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IRRIGATED WETLANDS OF THE COLORADO PLATEAU:

INFORMATION SYNTHESIS AND HABITAT EVALUATION METHOD

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DISCLAIMER

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SUMMARY

Wetlands of the Colorado Plateau that receive water from irrigation can, by their functions, support several societal values. For example, their capacity for removing nitrate and perhaps pesticides from nonpoint source runoff might be considerable. However, relatively little research has been conducted in irrigated wetlands, and their ability to alter water quality in particular remains relatively unknown.

Much more documentation exists concerning the importance of irrigated wetlands as habitat. About 72% of all reptiles, 77% of all amphibian species, 80% of all mammals, and 90% of all bird species which occur regularly in the Colorado Plateau region routinely use irrigated wetlands and riparian areas. About 30% of the region's bird species use wetlands and other aquatic areas to the exclusion of upland habitats. Wetland and riparian habitats also support a disproportionate number of species that are of concern because they migrate to neotropical areas, have small continental populations, or are declining. Virtually all wetland and riparian habitats in agricultural areas of the Colorado Plateau are sustained to some degree by runoff and seepage from irrigation.

No single characteristic (i.e., "indicator") reliably predicts which irrigated wetlands comprise the best habitat. Rather, habitat quality is associated with various combinations of the conditions of several indicators, at several scales. The most predictive indicators are probably patch size, water regime, vegetation form and species, aquatic organism abundance, and landscape context. However, attempts to identify indicators of "good" irrigated wetland habitat encounter a problem of defining "good for <u>which species</u>?" The importance of each indicator, or of each unique combination of indicator conditions, depends on the values placed on the species associated with it. Many indicator conditions are ideal for only a few species, but if these species are particularly valued (e.g., because they are regionally rare, declining, or hunted), then the indicator conditions can be considered important.

To help address the need for an explicit, integrated, local-scale approach to biodiversity assessment, this report introduces a new procedure for rapidly evaluating wetland and riparian habitat. In contrast to existing methods, it does not require the user to judge a habitat based on the habitat's suitability for just a few "indicator species." Rather, the procedure addresses the question, "good for which species" by estimating explicitly the quality of a habitat for <u>all</u> wetland/riparian species of the region's most diverse vertebrate taxonomic group -- birds. The procedure estimates the number of species likely to occur regularly in a particular wetland and uses this to assign importance to the wetland. The user can employ the procedure to evaluate a wetland using any subset of the species, and to select combinations of wetlands that will maximize avian diversity at local and regional scales. The procedure's emphasis on biodiversity and an ecosystems approach is consistent with current shifts in scientific thinking and the mandates and operations of many resource agencies. The procedure requires less than 30 minutes per wetland to implement. Information from systematic field testing has been used to improve the procedure and its supporting database. Additional validation, by comparing evaluation scores with actual species richness as measured by direct multitemporal surveys of birds and other vertebrates, is desirable.

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This report would not have been possible without the gracious assistance of many resource managers in Colorado and Utah, who provided background information and opinions on the wetland resource, irrigation practices, and local wildlife habitat requirements. In particular, I thank those who assisted with the field-testing of the habitat evaluation method and/or showed me irrigated wetlands in their locality: Nelson Boschen (Moab, UT), Brent Draper (Soil Conservation Service (SCS), Roosevelt, UT), Dave Galinat (Olathe, CO), Ron Lambeth (U.S. Bureau of Land Management (BLM), Grand Junction, CO), Steve McCall (U.S. Bureau of Reclamation (USBR), Grand Junction, CO), Doug Meaghley (SCS, Grand Junction, CO), Ed Neilson, Jr. (SCS, Grand Junction, CO), Paul Obert (SCS, Delta, CO), Maple Taylor (SCS, Montrose, CO), and Steve Woodis (SCS, Montrose, CO). Jim Garner (Colorado Division of Wildlife (CDW), Montrose, CO) and Wes Johnson (Utah Division of Wildlife Resources (UDWR), Salt Lake City, UT) kindly shared and facilitated transfer of computerized species databases of their agencies, which were helpful for developing the habitat relationships database for the Colorado Plateau. Michael Carter of the Colorado Bird Observatory generously shared his computerized database on conservation characteristics of neotropical migrants. More than 50 other persons were contacted and provided information for this study. I thank them all.

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1.0 INTRODUCTION

1.1 Problem Statement and Definitions

Many areas of the American West have been irrigated for almost a century to support agriculture. Water diverted from rivers is routed through pipes and canals to disperse it among agricultural lands in adjoining valleys. Traditionally, this river water has been used to flood fields, for about a day at a time, several times during the growing season. Water is applied in amounts and according to schedules that are not the same as natural precipitation. Much of the applied water leaves irrigated fields as groundwater from deep percolation and as surface runoff. As a result, the hydrologic, soil, and vegetation conditions that technically define wetlands have sometimes been unintentionally created, both within the on-farm areas which are irrigated directly, and particularly within many off-farm areas that receive irrigation runoff or seepage. These are termed "irrigated wetlands." Thousands of acres of irrigated wetlands that did not exist before this century have arisen on the landscape. In some instances the subsidizing irrigation water has extended the boundaries of the relatively few, historically present wetlands or increased the permanency of their water regime, to create what is termed "enhanced wetlands." In other instances irrigation water has caused wetland conditions to develop in soils that historically did not support wetlands, to create "induced wetlands."

As acreage of some wetland types has expanded regionally, wildlife species that once occurred seldom, if at all, in the region have become more widespread and dependent on irrigated wetlands. An example is the long-tailed vole (Ecology Consultants 1976). In some areas, the dependence of wildlife on irrigated wetlands has grown in proportion to loss of the very limited acreage of the few historically present, naturally formed wetlands or other natural land covers. Wildlife dependence on wetlands and other structurally intact vegetation also has increased as the quality or suitability of other wetlands and natural land cover has been diminished by artificial drainage, overgrazing, water diversions, water table drawdown, contamination, and other factors. In addition to sustaining wildlife, wetlands are capable of benefitting society in many other ways. Recent evidence from other regions in the U.S. points to the key role some wetlands -- whether natural or "artificial" -- can passively play in removing certain contaminants from farm runoff, reducing river flood peaks, maintaining water tables and low flows, and supporting recreation and tourism.

At the same time, concern exists over the fact that irrigation water, when it comes in contact with certain salt-rich soils at the land surface or in underlying aquifers, dissolves the salts and severely increases the water's salt content. Traditionally, fields in the region have been flooded as much to dilute and leach out the excess salts (which inhibit crop production) as to provide moisture for crops. As a result, at least 10% more water is applied than is needed to satisfy crop moisture requirements, and up to 60% of the applied water drains into rivers and wetlands downslope, bearing with it up to 70% of the salt once contained in the irrigated soil. Attempts to reuse this salt-enriched water at downriver locations for domestic, agricultural, or industrial needs are thwarted by the impalatability, toxicity, and corrosivity associated with high salt content.

Facilities are sometimes constructed at downstream locations to concentrate and remove the salt from river water, but they are costly. Attention has increasingly focused on introducing salt-tolerant crop strains, and reducing the introduction of salts at the source. Managers have begun to implement practices that reduce the amount of water leaving agricultural lands, and thus, the salt-loading of downriver areas. These practices involve adjusting the amount, timing, duration, and spatial distribution of irrigation water as it comes in contact with soils with high salt leaching potential. This is accomplished in many ways, such as lining dirt canals and stock ponds with concrete or other sealers, moving water through pipes instead of open ditches, and distributing water with sprinkler systems rather than by flooding fields. Government technical assistance and funding for these efforts has been facilitated by the Colorado River Salinity Control Act of 1974. Assistance is provided to farmers primarily by the U.S. Department of Agriculture's Soil Conservation Service (SCS) and the U.S. Bureau of Reclamation (USBR). Where the resulting improvements in on-farm efficiency of water use require less water to be drawn initially from rivers for irrigation use, aquatic ecosystems of the rivers might benefit from increased base flows as well as reduced salinity, and the acreage of riparian wetlands might increase toward levels historically present, perhaps compensating partly for whatever losses of irrigated nonriparian wetlands occur. However, flow regulation by dams, water rights restrictions, and institutional factors often prevent the realization of these potential benefits.

Reducing the amount of water that leaves irrigated fields surely reduces the amount of water available to sustain the functions of thousands of acres of wetlands that are located downslope from fields and supported by field runoff or seepage. In some instances, wetland hydrologic conditions in these wetlands have altogether ceased to exist. Wetlands that formerly existed along miles of canals and ditches can become dominated by upland plant species or other non-wetland land cover. Functions and values formerly provided to society by these wetlands could be lost or replaced by functions more typical of the nonwetland systems that prevail in the region. The long-term changes in vegetation species composition and dominance that occur with salinity control projects are being monitored by the USBR and SCS along permanent transects (pers. comm., S. McCall, USBR, Grand Junction, Colorado). Declines in wildlife associated with such vegetation changes were documented by Colorado Division of Wildlife (CDW) in a four-year, before-after, treatment-control study in the Grand Valley (CDW 1984). The study primarily addressed the effects on wildlife of lining the irrigation canals with concrete or other mostly impermeable material.

1.2 Study Background and Report Purpose

Despite these earlier efforts at identifying irrigation effects, it became apparent to EPA that a closer scrutiny and documentation of the possible functions and values of different types of irrigated wetlands was needed to strengthen wetland decision-making, especially in the context of mitigation planning and evaluation. Accordingly, this project was initiated and funded by EPA Region 8. The work was administered by EPA's Wetlands Research Program, headquartered at the Environmental Research Laboratory in Corvallis, Oregon. This report represents the first phase of an anticipated two-phase study, and primarily seeks to address the question:

> Are some of the irrigation-induced and -enhanced wetlands in EPA Region 8 capable of passively providing many of the **functions** attributed to wetlands generally? If so, which types of these wetlands are most capable of doing so, and which functions are they supporting?

This question is addressed through a review of key literature, interviews with scientists from both within and beyond Region 8 who are familiar with wetland functions, and the experience and professional judgement of the report's author. It has been beyond the scope of this project to employ field research and monitoring methods to determine the degree to which wetland functions occur in irrigated wetlands. One function is an exception -- the ability of irrigated wetlands **to provide habitat that sustains avian (bird) diversity.** In the context of this project, avian diversity is emphasized because (a) birds comprise the largest portion of the region's vertebrate diversity, and appear to be highly sensitive to irrigation inputs in this arid landscape, (b) avian diversity can be measured directly and cost-effectively, and (c) threats to biodiversity in general are a growing concern within EPA and other agencies. A second phase of the current EPA project may be implemented to address this topic more rigorously by collecting avian data from a series of irrigated wetlands. The project phase reported here has focused on literature review and analysis of existing regional data, and has covered hydrologic and water quality functions of wetlands (Section 3.0), as well as habitat functions (Section 4.0).

This report contains both a review of literature and expert judgement, and a description of a new, technically-documented procedure for rapidly evaluating wetland habitat (Section 5.0). Both are intended for use as one of several possible inputs to decision-making, where government actions attempt to mitigate the loss of wetland functions as caused by salinity control projects. Such government actions may involve decisions regarding (a) the desirable amount and type of replacement habitats or habitat enhancement measures, (b) methods used to measure and compile information on these, and (c) evaluations of their success. This report does not propose a classification system for irrigated wetlands or methods for distinguishing the degree to which a wetland is dependent on irrigation. Being a technical background report, this document uses the term "wetland" broadly and without specific definition, to include riparian, shallow water, and saturated soil habitats that contain woody or herbaceous hydrophytic vegetation.

2.0 CHARACTERIZATION OF IRRIGATED WETLANDS

2.1 Geographic Distribution

This report addresses irrigated wetlands that are associated with major salinity control projects of the Colorado Plateau (Figure 1) [1]. These wetlands are located primarily in the following five areas, termed "subregions" in this report:

Colorado
1. Grand Valley: the irrigated area surrounding the towns of Grand Junction and Fruita.
2. Lower Gunnison Valley: includes the Uncompahgre Valley and irrigated areas surrounding towns of Montrose and Delta.
3. Cortez: includes irrigated areas surrounding McElmo Creek and in the Mancos Valley.

Utah
4. Includes the Uinta Basin (irrigated areas surrounding towns of Vernal, Roosevelt, and Duchesne) and the Price-San Rafael area (irrigated areas surrounding towns of Price, Castle Dale, and Huntington)[2].

Wyoming
5. Includes the Big Sandy area (irrigated areas surrounding the town of Farson).

No comprehensive inventory exists of the wetlands in these subregions. Where information on wetland location or acreage exists, it is often of unknown or questionable quality. This is caused by several factors, including (1) a complete lack of National Wetland Inventory maps that are prepared by the U.S. Fish and Wildlife Service (USFWS) using standard methods, (2) changing government procedural definitions of "wetland," (3) changing acreage of wetlands as a result of ongoing irrigation management programs, and (4) lack of documentation and/or justification for methods used to arrive at previously published estimates of wetlands in some salinity control areas or subregions. In some areas, wetlands are being mapped on an ad hoc basis, farm-by-farm, as a salinity control contract with each farmer is considered. Digitization of all irrigated lands in the Upper Colorado Basin will be completed by USBR in 1993 (Henricksen and Hall 1992). All wetlands and land cover were digitized by USBR in the western half of the Grand Valley (Crane et al. 1986) and by SCS and others in the Uinta Basin (Ridd and Christensen 1980). However, neither of these data sets were made available to us for this report, and their quality is unknown.

Elsewhere in the United States, soil surveys sometimes are used to estimate the acreage of wetlands historically present. This approach cannot be used in the Colorado Plateau because only a very few soil series in the region are exclusively "hydric," whereas many span a gradient of hydric (wetland) to nonhydric (nonwetland). This occurs partly because hydric conditions often develop in a nonhydric soil after only a few years of direct application of water, or even of exposure to indirect irrigation seepage. Thus, any estimation based only on soils that are officially-designated as hydric is likely to severely underestimate the current acreage of wetlands.

2.2 Classification by Size and Type

As shown in Table 1, irrigated wetlands have not been classified in a systematic manner. This greatly complicates attempts to make comparisons among subregions. The most commonly applied classification

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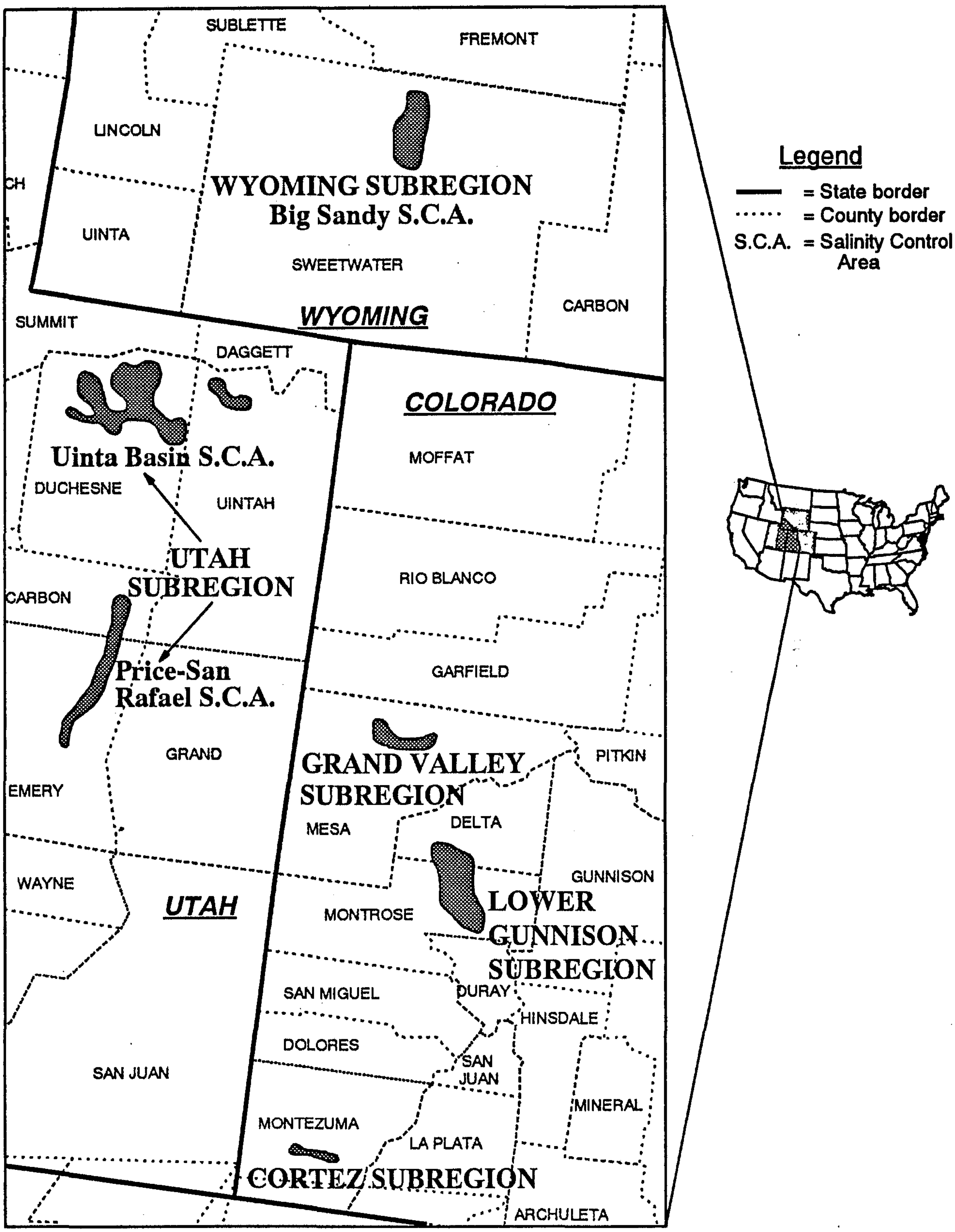
[1] Geographers differ with regard to the exact boundaries of the area considered to be the Colorado Plateau. Thus, the term is used loosely in this report, to include areas of Wyoming and Utah that some geographers consider to belong to other physiographic provinces.

[2] Irrigated areas also exist near Moab, Spanish Valley, and perhaps other places.

Figure 1. Subregions of the Colorado Plateau addressed by this report.



systems are based on wetland location, vegetation form, water depth and seasonal duration, and water source. Location (on-farm vs. off-farm, in-field vs. off-field), vegetation form, and water regime of irrigated wetlands are relatively easy to estimate during site visits. However, even after visiting a site it is difficult to determine conclusively the primary source of water that sustains a wetland. "Irrigated wetlands," as considered by this project, can range from wetlands that are completely supported by irrigation runoff at all seasons, to wetlands that exist naturally but for which any measurable amount of their water originates from irrigation, however indirectly (e.g., through seepage or raised water tables). In this sense, virtually all wetlands in irrigated regions could be considered "irrigated wetlands." However, determining whether the primary water source of a wetland is irrigation-related in many cases requires considerable judgement, and no highly replicable approach exists that is applicable to all situations. For distinguishing natural wetlands from those **recently** created by irrigation, analyses of sediments to determine seed bank species richness might be used. However, judging from seed bank data from other regions (Weinhold and van der Valk 1988), this approach would be unable to distinguish irrigated wetlands older than a few decades from natural wetlands. Similarly, soil organic matter may not be a suitable indicator of the origin, primary water source, or maturation rate of irrigated wetlands, because it probably does not accumulate consistently over time in most irrigated wetlands, but is probably mineralized to a large degree at the end of each growing season. In some wetlands, the presence of large cottonwood or willow stands, and resulting development of a soil litter layer, suggests considerable ecological maturity of the wetland. However, the lack of such woody vegetation does not necessarily mean a wetland is young because trees might have been cut or for other reasons might never have become established.

Most irrigated wetlands lack permanent water, are relatively small, are located near ditches and canals, and are dominated by just a few emergent (herbaceous) species of vegetation. Many are located on steep slopes, where seepage from irrigated fields in upslope plateau or mesa areas re-emerges at the land surface. This is in contrast to apparently "natural" wetlands of the same areas, which more often contain permanent water, are larger and mostly located in river bottomlands, and are often dominated by shrub and forested (riparian) vegetation. Anecdotal information suggests that few irrigated wetlands experience normal cottonwood regeneration because of overgrazing and the degree and manner in which river flooding is regulated throughout the region.

The mean size of irrigated wetlands along canals was about 24 acres in the Big Sandy, Wyoming, salinity control area, and about 4 acres in the Lower Gunnison salinity control area (Table 2). Forested wetlands that typically occur in bottomlands are generally much larger than emergent and shrub wetlands. However, estimates of the characteristics of irrigated wetlands are difficult to compare among studies. For example, in a rather comprehensive survey of the wetlands of the Lower Gunnison Valley, Rector et. al. (1979) reported more woody than emergent wetlands. Among the wetlands with woody vegetation, more were forested than shrub. Conversely, from a 3% sample of wetlands in the same area (mostly wetlands near canals), USBR (1991) reported shrub wetlands to cover a larger total area than forested wetlands. USBR (1991) also found forested wetlands in their sample to be generally smaller (mean of 1.3 acres, range 0.1-4.2 acres) than shrub wetlands (mean of 2.9 acres, range 0.1-12.1 acres) and especially emergent wetlands (mean of 5.2 acres, range of 0.1 to 22.3 acres).

2.3 Within-Region Differences

Land use and wetland data have not been collected in a manner that would allow comparisons among the subregions (Table 1). Thus, the following information is anecdotal, based entirely on the author's visit to each of the subregions during November 1992. The purpose of those visits was to ensure that the habitat evaluation method being developed (Section 5.0) included indicators appropriate for each subregion. Photographs of wetlands in each subregion are on file at the USEPA Environmental Research Laboratory, Corvallis, Oregon. The five subregions are characterized as follows:

1. Grand Valley subregion. Compared with the other subregions, wetlands here are more often surrounded by row crops (especially corn), are closer to human dwellings, and are smaller (mostly less than 20 acres).

Table 1. Acreage estimates for irrigated wetlands by location, wetland type, and water source.

Methods used to define, locate, and classify wetlands and estimate their acreage varied greatly among locations. Totals in each of the three blocks below should add independently to the "Total Wetland Acres Identified" on line two. Sources of discrepancies are unknown; the data are reproduced as given in original reports. Grand Valley data are from U.S. Fish and Wildlife Service (1984) and Crane et al. (1986). Lower Gunnison Valley data are from Rector et al. (1979). Uncompahgre Valley data are from a sample of wetlands in the Lower Gunnison area, as reported by the U.S. Bureau of Reclamation (USBR 1991). Cortez data are from SCS (1989). Utah data pertain only to the Price-San Rafael area and are from USBR and Soil Conservation Service (SCS 1991). Although other data exist for Utah (Uinta Basin wetland inventory by Ridd and Christensen 1980) they were not included because they were not received. Wyoming subregion data pertain to the Big Sandy salinity control area and are from the SCS (1989).

Salinity Control Area:	Grand Valley	Lower Gunnison	Uncompahgre	Cortez	Utah	Wyoming
Acreage of Area Surveyed	63156	179889		29100		
Total Wetland Acres Identified	3546	21670	751	4254	25250	10171
Total On Farm Acreage		13350		3775	15059	
o In Field					10293	
o Off Field					3577	
o Bottomland					1189	
Total Off Farm Acreage		8320			10191	
o Canals		613		217		
o River/Bottomland		7707		262		
Total Woody Acreage	1970	10970	222		3620	
o shrub	1377	2376	182			
o forested	593	8595	40			
Total Emergent Acreage	1576	9625	529		11439	
Emergent Wetland Acreage:						
o narrow-leaved		5933				
o water interspersed		785				
o vegetated flat		247				
o pasture/hay					9015	
o sedge/grass					1993	
o cattail/rush					431	
o Type 1 (seasonally flooded)						254
o Type 2 (fresh meadows)						3771
o Type 3 (shallow fresh marshes)						29
o Type 4 (deep fresh marshes)						152
o Type 9 (saline flats)						2378
Open Water Acreage	697					
o Type 5 (open fresh water)						3410
o Type 10 (saline marshes)						177
By Estimated Source of Water:						
o Natural		13014				2538
o Field Runoff		3315				5211
o Canals		378				143
o Reservoir Seepage						3857
o Natural + Fields		4157				
o Natural + Canals		178				
o Natural + Fields + Canal		22				1010
o Fields + Canals		605				
o Fields + Canals + Reservoir						1269

Table 2. Mean acreage of various wetland types in the Lower Gunnison and Big Sandy Valleys.

Methods used to define, locate, and classify wetlands and estimate their acreage varied greatly among locations. Data are reproduced as given in original reports. Under the heading "By Water Source," each wetland was assigned to only one category. Lower Gunnison data are from Rector et al. (1979). The Wyoming data are from the Big Sandy area, as reported in Soil Conservation Service (1989).

Subregion:	Lower Gunnison	Wyoming
Mean Wetland Size	27	
On Farm, mean size	23	
Off Farm, mean size		
o Canals	4	
o River/Bottomland	249	
Woody Wetlands:		
o shrub, mean size	14	
o forested, mean size	69	
Emergent Wetlands:		
o narrow-leaved	20	
o water interspersed	14	
o vegetated flat	8	
By Water Source:		
o Natural, mean size	63	2538
o Field, mean size	17	14
o Canal, mean size	4	24
o Reservoir, mean size		32
o Natural + Fields	21	
o Natural + Canals	4	
o Natural + Fields + Canals	2	
o Fields + Canals	14	

Tamarisk (salt cedar) and Russian olive are prominent features of the irrigated wetlands located in washes. Salinity management consists mainly of lining and burying water delivery ditches.

2. Lower Gunnison subregion. These wetlands are most similar to those of the Grand Valley, but fewer wetlands are located close to human dwellings. Pinyon-juniper vegetation is encountered along the edge of some wetlands.

3. Cortez subregion. Wetlands here are more often surrounded by or contain pastureland and alfalfa. Willows are prevalent. Several wetlands are large (>40 acres) and dominated by cattail and/or cottonwood-Russian olive. Pinyon-juniper borders wetlands at higher elevations within the subregion. Salinity management consists mainly of converting from field-flooding to sprinkler systems.

4. Utah subregion. These wetlands are generally similar to those of the Cortez subregion. Some wetlands have extensive stands of Russian olive.

5. Wyoming subregion. Wetlands here are largely pastureland. There is little wooded riparian or wash habitat. Willows are moderately prevalent but heavily grazed. There appears to be a greater density of small (<5 acre), seasonal ponds here than in the other subregions.

3.0 NON-HABITAT FUNCTIONS AND VALUES OF IRRIGATED WETLANDS

Wetlands, including ones artificially created by irrigation water, function in ways that have the potential to greatly benefit society. Probably the most widely recognized funtion of irrigated wetlands is their ability to support wildlife by providing habitat. This function (habitat) is the subject of a separate section of the report (4.0) and is the focus of a new evaluation method that is described in Section 5.0. To a large extent, habitat is supported by hydrological and biogeochemical functions of wetlands. These functions support other values, including but not limited to: improvement of water quality, maintenance of watershed hydrology, recreation, and production of harvested products. This section discusses these functions in the context of irrigated wetlands.

