Development of Plant and Animal Communities in the Holloman Constructed Wetland

Submitted to:

U.S. Army Corp of Engineers
CESWF-EV-EE, P.O. Box 17300
Ft. Worth, Texas 76102-0300

and

49 CES/CEV
550 Tabosa Ave
Holloman Air Force Base, NM 88330

by

Michael Freehling
Paul Neville
Teri Neville
and
Kristine Johnson

New Mexico Natural Heritage Program
Biology Department, University of New Mexico
167 Castetter Hall, Albuquerque, NM 87131
NMNHP Report: 02-GTR-212

22 May 2002

Table of Contents

List of Figures

List of Tables

Introduction

The Lake Holloman Wetlands Complex Area (LHWCA) is the wetland component of the secondary sewage treatment system at Holloman Air Force Base (HAFB). The LHWCA includes Stinky Playa, Lake Holloman, Lagoon G, and the Constructed Wetlands (CW). This complex is the largest permanent wetland in the Tularosa Basin and thus provides important wintering and stopover habitat for migratory birds. The CW was created to receive additional water from the recently remodeled HAFB wastewater treatment plant and to provide foraging habitat for stopover migrants and nesting habitat for breeding wetland birds.

In addition to causing dramatic changes in the hydrology of the area, the construction of the CW removed nearly all existing vegetation. The resulting combination of bare soil and abundant water invites plant succession by both native and invasive wetland plants. To properly manage the new CW for breeding and migrating wetland birds, it is necessary to monitor changes not only in the birds but also in the successional vegetation in bird habitats and the invertebrate food base. The purposes of this project were to: 1. create a vegetation map to serve as a baseline for monitoring successional changes and exotic plant invasions, 2. collect additional baseline data on invertebrate communities in the CW, to serve as a basis for future monitoring and management, and 3. suggest approaches to the complex problem of managing for invertebrates, birds, and desirable wetland vegetation, while discouraging plant species that are incompatible with the goal of enhancing wetland bird habitat.

Study Area

The study area encompasses approximately 385 ha (950 acres), west of the city of Alamogordo, NM and southwest of the airfield and residential area of HAFB (Figure 1). The CW was built on alkali flats averaging 1,175 m (3,855 ft) in elevation. Within the wetlands, soils are principally the Mead silty clay loams. These soils are poorly drained and have a high salt content because of frequent flooding. They become extremely sticky when wet. The soils are characterized by a 12.7 cm (5 in) thick surface layer of reddish-brown silty clay or clay loam, underlain by approximately 1.2 m (4 ft) of clay high in salt (Neher and Bailey 1976). Beyond 1.2 m (4 ft) deep, the subsoils are formed from lakebed sediments (Neher and Bailey 1976). The Holloman-Gypsum land-Yesum soil complex, shallow and deep well-drained soils and exposed gypsum, occurs around and throughout the playa wetlands. The area receives less than 25 cm (10 in) of precipitation per year, mostly in the form of sporadic summer thunderstorms, and summer temperatures can reach over 40° C (100° F). Despite this harsh climate and its location on a gypsum-encrusted substrate, the CW contains a wide variety of environments. Vegetation cover ranges from barren to wetland, grassland, shrubland, and woodland types. Shallow and deep surface water occur in the CW. Lagoon G is a perennial, moderately deep-water reservoir (Figure 2), and scattered throughout the wetlands are shallow water ponds and/or saturated soils. This diversity provides a unique set of habitats for wildlife in an otherwise arid landscape.

Part I: Vegetation Map

We developed the vegetation map using computer analysis of high spatial resolution satellite imagery and available Geographical Information System (GIS) data layers. We collected ground vegetation data to develop ecologically meaningful map units appropriate for use at a 1:12,000 to 1:6,000 scale. This project followed the creation of a base-wide, 1:24,000 vegetation map (Muldavin, et al. 1997). We made an effort in the wetland mapping project to use the Muldavin et al. (1997) map units whenever appropriate or, where more detail was available, to create map units representing sub-categories of the Muldavin et al. (1997) map units. Digital copies and hard copies of the annotated map were provided to HAFB in 2001. Since then, the map has been useful in developing invertebrate habitat maps (this study) and describing the nesting habitats of shorebirds in the CW (Smith and Johnson 2002).

Figure 1. Study area

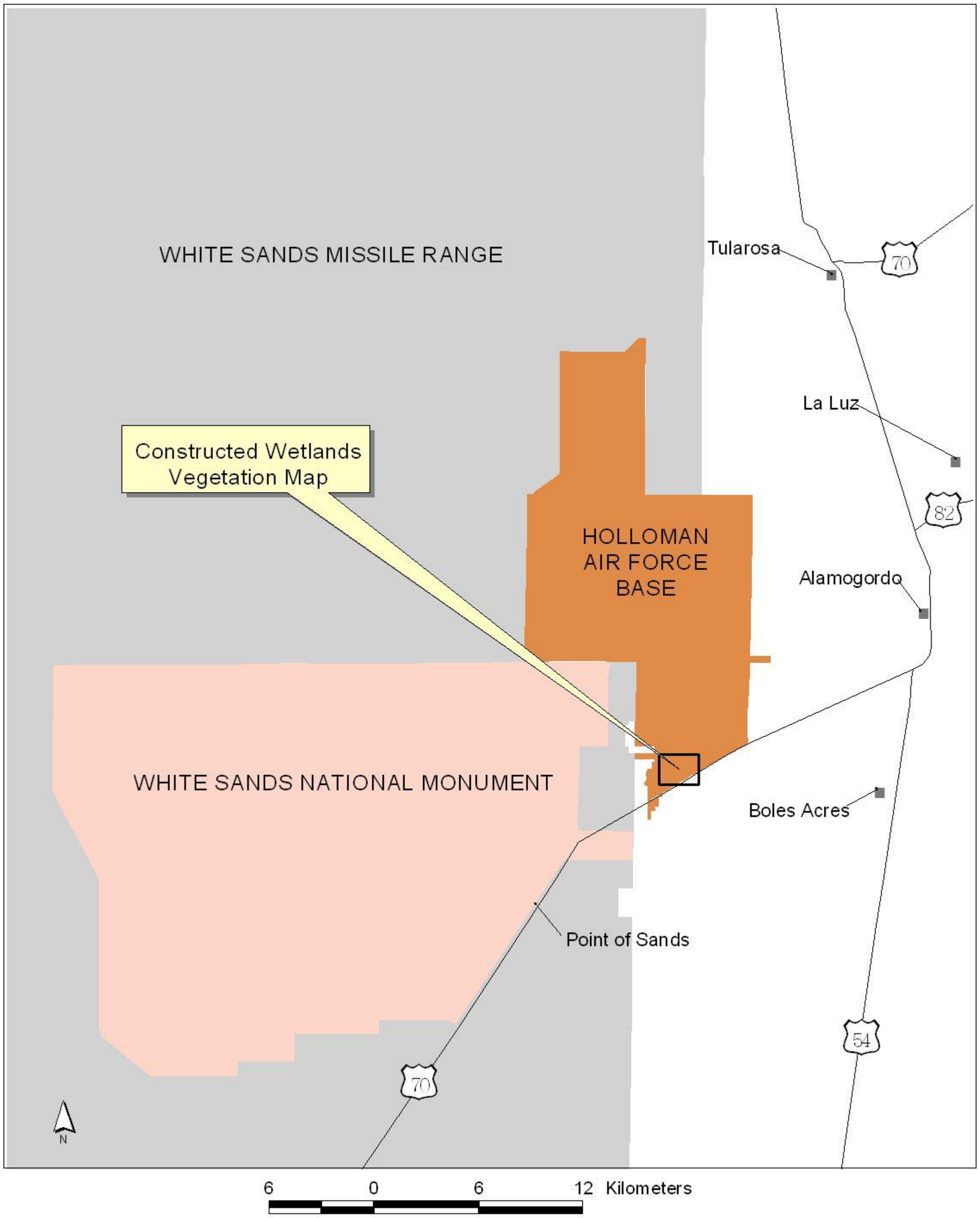
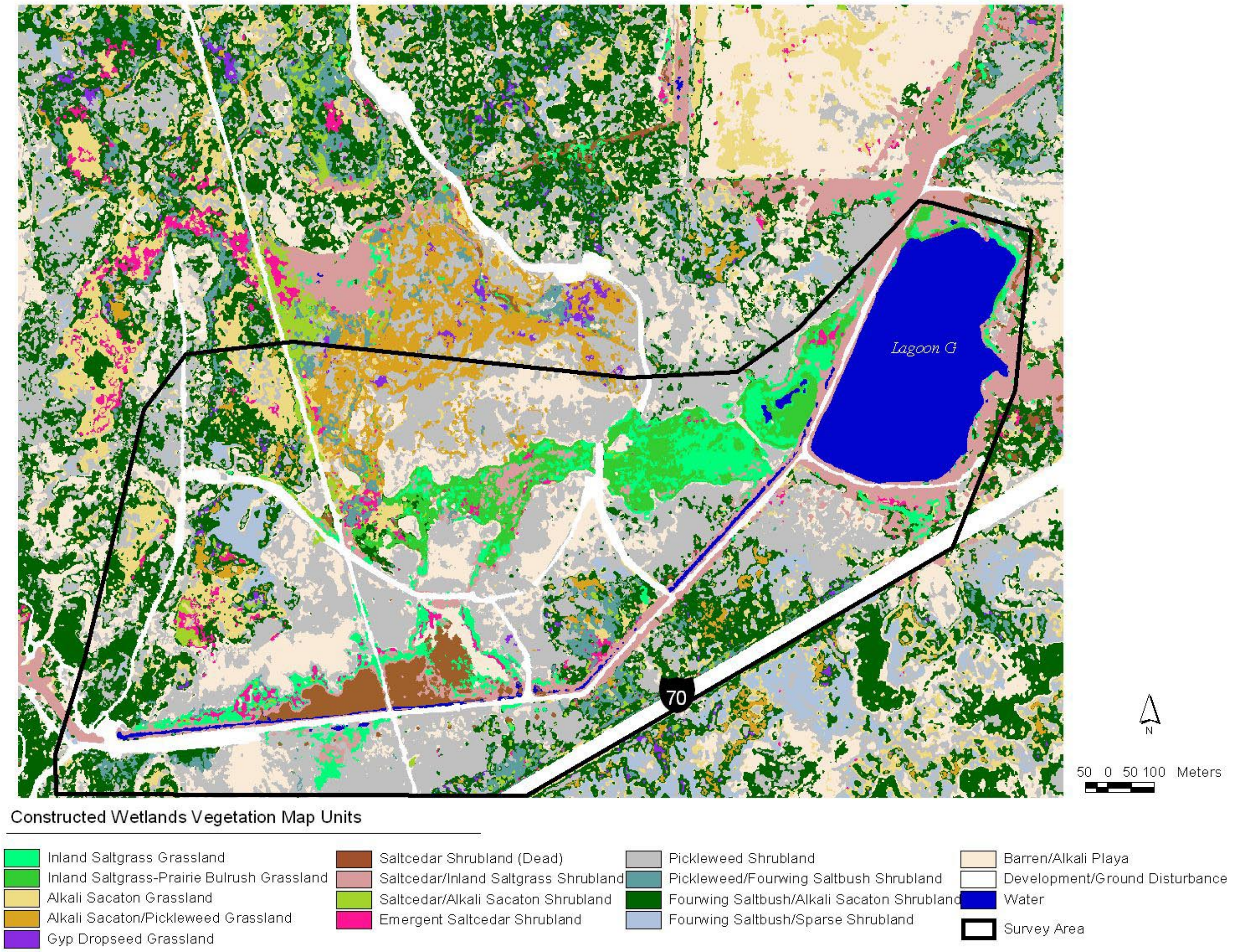


