AN EVALUATION OF ECOSYSTEM RESTORATION AND MANAGEMENT OPTIONS FOR THE OURAY NATIONAL WILDLIFE REFUGE, UTAH

Prepared For:

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EXECUTIVE SUMMARY

Ouray National Wildlife Refuge (NWR) contains 11,987 acres of riparian woodlands, floodplain wetlands, upland grasslands, and shrublands bordering 16 miles of the Green River in northeastern Utah. The majority of the refuge consists of a series of floodplain bottoms that adjoin the Green River behind channel bends. These bottoms support a diversity of habitats that are rare and decreasing throughout the Intermountain West. Many alterations to the physical structure and ecological processes of the Green River ecosystem have occurred since Ouray NWR was established. Most significantly, the hydrology of the Green River was greatly altered after Flaming Gorge Reservoir was built upstream on the Green River. Other major changes to the refuge include extensive construction of levees, ditches, and water-control structures; invasion of exotic plants and animals; contamination from selenium in irrigation water draining onto the refuge; and declining populations of many rare, threatened, and endangered animal species.

A primary challenge for future management of Ouray NWR is understanding how the Green River floodplain ecosystem can sustain historic ecological functions and values given its highly modified landscape and hydrologic regime. This report provides an analyses of options for restoring and managing native ecosystems at Ouray NWR. Objectives were to: 1) synthesize information on geological formations, geomorphic features, hydrologic condition, and natural history of the Green River ecosystem in the vicinity of Ouray NWR, 2) identify how the structure and function of the Green River ecosystem at Ouray NWR have been altered, and 3) identify restoration approaches and ecological attributes needed to restore and manage specific habitats and ecological conditions on Ouray NWR.

Ouray NWR is located within the Unita Basin of northeastern Utah; its geology was mostly shaped and formed during the Tertiary period. The modern day Green River that flows through the Unita Basin runs 730 miles from its headwaters in the Wind River Range in Wyoming to its confluence with the Colorado River. The Green River at Ouray NWR is a relative wide, low gradient, sand bed system that has cut meandering channels through the soft Unita geological formation. A complex of alluvial-derived surfaces are present in this stretch of the Green River and includes point bars, natural levees, floodplain terraces, backswamps, older abandoned channels, and the active channel of the Green River. Historic alluvial processes created a heterogeneous distribution of topography, soils, and hydrological regimes on Ouray NWR that support a diversity of habitats. During the last 70 years, channel migration of the Green River at Ouray has apparently been very limited and meander patterns may have been close to the present location for considerable time.

Ouray NWR has a semiarid climate. Because of relatively limited local precipitation, the hydrology of the Green River in the vicinity of Ouray NWR is controlled by spring snowmelt in the Rocky Mountains of Wyoming, Colorado, and Utah. Historically, annual discharge and peak yearly flows in the Green River were highly variable. Prior to closure of Flaming Gorge Dam, peak discharge of the Green River at Ouray NWR typically was in late May and averaged 24,000 cubic feet/second (cfs) with a range from 8,000 cfs to 37,000 cfs. During the last 100 years only 5 peaks occurred outside of May or early June; river discharges decline significantly in July to low base flows from September through March.

The historic Green River mean annual peak discharge of 24,000 cfs at Ouray NWR occurred at a frequency of about 2.3 years. From 1923-1962, recurrence intervals of 1.25, 2, 5, and 10 years were associated with flows of 15,764 cfs, 21,967 cfs, 27,952 cfs, and 30,707 cfs, respectively. This mean annual discharge of 24,000 cfs historically was equaled or exceeded 1.3% of the time (about 5 days/yr). Prior to construction of levees on Ouray NWR and closure of Flaming Gorge Dam, water from the Green River began overtopping banks of the river and extensively flooded floodplain bottoms at Ouray NWR from 14,000 to 18,600 cfs. The floodplain bottoms on Ouray have different sizes and flood frequencies, but recurrence intervals of initial flooding for all bottoms historically was from 1.2 to 1.7 years. Johnson and Woods bottoms are smaller than other bottoms on Ouray NWR and most areas in these bottoms are filled quickly once Green River flows overtop natural levees. In contrast, the large Wyasket Bottom begins to flood at about 19,000 cfs, but flows > 22,000 are required to fill it.

