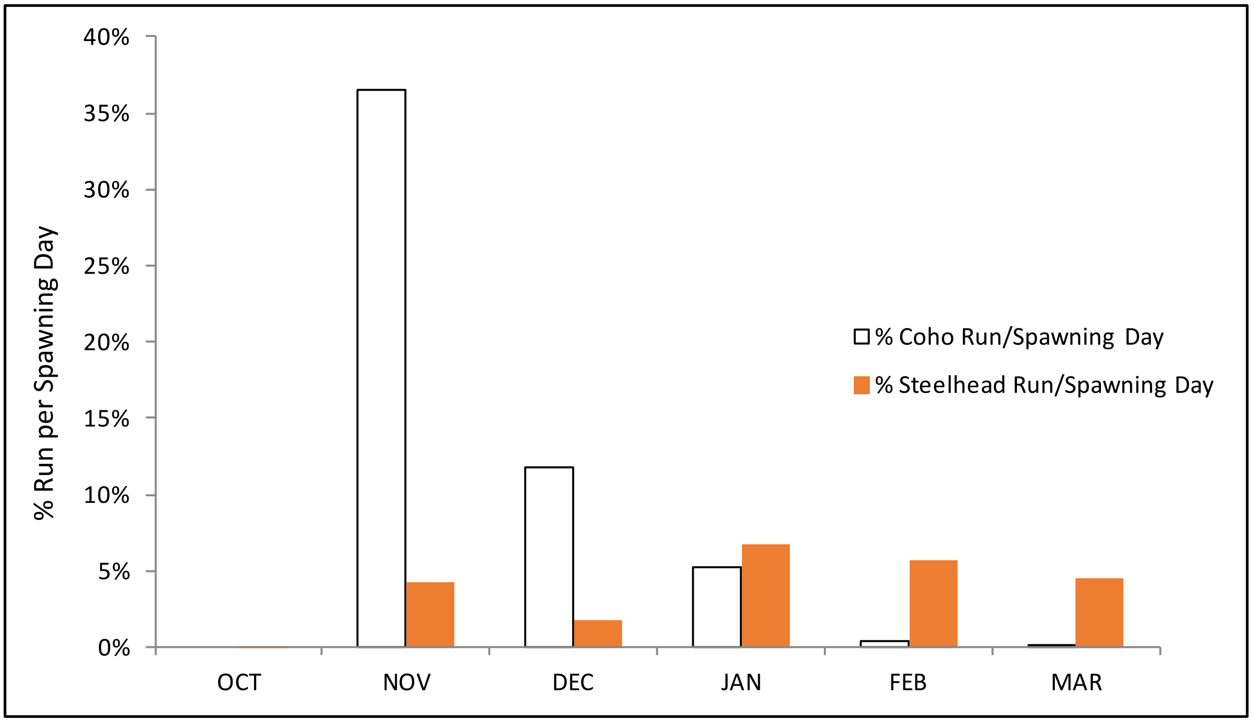

Fig. 6-1 Percent of Spawning Run (from Shapovalov and Taft, 1954) per Spawning Day at the Smallest Six Field Sites

Shifting diversion impacts to later in the winter could therefore have less biological significance with respect to protecting diversity in life history strategies. For example, losing one day in October out of two or three passage and spawning days total may be more biologically significant from a diversity perspective than losing one day in December out of 10 or more passage and spawning days. In the latter case, there are more opportunities for steelhead to migrate upstream and spawn such that while losing one day will have an effect, the population could conceivably compensate for this. Earlier in the season, every limited opportunity may be important for maintaining viability of coho salmon and early season steelhead upstream migrants.

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[17] The smallest streams are sites MC2, MC3, SC4, SC5, WC2 and WC6.

However, Scenario is A1 is likely not protective of natural flow variability, as evidenced by an estimated 15% reduction in the 1.5-yr flood magnitude.

Adding a higher MBF (Scenario A2) also protects sensitive passage and spawning in October and November. This is because, in this investigation, the regionally protective MBFs are generally higher than site-specific passage and spawning flows and, as such, very few passage and spawning days are lost. Scenario A2 is not protective of natural flow variability, though, as evidenced by an estimated 21% reduction in the 1.5-yr flood magnitude.

Adding an MCD equal to the February median flow (Scenario A3) is not protective of passage and spawning flows. Though the losses are not as significant when compared to Scenario D3, impacts in October and November are still significant and average over 10% of days per month. Because a cap is now set on the maximum permissible diversion rate, however, Scenario A3 is protective of natural flow variability, as evidenced by an estimated 2% reduction in the 1.5-yr flood magnitude.

Because these results show that adding single policy elements does not offer a fully protective solution, the next step taken was to analyze these policy elements in combination with the elements most likely to be fully protective.

Table 6-4 Percent Reduction in 1.5-year Flood Magnitude at 5% Maximum Cumulative Volume Depletion, Scenarios 3, A1, A2 and A3