Figure 2. Constructed wetlands vegetation map



Methods

Satellite Imagery

We acquired multi-spectral (MS) and panchromatic (PAN) data collected May 9, 2000 by the Space Imaging IKONOS satellite. The MS product records the surface reflectance in four discrete bandwidths representing the visible blue, visible green, visible red, and near-infrared wavelengths at a four-meter spatial resolution (Table 1). The quantitative recording of different responses across these wavelengths provides the ability to discriminate among different soil and vegetation types. The PAN data integrate these different responses across all wavelengths into one response, but at a finer spatial resolution (1 m). Both of these data sets were acquired with an 11-bit dynamic range, which allows the contrast to be divided into 2,048 different values ranging from black to white, an improvement over the 8-bit dynamic range (256 different values) used by most other commercially available satellite sensors.

Table 1 – IKONOS bands, their spectral ranges, descriptions, and spatial resolutions.

Band	Wavelength (microns)	Spectral Description	Spatial Resolution (meters)
MS1	0.445 -0.506	Visible Blue	4
MS2	0.506-0.595	Visible Green	4
MS3	0.632-0.698	Visible Red	4
MS4	0.757-0.853	Near-infrared	4
PAN	0.45-0.9	Visible, Near-Infrared	1

Geometric Correction

Both the MS and PAN data were part of the IKONOS Geo product line, their least accurate geometrically corrected imagery. Although the Geo product is advertised as having a +/- 50 m accuracy with less accuracy in areas of high topographic relief, we found both of these images to be very accurate, within a pixel or two in most places. This probably occurred because the study area was flat, and the images were acquired at near-nadir, which reduced the effects of parallax and angular distortion. The PAN image was rectified to a USGS DOQ (Digital Ortho-photo Quad) with one-meter spatial resolution and projected into UTM, Zone 13, using the 1983 North American Datum and the 1980 Geodetic Reference Spheroid. The MS image was then rectified to the PAN image and re-sampled to a one-meter spatial resolution, using a bilinear interpolation. These images were then combined into a five-band image file.

Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) enhances vigorous vegetation over other major surface features and soil responses. The NDVI also allows quick assessment of class signatures. For example, riparian areas should have a higher NDVI response than senescent grasslands. We created the NDVI using equation 1 and added it to the image file.

$$NDVI = (MS4 - MS3) / (MS4 + MS3) \quad (eq.\ 1),$$

where **MS4** is the near infrared band and **MS3** is the visible red band.

Texture Filters

To make use of the contextual information found in the high spatial resolution PAN image, we applied a second order algorithm, a variance filter, using equation 2:

$$V = \sum(DN - \mu)^2 / 9 \quad (eq.\ 2),$$

where **V** is the resulting variance, **DN** is the image value, and **μ** is the average value for the 3 x 3 filter kernel. There were several reasons for filtering these images. We expected that different vegetation types would have different spatial patterns; for example, a fourwing saltbush shrubland image might have a lot of spatial variation due to the shrub, grass, and barren components of this landscape, whereas a pickleweed shrubland, which is nearly barren, may have only have a small variation in response. We also applied a third-order version of the above filter, a 3x3 skewness filter, to the PAN image. Skewness measures how much the data within the window are skewed to the high or low values. Both of these filtered images were combined into the image file with the MS, PAN, and NDVI data.

Ground Survey Data

We used ground vegetation survey data to develop the map. In August 2000 we collected data from geo-referenced vegetation plots. We attempted to cover as much of the study area as possible. Figure 2 shows the area sampled in the field (black polygon). Sampling was directed toward large polygons of uniform spectral characteristics distributed throughout the study area. To complement the ground data, we established additional "photoplots" in more remote areas by photo interpretation of the satellite imagery. We collected 85 points using both methods.

Image Classification

Supervised Strategy and Seeding

The image classification procedure synthesizes satellite image data with field plot data and ancillary data derived principally from Geographic Information System (GIS) coverages. We adopted a supervised classification strategy to create the vegetation map, based on vegetation community types of HAFB. This strategy develops spectral classes based on precise ground locations with known characteristics such as vegetation composition, substrate type, and landscape context.

In a supervised classification strategy, the field data are applied to the image data through an interactive process called "seeding." In the seeding process, a pixel at the field plot location was selected in the imagery, and its spectral characteristics were used to gather other similar contiguous pixels to create a statistical model or "seed" of the field plot. The seeding algorithm searches around that point within user-defined parameters containing a seed within: 1) a certain distance, 2) a certain area, and 3) a certain spectral distance, defined in equation 3 as:

$$SD = \sqrt{\sum(\mu - X)^2} \text{ (\textit{eq. 3})},$$

where **SD** is the spectral distance between a new pixel and the mean of the current seed group pixels across all bands, **μ** is the mean of the seed pixel group for each image band, and **X** is the spectral value of the new pixel for each band.

In an iterative process, we constructed the best seed models by adjusting the parameters and comparing the seeds against field notes and the original imagery. A seed was developed for each field plot using the plot GPS location and associated field information. The maximum area of the seed was initially defined by the size of the vegetation community occurrence, as determined in the field. The actual seed was then defined by increasing the spectral distance iteratively until the spectral signature collected within the seed generated a covariance matrix which could be inverted, a requirement for the maximum likelihood decision rule used later in the actual classification.

We checked the seed shape and location against field notes and maps and by direct interpretation of the seed in the image on the screen. Each seed was saved in a signature file with its field plot number, mean values for each image band, variance, number of pixels that were used to create the seed, and minimum and maximum values.

Supervised Classification

We performed a supervised classification based on a maximum likelihood decision rule and using the statistics gathered in the seeding process. The maximum likelihood decision rule also contains a Bayesian classifier that uses probabilities to weight the classification toward particular classes. In this study, the probabilities were unknown, so the maximum likelihood equation for each of the classes is given as:

$$D = [0.5\ln(\text{cov}_c)]-[0.5(X-M_c)^T * (\text{cov}_c^{-1})*(X-M_c)] \text{ (\textit{eq. 4})},$$

where **D** is the weighted distance, $\mathbf{cov_c}$ is the covariance matrix for a particular class, **X** is the measurement vector of the pixel, $\mathbf{M_c}$ is the mean vector of the class and $^\mathbf{T}$ is the matrix transpose function (ERDAS,1994). Each pixel is then assigned to the class with the lowest weighted distance. This technique assumes the statistical signatures have a normal distribution.

This decision rule is considered the most accurate, because it not only uses a spectral distance (as the minimum distance decision rule), but it also takes into account the variance of each of the signatures. The variance is important when comparing a pixel to a signature representing, for example, a shrubland community which might be fairly heterogeneous, to a water class, which is more homogeneous.

