Assessing Streamflow Needs for Whitewater Recreation In the Upper Colorado River.

Integrating Specific and Overall Flow Evaluations for Whitewater Boating.
2008 (updated 2011)

Nathan Fey
American Whitewater

Evan Stafford
CK Consulting / Reel Motion Media

Abstract:

Streamflows have profound effects on the quality, quantity, and timing of whitewater boating opportunities in the Upper Colorado River. Until recently, flows that provide the full range of whitewater boating needs were not defined. In this study we used two approaches to assess the relationship between streamflows and recreation quality. An online survey was completed by 242 commercial and non-commercial paddlers, who evaluated flows for whitewater boating on targeted segments of the Colorado River basin. Respondent data was collected and organized to identify minimum, acceptable and optimum flows for whitewater boating, summarized by Flow-Evaluation curves describing the quality of boating opportunities for each measured stream-flow. Respondents also reported flows that provide certain recreation experiences or "niches", from technical low water to challenging high water trips. This report integrates the results of overall flow-comparisons with single flow assessments of recreation quality, to describe flows needed to sustain the whitewater boating opportunities in the Upper Colorado River basin. Understanding the relationship between whitewater recreation and streamflows can provide information critical to management of the Upper Colorado River.

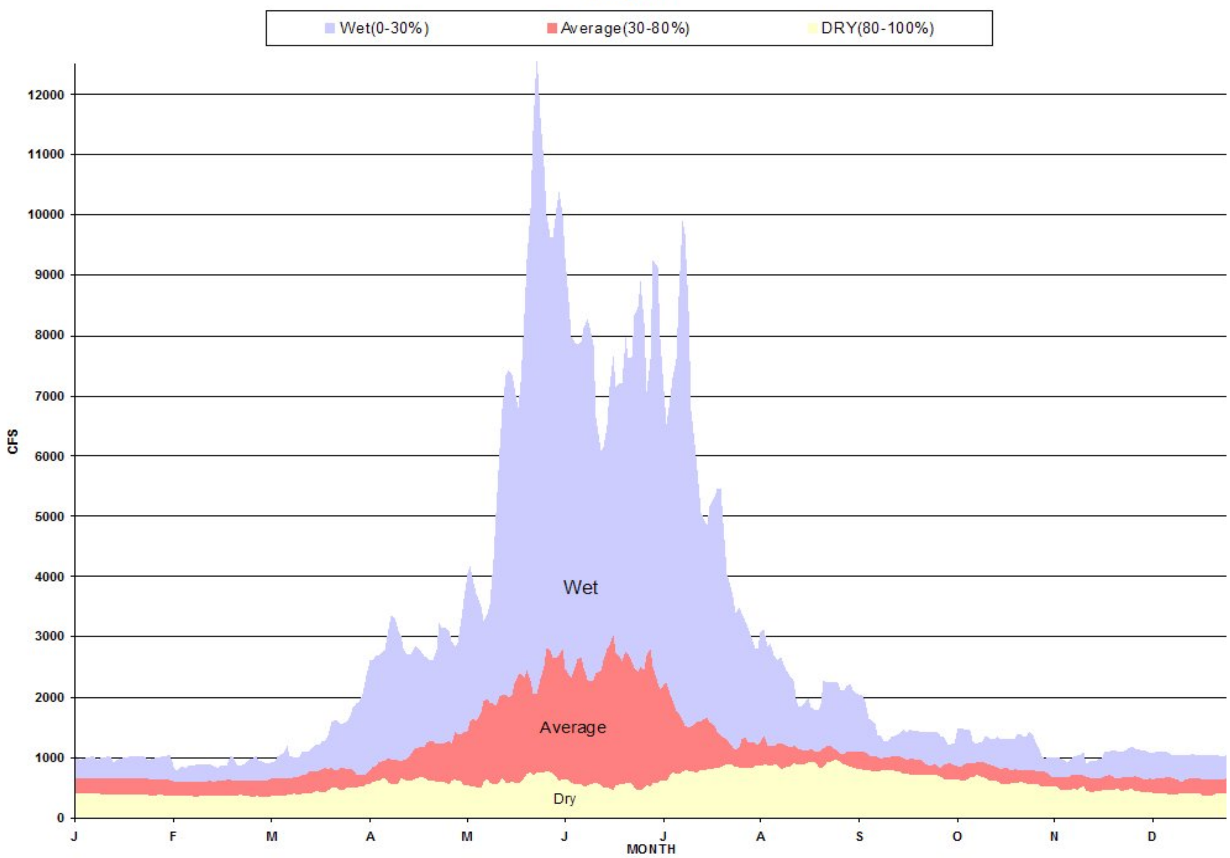
Contents

I. Introduction

The headwaters of the Colorado River, located on the western flanks of Colorado's Rocky Mountains, carves the upper reaches of the longest river system in the southwest. From its source in Rocky Mountain National Park, the Upper Colorado River traverses some of the most remarkable landscapes in the Central Rockies while providing high quality fish and wildlife habitats, and supporting significant riparian plant communities and other flow-influenced natural resource values. In addition, the Colorado River provides world-class recreation values such as whitewater boating, including rafting, kayaking, and canoeing. The condition of these ecological and recreational resources can be highly variable as flows in the Colorado River shift between wet, average and dry hydrologic conditions in any year. (Figure 1)

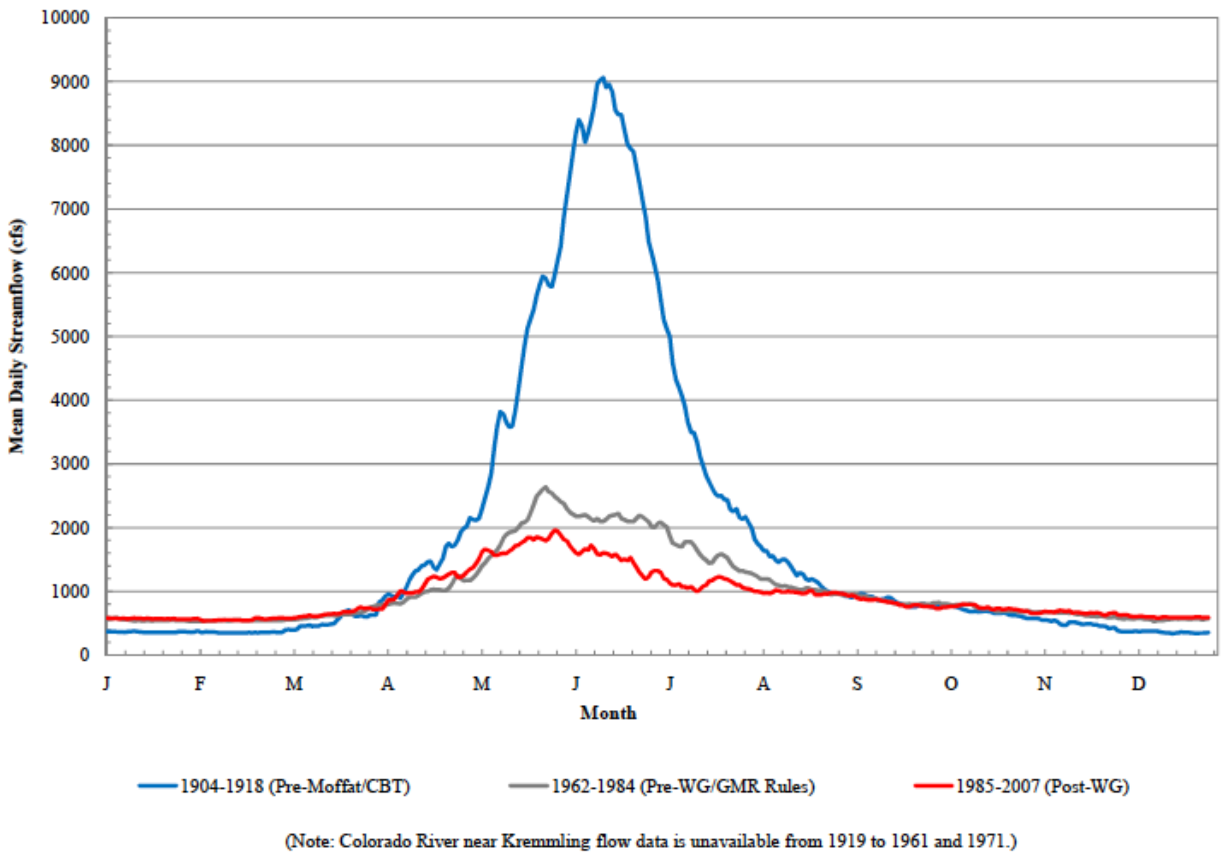
Figure 1

Colorado River near Kremmling – Hydrologic Year-Types (1984-2007)



The Colorado River is the largest supplemental source of water for Colorado's Front Range cities such as Fort Collins, Denver, and Colorado Springs. Diversions from the Colorado-Big Thompson, Windy Gap, and Moffat Collection systems have significantly altered streamflows in the Upper Colorado River (Figure 2), and have affected streamflows that provide for recreational and ecological needs. Management of water resources to preserve the full range of recreational opportunities in each year-type can be informed by greater understanding of the relationship between changes in flow and recreation quality.

Figure 2:
Colorado River near Kremmling - Mean Daily Flows (1904-2007)



Changes in streamflow can have direct effects on the quality of whitewater boating for various craft type, such as kayaks, canoes, and rafts. Direct effects may change quickly and directly as flows change, such as safety in running rapids, number of boat groundings, travel times, quality of rapids, and beach and camp access. Indirectly, flows affect wildlife viewing, scenery, fish habitat, and riparian vegetation over the long term as a result of flow regime (Shelby et al. 1992b; Whittaker et al. 1993). Streamflow regimes affect the channel features of river systems including beaches, pools, waves, riffles, banks, woody debris and rocks (Hill, Platts & Beschta, 1991). These channel features create riparian habitat and are also critical to specific types of river recreation (Whittaker & Shelby, 2002). Flow levels also influence the entire riparian environment, including habitat, food resources and population levels for fish (Bovee, 1996). Market and non-market benefits linked to river tourism are also strongly affected by streamflow.

Controlled dam releases and out-of-stream diversions are the two main ways that humans alter streamflows in the Colorado River and therefore, defined recreational and environmental flow-needs will aide in the development of management plans that balance project authorizations and contractual obligations, while delivering predictable flows for flow-dependant values, such as whitewater boating.

In 2007, the US Bureau of Land Management, Kremmling and Glenwood Springs Field Offices, published its Wild and Scenic River's Eligibility Report for the Upper Colorado River as a part of their Resource Management Plan revision process mandated by the Federal Land Policy and Management Act (FLPMA) (43 U.S.C. 1701 et seq.). The study evaluates which river and stream segments meet the criteria for inclusion into the National Wild and Scenic Rivers System. Of the 244 segments evaluated, 27 were identified as eligible for future study based on their regional or national significance for recreation, wildlife habitat, and cultural values. Of these segments, American Whitewater identified at least 11 where whitewater paddling is well documented[1] and where additional information is needed to identify streamflows that support Wild and Scenic Values. In 2008, American Whitewater conducted a study of flow-recreation relationships for the Upper Colorado River, which included the eleven segments under WSR consideration by the BLM for Whitewater Recreational values.

Considerable work evaluating flow-recreation relationships has occurred over the last several decades (Brown et al., 1991; Shelby, Brown, & Taylor, 1992; Whittaker et al., 1993). Many of the flow-recreation studies focus on whitewater boating, as flow often determines whether people have opportunities to take a trip and what level of challenge or social value is provided (Whittaker & Shelby, 2002). Different flow levels provide for varied whitewater boating opportunities. As flows increase from zero, different paddling opportunities and challenges exist within ranges of flows on a spectrum: too low, minimal acceptable, technical, optimal, high challenge, and too high. Standard methodologies[2] are used to define these flow ranges based on individual and group flow-evaluations. The various opportunities provided by different flow ranges are often described as occurring in various "niches" (Shelby et al., 1992).

Streamflow affects the recreation experience in a number of ways, from determining whether a stretch is boatable or fishable, to whether a stretch will provide a technical low water trip or a high water, high challenge trip. Understanding the relationship between streamflows and natural resource values can aid in the creation of standards for recreation use (Whittaker & Shelby, 2002). Flow-Recreation relationships can also inform management decisions that impact flow regimes and the trade-offs between various resource demands. In these decision-making settings, specific evaluative information on how flow affects recreation quality is critical, particularly where social values are often central to decision-making (Kennedy and Thomas 1995).

Researchers collecting and organizing evaluative information, often employ a normative approach using survey-based techniques. This approach is particularly useful for developing thresholds, or standards, that define low, acceptable, and optimal resource conditions for whitewater boating. Thresholds are crucial elements in any effective management or decision-making process (Shelby et al. 1992). The normative approach examines individuals' evaluations of a range of conditions (personal norms). Social Norms, defined by aggregate personal norms, describe a group's collective evaluation of resource conditions. This approach has been used to understand streamflows for whitewater boating on the Grand Canyon (Shelby et al. 1992), as well as several others rivers in Colorado (Vandas et al. 1990, Shelby & Whittaker 1995).

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[1] National Inventory of Whitewater Rivers; American Whitewater. http://www.americanwhitewater.org/content/River/view/

[2] Whittaker, D., B. Shelby, J. Gangemi. 2005. Flows and Recreation, A guide to studies for river professionals. US Department of Interior, National Park Service, Anchorage, AK

II. Study Approach

To define normative standards for whitewater boating flows in the Upper Colorado River basin, American Whitewater used two study approaches to collect and organize personal evaluations of resource conditions and recreation-relevant hydrology for eleven rivers (Table A). The first approach used an overall flow-comparison survey, while a second approach asked participants to make single-flow judgments of recreation quality. For each set of study questions, flows being evaluated were measured at United States Geological Survey (USGS) streamflow gages.

Table A: Whitewater Boating Attributes and Study Segments

Whitewater Resource	USGS Gage	Whitewater Boating Attribute
Fraser River: Tabernash to Granby	09033300	Fraser Canyon
Colorado River: Hot Sulphur Springs	09034250	Byers Canyon
Colorado River: Kremmling to Pumphouse	09058000	Gore Canyon
Blue River: Green Mountain Dam to Colorado River	09057500	Lower Blue
Colorado River: Pumphouse to State Bridge	09058000	Pumphouse
Piney River: Piney River Crossing to Colorado River	09059500	Piney River
Colorado River: State Bridge to Burns	09058000	State Bridge
Colorado River: Burns to Dotsero	09070500	Burns
Colorado River: Shoshone Dam to Powerplant	09058000	Barrel Springs
Colorado River: Shoshone to Grizzly Creek	09058000	Shoshone
Colorado River: Grizzly Creek to Two Rivers Park	09058000	Grizzly Creek

A web-based approach to data collection was chosen as the appropriate study option, allowing researches to address several challenges to data collection, including the ability to conduct in–person surveys during winter months, ability to collect input from experienced paddlers outside of local area, and limitations in reaching Commercial Outfitters during the commercial off-season. Using a third-party web-based survey tool[3], American Whitewater made both series of study questions available study participants. The web-based survey (included here as Appendix A) was announced to the public using a variety of outreach and discussion forums, including americanwhitewater.org, mountainbuzz.org, coloradokayaker.com, paddlinglife.com, and several email list-serves, including Colorado River Outfitters Association and the U.S. Bureau of Land Management Special Recreation Permit database. This approach allowed respondents to self-select study segments they were comfortable reporting on, and to opt-out of responding to questions relating to unfamiliar study segments.