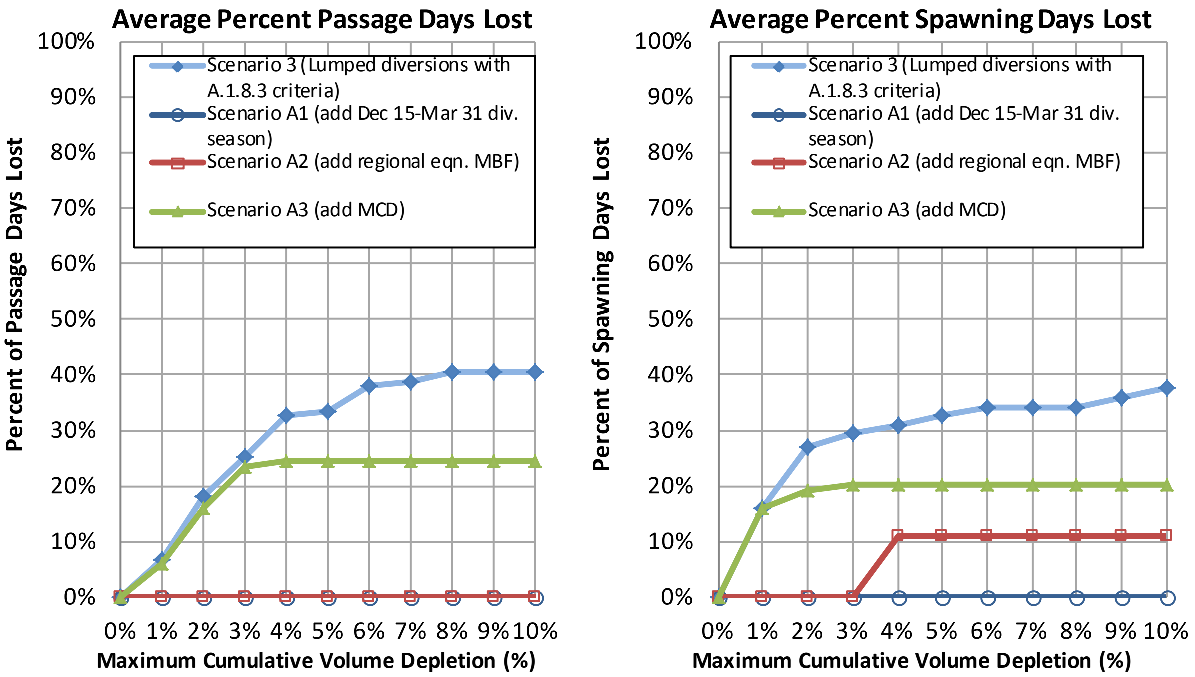
	Percent Reduction 1.5-year Flood Magnitude			
Site	**Scenario D3**	**Scenario A1**	**Scenario A2**	**Scenario A3**
MC2	27%	25%	49%	1.7%
MC3	25%	25%	38%	1.4%
MC5	11%	11%	14%	0.4%
SC4	13%	8%	13%	6.7%
SC5	7%	7%	0%	3.0%
SC6	6%	7%	8%	2.7%
WC2	6%	12%	27%	1.0%
WC4	0%	5%	6%	0.1%
WC6	30%	36%	36%	0.9%
Average	**14%**	**15%**	**21%**	**2.0%**

Table 6-5 Percent Reduction in 1.5-year Flood Magnitude at 10% Maximum Cumulative Volume Depletion, Scenarios 3, A1, A2 and A3

	Percent Reduction 1.5-year Flood Magnitude			
Site	**Scenario D3**	**Scenario A1**	**Scenario A2**	**Scenario A3**
MC2	27%	--	--	2.2%
MC3	25%	--	--	1.4%
MC5	13%	--	--	0.4%
SC4	18%	--	--	7.0%
SC5	8%	--	--	3.6%
SC6	9%	--	--	3.3%
WC2	15%	--	--	1.5%
WC4	5%	--	--	0.2%
WC6	30%	--	--	1.8%
Average	**17%**	**>15%**	**>21%**	**2.4%**

Note:
-- Value not computed since at 10% maximum cumulative volume depletion, reduction in flood magnitude will be equal or higher than value computed at 5% maximum cumulative volume depletion (see Table 6-4)

Comparison of Lost Passage and Spawning Days in October



Comparison of Lost Passage and Spawning Days in November

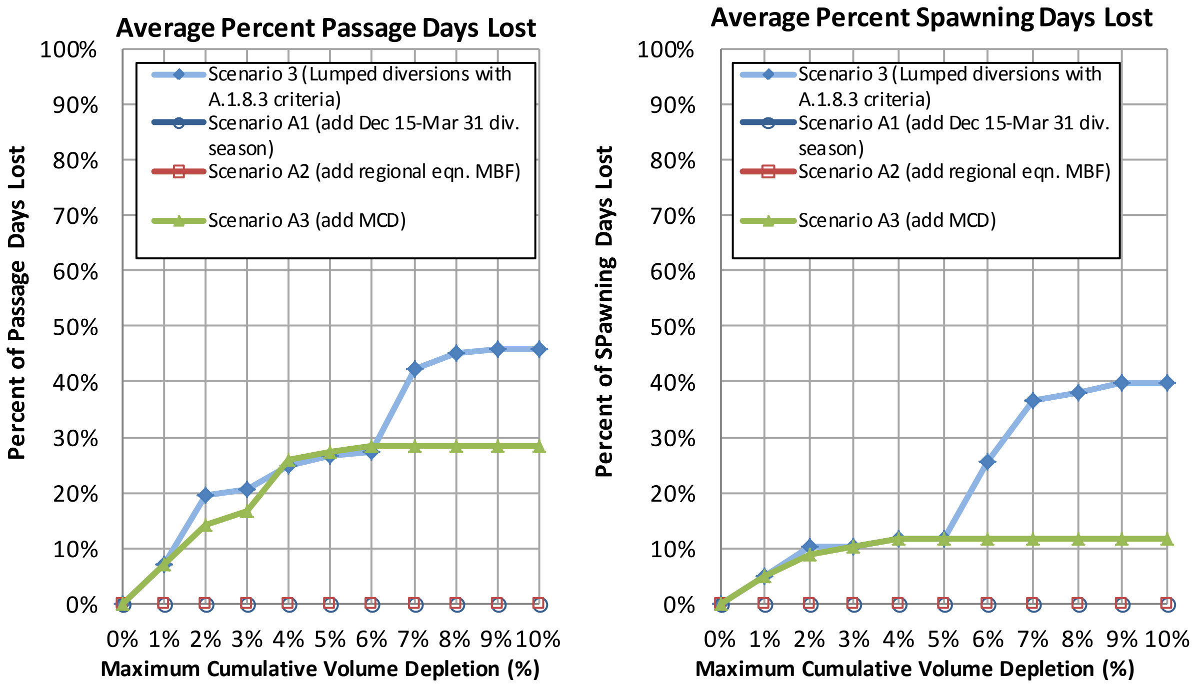


Fig. 6-2 **Comparison of Lost Passage and Spawning Days in October and November for Scenarios 3, A1, A2 and A3.**

