INSTREAM FLOW NEEDS ASSESSMENT

AQUATIC LIFE MAINTENANCE FLOW NEEDS ASSESSMENT

Definition of Instream Flow

Instream flow can be defined as the amount of water flowing through a stream course which is needed to sustain instream values at some acceptable level (Bayha 1978). The acceptable level of instream values can be defined many ways, but, for this study, acceptable levels were defined as those which would maintain the ecological integrity of the riverine ecosystem (maintaining the existing community structure at a defined level based on the application of hydrologic, hydraulic, and habitat based methodologies). The maintenance of fish and wildlife populations, outdoor recreation, navigation, hydropower generation, waste assimilation, conveyance of water to downstream diversion locations and ecosystem maintenance are potential instream values which occur when water remains within the stream channel.

Methods Used in Quantifying the Relationship Between Available Fishery Habitat and Flow and Developing the Seasonal Instream Flow Regime

Methods available for assessing instream flows vary greatly in the issues they address, the uses for which they are intended, the assumptions underlying their application, and the intensity (and cost) of the effort required for the application. Considerable analysis and planning are required to tailor an instream flow analysis to meet the unique requirements of the resource, as well as applicable law and administrative procedures.

There are numerous instream flow methodologies which could have been used for the aquatic life maintenance flow needs assessment. Methodologies were grouped into "office" and "field/office" methods. Target species, planning schedules, and the amount of information deemed necessary to quantify the relationship between available fishery habitat and flow and to develop the seasonal instream flow regime were considered in ultimate method selection. The “field/office” approach which was utilized relied upon hydraulic simulation of flow at each study site transect (cross section) for each representative stream reach, with relationships developed between flows and certain hydraulic variables. Hydraulic variables, in turn, were related to fish habitat criteria.

Descriptive data were needed to display the effects of different flow regimes on resource values. Evaluative information was also needed to determine which set of conditions (e.g., instream fishery values and/or riverine riparian maintenance flows) were better or more desirable to evaluate resource conditions in terms of values (e.g., to decide what range of flows creates minimally acceptable, incremental, or optimal conditions). Once resource uses were established (e.g., fishery maintenance and spawning flows, riverine riparian corridor maintenance flows), the needed or desired resource conditions for providing those uses could be established. This required a study approach that recognized and thoroughly delineated resource values, while using appropriate methods to describe how flows related to resource conditions, and which applied evaluative standards to identify needed flows. Ultimately, study results will translate into the identification of the water costs where resource benefits would start to accrue, and the incremental levels of resource improvements for instream and riparian resources, for additional water costs (Phase II of the Red River Valley MR&I Water Needs Assessment).

The value-based process, which was utilized in this aquatic life maintenance flow needs assessment, consisted of five basic steps: (1) preliminary assessment and study design, (2) description of flow-dependent values, (3) description and quantification of hydrology and geomorphology, (4) description of the effects of flows on resource values, and (5) identification of instream flows to protect values. The value-based process is further discussed in Appendices A-F.

The quantification between available fishery habitat and flow and the development of the aquatic life maintenance seasonal instream flow regime were ultimately formulated to satisfy two distinct life stage periods of the fisheries year: the spawning and initial growth period (encompassing select species reproduction times), and the maintenance period (to satisfy fry survival and sustenance of juvenile and adult fish for the remainder of the year). The most critical period of the year for regulated and unregulated streams is the maintenance period (which corresponds to the low flow period) since flows are most susceptible to depletion due to drought and consumption during naturally dryer portions of the year and at times when off stream demands may be greatest (Brunson 1981).

Methodology (Discussions Related to the Methods Utilized)

Developing Representative Stream Reaches

Existing channel cross section data from USGS gaging stations and additional sources [e.g., Reclamation, Houston Engineering, Inc. (December 1997), and the North Dakota State Water Commission (1997)] and on-the-ground reconnaissance were used in selecting the representative stream reaches for the Sheyenne River and the Red River of the North.

Analysis suggested four representative reaches for the Sheyenne River. The portion of the Sheyenne River from Harvey, North Dakota, to above Lake Ashtabula constituted Sheyenne River Reach 1. This river reach is an uncontrolled river segment and flows are primarily the result of surface runoff events. Sheyenne River Reach 2 was intended to represent the drift prairie physiographic region and was comprised of the portion of the Sheyenne River from below Lake Ashtabula (Baldhill Dam) to the Sandhills area near Kindred, North Dakota. This river reach was subsequently subdivided into two reaches (from Baldhill Dam to Lisbon, North Dakota, and Lisbon, North Dakota, to the Sandhills area upstream of Kindred, North Dakota). The Sheyenne River through the Sandhills constituted Sheyenne River Reach 3 and was represented by the river reach from upstream of Kindred, North Dakota. The Red River Valley

Lake Plain physiographic region, represented by Sheyenne River Reach 4, is the portion of the Sheyenne River from downstream of the Sandhills area near Kindred, North Dakota, to the confluence with the Red River of the North.

The Red River of the North reach consisted of the portion of the Red River of the North at Fargo, North Dakota (and was considered representative of the reach from Fargo, North Dakota, to the confluence with the Buffalo River near Halstad, Minnesota).

Physiographic setting, channel slope, stream cross-sectional area, and top width and depth as a function of discharge, were used to evaluate the representative stream reaches. The representative reaches were intended to represent average stream geometry and slope for specific portions of the Sheyenne River and the Red River of the North and the integration of representative fishery habitat types.

Selection of Study Sites

Staff from Reclamation's Technical Service Center, Denver, Colorado, conducted field work between October 21 and November 5, 1997, and June 8-11, 1998, to: (1) select study sites representative of specific portions of the Sheyenne River and the Red River of the North; (2) determine habitat types within each study site; (3) estimate the proportion of each habitat type within each study site; and, (4) place transects within the various habitat types and collect stream geometry data as well as depth and velocity information along the transects. As a result, six study sites were selected as representative of the following portions of the Sheyenne River and the Red River of the North (generally following ecoregion boundaries for North Dakota):

Sheyenne River

1. Warwick Study Site - Sheyenne River above Lake Ashtabula (near Warwick, North Dakota, Eddy County, T150N, R63W, NW1/4NW1/4 of Sec. 22). Although data were twice collected at this site, the HEC-RAS Model was unable to be calibrated utilizing the data collected. Lisbon Study Site data were used in the Warwick Study Site analysis [the Lisbon Study Site was very similar to the Warwick Site in associated instream habitat, vegetation, and channel geometry (see Appendix E for information comparing Warwick and Lisbon Study Site channel geometry)], however, ultimately, Houston Engineering, Inc. (1997) study site data were used in quantifying the relationship between available fishery habitat and flow.

2. Ft. Ransom Study Site - Sheyenne River below Lake Ashtabula (near Fort Ransom, North Dakota, Ransom County, T135N, R57W, NE1/4SW1/4 of Sec. 17).

3. Lisbon Study Site - Sheyenne River below Lake Ashtabula (near Lisbon, North Dakota, Ransom County, T135N, R57W, SW1/4SE1/4 of Sec. 12).

4. Pigeon Point Study Site - Sheyenne River through the Sandhills (at Pigeon Point Wildlife Area, North Dakota, Ransom, County, T135N, R53W, NW1/4NE1/4 of Sec. 18).

5. Norman Study Site - Sheyenne River through the Agassiz Lake Plain (near Norman, North Dakota, Cass County, T137N, R50W, SW1/4SW1/4 of Sec. 24).

Red River of the North

1. Red River Study Site - Red River of the North near Fargo (at Fargo, North Dakota, Lindenwood Park downstream of I-94 Bridge, Cass County, T139N, R48W, SW1/4SE1/4 of Sec. 18).

Locations of study sites are shown on Figure 1. A written description for each study site including detailed location maps and photographs are provided in Appendix A.

Hydrologic Methods

Five hydrologically based methods were used to assist in developing the aquatic life maintenance seasonal instream flow regime for representative river reaches along both the Sheyenne River and the Red River of the North. The five hydrologic methods that were used are: (1) Annual Mean Flow (AMF) Comparison; (2) Average (Mean) Flow for All Water Years - High (Spawning)/Low (Maintenance) Period Comparison; (3) Tennant Method; (4) 25% of the Annual Mean Flow (AMF) Comparison; and (5) Water Year Type Flow Comparison for Dry-Average-Wet Years for High (Spawning)/Low (Maintenance) Period Flow Comparisons. Flow data for selected gaging stations was determined from USGS Water Resources Data (U.S. Geological Survey 1990) available for the same hydrological modeling period of record being used for the Red River Valley MR&I Water Needs Assessment, 1931-1984. The USGS data used in the analysis were gaged and estimated monthly streamflows for the period 1931-1984 (same as used in the Phase I, Part A study) for selected sites in the Red River of the North basin in North Dakota and Minnesota (U.S. Geological Survey 1990). Appendix B contains more detailed information regarding the hydrologic methods.

Wetted Perimeter versus Flow Method Comparison

O'Shea (1995) developed a wetted perimeter versus flow comparison method to estimate minimum instream flow requirements for Minnesota streams using hydrologic data and watershed characteristics. The methodology was developed to be used as a rapid assessment tool for Minnesota streams. Minimum instream flow recommendations, identified as the inflection point on the curve describing the relation between stream discharge and wetted perimeter, were developed for 27 Minnesota streams (one stream located within the Red River basin in Minnesota) with annual mean discharges ranging from 41 to 568 cubic feet per second (cfs). The relation of instream flow recommendations to hydrologic and watershed variables was also examined to develop models for rapid assessment.

