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RESULTS OF A WHOOPING CRANE ROOSTING HABITAT MODEL WORSKSHOP

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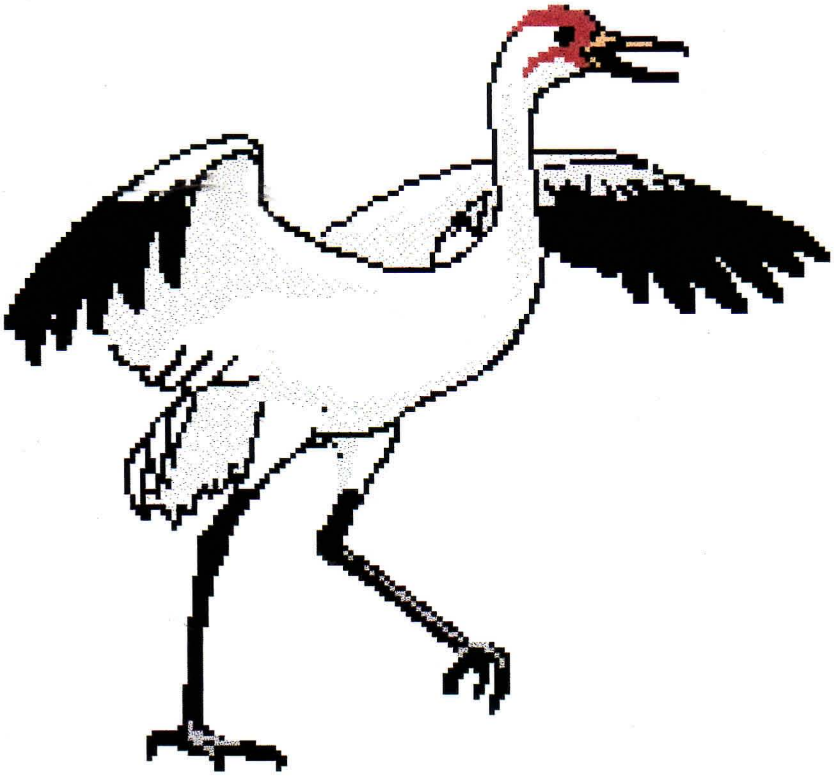

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INTRODUCTION

Since the early 1980's, the U.S. Fish and Wildlife Service has been refining a Habitat Suitability Index (HSI) model for the Whooping Crane (*Grus americana*) to aid in water management along the central Platte River of Nebraska. A comprehensive test (Farmer et al. 2000) of the most recent version of the HSI model (Carlson 1994) was performed based on data for all documented crane roost observations that have been made along the Platte River; comprising 66 different crane observations (for 46 different birds or groups of birds) that were obtained between 1966 and 1999. This evaluation provided support for the model; cranes tended to select river roost locations that had higher unobstructed channel widths and wetted widths. However, the evaluation also identified some possible model modifications, especially for the depth criteria, that might strengthen the model's predictive ability.

The Grand Island Field Office of the U. S. Fish and Wildlife Service asked us to conduct additional analyses of the model's depth criteria and then to convene a workshop, involving authorities on Whooping Crane ecology, to review progress to date in evaluating the habitat suitability index model, and to recommend model modifications that seemed appropriate in light of recent model evaluations. This workshop was held at the offices of the Whooping Crane Habitat Management Trust near Grand Island, Nebraska on the 13th and 14th on February 2001. The workshop objectives and agenda, as well as the list of participants are included at the end of this report.

This report presents the results of that workshop in roughly the same sequence as the workshop agenda. Instead of documenting the specific dialog that occurred, we have attempted to summarize each of the important issues, the different perspectives that were expressed during the workshop on a particular issue, and any recommendations concerning resolution of that issue. Questions about specific details that may have been discussed during the workshop should be referred to Adrian Farmer (MESC, Fort Collins, Colorado) or Dave Carlson (USFWS, Grand Island, Nebraska).

HISTORICAL OVERVIEW AND MODEL ISSUES

Model History

Dave Carlson presented the following historical overview of the planning decisions that have driven development of the habitat suitability index model. In 1983, the U.S. Bureau of Reclamation (Reclamation) and the U.S. Fish and Wildlife Service (Service) initiated the Platte River Management Joint Study (PRMJS) with a purpose, in part, of removing the Service's jeopardy determination for whooping cranes on Reclamation's proposed projects in Colorado and Nebraska. The development of a habitat suitability model coupled to the Instream Flow Incremental Methodology (IFIM) was viewed as a logical, structured, and objective alternative to the professional opinion-based flow standards that were at the time used by the Service to evaluate proposed water development projects on the Platte River.

The Whooping Crane Roost Habitat Model evolved in several discrete steps. In 1986, two workshops, one by the PRMJS Biology Workgroup and a second by the Service, resulted in the development of habitat suitability index model (Ziewitz 1988). This model was based on professional interpretation of measurements collected at various documented river roost sites in the flyway. At that time, data were available for only eight roost sites on the Platte River, and channel profiles had been measured at only three of those sites. The habitat model underwent several progressive reviews by crane authorities and modeling staff at the National Ecology Research Center (NERC) in Ft. Collins, Colorado. Also, during this period a field protocol was developed for measurement of habitat variables at roost sites in a manner consistent with the Physical Habitat Simulation (PHABSIM) model, allowing the habitat model to be coupled to hydraulic simulations of the river.

During 1987-1990, a number of alternative HSI models were developed and evaluated by the PRMJS based on measurements from 21-24 Platte River roost sites as well as measurements made at other riverine roost locations in the flyway (Carlson et al. 1990). Further investigations to refine the depth criteria were completed by the subcommittee during 1990-1991. The resulting model, known as model C4R, was used by the PRMJS Management Alternatives Workgroup (1991-1993), and later formally documented (Carlson 1994).

The Service used the Carlson (1994) model during its 1994 section 7 consultations with the Forest Service on the "Front Range" projects, and during all subsequent consultations on federal agency actions resulting in depletions to the Platte River system. It has been used in several water rights hearings in Nebraska. Also, the model was the primary tool used to determine the Service's whooping crane instream flow targets for the central Platte River.