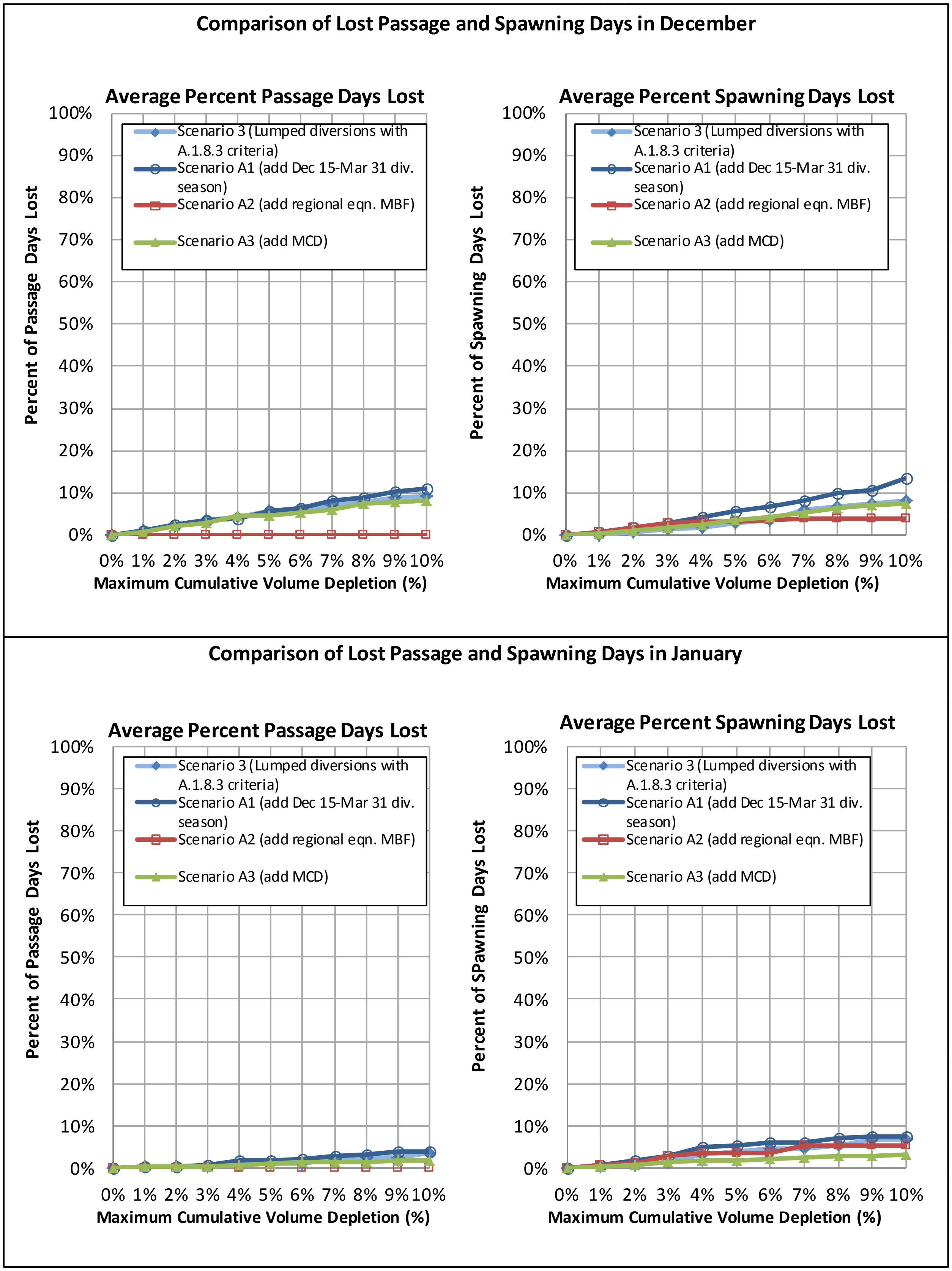


Fig. 6-3 Comparison of Lost Passage and Spawning Days in October and November for Scenarios 3, A1, A2 and A3.

6.2.4 Results for Combined Policy Elements (Scenarios A4 and A5)

The results of Scenarios A1, A2 and A3 show that adding individual Policy elements to the A.1.8.3 guidelines did not appear to be sufficiently protective of passage, spawning and natural flow variability. Accordingly, two additional scenarios were created to combine Policy elements more likely to be protective. In Scenarios A1 and A2, the diversion season element and regionally protective MBF, respectively, were protective of passage and spawning, but not flow variability; Scenario A3 (MCD element) was protective of flow variability. Therefore two additional scenarios (Table 6-6) were created to combine the MCD with both the diversion season and regionally protective MBF. The procedures in Section 4.3 were followed to compute flow impairments and flood frequency for Scenarios A4 and A5.

