Oklahoma Water Resources Board

UPPER ILLINOIS RIVER INSTREAM FLOW PILOT STUDY

DRAFT | June 2019

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Oklahoma Water Resources Board

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Abbreviations

AAF	average annual flow
AF	acre-feet
AFY	acre-feet per year
AGW	alluvial groundwater
ATM	Alternative Transfer Method
BSC	Basin Stakeholder Committee
CBWTP	Columbia Basin Water Transactions Program
cfs	cubic feet per second
ft/msl	feet above mean sea level
HIP	Hydroecological Integrity Assessment Process
HSM	habitat selection model
IFC	Instream Flow Council
IFIM	Instream Flow Incremental Methodology
ISF	Instream Flow
NGO	non-governmental organization
OCWP	Oklahoma Comprehensive Water Plan
OWRB	Oklahoma Water Resources Board
PHABSIM	Physical Habitat Simulation System
RVA	range of variability analysis
RWD	Rural Water District
sq mi	square mile
TNC	The Nature Conservancy
TSWG	Technical Study Workgroup
TU	Trout Unlimited
U.S.	United States
USGS	United States Geological Survey

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Chapter 1

INTRODUCTION

1.1 Overview of the Upper Illinois River Instream Flow Pilot

In response to one of eight major policy recommendations of the 2012 Update of the Oklahoma Comprehensive Water Plan (OCWP), the Oklahoma Water Resources Board (OWRB) conducted an Instream Flow (ISF) Pilot Study in the Upper Illinois River Basin in northeast Oklahoma. The pilot study effort included technical studies initiated by OWRB, following the Instream Flow Incremental Methodology (IFIM). IFIM is a decision-support system selected to assist resource managers in evaluating the benefits or consequences of different water management alternatives, particularly as they relate to water resources and riverine habitat resources. The IFIM is a commonly employed methodology used across the United States, as well as internationally.

ISFs are the amount of water flowing in a stream at all times necessary to sustain instream resource values at an acceptable level. Instream resources include fisheries, wildlife, water quality, recreation, aesthetics, and the ecological processes that support these resources. In the 2012 OCWP, OWRB described ISF as "Flows necessary to provide for a healthy ecosystem and support water-related recreation (such as fishing, hunting, swimming, and boating) as well as tourism."

With the completion of the work documented in this report, OWRB has completed the first five of six IFIM phases in the Upper Illinois River Basin for the Pilot Study:

1. Issue identification.
2. Study planning.
3. Study implementation.
4. Alternatives analyses.
5. Issue resolution.

A simplified timeline of OWRB's investigations into ISF efforts is provided in Table 1.1.

Table 1.1 Timeline of OWRB ISF Investigations

Year Completed	ISF Activity
2009	OWRB convened ISF Workgroup.
2011	Workgroup developed "Instream Flow Issues and Recommendations." Recommended performance of an ISF pilot study on a state-designated scenic river.
2012	OCWP completed, recommending an evaluation of nonconsumptive uses of water, including ISF.
2013	OWRB created Oklahoma ISF Advisory Group, expanding on the role of the ISF Workgroup.
2014	ISF Workgroup determined that an ISF pilot study should be conducted in the Upper Illinois River Basin. Identified scenic reaches of the upper Illinois River, Barren Fork Creek, and Flint Creek. IFIM selected as decision-support process. ISF pilot study approach submitted to OWRB, U.S. Army Corps of Engineers (USACE), and ISF Advisory Group.
2017	Illinois River ISF Assessment Physical Habitat Simulation (IFIM Phases 1-3) (CH2M HILL, 2017). Documents target flow ranges for ecological and recreational uses in pilot study area.

The overall goals for the pilot study were as follows:

- Test and refine a conceptual ISF framework and study process that could be considered for potential broader use within the State. While numeric results of technical studies may vary based on site-specific stream and species characteristics; the intent of the pilot is to determine whether a consistent process can be developed that could apply more broadly elsewhere in Oklahoma.
- Identify stakeholder recommendations for the Upper Illinois River including Barren Fork and Flint Creeks that are consistent with stakeholder interests and needs of the local watershed uses and users, determining the extent of consensus on possible approaches to ISF implementation and the process itself.
- Gain a greater understanding of the benefits and implications of an ISF process, consistent with the overall goal of managing water resources in Oklahoma for multiple uses.
- Identify questions and concerns with the process.

Issue identification - Phase 1 of the IFIM process - was accomplished in the 2012 OCWP, wherein public input identified strong interests in further investigations as to whether and how an ISF process should be formally adopted in Oklahoma. Phases 2 and 3 were completed in a technical study that quantified flow ranges that support suitable habitat conditions for the native fish community and recreational uses of the Upper Illinois River and two tributaries, Barren Fork Creek and Flint Creek (CH2M HILL Engineers, 2017). That study addressed questions such as, "How does aquatic species habitat quality correlate to flow rates?" and "What flows do recreational users need?" That work was completed in 2017 and is summarized in Section 1.3.

The current report documents Phases 4 and 5 of the IFIM process, which used projections of future consumptive water use upstream, overlaid on patterns of hydrologic variability in the stream segments, to predict the frequency and duration of future instances through 2060 where consumptive and nonconsumptive needs would not be fully satisfied. This analysis provided the

context, using state-adopted projections in water supplies and demands, to assess the potential for shortages between future consumptive and nonconsumptive uses, and to work with local stakeholders to consider alternative approaches to managing available supplies during times of low stream flows.

Throughout this pilot study, OWRB intentionally solicited grass-roots, locally-supported stakeholder input so that the potential management of ISF in the basin would reflect local values and needs. OWRB is now positioned to conduct the sixth IFIM phase, Process Evaluation, to assess the merits of the process used in the pilot study and whether this process, a modified version thereof, or an entirely different approach would be best suited for the needs of Oklahomans and the ecological resources of the state. Given the public input provided in the development of the 2012 OCWP, as well as recent legislative activity in the 2019 Oklahoma legislative session, it has been the premise of the present effort that public interest in considering an ISF process in Oklahoma remains strong.

1.2 Pilot Study Watersheds

The Upper Illinois River Basin watershed above Lake Tenkiller was selected for the pilot study by the ISF Advisory Group in 2014. The ISF Advisory Group was unable to reach concurrence on questions raised by its members regarding the legal authority for implementing a formal ISF program in Oklahoma, but did concur that the state's Scenic Rivers Act provided suitable authority for a pilot study in a designated Scenic River basin. Selection of the Upper Illinois River, Barren Fork Creek, and Flint Creek, all state-designated Scenic Rivers, was thus approved by the Advisory Group for the pilot study.

The Illinois River watershed originates in northwest Arkansas and is affected by upstream activities in Arkansas, including significant development and growth that has occurred in recent years. While impacts are not directly measured, the types of impacts that could be anticipated include increased runoff due to an increase in developed areas and the associated increase in impervious surfaces, and accompanying water quality degradation effects. Upstream water reclamation facilities and water management can also affect flows and quality in the watershed, such as diversions from one river basin and wastewater treatment and discharge in another, and changes in water reclamation permit requirements, technologies, and practices. Any increase in water reuse from upstream water reclamation facilities will also affect flows in the basin.

Studied locations for the present effort were set to align with those locations studied in the Phase 1-3 technical report on ecological and recreational flows (CH2M HILL 2017). Specifically, the United States Geological Survey (USGS) stream gages listed in Table 1.2 and shown in Figure 1.1 were used as the basis of subsequent analyses described later herein.

Table 1.2 USGS Gage Locations Used in Streamflow Analyses

Gage Name	USGS Gage Number	County	Drainage Area (sq mi)	Elevation (ft-msl)	Period of Record
Illinois River near Tahlequah, OK	07196500	Cherokee	950	664.14	1935-2017
Baron Fork Creek at Eldon, OK	07197000	Cherokee	312	701.14	1948-2017
Flint Creek near Kansas, OK	07196000	Delaware	116	854.59	1955-2017

Notes:
ft-msl feet above mean sea level sq mi square mile

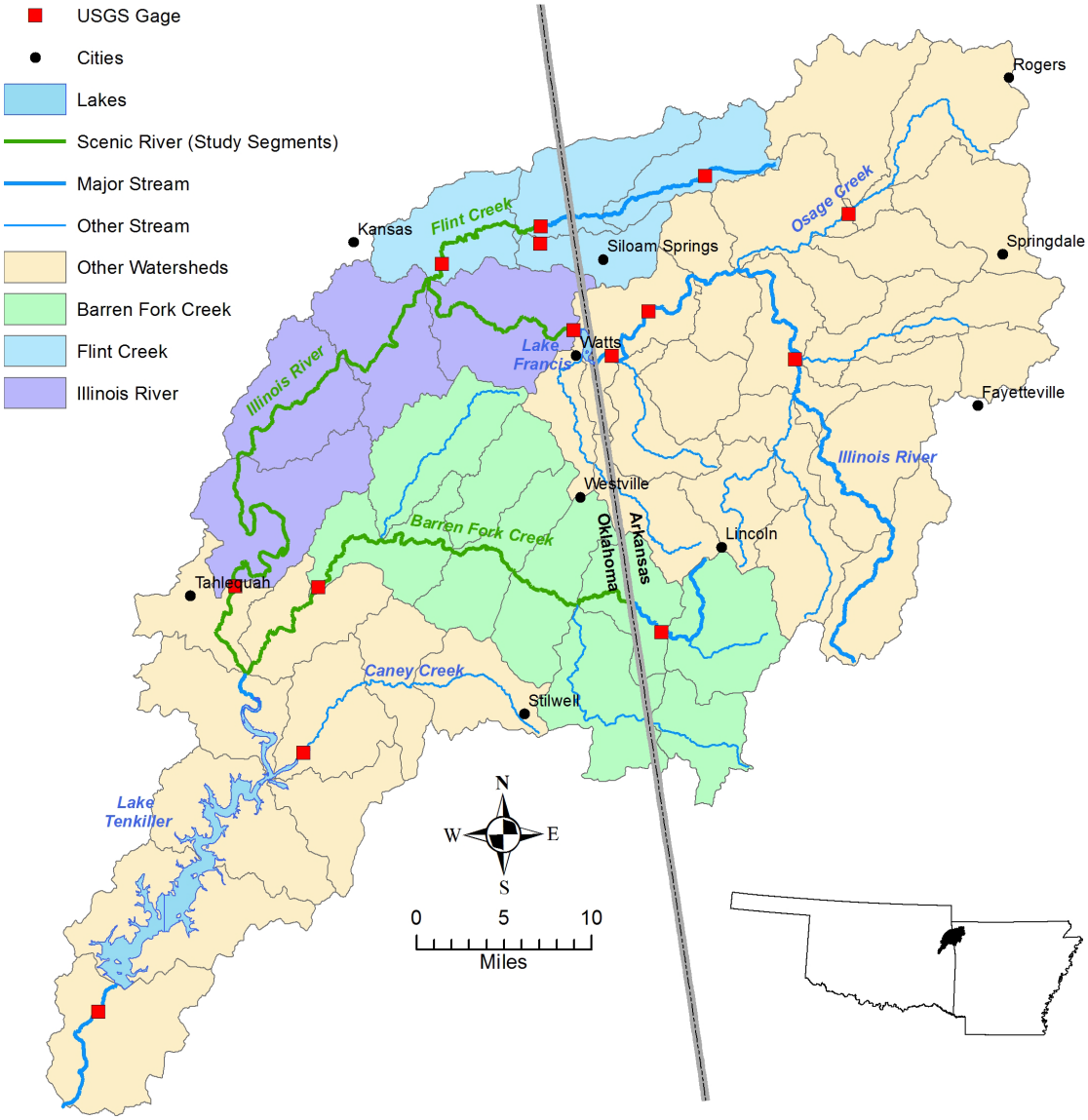


Figure 1.1 Pilot Study Watersheds

1.3 Previously Completed Physical Habitat Simulation Work

Phases 1 through 3 of the Pilot Study culminated in a final technical report titled, Illinois River Instream Flow Assessment: Physical Habitat Simulation (IFIM Phases 1-3)" (CH2M Hill Engineers, Inc., May 2017). That report identified flow ranges that support suitable habitat conditions for the native fish community and recreational uses of the Upper Illinois River, Barren Fork Creek, and Flint Creek. These target flow ranges at the studied sites, as documented in Section 4.3 of the May 2017 report, were used as the foundation of analyses for the present study.

It is noted, however, that the Technical Study Workgroup (TSWG) that provided input into the 2017 effort noted the following additional considerations in the application of the findings from the 2017 physical habitat simulation work:

- It is critical to continue forward using the weight of evidence approach for the current pilot study and all future ISF efforts.
- It is important for decision-makers to recognize that the subject stream reaches are designated Scenic Rivers that deserve special protection.
- However, the recommendations from the pilot study efforts should be science-based and focused on providing the protection dictated by the data.
- Adult smallmouth bass were weighted more heavily than juveniles because young of the year tended to have higher tolerances.
- Future projects should account for seasonal variability where necessary.
- The TSWG members used average and median flows to "check" the recommended flow rates.

The Physical Habitat Simulation report acknowledged that there is no single flow value or range for a given stream segment that can meet all the ecological needs of the stream system, let alone meet the ecological and the recreational needs. For ecology alone, at any given time, there are multiple species and life stages coexisting, each with their own flow needs. Those needs can change over the course of a year as life stages change. Recreational needs may differ significantly, and there may be conflicting goals between different types of recreation. A fishing recreationalist may desire flows that are entirely different than a kayaker or a canoeist. The report also noted that other streamflow dynamics make important contributions to the health of the natural ecological community. For example, secondary channels and occasional bankfull flows support many important ecological functions.

Considering these findings, the physical habitat flow goals concluded from the 2017 study have been used as the basis for assessing projected future flows in the current work, as summarized in Table 1.3. The Technical Study Workgroup advising the process suggested slightly different flow ranges, which were smaller ranges within the Table 1.3 ranges for Barren Fork Creek and Flint Creek, but ranging from 225 cubic feet per second (cfs) to 350 cfs for the Upper Illinois River. The current study used the Table 1.3 values, as a single consolidated set of recommendations supported in the 2017 report.

Table 1.3 Physical Habitat Flow Goals from 2017 Study

River	Target Flow Range for Physical Habitat (cfs)
Upper Illinois River	100-300
Barren Fork Creek	40-100
Flint Creek	10-60

The 2017 study further recognized that recreational use of the Upper Illinois River is a major activity. Table 1.4 presents the recreational flow goals concluded in the 2017 study for the Upper Illinois River. The optimal recreational flow range differs with the physical habitat target range of 100 to 300 cfs for the Upper Illinois River; however, the upper end of the physical habitat flow

range meets the minimum flow goals for canoe, kayak, and raft recreation. Noting that the physical habitat range has an upper end whereby too much flow reflects decreased aquatic habitat area and quantity, the analyses in the present effort employed the physical habitat target flow range of 100 to 300 cfs rather than the reported optimal recreational flow target.

Table 1.4 Recreational Flow Goals from 2017 Study

Type of Recreation	Target Flow (cfs)
Optimal range	400-1,200
Canoe / Kayak	Minimum 150
Raft	Minimum 250

1.4 Goals of the Current Phases of the Pilot Study

This report represents the culmination of the technical analyses of the pilot study, addressing critical questions about whether and to what extent conflicting consumptive and non-consumptive needs might be expected to arise in the future in the studied stream segments under various ISF management approaches. The previous phase of the work provided critical information regarding the target flow ranges necessary to support recreation and healthy ecosystems native to these stream segments. But until those data points are put in a context of future flow projections – i.e., the flows we can anticipate in the future as upstream consumptive demands grow over time – the results were abstract and difficult to derive meaningful insights.

The comparison of future flows to these target ranges provides the very crux of technical information supporting the resource management process of the ISF pilot study. Once stakeholders and policymakers understand when, how frequent, and for how long there may be an inability to simultaneously meet the future needs of consumptive and non-consumptive uses, an informed dialogue can then be had regarding how water can best be managed to meet the values of the members of the community that rely on the watershed for all its beneficial uses, both consumptively and non-consumptively. Such discussions can then focus upon what options there are for balancing competing needs, particularly in drought conditions when water resources in the system are stressed.

This report documents Phases 4 and 5 of the ISF pilot study, in which alternatives analyses were developed and performed, and issue resolutions were vetted through a local stakeholder process. Chapter 2 describes streamflow analyses, including projections of future upstream consumptive water use through 2060, and the projected impacts on flow in each of the three studied streams. This analysis was used to project the frequency and duration of future instances through 2060 where consumptive and nonconsumptive needs would not be fully satisfied during low flow periods in the stream.

Input gathered via meetings with four groups representing four types of consumptive and nonconsumptive water interests in the watershed is summarized in Chapter 3, along with additional streamflow management scenarios that were analyzed as a result of the input received. A watershed-wide workshop convened to gather input and seek consensus on direction for potential ISF management in the basin is also described in Chapter 3. Chapter 4 describes the lessons learned from the pilot study, observations, options, and potential path forward for a process for ISF management in Oklahoma that OWRB has concluded from conducting the ISF pilot in the Upper Illinois River basin.

Chapter 2

STREAM FLOW ANALYSES

A suite of quantitative technical analyses was conducted to support and facilitate dialogue with local stakeholders in the pilot study basin. Technical analyses that were initially conducted and presented to local stakeholders are presented in this chapter. A summary of stakeholder discussions and feedback is provided in Chapter 3. The quantitative analyses performed and presented as part of this phase of the Pilot Study focused primarily upon the readily available information base, as the scope of work herein did not allow for the performance of extensive additional analyses (e.g., socioeconomic impact assessments, site specific data analyses) that could potentially further inform the Pilot Study process described herein.

2.1 Definition of Initial Planning Scenarios for Analysis

In preparing the 2012 OCWP, OWRB developed the Oklahoma H_2O model, an analytic tool that calculates projected demands on a monthly timestep for a given stream gage location. Given its ready availability and precedent for use in the development of the 2012 OCWP, this tool was employed in the present analyses to project future stream flows in the study area. Impacts of projected future demands on stream flow were compared to the ISF habitat suitability ranges for each respective watershed to identify potential future water shortages. For purposes of these analyses, a "shortage" was defined as any future instance where projected consumptive water needs and/or the hypothetical ISF management target under consideration would not be met by available stream flows.

The analyses of potential future water shortages were conducted for multiple scenarios. A baseline analysis was conducted for the present status quo condition, i.e., no set ISF requirements or goals. Additional scenarios considering various hypothetical ISF management targets were then investigated to test the potential water quantity impacts and possible implications of those scenarios relative to the status quo baseline. Incremental consumptive demands in the watersheds above each gaged location (i.e., the increase in demands relative to current demands that are reflected in current stream flows) projected out to 2060 were compared to the historical record of stream flow, then adjusted for a given scenario's assumed flow reservation for ISF. The historical period of record was used for each gaged location, in order to capture the full range of historically-observed flow variation at each gaged location. Recognizing that future flow conditions may vary from historical observations, some conservatism should be exercised in interpretations of these results.

Assessments were then made of the frequency, magnitude, and duration of potential future shortages. This should not immediately imply which use (consumptive demand or non-consumptive flow target) is not fully satisfied; rather, this should be considered an opportunity to consider alternate approaches to manage flows in a way that best meets the local stakeholders' values and/or to reduce shortages. Accordingly, the finding of shortages in the Upper Illinois River basin during the current work spurred discussions of water management strategy options in the Upper Illinois River basin as part of the pilot study process.

2.2 Consumptive Demand Estimates for Sub-Watersheds through 2060

2.2.1 Methods

A desktop level analysis was performed to initially evaluate stream flows. For the subject area, consumptive demands were calculated from OCWP Basin 82 demands, which encompass the entire Illinois River watershed from below the Lake Tenkiller dam up to the Arkansas state line. The watersheds of interest (above the three gaged locations on the Upper Illinois, Barren Fork Creek, and Flint Creek indicated in Table 1.2) are much smaller subsets of Basin 82.

For consistency, demands were projected using the same seven consumptive use demand sectors as in the OCWP. However, in these sub-basins, only the following four categories have a projected demand by 2060: self-supplied residential, municipal and industrial (public water supply), crop irrigation, and livestock. No thermoelectric power, self-supplied industrial, or oil and gas demands are projected in the stream basins. For purposes of the current pilot study, 2060 demands were used as the basis of all analyses, as this represents the latest year of OCWP projections and thus the most significant potential for shortages to best inform long-term decision-making.

Crop irrigation, livestock, and self-supplied residential demands were calculated based on the 2012 OCWP county demand projections. The allocation between sources (surface water, alluvial groundwater, and bedrock groundwater) were maintained from the 2012 OCWP. Self-supplied residential demands were assumed to be supplied by alluvial groundwater (AGW). Municipal and industrial demand projections were based on the OCWP Public Water Provider Forecast. The allocation between sources was determined from water rights.

It is noted that the proportion of future demands between water use sectors will vary due to differing growth rates, and that the overall proportion of supplies used to meet demand will likely change due to differing growth rates amongst water use sectors. The objective of this portion of analysis was to characterize the surface water portion of projected demand, since potential impacts to surface water is the focus of this study. A monthly distribution was developed so it could then be applied to monthly stream flows from the Oklahoma H_2O tool. An embedded assumption within the Oklahoma H_2O tool that was brought forward for the present analyses herein is that the State of Oklahoma receives 60 percent of monthly stream flow at the Oklahoma/Arkansas state line per Compact conditions. The 2060 monthly demand distribution, by source type, is presented for each of the three basins in Figures 2.1, 2.2, and 2.3.

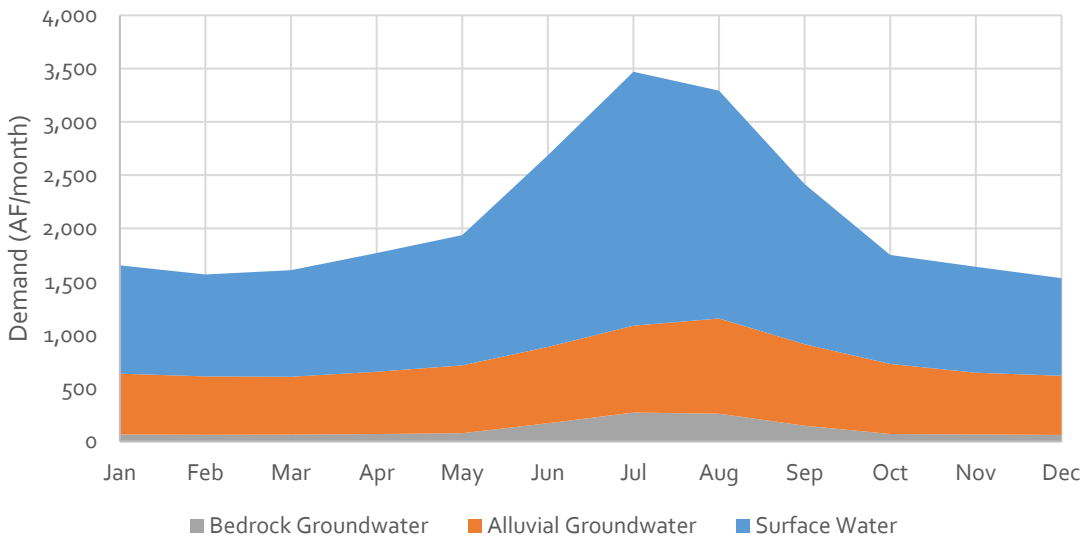


Figure 2.1 Illinois River Sub-Basin Projected 2060 Monthly Demand by Source

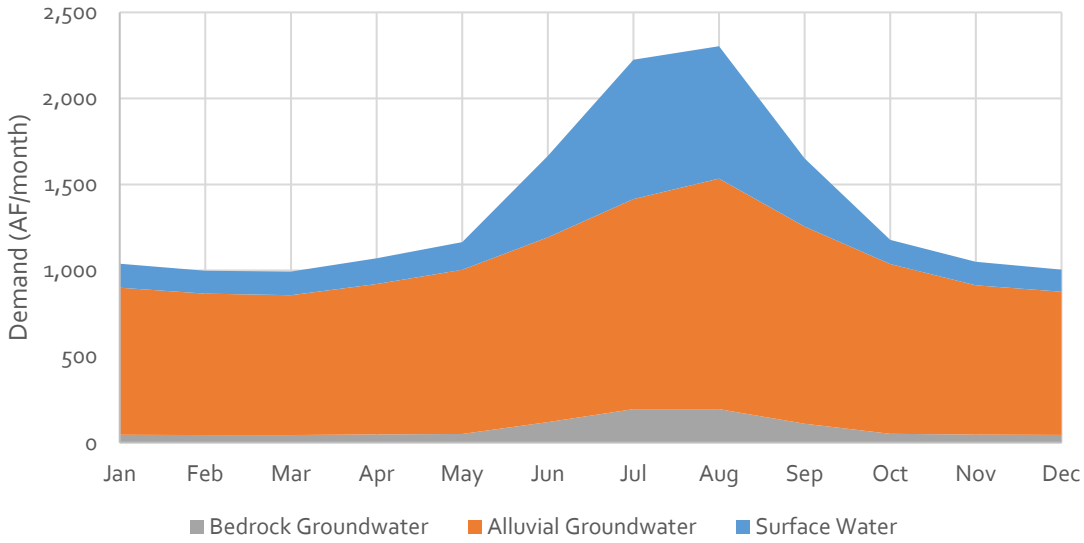


Figure 2.2 Barren Fork Sub-Basin Projected 2060 Monthly Demand by Source

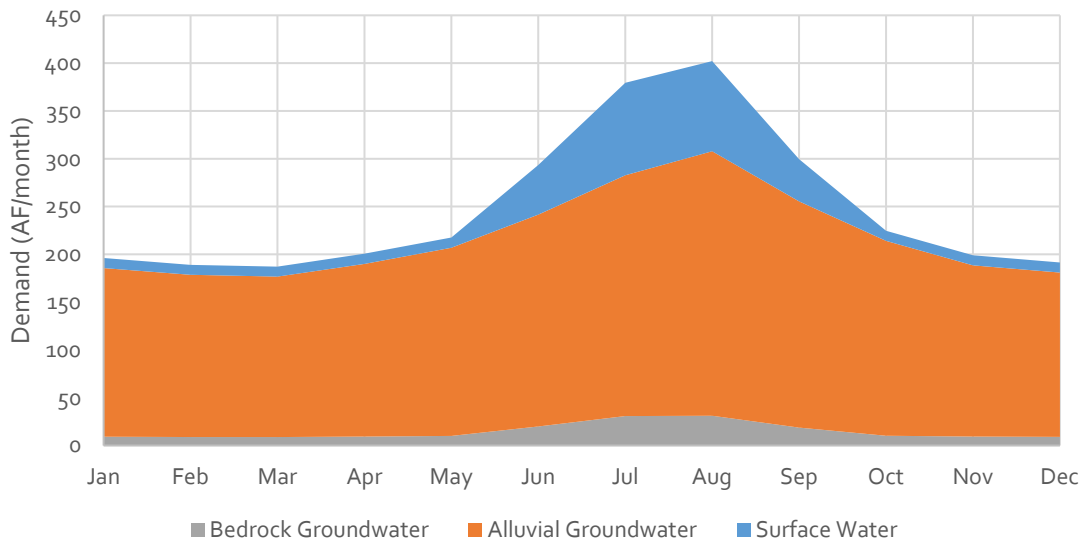


Figure 2.3 Flint Creek Sub-Basin Projected 2060 Monthly Demand by Source

2.2.2 Demand Projections

Projected 2060 consumptive demands for the watersheds tributary to the gaged locations on the Upper Illinois River, Barren Fork Creek, and Flint Creek are summarized in Tables 2.1, 2.2, and 2.3, respectively. Values listed for 2007 in the tables represent the OCWP baseline values, which form the basis for calculating the incremental growth in demand.