Model Structure

The habitat model produces an index of habitat suitability as a function of three habitat variables: unobstructed channel width, wetted width of the channel, and the cumulative distribution of depths in the wetted area. The model assigns a suitability index, from 0.0 (unsuitable) to 1.0 (optimum) (see Carlson 1994), to an entire cross-section as follows:

a. A channel cross-section is assigned a value of 0.0 if the unobstructed width is < 170 ft.
b. For channels that equal or exceed 170 ft. in width, the suitability is a product of two indices: an index of the wetted width (Fig. 1), and an index of the water depth. The water depth index is computed by overlaying Figure 2 with the cumulative depth distribution (CDF) for the channel at a given flow. If 100% of the CDF falls inside the envelope of Figure 2, the suitability index is 1.0; if only 50% falls within the envelope the suitability index is 0.5, and so on.

As implemented with outputs from PHABSIM, the suitability index for a cross-section, as computed above, is multiplied by the surface area of its associated river reach to produce the number of weighted-useable-area (WUA) units associated with the cross-section. This is repeated for other cross-sections in a 'study site', the WUA is added for all cross-sections, and the sum is converted to another index, the WUA/1000ft of channel. This index is multiplied by the length of a river segment (in 1000's of feet) to compute the WUA in that river segment. However, portions of a river segment are excluded from the length calculation if they are within ½ mile of a known human disturbance. Hence, disturbances reduce the 'length' of suitable river habitat to which the suitability index (WUA/1000 ft) is applied.

Identified Model Issues

Several modeling issues have been raised since 1990, especially in the State of Nebraska's Platte River instream flow hearings. These model issues include the following.

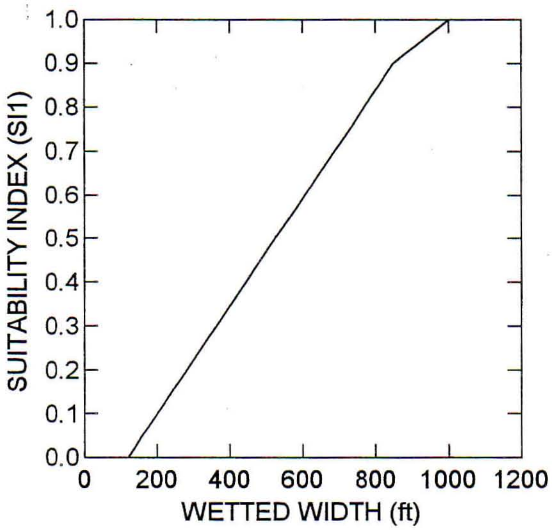

Figure 1. The suitability index for wetted width of channel (from Carlson et al. 1994).

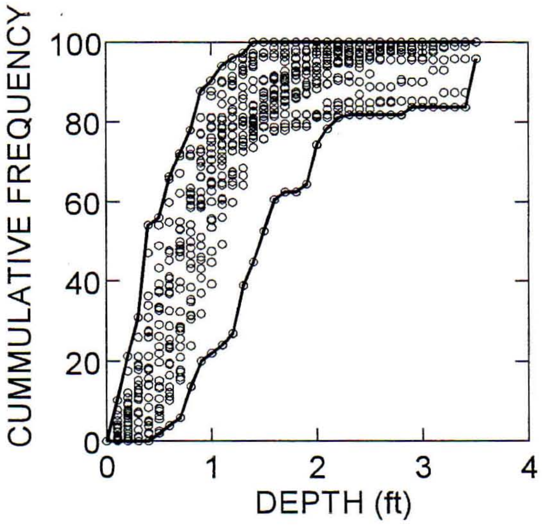

Figure 2. The cumulative depth distribution of cross-sections for 28 separate Whooping Crane observations. The plotted lines are the extreme of the 28 observations, and form an envelope used to compute a suitability index for other river cross-sections.

Water depth criteria.— The PRMJS Biology Workgroup subcommittee elected to use the CDF envelope for 28 crane observations (Fig. 2) to compute a suitability index for water depth because this approach was based on actual crane observations. Several conceptual problems are inherent to the approach and, consequently, it has been the object of criticism. The CDF approach reduces the suitability of wide, shallow channels (where cranes roost) if there is little or no deep water in the channel (where cranes can not roost). Furthermore, the spatial location of the required deep water is irrelevant; it may be located 1000's of feet from a specific roost point. Conversely, channels that are mostly deep water with little shallow area are given some suitability >0.0. Specific reasons for the requirement for deep water was not included in model documentation, nor is there any empirical evidence to support the need for deep water. These are conceptual issues, but a very practical criticism is that use of the CDF approach, which requires some deeper water, elevates the estimated flow requirements beyond that which is needed by the cranes. Elevating the discharge above the stage that first fills the channel, in fact, can reduce the proportion of wetted channel in depths (<1 ft) used for roosting. Furthermore, recent crane sightings (i.e., post-1990) are clustered toward the shallower range of Figure 2, suggesting that deeper channels (and higher flows) would be overvalued by the existing model.

Channel width criteria.— Lacking a sufficiently large database, modelers assigned a linear relationship to channel width suitability. For example, an 800-foot-wide channel was given twice the suitability value of a 400-foot-wide channel. The larger database and use/availability analysis suggest a curvilinear model relationship. In relation to their availability, 800-foot-wide channels are far more frequently used (roughly 10x) than are 400-foot-wide channels.

Repeated Observations of Crane groups.--Some of the deeper channels in the 1990 database were from a single crane group that used the river for an extended period and used several different roost sites. Measurements are routinely taken at all roost sites used. One criticism raised by NPPD is that repeated measurements from the one group of birds represents "pseudo-replication," over weights this single group, and cannot reliably be used to represent river use by the Aransas-Wood Buffalo population.

Association with Sandhill Cranes.--Among the data used in the existing model were a number of roost sites used by young whooping cranes migrating with sandhill cranes. The channels used by the young are among the widest in the original database. The argument is repeatedly raised that these data bias the model results (i.e., because the birds were influenced by sandhill cranes, they do not represent true whooping crane behavior).

Additional Model Variables.—Other habitat variables discussed in previous workshops, for which adequate data did not originally exist, could be re-examined. One example of the later is a "sandbar" criterion. Although sandbar presence at roost sites was reported in some literature, little quantitative information on this feature existed. As such, most biologists originally consulted did not consider it essential that a sandbar criterion be included in the model.