Table 6-6 Combined Scenarios Used to Evaluate Class II Policy Elements

Policy Element	Combinations of Policy Elements	
	Scenario A4	**Scenario A5**
Diversions	Lumped (D3)	Lumped (D3)
Div. Season	***Dec 15-Mar 31***	None
MBF	Feb Median	***Regional Eqn in Policy §2.2.1.2***
MCD	***Feb Median***	***Feb Median***

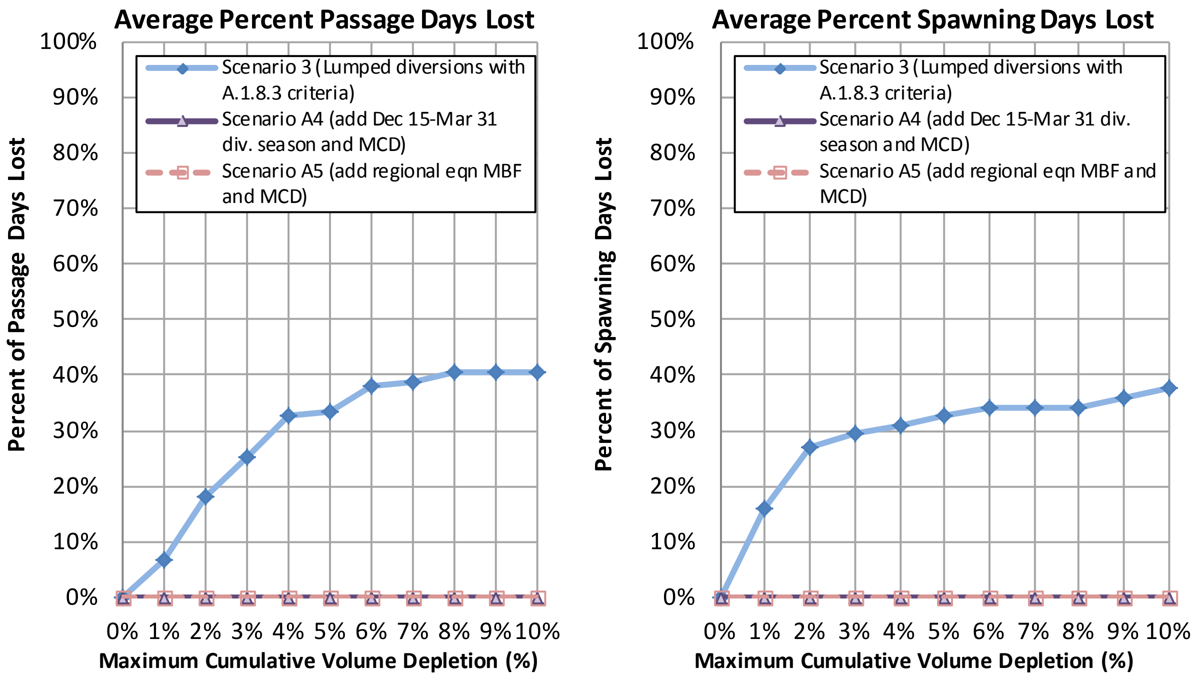
Note:
Italicized items are Policy elements that differ from or are in addition to the guidelines as written in A.1.8.3.

To compare the scenarios with each other and with the original A.1.8.3 guidelines, the percent loss of passage and spawning days was averaged for all nine POIs. The average values for the three scenarios are compared in Fig. 6-4 and Fig. 6-5. Full results by site for each scenario are given in Appendix E.

In Scenario A4, adding a diversion season and MCD as policy elements appears to protect sensitive passage and spawning in October and November as well as natural flow variability. In October and November, because of the diversion season restriction, no passage and spawning days are lost; in December and January, when the reservoirs are filling, some passage and spawning days are lost, but the average percent loss is less than 6%. The average reduction in 1.5-yr flood magnitude is less than 5% for both 5% and 10% maximum cumulative volume depletions.

In Scenario A5, increasing the MBF and adding an MCD also protects sensitive passage and spawning in October and November as well as natural flow variability. Notably, though, fewer study streams are impacted in Scenario A5 than in Scenario A4. In October through January, the highest average percent of passage or spawning days lost in a month is 2%. At each study site, the regionally protective MBF flow rate is generally higher than the passage and spawning thresholds developed at each site. Because of this, impaired flows generally do not decrease below the passage and spawning thresholds, leading to few lost days. The average reduction in 1.5-yr flood magnitude is less than 5% for both 5% and 10% maximum cumulative volume depletions (Table 6-8 and Table 6-9, respectively).

