ECOSYSTEM RESTORATION AND MANAGEMENT OPTIONS

A SUMMARY OF CONDITIONS

Information obtained and analyzed during this study were sufficient to conduct a HGM-based evaluation of historic and current ecological conditions on Benton Lake NWR and the surrounding region. The dominant feature of Benton Lake NWR is the historic Benton Lake bed formed during Pleistocene glacial and post-glacial events. The historic extent of the Benton Lake bed (Fig. 10) is intact, however, the physical integrity of the historic Benton Lake bed is highly altered from infrastructure developments for water management to enhance waterfowl production. These infrastructure developments and water management in Benton Lake since the early 1960s have dramatically changed historic seasonal and long-term water regimes and the associated distribution and extent of native plant communities. These changes in the primary ecological driver of the Benton Lake ecosystem (i.e. seasonally and annually dynamic water regimes within a closed basin) and structural elements of it (topography and plants) have impacted resources used by many animal species. Further, conversion of native grassland to agricultural crop-fallow rotation in much of the immediate watershed of the Benton Lake Basin has degraded quality of regional surface and groundwater and increased the number and severity of saline seeps that periodically flow into Benton Lake. Changes in local ground and surface water quality and runoff to Benton Lake are exacerbated by pumping irrigation return water (large amounts in some dry years) from Muddy Creek, into the Lake Creek channel and ultimately into Benton Lake. These regional land use changes and pumping schedules have caused increased salt and selenium deposition in some parts of Benton Lake.

The information obtained and analyzed in the first two sections of this report are critical precursors to the next step of this HGM evaluation for Benton Lake NWR, which is to "Identify Potential Approaches to Successfully Manage and Restore Specific Habitats and Conditions." The obvious challenge for this evaluation is to understand what management actions will be possible and most efficient/effective in restoring basic ecological attributes and processes to this unique ecosystem in a sustainable manner.

The key summary data and observations obtained in this study are:

1. The Benton Lake Basin, including the Benton Lake bed depression, were formed during the last Pleistocene glacial period when ice sheets dammed the ancestral Missouri River and formed glacial Lake Great Falls, which covered low-lying parts of this region.

2. Glacial drift associated with this last ice sheet was deposited northeast of Benton Lake and east of Priest Butte Lakes and created a hydrologically "closed" Benton Lake Basin where most surface waters ultimately flowed into Benton Lake proper and no outlet was present.

3. Gently dipping sedimentary bedrock underlies the unconsolidated glacial, alluvial, and lacustrine-type deposits at Benton Lake; the bedrock is mostly seleniferous marine shale of the Cretaceous Colorado Group.

4. Most geomorphologic surfaces at Benton Lake are Quaternary Lake (Ql) deposits. Secondary geomorphic surfaces are Quaternary alluvium-colluvium (Qac) deposits at the mouths of Lake Creek and other small tributaries where they entered Benton Lake; Quaternary terrace (Qt) deposits adjacent to the Benton Lake bed;

and Upper Cretaceous Bootlegger Member (Kbb) deposits on high ridges adjacent to “Qt” surfaces.

5. Surface soils at Benton Lake are predominantly clays and silty clays deposited in the lacustrine environments of glacial Lake Great Falls and later Benton Lake proper.

6. Topography at Benton Lake NWR reflects dominant geomorphologic surfaces (i.e., relatively flat lake bed, alluvial-colluvial fans, terraces, and old Cretaceous ridges). Within Benton Lake proper, elevations range from about 3,614 feet amsl in the lowest depressions to about 3,620 on terraces.

7. The climate of the Benton Lake region is generally characterized by pleasant summers with warm, mostly sunny, days and cool nights characteristic of Northern Great Plains regions where frequent Chinook winds occur. The growing season averages 121 days from mid-April through mid-September.

8. The Benton Lake Basin is semiarid with 70-80% of total annual precipitation (mean of 14.98 inches) occurring April to September. Consequently, rains and snowmelt during spring and summer contribute runoff water to Benton Lake and create a strongly unimodal seasonal peak of water levels in early summer followed by gradual declines, mostly caused by 40-41 inch/year evapotranspiration, to low stable (or dry in some years) water levels in fall and winter.

9. In addition to strong seasonal patterns of flooding, Benton Lake has evidence of long-term 15-20 year recurring patterns of peak lows and highs in regional precipitation, runoff, and therefore water levels are evident at Benton Lake. High water levels (followed by declines to lows) caused by natural runoff have occurred at Benton Lake in the late 1920s, early 1940s, late 1950s, mid 1970, and early 1990s.

10. Natural water inputs to Benton Lake come primarily (65-70%) from the 137 mile^2 Lake Creek watershed; the remainder is derived from on-site precipitation and runoff from small local drainages.

11. Deeper ground water beneath the Benton Lake Basin is confined primarily to the aquifer within the Colorado Shale formation and this ground-water is poor quality with low chloride concentration, moderate dissolved-solids, basic, and reduction conditions.

12. Shallow ground water in the Benton Lake Basin, in contrast, is acidic with high levels of calcium, sulfate, chloride, and magnesium.