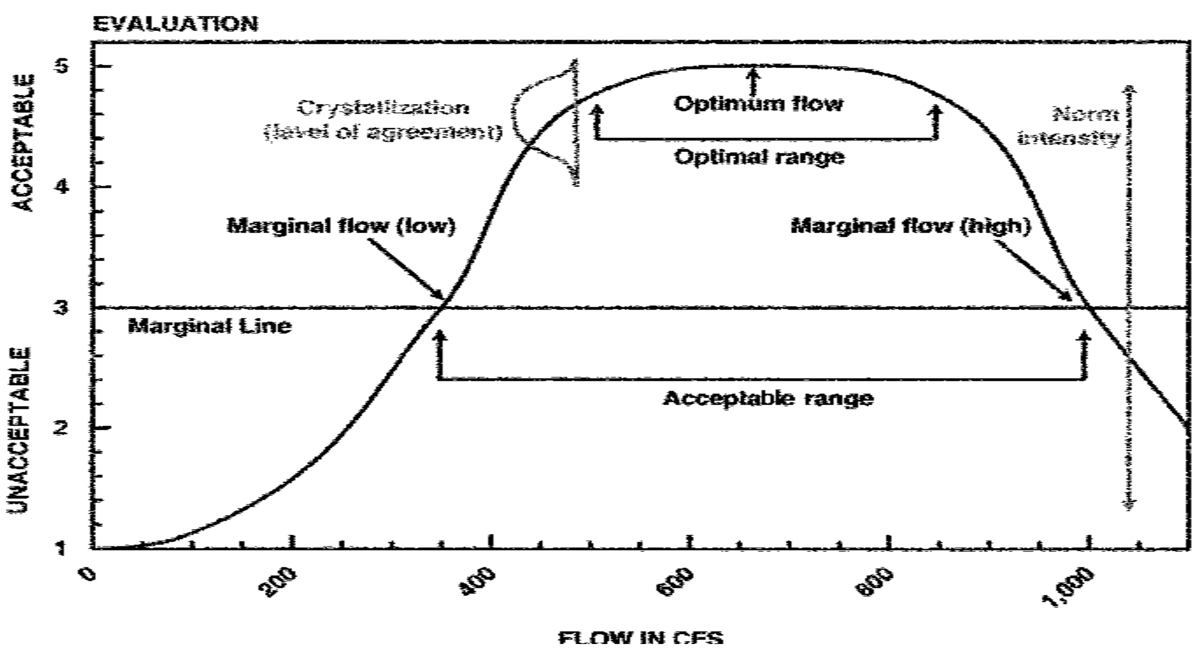
Respondents reported their primary preferred craft type, such as rafts, kayaks, or canoes, and their skill level in terms of the highest difficulty of whitewater they confidently paddled in their preferred craft type. Respondents were also asked to identify whether they were private paddlers, commercial guides or commercial customers. For each study segment, participants were asked to respond to each set of study questions, related to the recreational value of the Upper Colorado River segment in question. The web-based survey required respondents to provide personal contact information for additional follow-up to the survey in the future.

[3] www.surveymonkey.com

Using the overall flow-comparison approach, study participants evaluated each identified flow on a 7-point scale: totally unacceptable (-3), moderately unacceptable (-2), slightly unacceptable (-1), neutral (0), slightly acceptable (1), marginally acceptable (2) and totally acceptable (3). Respondents were also asked a set of open ended flow questions for each segment allowing respondent's to report single flows that provide minimum, optimal, technical, high challenge and highest acceptable flow for their craft type. Integrating the results of overall and specific flow evaluations can help further describe flow thresholds for whitewater boating, including minimum flows, lowest acceptable, and highest acceptable flows.

Flow-Evaluation Curves and the Potential for Conflict Index

This study collected evaluations of specific streamflows, measured at the individual level, and aggregated them to describe social norms. By plotting the central tendency of individual evaluations, a Flow-Evaluation curve is created to describe the range of acceptable flows, and the flow level(s) that provide an optimum recreation experience (Shelby, Vaske, &, Donnelly, 1996). Using this methodology, a set of specific streamflows are displayed on the horizontal axis while mean evaluations are displayed on the vertical axis, with negative evaluations on the bottom, a neutral line in the middle, and positive evaluations on top (Whittaker & Shelby, 2002).



The peak of the inverse u-shaped curve represents the optimum flow, or the flow that provides the greatest level of social value. The range of flows with average evaluations above the neutral line represents the range of acceptable flows. The points where the curve intersects with the neutral line define the standards to be associated with minimum and where available, maximum flows. The variation among evaluations at each flow level constitutes the crystallization of the norm, but is typically not visually displayed.

In this study, we include the Potential for Conflict Index (PCI) for the mainstem (Segments 4-7) of the Colorado River[4], including the associated "bubbles" that describe optimum flows, ranges of acceptable flows, norm intensity and level of norm agreement (Shelby et al. 1996). The Potential for Conflict index takes the graphic representation of social norms one step further by displaying information about their central tendency, dispersion and form (Vaske, Needham, Newman, Manfredo, & Petchenik, in press). In this study we combine these techniques to describe the streamflow-whitewater recreation relationships for Gore Canyon, Pumphouse, State Bridge and Glenwood Canyon segments of the Upper Colorado River.

Surveys gathering data for use in the structural norm approach commonly measure variables using response scales with an equal number of response options surrounding a neutral center point. Numerical ratings are assigned in ordinal fashion with the neutral point being 0 (e.g. -3, -2, -1, 0, 1, 2, 3 where -3 = highly unacceptable, 0 = neutral, and 3 = highly acceptable.). The use of the Potential for Conflict index requires this common form of measurement. The PCI describes the ratio of scoring on either side of a rating scale's center point. The greatest Potential for Conflict (PCI = 1) occurs when there is a bimodal distribution between the two extreme values of the response scale (e.g., 50% strongly support, 50% strongly oppose, 0% neutral). A distribution with 100% at any one point yields a PCI of 0 (i.e., no conflict). Following computation of the index, the results are displayed as bubble graphs. The size of the bubble depicts the PCI value and indicates the degree of dispersion (e.g., the degree of potential conflict over the acceptability of a flow level). Small bubbles indicate higher agreement over the acceptability of a specific flow; larger bubbles reflect less agreement. The center of the bubble, which is plotted on the Y-axis, represents the mean score (central tendency) for the variable.

III. Results and Discussion

A. Overall Flow Evaluations

Utilizing Flow-Evaluation curves, the range of acceptable and optimal flows for whitewater boating is described for each study segment. Mean responses from the overall flow comparison survey questions were plotted for each flow level, and connected to create a curve. The curves identify where low flows provide low quality recreation conditions, while medium flows provide more optimal conditions. In most of the segments studied, highest acceptable flows were not identified. The overall flow comparison study did not survey respondents on flows greater than 2500 cubic-feet/second, resulting in insufficient data on flow levels that provided low quality recreation (i.e. how high is too high). Future opportunities to survey for higher flows will help in defining high flows that drop below the neutral line for all study segments. Figure 3 provides an example of the graphic representation of overall flow-comparison data for Gore Canyon on the Colorado River. Measures of central tendency (mean values) for data collected on each study segment have been used to develop the overall Flow-Evaluations Curves in Appendix B. Table B summarizes these values for each study segment.

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[4] Final Wild and Scenic Eligibility Report, Kremmling and Glenwood Springs Field Offices; U.S. Bureau of Land Management (2007)

Figure 3:
Gore Canyon Flow-Evaluation Curve

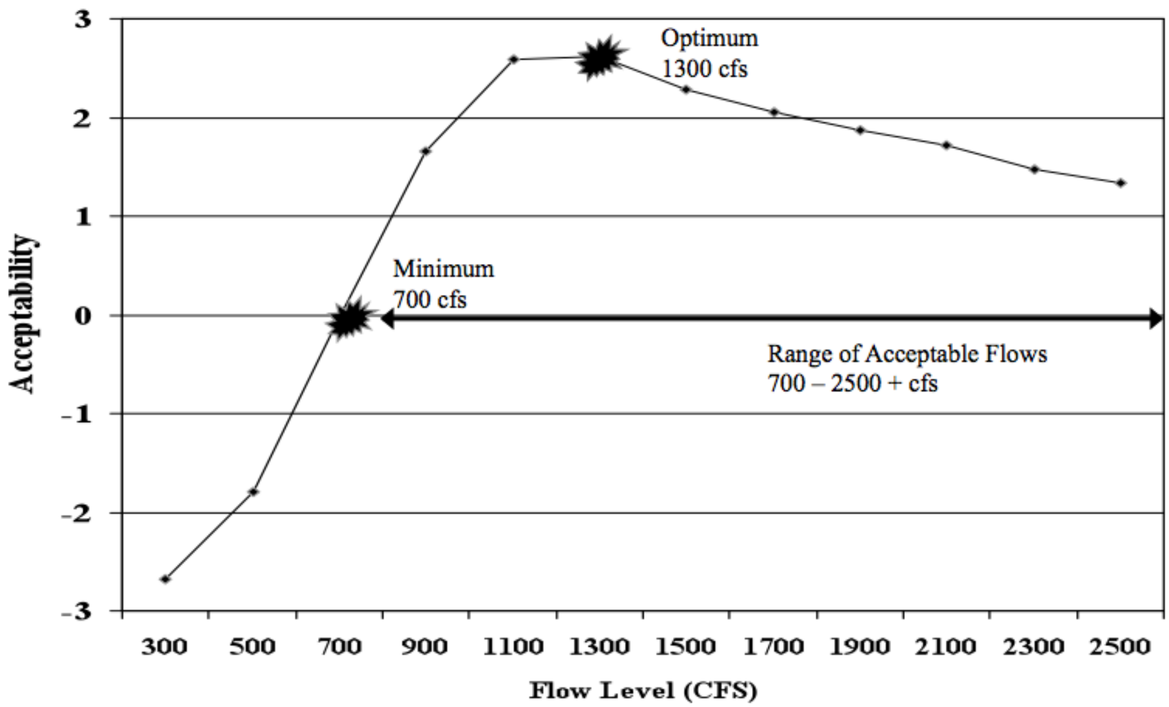


Table B:
Acceptable and Optimal Flows for Whitewater Boating

Whitewater Boating Attribute	Minimum Flow (cfs)	Optimal Flows (cfs)	Acceptable Flows (cfs)
Fraser River: Fraser Canyon	700	1300	700 - 1300+
Colorado River: Byers Canyon	700	1700	700 - 2500+
Colorado River: Gore Canyon	700	1300	700 - 2500+
Blue River: Green Mountain Dam to Colorado River	700	1500	700 - 2500+
Colorado River: Pumphouse to State Bridge	900	2500	900 - 2500+
Piney River: to Confluence w/ Colorado River	700	1500	700 - 1500+
Colorado River: State Bridge to Burns	900	2500	900 - 2500+
Colorado River: Burns to Dotsero	900	2500	900 - 2500+
Colorado River: Barrel Springs	900	1900	900 - 2500+
Colorado River: Shoshone to Grizzly Creek	900	2500	900 - 2500+
Colorado River: Grizzly Creek to Two Rivers Park	900	2500	900 - 2500+

B. Potential for Conflict Index

The Potential for Conflict Index was used to determine respondent agreement regarding the acceptability of each specific flow level for Colorado River segments 4-7 of the Bureau of Land Management's Wild and Scenic Eligibility Report. Respondent agreement over optimum flows was high for all segments but was generally the lowest around the point where the curve crossed the neutral line, more specifically over minimum flows.

BLM Segment 4 - Gore Canyon

Respondents (n=92) overall found the minimum acceptable (tolerable) streamflow to be 700 cfs and the range of acceptable flows to be between 700 and 2500+ cfs. The optimum overall flow was 1300 cfs (Figure 4). The potential for conflict index shows the lowest level of agreement between respondents for Gore Canyon over the acceptability of 700 cfs (PCI = .39). Figure 5 displays a possible reason for this disagreement, with kayakers on average finding 700 cfs to be acceptable while, rafters on average found 700 cfs to be an unacceptable level. Gore is an advanced and technical run for rafters and it is possible that at lower levels there is simply not enough room in the riverbed to safely negotiate the rapids in a raft at 700 cfs. Kayaks were the preferred craft for 75% of respondents, 13% preferred a raft, shredder or cataraft, and 10% would paddle either. Other crafts were such as whitewater canoes or inflatable kayaks made up 2% of respondents.

Agreement levels are extremely high (PCI < .05) regarding the unacceptability of flows under 500 cfs and the acceptability of flows between 1100 and 1300 cfs. The difference between kayakers and rafts provides a possible explanation for greater disagreement at the higher end of the flow spectrum. Kayakers found higher flows more acceptable than rafters, although both found all flows above 900 cfs, on average, to be acceptable. Mean acceptability scores, standard deviation and PCI for each specific instream flow measured in Gore Canyon are displayed in Table C.

Figure 4

Gore Canyon Potential for Conflict Index Curve

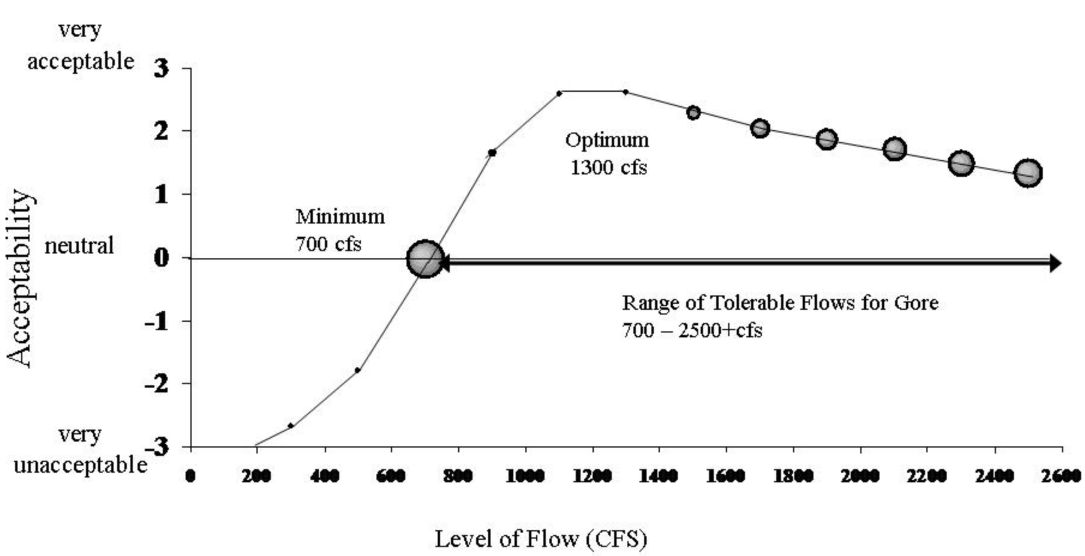
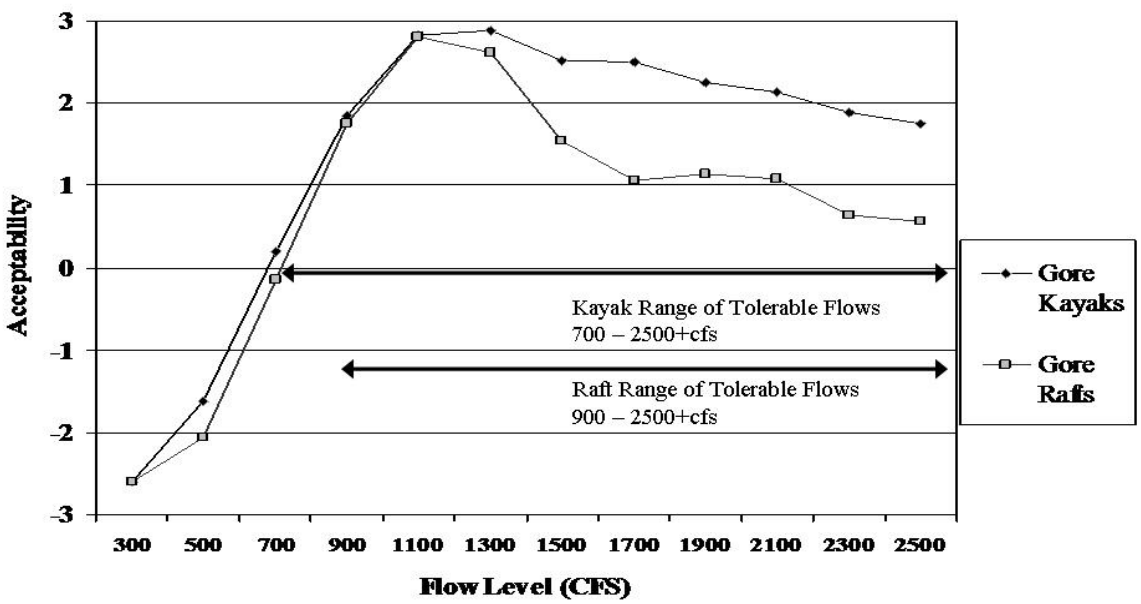


Table C
Gore Canyon Mean Acceptability Scores, Standard Deviation and Potential for Conflict Index

Specific Flow CFS	Mean Acceptability	Standard Deviation	PCI
300	-2.68	0.72	0.00
500	-1.79	1.36	0.05
700	-0.02	1.61	0.39
900	1.66	1.35	0.07
1100	2.59	1.08	0.05
1300	2.62	1.00	0.04
1500	2.29	1.63	0.14
1700	2.05	1.80	0.19
1900	1.87	1.87	0.21
2100	1.71	1.90	0.23
2300	1.48	2.03	0.26
2500	1.34	2.09	0.30

Figure 5
Gore Canyon Impact Acceptability Curves for Kayaks vs. Rafts



BLM Segment 5 – Pumphouse

Pumphouse begins downstream of Gore Canyon halfway between Kremmling and State Bridge. Pumphouse is a class III segment, providing very scenic paddling suitable for almost any kind of watercraft or skill level. In this survey, kayaks were the preferred craft for 43% of respondents, 33% preferred a raft, shredder or cataraft, and 14% would paddle either. Other crafts, such as whitewater canoes or inflatable kayaks made up 6% of respondents.