To locate problems, we performed informal accuracy checking, based on independent field data, personal knowledge of a site, and other ancillary data. If a distribution problem with a seed was detected, the seed was rechecked to insure it was properly modeling the vegetation type and landscape.

Map Unit Development

We created a preliminary map with as many map classes as seeds used to develop it. We then aggregated the seed map classes into a limited number of Mapping Units (MUs) for the final map. These were based on floristic composition, landscape position, spatial contiguity, and spectral similarity; e.g., floristically similar seed classes which had similar landscape positions and were spatially near each other were grouped into the same mapping unit. This iterative process based on informal accuracy checking was continued until all the seed classes were grouped into the most consistent and accurate mapping units. The final map is available both in hard copy and in a digital format suitable for integration into the installation GIS.

Results

We defined sixteen map units (Table 2). The dominant vegetation communities were the shrublands, which covered approximately 198 ha (489 acres) or 52% of the study area. The six map units where shrubs dominated were usually found in more erosive conditions or near the wetlands. The fourwing saltbush (*Atriplex canescens*) and pickleweed (*Allenrolfea occidentalis*) dominated classes are similar to the classes of the same name found on the base vegetation map (Muldavin et al. 1997). Fourwing saltbush was found with understory cover ranging from very sparse to highly herbaceous, and pickleweed generally was found in very sparse playa-type conditions. The high spatial resolution of the satellite imagery used to generate this map allowed further differentiation of plant communities. For example, we separated the larger barren areas between Pickleweed Shrubland and Fourwing Saltbush/Sparse Shrubland into a barren class, instead of lumping them into the shrublands. Similarly, transition areas within both the pickleweed and fourwing saltbush communities were separated into their own map unit (Pickleweed

Shrubland/Fourwing Saltbush, MU #8). The detailed imagery was also able to tease out four different saltcedar (*Tamarix ramosissima*) classes from the original saltcedar woodland class found on the Muldavin et al. (1997) base map. Two of these classes were more representative of the upland communities and therefore assigned to shrubland types (MUs #5 and #6); both classes had a significant alkali sacaton grass understory. The Emergent Saltcedar Shrubland (MU #6) map unit represents areas where saltcedar has recently invaded. These areas are important for future management considerations.

There were three predominantly grassland units, which covered only about 48 ha (119 acres) or 12% of the study area. The Alkali Sacaton (*Sporobolus airoides*) Grasslands (MU #11) were found outside of the main wetlands area and in the most stabilized areas. The Gyp Dropseed (*Sporobolus nealleyi*) Grasslands (MU #12) were found in more sparse conditions where the gypsic crust was more dominant. The third grassland, Alakali Sacaton/Pickleweed Grassland (MU #13) was a class not found on the previous base map and represents a transition between these grassland and shrubland types.

The wetland classes represent vegetation growing in standing water for much or all of the time. These classes covered about 45 ha (111 acres) or 11% of the study area. Two of the classes, the Inland Saltgrass (*Distichlis spicata*) and Inland Saltgrass-Prairie Bulrush (*Schoenoplectus maritimus*) Grasslands (MUs # 1 and # 2, respectively), represent further divisions of the wetland class found on the previous base vegetation map (Muldavin et al. 1997). In addition to these wetland classes, we considered two saltcedar classes to also be representative of wetland conditions: the Saltcedar/Inland Saltgrass Shrubland and the Saltcedar (Dead) Shrubland (MUs # 4 and # 3, respectively). The latter was a significant stand of dead or dying saltcedar important from a management perspective.

Three other classes representing areas of little or no vegetation covered approximately 95 ha (235 acres) or 25% of the study area. Two of the classes represent barren or playa areas and manmade disturbance (MUs #14 and #15, respectively). The other class represents surface water at the time the image was acquired, primarily in Lagoon G (MU # 16).

The intended scale for use of the map is 1:12,000. No map validation was done as part of this project, but we believe that the map units accurately reflect the vegetation composition of the area at the time of image acquisition. The map unit descriptions were chosen not only to describe the vegetation composition, but also to be useful for ongoing constructed wetland management, research, and monitoring.

Table 2 – Description of vegetation map units.

Vegetation Class	MU #	Vegetation Community	Brief Description
Wetland	1	Inland Saltgrass Grassland *Distichlis spicata*	Monotypic grassland with inclusions of saltcedar/inland saltgrass and scattered pickleweed shrubland.
	2	Inland Saltgrass-Prairie Bulrush Grassland *Distichlis spicata-Schoenoplectus maritimus*	This community can have monotypic stands of either saltgrass or bulrush.
	3	Saltcedar Shrubland (Dead) *Tamarix ramosissima*	This community appears to be dying, probably due to management actions.
	4	Saltcedar/Inland Saltgrass Shrubland *Tamarix ramosissima/Distichlis spicata*	Stands of saltcedar with an understory of saltgrass.
Shrubland	5	Saltcedar/Alkali Sacaton Shrubland *Tamarix ramosissima/Sporobolus airoides*	Stands of saltcedar with an understory of alkali sacaton grasses.
	6	Emergent Saltcedar Shrubland *Tamarix ramosissima*	Seedlings and young shrubs are emergent throughout, but found predominantly associated with either alkali sacaton or inland saltgrass.
	7	Pickleweed Shrubland *Allenrolfea occidentalis*	Nearly barren playas to dense shrublands.
	8	Pickleweed Shrubland/ Fourwing Saltbush *Allenrolfea occidentalis/ Atriplex canescens*	Sparse to densely vegetated shrubland of fourwing saltbush and pickleweed that are often co-dominants.
	9	Fourwing Saltbush/Alkali Sacaton Shrubland *Atriplex canescens/Sporobolus airoides*	Dominated by open canopied shrubland of fourwing saltbush with an alkali sacaton understory.
	10	Fourwing Saltbush/Sparse Shrubland *Atriplex canescens*	Very open shrubland to barren playa with occasional scattered forbs.

Vegetation Class	MU #	Vegetation Community	Brief Description
Grasslands	11	Alkali Sacaton Grassland *Sporobolus airoides*	Moderately dense grasslands dominated by alkali sacaton with small inclusions of gyp dropseed.
	12	Gyp Dropseed Grassland *Sporobolus nealleyi*	Sparse grassland with inclusions of alkali sacaton grasses.
	13	Alkali Sacaton/Pickleweed Grassland *Sporobolus airoides/Allenrolfea occidentalis*	Sparse grassland with pickleweed shrubs, often a co-dominant.
Other	14	Barren/Alkali Playa	Barren areas are higher in the landscape relative to the playas.
	15	Development/Ground Disturbance	Includes roads and berms within the constructed wetlands.
	16	Water	Individual water bodies such as Lagoon G and drainages. Also includes temporarily flooded playas within the CW at the time the imagery was taken.

Part II: Breeding Bird and Invertebrate Distributions

Our previous studies at the LHWCA (Freehling et al. 1999) documented the extent of shorebird use of wetland habitats and the diversity and high abundance of invertebrates associated with these habitats. Shorebird utilization and invertebrate abundance during early stages of development of the CW were included in these studies. This section summarizes additional studies of the CW during 1999-2000 and presents recommendations applicable to management of habitat for shorebirds and aquatic invertebrates.