Historically, the Green River first entered floodplain bottoms at Ouray NWR at low elevation sites along natural levees at downstream ends of bottoms, and last at higher elevation point bars on inside bends of the river. This pattern of flooding caused most flooding at Ouray NWR to occur as relatively slow "backwater" floods. For example, at Leota Bottom, slow backwater floods entered the south part of the bottom near L7A at flows of 13-14,000 cfs with a return interval of about 1-1.2 years, whereas higher velocity "headwater" floods that overtopped the inside bend point bar at L3 occurred only at flows > 27,000 cfs with a return interval of > 5 years.

Groundwater levels under Ouray NWR floodplains are influenced by geomorphic surfaces, soils, and subsurface connectivity with the Green River. The degree and location of subsurface connectivity on Ouray NWR has not been determined, however, sites that probably have the greatest connection include sites immediately behind point bars where water can move through sandy soils in and out of backswamp depressions. In these wetland sites, some seasonal "ponding" may occur when the Green River is at a high stage, even if the river does not overflow natural levees and backflood these areas.

The types and distribution of historic vegetation communities at Ouray NWR were determined using a combination of historic and contemporary information. A gradation of vegetation types and ecological processes occurred from high elevation upland benches to the present river channel. High elevation upland benches formed by the Unita Formation contain grasslands interspersed with low shrubs. Clay bluffs occur on slopes of upland benches and are barren and highly eroded. Terrace fan remnants contain material eroded from upland benches and bluffs and support sparse semidesert shrub communities. Occasional fire, herbivory, and local precipitation drive ecological processes in these upland areas.

Alkali flats occur between the bottom slopes of shrubland terraces and upland sides of floodplain wetlands. These flats contain many relatively salt tolerant shrubs, forbs and grasses and may be seasonally flooded depending on precipitation and snowmelt in the local area. During very high flood events on the Green River, alkali flats may be shallowly flooded for short periods and attract large numbers of shorebirds, gulls, swallows, wading birds, and waterfowl.

Backswamp floodplain wetlands are present in all floodplain bottoms on Ouray NWR. Historically each bottom had slightly different water regimes depending on topography and frequency of inundation by the Green River. The depth, duration, and extent of flooding in these wetlands was driven by flood pulses of the Green River and were highly variable among years; the norm being a relatively short pulse (1-2 weeks) of flood entry followed by gradual drying through summer and fall. Consequently, most floodplain wetlands, excepting deeper depressions, had seasonal or semipermanent water regimes. Vegetation in floodplain wetlands reflects water duration. Annual and perennial herbaceous plants occur at higher edges and more water tolerant emergentsoccur in deeper depressions. During wet periods with extended flooding, many aquatic-dependent birds, mammals, and amphibians use floodplain wetlands and many waterbirds nest in or near these wetlands. However, in most years few waterbirds nested successfully and most waterbird use occurs in fall and spring. Several native fish species historically moved into floodplain wetlands on the ascending limb of flood pulses and used resources for reproduction and survival depending on the species. Analyses of long-term river level data suggests that year-long inundation of at least some of the deeper depressions in at least Woods and Johnson bottoms historically occurred about every 5-7 years.

Perhaps the most basic and important alteration to the Ouray NWR ecosystem, since the refuge was established, has been the marked reduction in the frequency, magnitude, and duration of flooding from the Green River after Flaming Gorge Reservoir was built and its dam closed in November 1962. Mean annual peak flow in the Green River at Jensen, Utah immediately upstream of Ouray NWR decreased from 24,000 cfs prior to 1963 to 17,400 cfs after 1963. The total amount of water released from Flaming Gorge Reservoir is not different now from total annual discharges prior to closure of the dam, but the timing is altered such that spring flood peaks now are lower, shorter duration, and less frequent. Historic flows that would result in 2, 5, and 10-year flood recurrences at Ouray NWR now have been reduced 26%, 19%, and 13%, respectively, from the period prior to dam closure. The mean peak flow of 24,000 cfs prior to dam closure occurred about every 2.4 years, now that same flow occurs on average every 8+ years. The mean peak of 24,000 cfs historically was exceeded about 5 days/year. Now, that same discharge is equaled or exceeded only about 1 day/year. Prior to 1963, some overbank flooding of floodplain bottoms on Ouray NWR occurred almost every year; now substantial overbank flooding occurs only about 2 of every 5 years.