Respondents (n=85) overall found the minimum acceptable (tolerable) instream flow to be 900 cfs and the range of acceptable flows for the canyon to be between 900 and 2500+ cfs. Optimum flows were 1500+ cfs (Figure 6). The potential for conflict index (Table D), shows the lowest level of agreement between respondents for Pumphouse over the acceptability of 700 cfs (PCI = .30). Differences between kayaker and rafter flow preference did not factor into this disagreement as rafter and kayaker flow preferences for Pumphouse are nearly identical (Figure 7). It is possible that there is another variable involved that was not measured such as the differences between fisherman and general paddlers. Fishermen generally find lower flows more acceptable, even if they are floating the stretch in question. (Whittaker & Shelby, 2002). Attributes of the fishing experience, such as defined eddy lines and pools, can be better at lower flows, justifying the acceptability of slightly lower flows.

Agreement levels were high (PCI < .08) over the unacceptability of flows under 700 cfs and the acceptability of flows over 1100 cfs. Paddlers were united over the strong acceptability of flows over 1100 cfs. Acceptability levels increased for each water level recorded, indicating that higher flows were optimum for paddling this stretch. This finding is consistent with other class III segments where the degree of difficulty does not increase significantly with higher flows (Whittaker & Shelby, 2002). Mean acceptability scores, standard deviation and PCI for each specific instream flow measured for Pumphouse are displayed in Table D.

Figure 6
Pumphouse Potential for Conflict Index Curve

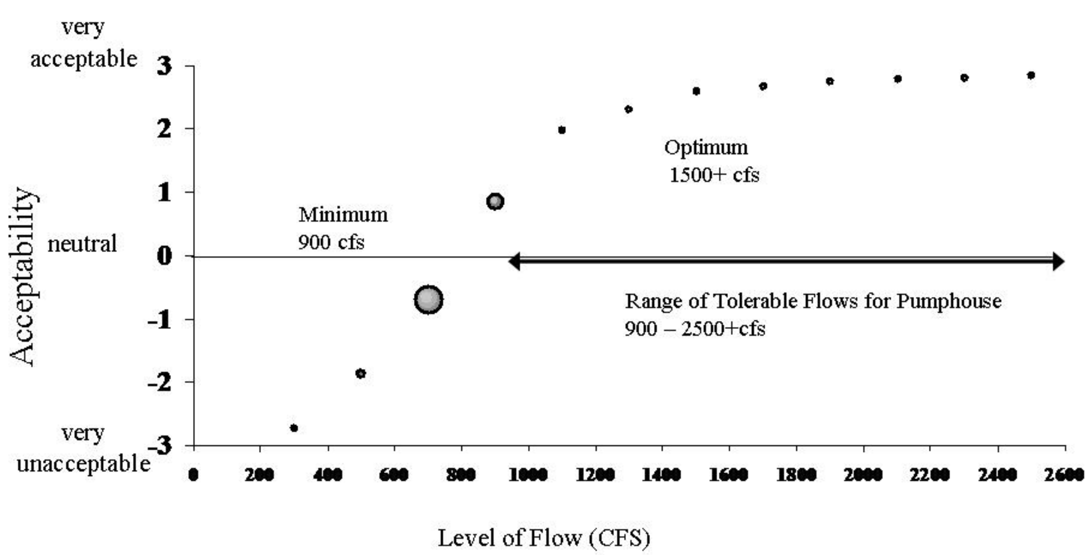
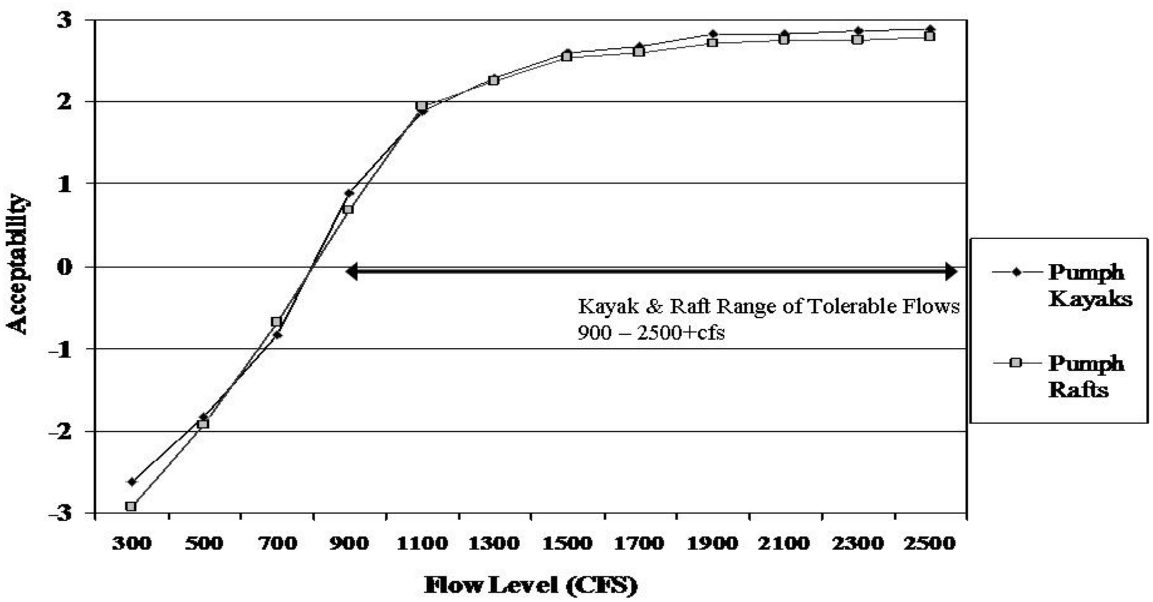


Table D
Pumphouse Mean Acceptability Scores, Standard Deviation and Potential for Conflict Index

Specific Flow CFS	Mean Acceptability	Standard Deviation	PCI
300	-2.73	0.89	0.03
500	-1.87	1.45	0.08
700	-0.70	1.81	0.30
900	0.86	1.51	0.17
1100	1.98	1.34	0.05
1300	2.31	1.05	0.01
1500	2.60	0.89	0.01
1700	2.67	0.82	0.01
1900	2.76	0.80	0.02
2100	2.78	0.75	0.02
2300	2.81	0.74	0.02
2500	2.84	0.71	0.02

Figure 7
Pumphouse Impact Acceptability Curves for Kayaks vs. Rafts



BLM Segment 6 - State Bridge to Dotsero

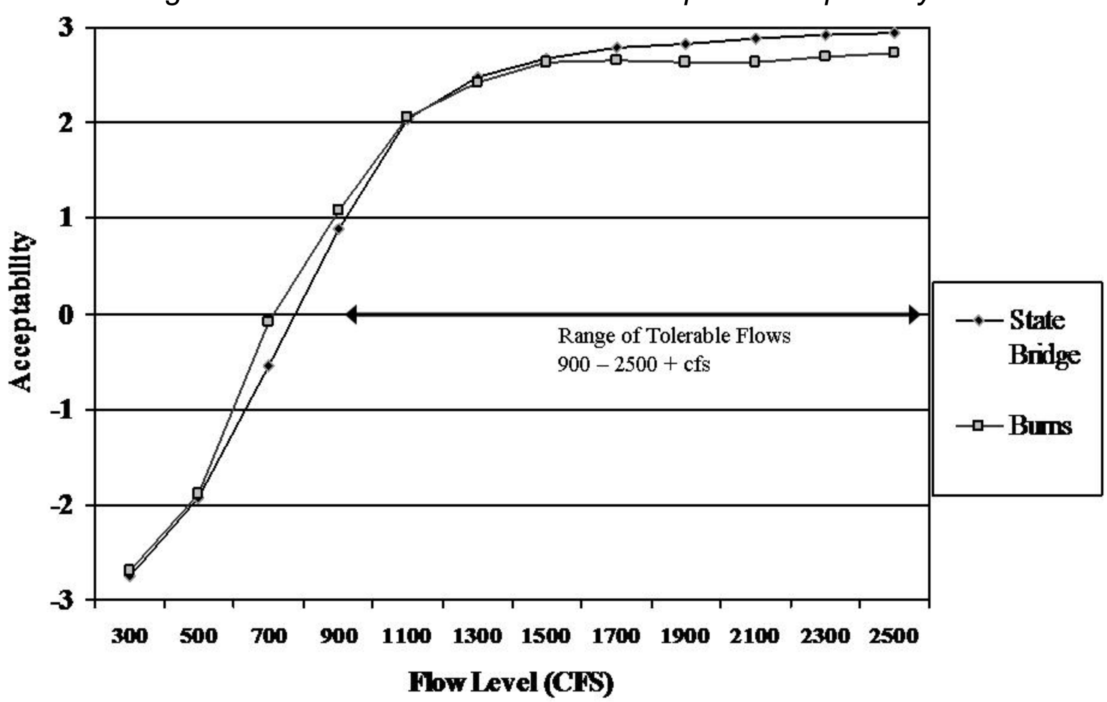
The State Bridge to Dotsero segment of the Upper Colorado River is a nearly 40-mile stretch with mild whitewater and easy access. This stretch is great for car supported or boat supported overnight trips, has multiple access points and different run options, many of which are suitable for beginners. Commercial fishing, rafting and kayaking operations utilize this segment for guided trips and lessons.

State Bridge to Burns is the most difficult section of whitewater in this segment, with class III difficulty for the majority of the run and one class IV rapid near the take-out. The class IV rapid is titled Burns Hole and is used as a “playspot” for advanced paddlers, similar to the features found at whitewater parks across the state. Below Burns Hole, there is little whitewater until the confluence with Sweetwater Creek. Below Sweetwater Creek there is a stretch of class II whitewater, with defined river features offering paddlers numerous opportunities to practice and fine-tune their river running skills.

Considering the variety of paddling stretches on this study segment, the State Bridge to Dotsero segment was separated into two different sub-reaches - State Bridge to Burns and Burns to Dotsero. Respondents for both stretches overall found the minimum acceptable (tolerable) instream flow to be 900 cfs and the range of acceptable (tolerable) flows for the entire segment to be between 900 and 2500+ cfs. Optimum flows were 1500+ cfs (Figure 8).

Figure 8

State Bridge to Burns and Burns to Dotsero Impact Acceptability Curves



For State Bridge to Burns, kayaks were the preferred craft for 33% of respondents, 55% preferred a raft, shredder or cataraft, and 12% would paddle either. There was some disagreement between kayakers and rafters over the minimum acceptable flow levels, where kayakers found 1100 cfs to be the minimum acceptable flow, while rafters found 900 cfs to be acceptable (Figure 9). It is possible that the play features sought after by kayakers do not appear until the river reaches 1100 cfs.

Figure 9

State Bridge to Burns Impact Acceptability Curves for Kayaks vs. Rafts

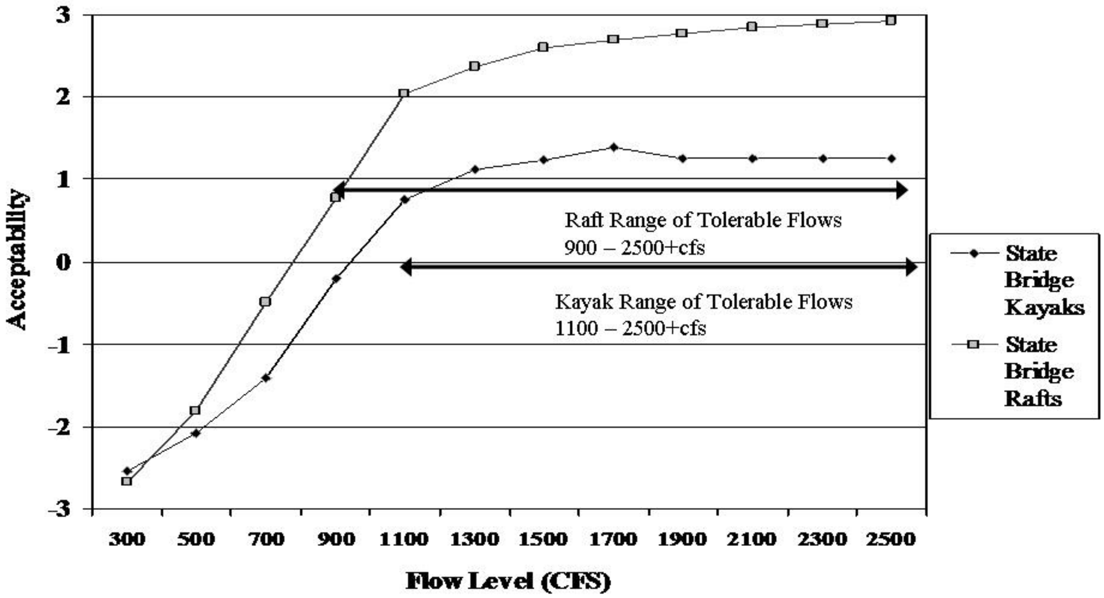
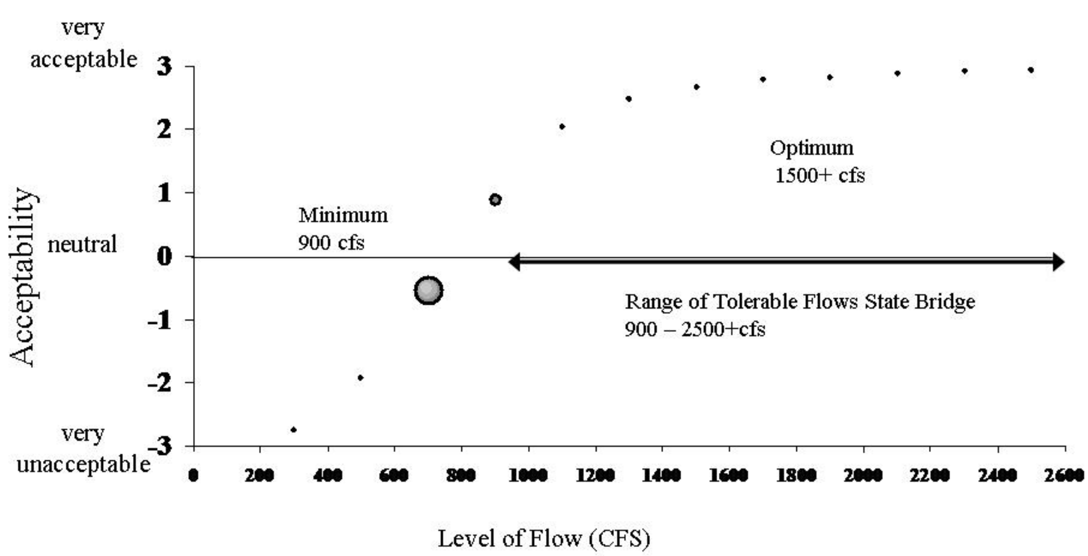


Figure 10

State Bridge to Burns Potential for Conflict Index



For Burns to Dotsero, kayaks were the preferred craft for 37% of respondents, 49% preferred a raft, shredder or cataraft, and 14% would paddle either. The potential for conflict index shows the lowest level of agreement between respondents for Burns to Dotsero over the acceptability of 700 cfs (PCI = .38, Figure 11). Differences between kayaker and rafter flow preference did not factor into this disagreement as rafter and kayaker flow preferences for Burns to Dotsero are nearly identical (Figure 12).

