TO: Governance Committee (GC)
FROM: Executive Director's Office (EDO)
SUBJECT: 2016 EDO Technical Series
#02 – Target Flow Performance Memo
DATE: August 31, 2016
CC: Technical Advisory Committee (TAC) and Independent Scientific Advisory Committee (ISAC)

Species Target Flows

A primary First Increment objective of the Platte River Recovery Implementation Program (Program or PRRIP) is to reduce deficits to the United States Fish and Wildlife Service (Service or USFWS) central Platte River annual species and pulse target flows (see figure) by an average of 130,000 to 150,000 acre-feet per year at Grand Island, Nebraska. The target flows were formulated in 1994 by the Service and Submitted to the Federal Energy Regulatory Commission (FERC) as Section 10(j) (Federal Power Act) recommendations for the relicensing of Kinsley Dam and associated facilities in Nebraska.[1] The target flows were subsequently incorporated into the Program as an initial reference point for determining periods of excess and shortage in the operation of Program reregulation and Program water will be used to reduce those shortages.

Average species and annual pulse flow targets

Origins of Species Target Flows

Target flows exist for each day of the year and vary by date and hydrologic year type.[2] Species target flows during the period of January 1 – 31, September 16 – 30, and November 16 – 31 are primarily based on maintenance of "a diverse and abundant assemblage of fish species." Species low targets during the February 1 – May 10 period are focused on proving roosting habitat for crane species with the period of February 1 – March 22 focused on Sandhill cranes and the period of March 23 – May 10 focused on whooping cranes.[3] The May 11 – September 15 species flows focus on in-channel least tern and piping plover nesting and maintenance of the native fish community. October 1 – November 15 species flows support roosting habitat during the fall whooping crane migration. Fish and crane flows were based on Physical HABitat SIMulation System (PHABSIM) models that were used to generate habitat availability

[1] Instream flow recommendations (now referred to as species flows) were submitted to FERC on May 19, 1994. Pulse and peak flow recommendations were submitted under separate cover on August 11, 1994.
[2] 25% of years are considered to be dry, 33% wet, and the remaining 42% normal.
[3] It should also be noted that the February 1 – March 22 targets are largely overridden by substantially higher early spring pulse flow targets as are 30 days of the May 11 – September 15 period due to the late spring pulse flow targets.

curves for fish and whooping cranes. Least tern and piping plover flows were based on a general discharge-habitat relationship that described changes in species habitat as discharge increases.[4]

Fish-Related Target Flows

Origin of Fish-Related Target Flows

The Service used the PHABSIM to model Weighted Usable Area (WUA) for central Platte River fish species across a range of discharges. The resulting WUA versus discharge curves were then normalized and combined into guilds that exhibited curves with similar shape and peak. The resulting guilds were identified by the letters A – E (see figure). Guilds A and B were comprised of species like sand shiner that make up the bulk of suitable least tern forage. Guilds C – E were comprised primarily of species like common carp and channel catfish that are not suitable forage.

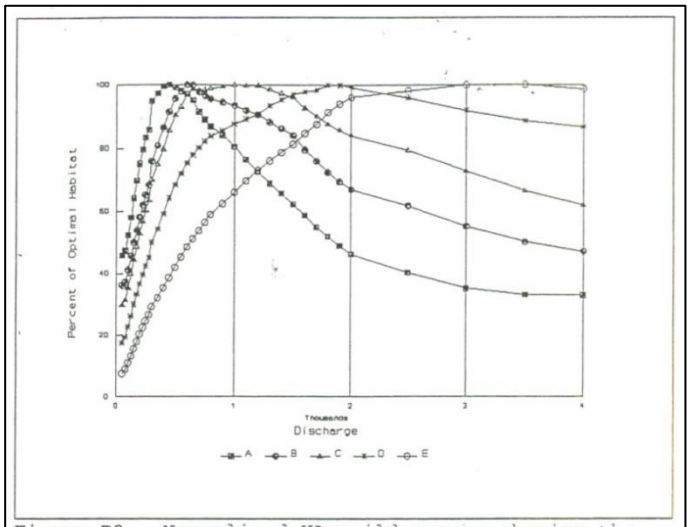


Figure B3. Normalized HA guild curves showing the percent of optimal habitat as a function of discharge for five guilds (A-E) during the fall BSP.