Local topography and hydrology on Ouray NWR also has been altered from the construction of roads, levees, water-control structures, spillways, ditches, and facilities of the Ouray National Fish Hatchery. Each floodplain bottom, except for Wyasket Bottom, has extensive levees, ditches, and water-control structures that have altered water permanence, entry and exit points for Green River flood flows, and vegetation composition and system processes. Many impounded floodplain wetlands have been managed for more permanent water regimes than historically occurred and created monotypic stands of emergent vegetation and reduced seasonally-flooded habitats needed, and used, by migrant waterbirds. Exterior levees have altered and reduced flood frequency from the Green River and changed deposition and scouring processes and allowed invasive species to increase.

Despite significant alterations to the Ouray NWR ecosystem, many areas retain at least parts of historic community structure and ecological processes. Floodplain wetlands comprise the largest, but also most altered, habitat type on Ouray NWR and restoration will require that each bottom be carefully evaluated to: 1) understand geomorphic surfaces; 2) realistically assess opportunities to emulate ecological processes especially flooding frequency, duration, and extent; and 3) determine relative costs and benefits of management actions. We offer certain ecological principles that can help guide decisions and restoration activities including: 1) what is the appropriate conservation objective for each area and habitat type, 2) how to restore both structure and function of wetlands, 3) restoring like-for-like habitats where degradations have been severe, 4) reconnecting the Green River to Ouray NWR floodplains, and 5) designing practical infrastructure that can reduce management intensity and cost.

Important general goals for habitat restoration on Ouray NWR are to: 1) maintain a complex of habitat types that match historic distribution related to soils, geomorphic surfaces, topography, and hydrological regime; 2) improve the connectivity between the Green River and floodplain wetlands; 3) emulate natural hydrological regimes where possible; 4) enhance riparian woodlands to provide a corridor of cottonwood-dominated forest along the Green River; and 5) enlarge the size of habitat "patches" where possible and reduce compartmentalization and/or restrictions to surface water flows into and across floodplains.

Upland areas are the most intact habitats on Ouray NWR and should be protected from further development or disturbance. Alkali flats also need protection from development and unnecessary roads and ditches should be removed to improve surface water sheetflow across these flats. Improved frequency of overbank flooding is needed to improve regeneration of cottonwood in riparian areas. Existing areas of cottonwood should be protected and mechanical soil disturbance on point bar ridges in Sheppard and Leota bottoms should be evaluated to stimulate cottonwood germination.

Wyasket Bottom is the least disturbed of floodplain bottoms on Ouray NWR and its topography and water flow patterns should be protected by eliminating roads and ditches where possible and restricting further development. All levees and water-control structures in the old Wyasket Pond area should be removed to restore ridge-and-swale topography, and the inlet structure and ditch that provided water to Wyasket Pond at flows of > 4000 cfs should be abandoned.

Slow backwater flooding of Johnson Bottom should be promoted by widening the current 200 foot breach and constructing at least one additional breach; breaches should not be constructed at the upstream end of Johnson Bottom. Water regimes in Johnson Bottom should be managed for regular seasonal and annual drying; it should not be continuously flooded for >2-3 years.

The upstream inlet and interior drain canals in Woods Bottom are in unnatural locations and costly to maintain. The inlet structure can be retained to provide management flexibility, however, the interior drains should be filled. All interior levees in Woods Bottom should be removed to facilitate sheetflow of water across this floodplain wetland. A new levee breach at least 400 foot wide should be constructed at the southern part of the Main Unit of Woods Bottom. Water regimes in Woods Bottom should be managed for long-term dynamics, and not continuously flooded for > 2-3 years.

Leota Bottom is the most modified of Ouray NWR floodplain areas and future management should seek to simultaneously enhance backwater flooding, reduce constrictions or diversions of flood water across the bottom, and maintain many units in intensive seasonally-flooded wetland management. Levees along the river-side of Leota Bottom and cross levees that impede sheetflow of water across Leota should be removed. The levee breach at L7A should be widened and armored. Levee breaches should not be constructed at point bar locations at the upper parts of Leota in L1, L2, and L3. Areas > 4663 feet elevation should be managed for riparian woodlands. Low elevations in L3, L5, and L7/L7A should be managed as semipermanent wetlands. L4, L6, L8, L9, and L10 should be managed as seasonal wetlands with shorter duration flooding regimes.