3.1 Water Quality Functions and Values

Hundreds of studies have documented the ability of wetlands, as a whole, to purify water. However, no credible studies have examined the water quality role specifically of **irrigated** wetlands or, for that matter, any lowland wetlands in the Colorado Plateau. If these wetlands serve the same functions as many wetlands elsewhere, they could be important in reducing nonpoint source pollution and maintaining watershed water quality in a variety of ways, such as:

1. Irrigated wetlands could be important for removing **excessive nutrients** (nitrogen and phosphorus) that cause algae problems in livestock watering ponds and dissolved oxygen deficits in lakes and river systems. For example, a Wyoming study (Hussey et al. 1985) found that riparian areas, compared to desert scrub areas, have much higher densities of microorganisms that remove nitrogen from runoff. Irrigated wetlands would be expected to play a greater role in removing nitrogen than retaining phosphorus, because of their relatively high soil organic content and the likelihood that much phosphorus is adsorbed by the clay-rich upland soils of the region before it reaches wetlands in runoff. Increases in irrigation efficiency, by reducing field runoff, can reduce off-farm export of phosphorus in runoff but might, by reducing wetland area, increase nitrate export to downslope rivers and reservoirs.

2. **Pesticides** and other toxic substances are often degraded and detoxified in areas that have high levels of organic detritus. The expected high plant production in irrigated wetlands probably supports a seasonally high level of organic detritus. Thus, irrigated wetlands, compared with other regional land cover types, might be particularly capable of degrading pesticides, and in some instances might do so without increasing the accumulation of pesticides in wetland food chains.

3. Irrigated wetlands, especially on grazed slopes, could be important to retaining and stabilizing runoff-borne **sediment**, at least temporarily. Such sediment otherwise diminishes the storage capacity of stock ponds and flood storage reservoirs, blocks light, and lessens the biological productivity of some waters.

4. Irrigated wetlands are likely to maintain water quality and reduce the toxicity of various contaminants by maintaining or reducing summertime water **temperature**, just as any plant cover does.

It is probable that many aridland wetlands, especially those that historically lacked permanent water but are located within washes, are located at sites where groundwater is naturally recharged (Heath 1982, Wood and Osterkamp 1984, Loken 1991). However, there is probably nothing about an irrigated wetland that encourages infiltration and recharge of groundwater; rather, some wetlands just happen to occur in places where recharge would occur regardless of wetland presence. Moreover, even if irrigated wetlands facilitate recharge of groundwater, the benefits of their doing so are seldom apparent in this region. In contrast to many other regions, only a small portion of the domestic drinking water in the Colorado Plateau is drawn from wells. Thus, even if some of the region's irrigated wetlands are capable of recharging groundwater, the benefits to the local welfare and economy would be relatively small. Ecological benefits are also unclear. Infiltration of runoff through soils in many parts of the Colorado Plateau is ecologically and economically undesirable, because such infiltration can increase salinity in wetlands and other receiving waters farther downslope.

Apparently only one study (Fannin et al. 1985) has attempted to statistically examine the natural landscape factors that influence nonpoint source pollution across the region. That study found that phosphorus concentration in rivers to be correlated with watershed soil erodibility, and nitrate concentration was correlated with the extent of Cretaceous rock formations. However, the role of wetlands was not examined.

It is difficult to speculate as to which characteristics of a particular irrigated wetland would make it more capable than others for retaining sediment, and for removing nutrients and pesticides. Processes that occur in irrigated wetlands and that are important to improving water quality include the following:

Water Deceleration/Storage: Wetlands, more than other landscape types, delay the downslope movement of water and increase pollutant processing time. They do so by increasing frictional resistance to runoff and focusing infiltration. Irrigated wetlands most capable of this might include those that lack outlets (e.g., farm ponds) or, to a lesser degree, those that have flat gradients with dense perennial vegetation and low hydraulic loading (i.e., large wetland area relative to amount of incoming runoff, such as wetlands fed mainly by groundwater).

Filtration, Settling, Burial, and Stabilization: Wetlands can physically confine suspended sediments or chemicals, causing their settling by physical processes (e.g., gravity), and their possible burial by erosion-resistant, accumulating layers of sediment or precipitate. Irrigated wetlands are most likely to cause filtering, settling, burial, and longer-term stabilization of incoming sediment where (a) such sediment is relatively coarse-particled, (b) the wetland is relatively sheltered from wind turbulence (e.g., deep, permanent water overlies the accumulating sediment layer), and (c) warm, hypersaline conditions (which otherwise can keep fine sediments buoyant and inhibit growth of stabilizing plants) are not present.

Deoxygenation: Partly because wetlands occur in flat terrain, water that passes through them experiences little turbulence and as a result, the water in wetlands typically has the lowest dissolved oxygen concentrations of any landscape type. This facilitates retention of some substances that influence water quality but mobilizes others. Irrigated wetlands having the least dissolved oxygen might be those that have the greatest potential to decelerate and store runoff (see paragraph above). In addition, irrigated wetlands that are highly saline, sheltered from wind turbulence (e.g., ponds recessed within washes), subject to warmer temperatures (because of elevation or exposure), and/or which have fine sediments and high primary production would be most likely to experience oxygen deficits.

Adsorption and Physico-chemical Precipitation: Wetlands typically retain finer-particled sediments and more organic detritus than upland sites. This is important because many incoming contaminants can become chemically bound to the fine sediments and detritus. Irrigated wetlands most capable of this might include those on soils having a high content of clay, organic carbon, iron, or aluminum; and ones whose salinity is approximately 5 ppt, which promotes deposition through chemical flocculation (Akhurst and Breen 1988).

Uptake and Accumulation: Wetland organisms directly take up and/or transform chemicals and sediments as part of their normal metabolic processes. This is usually of minor importance in the long-term, but can be an important determinant of water quality seasonally. The ability of a particular irrigated wetland to purify water through uptake and accumulation depends on the contaminant of concern. Uptake can increase with increases in growing season length (as affected by elevation, latitude, etc.). Accumulation can increase with increases in the resistance of plant litter to decomposition (as indicated by plant species, acidic or saline conditions, cool water temperatures, lack of water circulation, and other factors).

Denitrification: Wetlands are the most favorable sites on the landscape for the types of bacteria that remove (by transforming to a gas) the nitrogen in nonpoint source runoff (Groffman and Tiedje 1989a,b, Groffman et al. 1992). In one experiment, irrigated wetlands (flooded meadows) in Gunnison and Jackson Counties, Colorado, probably removed 50-85% of the applied nitrogen (Rumberg 1969, Ludwick et al. 1978). Artificial wetlands elsewhere have been documented as removing nitrate via denitrification (Stengel et al. 1987). Irrigated wetlands that are likeliest to have high denitrification rates are those that (a) are fed mainly by runoff, not groundwater, and especially runoff from alfalfa fields or feedlots, (b) have the highest soil organic content (as usually associated with high plant production and ungrazed, nonsaline conditions), (c) remain flooded or moist for the longest duration of the growing season, (d) warm up the soonest in spring (or never freeze over), and (e) are not highly saline. Wetlands having such conditions are also those most likely to support microbial populations capable of detoxifying many pesticides and other contaminants. Literature that documents the purification capacity of wetlands or other carbon-rich systems in agricultural areas, especially in arid regions, includes: Rice and Smith 1982, Gersberg et al. 1983, Linn and Doran 1984, Schimel et al. 1985, Lemme 1988, Fraser et al. 1988, Neely and Baker 1989, and Parkin and Meisinger 1989.

Consumption by Wide-Ranging Animals, and Combustion: Wetlands of the Colorado Plateau are a focal point for concentrations of migratory animals, as well as livestock that link several ecosystem types. Nutrients and other chemicals contained in wetland food sources are both imported to and exported from wetlands by these animals. Burning of wetlands also exports chemicals beyond wetland boundaries as smoke.

In the absence of any regional studies, hypotheses about the ability of particular variables to predict any water quality process, or about the net effect of the various processes on concentration of a particular contaminant, would be highly speculative. For example, wetlands that contain dense vegetation normally would seem better able to purify water. However, in the Colorado Plateau region, the irrigated wetlands that are more sparsely vegetated might be better purifiers than those that are more densely vegetated, for the following theoretical reasons:

- Vegetation in the densely vegetated wetlands produces large amounts of detritus. Detritus causes oxygen deficits in sediments and water[3]. Deoxygenated conditions can facilitate remobilization (not retention) of phosphorus and many contaminants.
- Vegetation reduces sunlight and wind, and thus reduces open water evaporation. Consequently, sheltered wetlands might stay wetter longer during the season than unsheltered wetlands. If the wetland substrate is constantly saturated, it has less storage space for additional runoff than if it is periodically and partially dried out. Whatever pollution-bearing runoff then enters the wetland is quickly shunted through, rather than being slowly processed.
- Densely vegetated wetlands are often those that have been less heavily grazed. Grazing has the potential to increase denitrification rates by increasing the availability of nitrogen to microbial denitrifiers.

[3] However, limited evidence from measurements of Colorado wetlands (Smith 1989) suggests that chemically reducing conditions are generally not present at the sediment surface or in the water column, except in the most stagnant wetlands.

Literature from other regions could be cited to support any of the above arguments. The point here is not to suggest that sparsely vegetated wetlands provide more water quality benefits, but rather, to emphasize the complexity of the issue and the fact that we just don't know how various competing processes balance out in irrigated wetlands. Vegetation is just one of several factors of potential use as indicators of water quality function. There would be equally frustrating paradoxes to resolve in considering other indicators, such as many of those associated with processes described earlier in this section. If this uncertainty is not understood and articulated, unwarranted credibility can be attached to the results of rapid methods intended to evaluate wetland water quality functions.

3.2 Hydrologic Functions and Values

As is true for water quality functions, many studies have documented the ability of wetlands, as a whole, to reduce flood peaks and, in more limited instances, to sustain summertime low flows and soil moisture of surrounding cropland. But again, no credible studies have examined the hydrologic role specifically of **irrigated** wetlands or, for that matter, any lowland wetlands in the Colorado Plateau. Wetlands can either remove water from local surface flow systems (sink function) or conserve water and sustain the moisture of local areas (source function). Various processes that control the water budget within a wetland determine whether sink or source functions prevail. Sink functions prevail where runoff entering wetlands infiltrates or is converted to water vapor by means of transpiring vegetation. Source functions usually prevail where wetlands act as conduits for discharging groundwater, or where water inputs are increased or conserved because wetlands are good at intercepting precipitation, detaining drifting snow, or reducing open water evaporation.

Processes that occur in an irrigated wetland and that determine whether it is a hydrologic source or sink include:

> **Water Loading:** The amount and rate at which water is introduced or becomes available to an irrigated wetland determines how much can be assimilated. Most irrigated wetlands are fed mainly by lateral subsurface seepage and overland runoff, but other sources of water include direct inputs from channels, ditches, and pipes, direct precipitation, condensation, and groundwater discharge. For wetlands fed entirely by natural sources, the extent of their upslope drainage area -- weighted by slope, soil permeability, local precipitation, land cover type, shape, and other factors -- is frequently used to estimate water loading.
>
> **Water Removal:** Some irrigated wetlands are more able than others to significantly delay or stop the downslope movement of water. They do so by facilitating the processes of evaporation, transpiration, infiltration, and recharge. Indicators of these processes include number of ice-free days, vegetation density and type, wind and sun exposure, soil type, depth to water table, open water area, and landscape position.
>
> **Water Deceleration/Storage:** Irrigated wetlands can also delay the downslope movement of water by increasing a landscape's frictional resistance and sometimes the storage of water above ground. Irrigated wetlands most able to perform this process are probably those that lack outlets (e.g., stock ponds). Among open-ended wetlands, those that lack well-defined channels and are almost totally vegetated (especially with dense stands of robust vegetation) are most likely to decelerate runoff.
>
> **Water Routing:** The spatial arrangement of irrigated wetlands within the landscape also influences their cumulative capacity to affect the timing and amount of downstream flow or soil moisture, but in ways that are not predictable without sophisticated computer models calibrated to a particular watershed.

Although irrigated wetlands that are sinks for runoff (e.g., stock pond wetlands) are most able to control downstream flooding, almost any irrigated wetland contains vegetation that offers resistance (quantified by a "roughness coefficient") at points in the landscape where runoff is usually concentrated. For example, Burkham (1976) reported that the removal of riparian vegetation in an Arizona floodplain lowered the roughness coefficient 0.026 and resulted in a velocity increase of 0.8 ft/s velocity during floods. An increase in the roughness coefficient of only 0.008, following vegetation reestablishment, caused a 0.2-ft/s reduction in velocity.

The slowing of runoff by wetlands that are dispersed throughout a watershed has the potential for reducing flood peaks by staggering runoff arrival in downstream areas. Such deceleration also reduces channel erosion and allows greater time for processing of waterborne contaminants. This could be particularly important because irrigation, by increasing the antecedent moisture condition of soils, makes irrigated watersheds more "flashy" (sharp, steep runoff response to summer rainfall) and prone to channel erosion and downcutting, which removes the edges of valuable farmland and degrades water quality. Major (e.g., 100-year) flood events are, in contrast, less a concern in the region now than historically, because most large floods are now largely controlled by regulated impoundments.

Evidence of wetlands performing as passive sources of water to streams and adjoining cropland is limited. If a study of the watershed role of stockponds in Arizona is any indication, the cumulative role of irrigated wetlands on baseflow might not be great. In that study, Milne and Young (1989) reported virtually no measurable effect on streamflow of stockponds that were present in a river basin at a density of 0.2 ponds per km^2 (and having an average storage capacity of 1,803 m^3). Nonetheless, some studies of western restoration projects suggest that certain headwater riparian wetlands can promote water conservation (Winegar 1977, Stabler 1985, Van Haveren 1986, Debano and Schmidt 1990, Ponce and Lindquist 1990). These wetlands do so partly by reducing wind, channel erosion, and water temperature, increasing infiltration of runoff, and reducing stream velocity. If some irrigated wetlands do serve such a function, and if the water they conserve and export is not highly saline, then their potential value to other ecosystems and cropland in this arid region could be considerable. However, it is difficult to speculate as to which characteristics of a particular irrigated wetland would make it more capable than others for conserving water or influencing downstream floods.

3.3 Recreation and Harvest Values

As a whole, wetlands can provide opportunities for many recreational activities, such as hunting, fishing, trapping, swimming, canoeing, birding, hiking, foraging, photography, and ice skating. Wetlands in general can also provide opportunities for education, research, and simple enjoyment of open space and natural beauty. Commercially, wetlands can provide income to their owners through hunting and grazing leases, and sustainable harvest of hay, timber, furbearers, bait animals, and decorative plants.

The extent to which these activities occur in irrigated wetlands is, again, unknown. Foraging for wild asparagus is popular in some irrigated wetlands (Rector et al. 1979). Most irrigated wetlands are too shallow for activities such as canoeing and swimming. Fishing is generally poor because of the lack of much natural reproduction in these drastically manipulated systems. Probably no irrigated wetlands have sufficient timber to allow sustainable logging. Irrigated wetlands support only the occasionaly harvest of fallen limbs for firewood. Of greater importance in limiting the recreational use of irrigated wetlands is the fact that nearly all are located on private property. Because most owners prohibit public trespass, recreational and harvest values of the wetlands are realized most directly, if at all, by the private landowners. Nonetheless, large numbers of migratory birds that depend on irrigated wetlands are later enjoyed by visitors to non-irrigated wetlands that are open to the public, both locally and in other regions. Also, many citizens who never visit wetlands appreciate the resource simply for its existence and heritage values.

The greatest commercial values of irrigated wetlands are probably related to opportunities for hunting and grazing leases and the harvest of hay and furbearers (mainly muskrat). Communications with local biologists indicated that hunting leases, primarily for irrigated wetlands and adjoining farmlands that have been stocked with captive-raised pheasants, are selling for several hundred dollars each. In Utah, commercial hunting areas must be between 160 and 1280 acres in size and at least one mile apart. Lining of canals and conversion to sprinkler systems would be expected to have little effect on the area of natural hay in wetlands that is available for harvest.

3.4 Multiple Use Considerations

It is unlikely that any single irrigated wetland is optimal for all functions. More often, functions are likely to be in conflict with one another. For example, irrigated wetlands that retain contaminants and sediments can, in some instances, be hazardous to wildlife. Recreation sometimes is incompatible with habitat values (e.g., jogging trails through riparian habitat), but also fosters increased public awareness and appreciation of wetlands. Riparian restoration programs can degrade water quality if new vegetation attracts excessive numbers of shade- and forage-seeking livestock (or wild herbivores) to streams, degrading water quality with their wastes (unless fences are simulataneously installed to exclude livestock). Such considerations must enter into decisions based on the relative values of various types of irrigated wetlands.

4.0 HABITAT FUNCTIONS AND VALUES OF IRRIGATED WETLANDS

4.1 Definitions of "Good" Habitat

Wetlands support plants and animals partly by providing habitat. That is, they provide conditions that are suitable for sustaining the reproduction, growth, and dispersal of natural populations. Of course, virtually all land and water provides habitat for <u>some</u> species. Specifically, how are **wetlands** important? Many studies in the Colorado Plateau region have compared the suitability of wetland habitats with that of nonwetland habitats. A few have specifically compared **irrigated** wetlands with nonwetlands and with wetlands not highly influenced by irrigation.

In examining these studies, it is crucial to first define some endpoints that comprise "good" (or "high-quality") habitat. Most ecologists define quality habitat operationally as habitat which:

(a) contains a large number of species, or species per unit area (i.e., richness[4]);

(b) contains a large number of individuals, or individuals per unit area (density);

(c) contains species having special status because of their rarity[5], narrow environmental tolerance, key influence on other ecosystem components, or recreational/commercial value, especially if the wetland supports high production of these species;, and/or

(d) **supports** conditions a, b, or c indirectly, i.e., the wetland has features that support high species richness, density, or important species in surrounding habitats, although the wetland itself may not be so characterized.

Of these various habitat endpoints, species richness was chosen as the main focus of this project. Species richness was chosen because (a) it is a component of "biodiversity," which is a theme of growing interest among resource agencies and the public, (b) its prediction (in relative terms) for any irrigated wetland is believed possible within the constraints of this project, and (c) it can be quantified as a real number, rather than as an ordinal rating (scaler). The endpoint is narrowed even further to "avian species richness" because, in the Colorado Plateau region, (a) wetland data are much more available for birds than for mammals, amphibians, or other animals or plants, and (b) birds are the most diverse terrestrial vertebrate group in the region.

4.2 Results of Previous Assessments of Irrigated Wetland Habitat

In the five combined subregions of the Colorado Plateau, approximately 183 bird species occur regularly, i.e., are not considered accidental, rare, or casual (Kingery 1988). Of these, 165 (90%) occur regularly in wetland or riparian habitats during at least one season of the year (Appendices A, B, C). Of these 165 species, about 15% require water as a substrate, another 20% occur only in wetland, riparian, or deepwater habitats, and the remaining 65% use uplands as well as wetlands and riparian areas, but occur much less often in uplands (Table 3). For this report, I used the following procedure to arrive at these estimates. I began by creating a source list of regional birds from Kingery (1988). All species listed in that report as occurring in aquatic, riparian,

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[4] In this report, the term "diversity" is sometimes used interchangeably with "richness," although strictly speaking, richness is only one component of diversity, the other being "evenness" or "equitability."

[5] Wetlands containing such species are often said to be most important as contributors to "gamma" (regional) diversity, whereas wetlands containing the most species, regardless of the rarity of the species, are said to have the most "alpha" (within-wetland) diversity.

Table 3. Number of bird species in each wetland dependency category by seasonal abundance and neotropical migrant status.

	Number of Colorado Plateau[6] Species, by Dependency Category:			
	Highly Dependent[7]	Intermediate	Dependent	TOTAL Wetland
Total Species	25	33	107	165
# of Breeding Species:				
Abundant	0	0	6	6
Common	1	4	13	18
Fairly Common	2	3	19	24
Uncommon	2	4	16	22
TOTAL	5	11	54	70
# of Migrating Species:				
Abundant	2	0	8	10
Common	3	3	8	14
Fairly Common	7	1	32	40
Uncommon	6	21	32	59
TOTAL	18	25	80	123
Type A[8]	0	2	31	33
Type B	0	5	28	33
TOTAL	0	7	59	66
# of Wintering Species:				
Abundant	1	1	8	10
Common	2	1	3	6
Fairly Common	2	0	10	12
Uncommon	3	4	19	26
TOTAL	8	6	30	54

[6] Based on knowledge of the author and interviewed local experts. Numbers of species are those occurring in the Grand Valley subregion; other subregions would differ only slightly. Terms for abundance are as used in Kingery (1988).

[7] "Highly Dependent" means that surface water is the species' primary substrate: e.g., common goldeneye. "Intermediate" means the species occurs only where water/wetland is present: e.g., spotted sandpiper. "Dependent" means species also uses uplands, but uses wetlands frequently: e.g., warbling vireo.

[8] Type A species breed only in the United States and/or Canada and migrate to the Neotropics. Type B species also breed in the Neotropics. Other regional species generally do not migrate to Neotropics. Species were also counted in the total for "Migration." Information on neotropical migrant status is as compiled in Carter and Barker (1992).

or wetland habitats of Colorado were included. Next, I added three species to the Kingery list[9] on the advice of local ornithologists: savannah sparrow (use of lowland riparian in migration), and western meadowlark and Gambel's quail (use of lowland riparian in winter). The degree of dependence on wetland/riparian habitats varies greatly among the listed species, but all would experience population declines at least locally, if these aquatic habitats were diminished. Only regularly-occurring species are included, because they are perhaps the most reliable indicators of habitat quality. I excluded species that were categorized as "occasional" or "rare" in USFWS refuge lists for the region, or "rare" (or even less regular) by Dexter and Lavad (1992), because few such species occur regularly. I also excluded species occurring in the local area, but only at higher elevations (>7000 ft) where irrigated wetlands are uncommon. Finally, I excluded seven species that probably are little-affected by irrigation water inputs because they use only large reservoirs, lakes, and rivers: common loon, eared grebe, horned grebe, western grebe, tundra swan, snow goose, and common merganser.

Within the Colorado Plateau region, the Cortez subregion appears to have the richest wetland and riparian avifauna, whereas the Wyoming subregion seems to have the poorest[10]. The number of species that use wetland and riparian habitats for nesting appears to be greatest in the Utah subregion and least in the Grand Valley. Seasonally, the number of wetland/riparian species is greatest during migration (May and September), secondary during the breeding season (June-July), and least in winter (Table 3). Of the Colorado Plateau's 165 regularly occurring wetland and riparian species, a greater percentage of uncommon species occur during winter and migration than during the breeding season (Table 3, p. 17). Avian densities probably follow the same seasonal pattern (Ecology Consultants 1976, Somers 1979). Although density and diversity are low in winter compared with the rest of the year, wetlands in winter provide wildlife with shelter unavailable in much of the surrounding landscape, and thus at this season may be the most important landscape component for regional wildlife. Also, some of the irrigated wetlands that receive water mainly from warmer, more saline subsurface seepage (e.g., wetlands recessed within washes or at the toe of escarpments) seem to remain unfrozen longer in winter than other wetlands, thus providing habitat for lingering waterbirds. Studies that have compared bird diversity in irrigated wetland habitats (marshes, cottonwoods, tamarisk) with diversity in nonirrigated habitats have generally supported the greater importance of wetlands. For example, Ecology Consultants (1976) surveyed birds at several seasons in various Grand Valley habitats -- saltbush, greasewood, greasewood-saltbush, cottonwood, tamarisk, and marsh. Based on a single transect in each habitat, they estimated that the most songbird species during May and August occurred in the riparian cottonwood habitat (Figure 2). In January, greasewood had the most species but cottonwood was ranked second. The marsh habitat in May and August had nearly as many species as the riparian cottonwoods. Wintertime avian diversity of the marsh was termed "intermediate" among the habitat types sampled. Also in the Grand Valley, the four-year study by CDW (1984) found more species along the marsh transect than along transects in either the

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[9] I also compared the Kingery (1988) designations of wetland and riparian species with similar designations in a list for eastern Utah by Dalton et al. (1990), which categorizes wetland/riparian habitat as "critical," "high-priority," or "substantially used" for each of 178 regularly occurring birds. In general, the Dalton et al. (1990) list is more inclusive. That list agreed that all but four of the 165 species which I had listed as wetland/riparian are, indeed, dependent on wetland/riparian habitat (i.e., such habitat was labeled "critical" or "high-priority"). The four exceptions to my list were Brewer's sparrow and western meadowlark, which Dalton et al. did not list at all for wetland/riparian habitats, and pinyon jay and plain titmouse, for which Dalton et al. nonetheless considered wetland/riparian habitat to be "substantially used." The Dalton et al. list includes 15 species which I did not include. For these 15 species, Dalton et al. consider wetland/riparian habitat to be "critical" for four (rough-legged hawk, chukar, mountain bluebird, sage sparrow), "high-priority" for seven (prairie falcon, sage grouse, Say's phoebe, scrub jay, canyon wren, sage thrasher, vesper sparrow), and "substantially used" by four (burrowing owl, common poorwill, white-throated swift, rock wren).

[10] Total numbers of bird species that occur regularly in wetlands and/or riparian habitats are as follows: Cortez subregion, 147 (78 nesting, 135 migrants, 50 wintering); Grand Valley subregion, 133 (70 nesting, 123 migrants, 54 wintering); Utah subregion, 121 (86 nesting, 112 migrants, 28 wintering); Wyoming subregion, 114 (72 nesting, 107 migrants, 22 wintering). Apparent differences among regions are probably not biologically meaningful because they likely reflect differences in the extent of inventory efforts among subregions, rather than actual differences in species richness.

greasewood or saltbush stands. A species richness of from 10 to 50 species appears to be typical of individual irrigated wetlands (Table 4). The potential for discovering even greater avian diversity, given more frequent or long-term surveys of large wetlands with considerable open water and forested acreage, is indicated by the results of surveys of a river bottomland site in the Grand Valley (Dexter 1992), where 225 species have been recorded so far, and from a similar site farther downriver -- the Moab Slough (Boschen 1992), where more than 170 species have been recorded to date.

Various studies (e.g., Knopf 1985) also have documented the **density** of birds to be greater in forested riparian wetlands than in upland habitats in Colorado. Although by itself avian density does not necessarily reflect habitat quality (Van Horne 1983), it can be a useful reflection of habitat quality when paired with other endpoints, such as species richness and community composition. The Ecology Consultants (1976) study found greater densities of songbirds in the riparian cottonwood habitat than in the other habitats during May. In January and August, greasewood had the greatest densities, but cottonwoods were ranked second. In May the marsh habitat was second only to the riparian cottonwoods in density of individuals, but that density was only half that of the cottonwoods. Wintertime avian diversity and density in both the marsh and the tamarisk habitat was termed "intermediate" among the habitat types sampled. Also in the Grand Valley, the four-year study by CDW (1984) reported greater bird densities along the marsh transect than along transects in either the greasewood or saltbush stands.