Comparison of Lost Passage and Spawning Days in October



Comparison of Lost Passage and Spawning Days in November

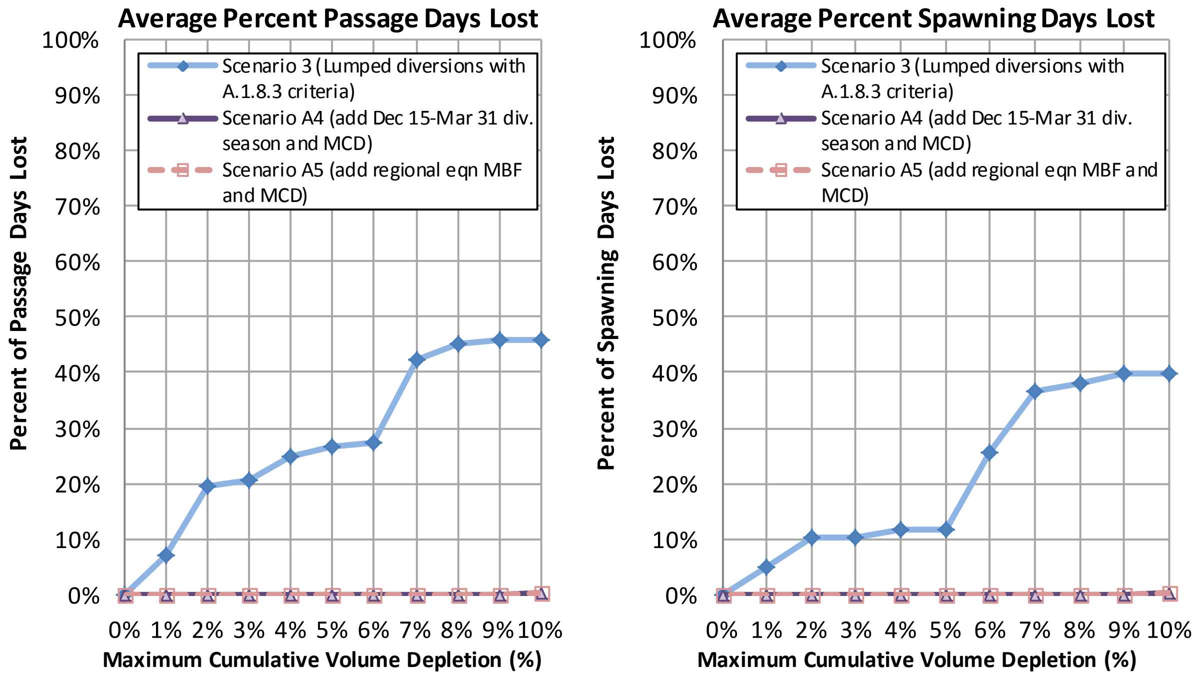


Fig. 6-4 **Comparison of Lost Passage and Spawning Days in October and November for Scenarios 3, A4 and A5.**

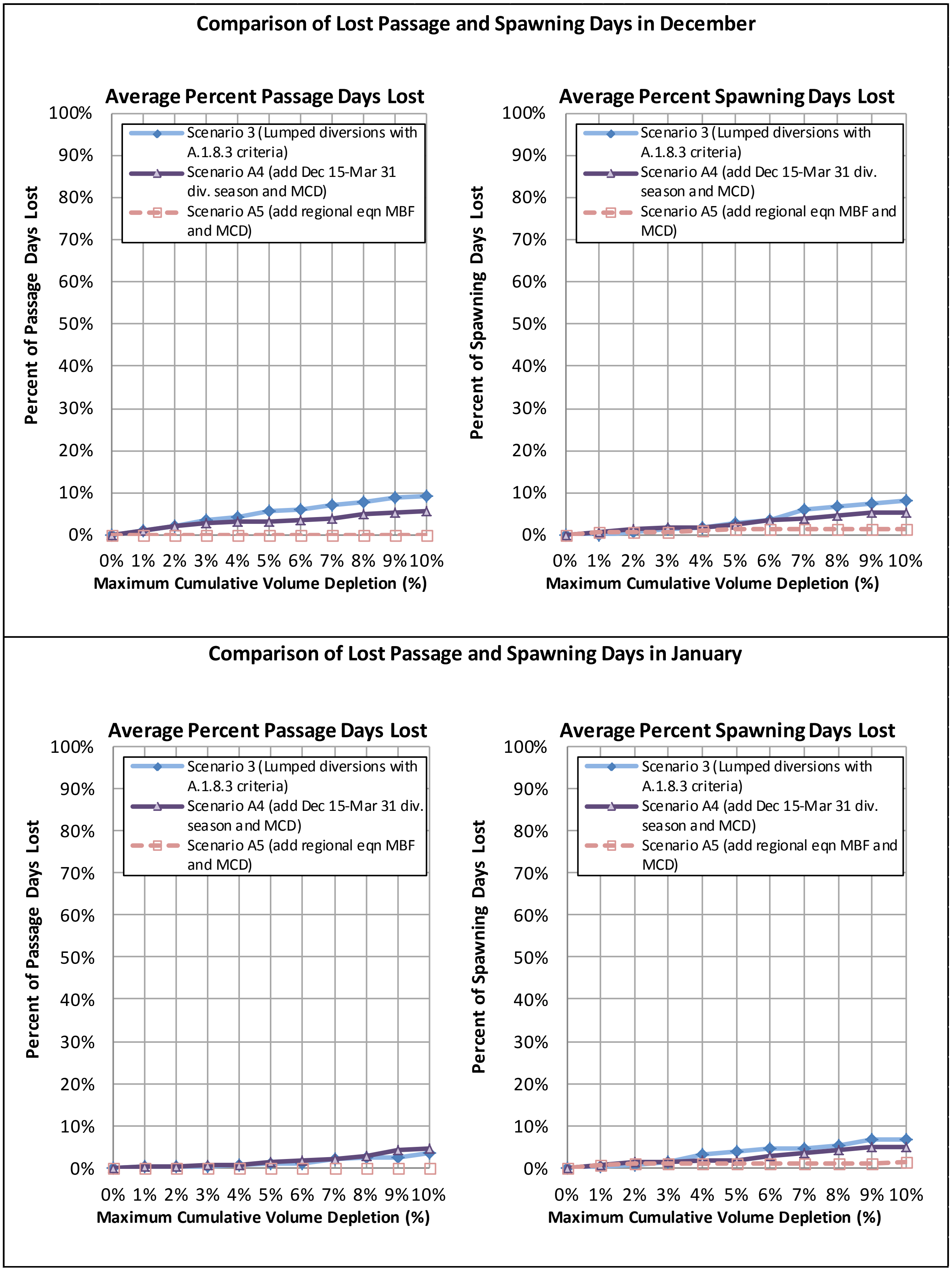


Fig. 6-5 **Comparison of Lost Passage and Spawning Days in December and January for Scenarios 3, A4 and A5.**

Table 6-7 **Percent Reduction in 1.5-year Flood Magnitude at 5% Maximum Cumulative Volume Depletion, Scenarios 3, A4 and A5**