Table 2.1 Projected Upper Illinois River Basin 2060 Consumptive Demands

Demand Sector	2007 (AFY)	2060 (AFY)	Incremental 2060 (AFY)
Crop Irrigation	1,500	2,800	1,300
Livestock	300	300	0
Municipal and Industrial	8,100	14,100	6,000
Self-Supplied Residential	4,500	8,100	3,600
Total	**14,400**	**25,300**	**10,900**

Table 2.2 Projected Barren Fork Creek Basin 2060 Consumptive Demands

Demand Sector	2007 (AFY)	2060 (AFY)	Incremental 2060 (AFY)
Crop Irrigation	1,000	2,100	1,100
Livestock	500	500	0
Municipal and Industrial	800	1,400	600
Self-Supplied Residential	6,700	12,200	5,500
Total	**9,000**	**16,200**	**7,200**

Table 2.3 Projected Flint Creek Basin 2060 Consumptive Demands

Demand Sector	2007 (AFY)	2060 (AFY)	Incremental 2060 (AFY)
Crop Irrigation	300	300	-
Livestock	100	200	100
Municipal and Industrial	-	-	-
Self-Supplied Residential	1,400	2,500	1,100
Total	**1,800**	**3,000**	**1,200**

With these projected 2060 surface water demands for each watershed derived for each basin of interest, initial stream flow analyses were then performed to assess their relative impacts in the context of the identified ISF habitat suitability range for each basin. The results of these analyses are presented by basin in the sections below.

2.3 Illinois River Projected Future Flow Scenario Analyses

The identified ISF habitat suitability range for the Illinois River watershed, ranging from 100 cfs, which is low, to 300 cfs (high) as described in Chapter 1, was compared to various statistical depictions of historically observed stream flow. For this initial evaluation, various statistics on historical stream flow over the observed period of record were developed from observations from United States Geological Survey (USGS) Gage No. 07196500 (Illinois River near Tahlequah, OK). The annual flows observed at this gage location, presented in Figure 2.4, when presented along with the annual ISF amounts enumerated above, provide an initial, high-level perspective as to both the magnitude of the ISF amounts relative to historical stream flow, as well as the frequency at which the ISF amounts have been exceeded historically.

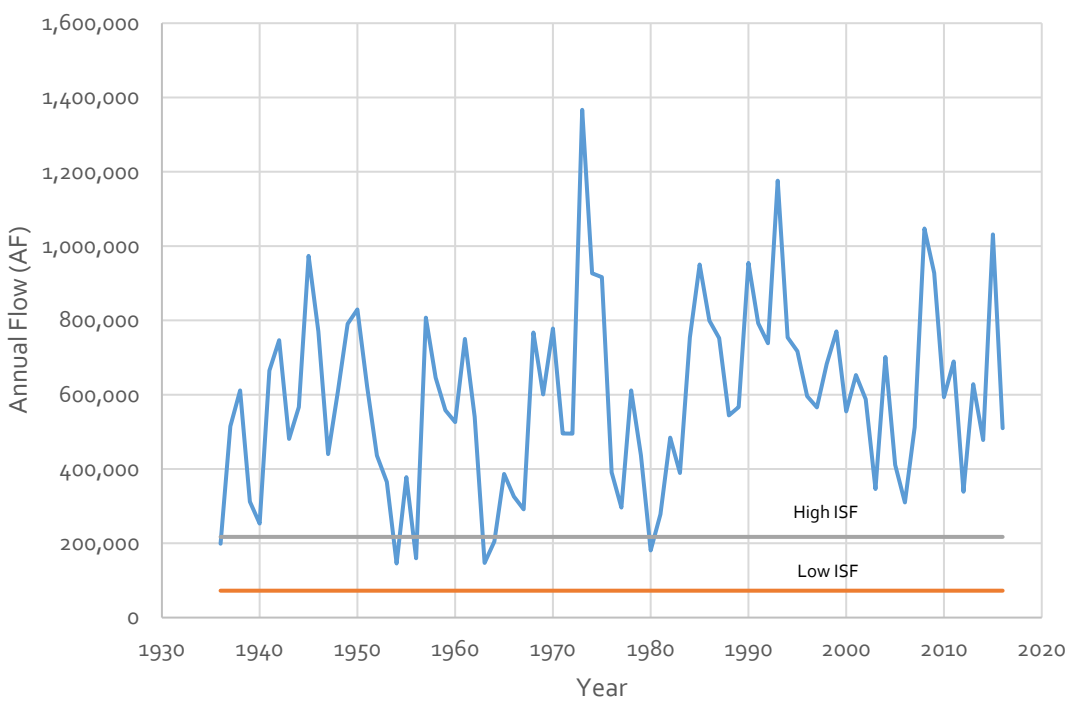


Figure 2.4 Observed Annual Flows at USGS Gage No. 07196500, Illinois River near Tahlequah, OK, in Comparison to Identified ISF Habitat Suitability Amounts (1936-2016; AFY)

Although such an annual depiction is somewhat informative, it should be noted that such a characterization fails to address critical intra-annual monthly variations crucial to both ecological and water supply uses, which both focus upon timescales at a finer resolution. While daily stream flow data are available, the aforementioned projections on demand are only available in a monthly context. Thus, the monthly timestep is the smallest temporal resolution presently available for analysis. It is important to note, however, that the subsequent analyses of monthly flows cannot address the day-to-day variations observed in the watershed. This is significant in the sense that characterizations of "shortages," as defined herein as failures to meet consumptive and/or non-consumptive needs, should not be interpreted to mean that flow would not be available for spans of 1 or more months. Rather, a more appropriate interpretation would be that total flows in a particular month may not exceed a specified monthly target.

Initial consideration was given to how average monthly flows in the basin vary. This comparison is presented in Figure 2.5, whereby it was observed that average monthly stream flows are lowest during the late-summer months. This provides some indication as to the time of the year where it could be anticipated that shortages in monthly stream flow may occur. However, while such a depiction is a worthwhile characterization of "average" conditions, this characterization does not shed light upon the more extreme hydrologic condition of drought that is the focus for both water supply planning and ecological resource management during such a stressed condition.

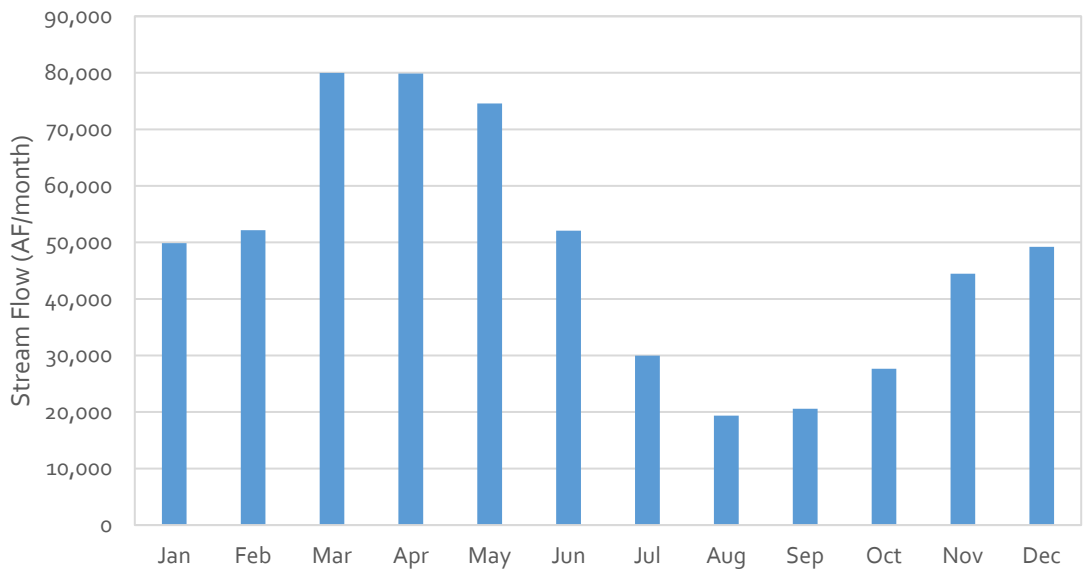


Figure 2.5 Average Monthly Stream Flows under Baseline Scenario for Illinois River Basin

To address the more extreme, low-flow conditions, a frequency-based comparative analysis was employed, whereby monthly flow frequency curves were generated for each ISF scenario, including the baseline "No ISF" scenario. Observation of the monthly flow frequencies may then be focused upon the low flow conditions, in order to assess the extent to which the 2060 incremental demand in the watershed (i.e., the increase in demand from present day demands to the projected 2060 demands) can be met by available stream flow. The resultant monthly flow frequency is thus plotted for each scenario in Figure 2.6, in comparison to the 2060 incremental demand for the watershed.

Within Figure 2.6, the x-axis (Percent Exceedance) represents the percent of time the flow (the y-axis) is exceeded. Infrequent high flows have a lower percent exceedance than more frequent low flows. This figure focuses upon the low end of the flow regime, given that the majority of monthly flows in all three scenarios exceed the projected incremental 2060 demands in the basin.

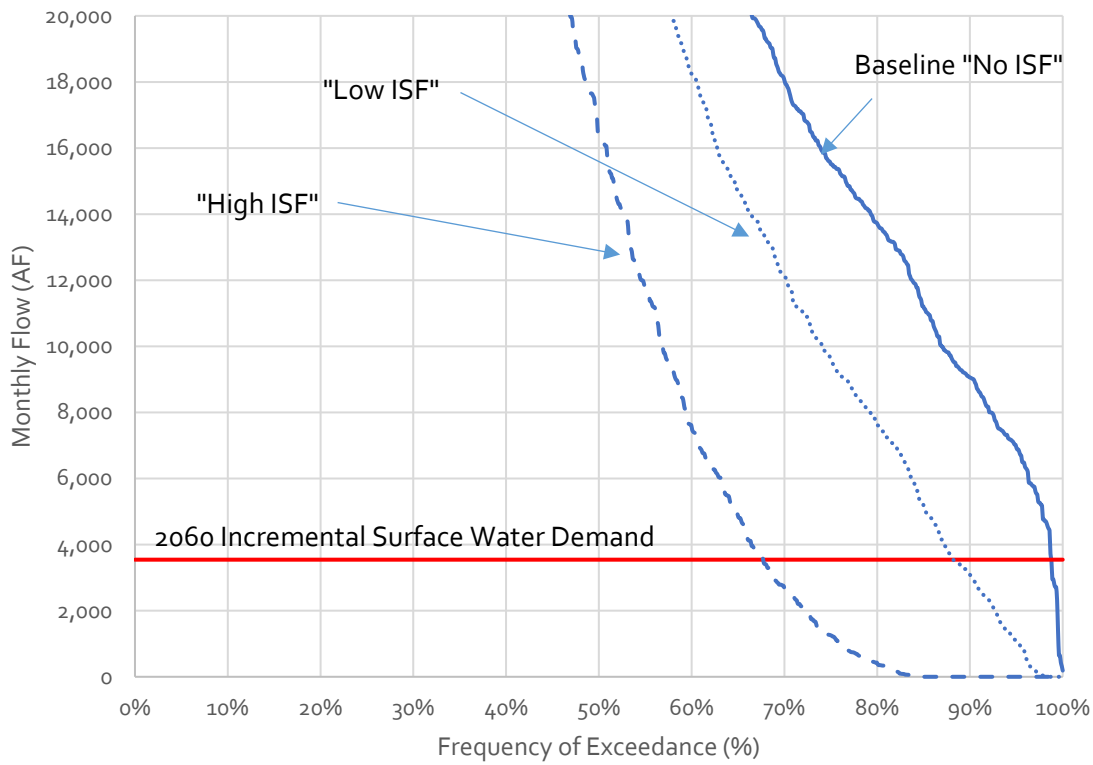


Figure 2.6 Low-end Monthly Flow Frequencies for Three ISF Scenarios in comparison to Projected 2060 Incremental Surface Water Demand for Illinois River Basin (1935-2017)

Several items of note are observed from this comparison:

- Under the Baseline scenario with no ISF reservations, there are approximately 1 percent of months over the 82-year period analyzed whereby monthly flows would not exceed the projected incremental 2060 demands for the basin. Said another way, monthly flows would be insufficient to meet the projected incremental 2060 demand roughly 1 percent of the months, even with no ISF implementation.
- Under the "Low ISF" scenario (100 cfs), the frequency of monthly flows exceeding 2060 incremental demand decreases to approximately 89 percent of the months, a decrease of 10 percentage points from the baseline "No ISF" scenario. Another interpretation would be that there are insufficient monthly flows to meet both the Low ISF amount and the projected 2060 incremental demand in the Illinois River Basin roughly 11 percent of the months.
- Under the "High ISF" scenario (300 cfs), the decrease is more significant, whereby monthly flows would exceed projected incremental 2060 demand approximately 68 percent of the months, a decrease from the baseline scenario of 31 percentage points. Thus, there would be insufficient monthly flows to meet both the High ISF amount and the projected 2060 incremental demand approximately 32 percent of the months.

Expressed in terms of shortages, as defined herein, under the baseline "No ISF" scenario (i.e., the present status quo) shortages in monthly flows would be expected roughly 1 percent of the months. Were the "Low ISF" goal to be established, monthly shortages are projected to increase to roughly 12 percent of the months. If the "High ISF" goal were to be established, shortages are projected to occur approximately 32 percent of the months. To reiterate, a shortage means that there is insufficient flow in the stream to meet the ISF flow goal if the consumptive demands are satisfied, vice versa, or neither use is fully satisfied.

Utilizing the Oklahoma H_2O tool (ver. 1.7.2) with the analysis period of 1950 to 2007, seasonal shortage analyses for the three scenarios were also evaluated. Calculations were made to derive general seasonal characteristics regarding shortages between meeting incremental 2060 surface water demand (alone in the case of the baseline "No ISF" scenario), or meeting both the incremental 2060 surface water demand and the specified ISF target for the given scenario. Seasons have been defined herein as follows:

- Winter: December through February.
- Spring: March through May.
- Summer: June through August.
- Fall: September through November.

For this initial characterization, focus was given to identifying the maximum and average seasonal shortage amounts, as well as their probability. The calculated maximum amounts reflect the maximum shortage over the identified season, whereas the average shortage reflects the average magnitude of shortage based only on the months for which shortages were identified. Probability, in this context, reflects the frequency of occurrence of shortages observed, and is based upon the number of years that a shortage occurs in at least 1 month of a season over the period of record. The resultant seasonal shortage evaluation presented in Tables 2.4, 2.5, and 2.6 offer a high-level characterization of the extent and magnitude of potential shortages in meeting both consumptive and non-consumptive needs, both in the seasonal and annual context[1].

Table 2.4 Illinois River Area Projected 2060 Seasonal and Annual Surface Water Shortages for Baseline "No ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	0	0	0%
Spring (AF/month)	0	0	0%
Summer (AF/month)	440	440	2%
Fall (AF/month)	510	370	5%
Annual (AFY)	**950**	**510**	**5%**

Notes:
AF acre-feet

[1] Local shortages may vary from the basin-level amounts derived herein due to local variations in demands and local availability of supply sources.

Table 2.5 Illinois River Area Projected 2060 Seasonal and Annual Surface Water Shortages for "Low ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	430	300	7%
Spring (AF/month)	0	0	0%
Summer (AF/month)	990	740	16%
Fall (AF/month)	630	450	21%
Annual (AFY)	**4,250**	**1,740**	**21%**

Table 2.6 Illinois River Area Projected 2060 Seasonal and Annual Surface Water Shortages for "High ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	430	400	36%
Spring (AF/month)	520	430	14%
Summer (AF/month)	990	880	69%
Fall (AF/month)	630	510	88%
Annual (AFY)	**6,260**	**2,550**	**91%**

2.3.1 Shared Shortage Scenario

Based on input received during the first round of stakeholder workshops (described in more detail in Chapter 3), additional analyses were performed in order to more readily address specific concerns and questions raised by the workshop participants. Most participants in the first round of discussions expressed concern over potential impacts to the consumptive or nonconsumptive water use they represented – water supply, recreation, and/or ecological benefits. While the initial analyses (described above) offered perspectives on impacts for scenarios reflecting no ISF implementation, Low ISF implementation (e.g., 100 cfs for the Upper Illinois River), and High ISF implementation (e.g., 300 cfs for the Upper Illinois River), no analysis had yet offered a depiction of what a compromise approach might look like, or what potential impacts might look like from such an approach.

Hence, a "shared shortage" scenario was developed, with a focus upon the analysis of the Upper Illinois watershed. The Upper Illinois was selected as a representative basin for these analyses, assuming similar ranges of potential impacts would be seen if similar analyses were applied to the smaller Flint Creek and Barren Fork Creek watersheds.

Given the noted reticence of consumptive water users to potentially impact water supplies during drought conditions, and the expressed concerns from environmental interests that the ecological targets should be considered as the minimum of flows necessary for the ecological health of the watershed, the shared shortage scenario was crafted. This scenario was developed to explore the temporary impacts on both water users, where all parties would yield some water in the spirit of mutual endurance of the worst of the drought conditions.

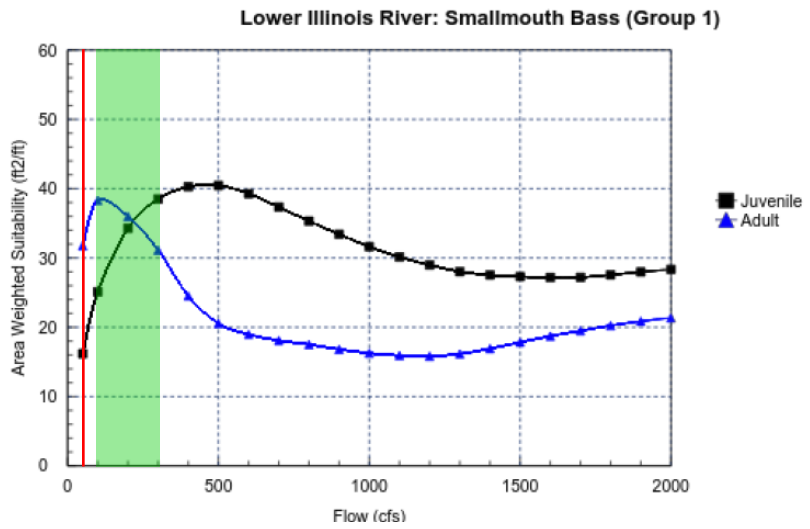
Noting that the low ISF amount identified for the Illinois River watershed is 100 cfs, a 50 percent decrease in that ISF was presented and evaluated, resulting in a "Shared Shortage" scenarios with a 50 cfs ISF amount. An assessment of the average weighted suitability curves developed

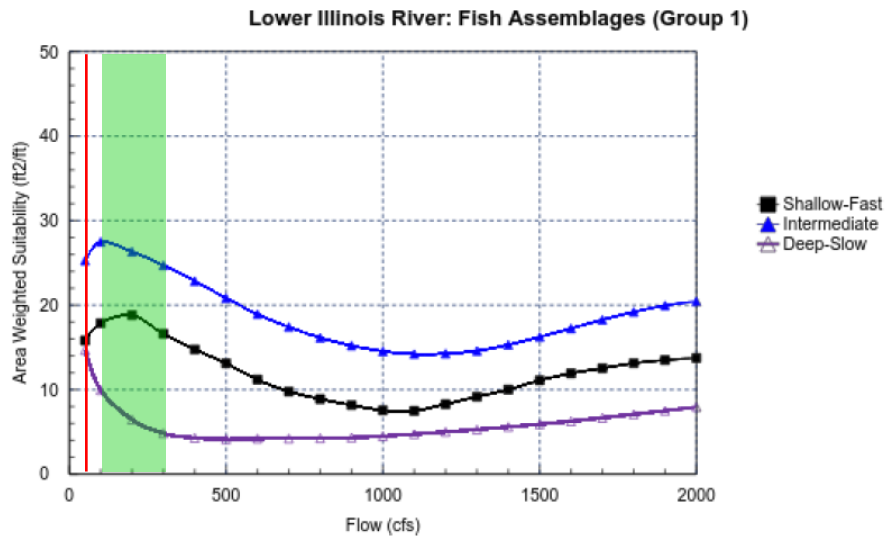
for various biological assemblages in the Illinois River watershed (from CH2M Hill 2017) was then made to assess what, if any, impacts could be characterized from the available technical information. Figure 2.7 is a compilation of these curves for the Illinois River Basin, modified only to reflect the 100 to 300 cfs habitat suitability range (shaded green), and the 50 cfs "Shared Shortage" ISF amount (the solid red line). It was observed that given the varying ecological needs of each organism (and/or assemblage), the identified flow range represents where average weighted habitat suitability area may be less than optimum when flows are both lower or higher than the identified habitat suitability flow range.

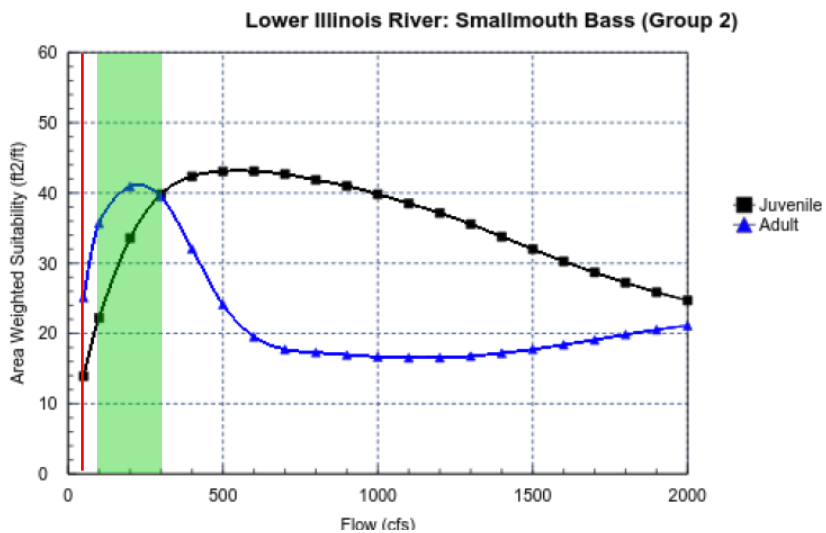
Accordingly, a decrease to 50 cfs would not necessarily result in a 50 percent decrease in average weighted suitable habitat area, but rather an average decrease of approximately 23 percent. However, it has been noted that significant caution should be given to interpretation of these curves, given they represent selected organisms and/or organism assemblages selected as representative ecological indicators for the basin, but do not represent all aspects of the effects of ISF on the watershed's ecological functions. Further consideration was given to recreational activities in the Illinois Basin as well. Presented in Table 2.7 is a summary of the flows necessary for recreational activity as identified in CH2M Hill (2017), given interests expressed by local stakeholders. An analysis of the monthly frequency of occurrence of recreational boat users is presented in Figure 2.8, where it is observed that peak use normally occurs during summer months, as would be expected.