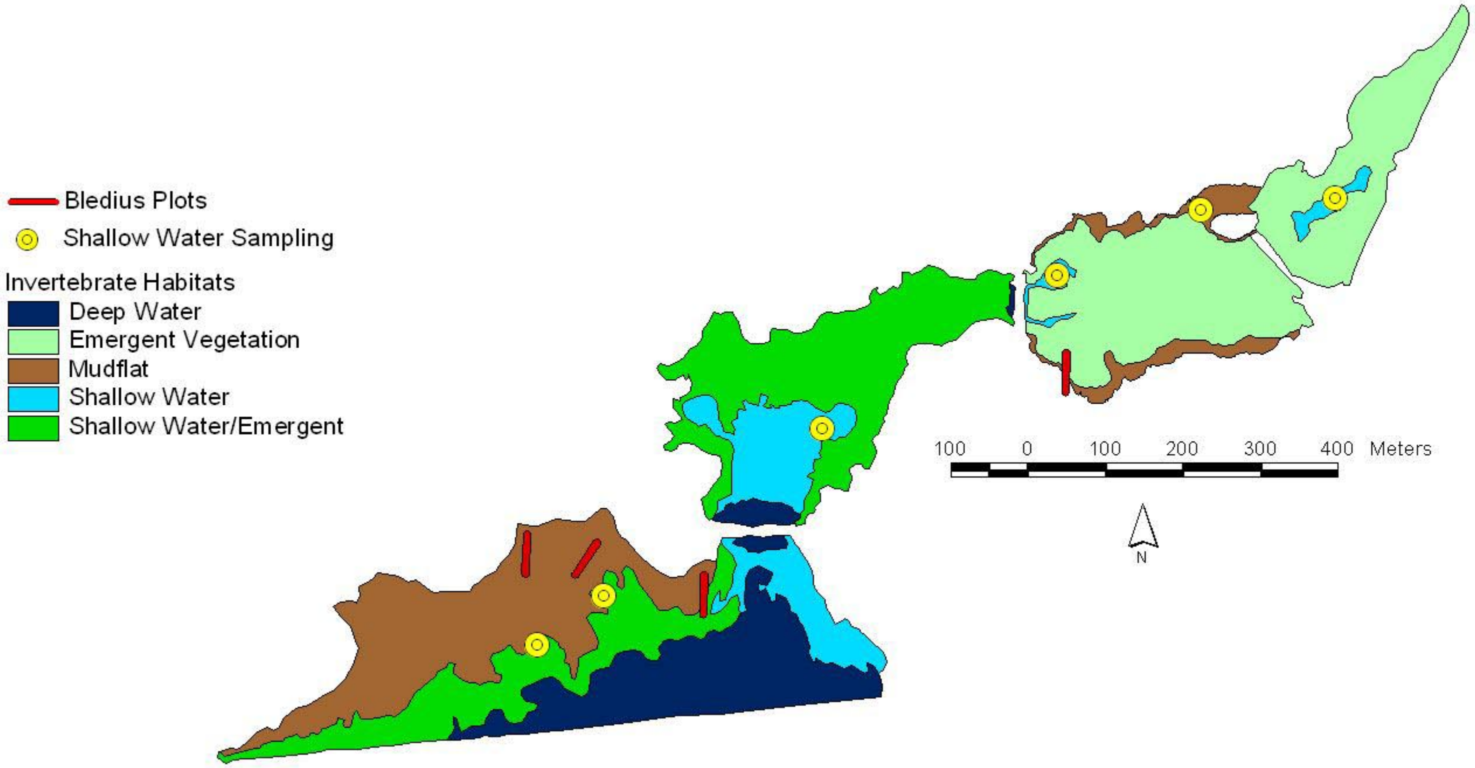
Methods

We conducted field work September 28-October 3, 1999 and May 17-23, 2000. Invertebrate sampling was done at both times. In May 2000, we monitored habitats for breeding or potentially-breeding shorebird species. A preliminary ground survey with field notes for the vegetation map of the CW was done in May 2000.

Aquatic sampling was limited to Pond 1 in May 2000 because of the lack of water in the other ponds. We used methods employed previously in similar habitats at HAFB (Freehling et al. 1999). An aquatic D-net with 0.15 mm mesh bottom was used to collect bottom-dwelling (benthic) organisms. A D-net sample consists of three one-meter sweeps from the interior to the margin of the pool, pulling the net along the bottom toward the shore. Each sweep was parallel to and outside the zone of disturbance created by the previous sweep. Aquatic light traps (BioQuip Products) were used to attract and capture invertebrates inhabiting the water surface and water column. We placed a trap at a sampling site in late afternoon. After approximately 18 h we retrieved the trap, collecting the invertebrates by pouring and rinsing the trap contents through a 0.15 mm net. D-net and light-trap sampling sites are identified as "shallow water sampling" in Figure 3. Field-collected samples were preserved in 80% ethyl alcohol and transported to the laboratory for sorting and identification.

In March 1998, we established permanent plots (5 x 50 m) to monitor the abundance of soil-dwelling beetles, *Bledius mandibularis*, in the mudflat areas of Ponds 2 and 4 (see Figure 3 for plot locations). The purpose was to initiate a methodology to assess mudflat habitat quality based on *Bledius* colonization and activity over time as the wetland developed. We continued to census these plots in 1999 and 2000. At each census all burrow openings within the plot were counted. We did not differentiate active from inactive burrows. Since the interval between censuses was much longer than the time that would be necessary to track small-scale fluctuations in burrow turnover, whether or not burrows were active or inactive was not important for the time scale at which we were monitoring. Based on our previous field observations, we assumed burrow counts to be indicative of conditions within two weeks before a census. A soil core was taken within the plot for a visual assessment of the algal layer below the surface crust, and soil moisture conditions were noted. Beetles, if present, were collected from burrows for identification.

Figure 3. Invertebrate habitat map of the constructed wetlands.



Results

Shorebirds

In May 2000, areas previously identified as potential shorebird breeding habitat were monitored for breeding behavior or nesting. Breeding evidence was seen for two species, Snowy Plover (*Charadrius alexandrinus*) and Black-necked Stilt (*Himantopus mexicanus*).

Snowy Plover

(1) Stinky Playa (north of Hwy 70): Nine adults and 3 chicks were seen on May 18. From May 19-23, two adults and 3 chicks were seen daily on the playa, sometimes foraging at the "seeps" below the dam

(2) Constructed Wetland: At Pond 4, two adults were consistently seen in the same area over a 2-hour period daily from May 20-22. Their behavior suggested that a nest site may have been nearby, but we did not find one.

(3) Lake Holloman (north end): Three adults and 2 juveniles were observed foraging in the mudflat on May 17. They were not seen after this date.

Black-necked Stilt

On May 22, an adult was observed on a nest containing 4 eggs. The nest was located on exposed shoreline at the southwest corner of Lake Holloman, between the west end of the dam and the overflow outlet to Stinky Playa.

Invertebrates

The taxa collected at the Constructed Wetland in 1999/2000 are summarized in Table 3, along with a comparison to collections from similar habitats in 1998 (Freehling et al. 1999). For each taxonomic group, qualitative estimates of abundance are indicated as *present* (<10 individuals collected in all samples or individuals occurred at one sample site), *low* (relative abundance < 20% of the total individuals collected for that taxon), *medium* (relative abundances of 20% – 50%), or *high* (relative abundances > 50%).

As in 1998, the taxa occurring in highest abundance in shallow-water and emergent habitats were corixids (water boatmen), hydrophilid beetles (*Berosus* spp.), and chironomid larvae. In 1999/2000 we collected seven aquatic groups not reported previously: damselfly larvae, adult hydraenid and noterid beetles, adult and larval *Tropisternus* (water scavenger beetles), biting midge (Ceratopogonidae) larvae, crane flies (Tipulidae), and water mites (Table 3).

Table 3 – Relative abundance of macroinvertebrates at the Holloman AFB Constructed Wetland, Sep/Oct 1999 and May 2000. --, absent; #, present; +, low; ++, medium; +++, high (see text for definitions). Occurrence in 1998 from Freehling et al. (1999).

Holloman AFB Constructed Wetland

CLASS Order Family	Genus	adults, nymphs, larvae	Pond 1		Pond 2	Pond 3	Pond 4	Occurrence in 1998 samples
			1999	2000	1999	1999	1999	
CRUSTACEA								
Cladocera (water fleas)			+	--	+	+	+	+
Copepoda (copepods)			+	--	+	+	+	+
Ostracoda (seed shrimps)			++	+++	--	+	--	++
INSECTA								
Odonata								
Libellulidae (common skimmers)		l	+	--	++	+	++	+
Zygoptera: undetermined family (damselflies)		l	++	+	+	++	++	--
Hemiptera								
Belostomatidae (giant water bugs)		a	#	--	--	--	--	+
Corixidae (water boatmen)	*Trichocorixa*	a	++	++	+	+	++	+++ (as *Corisella)*
Coleoptera								
Dytiscidae	sp. 1	a	+	+++	--	--	+	+ (as Dytiscidae)
(predaceous diving beetles)	sp. 2	a	--	+++	--	+	+	
	Hydrobius	l	--	--	--	#	--	
Hydraenidae (minute moss beetles)	*Ochthebius*	a	--	#	--	--	--	--
Hydrophilidae	*Berosus*	a,l	+	+	+	+++	+	+++
(water scavenger beetles)	*Tropisternus*	a,l	--	#	#	#	--	--
Noteridae (burrowing water beetles)	*Pronoterus* ?	a	--	--	--	--	#	--
Staphylinidae (rove beetles)	*Bledius*	a	--	--	[see Figure 1]			+
Diptera								
Ceratopogonidae (biting midges)	*Culicoides*	l	+	--	+++	--	--	-- (core samples)
Chironomidae (midges)	*Dicrotendipes*	l	+	+++	+	+	+	+++
Culicidae (mosquitoes)		l	--	--	#	--	--	++
Ephydridae (shore flies)		l	--	--	#	--	--	++
Tipulidae (crane flies)		a	#	--	--	--	--	--
ARACHNIDA								
Hydrachnida (water mites)								
Arrenuridae		a	+	+	+	++	++	--