Target Flow Analysis Fish Guild Habitat Area Curves

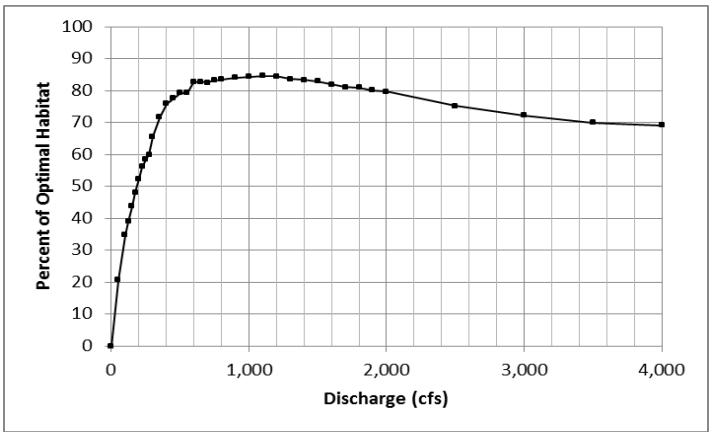
The individual curves in each guild were then combined into one Habitat Area (HA) curve for each guild and the flow target was determined by averaging the HA curves for all guilds. The highest average value in the fall biologically significant period[5] occurred at 1,000 cfs, which was selected as the wet and normal flow target. A flow of 600 cfs was chosen for the dry year target because the Service determined the percent of optimum habitat diminishes most rapidly at flows below 600 cfs during the fall.[6]

Assessment of Fish-Related Target Flows

After examining the guild analysis, two items stand out. First, equal weight was given to all guilds in the averaging procedure regardless of number of guild species present in the central Platte River, abundance of species that are present, or importance of guilds as least tern forage. Only using guilds A and B, which comprise the bulk of least tern forage base, would reduce the flow target to 450 cfs. Retaining all guilds and weighting the average by number of species in each guild would produce a flow target of 600 cfs.

[4] The target flow documentation does not provide specific data/models associated with least tern and piping plover discharge-habitat relationships.
[5] The fall HA curves were used to set winter flow targets for the fish community.
[6] Suitability for Guilds A-C are near peak at 600 cfs. As such, average suitability for all guilds diminishes quickly below that flow.

Second, the averaged HA curve indicates very little difference in percent of optimal habitat area across a range of flows (see figure). The averaged curve indicates that there is only a 1.9% change in the percent of optimal habitat for the range of discharges from 600 cfs to 1,000 cfs. The average annual normal hydrologic condition deficit to meet the baseline fish-related target flow of 1,000 cfs is on the order of 222,700 acre-ft. The deficit to meet a baseline fish-related target flow of 600 cfs would be 76,500 cfs.



Averaged Habitat Area curve for all guilds showing the percent of optimal habitat as a function of discharge.

The Program's Adaptive Management Plan (AMP) addresses flow-fish relationships through priority hypothesis T2, which postulates least tern productivity is related to the number of prey fish and fish numbers limit least tern production below 800 cfs from May – September. The Program analyzed least tern productivity during the period of 2001-2014 in relation to river flow. During that period 79% of broods were exposed to flows below 800 cfs within 7 days of brood fate determination and 50% were exposed to discharges below 200 cfs. Least tern productive success was generally high and low flows during the brood rearing season did not negatively affect productivity. This strongly suggests forage fish abundance is not a limiting factor in the AHR.[7]

Potential Outcomes of Fish-Related Target Flow Update

From a Program target species perspective, the primary fish-related target flow objective would be maintenance of a diverse and abundant forage fish prey base for least terns. Analysis of Program monitoring data indicates the flow regime experienced during the period of 2001-2014 was sufficient to support an adequate forage fish population. Given that 50% of broods were exposed to flows below 200 cfs and still experienced high productivity, that discharge may be a reasonable minimum target.

If the original PHABSIM analysis methods were used to revise the target flow, the analysis would likely be updated to only include least tern prey species guilds. Removal of the non-prey guilds (catfish and carp) guild would produce HA curves that optimize habitat availability at approximately 450 – 600 cfs. Overall, updated fish-related target flows to protect the least tern prey base would be somewhat lower than the existing targets, likely in the rage of 200 – 600 cfs.

Least Tern and Piping Plover Target Flows

Origin of Least Tern and Piping Plover Target Flows

The Service's target flow recommendations indicate that the period from May 11 – September 15 is the time when water shortages are most critical and proportionately greater biological stress and ecological

[7] This research will be published in Great Plains Research in the fall of 2016.

effects can occur. Target flows during this period are intended help prevent least terns and piping plovers from nesting at low elevations in the channel, provide a barrier to terrestrial predators, and maintain the native fish community by curtailing rises in water temperature which would be detrimental or lethal. The Service rationale for the flow targets during this period appears to be the convergence of flows thought to be necessary for protection of the fish community and maintenance of least tern and piping plover habitat.