Regardless of whether wetlands have many species or dense populations, they nonetheless are critical for supporting particular species. An individual wetland that is ranked lower than other wetlands or upland habitats (because it lacks large numbers of individuals or a high species total) may nonetheless be important to maintaining regional biodiversity if the species that are present are ones that occur seldom, if at all, in the other habitats.

Categorizing species according to their "wetland dependence" is difficult. Some species clearly would vanish from local areas within the Colorado Plateau if all wetlands in these areas were eliminated, even if rivers and lakes remained. This is sometimes apparent from their life history characteristics. More typical are species that seem to use wetland and riparian areas extensively, but are also found regularly in nonwetland areas. If wetlands were locally eliminated, some of these species might survive in the nonwetland habitats, although at diminished population levels, but such determinations are difficult to make. One study (Szaro and Jakle 1985) reported that the number of typically upland species that used Arizona riparian areas was much less than the number of riparian species that used upland areas. In the Grand Valley, of the habitats surveyed by Ecology Consultants (1976) in January, the cottonwood, marsh, and tamarisk habitats each contained one species that was found in no other habitat at this season (yellow-rumped warbler, song sparrow, and Bewick's wren, respectively). When the six habitats were surveyed in May, the cottonwood habitat had the most exclusively occurring species (11), followed by the marsh (5). In August, both the cottonwood and marsh habitats had more exclusively occurring species (7) than any of the six habitats surveyed. Another Grand Valley study (CDW 1984) covered a smaller number of habitats (marsh, saltbush, and greasewood), but more intensively and over a four-year period. Of these three habitat types, "marsh" contained 17 **breeding** bird species that did not occur in the other two habitats. Neither of the other habitats contained more than two species that were absent from the marsh. Considering the data from **all seasons** pooled together, 19 species occurred only in the marsh, whereas only 7 occurred exclusively in greasewood and none occurred only in saltbush. The 19 marsh species represent 39% of the 49 species found in the marsh over the 4-year period.

In summary, it is apparent that Colorado's irrigated wetlands, like most wetlands elsewhere, support the greatest diversity and density of birds of all habitat types within their landscape. Their importance is highlighted further by the fact that their avifauna is composed largely of species that do not occur regularly in other habitat types.

Much less is known about the amphibians, mammals, and reptiles that regularly use wetland or riparian habitats of the Colorado Plateau, but their diversity is less than that of birds. Appendices D and E show that

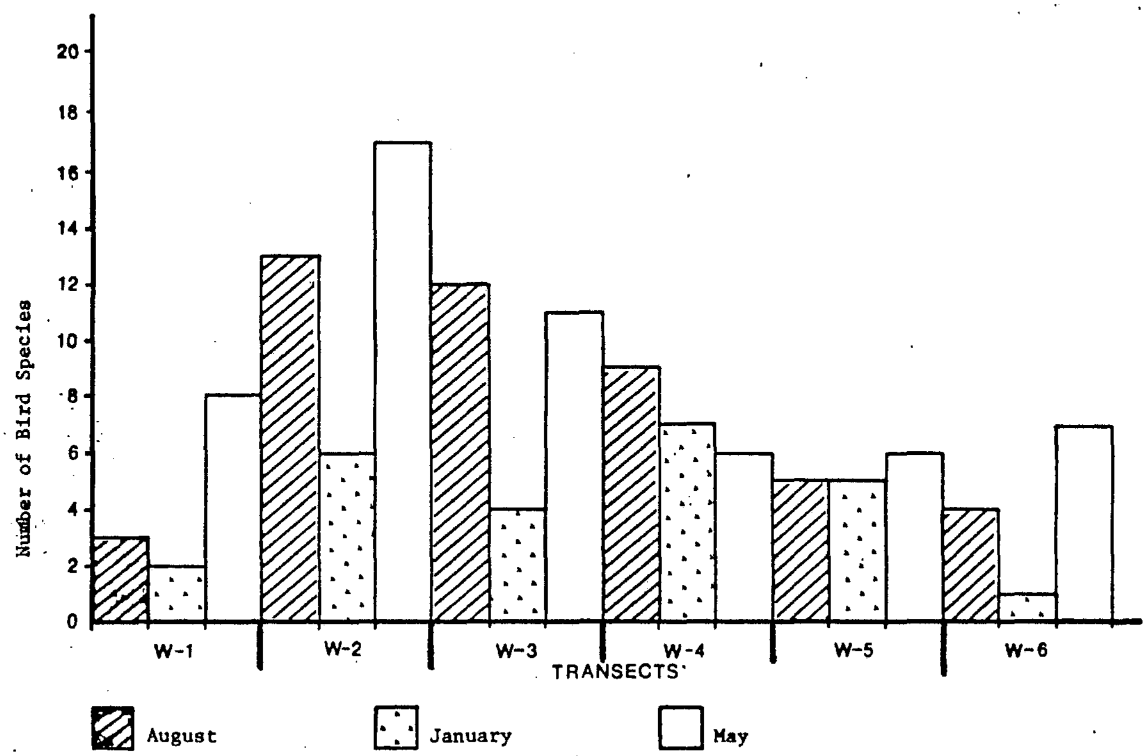
Table 4. Estimates of avian richness from prior surveys of riparian or wetland areas in Colorado and eastern Utah.

Habitat Type/Location	# of Spp.	Source	Method/Coverage
Irrigated marsh, Grand Valley		(1)	0.5 mi Emlen strip census, 3 visits/month, one year (1975)
in May	11		
in August	12		
in January	4		
Irrigated marsh, Grand Valley	49	(2)	0.25 mi transect, weekly Apr.-June, 4 yrs.
About 20 irrigated wetlands (emergent, shrub, forested), Grand Valley, Colorado	11-27	(3)	Roadside point counts 0.5 mi apart; monthly except not Jan, Feb, July, Aug.; 40 points per month, for 4 years
30 irrigated wetlands (emergent, shrub, forested), Lower Gunnison Valley, Colorado	2-26	(4)	Emlen strip census, April 18-July 22, 1977, 3 hours per morning
Irrigated marsh, Cortez area	27	(5)	Unstructured survey, 11/77-10/78
Irrigated marsh with pond, Cortez area, Colorado	42	(6)	Unstructured survey, 11/77-10/78
3 riparian areas (relatively undisturbed watersheds), e. Utah	22-37	(7)	Point counts, 10 per site, 8 minutes/count, twice during June 1992
Floodplain (Colorado River) forested wetland, Grand Valley	45	(8)	Emlen strip census on 5/77; 3,5/79; 4,6,10/81; 3,7/82; 5/83; 8/85; 9/88
Riparian areas, Douglas Cr., northwestern Colorado	93 total 47-76 per seg.	(9)	Variable circular plots, 11 stream segments, 16 visits during June 1991-1992
Cottonwood willow creekbottom (20 acres), El Paso County, eastern Colorado	16	(10)	June 1980
Semi-wooded riverbottom pasture, eastern Colorado	27	(11)	6-year June average, 1973-1979
Urban cattail marsh and cottonwood woodland (8 acres), El Paso Co., eastern Colorado	17	(12)	2-year June average
Floodplain cottonwood forest, 129 acres, Weld Co., eastern Colorado	18	(13)	21-year June average, 1971-1986
Floodplain pond, 21 acres, Weld Co., eastern Colorado	5	(14)	5-year June average

Sources:
1. Ecology Consultants 1976
2. Colorado Division of Wildlife (CDW) 1984
3. Colorado Division of Wildlife (CDW) 1984
4. Rector et al. 1979
5. Somers 1979
6. Somers 1979
7. Utah Division of Wildlife Resources 1992
8. U.S. Bureau of Land Management (USBLM) 1992
9. Baker et al. 1992
10-13. Breeding Bird Census database, Laboratory of Ornithology, Cornell Univ., Ithaca, NY

Figure 2. Comparison of avian richness among seasons and habitats in the Grand Valley, Colorado.

Source: Ecological Consultants (1976)
W-1: Desert Shrub (saltbush) transect
W-2: Riparian Woodland (cottonwood) transect
W-3: Marsh transect
W-4: Phreatophytic Shrub transect (greasewood)
W-5: Phreatophytic Shrub transect (tamarisk)
W-6: Desert Shrub transect (saltbush-greasewood)



10 amphibian, 26 reptile, and 85 mammal species use wetland/riparian areas, as compared with 165 bird species. This represents about 77% of all amphibian species, 72% of all reptiles, and 80% of all mammals occurring in the region (Dalton et al. 1990). Information on use of irrigated wetlands by mammals, amphibians, and reptiles is limited to a very few reports (McCoy 1962, Ecology Consultants 1976, Somers 1976a, 1976b, 1977, 1979, 1980, CDW 1984). In the Cortez area, the surveys by Somers (1979) revealed a few species that used emergent wetlands almost exclusively: chorus frog, Western harvest mouse, and montane vole.

Information on **fish and invertebrates** of irrigated wetlands appears to be even scarcer. According to Dalton et al. (1990), only 12 of the 42 fish species in the region are native (i.e., not exotic/introduced) Limited sampling by CDW (1984) of four natural washes receiving irrigation water in the Grand Valley revealed a total of 13 fish species. This represents about 31% of all fish species inhabiting the region (Dalton et al. 1990). All four washes contained two species -- flannelmouth sucker (Catostomus latapinnis) and roundtail chub (Gila robusta). Three of the four washes contained another species -- bluehead sucker (Catostomus discobolus). Species occurring in only one wash were rainbow trout (Oncorhynchus gairdneri), red shiner (Notropis lutrensis), black bullhead (Ictaluris melas), channel catfish (Ictalurus punctatus), and black crappie (Pomoxis nigromaculatus). The wash with the most fish (as collected by wintertime electrofishing) had 11 of the 13 species as pooled from all washes; 5 of these species (and 50 individuals) occurred within one 50-ft reach.

Sampling the same four natural washes, the CDW (1984) study found 21 taxa of invertebrates. Even considering the infrequency of sampling and the fact that few of the invertebrates were keyed to genus or species, by comparison with other studies this represents an extremely low species richness. No sample from the wash having the most taxa had more than 8 of the 21 taxa as pooled from all washes, and many summertime efforts failed completely to collect any invertebrates. The largest number of invertebrates collected (about 1138 individuals per ft^2) was collected in winter. Dominant invertebrates included midges (Chironomidae), blackflies (Simuliidae), and the caddisfly, Hydropsyche. Another study from the Grand Valley (Hayes and Nielsen 1978) reported on mosquitoes in irrigated wetlands as a possible vector of deadly equine encephalitis, although the number of documented cases of this disease in the region is relatively few. Risks are perhaps greatest in irrigated wetlands of the Uinta Basin, where pasture and horses are most prevalent. Elsewhere in the western part of EPA Region 8, most invertebrate studies have focused on streams and lakes, but a few (USFWS 1979, Severn 1992) have addressed wetlands. Literature from other regions has sometimes documented high densities of invertebrates important to wildlife in some irrigated, agricultural, or created emergent wetlands (Broschart and Linder 1986, Scheffer et al. 1984, Kreil and Crawford 1986, Stephens et al. 1988, Euliss et al. 1991, Severn 1992).

Although not comparative, many other studies and literature reviews document considerable wildlife use of irrigated wetlands, agricultural wetlands, and created ("artificial") wetlands. These include the following (* indicates information from Colorado or eastern Utah):

Wildlife Use of Irrigated Wetlands:
Earl 1950, Harris 1953, Ecology Consultants 1976*, Dalton et al. 1978*, Rector et al. 1979*, Guthery et al. 1982, Colorado Division of Wildlife 1984*, Gatz et al. 1984, Ohmart et al. 1985, Lewis and Bockelman 1988, Boschen 1992*.

Wildlife Use of Wetlands and Riparian Areas in Irrigated Regions:
Twomey 1942*, Copelin 1953, Austin 1970, Bottorff 1974*, Gaines 1974, Carothers et al. 1974, Carothers and Johnson 1975, Lewke 1975, Logan 1975, Whitmore 1975, Somers 1976a*, 1976b*, 1977*, 1980*, Tolle 1977*, Stevens et al. 1977, Conine et al. 1978, Henke and Stone 1978, Tubbs 1980, Hobaugh and Teer 1981, Briggs 1982, Cook 1984*, Stinnett and Klebenow 1986, Hunter et al. 1987, Faber et al. 1989, Dalton et al. 1990*, Peterson and Cooper 1991, Dexter 1992*, U.S. Bureau of Land Management 1992*, Utah Division of Wildlife Resources 1992*.

Wetland Wildlife Use of Western Croplands:
Glover 1956, Gates 1965, Evans 1967, Duebbert and Lokemoen 1976, Higgins 1977, Kantrud 1981, 1986, Cowan 1982, Baldassarre et al. 1983, Duebbert and Frank 1984, Guthery et al. 1984, Baldassarre and Bolen 1984, Baldassarre and Fischer 1984, Balsore et al. 1986, Duebbert and Kantrud 1987, LaGrange and Dinsmore 1989, Budeau and Snow 1992.

Wildlife Use of Stockponds and Other Created Emergent Wetlands:
Nelson 1953*, Smith 1953, Nelson 1954, Berg 1956, Yeager and Swope 1956, Hopper 1972*, Lokemoen 1973, Schroeder et al. 1976*, Evans and Kerbs 1977, Flake et al. 1977, Ruwalt 1979, Rossiter and Crawford 1981, Hudson 1983, Kreil and Crawford 1986, Belanger and Couture 1988, Buckner 1988*, Matter and Mannan 1988, Payne 1992, Taylor and Trost 1992.

4.3 Habitat "Indicators" and Evaluation Procedures: Definition and Historical Uses

Many biologists use the term "indicator" to describe **species** that indicate the suitability of a habitat for many other species, or that tell us something about a habitat's ecological "health." In the following pages I use the term in a much broader sense, to refer not only to biological features, but also to the **physical and chemical features** (or variables) of a habitat, at both site-specific and landscape scales, that can be **estimated rapidly** and that relate, either empirically or deterministically, to the habitat's suitability for supporting individual species and/or avian diversity in general. The characteristics of a particular indicator are termed the **indicator conditions.** For example, one indicator of avian diversity in irrigated wetlands is the extent of woody vegetation. Acreage categories of "0.1-1" and ">1" represent two conditions of this indicator. The use of indicators is a popular practice because indicators can be estimated rapidly, whereas it is seldom practical to directly observe wildlife use of all wetlands in an area. To be credible, direct surveys require lengthy visits to all wetlands during carefully specified seasonal periods.

Indicators have often been organized into standardized evaluation procedures (e.g., questionnaires or checklists) and models that are used to evaluate wetlands. Examples are the Habitat Evaluation Procedures (HEP) of the U.S. Fish and Wildlife Service (1980) and others reviewed by Adamus (1992). When indicators are organized in standardized procedures and used to classify or rank wetlands, it can promote efficiency in government. This is because the classification and ranking process can quickly focus management and regulatory policies and effort on the wetlands that are likely to be most important. Moreover, organizing the indicators in a standardized protocol allows different persons evaluating the same wetland to more often arrive at the same conclusion regarding the relative habitat quality of a particular wetland. Such consistency and comparability is important to help ensure public confidence in the evaluations, rankings, and management decisions.

Specifying the best indicators of habitat suitability begs the question, "best habitat for what?" Wetland features that are good indicators of habitat suitable for some species are often less useful for other species. HEP addresses this dilemma by requiring that the user determine habitat suitability for just a few species presumed to be representative of the larger set. The Golet-Larson (Golet 1972) and Colorado SCS method (Rector et al. 1979, SCS 1992a) do not clearly specify which habitat endpoint is being evaluated. These methods imply that their indicators describe "good" habitat, leaving the user to wonder if "good" habitat means species-rich habitat, habitat with high vertebrate densities (which groups? which seasons?), habitat productive mainly for open-water, recreational, or rare species, or (improbably) all of these endpoints. Many of the indicators that they use (e.g., ratio of open water to vegetation) are based mainly on research documenting importance to waterfowl production, not necessarily to the conservation of biodiversity.

Within the study region, perhaps the first habitat evaluation method to be widely used on irrigated wetlands was one sponsored by SCS and USBR, and developed and used by Rector et al. (1979) for the Lower Gunnison area. That method was based largely on work in Massachusetts wetlands (Golet 1972), and was revised several times by Paul Obert and others of the SCS (SCS 1992a). Variations of the model have subsequently been used to evaluate a statistical sample of Uncompahgre Valley wetlands (USBR 1991) and all irrigated wetlands of the Cortez subregion (SCS 1989).

4.4 Which Indicators Predict "Good" Habitat?

I identified five major indicators of the habitat suitability of irrigated wetlands:

1. Wetland Size and Related Indicators
2. Water Regime ("Wetness")
3. Vegetation Characteristics
4. Other Animals and Water Quality
5. Landscape Land Cover and Seclusion

Various formulations of these indicators are applied collectively as a part of a new method for evaluating wetland habitat -- the avian richness evaluation method (AREM) -- described in Section 5.0. The importance of these indicators and their general relationship to the evaluation method are documented in the following sections. I identified these indicators of bird diversity mainly from personal experience and through interviews with local avian experts[11]. In these interviews, habitat requirements of all local species listed in Appendices A-C were discussed, species-by-species. This was the primary approach because it appears that only two published studies (Rector et al. 1979 in the Lower Gunnison Valley, Ohmart et al. 1985 along the lower Colorado River in Arizona) have tried to systematically relate avian species richness, or the presence/absence of particular species, to habitat variables (indicators) in irrigated wetlands.

I considered other indicators but found the local information insufficient to link them to bird habitat quality or avian richness. In particular, I considered using "water source" as an indicator because of its potential relevance to wetland policies and frequent use in previous classifications of irrigated wetlands. However, as noted earlier, determining the primary water source of an irrigated wetland is a subjective process, and other indicators are likely to be more directly linked to habitat quality. If statistical relationships could be established between the more direct indicators and "water source," and if a consistent method for determining "water source" could be developed, then "water source" might be validly used. One study (Rector et al. 1979) did attempt to relate wildlife use of irrigated wetlands to apparent water sources. In the Lower Gunnison Valley, they reported greatest diversity of spring and summer birds in "natural" wetlands, followed by "canal" wetlands, "irrigation management wetlands," and an "open drain" (ditch). Small mammal diversity did not differ among the types, but small mammal density (trap catch) was greatest in natural wetlands, followed by irrigation management wetlands and canal wetlands. Bird densities were similar among natural and irrigation management wetlands, but canal wetlands had much lower densities.

4.4.1 Wetland Size and Related Indicators

The importance of wetland size as a positive indicator of habitat suitability is suggested by its common use in rapid evaluation methods. For example, of nine wetland evaluation methods reviewed by Adamus (1992), all used wetland size or related morphologic features to indicate suitable habitat.

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[11] I spent two full days with each of the following avian experts who were recommended to me by several biologists in the region:
Ronald Lambeth (Grand Valley area) has been a birder for over 20 years, 13 of which have been in the Grand Valley. He has an M.S. in Wildlife Biology and is employed as a biologist by the Bureau of Land Management, where he conducts bird surveys and is developing BLM's agency strategy for conservation of neotropical migrants.
David Galinat (Lower Gunnison area) has been a birder for 25 years, including 10 in the Lower Gunnison area (Olathe) and 10 in the Grand Valley. He has a B.S. in Wildlife Science and has served on the Colorado Field Ornithologists Records Committee.

Species vary greatly in the habitat patch sizes that they regularly use (Opdam et al. 1985). No species in the Colorado Plateau region appears to favor or use relatively small wetlands disproportionately. In some agricultural landscapes, relatively large wetlands have more species than relatively small wetlands (Brown and Dinsmore 1986, 1988, Gutzwiler and Anderson 1987, Budeau and Snow 1992). This is partly because large wetlands normally contain a wide range of vegetation types and water depths, and a larger "core" area that shields birds from predators and disturbances such as people on foot. However, regular use by waterbirds of agricultural wetlands (mainly pools of open water) smaller than 0.1 acre was documented by Budeau and Snow (1992) in Oregon. In prairie regions where small ponds are abundant, many species nest in wetlands smaller than an acre (Rumble and Flake 1983). I estimate that of the 165 wetland species in the Colorado Plateau region, 13 are unlikely to use open water patches smaller than about one acre (Table 5). The minimum sizes of vegetated patches used by most species are unknown. Irrigated wetlands in the Colorado Plateau range in size from less than 0.1 acre to several hundred acres. Mean size of the Lower Gunnison on-farm wetlands is about 22 acres (Table 2, p. 8).

However, wetland size is not a consistent indicator of avian diversity. Many other indicators confound the relationship. One of these confounding indicators is wetland **location.** In a survey of 30 wetlands in the Lower Gunnison Valley, Rector et al. (1979) tended to find more bird species and greater densities of individuals in relatively large wetlands. These large wetlands also tended to be forested and located in off-farm, river bottom sites. They also had relatively great densities of small mammals and slightly greater mammalian diversity. However, it was unclear whether they had more species because of their large size, their bottomland location, their woody vegetation, or the likelihood that they received proportionately less irrigation water inflow than wetlands farther upslope. Local avian experts whom I interviewed indicated that many species occur only in wetlands along major rivers, such as the Colorado, and on major lakes. Based on these discussions, I estimate that about 19% of the region's wetland/riparian habitats species are almost totally restricted to habitats close to major rivers or lakes, and another 19% probably occur more regularly in such habitats than in drier areas. Such bottomland habitats are required or preferred by 44% of species that require water as a substrate, 55% of the species that use only wetland/riparian habitats, and 30% of the species that use upland habitats as well (Table 5).

Another indicator that confounds the prediction of avian diversity from wetland size is wetland **width.** Large wetlands probably are less useful to some birds and small mammals if they are narrow. Linearly shaped, narrow wetlands, such as the canal wetlands in the Lower Gunnison Valley (Rector et al. 1979), and riparian strips in Arizona (Carothers and Johnson 1975), California (Henke and Stone 1978), Iowa (Stauffer and Best 1980), and Pennsylvania (Croonquist and Brooks 1993) have relatively few species and sometimes relatively few individuals, even if with their great length they have large area. In Arizona riparian habitats, forested patch forested patch size was not a statistically significant indicator of breeding-season avian richness, perhaps because none of the forested strips exceeded 50 m width (Strong and Bock 1990). Narrow wetlands provide less protection from wind and sun, and the linear corridors that they form might facilitate movements of mammalian predators (e.g., Peterson and Cooper 1991). Nests of many songbirds, if located within forested riparian patches narrower than about 0.5 mi (Wilcove 1985), are highly susceptible to loss from cowbird parasitism. Some computer simulations (Henein and Merriam 1990) suggest that increasing the number of "high quality" (e.g., wide) corridors can benefit small mammals in habitat patches, but increasing the number of "low quality" corridors (beyond just one) can have a negative effect.

Although some ducks in the Grand Valley nest in the larger, unlined canals and natural washes, especially where elevated spoil banks and dense vegetation are present, they seldom use narrower canals or sides of drains and laterals, where nests are probably more vulnerable to predation (CDW 1984). Vegetation along the laterals is frequently disturbed by burning, weed control, and other agricultural activities. In Arizona croplands, waterbirds that particularly shun irrigation canals included geese, sandhill crane, and white-faced ibis (Ohmart et al. 1985). Narrow wetlands are not, however, unsuitable as habitat to all species. If they contain at least minimal vegetative cover, irrigation canals might provide travel corridors for mammals

Table 5. Number of wetland bird species, by habitat type and wetland dependency category.

	Number of Colorado Plateau Species:			
	Highly Dependent[12]	Intermediate	Dependent	TOTAL
Total Species	25	33	107	165
Require[13] large water bodies	10	16	5	31
Prefer large water bodies	1	3	27	31
Seldom use small (<1 acre) ponds	13	0	0	13
Mudflats required	0	15	0	15
Mudflats used	1	0	9	10
Woody vegetation required[14]	1	1	85	87
Woody vegetation used	1	4	13	18
Trees required	1	1	26	28
Trees used	1	3	5	9
Big trees especially	1	1	24	26
Snags especially	1	0	20	21
Shrubs required[15]	0	0	24	24
Shrubs used	0	2	43	45
Willow required	0	0	2	2
Willow preferred	0	1	4	5
Russian olive preferred	0	0	19	19
Tamarisk preferred	0	0	4	4
Pinyon-juniper preferred	0	0	7	7
Greasewood preferred	0	0	1	1
Herbaceous vegetation required[16]	4	8	20	32
Herbaceous vegetation used	11	8	13	32
Robust emergents preferred	0	6	1	7
Other wet emergents preferred	0	2	2	4
Drier grasses preferred	0	0	0	0
Broad-leaved forbs preferred	0	0	7	7
Aquatic plants preferred	8	0	0	8

[12] "Highly Dependent" means that surface water is the species' primary substrate. e.g.: common goldeneye. "Intermediate" means the species occurs only where water/wetland is present. e.g.: spotted sandpiper. "Dependent" means species also uses uplands, but uses wetlands frequently. e.g.: warbling vireo. All estimates of wetland dependence and use of particular habitats were based on the author's judgement and that of interviewed local experts. A species can be counted in more than one row in this table, but is counted in only one column.

[13] In this and the subsequent categorizations of "required" and "used" habitat, the tally of species for "used" habitat does NOT include species that "require" the habitat. All determinations of "required" vs. "used" (or "preferred") are based on the author's knowledge of the species and on interviews with local experts. The habitat terms correspond to similar terms on the field form; refer to Appendix F for precise definitions.

[14] Tallies for woody vegetation include tallies for species requiring/using trees and shrubs, as listed under tree and shrub headings.

[15] Tallies include, but are not limited to, bird species tallied for the individual shrub species in the subsequent block.

[16] Tallies for herbaceous vegetation include, but are not limited to, tallies of bird species occurring in the individual types listed in the subsequent block.

Table 5. (continued)

	Number of Colorado Plateau Species:			
	Highly Dependent	Intermediate	Dependent	TOTAL
Fish required	1	4	0	5
Dirt banks required	0	1	3	4
Strongly avoid areas grazed/ burned/mowed in spring	8	10	14	32
Avoid such areas (less strongly)	0	0	12	20
Benefitted by grazing	0	4	5	9
Benefitted by cropland	1	8	23	32
Benefitted by enriched runoff	9	6	10	25
Benefitted by clear water	12	5	0	17
Prefer highly secluded areas	23	22	11	56
Strongly avoid predation-vulnerable wetlands	0	3	24	27
Avoid such areas (less strongly)	25	30	83	138
TOTAL SPECIES	25	33	107	165

(Bennett 1990). Rector et al. (1979) hypothesized that canal wetlands might still be important because they could provide a protected corridor for wildlife traveling among larger, wider patches of natural habitat.