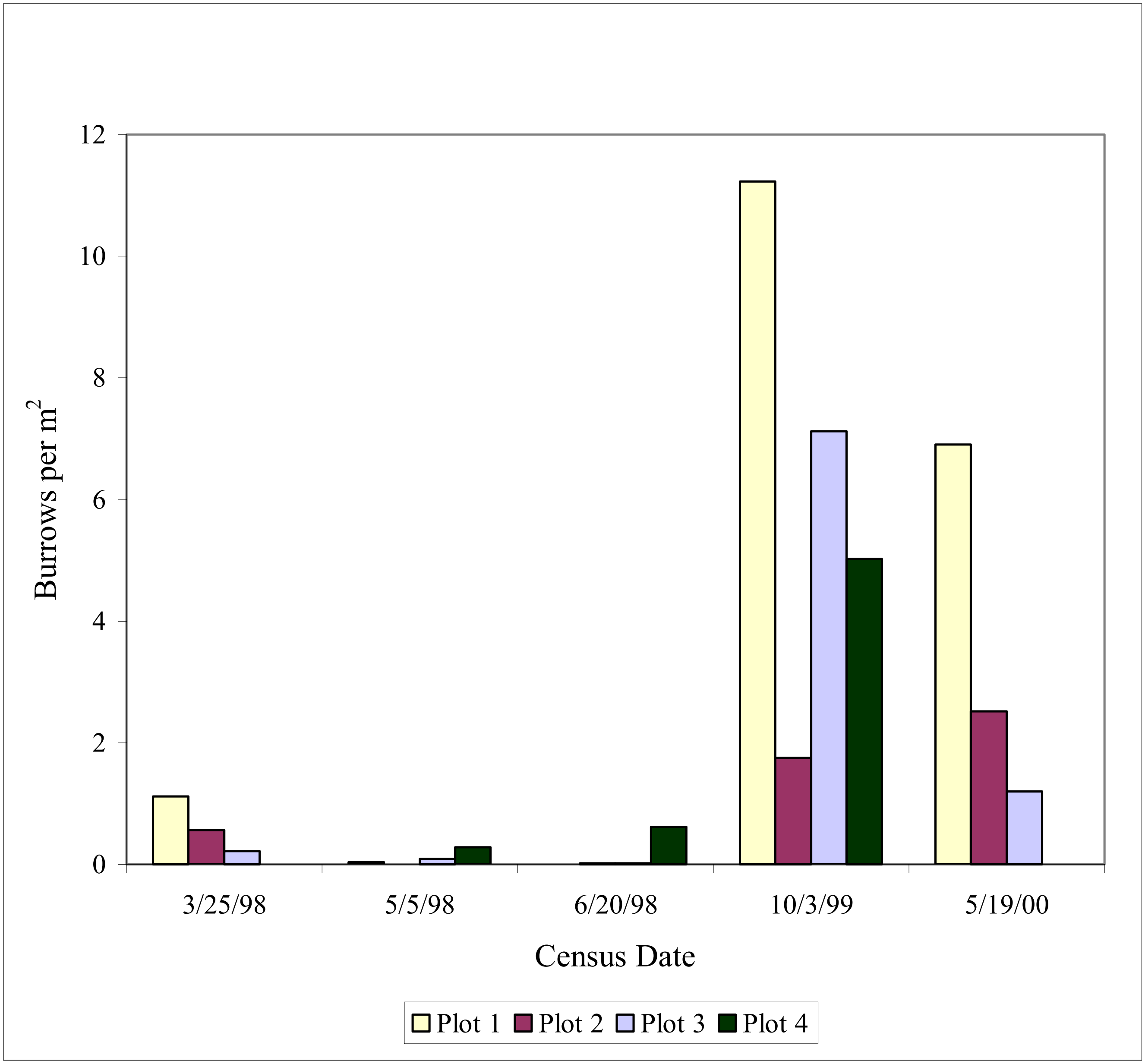
Two taxa reported in 1998 from shallow-water or emergent habitats were not found in 1999/2000 samples: larvae of syrphid flies (*Eristalis* sp.) and adult haliplid beetles (*Haliplus* sp.). Both are distinctive in appearance and are not likely to be misidentified or overlooked. *Eristalis* larvae often occur in waters with high organic content. Their absence may be related to changes in water quality due to the improvement of effluent entering the CW. There is no obvious explanation for the lack of haliplids. They are active year round and are associated with emergent vegetation.

Except for *Bledius* beetles, we did not sample for the suite of terrestrial insects collected in saltflat and mudflat habitats elsewhere at the Holloman wetland complex (Freehling et al. 1999). These groups include ants (Formicidae), ground beetles (Carabidae), tiger beetles (Cicindelidae), weevils (Curculionidae), and anthicid beetles. They were collected by pitfall trapping, a method not used in 1999/2000 sampling.

In March 1998, presence of *Bledius* burrows at low densities (Figure 4) suggested that beetles had colonized the area by aerial dispersal from adjacent habitats and that soil moisture conditions were suitable for burrow construction. The decrease and virtual loss of *Bledius* habitat in Plots 1, 2, and 3 by June 1998 is likely correlated with the drawdown of Pond 4 during this period. Regardless of the causes for the decline, conditions were not conducive to successful establishment and maintenance of habitat. Nevertheless, a dramatic increase in abundance occurred by October 1999, and burrow densities, although diminished, persisted at intermediate levels through May 2000 (Figure 4). Plot 4, at the southern margin Pond 2, was dry at the May 2000 census and showed no burrow activity. A visible layer of soil algae was not present in 1998 at any plot. By May 2000, an algal band 0.5 to 1.0 mm in thickness had developed just below the soil surface.

We attribute the observed increase in *Bledius* abundance to the development of soil algae, necessary as food for both adults and larvae. The persistence of *Bledius* populations and the presence of soil algae are indications that organic material, both detrital and algal, is developing within the upper soil layer of the CW, which was disturbed during construction and associated earth-moving activities. Other aquatic and semiaquatic invertebrates will respond positively to an increase in soil organic matter, with an eventual increase in biotic diversity and wetland function.

Figure 4. Densities of *Bledius mandibularis* burrows at the Constructed Wetland, Holloman AFB. Plot 4 established 5/5/98.



Conclusions

Development of the Constructed Wetlands

Plants

The current map is the first detailed map of the LHWCA. The Muldavin et al. (1997) vegetation map of the entire base relied on a limited number of samples in the LHWCA and does not accurately depict finer-scale variation in the CW vegetation. Thus, there are few baseline data on which to base an evaluation of vegetation changes since the CW was constructed. Based on Muldavin et al. (1997), Freehling et al. (1999), and personal observations by M. Freehling, we can provide general descriptions of the CW area before construction, for comparison with this first map.

What is now Pond 1 was previously the wettest part of the future CW. It was dominated by inland saltgrass, alkali bulrush, and scattered alkali sacaton. It is still covered mainly in saltgrass, with some bulrush and emergent saltcedar.

In November, 1997, we conducted a ground survey of the vegetation at the site of Pond 2, before it was inundated by water flowing in from the surface ditch (Freehling et al. 1999). Data from eleven vegetation plots indicate that the community type corresponded to the saltgrass community of Muldavin et al. (1997), although considerable variation occurred among the plots. Other important species represented, in order of abundance, were silky cressa (*Cressa truxillensis*), pickleweed, seepweed (*Suaeda moquinii*), saltcedar , and alkali bulrush. Currently, Pond 2 typically contains some water or moist soil most of the time. The eastern part of the pond is dominated by saltgrass, and the western part is filling in with bulrush, leaving only small areas of open water. This is a target area for bulrush control.

Prior to construction of the CW, the area which is now Pond 3 was dominated by upland vegetation, including pickleweed, four-wing saltbush, alkali sacaton, and gyp dropseed. Now the northeast part contains saltgrass, bulrush, and the emerging saltcedar/saltgrass vegetation class. The southern area is now barren alkali playa, sparsely vegetated with pickleweed and containing areas of good mudflat habitat. The pond contains water periodically, depending on rainfall and management of the experimental ponds.

The Pond 4 area previously contained gyp dropseed and four-wing saltbush in the northwest and saltgrass in the northeast. In the south, a large stand of saltcedar occurred. Now, the north is classified as barren playa and inland saltgrass. The northwest contains pickleweed, barren playa, saltgrass, and emergent saltcedar. The saltcedar in the southwern end of Pond 4 has been flooded and is now dead. Remnants of upland vegetation such as pickleweed and four-wing saltbush persist at higher elevations surrounding Ponds 3 and 4.

In summary, the CW now has more water, more sparsely vegetated areas, and more areas covered by bulrush than before it was filled. Upland vegetation has become more sparse, and the distribution of wetland vegetation has expanded. Living saltcedar has been reduced, but it continues to be an emergent problem throughout the CW.

Invertebrates

For this study, we sampled the CW somewhat differently from previous studies at Lake Holloman, Stinky Playa, and other parts of the LHWCA. We did not set traps for terrestrial invertebrates, which explains why these previously-collected taxa (ants, ground beetles, tiger beetles, weevils, and anthicid beetles; Freehling et al. 1999) are not represented in the current samples. Of the two aquatic taxa that appeared to have dropped out, syrphid larvae may be expected to remain absent, if water quality remains good, but we expect haliplid beetles will appear again in future samples.

As in 1998, the taxa occurring in highest abundance in shallow-water and emergent habitats were corixids (water boatmen), hydrophilid beetles (*Berosus* sp.), and chironomid larvae, which suggests that they provide a consistent, reliable, and abundant invertebrate food base. Seven aquatic groups not reported previously were collected in 1999/2000: damselfly larvae, adult hydraenid and noterid beetles, adult and larval *Tropisternus* (water scavenger beetles), biting midge (Ceratopogonidae) larvae, crane flies (Tipulidae), and water mites (Table 3). These groups are either predators (damselflies, noterid adults, *Tropisternus* larvae, biting midges, water mites) or collector-gatherers (hydraenid adults, *Tropisternus* adults, crane flies). Except for biting midges and water mites, all are dependent on vascular hydrophytes to some extent for climbing, oviposition, or feeding sites. The presence of these "new" taxa is most likely a function of greater prey abundance for predaceous invertebrates and the increase in emergent vegetation, which contributes greater structural complexity and more detrital resources for collector-gatherers. A conspicuous example of the former is the noticeable increase of arrenurid water mites at all collection sites. The larvae are parasitic on dipterans and odonates; adults and deutonymphs prey on ostracods, cladocerans, and dipteran larvae.