SUMMARY OF MODEL TESTING

The following is a summary of model tests presented by Adrian Farmer and Brian Cade, and described in more detail in Farmer et al. 2000. The model was tested with data on 66 different crane roosting locations, collected from 1966 through 1998. Most of these roost observations were associated with specific data: river mile of the roost site, a depth profile at the site, river discharge at the time, and ancillary habitat data from the surrounding river reach. These data were used to test the model at two different spatial scales: river segments, and individual cross sections.

Large-scale (River segment) Model Evaluation

Two hypotheses concerning the distribution of roost sites with respect to attributes of the river channel were tested. First, if whooping crane roost locations were randomly distributed along the Platte River (i.e., there was no apparent selection), then the number of roost locations in each segment would be expected to be proportional to segment length. Thus, the following hypothesis was tested:

> H_0 - whooping crane (roosting) observations are distributed randomly along the river (i.e., the number of observations in each segment is proportional to segment length); versus
>
> H_A - whooping crane (roosting) observations are not distributed randomly.

Second, if whooping cranes roost sites were not randomly distributed along the river, such sites might be found in the wider river channels. It was assumed that the average width of the study site was representative of an entire segment in order to test the following:

H_0 - the number of whooping crane (roosting) observations is not related to unobstructed channel width; versus

H_A - whooping crane (roosting) observations are related to unobstructed channel width.

These hypothesis were tested using two different statistical approaches: 1) the correlation (Spearman's) between a segment's rank based on length, or width and its rank based on the number of crane observations, and 2) probabilities (based on multiresponse permutation procedures (MRPP) (Mielke 1991)) that river segments containing roost observations could be selected randomly from the 15 available segments with respect to their length (or width) and rank of length (or rank of width).

A test was also conducted to determine whether roost locations were selected in the more suitable river locations, as defined by the habitat model:

H_0 - whooping crane (roosting) locations are found in the river segments with the highest habitat suitability, defined as WUA/1000 ft; versus

H_A - whooping crane (roosting) locations are not distributed with respect to segment quality.

Each crane observation was assigned the habitat quality ranking for the segment and the discharge at which it occurred (1 = the highest quality segment at the discharge; 15 = the lowest quality segment at the discharge). Then a one-sample permutation test was conducted to determine if the ranks of the observations clustered about the median value (= 8.0 for 15 segments). If crane observations tended to be centered about the median value, there would be no evidence of selection for quality habitats (as defined by the suitability criteria). Conversely, crane observations displaced from the median toward numbers (< 8) representing higher quality habitat would be evidence that habitat selection is occurring and would provide support for the habitat model.

Of 15 river segments, 10 had roost observations (04a, 04b, 005, 006, 009, 8an, 8as, 08b, 10, and 12a) and 5 did not (2, 7, 8c, 11, 12b). There was no correlation (Spearman's rho) between a river segment's rank of length and number of roosting observations ($P = 0.487$). The lengths, or rank of lengths, of the 10 segments used by cranes were no different than a random selection of the 15 segments ($P = 0.386$ and $P = 0.384$ respectively), whereas if use were random with respect to segment length we would expect segments used by cranes to be the longer ones. Thus, it appears that whooping cranes roost observations are not distributed randomly along the Platte River.

There was a moderate correlation (Spearman's rho = 0.372) between a segment's rank of width and number of roosting observations ($P = 0.081$). The probability level of this test declines significantly ($P = 0.02$) if segment 12A is excluded. This very wide segment on the eastern end of the study area had only one roost site observation and, consequently, it is somewhat of a statistical outlier. Nonlinear functions (number of crane observations = $exp[\beta_0 + \beta_1 *$ average channel width]) for the 15 river segments were constructed with regression quantiles (Cade et al. 1999). These functions show a pattern that is consistent with an interpretation that wide channel width was a necessary condition for large numbers of cranes to occur but was not sufficient to guarantee that cranes would use a segment; however, narrow channel widths were sufficient to preclude large numbers of cranes.

Each of the 66 roost observations was assigned a ranking (1 to 15) based on the segment habitat suitability (WUA/1000 ft) ranking at the flow measured at the time of the roost observation. A one-sample permutation test shows a significant displacement from the median rank toward higher suitability ranks ($P < 0.0001$). Thus, it appears that whooping crane roosts are selected in the higher quality segments as defined by the model C4R. However, it could be argued that some of the earlier observations were actually used to construct the model and, thus, are not independent observations. We repeated the permutation test using only the roost observations made after 1993 ($n = 30$) and also found a positive relationship between habitat suitability and roost locations ($P < 0.001$).

Small-scale (Cross-section) Model Evaluation

The habitat model was also evaluated at the level of individual cross sections by comparing the characteristics of cross sections used for roosting by whooping cranes ("used") with characteristics of all channels within the corresponding study site ("available"). Forty-six observations of habitat use by whooping cranes were documented by the Service between 1980 and 1999 for which there were recorded discharges and channel depth profiles. Each of these 46 channel profiles was analyzed at the measured discharge to compute the following variables: 1) unobstructed channel width (UW_{used}), 2) wetted channel width (WW_{used}), and 3) the suitability index for the cumulative frequency distribution of depths (SId_{used}). An alternative variable for depth that had been used in earlier versions of the model, the wetted channel width <0.7 ft in depth ($WW<0.7_{used}$), was also computed.

The habitat considered "available" for these comparisons was the set of channel cross sections comprising the study site(s) within a river segment. Study sites had as many as 9 separate cross sections and, at some discharges, some cross sections spanned multiple channels. The same 4 variables were computed for each channel at the discharges associated with crane use. A single estimate of available habitat was obtained for a segment, at a given discharge, by computing an average value for each variable (UW_{avail}, WW_{avail}, $WW<0.7_{avail}$, and SId_{avail}), weighted by the reach length associated with each cross-section.