13. Historically, the relatively low amount of annual precipitation in the basin was captured quickly and used by native grassland; little water moved deeply into soil or subsoil layers. Where water did percolate downward, it subsequently moved slowly and occasionally exited slopes as springs and saline seeps.

14. Deposition of salts and elements such as selenium did not historically accumulate to high levels in Benton Lake because of lower natural inputs from water, low ground water discharge, wind erosion, and elemental volatilization in water, sediment, and wetland plants during dry periods of the long-term hydrological cycle.

15. Historic vegetation communities at Benton Lake ranged from dense emergent wetland species in low elevations with more permanent water regimes to upland grassland on terraces and ridges. This gradation of communities included: 1) robust emergent, 2) sedge-rush, 3) seasonal herbaceous, 4) wet grassland, and 5) upland grassland habitat types.

16. The distribution of vegetation communities at Benton Lake were related to both geomorphology and elevation/flood frequency both seasonally and long-term; precise community distribution likely varied to some degree during wet vs. dry long-term water and flooding regimes. Sedge-rush communities apparently composed more area of historic Benton Lake than other vegetation associations.

17. A rich diversity of animal species historically used the Benton Lake ecosystem, especially birds. Waterbird use and production of Benton Lake proper varied among years depending on extent and duration of annual flooding.

18. Native people occupied the Benton Lake region since about 10,000 years BP but apparently had little influence on local ecosystems because of their mobile lifestyles, except to occasionally set fires in upland grasslands.

19. European settlers were not common in the area until the mid 1800s and the Benton Lake Basin remained relatively unchanged from historic condition until about 1880.

20. Lands within the Benton Lake Basin were acquired as part of the Louisiana Purchase and were kept in U.S. Government ownership until the early 1900s. Lands in and immediately adjacent to Benton Lake were owned and managed by the Bureau of Reclamation as part of the Sun River Reclamation (late Irrigation) Project with the intent of using it as a water storage reservoir. Dynamic water levels and climate in the region prohibited this use.

21. One early attempt was made to ditch and drain Benton Lake, but the "closed" basin topography and hydrology caused this effort to fail.

22. Conversion of native grassland to agricultural crops in the region began in earnest in the 1920, following development of the Greenfields Irrigation Division of the Sun River Project and accompanying markets and transportation mechanisms for locally-grown grain, mostly wheat. Much of the native grassland adjacent to Benton Lake was converted to "dry-land" crop-fallow rotation from 1930 to 1950.

23. The alternate crop-fallow rotation in the region has gradually increased the number and severity of saline seeps within the Benton Lake Basin; over 250 saline seeps now are mapped. Ground water flows in crop-fallow areas move to nearby hill slopes where it discharges and evaporates, forming areas of salt precipitates, increasing water salinity, and depositing dissolved metallic elements including potential contaminants such as selenium.

24. Benton Lake NWR was established by Executive Order in 1929 but little development or management occurred until the late 1950s and early 1960s; until that time it was administered by the National Bison Range in western Montana.

25. A pump station located on Muddy Creek, about 15 miles east of Benton Lake NWR, and a pipeline were constructed 1958-1962 to bring irrigation return flow water to the refuge to provide an annual available source of water to flood Benton Lake. Water from the Muddy Creek pump station is moved 5 miles through underground pipe and then is discharged into the Lake Creek channel where it flows about 12 miles to its mouth at Benton Lake.

26. In addition to the pump station and pipeline, the historic Benton Lake bed was subdivided during 1960-62 into 6 pools by dikes, levees, ditches, and water-control structures to facilitate management of water and vegetation for waterfowl production. Later, Pool 4 was subdivided into 3 pools (4a-4c). Pumped and natural runoff water in Lake Creek flows into Pools 1 and 2,, which were constructed at the mouth of Lake Creek, and then by gravity flow into other pools. Other physical developments on the refuge have altered natural topography, water flow patterns, and local hydrology.

27. Water management within Benton Lake from the early 1960s through the late 1980s typically sought to regularly pump water to the lake from Muddy Creek and to extensively flood most wetland pools for prolonged periods each year to provide waterbird breeding habitat, brood-rearing areas, and waterfowl fall migration and hunting areas. This management ultimately changed historic hydrological patterns to more prolonged, less dynamic, and more consistent regimes. The relative amounts of water pumped to Benton Lake from Muddy Creek compared to natural runoff from Lake Creek varied substantially over years.

28. More permanent water regimes in Benton Lake gradually changed vegetation communities to more water tolerant types, increased salinity and selenium accumulation, promoted expansion of invasive plant species, and increased severity and occurrence of avian botulism outbreaks that killed thousands of waterbirds in some years.

29. Water management at Benton Lake since the early 1990s has reduced pumping during summer and now employs more seasonal water regimes, except in Pools 1 and 2, which continue

to be managed for permanent flooding to store water and provide summer waterbird habitat. Most pools received pumped or natural runoff water in spring, are allowed to dry to varying degrees during summer, and then receive more pumped water in early fall to provide habitat for waterfowl hunting and to store water for the following year.