Birds

Before 2001, bird studies focused on surveys of stopover migrants ((Freehling et al. 1999, this study). Although limited nest searching was done prior to 2001, most data on wetland bird nesting were collected opportunistically. Thus, it is not possible to know for certain the magnitude of changes in the numbers of nesting waterbirds at the LHWCA. In 1997, we estimated that four or five pairs of Snowy Plovers bred at the LHWCA. Mark Proctor estimated 16 pairs in the same year. In 2001, we monitored 11 Snowy Plover nests in the LHWCA (Smith and Johnson 2002), which suggests that numbers of breeding Snowy Plovers have not increased greatly since the CW was created.

In contrast, numbers of American Avocet (*Recurvirostra americana*) and Black-necked Stilt nests have increased substantially since 1998-1999. We found the first evidence of avocets breeding at the CW in 1998, with two nests (Freehling et al. 1999). In 2001, we monitored 56 avocet nests, 25 at Lake Holloman, 19 in the CW, seven at Stinky Playa, three at the experimental ponds, and two at Lagoon G (Smith and Johnson 2002). In 1999, we found at least 10 nests that could have been made by either avocets or stilts in the CW (Freehling et al. 1999). By 2001 there were 33 stilt nests, 25 in the CW, seven at Lake Holloman, and one at Lagoon G (Smith and Johnson 2002). Killdeer (*Charadrius vociferus*), like Snowy Plovers, have apparently been nesting in the area in small numbers since before the CW construction (Freehling et al 1999), and we found seven nests in 2002 (Smith and Johnson 2002).

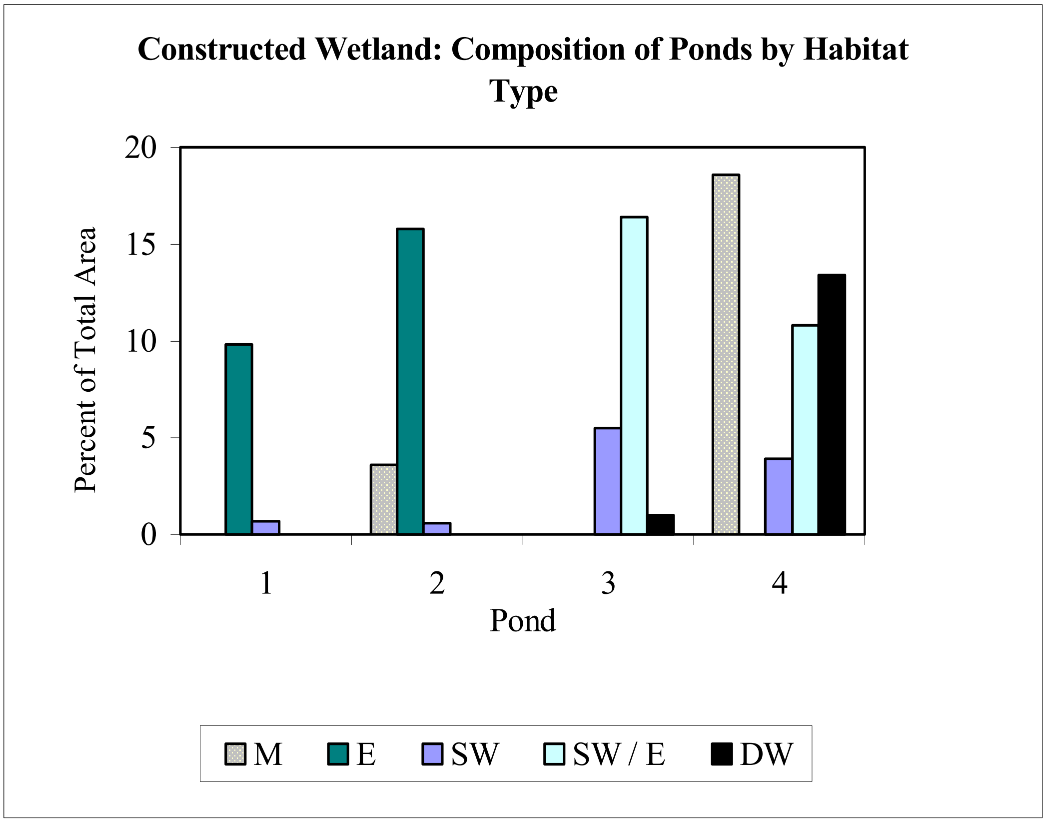
In conclusion, the CW appears to be increasing in invertebrate species richness and nesting bird abundance. As plant and invertebrate communities continue to become more complex, the increasing prey base may support further increases in bird abundance, as well as bird species richness. Continued development of the plant, invertebrate, and bird communities at the CW could be hampered if water, nesting habitat, and foraging habitat are not managed appropriately. In the next section, we suggest a water management scheme designed to manage for invertebrates, wetland birds, and desirable wetland vegetation, while discouraging plant species that are incompatible with the goal of enhancing shorebird bird habitat.

Management Recommendations

Management for <u>shorebird foraging habitat</u> at small wetlands in the midwestern U.S. emphasizes flooding and gradual drawdown (Helmers 1992). However, recommendations specific to shorebird management in southern New Mexico are apparently nonexistent. Recent studies on migrant shorebirds at playa wetlands in the Texas Southern High Plains also emphasize the use of flooding and drawdown (Davis and Smith 1998), and their results may be relevant to wetland management at HAFB. They recommend that management focus on creation and maintenance of sparse vegetative cover (<25% cover), adequate mudflat (at least 10-15%) and shallow water (at least 10-20%). Our analysis of the composition of the CW by habitat types shows that it is possible to maintain mudflat and shallow water habitats at these minimum percentages at the HAFB constructed wetland (Figure 5).

In western North America, availability of suitable <u>nesting habitat</u> is often cited as a potential limiting factor for Snowy Plovers, which are selective in nest site characteristics, usually preferring sparsely vegetated salt flats near hypersaline lakes (Page et al. 1985, 1991). American Avocet, Black-necked Stilt, and Killdeer often nest in similar habitats if available (Helmers 1992). Paton and Bachman (1996) used impoundment drawdown to create sparsely vegetated habitats for shorebirds at Great Salt Lake, Utah. A waterfowl management area on the eastern shore of Great Salt Lake historically was a saltgrass pasture. In 1990 the area was dominated by dry salt flats interspersed with small patches of greasewood (*Sarcobatus vermiculatus*), seepweed (*Suaeda* spp.), pickleweed (*Salicornia rubra*), and other salt-tolerant chenopods. By late 1993, six freshwater impoundments had been developed, with dramatic increases in alkali bulrush (*Scirpus maritimus*) and cattail (*Typha* spp.), resulting in reduction of nesting

Figure 5. Habitat types of the constructed wetland. M, mudflat; E, emergent; SW, shallow water; SW/E, shallow water/emergent; DW, deep water. Total area = 32 ha.



habitat. The objective was to create nesting and foraging habitat by eliminating vegetation and exposing soil substrate by drawdown. Snowy Plovers, American Avocets, and a pair of Long-billed Curlew nested in a 12-ha impoundment after drawdown.

Vegetation encroachment in shorebird habitat is also a major concern at the Holloman CW. Several of Paton and Bachman's (1996) assumptions and recommendations may apply to the Holloman CW: (1) a small (<50 ha), proportional, well drained, drawdown area located adjacent to stable water areas and within a large wetland complex, (2) drawdown area without high waterfowl or colonial waterbird nesting densities or a history of botulism, (3) a chronology beginning March 15 with a slow, evaporative drawdown and ending May 1 with the area completely dewatered and the soil surface dry throughout the summer, followed by a slow continuous refill starting in late August. We documented a natural fill and 6-week drawdown at Pond 4 in 1998 (March 25-May 6) that is similar to Paton and Bachman's chronology. We assessed invertebrate abundance and shorebird foraging within the resulting mudflat habitat and documented its suitability for shorebird foraging at this early stage of wetland development (Freehling et al. 1999).