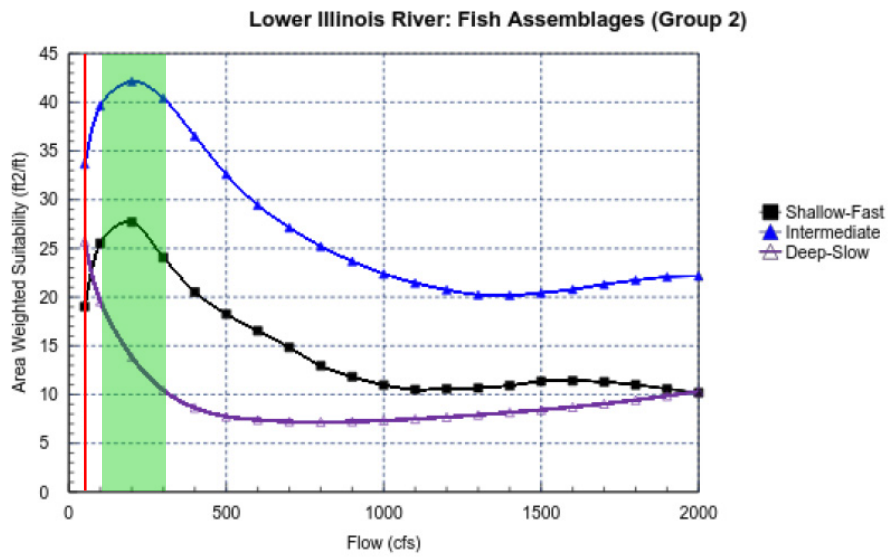
Table 2.7 Recreational Flow Targets for the Illinois River Basin (from CH2M Hill 2017)

Lower Illinois Recreational Activity	Flow (cfs)*
Minimum for Canoe and Kayak Passage	150
Minimum for Raft Passage	250
Optimal Range for All Flotation Device Use	400-1,200
Maximum Safe Flow for General Public	1,200
Maximum Safe Flow for Experienced Users	4,000


Lower Illinois River: Smallmouth Bass (Group 1)
Area Weighted Suitability (ft2/ft)
Flow (cfs)
Juvenile
Adult


Lower Illinois River: Fish Assemblages (Group 1)
Area Weighted Suitability (ft2/ft)
Flow (cfs)
Shallow-Fast
Intermediate
Deep-Slow


Lower Illinois River: Smallmouth Bass (Group 2)
Area Weighted Suitability (ft2/ft)
Flow (cfs)
Juvenile
Adult


Lower Illinois River: Fish Assemblages (Group 2)
Area Weighted Suitability (ft2/ft)
Flow (cfs)
Shallow-Fast
Intermediate
Deep-Slow

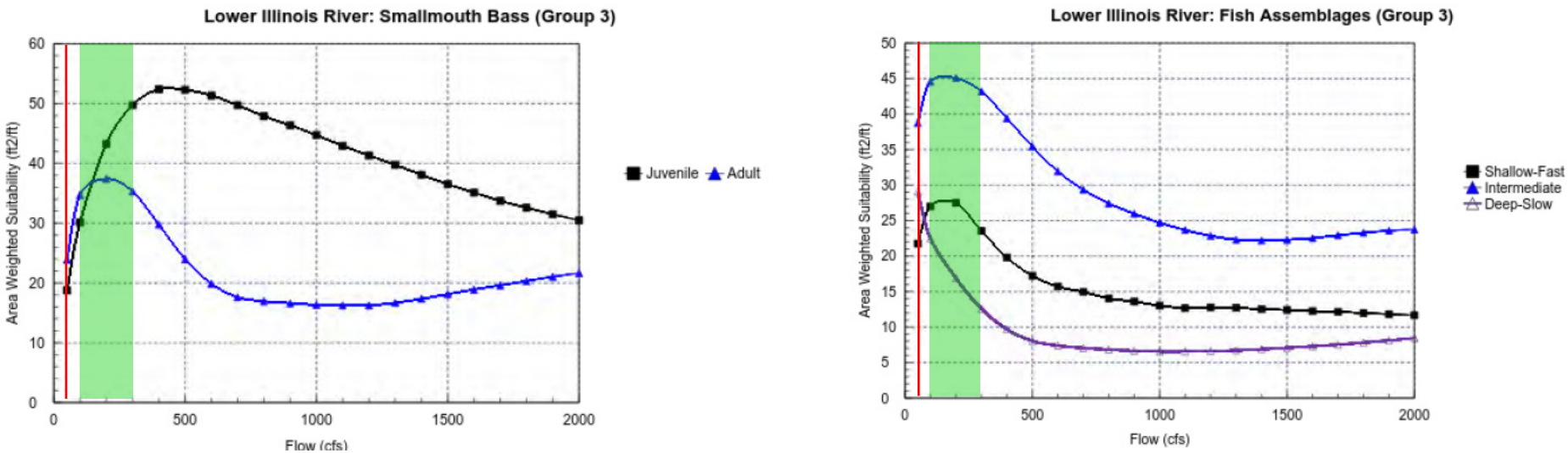


Figure 2.7 Compilation of Average Weighted Suitability Curves for Selected Organisms and Fish Assemblages in the Illinois River Basin, with ISF Amounts Identified (modified from CH2M Hill 2017)

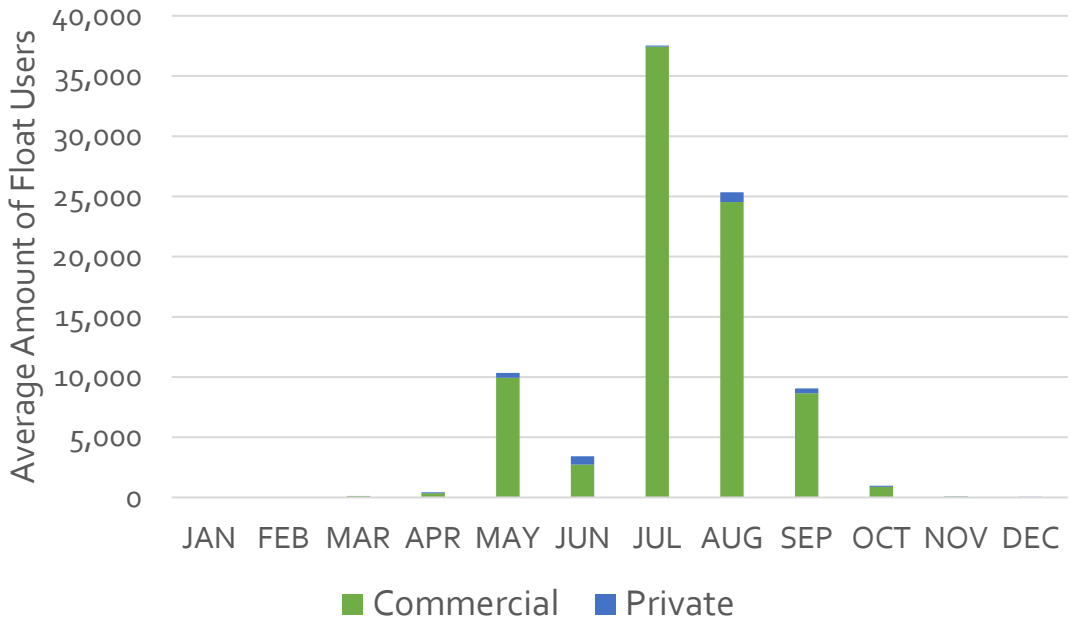


Figure 2.8 Monthly Average Number of Commercial and Private Float Users by Month in Illinois River Basin (2003-2008)

Lastly, shortages were characterized via comparison with projected incremental 2060 surface water demands in a manner similar to the initial frequency-based analyses. As evidenced in Figure 2.9, the calculated frequency of shortages (4 percent) when compared to projected 2060 incremental surface water demand in the Illinois River Basin is still increased from the baseline frequency of 1 percent, and is lower than the frequency of shortages identified in the "Low ISF" scenario of 12 percent. In approximately 96 percent of months, no monthly demand shortages are projected to occur under the "Shared Shortages" scenario. Again, it is noted that while the total monthly amounts may not exceed the projected 2060 incremental surface water demand, it is expected that daily variations throughout the watershed would likely differ given localized effects of water use and hydrologic conditions.

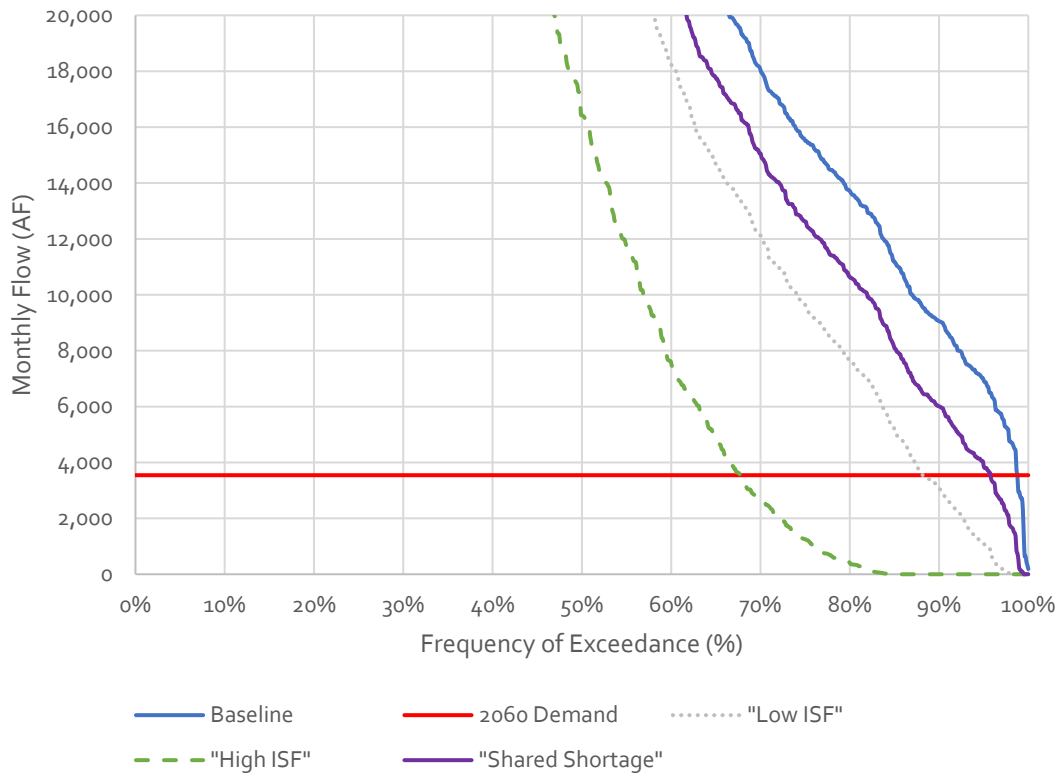


Figure 2.9 Low-end Monthly Flow Frequencies for Alternative Scenarios in comparison to Incremental 2060 Demand for Illinois River Basin, Now including "Shared Shortage" Scenario (1935-2017)

2.3.2 Shortage Characterization

At the request of stakeholders, additional analyses were performed to more precisely characterize the magnitude, frequency, and duration of potential shortages. A suite of characterizations based on the available data was developed for stakeholder consideration. Again, focus was given to the Illinois River Basin, for use as the primary means to facilitate and simplify stakeholder discussions, with the stated assumption that similar characteristics would be observed in the Flint Creek and Barren Fork Creek watersheds.

The previously presented analyses present informative aspects to individual characteristics of possible shortages. Given the expressed interest in gaining a greater understanding of these characteristics more holistically, a heat map of shortages for all of the evaluated scenarios was developed to better characterize both the frequency and duration of projected shortages ("gaps") in flow, as presented in Figure 2.10.

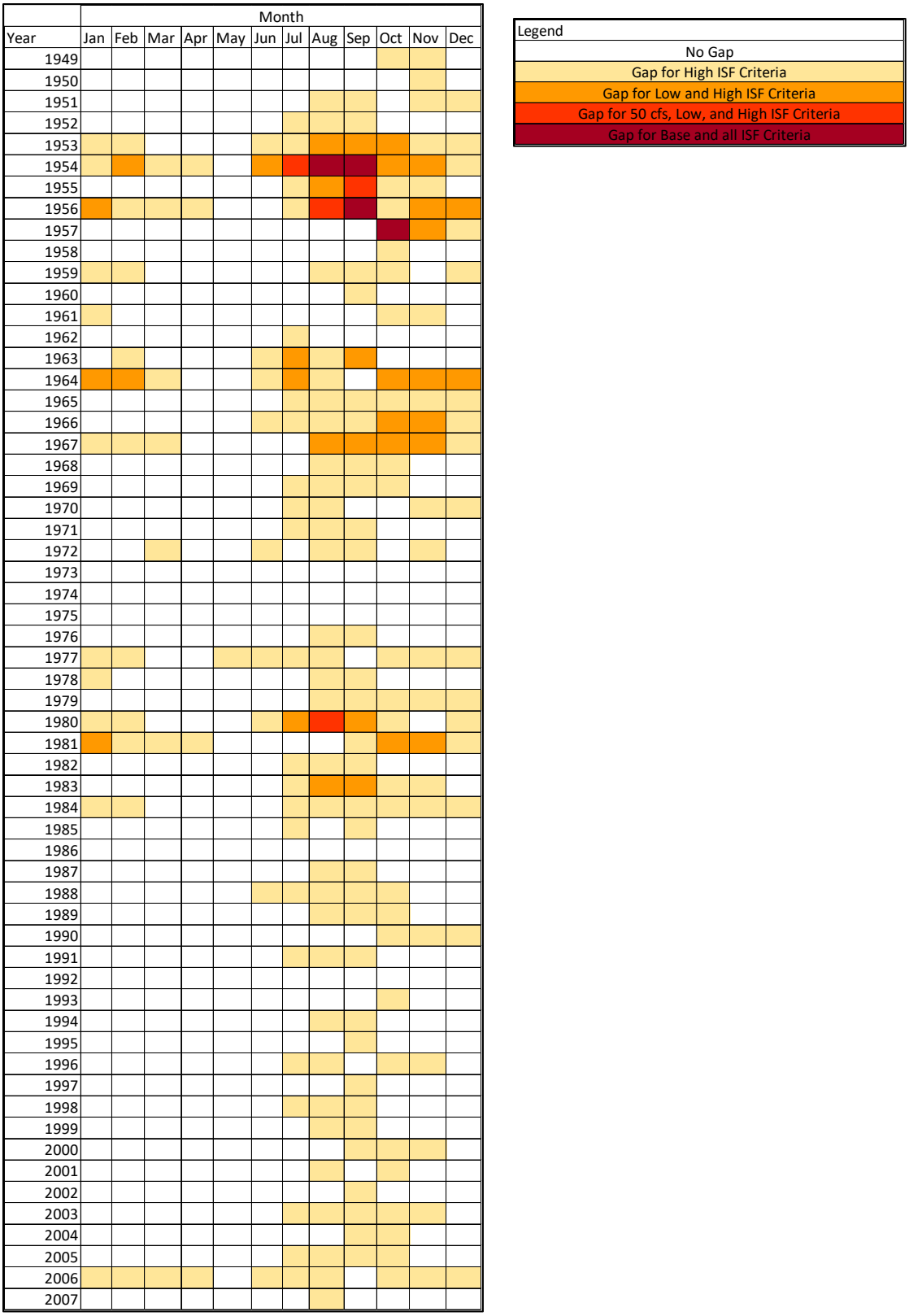


Figure 2.10 Heat Map depicting Monthly Time Series of Projected Shortages (1949-2017 Hydrologic Conditions)

Several observations are proffered from review of the monthly heat map depicted in Figure 2.10:

- Under the baseline scenario with no ISF, a shortage 2 months in duration is projected to occur during August and September of 1954, with 1-month shortages in September 1956 and October 1957. Shortages in this timeframe are indicative of the extreme 1950s drought conditions in the hydrologic period of record in the basin.
- Under the Shared Shortage scenarios (i.e., 50 cfs ISF), the duration of the 1954 shortage extends by 1 month, the 1956 shortage extends by a single month to 2 months, and additional 1 month shortages are projected for September 1955 and August 1980.
- In the Low ISF scenario (i.e., 100 cfs ISF), more shortages at greater durations would occur at an increased frequency (1950s, 1960s, and early 1980s).
- With the High ISF scenario (i.e., 300 cfs ISF), shortages would be projected to occur at the highest frequency throughout the period of analysis, extended in duration to as long as 11 consecutive months.

Figure 2.11 presents a summary of the monthly frequency and duration of shortages for the alternative scenarios evaluated herein for the Illinois River Basin. Inspection of this characterization indicates that the frequency of occurrence of shortages doubles when going from the baseline "No ISF" scenario to the "Shared Shortage" scenario, whereas going from the baseline to the "Low ISF" scenario projects a 10-fold increase in the frequency of shortages. Focusing upon duration, the "Shared Shortage" scenario extends the duration maximum by 1 month (50 percent) from the baseline scenario, and the "Low ISF" scenario triples the maximum duration to up to 6 consecutive months.

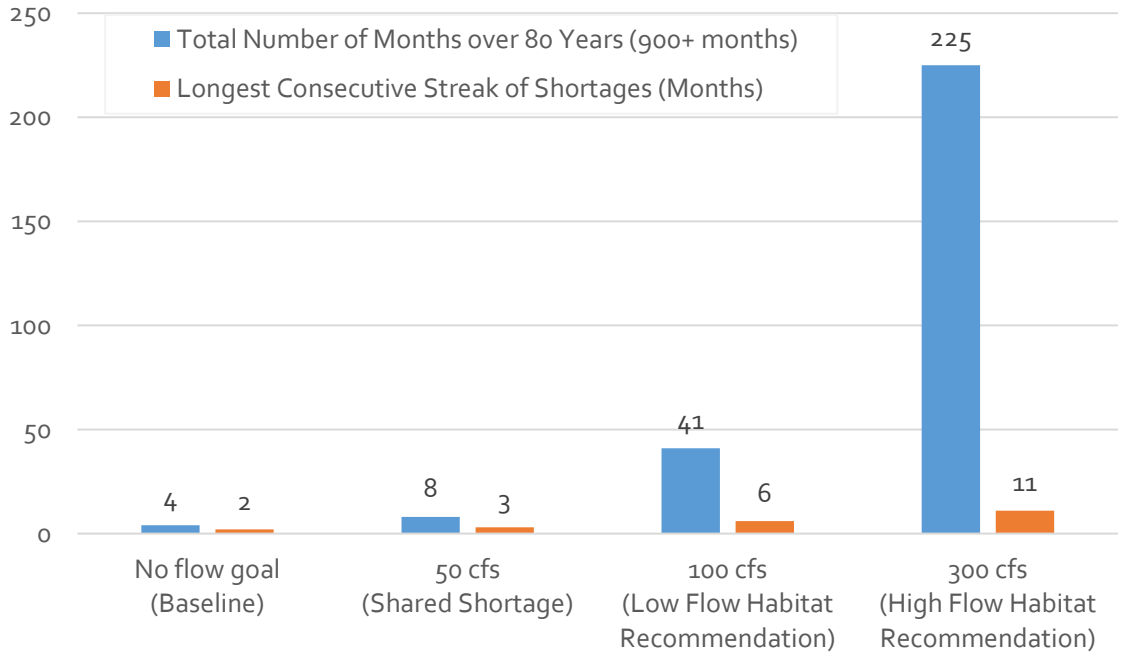


Figure 2.11 Summary of Frequency and Duration of Projected Monthly Shortages for Alternative Scenarios in Illinois River Basin (1949-2017)

Figure 2.12 addresses the time of the year that monthly shortages are projected in the Illinois River Basin for the various scenarios evaluated. As suggested previously, shortages occur at greater frequencies during late-summer months.

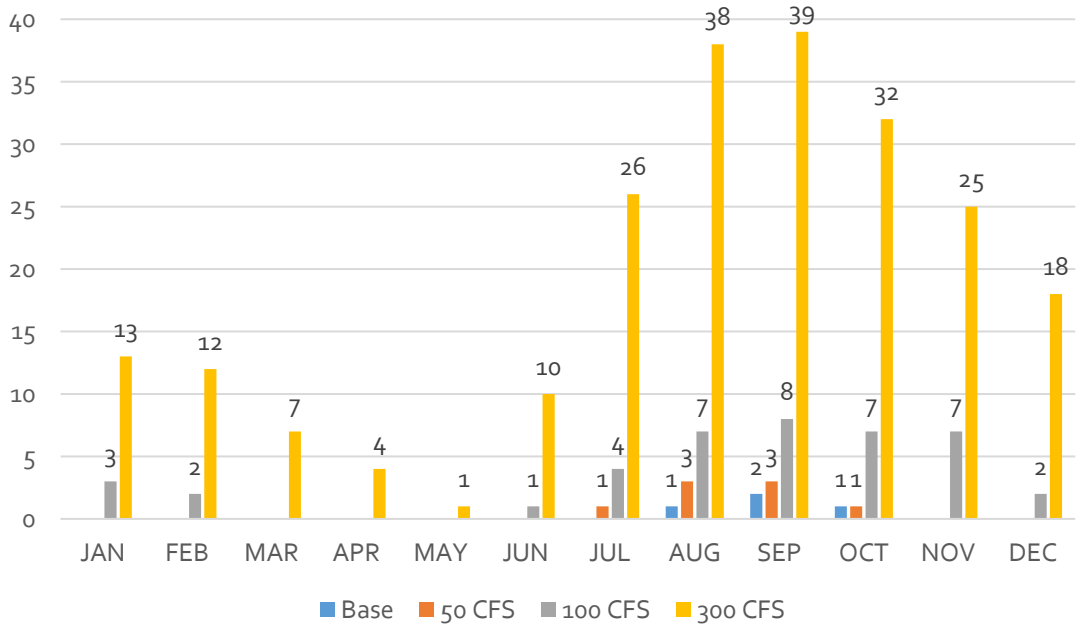


Figure 2.12 Median Size of Shortages by Month (AF/month)

A number of analyses were made to more specifically characterize the magnitude of projected shortages. For each scenario evaluated, Figures 2.13 through Figure 2.16 present the monthly time series of the magnitude of shortages over the period of record.

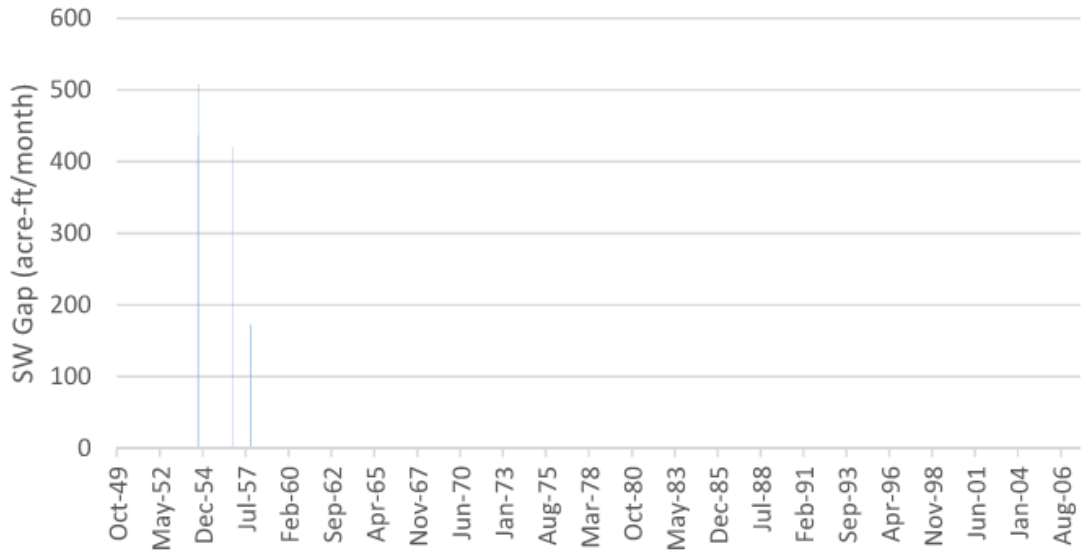


Figure 2.13 Monthly Time Series of Projected Shortage Magnitude in Illinois River Basin for Baseline "No ISF" Scenario (1949-2007)

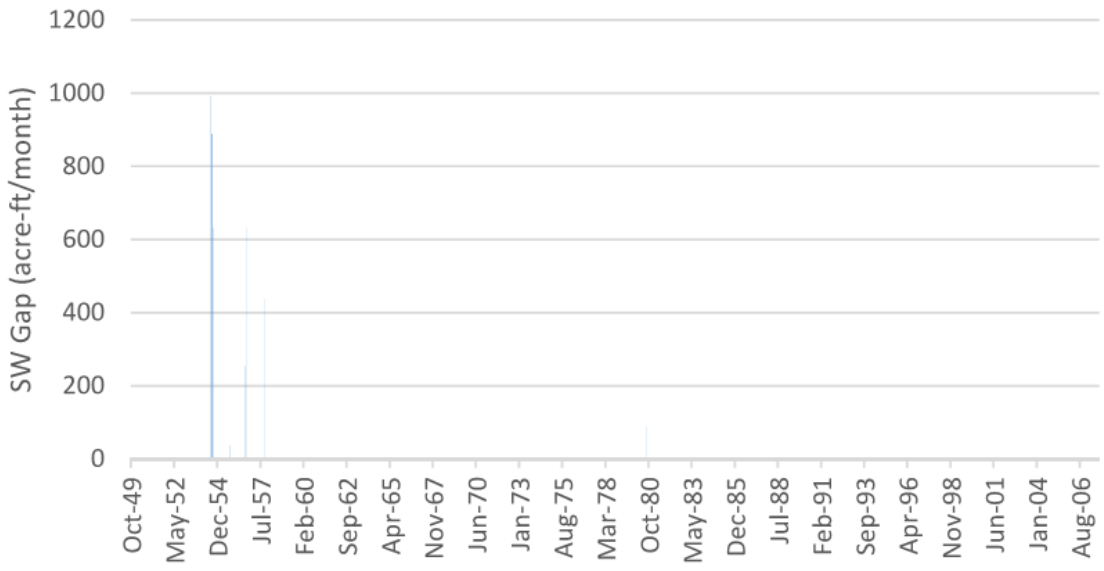


Figure 2.14 Monthly Time Series of Projected Shortage Magnitude in Illinois River Basin for "Shared Shortage" Scenario (1949-2007)

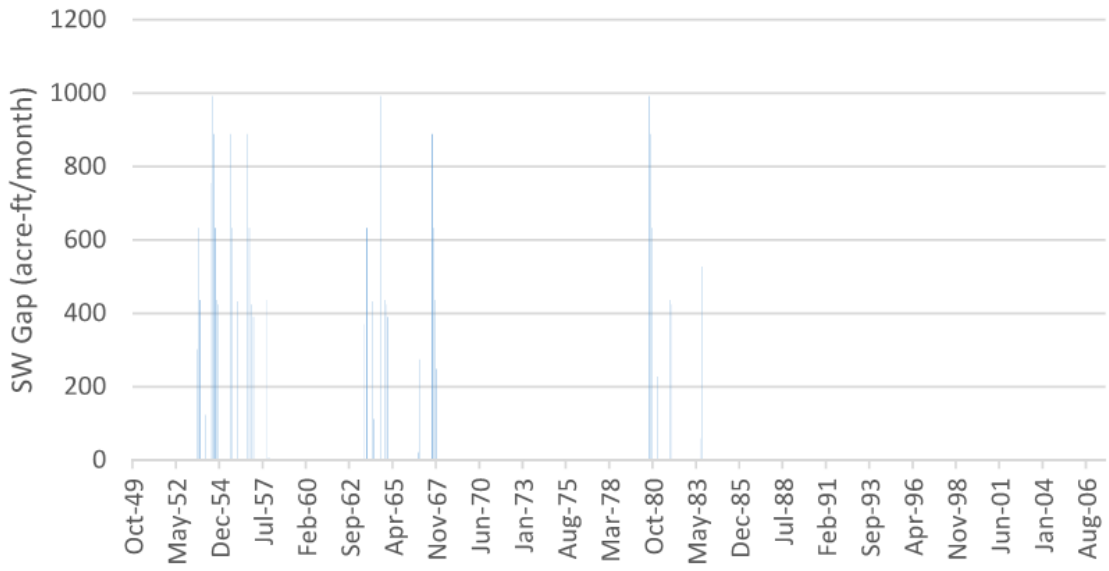


Figure 2.15 Monthly Time Series of Projected Shortage Magnitude in Illinois River Basin for "Low ISF" Scenario (1949-2007)

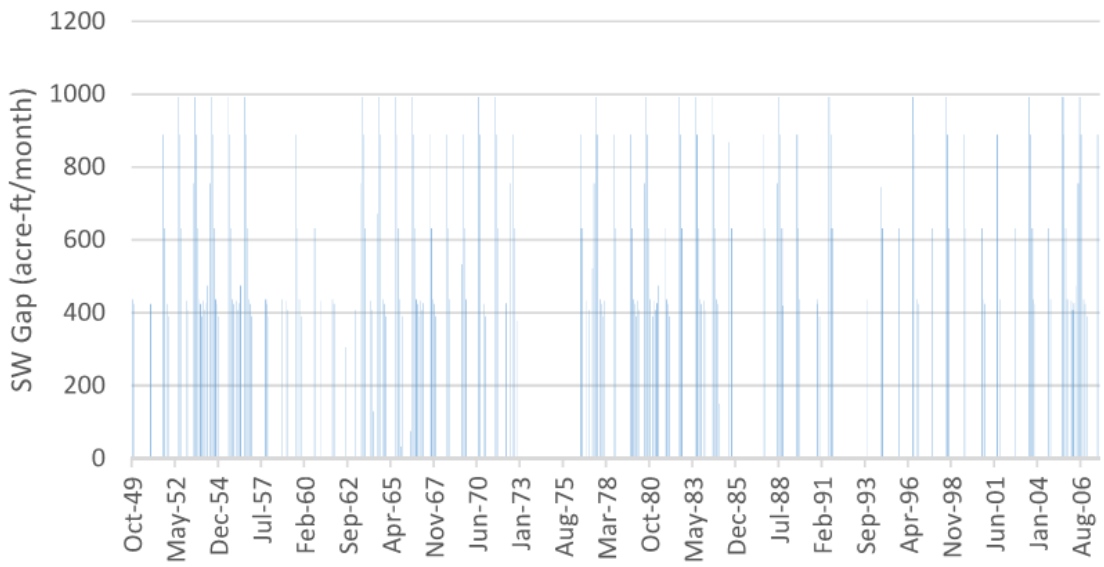


Figure 2.16 Monthly Time Series of Projected Shortage Magnitude in Illinois River Basin for "High ISF" Scenario (1949-2007)

While the above time series offer a finer resolution as to the magnitude and extent of shortages, a more general characterization focusing upon the median size of monthly shortages was developed for a more ready comparison between scenarios, as shown in Figure 2.17.