According to O'Shea (1995), the instream flow recommendation occurs at the streamflow corresponding to the inflection point of the wetted perimeter versus streamflow plot. O'Shea's method, in essence, estimates the flow at which the inflection point occurs using mean annual flow as a predictor variable. A linear relationship was derived through least squares regression from data obtained primarily from the 27 streams sampled in northeastern and southeastern Minnesota. The regression equation developed by O'Shea is as follows:

$$IFR \ ? \ 14.898 \ ? \ 0.654\overline{Q}$$

Hydraulic Rating Method

The wetted perimeter technique (Nelson 1980) is another method frequently used with some success in instream flow studies, especially in Montana. Wetted perimeter is the distance along the bottom and sides of a cross section of a stream in contact with water. It is roughly equal to the width plus two times the mean depth. In this hydraulic approach, a desired low-flow value is chosen from a habitat index that incorporates stream channel characteristics (Trihey and Stalnaker 1985). The wetted perimeter technique generally selects the narrowest wetted bottom of the stream cross section that is estimated to protect the minimum habitat needs (which frequently defines a limiting characteristic on the stream such as a riffle area). The relationship of wetted perimeter to cross section is illustrated in Figure 6.

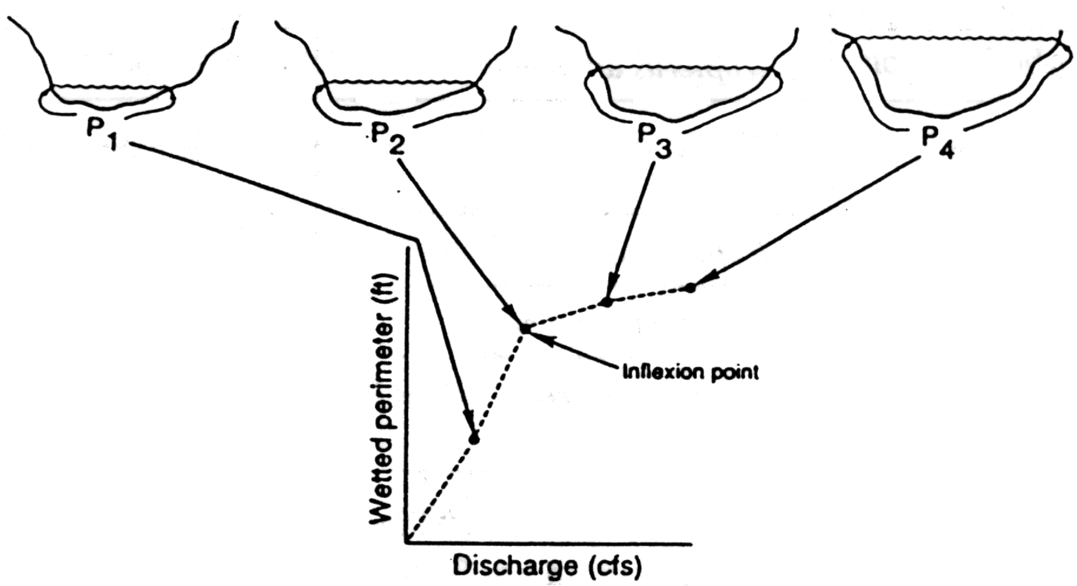

Figure 6. Use of the wetted perimeter technique to estimate instream flows; from Stalnaker et al. (1994).

The analyst selects a critical area (typically a riffle) as an index of habitat for the rest of the stream. When a riffle is used as the indicator area, the assumption is that minimum flow satisfies the needs for food production, fish passage, and spawning. The usual procedure is to choose the break or "inflection point" in the stream's wetted perimeter versus discharge relation as a surrogate for minimally acceptable habitat. The inflection point represents that flow above which the rate of wetted perimeter gain begins to slow. Once this level of flow is estimated, other habitat areas, such as pools and runs, are also assumed to be satisfactorily protected. Because the shape of the channel can influence the results of the analysis, this technique is usually applied to streams with cross sections that are wide, shallow, and relatively rectangular.

Appendix C contains additional information on the results of the site specific wetted perimeter technique application. Warwick Study Site data would not calibrate using the HEC-RAS Model and, therefore, Lisbon Study Site data were used in this portion of the analysis. The Lisbon Study Site was very similar to the Warwick Study Site in associated instream habitat, vegetation, and channel geometry (see Appendix E for information comparing Warwick and Lisbon Study Site channel geometries).

Modified Habitat Preference Method

Selection of guild representatives for performing assessment

Aadland et al. (1991) identified representative fish species for six specific guilds: (1) shallow pool, (2) medium pool, (3) deep pool, (4) raceway, (5) slow riffle, and (6) fast riffle. Representative species from these guilds were used in performing the aquatic life maintenance flow needs assessment. The work of Owen et al. (1981), Peterka (1978), and Niemela et al. (1997) were used to ensure that species selected as guild representatives occurred within the study area. Several of the species selected as guild representatives came from both slow and fast riffle guilds. The use of riffle guild species to evaluate instream flow needs is typically considered protective for species using other types of habitat. Riffle areas are generally the first areas to become dewatered as stream depth declines, and species representing riffle guilds are most sensitive to changes in flow.

Fish species presence and absence data for the Sheyenne River and the Red River of the North were compared to existing preference curves developed by Aadland et al. (1991) to ensure the availability of habitat preference data. The fish species selected as guild representatives are shown in Table 2. Comparison of the velocity and depth preference curves for these species shows "coverage" throughout the ranges in velocity and depth within the representative reaches. The depth and velocity preference curves developed by Aadland et al. (1991) for the guild representatives, were used to calculate weighted usable area (WUA) or available habitat. Preference curves for substrate are typically included in computing WUA when using habitat preference methods, however, for this assessment substrate preference curves were not used. Substrate preference is normally not as important as velocity and depth in computing WUA (Houston Engineering, Inc 1997). See Appendix D for more detailed information regarding the

Table 2

Guild Representatives Used for Performing Instream Flow Needs Assessment
Sheyenne River and Red River of the North

Common Name	Scientific Name	Guild(s)
Spawning and Initial Growth Period (March-June)		
Smallmouth bass fry (SBFR)	*Micropterus dolomieui*	Shallow pool
Smallmouth bass fingerling (SBFI)	*Micropterus dolomieui*	Medium pool, fast riffle
Sand shiner young (SSY)	*Notropis stramineus*	Shallow pool
Walleye spawning (WS)	*Stizostedion vitreum*	Medium pool
Shorthead redhorse spawning (SRS)	*Moxostoma macrolepidotum*	Fast riffle
Shorthead redhorse young (SRY)	*Moxostoma macrolepidotum*	Slow riffle
White sucker young (WSY)	*Catastomus commersoni*	Slow riffle
Slenderhead darter spawning (SDS)	*Percina phoxocephala*	Fast riffle
Channel catfish young (CCY)[1]	*Ictalurus punctatus*	Medium pool
Maintenance Period (July-February)		
Smallmouth bass juvenile (SBJ)	*Micropterus dolomieui*	Medium pool, raceway, slow riffle
Smallmouth bass adult (SBA)	*Micropterus dolomieui*	Deep pool, raceway
Sand shiner adult (SSA)	*Notropis stramineus*	Shallow pool
Shorthead redhorse juvenile (SRJ)	*Moxostoma macrolepidotum*	Raceway
Shorthead redhorse adult (SRA)	*Moxostoma macrolepidotum*	Raceway, fast riffle
White sucker juvenile (WSJ)	*Catastomus commersoni*	Slow riffle
Slenderhead darter adult (SDA)	*Percina phoxocephala*	Fast riffle
Channel catfish juvenile (CCJ)	*Ictalurus punctatus*	Medium pool
Channel catfish adult (CCA)	*Ictalurus punctatus*	Medium pool

[1]Channel catfish adult (CCA) preference curves were not used in determining spawning flows due to the fact that medium pool habitat was already covered by walleye spawning (WS) and channel catfish young (CCY). Channel catfish spawning preference curves were not available for use in this analysis (no reliable curves available), therefore, rather than use the CCA maintenance curves, no adult curves were used.

guilding process used for assessment purposes. Additional detailed information regarding species selection and depth and velocity preference coverage can be found in Appendices D and F.

Selecting discharges for computing fisheries habitat

Stream discharge data were needed for each representative stream reach and study site to determine stream cross-sectional velocity and depth distributions so that hydraulic modeling could be accomplished for the range of flows of interest. A range of discharges were selected for each representative stream reach and study site that represented some specific stream discharge [e.g., monthly annual mean flow for high flow (spawning), low flow (maintenance), and monthly mean flow by water year type]. This information, although not necessary for developing the relationship between WUA and discharge for a particular fish species, will be useful in Phase II of the Red River MR&I Water Needs Assessment.

Performing hydraulic modeling of representative stream reaches

Hydraulic modeling was used to approximate the depth and mean velocity distribution of each representative stream reach study site using the U.S. Army Corps of Engineers HEC-RAS Model and appropriate protocols. Reclamation utilized a simple 3-part model and defined Manning's n-values for overbank and main channel areas only. Data collected in the field at each study site were used to calibrate and/or check the calibration of the model (both water surface elevations and velocity measurements were used to calibrate and/or check the calibration of the model). A description of the HEC-RAS modeling effort (Hydraulic Properties Study) and results are contained in Appendix E.