In Sheppard Bottom the drain canal in S3 should be isolated from the floodplain. As with other floodplain bottoms, levee breaches should not be constructed at the upstream ends of Sheppard Bottom; the more natural breach site is on the south side of S1. S1, S2, and S4 should be managed as a complex of seasonal and semipermanent wetlands. Higher elevations can be managed as riparian woodland, and crop fields should continue to be provided for predictable forage for geese, sandhill cranes, and ungulates. The Parker impoundments should be managed as seasonally flooded units to produce herbaceous vegetation and moist-soil foods.

Habitat restoration projects on Ouray NWR should be accompanied by an active monitoring and evaluation program. At Ouray NWR, 4 restoration and management issues have considerable uncertainty and will require careful evaluation; they include: 1) long-term impacts of levee breaches, 2) mechanical disturbance to increase cottonwood germination and survival, 3) intensive management of wetland impoundments, and 4) location and degree of subsurface groundwater connection between the Green River and floodplain wetlands.

INTRODUCTION

Ouray NWR contains 11,987 acres of riparian woodlands, floodplain wetlands, upland grasslands, and shrublands bordering 16 miles of the Green River in northeastern Utah (Fig. 1). The refuge was established in 1960 with an original purpose to provide breeding, resting, and feeding areas for migratory waterfowl in the Green River corridor. Most (5,032 acres) land in the refuge is owned in fee title by the U.S. Fish and Wildlife Service (USFWS) and was purchased using Duck Stamp funds. Other lands in the refuge include 3,110 acres transferred to the USFWS by the Bureau of Land Management (BLM), 2,692 acres leased from the Ute tribe, and 1,153 acres leased from the state of Utah (Fig. 2). The majority of the refuge consists of a series of floodplain bottoms that adjoin the Green River behind channel bends (Fig. 3).

Located in the Uinta Basin of Utah, the Green River and its floodplain at Ouray is a relatively wide, low gradient, sand bed system that has cut meandering channels through the soft Uinta geological formation. A complex of alluvial-derived geomorphic surfaces are present in this stretch of the Green River and includes point bars, natural levees, floodplain terraces, backswamps, older abandoned channels, and the active channel of the river. Historic alluvial processes created a heterogenous distribution of topography, soils, and hydrological regimes on Ouray NWR that support a diversity of habitats. Riparian and floodplain wetland habitats such as those found at Ouray NWR are relatively rare and decreasing throughout the Intermountain West. These remnant habitats are critical to supporting a rich diversity of endemic plant and animal species (e.g., Knopf et al. 1988).

Many alterations to the physical structure and ecological processes of the Green River ecosystem have occurred since Ouray NWR was established. Most significantly, the hydrology of the Green River was greatly altered after Flaming Gorge Reservoir was built upstream on the Green River. Flood frequency, duration, peak and base flows, sediment loading, and channel dynamics of the Green River were changed after Flaming Gorge Dam was closed in 1962 and these changes have affected vegetation distribution, nutrient flow, and animal populations on Ouray NWR. Other major changes to the refuge since its establishment include extensive construction of levees, ditches, and water control