A third factor that confounds the prediction of avian diversity from wetland size concerns **the manner in which "wetland size" is measured.** For many species, the overall wetland size (i.e., acreage including large stands of contiguous unflooded wetland vegetation) is a weaker indicator of wetland quality than the size of a particular habitat within a wetland (e.g., open water area). For others, especially those with large home ranges, overall wetland size is probably a weaker indicator than cumulative (landscape-level) acreage of the wetland plus that of contiguous or closely accessible, structurally similar, upland habitat. Thus, "scale" is an important qualifier in any description of species-area relationships of Colorado Plateau species (Gutzwiler and Anderson 1987, Van Horne and Wiens 1991).

In summary, it is apparent that "wetland size" should be used as an indicator of habitat suitability only (a) if it is related to the particular species that could occur in an area, (b) if other indicators -- particularly wetland width and landscape position -- are used simultaneously, and (c) if it is represented not as total wetland size, but as the size of particular habitat types relevent to named species within a wetland.

Accordingly, these recommendations have been incorporated into the design of the new avian richness evaluation method (AREM) described in Section 5.0. Specifically:

(a) A wetland score that results from using AREM reflects the collective results from component **species** models. These models in turn have addressed the effect of habitat size individually for each species. The overall size of a wetland is not used as an indicator; rather, the collective area of particular cover type(s) within the wetland is used. The particular area required is stipulated by species. For some species, patches of suitable habitat larger than 1 acre are considered better than smaller ones, whereas for other species, patches larger than 10, 20, or 40 acres are considered even better. For a few species, patch size is not used at all as an indicator.

(b) A wetland score that results from using AREM reflects the confounding effects of **other indicators.** Wetland size is not used as the sole indicator for any species. For most species, other indicators are addressed simultaneously. For example, AREM assigns the same or higher scores to small wetlands containing otherwise optimal habitat than large wetlands with habitat that is suboptimal because of narrow patch width, landscape location, or conditions of other indicators.

4.4.2 Surface Water Regime ("Wetness")

If "wetness" is used as the only indicator of bird diversity, "wetter" is often -- but not always -- better. That is, wetlands with water regimes characterized by relatively deep, seasonally permanent water can often support many species. Partly to provide a greater area of open water and permanently flooded wetland habitat for water-dependent species, more than 100 wetlands in the Colorado Plateau have been intentionally altered, or have been created from upland by excavation or damming of intermittent drainageways (database from SCS 1992b). These projects have been completed voluntarily by farmers on their own land, in cooperation with salinity control projects that provide subsidies and technical assistance (from the U.S. Department of Agriculture, as provided by various public laws). Priorities for these projects, and the particular enhancement or creation practices that are employed, are established by biologists in local SCS offices. Some completed projects are monitored annually using habitat evaluation methods, primarily HEP. Actual wildlife use, species richness, and productivity has been systematically monitored in few if any of these projects.

Part of the reason why "wetter" wetlands seem to support many species is because they are likelier to be flooded more predictably and for longer duration. This allows additional invertebrate species with long aquatic development times (e.g., some dragonflies) to be present (Driver 1977, Ebert and Balko 1987). These types of invertebrates in turn help support additional species of birds. In Oregon, agricultural wetlands that remained flooded longer in spring had greater species richness of waterbirds (Budeau and Snow 1992). Grazing of a wetland's upslope drainage area can sometimes increase the amount of runoff delivered to the wetland and thus, its flooding duration and waterbird diversity (Guthery and Stormer 1984). However, in the Colorado Plateau, intensive grazing of vegetation overlying some soils can exacerbate salinity problems that are potentially detrimental to aquatic diversity (see p. 37).

Little is known about the effects on wildlife of shifting from a regime of periodic flooding by lateral ditch overflows (about 5 times per growing season, 12-24 hr at a time), to continuous and less intense watering from sprinklers. Direct flooding from ditch overflows, as well as plowing, can drive some soil invertebrates to the surface of plowed fields (Edwards and Lofty 1975), and can distribute over the exposed field whatever organisms were contained in the river source water. This probably attracts a few species (e.g., gulls, white-faced ibis, killdeer, swallows, American pipit, American robin, blackbirds) for short periods. But unlike in some other regions where "backflood irrigation" or natural seasonal flooding of agricultural land provides major feeding opportunities and/or territorial areas for shorebirds and waterfowl (Wishart et al. 1984, Ohmart et al. 1985, LaGrange and Dinsmore 1989), in the Colorado Plateau, the overflow water usually infiltrates so quickly, even where soils have the lowest permeability, that bird use is ephemeral. When sprinklers are used, even less water "ponds" on the fields.

Many wildlife species colonize and begin to use ephemerally flooded or newly created wetlands almost as soon as they arise on the landscape, if they are otherwise suitable as indicated by the soil development rate and vegetative community maturation rate (Spencer 1963, Lathwell et al. 1969, 1973, Danell and Sjoberg 1982, Hudson 1983, Kadlec and Smith 1984, Weller et al. 1991). Wildlife densities and perhaps species richness continue to increase for a period of years while a new wetland "matures," i.e., while vegetation develops, diverse seeds are transported in by animals and wind, and an organic soil layer important to invertebrates is deposited by annual plant production. However, instances have been documented (Heitmeyer and Vohs 1984) of birds continuing to prefer using natural wetlands despite the availability of many created wetlands.

To some people, the "drier" wetlands that lack surface water are "not really wetlands" because when observed casually they may not appear to support much wildlife. However, their importance to individual species can be considerable. In the San Luis Valley of south-central Colorado, wetlands having the greatest diversity of herbaceous plants are not the permanently inundated or saline ones, but rather seasonal ones that have low salinity (conductivity <1000 μmhos/cm^2) and high water tables (located at or within 24 inches below the soil surface)(Cooper and Severn 1992). In the Colorado Plateau region, at least 113 bird species (68% of the total wetland/riparian species) use such wetlands regularly (Table 5, p. 26). For some of these species, deep open surface water occupies space that, if alternatively occupied by woody vegetation or even by emergent vegetation, would provide habitat to more species, especially species that are of highest conservation interest. This group of "drier end" species comprise a greater proportion of uncommon species during winter and migration[17], as compared with wetland/riparian species that require water as a substrate. As shown in Tables 6 and 7, they also comprise a higher proportion of neotropical migrants[18], and a higher proportion of species

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[17] For example, although 48% of all the region's wintering wetland/riparian species are considered uncommon (by Dexter and Lavad 1992), only 33% of those that require water as a substrate are uncommon. Similarly, although 48% of all the region's migrant species are considered uncommon, only 38% of those that require water as a substrate are uncommon. At all seasons, many more uncommon species are classified as "dependent" (prefer wetlands but do not require open water) than "highly dependent" (require open water as a substrate). See Table 3.

[18] None of the region's species which require water as a substrate are neotropical migrants. Of 33 species that occur only where water or wetlands are present, 7 (21%) are neotropical migrants. Of the 107 species that prefer wetlands but occur in uplands as well, 59 (55%) are neotropical migrants. About 61% of all species that regularly occur in the Colorado Plateau are neotropical migrants, and 86% of these are species that regularly occur in irrigated wetlands (Table 6). The importance of conserving neotropical migrants in particular is emphasized by EPA's signing of an interagency memorandum of agreement in support of an international program focusing on these species (Partners in Flight Information and Education Working Group 1992).

Table 6. Number of neotropical migrants in various wetland dependency categories, by conservation characteristics.

	Number of Colorado Plateau Species, by Dependency Category[19]:				
	Highly Dependent	Intermediate	Depend.	Total Wetland	Upland
Total Neotropical[20] Migrants	0	8	78	86	14
# of species with threats to breeding areas (species breeding in and/or visiting region):					
No known threat, "generalist" species	0	1	10	11	2
Minor threat, moderate generalists	0	2	21	23	7
Moderate threat, "specialist" species	0	0	33	33	2
Extensive threat, specialists	0	5	11	16	3
Extirpation likely, extreme specialists	0	0	3[21]	3	1
# of species with threats to breeding areas (only species breeding in Colorado Plateau):					
No known threat, "generalist" species	0	1	8	9	2
Minor threat, moderate generalists	0	0	8	8	7
Moderate threat, "specialist" species	0	0	15	15	2
Extensive threat, specialists	0	4	3	7[22]	3
Extirpation likely, extreme specialists	0	0	1	1	1
# of species with threats to wintering areas (species breeding in and/or visiting region):					
No known threat, "generalist" species	0	1	14	15	2
Minor threat, moderate generalists	0	2	33	35	5
Moderate threat, "specialist" species	0	3	24	27	6
Extensive threat, specialists	0	2	7	9	2
Extirpation likely, extreme specialists	0	0	0	0	0
# of species with threats to wintering areas (only species wintering in Colorado Plateau):					
No known threat, "generalist" species	0	0	9	9	1
Minor threat, moderate generalists	0	1	4	5	1
Moderate threat, "specialist" species	0	1	6	7	2
Extensive threat, specialists	0	2	0	2[23]	0
Extirpation likely, extreme specialists	0	0	0	0	0
Breeding Range Sizes of Component Species					
Very widespread (>75% of N. America)	0	5	26	31	?
Widespread (51-75% of N. America)	0	0	21	21	?
Intermediate (26-50% of N. America)	0	3	24	27	?
Local (11-25% of N. America)	0	0	6	6[24]	?
Very local (<11% of N. America)	0	0	1	1[25]	?

[19] Dependence categories are based on the author's judgement and interviews with local experts. "Highly Dependent" means that surface water is the species' primary substrate. e.g.: common goldeneye. "Intermediate" means the species occurs only where water/wetland is present. e.g.: spotted sandpiper. "Dependent" means species also uses uplands, but uses wetlands frequently. e.g.: warbling vireo.

[20] Neotropical migrants are species that spend the winter in Central and South America. Conservation biologists consider neotropical migrants to be of critical concern because of the long distances they migrate and the rapid loss of their wintering habitat. This table was prepared with information from the database of Carter and Barker (1992).

[21] yellow-billed cuckoo, loggerhead shrike, willow flycatcher

[22] peregrine falcon, short-eared owl, band-tailed pigeon, loggerhead shrike, marsh wren, Hammond's flycatcher, olive-sided flycatcher

[23] northern harrier, marsh wren

[24] rufuous hummingbird, Cordilleran flycatcher, dusky flycatcher, Hammond's flycatcher, MacGillivray's warbler, green-tailed towhee

[25] Virginia's warbler

Table 7. Number of bird species in various wetland dependency categories, by taxonomic uniqueness, harvest status, and official conservation designations.

	Number of Species of Colorado Plateau, by Dependency[26] Category:				
	Highly Dependent	Intermediate	Dependent	Wetland Total	Upland
Probable Taxonomic Uniqueness of Component Species					
Very High (only species of its genus in region)	1	3	7	11	1
High (one of 2 species of its genus in region)	0	2	3	5	1
Moderate (one of 3 species of its genus in region)	1	2	8	11	1
Low (one of 4 species of its genus in region)	1	6	9	16	2
Very Low (one of >4 species of its genus in region)	22	20	80	122	19
Hunted Species	18	4	3	25	2
Official Designations[27]					
Endangered				1	0
Threatened				2	0
Candidate for T/E listing				2	1
G3 ("rare/uncommon globally but not imperiled")				2	0
G4 ("not rare; apparently secure but cause for longterm concern")				6	2
S1 (rare statewide, CO)				1	0
S2 (uncommon statewide, CO)				1	1
S3 (fairly common statewide, CO)				19	4
"Watch List" (Colorado)				11	4

[26] Dependency of each species was based on the author's judgement and interviews with local experts. "Highly Dependent" means that surface water is the species' primary substrate: e.g., common goldeneye. "Intermediate" means the species occurs only where water/wetland is present: e.g., spotted sandpiper. "Dependent" means species also uses uplands, but uses wetlands frequently: e.g., warbling vireo. Lists of species assigned official designations were provided by the Colorado Natural Heritage Program.

[27] These tallies include some regional species that occur so irregularly that they were not included in the habitat database or in tallies of previous characteristics. Wetland species include:
Endangered (nonbreeding): bald eagle
Threatened (nonbreeding): Arctic peregrine falcon, sandhill crane
Candidate species (breeding): ferruginous hawk, loggerhead shrike
G3: (nonbreeding): Arctic peregrine falcon, bald eagle
G4: American bittern, Cooper's hawk, ferruginous hawk, loggerhead shrike, merlin, northern goshawk
S1: yellow-billed cuckoo
S2: Arctic peregrine falcon, gray vireo, least bittern, long-billed curlew, snowy egret, wood duck
S3: American bittern, black-throated sparrow, bobolink, Cassin's kingbird, Cooper's hawk, eared grebe, ferruginous hawk, golden eagle, grasshopper sparrow, gray catbird, great blue heron, indigo bunting, long-eared owl, loggerhead shrike, marsh wren, northern harrier, red-eyed vireo, red-headed woodpecker, sage sparrow, sharp-shinned hawk, short-eared owl, snow goose, sora

that contribute importantly to regional genetic diversity because of their relative taxonomic uniqueness[28]. Also, it is notable that many of the bird species that prefer the drier types of wetlands seem to be declining in the region (Table 8). Conceivably, the conversion of drier emergent and wooded wetlands to wetter open water habitats could fragment the drier wetland habitats so much that it might reduce the suitability of the remaining dry-wetland patches for many of their characteristic species.

Moreover, the habitat suitability of many of the wetter wetlands declines over time. This is most likely to happen (a) if these wetlands never receive any overflow flooding from rivers or tributaries, (b) if their water levels are kept relatively constant, and/or (c) most of their sediment is seldom exposed to the air. Natural water exchange rates and fluctuations are needed to help remobilize nutrients bound chemically to the substrate and to trigger the germination of seeds lying dormant in the sediment (Welling et al. 1988). Consequently, dynamic water conditions are needed in wetter wetlands to increase the food resources for a wide variety of animals and stimulate invertebrate production (Severn 1992). Overbank flooding can also increase plant and animal production (and perhaps diversity) in normally isolated wetlands by diluting the high salinity and accumulated toxicants, resuspending excessive accumulations of sediment, scouring and rejuvenating dense homogeneous stands of emergent vegetation, and facilitating recolonization by crayfish, other noninsect invertebrates, fish, and waterborne seeds. For example, stock ponds that are created by damming washes (and which therefore receive outside waters) probably support more waterfowl than isolated, pit-type stock ponds (Tolle 1977).

The seasonal timing of surface water is at least as important as its amount (Sangster 1977). Wetlands that contain the most surface water during freezing months naturally receive less use by water-dependent species at that time. Few Colorado Plateau wetlands have such a flooding regime. Most irrigated wetlands of the region receive surface runoff or subsurface inputs from approximately April to October. This permits their use by many wetland species. Use by shorebirds, however, is not great. This is partly because water levels do not begin to drop until at least October, when most migrating shorebirds have already passed through the region. Dropping water levels in canals at this season do, however, cause stranding of some fish, making them more available to eagles, corvids, and mammalian scavengers. Shorebirds along inland migration routes prefer large flats of mud rather than sand, clay, or rock (Taylor and Trost 1992).

In summary, water regime clearly has a major influence on avian diversity in irrigated wetlands, and "wetter" wetlands generally support more species. However, actions based solely on a philosophy of "wetter is better" may neglect the needs of some species. More appropriate is an approach that takes a landscape and species-specific perspective, considering the relative scarcity of open water vs. other wetland types within a local area, the conservation characteristics of open water species vs. other wetland species, the seasonal and daily timing and duration of flooding, and the need for periodic disturbance (e.g., drawdowns, overbank flooding) to maintain the avian productivity of the wetter wetlands.

Accordingly, these findings have been incorporated into the design of the new avian richness evaluation method (AREM) described in Section 5.0. Specifically:

(a) A wetland score that results from using AREM addresses the collective results from component **species** models, which in turn have addressed the effect of water regime individually for each species. Water regime is not used as an indicator for some species, whereas for others, wetlands lacking surface water are considered more suitable, and for still others, wetlands containing open water or flooded vegetation are considered more suitable;

[28] Of the region's 165 wetland/riparian species, 16 (10%) contribute highly to genetic diversity because of their taxonomic uniqueness. That is, their genus is represented by only one or two species in the region. Of these 16 species, 10 (63%) occur sometimes in uplands, although they prefer wetlands. Only one requires water as a substrate. See Table 7. The importance of focusing conservation efforts on the more taxonomically (and presumably, genetically) unique species is explained, for example, by Vane-Wright et al. (1991).

Table 8. Wetland and riparian birds whose abundance during the breeding period is significantly changing.

These species are either declining (D) in significantly ($p<.10$) more areas within the named state than areas where they are increasing, or are increasing (I) in significantly ($p<.10$) more areas of the named state than areas where they are declining. Species found fewer than 14 times in the survey area during the survey years were not included, following recommendations of the source of these data (the Breeding Bird Survey, U.S. Fish and Wildlife Service 1991). Notations in the last column denote wetland/riparian species (W) or species that use upland habitat almost exclusively (U).

Species	State	Trend 1982-1991	Trend 1966-1991	Wetland or NonWetland Sp.
AMERICAN GOLDFINCH	CO		I	W
	WY	I		W
AMERICAN KESTREL	WY	I		W
AUDUBON'S WARBLER	UT		I	W
BARN SWALLOW	UT	D	D	W
BEWICK'S WREN	CO		I	W
BLACK-BILLED MAGPIE	WY		D	W
BLACK-CAPPED CHICKADEE	WY		D	W
BLACK-HEADED GROSBEAK	CO		I	W
BLUE-WINGED TEAL	CO		I	W
	WY	I	I	W
BREWER'S BLACKBIRD	UT	D	D	W
BREWER'S SPARROW	WY	D	D	W
BROAD-TAILED HUMMINGBIRD	CO		I	W
BULLOCK'S ORIOLE	WY		D	W
CANADA GOOSE	WY	I	I	W
CHIPPING SPARROW	UT	D	D	W
	WY		D	W
CLIFF SWALLOW	CO	I	I	W
	WY		I	W
COMMON GRACKLE	CO		I	W
COMMON RAVEN	WY		D	U
COMMON YELLOWTHROAT	CO		I	W
	WY		D	W
DUSKY FLYCATCHER	CO		I	W
	UT	I		W
	WY		I	W
EUROPEAN STARLING	CO	D		W
	UT	D		W
GREAT BLUE HERON	CO		I	W
	WY		I	W
GREEN-TAILED TOWHEE	CO	D		W
HOUSE FINCH	WY		D	W
HOUSE SPARROW	UT	D	D	U
KILLDEER	UT	D		W
LARK SPARROW	UT		I	W
LOGGERHEAD SHRIKE	CO		I	W
MACGILLIVRAY'S WARBLER	WY		I	W
MOUNTAIN BLUEBIRD	CO		I	U
	UT	I		U
MOURNING DOVE	UT		D	W
	WY	I		W
NORTHERN HARRIER	CO		D	W
	UT		D	W

Species	State	Trend 1982-1991	Trend 1966-1991	Wetland or NonWetland Sp.
PIED-BILLED GREBE	WY		I	W
PINE SISKIN	CO	D		W
PRAIRIE FALCON	UT		I	U
	WY		I	U
RED-BREASTED NUTHATCH	WY	I	I	W
RED-SHAFTED FLICKER	UT	D		W
RED-TAILED HAWK	CO	I	I	W
	WY	I		W
RING-NECKED PHEASANT	CO	D	D	W
ROCK DOVE	CO		D	U
RUFOUS-SIDED TOWHEE	CO		I	W
SAGE THRASHER	WY		D	U
SAY'S PHOEBE	WY		I	U
SWAINSON'S HAWK	WY	D		W
TOWNSEND'S SOLITAIRE	WY		I	W
TREE SWALLOW	CO	I		W
	UT		D	W
TURKEY VULTURE	CO		I	W
	UT		I	W
	WY		I	W
WESTERN MEADOWLARK	CO	D	D	W
	UT	D		W
WHITE-THROATED SWIFT	CO		D	U
WILLOW FLYCATCHER	WY	I	I	W
YELLOW WARBLER	UT	D		W
YELLOW-HEAD. BLACKBIRD	WY	I	I	W

(b) A wetland score that results from using AREM addresses the confounding effects of **other indicators** by including other indicators simultaneously. A wetland's "wetness" is not used as the sole indicator for any species. For example, for some species the scores that AREM assigns to dry wetlands which contain otherwise optimal habitat are the same or greater than scores it assigns to wetter wetlands that have habitat which is suboptimal because of other specified factors;

(c) For many species, a wetland score that results from using AREM is higher in a surface-water wetland that experiences periodic disturbance of its water regime, than in one that does not, other factors being equal.

4.4.3 Vegetation Characteristics

Vegetation provides the physical substrate for many birds that nest in irrigated wetlands. In addition, vegetation provides food directly (e.g., seeds, berries) and indirectly (e.g., serving as a substrate for invertebrates), and shelters wildlife from strong winds, sun, and predators. The physical form of the dominant plant species in a wetland, the number of different vegetation forms present in a wetland, and/or the co-occurrence of vegetation with open water are used as habitat suitability indicators in all nine wetland evaluation methods reviewed by Adamus (1992).

Wetland vegetation is commonly categorized according to its form as woody (includes trees and shrubs) or herbaceous (includes emergent, floating-leaved, and submersed vascular plants). Wetlands of the Colorado Plateau that are most visibly supported by irrigation water tend to be dominated by emergent vegetation, and seldom are dominated by floating-leaved or submersed vegetation. From the information provided partly by the interviewed experts, of the 165 bird species regularly occurring in irrigated wetlands of the Colorado Plateau, I calculated that 19% require herbaceous vegetation and an additional 19% prefer (but do not require) wetlands containing herbaceous vegetation. In contrast, many more wetland/riparian species require or use woody vegetation[29].

However, wetlands containing the greatest number of bird species are usually not those that contain a single vegetation form in abundance, but rather are those that contain a mixture of many types and also some unvegetated open water. For example, the Rector et al. (1979) study of the Lower Gunnison Valley found that whereas forested wetlands, shrub wetlands, and many emergent wetlands had similar bird density (and to a lesser degree bird diversity), diversity was greatest in wetlands where open water, in addition to emergent vegetation, was present. The avian density and diversity such wetlands also surpassed that of wetlands dominated by shrub or tree vegetation[30]. Even for small mammals, wetlands where both open water and emergent vegetation were present together had greater density and diversity than wetlands dominated by trees or shrubs, or where emergent vegetation occurred in the absence of open water. The importance of wetlands containing **both** open water and vegetation is recognized by most existing wetland evaluation methods. For example, when Rector and others (1979) applied their evaluation method to 30 Lower Gunnison wetlands, it tended to give highest ranks to emergent wetlands that contained some open water, followed by forested wetlands, shrub wetlands, and emergent wetlands without open water. When SCS applied a similar version of the evaluation method to the Cortez subregion's wetlands (SCS 1989), it tended to rank forested wetlands

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[29] About 53% of the species require woody vegetation and an additional 11% prefer (but do not require) wetlands containing woody vegetation. More specifically, 15% require shrubs and an additional 27% prefer wetlands containing shrubs. About 17% require trees and an additional 5% prefer wetlands containing trees. Cavity-nesting species comprise 13% of all the region's wetland/riparian species. See Table 5.

[30] Also, several studies from other regions (Kaminski and Prince 1981, Harris et al. 1983, Murkin and Kadlec 1986) and other parts of Colorado and Utah (Weller et al. 1958, Hooper 1962, Robinson 1971, Rector et al. 1979) demonstrate that wetland use by some bird groups, notably waterfowl, increases when both open water and emergent vegetation are present. In dense cattail stands, water openings of 0.37 acre were found to be preferred by mallards (Ball and Nudds 1989).

the highest, followed by cattail, shrub, and sedge-dominated wetlands. A similar version that was applied to a subset of the Lower Gunnison wetlands rated forested wetlands the highest, followed by emergent wetlands and shrub wetlands (USBR 1991).

Perhaps almost as important as open water to bird diversity is the presence in a wetland of exposed **mud.** Fifteen (9%) of the region's 165 species that regularly occur in irrigated wetland/riparian habitats require mudflats as a substrate, and an additional 10 (6%) regularly use or prefer such habitats (Table 5, p. 26).

Avian use of wetlands is related not only to the area of various vegetation forms, but to vegetation species, density, and height. In fact, contrary to findings from studies of forests, at least one study of southwestern riparian habitats (Rice et al. 1983) suggests that the species of dominant tree or shrub can influence avian richness and the presence of many individual species to at least as great an extent as the diversity of vegetative life forms (i.e., foliage height diversity).

Willow and cottonwood appear to be at least as capable as open water in their ability to increase the avian diversity of an emergent wetland. Describing irrigated valley wetlands of the Cortez subregion, Somers (1979) commented:

> "We found that marshes dominated by short, resistant grasses are least productive of birds and mammals. Those dominated by cattails and rushes are only slightly more productive. But those with even small **willow thickets** [emphasis mine] harbor many birds."

Willows, particularly when forming tall, broad stands, seem to be used preferentially by wintering sparrows, migrant passerines, and nesting willow flycatchers and yellow warblers. Cottonwoods, because of their larger size, provide much better sites for cavity-nesting species and perching hawks than most shrubs. As long as water continues to be present, wetlands dominated by exotic plant species are not necessarily species-poor for birds, and in many cases have greater species richness[31]. Russian olive, for example, greatly increases habitat suitability for at least 38 (23%) of the 165 wetland/riparian species of the region, and is specifically preferred by 19 (12%). The much-maligned tamarisk (salt cedar) tolerates conditions inhospitable for many other trees and appears to be used preferentially during some seasons by long-eared owls, mourning doves, western meadowlarks, blue grosbeaks, and perhaps some other species (Hunter et al. 1985).

Among emergent wetlands, those dominated by robust plants with stiff, persistent stems (e.g., cattail, common reed, bulrush) are used preferentially by several species (e.g., rails, marsh wren, blackbirds, pheasant; Glahn 1974, Sather-Blair and Linder 1980, Guthery and Stormer 1984); bulrush in Colorado requires less than 2 months of flooding to become established (Cooper and Severn 1992). Wetlands with weedy forbs attract sparrows and other finches, especially if located near trees or brushy cover (Strong and Bock 1990). Flowering forbs attract hummingbirds. Wetlands with submerged sago pondweed or coontail are particularly attractive to wigeon, canvasback, coot, and some other Colorado waterfowl (Gorenzel et al. 1981, Kantrud 1990). Irrigated wetlands with beds of watercress attract many invertebrate-feeding marsh birds (e.g., common snipe). The type of crop present in a flooded field also influences aquatic insect density and thus, probably the occurrence of nighthawks, swallows, and other insect-hawking species. A study in the Grand Valley indicated that irrigated pasture supported greater density of some aquatic insects than irrigated alfalfa, corn, or orchards (Hayes and Nielsen 1978). Density and height of wetland vegetation are often influenced by grazing, mowing, and burning. Ditches in some wetlands in all subregions are burned, generally in the spring, to increase the capacity of ditches to convey water and reduce weed sources. This can adversely affect wetland habitat of many

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[31] However, some woody exotic plants are capable of severely drawing down the water table in their immediate vicinity. If this results in loss of the only local wetland habitat that contains surface water during much of the growing season, then gains to some species might be offset by losses of other species (e.g., common snipe) which are more restricted in their habitat selection.

species (Fritzell 1975, Gorenzel et al. 1981, Kantrud 1986). Herbicides are also sometimes used to remove vegetation along irrigation canals.