Calculation of weighted usable area and quantification of the relationship between available fishery habitat and flow

Weighted usable area (WUA) within each representative stream reach and study site and each cross-sectional transect were calculated for each discharge of interest (see Appendix E for list of discharges used in the assessment) for each guild species. The WUA for each species within the guild was computed by integrating the products of depth and the preference curve value for depth and the mean column velocity and the preference curve value for velocity, across the representative cross section in a Lotus (Release 5) software spreadsheet. Combined habitat suitability was then multiplied by the amount of representative stream reach area which was measured at the specific study site and integrated over the representative reach to compute WUA. Available fishery habitat, expressed as percent of maximum WUA for all fish species versus flow was determined. Appendix F contains summary sheets for each study site and species specific WUA by discharge and other quantitative relationship information.

Establishing an aquatic life maintenance seasonal instream flow regime utilizing the modified habitat preference method

As previously stated, a variation of the computational methods used by PHABSIM of the IFIM was developed and used to evaluate instream flow needs for the Modified Habitat Preference Method. The variation consisted of selecting representative stream reaches (and establishing and collecting representative cross-sectional data) on the Sheyenne River and the Red River of the North, performing hydraulic modeling (using the U.S. Army Corps of Engineers HEC-RAS Model) to approximate velocity and depth distribution for site-specific data collected, and using habitat preference curves for fish species (developed for similar watersheds in Minnesota) from a variety of guilds as developed by Aadland et al. (1991), to calculate WUA for each representative stream reach in a Lotus (Release 5) software spreadsheet format. The Modified Habitat Preference Method was used to develop the seasonal instream flow regime by applying the technique of Bovee (1982) to WUA calculated by the multiplicative technique. Application of this technique to maintenance and spawning periods required identifying the minimum amount of habitat for all species over a range of discharges. This method consisted of optimizing the WUA for each species/life stage by the maximum WUA value.

Developing an aquatic life maintenance seasonal instream flow regime

In addition to utilizing the Modified Preference Method, a Goal Oriented Methodology was explored to help develop the seasonal instream flow regime as well as to provide an example for resource managers and for consideration in utilizing the seasonal instream flow regime for future planning and management purposes. For the Sheyenne River, the Goal Oriented Methodology was to maintain 50 percent of the WUA for all species during the maintenance period and maintain 50 percent of the WUA for all and/or select (target) species during the spawning period of the year (for the spawning period, selecting the flow which maintains the greatest amount of habitat for either all or target species, whichever was deemed to be reasonable based on professional judgement).

For the Red River of the North, the Goal Oriented Methodology was developed to consider two goals in developing the seasonal instream flow regime: (1) maintain 50 percent of the WUA in the stream during the maintenance and spawning periods of the year for all species, and (2) maintain 50 percent of the WUA in the stream during the spawning period of the year for all species (three options) plus maximize spawning WUA for channel catfish young (CCY) at 80 percent of available WUA (for the spawning period, selecting the flow which maintains the greatest amount of habitat for either all or select (target) species, whichever was deemed to be reasonable based on professional judgement).

Appendix F should be consulted for additional information regarding the application of the Modified Habitat Preference Method and the Goal Oriented Methodology.

Results and Discussion

Table 3 displays the results for each of the hydrologic methods analyzed, the wetted perimeter versus flow method comparison (O'Shea 1995), the hydraulic rating method (wetted perimeter technique)(Nelson 1980), and the Modified Habitat Preference Method (which includes the results of the application of the Goal Oriented Methodology). Considering the results of all of these applications, an aquatic life maintenance seasonal instream flow regime is displayed in the "Reclamation" Aquatic Life Maintenance Seasonal Instream Flow Regime row of the table (also see Table 1). This seasonal instream flow regime is compared to Houston Engineering, Inc. (December 1997) flow recommendations as provided to the Garrison Diversion Conservancy District (GDCD) for reader convenience (displayed in the "Houston" Flow Recommendation row of the table). It should be noted, however, that the Houston Engineering, Inc., did not report flow recommendations for aquatic life maintenance, instead, reported recommendations for spawning and non-spawning periods of the year. These flow recommendations were primarily developed by using a modified habitat preference method and did not consider a goal oriented methodology or utilize the method of O'Shea (1995).

The aquatic life maintenance seasonal instream flow regime can readily be compared to the annual mean flow displayed for each gaging station in the table as well. The discussions presented below will briefly cover hydrologic and hydraulic method results. Most of the narrative that is presented concentrates on the Modified Habitat Preference Method and the Goal Oriented Methodology results displayed in Table 3.

Hydrologic Methods

The flows derived using hydrologic methods displayed in Table 3 are fairly self-descriptive. For example, on the Sheyenne River near Warwick, North Dakota, the annual mean flow (AMF) for the period of record from 1931 to 1984, derived from USGS gaging station data, was 49 cfs. As expected, as the drainage basin increases in size, downstream AMF's increase (e.g., Cooperstown, North Dakota, AMF is 90 cfs). The same situation is true for the Red River of the North (e.g., 524 cfs at Wahpeton, North Dakota, to 3,589 cfs at Emerson, Manitoba, Canada). The 25% AMFs are self-descriptive as well and follow the same type of downstream increasing pattern.

For both the high flow (March-June) and low flow (July-February) periods, average (mean) flows (in cfs) show a similar increasing downstream pattern from above Harvey, North Dakota (21 and 2 cfs, respectively), to the mouth of the Sheyenne River (566 and 94 cfs, respectively), and from Wahpeton, North Dakota (927 and 328 cfs, respectively), to Emerson, Manitoba, Canada (7589 and 1588 cfs, respectively), on the Red River of the North.

Table 3. Sheyenne River and Red River of the North Methodology Results and Aquatic Life Maintenance Seasonal Instream Flow Regime.

		05054500 Sheyenne River above Harvey, ND 1931-1984		05056000 Sheyenne River near Warwick, ND 1931-1984		05057000 Sheyenne River near Cooperstown, ND 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)		8		49		90	
Flow Period (High/Low) [Mean (Avg) cfs/period] and Monthly Mean (Avg)		Mar-Jun 21 18/40/15/10	Jul-Feb 2 5/1/1/2/2/1/.5/.2	Mar-Jun 124 86/266/93/51	Jul-Feb 11 29/12/9/10/10/6/4/27	Mar-Jun 226 129/485/187/103	Jul-Feb 22 56/25/19/21/20/13/9/9
Tennant Method: Flushing Flow (200% AMF)		16		98		180	
Optimum Range (60-100% AMF)		5-8		29-49		54-90	
Outstanding (60/40% AMF)		5	3	29	20	54	36
Excellent (50/30% AMF)		4	2	24	15	45	27
Good (40/20% AMF)		3	2	20	10	36	18
Fair (30/10% AMF)		2	1	15	5	27	9
Poor (10/10% AMF)		1	1	5	5	9	9
25% AMF Method		2		12		23	
Dry Water Year [Mean (Avg)]		Mar-Jun 7 8/9/5/4	Jul-Feb 1 2/1/1/1/1/1/.5/1	Mar-Jun 34 32/54/28/23	Jul-Feb 7 15/7/8/6/6/4/3/3	Mar-Jun 61 54/108/46/36	Jul-Feb 11 26/10/11/10/13/8/6/6
Average Water Year [Mean (Avg)]		Mar-Jun 22 26/39/15/8	Jul-Feb 1 3/1/1/1/2/1/.2/1	Mar-Jun 115 103/250/63/45	Jul-Feb 12 25/13/10/12/11/6/4/13	Mar-Jun 195 123/418/109/131	Jul-Feb 22 57/22/25/21/20/12/8/13
Wet Water Year [Mean (Avg)]		Mar-Jun 48 30/101/36/23	Jul-Feb 3 10/2/2/2/2/1/1/5	Mar-Jun 266 147/596/222/97	Jul-Feb 17 56/18/9/16/14/8/5/11	Mar-Jun 486 236/1073/474/159	Jul-Feb 35 97/48/23/35/30/21/12/10
Wetted Perimeter vs. Flow Method		Mar-Jun 29 27/41/25/21	Jul-Feb 16 18/16/16/16/16/15/15/16	Mar-Jun 96 71/189/76/48	Jul-Feb 28 48/34/23/21/22/21/19/ 18/20	Mar-Jun 163 99/332/137/83	Jul-Feb 29 52/31/28/28/28/24/21/21
Hydraulic Rating Method (Wetted Perimeter Technique)				Reclamation: Range- 12-17 Mean- 15 n = 1 (riffle)	Houston: Range- 50-100 Mean- 75 n = 4 (riffle/run)		
Modified Habitat Preference Method	Reclamation	Mar-Jun -* 25**	Jul-Feb -* 15**	Mar-Jun 75 (all sp), 225(target sp)* 35 (all sp), 70 (target sp)**	Jul-Feb 70 (all sp)* 25 (all sp)**	Mar-Jun 75 (all sp), 225(target sp)* 35 (all sp), 70 (target sp)**	Jul-Feb 70 (all sp)* 25 (all sp)**
	Houston	Mar-Apr 100	May-Feb 25	Mar-Apr 100	May-Feb 25	Mar-Apr 100	May-Feb 25
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 25	Jul-Feb 15	Mar-Jun 100	Jul-Feb 25	Mar-Jun 125	Jul-Feb 50
	Houston	Mar-Apr 6	May-Feb 2	Mar-Apr 50	May-Feb 25	Mar-Apr 71	May-Feb 25

*Multiplicative Technique Results for all species (all sp) and target species (target sp).
**Maintaining approximately 50% of the Weighted Usable Area (WUA) available in the stream for both all species (all sp) and target species (target sp).