Figure 11

Burns to Dotsero Potential for Conflict Index

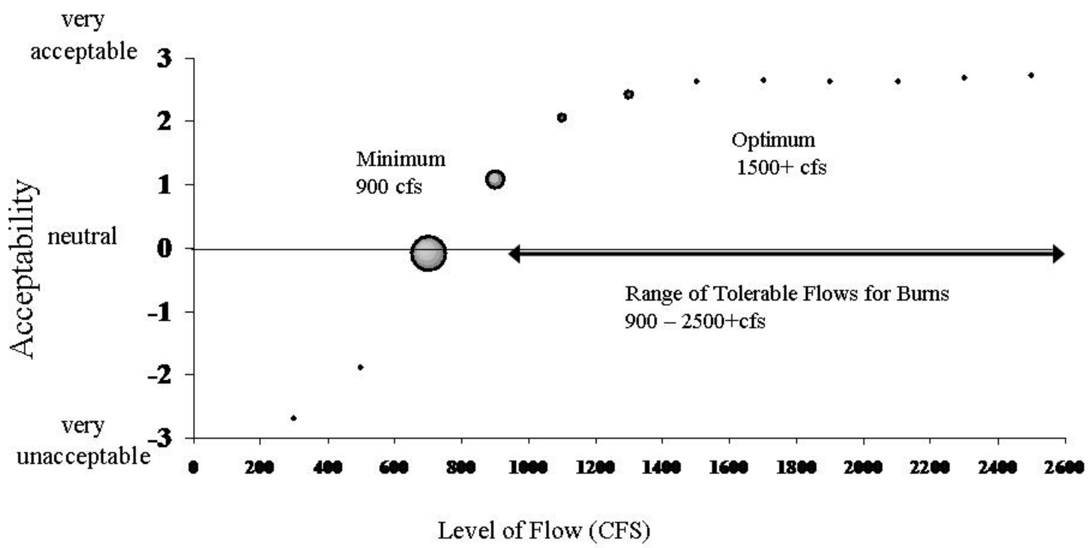
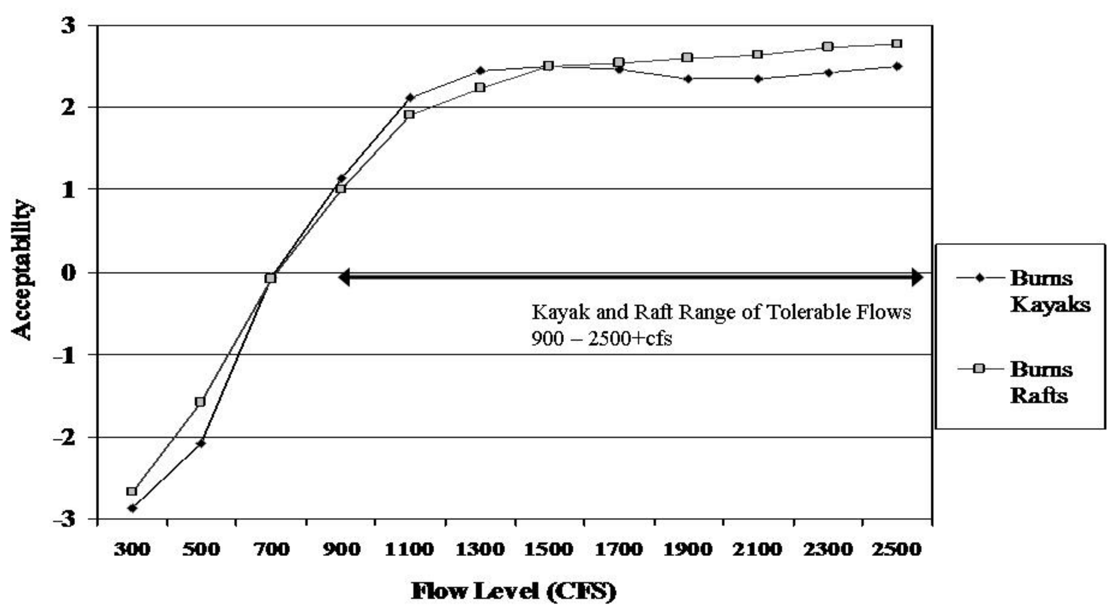


Figure 12

Burns to Dotsero Impact Acceptability Curves for Kayaks vs. Rafts



For both sub-segments, agreement levels were high (PCI < .08) regarding the unacceptability of flows under 700 cfs and the acceptability of flows over 1100 cfs. Paddlers were united over the strong acceptability of flows over 1100 cfs. Acceptability levels increased for both stretches the higher the water level recorded, indicating that higher flows were optimum for paddling these stretches, similar to Pumphouse. Mean acceptability scores, standard deviation and PCI for each specific streamflow measured for State Bridge to Burns and Burns to Dotsero are displayed in Tables E and F.

Table E

State Bridge to Burns Mean Acceptability Scores, Standard Deviation and Potential for Conflict Index

Specific Flow CFS	Mean Acceptability	Standard Deviation	PCI
300	-2.76	0.68	0.00
500	-1.92	1.30	0.04
700	-0.55	1.69	0.28
900	0.89	1.39	0.11
1100	2.05	1.26	0.05
1300	2.49	1.02	0.03
1500	2.68	0.80	0.02
1700	2.78	0.63	0.00
1900	2.83	0.45	0.00
2100	2.89	0.32	0.00
2300	2.92	0.28	0.00
2500	2.94	0.24	0.00

Table F

Burns to Dotsero Mean Acceptability Scores, Standard Deviation and Potential for Conflict Index

Specific Flow CFS	Mean Acceptability	Standard Deviation	PCI
300	-2.69	0.82	0.00
500	-1.88	1.36	0.06
700	-0.09	1.65	0.38
900	1.09	1.75	0.20
1100	2.06	1.33	0.08
1300	2.43	1.24	0.08
1500	2.63	1.14	0.06
1700	2.65	1.12	0.06
1900	2.64	1.17	0.06
2100	2.64	1.11	0.06
2300	2.7	0.98	0.04
2500	2.73	0.88	0.02

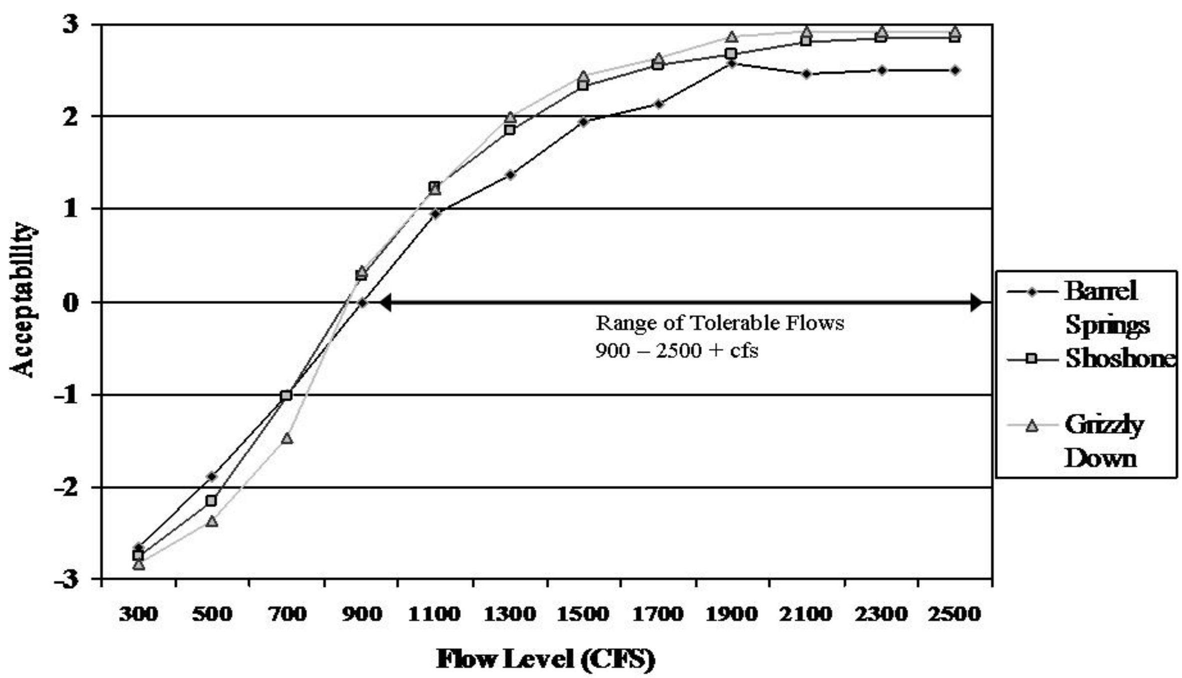
BLM Segment 7 - Glenwood Canyon

Glenwood Canyon is one of the most commonly paddled segments of whitewater in the state. With commercial rafting user days hovering around 70,000[5], only the Arkansas River Valley sees more rafter user days across the entire state. Glenwood Canyon has multiple access points along the interstate and many different run options, from the class V of “Upper Death” rapid to the class II wave trains below No Name, there is whitewater suitable for any level of paddler. Glenwood Canyon is generally split into three different whitewater sections, Barrel Springs, Shoshone and Grizzly Creek. American Whitewater divided Glenwood Canyon into three separate segments for individual analysis in this study.

Barrel Springs is a short stretch of advanced whitewater (class V at most levels) directly below the Shoshone Dam. This stretch is de-watered during a good portion of the year, when the flow below Shoshone Dam is diverted to the Shoshone Hydroelectric power plant. Immediately downstream from the Power plant’s return flow is the Shoshone segment, a class III section of whitewater. Grizzly Creek is immediately downstream of the 1.5 mile Shoshone segment. Respondents for all stretches overall found the minimum acceptable instream flow to be 900 cfs and the range of acceptable flows for the entire segment to be between 900 and 2500+ cfs. Optimum flows were 1500+ cfs (Figure 13).

Figure 13

Barrel Springs, Shoshone and Grizzly Creek Impact Acceptability Curves



5 Colorado River Outfitters Association

For all segments, agreement levels were high (PCI < .08) regarding the unacceptability of flows under 700 cfs and the acceptability of flows over 1900 cfs. Acceptability levels increased for all stretches, as flow levels increased, indicating that high flows were optimum for paddling Glenwood Canyon. Mean acceptability scores, standard deviation and PCI values for each specific streamflow measured for Glenwood Canyon, are displayed in Tables G, H and I.

For Barrel Springs (n=43), kayaks were the preferred craft for 93% of respondents, 5% preferred a raft, shredder or cataraft, and 2% paddled other crafts. There were not enough respondents using crafts other than kayaks to make any meaningful comparisons between different user groups, though levels of disagreement (Figure 14) can be attributed to differences in craft and skill levels within the respondent pool, possibly.

Figure 14
Barrel Springs Potential for Conflict Index

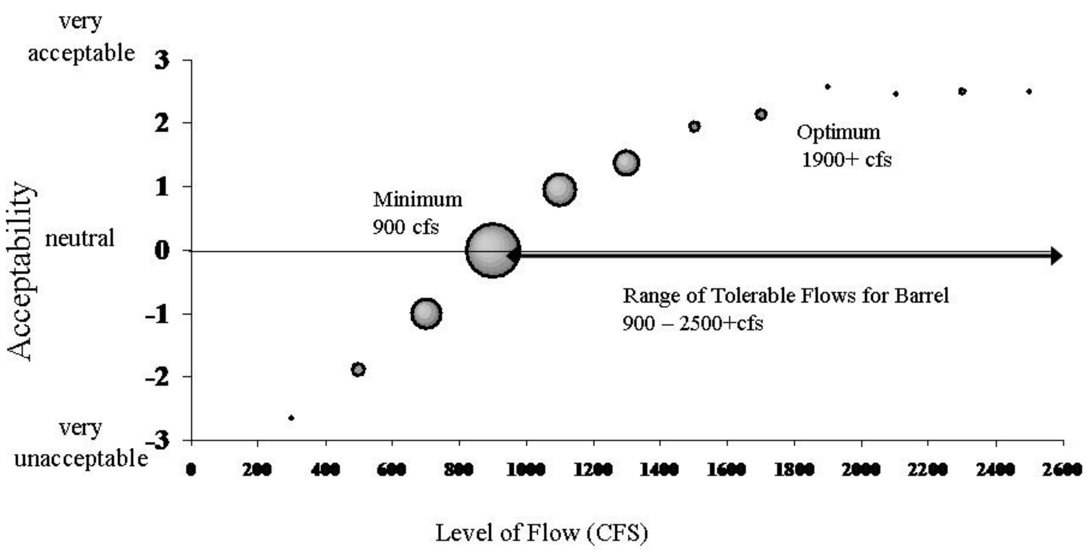


Table G
Barrel Springs Mean Acceptability Scores, Standard Deviation and Potential for Conflict Index

Specific Flow CFS	Mean Acceptability	Standard Deviation	PCI
300	-2.66	0.80	0.00
500	-1.89	1.66	0.14
700	-1	2.04	0.32
900	0	2.09	0.58
1100	0.95	2.18	0.35
1300	1.37	2.03	0.26
1500	1.95	1.59	0.12
1700	2.13	1.49	0.11
1900	2.57	0.69	0.00
2100	2.46	1.14	0.05
2300	2.5	1.21	0.06
2500	2.51	1.19	0.04

For Shoshone (n = 84), kayaks were the preferred craft for 79% of respondents, 14% preferred a raft, shredder or cataraft, 6% would paddle either a kayak or a raft, and 1% paddled other crafts. The Potential for Conflict Index shows the lowest level of agreement between respondents for Shoshone over the acceptability of 900 cfs (PCI = .4, Figure 15). Differences between kayaker and rafter flow preference did not factor into this disagreement as rafter and kayaker flow preferences for Shoshone are nearly identical.

Figure 15
Shoshone Potential for Conflict Index

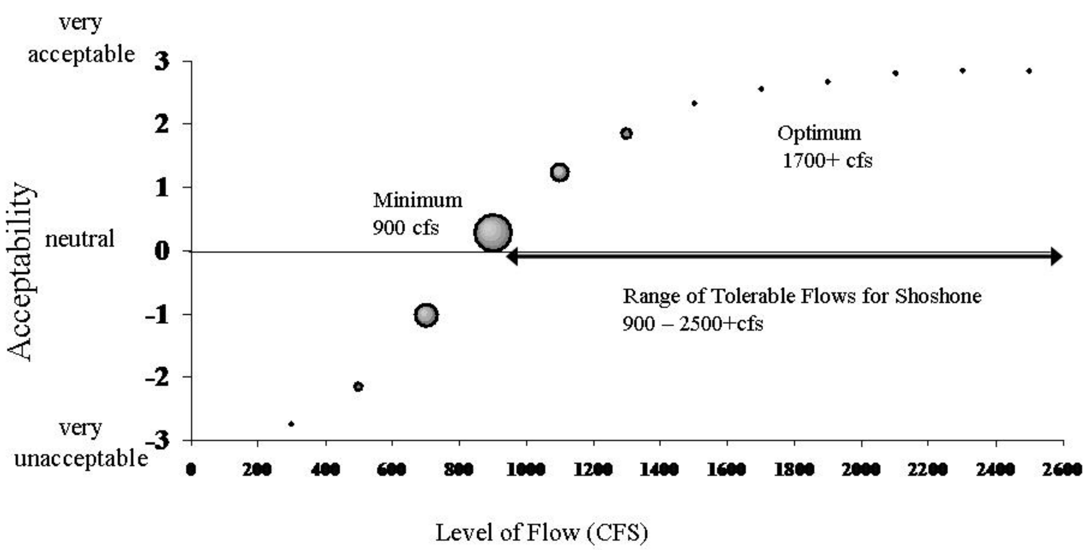


Table H
Shoshone Mean Acceptability Scores, Standard Deviation and Potential for Conflict Index

Specific Flow CFS	Mean Acceptability	Standard Deviation	PCI
300	-2.76	0.70	0.00
500	-2.16	1.42	0.08
700	-1.03	1.85	0.25
900	0.27	1.84	0.40
1100	1.24	1.65	0.18
1300	1.85	1.54	0.12
1500	2.32	1.20	0.04
1700	2.56	0.99	0.03
1900	2.67	0.84	0.02
2100	2.81	0.59	0.00
2300	2.84	0.47	0.00
2500	2.84	0.52	0.00

For Grizzly Creek (n=47), kayaks were the preferred craft for 58% of respondents, 26% preferred a raft, shredder or cataraft, 12% would paddle either a kayak or a raft, and 4% paddled other crafts. Rafter and kayaker flow preferences for Grizzly Creek were also nearly identical.