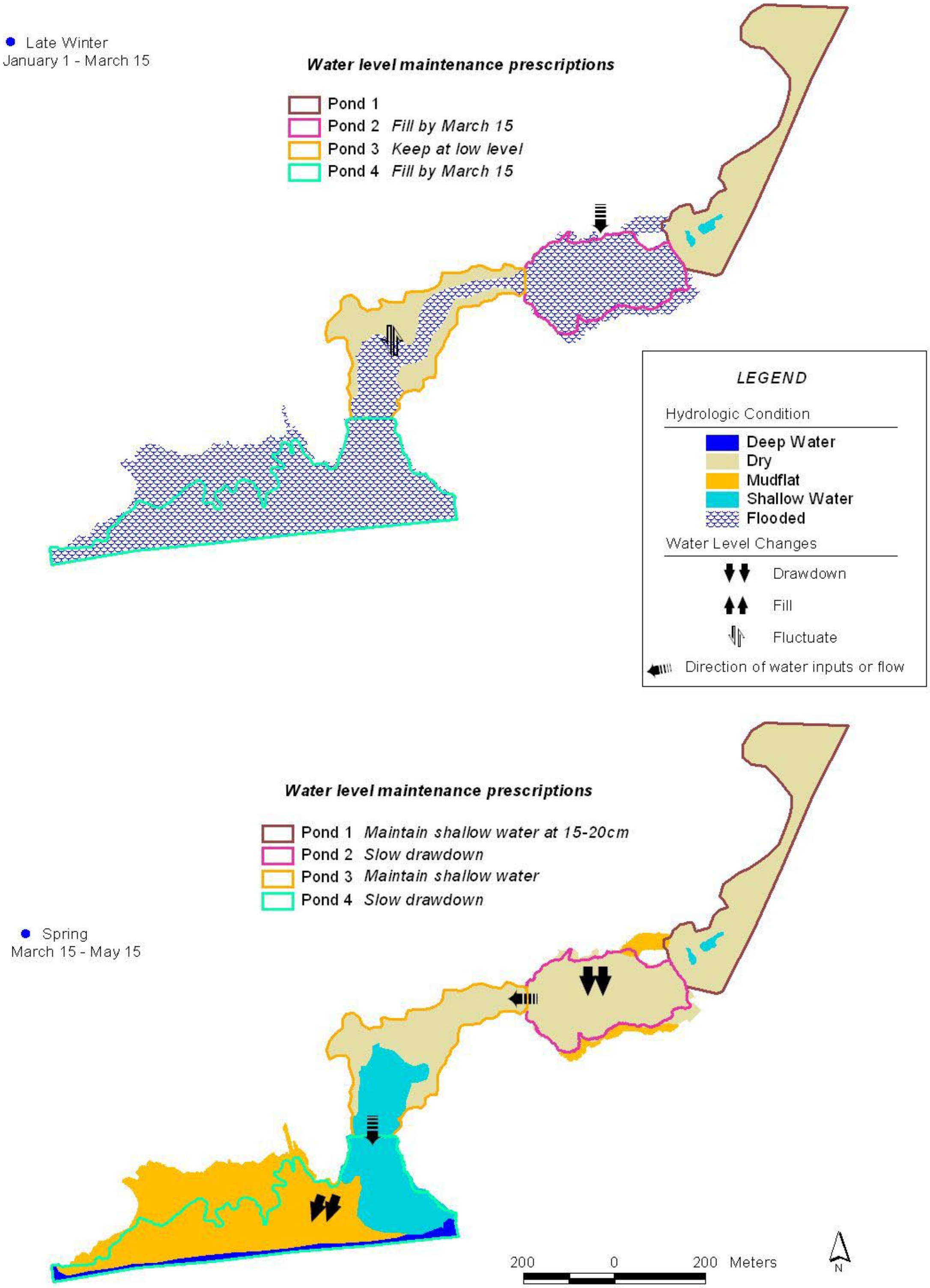
A potential drawdown-and-refill chronology for Pond 2 and Pond 4 would be as follows (see Figure 6 for a schematic summary of water-level management of the entire Constructed Wetland):

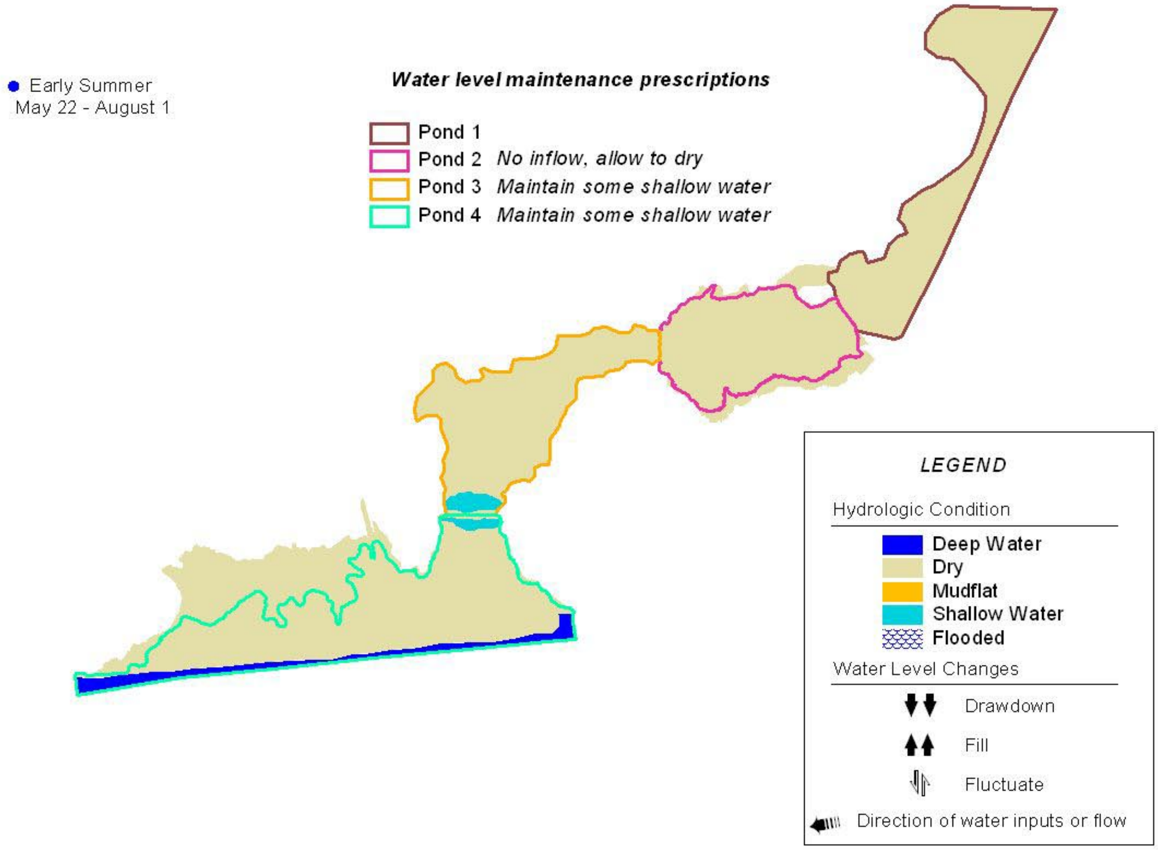
By March 15: Fill both ponds to inundate maximum potential mudflat habitat.
March 15 – May 15: Allow slow drawdown, exposing as much soil surface area as possible. This 8-week period would provide both nesting area on dry sites and moist substrate for foraging as the drawdown continues. An advantage would be the creation of invertebrate habitat for *Bledius* beetles, chironomid larvae, and other taxa important for shorebird foraging. A disadvantage would be the promotion of *Tamarix* seedling establishment in moist soil.
Late May through July: Maintain dry surface conditions, which are normal this time of year because of high temperatures and lack of precipitation. This period could be used for bulrush control. Disking and burning are effective control techniques, especially in conjunction with flooding after treatment. Flooding over cut or burned stems disrupts oxygen transport to the roots; without flooding, emergents will rapidly regenerate from the roots (Smith and Kadlec 1985). See Freehling et al. (1999) and references cited therein for detailed discussion of saltcedar and bulrush management techniques.
August 1: Begin a slow, continuous refill to provide foraging habitat for fall migrants. The length of time and the amount of area to be re-flooded would depend on other management goals. An advantage here is that a prolonged fall inundation could be used to suppress or kill saltcedar seedlings that have become established after spring drawdown. Also, flooding could be incorporated into a bulrush control program.

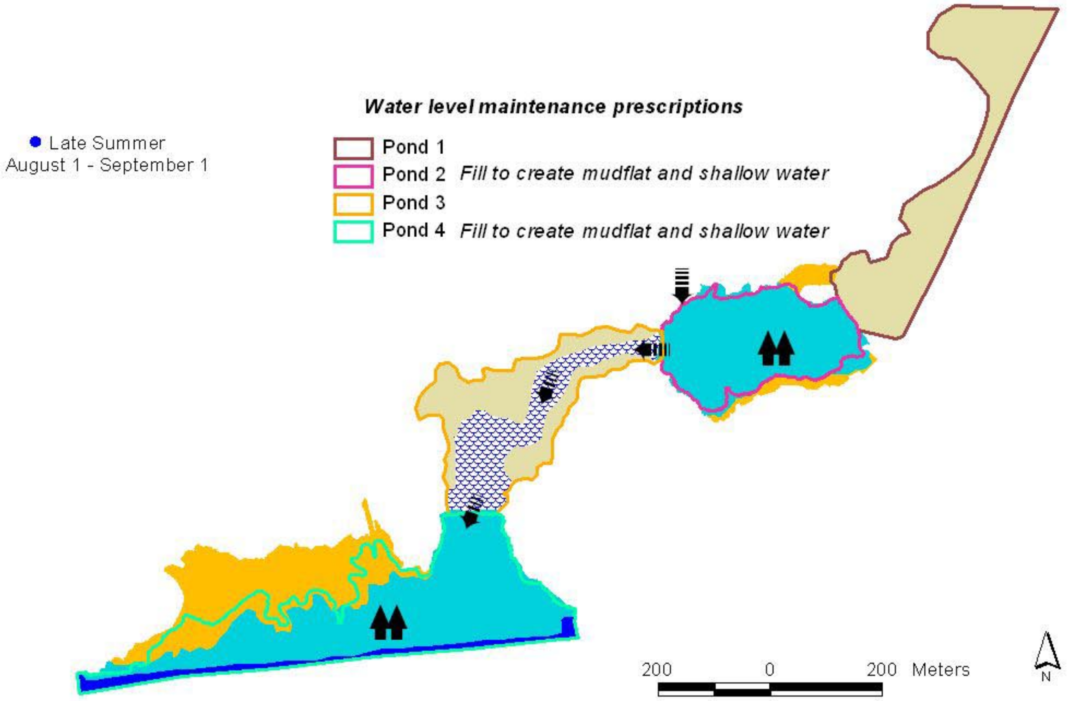
We incorporate the results of a shorebird breeding and nesting study conducted by NMNHP in spring and summer of 2001 (Smith and Johnson 2002) into the proposed management of the ponds. Black-necked Stilts had a peak nesting period of May 19-31, with most nests in the emergent vegetation of Ponds 1, 2, and 3. The spring and early summer schedules for Ponds 1 to 3 would be compatible with these requirements. American Avocets nested later than the stilts, with some nests active through the third week of July. Most were found in upland habitat adjacent to the ponds and would not be directly affected by the proposed water level manipulations. Snowy Plovers did not nest in the Constructed Wetland (except for one abandoned nest) and preferred the more exposed saline areas on the western shore of Lake Holloman and at Lagoon G. Information from the Spring 2002 breeding survey may provide a better assessment of the suitability of the CW for Snowy Plover nesting habitat. However, water-level manipulations to enhance shorebird foraging habitat in the CW would benefit Snowy Plovers, whether they nested there or in contiguous areas.