The fish community protection rationale is based on modeling performed as part of a master's thesis. The thesis analysis utilized data from 1989-1990 in conjunction with the Stream Network Temperature (SNTEMP) model to predict changes in water temperature in relation to increases and decreases in flow. The modeling indicated water temperature during the summer is correlated with flow and concluded flows of 400 cfs at Grand Island provided little or no protection to the fish community; flows of 800 cfs reduced the average daily maximum water temperatures and the number of days when temperature exceeded lethal levels; and a flow of 1,200 cfs further reduced daily maximum temperature as well as the number of days when temperatures exceeded lethal levels. The Service documentation does not indicate whether there is a minimum level of protection that must be maintained or discuss the magnitude or duration of impacts to the fish community if lethal temperatures are exceeded.

The least tern and piping plover habitat component of the rationale includes two parts. The first is related to the fish community as the Service stated "at 1,200 cfs, optimum habitat is achieved for the forage fish of the least tern." This statement is presumably linked to the PHABSIM fish modeling discussed earlier. The optimized flow in that model for the summer biologically significant period was 1,200 cfs. It should be noted that the PHABSIM model optimization was based on all guilds, not solely on the guilds that comprise forage fish species. If the guilds that include common carp and channel catfish are removed from the analysis, optimal habitat would be achieved at a flow of approximately 600 cfs.

The second least tern and piping plover habitat rationale is based on a generic habitat versus discharge relationship for segments of the central Platte River frequently occupied by nesting least terns and piping plovers.[8] The Service indicated the water surface area within the channel in these areas increases most rapidly from 0 to 800 cfs, continues to increase at a slower rate up to 1,300 cfs, and increases at a uniform rate above that level. Additionally, between 1,200 and 1,500 cfs, nesting habitat receives a predator barrier and varying amounts of damp sandbars are exposed for piping plover foraging. And finally, beyond 1,500 cfs, damp sandbars disappear. No data was provided in support of the predator barrier or foraging habitat versus flow relationships. Overall, the wet and normal year flow target of 1,200 cfs and dry year target of 800 cfs appear to be based on the PHABSIM fish analysis which the Service further supported by the water quality (temperature) and channel habitat versus discharge relationships.

Assessment of Least Tern and Piping Plover Target Flows

In 2015, the GC officially concluded sandbars created by short-duration high flow releases would not be suitably high for nesting given the frequency of inundation.[9] In addition, mechanical creation and maintenance of on-channel nesting would not provide for adequate on-channel productivity due to low

[8] The Service documentation does not indicate where these segments are located within the associated habitat reach.
[9] Peak flow magnitudes of 13,000-15,000 cfs are necessary to increase sandbar height to the Program's minimum height suitability criterion of 1.5 ft above 1,200 cfs stage.

utilization and island erosion. The GC entered into a Structured Decision Making (SDM) process to adjust management actions to meet least tern and piping plover management objectives. The revised management approach focuses on creation and maintenance off-channel sand and water nesting habitat along with a small amount of mechanically-created in-channel habitat. The GC also addressed the use of flow, concluding that Program water should not be used solely for the purpose of least tern and piping plover nest initiation or island moating.[10,11]

Potential Outcomes of Least Tern and Piping Plover Target Flow Update

Given the Program's shift away from on-channel least tern and piping plover nesting habitat, it is unlikely a target flow update would include flows to encourage on-channel nest initiation and/or moat islands. In absence of on-channel nesting flows, targets would likely be associated with maintenance of an abundant and diverse forage base for least terns. As discussed previously, flow targets in the range of 200 – 600 cfs would likely be sufficient to achieve this objective.

Whooping Crane Target Flows

Origin of Whooping Crane Target Flows

The rationale for flow targets during the spring and fall whooping crane migration periods is optimization of suitable whooping crane channel roosting habitat availability in the associated habitat reach. The Service's CR4 PHABSIM whooping crane model was used to model the relationship between habitat and flow. Generally speaking, the model calculates habitat suitability based on channel wetted width and cumulative depth distribution functions. The C4R model indicates roosting habitat availability is optimized at a flow of 2,400 cfs, which was selected as the wet and normal year flow target in the spring. The spring dry year target was set at 1,700 cfs because the model indicates suitability declines rapidly below that discharge.