Figure 16
Grizzly Creek Potential for Conflict Index

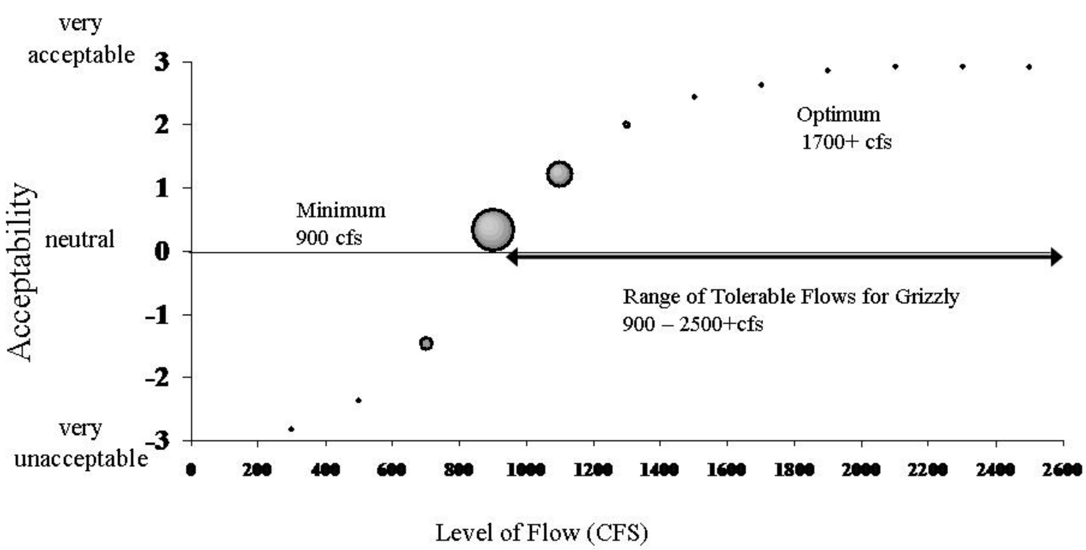


Table I
Grizzly Creek Mean Acceptability Scores, Standard Deviation and Potential for Conflict Index

Specific Flow CFS	Mean Acceptability	Standard Deviation	PCI
300	-2.82	0.64	0.00
500	-2.37	1.28	0.05
700	-1.46	1.67	0.15
900	0.34	1.96	0.44
1100	1.21	1.99	0.26
1300	2	1.43	0.06
1500	2.44	0.93	0.00
1700	2.64	0.69	0.00
1900	2.86	0.42	0.00
2100	2.93	0.34	0.00
2300	2.93	0.34	0.00
2500	2.93	0.35	0.00

C. Specific Flow Evaluation

In order to further refine the overall flow-evaluation curves described in Section III A, a second set of single-flow evaluations were presented to survey respondents. For each study segment, survey respondents reported a single flow value that provides a distinct paddling experience or "niche" along a spectrum: low, technical, standard, high challenge, and highest acceptable flow. These "niches" relate stream flow to the full range of whitewater boating opportunities and aid in understanding the relationship between streamflows and recreation quality described in each Flow-Evaluation Curve. Overlaying the specific and overall flow-evaluation results is a helpful approach to assessing the affects of streamflows on recreation quality.

With single preference norms reported as specific evaluations, measures of central tendency, such as the mean and median, are useful representations of the flow in question. Median values for each study segment are described in Table J.

Table J

MEAN: Low, Standard, Technical, High Challenge and High Acceptable Flows

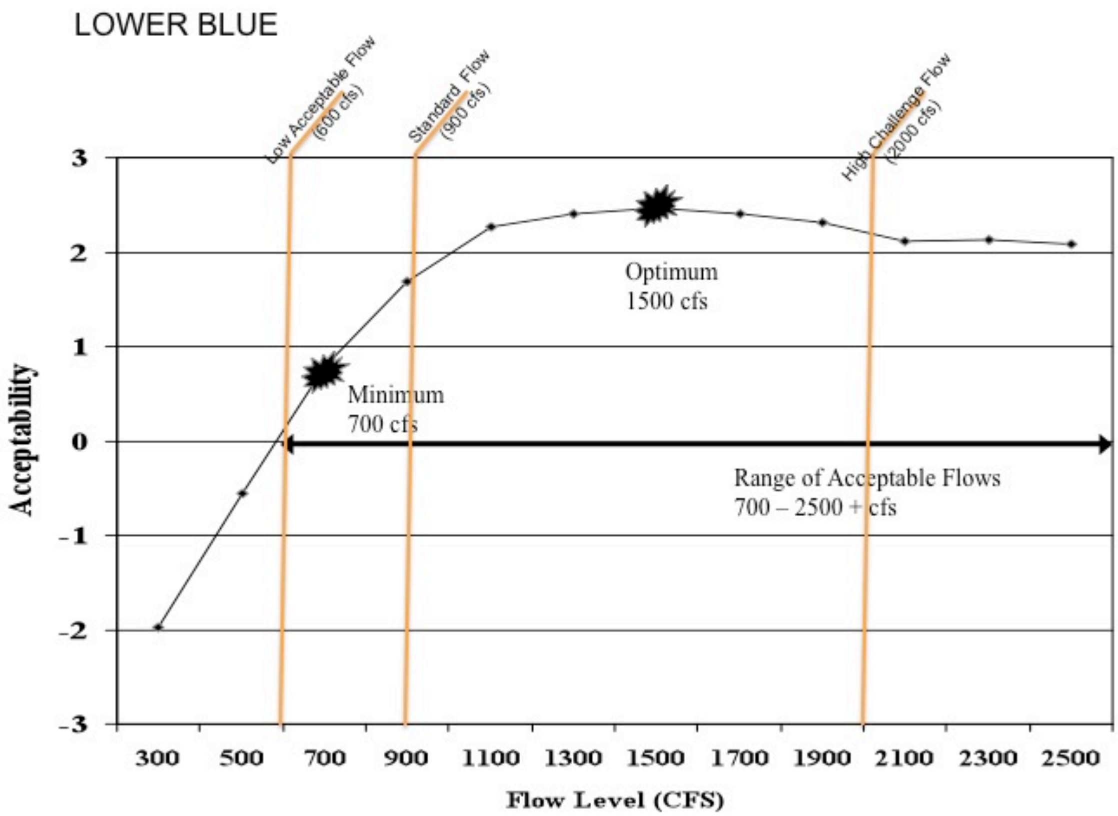
Whitewater Boating Attribute	Low Acceptable Flow (cfs)	Standard Flow (cfs)	Technical Flow (cfs)	High Challenge Flow (cfs)	High Acceptable Flow (cfs)
Fraser River: Fraser Canyon	600	1000	600	1800	2400
Colorado River: Byers Canyon	600	1000	600	2200	3200
Colorado River: Gore Canyon	750	1050	750	2000	2500
Blue River: Lower Blue	600	900	600	2000	3000
Colorado River: Pumphouse to State Bridge	900	1500	800	3500	Un-determined
Piney River: Piney Crossing to State Bridge	700	1000	700	4400	5100
Colorado River: State Bridge to Burns	900	1300	800	4000	7400
Colorado River: Burns to Dotsero	800	1400	750	4500	8800
Colorado River: Barrel Springs	1000	1600	1000	5400	6400
Colorado River: Shoshone to Grizzly Creek	1000	1900	1000	4900	9400
Colorado River: Grizzly Creek to Two Rivers Park	1250	1800	1100	5500	8600

Note: mean flow-values have been rounded to the nearest whole number.

D. Integrating Single Flow Judgments and Overall Flow-Evaluation Curves

For most segments, single-flow evaluations are shown to closely mimic relative values identified by the Flow-Evaluation curves for lowest acceptable, standard (optimal), and high flows. Mean single-flow evaluations have been helpful in describing specific flow-dependant "niches" for whitewater boating experiences along each Flow-Evaluation curve. Overlaying the specific and overall flow-evaluation results is a helpful approach to analyzing the results of the study. An example of this integration, using the Lower Blue River study segment is provided in Figure 17.

Figure 17:
Integrating Single Flow Judgments and Overall Flow-Evaluation Curves



Following along the curve, the mean flow reported for minimum whitewater boating, is 600 cfs for the Lower Blue River. This is close to the point on the overall flow-evaluation curve where the neutral line between un-acceptable and acceptable is crossed. The same integration can be made, in this example, for standard and high challenge flows (900cfs and 2000cfs respectively), where standard flows track closely with optimal flows, and high challenge flows are described as greater than optimal flows. Integrating results from both overall and specific flow-evaluation questions can provide more information than either format by itself. The full suite of Integrated Flow-Evaluations is included in Appendix D.

IV. Conclusion

To establish flow ranges for acceptable and optimal recreational opportunities in the Upper Colorado River basin, American Whitewater collected and organized personal evaluations of recreational resource conditions, and recreation-relevant hydrology, consistent with standard methodologies. An online survey conducted in 2008 involved 242 volunteer paddlers, representing a range of experience and skill level. Survey respondents were asked to participate in two approaches to evaluating streamflows and recreation quality on eleven river segments, including four segments of the Colorado River found eligible for inclusion into the National Wild and Scenic Rivers System by the U.S. Bureau of Land Management.

In one set of questions, study participants we asked to evaluate overall recreation quality for each measured flow, using a seven-point “acceptability” scale. Using a survey-based normative approach, individual evaluations of flows are aggregated into social norms, which describe the group’s collective evaluation of those same stream flows. Flow-evaluation curves and the Potential for Conflict Index were used to help describe minimum, optimal and the range of acceptable flows, and respondent agreement, regarding each specific flow level. For each of the river segments surveyed, high levels of agreement on optimal flows were recorded. Minimum acceptable flows were identified for each segment. For many segments, respondents reported no maximum acceptable flow.

Study participants were also asked to report single flows that provide distinct recreational resource outputs, such as minimum whitewater and high whitewater flow conditions. Mean responses to specific flow-evaluation questions helped to identify distinct recreational “niches”, where recreation opportunities exist along a range of conditions - minimum, low, optimal, and high challenge. Good whitewater conditions require higher flows than those identified as providing minimum boatable flows. For each study segment, the median response for minimum whitewater corresponds to the point where the overall flow-evaluation crosses the neutral line. The median response for optimal flows however corresponds with the peak of the curve where ratings are highest. Overall Flow-evaluation curves are relatively flat at the top of most segments, which is attributed to the multiple tolerance norms captured in the study data.

Whitewater flow-preferences described in this report make it possible to analyze and evaluate the impacts to whitewater boating under future water supply scenarios being considered by the Colorado Basin Roundtable. A quantitative metric of “usable days” or “boatable days” can be developed using the flow-ranges for whitewater recreation described by this study. This metric can aid in establishing a relative comparison value to evaluate effects of flow manipulation under various scenarios for supply and demand in the Colorado River basin. To the extent that flow regimes can be managed to produce different resource outputs, these flow-evaluations can aide decision-makers in determining how flow management can result in different combinations of recreation opportunities.

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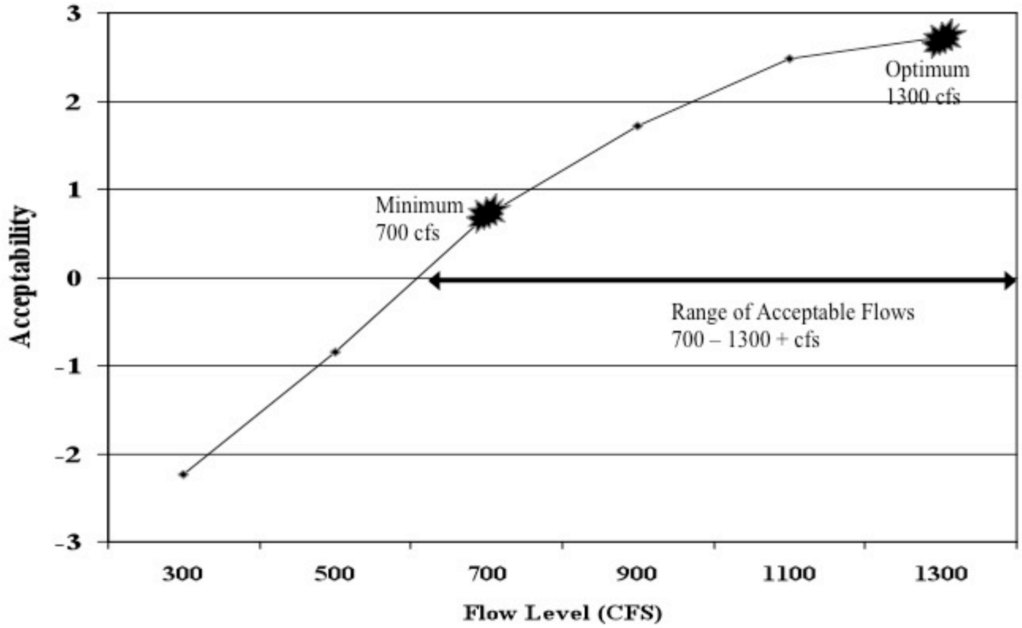
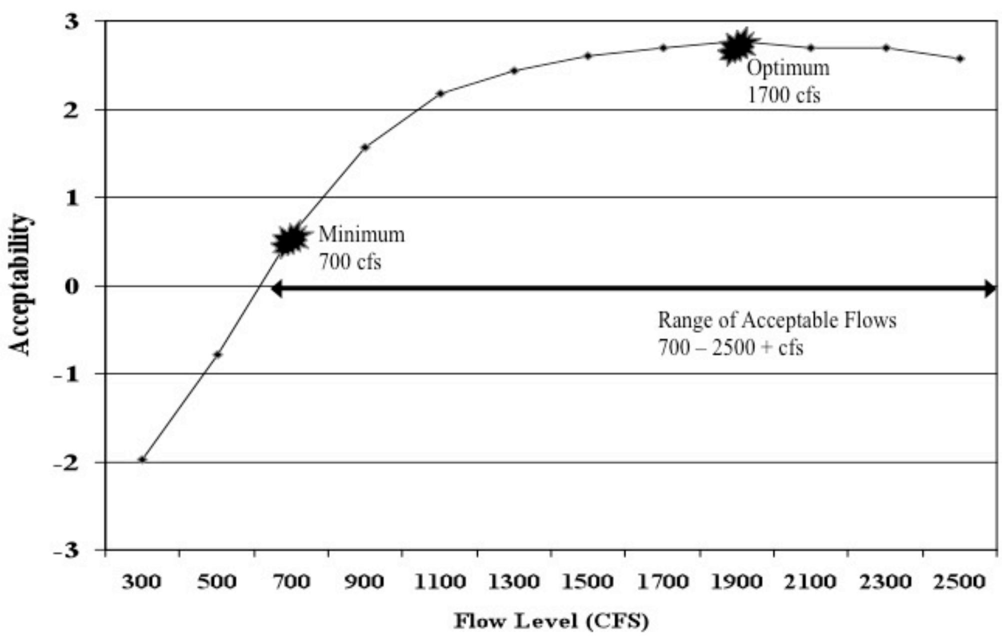
Appendix A: Upper Colorado River Flow Survey, attached.