		05058000 Sheyenne River below Baldhill Dam, ND 1931-1984		05058500 Sheyenne River at Valley City, ND 1931-1984		05058700 Sheyenne River at Lisbon, ND 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)		110		118		139	
Flow Period (High/Low)[Mean (Avg) cfs/period] and Monthly Mean (Avg)		Mar-June 250 142/489/236/135	July-Feb 39 67/29/28/32/45/37/35/40	Mar-June 273 163/532/251/146	July-Feb 41 74/31/30/33/45/36/34/41	Mar-June 321 204/609/298/175	July-Feb 47 106/36/33/36/48/40/36/ 43
Tennant Method: Flushing Flow (200% AMF)		220		236		278	
Optimum Range (60-100% AMF)		66-110		71-118		83-139	
Outstanding (60/40% AMF)		66	44	71	47	83	55
Excellent (50/30% AMF)		55	33	59	35	69	42
Good (40/20% AMF)		44	22	47	24	55	28
Fair (30/10% AMF)		33	11	35	12	42	14
Poor (10/10% AMF)		11	11	12	12	14	14
25% AMF Method		28		30		35	
Dry Water Year [Mean (Avg)]		Mar-Jun 66 68/98/45/53	Jul-Feb 22 32/17/21/17/25/22/22/22	Mar-Jun 75 79/110/51/61	Jul-Feb 23 35/19/23/18/24/21/21/23	Mar-Jun 96 107/138/64/74	Jul-Feb 31 46/23/37/29/37/26/23/28
Avg Water Year [Mean (Avg)]		Mar-Jun 213 95/476/144/138	Jul-Feb 39 67/22/39/39/45/34/32/33	Mar-Jun 231 111/514/151/149	Jul-Feb 41 80/26/41/40/45/33/31/32	Mar-Jun 311 179/675/203/187	Jul-Feb 46 132/30/28/32/37/34/35/ 38
Wet Water Year [Mean (Avg)]		Mar-Jun 573 306/1101/628/258	Jul-Feb 65 120/54/28/48/75/64/57/ 75	Mar-Jun 621 348/1197/664/275	Jul-Feb 67 128/57/31/49/76/63/55/ 78	Mar-Jun 708 387/1335/777/332	Jul-Feb 75 180/65/31/51/75/69/58/ 74
Wetted Perimeter vs. Flow Method		Mar-Jun 179 108/334/169/103	Jul-Feb 41 59/34/33/36/44/39/38/41	Mar-Jun 194 122/363/179/111	Jul-Feb 42 64/35/35/37/44/39/37/42	Mar-Jun 225 148/413/210/129	Jul-Feb 46 84/39/37/38/46/41/38/43
Hydraulic Rating Method (Wetted Perimeter Technique)				Reclamation: Range- 25 Mean- 25 n = 1 (riffle/run)		Reclamation: Range- 12-17 Mean- 15 n = 1 (riffle/run)	Houston: Range- 50-150 Mean- 94 n = 3 (riffles)
Modified Habitat Preference Method	Reclamation	Mar-Jun 340 (all sp), 125 (target sp)* 125 (all sp), 340 (target sp)**	Jul-Feb 70 (all sp)* 55 (all sp)**	Mar-Jun 340 (all sp), 125 (target sp)* 125 (all sp), 340 (target sp)**	Jul-Feb 70 (all sp)* 55 (all sp)**	Mar-Jun 75 (all sp), 225 (target sp)* 35 (all sp), 70 (target sp)**	Jul-Feb 70 (all sp)* 25 (all sp)**
	Houston	Mar-Apr 250	May-Feb 75	Mar-Apr 250	May-Feb 75	Mar-Apr 250	May-Feb 75
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 125	Jul-Feb 50	Mar-Jun 125	Jul-Feb 50	Mar-Jun 225	Jul-Feb 70
	Houston	Mar-Apr 74	May-Feb 25	Mar-Apr 74	May-Feb 25	Mar-Apr 185	May-Feb 55

		05059000 Sheyenne River near Kindred, ND 1931-1984		05059500 Sheyenne River at West Fargo, ND 1931-1984		05060400 Sheyenne River at Harwood, ND 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)		174		177		251	
Flow Period (High/Low)[Mean (Avg) cfs/period] and Monthly Mean (Avg)		Mar-June 374 206/658/392/241	July-Feb 73 171/73/57/57/68/55/48/55	Mar-June 379 191/671/401/253	July-Feb 75 181/78/57/58/70/56/48/55	Mar-June 566 331/1099/497/337	July-Feb 94 280/93/66/67/79/60/50/56
Tennant Method: Flushing Flow (200% AMF)		348		354		502	
Optimum Range (60-100% AMF)		104-174		106-177		151-251	
Outstanding (60/40% AMF)		104	70	106	71	151	100
Excellent (50/30% AMF)		87	52	89	53	126	75
Good (40/20% AMF)		70	35	71	35	100	50
Fair (30/10% AMF)		52	17	53	18	75	25
Poor (10/10% AMF)		17	17	18	18	25	25
25% AMF Method		44		44		63	
Dry Water Year [Mean (Avg)]		Mar-Jun 132 130/205/102/89	Jul-Feb 39 74/35/26/35/41/30/31/36	Mar-Jun 133 127/221/105/79	Jul-Feb 38 68/36/27/36/41/30/31/35	Mar-Jun 199 174/319/157/146	Jul-Feb 58 115/56/57/52/62/44/37/41
Average Water Year [Mean (Avg)]		Mar-Jun 328 184/627/292/210	Jul-Feb 71 133/63/75/60/72/58/49/59	Mar-Jun 326 166/625/282/229	Jul-Feb 74 157/68/73/60/72/59/46/56	Mar-Jun 524 338/1077/380/301	Jul-Feb 69 162/63/51/56/63/54/47/56
Wet Water Year [Mean (Avg)]		Mar-Jun 775 344/1322/939/493	Jul-Feb 123 360/139/73/83/100/86/71/73	Mar-Jun 749 302/1275/924/495	Jul-Feb 123 352/142/71/83/104/85/72/77	Mar-Jun 1116 548/2217/1067/633	Jul-Feb 163 602/169/90/98/115/87/70/76
Wetted Perimeter vs. Flow Method		Mar-Jun 260 150/445/272/172	Jul-Feb 63 127/63/52/52/60/51/47/51	Mar-Jun 263 140/454/277/180	Jul-Feb 64 134/66/52/53/61/52/46/51	Mar-Jun 385 232/733/340/235	Jul-Feb 79 198/76/58/59/87/54/47/51
Hydraulic Rating Method (Wetted Perimeter Technique)		Reclamation: Range- 25-130 Mean- 58 n=5 (runs)	Houston: Range- 100-200 Mean-142 n=4 (runs)	Reclamation: Range- 25-130 Mean- 78 n= 2 (riffles)	Houston: Range- 100-200 Mean- 142 n = 4 (riffle/run)		
Modified Habitat Preference Method	Reclamation	Mar-Jun 70 (all sp), 155 (target sp)* 50 (all sp), 100 (target sp)**	Jul-Feb 50 (all sp)* 50 (all sp)**	Mar-Jun 100 (all sp), 150 (target sp)* 100 (all sp), 100 (target sp)*	Jul-Feb 130 (all sp)* 50 (all sp)**	Mar-Jun 100 (all sp), 150 (target sp)* 100 (all sp), 100 (target sp)*	Jul-Feb 130 (all sp)* 50 (all sp)**
	Houston	Mar-Apr 38	May-Feb 15	Mar-Apr 50	May-Feb 25	Mar-Apr 50	May-Feb 25
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 155	Jul-Feb 50	Mar-Jun 100	Jul-Feb 50	Mar-Jun 100	Jul-Feb 50
	Houston	Mar-Apr 135	May-Feb 45	Mar-Apr 135	May-Feb 45	Mar-Apr 135	May-Feb 45

Table 3 (Cont'). Sheyenne River and Red River of the North Methodology Results and Aquatic Life Maintenance Seasonal Instream Flow Regime.

		05051500 Red River of the North at Wahpeton, ND 1942-1984		05051522 Red River of the North at Hickson, ND 1976-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)		524		511	
Flow Period (High/Low) [Mean (Avg) cfs/period] and Monthly Mean (Avg)		Mar-Jun 927 570/1168/977/993	Jul-Feb 328 704/357/249/276/275/258/250/254	Mar-Jun 966 620/1677/790/776	July-Feb 284 588/311/199/239/230/224/230/252
Tennant Method: Flushing Flow (200% AMF)		1048		1022	
Optimum Range (60-100% AMF)		314-524		307-511	
Outstanding (60/40% AMF)		314	210	307	204
Excellent (50/30% AMF)		262	157	256	153
Good (40/20% AMF)		210	105	204	102
Fair (30/10% AMF)		157	52	153	51
Poor (10/10% AMF)		52	52	51	51
25% AMF Method		131		128	
Dry Water Year [Mean (Avg)]		Mar-Jun 347 385/405/309/290	Jul-Feb 201 324/181/136/193/203/187/181/199	Mar-Jun 335 458/447/242/194	Jul-Feb 188 200/179/152/215/202/182/168/203
Average Water Year [Mean (Avg)]		Mar-Jun 749 492/906/832/765	Jul-Feb 279 448/270/211/274/275/255/253/242	Mar-Jun 905 660/1511/767/680	Jul-Feb 279 401/238/129/282/284/265/305/327
Wet Water Year [Mean (Avg)]		Mar-Jun 1485 756/1930/1571/1684	Jul-Feb 461 1216/574/360/326/318/304/289/298	Mar-Jun 1847 810/3426/1536/1614	Jul-Feb 417 1230/537/308/244/232/252/262/ 268
Wetted Perimeter vs. Flow Method		Mar-Jun 621 388/779/654/664	Jul-Feb 229 475/248/178/196/195/184/178/181	Mar-Jun 771 421/1262/648/752	Jul-Feb 201 400/219/145/172/165/161/165/180
Hydraulic Rating Method (Wetted Perimeter Technique)					
Modified Habitat Preference Method	Reclamation	Mar-Jun -* 450**	Jul-Feb -* 100***	Mar-Jun -* 450**	Jul-Feb -* 100***
	Houston	None	None	None	None
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 450	Jul-Feb 100	Mar-Jun 450	Jul-Feb 100
	Houston	None	None	None	None

*Multiplicative Technique Results for all species (all sp) and target species (target sp).
**Maintaining approximately 50% of the Weighted Usable Area (WUA) available in the stream for both all species (all sp) and target species (target sp).
***Maintaining approximately 50% of the Weighted Usable Area (WUA) available in the stream for various target species and approximately 80% of the available habitat for channel catfish young (CCY).