30. The primary source of dissolved solids and selenium that enters Benton Lake is agricultural irrigation drainage water pumped from Muddy Creek and surface and subsurface ground water flow from numerous saline seeps in the Lake Creek watershed. The mean annual selenium load delivered to Benton Lake was 151 lbs/year from 1970 to 2008, with natural runoff contributing an average of 60.9% of the selenium.

31. A model of selenium cycling within Benton Lake pools was developed (Zhang and Moore 1997a), and is currently being refined, to predict when selenium concentrations in Benton Lake sediments would become hazardous. The 1997 model predicted that more permanent water regimes in Pools 1 and 2 and an area near saline seeps in Pool 4c would exceed toxicity thresholds by 2008 and 2014, respectively. Recent sampling indicates these toxicity threshold levels have not been exceeded, but potential accumulation rates are of concern.

32. Vegetation communities at Benton Lake NWR now contain highly altered communities and expansion of the aggressive introduced creeping foxtail.

33. Documentation of long-term changes in animal populations at Benton Lake NWR is constrained by lack of, or short tenure, surveys and monitoring. Certain evidence suggests reduced occurrence and productivity of waterbirds, with some potential contamination to toxic levels of selenium.

GENERAL RECOMMENDATIONS FOR RESTORATION AND MANAGEMENT OBJECTIVES

This study is an attempt to evaluate restoration and management options that will protect, restore, and sustain natural ecosystem processes, functions, and values at Benton Lake NWR rather than to manage for specific plant/animal guilds or species. Benton Lake NWR provides key resources to meet annual cycle requirements of certain trust, priority, and concern species, and these needs will continue to be addressed, but within the context of more holistic regional landscape- and system-based management objectives. The National Wildlife Refuge System Improvement Act of 1997 seeks to ensure that the biological integrity, diversity, and environmental health of the (eco)system (in which a refuge sets) are maintained (USFWS 1999,Meretsky et al. 2006). Administrative policy that guides NWR goals includes mandates for: 1) comprehensive documentation of ecosystem attributes associated with biodiversity conservation, 2) assessment of each refuge's importance across landscape scales, and 3) recognition that restoration of historical processes is critical to achieve goals (Mertetsky et al. 2006). Most of the CCP's completed for NWR's to date have highlighted ecological restoration as a primary goal, and choose historic conditions (those prior to substantial human-related changes to the landscape) as the benchmark condition (Meretsky et al. 2006). General USFWS policy, under the Improvement Act of 1997, directs managers to assess not only historic conditions, but also "opportunities and limitations to maintaining and restoring" such conditions. Furthermore, USFWS guidance documents for NWR management "favor management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s)." (USFWS 2001)

Given the above USFWS policies and mandates for management of NWR's, the basis for developing recommendations for Benton Lake NWR, and use in developing the CCP for the refuge, is the HGM-approach used in this study. The HGM approach objectively seeks to understand how this ecosystem was created, the fundamental processes that historically "drove" and "sustained" the structure and functions of the system and its communities, and what changes have occurred that have caused degradations and that might be reversed and restored to historic and functional conditions within a "new desired" environment. This HGM approach also sets the NWR within the context of appropriate regional and continental landscapes it sets, and identifies its "role" in meeting larger conservation goals and needs at all geographical scales. In many cases, restoration of functional ecosystems on NWR lands helps that refuge serve as a "core" of critical, sometimes limiting, resources than can complement and encourage restoration and management on adjacent and regional private and public lands.

Based on the HGM context of information obtained and analyzed in this study, we believe that future management of Benton Lake NWR should seek to:

1. Maintain the physical integrity of the hydrologically closed Benton Lake Basin and emulate a more "natural" seasonally- and annually-dynamic water regime within Benton Lake proper.

2. Control and reduce accumulation of salts and contaminants such as selenium within the Benton Lake system.
3. Restore and maintain the diversity, composition, distribution, and regeneration of wetland and upland vegetation communities on Benton Lake NWR in relationship to topographic and geomorphic landscape position.

4. Provide functional complexes of resource availability and abundance including seasonal food, cover, reproductive, and refuge resources for endemic animal species.

The following general recommendations are suggested to meet these goals for Benton Lake NWR:

1. Maintain the physical integrity of the hydrologically closed Benton Lake Basin and emulate a more "natural" seasonally- and annually-dynamic water regime within Benton Lake proper.

The Benton Lake ecosystem developed under, and was adapted to, strong seasonally- and annually-dynamic flooding regimes caused by variable regional precipitation and runoff within the hydrologically closed Benton Lake Basin. Benton Lake proper received most of the runoff within this basin, primarily through the Lake Creek watershed, and was the terminal repository of water and dissolved or suspended constituents including sediments, salts, and elements. In general, this ecosystem was characterized by spring flooding from regional rain runoff and snowmelt followed by gradual drying to low water conditions in fall and winter. The degree of spring flooding and subsequent summer drying varied among years, with regular peaks and lows of wet and dry periods occurring on about 15-20 year patterns. Historic and current hydrological information suggests wet, highly flooded, periods typically lasted 2-3 years; followed by gradual drying to extreme dry periods of 3-5 years, and then gradual return to wet conditions. This undulating pattern of flooding and drying greatly influenced plant communities and evolution of endemic animal populations in this Great Plains ecosystem.