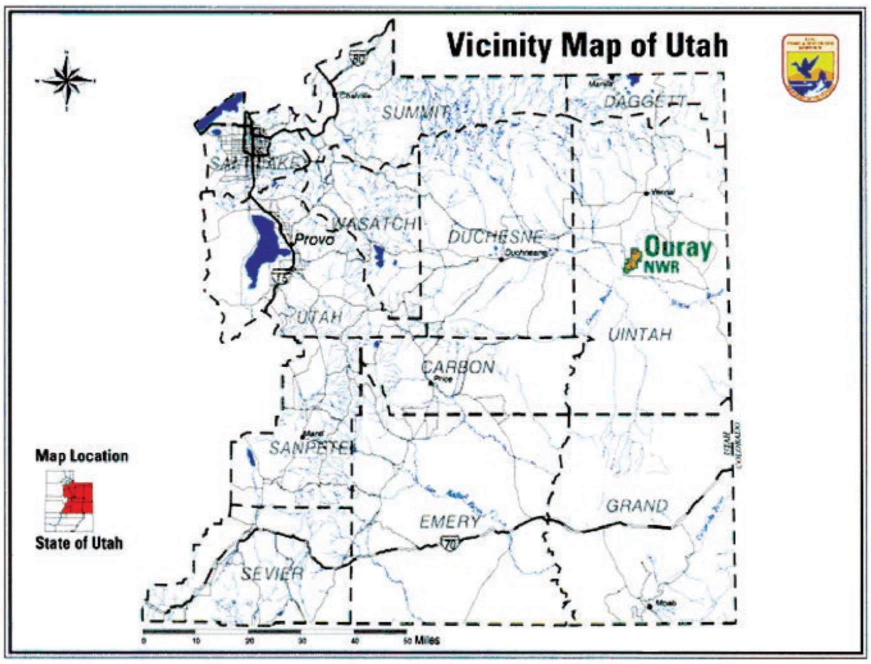

Figure 1. Location of Ouray National Wildlife Refuge, Utah.

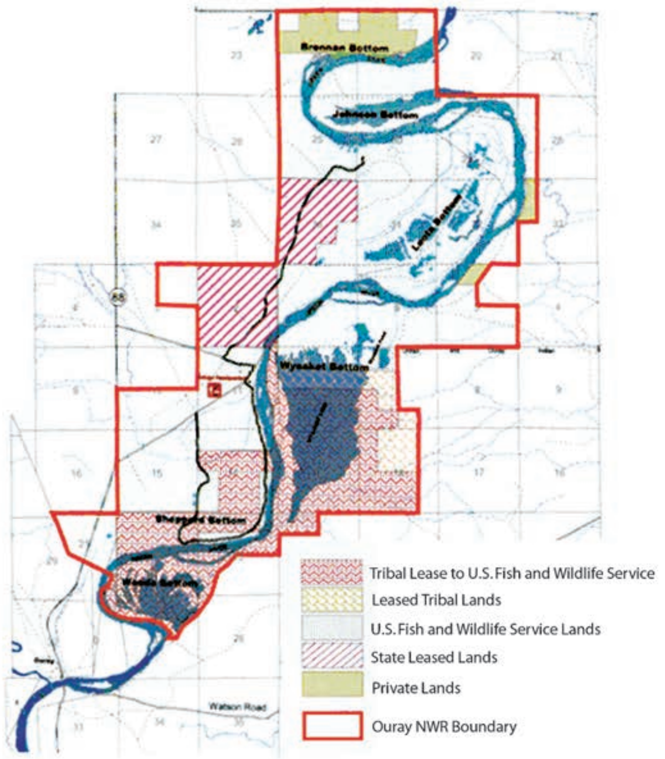

Figure 2. Ownership of lands within Ouray National Wildlife Refuge, Utah.

structures; invasion of exotic plants and animals; contamination from selenium in irrigation water draining onto the refuge; and declining populations of many rare, threatened, and endangered animal species.

A primary challenge for future management of Ouray NWR is understanding how the Green River floodplain ecosystem can sustain historic ecological functions and values given its highly modified landscape and hydrologic regime. Integrating habitat restoration projects on Ouray NWR in the mix of sometimes competing objectives requires that restoration projects be "system-based", and strategically located, to emulate natural distribution of habitats in relation to geomorphic setting, topography, and hydrologic condition (e.g., Heitmeyer et al. 2002). Options for restoration projects on Ouray NWR must be carefully evaluated to identify the most economically and ecologically feasible opportunities that can reduce certain problems (e.g., invasive species) while simultaneously restoring at least some elements of ecosystem integrity and sustainability (e.g., overbank flooding into floodplain bottoms) within constraints of past degradations.

This report provides an analyses of options for restoring and managing native ecosystems and habitats at Ouray NWR. Objectives were to:

1. Synthesize information on the geologic formations, geomorphic features, hydrologic condition, and natural history of the Green River ecosystem in the vicinity of Ouray NWR.
2. Idenfity how the structure and function of the Green River ecosystem at Ouray NWR have been altered.
3. Idenfity restoration approaches and ecological attributes needed to restore and manage specific habitats and ecological conditions on Ouray NWR.

For purposes of this report, we use the period prior to construction and closure of Flaming Gorge Reservoir in the mid-1900s as the benchmark to determine what ecosystem elements should be restored to if possible. We use this benchmark time because in the mid-1900s the Green River was relatively unaltered by upstream reservoirs and water use, exotic plants and animals were not abundant in Green River floodplains, and agricultural production on Ouray NWR was limited.