If whooping crane roosts were located randomly with respect to channel characteristics within a segment, the channel variables (1- 4 above) at crane roosts would be centered on the measures of available habitat, as defined by the weighted averages defined above. Because the tests compared channels used by cranes to those available across discharges and study sites where available channel characteristics might differ greatly, proportionate differences (e.g., $\Delta WW = [WW_{used} - WW_{avail}]/ WW_{avail}$) were chosen as the summary variable. The null hypothesis that the proportionate differences (ΔUW, ΔWW, $\Delta WW<0.7$, and ΔSId) had a median of zero was tested using a matched pairs variant of multiresponse permutation procedures (Mielke and Berry 1982). There was also an interest in learning if habitat selection varied with discharge, and therefore the change in proportionate differences as a function of river discharge was estimated with the 50th (median) regression quantile (Koenker and Portnoy 1996, Cade et al. 1999).

Comparisons of crane roosts with available channels indicated that habitat use was not random for all 4 variables ($P < 0.001$). Cranes used channels with greater unobstructed width, greater wetted width, greater wetted width <0.7 ft deep, and greater suitability indices for depth based on the cumulative distribution function. The magnitude of differences was greatest for $\Delta WW<0.7$ and was always positive, indicating consistent selection of roost channels with greater widths of channels <0.7 ft deep than available within study sites at all flows. Other variables had some negative differences and, thus, less consistent selection patterns.

There was little evidence that median proportionate difference in unobstructed channel width and wetted channel width changed as a function of discharge ($P > 0.175$). Thus, habitat selection for these variables appears to be constant across discharge. However, there was a strong increase in selective use of wetted widths of channels <0.7 ft deep ($\Delta WW<0.7$) as a function of discharge

($P = 0.001$), with increases across 3000 cfs an order of magnitude greater than for ΔSId. The pattern in $\Delta WW<0.7$ occurs because available wetted widths of channels <0.7 ft deep declined with an increase in discharge, whereas the cranes roosted in channels with a more constant distribution of wetted widths of channels <0.7 ft deep across discharges.

Alternative Suitability Criteria

Evaluation of the habitat model shows that it has some utility for predicting river channels more likely to be used by cranes. Evaluation of large-scale patterns indicates that cranes tend to use river segments that, on average, have greater unobstructed channel widths, and the small-scale results show that cranes also tend to select the wider, wetted cross-sections within a segment. Thus, the Service could continue to use the model with some confidence that habitat ratings at the segment and transect level would be technically sound and defensible.

The analyses suggest, however, that there is substantial room for improvement. The suitability index for cumulative depth distributions (*SId*), for example, was a weak predictor of crane usage. This particular function is complex, difficult to explain, and cannot be defended on purely ecological terms. An alternative is to replace the cumulative depth function with a much simpler variable such as 1) the wetted width of channel <0.7 ft deep, or 2) the wetted width of channel <0.7 ft deep and more than 80 ft from an obstruction. Such a variable was, in fact, used in an earlier version of the model. The preceding evaluation showed that wetted width <0.7 ft has the strongest pattern of selective channel use by cranes as a function of discharge. Furthermore, it is related to an easily justified physical restriction on depths where cranes can stand in moving water.

There would be several ways to implement a variable based on 0.7 ft depth in place of the cumulative depth function. For example, a simple suitability function would assign an index = 1.0 for any channel transect that exceeds the weighted average for wetted width <0.7 ft deep within a segment at a specified discharge, and would assign an index = 0.0 for any channel transect that is less than this weighted average. A second alternative suitability function would be to assign an index =1.0 for any channel transect with ≥ 100 ft of wetted width < 0.7 ft deep (nearly all crane observations exceeded this width) and to assign an index = 0.0 for any channel transect with < 100 feet of wetted width <0.7 ft deep. Any alternative function based on wetted width <0.7 ft deep, however, is likely to result in less WUA at higher discharges compared to the original depth suitability (*SId*).

EVALUATION OF ALTERNATIVE DEPTH CRITERIA

Based on the previous model evaluation (Farmer et al. 2000), the Midcontinent Ecological Science Center was asked to go farther and perform additional evaluations of alternative depth criteria. Farmer and Cade described the additional evaluations that were recently conducted. Eighteen alternative depth criteria, based on a range of suitable depths, were defined (Table 1). Each of these criteria were applied in a binary fashion: any portion of the river channel between the specified minimum and maximum depths, and at least a "Buffer" away from a visual obstruction was deemed to be suitable. All other portions of the river channel not meeting the criteria were deemed unsuitable. In turn, each of the criteria was substituted in the model for the cumulative depth criteria, and a series of computer runs were made with the model to compare the cumulative depth criteria with the 18 alternatives. Two analyses were conducted: 1) a sensitivity analysis to investigate the relative effects of varying minimum depths, maximum depths, and 2) a comparison of alternatives based on the crane observations.

Table 1. A description of 18 alternative depth criteria evaluated for modeling Whooping Crane roosting habitat. For each criteria, suitable roost sites have water depths between the specified minimum and maximum and must be at least as far as "Buffer" from a visual obstruction.

Criteria	Min. Depth (ft)	Max. Depth (ft)	Buffer (ft)
1	0.0	0.7	0.0
2	0.0	1.0	0.0
3	0.0	1.5	0.0
4	0.0	0.7	40.0
5	0.0	1.0	40.0
6	0.0	1.5	40.0
7	0.0	0.7	85.0
8	0.0	1.0	85.0
9	0.0	1.5	85.0
10	0.25	0.7	0.0
11	0.25	1.0	0.0
12	0.25	1.5	0.0
13	0.25	0.7	40.0
14	0.25	1.0	40.0
15	0.25	1.5	40.0
16	0.25	0.7	85.0
17	0.25	1.0	85.0
18	0.25	1.5	85.0

Effects of Depth Criteria on Maximizing Flows: A Sensitivity Analysis

Each of the alternative depth criteria were substituted in place of the cumulative depth function and then the model was run using randomization procedures described in Farmer et al. 2000 to identify 1) the discharge that would maximize the WUA of roosting habitat based on that depth criteria, and 2) the 95% confidence limits around the maximizing discharge. The results of that series of model runs for the entire study area (river segments 2, 4a, 4b, 6, 7, 8as, 8an, 8b, 8c, 9be, 9bw, 10, 11, 12a, 12b) are shown in Figure 3. Several patterns were apparent.