Appendix B: Overall Flow-Evaluation Curves

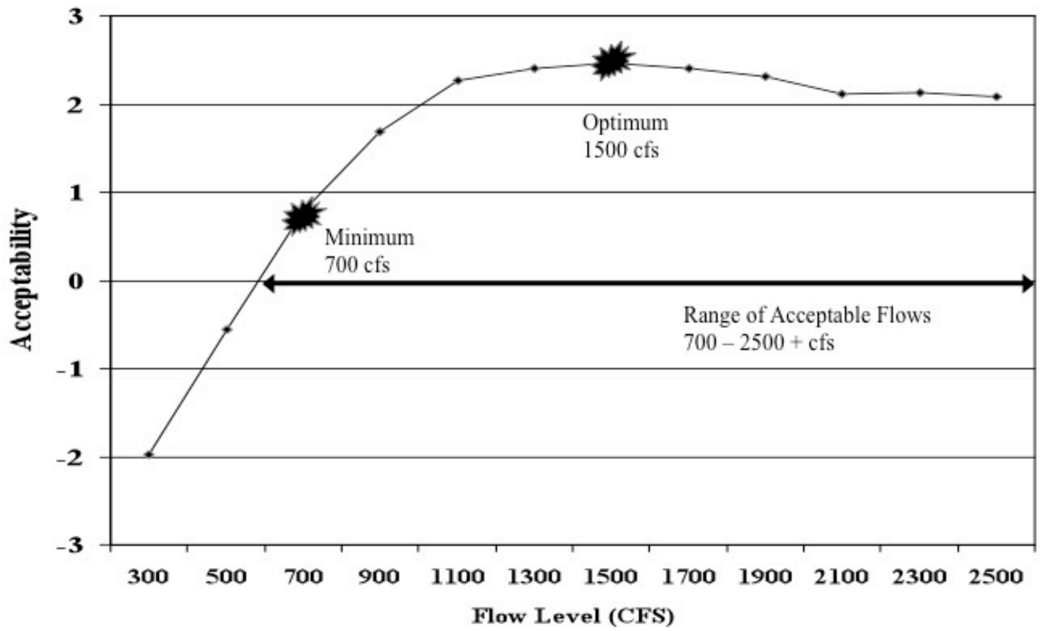
FRASER RIVER



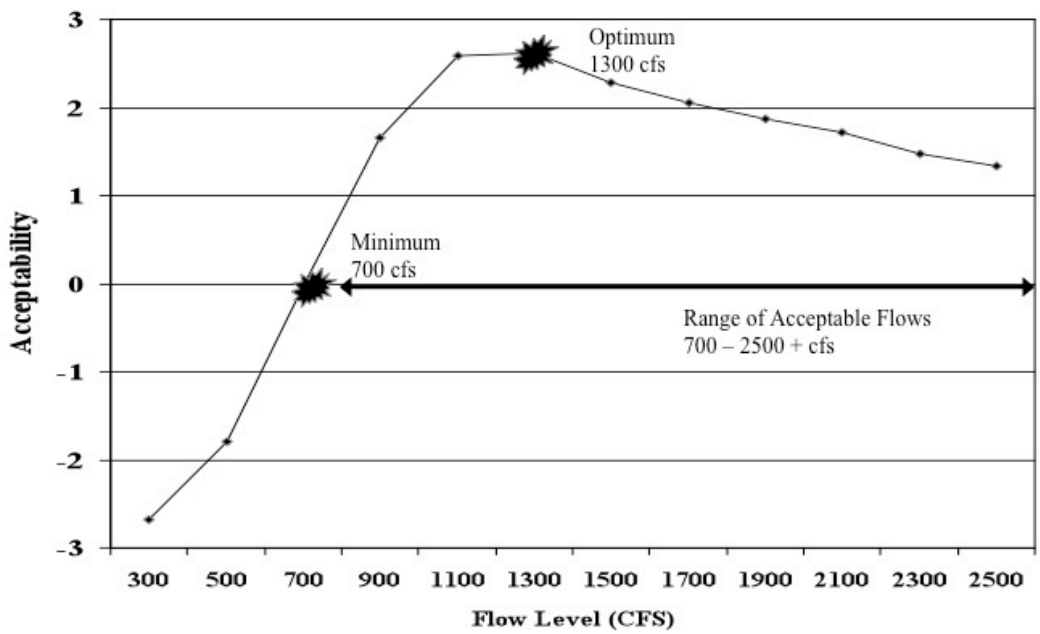
BYERS CANYON



LOWER BLUE



GORE CANYON



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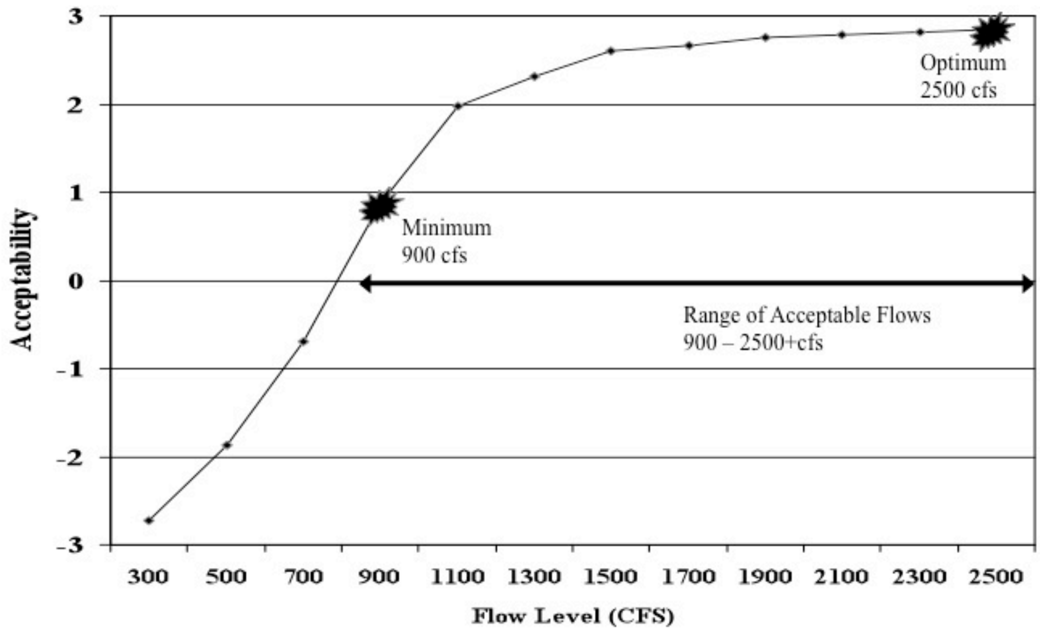
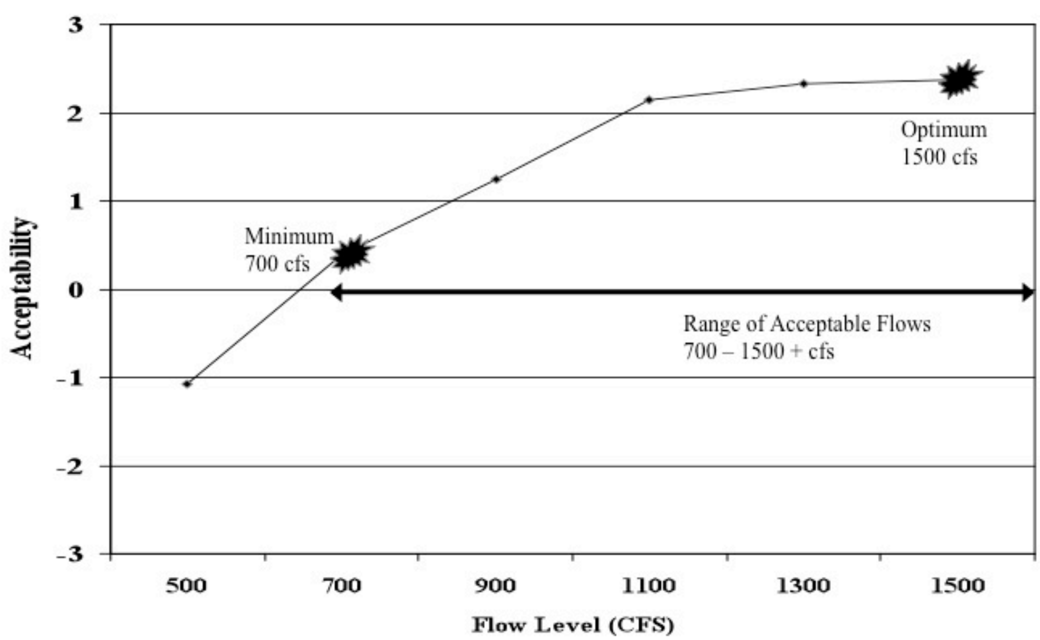
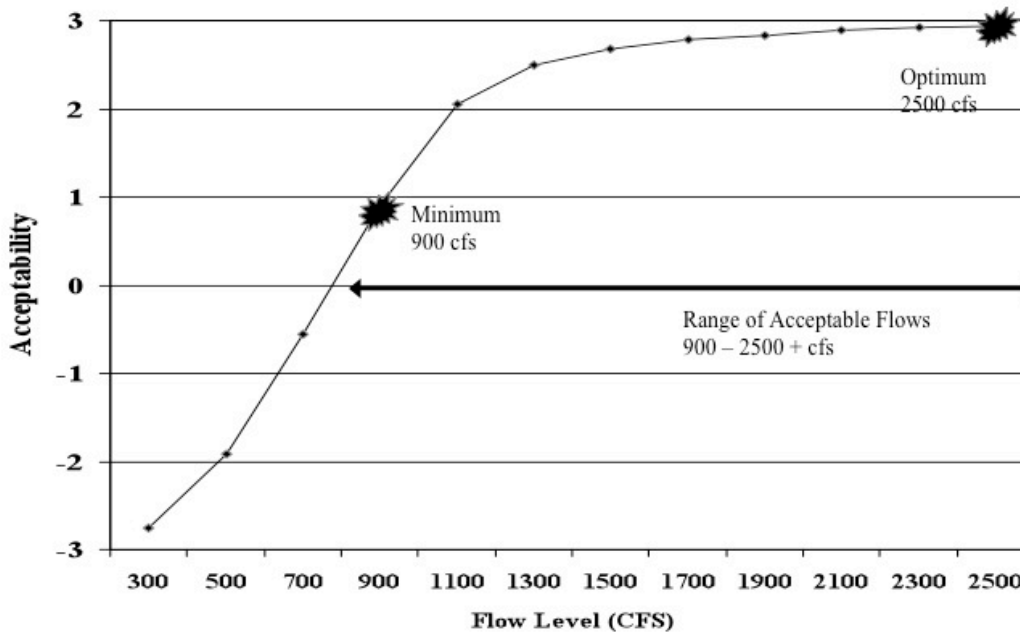