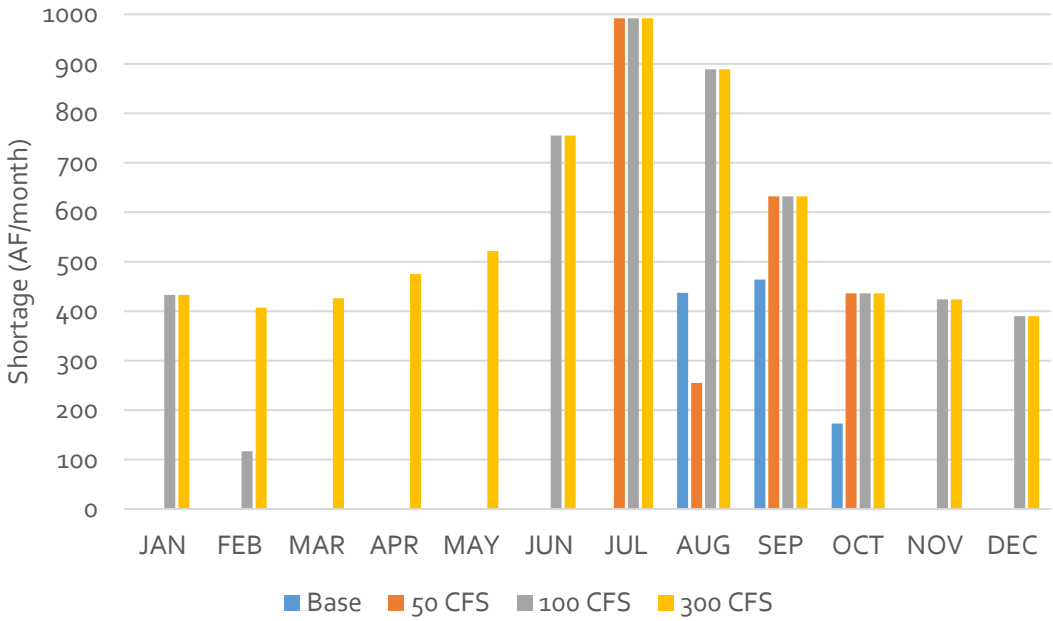


Figure 2.17 Median Size of Projected Shortages by Month for Alternative Scenarios in Illinois River Basin

From the above analyses, it was noted that over the approximate 80-year period of analysis (>900 months), in the baseline scenario there would be 30 months with stream flow lower than the 100 cfs "Low ISF" value. An analysis was then performed to characterize the

extent to which flows are at or below 100 cfs. Figure 2.18 presents monthly median flows for those months with flow below 100 cfs, as well as a depiction of the number of months flow is below 100 cfs. Such a depiction offers insight as to how much flows may be when under the low end of the habitat suitability range identified for the Illinois River Basin. Generally, it is observed that 50 percent of the months when flows are below 100 cfs, flow exceeds 50 cfs. The lowest median monthly flow during these low flow months is again in late summer, where the greatest frequency of months below 100 cfs also occurs.

The quantitative analyses presented in this section were developed and presented over the course of this phase of the Pilot Study, which entailed multiple interactions and workshops with local stakeholders that are described in more detail in Chapter 3. Presented in the next sections of this chapter are the similar analyses performed for the Barren Fork Creek and Flint Creek watersheds.

2.4 Barren Fork Creek Projected Future Flow Scenario Analyses

Initial analyses of the Barren Fork Creek hydrology were similarly performed over the available period of hydrologic record, utilizing stream flow observations from USGS Gage No. 07197000 (Baron Fork Creek at Eldon, OK). The annual flows observed at this gage location, presented in Figure 2.18, when presented along with the annual ISF amounts enumerated previously for the Barren Fork Creek watershed, provide an initial, high-level perspective as to both the magnitude of the ISF amounts relative to historical stream flow, as well as the frequency at which the annualized ISF amounts have been exceeded historically.

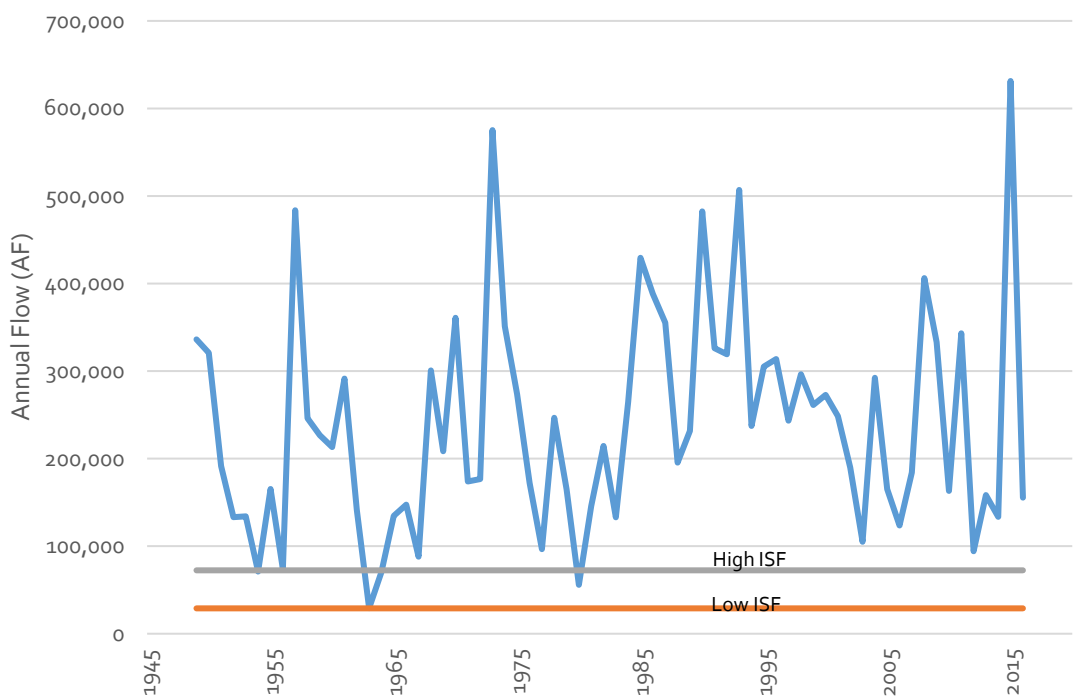


Figure 2.18 Observed Annual Flows at USGS Gage No. 07197000, Baron Fork Creek at Eldon, OK, in Comparison to Identified ISF Habitat Suitability Amounts (1949-2016; AFR)

As noted previously, the finest temporal resolution presently available for analyses of scenarios considering projections of 2060 incremental surface water demands along with stream flow is at the monthly timestep. Again, analyses at this monthly timestep cannot address the day-to-day

variations observed in the watershed, meaning that characterizations of "shortages," as defined herein as failures to meet consumptive and/or non-consumptive needs, should not be interpreted to mean that flow would not be available for spans of 1 or more months. Rather, a more appropriate interpretation would be that total flows in a particular month may not exceed a specified monthly target.

Initial consideration was given to how average monthly flows in the basin vary. This comparison is presented in Figure 2.19 for Barren Fork Creek, whereby it was observed that average monthly stream flows are lowest during the late-summer months. This provides some indication as to the time of the year where it could be anticipated that shortages in monthly stream flow may occur. However, while such a depiction is a worthwhile characterization of "average" conditions, this characterization does not shed light upon the more extreme hydrologic condition of drought that is the focus for both water supply planning and ecological resource management during such a stressed condition.

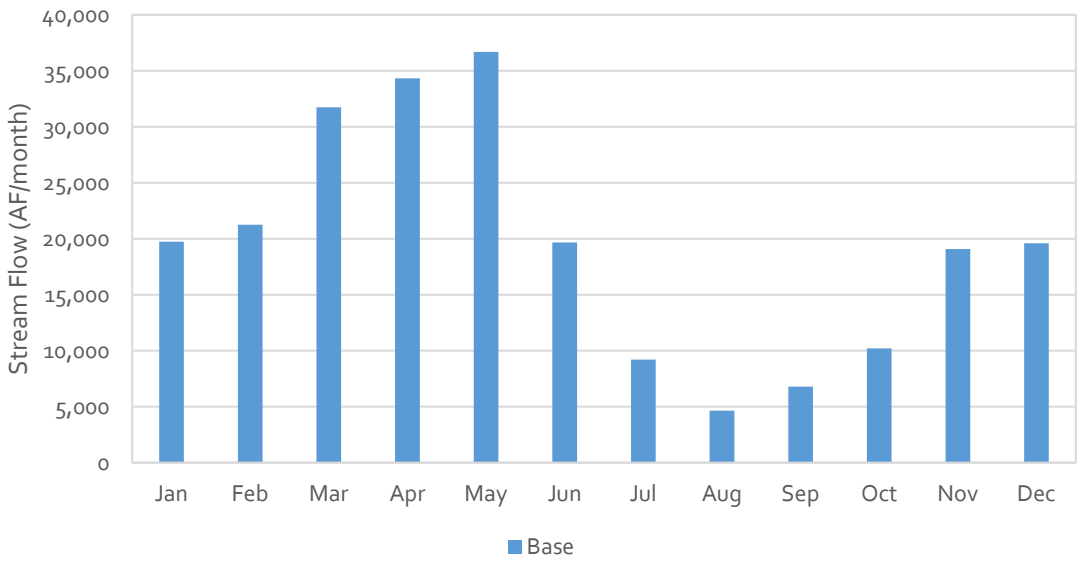


Figure 2.19 Average Monthly Stream Flows under Baseline Scenario for Barren Fork Creek Basin

To address the more extreme, low-flow conditions, a frequency-based comparative analysis was again adopted, whereby monthly flow frequency curves were generated for each ISF scenario, including the baseline "No ISF" scenario. Observation of the monthly flow frequencies may then be focused upon the low flow conditions, in order to assess the extent to which the 2060 incremental demand in the Barren Fork Creek watershed (i.e., the increase in demand from present day demands to the projected 2060 demands) can be met by available stream flow, and where shortages could be expected.

The resultant monthly flow frequency is thus plotted for each scenario in Figure 2.20, in comparison to the 2060 incremental demand for the Barren Fork Creek watershed. Within Figure 2.20, the x axis (Percent Exceedance) represents the percent of time the flow (the y-axis) is exceeded. Infrequent high flows have a lower percent exceedance than more frequent low flows. This figure focuses upon the low end of the flow regime, given that the majority of monthly flows in all three scenarios exceed the projected incremental 2060 demands in the basin.

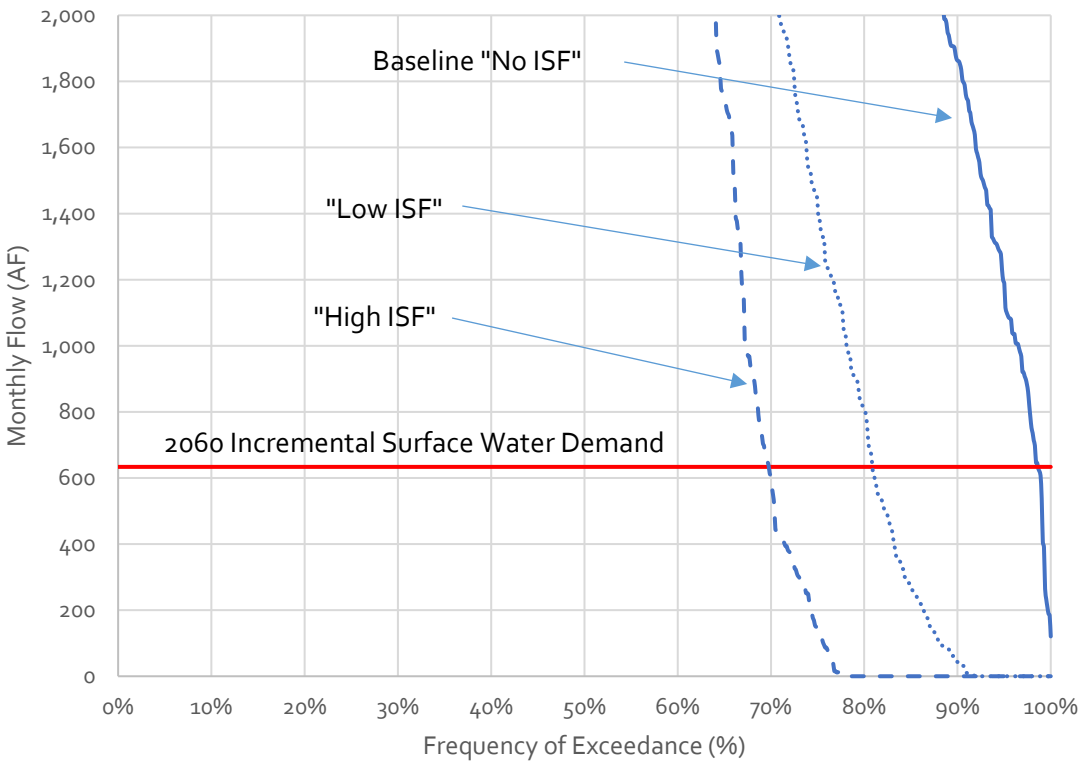


Figure 2.20 Low-End Monthly Flow Frequencies for Three ISF Scenarios in Comparison to Projected Incremental 2060 Surface Water Demand for Barren Fork Creek Watershed (1949-2017)

Several items of note are observed from this comparison:

- Under the Baseline scenario with no ISF reservations, there are approximately 1 percent of months over the 68-year period analyzed whereby monthly flows would not exceed the projected incremental 2060 surface water demands for the watershed. Said another way, monthly flows would be insufficient to meet the projected incremental 2060 demand roughly 1 percent of the months, even with no ISF implementation.
- Under the "Low ISF" scenario, the frequency of monthly flows exceeding 2060 incremental demand decreases to approximately 81 percent of the months, a decrease of 18 percentage points from the baseline "No ISF" scenario. Another interpretation would be that there are insufficient monthly flows to meet both the Low ISF amount and the projected 2060 incremental surface water demand in the Barren Fork Creek watershed approximately 19 percent of the months.
- Under the "High ISF" scenario, the decrease is more significant, whereby monthly flows would exceed projected incremental 2060 demand approximately 70 percent of the months, a decrease from the baseline scenario of 29 percentage points. Thus, there would be insufficient monthly flows to meet both the High-ISF amount and the projected 2060 incremental surface water demand approximately 30 percent of the months.

Expressed in terms of shortages, as defined herein, under the baseline "No ISF" scenario (i.e., the present status quo) shortages in monthly flows would be expected roughly 1 percent of the months. Were the "Low ISF" goal to be established, monthly shortages are projected to increase

to roughly 19 percent of the months. If the "High ISF" goal were to be established, shortages are projected to occur approximately 30 percent of the months.

The Oklahoma H_2O tool was again employed with the analysis period of 1950-2007, to perform seasonal shortage analyses for the three scenarios. Seasons for the Barren Fork Creek watershed were the same as those employed for the Illinois River Basin. Calculations were performed to derive general seasonal characteristics regarding shortages between meeting incremental 2060 surface water demand (alone in the case of the baseline "No ISF" scenario), or meeting both the incremental 2060 surface water demand and the specified ISF target for the given scenario.

For this initial characterization, focus was given to identifying the maximum and average seasonal shortage amounts, as well as their probability. The calculated maximum amounts reflect the maximum shortage over the identified season, whereas the average shortage reflects the average magnitude of shortage based only on the months for which shortages were identified. Probability, again, reflects the frequency of occurrence of shortages observed, and is based upon the number of years that a shortage occurs in at least one month of a season over the period of record. The resultant seasonal shortage evaluation presented in Tables 2.8, 2.9, and 2.10 offer a high-level characterization of the extent and magnitude of potential shortages in meeting both consumptive and non-consumptive needs, both in the seasonal and annual context[2].

Table 2.8 Barren Fork Creek Watershed Projected 2060 Seasonal and Annual Surface Water Shortages for Baseline "No ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	0	0	0%
Spring (AF/month)	0	0	0%
Summer (AF/month)	250	110	10%
Fall (AF/month)	120	60	14%
Annual (AFY)	**510**	**130**	**17%**

Table 2.9 Barren Fork Creek Watershed Projected 2060 Seasonal and Annual Surface Water Shortages for "Low ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	60	50	24%
Spring (AF/month)	20	20	3%
Summer (AF/month)	350	270	59%
Fall (AF/month)	170	100	71%
Annual AFY	**1,270**	**500**	**79%**

Table 2.10 Barren Fork Creek Watershed Projected 2060 Seasonal and Annual Surface Water Shortages for "High ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	60	60	41%

[2] Local shortages may vary from the basin-level amounts derived herein due to local variations in demands and local availability of supply sources.

Spring (AF/month)	70	60	14%
Summer (AF/month)	350	310	88%
Fall (AF/month)	170	100	93%
Annual (AFY)	**1,540**	**820**	**98%**

2.5 Flint Creek Projected Future Flow Scenario Analyses

Initial analyses of the Flint Creek hydrology were similarly performed over the available period of hydrologic record, utilizing stream flow observations from USGS Gage No. 07196000 (Flint Creek near Kansas, OK). The annual flows observed at this gage location, presented in Figure 2.21, when presented along with the annual ISF amounts enumerated previously for the Flint Creek watershed, provide an initial, high-level perspective as to both the magnitude of the ISF amounts relative to historical stream flow, as well as the frequency at which the annualized ISF amounts have been exceeded historically.

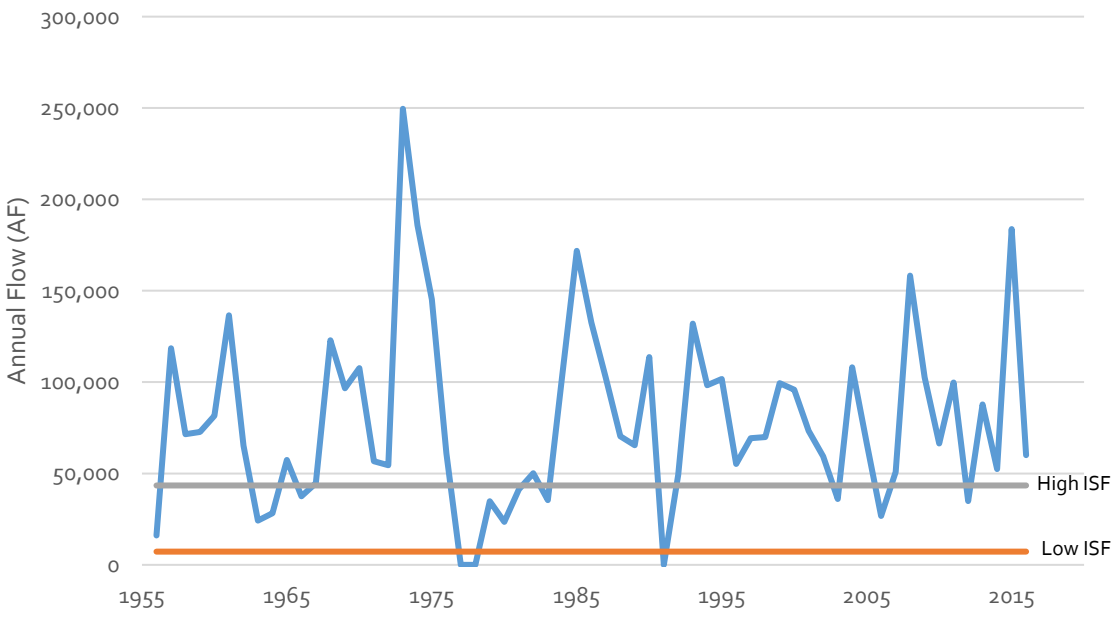


Figure 2.21 Observed Annual Flows at USGS Gage No. 07196000, Flint Creek near Kansas, OK, in Comparison to Identified ISF Habitat Suitability Amounts (1956-2016; AFY)

As noted previously, the finest temporal resolution presently available for analyses of scenarios considering projections of 2060 incremental surface water demands along with stream flow is at the monthly timestep. Again, analyses at this monthly timestep cannot address the day-to-day variations observed in the watershed, meaning that characterizations of "shortages," as defined herein as failures to meet consumptive and/or non-consumptive needs, should not be interpreted to mean that flow would not be available for spans of 1 or more months. Rather, a more appropriate interpretation would be that total flows in a particular month may not exceed a specified monthly target.

Initial consideration was given to how average monthly flows in the basin vary. This comparison is presented in Figure 2.22 for Flint Creek, whereby it was observed that average monthly stream flows are again lowest during the late-summer months. This provides some indication as to the time of the year where it could be anticipated that shortages in monthly stream flow may occur.

However, while such a depiction is a worthwhile characterization of "average" conditions, this characterization does not shed light upon the more extreme hydrologic condition of drought that is the focus for both water supply planning and ecological resource management during such a stressed condition.

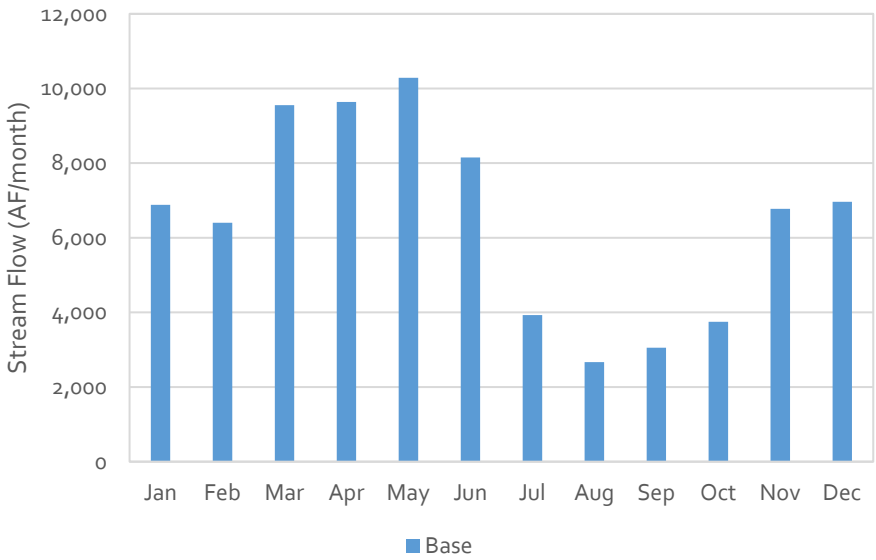


Figure 2.22 Average Monthly Stream Flows under Baseline Scenario for Flint Creek Basin

To address the more extreme, low-flow conditions, a frequency-based comparative analysis was again employed, whereby monthly flow frequency curves were generated for each ISF scenario, including the baseline "No ISF" scenario. Observation of the monthly flow frequencies may then be focused upon the low flow conditions, in order to assess the extent to which the projected 2060 incremental surface water demand in the Flint Creek watershed (i.e., the increase in demand from present day demands to the projected 2060 demands) can be met by available stream flow, and where shortages could be expected.

The resultant monthly flow frequency is thus plotted for each scenario in Figure 2.23, in comparison to the projected 2060 incremental surface water demand for the Flint Creek watershed. Within Figure 2.23, the x-axis (Percent Exceedance) represents the percent of time the flow (the y-axis) is exceeded. Infrequent high flows have a lower percent exceedance than more frequent low flows. This figure focuses upon the low end of the flow regime, given that the majority of monthly flows in all three scenarios exceed the projected incremental 2060 demands in the basin.