1. *Buffers have little affect except in combination with the deeper criteria.* Three buffer distances, up to a maximum of 85 ft or half the width of the narrowest channel used by cranes (170 ft), were analyzed. The intent of introducing a buffer was to add a spatial aspect to the analysis. Whooping cranes select shallow water (as defined by the depth criteria) for roosting, but those shallow areas near visual obstructions may not be useable because cranes avoid sites near banks and tall vegetation. Buffer size has some effect on maximizing flows when used in conjunction with a maximum depth of 1.5 ft. However, for maximum depths of 1.0 ft or less, more realistic values for whooping crane roosting areas, the choice of buffer distance would have little effect on recommended flows.
2. *Changing the minimum depth has little effect.* As with the buffer distance, changing the minimum depth between 0 and .25 ft (3 inches) makes little difference in maximizing discharge. The biggest effect occurs in conjunction with a maximum depth of 1.5 ft.
3. *The maximum depth can significantly affect the maximizing flow.* The choice of maximum depth between 0.7 ft. and 1.0 ft has little effect on the maximizing flow. However, defining suitable depths to include a maximum of 1.5 feet significantly elevates the maximizing flow. A conclusion that can be reached here is that modeling results are relatively insensitive to the choice of a maximum depth, as long as it is between 0.7 and 1.0 ft.; the range supported by all earlier versions of the habitat model.
4. *The CDF gives the highest maximizing flow.* Compared to all the alternative depth criteria, the currently used CDF results in the highest maximizing flow.

The amount of WUA was plotted against discharge for the <0.7, <1.0, and <1.5 foot depth criteria for segment 6. There was a strong decline in WUA with discharge for both the <0.7 and <1.0 foot depth criteria but very little change with the <1.5 foot depth criterion (Fig. 4). Farmer and Cade also examined the distribution of individual wetted channel widths by discharge for the <0.7, <1.0, and <1.5 foot depth criteria as well as total wetted width. Wetted channel widths obviously decreased from the <1.5 foot depth to <0.7 foot depth criteria but there was only a very modest decrease in the average wetted channel width with increasing discharge as indicated by a lowess smoothing function (Fig 4).

Comparing Depth Criteria Based on Crane Observations

The alternative depth criteria were evaluated with the crane observations from river segment 6 where the majority of crane roosting observations occurred ($n = 23$). To compare channels used by cranes to those that were available within segment 6, at the discharges corresponding to crane use, proportionate differences (e.g., $\Delta WW{<}0.7 = [WW{<}0.7_{\text{used}} - WW{<}0.7_{\text{avail}}]/WW{<}0.7_{\text{avail}}$) were used as the summary variable. The null hypothesis, that proportionate differences were centered about zero, was tested using a matched pairs variant of the multiresponse permutation procedures (Mielke and Berry 1982), which assumed that channel availability in all of segment 6 was proportional to representative reach lengths within the study site. Farmer and Cade computed the proportion of the available channels for which wetted width was less than or equal to the wetted width of the channel where the cranes were roosting, and also computed these proportions based on the suitability index for the original CDF depth function. These proportions were then tested against the null hypothesis that they were centered about 0.5 (the median) using a matched pairs variant of multiresponse permutation procedures. This null hypothesis corresponds to channel widths used by cranes having the same distribution as channel widths available at a given discharge; i.e., cranes are choosing roost sites randomly.

Within segment 6 there was little evidence that channels used by cranes differed from those available when based on the depth suitability described by the original CDF function (MRPP, $P = 0.3503$). If anything, the analysis suggests that there were many channels available that exceeded the suitability of channels used by cranes when described by the CDF function, especially at lower discharges (Fig. 5). However, the <0.7, <1.0, and <1.5 foot depth criteria indicated that channels used by cranes were greater in width than 70% of the channels available at a given discharge (MRPP, all $P < 0.0001$).

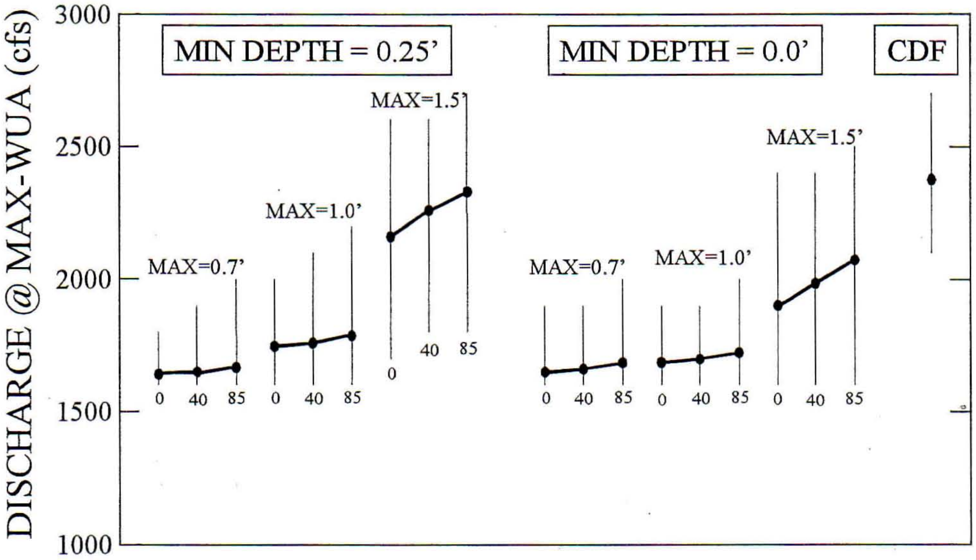

Figure3. The WUA-maximizing discharges for the cumulative depth distribution and 18 alternative depth criteria, for all 15 river segments combined. The vertical bars are the 95% confidence limits around the median maximizing discharge. Numbers at the bottom of the vertical bars are the assumed buffer distance (ft).