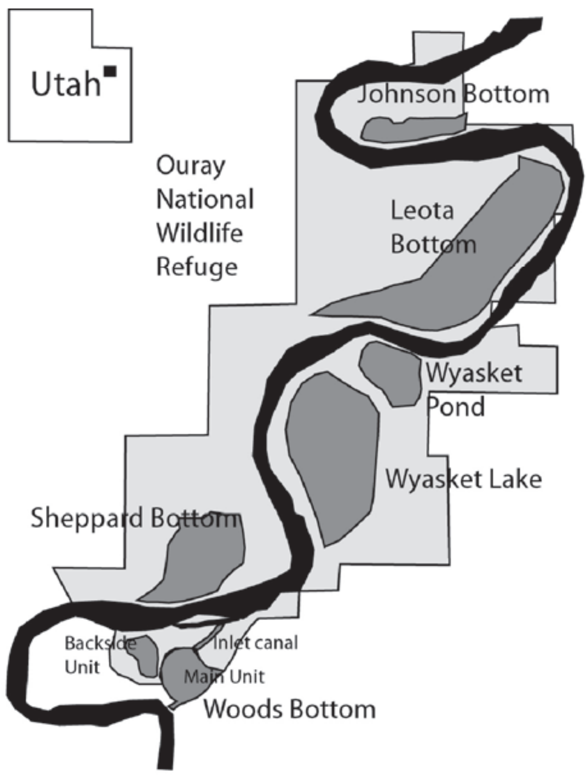

Figure 3. Floodplain "bottoms" on Ouray National Wildlife Refuge, Utah.

HISTORIC CONDITIONS AND PROCESSES

GEOLOGY

Ouray NWR is located within the Uinta Basin of northeastern Utah. The modern day Green River flows approximately 730 miles from its headwaters in the Wind River Range in Wyoming to its confluence with the Colorado River (Woolley 1930). The path of the river is a result of geologic processes that began 2.5 billion years ago; most of the present day landscape and course of the Green River at Ouray NWR is a result of processes that began during the Tertiary period beginning about 65 million years ago. During the Tertiary period the Rocky Mountains including the Uinta Mountains were formed by tectonic uplifting and coincided with downwarping of adjacent asymmetrical synclinal basins such as the Uinta Basin. The Uinta Basin subsided in its interior and is bounded to the north by the east-west trending Uinta Mountains, to the south by the Tavaputs Plateau, to the east by a high area in Colorado around Douglas Creek, and to the west by the Wasatch Mountains (Baker et al. 1949). This region is connected hydrologically within the Colorado Drainage, which is an open system allowing water to flow from the basin to the Pacific Ocean (Welsch et al. 1987).

Material eroded from the Uinta Mountains has been deposited in the Uinta Basin (Osmond 1964, Hintz 1988) and the area included in the Uinta Basin is determined by the presence of these underlying Tertiary sediments (Marsell 1964) which are approximately 10,000 feet thick in some locations (Baker et al. 1949). Sediment deposition in the Uinta Basin continued throughout the Tertiary period and includes the Green River, Unita, Duchesne River, and Browns Park depositional formations. The Uinta Basin sits on past geological structures such as the stable shelf east of the Wasatch Line created during the Paleozoic period (Osmond 1964).

The Uinta Formation is comprised of interbedded sandstones, mudstones, siltstones, and bedded calcareous shale of fluviatile origin and is approximately 5,000 feet thick in the center of the Uinta Basin (Unterman and Unterman 1964, Glover 1996). The Duchesne River and Green River Formations lie above and below the Uinta Formation, respectively. The Duchesne River Formation, which is about 3,000 feet thick in the center, was created during the lower Oligocene and is comprised mostly of red-shale, sandstones, siltstone and some conglomerates of fluvial origin that came from the Uinta Mountains (Glover 1996). Depositions occurred as rivers, including the Green River, meandered across floodplains creating discontinuous sand lenses and alternating beds of sandstones, mudstone, shale, and siltstones (Williams 1950). These depositions underlie Ouray NWR floodplains.

During the Ice Age of the Pleistocene, glaciers and ice streams formed in the Uinta Mountains and influenced landscapes and current courses of rivers including the Green River. During the post-lower Pliocene a major tectonic event produced faulting and tilting which collapsed the eastern Uinta Mountain area arch and set a new course for the Green River (Marsell 1964) over the Colorado Plateau (Hunt 1969). This new course superimposed the Green River on the Browns Park Formation (derived from Uinta Mountain quartzite, limestones, and sandstones and some volcanic tuff and chert [Atwood 1909]). Continued uplifting and easily eroded materials along fault lines dramatically influenced the course of the Green River (Atwood 1909, Hunt 1969). These events suggest that the Green River is “antecedent” where a river is formed after a consequent river drainage has been folded or displaced.