Grazing and mowing are most prevalent in wetlands of the Utah subregion, where pasture is a predominant land use. Limited evidence from other western regions suggests that moderate grazing of wetlands, by increasing visibility of predators and access to food sources, might increase habitat suitability for perhaps nine of the region's wetland/riparian species, e.g., some shorebirds, geese, barn owl, American robin, Brewer's blackbird (Table 5, p. 26). However, partly by altering ground cover density and causing clumping of shrubs (Crouch 1961, Cannon and Knopf 1984, Knopf et al. 1988), grazing can decrease suitability for at least 52 others[32]. Grazed riparian areas also can have fewer mammal species (Medin and Clary 1989). Especially among the forested types of irrigated wetlands, those with dense canopy might be more important to wintering wildlife (for shelter), whereas those with individually large trees might be more important in summer (Anderson and Ohmart 1977, Morrison et al. 1986).

The season of grazing, mowing, or burning probably influences avian communities more than the intensity of these activities (Wiens 1973). Adverse effects on birds are probably greatest when grazing, mowing, or burning are conducted during the nesting season (May through mid-July). Moderate, late-fall grazing appears to have minimal effect on the use of some riparian habitats during the following breeding season (Sedgwick and Knopf 1987). Late-season mowing can increase wetland invertebrate biomass and waterfowl use (Beck et al. 1987, Ball and Nudds 1989).

In summary, no single vegetation type is "best" for bird communities. Rather, irrigated wetlands that are most similar to natural bottomland (river) wetlands (e.g., presence of open water, extensive trees and shrubs, multispecies emergent vegetation, etc.) probably support the largest number of species. Human activities potentially alter the density, height, and species composition of wetland vegetation, and consequently affect bird diversity. As a result of these findings, the following features have been incorporated into the design of the avian richness evaluation method (AREM) described in Section 5.0. Specifically:

(a) A wetland score that results from using AREM reflects the collective results from component **species** models, which in turn have addressed the suitability of each vegetation form (and some dominant vegetation species) for each species. Vegetation form or species is used as an indicator for a majority of bird species, as are the effects of vegetation height and density. The effects specifically of burning, mowing, or intensively grazing wetlands during the springtime are reflected in the models for 61 species.

(b) A wetland score that results from using AREM reflects the confounding effects of **other indicators.** A wetland's vegetation form or species is seldom used as the sole indicator for any species. For most species, other indicators -- particularly the presence of open water -- are incorporated simultaneously and, in some cases, independently.

4.4.4 Other Animals and Wetland Water Quality

Use of wetlands by many bird groups is strongly influenced by the amount of aquatic invertebrates and fish supported by the wetland, and the seasonal timing of their availability (Joyner 1980, Ball and Nudds 1989, Hands et al. 1991). The abundance of invertebrates and fish is, in turn, influenced by water quality and by the

[32] Literature reports adverse grazing impacts on the following: northern harrier, great horned owl, broad-tailed hummingbird, house wren, eastern and western kingbirds, western wood pewee, willow flycatcher, blue-gray gnatcatcher, yellow warbler, common yellowthroat, yellow-breasted chat, orange-crowned warbler, white-crowned sparrow, song sparrow, dark-eyed junco, green-tailed towhee, red-winged blackbird, and northern oriole (Kantrud 1981, Taylor 1986, Sedgwick and Knopf 1987, Szaro and Rinne 1988, Szaro 1991, Schultz and Leininger 1991, Krueper 1992, Baker et al. 1992).

indicators described above, such as water regime (Driver 1977, Broschart and Linder 1986, Euliss et al. 1991) and vegetation type/interspersion (Scheffer et al. 1984).

Irrigated wetlands appear to be deficient in fish and noninsect invertebrates (as discussed previously on p. 22). This is partly because all surface water disappears from most irrigated wetlands at some time of the year (usually in winter). Surface water that is reintroduced to wetlands in the spring contains whatever small fish, amphibians, and invertebrates happened to be in the water source (i.e., river) at the time, and that are capable of surviving turbulent conditions while being transported through miles of canals, ditches, diversion pipes, and (sometimes) holding ponds before reaching the wetland.

Habitat quality and bird diversity of irrigated wetlands are also affected by water quality. The high salinity and turbidity of some wetlands undoubtedly limits the production and presence of some wetland plants (Kauskik 1963, McKnight and Low 1969, Christiansen and Low 1970, Cooper and Severn 1992). Of the region's 165 wetland/riparian species, at least 17 (10%, see Table 5, p. 26) can suffer reduced feeding capacity as a result of high turbidity visually obscuring their prey and perhaps limiting the production of aquatic prey. When plant production is reduced, so are the numbers of invertebrates that depend heavily on aquatic plants (Rawson and Moore 1944), and which themselves provide essential foods for many waterbirds. Such a situation has been documented in irrigated wetlands of the San Luis Valley (Severn 1992). High salinity can also limit directly the abundance of invertebrates and some fish and amphibians. Consequently, most isolated, saline, irrigated wetlands are not used heavily by piscivorous birds (e.g., kingfisher, loons, grebes, herons, egrets)[33].

Because heavy sediment loads, high salinity, winter freezing of sediments, and the frequent lack of permanent water hinder the maturation of many species (Adamus and Brandt 1990), the aquatic insect fauna of most irrigated wetlands probably consists mainly of opportunistic species with short life cycles (e.g., midges), rather than long-lived species (e.g., dragonflies). Studies of western river segments receiving irrigation return waters have shown they have more aquatic worms and leeches, and fewer mayflies, caddisflies, water beetles, and isopods, than unaffected waters (Kreis and Johnson 1968).

In localized areas of the Colorado Plateau, selenium and possibly other trace metals have sometimes become concentrated in irrigation tailwaters (Stephens et al. 1988) and have killed wetland birds and possibly other aquatic life. Pesticides are widely used in this agricultural region. Studies of isolated prairie wetlands have demonstrated severe impacts on invertebrate populations and wetland birds from regular pesticide use (Grue et al. 1988), but apparently this potential threat to wetland wildlife remains uninvestigated in salinity control areas. A more obvious threat is the great turbidity of irrigation tailwater. Highly erodible, clayey soils become suspended in water running off flooded fields and into wetlands. In many parts of the region this severely impedes light penetration and limits the establishment and growth of submerged aquatic plants valuable to waterfowl. It also raises questions about the long-term sustainability of wetland creations or enhancements in this heavily agricultural region. In many areas, heavy sediment runoff combines with the effects of intensive springtime grazing, severe eutrophication, local water table disruption, and possible contamination with metals and pesticides to cumulatively threaten the functional longevity of created wetlands, as much or more so than natural wetlands.

In summary, it is apparent that water quality in irrigated wetlands can affect the amount and availability of aquatic plants and animals important as food to birds. Salinity and sediment are the most obvious pollutants of concern to birds, and they probably affect some species more than others. In response to these findings,

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[33] A review of primary production by Hammer (1981) concluded that the most productive saline lakes have high alkalinity, are not highly saline (<30mS/cm^2), and are rich in soluble phosphorus. A few bird species (e.g., red-necked phalarope, American white pelican, American avocet) are heavy users of alkali lakes or wetlands, and some invertebrates (e.g., brine flies) can reach very high densities in saline lakes (Timms 1981, Vareschi 1987). However, salinity greater than about 1.5 dS/m causes digestive stress in some birds, and salinity greater than 5.0 dS/m is considered unsatisfactory for livestock (National Academy of Sciences 1974).

the new avian richness evaluation method (AREM) described in Section 5.0 takes a species-specific approach. Excessive turbidity (from suspended sediment) is assumed to have the greatest influence in wetlands containing surface water. The primary impact is assumed to be to species that feed visually on subsurface prey (e.g., kingfisher on small fish) and on submersed plants, and a secondary impact is assumed for species that depend largely on aquatic insects (e.g., swallows). The AREM models for shorebird species reflect the likely reduced suitability of highly saline mudflats.

4.4.5 Landscape Land Cover and Seclusion

Birds are highly mobile. Thus the suitability of a wetland's habitat for many species depends as much or more on the suitability of the surrounding nonwetland land cover. Land cover in the Colorado Plateau is influenced by elevation, which ranges from under 5000 ft in the southern part of the Utah subregion to slightly over 7000 ft in the Wyoming subregion. Most irrigated wetlands are surrounded by cropland or desert scrub -- mainly greasewood, saltbush, and sagebrush. None are surrounded by upland forest, although above the valley floors (e.g., parts of Uinta Basin and Uncompahgre Valley), pinyon-juniper scrub becomes slightly more prevalent. When large patches of pinyon-juniper scrub are present, at least seven wetland/riparian species which seem to require both the scrub and wetlands become more regular, e.g., Townsend's solitaire, plain titmouse (Table 5, p. 26).

Within the agricultural areas, wetland use by geese and mallards seems to be influenced the most by proximity to cropland, especially the proximity to partly-harvested corn. Of the region's 165 wetland/riparian species, about 32 (19%) tend to occur in wetlands that have fields with grain nearby (Table 5, p. 26). In Arizona, wetlands (cottonwood stands) adjacent to agricultural lands had greater densities of birds than those surrounded by pinyon-juniper or other woody vegetation (Carothers 1977). However, species richness can decline in relict stands following agricultural conversion of surrounding natural habitat (Conine et al. 1978). Crop type and height also can affect use of adjoining irrigated cropland by some waterbird species (Ohmart et al. 1985). A study of narrow woodlots in Pennsylvania suggested that breeding bird diversity can be greater in woodlots adjoining croplands than in those adjoining pastureland (Yahner 1983).

Surrounding land uses can also affect the trophic condition of a wetland. Some wetlands that have been enriched by fertilizer runoff, livestock waste, or domestic wastewater have shown high levels of waterfowl production (Piest and Sowls 1985, Wilhelm et al. 1988, Hoffman et al. 1990), at least partly in response to elevated invertebrate production. About 25 (15%) of the region's 165 wetland/riparian species appear to prefer such situations; examples include barn owls and Brewer's blackbirds. Enrichment of saline wetlands also can increase the production of some characteristic plants (Loveland and Ungar 1983).

Some species appear to avoid small irrigated wetlands that are deeply recessed within washes or are completely surrounded by tall, woody vegetation. For example, most species of shorebirds, loons, grebes, cormorant, and geese avoid wetlands where ground-level visibility of the surrounding land (and predators) is restricted and space is too confining for their running take-offs (Dwyer 1970, Evans and Kerbs 1977). On the other hand, some species that use wetlands in more heavily developed areas appear to favor wetlands surrounded by dense, moderately tall vegetation that provides a visual buffer against disturbance (Milligan 1985). Of the region's 165 wetland/riparian species, about 56 (34%) appear to benefit from a high degree of visual seclusion (Table 5). About 23 of these are species that require water as a substrate, i.e., are categorized as "highly dependent." Greatest disturbance is usually caused by people on foot (LaGrange and Dinsmore 1989). Species that seem most wary of approaching humans are generally the larger-bodied ones, e.g., herons, egrets, waterfowl, raptors (Dahlgren and Korschgen 1992), and long-distance migrants that feed in large flocks at the ground or water level (Burger 1981)[34]. Reduced use of human-visited wetlands by waterfowl or nongame waterbirds has been

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[34] Of the region's 165 wetland/riparian species, about 56 (34%) appear to benefit from a high degree of visual seclusion. About 23 of these are species that require water as a substrate.

demonstrated by Kaiser and Fritzell (1984) and Hoy (1987). Seclusion (i.e., distance from human dwellings) is also important to many songbird species because it reduces harrassment and predation by domestic animals, notably house cats. Constant presence of cattle in wetlands during the nesting season can also reduce nesting success of some species (Tolle 1977). Of the region's 165 wetland/riparian species, at least 27 (16%) avoid wetland habitats where predation pressures are likely to be great.

Other landscape variables that might influence bird use of wetlands in western regions include watershed size and orientation (Dobkin and Wilcox 1986, Gutzwiler and Anderson 1992). Evidence of the importance of these indicators has, to date, been limited to a few species that occur in wooded wetlands.

In summary, wetland habitat suitability should not be judged independently of the habitat suitability of the surrounding landscape. No particular surrounding habitat type is optimal for all species, or always results in higher avian diversity of adjoining wetland/riparian areas. Although (other factors being equal) secluded wetlands might be likelier to be visited by more species, the response of birds to disturbance is probably species- or group-specific. Accordingly, the new avian richness evaluation method (AREM) described in Section 5.0 takes a species-specific approach. The fact that certain surrounding land covers benefit some species but not others is factored into the method. At a species level, the method accounts for the varying effects of the presence of cropland, other wetlands, land uses that add high concentrations of nutrients, and secluded areas. When assessing habitat acreage for some wide-ranging wetland species, the AREM user also is asked to include the acreage of continguous, structurally similar habitat even if such habitat is not within the evaluated wetland.

4.5 Summary of Remaining Information Needs

As a result of the foregoing review of habitat indicators, it appears that several questions, all of possible interest to EPA because of their regulatory/mitigation implications, require further research and clarification. These are presented in no particular order, and should not be considered comprehensive:

- Do wetlands that support a diverse avifauna also support a high diversity of vertebrates, plants, and invertebrates?

- Are the wetlands that have the greatest species richness (or that contribute the most to regional biodiversity) the same ones that are highest-functioning for hydrologic and water quality functions?

- Can avian species richness, or at least the occurrence of some component species, be predicted accurately and consistently through use of rapid indicators?

- Can statistically sound relationships be defined between habitat indicators, avian richness, and simple **management classifications** (e.g., on-farm vs. off-farm)?

- Do wetlands that have more permanent **water regimes** have more species, and/or more species that are of conservation concern (e.g., neotropical migrants, regionally declining species, habitat specialists, etc.)? Or are riparian fringe and irrigated emergent wetlands more important?

- To what degree do birds use various types of irrigated wetlands in **Utah and/or Wyoming?** Is the relative importance of various types of irrigated wetlands the same as found previously in the Lower Gunnison Valley in Colorado?

Although some previous studies have provided clues to the above questions, or answered them for particular wetlands, sufficient data have not been collected in a systematic manner that would permit a general extrapolation of findings to irrigated wetlands of the Colorado Plateau. Such data are essential to ensure the credibility of any evaluation method or classification system applied to these wetlands.

5.0 AVIAN RICHNESS EVALUATION METHOD (AREM) FOR THE COLORADO PLATEAU

5.1 AREM and What It Can Do

I used the indicators documented in Section 4.0 to formulate a procedure for rapidly evaluating the suitability of irrigated wetland habitat for birds. This procedure, termed the "Avian Richness Evaluation Method" (AREM), can:

- o Assign a score to each evaluated wetland, which represents the number of bird species that could occur in the wetland, multiplied by an estimate of the suitability of the wetland for each.

- o List the species likely to occur in a particular wetland. Such a list can be combined with lists predicted for other wetlands, to identify minimum combinations of wetlands that will provide habitat for all bird species in an area.

- o Tally the number of species likely to occur in the wetland and which have particular characteristics, e.g., neotropical migrants, uncommon or game species. If desired, the user can assign scores to these characteristics and use them as "weights" in deriving the wetland score.

The following pages introduce AREM by describing its conceptual basis and demonstrating how it works. Its advantages are summarized in Table 9, its limitations and assumptions are summarized in Table 10, and recommendations for identifying its proper context of use are presented in Table 11.

5.2 Conceptual Basis for AREM

Biodiversity is the organizing theme and endpoint of AREM. Biodiversity can be defined as the variety of biological material at any or all levels of organization: genetic, species, community, and function. Biodiversity is of fundamental concern for scientific, economic, and aesthetic reasons. Scientific evidence suggests that, in some situations, balanced and diverse (species-rich) biological communities are better able than nondiverse communities to endure environmental change with minimal loss of function. It is important to minimize loss of wetland function because increased costs to society can be incurred to replace products and services otherwise supplied passively and at no direct cost by wetlands. For example, loss of a wetland's natural ability to purify runoff can pose a burden on users of lakes and rivers that depend on wetlands to maintain water quality. When this happens, there is often a demand to alleviate the pollution by investing in construction of wastewater treatment facilities. Moreover, because diverse natural communities (as well as some productive ones) are aesthetically attractive to many people, regions with high biodiversity often enjoy greater economic benefits from tourism. Recognizing the importance of biodiversity, EPA's Science Advisory Board in 1990 recommended that biodiversity be accorded highest priority in the Agency's programs. EPA is not alone in this concern; the U.S. Forest Service, U.S. Fish and Wildlife Service, and other agencies have legal mandates for maintaining biodiversity, and the concept of a National Biological Survey that will focus on biodiversity using ecosystem approaches is currently under discussion within the U.S. Department of the Interior.

Some wetland evaluation methods may have included biodiversity as an endpoint, but seldom say so explicitly. For example, the Golet method, which is used as the basis for SCS's current (1992) wetland evaluation method, rates habitat without stating what species a "good" habitat would contain, or even whether it will be biodiverse. Another method -- WET (Adamus et al. 1987) -- assigns highest ratings to habitats that indicators presumably predict will be "diverse and/or productive," but does not document this assumption by quantifying the number of species or listing them. The Habitat Evaluation Procedure, or "HEP" (USFWS 1980), is often used to evaluate irrigated wetlands, and its users sometimes assume, without any documented basis, that habitat which HEP shows is highly suitable for a few selected indicator species will be suitable for supporting a high diversity of species. "Bottom-up" attempts have been made to aggregate HEP's individual species models into a general model for a particular habitat type (e.g., Bain and Robinson 1988), or to take a "top-

Table 9. Advantages of using AREM.

1. Using AREM is relatively **simple and rapid**. Field data collection requires less than 15 minutes per wetland. Data entry and analyses require less than 30 minutes per wetland.

2. Models used to predict habitat suitability for individual species are mathematically simpler than those used by HEP (the Habitat Evaluation Procedure), so may be easier to understand and explain.

3. The synthesis scores that result from an AREM evaluation (see Section 5.3) have a high level of **accountability**. Users can call up the database for any species in order to closely examine the habitat model supporting that species. Users can also call up any indicator condition, to identify all species predicted by that condition. This is of potential use in predicting a species' response to wetland change, e.g., for impact analysis or planning of wetland enhancements.

4. Users with little computer knowledge can **interactively edit** the database and revise models for any species. AREM provides this capacity while ensuring that the original database is not erased. This also allows users to adapt AREM for other regions and wetland/riparian types, provided habitat requirements of all bird species in these areas are known or can be determined with sufficient accuracy.

5. AREM is perhaps the only rapid habitat evaluation method whose major organizing theme and endpoint is **biodiversity**. This is of interest because many government agencies are mandated to account for the impacts of their activities on biodiversity, and public concern over the global and regional loss of biodiversity appears to be growing.

6. In contrast to HEP, AREM does not require the user to base a wetland's score on a few presumed "indicator species." Users do not need to assume that habitats which are found to be optimum for a few species will also be suitable for many species, i.e., be biodiverse.

7. Species lists predicted by AREM for various wetlands can be combined in any local area or subregion to determine which particular combination of wetlands cumulatively supports the greatest number of species (see Table 15 for an example). This "optimization process" can be further focused by applying constraints related to species characteristics, land ownership, management costs, or other factors. As such, use of AREM can provide a complementary, local refinement of the "gap analysis" approach currently being applied at state and regional levels by the U.S. Fish and Wildlife Service (Scott et al. 1987).

8. AREM's synthesis scores may be less subject than those of other rapid methods to bias from imperfect science. This is because the synthesis scores are a composite of both a wetland's number of species and its suitability rating for each species.

9. One of AREM's outputs -- the "unweighted richness" score -- is the actual number of species predicted to occur in a wetland. As such, this is an ecological parameter that can be validated empirically.

10. AREM does not require the user to conduct bird surveys or, for that matter, be an expert on birds or other wildlife.

Table 10. Limitations and assumptions of AREM.

1. AREM has not been validated scientifically, either in total, or in terms of its habitat relationship models for individual species. This is true of probably all other rapid methods for habitat assessment.

2. AREM is a compromise between convenience and technical certainty. The technical certainty of many of the species habitat models that comprise AREM might be increased, and details and assumptions explained at greater length, but probably only at the expense of speed of application, replicability, and clarity. AREM is intended to be intermediate in complexity between the simple, few-indicator wildlife habitat relationship (WHR) models used in landscape classification and the multi-indicator, few-species HEP models used for site evaluations. It shares many of the limitations of WHR's as described by Morrison et al. (1992) and limitations of HEP described by Van Horne and Wiens (1991), but avoids others.

3. Indicator conditions used in AREM's species models in some cases are related to a species' presence in a loosely deterministic manner, but in other instances are related only empirically, i.e., they correlate with a species' presence but have necessarily been shown to control use of habitats through explicit effects on food, cover, or reproduction.

4. Wetlands are dynamic systems, and scores assigned by any evaluation method can change as a result of natural vegetative succession, flood or drought, management actions, and other factors.

5. AREM pertains only to avian biodiversity. We do not know if wetlands that contain a relatively great number of bird species usually also have a relatively great number of plants, insects, amphibians, or whatever.

6. It cannot be assumed that wetlands that are species-diverse will always be diverse at genetic, community, or functional levels, although this is often the case.

7. It cannot be assumed that wetlands that are species-diverse will always have greater ecological "integrity," "health," or "sustainability," although this is usually the case.

Table 11. The context for properly using AREM.

1. AREM is intended for application only to lowland irrigated wetlands and riparian areas larger than 0.1 acre, and located within the Colorado Plateau region of western Colorado, eastern Utah, and southwestern Wyoming.

2. Users should be capable of recognizing all indicator conditions specified in the field forms (Appendix F). When evaluating a wetland, note situations in which you feel information requested by the field forms has required considerable judgement, and report this with the results.

3. As is true of other rapid methods for habitat assessment, AREM's habitat relationship models for individual species cannot be used to estimate the relative or absolute abundance or density of these species' populations. Many factors not included in the species models, e.g., weather, determine population size and even presence/absence in a given wetland.

4. AREM should not be used to compare wetland/riparian habitats with other habitats. Species habitat scores from AREM estimate the suitability of a wetland or riparian habitat relative only to the suitability of other irrigated wetlands and riparian habitats of the Colorado Plateau. In some circumstances, some species included in AREM might find nonwetland habitats more suitable.

5. Scores from AREM should not be used in lieu of species occurrence data from actual surveys of a wetland, provided such data have been collected with sufficient intensity and using appropriate methods.

6. Scores from AREM should be considered as only one of several possible inputs used in the decision-making process. Under most circumstances it is inappropriate to use AREM as the only means for deciding whether mitigation should be required. A habitat index, defined as the product of an AREM score and wetland acreage, can be computed if desired. The values from such an index can potentially be used as one input in mitigation deliberations, monitoring of restoration/enhancement projects, and description of the future biodiversity consequences of specified impacts to the indicator conditions. However, the commonly associated practice of using values from such indices to rationalize a decision to offset the loss of a collectively large acreage of low-quality wetlands with the creation of a small acreage of high-quality wetlands must be viewed cautiously. As is true of other methods, caution is needed because use of simple multiplication presumes that species richness is related to habitat acreage (wetland size) in a direct, linear manner. This is not necessarily valid because (a) the effect of wetland size on richness can vary by species composition, season, surrounding landscape characteristics, wetland size and shape, and other factors, (b) wetland size is "double-counted," first as it is included in individual species models, and second as it is applied as a multiplier, and (c) "enhanced" habitat quality does not necessarily compensate for lost habitat space.

down" approach in which a series of general statements about a system are used to focus and incorporate more specific detail only as needed (e.g., Schroeder 1986). Both of these approaches produce an ordinal score rather than a real variable (species richness) and contain many implicit assumptions (Van Horne and Wiens 1991). Another method, the Habitat Assessment Technique (HAT, Cable et al. 1991), does equate wetland habitat suitability directly with species richness but is time-consuming to use because it requires that birds be surveyed directly rather than estimating their presence through use of indicators. Finally, wildlife habitat relationship (WHR) models or matrices have been developed by many government agencies (Morrison et al. 1992). WHR's can be aggregated, in what is called "gap analysis," to estimate species richness of a habitat area or region (Scott et al. 1987). However, the WHR models are crude and seldom use more than a few indicators, e.g., gross land cover type. Conventional WHR models typically do not differentiate among various wetland types. Thus, applying such models to a series of wetlands would result in all wetlands having the same species composition and richness.

5.3 How AREM Works

When you use AREM, how does the information you collect on a wetland's indicators get converted to scores and species lists for a wetland? First, understand that the tools AREM uses to generate the products are:

- The data that you enter from your completed field form (Appendix F), representing the indicator conditions of the evaluated wetland;

- Three databases that are used to match the data from your field form with information on each species' habitat requirements, geographic/seasonal distribution, and conservation characteristics; and

- A computer program that does the matching described above.

These tools interact sequentially to generate scores and species lists. A wetland evaluation using AREM proceeds in the following manner. First, you briefly visit the wetland and check off habitat indicators observed, using a standardized checklist (the field form, Appendix F). Next, you take your completed data form indoors to a computer, where a menu-driven program explains how to generate scores and species lists for the evaluated wetland. It instructs you to compare the list of indicator conditions you noted on your field form (Appendix F) with a similar list on the computer screen, and mark the conditions that are common to both lists. Then, the computer program compares the marked conditions with the databases. Finally, it calculates three types of scores for the wetland, based on sums of the scores for all the individual species.

The main database that is the foundation of AREM is a habitat relationships matrix which I prepared from literature, professional experience, and especially, from interviews with local avian experts. When developing the database, the literature that I found to be most relevant included the citations in Chapter 4.0, as well as various Habitat Suitability Index (HSI) models (Schroeder 1982, 1983a, b, Prose 1985, Short 1985, Short and Cooper 1985, Sousa 1987, Schroeder and Allen 1992), and the following journal papers, books, and reports: Provost 1947, Johnsgard 1956, Johnson and Ryder 1977, Whitmore 1977, Thomas 1979, Faanes 1982, Bull and Skovlin 1982, Rice et al. 1983, and Ehrlich et al. 1988.

One axis of AREM's supporting database matrix is a list of all 71 indicator conditions that are contained on the field form (Appendix F). The other axis contains a list of the 165 bird species that regularly use irrigated wetlands in the region (p. 16 explains the basis for this list). I assigned <u>one</u> of the codes shown in Table 12 to each cell in the matrix. When used together, these codes form a simple habitat relationship model for each species. Table 13 shows an example.

Table 12. Meaning of codes used in the species habitat relationships database.

X	means the species <u>requires</u> that indicator condition (i.e., habitat feature)
f	means the species requires either that condition <u>or</u> another one (or more), also pre-labeled in the database with an "f"
1	a number (could also be 2, 3, or 4) representing the species' preference for that indicator condition, relative to other indicator conditions for that species in the database (4= more important, 1= less important)
+2	a number (could also be +2 or +3, or could be preceded by a minus sign) that describes a condition that is not essential to the species, but influences its probability of occurrence in a particular area (+2 = more influential than +1)
(blank)	means the indicator condition is not sufficiently relevant to predicting the suitability for the species (i.e., other indicator conditions are more predictive)

Table 13. Example of the marsh wren species model, as defined by database coding.