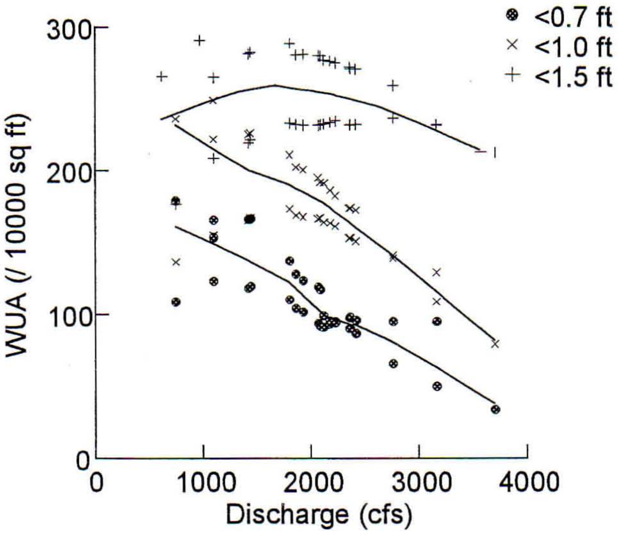

Figure 4. The area of suitable roosting habitat as a function of discharge for three maximum depth criteria (minimum depth = 0, buffer = 0) in segment 6.

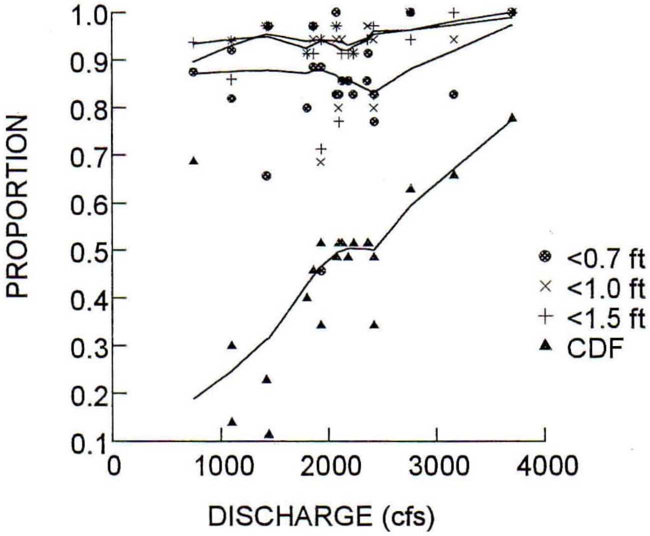

Figure 5. Proportion of simulated channel wetted widths less than or equal to the wetted widths used by cranes based on three maximum depth criteria (minimum depth = 0, buffer = 0) and the CDF in segment 6. Lines are 'lowess' smoothing functions fitted through the respective data points.

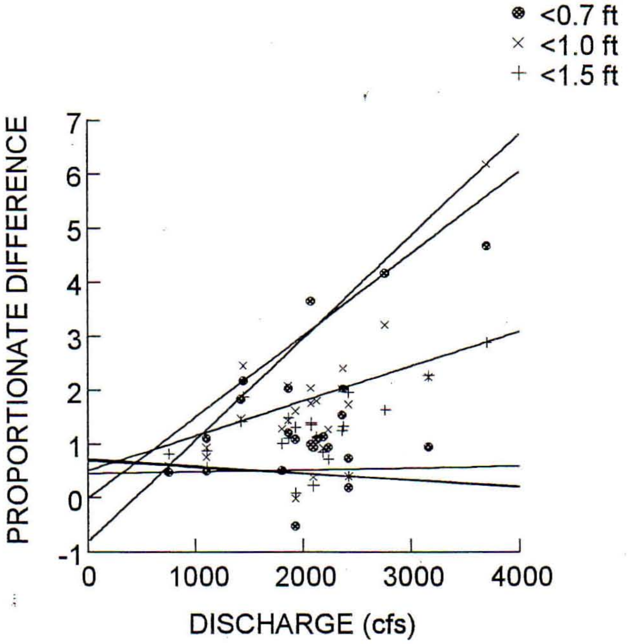

Figure 6. Proportionate differences in wetted channel widths used by cranes and the weighted average wetted widths from simulations for three maximum depth criteria (minimum depth = 0, buffer = 0) in segment 6. The 90th (higher lines) and 10th (lower lines) regression quantiles are shown.

The proportionate differences based on weighted averages for available channels also indicated nonrandom selection for the <0.7, <1.0, and <1.5 foot depth criteria (MRPP, all *P* <0.0001), with the variation in proportionate differences increasing with increasing discharge as estimated by 10th and 90th regression quantiles (Fig. 6). This analysis lends additional support to considering one of the alternative depth criteria (wetted channel widths <0.7, <1.0, or <1.5 foot depth) for describing suitability of channels for roosting cranes.

ANALYSIS OF WETTED WIDTHS VERSUS DISCHARGE

Mike Armbruster described an analysis that had been conducted by the U.S. Bureau of Reclamation aimed at understanding the overall relationship between discharge, channel morphology, and habitat suitability. This analysis looked at the discharge-depth relationship for Sandhill crane roosting habitat at eight sites located from below (downstream) the J-2 return (Site 2) downstream to Chapman (Site 12A), and represented by multiple transects (n = 47) measured between 1984 and 1986.

Roosting area— represented by mean transect length in a 3-9" depth range—was maximized in a range of discharges between 900 and 1,600 cfs at these eight sites. The average discharge at which transect length in a 3-9" depth range was maximized was 1,200 cfs. At 1,200 cfs, the average transect length in the 3-9" depth range was 303 feet at the eight sites. As discharge increases, roosting area—represented by the 3-9" depth range —is reduced. For example, at 2,400 cfs the mean transect length in the 3-9" depth range was 168 feet. Six of the sites were resurveyed between 1998 and 2000, and illustrate a similar pattern. Roosting area (3-9" depth range) was maximized (401 feet) at 1,033 cfs. At 2,400 cfs, four sites exhibited a mean transect length in the 3-9" depth range of 235 feet.

These simulated values can change with changes in measured flow at the sites, and with evaluation of different depths. However, a similar pattern remains. There is a range of discharges (700 to 1,600 cfs for the 3-9" depth range at surveyed sites) that occur after the channel first fills that maximize roosting area for Sandhill cranes. The discharge at which the channel first fills varies at each site. When the mean transect data (1984 to 1986) for the eight sites discussed above are plotted (discharge vs. wetted transect length), a few sites show a distinct flattening of the wetted width curve at 1,200 cfs (Fig 7). Such flattening in the curve occurs because wetted width increases sharply for initial increases in discharge, however the rate of increase in wetted width declines after the riverbed becomes fully wetted. At higher discharges, there is little remaining uninundated channel for the additional water to occupy.