The fall target during wet conditions is 2,400 cfs, which is intended to optimize roosting habitat availability. The fall flow target during normal conditions is 1,800 cfs, which corresponds to dry conditions during the spring migration, and the fall dry target is 1,300 cfs. The Service did not explain why normal and dry year targets are lower in the fall although the likely candidate is the hydrologic record which indicates flows during the fall migration period are typically lower than during the spring migration period.

Assessment of Whooping Crane Target Flows

The C4R model, specifically the cumulative depth distribution function, has been the subject of much criticism since target flows were established. The Nebraska Game and Parks Commission (NGPC) filed a 2,400 cfs instream flow application with Nebraska Department of Water Resources (NDWR; now known as the Nebraska Department of Natural Resources) in 1993 for protection of whooping crane roosting habitat based on the C4R model output. That application was contested and a significant portion of the testimony focused on whether or not the depth distribution function was inherently flawed. The NDWR

[10] Least tern and piping plover benefits could be identified as part of the rationale water releases made for other purposes.
[11] This was a consensus recommendation to the USFWS acknowledging that they have authority over flow releases.

ultimately concluded that the NGPC analysis did overestimate the flow necessary to protect roosting habitat and ruled that a discharge of 1,350 cfs was appropriate for protection of roosting habitat.[12]

The discrepancy between spring and fall targets was also a significant area of contention during the NGPC instream flow application hearings and played a role in the final outcome of that application process. The basic NDWR question was this: If one magnitude of flow is critical to protect whooping crane roost habitat in the spring, why would some lesser flow be adequate in the fall? Conversely, why are higher flows needed in the spring if lower flows are sufficient in the fall?

Following the NDWR ruling, the United States Geological Survey (USGS) undertook an independent evaluation of the C4R model. The results of that evaluation were published as Scientific Investigations Report 2005-5123 (Farmer et al. 2005). The evaluation indicated the C4R model has some utility for predicting river channels more likely to be used by cranes. However, the authors concluded the model's depth function leads to a serious numerical bias in the estimated optimal flow. This is because the depth profile from a single group of whooping cranes that roosted in a narrow channel during high flows drives the results all model analyses. The authors modified the depth function to remove the bias and the resulting optimal flow was 1,350 cfs.

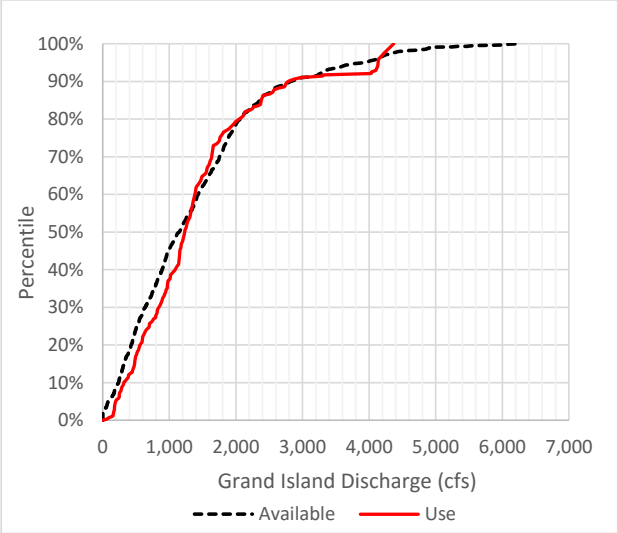
The Program's AMP addresses the relationship between flow and whooping crane use through priority hypothesis WC2 which postulates that whooping cranes select for a flows of 2,400 cfs at Grand Island. In 2014, the Program conducted a resource selection analysis using systematically-collected use data during the period of 2002-2013. That analysis included flow metrics like wetted width, proportion of the channel wetted, mean channel depth, and unit discharge as well as a variety of land use and vegetation metrics. The analysis was unable to establish a strong relationship between flow-related metrics and whooping crane use as flow metrics were absent from the top four models. This does not mean that flow is not important for crane use, instead it may indicate that areas of suitable depth and wetted width were equally available and adequate at flows observed during times of whooping crane use.

[12] This is based on the June 26, 1998 order that granted instream flow rights to NGPC. That order contains a record of the discussion of the hearings conducted by NDWR in relation to the flow applications.