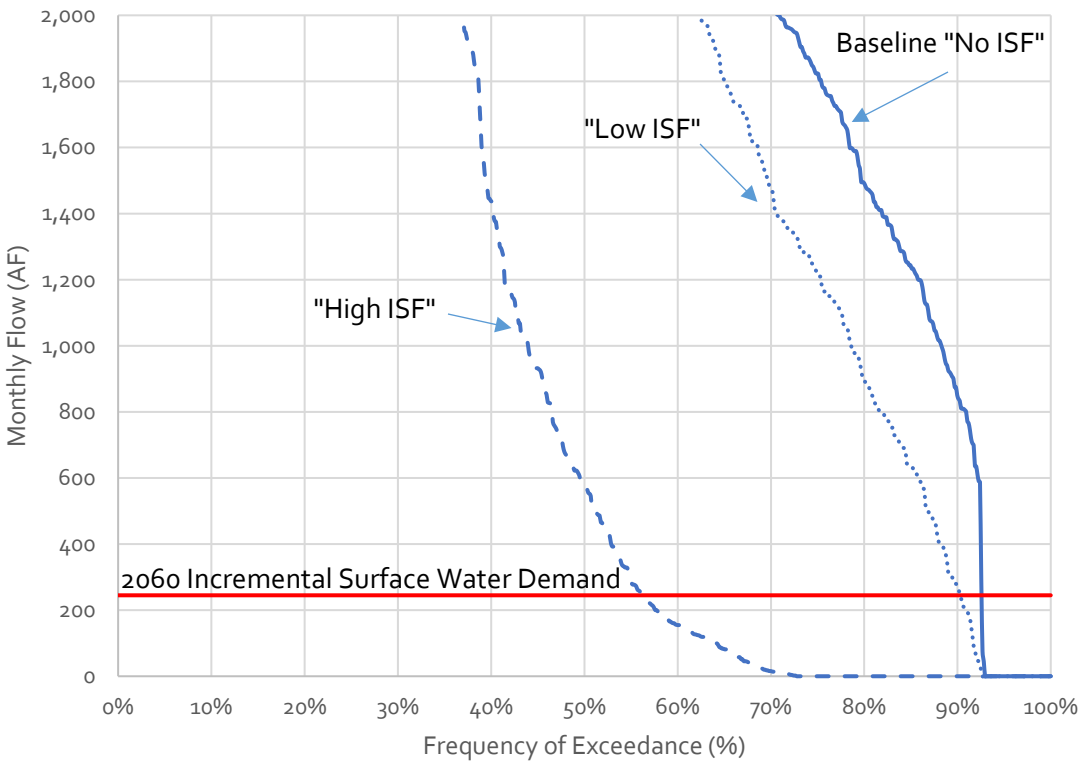


Figure 2.23 Low-End Monthly Flow Frequencies for Three ISF Scenarios in Comparison to Projected Incremental 2060 Surface Water Demand for Flint Creek Watershed (1955-2017)

Several items of note are observed from this comparison:

- Under the Baseline scenario with no ISF reservations, there are approximately 7 percent of months over the 68-year period analyzed whereby monthly flows would not exceed the projected incremental 2060 surface water demands for the watershed. Said another way, monthly flows would be insufficient to meet the projected incremental 2060 demand roughly 7 percent of the months, even with no ISF implementation.
  - Under the "Low ISF" scenario, the frequency of monthly flows exceeding the projected 2060 incremental surface water demand marginally decreases to approximately 90 percent of the months, a decrease of 3 percent from the baseline "No ISF" scenario. Another interpretation would be that there are insufficient monthly flows to meet both the Low ISF amount and the projected 2060 incremental surface water demand in the Flint Creek watershed approximately 10 percent of the months.
- Under the "High ISF" scenario, the decrease is observed to be much greater, whereby monthly flows would exceed projected incremental 2060 surface water demand approximately 57 percent of the months, a decrease from the baseline scenario of 36 percent. Thus, there would be insufficient monthly flows to meet both the High-ISF amount and the projected 2060 incremental surface water demand approximately 43 percent of the months.

Expressed in terms of shortages, as defined herein, under the baseline "No ISF" scenario (i.e., the present status quo) shortages in monthly flows would be expected roughly 7 percent of the months. Were the "Low ISF" goal to be established, shortages are projected to marginally increase to roughly 10 percent of the months. If the "High ISF" goal were to be established, shortages are projected to occur approximately 43 percent of the months.

The Oklahoma H_2O tool was again employed with the analysis period of 1950 to 2007, to perform seasonal shortage analyses for the three scenarios. Seasons for the Flint Creek watershed were the same as those employed for the Illinois River Basin and Barren Fork Creek watershed. Calculations were performed to derive general seasonal characteristics regarding shortages between meeting the projected incremental 2060 surface water demand (alone in the case of the baseline "No ISF" scenario), or meeting both the projected incremental 2060 surface water demand and the specified ISF target for the given scenario.

Focus was again given to identifying the maximum and average seasonal shortage amounts, as well as their probability. The calculated maximum amounts reflect the maximum shortage over the identified season, whereas the average shortage reflects the average magnitude of shortage based only on the months for which shortages were identified. Probability, again, reflects the frequency of occurrence of shortages observed, and is based upon the number of years that a shortage occurs in at least one month of a season over the period of record. The resultant seasonal shortage evaluation presented in Tables 2.11, 2.12, and 2.13 offer a high-level characterization of the extent and magnitude of potential shortages in meeting both consumptive and non-consumptive needs, both in the seasonal and annual context[3].

Table 2.11 Flint Creek Watershed Projected 2060 Seasonal and Annual Surface Water Shortages for Baseline "No ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	0	0	5%
Spring (AF/month)	0	0	3%
Summer (AF/month)	30	20	5%
Fall (AF/month)	20	10	10%
Annual (AFY)	**130**	**50**	**10%**

Table 2.12 Flint Creek Watershed Projected 2060 Seasonal and Annual Surface Water Shortages for "Low ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	0	0	7%
Spring (AF/month)	0	0	3%
Summer (AF/month)	30	20	10%
Fall (AF/month)	20	10	16%
Annual (AFY)	**130**	**50**	**17%**

[3] Local shortages may vary from the basin-level amounts derived herein due to local variations in demands and local availability of supply sources.

Table 2.13 Flint Creek Watershed Projected 2060 Seasonal and Annual Surface Water Shortages for "High ISF" Scenario

Season	Maximum Shortage	Average Shortage	Probability (%)
Winter (AF/month)	0	0	64%
Spring (AF/month)	0	0	34%
Summer (AF/month)	30	30	91%
Fall (AF/month)	20	10	93%
Annual (AFY)	**130**	**80**	**98%**

2.6 Comparison of Shortages Between Watersheds

The detailed statistical characterizations presented above were developed to inform stakeholders and decision makers as to the various specific aspects of potential future shortages that can be presently identified, such that informed decision-making and dialogue might be facilitated in attempting to balance the competing needs for limited water resources, specifically during drought conditions. It was also deemed informative to provide a higher-level, summary comparison between the watersheds of interest in this Pilot Study of the projected shortages under the various scenarios evaluated. Such a comparison informs upon the similarities and differences observed between the watersheds.

To present such a comparison in a readily understandable format, focus was given to characterizing projected shortages in each watershed in terms of the maximum annual amount of shortage, as well as the frequency of occurrence of projected shortages, as shown in Figures 2.24 and 2.25, respectively. Annual amounts and frequencies in this context mean that for a given year, if for any month in that calendar year has an identified shortage, then the monthly shortages for that year were summed and the year was identified as having a shortage. As expected, magnitudes of shortage vary with the magnitude of observed stream flows for a given watershed. The extent of the magnitude of shortage between the baseline, Low ISF, and High ISF scenarios varies from basin to basin. In terms of frequency of occurrence, shortages occur in greater frequency when comparing projected 2060 incremental surface water demand to higher ISF targets.

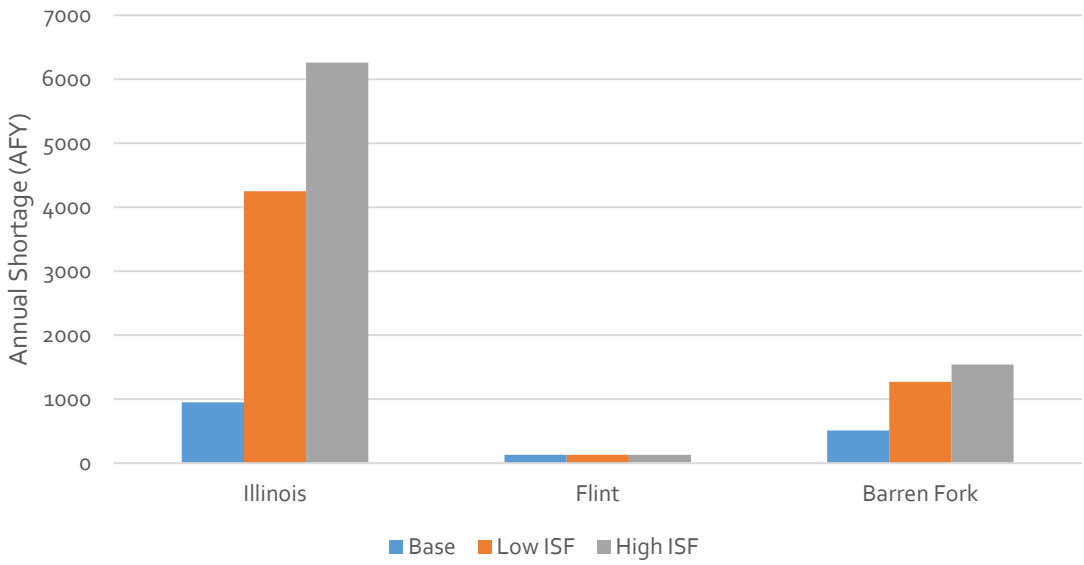


Figure 2.24 Maximum Annual Projected Shortage for Illinois River, Flint Creek, and Barren Fork Creek Basins (AFY)

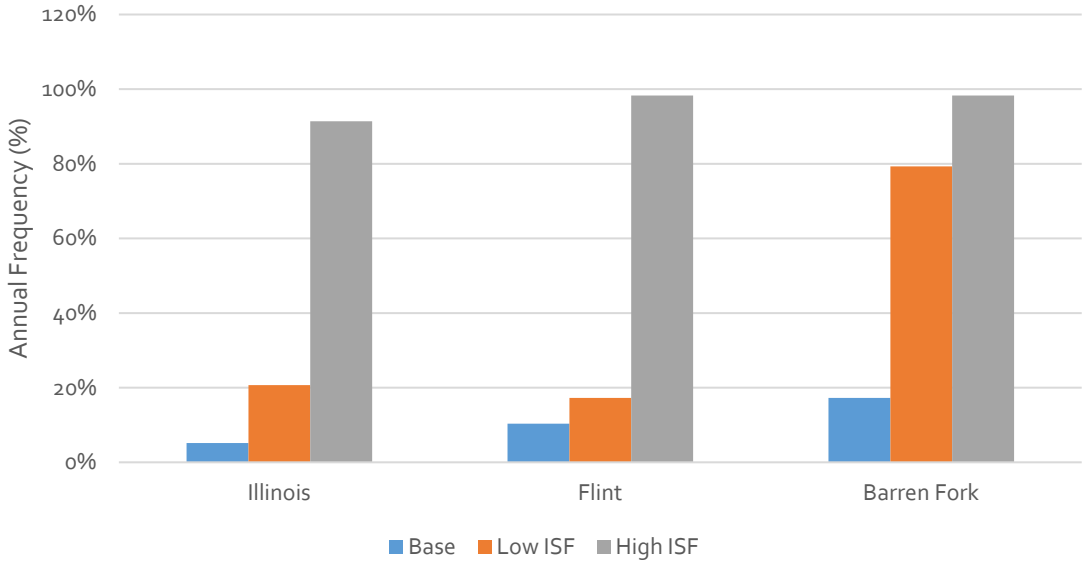


Figure 2.25 Annual Frequency of Occurrence of Shortages for Illinois River, Flint Creek, and Barren Fork Creek Basins (AFY)

Chapter 3

PILOT STUDY STAKEHOLDER PROCESS

Just as important as the quantitative characterization of potential shortages is the process by which local stakeholders are engaged in resolving (i.e., balancing) competing needs for water resources. Irrespective of the result of the process, it is critical to ensure that opportunities are provided to incorporate multiple viewpoints from local stakeholders. The stakeholder engagement process for the Pilot Study of the Illinois River, Barren Fork, and Flint Creek basins is described in this chapter.

The objectives of this stakeholder process were to:

- Inform local stakeholders as to the extent that future water resources were limited in ability to meet consumptive and non-consumptive water needs.
- Understand how to characterize specific elements to help inform stakeholders as to the extent of such shortages.
- Engage stakeholders in a consensus-based balancing process to develop a recommendation for how stream flows could best be managed to meet local needs, if the OWRB were to implement the stakeholders' recommendations. Because this was a pilot study of the ISF process, OWRB does not currently plan to implement its findings.

More broadly, the purpose was to help define a local stakeholder-driven process that could be considered as a framework for development of locally driven ISF recommendations for basin-level evaluations. It is noteworthy that there was no specific mandate, legislative or otherwise, for stakeholders to participate. The Pilot Study team found that significant effort was necessary to engage local interests to voluntarily participate. Through the efforts of the OWRB, a number of varying interests were identified and invited to participate.

Two of the final phases of a traditional IFIM process involve alternatives analysis (Phase 4) and issues resolution (Phase 5). The alternatives analysis is critical because the technical study's identified habitat suitability range of flows form a basis for dialogue between the varying stakeholder interests. Alternative scenarios (described in Chapter 2) were compared to a baseline scenario to facilitate understanding of potential impacts, and to initiate negotiations and development of new scenarios that could be potentially considered by stakeholders as being more compatible with multiple objectives.

The various scenarios were presented to the stakeholders to facilitate evaluation of their effectiveness and habitat sustainability, feasibility (e.g., impacts to projected future demand), and risk. To initiate the process, two rounds of workshops were held to independently engage consumptive and non-consumptive users. This allowed an open and frank dialogue about expectations and concerns regarding an ISF process from specific interests. Later, the varying stakeholder interests would be brought together to develop a basin-wide consensus.

Stakeholder groups were subdivided based on specific interest, as shown in Table 3.1.

Table 3.1 Stakeholder Interest Groups

Consumptive Uses	Non-Consumptive Uses
Municipal / Industrial	Aquatic Species / Environmental
Agricultural	Recreation

3.1 Stakeholder Workgroup Meetings

Two rounds of workgroup meetings were held with the stakeholder interest groups identified above. A high-level summary of these workgroup meetings follows.

3.1.1 Stakeholder Workgroup Round 1

The first round of workgroup meetings was held on May 10 and May 15, 2018. The stated objectives of the first round of workgroup meetings were as follows:

- Review the overall objectives of the ISF Pilot Study.
- Review the conclusions of the Upper Illinois River habitat assessment and initial results of flow projection/ISF analyses.
- Identify and discuss concerns/issues.
- Develop alternative scenarios for consideration.

Materials presented to each workgroup were the same for each meeting, in order to ensure consistent information was given to all participants. Initial quantitative analyses on shortages were presented to each workgroup, and discussions were then held regarding the content presented, what additional information would be informative for the given stakeholder interest's consideration, and what alternative scenarios might be possible for developing a consensus approach to consider for recommendation of ISF implementation.

The general input received from each of the Round 1 workgroups is summarized in the following sections. Comments listed in the tables reflect input expressed by meeting participants; they are not OWRB policy or representative of any group consensus at the meetings.

3.1.1.1 Agricultural

Attendees: Harvey Chaffin, Nick Hand, Seth Walters, and Randy Davis

No.	Summary of Discussion Comments
1	Concerns expressed regarding the magnitude of projected crop irrigation numbers, whereby it was noted that the projected demands employed for this Pilot Study were derived from the OCWP. Noted that the specific amounts for the given planning scenario were useful to inform stakeholder deliberations.
2	Urbanization is causing recent upward trends in flow in the Illinois River Basin.
3	It would be useful if the duration of shortages was characterized along with the magnitude and frequency.
4	Additional science speaking to the recovery capability of habitat after a prolonged drought would help to manage from the perspective of survival, rather than managing for optimal conditions.
5	Storage for environmental purposes may be a better solution for ISF management in these watersheds, although such a solution could be cost prohibitive.

No.	Summary of Discussion Comments
6	The use of alternative sources (e.g., groundwater) is not considered practical for the local nurseries, particularly in relation to the abundance of surface water in the region.
7	Onsite recapture and reuse of irrigation runoff has been implemented by one nursery in the region.
8	Dry-land farming is typical in this area, and farms do not typically irrigate. During droughts, it is more cost-efficient to sell cattle than supply water for them.
9	Small operations are expected to diminish or cease entirely with some very large corporate operations starting up.

3.1.1.2 Aquatic Species / Environmental

Attendees: Jeanne Hayes, Nicole Hardiman, Sancharo Ghosh, Jahna Hill, Norma Boren, Ed Brocksmith, Tom Elkins, Sara Hill, Wayne Isaacs

No.	Summary of Discussion Comments
1	It would be informative to show the monthly breakdown of projected 2060 incremental surface water demand.
2	Shortages at this point are conceptual, as these issues are not present today; rather, we need to plan now to address these potential shortages to avoid potential future conflict.
3	Support for water trading and water banking solutions.
4	The state should set limits on future increases in demand.
5	It could be informative to look at recent hydrologic extremes to identify changes correlating to development occurring in Arkansas.

3.1.1.3 Recreation

Attendees: Larry Stinnett, Jeremy Tubbs, Denise Toyne

No.	Summary of Discussion Comments
1	Between 800 and 1,000 new poultry operations are expected in the watershed.
2	Anything done on ISF in these watersheds should be coordinated with the State of Arkansas.
3	Preference for flows of 400 to 600 cfs.
4	Expressed interest in "sharing" pain during low flow conditions, as long as it is not "one sided pain."
5	Consider implementation of land management practices.
6	Streambank stabilization should also be investigated.

3.1.1.4 Municipal / Industrial

Attendees: James Thompson, Rick Subblefield, Dewayne Palmer, Mike Doublehead

No.	Summary of Discussion Comments
1	At high flows, the City of Tahlequah withdraws water from its 45-day storage lakes.
2	The predominance of baseflow derives from Arkansas discharges.
3	Gravelization has increased rapidly in recent years.
4	It is likely that upstream demand projections (including in Arkansas) will significantly increase in the near-term.
5	The City of Tahlequah has recently obtained a new permit for their river intake, anticipating an increase of approximately 30 percent.
6	Although the Illinois River Village is entirely supplied by groundwater sources, this is not typical for the region. Groundwater is not typically a source of water supply, given that wells must be deep and have water quality concerns.
7	Stream fishing is a very small part of the much larger lake-fishing community.
8	Characterization of potential socioeconomic impacts would be beneficial.
9	Opinion that recreational use manages well during low flow periods.

3.1.1.5 Summary of Feedback on Round 1 Quantitative Analyses

Generally, feedback from the first round of workgroup meetings regarding the quantitative analyses focused on how the characterization of shortages might be simplified, such that stakeholders can more easily assess potential benefits and/or impacts. It was noted that the duration of such shortages was also considered to be of significance. An evaluation of potential socioeconomic impacts was also discussed, although it was noted that such analyses were beyond the present scope of the Pilot Study.

Additionally, it was noted that while summary statistics were informative, more detail on the quantitative specifics of the projected shortages for each watershed would also be useful. Noting interest in "sharing the pain," an additional preliminary scenario described as a "Shared Shortage" scenario was added to the Baseline "No ISF," "Low ISF," and "High ISF" scenarios to be analyzed. Noting similarities in trends between the watersheds, focus was thus given to the Illinois River watershed as representative of the types of impacts for these additional quantitative analyses to be considered in the second round of workgroup meetings. Details as to the results of these additional quantitative analyses are presented in Chapter 2.

3.1.2 Stakeholder Workgroup Round 2

The second round of workgroup meetings was held on July 12, 2018. For the second round of meetings, workgroups were combined into two sessions: consumptive and non-consumptive users. The stated objectives of this second round of workgroup meetings were as follows:

- Better understand of the impacts to consumptive and non-consumptive users of the various ISF scenarios presented at the May 2018 meeting.
- Explore a new "shared shortage" scenario based on feedback from last meeting.
- Understand options for implementation.
- Clearly express preferences and recommendations for managing stream flows in the watershed.

Potential management approaches were brought forward for the consideration of each workgroup, utilizing information regarding ISF implementation in other states, along with the additional analyses developed from input received during the first round of meetings. The input received from each workgroup was also summarized and shared, with the objective being to begin development towards consensus on an ISF management approach to be developed for recommendation at a subsequent public meeting wherein all parties would participate and collaborate. Again, materials presented to both workgroups were the same for each meeting. The general input received from each of the Round 2 workgroups is summarized in the following sections.

Four general ISF approach categories were also presented and discussed with each workgroup. Implementation approaches were categorized as follows:

1. Adoption / Implementation of a Numeric Standard.
2. Voluntary Mechanisms.
3. Monitoring and/or Adaptive Management.
4. No Action.

The benefits and risks of each category were discussed with the stakeholders to solicit their initial perspectives regarding each category. A more detailed breakdown of these categories is presented later in this chapter. A summary of the discussions with each workgroup is presented in the sections below. Comments listed in the tables reflect input expressed by meeting participants; they are not OWRB policy or representative of any group consensus at the meetings.

3.1.2.1 Consumptive User Group

Attendees: Nick Hand, Randy Davis, Harvey Chaffin, Michael Doublehead

No.	Summary of Discussion Comments
1	Concern over the accuracy of the 2060 projections, noting that any plan will only be as good as its assumptions. With improved Best Management Practices implemented, agricultural uses may consume less water or result in less runoff.
2	Opinions expressed that habitat and recreational targets cannot be managed in this region except by cutting consumptive uses, but if it is late summer and plants are dying, that is not an option.
3	Considering surface water permit limitations, potential support was expressed for grandfathering of existing permits and possibly limiting future permits.
4	Expressed an opinion that the solution is storage, rather than permitting.
5	Significant concerns expressed over potential future large users seeking interbasin transfers of water supply from the region.
6	No support expressed for implementation of ISF via permit restrictions, regardless of the scenario.

3.1.2.2 Non-Consumptive User Group

Attendees: Denise Deason-Toyne, Sanchari Ghosh, Larry Stinnett, Jahna Hill, Tom Elkins, Glenda Elkins, Nicole Hardeman

No.	Summary of Discussion Comments
1	Inquired as to whether conservation of consumptive use might allow sufficient water to meet the 50 cfs target under the shared shortage scenario.
2	Concern expressed that although the habitat suitability range may support sufficient habitat, lower flows decrease water quality to the point that 100 cfs is not equitable to 300 cfs of flow.
3	Open to water trust options, handled publically, privately, or both.
4	Open to 10-year period to come back and review/adjust ISF implementation.
5	Disappointment that the shared shortage scenario started with the low end of the habitat suitability range (100 cfs). Given that the science is not perfect, would prefer erring on the side of higher ISF amounts since the effects on the environment could be more damaging than projected. Balancing should start from the present, not with projected 2060 numbers in mind.
6	Interest expressed in limiting permits only to water available above ecological needs.
7	Grandfathering would be acceptable if it were to be based on actual use and not on the total permitted amount.
8	It is not clear how water users would be encouraged to utilize a Water Trust.
9	Suggested groundwater use could be an option during summers for nurseries.
10	Storage could be an option for consideration.
11	Higher ISF goals could be met by encouraging more efficient use of water by consumptive users.
12	Reticence towards any compromise below the identified habitat suitability range, with some indicating that ISF flow targets should be higher.

An additional item of note was that recreational users did not respond to OWRB direct outreach efforts soliciting their participation in this process.

3.1.2.3 Supplemental Workgroup Meeting

An additional workgroup meeting was held in Tulsa on August 17, 2018 for participants unable to attend the previous workgroup sessions, a brief summary of which is presented here.

Attendees: Tyler Gipson, Brad Vickers, James Thompson

No.	Summary of Discussion Comments
1	Support for "Low ISF" target.
2	Suggestion for a "Shared Shortage" Committee, whereby when flows go below some set amount the committee would meet and decide what to do.

3.1.2.4 Summary of Feedback from Round 2 Workgroups

Now armed with more informative details on the extent of shortages, although such shortages were determined to be relatively infrequent, both consumptive and non-consumptive stakeholder interests were reluctant to support a compromise or consensus approach for ISF management in the area. Reduction, or restrictions to, consumptive use during drought conditions, even for infrequent periods of time, were considered by consumptive users as not

being a viable option. In contrast, while non-consumptive stakeholder interests were supportive of voluntary implementation approaches, the general position expressed by the non-consumptive users was that the habitat suitability range should be preserved, with support expressed for perhaps higher ISF amounts, rather than compromising to a lower ISF amount.

Generally, the preference expressed was to avoid shortages rather than managing shortages, via possible mechanisms such as conservation or storage solutions. Further, intermittent shortages were considered to be more tolerable than extended shortages. In summary, no immediate consensus approach was expressed or identified.

3.2 Categories of Options for Implementation of ISF

The Instream Flow Council (IFC) has recognized and evaluated over 30 different documented methods employed throughout the United States (U.S.), ranging from low effort (e.g., desktop) to high effort (e.g., fieldwork and modeling) (Annear et. al., 2004). ISF methods have been generally categorized into three general types: 1) Standard setting, 2) Incremental, and 3) Monitoring/diagnostic. With this as background for the present effort, ISF implementation options were grouped into four general categories of feasible implementation options, as presented in Table 3.2.

Table 3.2 Overview of Four Categories of ISF Implementation Options

Category	Adoption / Implementation of a Standard	Voluntary Mechanism	Monitoring / Adaptive Management	No Action
Characteristics and Considerations	Stakeholder consensus on balancing	Non-regulatory	Approach from the "top" or from the "bottom"	Status quo
	Selection of an ISF amount	Approach from the "top" or from the "bottom"	Establish what to monitor	No stakeholder recommendation for action
	Decide how to regulate	Water Bank / Trust	Establish who monitors and how often	No formal protection for non-consumptive uses

Consideration of these options by the stakeholders focused upon the opportunity for present management and planning to develop an approach to have in place when future conditions (such as during times of drought) might lead to an increased likelihood of competing needs for limited resources. Presented in the sections below is a summary of the various aspects considered during the Pilot Study process.

3.2.1 Adoption / Implementation of a Numeric Standard

A variety of approaches may be used to implement ISF as a standard, ranging from explicitly granting ISF water rights to the application of special conditions to future consumptive appropriations or amendments to existing appropriations. Adoption and implementation of a numeric ISF standard presents a number of considerations warranting attention by stakeholders. Standard setting usually employs establishing limits below which water cannot be diverted (Stalnaker et al. 1995). The analysis of ecological/habitat responses to determine

purely environmental needs was observed to be more time and labor intensive, but allowed for more informed deliberations on relevant ISF amounts when comparing alternative flow scenarios evaluated.

The first element which stakeholders would initially focus upon was "what number," i.e., the amount of water that might be implemented as some form of an ISF management goal. The technical analyses performed in Chapter 2 presented four alternative scenarios for consideration by the stakeholders, from no ISF, to the low and high ends of the identified habitat suitability range for each watershed, as well as a "shared shortage" scenario approximating a midpoint that could provide some reduced level of protection for elements of the ecology and recreation while yielding potential lower impacts to projected future growth in consumptive demand.