The analysis presented here is based on aggregation of transects from eight sites, and the channel filling discharge likely varies at each site based on channel width, depth, and bed morphology. It is likely, however, that the channel filling discharge for individual sites is less than 1500 cfs.

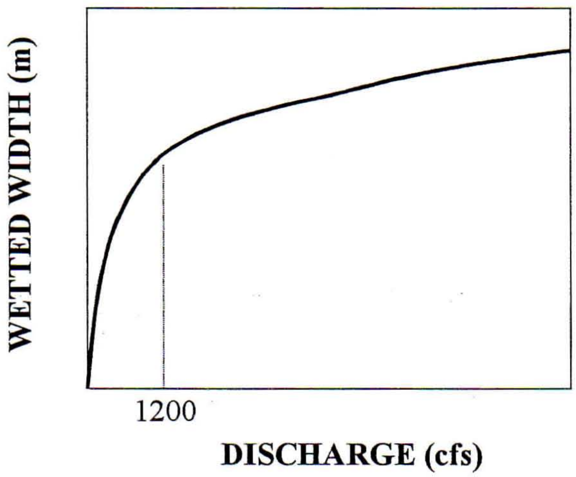

Figure 7. Approximate form of the relationship between wetted width of channel and discharge as observed at selected Platte River channels by U.S. Bureau of Reclamation in their simulations.

DISCUSSION OF DEPTH CRITERIA

There was considerable discussion following the presentations on the various evaluations of depth criteria. There was a consensus that the simple depth criteria, such as in Table 1, seemed to be the appropriate way to model suitability, but there was no consensus which specific depth criteria, including possible criteria not identified in Table 1, was best.

The concept of using the model to identify the discharge that maximizes roosting habitat was questioned, however. Historically the model has been used to identify the discharge that would maximize WUA of roosting habitat. When using the alternative depth criteria in Table 1, however, it may not be desirable to maximize the total amount of river channel within the specified depth range, per se. That is because Whooping Cranes appear to be roosting on the "tops" of inundated sandbars, and it was suggested that they seldom roost in troughs even if the water depths are correct according to the model criteria (Figure 8). Hence, the appropriate management strategy might be to use the model to identify the discharge that maximizes the amount of inundated sandbar "tops." Further discussion led to the realization that this would require some operational definition of a "top", to distinguish them from "bottoms." Farmer and Cade agreed to perform further computer modeling in an attempt to define an alternative depth criteria involving sandbar "tops" and to compare that criteria to those previously analyzed.

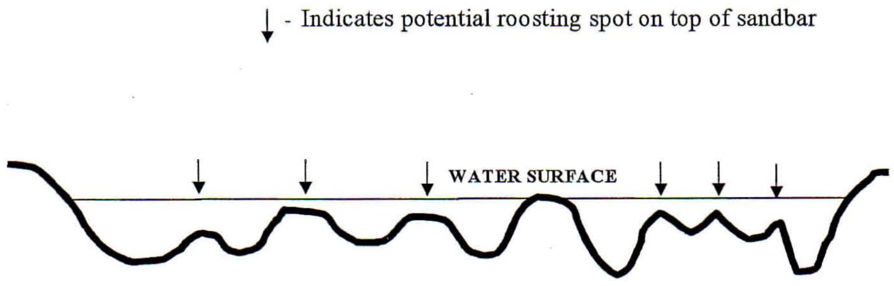

Figure 8. Conceptual diagram illustrating that crane roost sites tend to be located on the "tops" of sandbars.

The discussion of sandbar tops led to a discussion of the two-dimensional, landscape context of individual roost sites. Those who had conducted Whooping Crane aerial surveys have noticed that roost sites are clearly visible as relatively large, inundated "macroforms." Thus, it appears that cranes may select roost sites not based on depth alone, but also based on the presence of an inundated sandbar that has a minimum area, width, or breadth. Furthermore, a suitable macroform may need to be located a minimum distance away from the banks, as well as from perceived obstructions both up- and downstream. There was discussion about how one might use the existing crane roosting data to evaluate these landscape factors, and it was concluded that the existing data were not sufficient for that purpose. However, in the coming years there will be renewed efforts by the Whooping Crane Trust and the Service to survey Whooping Crane Roost sites along the river, and the workshop group focused on defining protocols for future data collection that would help understand the landscape context of suitable roost sites. This protocol is defined as follows.

A Recommended Whooping Crane Survey Protocol

1. From an aerial survey, if a Whooping Crane is spotted in the river, acquire an aerial photo of the roost site with sufficient detail to delineate submerged bars and deeper channels. (It would also be desirable to photograph the high-use sites, to analyze the changes in bars through time).
2. Record discharge at the time of observation, as in the past.
3. Identify with the highest possible resolution, the specific coordinates of the crane's location in the river, especially with respect to the particular bar used for roosting.
4. Run three cross-sections across the roost bar to characterize the bar in two dimensions, i.e., its width and size. Measure depths and identify obstructions as in the past, and also measure unobstructed channel width.
5. Also collect random cross-section data in the same segment for later analysis to determine if there is selection for particular sandbar traits.
6. Measure distances to the following landscape features:
    a. nearest wet meadow
    b. nearest obstruction (however obstructions are defined – see next section).
7. Identify if Whooping Crane is associated with Sandhill Cranes or not.

Finally, it was recognized that the habitat model, with its associated depth criteria, only measures the amount of physical roosting habitat. The preceding model evaluations suggest that an alternative depth criterion be used in lieu of the CDF function and if such a decision were made, the result would likely be a lowering of the estimated discharge necessary to maximize roosting habitat. However, this remains only an estimate based on characteristics right at the roost site, and does not consider other factors. One such factor that was discussed is the perception that suitable roost sites must not only have the proper water depths, but they must also occur in close proximity to a wet meadow. Moreover, discharges higher than those required to produce the proper depths may be required to recharge wet meadows near the channel and, thus, the long-term maintenance of wet meadow habitat may necessitate higher flows than would be indicated by this model, which is a model of instream roosting habitat. This is an important area for future investigation, but is not an issue that is not pertinent to the roosting habitat model addressed in this report

OTHER HABITAT MODEL ISSUES

Several issues concerning the habitat model and its application were identified during the workshop. Each of these issues is briefly summarized below, along with recommendations made to resolve each particular issue.