		05054000 Red River of the North at Fargo, ND 1931-1984		05064500 Red River of the North at Halstad, MN 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)		578		1326	
Flow Period (High/Low) [Mean (Avg) cfs/period] and Monthly Mean (Avg)		Mar-June 1120 598/1810/1014/1059	July-Feb 307 814/339/227/240/233/204/198/202	Mar-Jun 2760 1251/5230/2422/2136	Jul-Feb 610 1702/655/487/488/518/393/319/314
Tennant Method: Flushing Flow (200% AMF)		1156		2652	
Optimum Range (60-100% AMF)		347-578		796-1326	
Outstanding (60/40% AMF)		347	231	796	530
Excellent (50/30% AMF)		289	173	663	398
Good (40/20% AMF)		231	116	530	265
Fair (30/10% AMF)		173	58	398	133
Poor (10/10% AMF)		58	58	133	133
25% AMF Method		145		332	
Dry Water Year [Mean (Avg)]		Mar-Jun 309 311/431/271/224	Jul-Feb 107 229/89/77/91/92/87/88/105	Mar-Jun 971 539/1778/882/685	Jul-Feb 246 535/231/194/211/254/192/168/180
Average Water Year [Mean (Avg)]		Mar-Jun 946 639/1312/902/929	Jul-Feb 297 550/277/244/275/288/265/240/233	Mar-Jun 2571 1556/4257/2175/2294	Jul-Feb 617 1258/589/597/610/672/529/350/334
Wet Water Year [Mean (Avg)]		Mar-Jun 2331 936/4121/1985/2281	Jul-Feb 581 1863/719/407/401/364/299/301/293	Mar-Jun 5492 1884/11229/4874/3979	Jul-Feb 1110 3870/1328/767/730/704/512/494/477
Wetted Perimeter vs. Flow Method		Mar-Jun 748 406/1199/678/707	Jul-Feb 216 547/237/163/172/167/148/145/147	Mar-Jun 1820 833/3435/1599/1412	Jul-Feb 414 1128/443/334/334/354/272/224/220
Hydraulic Rating Method (Wetted Perimeter Technique)		Reclamation: Range- 75-125 Mean- 82 n = 7 (pools)	Houston: Range- 150-225 Mean- 181 n = 4 (runs)		
Modified Habitat Preference Method	Reclamation	Mar-Jun 75-133 (various sp)** 450 (various sp)***	Jul-Feb 100 (all sp)* 50 (all sp)**	Mar-Jun -* 1125**	Jul-Feb -* 200***
	Houston	Mar-Apr 200	May-Feb 200	None	None
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 450	Jul-Feb 100	Mar-Jun 1125	Jul-Feb 200
	Houston	Mar-Apr 200	May-Feb 200	None	None

		05082500 Red River of the North at Grand Forks, ND 1931-1984		05092000 Red River of the North at Drayton, ND 1931-1984		05102500 Red River of the North at Emerson, Manitoba, Canada 1931-1984	
Annual Mean Flow (AMF) in cubic feet per second (cfs)		2698		3180		3589	
Flow Period (High/Low)[Mean (Avg) cfs/period] and Monthly Mean (Avg)		Mar-Jun 5388 2112/10030/5261/4148	Jul-Feb 1354 3112/1449/1293/1360 /1196/962/840/618	Mar-Jun 6558 2080/12231/7212/4709	Jul-Feb 1492 3555/1615/1401/1442/127 6/981/846/816	Mar-Jun 7589 1867/13398/9615/5475	Jul-Feb 1588 3909/1763/1513/1509 /1377/1007/836/792
Tennant Method: Flushing Flow (200% AMF)		5397		6361		7177	
Optimum Range (60-100% AMF)		1619-2698		1908-3180		2153-3589	
Outstanding (60/40% AMF)		1619	1079	1908	1272	2153	1435
Excellent (50/30% AMF)		1349	810	1590	954	1794	1077
Good (40/20% AMF)		1080	540	1272	636	1435	718
Fair (30/10% AMF)		810	270	954	318	1077	359
Poor (10/10% AMF)		270	270	318	318	359	359
25% AMF Method		675		795		897	
Dry Water Year [Mean (Avg)]		Mar-Jun 175 5877/3280/1661/1201	Jul-Feb 473 1012/491/432/461 /419/336/361/269	Mar-Jun 1990 919/3789/1791/1460	Jul-Feb 544 1087/562/515/574 /499/387/358/367	Mar-Jun 2326 1150/4555/2121/1478	Jul-Feb 607 1154/605/569/707 /587/449/394/387
Average Water Year [Mean (Avg)]		Mar-Jun 4663 2739/7970/3995/3946	Jul-Feb 1562 2934/1635/1812/1711 /1541/1193/981/692	Mar-Jun 5724 2966/10553/4979/4399	Jul-Feb 1673 3545/1822/1984/1611 /1412/1071/984/959	Mar-Jun 6785 2452/13346/5917/5424	Jul-Feb 1866 3989/1978/2076/1932 /1797/1253/969/937
Wet Water Year [Mean (Avg)]		Mar-Jun 10563 2833/20494/11039/7888	Jul-Feb 2152 5816/2368/1698/2010 /1711/1430/1243/943	Mar-Jun 13023 2427/24213/16393/9060	Jul-Feb 2346 6566/2661/1796/2095 /1772/1455/1258/1168	Mar-Jun 15327 1996/24667/24040/10606	Jul-Feb 2462 7293/2944/1960/1959 /1818/1386/1219/1113
Wetted Perimeter vs. Flow Method		Mar-Jun 3539 1396/6575/3455/2728	Jul-Feb 900 2050/963/860/904 /797/644/564/419	Mar-Jun 4304 1375/8014/4731/3095	Jul-Feb 990 2340/1071/931/958 /849/657/568/549	Mar-Jun 4978 1236/8777/6303/3595	Jul-Feb 1054 2572/1168/1005/1002 /915/674/562/533
Hydraulic Rating Method (Wetted Perimeter Technique)							
Modified Habitat Preference Method	Reclamation	Mar-Jun -* 2160**	Jul-Feb -* 440***	Mar-Jun -* 2610**	Jul-Feb -* 480***	Mar-Jun -* 3060**	Jul-Feb -* 520***
	Houston	None	None	None	None	None	None
Aquatic Life Maintenance Seasonal Instream Flow Regime	Reclamation	Mar-Jun 2160	Jul-Feb 440	Mar-Jun 2610	Jul-Feb 480	Mar-Jun 3060	Jul-Feb 520
	Houston	None	None	None	None	None	None

The flows derived by applying the Tennant Method to the AMF's are also self-descriptive. Optimum flows (60%-100% AMF) ranged from 5 to 8 cfs above Harvey, North Dakota, from 83 to 139 cfs at Lisbon, North Dakota, on the Sheyenne River, from 347 to 578 cfs at Fargo, North Dakota, on the Red River of the North. The flows displayed again follow the same downstream increasing flow pattern as described above. Depending upon the habitat goals desired by the resource agencies responsible for fishery management (e.g., the North Dakota Game and Fish Department), instream flows using the Tennant Method could vary by river and river reach (e.g., the Sheyenne River upstream of Lake Ashtabula and downstream from Baldhill Dam as well as the Red River of the North upstream of Fargo, North Dakota, and downstream of the Buffalo River confluence near Halstad, Minnesota). For example, maintaining good habitat on the Sheyenne River at Warwick, North Dakota, would require a flow of 20 cfs from March-June and a flow of 10 cfs from July-February. These flows correspond to the high and low flow periods which were defined in this study for the Sheyenne River. Comparing these flows to the high and low flow average (mean) flows for the period of record from 1931 to 1984 (encompassing all water year types), the actually occurring high flows are quite a bit greater (124 vs. 20 cfs), but the low flows were similar (10 vs. 11 cfs).

To maintain good habitat on the Red River of the North at Fargo, North Dakota, requires a flow of 231 cfs from March-June and 116 cfs from July-February. These flows also correspond to the high and low flow periods which were defined in this study for the Red River of the North. Comparing these flows to the high and low flow average (mean) flows for the period of record from 1931 to 1984 (encompassing all water year types), the high and low flows are much lower (231 vs. 1120 cfs for high flows; and, 116 vs. 307 cfs for low flows). The Tennant Method flows to maintain good habitat quality are also much less than those displayed for an average water year type (231 vs. 946 cfs), but they do approximate flows associated with a dry water year type (116 vs. 107 cfs). An evaluation of how frequently low flows might occur and the amount of time required for aquatic community recovery would assist the resource agencies in setting habitat goals utilizing the Tennant Method.