Concurrent with the discussion of how much water should be adopted as an ISF goal is the consideration of the means by which such a goal might be implemented. As noted above, options in this context include, but are not limited to:

- Granting of surface water permits for the specific reservation of identified ISF flow amount(s).
- Adopting standards for ISF target flows to restrict permitting of consumptive uses.
- Setting ISF target flows to be incorporated into state and regional water planning.

Each of these options was presented and discussed with local stakeholders. Consideration was additionally given to the possibility of "grandfathering" existing surface water permits, utilizing varying ISF target flows based upon hydrologic conditions (i.e., higher targets during wetter periods, lower/no targets during drier hydrologic conditions), and possible variation of the selected ISF target by season.

Accordant with the selection of an ISF amount (or amounts) and selection of an implementation approach, consideration was also given to the potential effects to future surface water demand in the region, upon the recreation industry, and on the ecological health of the local watershed. Identified advantages and disadvantages of this approach were as follows:

- Potential impacts to existing and/or future consumptive users.
- Establishment of an ISF approach by the State that is supported by local stakeholders may assist in addressing or informing external drivers or processes, such as federal processes or legal proceedings.
- Adoption of ISF standards assists local, regional, and state water management more comprehensively plan for future human and ecological needs.

3.2.2 Voluntary Mechanisms

A suite of voluntary mechanisms were presented and considered by the stakeholders. Based on interests expressed during the initial workgroup meetings, particular attention was paid to the possibility of establishing some form of a water bank or trust.

Not all governance and water management activities are necessarily carried out by the government through controlling regulations via ISF requirements or permits. Water trusts have emerged in the western U.S. as important management components to ISF protection for a number of states. Such water trusts have evolved to function within existing water law and regulatory frameworks to complement and support state ISF programs, and represent a move towards voluntary conservation approaches using market transactions as part of public/private

partnerships. Across the western U.S., environmental water transaction programs work to maintain or restore environmental flows through acquisition of water rights and incentivizing changes in water management (Kendy et al., 2018).

Aylward (2013) offers the following definition for environmental water transactions:

> "An environmental water transaction is any agreement (or set of related agreements) by which a water right holder, contractor, or user commits to a change in their water use and/or water right leading to legal or de facto protection of additional water in a waterway or water body to serve environmental purposes."

Further offered in Aylward (2013) are the following water transaction types:

- Water Management:
  - Upstream Management:
    - Timing of storage releases, i.e., releasing storage during salmonid migration.
    - Source switch, i.e., using groundwater in place of natural flow.
    - Point of diversion change, i.e., moving a diversion downstream.
  - Conveyance Efficiency:
    - Diversion efficiency, i.e., modification of diversion structures.
    - Deliver efficiency, i.e., ditch controls, scheduling and distribution.
    - Transmission efficiency, i.e., piping and lining.
  - On-Farm Efficiency.
- Consumptive Use:
  - Reducing crop consumptive use, i.e., switching to lower water use crops.
  - Taking land out of agricultural production, i.e., fallowing or transferring water off land.

Kendy et al., (2018) summarizes transactions detailed by Aylward (2013), to include (but not limited to) the following:

- Forbearance agreements (e.g., U.S. Bureau of Reclamation, 2007).
- Dry-year options.
- Deficit irrigation.
- Water conservation agreements.
- Crop substitution.
- Split-season leases.
- Infrastructure construction or reoperation.
- Groundwater recharge and storage.
- Use of alternative water sources.
- Traditional water rights sales and leases.

There are a number of non-government organizations that collaborate with state agencies in water management activities. From Loehman and Charney, (2011):

> "Water trusts (patterned after land trusts and The Nature Conservancy) specialize in fostering voluntary approaches and market solutions to water acquisition. [The] Oregon Water Trust, founded in 1993, was the first water trust founded in the US; it was based on finding "a market solution that balances instream needs for fish and wildlife with the continued use of water for agricultural production and urban communities" (Buy that Fish a Drink, PERC Reports 25(2), Summer 2007, www.perc.org/articles). Ecological, hydrologic

and water rights data are used to identify priority stream for potential water right acquisitions. It has worked with communities to create co-operative solutions and has provided for [ISF] in 86 streams and restoration projects in four major rivers in Oregon (2010, www.wikipedia.org/wiki/Oregon_Water_Trust). In 2009, it merged with Oregon Trout to form The Freshwater Trust (www.thefreshwatertrust.org).

The Washington Water Trust has been using voluntary agreements to restore stream flows since 1998. Engaged in stream restoration and protection, it helps execute water rights sales and leases, design and assess water management alternatives, and leverage funds for projects. Work focuses statewide on eight major river basins as well as on coastal areas. Uniquely, it develops and administers water banking and water auctions. It also provides education and outreach about water management issues and methods (http://washingtonwatertrust.org).

The Colorado Water Trust was formed in 2001 to support and restore the state's stream flows (www.coloradowatertrust.org). The water trust works in coordination with the agricultural community, watershed groups and other non-profits in acquiring water rights for transfer to the Colorado Water Conservation Board. It helps to provide physical and structural solutions for ecosystem restoration, and provides technical support to landowners for water conservation practices.

The Montana Water Trust was founded in 2001 to help identify and manage senior water rights for transfer to instream flow. It focuses on smaller tributaries of the 4,000 miles of Montana's dewatered streams. Leasing of various types and improving irrigation efficiency are its main tools for [ISF] provision. Work is carried out in partnerships with other non-profit groups and government agencies. Fifteen agreements for [ISF] have restored over 35 million gallons of water (132,500 cubic meters) per day to Montana's rivers and streams (www.montanawatertrust.org)."

The Texas Water Trust (http://www.twdb.texas.gov/waterplanning/waterbank/trust/index.asp) is not private, but rather was created as a program within the Texas Water Bank, implemented by the Texas Water Development Board. The Texas Water Trust offers a significant opportunity to acquire, by donation, lease, or purchase, existing water rights for environmental purposes including preservation of aquatic life and habitat. In cooperation with the Texas Commission on Environmental Quality and the Texas Parks and Wildlife Department, an existing water permit may be amended to transfer the permit to the Texas Water Trust.

Within the Columbia River basin in the northwestern U.S., the Columbia Basin Water Transactions Program (CBWTP; www.cbwtp.org) was created in 2002 to address significant impacts of water withdrawals, which were determined by the National Marines Fisheries Service to have significant consequences imperiling salmon, steelhead, trout, and other creatures. The CBWTP supports program partners in Oregon, Washington, Idaho, and Montana to assist landowners who wish to restore flows to existing habitat using permanent acquisitions, leases, investments in efficiency, and other incentive-based approaches. The CBWTP is managed by the National Fish and Wildlife Foundation, in partnership with the Bonneville Power Administration, which provides the majority of the funding in cooperation with the Northwest Power and Conservation Council.

All water trusts funded by the CBWTP consider endangered species as a driver; however, recreation and ecosystem maintenance and protection serve as drivers for states as well (Loehman and Charney, 2011), as evidenced in Table 3.3.

Table 3.3 Drivers of Protection (from Loehman and Charney, 2011)

Source	Government Agencies	Non-Governmental Organizations (NGO)
Recreation	AZ, CO, MT(1), WA	AZ, CO, ID(1), MT, OR
Endangered Species	AZ(1), ID(1), MT, WA(1)	AZ, CO, ID, MT, OR(1), WA(1)
Ecosystem Protection	AZ, CO, MT, OR(1), WA	CO, MT(1), OR

Notes:
(1) Single most important item.

From Loehman and Charney (2011):

> "State agencies and NGOs are involved in identifying lease or rights purchase opportunities. NGOs specialize in "making deals" for voluntary market transactions. Both agencies and NGOs identify priority streams. Activities of both government agencies and NGOs go far beyond provision of flow" (See Table 3.4.).

Table 3.4 State and NGO Management Activities (from Loehman and Charney, 2011)

Activity	Government Agencies	NGOs
Identifying Priority Streams	CO, ID, MT, OR, WA	AZ, ID, MT(1), OR, WA(1)
Improving Storage of Water	CO(1), MT, OR, WAS	
Improving Water Efficiency	ID, MT, OR, WA	ID(1), MT(1), OR
Identifying Leases or Rights	AZ, CO, ID, MT, OR, WA(1)	AZ, CO, ID(1), MT(1), OR(1), WA(1)
Negotiating Leases or Rights	AZ, CO(1), ID, MT, WA	CO, ID, MT(1), OR(1), WA(1)
Review of Applications for ISF Rights	AZ	
Stream Restoration	CO, MT, OR, WA	AZ, CO, ID(1), MT(1), OR, WA
Monitoring Stream Flow	CO, ID, MT(1), OR, WA	CO, ID, MT(1), OR, WA
Monitoring ISF Rights	CO(1), ID, MT(1), OR, WA	AZ, ID, MT(1), WA
Drought Planning	CO(1), ID, MT(1), OR, WA	ID, MT
Education	CO(1), ID, MT, OR, WA	ID(1), MT, OR, WA
Research and Data Collection	CO(1), ID, MT, OR, WA	AZ, CO, ID, MT

Notes:
(1) Activities that receive the main emphasis in terms of effort.

> "Methods used to set priorities for protecting streams vary by state [Table 3.5]. All NGOs make use of models to indicate problem streams. Opportunity and direct observation are other prominent methods of setting priorities for streams to protect."

Table 3.5 Methods of Setting Priorities for Stream Protection (from Loehman and Charney, 2011)

Method	Government Agencies	NGOs
Model	CO(1), ID, OR, WA	AZ, CO, ID(1), MT(1), OR, WA
Nomination by Agencies	CO(1), ID, OR, WA	CO(1)
Observe Impaired Streams	OR, WA	ID, MT(1), OR, WA
Opportunity	AZ(1), CO, MT(1), WA	CO, ID, OR, WA
Coordinate with Watershed Plan		WA

Notes:
(1) Predominant method used.

"...NGOs have different funding sources than state agencies [Table 3.6]. State agencies have more secure funding through state line items and license fees, while NGOs can receive private foundation grants."

Table 3.6 Funding Sources (from Loehman and Charney, 2011)

Source	Government Agencies	NGOs
State, Informal	AZ	WA
State Line Item	CO, MT, WA, OR	
State Funds (leases, licenses, etc.)	CO, MT	
Federal Grants	ID, MT, WA, OR	AZ, MT, WA
Private Foundation Grants		CO, ID, MT, OR, WA
Conservation Buyers		AZ
BPA Ratepayer Funds		OR

Loehman and Charney (2011) also identify common problems between the surveyed states (see Table 3.7), where it is noted:

"Funding is a stated problem for all NGOs. Funding was only indicated as a problem for two of the state agencies: those without access to [Colorado Water Conservation Board] funds. Citizen support - that could help to promote budgets and political support - was also indicated as lacking in these same two states, as were lack of government commitment and legal foundation. Evidently, lack of sufficient resources is conjoined with lack of government and citizen support. Policy change is a major need of most NGOs: for example, several states noted that owners are reluctant to sell water rights to government entities..."

Table 3.7 Problems (from Loehman and Charney, 2011)

Problem	Government Agencies	NGOs
Funding	AZ, MT	AZ, CO, ID, MT, OR, WA
Legal Foundation	AZ(1), ID(1), MT	AZ, ID(1), OR
Lack of Government Commitment	AZ, MT	
Policy Changes	MT	AZ, CO, ID, OR, MT
Lack of Citizen Support	AZ, CO, MT, WA(1)	AZ, CO, ID, OR, MT
Other: Time of adjudication process, reluctance to sell water rights		MT, OR, WA

Notes:
(1) Most pressing problem.

Most interaction between state agencies and NGOs are reported by Loehman and Charney (2011) to occur in terms of identifying priority streams, monitoring stream conditions and education activities, with few cooperative restoration projects. Complementary activities reported include that "NGOs have a comparative advantage in working with local agriculturists to identify lease opportunities and efficiency opportunities, whereas state agencies have an

advantage in monitoring, data collection, research, and planning activities which require some continuity and consistency over time." (Loehman and Charney, 2011)

ISF efforts beyond water trusts also occur at the local level through local chapters of national conservation organizations (e.g., Trout Unlimited and The Nature Conservancy). From Loehman and Charney (2011):

> "Generally, Trout Unlimited (TU) works cooperatively with state policy makers to draft legislation concerning water transactions for instream flows. The Nature Conservancy has purchased lands that are fallowed with conservation easements to limit consumptive use (Buy that Fish a Drink, PERC Reports 25(2), Summer 2007, www.perc.org).
>
> Idaho and Arizona do not have water trusts but instead have active branches of national NGOs. The Idaho Council of Trout Unlimited works to protect important habitat for several native trout and salmon species such as the Yellowstone cutthroat trout of eastern Idaho, bull trout in remote areas of central and northern Idaho, and salmon that spawn in the pristine waters of Idaho before migrating to the Pacific Ocean. It works through eight local chapters and draws on the professional staff funded by the national TU organization. Funds for Idaho projects (Embrace-A-Stream) have also been received from the national organization for use by local chapters. One example is a major urban watershed and fisheries habitat restoration project along the Boise River. Another case is riparian improvements along the Salmon River carried out by TU volunteers, using contributed funds and funding from Idaho Fish and Game department obtained from litigation damages. TU works with Idaho Fish and Game and the US Fish and Wildlife Service on a number of projects to restore salmon and trout (http://idahotrout.org). TU has a Western Water Project that - in addition to Arizona and Idaho - promotes instream flows in California, Colorado, Washington, Montana, Utah, and Wyoming.
>
> In Arizona, The Nature Conservancy (TNC) purchased the historic Shield Ranch in 2010; this is a significant step in the protection of the Verde River, which is adjacent to the property and one of the Southwest's few remaining free-flowing rivers. Partial funding was provided by the Doris Duke Charitable Foundation as part of funding to TNC for five Rocky Mountain states. TNC has worked with partners to conserve nearly 6,000 acres along the Verde's headwaters. Another TNC project works with partners in Mexico to protect the San Pedro River, which flows north from Mexico to the U.S. and is one of the last large undammed rivers in the Southwest. The San Pedro is home to the jaguar and Mexican grey wolf, as well as numerous mammals, reptiles, birds and fish; the endangered Gilachub is found there. Because of increasing development along parts of the river and the aridity of the area, parts of the San Pedro are no longer perennially flowing. TNC has purchased a farm and a cattle ranch along the river, and a 90 percent reduction in agricultural use over the last five years has resulted in restoration of natural flows (www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arizona)."

Loehman and Charney (2011) also compiled a number of critiques regarding voluntary approaches using water leasing, ISF set asides, appropriations of unclaimed waters, and reservations. These were as follows:

> "With appropriation for [ISF] in the form of junior rights (as in Colorado), no streamflow is provided when "senior rights" take precedence in times of drought or storage.

Reservations or minimum streamflow rights work only for areas not fully appropriated.

Basin closure to further withdrawals for basins with full appropriation does not itself provide [ISF]. For closed basins, transfer of use to [ISF] by leasing or purchase may be difficult and expensive.

Minimum flow rights may not protect all desired stream characteristics depending on the definition of "beneficial use," "minimum flow," and available quantification methodologies[1].

In states that permit only a government agency to hold [ISF] rights, there may be reluctance for voluntary transfer or leasing for streamflow purposes.

Urban areas may be amenable to habitat restoration, but because of cost and controversy, main [ISF] protection has been in rural areas. Recreation Rights provide a new mechanism, applied recently for urban areas such as Fort Collins, Colorado.

Resources are inadequate. For example in Colorado, CWCB lacks adequate resources to monitor [ISF] rights. Because there are relatively few stream gauges, [ISF] rights cannot be adequately monitored and enforced in times of drought or shortage."

Establishment of such a program would represent a move toward voluntary management that could be potentially established by the State of Oklahoma, or as part of a public/private partnership. This approach could work within the existing legal and regulatory framework within Oklahoma, and complement a possible form ISF program were such a program established, or function independently.

Voluntary management mechanisms in this context could include:

- Forbearance agreements, dry-year options, water conservation agreements.
- Crop substitution, deficit irrigation, split-season leases, infrastructure construction or reoperation, water efficiency programs.
- Groundwater recharge and storage, use of alternative water sources, and traditional water rights sales and leases.

ATM (Alternative Transfer Method) is an acronym generally used to describe a suite of newer types of approaches to facilitate additional water transfers from agricultural water uses, but in a manner that minimizes local impacts or, in some cases, produces local economic and/or environmental benefits (CWCB, 2012). ATMs typically differ from buy-and-dry approaches in three ways: transfers are temporary, land is not permanently taken out of production, and ownership of the water right (at least in part) is retained by the irrigator (Kenney, 2015).

Participants may include state and local governmental agencies, water users, non-governmental organizations, recreational businesses, and the environmental community.

[1] For example in Colorado, "beneficial use" does not limit [ISF] appropriations to just preserving coldwater fisheries. In fact, there have been a few [ISF] rights decreed for aesthetics, including Deadhorse Creek and Hanging Lake. The problem is how to quantify flow needs: there are no standard, court-approved methodologies for aesthetics as those for quantifying fishery needs.

Advantages and disadvantages to this alternative that were discussed by the stakeholders included:

- Lower risk to existing water users than regulatory options.
- Greater likelihood of adoption.
- Fosters communication and cooperation.
- Provides for future consumptive needs.
- No guarantee of required in-stream flows.
- Requires cooperation of existing and/or future surface water permit holders.
- May require new infrastructure for flow management.
- May require funding sources.

3.2.3 Monitoring and/or Adaptive Management

Although there are numerous formal definitions, adaptive management is commonly viewed as an approach to resource management that attempts to incorporate the views of all stakeholders, accepting that management must proceed even if not all information is presently available, or if all potential impacts are certain. Such an approach can allow for achievement of present objectives, but can also establish a process for developing more information about the system being managed. As more information becomes available, whether through observation of changes in future growth and accordant water use for both consumptive and recreational purposes, or through monitoring of the ecological system, policies adopted at present can be adapted to improve management success and be more responsive to future conditions in the watershed of interest.

In the present context of the Pilot Study, adaptive management necessitates selecting and implementing one or more implementation approaches, then some form of monitoring to determine if adjustments are needed. Such monitoring would necessarily include clear management targets, readily monitored variables linked to the management targets, and a system of data collection and analysis that allows observations to be incorporated into subsequent management decisions. Consideration also needs to be given to:

- What to monitor?
  - New information/data.
  - Development in:
    - Hydroclimatology.
    - Consumptive uses.
    - Water quality.
    - Water quantity.
- Frequency of Review?
  - 5-year.
  - 10-year.
  - Development threshold.
- Who performs the review?
  - State/OWRB.
  - The present voluntary local stakeholder group.
  - Establishment of a perpetual local stakeholder group.

Presented and considered was the establishment of a perpetual, independent, locally driven stakeholder group to continue work towards protecting the ecological, cultural, and economic integrity of the watershed. Such a group could monitor the system, both in terms of growth and ecology, to establish approaches that might benefit the ecology and recreational uses during wetter periods, and develop and implement voluntary plans for management during times of drought.

Some stakeholders expressed interest this approach because of a perceived lack of an imminent need to act, in lieu of present-day shortages. From that perspective, it may be acceptable - if not preferable - to monitor conditions over the coming years and adaptively manage the stream system as time goes on and as the impacts of increasing upstream consumptive uses begin to have a larger impact on stream flows in the basin.

3.2.4 No Action

At present, there is no formal statewide implementation of ISF management. The "No Action" alternative represents continuing with this approach, i.e., the "status quo." Without a consensus recommendation from local stakeholders, ISF management for the region defaults to the present "No Action" alternative.

Several advantages and disadvantages were noted as being associated with the "No Action" alternative:

- No regulatory or stakeholder recommended approach for maintenance of ISF.
- No impacts to future or existing water consumption.
- No monitoring to ensure maintenance of ecology.
- Risk of external implementation of ISF maintenance without opportunity for stakeholder input (e.g., through courts, federal processes).
- Establishes precedent for lack of agreement in the selected pilot-study area that has been viewed as more likely to achieve consensus. If a consensus stakeholder recommendation for a path forward for ISF management could not be developed for a Scenic River watershed with a strong recreational economy, such a precedent may affect broader statewide considerations regarding ISF management.

3.3 Public Workshop

Subsequent to the independent workgroup meetings, a public workshop was then held to bring all the local stakeholders together to identify and recommend a consensus approach for ISF management in the region. Approximately 33 meeting participants (including presenters/ facilitators) attended this public meeting, held at the Armory Municipal Center in Tahlequah on November 15, 2018. The stated objective of this meeting was to discuss the findings of the Pilot Study, share input received from the preceding independent workgroup meetings, and identify and facilitate stakeholder deliberations regarding the potential options for instream flow management in the Upper Illinois River watershed.

In advance of the meeting, OWRB made efforts to encourage balanced participation from representatives of consumptive and non-consumptive users/uses in the watershed. Users from environmental, habitat, aquatic species, recreation, municipal, industrial, and agricultural groups were directly notified and invited in advance of the meeting. Notifications were distributed via a longstanding email list from former meetings and the statewide ISF Advisory Group, as well as a separate email encouraging participants from the workgroups to attend. A press release was also circulated to encourage broad participation in the public meeting.

Despite these efforts, there was minimal attendance at the meeting from consumptive users. From the polling conducted near the meeting outset and from review of the meeting sign-in sheet, meeting attendees predominantly represented nonconsumptive instream flow interests. The input received from this public meeting and the informal polling conducted as part of it should be interpreted as reflective only of the views of the individuals who chose to attend and participate in the meeting. Due to the lack of significant participation from consumptive users at the meeting, the views expressed at the meeting cannot and should not be interpreted as being representative of the broader basin stakeholder needs and interests as a whole.

In general, the audience included a large number of attendees who had not attended the previous ISF public meetings in Tahlequah or the workgroup meetings. This thus necessitated additional discussion of the Pilot Study background and discussion of potential path forward at a higher level, with fewer discussions of detailed options for potential implementation in the watershed. Discussions in breakout groups during the meeting were found to be productive and interactive, and some attendees indicated an interest in having more time to explore and consider the options at hand than the 2-hour meeting schedule allowed.

3.3.1 Discussion Items from Public Meeting

A high-level aggregation of the public comments and questions discussed at the public meeting is presented in Table 3.8. Comments listed in the table reflect input expressed by meeting participants. They are not OWRB policy or representative of any group consensus at the meeting.

Table 3.8 Public Meeting Discussion, Comments, and Questions

No.	Discussion
1	Clarified that analysis included consumptive and non-consumptive needs/shortages.
2	Confirmed period of historical data used for Illinois River Basin as 1949 to 2007.
3	Comment (repeated in various forms) about need for water quality to be included in analysis. Water quantity is only one aspect; water quality is very important in terms of river health and meeting stakeholder needs (including property owners at north end of Tenkiller), and water quality is affected by water flows.
4	Clarified that summer 2018 workgroups targeted 3 to 10 participants to encourage candid feedback from stakeholders.
5	Questioned why homeowners on Lake Tenkiller were not represented in stakeholder meetings. Noted that home owners on small rural water district (RWD) cannot drink water from Illinois River when flow is very low because RWD treatment cannot handle quality. Clarified that the Upper Illinois River was defined as Scenic River reaches upstream of Lake Tenkiller for purposes of the Pilot Study.
6	Questioned what type of reduction would be made for consumptive uses.
7	Questioned (repeated in various forms) about limiting new consumptive users.
a	Discussion about OWRB mandate to issue water right if requestee meets requirements.
b	Discussion about changing legislation to provide OWRB more discretion or requiring OWRB to consider water quality, endangered species/habitats, etc. when issuing water rights.
8	Concern expressed about "non-binding" polls conducted during meeting

No.	Discussion
9	Question regarding what good it does to pick a flow if it can't be enforced? Concern expressed that a minimum flow was picked for the Barren Fork, but it has not been strictly enforced.
10	Concern regarding Illinois River habitat recommendation of 100 to 300 cfs. River flow is currently at 323 cfs. Commenter noted he was looking at riffles and they are low. The Illinois River was lower a few weeks ago. Commenter opinion was that the high ISF level proposed (300 cfs) is too low and he wants to see something higher. There was discussion as to how this low of a level could possibly be "optimum" for habitat.
11	Question as to whether we are measuring the right thing. Is habitat sustainability the right thing to measure? Should we measure water quality, oxbows (flow, count, health) instead?
12	Comment expressed opinion that OWRB should not issue any more permits; doing so affects businesses.
13	Comment expressed opinion that OWRB is issuing permits without science, not just in the Illinois River, but across the state (e.g., Kiamichi Basin).
	a. If there is no science, water right should not be issued.
	b. No consensus, but discussed recommending that use of best science available be used as part of water right consideration.
14	Discussed making future permits conditional on meeting ISF requirements.
15	Question from attendee about who at meeting has read the 2017 OWRB Illinois River ISF Assessment Physical Habitat Simulation report? Only 2-4 hands raised. Commenter opined that only people who had read the report in its entirety should be offering opinions regarding flow goals relative to habitat needs.
16	Numeric standard and adaptive management must go together.
17	Attendee expressed opinion in support of protecting environment when it is at its most stressed (late summer/early fall for the upper Illinois River watershed).
	a. Discussed seasonal limits.
	b. Discussed that other user groups also need water most in August too.
18	Attendee expressed opinion that in twenty years, this will be a different watershed and water situation. Now is the time to act.
19	Attendee expressed opinion that if grandfathering of existing water rights is used, these should only be grandfathered for a certain number of years, or forced to ratchet back use over time. They need to be encouraged to be more efficient with water even if that means switching industries (like agricultural users in Kansas).
20	Attendee expressed opinion that voluntary limits are not the answer - look at Barren Fork.
21	Attendee noted that OWRB is already monitoring. Monitoring and adaptive management are not correctly paired in categories.
22	The attendees expressed more support for a Numeric ISF Standard than they did for a Voluntary Mechanism or Monitoring/Adaptive Management or No Action. With a Numeric ISF Standard, there was interest in:
	a. Seasonal approach to setting limits.
	b. Use of hydrologic data for establishing limits.
23	Collectively, the group did not reach a consensus or agreement on an actual ISF limit or range.