This physical integrity of the Benton Lake bed was sustained because:

a. No outlet to the lake bed was present and the primary tributaries to the lake were not diverted or altered.

b. Native grassland in the watershed filtered and reduced erosion and sediment entry to tributaries, thereby reducing sedimentation of the lake bed.

c. Drying of most, and occasionally all, of the lake bed during dry long-term climatic periods prohibited accumulation of organic material and contaminants through accelerated decomposition of vegetative material, wind erosion of accumulated salts, and volatilization of trace elements including selenium.
d. Seasonal flooding and drying also reduced organic and contaminant accumulation through annual decomposition and wind erosion/volatilization

Vegetation and animal communities, nutrient cycling, and energy flow within Benton Lake were sustained because:

a. Seasonal flooding dynamics provided heterogeneous wet and dry surfaces for germination of diverse wetland plant communities and production of seasonal resources used by many animals. Most animal groups used Benton Lake only seasonally and their entry to, and exit from, the lake system helped form complex food and energy webs.

b. Long-term flooding and drying cycles within a closed basin conserved and recycled nutrients and energy through periodic "pulses" of energy flow into the system and decomposition/recycling of nutrients and elements.

c. Grasslands on uplands and terraces adjacent to the lake and within the Benton Lake watershed prevented excessive groundwater infiltration and subsequent solution and transport of salts and trace elements, such as selenium that originates from the underlying Colorado Shale deposits of the region, into seeps that then flowed into tributaries or slope edges of Benton Lake.

Maintaining and restoring the physical and biotic attributes that created the above dynamic hydrological regime within Benton Lake should be a priority to allow natural ecological processes to sustain this ecosystem. Few, if any alterations to the physical and hydrological attributes of the Benton Lake ecosystem occurred until the early 1900s, and unfortunately, most site-specific alterations have occurred since the early 1960s when the refuge began intensive development and management. Certain of these alterations may be difficult to reverse, while others are directly under the control of the NWR.

2. *Control and reduce accumulation of salts and contaminants such as selenium within the Benton Lake system.*

Terminal wetland basins in semiarid environments of the Northern Great Plains, such as Benton Lake, typically are alkaline, but have equilibrium-dynamic of elements and salts that prevent the system from becoming highly saline and with depauperate vegetation communities. Wetland ecosystems that retain the physical, hydrological, and biotic components that provide system integrity (such as listed under #1 above) are capable of supporting more diverse, and productive plant and animal communities. When these Northern Great Plains wetlands become degraded from naturally-occurring historic conditions, either from regional or site-specific alterations, then the balances of salt and elemental inputs vs. outputs becomes altered and accumulation and contamination often occurs.

Since the early 1900s, conversion of native grassland to crop-fallow rotations in the Benton Lake watershed have gradually changed chemical balances within soils and water in the region. The most critical changes have been the increased development of saline seeps in the watershed that developed when ground water infiltration increased greatly in fallow fields and subsequently caused salts and metallic elements, especially selenium, to become dissolved and be transported to seeps. Water discharged from the seeps formed precipitates that accumulated either locally near the seep site or were transported ultimately to Benton Lake through multiple small drainages and Lake Creek. Increased transport and accumulation of salts and elements in Benton Lake was exacerbated when irrigation return water from Muddy Creek also was pumped to the lake after 1962. Development and management of wetland pools within Benton Lake proper in the early 1960s promoted extended seasonal inundation of many parts of the historic lake bed and effectively removed long-term dynamics of periodic very dry vs. very wet periods. This "dampening" of both seasonal and long term hydrological cycles, with more consistent and prolonged flooded, also caused accumulation of salts and elements within the closed system of Benton Lake, because the dry periods when wind erosion and volatilization occurred were reduced or eliminated. Fortunately, most pools on Benton Lake have been managed for more natural water regimes in the last decade or so, however, Pools 1 and 2 continue to be managed for more permanent water regimes and water storage. Modeling of selenium accumulation at Benton Lake has forecast additional accumulation (potentially to toxic levels for many biota) if this more permanent water management continues in Pools 1 and 2 and actions to reduce the extent and severity of saline seeps, at least immediately adjacent to Benton Lake, are not pursued.

Obviously, the threats of potential continued, or accelerated, accumulation of salts and selenium in Benton Lake are serious and must be addressed. Lessons from sites of salt and selenium accumulation on other NWRs (e.g., Skorupa and Ohlendorf 1991, Seiler et al. 2003) mandate actions to assure that salts and selenium do not accumulate and cross sometimes irreversible toxicity thresholds for water quality, sediment, and vegetation. These actions will require land use and water management changes both on and off Benton Lake NWR.