For marsh wren, the database includes characters in 10 data fields[1] as follows:

Data Field Name	Code	Brief Description of Data Field
Anywater:	+1	Wetland has >2 inches of surface water
Drawdown:	+1	Wetland sediments are occasionally exposed, or wetland receives floodwater input from a major river
EmIn:	X	Wetland has >0.1 acre herbaceous, emergent vegetation
RbMuchDens:	3	Wetland has >1 acre robust, dense vegetation
RbMuchOpen:	2	Wetland has >1 acre robust, open vegetation
RbSomeDens:	2	Wetland has 0.1-1.0 acre robust, dense vegetation
RbSomeOpen:	1	Wetland has 0.1-1.0 acre robust, open vegetation
WEMuchDens:	1	Wetland has >1 acre wet, grassy, dense vegetation
PredHPot:	-1	Wetland is likely to be subject to high predation pressure
GrazBurnMo:	-2	Wetland is intensely grazed, mowed, or burned during nesting season

[1] The terms "data field" and "indicator condition" are used interchangeably because each indicator condition is allocated to one data field in the habitat relationships database. In this example, the other 60 fields of the database are blank because their indicator conditions were judged to be insufficiently relevant to estimating the habitat suitability of Colorado Plateau irrigated wetlands for the marsh wren. At least one other species is associated with each of the 71 data fields in the database.

A unique feature of the computer program that supports AREM is that it allows users (regardless of their computer skills) to edit the main database. For example, users can (a) add or delete species, e.g., to reflect a different opinion regarding a species' dependence on wetland/riparian habitats, or to narrow the analysis just to game species, (b) change the indicator conditions (from the current set of 71 in Appendix F) which support the habitat model for any species, and (c) change the manner in which a particular indicator condition contributes to a model. Moreover, AREM provides this capacity while ensuring that the original database is not erased.

To demonstrate how the AREM analysis program works, consider one species -- marsh wren -- whose habitat is defined by the model in Table 13. The computer program compares the model (as defined by the database) with data you entered from your field form. The analysis proceeds in the following sequence:

Step 1. Before evaluating the suitability of the habitat for marsh wren, it is necessary to determine if the geographic range of the marsh wren during a specified season includes the evaluation area. To determine this, the computer program scans a database that has cataloged the within-region geographic and seasonal distribution of each of the region's 165 wetland/riparian birds. If the database shows the marsh wren does not occur in the season and subregion marked on the field form, then the marsh wren is dropped from consideration and the program proceeds to the next species on the seasonal list of regionally-occurring species. If marsh wren does occur in the subregion during the season of interest, the analysis of the wetland using the marsh wren's habitat model proceeds.

Step 2. Next, it is essential to determine if the wetland is **minimally acceptable** to the marsh wren. To do this, the program scans the marsh wren model in the database. If the database contains an "X" or an "f" in one of the data fields that you checked off on your field form, then the program considers the wetland to be minimally acceptable, because a required condition is present. The program assigns marsh wren a "base score" of 5. If neither an "X" nor an "f" are present, further analysis is considered moot and marsh wren is assigned a score of 0. For marsh wren, the database considers a minimally acceptable wetland to be any one that contains at least 0.1 acre of herbaceous vegetation (EmIn). That is, data field EmIn is marked with an "X" or "f."

Step 3. Next, it is important to determine if conditions are present that would make the wetland more than minimally acceptable for the marsh wren. The manner in which the program does this is described here and in Step 4. Initially, the program identifies beneficial, **compensatory** indicator conditions that are defined by the marsh wren model and are also present in the wetland. "Compensatory" means that if more than one of these conditions is present, their effects are not additive. For example, marsh wrens usually prefer robust vegetation that is dense, but benefit somewhat from robust vegetation even if it is relatively open. In the database, the best compensatory indicator condition has been assigned the largest number, generally on a 1 to 3 scale. From the numbers for marsh wren in the database, the computer program selects the maximum value for any indicator that is also present in the evaluation wetland. The maximum rather than the sum is used because the sum would erroneously imply that habitat is optimal when both dense and open robust vegetation stands are present, i.e., the two density conditions would be treated as if they were functionally additive.

To demonstrate, the marsh wren model part of the database contains the following compensatory indicator conditions:

Data Field Name	Code	Brief Description of Data Field
RbMuchDens:	3	Wetland has >1 acre robust, dense vegetation
RbMuchOpen:	2	Wetland has >1 acre robust, open vegetation
RbSomeDens:	2	Wetland has 0.1-1.0 acre robust, dense vegetation
RbSomeOpen:	1	Wetland has 0.1-1.0 acre robust, open vegetation
WEMuchDens:	1	Wetland has >1 acre wet, grassy, dense vegetation

If you showed (on the field form) that the wetland contains only RbSomeDens and RbSomeOpen, then the program will select RbSomeDens because its number (2) is larger than the value for RbSomeOpen (1). The program then adds this number (2) to the base score (5) determined in Step 2, giving a total of 7, and the analysis continues. If the base score had been 0, nothing would have been added because the analysis for marsh wren would have been terminated at Step 2.

Step 4. The program also determines if one or more **cumulative** indicator conditions are present. As with compensatory conditions, these are conditions that are not required by marsh wren, but which alter its probability of occurrence in a wetland. "Cumulative" means that if more than one of these conditions is present, their individual effects are combined. For this reason they must be treated differently from compensatory conditions in the calculations. Each cumulative indicator condition in the database is represented by a number preceded by a sign (+ or -) indicating whether that condition tends to increase (+) or decrease (-) the probability of that species occurring in a wetland. This cues the computer to recognize that it is a cumulative condition, not a compensatory condition. A number (+1 to +3, or -1 to -3) indicates the intensity of the effect, with larger positive or negative numbers indicating stronger effects.

Consider again the marsh wren. According to the database, the chances of the wren using an herbaceous wetland with dense, robust vegetation increase if:

(a) the wetland also contains at least 2 inches of surface water (i.e., the indicator condition "Anywater" was checked on the field form), and/or

(b) the wetland's sediments are occasionally exposed, or the wetland receives floodwater input from a major river (i.e., the indicator condition "Drawdown" was checked on the field form).

At the same time, the probability of the wren using the wetland decreases if:

(c) the wetland is likely to be subject to high predation pressure, and/or

(d) the wetland is intensely grazed, mowed, or burned during nesting season.

In the database, the above statements are coded in the marsh wren model in the following manner:

Data Field Name	Code
Anywater:	+1
Drawdown:	+1
PredHPot:	-1
GrazBurnMo:	-2

In this case, the database considers the negative effect (-2) of nesting-season grazing, mowing, or burning to be greater than the effects of any of the other indicator conditions (+1 or -1).

At this point the program adds to the sum (7) from Step 3 all of the cumulative indicator conditions present in the evaluated wetland. For example, if this wetland contains just two of these conditions -- Anywater (+1) and GrazBurnMo (-2) -- their sum (-1) is added to the sum (7) from Step 3. If none of the cumulative indicator conditions are present, the sum (7) is brought forward and the analysis continues.

Step 5. Next, it is crucial that the species scores be standardized, so that no species is implicitly given more weight. If the scores are not standardized, species whose models specified many indicator conditions would be implicitly biased toward higher scores and would contribute disproportionately to the total, whereas species having models that specified fewer indicator conditions would artificially tend to score lower. To standardize the species scores, the program divides the total by a "potential maximum" (PotMax) number, which is the largest point total the marsh wren could theoretically receive. That number represents the optimum habitat suitability as defined by the marsh wren model ("optimum" meaning that these conditions represent the best habitat likely to be currently available within any Colorado Plateau irrigated wetland). Because different species models use different numbers of indicator conditions, each species has its own value for PotMax. In the example of the marsh wren, the Step 4 total (6) is divided by a PotMax value of 10, to give a final score (termed the **species habitat score**) for marsh wren of 0.6. By dividing by PotMax, the program ensures that no species' score can exceed 1.0, so that if a wetland's habitat were optimum for all species, they would be counted equally and the sum of all the species habitat scores would equal the number of species.

Step 6. Having assigned the wetland a score for marsh wren, the computer program now proceeds in similar manner to assign scores to the other 164 potentially occurring species. The sum of the scores from all species is the **unweighted habitat** score. An example is shown in Table 14. The unweighted habitat score represents both the number of species for which the wetland is minimally suitable, and the degree of suitability for each species. This type of score, based on the individual scores of many species, is termed a **synthesis score.** In theory, the maximum value for the unweighted habitat score would be 165 (the number of species potentially occurring in irrigated wetlands at any season, multiplied by 1.0, which is the maximum species habitat score of each). However, because habitat conditions that are optimal for some groups of species are less than optimal for other groups (i.e., are mutually exclusive), the actual habitat score usually will be much less than 165.

Step 7. At this point the analysis can be stopped and the unweighted habitat score can be used to represent the wetland. Or, users can choose to use one or both of two other types of synthesis scores to represent the wetland. Although probably correlated with each other, each synthesis score represents a conceptually different evaluation of the wetland's potential to support biodiversity.

The **unweighted richness** score is simply the number of species that have scores above a certain threshold score (>0, >0.25, >0.50, >0.75) that the program prompts you to select. For example, if you specify the threshold of ">0," the program will count the number of species for which the wetland is even minimally suitable, whereas if you specify "0.75," the program will produce a more conservative (lower) tally comprised just of species for that the evaluation wetland's conditions resulted in a species habitat score exceeding 0.75. An example is shown in Table 14. The purpose of the unweighted richness score is to provide an estimate of avian species richness that is more suitable for use in later validation testing, because species richness can be determined empirically (e.g., by conducting an appropriate bird survey). Users are given the option of specifying different probability levels because at this point in the development of AREM, the level which most often corresponds to actual species richness is unknown. The maximum value for the unweighted richness score at a cutoff level of >0 is, like the unweighted habitat score, 165 (i.e., the number of species potentially occurring in irrigated wetlands at any season). Again, because habitat conditions that are optimal for some groups of species are less than optimal for other groups, the actual habitat score usually will be much less than 165. Initial experience using AREM suggests that the maximum values would be approximately 104, 104, 102, and 89 at the >0, >0.25, >0.50, and >0.75 cutoff levels, respectively.

To obtain the **weighted habitat** score, the computer program multiplies the habitat score of each species by a conservation priority weight for that species, and the products are then summed as shown in Table 14. The "conservation priority weights" are preassigned numbers, on a 1 to 10 scale, that represent categories of a

Table 14. Example of calculation of synthesis scores.

WETLAND #1:

Species	Species Habitat Score (calculated)[36]	Conservation Priority Weight[37]	Score X Weight
Downy Woodpecker	0.77	2	1.54
American Crow	0.63	2	1.26
Black-billed Magpie	0.27	2	0.54
Lewis' Woodpecker	0.18	2	0.36
Marsh Wren	0.60	6	1.20
Wilson's Phalarope	0.31	6	0.62
Pied-billed Grebe	0.84	10	8.40
Bonaparte's Gull	0.22	10	2.20
Common Goldeneye	0.43	10	4.30

Unweighted Habitat Score: 4.25 (=sum of the species habitat scores)

Unweighted Richness Scores:

@ species habitat score cutoff of >0.75 = 2
(2 species: downy woodpecker (.77), pied-billed grebe (.84))

@ species habitat score cutoff of >0.50 = 4
(above 2 species, plus American crow (.63), marsh wren (.60) = 4 species)

@ species habitat score cutoff of >0.25 = 7
(above 4 species, plus magpie, phalarope, goldeneye =7 species)

@ species habitat score cutoff of >0 = 9
(all species above, = 9 species)

Weighted Habitat Scores (weighting factor= "water dependence"):

@ species habitat score cutoff of >0.75 = 9.94
(add downy woodpecker (1.54) to pied-billed grebe (8.40))

@ species habitat score cutoff of >0.50 = 12.40
(above, + American crow (1.26) + marsh wren (1.20))

@ species habitat score cutoff of >0.25 = 17.86
(above, + magpie (0.54) + phalarope (0.62) + goldeneye (4.30)

@ species habitat score cutoff of >0 = 20.42
(sum of all Score x Weight)

[36] Species having a score of 0 are not included in this example. Also, expect that species lists from most wetlands will be longer than this example.

[37] In this example, weights in the database that define each species' relative **dependence on water** are used (these weights are defined further in the footnote to Table 10). Users have the option to select other conservation characteristics for which the database contains a weight for each species (e.g., relative regional abundance, status as a neotropical migrant).

species characteristic that could be important to the conservation of biodiversity, e.g., relative abundance, water-dependence. From a list of these weighting characteristics for which the database contains information (i.e., the weight of 1-10) for each species, the program prompts you to select and mark characteristics of greatest relevance to your objectives. You may also redefine the preassigned weights (e.g., make the lowest weight a 0 instead of a 1). In addition to (or in lieu of) summing the products for all species as just described (i.e., all species with habitat score >0) the user can choose to sum the products only for species having a specified minimum habitat score (>0.75, >0.50, >0.25, >0, as before). Table 14 shows this. The purpose of the weighted habitat score is to allow the user to emphasize species of greatest interest because of agency mandates, management goals, or other reasons. The option of specifying thresholds is provided so that users can focus mainly on species most likely to occur in a wetland.

In addition to providing up to three synthesis scores, AREM also provides the option of printing out the list of (a) species that were tallied to produce the score, (b) the species habitat scores associated with each species, as calculated for the evaluation wetland, and/or (c) the weighted habitat scores for all species. These options are provided to facilitate field testing of AREM (e.g., Do the particular species predicted to occur in the wetland actually occur in it?) and to generally document the basis for any generated score. In addition, users have the option of using the output to define which particular combination of wetlands or wetland types cumulatively supports the greatest number of species (see example, Table 15).

Although no testing has yet been conducted to characterize the sensitivity of AREM's three synthesis scores to different types of irrigated wetlands, knowledge of the species suggests that the unweighted habitat and unweighted richness scores might be highest for large (>40 acre), wide, secluded, ungrazed, periodically desiccated or flooded wetlands that adjoin lakes or rivers within agricultural landscapes, and contain multiple water depths and multiple vegetation life forms and species. Such wetlands are usually, but not necessarily, "natural" in origin.

5.4 Results of Initial Testing

I applied an early version of AREM during visits in November 1992 to 20 irrigated wetlands in the Grand and Lower Gunnison Valleys, Colorado. AREM was evaluated through a quality assurance (QA) protocol designed to estimate AREM's replicability, practicality, and comparability. **Comparability** refers to the extent to which AREM rated a series of wetlands the same as local avian experts. Local experts checked off species they believed likely to be seen in each wetland, based on personal knowledge of habitat requirements. The wetland score from this approach was the number of species that the experts checked off. The expert's results and those obtained from using AREM also were compared with results from using the SCS method (SCS 1992a). **Replicability** was measured as the frequency with which different users responded the same to a particular indicator question (see Appendix F for a similar series of questions). **Practicality** was assessed by measuring the time required to evaluate a wetland and by asking users to identify questions they felt were most subjective or difficult to answer.

5.4.1 Comparability

With regard to comparability, the results (Table 16) suggest limited congruence among scores based on expert opinion, the SCS (1992a) method, and the early version of AREM. In no case did two or more of these three approaches agree on which wetland was the most important or least important. Of the five wetlands that were ranked highest based on the avian expert's species list, only two were in the top five based on AREM score and only two were in the top five based on the SCS method. Of the five wetlands that were ranked **lowest** based on the avian expert's species list, only one was in AREM's bottom five and none were in SCS's bottom five. Conversely, of the five wetlands ranked highest by this early version of AREM, only two were in the

Table 15. Use of AREM to select wetland combinations that optimize protection of regional avian diversity.

This simplified example demonstrates the importance of using AREM (or other methods) to consider wetland functions and values at a cumulative, regional basis as well as individually[38]. If the only basis for a wetland decision was the scores for individual wetlands, then wetlands A and B below would be selected because they individually have the most species (i.e., highest unweighted richness score) of any of the wetlands. However, if the objective is to maintain biodiversity at a regional level rather than exclusively at an individual site level, then wetlands C and D, which individually are the poorest in species, would be the best choice because together they have a larger species list (8 species) than the two richer wetlands combined (6 species), or the combination of either poorer wetland (C or D) with either of the richer wetlands (A or B). Wetlands C and D also would usually be chosen if the unweighted habitat score were used instead of the unweighted richness score. These selection principles can be applied to more than two wetlands at a time, although for large sets of wetlands use of a computer greatly facilitates the calculations. In instances where one or both members of an "optimal pair" (as determined by this process) cannot be protected because of cost or other reasons, a next-best pairing of sites can be determined; some authors have even proposed that cost-per-species-protected be calculated and used to optimize conservation strategies, i.e., by calculating and comparing for all possible wetland combinations both the number of species protected and the associated land stewardship costs. Of course, sustaining the populations of all species requires some amount of redundancy of species composition among wetlands.

	Occurs in Wetland:			
Species	A	B	C	D
Mallard	x	x		x
Mourning Dove	x	x		x
Black-billed Magpie	x	x	x	
European Starling	x	x	x	
Song Sparrow	x	x	x	
Killdeer	x			x
Sora			x	
Yellow-headed Blackbird				x
TOTAL Species (Unweighted Richness)	6	5	4	4

Collective # of Species, by Combination of Wetlands:

Wetlands A + B = 6 (all species but Killdeer are redundant)
Wetlands A + C = 7
Wetlands A + D = 7
Wetlands B + C = 6
Wetlands B + D = 7
Wetlands C + D = 8 (no species are redundant)

[38] Despite a continuing and necessary focus of resource agencies on the individual site level when setting wetland priorities, the cumulative assessment principles upon which this example is based are also relevant and have been noted for years by conservation biologists (e.g., Samson and Knopf 1982, Usher 1986, Pressey and Nicholls 1989).

Table 16. Comparison of rankings of wetlands by SCS method, AREM, local avian experts, and field biologists.

Wetlands 1-10 are located in the Grand Valley subregion and the local expert who was consulted was Ronald Lambeth. The local biologists were Meaghley, McCall, and Neilson. Wetlands 11-25 are located in the Lower Gunnison subregion and the local expert who was consulted was David Galinat. Local biologists in this subregion were Obert, Taylor, and Woodis. The "SCS Method" is SCS (1992). "AREM" is the November 1992 draft of the Avian Richness Evaluation Method; the score is the unweighted number of species predicted. The score in the "Expert" column is the unweighted number of species predicted by the expert to occur. Numbers in the remaining columns are the ranks (1= best habitat, 5= poorest habitat) assigned within each series of wetlands by the biologists.

Wetland No.	SCS Method	AREM	Expert	Meaghley	McCall	Neilson	Obert	Taylor	Woodis
01	6.4	72	45	3	3	1			
02	5.2	68	47	2	4	3			
03	4.2	59	40	4	5	5			
04	6.8	54	38	5	2	4			
05	8.0	42	55	1	1	2			
06	5.6	35	42	2	2	2			
07	6.0	35	44	5	4	5			
08	6.4	50	53	3	3	1			
09	7.2	35	41	4	5	4			
10	6.8	59	40	1	1	3			
11	6.4		36						
12	8.0	53	37						
13	7.2	44	61						
14	6.4		40						
15	7.2						5	6	6
16	7.2	43					4	5	3
17	6.8	42					1	4	2
18	7.2	35					6	3	5
19	7.6	46					3	2	4
20	7.6	57					2	1	1
21	6.8	48	23				2	2	2
22	6.4	68	41				1	1	1
25		46							

expert's top five; of the five wetlands ranked lowest by AREM, only one was in the expert's bottom five. Similarly, of the five wetlands ranked highest by the SCS method, only two were in the expert's top five; of the wetlands ranked lowest by the SCS method, none were in the expert's bottom five.

Also, the scores were compared statistically, two methods at a time, using two nonparametric tests -- the Spearman rank-correlation test and the Kendall Tau-b rank correlation test. At a one-tailed significance level of $p<.01$, none of the approaches were correlated. That is, no two methods ranked the series of wetlands in approximately the same order.

In addition to the above, I asked each of three local government biologists to independently rank two series of wetlands, five per series, according to "habitat quality" as they perceived it. In both series of wetlands, two of the three biologists selected the same wetland as representing the "best habitat," and the other biologist rated it second. Also, two of the three biologists agreed on the wetland representing "poorest habitat," and the other biologist ranked it next-to-poorest. Comparing the biologists' rankings with those based on species richness (as predicted by the local avian expert), I found that for the first series of wetlands, the biologists mostly agreed with the avian expert and the SCS method, but not AREM, on which wetland would be the lowest- and highest-ranking. However, for the second series of wetlands, the wetland which the expert predicted to have highest species richness was considered the best habitat by only one of the three biologists. The wetland that most of the biologists and AREM believed represented the best habitat was predicted by the avian expert to actually have the lowest species richness. The wetland that the SCS method ranked highest was ranked next-to-lowest by most of the biologists and the avian expert. Because of the small sample size, none of these data were analyzed statistically.

5.4.2 Replicability

For 22 (75%) of the 30 main questions, users concurred in the majority (>9) of the wetlands evaluated. This was considered a reasonable level of replicability. Still, some questions have since been modified to increase replicability even further.

5.4.3 Practicality

Users took between 4 to 13 minutes per wetland to complete the evaluation. Longer times were mostly associated with the use of the "long form" (see Appendix F). After becoming familiar with the method through use of the long form, users instead began using the "short form." Users indicated that they believed all questions were reasonably practical to answer. Those which they sensed were most likely to require judgement, because of difficulty of onsite estimation, were the questions asking about land cover or habitat features in the general landscape rather than the wetland. In some instances, this information could be obtained from aerial photographs.

5.4.4 Field Testing Conclusions

Results from the initial field testing indicated that AREM, although not perfect, is generally practical to use and results are reasonably replicable. AREM's disadvantages are mostly ones shared with other methods for rapidly evaluating wetland habitat. Results of testing AREM's comparability are difficult to interpret because it is uncertain, when various methods give different results, which method is the "correct" method. Therefore, future validation should occur not through comparison with other methods, but by comparing AREM results with data from actual bird surveys. In such a study, a list of birds found to occur in a series of irrigated wetlands should be compared with a list of birds predicted to occur based on a simultaneous evaluation of each of the wetlands using AREM. A professional statistician and field ornithologist should be involved in the design and execution of the study. Data from the study should be used to examine the following questions, at a minimum. These questions should be examined sequentially in the order listed. The order reflects decreasing probability of successful validation.

- Is there a statistically significant difference in the **ranking** of the study wetland sites based on AREM synthesis scores vs. actual measurement of bird species richness?

- Which type of AREM synthesis score, when used to rank the wetlands, produces a pattern of ranks closest to those based on the measured species richness?

- Is there a statistically significant difference between the number of species predicted by AREM (at each of the probability levels) and **absolute** number of species as determined by the field inventory?

- Which species are most consistently underpredicted or overpredicted, and what types of irrigated wetlands are associated with such errors? Based on previous experience, I would expect there to be more Type I errors (species predicted by AREM to be present but were absent) than Type II errors (species found by surveys but not predicted by AREM to be present).

A field survey of this type is essential to further define the validity of AREM and situations in which its use is most and least appropriate. However, in the meantime it is essential to understand that the results reported above were based on an early version of AREM. The version of AREM contained in Appendix F represents a major revision of the earlier version, largely reflecting what was learned from the local expert. The supporting database also has been extensively revised, taking into account knowledge gained through the initial field-testing.

6.0 STUDY CONCLUSIONS

No single characteristic (i.e., "indicator") reliably predicts which irrigated wetlands comprise the best habitat. Rather, habitat quality is associated with various combinations of the conditions of several indicators, measured at several scales. The most predictive indicators are probably patch size, water regime, vegetation form and species, aquatic organism abundance, and landscape context. However, attempts to identify indicators of "good" irrigated wetland habitat encounter a problem of defining "good for which species?" The importance of each indicator, or of each unique combination of indicator conditions, depends on the values placed on the species associated with it. Many indicator conditions are ideal for only a few species, but if these species are particularly valued (e.g., because they are regionally rare, declining, or hunted), then the indicator conditions can be considered important. For this reason, it became essential to develop a new evaluation method (AREM) that would allow flexibility in selecting which species are used to define habitat quality, and that could identify indicators important to the "most" species. Initial testing has demonstrated AREM's general replicability and practicality. Future validation should involve a comparison of AREM results with results from appropriately designed and executed field surveys. Additional research on water quality functions of irrigated wetlands, particularly their potential for removing nitrate from agricultural runoff, is also warranted.

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Appendix A. Relative abundance, by subregion, of birds that regularly **breed** in lowland riparian and wetland habitats of the Colorado Plateau.

Species are listed in phylogenetic order. Codes are reproduced from the original information sources, which seldom define the relative terms, and are as follows: A= abundant, C= common, F= fairly common, U= uncommon. A blank means the species does not regularly occur in, and/or is not dependent on, wetlands and riparian habitats of the specified subregion during its breeding period. Asterisks (*) in the Utah column indicate the species was reported specifically from irrigated wetlands of the Price-San Rafael salinity control area (USBR and SCS 1991).

Information for the Grand Valley is mostly from Dexter and Lavad (1992) and secondarily from Andrews and Righter (1992) and Dexter (1992). The Grand Valley information is probably the most accurate because of the relatively high intensity of coverage in this subregion. No similar information was available for the Lower Gunnison subregion, but bird abundance can probably be assumed to be identical to the nearby Grand Valley area. Information for the Cortez subregion is mostly from Sommers 1979, 1980, and secondarily from Andrews and Righter (1992). The Cortez list, although based on surveys of irrigated wetlands and probably quite complete, does not discriminate relative abundance as finely as the Grand Valley list. The Utah and Wyoming lists also do not discriminate well, categorizing most species only as common or uncommon. The Utah information is mainly derived from the Ouray National Wildlife Refuge list (USFWS n.d.). Although this refuge contains wetlands and is in the same subregion, most irrigated wetlands of the subregion are probably smaller and their avifauna has not been inventoried. Other sources for the Utah list were Twomey 1942, Hayward 1967, Behle 1981, Cook 1984, Boschen 1992, and Dalton et al. 1978, 1990. The Wyoming subregion list is probably the least comprehensive and accurate, because few birders have visited the Big Sandy area. The information is mainly from the bird list of the Seedskadee National Wildlife Refuge (USFWS n.d.), located about 30 miles southwest of the Big Sandy area and containing somewhat different habitat.