Site	Percent Reduction 1.5-year Flood Magnitude		
	Scenario D3	**Scenario A4**	**Scenario A5**
MC2	27%	1.7%	2.6%
MC3	25%	1.4%	2.3%
MC5	11%	0.4%	0.6%
SC4	13%	3.5%	3.6%
SC5	7%	2.8%	3.6%
SC6	6%	2.9%	2.2%
WC2	6%	1.1%	1.5%
WC4	0%	0.1%	0.2%
WC6	30%	1.4%	1.9%
Average	**14%**	**1.7%**	**2.0%**

Table 6-8 **Percent Reduction in 1.5-year Flood Magnitude at 10% Maximum Cumulative Volume Depletion, Scenarios 3, A4 and A5**

Site	Percent Reduction 1.5-year Flood Magnitude		
	Scenario D3	**Scenario A4**	**Scenario A5**
MC2	27%	2.0%	2.7%
MC3	25%	1.6%	2.3%
MC5	13%	0.4%	0.6%
SC4	18%	3.5%	4.0%
SC5	8%	3.4%	3.6%
SC6	9%	3.3%	2.2%
WC2	15%	1.5%	1.5%
WC4	5%	0.2%	0.2%
WC6	30%	1.9%	2.6%
Average	**17%**	**2.0%**	**2.2%**

6.2.5 Recommended Conditions for Class II Diversions with Maximum Cumulative Volume Depletion no greater than 5%

The results for Scenario D3 in Section 5.1.2 show that in cases when the maximum cumulative volume depletion is less than 5%, losses of passage and spawning days may exceed 10% in a given month (see Fig. 5-7, Fig. 5-8, and Fig. 5-11). Because of this, additional policy elements are recommended for Class II streams with maximum cumulative volume depletion equal to or less than 5%. However, since these recommendations can only be implemented if and when the State Water Board revises the Policy, the recommendations are provided here for informational purposes only. The additional Policy elements in Scenario A5 are recommended for Class II streams, where, if the maximum cumulative volume depletion is equal to or less than 5%, diversions could be permitted to operate without a diversion season on the condition that both of the following elements apply:

- An MBF computed using the regionally protective criteria in Policy Section 2.2.1.2 and
- An MCD equal to the February median unimpaired flow rate.

6.2.6 Additional Conditions for Class II Diversions with Maximum Cumulative Volume Depletion greater than 5% but no more than 10%.

The results for Scenario D3 in Section 5.1.2 show that when the maximum cumulative volume depletion is greater than 5% but no more than 10%, losses of passage and spawning days often exceed 10% in a given month (see Fig. 5-7 through Fig. 5-12). Because of this, additional conditions have been developed for Class II streams, per Option 3 of the A.1.8.3 guidelines for Class II streams.

Scenario A5, which combines the regionally protective MBF with the February median MCD, is more protective than Scenario A4. Overall, using the regionally protective MBF leads to fewer lost passage and spawning days than the February median MBF and diversion season in Scenario A4. The additional policy elements in Scenario A5 represent regionally protective conditions for Class II streams.

In Class II streams, if the maximum cumulative volume depletion is greater than 5% but less than 10%, diversions should be permitted to operate without a diversion season, but with both of the following:

- An MBF computed using the regionally protective criteria in Policy Section 2.2.1.2 and
- An MCD equal to the February median unimpaired flow rate.

6.2.7 Calculated Diversion Volumes with Additional Conditions

Fig. 6-6 compares the average annual calculated diversions at the POIs for Scenarios 3 and A5. The graph shows that, with the addition of Policy elements, the calculated average annual diversion volume under Scenario A5 (adding the regionally protective MBF and an MCD) is about 5 to 30% less than the calculated diversion volume under the original A.1.8.3 guidelines (Scenario D3). The reduction increases with increasing maximum cumulative volume depletion percentage. Calculated diversions are reduced under Scenario A5 because the regionally protective MBF combined with an MCD reduces the number of days on which diversions may occur and the flow rate at which diversions are taken.