3. *Restore and maintain the diversity, composition, distribution, and regeneration of wetland and upland vegetation communities on Benton Lake NWR in relationship to topographic and geomorphic landscape position.*

A rich diversity of vegetation communities historically was present on Benton Lake NWR and they were distributed along geomorphic surface, topography, and flood frequency gradients (Fig. 12). In this closed basin, the dominant factor determining distribution of plant species was topography as it was related to the seasonal flooding regime caused by interannual and intraannual dynamics of water flow into the lake bed and its subsequent surface water retention and recession in this semiarid environment with high annual evapotranspiration rates. Most historic vegetation communities at Benton Lake still are present, however, the extent, distribution, and composition of these communities has changed. Also, native communities are increasingly being replaced by invasive or exotic species. Many factors have changed these communities; the most important influences have been physical and hydrological changes to the lake bed and altered water chemistry, especially salt balances. Certain of these changes may be reversible, while others may not be possible or desirable depending on regional land use and on-site NWR management objectives.

Generally, ecosystem restoration and wetland management strategies should seek to restore elements of the diversity and natural distribution patterns of habitats in a region/site where they have been altered. This is a goal of Benton Lake NWR. Such restoration is important to sustain native plant and animal communities and provide critical ecosystem functions and values such as nutrient flow, carbon sequestration, water storage and filtration/volatilization, sediment reduction, groundwater recharge, etc. The challenge for system managers will be to understand what habitat/community types can be restored given the long-term physical and hydrological changes to this system. Additionally, management must consider: 1) whether patch sizes of restored habitats are large enough to be sustainable; 2) whether configuration of habitats will create and enhance basic desirable landscape attributes such as providing travel and energy corridors, refuge, and seasonal foods; 3) the balance between tolerating short- and long-term natural flooding and dry periods/years vs. desires to provide predictable resources for select animal species or groups (e.g., breeding waterbirds); 4) what management actions will be required to control invasive species and how this control may impact restoration of native communities; and 5) what intensity and cost of management (water, manipulation, etc.) will be required to maintain habitats. The primary ecological factor that will control the success of restoring sustainable native habitats at Benton Lake is future water management and the capabilities to manage primarily for seasonal hydroperiods and occasional extended dry conditions in pools.

4. *Provide functional complexes of resource availability and abundance including seasonal food, cover, reproductive, and refuge resources for endemic animal species.*

Annual primary and secondary productivity and total community biomass historically were high in the Benton Lake wetland ecosystem primarily because of the diverse vegetation communities that were supported by rich alluvial/lacustrine-type soils and dynamic seasonal pulses of water, nutrients, and energy flow. Upland grasslands adjacent to Benton Lake were critical for the wetland system to function properly because they buffered erosion and movement of sediments, salts, and trace elements into the lake, created continuums of communities and nutrient flow, and provided corridors for animal movement into and out of the basin. Each community type on Benton Lake NWR provided different, yet complementary seasonal resources that ultimately supported large populations of many animals, especially migrant waterbirds. The long-term interannual dynamics of water in Benton Lake proper caused irregular use and abundance of many species with alternating "booms" and "busts" in use and productivity during respective wet and dry periods. Basic adaptations of animals in this highly dynamic system included relative long life span, high mobility or seasonal torpor, seasonal omnivory, and diverse diets within a trophic level (Van der Valk 1989). Historically, many small and large wetland basins were present throughout the western Great Plains and foothills/valleys of adjacent mountain ranges, therefore animals, especially birds, had many options for obtaining resources and reproducing within and among years. For example, several small wetland basins in addition to Benton Lake proper were present within or near the Benton Lake Basin including Freezeout Lake, Black Horse Lake, etc. Unfortunately, many regional wetland basins in the Western Great Plains have been destroyed or are no longer functional to provide key resources to certain animals (e.g. Knopf and Samson 1997). This reduction in regional habitat base places greater importance on resources in remaining habitats such as on Benton Lake. A primary management challenge for Benton Lake NWR is to consistently provide key resources without significantly altering, or potentially destroying, the capability of that system to be sustainable.

Restoration and management of Benton Lake NWR ultimately must understand what, and where, native resources historically were present and how the new desired state of habitats can restore or replace them. Collectively, retaining the physical and hydrological integrity of the Benton Lake bed, emulating natural hydroperiods, improving water quality issues, and restoring natural vegetation communities are critical to maintaining long-term sustainable resources, in a pulse-type provision, in this closed basin system. Benton Lake NWR cannot provide highly abundant and diverse resources every year for many consecutive years without compromising basic and inherent capabilities of the system to recycle nutrients and energy, remove salts and contaminants, regenerate native plant communities, and maximize productivity. Understanding and accepting the need for water dynamics in this system is key and will require more regionally- and continentally-comprehensive strategies and planning to protect, restore, and provide essential habitat and resources for animal species using the Western Great Plains.