Common Name	Grand Valley, CO	Cortez, CO	Utah	Wyoming
PIED-BILLED GREBE		C	C	C
AMERICAN BITTERN		U		U
GREAT BLUE HERON	C	C	C	C
BLACK-CROWNED NIGHT-HERON		C	C	U
WHITE-FACED IBIS		U		
CANADA GOOSE	C	C	C	C
WOOD DUCK	U			
GREEN-WINGED TEAL	F	U	C	C
MALLARD	C	C	C	A
NORTHERN PINTAIL		U	C	C
CINNAMON TEAL	U	C	C	C
NORTHERN SHOVELER		U		C
GADWALL		U	C	C
RUDDY DUCK		U	C	C
TURKEY VULTURE	F	C	C	
NORTHERN HARRIER		C	C	C
RED-TAILED HAWK	F	C	C	C
AMERICAN KESTREL	C	C	C	C
RING-NECKED PHEASANT	F	C	C	
GAMBEL'S QUAIL	F	C		
VIRGINIA RAIL	U	C	C	
SORA	U	C	C	U
AMERICAN COOT	U	C	C	C
KILLDEER	C	C	C	C
SPOTTED SANDPIPER	F	C	U	C
COMMON SNIPE	F	C	U	C
WILSON'S PHALAROPE		U	C	U

Common Name	Grand Valley, CO	Cortez, CO	Utah	Wyoming
BAND-TAILED PIGEON		C		
MOURNING DOVE	A	C	C	C
BARN OWL	U			
WESTERN SCREECH-OWL	U			
GREAT HORNED OWL	U	C	C	C
LONG-EARED OWL	U			
COMMON NIGHTHAWK	C	C	C	C
BLACK-CHINNED HUMMINGBIRD	F	C	C	
BROAD-TAILED HUMMINGBIRD		C	C	U
BELTED KINGFISHER	U	C		
LEWIS' WOODPECKER	U	C	C	U
DOWNY WOODPECKER	U	C	U	U
HAIRY WOODPECKER		C	U	U
NORTHERN FLICKER	F	C	C	C
WESTERN WOOD-PEWEE	F	C	U	U
ASH-THROATED FLYCATCHER	F	C		
WESTERN KINGBIRD	C	C	C	U
TREE SWALLOW	U	C	U	A
VIOLET-GREEN SWALLOW	U	C	U	A
NORTHERN ROUGH-WINGED SWALLOW	U	C	U	
BANK SWALLOW	C		U	A
CLIFF SWALLOW	A	C	C	A
BARN SWALLOW	A	C	C	A
BLACK-BILLED MAGPIE	A	C	C	C
AMERICAN CROW	U	C		
BLACK-CAPPED CHICKADEE	U	C	C	U
WHITE-BREASTED NUTHATCH	U	C		U
BEWICK'S WREN	U	C		C
HOUSE WREN	U	C	C	C
BLUE-GRAY GNATCATCHER	F	C	U	
AMERICAN ROBIN	C	C	C	C
GRAY CATBIRD		C		
LOGGERHEAD SHRIKE	U	C	U	U
EUROPEAN STARLING	A	C	C	C
WARBLING VIREO	C	U	U	U
ORANGE-CROWNED WARBLER		C	U	
VIRGINIA'S WARBLER		C	U	
YELLOW WARBLER	C	C	C	A
COMMON YELLOWTHROAT	U	C	U	C
YELLOW-BREASTED CHAT	U	U	U	
BLACK-HEADED GROSBEAK	F	C	U	C
BLUE GROSBEAK	F	C	U	
LAZULI BUNTING	F	C	U	
GREEN-TAILED TOWHEE		C		C
RUFOUS-SIDED TOWHEE	C	C	U	
CHIPPING SPARROW	U	C		C
LARK SPARROW	F	C	U	
SONG SPARROW	U	C	C	C
RED-WINGED BLACKBIRD	A	C	C	C
YELLOW-HEADED BLACKBIRD	C	C	C	C
BREWER'S BLACKBIRD	F	C	C	C
COMMON GRACKLE	U	C		
NORTHERN ORIOLE	F	C	U	
PINE SISKIN		U		C
LESSER GOLDFINCH	U	C		
AMERICAN GOLDFINCH	U	C	C	

Appendix B. Relative abundance, by subregion, of birds that regularly **winter** in lowland riparian and wetland habitats of the Colorado Plateau.

See Appendix A for explanation of abbreviations and information sources.

Common Name	Grand Valley	Cortez	Utah	Wyoming
GREAT BLUE HERON	C	U	U	
CANADA GOOSE	A	C	C	U
WOOD DUCK	F			
GREEN-WINGED TEAL	C	U		U
MALLARD	A	C		C
NORTHERN PINTAIL	U			
GADWALL				U
AMERICAN WIGEON	U	U		U
CANVASBACK			U	
RING-NECKED DUCK	C		U	
LESSER SCAUP	U			
COMMON GOLDENEYE	F	C	U	A
BARROW'S GOLDENEYE				U
BUFFLEHEAD			U	C
BALD EAGLE	U	C	C	C
NORTHERN HARRIER	U	C	C	
SHARP-SHINNED HAWK	U	C		
COOPER'S HAWK	U	C		
NORTHERN GOSHAWK		U		U
RED-TAILED HAWK	F	C	C	
FERRUGINOUS HAWK	U			U
AMERICAN KESTREL	F	C	U	
PEREGRINE FALCON		U		
RING-NECKED PHEASANT	F	C	C	
GAMBEL'S QUAIL	F	C		
AMERICAN COOT			U	
COMMON SNIPE	U	U		
MOURNING DOVE	A	C		
BARN OWL	U			
WESTERN SCREECH-OWL	U			
GREAT HORNED OWL	U	C	C	C
LONG-EARED OWL	U			
BELTED KINGFISHER	U	U		
DOWNY WOODPECKER	U	C		
HAIRY WOODPECKER		C		
NORTHERN FLICKER	C	C	C	
PINYON JAY	F	C		
BLACK-BILLED MAGPIE	A	C	C	C
AMERICAN CROW	F	C		
BLACK-CAPPED CHICKADEE	F	C	C	C
PLAIN TITMOUSE	U	C		
BUSHTIT	U	C		U
RED-BREASTED NUTHATCH	U			U
WHITE-BREASTED NUTHATCH	U	C		U
BROWN CREEPER		C		
BEWICK'S WREN	U	C	U	
MARSH WREN	U	C		
TOWNSEND'S SOLITAIRE	U	C		
AMERICAN ROBIN	A	C		
AMERICAN PIPIT	U			
CEDAR WAXWING	F	C		C

Common Name	Grand Valley	Cortez	Utah	Wyoming
NORTHERN SHRIKE	U	U	U	U
LOGGERHEAD SHRIKE	U	U	U	U
EUROPEAN STARLING	A	C	C	C
RUFOUS-SIDED TOWHEE	U	C		
AMERICAN TREE SPARROW	U	C	U*	
SONG SPARROW	C	C	U	
WHITE-CROWNED SPARROW	A	C	U	
DARK-EYED JUNCO	A	C	U	
RED-WINGED BLACKBIRD	A	C	U	
WESTERN MEADOWLARK	C	C	U	
BREWER'S BLACKBIRD			U	
CASSIN'S FINCH		U		
HOUSE FINCH	A	C		
PINE SISKIN	U	C		
AMERICAN GOLDFINCH	F	C	U	
EVENING GROSBEAK	F	C		C

Appendix C. Relative abundance, by subregion, of birds that regularly occur during **migration** in lowland riparian and wetland habitats of the Colorado Plateau.

See Appendix A for explanation of abbreviations and information sources.

Common Name	Grand Valley	Cortez	Utah	Wyoming
PIED-BILLED GREBE	U	C	C	C
DOUBLE-CRESTED CORMORANT		U	U	
AMERICAN BITTERN		U		
GREAT BLUE HERON	C	C	C*	C
SNOWY EGRET	U	C	C*	U
BLACK-CROWNED NIGHT-HERON		C	C*	U
WHITE-FACED IBIS	U	C	C*	C
CANADA GOOSE	C	C	C*	C
WOOD DUCK	U			
GREEN-WINGED TEAL	A	C	C*	C
MALLARD	A	C	C*	A
NORTHERN PINTAIL	U	C	C*	A
BLUE-WINGED TEAL	U	C	C*	C
CINNAMON TEAL	C	C	C*	C
NORTHERN SHOVELER	F	C	C	A
GADWALL	F	C	C*	C
AMERICAN WIGEON	F	C	C	C
CANVASBACK			U*	C
REDHEAD	U	C	C*	C
RING-NECKED DUCK	C	C	U	C
GREATER SCAUP				U
LESSER SCAUP	F	C	C	C
COMMON GOLDENEYE	F	C	U	C
BARROW'S GOLDENEYE				U
BUFFLEHEAD	F	C	U	
RUDDY DUCK	F	C	C	C
TURKEY VULTURE	F	C	C*	
OSPREY		U		U
BALD EAGLE	U	C		U
NORTHERN HARRIER	U	C	C*	C
SHARP-SHINNED HAWK	U	C	U	U
COOPER'S HAWK	U	C	U*	U
NORTHERN GOSHAWK				U
SWAINSON'S HAWK			U	C
RED-TAILED HAWK	F	C	C*	C
FERRUGINOUS HAWK	U			U
AMERICAN KESTREL	C	C	C*	C
MERLIN				U
PEREGRINE FALCON		U		
RING-NECKED PHEASANT	F	C	C*	
GAMBEL'S QUAIL	F	C		
VIRGINIA RAIL	U	C	U	
SORA	U	C	U	U
AMERICAN COOT	C	C	A	C
SANDHILL CRANE	F		C	U
SEMIPALMATED PLOVER		U		
KILLDEER	C	C	C*	C
BLACK-NECKED STILT		U	C*	U
AMERICAN AVOCET	U	C	C*	U
GREATER YELLOWLEGS	U	U		U
LESSER YELLOWLEGS	U	U	U*	U

Common Name	Grand Valley	Cortez	Utah	Wyoming
SOLITARY SANDPIPER		U		U
WILLET		C	U	C
SPOTTED SANDPIPER	F	C	U*	C
MARBLED GODWIT		C	U	C
WESTERN SANDPIPER	U	C		
LEAST SANDPIPER	U	C		
LONG-BILLED DOWITCHER	U	C	U	
COMMON SNIPE	U	C	U*	C
WILSON'S PHALAROPE	U	C	C*	C
RED-NECKED PHALAROPE		U	U*	
FRANKLIN'S GULL	U	U	U	
BONAPARTE'S GULL	U	U		
RING-BILLED GULL	U	C	C	
CALIFORNIA GULL	U		C*	C
FORSTER'S TERN		U	U*	
BLACK TERN		U	U	
BAND-TAILED PIGEON		C		
MOURNING DOVE	A	C	A*	C
YELLOW-BILLED CUCKOO				U
BARN OWL	U			
WESTERN SCREECH-OWL	U			
GREAT HORNED OWL	U	C	C*	C
LONG-EARED OWL	U			
SHORT-EARED OWL			U*	
COMMON NIGHTHAWK	A	C	U*	
BLACK-CHINNED HUMMINGBIRD	F	C	U	
BROAD-TAILED HUMMINGBIRD	F	C	U	U
RUFOUS HUMMINGBIRD	F	C		U
BELTED KINGFISHER	U	C	U	
LEWIS' WOODPECKER	U	C	U	U
RED-NAPED SAPSUCKER		C	U	U
DOWNY WOODPECKER	U	C	U	U
HAIRY WOODPECKER	U	C	U	U
NORTHERN FLICKER	C	C	C*	C
OLIVE-SIDED FLYCATCHER				U
WESTERN WOOD-PEWEE	U	C	U	U
WILLOW FLYCATCHER		U		C
HAMMOND'S FLYCATCHER		U		U
DUSKY FLYCATCHER	F	U	U	U
CORDILLERAN FLYCATCHER	U	C		U
ASH-THROATED FLYCATCHER	U			
WESTERN KINGBIRD			U*	U
EASTERN KINGBIRD			U*	
TREE SWALLOW	F	C	U*	C
VIOLET-GREEN SWALLOW	F	C	U*	C
NORTHERN ROUGH-WINGED SWALLOW	U	C	U*	
BANK SWALLOW	F	U	U*	C
CLIFF SWALLOW	F	C	U*	C
BARN SWALLOW	C	C	U*	C
PINYON JAY	F	C		
BLACK-BILLED MAGPIE	A	C	C*	C
AMERICAN CROW	F	C		U

Common Name	Grand Valley	Cortez	Utah	Wyoming
BLACK-CAPPED CHICKADEE	U	C	C*	U
RED-BREASTED NUTHATCH				U
WHITE-BREASTED NUTHATCH	U	C		U
BROWN CREEPER		C		
BEWICK'S WREN	F	C		U
HOUSE WREN	F	C	C	C
MARSH WREN	U	C	C*	U
RUBY-CROWNED KINGLET	F	C	U	U
BLUE-GRAY GNATCATCHER	F	C	U	
WESTERN BLUEBIRD	U	C		
TOWNSEND'S SOLITAIRE	U	C		
HERMIT THRUSH	U	C		
AMERICAN ROBIN	C	C	C*	C
GRAY CATBIRD		U		
NORTHERN MOCKINGBIRD	U	U		
AMERICAN PIPIT	U	C	U	U
CEDAR WAXWING	F	C		U
LOGGERHEAD SHRIKE	U	C	U*	U
EUROPEAN STARLING	A	C	C*	C
SOLITARY VIREO	U	C	U	U
WARBLING VIREO	U	C	U	U
ORANGE-CROWNED WARBLER	F	C	U	
VIRGINIA'S WARBLER	F	C	U	
YELLOW WARBLER	F	C	U	A
YELLOW-RUMPED WARBLER	A	C	C*	A
BLACK-THROATED GRAY WARBLER	U	U	U	
TOWNSEND'S WARBLER			U	
MACGILLIVRAY'S WARBLER	U	C	U	C
COMMON YELLOWTHROAT	U	C	U*	C
WILSON'S WARBLER	F	C		C
YELLOW-BREASTED CHAT		C	U	
WESTERN TANAGER	F	C		C
BLACK-HEADED GROSBEAK	U	C	U	U
BLUE GROSBEAK	F	C	U	
LAZULI BUNTING	U	C	U	
GREEN-TAILED TOWHEE	F	C	U	C
RUFOUS-SIDED TOWHEE	F	C	U	
CHIPPING SPARROW	C	C	U	C
BREWER'S SPARROW	F	C	U*	C
LARK SPARROW			C*	
SAVANNAH SPARROW	U	C	U*	C
SONG SPARROW	C	C	C*	C
LINCOLN'S SPARROW	F	C	U*	C
WHITE-CROWNED SPARROW	A	C	U*	A
DARK-EYED JUNCO	A	C	C*	A
RED-WINGED BLACKBIRD	A	C	C*	C
YELLOW-HEADED BLACKBIRD	U	C	C*	C
BREWER'S BLACKBIRD	F	C	C*	A
COMMON GRACKLE	F	C		
NORTHERN ORIOLE	U	C	U	
CASSIN'S FINCH				C
PINE SISKIN	C	C	U*	C

Common Name	Grand Valley	Cortez	Utah	Wyoming
LESSER GOLDFINCH	U	C		
AMERICAN GOLDFINCH	C	C	C	
EVENING GROSBEAK	U	C		C

Appendix D. Amphibians and reptiles that use riparian and wetland areas of the Colorado Plateau.

Species are listed alphabetically by genus and species. The column "Wet/Rip" lists species that occur in Colorado wetland or riparian habitats according to Langlois 1978 (L). Species not so categorized by Langlois (1978) but which are considered to depend on wetland or riparian habitats in Utah by Dalton et al. 1990 (D) or the Colorado State Heritage Program's (HP) Vertebrate Characterization Abstracts (HP) are also marked. An "O" in a subregion column indicates the species regularly occurs in wetlands and riparian habitats of the specified subregion. A blank means the species does not regularly occur in, and/or is not dependent on, wetland/riparian areas of that subregion. For the Grand Valley, Lower Gunnison, and Cortez subregions, occurrence information is mainly from Langlois (1978). Utah information is from Dalton et al. (1990). Species occurring in the Wyoming subregion were inferred from Langlois's (1978) list for the northwesternmost part of Colorado. Entries with an asterisk (*) indicate the species was found within irrigated wetlands in the Grand Valley by Ecology Consultants (1976), in the Lower Gunnison Valley by Rector et al. (1979), or the Cortez area by Somers et al. (1979). In the next-to-last column, the abundance codes pertain only to Colorado, and are reproduced from the original information source (Langlois 1978) as follows: A= abundant, C= common, F= fairly common, U= uncommon, ?= unknown abundance.

Genus and Species	Wet/Rip	Grand Valley	L. Gunnison	Cortez	Utah	Wyoming	Abund.	Common Name
AMBYSTOMA TIGRINUM (subspecies)	L	O				O	A	BLOTCHED TIGER SALAMANDER
AMBYSTOMA TIGRINUM (subspecies).	L	O	O	O	O	O	A	ARIZONA TIGER SALAMANDER
BUFO COGNATUS	D				O		C	GREAT PLAINS TOAD
BUFO PUNCTATUS	L	O*	O	O*	O		?	RED-SPOTTED TOAD
BUFO WOODHOUSEI	L	O*	O*	O*	O	O	A	WOODHOUSE'S TOAD
CNEMIDOPHOROUS VELOX	L	O*	O	O			?	PLATEAU WHIPTAIL
CNEMIDOPHORUS TIGRIS	L	O*	O*	O		O	?	NORTHERN WHIPTAIL
COLUBER CONSTRICTOR	L	O			O		?	WESTERN YELLOW-BELLIED RACER
CROTALIS VIRIDIS (subspecies)	L	O	O		O		U	MIDGET FADED RATTLESNAKE
CROTALUS VIRIDIS (subspecies)	HP		O	O		O	F	PRAIRIE RATTLESNAKE
CROTALUS VIRIDIS (subspecies)	L			O			?	HOPI RATTLESNAKE
CROTAPHYTUS COLLARIS	L	O*	O	O			?	YELLOW-HEADED COLLARED LIZARD
CROTAPHYTUS WISLIZENI	HP	O*		O			?	LONG-NOSED LEOPARD LIZARD
DIADOLPHIS PUNCTATUS	NR				O		U	RING-NECK SNAKE
ELAPHE GUTTATA	HP	O	O				?	GREAT PLAINS RAT SNAKE
EUMECES MULTIVIRGATUS	L			O			?	SOUTHERN MANY-LINED SKINK
HOLBROOKIA MACULATA	HP			O*			?	SPECKLED EARLESS LIZARD
HYLA ARENICOLOR	L	O	O		O		?	CANYON TREE FROG
HYPSIGLENA TORQUATA	HP	O		O	O		U	MESA VERDE NIGHT SNAKE
LAMPROPELTIS TRIANGULUM (subsp)	HP	O	O		O		?	UTAH MILK SNAKE
LAMPROPELTIS TRIANGULUM (subsp)	L			O			?	NEW MEXICO MILK SNAKE
LAMROPELTIS GETULUS	L			O			?	CALIFORNIA KINGSNAKE
MASTICOPHIS TAENIATUS	L	O	O	O	O	O	?	DESERT STRIPED WHIPSNAKE
OPHEODRYS VERNALIS	L			O			?	WESTERN SMOOTH GREEN SNAKE
PHRYNOSOMA DOUGLASSI (subsp.)	HP	O	O	O			?	MOUNTAIN SHORT-HORNED LIZARD
PHRYNOSOMA DOUGLASSI (subsp.)	L	O	O	O	O	O	F	DESERT SHORT-HORNED LIZARD
PITUOPHIS MELANOLEUCUS	L	O	O	O	O	O	F	GREAT BASIN GOPHER SNAKE
PSEUDACRIS TRISERIATA	L	O	O	O*	O	O	A	BOREAL CHORUS FROG
RANA CATESBIANA	L	O					F	BULLFROG
RANA PIPIENS	L	O*	O*	O	O	O	A	LEOPARD FROG
RHINOCHEILUS LECONTEI	NR				O		U	LONG-NOSED SNAKE
SCAPHIOPUS HAMMONDI	L		O	O	O		A	WESTERN SPADEFOOT
SCAPHIOPUS INTERMONTANUS	L	O	O		O		A	GREAT BASIN SPADEFOOT
SCELOPORUS GRACIOSUS	L	O*	O	O*		O	F	NORTHERN SAGEBRUSH LIZARD
SCELOPORUS MAGISTER	L			O	O		?	TWIN-SPOTTED LIZARD
SCELOPORUS UNDULATUS	L	O*	O*	O		O	F	NORTHERN PLATEAU LIZARD
TANTILLA UTAHENSIS	HP	O					?	UTAH BLACK-HEADED SNAKE
THAMNOPHIS CYRTOPSIS	HP	O	O				?	W. BLACK-NECKED GARTER SNAKE
THAMNOPHIS ELEGANS	L	O	O*	O*	O	O	F	WANDERING GARTER SNAKE
UROSAURUS ORNATUS	L	O	O	O	O	O	F	NORTHERN TREE LIZARD
UTA STANSBURIANA	L	O*	O	O	O	O	?	NORTHERN SIDE-BLOTCHED LIZARD

Appendix E. Mammals that use riparian and wetland areas of the Colorado Plateau.

Species are listed alphabetically by genus and species. The column "Wet/Rip" indicates whether a species was listed as occurring regularly in wetland or riparian habitats in Utah by Dalton et al. 1990 (D), in Colorado by Bissell 1978 (B), or in Colorado by the State Heritage Program's Vertebrate Characterization Abstracts (HP). A "B" in a subregion column indicates the species regularly breeds in wetlands and riparian habitats of the specified subregion, and an "M" indicates that it uses such habitats during migration, but probably does not breed in them. A blank means the species does not regularly occur in, and/or is not dependent on, wetland/riparian areas of that subregion. For the Grand Valley, Lower Gunnison, and Cortez subregions, information is mainly from Bissell (1978). Utah information is from Dalton et al. (1990). Species occurring in the Wyoming subregion were inferred from Bissell's (1978) list for the northwesternmost part of Colorado. Entries with an asterisk (*) indicate the species was found within irrigated wetlands in the Grand Valley by Ecology Consultants (1976) or CDW (1984), in the Lower Gunnison Valley by Rector et al. (1979), in the Cortez area by Somers et al. (1979), or in the Price-San Rafael salinity control area by USBR and SCS (1991). In the next-to-last column, the abundance codes pertain only to Colorado, and are reproduced from the original information source (Bissell 1978) as follows: A= abundant, C= common, F= fairly common, U= uncommon, ?= unknown abundance.

Genus and Species	Wet/Rip	Grand Valley	L. Gunnison	Cortez	Utah	Wyoming	Abund.	Common Name
AMMOSPERMOPHILUS LEUCURUS	HP	B*	B	B	B	B	R	WHITE-TAILED ANTELOPE SQUIRREL
ANTILOCAPRA AMERICANA	HP	B	B		B	B	C	PRONGHORN ANTELOPE
ANTROZOUS PALLIDUS	HP	B	B	B	B	B	?	PALLID BAT
BASSARISCUS ASTUTUS	HP	B	B	B	B	B	?	RINGTAIL
CASTOR CANADENSIS	B	B*	B*	B	B	B	C	BEAVER
CERVUS ELAPHUS	HP	B*	B	B	B	B	C	AMERICAN ELK
CYNOMYS GUNNISONI	B		B	B*			C	GUNNISON'S PRAIRIE DOG
CYNOMYS LEUCURUS	HP	B*				B	C	WHITE-TAILED PRAIRIE DOG
DIPODOMYS ORDII	HP	B	B	B	B	B	A	ORD'S KANGAROO RAT
EPTESICUS FUSCUS	HP	B	B	B	B	B	C	BIG BROWN BAT
ERETHIZON DORSATUM	HP	B	B	B	B	B	C	PORCUPINE
EUDERMA MACULATUM	D				B		R	SPOTTED BAT
EUTAMIAS MINIMUS	HP	B	B*	B		B	C	LEAST CHIPMUNK
EUTAMIAS QUADRIVITTATUS	HP	B	B	B		B	C	COLORADO CHIPMUNK
EUTAMIAS UMBRINUS	HP	B					C	UINTA CHIPMUNK
FELIS CONCOLOR	HP	B	B	B	B	B	R	MOUNTAIN LION
LAGURUS CURTATUS	HP	B				B	?	SAGE-BRUSH VOLE
LASIONYCTERIS NOCTIVAGANS	HP	M	M				?	SILVER-HAIRED BAT
LASIURUS CINEREUS	HP	M		M	M	M	C	HOARY BAT
LEPUS CALIFORNICUS	HP	B*	B*	B	B*		C	BLACK-TAILED JACKRABBIT
LEPUS TOWNSENDII	HP	B*	B*		B	B	A	WHITE-TAILED JACKRABBIT
LUTRA CANADENSIS	D				B		R	RIVER OTTER
LYNX RUFUS	B	B*	B	B	B	B	C	BOBCAT
MARMOTA FLAVIVENTRIS	HP	B	B			B	C	YELLOW-BELLIED MARMOT
MEPHITIS MEPHITIS	B	B*	B*	B	B*	B	C	STRIPED SKUNK
MICROTUS LONGICAUDUS	HP	B*	B	B	B	B	C	LONG-TAILED VOLE
MICROTUS MONTANUS	HP	B	B*	B*	B*		A	MONTANE VOLE
MICROTUS PENNSYLVANICUS	B		*		B*		?	MEADOW VOLE
MUS MUSCULUS	HP	B*	*		B		C	HOUSE MOUSE
MUSTELA ERMINEA	HP	B		B			?	ERMINE
MUSTELA FRENATA	B	B*	B	B	B*	B	C	LONG-TAILED WEASEL
MUSTELA VISON	B	B*		B		B	?	MINK
MYOTIS CALIFORNICUS	HP	B	B	B	B		?	CALIFORNIA MYOTIS
MYOTIS CILIOLABRUM	D				B		U	SMALL-FOOTED MYOTIS
MYOTIS EVOTIS	HP	B	B	B		B	C	LONG-EARED MYOTIS
MYOTIS LEIBII	HP	B	B	B		B	C	SMALL-FOOTED MYOTIS
MYOTIS LUCIFUGUS	HP	B	B		B		?	LITTLE BROWN BAT
MYOTIS THYSANODES	HP			B	B		R	FRINGED MYOTIS
MYOTIS VOLANS	HP	B	B	B	B	B	R	LONG-LEGGED MYOTIS
MYOTIS YUMANENSIS	HP	B			B	B	?	YUMA MYOTIS
NEOTOMA ALBIGULA	HP		B	B*			C	WHITE-THROATED WOOD RAT
NEOTOMA CINEREA	HP	B	B	B	B	B	C	BUSHY-TAILED WOOD RAT
NEOTOMA LEPIDA	HP	B			B	B	R	DESERT WOOD RAT
NEOTOMA MEXICANA	HP	B	B	B			C	MEXICAN WOOD RAT

Genus and Species	Wet/Rip	Grand Valley	L. Gunnison	Cortez	Utah	Wyoming	Abund.	Common Name
ODOCOILEUS HEMIONUS	B	B*	B*	B*	B*	B	C	MULE DEER
ONDATRA ZIBETHICUS	B	B*	B*	B*	B*	B	C	MUSKRAT
ONOCHOMYS LEUCOGASTER	HP	B*	B	B		B	C	NORTHERN GRASSHOPPER MOUSE
OVIS CANADENSIS	D				B		C	BIGHORN SHEEP
PEROGNATHUS APACHE	HP	B	B	B		B	?	APACHE POCKET MOUSE
PEROGNATHUS FASCIATUS	HP					B	?	OLIVE-BACKED POCKET MOUSE
PEROGNATHUS FLAVUS	HP			B			C	SILKY POCKET MOUSE
PEROMYSCUS BOYLII	HP		B	B	B		?	BRUSH MOUSE
PEROMYSCUS CRINITUS	HP	B	B	B	B	B	C	CANYON MOUSE
PEROMYSCUS MANICULATUS	B	B*	B*	B*	B*	B	A	DEER MOUSE
PEROMYSCUS TRUEI	HP	B	B	B	B	B	C	PINON MOUSE
PIPISTRELLUS HESPERUS	HP	B*	B	B	B	B	C	WESTERN PIPISTRELLE
PLECOTUS TOWNSENDII	HP			B	B	B	C	TOWNSEND'S BIG-EARED BAT
PROCYON LOTOR	B	B*	B*	B*	B		C	RACCOON
REITHRODONTOMYS MEGALOTIS	B	B*	B*	B*	B*	B	A	WESTERN HARVEST MOUSE
SOREX CINEREUS	B	B	B	B			C	MASKED SHREW
SOREX MERRIAMI	HP	B		B	B		?	MERRIAM'S SHREW
SOREX MONTICOLUS	B		*		B		?	MONTANE (DUSKY) SHREW
SOREX NANUS	D				B			DWARF SHREW
SOREX PALUSTRIS	B		*	B	B		C	WATER SHREW
SOREX VAGRANS	B	B	B	B*	B		C	WANDERING SHREW
SPERMOPHILUS LATERALIS	HP	B	B*	B	B	B	A	GOLDEN-MANTLED GROUND SQUIRREL
SPERMOPHILUS RICHARDSONII	B	B				B	C	RICHARDSON'S GROUND SQUIRREL
SPERMOPHILUS SPILOSOMA	HP			B			C	SPOTTED GROUND SQUIRREL
SPERMOPHILUS TRIDECEMLINEATUS	HP	B			B	B	C	THIRTEEN-LINED GROUND SQUIRREL
SPERMOPHILUS VARIEGATUS	B	B*	B*	B*	B		C	ROCK SQUIRREL
SPILOGALE PUTORIUS	B	B	B	B	B	B	C	SPOTTED SKUNK
SYLVILAGUS AUDUBONII	HP	B*	B*	B	B	B	A	DESERT COTTONTAIL
SYLVILAGUS NUTTALLII	HP	B	B	B		B	C	NUTTALL'S COTTONTAIL
TADARIDA BRASILIENSIS	HP			M	M		?	BRAZILIAN FREE-TAILED BAT
TADARIDA MACROTIS	HP	M					?	BIG FREE-TAILED BAT
TAMIAS DORSALIS	D				B		U	CLIFF CHIPMUNK
TAMIAS UMBRINUS	D				B		C	UINTAH CHIPMUNK
TAXIDEA TAXUS	B	B*	B	B	B	B	C	BADGER
THOMOMYS BOTTAE	HP	B*	B	B	B		C	VALLEY POCKET GOPHER
THOMOMYS TALPOIDES	HP	B	B		B	B	C	NORTHERN POCKET GOPHER
UROCYON CINEREOARGENTEUS	B	B*	B	B	B	B	C	GRAY FOX
URSUS AMERICANUS	B	B*	B	B	B	B	C	BLACK BEAR
VULPES MACROTIS	HP	B*	B	B	B		?	KIT FOX
VULPES VULPES	B	B*	B	B	B	B	C	RED FOX
ZAPUS PRINCEPS	B	B	B	*			C	WESTERN JUMPING MOUSE

APPENDIX F.