3.3.2 Attendees and Responses to Questions

In addition to the comments and discussion enumerated above, anonymous electronic polling was used at various points throughout the public meeting to readily inform the participating stakeholders on the views held by others attending. The meeting attendees were predominantly residents of the Illinois River basin in Oklahoma. Of 23 people responding, 14 identified themselves as being affiliated with aquatic species/environmental interests, while six were affiliated with recreation (including fishermen), and one self-identified as being affiliated with municipal water supply.

Respondents overwhelmingly indicated that it is very, or extremely, important to always have enough flow to maintain flows for aquatic habitat, moderately important to always have enough flow for recreation, and extremely important to always have enough flow to maintain flows for public water supply. In times of drought, the majority of respondents supported a concept of "shared shortages" between consumptive and non-consumptive water users.

Twice during the public meeting, the attendees were polled regarding which ISF management category they deemed best for the Upper Illinois River watershed. Initially, poll respondents supported both the adoption and implementation of a numeric ISF standard and monitoring through adaptive management. Subsequent to breakout sessions providing the opportunity for more discussion as to the specific components of importance for each category, findings from the second polling were even more supportive of adoption and implementation of a numeric ISF standard, but less supportive for monitoring through adaptive management.

3.3.3 Summary of Feedback on Options for ISF Implementation

In general, the findings from the public meeting regarding the options for ISF implementation were very supportive for the adoption of numeric standard. However, no consensus was achieved as to what the specific ISF amount should be, nor how such a standard might be implemented (e.g., granting of an ISF water right, reservation of ISF, etc.).

Discussions regarding the selection of a specific amount for ISF included questions as to whether the existing science from the technical study was sufficient for decision-making, supposition that higher flows were necessary, and statements that any balancing or negotiation would be of too much risk to the ecological health of the system.

Although maintaining sufficient flows for public water supply was identified as important during the initial polling, subsequent discussions of balancing between consumptive and non-consumptive use were dismissed in favor of discussing means for restricting existing and potential future consumptive use. Input from the meeting's attendees primarily focused upon a desire for the State to limit existing and potential future surface water use to ensure higher flows for the environmental benefit of the watershed.

3.3.4 Limitations of Public Workshop

As noted at the outset of this section, attendees at the public workshop primarily represented environmental and recreational interests. Although directly offered the opportunity to participate, very few representatives of consumptive water users in the watershed chose to attend the public workshop. The results of the workshop, as indicated above, were thus biased towards the interests of those who voluntarily attended, meaning that the public workshop did

not and could not produce a consensus recommendation representing the full breadth of stakeholder interests in the entire community.

Although this may be perceived as a failure in the context of developing a consensus recommendation, it does offer a key observation warranting consideration as to the *process* by which ISF management might be developed at the broader state level. Specifically, without an external force (such as federal requirements through the Endangered Species Act, or by court action), nor with a state-driven mandate requiring participation in an ISF process, from the perspective of consumptive users it is likely perceived as more beneficial to simply not participate in such a process, as:

- Any limitation on existing or future water use could be seen as detrimental from a water supply perspective.
- The present status quo is no limitation on water supply beyond what is legally and physically available to the watershed.

It is observed that in this context, the mandate establishing stakeholder participation can be seen as a must for successful development of a consensus-based stakeholder process. A mandate does not need to require ISF implementation; it could simply require that the stakeholders come together to form a consensus on ISF action/inaction. This consideration thus informs the following discussion on the findings regarding the ISF Pilot Study process presented in Chapter 4.

Chapter 4

LOOKING FORWARD

The Pilot Study has provided insights into a potential process for the technical identification of localized ecological flow ranges, comparing those flow ranges to future conditions in a watershed, and establishing a locally-driven dialogue among basin stakeholders to assess whether and how to implement ISF planning, management, and awareness. Here, lessons learned from the Pilot Study may be characterized in terms of both successes and limitations, and attention given to what options may be viable for moving forward with potential implementation of ISF protection activities more broadly in Oklahoma.

4.1 Pilot Study Synopsis

The Pilot Study was designed to put several years of abstract discussion regarding the management of instream flows into physical and numeric context. Facilitated by the OWRB, the ISF Advisory Group has led the dialogue of ISF and non-consumptive water needs across Oklahoma following the 2012 OCWP Update. Through the course of those discussions, it became clear to many that hypothetical scenarios - and in some cases conflicting predictions about whether the state's rivers and streams would have sufficient flow to support non-consumptive uses - could not be resolved in the abstract. This gave increased significance to the value of conducting a pilot study.

Conducted in one of Oklahoma's designated Scenic River basins, the setting for the pilot was unique in some ways and yet quite representative in others. It was unique in that it was conducted in one of the state's very few Scenic River basins, and in a basin that some perceive as being water-rich with a strong recreational water industry and lower population density than many other areas of the state. But it is representative in that the Pilot Study forecasted that seasonal and long-term droughts will impact the ability to meet all desired uses in the future.

At its outset, some questioned whether a Scenic River setting in northeast Oklahoma - perceived to be relatively wet compared to many parts of the state, and with relatively low consumptive demands - would ever run short of water. Questions arose, such as, "Could the Upper Illinois River ever show a shortage? Is this the right basin to test an ISF process, or will there always be plenty of water?"

As demonstrated in Chapter 2, the projections to 2060 did uncover numerous scenarios in the Upper Illinois River, Flint Creek, and Barren Fork Creek basins where there is projected to be insufficient flow to meet consumptive and non-consumptive uses in the future. This highlighted the future impacts to non-consumptive uses under status quo practices, and provided a baseline condition for comparison of alternative ISF management scenarios in the stakeholder and public workshops.

Others questioned the transferability of the results. With the pilot study watershed so different than, say, an intermittent stream in western Oklahoma, could the process possibly be used in both places?

It is critical to distinguish that the intent of the Pilot Study was to evaluate a process that could potentially be replicated in other basins - not the results of the pilot. The Pilot Study employed the IFIM method to assess the habitat suitability relative to flows specific to the stream channel dimensions and the species that are unique to each basin studied. A different stream channel system - with different habitat dynamics, geomorphologic characteristics, hydraulics, hydroclimatology, differing native species, and different recreational values - would have entirely different ecological flow targets. Equally importantly, the basin stakeholder dialogue that is supported by the ecological flow targets is necessarily unique to the specific basin, and inherently reflective of the values and priorities of members of the local basin community.

The Pilot Study was successful in its goals of quantifying the potential for shortages in the ability to meet future consumptive and non-consumptive flow needs. That said, certain consumptive and non-consumptive stakeholder user groups were more difficult to engage than anticipated. For example, municipal (public water supply) and recreational users' participation was limited in the dialogue, and as such, those groups' input may not be thoroughly reflected in this report.

Using data and future supply/streamflow scenarios was useful in supporting stakeholder dialogue. However, the position voiced by several stakeholders - both consumptive and non-consumptive users - was that other stakeholders would need to yield in times of drought. A limited number of non-consumptive interests expressed interest in developing a compromise approach, noting that at present there was no implementation of ISF management in the watershed. Consumptive users noted the importance of maintaining the ecology of the watershed, but appeared reticent to make any decision that could result in an impact to water supply during drought conditions. Some stakeholders suggested that the projected shortages would simply need to be avoided, but did not offer practical solutions to accomplish such a goal.

The stakeholder process culminated in a basin-wide workshop, which was intended to provide a forum for these types of conflicting viewpoints to be resolved through facilitated discussion. Despite significant outreach efforts, however, attendance at the workshop did not include balanced representation from a diverse set of viewpoints. Workshop attendees offered input and a general preference toward implementation of a numeric ISF standard, as detailed in Chapter 3.

Limitations in the Pilot Study and their possible resolution are summarized in Table 4.1. The Pilot Study process could be utilized in other basins in Oklahoma, as further described in the subsections that follow. Broader implementation of the process would be potentially enhanced by the lessons learned from the Pilot Study.

Table 4.1 Limitations in Pilot Study Conclusions and Potential Resolution

Limitation	Attribute	Potential Resolution
Final workshop input did not include diverse representation from basin interest groups	Primarily Aquatic Species/Environmental stakeholder interest group	Confirm attendance from all stakeholder interest groups in advance; form a more formal Basin Stakeholder Committee
No formal recommendation from local stakeholders on preferred path forward	No one in the basin charged with specific duty/ responsibility to develop consensus	Form a formal Basin Stakeholder Committee and charge them with this responsibility
Lack of stakeholder familiarity with State OCWP demand projections and methods	Significant time devoted to addressing stakeholder concerns regarding projections, when focus should have been more upon balancing needs	In development of next OCWP update, inform stakeholders about opportunities to learn about the development of water demand projections
Lack of technical information regarding potential socioeconomic impacts of shortages	Analyses within pilot study utilized readily available hydrologic and demand data, allowing for assessments of impact on water quantity, but did not quantify the potential economic impacts from water shortages, which could more inform stakeholders when attempting to balance competing water needs during drought conditions	Incorporate time and budget for a socioeconomic impact analysis of the potential impacts of shortages for comparisons between identified ISF scenarios
Lack of technical information regarding water quality impacts from shortages	Weighted habitat suitability curves for select organism assemblages offer one aspect, but other parameters (e.g., water quality) were identified by stakeholders as equally important	Incorporate time and budget for water quality modeling and analysis of the potential impacts of shortages for comparisons between identified ISF scenarios

Although a grass-roots, locally-supported decision was sought, no local entity or group was charged with the responsibility of finding consensus. This ultimately led to no firm recommendation regarding whether or how to manage ISF in the watersheds of interest in the Pilot Study. Had a local committee been appointed and charged with this responsibility, a stronger local recommendation may have resulted. In lieu of designation of this responsibility to local stakeholders in the Upper Illinois River Pilot Study, opinions were shared but no clear recommendations were offered by the basin stakeholders when difficult decisions and tradeoffs between ISF management options to balance competing needs for projected limited water resources had to be made. If the ISF process were to be continued or expanded, consideration should be given to assigning formal responsibility to a local Basin Stakeholder Committee or similar entity, with representation from diverse interests, to develop a recommendation on ISF management in the basin.

Other limitations observed from the Pilot Study offer insights where additional analysis and outreach may allow the process to be more efficient, as well as allow for anticipation of important information necessary for stakeholders to make informed decisions. Given the utility of projections on future water demand, and the availability of such projections from the broader OCWP process, it would be beneficial to any future stakeholder-driven ISF process to start out with a better understanding of the technical underpinnings of the OCWP's future water demand projections. This could be accomplished by simply making stakeholder participants in the ISF process more aware of opportunities to hear and/or learn about the development of these projections over the course of the development of the OCWP, with emphasis placed early in an ISF process as to why such projections play an important role in the potential balancing of competing needs within the ISF process.

At a technical level, a number of stakeholders expressed concerns regarding the extent of the characterization of potential impacts to their interest. Consumptive users expressed a desire for more information regarding economic impacts if water supply was not met, while non-consumptive use interests expressed a desire for more science regarding potential impacts of lower flows on water quality. Analyses addressing such concerns would likely provide information - beyond the characterization of impacts to water quantity - useful for stakeholder deliberations when attempting to manage balancing competing needs during times where water resources may be limited, such as drought.

4.2 Core Elements of ISF Program

With the pilot study complete, the focus shifts to building on lessons learned and considering specific foundational elements required to develop an ISF process, considering the spectrum of voluntary, incentive-based approaches to regulatory approaches. Core elements of any ISF program should include:

- Stream Basin Selection and Prioritization — adopting a method for selecting or prioritizing basins for consideration for study or ISF process development.
- Study Criteria and Assessment Methodologies — ensuring consistency in the derivation and application of scientifically-based methods for quantifying ecological flows, flow ranges, or flow regimes for a watershed(s).
- Basin Stakeholder Involvement and Structure— establishing a basin stakeholder structure for including local values and needs, directing consensus-based recommendations from basin stakeholders; and
- Administrative Approaches — range of options for consideration for implementing, monitoring, and administering ISFs.

These core elements should, in general, be consistently administered across basins, recognizing that processes can be similar even though identified flow range(s) and resultant ISF implementation can vary widely from basin to basin due to their wide-ranging hydrologic and ecologic diversity. Various options for approaches are discussed in the following sections, informed by lessons from the pilot study and elements of ISF approaches in other states.

4.2.1 Stream Basin Selection and Prioritization

ISF management considerations are driven, in large part, by local values and needs. Inherently, some basins will have more local support for studying and/or implementing ISF protections than others. This may reflect the degree to which streamflow is a foundation of the local economy

and society, through tourism, recreation, tribal and cultural values, or other drivers, versus where consumptive uses of water are predominant drivers or natural streamflow is intermittent or ephemeral, for example. Table 4.2 outlines a number of potential methods for prioritizing or selecting basins for ISF analysis and potential implementation.

Another ISF management consideration is the extent of the basin and proximity to stream gages. Clearly, measurement of stream flows is critical to the ability to establish and monitor an ISF target in a given stream segment. Because the 2012 Update of the OCWP is based on 82 planning basins, most of which include a USGS stream gage at or near the basin outlet, it is recommended that any ISF analyses be developed at the same basin scale. Sub-basins could be defined within those basins if desired by local stakeholders.

Table 4.2 Potential Approaches for Prioritizing or Selecting Basins for ISF Analysis

Approach	Description	Considerations
Self-Nomination	Local stakeholder groups petition the state for ISF analysis based on perceived need for protections in the basin.	Bottom-up, locally-driven process that can assess ecological/recreational needs. May not prioritize stream systems with greatest ISF need across state Could lead to high backlog of basins for analysis. Still requires some means of prioritizing basis that are self-nominated, e.g., first in time, population, economic factors.
Permits-based Analysis	Prioritize basins based on percent of surface water allocated or excess and surplus water, starting with over-allocated basins.	Prioritizes based on consumptive use analysis. Based on permitted amount but may not reflect actual consumption. Effectiveness of ISF process may be limited if basin is already over-allocated.
East to West	Given hydroclimatology of the State, prioritize eastern basins where unappropriated water remains available.	Prioritizes basins with historically greater amounts of streamflow. Presumes ISF process would, at a minimum, be more effective in areas where flows have not already been legally allocated. Could consider biological "hot spots" whereby updated projections of population and demand could be matched with existing state biological surveys to determine target locations. ISF may be more limiting to future water management strategies, as future plans focus more upon higher reliability of available future sources in historically wetter regions.

Approach	Description	Considerations
Ecoregion	Stream groupings established by OSU and USGS effort (Turton et. al. 2008) based on ecoregions with like characteristics of climate, geology, soils, and vegetation.	Based on groupings potentially helpful for developing environmental flow quantifications that are stream and organism specific. Information available on components of the natural flow regime From application of the Hydroecological Integrity Assessment Process (HIP). May not reflect other factors of importance to local and state interests.
Rivers with Special Designation	Initiate analyses on designated Scenic Rivers; expand from there.	Established authority and protocol. May not reflect the state's most critical needs for ISF protection.
Legislatively Driven	Prioritize basins based on legislative mandate.	Prioritizes based on direction from legislature, representing public will. Leverages legislative process to determine salient factors for basin prioritization. May be driven by factors other than ecological/recreational need.

4.2.2 Study Criteria and Assessment Methodologies

The Pilot Study was based on the IFIM process, which includes the use of Physical Habitat Simulation System (PHABSIM) modeling to establish relationships between streamflow and habitat quality. IFIM/PHABSIM is recognized in the ISF community as being a thorough approach for developing streamflow recommendations, yet the approach is costly and time-consuming. Other states have adopted alternative, and in some cases more simplified, methods as a tradeoff between accuracy, update frequency, and cost.

Input received from some members of the Technical Study Work Group in the previous phase of the Pilot Study suggested reconsideration of the IFIM method for use in other basins. Because of the rigor and cost associated with IFIM and PHABSIM modeling, additional consideration is warranted before selection of this method as the standard approach. In any case, it is important that widely-accepted, technically defensible scientific methods be used to establish ISF flow targets, and that the methods and results be vetted by OWRB before the results are formally incorporated into an ISF process for a given basin. Additional evaluation of candidate methods for establishing ISF flows, ranges, or regimes should be undertaken, to establish the method or methods that would be acceptable to OWRB when utilized by any local ISF process.

The broader evolution of ISF programs, both nationally and internationally, has occurred concurrently with the evolution of the science used to assess and quantify ISF needs, which often varies depending on regional/local objectives and the extent and type of competing uses in a given watershed. The establishment of a technically defensible methodology for quantifying ISFs needed to protect the environment is important because:

- It is necessary to specify the amount of water needed for protection, whether as an explicit ISF right, a minimum flow requirement, a voluntary goal, or as a condition within a permit.

- Decision makers and stakeholders need reliable information to appropriately balance the array of competing uses for a given stream.
- If contested in court, it is necessary to be able to defend the ISF with a scientifically repeatable approach.

Of key importance to a path forward for Oklahoma is that technical studies be developed and performed in a manner that is consistent and technically defensible, while accommodating the necessary flexibility to scientifically address varying conditions basin to basin. Consideration of a number of various scientific approaches deemed by states to be technical defensible is provided here, for additional context regarding how ISF are maintained/protected from state to state.

The IFC has recognized and evaluated over 30 different documented methods used throughout the U.S., ranging from low effort (e.g., desktop) to high effort (e.g., fieldwork and modeling) (Instream Flows Council, 2002). Annear et al. (2004) categorizes ISF methods into three general types: 1) Standard setting, 2) Incremental, and 3) Monitoring/diagnostic. Standard setting usually employs a desktop approach that generally sets limits below which water cannot be diverted (Stalnaker et al. 1995). Incremental methods are much more time and labor intensive, whereby ecological/habitat responses are analyzed and compared under alternative flow scenarios (Stalnaker et al. 1995; Annear et al. 2004). Monitoring/diagnostic methods stress the importance of adaptive management, whereby river conditions over time are assessed with respect to flow regimes and associated ecological responses. Various ISF methods can also be characterized by the specific ecological component under analysis, e.g., hydrology, biology, geomorphology, water quality, and/or connectivity (floodplain and/or oxbow inundation).

The method(s) used for evaluating ISFs is often related to the level of risk to fish and wildlife resources, available expertise, funding resources, the nature of the particular system under consideration, and the necessary complexity of the issues related to the water resource. Ordinarily, desktop-level approaches are used for situations with low-risk and minimal complexity. Whereas, more complex scenarios typically necessitate the use of incremental or comprehensive methods.

4.2.2.1 Desktop Methods

Empirical desktop methods are generally based upon the most readily available information, which in most cases is historical hydrologic data. Such methods typically establish minimum flows for protecting ISFs, although in some instances more sophisticated flow regimes have been statistically derived. Often, minimum flows are based on a selected percentage of a statistic (e.g., 50 percent of average monthly flow) or a percentile from a flow-frequency curve (e.g., 10th percentile). The Tennant (Montana) Method was historically used by a large number of western states, using percentages of average annual flow to describe the suitability of seasonal ISF conditions for aquatic life and habitat, e.g., for summer conditions 10 percent average annual flow (AAF) equals a poor habitat; 50 percent AAF equals an excellent habitat. Texas historically employed the Lyons Method, which is a derivation of the Tennant Method that focused on selected monthly statistics[1]. Although the Tennant Method does not provide specific information on the effects of altered flows on fish habitat, it has the advantage of requiring no field studies, and thus allows recommendations to be made early in the planning process (Orth and Maughan, 1982).

[1] Texas has more recently moved away from the Lyons Method, focusing upon more sophisticated characterizations of the broader flow regime (i.e., subsistence, base flow, and pulse flows).

Other similar desktop methods include Aquatic Base Flow (employed in New England, based on median August flow) (Lang, 2002), percentage daily withdrawal limitations (European Union, Southwest Florida Management District), wetted perimeter (Michigan and Montana, Leathe and Nelson, 1986), R2CROSS (a one-dimensional model to quantify streamflow to maintain hydraulic parameters used in Colorado and Wyoming, Espegren, 1996). Many states employ standards for maintaining water quality (e.g., 7-day, 2-year low flow, i.e., 7Q2; or 7-day, 10-year low flow, i.e., 7Q10). Ranges of variability analyses (RVAs) have also been commonly employed, which defines target stream flows as measured by the interquartile range for each of 33 statistical indicators of hydrologic alteration (IHA) parameters. Half of these statistics measure the central tendency of the magnitude or rate of change of flow conditions, and half focus on the magnitude, duration, timing, and frequency of extreme events (Parker and Armstrong, 2001).

4.2.2.2 Incremental and Comprehensive Methods

Incremental and comprehensive methods necessitate more rigorous data sampling and collection, site-specific studies, and modeling to evaluate and quantify more complex flow regimes and their relation to multiple factors. Several methodologies have been developed to relate the amount or quality of usable habitat to discharge, differing in the specificity with which they define habitat needs of fishes, the manner in which habitat is measured, and the prediction method used for quantifying habitat conditions at different flow levels (Orth and Maughan, 1982). One of the more common comprehensive methodologies employed in the U.S. and globally is the IFIM. From TXEFSAC (2004):

> "This methodology, developed in the mid-1970s in the United States… uses a set of analytical and modeling tools to address habitat, water quality, sediment transport, and hydrology. Within the IFIM, physical habitat types are described using transects set across stream channels, and corresponding measurements are made of velocity, depth, substrate, and vegetative cover. Data are entered into a spatially one- or two-dimensional hydraulic model to simulate depth-flow relationships, and with data describing how habitat is used by fish and other organisms (i.e., habitat suitability criteria), estimates of how much suitable and unsuitable habitat is available at different flow levels are predicted."

IFIM has been characterized as a multifaceted decision support system for evaluating riverine ecology for water management. Within the suite of IFIM modeling approaches, a number of habitat selection model (HSM) applications have been developed. Most noteworthy is the PHABSIM, whereby a hydraulic simulation is performed to calculate riverine surface area suitable (or unsuitable) for life stages by way of changes in depth and velocity. The simulation characterizes, by life stage, habitat classes of varying quality.

Other comprehensive instream flow methods for rivers and streams include (TXEFSAC, 2004):

> "MESOHABSIM (northeast United States), RHY-HABSIM (New Zealand), CASI-MIR (Europe), Building Block Method (South Africa), the Holistic Approach (Australia), the Range of Variability Approach (U.S. States, Canada, and South Africa), and the Riverine Community Habitat Assessment and Restoration Concept (United States), and Ecological Limit of Hydrologic Alteration (ELOHA, Poff et al., 2009)."

A consistent trend in adopting ISFs has been the recognition that as the science evolves, management practices can be revised. It is also necessary to acknowledge changing management needs in response to variable hydrologic and climatic conditions. This has led to

the concept of "Adaptive Management," a framework including monitoring, governance, and funding mechanisms (Richter et al., 2003).

4.2.3 Basin Stakeholder Involvement and Structure

If support is to be given toward a locally backed ISF process, consideration should then be given to formation of a Basin Stakeholder Committee (BSC) in each basin for which ISF analysis and/or implementation is to be conducted. The Pilot Study lacked such a group, and in turn, did not result in a firm local stakeholder consensus about the basin's preferred path forward.

A BSC could be delegated with the responsibility of overseeing the analysis of ISF goal setting, and ultimately making a consensus-based recommendation to OWRB regarding the preferred path forward, choosing from the four key strategies outlined in Chapter 3 and recommending the details of the preferred strategy:

- Adoption/Implementation of a Numeric Standard.
- Voluntary Mechanisms.
- Monitoring and/or Adaptive Management.
- No Action.

The BSC could oversee the basic phases of ISF planning, including:

- Issue planning.
- Study planning.
- Study implementation.
- Alternatives analysis (deliberating between and selecting among the four strategies noted above).
- Development of findings and recommendations.

Using a consensus-based process for the BSC's decision-making, the BSC would then submit its recommendations to the OWRB for review and consideration for adoption. OWRB would need to implement new procedures for this process, similar to other applications with the ability for opposing viewpoints to voice concerns at OWRB Board meetings.

BSC membership should include diverse interests from consumptive and non-consumptive water uses in the basin. Appointments to the BSC could be made by OWRB or by other independent means that provides for broad representation of local stakeholder interests. Interests could include, but not be limited to, the following if they have a presence in a particular river basin:

- Agricultural.
- Commercial fishing.
- Cultural and tribal interests.
- Environmental interests.
- Industrial water users.
- Municipalities.
- Power generation.
- Public interest groups.
- Recreational.
- River authorities/water districts.

4.2.4 Administrative Approaches

As described in the previous subsections herein, core elements of an ISF process would include considerations relating to prioritization of which basins to study, development of technically defensible science to identify flows necessary for maintaining a watershed's ecological environment, and establishing a local stakeholder group. These steps, some of which could occur sequentially or in parallel, support a bottom-up approach to establishing ISF management. Just as important is the administration of ISF management, to ensure a level of consistency within the process.

Administration of ISFs, if established, could potentially be conducted at either the state or local level. Most states administer ISFs at the state level, just as water rights or permits are administered by a state agency. Administration of the ISF system would also depend significantly on the type of ISF system implemented in a given basin. For example, a numeric standard with enforceable limits would require direct monitoring and enforcement - possibly by OWRB - whereas an adaptive management approach could be as simple as a voluntary local task force monitoring stream flows at some selected frequency and comparing them to long-term historical ranges or other available information. Alternatively, establishment of a water bank or trust might be more readily implementable at the broader state level.

An ISF program's responsibilities may include (SARP, 2018):

- Developing rules and regulations to administer state laws for instream flow protection.
- Selecting appropriate methods to determine instream flow criteria.
- Obtaining and evaluating information on instream flow requirements.
- Setting instream flow criteria.
- Assisting planning agencies with incorporation of instream flow criteria into water management plans.
- Using water allocation guidelines or limits from water management plans to inform permitting decisions.
- Issuing water use permits.
- Enforcing permit instream flow limits.
- Monitoring and evaluating the program effectiveness.
- Managing adaptive management issues.
- Advising on development of water conservation, drought, and other water management plans.
- Informing the public and building awareness about instream flow issues.

A range of administrative approaches will likely be needed to respond to the range of ISF approaches that would result from implementation of a locally backed ISF program. It is important to note, however, that while the process is locally backed, the overall implementation, administration, and potential regulation of ISF is managed at the state level. Such a process necessitates support within the legal and regulatory framework of the state in order to ensure a consistent, technically defensible process is established, maintained, and supported by the people of the state.