The above geologic events and processes, and more recent Holocene river dynamics of deposition and scouring, have formed soils and topography at

Ouray NWR. Elevations on Ouray NWR range from 1417 m in river bottoms to 1546 m on bluffs (USFWS 2000). Currently, 18 soil types are mapped on Ouray and vary depending on parent material, slope, and juxtaposition to the Green River (Table 1, Fig. 4).

The pinkish rocks that form bluffs along the Green River at Ouray NWR are from the Uinta Formation and include cross-bedded sandstone, conglomerate and unconsolidated siltstone and mudstone layers. The siltstone and mudstone layers are easily eroded. Cobbles and gravel on top of bluffs were transported to the area by ancient streams from the Uinta Mountains mainly in the Pleistocene (Goodknight and Ertel 1987). The clay bluffs on benches adjacent to the Green River floodplain at Ouray are Morrison Formation deposits formed during the Jurassic period. Soils on upland benches, terraces, and bluffs were derived from a range of parent materials including sedimentary, metamorphic, and igneous rocks and include Badland and Greybull-Utaline rock outcrop complexes and Nakoy loamy fine sands (Fig. 4, Table 1).

Alluvial fans and terraces comprised of eroded materials from surrounding benches are dominant within the low-lying areas of the Uinta Basin and are located between bluffs and the recent alluvial floodplain of the Green River (Untermann and Untermann 1964). Remnant fans typically have 2-8% slopes and include Blackstone loam and Utaline sandy loam soils (Table 1). Sites immediately adjacent to active floodplains are relatively flat (0-2% slopes) and include desert sandy loams and alkali flat soils such as Shotnick and Turzo loams (Table 1).

The Green River has cut a series of meander loops through the Uinta Formation where it leaves the Mesa Verde Formation south of Highway 40 to its confluence with the Duchesne River. In this stretch, a series of old river terraces occur where former floodplains marked the advance and retreat of glaciers during the Pleistocene (Chronic 1990). Soils in Green River floodplains are primarily alluvium, slope alluvium, and some Eolian deposits. Green River floodplain soils range from clay loams to fine sands depending on position relative to the current and past river channels and subsequent geomorphic surfaces and include Green River and Wyasket loams in floodplains and riverwash sands on river bars and banks.

Table 1. Primary soil types on Ouray National Wildlife Refuge, Utah

Soil Type	Location	Ecological site	Native vegetation
Badland-Rock Outcrop	Upland bluffs	Desert	
Blackstone Loam	Fan remnant	Desert Loam	Indian rice grass, saltbush, sage brush, winterfat
Green River Loam	Floodplain	Stream bank, alkali bottom	Alkali sacaton, greasewood, sandbar willow, cottonwood
Greybull-Utaline Badland Complex	Upland Benches	Desert	Wheatgrass, saltbrush
Jenrid sandy loam	Floodplain	Old Point bar	Sandbar willow, greasewood, cottonwood
Nakoy loam fine sand	Upland benches	Semi-desert	Wheatgrass, saltbrush
Ohtog-Parohtog Complex	Alluvial flat	Loamy bottom	Wild rye, wheat grass, rabbit brush
Riverwash	Floodplain	River bars	Sandbar willow
Shotnick loamy sand	Alluvial flat	Desert sandy loam	Gelletz, saltbush, globemallow
Shotnick-Walkup Complex	Alluvial flat	Desert sandy loam	Ricegrass, saltbush, Torrey's joint fir
Stygee clay/silty clay	Alluvial flat	Alkali flat	Greasewood, alkali sacaton, bottlebrush
Tipperary Loam	Upland benches	Semi- desert	Wheatgrass, saltbush
Turzo Loam	Alluvial flat	Alkali flat	Alkali sacaton, greasewood
Utaline sandy Loam	Fan remnant	Desert loam	Saltbrush, wheatgrass