As explained in Appendix B, for all water years from 1931-1984, the average flow (cfs) for the High (Spawning - March-June) Flow and the Low (Maintenance - July-February) Flow periods, by water year type (Dry, Average, and Wet Water Year Types) were determined from USGS Water Resources Data. The percentage ratio of time that water year type was Dry-Average-Wet for 1931-1984, by river was: Sheyenne River = 41:31:28 and Red River = 36:35:29. Average water year type flows are similar to the average flows reported for the same high and low flow periods of the year. The flow pattern range between dry and wet water year types is readily evident (see Appendix B, Tables, for additional information as well as identification of which years of record were classified as Dry-Average-Wet per gaging station).

<u>Wetted Perimeter Versus Flow Method Comparison</u>

Wetted perimeter versus flow methodology (O'Shea 1995) flow results were usually less than average water year type flows but greater than dry water year type flows. They were less than average (mean) flows over the period of record for the spawning period (March-June) and maintenance period (July-February), for the Red River of the North. They were less than the average (mean) flows over the period of record for the spawning period (March-June), but were greater than average (mean) flows for gaging stations located upstream of Kindred, North Dakota, on the Sheyenne River. This difference between the two river systems is attributable to the need to provide more flow in smaller watershed streams during the low flow period of the year.

Houston Engineering, Inc., evaluated the applicability of the linear regression equation for use in eastern North Dakota by plotting wetted perimeter data versus streamflow exclusively from riffle habitat obtained from the Sheyenne River [i.e., Houston Engineering, Inc. (1997)], study performed for the Garrison Diversion Conservancy District study. Comparison of the flows at the inflection point of each curve and the instream flow recommendations obtained from the linear regression equation showed that O'Shea's method generally overestimated the flow at which the inflection point occurred.

The reason for the overestimation of instream flow recommendations made by O'Shea's method may be attributed to the geomorphologic differences in the streams from which the linear regression equation was developed and then later applied. The character of most streams, e.g. bankfull discharge, located in eastern Minnesota is markedly different than that of streams located in eastern North Dakota. As a result, O'Shea's method may not be totally applicable to streams located in eastern North Dakota. However, the methodology does provide another tool for evaluating instream flows.

Further, and more detailed, information regarding the use of the O'Shea method can be found in Appendix B (to include the Houston Engineering, Inc.'s evaluation).

Hydraulic Rating Method (Wetted Perimeter Technique)

Recommended flows ranged from 12 to 17 cfs at Warwick, North Dakota, from 25 to 130 cfs near Horace, North Dakota, on the Sheyenne River and from 75 to 125 cfs at Fargo, North Dakota, on the Red River of the North. Houston Engineering, Inc. (December 1997) reported flows ranging from 50 to 100 cfs at Warwick, North Dakota, from 75 to 100 cfs near Horace, North Dakota, on the Sheyenne River, and from 150 to 225 cfs at Fargo, North Dakota, on the Red River of the North. As noted in Table 3, habitat types other than riffle habitat were also presented in the analysis (run habitats for the Kindred Study Site and pool habitats for the Red River Study Site) for both Reclamation and Houston study sites.

In a true application of the wetted perimeter technique, comparisons should only be made for site-specific cross sections where riffle habitat is encountered, as previously explained in this report. As Houston Engineering, Inc. (December 1997) reported, recommendations derived using the wetted perimeter technique could be improved by evaluating the relationship between wetted perimeter and discharge for a greater number of cross sections taken specifically from riffle habitat. This was done by O'Shea (1995) for streams in Minnesota as reported for the wetted perimeter versus flow methodology application. The instream flow recommendations should be evaluated within the context of whether they are similar in magnitude to the recommendations derived from the Tennant Method and the Modified Habitat Preference Method. From analyzing these data, it appears that the flows reported for the wetted perimeter technique are similar to those reported for the Tennant Method, low flow period, good habitat range, as well as the 25% AMF results for each gaging station, and comparable to the reported Modified Habitat Preference Method maintenance flows.

Assuming the relatively few cross sections used in both analyses are representative of riffle habitat for a much larger portion of the Sheyenne River and/or Red River of the North is tenuous. The wetted perimeter technique resulted in a wide range of flows. It is anticipated that this wide range resulted from using multiple cross sections from many differing sites with differing geometric channel conditions. The sites identified as Reclamation, reported a consistently lower flow than those site reports for Houston. One explanation for the difference may be that several Reclamation sites were narrow and deep while more of the Houston sites were wide and shallow. The Reclamation sites would have exhibited greater velocities at lower discharges (flows), and resulted in the wetted perimeter technique results as displayed in Table 3. This geometric channel configuration could account for the reported disparities between the Reclamation and Houston sites. However, if enough additional cross sections could be analyzed, it would be expected that a relatively good minimum flow could be calculated using this technique.

Modified Habitat Preference Method

Results (instream flows) reported for the Modified Habitat Preference Method upstream and downstream of Lake Ashtabula are generally greater than those reported for Houston. In an attempt to determine what caused the differences in results, Houston Engineering, Inc., completed an analysis of hydraulic calculations used in both studies and reviewed the preference curves associated with the fish species used in the analyses.

First, Houston Engineering, Inc., compared the results of hydraulic calculations made at the Lisbon, North Dakota, study site (see Appendix E for details associated with this analysis). The velocity and depth, relative frequency and cumulative frequency distributions obtained from the GDCD study and the Reclamation study show considerable similarity. Although some differences are present between the relative frequency distributions, the cumulative frequency distributions "average out" the differences over the range of stream velocities and depths. When considering that the transects analyzed in each study represented different river reaches, the "averaged" results show that overall, the hydraulic analyses are quite similar.

As a result, the differences between the instream flow recommendations made in the GDCD study and the Reclamation aquatic life seasonal instream flow regime were deduced to not likely be associated with the hydraulic calculations, but rather the fish species selected for evaluation.

Velocity and depth preference curves for both the spawning period and the non-spawning period (or maintenance period) of selected fish species were evaluated. Because the velocity and depth preference curves for a particular fish species changes according to the spawning and non-spawning periods, different fish species were selected to cover the possible range of habitats for these periods. The analysis showed that there was a gap in the non-spawning period, velocity and depth preference curves, for the species evaluated in the GDCD study. Since the hydraulic calculations of each study were shown to be similar, it is expected that this gap is responsible for the differences in instream flow results, and ultimately, instream flow regimes (see Appendices E and F for details associated with these analyses).

Multiplicative technique flows generally result in more water and habitat (expressed as WUA) being maintained in the stream than most flows derived by applying the Goal Oriented Methodology (see Table 4, Appendix F - Summary Tables, and Tables 6 through 10 which appear later in the text).

As an example, at the Lisbon Study Site, Sheyenne River, multiplicative technique flows for all species would maintain 777135 WUA compared to 585300 WUA for the Goal Oriented Methodology (59 percent of the maximum available WUA versus 49 percent for the maintenance period and 59 versus 43 percent respectively, during the spawning period)(Table 7). For target species (or life stages), e.g., smallmouth bass fingerlings, walleye spawning, shorthead redhorse spawning, and channel catfish young, multiplicative technique flows would maintain 799612 WUA compared to 621028 WUA for the Goal Oriented Methodology (64 percent of the maximum available WUA versus 58 percent for the maintenance period and 68 versus 58 percent, respectively, during the spawning period)(Table 7).

The average depth and velocity of the stream at the Lisbon Study Site during the maintenance period (70 cfs flow for the multiplicative technique) was calculated to be 1.50 feet at 0.98 cfs. For spawning period flows (75 cfs for all species and 225 cfs for target species for the multiplicative technique), average depth and velocity was calculated to be 1.53 feet at 1.02 cfs and 2.13 feet at 1.90 cfs, respectively. Goal Oriented Methodology maintenance and spawning flows would result in less average depth and velocity at the site.

The surface area of the study reach increases from 7,892 ft^2 (wetted perimeter surface area of 7,980 ft^2) during maintenance flows to 7,927 ft^2 for all species and 8,728 ft^2 for target species, respectively, during spawning flows (see Appendix F - Summary Tables).

For the Red River of the North at Fargo, North Dakota, multiplicative technique flows for all species would maintain 117800980 WUA compared to 76960536 WUA for the Goal Oriented Methodology (51 percent of the maximum available WUA versus 47 (Goal # 1) or 49 percent (Goal # 2) for the maintenance period and 48 versus 65 (Goal # 1) and 70 (Goal # 2) percent, respectively, during the spawning period)(Table 10). For target species (or life stages), e.g., channel catfish young, multiplicative technique flows would maintain 117800980 WUA compared to 76960536 WUA for the Goal Oriented Methodology (35 percent of the maximum available

Table 4. Summary of the Multiplicative Technique and Goal Oriented Methodology Results.

STUDY SITE	MULTIPLICATIVE TECHNIQUE					AQUATIC LIFE MAINTENANCE GOAL				
	Maintenance All Species	Spawning All Species	Spawning Select Species			Maintenance All Species	Spawning All Species	Spawning Select Species		
Warwick[1]	25	100	-			-	-	-		
Lisbon	70	75	225			25	35	70		
Ft. Ransom	70	125	340			55	340	125		
Pigeon Point	50	70	155			50	50	100		
Norman	130	100	150			50	100	100		
	Maintenance All Species	Spawning All Species	Spawning - All except WS, CCY	Spawning - Select except WS	Spawning - CCY	Maintenance All Species	Spawning All Species	Spawning - All except WS, CCY	Spawning - Select except WS	Spawning - CCY
Red River	100	125	133	125	75	50	375	450	450	450

[1]Results displayed for Houston Engineering Inc., Study (1997)

WUA versus 80 percent for the maintenance period and 48 versus 70 percent, respectively, during the spawning period)(Table 10).