SPECIFIC RECOMMENDATONS TO MEET ECOSYSTEM RESTORATION GOALS

Protect the Physical Integrity of the Benton Lake Basin and Emulate Natural Hydrological Regimes

1. *Retain the closed nature of Benton Lake proper and protect watersheds and drainage routes of its tributaries.*

The Benton Lake Basin is a hydrologically closed system with Benton Lake proper being the terminal basin for most water runoff in the region. Physical and biotic features of this system reflect historic creation of the basin and the energy/nutrient dynamics of this system. The fundamental sustainability of this system depends on maintaining the balance of natural water, energy, and nutrient inputs vs. exports from evapotranspiration, wind erosion, and animal movements. Attempts to alter the closed nature of the basin, especially Benton Lake proper, run the risk of altering natural constituent balances, basic ecological processes, and endemic plant and animal communities. At various times in the last 100 years, attempts have been made (or at least were suggested) to physically alter this closed system, especially Benton Lake proper, by creating artificial drainage from the lake, inputting more water to the basin and Benton Lake from other basins, and conversely diverting Benton lake water to other wetlands and basins. Pumping water to Benton Lake from Muddy Creek is the primary outside influence to date.

The following actions seem important to maintain the physical integrity of Benton Lake:

- Retain Benton Lake proper as a closed basin with no additional water delivered to it from non-basin sources and no creation of drainage from the basin.

- Maintain the physical and chemical structure and attributes of tributaries to Benton Lake, especially the Lake Creek watershed.

- Do not divert Benton Lake water to other basins or other wetland depressions within the Benton Lake Basin.

2. *Restore natural topography and reconnect natural water flow corridors and patterns where possible.*

Restoration of natural topography, especially reconnecting water flow pathways and types within Benton Lake NWR is important to allow water, nutrients, and animals to move through the system in more natural patterns. Historically, water entered Benton Lake mainly from Lake Creek and then moved across the lake bed in a sheetflow manner, first into deeper depressions and then expanding sequentially onto higher elevations as waters rose from additional inputs. The development of management pools within Benton Lake has greatly disrupted this flow. Ideally, natural water flow patterns, including source, timing, and distribution could be restored at Benton Lake. This is especially desirable at the mouth of Lake Creek.

Important specific restoration items include:

- Restore more natural topography within the Benton Lake bed, including removing artificial islands, filling internal-pool ditches, and restoring natural depressions and drainages.

- Evaluate all levees, roads, and water-control structures to determine if they are necessary, or are detrimental, to desired water management. Priority should be given to removing levees and water-control structures in Pools 1 and 2 where Lake Creek water enters Benton Lake. Remove unnecessary levees and roads and construct spillway breaches in some pools, if the current pool configuration is retained, to allow water to move among units during high water periods. The freeboard between full pool and top levee elevations should not be greater than one foot for interior pools.

- Do not construct additional levees, roads, or ditches within Benton Lake proper.

- Evaluate and restore the historic Lake Creek channel(s) at its mouth in Pools 1 and 2 and restore at least some capability for sheetwater overflow onto the adjacent "Qac" geomorphic surface.

3. *If the "Pool" configuration of Benton Lake is retained, improve water-delivery and control infrastructure and manage wetland pools for more natural seasonal and annual water regimes.*

The most important factor that will enable restoration of the Benton Lake ecosystem will be to change water management to more closely emulate natural hydrological regimes. This means that retained wetland pools within the historic Benton Lake bed should have seasonally- and annually-dynamic water levels. Retained pools should be managed as seasonally flooded wetlands where water inputs occur in spring and then surface waters are subsequently allowed to recede from evapotranspiration or perhaps movement into other pools during summer and fall to low sustained levels over winter. Higher elevations in all existing pools were not historically flooded except during very wet years and even in these years the higher elevations apparently were flooded only for short periods in spring and summer. Pools also should be managed for periodic times of more extensive flooding and also more extended drying. The current water-control infrastructure at Benton Lake is capable of gravity flowing water from Pools 1 and 2 into lower pools and some additional inter-pool transfer. However, levees have disrupted the capability of water moving first into low depressions and then expanding to higher elevations. Further, some ditches and levees appear to have seepage, which may be making some parts of some pools (e.g., the southeast part of 4c) saturated for extended periods.

The following water management and water-control infrastructure items should be considered:

- Manage pools for interannually-variable seasonal water regimes.

- Allow lower elevation pools and depressions to become more extensively flooded in some years.

- Allow all pools to have extended (2-4 years) drying periods during each ca. 15 year cycle.

- Rotate flooding and drying regimes among pools so that some pools are either dry or more flooded in most years – this will allow the basin to have complexes of habitats and resources available to priority species in most seasons and years.

- Reduce annual water pumping from Muddy Creek to Benton Lake. In wet years when more runoff from Lake Creek occurs, pumping from Muddy Creek could be greatly curtailed or eliminated.

- Evaluate all infrastructure to determine efficiency in water movement into and among pools and to reduce seepage.