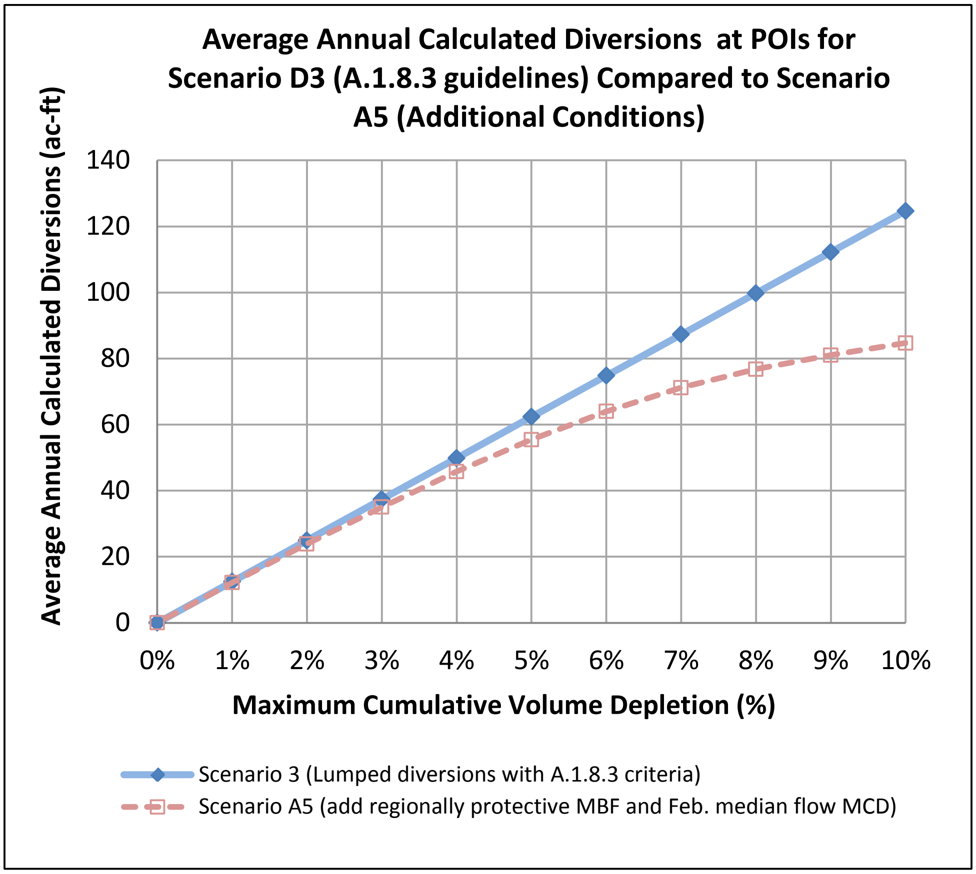


Fig. 6-6 Average Annual Calculated Diversions at POIs for Scenario D3 (A.1.8.3 Guidelines) Compared to Scenario A5 (Additional Conditions)

6.3 Summary of Protective Conditions for Class III and II Streams

The purpose of this Study was to develop additional protective conditions necessary under A.1.8.3 for maximum cumulative volume depletions greater than 5% but no more than 10% of the seasonal unimpaired flow volume. The protectiveness analysis shows that no additional conditions are necessary for Class III streams. For Class II streams, additional conditions of the regionally protective MBF and February median MCD are required. Table 6-9 summarizes the proposed conditions for Class III and II streams with maximum cumulative volume depletion greater than 5% but no more than 10%.

Like all studies that employ field measurements and model simulations, there is inherent uncertainty in the results of this Study. Efforts were made throughout the Study to minimize that uncertainty, though quantification of the level of uncertainty was outside the scope of work.

Table 6-9 Protective Conditions for Class III and II Applicants for Maximum Cumulative Volume Depletion Greater Than 5% But No More than 10%.

Stream Class	Maximum Cumulative Volume Depletion	Proposed Policy Elements		
		Diversion Season	MBF	Maximum Diversion Rate
III	>5%, <=10%	None	February Median Unimpaired Flow	None
II	>5%, <=10%	None	***Regional Equation MBF from Policy §2.2.1.2***	***February Median Unimpaired Flow***

Note:
Italicized items are modified or additional conditions not originally included in Policy section A.1.8.3.

The findings of this investigation show that, for maximum cumulative volume depletions ranging from 0 to 10%, the A.1.8.3 guidelines as written are protective for Class III diversions.

For Class II streams, the A.1.8.3 guidelines do not appear to be sufficiently protective in cases when the maximum cumulative volume depletion is less than or equal to 5%. Because of this, additional conditions were investigated. However, the A.1.8.3 guidelines for Class II diversions with maximum cumulative volume depletions equal to or less than 5% cannot be changed through the results of this Study and must be done through a Policy revision. Accordingly, recommendations here are presented for informational purposes. If the State Water Board revises the Policy in the future, it is recommended that additional conditions be applied to Class II applications with no more than 5% maximum cumulative volume depletion. In these cases, adding an MCD equal to the February median flow would be protective of natural flow variability. To protect passage and spawning in October and November, the regionally protective MBF in Policy Section 2.2.1.2 would be protective.

For Class II streams with maximum cumulative volume depletions greater than 5% but no more than 10%, the A.1.8.3 guidelines are clearly not protective. Additional conditions are required. It is our recommendation that both the regionally protective MBF from Policy Section 2.2.1.2 and an MCD equal to the February median unimpaired flow are required as additional conditions under Option 3 of the A.1.8.3 Class II guidelines.

Fig. 6-7 is a flow chart that illustrates the decisions and procedures for determining applicable conditions under Policy Section A.1.8.3. The flow chart shows the options available to an applicant, including the conditions developed in this Study per Option 3 of the A.1.8.3 guidelines. For Class III streams, since the A.1.8.3 guidelines were found to be protective and no additional conditions have been recommended, the three previous options are not necessary, and applicants in these cases would be required to observe the February median flow MBF criterion, but no other conditions would be necessary. The flow chart also illustrates the applicable guidelines if the maximum cumulative volume depletion is equal to or less than 5% or greater than 10%. The recommendations discussed above for Class II streams with volume depletion equal or less than 5% are not included in the flow chart, as they can only be implemented through revision of the Policy.

Special considerations for frost protection: If an applicant applies to re-fill a reservoir after March 1 for the purpose of frost protection and the maximum cumulative volume depletion is greater than 5% but no more than 10%, there are no conditions examined in this Study which would necessarily be fully protective. Because the main habitat concerns in March, April and May are temperature and downstream migration, for which regional criteria are not readily established, the metrics used for this Study cannot be used to assess regional protectiveness at that time of year. Accordingly, it is recommended that if an applicant applies to re-fill a reservoir after March 1 for the purpose of frost protection and the maximum cumulative volume depletion is greater than 5% but no more than 10%, these additional conditions should not apply and the applicant may pursue the other options available under A.1.8.3 (CDFW/NMFS approval or an additional study).

6.4 Implementation of A.1.8.3 Guidelines and Future Policy Review

To use the Volume Depletion Approach described in Section A.8.1.3, applicants will need to compute the percentage volume depletion for a proposed project. Appendix F provides guidance on how to calculate the percentage volume depletion for proposed projects using methods consistent with this Study.