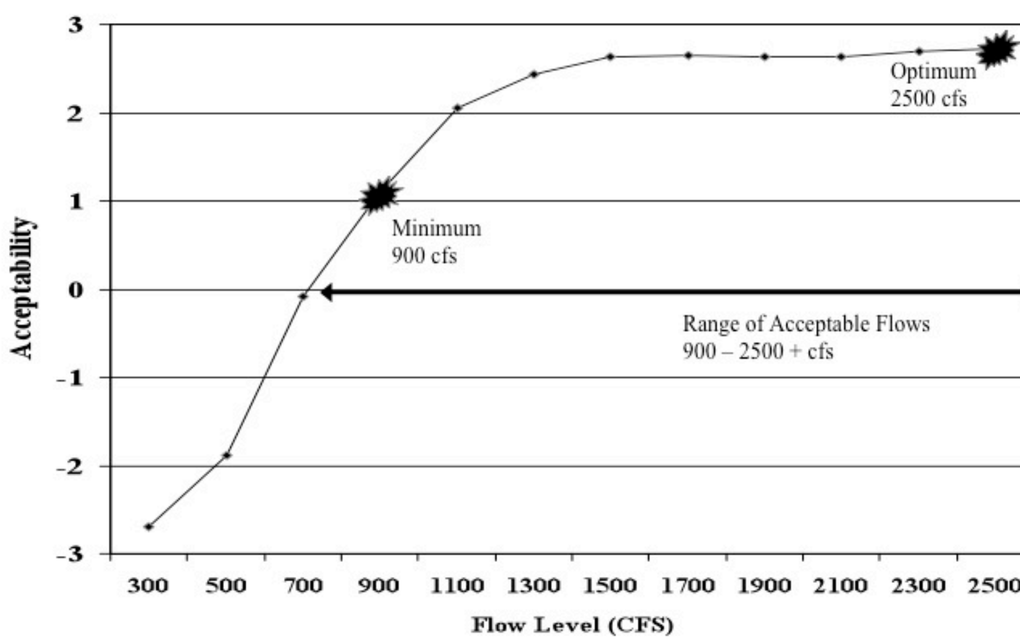
PINEY RIVER TO STATE BRIDGE



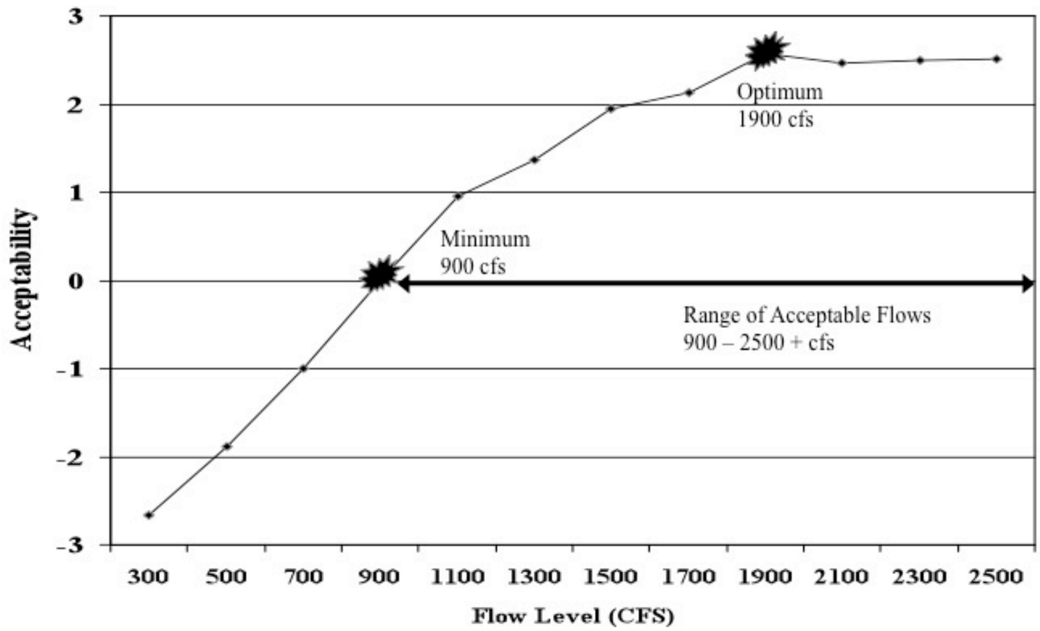
STATE BRIDGE TO BURNS



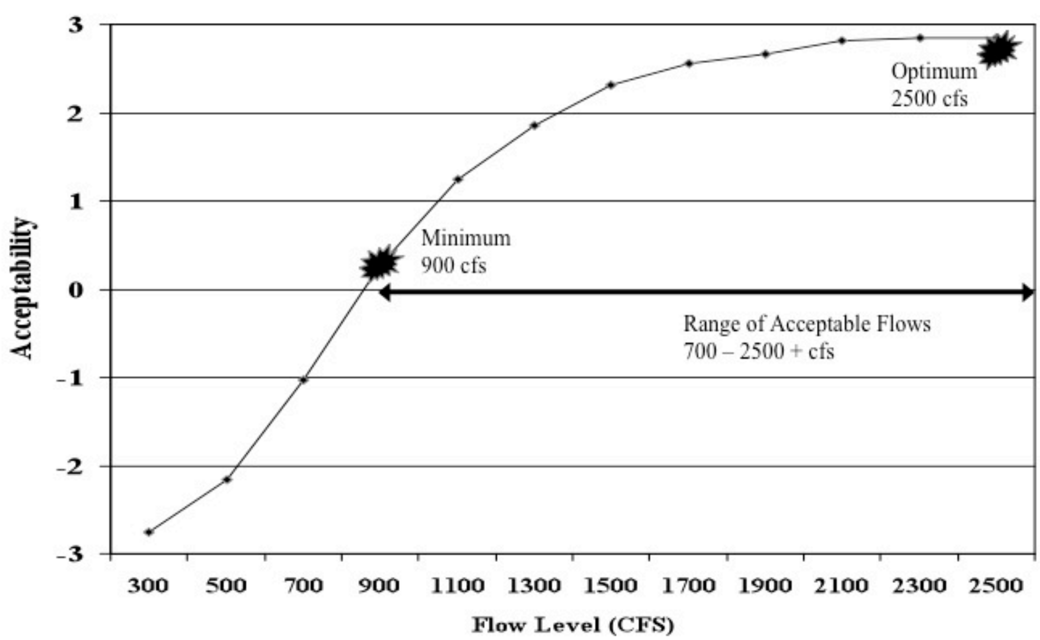
BURNS TO DOTSERO



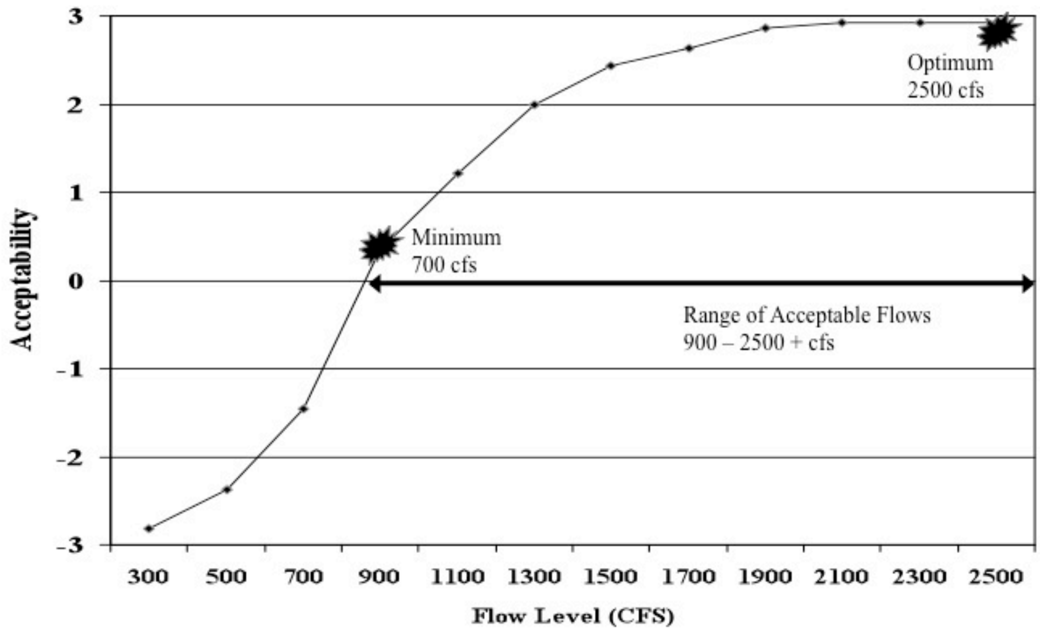
BARREL SPRINGS



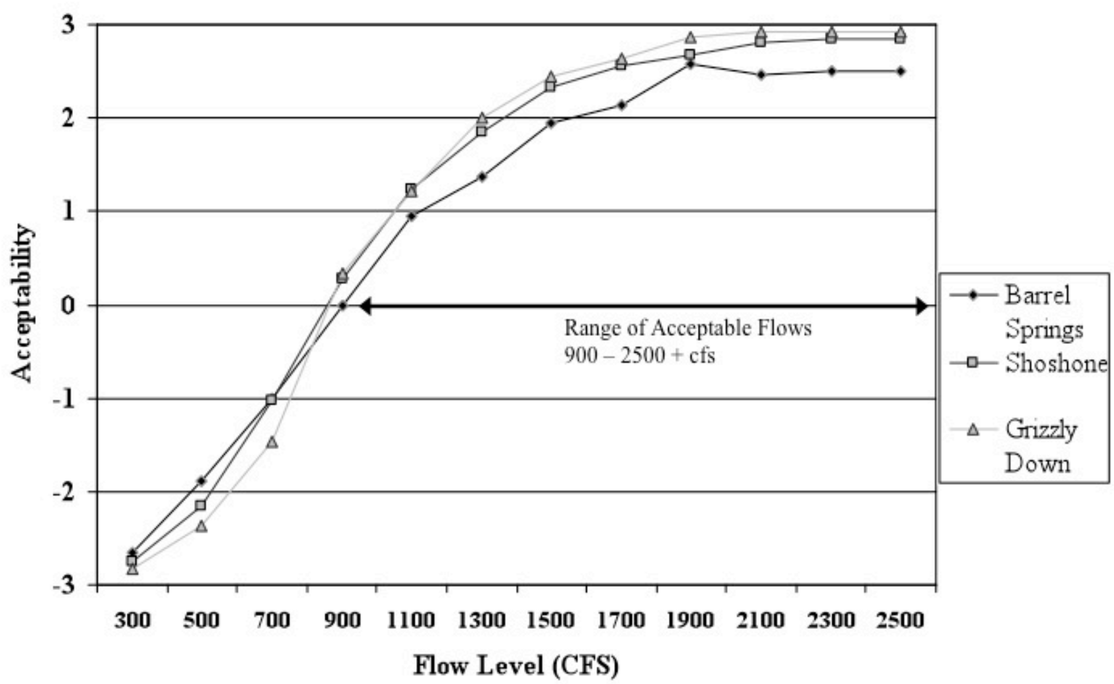
SHOSHONE



GRIZZLY CREEK TO TWO RIVERS PARK

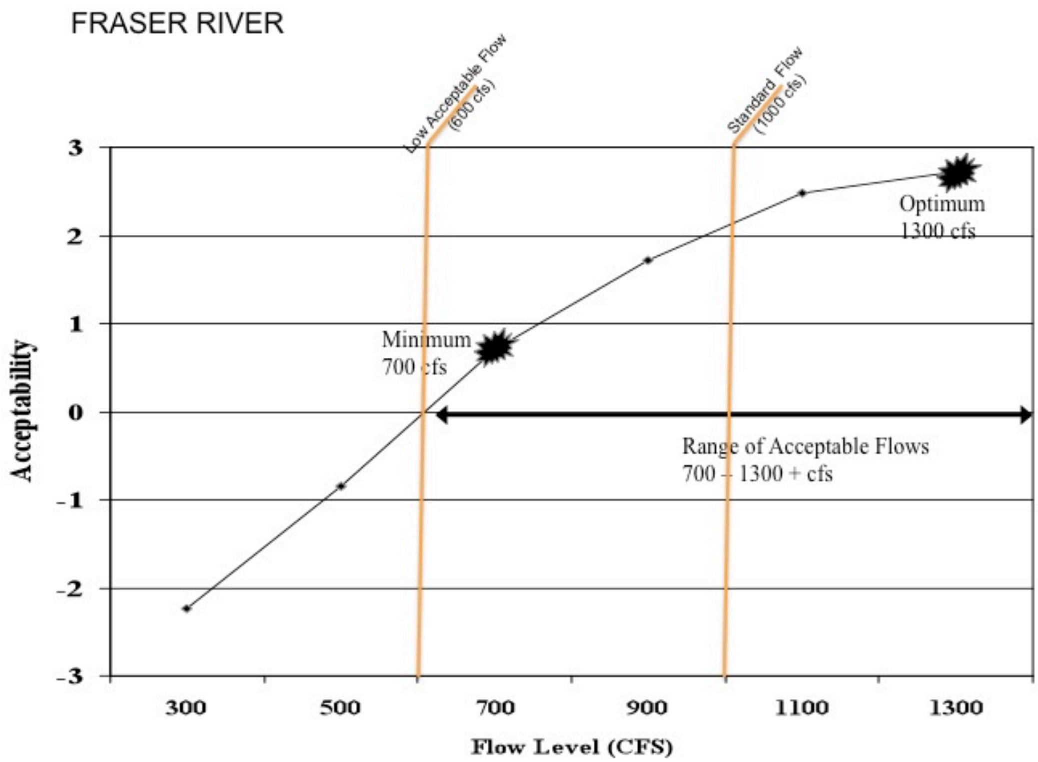


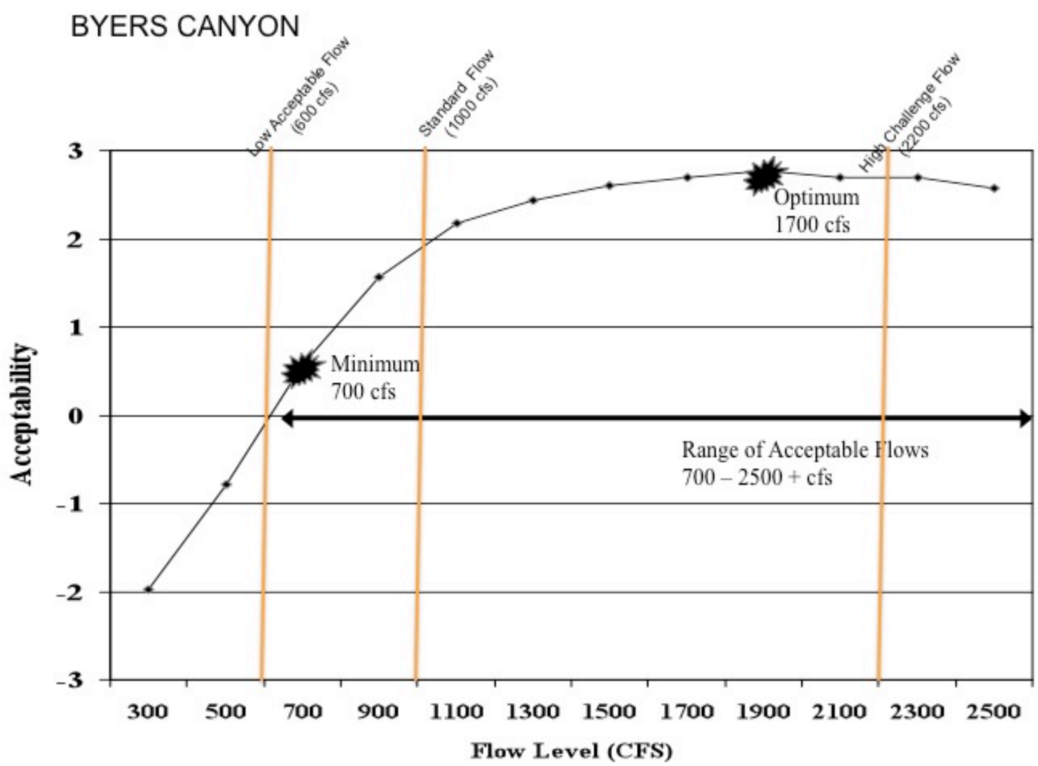
Glenwood Canyon – All Segments

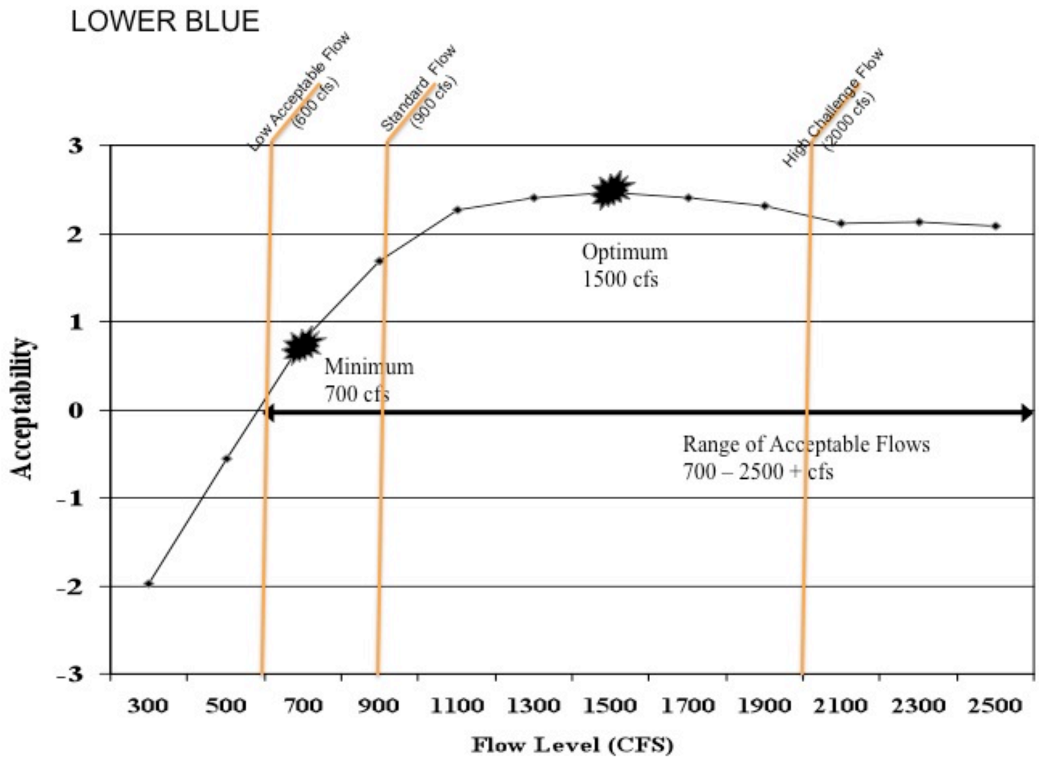


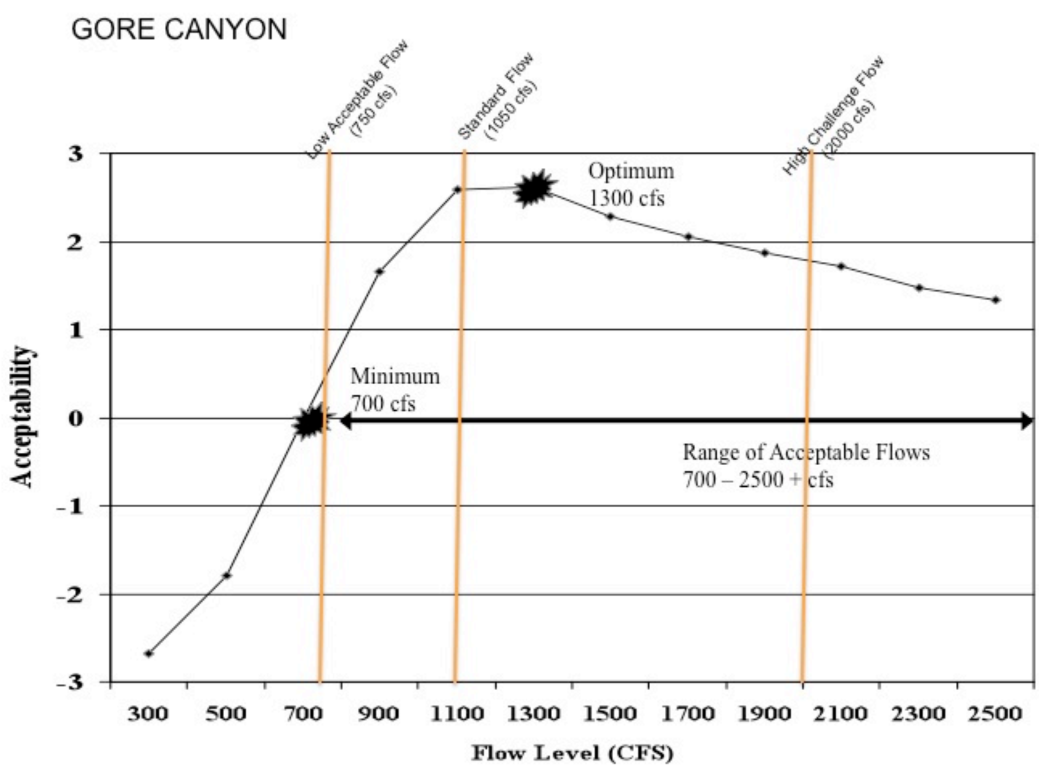
Appendix C:

Integration of Single-Flow Judgments with Overall Flow-Evaluation Curves






LOWER BLUE
Low Acceptable Flow (600 cfs)
Standard Flow (900 cfs)
High Challenge Flow (2000 cfs)
Optimum
1500 cfs
Minimum
700 cfs
Range of Acceptable Flows
700 – 2500 + cfs
Acceptability
Flow Level (CFS)
3
2
1
0
-1
-2
-3
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500