Control and Reduce Accumulation of Salts and Contaminants

1. *Restore natural hydroperiods to Benton Lake proper and balance seasonal and long-term inputs from Muddy Creek pumping vs. natural runoff in the Lake Creek watershed.*

Accumulation of salts and selenium within water, sediments, and biota of Benton Lake has occurred over time, in part because the natural hydroperiods of the system have been changed to more permanent, and annually consistent, flooding regimes. Management should seek to restore the natural dynamic equilibrium where the amount of selenium and salt removal from the basin through volatilization and wind erosion equals the amount of salt and selenium accumulation in the system. Volatilization and wind erosion are controlled by various environmental factors with high summer temperatures, higher air flow, evapotranspiration, natural flooding-drying cycles, exposure of mudflats and wetland soil surfaces, and decomposition of plants increasing the removal rates. Consequently, a key to restoring this equilibrium and reducing accumulation will be restoring more natural hydroperiods, both seasonally and annually.

Strategies and options to achieve this were provided in the previous "Emulating natural water regimes" section and include:

- If the pool configuration is retained, manage pools in an annually rotated manner to provide extended drying periods for all pools in more natural long-term patterns.

- Manage all higher elevations including "Qac" and "Qt" geomorphic surfaces for seasonally flooded regimes.

- Reduce non-basin water inputs to Benton Lake with most delivery occurring for select pools in dry years.

- Develop water-control infrastructure to allow more independence in pool water management.

2. *Encourage and participate in conservation programs in regional watersheds to reduce the extent and severity of saline seeps.*

The primary source of increased salts and elements, especially selenium, into Benton Lake is the numerous saline seeps within the watershed of the lake. Development and expansion of these seeps has been caused by extensive crop-fallow rotation farming in the region. Efforts to reduce seeps include landscape programs to revegetate fallow areas and/or reduce their extent and frequency of use. Efforts to change some land use in the region should be supported by the USFWS and Benton Lake NWR should encourage and participate in these programs as possible. Specific landscape programs might include:

- Expansion and maintenance of CRP programs within the Benton Lake watershed with native grassland used as the cover crop.

- Possible rest-rotational subsidies to discourage fallowing and with longer-term cycles of production.

- Conversion of some marginal small-grain cropland or highly erodible sites to native grassland or pasture/hay land (e.g., Brown 1972).

3. *Evaluate vegetation manipulation techniques for possibilities of reducing accumulation of selenium.*

Certain evidence (Zhang and Moore 1997a,b) suggests that significant amounts of selenium can be removed from the Benton Lake system when wetland plants burn and volatilization increases. Accelerated decomposition of wetland plants occurs during dry periods and naturally occurring fires in the Benton Lake Basin may also have occurred more frequently during those years. Fire is an important ecological process in western Great Plains grasslands and wetland basins and helps recycle nutrients and energy, facilitates regeneration of diverse native communities, and maintains structure of these ecosystems. Fires in upland grasslands moved into lower elevation wet area of basins and riparian areas during dry periods and provided similar benefits to these sites. Manipulation of wetland plants during dry periods should be evaluated within Benton Lake Pools, including:

- Occasional fires within select pools during dry periods, especially those pools that have become more monotypic, had expansion of invasive, and greater coverage by robust emergent species.

- Mechanical manipulation of dense monotypic or invasive stands of vegetation during dry years, including tillage and mowing.

Restore Natural Vegetation Communities

1. *Restore more natural distribution and composition of communities.*

Several distinct plant communities occurred within and adjacent to Benton Lake proper. These communities were arrayed primarily along elevation/flooding frequency gradients modified by underlying geomorphologic surfaces and soils. Small areas of robust emergent occurred in the very lowest elevation depressions within the lake bed where surface water was more frequent and prolonged. The most extensive plant communities within Benton Lake were sedge/rush type that covered most of the lower elevations of the lake bed and wet grasslands on the edges of the lake bed. Relatively narrow bands of annual herbaceous plants, often called moist-soil plants, occurred in seasonally flooded areas in between the sedge/rush and wetland grassland communities. Upland grasslands occupied extensive terraces and hills adjacent to the lake bed. Most of these communities still are present in Benton Lake, however their distribution and extent is highly altered. For example, more permanent and annually consistent water regimes have favored expansion of robust emergent and reduced wetland grassland zones.

Restoring more natural distribution and extent of communities will require changes in water management recommended above and would help achieve:

- Reduced area of robust emergent communities to the lowest elevations where water regimes will be more prolonged.
- Increased area of sedge/rushes, especially alkali bulrush and Carex species.
- Relatively narrow bands of annual herbaceous species in seasonally drawdown zones.
- Expansion of native wet grassland on the edges of the historic lake bed.
- Reduction of saltgrass to more saline sites.
- Expansion of prairie cordgrass on "Qac" geomorphic surfaces.