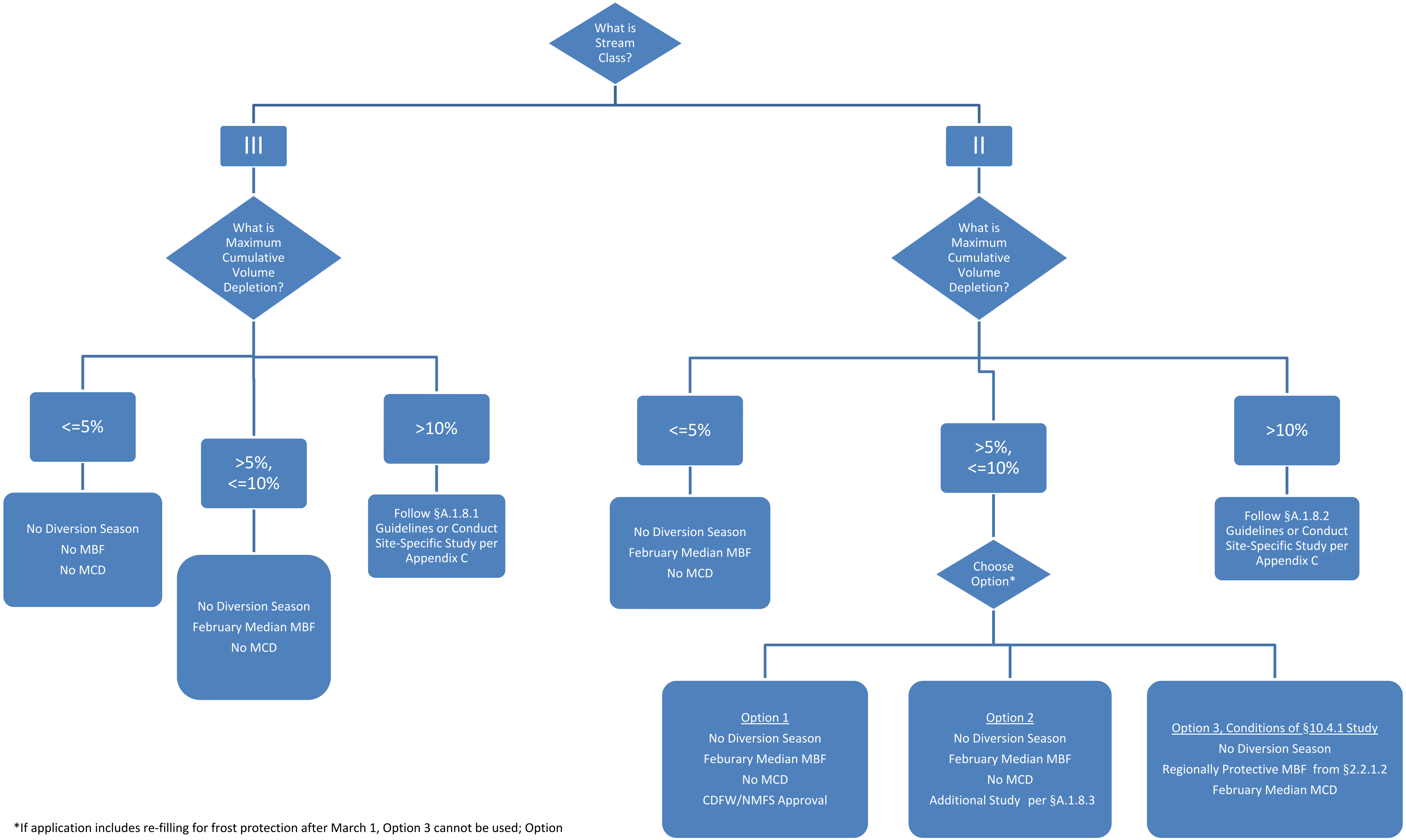
The results of this Study include recommendations that may only be implemented through a revision of the Policy. Section 10.4 of the Policy describes review procedures and a proposed monitoring program. The Policy proposes establishing a Regional Monitoring and Policy Effectiveness Review program to collect field data and evaluate the effectiveness of the Policy. In addition, that section describes the review timeline for the Policy:

> “Five years from the effective date of the policy, and periodically thereafter, the State Water Board will review the policy and determine whether it should be revised. The program may coordinate with and utilize and incorporate data from other ongoing monitoring programs carried out by other state, federal, and local agencies, to the fullest extent practicable.” (§10.4)

Appendix F summarizes findings from this Study which we recommend be considered in future reviews of the Policy.

FIGURE 6-7

FLOW CHART ILLUSTRATING IMPELEMENTATION OF POLICY SECTION A.1.8.3 WITH ADDITIONAL CONDITIONS FROM VOLUME DEPLETION APPROACH STUDY



*If application includes re-filling for frost protection after March 1, Option 3 cannot be used; Option 1 or 2 must be used.

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[18] Effective January 1, 2013, California Department of Fish and Game changed their name to the California Department of Fish and Wildlife (CDFW).

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Hyperlinks to Appendices

Appendix A Final Field Study Report

https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/vdas/docs/apxa_ffsr.pdf

Appendix B Final Hydrologic Modeling Report

https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/vdas/docs/apxb_fhmr.pdf

Appendix C Habitat Flow Curves

https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/vdas/docs/apxc_hfc.pdf

Appendix D Flood Frequency Results

https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/vdas/docs/apxd_ff.pdf

Appendix E Passage and Spawning Day Results

https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/vdas/docs/apxe_psr.pdf

Appendix F Implementation of A.1.8.3 Guidelines and Policy Review

https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/vdas/docs/apxf_ipr.pdf

NOTE: Some appendix material contains large data files not posted above. This information may be viewed upon request.