GORE CANYON
Low Acceptable Flow (750 cfs)
Standard Flow (1050 cfs)
High Challenge Flow (2000 cfs)
Optimum
1300 cfs
Minimum
700 cfs
Range of Acceptable Flows
700 – 2500 + cfs
Acceptability
Flow Level (CFS)
3
2
1
0
-1
-2
-3
300
500
700
900
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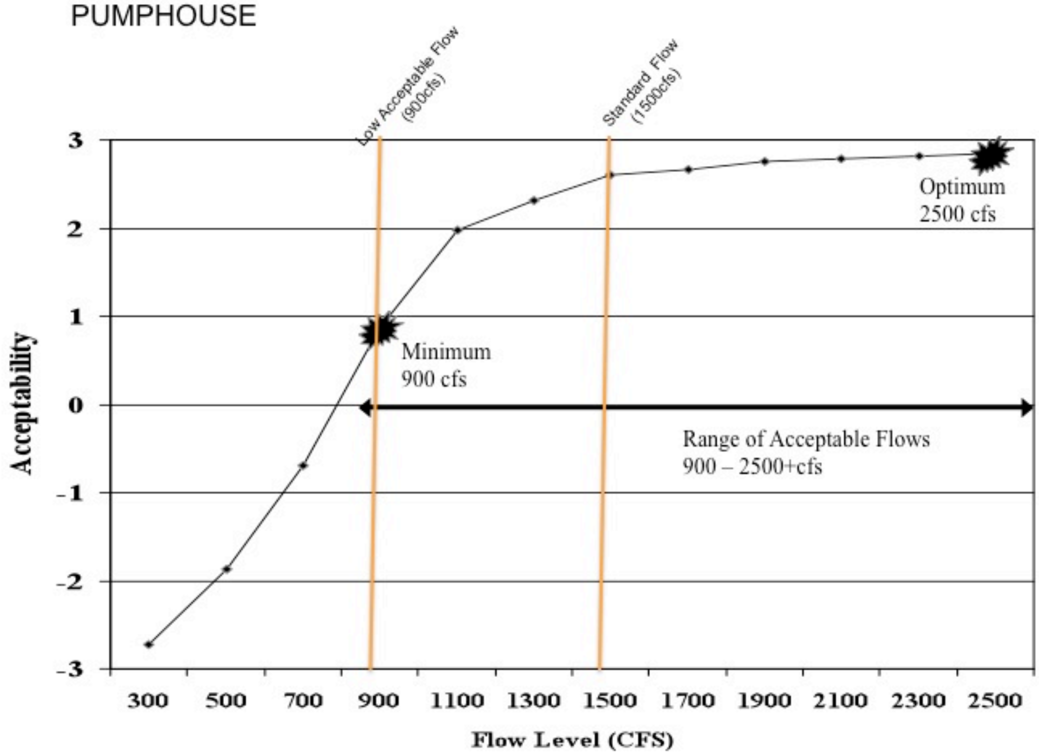
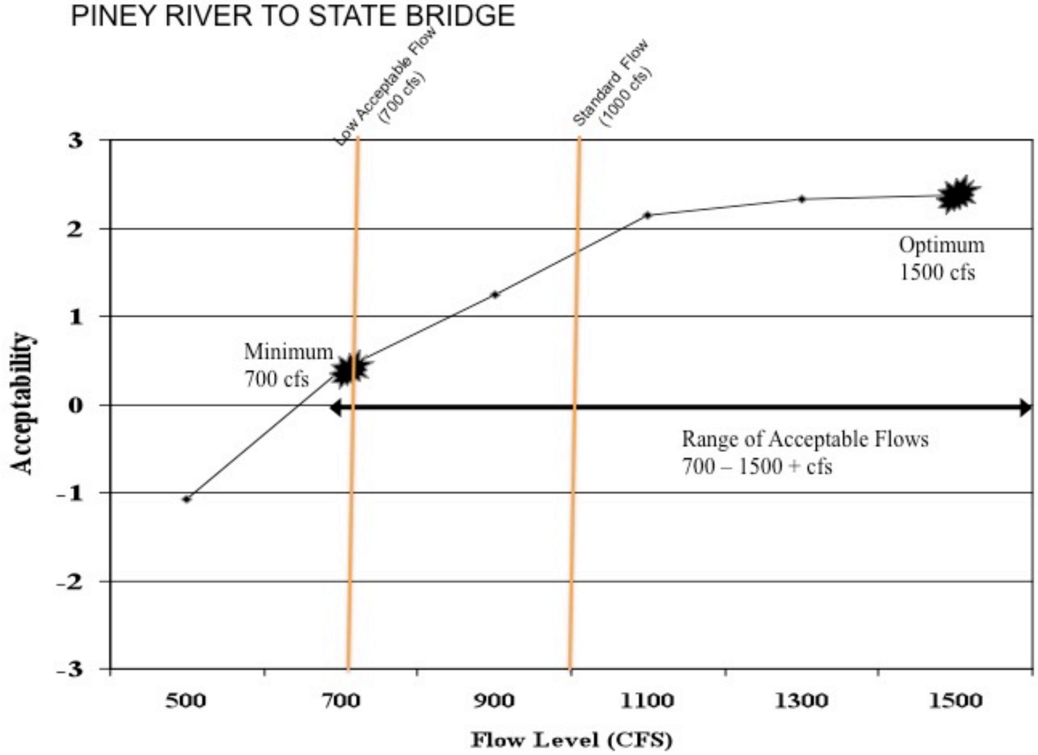
1900
2100
2300
2500

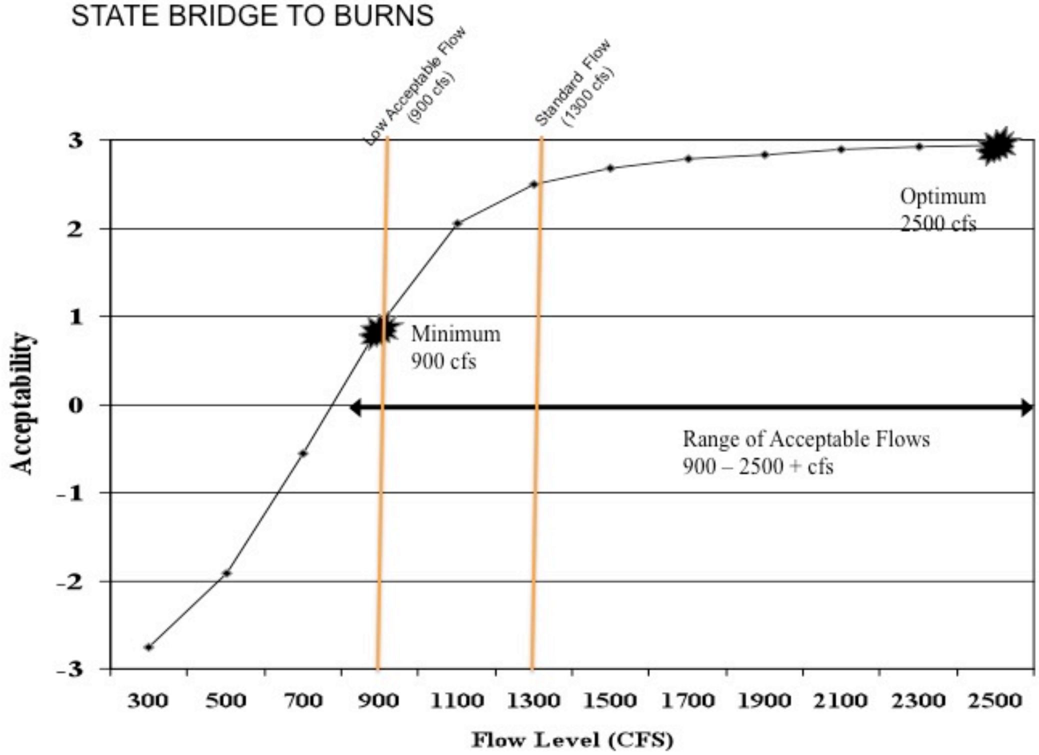
PUMPHOUSE



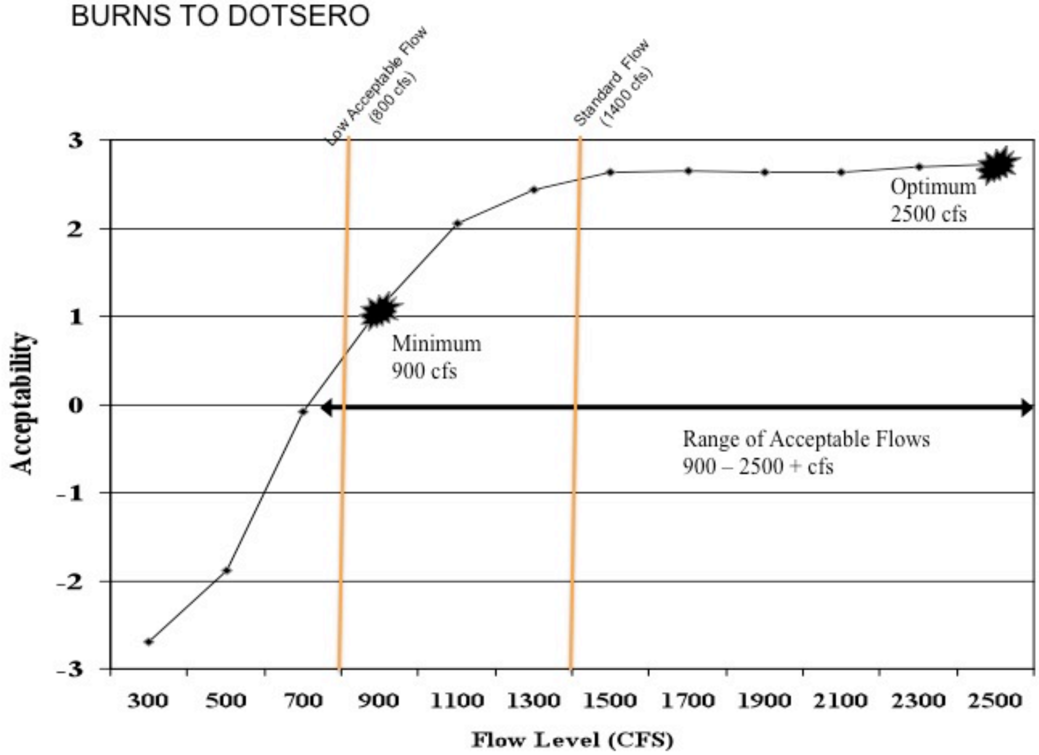
PINEY RIVER TO STATE BRIDGE



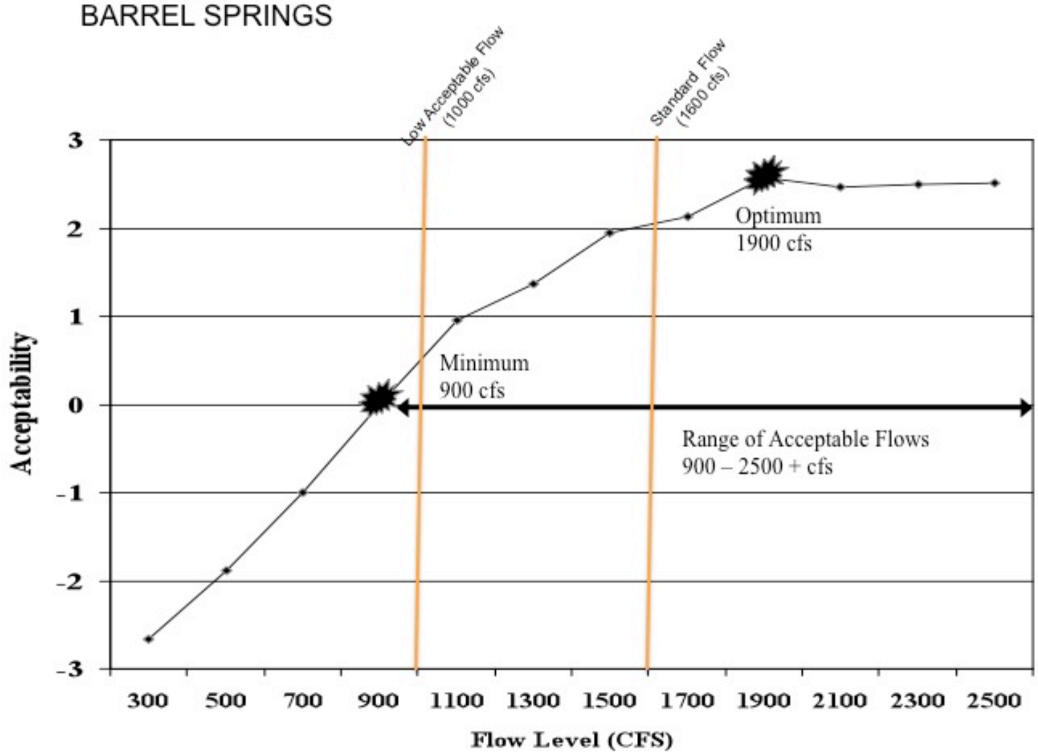
STATE BRIDGE TO BURNS



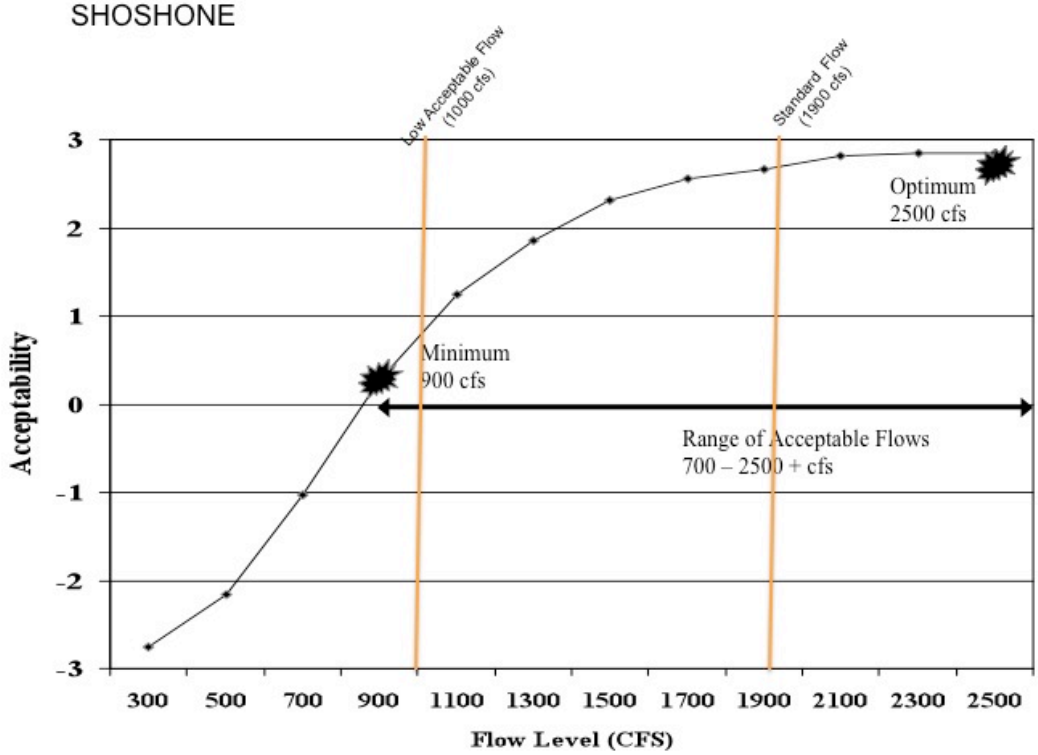
BURNS TO DOTSERO

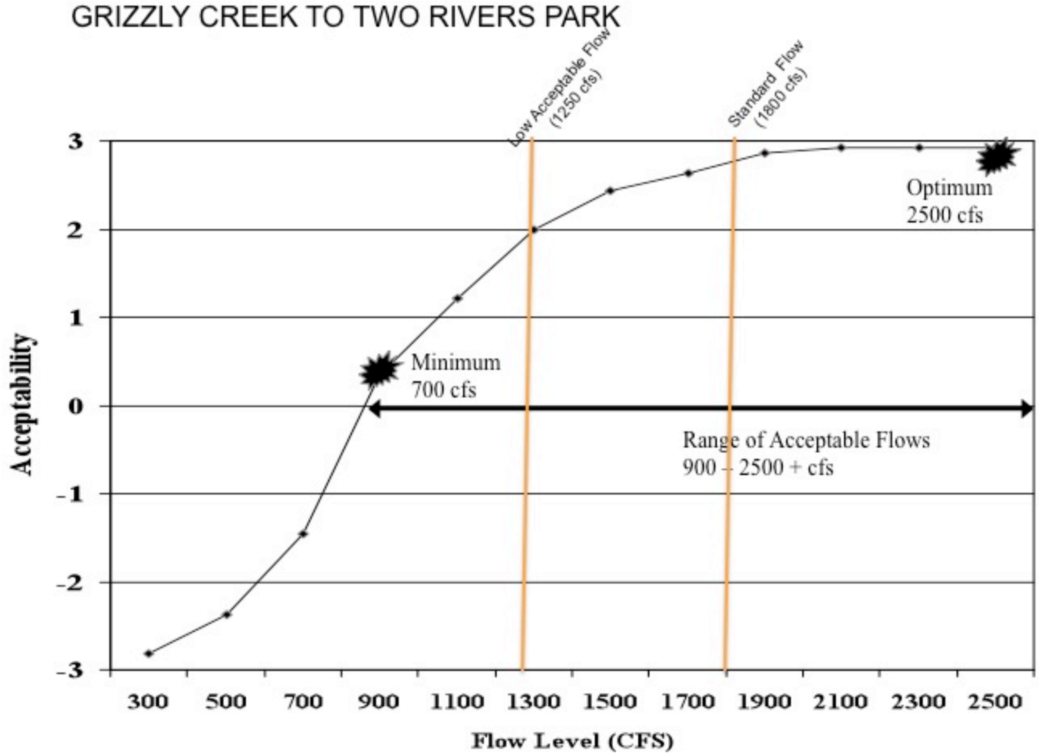


BARREL SPRINGS



SHOSHONE




GRIZZLY CREEK TO TWO RIVERS PARK
Low Acceptable Flow (1250 cfs)
Standard Flow (1800 cfs)
Optimum 2500 cfs
Minimum 700 cfs
Range of Acceptable Flows 900 - 2500 + cfs
Acceptability
3
2
1
0
-1
-2
-3
300 500 700 900 1100 1300 1500 1700 1900 2100 2300 2500
Flow Level (CFS)