1. *Additional data collection at Whooping Crane Roost sites.* At several points during the workshop, participants suggested that additional data be collected at future crane roost sites in order to further clarify roosting habitat requirements. The additional data needs were combined into the recommended protocol presented earlier in this report.
2. *The definition of an obstruction.* The term 'obstruction', as used to define the boundaries of channels, is not as clearly defined as it might be. Generally, an obstruction has been taken to be any bank or vegetation in the channel that is taller than 1 m. There was a discussion about revising the definition, including: 1) using a height different than 1 m; 2) using a height for vegetation different than for banks; 3) clarifying how to measure height; 4) using different heights for different types of vegetation that vary in density; and 5) using a 360^0 panoramic video-view of selected sites to better characterize the obstruction from the crane perspective. However, no consensus was reached on these issues.

3. *Inconsistent coding of obstructions (code 50) in the IFG data files.* When the river cross-sectional data were collected, more than 100 data points were established for some of them. However, the data had to be trimmed to no more than 100 data points in order to execute in the older PHABSIM software and when this was done, some points representing obstructions were eliminated. Hence, the location of obstructions appears to change significantly among the different visits to a study site, and some of this variation is an artifact of the way the data were trimmed. This was recognized by Farmer et al. 2000, and Dave Carlson indicated that he was attempting to use the original field notes to correct these errors, although the process was very tedious.
4. *Updating river cross-sections.* The U.S. Bureau of Reclamation in updating many of the study site cross-sections and it was generally believed that these new data, representing current channel conditions, should be incorporated into future model runs.
5. *What is the correct width for disturbance buffers?* Sections of the river within ½ mile of a defined human disturbance (e.g., roads, bridges) are defined as unsuitable, and are excluded from the WUA calculations. There was some discussion about revising the buffer distance, but no consensus was reached.
6. *Incorporating other variables into the habitat model?* The habitat model has historically included only channel related variables because it was developed, at least in part, to help develop recommendations for river flows necessary to sustain roosting habitat. Other non-river habitat components might also be included, and several possibilities were discussed (e.g., proximity to wet meadows). However, it was recognized that the purpose of the model must be resolved before decisions are made to expand the model.
7. *Model purpose?* The habitat model has been used to set flow recommendations, and it is used in some sense to support impact assessments for projects that would alter the river flows. However, the protocol for applying the model to assessments is not clearly articulated, and there are other potential management applications for the model. Further model evaluation and modification would be facilitated by clarifying these potential applications.
8. *Algebraic issues with the habitat model.* In applying the habitat model, the suitability index of a cross section is multiplied by the unobstructed area (not just the wetted area) of the channel to produce WUA, even though cranes use only the wetted portions of the channel. This implies that the un-wetted, but open channel area is an important

component of the habitat. There was a consensus that this seemed to be a justifiable assumption.

9. *Single Whoopers roosting with Sandhill Cranes.* The question arises as to whether single Whooping Cranes that roost within a flock of Sandhill Cranes are good indications of Whooper habitat preferences. This was perceived as something of a "red herring" because there is no evidence that Whooping Cranes that roost in association with Sandhill Cranes choose roost sites with different characteristics than those they choose in the absence of Sandhill Cranes. Nonetheless, it was suggested that the Whooping Crane roosting data could be partitioned into two groups, those with and without Sandhills, and the tests repeated to look for any differences that might occur. However, the covariate presence/absence of Sandhills was not recorded for the observations in the current database
10. *Multiple observations of single Whooping Cranes.* Several people have questioned whether it is proper to utilize multiple observations of individual cranes to evaluate the model. As there were relatively few instances in the present database where known individuals were observed >1 time during a given year, there is really no effective way to deal with this issue in a formal statistical sense. Some of the concern related to this issue may be defused by recognizing that the 'statistical population' for inferences in the present analysis was the population of roost locations, not Whooping Cranes.

WORKSHOP FOLLOWUP ACTIVITIES

1. The Midcontinent Ecological Science Center (MESC) will attempt to identify additional specifications for the protocol for collecting Whooping Crane roosting data, as they perform additional evaluations of the habitat model.
2. A full report of the workshop proceedings, including details of the model testing, will be sent to workshop participants for their review.
3. Farmer and Cade will attempt to identify and evaluate additional depth criteria and, in particular, will try to develop an algorithm for identifying and the "tops" of sandbars.
4. Dave Carlson will send additional data on specific crane locations that were not given to MESC for the initial analyses of cross-sections used by cranes. MESC, in turn, will look for ways the crane location data may be used to analyze the landscape context of roost sites.

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WORKSHOP OBJECTIVES

1. Review the C4R (Carlson 1994) habitat suitability model in light of USGS/MESC testing results.
2. Identify and assess alternative depth criteria, and reach a consensus on the best alternative(s) based on crane observations and expert opinion.
3. Identify additional variables that should be incorporated into the model, and develop a plan for accomplishing model revisions.

WORKSHOP AGENDA

13 February	
8:00 – 8:30am.	Introduction of workshop participants.
8:30 – 8:45am.	Review workshop agenda.
8:45 – 9:45am.	Platte River Whooping Crane habitat model – Historical overview.
9:45 – 10:15am.	Break.
11:00 – 12:00am.	Results of model testing by USGS/MESC.
12:00 – 1:00pm.	Lunch
1:00 – 1:30pm.	Overview of alternative depth criteria
1:30 – 2:45pm.	MESC's evaluation of alternative depth criteria.
2:45 – 3:00pm.	Break
3:00 – 5:00pm.	Discussion of alternative depth criteria

14 February	
8:00 – 9:30am.	Continued discussion of alternative depth criteria.
9:30 – 10:00am.	Break.
10:00-12:00am.	Consideration of additional model variables and relationships.
12:00 – 1:00pm.	Lunch.
1:00 – 3:00 pm.	Identification of IFG hydraulic model issues.
3:00 – 5:00pm.	Workshop synthesis: identification of follow-up activities and responsibilities

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