2. *Control expansion of invasive species, especially creeping foxtail.*

Creeping foxtail appears to be rapidly expanding in many wetland pools and may be replacing native species, such as alkali bulrush. Creeping foxtail produces aggressive underground rhizomes, does not go dormant during summer, tolerates a wide range of poorly drained soils, and is well adapted to high moisture conditions (NRCS 2007). It is often found in the hydrological zone adjacent to robust emergent species like cattail and hardstem bulrush and can withstand periodic flooding for up to 2 months. Wetter flooding regimes in the Benton Lake bed probably have contributed to expansion of this species and currently it is thriving where soil saturation, but not surface flooding, is prevalent during summer and fall. Little is known about controlling this species, as it mainly has been promoted as a preferred forage crop for livestock in the Northern Great Plains. Garrison creeping foxtail is often compared to reed canary grass (Phalaris arundinacea), and unfortunately it has similar characteristics of being high aggressive, spreading rapidly and outcompeting native associates, and being difficult to control. The following management may help reduce the presence and expansion of creeping foxtail and other invasive species:

- Return Benton Lake to more natural water regimes, especially extended drying periods both seasonally and annually.
- Disturbance, either mechanical or with fire, during dry periods.
- Chemical applications.

Providing Key Resources

1. *Provide a rotational complex of wetland habitats and seasonal resources.*

The Benton Lake ecosystem historically attracted, and supported, a rich diversity and abundance of animals, especially during wet periods of the long-term hydrological cycle. Most animal species exploited seasonally available resources, and were present during seasons and years when key resources were available to meet specific life-cycle requirements. During wet periods, soon after the lake was flooded, breeding and migration waterbird numbers in particular were spectacular and attracted the attention of hunters and naturalists. Historic management of Benton Lake NWR, and many other Northern Great Plains wetlands owned and managed by state and federal agencies, has sought to create habitat conditions that occurred during wetter periods to maximize production of food/cover resources that increased waterbird production. Unfortunately, water management on many areas, including Benton Lake, has attempted to replicate wetter conditions and communities annually, or least in most years, and consequently has disrupted natural hydrological patterns and basic ecological processes that sustained these systems. Specifically, water management at Benton Lake until the 1990s sought to deeply flood many pools throughout spring, summer, and fall. This alteration to natural hydrological regimes coupled with regional land use changes gradually converted the lake bed to more robust emergent plant communities, increased accumulation of salts and selenium, increased presence of invasive species, reduced abundance and availability of key resources, and ultimately reduced diversity and presence of native plant and animal communities.

Historically, animals, especially waterbirds, using wetlands within the Northern Great Plains had access to many wetlands and habitat types throughout the region. This abundance and wide distribution of wetlands enabled species to withstand dry periods in specific areas because alternate resources usually were present somewhere else. Unfortunately, many wetlands in the region now are destroyed and remaining ones, like Benton Lake, become more critical to support populations, especially those with reduced numbers or specific life-cycle requirements and adaptations. The temptation, therefore, is to try and manage Benton Lake for all species/habitats and to maximize flooded area each year. This temptation has been manifested at Benton Lake by past water management practices. It is important for Benton Lake NWR to continue to provide key resources for endemic animal species and populations, however, management must seek some balance between trying to provide many resources every year vs. sustaining the basic ecological processes, integrity, and productivity of the system. Given this goal, some compromise in management strategy may be possible if:

- Wetland pools can be managed for interannually dynamic water regimes that more closely emulate seasonal and long-term dynamics. Pools should go through rotations of wet vs. dry periods among sequential years and all pools and higher elevation area must have extended dry periods within ca. 15 year periods.

- If a pool has been managed for more prolonged flooding within a year, it must be closely monitored to assure that incidence and severity of disease (e.g., botulism) outbreaks and accumulation of salt/selenium levels do not occur.

2. *Protect native terrace and upland grasslands.*

Grassland communities on the edges of, and adjacent to, Benton Lake were critical to maintaining ecological processes within the lake and its functions and values. These communities buffered water, sediment, and salt/selenium entry to the lake; provided corridors of movement for many species in and out of the lake bed; and provided complementary resources and habitats, such as nesting or winter refuge sites, for species. Consequently, these grassland communities should be sustained by:

- Maintaining an adequate boundary of grassland around the entire Benton Lake bed and its tributaries.

- Convert any cropland immediately adjacent to the lake to grassland. This may require programs to encourage this conversion on private lands or additional acquisition to secure adequate grassland buffers.

- Manage terrace and upland grassland to sustain native species composition and structure.

3. *Maintain functional seasonal refuges.*

A key function of NWRs, including Benton Lake NWR, is the provision of refuge/sanctuary areas that have reduced disturbance and security for animals during specific life-cycle events, such as nesting, over-wintering, and migration. With reduced wetland habitat available in the western Great Plains, options for animals to find refuge are reduced, and areas like Benton Lake become even more important to sustain populations. Management practices that can improve refuge capabilities include:

- Controlling public access to specific areas that are important nesting, foraging, hibernacula, or brood rearing habitats during the seasons of importance.

- Managing hunting programs, especially waterfowl hunting, to reduce disturbance temporally and spatially. This includes setting aside some areas as inviolate sanctuaries during hunting seasons.

- Providing waterfowl/waterbird refuges in both seasonally-flooded and more prolonged-flooded areas each year if possible; some wetland pools should be permanently set aside as sanctuary to encourage and sustain traditions of use to the region. In some dry years, little flooded area may be present and waterfowl hunting may not be possible on the refuge.