A simple cumulative percentile analysis of discharge at Grand Island during the entirety of the 2001 – spring 2016 migration seasons along with discharge on crane use days indicates a disparity in whooping crane use as compared to available discharge at flows below 1,230 cfs ($p<0.001$; see figure). Above 1,230 cfs, there is no difference. This may indicate whooping cranes choose to roost in the AHR slightly less frequently when flows are below 1,230 cfs.

Potential Outcomes of Whooping Crane Target Flow Update

The Program's resource selection analysis did not indicate selection for discharge-related habitat metrics. This could indicate discharge is not important and, accordingly, there is no need for a whooping crane target flow. Conversely, it could only indicate that flow is not an important determinant of specific roost location. This uncertainty taken in conjunction with the difference in discharge availability and use below 1,230 cfs indicate that discharge may influence whether or not cranes roost on the channel.



Cumulative discharge curves for spring 2001 – 2016 whooping crane migration seasons.

Updated whooping crane target flows would likely be developed by updating the Service's C4R model or developing a similar habitat availability model. Either way, the roosting depth bias present in the C4R model would need to be remedied. The resulting target flows would likely be similar to the 2005 USGS update effort, which produced an optimized flow of 1,350 cfs.

Updated Species Flows in relation to PRRIP Water Supply and Management

The Program's First Increment water objective is to reduce deficits to USFWS target flows by an average of 130,000 – 150,000 acre-ft annually. Average USFWS species target flow deficits (no pulse flows) are on the order of 180,000 acre-ft in wet years, 370,000 acre-ft in normal years, and 330,000 acre-ft in dry years. If species target flows were revised to 600 cfs for optimization of forage fish habitat across all hydrologic year types and 1,350 cfs during whooping crane migration, average deficits would be on the order of 22,000 acre-ft during wet years, 100,000 acre-ft during normal years, and 240,000 acre-ft in dry years.

Hydrologic Year Type	USFWS Species Target Flow Deficits (acre-ft)	Forage Fish and Whooping Crane Optimized Deficits (acre-ft)
WET	180,000	22,000
NORMAL	370,000	100,000
DRY	330,000	240,000

Species Target Flows in Relation to Existing Hydrology and Channel Form

The target flows discussed in this memorandum are largely based on habitat suitability relationships which, in turn, are based on existing channel morphology. Existing channel morphology is largely dictated by the existing annual hydrograph and sediment supply recognizing the potentially controlling effects of vegetation and localized disturbance on channel form.[13] Based on Program learning to date, revised species-specific target flows may be lower than the current targets. However, that does not mean that flows in excess of those targets would be excesses from a hydraulic perspective. This is because further reductions in annual flows and/or peak flow magnitude and duration would result in future channel adjustment, most likely through continued narrowing of the active channel. The existing flow regime is not competent to maintain suitably-wide unobstructed channel widths for whooping crane roosting in most years and Program short-duration high flow releases will likely not substantially increase channel width. As such, the Program will have to invest in mechanical channel maintenance into the foreseeable future. Any further reductions in annual and/or peak flows and durations will increase the amount of mechanical intervention that is necessary.

Process for Updating Species Target Flows

In November of 2012, the Program's Independent Scientific Advisory Committee (ISAC) provided guidance to the GC on a proposed process for testing of target flows. The proposed process steps are summarized below and are a potential path forward to addressing target flows during the Extension.

1. EDO summarizes and distributes a summary of relevant target flow information to the TAC. *This was done in 2012.*
2. EDO does further homework on target flows and distributes a summary of relevant info to TAC. *The information in this memorandum is a first step towards completion of this task. It has been provided to the GC before the TAC given the time sensitive nature of Extension negotiations.*
3. Conduct a target flow symposium comprised of carefully selected leading scientists who are practical, neutral, and have applied concepts in different systems. Presenters would be prepared with all of the hard and soft constraints of the Platte River and how methods would apply to this system.
4. EDO and/or contractors would implement retrospective modeling approaches to gain a better understanding of methods, strengths and weaknesses of alternative approaches for the Platte River and the ability to combine species' and physical process needs.
5. Report findings to the GC including a summary of the symposium and recommendations on the way forward (includes written review by ISAC and potential peer review).
6. Conduct PRRIP workshops to develop conceptual model & hypotheses, using a variety of approaches.
7. Implement retrospective & prospective modeling to explore, develop, and converge on species-specific flow targets, building support gradually with frequent GC updates.
8. Develop technical report documenting results and rationale, with summary to GC.
9. Peer review the technical report.

[13] Disturbance is typically due to mechanical actions although in some locations livestock grazing of the channel also occurs.