Table F-1. AREM field form: Documenting information

I. DOCUMENTING INFORMATION (not used in the analysis):

Wetland Name: ______________________ Date Evaluated: ______________

Name of Associated Computer File (assign one, having 8 characters): ______________

Evaluator (s): ______________________________________

Type of Wetland (check one):

_____ On-farm _____ Off-farm

Wetland Water Source (check one or more):

____ Subsurface seepage - Mostly Natural
____ Subsurface seepage - Mostly Irrigation-related
____ Overland runoff - Mostly Natural
____ Overland runoff - Mostly Irrigation-related
____ Channel or lake overflow - Mostly Natural
____ Channel or lake overflow - Mostly Irrigation-related

WETLAND SCORES (insert here after completing the data analysis):

	Cutoff Level for Species Habitat Scores: >0% (all possible spp.)	>25%	>50%	>75% (most conservative)
Unweighted Habitat Score				
Unweighted Richness Score				
Habitat Score Weighted[1] By Species': Relative Dependency on Wetlands				
Relative Abundance				
Taxonomic Uniqueness				
Neotropical Migrant Status				
Official Conservation Designations				
Hunted Status				

[1] For "Dependency on Wetlands," largest weights are assigned to species using water as a substrate; smallest weights to species that regularly use upland habitat. For "Relative Abundance," largest weights are assigned to uncommon species, smallest to abundant species. For "Taxonomic Uniqueness," largest weights are assigned to species that are the only ones of their genus in the region; smallest to species having many congeners. For Neotropical Migrant Status, largest weights are assigned to species breeding only in the U.S. or Canada and migrating to the Neotropics; smallest weights to nonmigratory species. For "Official Conservation Designations," largest weights are assigned species with state, federal, or Heritage Program designations; smallest weights to others. For "Hunted Status," largest weights are assigned species that are legally hunted; smallest weights to others.

Table F-2. AREM long form

II. FIELD DATA

For each numbered item, check only one response unless noted otherwise. Then proceed to the next question unless noted otherwise. Parenthetical file names are the names of fields in the supporting database.

1. LOCATION. Is the wetland part of, or is it within 0.5 mile of, a major* river or lake?
* River wider than 100 ft or lake larger than 40 acres
____ Yes (file BigWater) ____ No

2. SURFACE WATER. Is there at least 0.1 acre* of surface water in the wetland during most of the growing season?
* See Figure F-1 for guidance in estimating acreage categories.
____ Yes (file AnyWater). Go to next question.
____ No. **Skip to question #5.**

3. OPEN WATER. How much open* water is present in the wetland during the growing season?
* Water deeper than 2 inches and mostly lacking vegetation (except submerged plants).
____ > 20 acres <u>and</u> it is mostly wider than 500 ft (file OpenBig)
____ < 1 acre, <u>or</u>, >1 acre but mostly narrower than 3 ft (file OpenSmall)
____ Other conditions (file OpenOther)

4. SPECIFIC AQUATIC CONDITIONS
Check all that apply:
____ > 0.1 acre of the surface water is still, i.e., usually flows at less than 1 ft/s (file StillWater)
____ Wetland can be assumed to contain fish (file Fish)
____ Wetland can be assumed to contain frogs, salamanders, and/or crayfish (file Amphibs)
____ Water transparency in the deepest part of the wetland is (or would be, if depth is shallow) sufficient to see an object 10 inches below the surface, <u>and</u> wetland is not known to have problems with metal contamination (file Clear)
____ Wetland is highly enriched by direct fertilizer applications, water from nearby feedlots, or other sources (file Enriched)
____ Most of the normally-flooded part of the wetland **goes dry** at least one year in five, or, is subject to flooding from a river at least as often (file Drawdown)

5. MUD. Is there at least 0.1 acre of exposed mud*, **which contains water before any week in the period April 15-May 30, or July 10-Sept. 10**, and then goes dry?
* "Mud" can include tilled, sandy, alkali, or very sparsely vegetated soil.
____ Yes (file Mud). Go to next question.
____ No. **Skip to question #7.**

SHAPE
(Not to Scale)

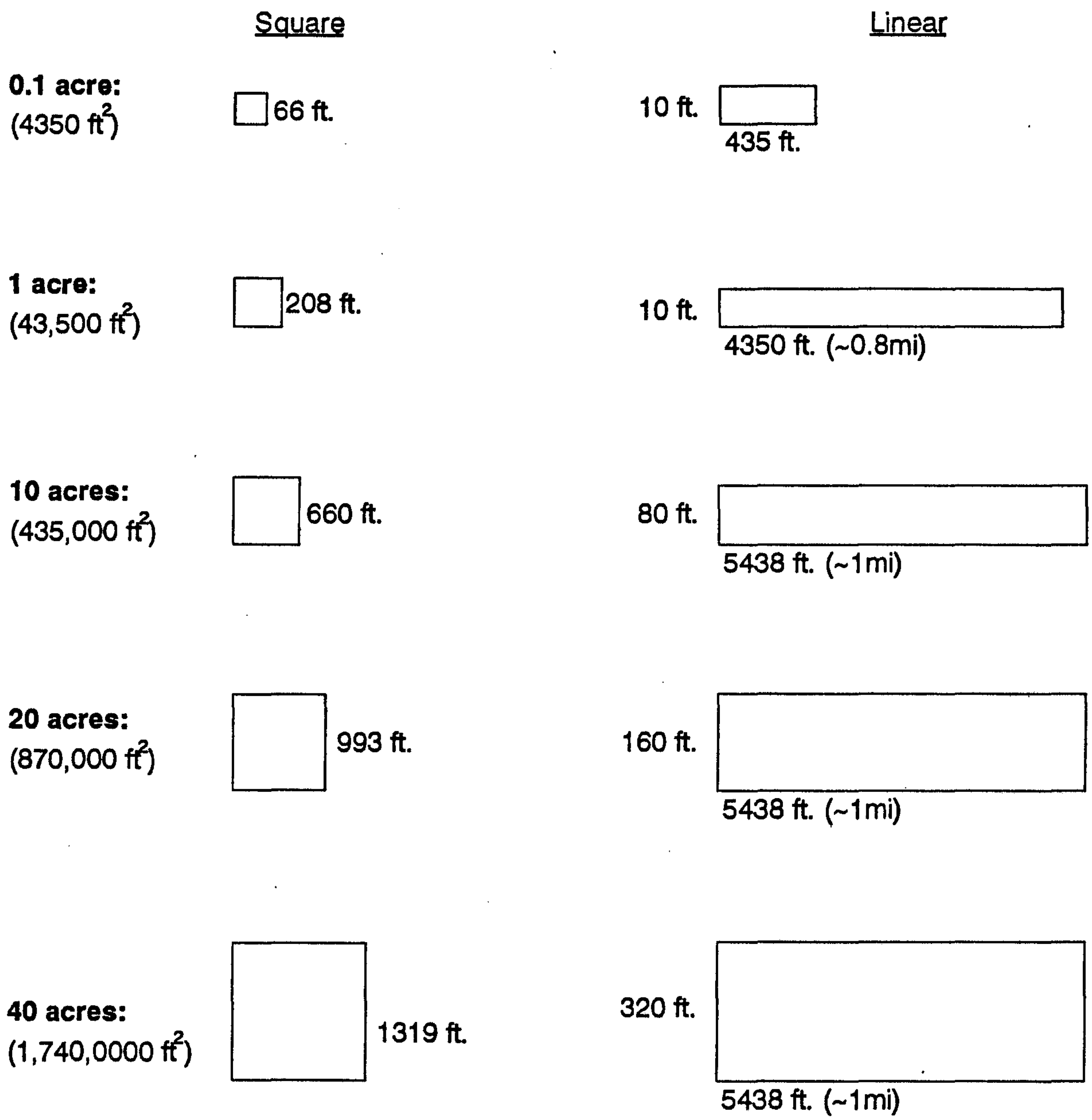

Figure F-1. Examples of wetland dimensions for various wetland shapes and acreages.

6. LARGE MUDFLAT. Does the mud habitat have all these features?:
- o At least 1 acre in size
- o Maximum dimension is greater than 100 ft
- o Salt crust or salt stains are not apparent
- o Not recessed within a wash or canal whose depth (relative to surrounding landscape) is greater than half its width.

____ Yes (file MudBig) ____ No

7. TREES. Are there at least 3 trees*:
* Cottonwood, Chinese elm, ash, or other plants taller than 20 ft.

____ within 1000 ft of the wetland (including the wetland itself)? (file TreeInBy)
____ in the wetland or within 300 ft? (file TreeIn)
(Both of the above may be checked if appropriate)
____ Neither of the above. **Skip to #11.**

8. TREE COVER. Add the tree acreage within 300 ft of the wetland, to the tree acreage actually within the wetland. Then check the response below that best represents the overall extent of tree cover:

____ >1 acre, dense*, with maximum tree-stand dimension >300 ft (file ForestDens)
____ >1 acre, open, with maximum tree-stand dimension >300 ft (file ForestOpen)
____ 0.1-1 acre, dense*, or greater acreage but narrower than 300 ft (file WoodDens)
____ 0.1-1 acre, open, or greater acreage but narrower than 300 ft (file WoodOpen)
____ <0.1 acre

* Dense= the tree canopy, viewed from the ground during midsummer, appears at least 50% closed, as averaged across an area that is at least as large as the acreage specified.

9. BIG TREES. Are there at least three trees of >12 inch diameter within the wetland or within 300 ft of its perimeter?
____ Yes (file TreesBig) ____ No

10. SNAGS. Are there at least three snags, or trees with dead limbs with diameter >5 inches, within the wetland or within 300 ft of its perimeter?
____ Yes (file Snags) ____ No

11. SHRUBS. Is there at least 0.1 acre of shrubs*:
* Tamarisk, willow, Russian olive, greasewood, or others 2-20 ft in height.

____ within 1000 ft of the wetland (including the wetland itself)? (file ShrubInBy)
____ in the wetland or within 300 ft? (file ShrubIn)
(Both of the above may be checked if appropriate).
____ Neither of the above. **Skip to #13.**

12. SHRUB SPECIES AND DENSITY. For each shrub type listed below, add the acreage of the same shrub within 300 ft of the wetland, to the acreage within the wetland. Then check the response below that best represents the overall condition for that shrub:

Willow:
____ >1 acre, dense (file WwMuchDens)
____ >1 acre, open or very clumped (file WwMuchOpen)
____ 0.1-1 acre, dense* (file WwSomeDens)
____ 0.1-1 acre, open or very clumped (file WwSomeOpen)

Greasewood or other tall desert shrubs:
____ >1 acre (file GreaseMuch)
____ 0.1-1 acre (file GreaseSome)

Russian olive or others with succulent fruit:
____ >1 acre, dense (file OvMuchDens)
____ >1 acre, open (file OvMuchOpen)
____ 0.1-1 acre, dense (file OvSomeDens)
____ 0.1-1 acre, open (file OvSomeOpen)

Tamarisk (salt cedar):
____ >1 acre, dense (file TmMuchDens)
____ >1 acre, open (file TmMuchOpen)
____ 0.1-1 acre, dense (file TmSomeDens)
____ 0.1-1 acre, open (file TmSomeOpen)

Pinyon - juniper:
____ >1 acre (file PJMuch)
____ 0.1-1 acre (file PJSome)

* Dense= the shrub canopy, as viewed from a height of 100 ft during midsummer, appears to be >50% closed, as averaged across an area that is at least as large as the acreage specified.

13. HERBACEOUS VEGETATION. Is there at least 0.1 acre of emergent vegetation*:
* Nonwoody cattail, bulrush, sedges, grasses, and forbs.
____ within 1000 ft of the wetland (including the wetland itself)? (file EmInBy)
____ in the wetland or within 300 ft? (file EmIn)
(Both of the above may be checked if appropriate).
____ Neither of the above. **Skip to #15.**

14. HERBACEOUS SPECIES. For each cover type listed below, add the acreage of the same cover within 300 ft of the wetland, to that present within the wetland. Then check the response below that best represents the overall condition for that cover type:

Robust emergents (e.g., cattail, phragmites)
- ____ >1 acre, dense* (file RbMuchDens)
- ____ >1 acre, open (file RbMuchOpen)
- ____ 0.1-1 acre, dense (file RbSomeDens)
- ____ 0.1-1 acre, open (file RbSomeOpen)

Other wet** emergents (e.g., bulrush, sedge)
- ____ >1 acre, dense*, height >4 in (file WEMuchDens)
- ____ >1 acre, open, height >4 in (file WEMuchOpen)
- ____ >1 acre and height <4 in (file WEMuchShrt)
- ____ 0.1-1 acre, dense, height >4 in (file WESomeDens)
- ____ 0.1-1 acre, open, height >4 in (file WESomeOpen)
- ____ 0.1-1 acre, height <4 in (file WESomeShrt)

Drier emergents (e.g., grasses)
- ____ >1 acre, dense* (file DEMuchDens)
- ____ >1 acre, open (file DEMuchOpen)
- ____ 0.1-1 acre, dense (file DESomeDens)
- ____ 0.1-1 acre, open (file DESomeOpen)

Broad-leaved Forbs (e.g., milkweed, thistle, alfalfa)
- ____ >1 acre (file ForbMuch
- ____ 0.1-1 acre (file ForbSome)

Aquatic plants (e.g., watercress, sago pondweed, duckweed)
- ____ >10 acres (file AqMuch)
- ____ 0.1-10 acres (file AqSome)

* Dense= these plants are at least 4 inches high and mostly obscure the soil or underlying water, as viewed from a height of 100 ft during midsummer.
** Wet = at least 2 inches of surface water underlay the plants during most of the growing season.

15. SURROUNDING LAND COVER. Within 0.5 mi of the wetland, is the land cover >60% pasture, alfalfa, grain crops, row crops, other wetlands, grass lawns, and/or weed fields?
- ____ Yes (file SurrCover). **Skip to #17.**
- ____ No. Go to next question.

16. LOCAL LAND COVER. Within 3 mi of the wetland, is the land cover >60% pasture, alfalfa, grain crops, row crops, other wetlands, grass lawns, and/or weed fields?
- ____ Yes (file LocalCover).
- ____ No

17. VISUAL SECLUSION

Check only one:

____ Both of the following: (a) wetland is seldom visited by people on foot or boat (less than once weekly), (b) there are no paved roads within 600 ft, or if there are, wetland is not visible from the roads (file SeclusionH).

____ Either (a) or (b) above (file SeclusionM).

____ Other condition.

18. PREDATION POTENTIAL

Check only one:

____ Wetland adjoins a heavily-traveled road (usual maximum of >1 car/minute), and/or is in a high-density housing area (>1 house/5 acres), and/or is linear (i.e., no more than 10% of the wetland is farther than 25 ft from a road, canal, or other artificially linear feature) (file PredHPot)

____ Wetland adjoins a less-traveled road, and/or is in an area with sparser housing density but is closer than 1000 ft from a normally-occupied building (file PredMPot)

____ Other condition.

19. GRAZED, BURNED, MOWED. Is the wetland mowed, burned, or intensively grazed between April and mid-July?

____ Yes (file GrazBurnMo)

____ No

20. NESTING LOCATIONS

Check all that apply:

____ Semi-open structures (bridges, barns) suitable for nesting swallows are present within 300 ft (file SwallNest)

____ Platforms suitable for nesting geese are present in the wetland or along its perimeter (file GooseNest)

____ Vertical, mostly bare dirt banks at least 15 ft high are present within 0.5 mi., of potential use to nesting kingfishers, barn owls, and swallows (file Banks)

This concludes the initial evaluation. If you intend to infer the value of this wetland at seasons or years other than the present one, you should go back over all your responses and, on a new form, change the responses that would be different at that season/year. Then, proceed to the analysis. Refer to Section 5.0 for instructions on how to convert the above information into wetland scores and a species list.

Table F-3. AREM short form
(A= acre, ft= feet, in= inches, mi= miles)

1. Location: river/lake <0.5 mi?
___BigWater

2. Surface Water: >0.1 A in growing season?
___AnyWater [skip to #5 if no]

3. Open Water: in growing season:
___OpenBig: >20 A and width mostly >500 ft
___OpenSmall: < 1 A, or >1 A but width <3 ft
___OpenOther: all other

4. Specific Aquatic Conditions:
___StillWater: >0.1 A that flows at <1 ft/s
___Fish
___Amphibs: crayfish, frogs, salamanders
___Clear: 10 inch visibility and no metals problem
___Enriched: feedlots etc.
___Drawdown: most of wetland dries out or floods from river 1 year in 5

5. Mud: >0.1 A of exposed mud is wet-then-dry, April 15 - May 30, or July 10- Sept. 10
___Mud [skip to 7 if no]

6. Large Mudflat: >1 A + width>100 ft + no salt + not recessed
___MudBig

7. Trees: >2 trees...
___TreeInBy: within 1000 ft, or in
___TreeIn: in wetland
[skip to 11 if no]

8. Tree Cover: tree acres within 300 ft + acres in wetland
___ForestDens: >1 A, closed canopy, and >300 ft wide
___ForestOpen: >1 A, open, and >300 ft wide
___WoodDens: 0.1-1.0 A closed, or larger but narrower than 300 ft
___WoodOpen: 0.1-1.0 A open, or larger but narrower than 300 ft

9. Big Trees: >2 trees, >12 inch diameter within 300 ft or in?
___TreesBig

10.Snags: >2 snags (>5 inch diameter), within 300 ft or in wetland?
___Snags

11.Shrubs: >0.1 acre of shrubs (2-20 ft height)...
___ShrubInBy: within 1000 ft, or in
___ShrubIn: in wetland
[skip to 13 if no]

12.Shrub Species and Density: shrub acres within 300 ft + in wetland:
___WwMuchDens: willow >1 A, closed
___WwMuchOpen: willow >1 A, open or clumped
___WwSomeDens: willow 0.1 - 1.0 A, closed
___WwSomeOpen: willow 0.1 - 1.0 A, open or clumped
___GreaseMuch: greasewood >1 A
___GreaseSome: greasewood 0.1 - 1.0 A
___OvMuchDens: Russian olive >1 A, closed
___OvMuchOpen: Russian olive >1 A, open or clumped
___OvSomeDens: Russian olive 0.1 - 1.0 A, closed
___OvSomeOpen: Russian olive 0.1 - 1.0 A, open or clumped
___TmMuchDens: tamarisk >1 A, closed
___TmMuchOpen: tamarisk >1 A, open or clumped
___TmSomeDens: tamarisk 0.1 - 1.0 A, closed
___TmSomeOpen: tamarisk 0.1 - 1.0 A, open or clumped
___PJMuch: pinyon-juniper >1 A
___PJSome: pinyon-juniper 0.1 - 1 A

13. Herbaceous Vegetation: >0.1 A of herbaceous
___EmInBy: within 1000 ft, or in wetland
___EmIn: in wetland

14. Herbaceous Species and Density: herbaceous acres within 300 ft + in wetland:
___RbMuchDens: robust cattail etc. >1 A, dense
___RbMuchOpen: robust cattail etc. >1 A, open
___RbSomeDens: robust cattail etc. 0.1 - 1.0 A, dense
___RbSomeOpen: robust cattail etc. 0.1 - 1.0 A, open
___WEMuchDens: wet emergents (sedge, bulrush) >1 A, dense, >4 in tall
___WEMuchOpen: wet emergents (sedge, bulrush) >1 A, open tall
___WEMuchShrt: wet emergents (sedge, bulrush) >1 A, short <4 in
___WESomeDens: wet emergents (sedge, bulrush) 0.1 - 1.0 A, dense, >4 in tall
___WESomeOpen: wet emergents (sedge, bulrush) 0.1 - 1.0 A, open tall
___WESomeShrt: wet emergents (sedge, bulrush) 0.1 - 1.0 A, short <4 in
___DEMuchDens: dry emergents (grasses etc.) >1 A, dense, >4 in tall
___DEMuchOpen: dry emergents (grasses etc.) >1 A, open
___DESomeDens: dry emergents (grasses etc.) 0.1 - 1.0 A, dense, >4 in tall
___DESomeOpen: dry emergents (grasses etc.) 0.1 - 1.0 A, open

14 (continued). Herbaceous Species and Density: acres within 300 ft + in wetland:
___ForbMuch: alfalfa, milkweed, etc. > 1 A
___ForbSome: alfalfa, milkweed, etc. 0.1 - 1.0 A
___AqMuch: watercress, sago, duckweed etc. > 1 A
___AqSome: watercress, sago, duckweed etc. 0.1 - 1.0 A

15. Surrounding Land Cover: within 0.5 mi...
___SurrCover: >60% pasture, alfalfa, grain, row crops, other wetlands, weeds, grass [skip to 17 if yes]

16. Local Land Cover: within 3.0 mi of wetland...
___LocalCover: >60% pasture, etc.

17. Visual Seclusion: check ONLY ONE:
___SeclusionH: no road within 600 ft or not visible if road present, <u>and</u> <1 visit/week on foot
___SeclusionM: EITHER of above
___other

18. Predation Potential: check ONLY ONE:
___PredHPot: major road, urban, or linear
___PredMPot: other road or building within 1000 ft
___other

19. Burned, mowed, or intensively grazed, April to mid-July?
___GrazBurnMo

20. Nesting Locations:
___SwallNest: swallow sites -- barns, bridges within 300 ft
___GooseNest: goose platforms, in wetland or on perimeter
___Banks: within 0.5 mi, height >15 ft, vertical

MANAGEMENT TECHNOLOGY

EPA – REGION 10
RECEIVED

MAY 17 1993

WATER DIVISION
SURFACE WATER BRANCH

May 12, 1993

Fred Weinmann
USEPA Region 10 - Wetlands
1200 Sixth Ave.
Seattle, WA 98101

Dear Mr. Weinmann:

The enclosed report describes a new method ("AREM") which assesses biodiversity by assessing habitat. Although this method may in some ways be less sophisticated than HEP (the Habitat Evaluation Procedure of the U.S. Fish and Wildlife Service), it is faster and simpler to use (<30 minutes per wetland). Most importantly, it is relatively comprehensive in addressing wildlife diversity. Its current focus is on wetland habitats and birds, which are the richest group of terrestrial vertebrates in most regions of the U.S., but it can be adapted for other resources and regions. Given a list of habitat features, AREM predicts the number of species present, their identities, and relative suitability of habitat for each. If desired, users can assign greater weight to species of particular interest (e.g., neotropical migrants) and less weight to less desirable species (e.g., abundant habitat-generalists). Initial tests of the method's accuracy are ongoing. It is understood that habitat values are just one of several potential values of wetlands, the others possibly including (for example) purification of nonpoint source pollution, flood storage, and open space/recreation. These would need to be addressed by methods other than AREM.

When adapted for other regions and resources, AREM might be useful as a **local**-level complement to **region**-level biological surveys, Gap Analysis, and ecosystems planning; or as a complement to HEP in watershed assessments, impact analyses, and monitoring of mitigation/restoration projects. The enclosed report describing AREM has already undergone review by many scientists from outside EPA, and I continue to appreciate comments and suggestions from any source.

The software and instruction manual that support AREM are nearing completion and will be publicly available at no cost later this year. If you are interested in receiving a copy at that time, please let me know of your interest.

Sincerely,

Paul

Paul R. Adamus,
Wildlife Biologist

ManTech Environmental Technology, Inc.

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