4.2.4.1 Examples of ISF Management in Other States

The remainder of this subsection is devoted to characterizing the broad palette of management approaches and mechanisms potentially available to the State, as characterized by actions other states have taken in regard to ISF management. There is a vast array of technical literature

regarding various ISF management approaches throughout the U.S., including previous summary documents developed for OWRB (see CDM 2009). The summary below relies upon and adapts information originally presented by Charney et. al. (2005), which characterizes programs and accomplishments for a number of western states as they relate to ISF protection and management. This document, as referenced herein (and updated where noted) along with other supporting source material provides a good characterization of the myriad administrative mechanisms by which ISF can potentially be managed. Ultimately the selection of administrative mechanisms that align with both State and regional objectives and the legal and regulatory framework in which such objectives may be achieved will be essential.

A fundamental component of ISF programs is the legal capability of the state to reserve water in a stream or lake (i.e., what could be considered a non-consumptive use) for environmental purposes. This is sometimes referred to as legally designating instream flow protection as a "beneficial use" similar to municipal, domestic, industrial, agricultural, and other human uses. Table 4.3 presents which states legally recognize some form of instream flows, while Table 4.4 summarizes the extent of ISF in states.

Table 4.3 Legal Recognition of Instream Flows (updated from Charney et al., 2005)

State	ISF Legally Recognized as a Beneficial Use	Special Status Exists for ISF Water Rights
Alaska	Yes	Yes
Arizona	Yes	Yes
California	Yes	Yes
Colorado	Yes	Yes
Idaho	Yes	Yes
Kansas	Yes	Yes
Montana	Yes	Yes
Nebraska	Yes	Yes
Nevada	Yes	No
New Mexico	No	No
North Dakota	No	No
Oklahoma	No	No
Oregon	Yes	Yes
South Dakota	Yes	No
Texas(1)	Yes	Yes
Utah	Yes	Yes
Washington	Yes	Yes
Wyoming	Yes	Yes

Notes:

(1) In 2007, the Texas Legislature passed Senate Bill 3, establishing a process for adopting rules related to environmental flows (both instream and freshwater inflows for estuaries). The state does not grant permits for environmental flows. It instead sets instream and freshwater inflow standards across priority basins. Future permits for water use in these areas are conditioned by the amount of water needed instream and for freshwater inflows.

Table 4.4 Summary of Extent of ISF in States (from www.freshwaterinflow.org)

	States	Number
States with no instream flow laws or statutes, and do not require a permit for water allocation	AL, AR, IL, IN, KY, LA, MI, MS, NV, NM, OH, PA, RI, SC, SD, TN, WV	17
States with some instream flow requirements, e.g., water permits	AZ, CO, CT, DE, FL, GA, IA, KA, ME, MD, MA, MN, MT, NE, NH, NJ, NY, NC, ND, OK, OR, UT, VA, WA, WI, WY	26
States with specific instream flow statutes	AK, CA, HA, TX	4

States' water management typically utilize two mechanisms for ISF protection: 1) ISF permits, and/or 2) ISF permit conditions. Many states allow ISFs to be secured either as a new appropriation or as a transfer of an existing water right to an ISF of some form. Some states are more restrictive and only allow transfers of existing water rights. California, New Mexico, Texas, and Utah allow transfers, but do not allow new appropriations (Charney et al. 2005). Table 4.5 summarizes the extents of how various states allow for granting of ISF water rights, while Table 4.6 provides a tabulation of the number of states employing various approaches.

Table 4.5 Types of Instream Flow Water Rights (adapted from Charney et al., 2005)

State	New Appropriation of ISF Water Right Allowed	Transfers or Conversions to ISF Water Rights Allowed	Review Required
Alaska	Yes	Yes(1)	Yes, 10 years
Arizona	Yes	Yes	No
California	No	Yes	Yes (frequency unknown)
Colorado	Yes	Yes	No
Idaho	Yes	Yes(2)	No
Kansas	Yes	Yes(3)	No
Montana	Yes	Yes	Yes, 10 years
Nebraska	Yes	Yes(4)	Yes, 15 years
Nevada	Yes	Yes	No
New Mexico	No	Yes	n/a
North Dakota	No	No	n/a
Oklahoma	No	No	n/a
Oregon	Yes	Yes	No
South Dakota	Yes	Yes	No
Texas	No(1)	Yes	Yes, 5 - 10 years
Utah	No	Yes	No
Washington	Yes	Yes	No
Wyoming	Yes	Yes	No

Notes:

(1) Current law does not prohibit transfers to instream flow reservations.

(2) The legal mechanisms for permanent donation to a minimum streamflow have not been developed and no such transactions have taken place. Short-term leases have been authorized through the Idaho Natural Flow Water Bank.

(3) The State has the authority to purchase water rights in over-appropriated areas and retire those rights to the stream, barring that water from future appropriation for out-of-stream purposes. However, it is not converted into an instream flow right or "minimum desirable streamflow."

(4) Texas sets environmental flows across priority basins; however, the state does not grant permits for instream flow use. The levels set have been used to condition what can be diverted out-of-stream under permits junior in priority to the date environmental flow standards were established.

Table 4.6 Summary of New Appropriations and Transfers (from Charney et al., 2005)

	New Appropriation of ISF Water Rights		Transfers or Conversions of ISF Water Rights	
	Yes	**No**	**Yes**	**No**
Number of States	12	6	16	2

Some states have requirements for periodic reviews of ISF rights. As noted in Table 4.5, Alaska, California, Montana, and Nebraska have such requirements, although for Montana and Nebraska, a review is not required for transferred ISF rights. Further, California reviews all rights, not just ISF rights. A summary of review requirements is presented in Table 4.7.

Table 4.7 Summary of Review Requirements (from Charney et al., 2005)

	Review Required	No Review Required
Number of States	4	11

Also noteworthy is specifically which persons (or entities) are allowed to secure ISFs, and the process by which it is allowed. From Charney et al. 2005:

> "Most states require a governmental agency to acquire and hold an instream flow water right. Alaska, Arizona and Nevada are the only states that allow any person, organization or agency to hold an instream flow. These three states and Montana and South Dakota allow federal agencies to hold state instream flow water rights. Nebraska and Oregon allow multiple state agencies to hold an instream flow water right. All other states either do not grant any instream flow water rights or allow only one state agency to hold those rights. In Kansas and Idaho, the legislature must approve instream flow water rights that are then administered by the state's division or department of water resources..."
>
> "Little difference exists among the Western states on who proposes and reviews instream flow recommendations. In most states, any person can suggest or recommend a stream for protection. Typically though, recommendations come from a state's wildlife agency or, in some instances, from federal agencies. One consistency among all states is that the wildlife agency is authorized to provide comment and input."

Tables 4.8 and 4.9 list the agencies or entities that can hold an ISF water right, either through new appropriation or transfer of existing rights. Tables 4.10 and 4.11 list the agencies and entities that participate in administration, recommendation or review of instream flows, and which agency or agencies grant and administer the ISFs.

Table 4.8 Participation in ISF Water Rights Appropriations or Transfers (adapted from Charney et al., 2005)

State	Who Can Appropriate ISF Water Rights	Who Can Transfer Existing Water Rights to ISF
Alaska	Any local, state or federal government agency and any private person or organization	Not allowed
Arizona	Any person, the state of Arizona or a political subdivisions thereof (including, but not limited, to counties, incorporated cities, towns, and irrigation, power, electrical, agricultural improvement, drainage, and flood control districts)	The state and political subdivisions of the state (private individuals can retain the right but lose the original priority date)
California	Not allowed	Any water right holder can transfer a right to ISF purposes if established criteria are met
Colorado	Colorado Water Conservation Board (CWCB)	Government entities or organizations, can transfer rights to the CWCB for conversion to ISF
Idaho	Idaho Department of Water Resources (IDWR)	The U.S. Bureau of Reclamation can lease water from Idaho's water bank for use in the Snake River system.[1]
Kansas	Legislature	The state (through the Division of Water Resources)
Montana	Federal and state agencies and any political subdivision of the state	Any public or private entity can lease for ISF purposes
Nebraska	Natural Resource Districts (NRD) and Nebraska Game and Parks Commission (GPC)	Any water right holder can lease to the GPC Commission or NRDs for up to 30 years at a time
Nevada	Any "person" including individuals, organizations, corporations, government agencies, etc.	Same as appropriations
New Mexico	Not allowed	Same as other water right transfers
North Dakota	Not allowed	Not allowed
Oklahoma	Not allowed	Not allowed
Oregon	Department of Fish and Wildlife, Department of Environmental Quality, State Parks and Recreation Department can apply for new water rights, then held in trust by the Water Resources Department	Any entity can purchase, lease, or receive ISF as a gift but converted ISF use must be held in trust by the Water Resources Department
South Dakota	Not explicitly determined. So far, Division of Wildlife, Game, Fish and Parks, private organization and U.S. Fish and Wildlife Service granted permits or transfers of use.	Not explicitly determined. So far, Division of Wildlife, Game, Fish and Parks, private organization and U.S. Fish and Wildlife Service granted permits or transfers of use.

State	Who Can Appropriate ISF Water Rights	Who Can Transfer Existing Water Rights to ISF
Texas	Not allowed (desired ISF established through standards)	Any individual or entity with an existing water right can transfer to ISF. Rights can be donated to Texas Water Trust of the Texas Water Development Board in perpetuity or for a given number of years.
Utah	Not allowed	Division of Wildlife Resources (DWR) and Division of Parks and Recreation (DPR)
Washington	Department of Ecology	Individuals can donate rights, which are then held by the Department of Ecology
Wyoming	State of Wyoming (initiated by the Game and Fish Department; Water Development Commission applies to the State Engineer's Office)	Anyone can give as a gift or voluntary transfer to the state (Game & Fish Department acts as petitioner, administered by the State Engineer and the Board of Control)

Notes:
(1) Idaho's Water Supply Bank is intended to transfer water from willing lessor to willing lessee.

Table 4.9 Summary of Participation in Appropriations and Transfers (from Charney et al., 2005)

	No One	Legislature	1 State Agency	>1 State Agency	State & Federal Agencies	Anyone
Appropriations	CA, ND, NM, OK, TX, UT	KS, ID	CO, WA, WY	NE, OR	MT, SD	AK, AZ, NV
Transfers	AK, ID, NM, OK	--	CO, KS, OR, WA	UT, WY	SD, NM	AZ, CA, MT, NE, NV, TX

Table 4.10 Participation in ISF Administration (adapted from Charney et al., 2005)

State	Who Proposes, Reviews, or Provides Other Official Input	Who Authorizes and Administers the ISF Water Right
Alaska	Alaska Department of Fish & Game's Statewide Aquatic Resources Coordination Unit, Federal Agencies, Private Individuals and Organizations	Division of Mining, Land and Water (Department of Natural Resources)
Arizona	Any entity can propose. Arizona Department of Water Resources (ADWR) reviews applications. Arizona Game and Fish Department is asked to comment as well.	ADWR (note that ADWR does not have enforcement authority. County attorney and sheriff are authorized to enforce surface water rights).
California	Department of Fish and Game (transfers only)	State Water Resources Control Board
Colorado	Division of Wildlife, Division of Parks and Outdoor Recreation, Division of Water Resources, U.S. Department of Agriculture, U.S. Department of the Interior make ISF recommendations to the CWCB. Any entity may recommend streams to the CWCB.	Appropriated, monitored, and protected by the CWCB, Water Court adjudicates all water rights and the Division of Water Resources administers all water rights.
Idaho	Anyone may petition IDWR Board, review and comment provided by Departments of Fish and Game, Parks and Recreation, Environmental Quality	Legislature must approve rights either explicitly or by not rejecting them in a given legislative year. Idaho Department of Water Resources (IDWR) and its Board administer ISF rights
Kansas	Kansas Water Office (KWO) currently monitors[(1)]	Legislature authorizes, Division of Water Resources (DWR) administers flow
Montana	Federal, and state agencies and political subdivisions of the state may reserve ISF	Department of Natural Resources and Conservation (DNRC) processes, issues and administers ISF reservations
Nebraska	NRDs and Nebraska Game and Parks Commission (GPC), Department of Natural Resources, Water Division	Department of Natural Resources, Water Division
Nevada	Any entity may appropriate water for instream flow purposes	Division of Water Resources
New Mexico	Unknown (transfers only)	Office of the State Engineer administers water rights
North Dakota	Not applicable	Not applicable (State Engineer administers other water rights)
Oklahoma	Not applicable	Not applicable (OWRB main agency facilitating Oklahoma water rights)
Oregon	The Department of Fish and Wildlife, the Department of Environmental Quality and the State Parks and Recreation Department provide input.	Water Resources Department

State	Who Proposes, Reviews, or Provides Other Official Input	Who Authorizes and Administers the ISF Water Right
South Dakota	Anyone may recommend, Department of Game, Fish and Parks most involved	Water Rights Program of Department of Environment and Natural Resources, Water Management Board
Texas	Texas Parks and Wildlife Department, Texas Water Development Board and the Texas Commission on Environmental Quality (TCEQ) and other stakeholders can make recommendations.	Not applicable (the Texas Commission on Environmental Quality administers water permits)
Utah	Division of Wildlife Resources and Division of Parks and Recreation (transfers only)	State Legislature must approve purchase of water rights for ISF purpose and State Engineer administers the water rights.
Washington	Department of Fisheries and Wildlife, groups associated with the Water Resource Inventory Areas (WRIA) process	Department of Ecology
Wyoming	State Game and Fish Commission	Wyoming Water Development Commission holds ISF water right, State Engineer receives and processes applications and administers rights.

Notes:
(1) 1980 recommendations were made by DWR, Kansas State Board of Agriculture, KWO, Kansas Department of Health and Environment and Kansas Department of Wildlife and Parks, which met to negotiate minimum desirable streamflow values to recommend to the Legislature.

Table 4.11 Summary of Participation in ISF Administration (from Charney et al., 2005)

	1 State Agency	>1 State Agency	Any Entity (including Federal)
Recommendations	CA, WY	KS, NE, OR, UT	AK, AZ, CO, ID, MT, NV, SD, TX, WA
Water Right Administration	AK, AZ, CA, MT, NE, NV, OR, TX, WA	CO, ID, KS, SD, UT, WY	--

A variety of methods are used to protect ISFs, ranging from explicitly granting ISF water rights to the application of special conditions to future consumptive appropriations or amendments to existing appropriations. Table 4.12 summarizes various methods used by states to preserve ISFs.

Table 4.12 Tools Available for ISF Protection, by State (adapted from Charney et al., 2005)

State	Tools for ISF Protection
Alaska	• Reservation[1]. • Department of Natural Resources (DNR) has authority to condition permits for ISF.
Arizona	• General ISF water right appropriations[2].
California	• California Wild and Scenic Rivers Act. • Administrative review of new and existing permits resulting in conditions for ISF. • Conversion of existing right to ISF right.
Colorado	• General ISF water right appropriation. • Conversion of existing right to ISF right. • Short-term loan or lease of water right from private individual or water bank to the CWCB.
Idaho	• Minimum streamflow ISF water right appropriation. • Protected river status, designate stream reach or sub-reach as natural or recreational river. • Idaho Water Bank provides for rental of existing rights for ISF use. • Legislative approval required for new ISF right.
Kansas	• Minimum desirable streamflow. • Kansas Water Assurance Program (indirect).
Montana	• Reservation. • Water rights leasing programs. • Conversion of conserved water to ISF reservations.
Nebraska	• General ISF water right appropriation. • Transfer of existing rights to ISF use (up to 30 years at a time).
Nevada	• General ISF water right appropriation.
New Mexico	• Transfer of an existing water right to ISF right. • Strategic Water Reserve, created and funded in 2005, allows for the acquisition of water for endangered species, their habitat, and Interstate Compact obligations.
North Dakota	• No specified method. Public interest criteria, including fish, wildlife, and recreation, may be considered when issuing a permit, which could result in conditions placed to protect these interests.
Oklahoma	• No specified method, Oklahoma Scenic Rivers Act may indirectly provide protection for ISF.
Oregon	• Conversion of minimum stream flows (from 1955 legislation) to ISF rights. • General ISF water right appropriation. • Conversion of conserved water to ISF right. • Transfer, gift, acquisition to ISF right.
South Dakota	• General ISF water right appropriation (not explicit in law, but treated same as other consumptive uses). • A judicial determination holds that diversion is not necessary. Recreation and fish and wildlife propagation are considered beneficial uses. • Transfer of existing right for ISF use.

State	Tools for ISF Protection
Texas	• Legislation exists to protect instream and freshwater inflows for rivers and estuaries. • Studies performed for segments and/or basins, standards adopted for priority basins and reviewed at minimum of 10-year increments. • Environmental flows applied as condition to future permits and amendments to existing permits that seek to increase the amount of water to be stored, taken, or diverted. • Texas Water Trust allows voluntary transfer of existing right.
Utah	• Permanent or temporary acquisition of ISF rights through donation or by purchase (funds for purchase require legislative authorization). • Utah Code authorizes the State Engineer to reject an application to appropriate water or to change use of a water right if approval would unreasonably affect public recreation or the environment.
Washington	• Minimum flows set through administrative rulemaking procedure(3). • Trust Water Rights Program allows conserved water to be dedicated to ISF.
Wyoming	• General ISF water right appropriation. • Acquisition through voluntary transfer or gift (no purchase).

Notes:
(1) Recognized by 1980 amendments as "an appropriation of water" AK ST 46-15-145, although locally referred to as a "reservation."
(2) AZ Legislature added "wildlife, including fish" to the state's list of beneficial uses in 1941 and "recreation" in 1962. Furthermore, a diversion is not required to appropriate a water right (Dishlip 1988).
(3) Washington water code amended in 1979 to clarify that minimum flows are appropriations.

Appendix A

REFERENCES

REFERENCES CITED OR CONSULTED

Annear, T., I. Chisholm, H. Beecher, A. Locke, P. Aarrestad, C. Coomer, C. Estes, J. Hunt, R. Jacobson, G. Jöbsis, J. Kauffman, J. Marshall, K. Mayes, G. Smith, R. Wentworth, and C. Stalnaker. 2004. Instream Flows for Riverine Resource Stewardship, Revised Edition. Instream Flow Council, Cheyenne, WY. 268 pp.

Aylward, Bruce, ed. (2013). *Environmental Water Transactions: A Practitioner's Handbook.* Ecosystem Economics, Bend, OR.

CDM (October 5, 2009). *Oklahoma Comprehensive Water Plan 2011 Update: Technical Memorandum, Instream Flows in Oklahoma and the West*. Oklahoma Water Resources Board. Oklahoma City, OK.

Charney, Sasha. (July 2005). *Decades Down the Road - An Analysis of Instream Flow Programs in Colorado and the Western United States.* Prepared for the Colorado Water Conservation Board. Denver, CO.

CH2MHill (February 2013). *Background Report: Instream Flow Advisory Group Support.* Prepared for Oklahoma Water Resources Board and U.S Army Corps of Engineers, Tulsa District, Tulsa, OK.

CH2MHill (November 2016). *Final Technical Report: Illinois River Instream Flow Assessment*. Prepared for Oklahoma Water Resources Board and U.S. Army Corps of Engineers, Tulsa District., Tulsa, OK.

Dellapenna, Joseph W. (January 2012). *Global Climate Disruption and Water Law Reform*. Widener Law Review, 15:409, Wilmington, DE.

Dishlip, Herb, "Instream Flow Water Rights: Arizona's Approach" (1988). Instream Flow Protection in the Western United States: A Practical Symposium (March 31-April 1). Phoenix, AZ.

Espegren, Gregory D. (January 1996). *Development of Instream Flow Recommendations In Colorado Using R2CROSS.* Colorado Water Conservation Board, Denver, CO.

Kenney, Doug. (October 2015). *Improving the Viability of Alternative Water Transfer Methods (ATMs) in Colorado: A Synthesis of Research and Findings from the Getches-Wilkinson Center, 2014-2015*. Getches-Wilkinson Center for Natural Resources, Energy, and the Environment, University of Colorado Law School, Boulder, CO.

Kendy, Eloise, Bruce Aylward, Laura S. Ziemer, Brian D. Richter, Bonnie G. Colby, Theodore E. Grantham, Leslie Sanchez, Will B. Dicharry, Emily M. Powell, Season Martin, Peter W. Culp, Leon F. Szeptycki, and Carrie V. Kappel, 2018. Water Transactions for Streamflow Restoration, Water Supply Reliability, and Rural Economic Vitality in the Western United States. Journal of the American Water Resources Association (JAWRA) 54(2): 487–504. https://doi.org/10.1111/1752-1688.12619

Klein, J. (2016). *Instream flow protection in Alaska, 2015.* Alaska Department of Fish and Game, Special Publication No. 16-09, Anchorage, AK.

Lang, Vernon (1999). *Questions and Answers on the New England Flow Policy*, revised 2002. U.S. Fish and Wildlife Service, Concord, NH.

Leathe, Stephen A. and Frederick A. Nelson (1986). *Montana's Wetted Perimeter Inflection Point Method, Excerpts from a 1986 Montana DFWP report.* Retrieved from file:///C:/Users/tlsmith/Documents/9955A.00%20Oklahoma%20ISF/References/usdaCompact_wetted_perimeter.pdf

Loehman, Edna T. and Sasha Charney (2011). Further down the road to sustainable environmental flows: funding, management activities and governance for six western US states, Water International, 36:7, 873-893, DOI: 10.1080/02508060.2011.628803.

Oklahoma Water Resources Board (OWRB), (February 2012). *Oklahoma Comprehensive Water Plan Executive Report.* Tulsa, OK.

Orth, Donald J. and O. Eugene Maughan (1982). *Evaluation of the Incremental Methodology for Recommending Instream Flows for Fishes.* Transactions of the American Fisheries Society 111:413-445, Stillwater, OK.

Poff, N. Leroy, Brian D. Richter, Angela H. Arthington, Stuart E. Bunn, Robert J. Naiman, Eloise Kendy, Mike Acreman, Colin Apse, Brian P. Bledsoe, Mary C. Freeman, James Henriksen, Robert B. Jacobson, Jonathan G. Kennen, David M. Merritt, Jay H. O'Keeffe, Julian D. Olden, Kevin Rogers, Rebecca E. Tharme, and Andrew Warner, (2009). *The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards.* Freshwater Biology, doi: 10.1111/j.1365-2427.2009.02204.x. Fort Collins, CO.

Richter, B., Ruth Mathews, David L. Harrison, Robert Wigington, (February 2003). Ecologically sustainable water management: managing river flows for ecological integrity, Ecological Applications, 13(1), 206–224.

Schellbach, Ruth (February 1992). *The Protection of Instream Flows in Idaho, a Research Paper*. Department of Geosciences, Oregon State University, Corvallis, OR.

Southeast Aquatic Resources Partnership (SARP) (2018, June 21). *Instream Flow Protection Policy Overview*. Retrieved from http://southeastaquatics.net/sarps-programs/sifn/southeastern-state-instream-flow-programs/instream-flow-protection-policy-document

Southwest Florida Water Management District (February 2010). Anclote River System Recommended Minimum Flows and Levels, pursuant to 373.042 F.S. Ecologic Evaluation Section, Resource Projects Department. Brooksville, FL.

Stalnaker, C., B.L. Lamb, J. Henriksen, K. Bovee, and J. Barthalow (1995). The instream flow incremental methodology: a primer for IFIM. National Biological Service Biological Report 29, Fort Collins, CO.

Texas Environmental Flows Science Advisory Committee (TXEFSAC) (October 2004). *Final Report: Science Advisory Committee Report on Water for Environmental Flows, Senate Bill 1639, 78th Legislature,* prepared for the Study Commission on Water for Environmental Flows. Austin, TX.

Zorn, Troy. G., Paul W. Seelbach, and Michael J. Wiley (July 2009). Relationships between Habitat and Fish Desnity in Michigan Streams, State of Michigan, Department of Natural Resources, Fisheries Division Research Report 2091, MI.

Web Sites Consulted

- http://www.dnr.state.ak.us/mlw/factsht/wtr_fs/instream.pdf - Alaska Department of Natural Resources, Reserving Water for Instream Use Fact Sheet
- http://www.azwater.gov/azdwr/SurfaceWater/SurfaceWaterRights/documents/RevisedISFapplication.pdf - Application Review Process, State of Arizona
- https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=118447&inline - California Instream Flow Program, Common Methods and Models
- https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=139778&inline - California Instream Flow Program, Low Flow Threshold Fact Sheet
- http://cwcb.state.co.us/environment/instream-flow-program/Pages/main.aspx - CWCB Instream Flow Program
- http://cwcb.state.co.us/water-management/Pages/WaterManagementHome.aspx - Colorado Water Conservation Board
- http://cwi.colostate.edu/media/files/Seminars/GRAD592/2017/214_Presentation.pdf - Overview of Colorado's Instream Flow Program & Analysis Tools, Colorado Water Conservation Board, Department of Natural Resources
- https://www.idwr.idaho.gov/waterboard/WaterPlanning/Minimum%20Stream%20Flow/PDFs/MSF_Brochure.pdf - Idaho Minimum Stream Flow Program
- http://dnrc.mt.gov/divisions/reserved-water-rights-compact-commission/docs/usdacompact_wetted_perimeter.pdf/at_download/file - Montana Wetted Perimeter Method
- https://outdoornebraska.gov/wp-content/uploads/2015/11/Instream_Flows_Q_A.pdf - Questions and Answers on Instream Flows, Nebraska
- http://water.nv.gov/programs/planning/stateplan/documents/pt3-3b.pdf - Water for Wildlife and Environmental Purposes, Nevada Division of Water Planning
- https://pdfs.semanticscholar.org/presentation/e011/590ba6ec2b3b6601e3e3049599b4a964a09e.pdf - Ecological Flows in New Mexico - It Has Been Done, The Nature Conservancy
- https://www.fws.gov/newengland/pdfs/Flowpolicy.pdf - Questions and Answers on the New England Flow Policy
- http://www.twdb.texas.gov/waterplanning/waterbank/trust/index.asp - Texas Water Trust, Texas Water Development Board
- https://www.tceq.texas.gov/permitting/water_rights/wr_technical-resources/eflows - Environmental Flows, Texas Commission on Environmental Quality
- https://www.utahfarmbureau.org/page/file?path=Files%2Fpage-426%2FFINAL%20-%20Instream%20Flow%20PDF.pdf - Instream Flows, Policy Issue Research Committee Report, Utah Farm Bureau Federation, June 2017
- https://ecology.wa.gov/Water-Shorelines/Water-supply/Protecting-stream-flows/Instream-flow-implementation - Department of Ecology, Instream flow & water management rule implementation
- https://fortress.wa.gov/ecy/publications/documents/981813wr.pdf - Setting Instream Flows in Washington State, Department of Ecology, Water Resources Program, State of Washington