The feasibility and consequences of an annual fill-drawdown-refill cycle are not known. A potential strategy might be to use the previous chronology at one pond, followed by a year without filling, to use the dry conditions for vegetation control. Alternating the cycle between Ponds 2 and 4 would allow one site to be dry while the other was available for shorebirds. If waterfowl management becomes a requirement, an interval of 3-5 years between drawdowns in a specific area would be needed to maintain productivity of emergent vegetation. Use of the experimental ponds above Pond 2 for pupfish research will be an overriding factor in the management of Ponds 2, 3, and 4 (H. Reiser, pers. comm., Sep. 2001).

Figure 6. Suggested management strategies for the constructed wetlands.



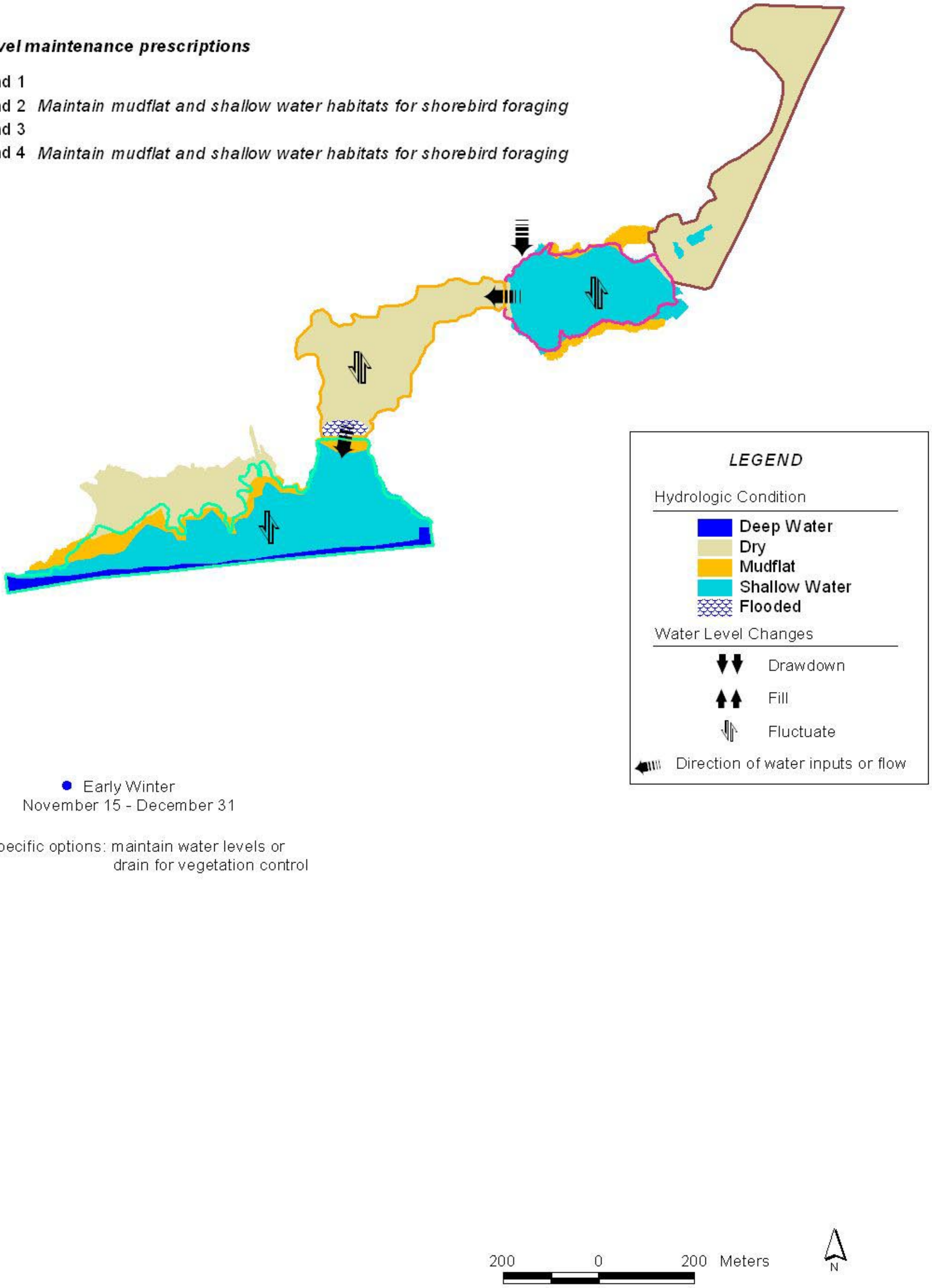

● Early Summer
May 22 - August 1
Water level maintenance prescriptions
Pond 1
Pond 2 No inflow, allow to dry
Pond 3 Maintain some shallow water
Pond 4 Maintain some shallow water
LEGEND
Hydrologic Condition
Deep Water
Dry
Mudflat
Shallow Water
Flooded
Water Level Changes
Drawdown
Fill
Fluctuate
Direction of water inputs or flow


● Late Summer
August 1 - September 1
Water level maintenance prescriptions
Pond 1
Pond 2 Fill to create mudflat and shallow water
Pond 3
Pond 4 Fill to create mudflat and shallow water
200
0
200 Meters
N

● Fall
September 1 - November 15

Water level maintenance prescriptions

- **Pond 1**
- **Pond 2** *Maintain mudflat and shallow water habitats for shorebird foraging*
- **Pond 3**
- **Pond 4** *Maintain mudflat and shallow water habitats for shorebird foraging*



● Early Winter
November 15 - December 31

Pond specific options: maintain water levels or
drain for vegetation control

Literature Cited

Davis, C. A. and L. M. Smith. 1998. Ecology and management of migrant shorebirds in the playa lakes region of Texas. Wildlife Monographs 140: 1-45.

ERDAS Imagine. 1994. Earth Resources Digital Analysis System. A registered trademark of ERDAS, Inc. Atlanta, Georgia. Software version 8.5.

Freehling, M., K. Johnson, and L. DeLay. 1999. Shorebird foraging and invertebrate occurrence at the Holloman Wetlands, Holloman Air Force Base, 1996-1998. New Mexico Natural Heritage Program.

Helmers, D. L. 1992. Shorebird management manual. Western Hemisphere Shorebird Reserve Network, Manomet, MA.

Muldavin, E., G. Harper, P.Neville, T. Bennett, and K. Johnson, 1997. A vegetation map for Holloman Air Force Base, New Mexico – Final Report. New Mexico Natural Heritage Program Technical Report.

Neher, R.E. and O.F. Bailey, 1976. Soil survey of White Sands Missile Range, New Mexico, Parts of Dona Ana, Lincoln, Otero, Sierra, and Socorro Counties, USDA Soil Conservation Service in cooperation with U.S. Department of the Army, White Sands Missile Range, and the New Mexico Agricultural Experiment Station.

Page, G. W., L. E. Stenzel, and C. A. Ribic. 1985. Nest site selection and clutch predation in the Snowy Plover. Auk 102: 347-353.

Page, G. W., L. E. Stenzel, W. D. Shuford, and C. R. Bruce. 1991. Distribution and abundance of the Snowy Plover on its western North American breeding grounds. Journal of Field Ornithology 62: 245-255.

Paton, P. W. C. and V. C. Bachman. 1996. Impoundment drawdown and artificial nest structures as management strategies for Snowy Plovers. International Wader Studies 9: 64-70.

Smith, J. and K. Johnson. 2001. Monitoring shorebird habitat and breeding at Holloman AFB Constructed Wetlands, Holloman Air Force Base, 2001. Draft year-end report. New Mexico Natural Heritage Program.

Smith, L. M. and J. A. Kadlec. 1985. Comparisons of prescribed burning and cutting of Utah marsh plants. Great Basin Naturalist 45: 462-466.