The average depth and velocity of the stream at the Red River (Fargo) Study Site during the maintenance period (100 cfs flow for the multiplicative technique) was calculated to be 3.59 feet at 0.39 cfs. For spawning period flows (125 to 133 cfs for all species or variations of target species for the multiplicative technique), average depth and velocity was calculated to be 4.02 to 4.17 feet at 0.38 cfs, respectively. Goal Oriented Methodology maintenance flows (50 cfs) would result in less average depth but greater velocity at the site (2.47 feet at 0.41 cfs). Goal Oriented Methodology spawning flows (375 to 450 cfs) would result in greater average depth (7.17 to 7.87 feet) and velocity (0.43 cfs) at the site.

The surface area of the study reach increases from 55,356 ft^2 (wetted perimeter surface area of 56,358 ft^2) during maintenance flows to 62,548 ft^2 for all species and 63,758 ft^2 for variations of target species, respectively, during spawning flows (see Appendix F - Summary Tables).

See Tables 6 through 10 which appear later in this text as well as Appendix F - Summary Tables, for comparative information related to the other study sites and results of applying the multiplicative technique and the Goal Oriented Methodology.

Aquatic Life Maintenance Seasonal Instream Flow Regime

The aquatic life maintenance seasonal instream flow regime was developed to provide an instream flow foundation for the current Red River Valley MR&I Water Needs Assessment. The rational in completing this study was to provide sufficient analyses for the development of defensible recommendations for immediate planning purposes and to lay the foundation for additional future refinement. Reclamation believes that the aquatic life maintenance seasonal instream flow regime represents a flow regime which is capable of maintaining an acceptable level of instream values in the Sheyenne River and Red River of the North systems. An acceptable level of instream values was previously defined as those which would maintain the ecological integrity of the riverine ecosystem (maintaining the existing community structure at a defined level based on the application of hydrologic, hydraulic, and habitat based methodologies).

The data presented in Table 3 demonstrate that the application of different methodologies will result in differing instream flow recommendations for any given location on the Sheyenne River and/or the Red River of the North. Use of the Modified Habitat Preference Method, both the multiplicative technique and the Goal Oriented Methodology (plus consideration of historic flows and hydrologic and hydraulic method results) resulted in the most defensible approach to developing an aquatic life maintenance seasonal instream flow regime for the study area for this appraisal level of analysis. Again, the aquatic life maintenance seasonal instream flow regime is presented in Table 3 and displayed in the “Reclamation” Aquatic Life Maintenance Seasonal Instream Flow Regime row of the table and also displayed in Table 5 below.

Table 5
Sheyenne River and Red River of the North
Seasonal Instream Flow Regime for Aquatic Life Maintenance

Location	Flows in Cubic Feet Per Second (cfs)											
	Jan[1]	**Feb**	**Mar[1]**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sheyenne River												
Harvey, ND	15	15	25	25	25	25	15	15	15	15	15	15
Warwick, ND[2]	25	25	100	100	100	100	25	25	25	25	25	25
Cooperstown, ND	50	50	125	125	125	125	50	50	50	50	50	50
Baldhill Dam, ND	50	50	125	125	125	125	50	50	50	50	50	50
Valley City, ND	50	50	125	125	125	125	50	50	50	50	50	50
Lisbon, ND[2]	70	70	225	225	225	225	70	70	70	70	70	70
Kindred, ND[2]	50	50	155	155	155	155	50	50	50	50	50	50
West Fargo, ND[2]	50	50	100	100	100	100	50	50	50	50	50	50
Harwood, ND	50	50	100	100	100	100	50	50	50	50	50	50
Red River of the North												
Wahpeton, ND	100	100	450	450	450	450	100	100	100	100	100	100
Hickson, ND	100	100	450	450	450	450	100	100	100	100	100	100
Fargo, ND[2]	100	100	450	450	450	450	100	100	100	100	100	100
Halstad, MN	200	200	1125	1125	1125	1125	200	200	200	200	200	200
Grand Forks, ND	440	440	2160	2160	2160	2160	440	440	440	440	440	440
Drayton, ND	480	480	2610	2610	2610	2610	480	480	480	480	480	480
Emerson, Manitoba, Canada	520	520	3060	3060	3060	3060	520	520	520	520	520	520

[1]Maintenance flows provided for the months of July-February; Spawning flows provided for the months of March-June.
[2]Actual data collection resulted in flow regime (either Reclamation or Houston Engineering, Inc. sites; all other site flow regimes based on estimated needs).

Tables 6 through 10 display comparisons between mean monthly flow rates and WUA for all species (and/or species life stages) and the developed aquatic life maintenance seasonal instream flow regime flow WUA for all species (and/or species life stages), for selected sites on the Sheyenne River and the Red River of the North. For the both the Sheyenne River and the Red River of the North, aquatic life maintenance seasonal instream flow regime flows would generally result in similar amounts of habitat being maintained for all sites considered (mean historic flows versus seasonal instream flows) but require less water (instream water) to produce the results.

For the Sheyenne River, an average of 61 percent of the maximum WUA for all species would be maintained during the maintenance period of the year and 66 percent of the maximum WUA for all species would be maintained during the spawning period of the year. For the Red River of the North, an average of 50 percent of the maximum WUA for all species would be maintained during the maintenance period of the year and 70 percent of the maximum WUA for all species would be maintained during the spawning period of the year.

On the Platte River in Nebraska, the U.S. Fish and Wildlife Service has developed a flow regime for fisheries which provided approximately 72 percent of the optimum physical habitat for all groups of fish analyzed [Biological Opinion for Kingsley Dam (FERC Project No. 1417) and North Platte/Keystone Diversion Dam (FERC Project No. 1835) Projects, Nebraska]. The aquatic life maintenance seasonal instream flow regime developed for this study compares favorably with the Platte River study (Sheyenne River - maintaining an average of 61 percent of the maximum WUA available for all species during the maintenance period of the year and 66 percent of the maximum WUA available for all species during the spawning period of the year; Red River of the North - an average of 70 percent of the maximum WUA available for all species would be maintained during the maintenance period of the year and 70 percent of the maximum WUA available for all species would be maintained for the spawning period of the year).

Table 6. Sheyenne River at Warwick Aquatic Life Maintenance Seasonal Instream Flow Regime.

														Houston Eng
	Mean Monthly	Multiplicative	Multiplicative	Goal	Goal	O'Shea Method	Houston Eng		Multiplicative	Multiplicative	Goal	Goal	O'Shea	Mod Hab Pref
	Period of	Technique	Technique	Methodology	Methodology	Recomm-	Mod Hab Pref	Mean Monthly	Technique	Technique	Methodology	Methodology	Method	Method
	Record	All Species	Target Species	All Species	Target Species	endations	Method Recomm	All Species	All Species	Target Species	All Species	Target Species	All Species	All Species
Month	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA
January	4	70	70	25	25	36	25	66715	79494	79494	60292	60292	66715	60292
February	27	70	70	25	25	43	25	69881	79494	79494	60292	60292	69881	60292
March	86	75	225	35	70	148	100	41327	35296	40915	25741	34673	40719	38413
April	266	75	225	35	70	413	100	32431	35296	40915	25741	34673	37648	38413
May	93	75	225	35	70	210	100	39564	35296	40915	25741	34673	41209	38413
June	51	75	225	35	70	129	100	41075	35296	40915	25741	34673	40468	38413
July	29	70	70	25	25	84	25	86084	79494	79494	60292	60292	82057	60292
August	12	70	70	25	25	36	25	66715	79494	79494	60292	60292	66715	60292
September	9	70	70	25	25	33	25	65069	79494	79494	60292	60292	65069	60292
October	10	70	70	25	25	36	25	66715	79494	79494	60292	60292	66715	60292
November	10	70	70	25	25	46	25	72142	79494	79494	60292	60292	71237	60292
December	6	70	70	25	25	40	25	68524	79494	79494	60292	60292	68524	60292
TOTALS								716242	777136	799612	585300	621028	716957	635988
AVERAGES	50	72	122	28	40	105	50							
									Multiplicative	Multiplicative	Goal	Goal		Houston Eng
								Mean Monthly	Technique	Technique	Methodology	Methodology	O'Shea Method	Mod Hab Pref
								% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg
								and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA
								for All Species	All Species	Target Species	All Species	Target Species	All Species	All Species
								Maint/Spawn	Maint/Spawn	Maint/Spawn	Maint/Spawn	Maint/Spawn	Maint/Spawn	Maint/Spawn
								Period	Period	Period	Period	Period	Period	Period
								43/60	79/59	79/64	55/49	55/58	67/63	55/63
								40/61	62/59	62/68	47/43	47/58	55/67	47/64

Table 7. Sheyenne River at Lisbon Aquatic Life Maintenance Seasonal Instream Flow Regime.

	Mean Monthly	Multiplicative	Multiplicative	Goal	Goal	O'Shea Method		Multiplicative	Multiplicative	Goal	Goal	O'Shea
	Period of	Technique	Technique	Methodology	Methodology	Recomm-	Mean Monthly	Technique	Technique	Methodology	Methodology	Method
	Record	All	Target Species	All Species	Target Species	endations	All Species	All Species	Target Species	All Species	Target Species	All Species
Month	Flow(cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA
January	36	70	70	25	25	36	66715	79494	79494	60292	60292	66715
February	43	70	70	25	25	43	69881	79494	79494	60292	60292	69881
March	204	75	225	35	70	148	41327	35296	40915	25741	34673	40719
April	609	75	225	35	70	413	32431	35296	40915	25741	34673	37648
May	298	75	225	35	70	210	39564	35296	40915	25741	34673	41209
June	175	75	225	35	70	129	41075	35296	40915	25741	34673	40468
July	106	70	70	25	25	84	86084	79494	79494	60292	60292	82057
August	36	70	70	25	25	36	66715	79494	79494	60292	60292	66715
September	33	70	70	25	25	33	65069	79494	79494	60292	60292	65069
October	36	70	70	25	25	36	66715	79494	79494	60292	60292	66715
November	48	70	70	25	25	46	72142	79494	79494	60292	60292	71237
December	40	70	70	25	25	40	68524	79494	79494	60292	60292	68524
TOTALS							716242	777136	799612	585300	621028	716957
AVERAGES	139	72	122	28	40	105						
								Multiplicative	Multiplicative	Goal	Goal	
							Mean Monthly	Technique	Technique	Methodology	Methodology	O'Shea Method
							% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg
							and	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA
							for	All Species	Target Species	All Species	Target Species	All Species
							Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn
							Period	Period	Period	Period	Period	Period
							67 / 61	79 / 59	79 / 64	55 / 49	55 / 58	67 / 63
							55 / 65	62 / 59	62 / 68	47 / 43	47 / 58	55 / 67

Table 8. Sheyenne River at Kindred Aquatic Life Maintenance Seasonal Instream Flow Regime.

	Mean Monthly	Multiplicative	Multiplicative	Goal	Goal	O'Shea Method		Multiplicative	Multiplicative			
	Period of	Technique	Technique	Methodology	Methodology	Recomm-	Mean Monthly	Technique	Technique	Methodology	Methodology	Method
	Record	All	Target Species	All Species	Target Species	endations	All Species	All Species	Target Species	All Species	Target Species	All Species
Month	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA	Flow WUA
January	48	50	50	50	50	47	73953	75781	75781	75781	75781	72953
February	55	50	50	50	50	51	79569	75781	75781	75781	75781	76539
March	206	70	155	50	100	150	57014	31115	56510	33239	47303	55736
April	658	70	155	50	100	445	40125	31115	56510	33239	47303	50651
May	392	70	155	50	100	272	54256	31115	56510	33239	47303	57854
June	241	70	155	50	100	172	57394	31115	56510	33239	47303	56734
July	171	50	50	50	50	127	83312	75781	75781	75781	75781	75836
August	73	50	50	50	50	63	87420	75781	75781	75781	75781	82781
September	57	50	50	50	50	52	80781	75781	75781	75781	75781	78781
October	57	50	50	50	50	52	80781	75781	75781	75781	75781	78781
November	68	50	50	50	50	60	88933	75781	75781	75781	75781	82000
December	55	50	50	50	50	51	78781	75781	75781	75781	75781	76781
TOTALS							862319	730708	832288	739204	795460	845427
AVERAGES	173	57	85	50	67	129						
								Multiplicative	Multiplicative	Goal	Goal	
							Mean Monthly	Technique	Technique	Methodology	Methodology	O'Shea Method
							% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg
							and	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA
							for	All Species	Target Species	All Species	Target Species	All Species
							Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn
							Period	Period	Period	Period	Period	Period
							60 / 50	55 / 53	55 / 53	55 / 53	55 / 53	60 / 55
							61 / 63	57 / 37	57 / 57	57 / 40	57 / 57	59 / 66

Table 9. Sheyenne River at West Fargo Aquatic Life Maintenance Seasonal Instream Flow Regime.

Month	Mean Monthly Period of Record Flow(cfs)	Multiplicative Technique All Flow (cfs)	Multiplicative Technique Target Species Flow (cfs)	Goal Methodology All Species Flow (cfs)	Goal Methodology Target Species Flow (cfs)	O'Shea Method Recomm-endations Flow (cfs)	Mean Monthly All Species Flow WUA	Multiplicative Technique All Species Flow WUA	Multiplicative Technique Target Species Flow WUA	Goal Methodology All Species Flow WUA	Goal Methodology Target Species Flow WUA	O'Shea Method All Species Flow WUA
January	48	130	130	50	50	46	182932	116210	116210	202745	202745	163114
February	55	130	130	50	50	51	171135	116210	116210	202745	202745	196423
March	191	100	150	100	100	140	53891	47984	51716	47984	47984	50725
April	671	100	150	100	100	454	57933	47984	51716	47984	47984	57631
May	401	100	150	100	100	277	58018	47984	51716	47984	47984	56280
June	253	100	150	100	100	180	55433	47984	51716	47984	47984	53091
July	181	130	130	50	50	134	133618	116210	116210	202745	202745	121210
August	78	130	130	50	50	66	121017	116210	116210	202745	202745	76315
September	57	130	130	50	50	52	170135	116210	116210	202745	202745	194423
October	58	130	130	50	50	53	169135	116210	116210	202745	202745	196423
November	70	130	130	50	50	61	76315	116210	116210	202745	202745	139315
December	56	130	130	50	50	52	169135	116210	116210	202745	202745	194423
TOTALS							1418697	1121616	1136544	1813896	1813896	1499373
AVERAGES	177	120	137	67	67	131						
							Mean Monthly % WUA Avg and for Maint / Spawn Period	Multiplicative Technique % WUA Avg and % Max WUA All Species Maint / Spawn Period	Multiplicative Technique % WUA Avg and % Max WUA Target Species Maint / Spawn Period	Goal Methodology % WUA Avg and % Max WUA All Species Maint / Spawn Period	Goal Methodology % WUA Avg and % Max WUA Target Species Maint / Spawn Period	O'Shea Method % WUA Avg and % Max WUA All Species Maint / Spawn Period
							50 / 72	56 / 65	56 / 74	54 / 65	54 / 65	46 / 73
							58 / 89	45 / 76	45 / 82	79 / 76	79 / 76	66 / 87

Table 10. Red River of the North at Fargo Aquatic Life Maintenance Seasonal Instream Flow Regime.

Month	Mean Monthly Period Record Flow	Multiplicative Technique All Flow (cfs)	Multiplicative Technique All Species Flow (cfs)	Multiplicative Technique All Sp - WS Flow (cfs)	Multiplicative Technique CCY Flow (cfs)	Goal # 1 Methodology All Species Flow (cfs)	Goal # 2 Methodology All Species Flow (cfs)	Goal Methodology All Species - WS, CCY Flow (cfs)	Goal Methodology All Sp - WS Flow (cfs)	Goal Methodology CCY Flow (cfs)	Combination Methodology All Species & CCY Max Flow (cfs)	O'Shea Method Recomm-endations Flow (cfs)	Mean Monthly All Species Flow WUA	Multiplicative Technique All Species Flow WUA	Multiplicative Technique All Species - WS, CCY Flow WUA	Multiplicative Technique All Sp - WS Flow WUA	Multiplicative Technique CCY Flow WUA	Goal # 1 Methodology All Species Flow WUA	Goal # 2 Methodology All Species Flow WUA	Goal Methodology All Species - WS, CCY Flow WUA	Goal Methodology All Sp - WS Flow WUA	Goal Methodology CCY Flow WUA	Combination Methodology All Species & CCY Max Flow WUA	O'Shea Method All Species Flow WUA
January	198	100	100	100	100	50	50	50	50	50	100	135	1475233	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1213372
February	202	100	100	100	100	50	50	50	50	50	100	137	1491625	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1223372
March	598	125	125	133	125	375	450	450	450	450	450	407	327508	204461	204461	216884	204461	273714	294916	294916	294916	294916	294916	280781
April	1810	125	125	133	125	375	450	450	450	450	450	1202	388906	204461	204461	216884	204461	273714	294916	294916	294916	294916	294916	388906
May	1014	125	125	133	125	375	450	450	450	450	450	680	388906	204461	204461	216884	204461	273714	294916	294916	294916	294916	294916	341877
June	1059	125	125	133	125	375	450	450	450	450	450	709	388906	204461	204461	216884	204461	273714	294916	294916	294916	294916	294916	346566
July	814	100	100	100	100	50	50	50	50	50	100	509	25300566	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	24772560
August	339	100	100	100	100	50	50	50	50	50	100	220	2033756	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1523598
September	227	100	100	100	100	50	50	50	50	50	100	152	1583938	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1294474
October	240	100	100	100	100	50	50	50	50	50	100	160	1664278	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1324474
November	233	100	100	100	100	50	50	50	50	50	100	155	1603938	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1304474
December	204	100	100	100	100	50	50	50	50	50	100	138	1483598	14622892	14622892	14622892	14622892	9472609	9472609	9472609	9472609	9472609	14622892	1233372
TOTALS													38131158	117800980	117800980	117850672	117800980	76875728	76960536	76960536	76960536	76960536	118162800	35247826
AVERAGES	578	108	108	111	108	158	183	183	183	183	217	384												
																							Combination	
														Multiplicative	Multiplicative	Multiplicative	Multiplicative	Goal # 1	Goal # 2	Goal	Goal	Goal	Methodology	
													Mean	Technique	Technique	Technique	Technique	Methodology	Methodology	Methodology	Methodology	Methodology	All Sp & CCY Max	O'Shea Method
													% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg	% WUA Avg
													and	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA	and % Max WUA
													for	AllSpecies	AllSp - WS, CCY	All Sp - WS	CCY	All Species	All Species	All Sp - WS, CCY	All Sp - WS	CCY	CCY	All Species
													Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn	Maint / Spawn
													Period	Period	Period	Period	Period	Period	Period	Period	Period	Period	Period	Period
													58 / 61	62 / 51	62 / 61	62 / 73	62 / 35	54 / 47	54 / 49	54 / 52	54 / 71	54 / 80	62 / 80	59 / 58
													16 / 87	50 / 48	50 / 48	50 / 51	50 / 48	32 / 65	32 / 70	32 / 70	32 / 70	32 / 70	50 / 70	5 / 81