GREEN RIVER GEOMORPHOLOGY

The Green River at Ouray NWR is a typical sand-bed (Rosgen 1994) system and has a mild river slope of about 1.2 feet fall/mile and a channel sinuosity of 1.7 (Fig. 5, FLO Engineering, Inc. 1996). The river has a broad valley bottom and wide floodplain where it has eroded the relatively "soft" Uinta Formation. This contrasts to the steep river slopes and narrow floodplain in the canyon reaches upstream in the Mesa Verde Formation and downstream canyonlands as the Green approaches the Colorado River (Fig. 5). The Green River at Ouray NWR is self-formed and has a "cropped" meander pattern that is restricted by resistant bedrock deposits of Pleistocene age. This bedrock influences the width of the meander belt but does not confine individual meanders within the current floodplain belt. Contact of the river with the bedrock controls slope, constrictions, erosion on outside bends of the river, and channel incision. Where the river contacts bedrock on the outside of meander bends, the river current is directed downward and creates a deep thalweg that scours the river channel during high flows and then subsequently partly refills with sediment during low flow. This action creates incised "ingrown bends" that tend to hold the position of the river at a location and limit the opportunity for the river to migrate across the floodplain. During the last 70 years, channel migration of the Green River has apparently been very limited in the vicinity of Ouray NWR (Jurado and Fields 1978, Andrews and Nelson 1989) and meander patterns may have been close to the present location for considerable time.

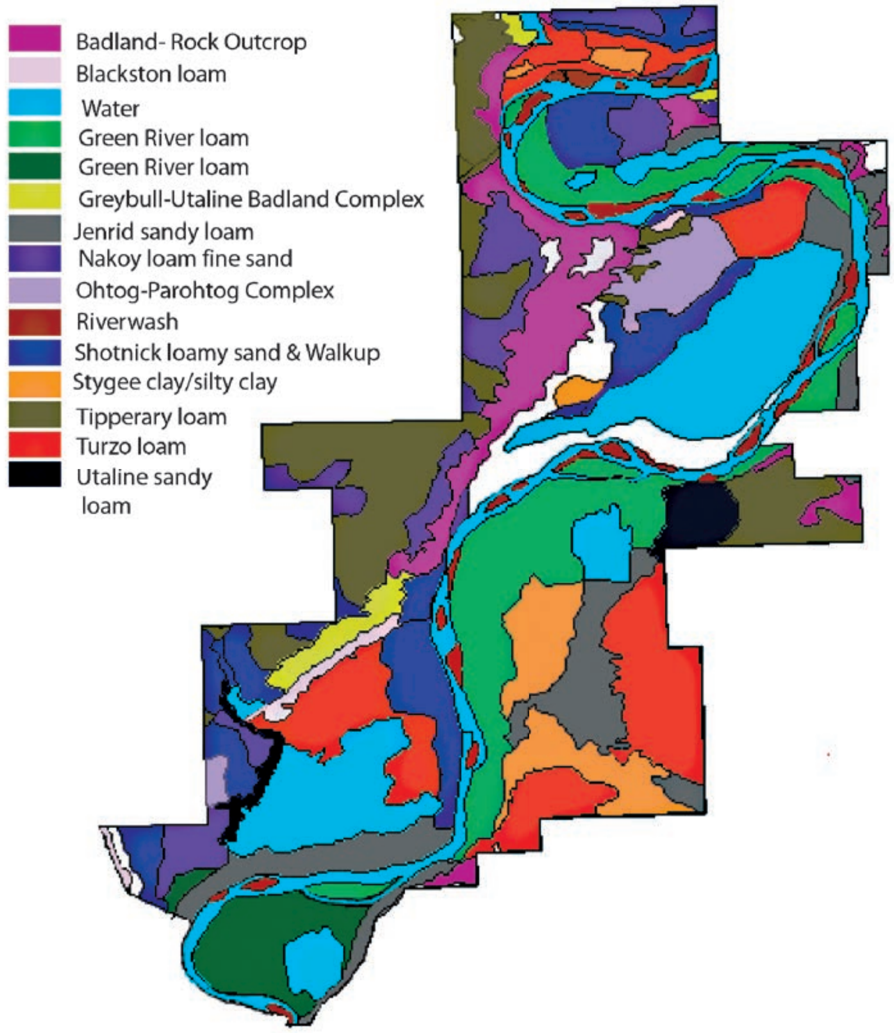

Figure 4. Soils on Ouray National Wildlife Refuge, Utah.

Channel dimensions of the Green River depend on discharge which is function of watershed size and type, sediment type, bank characteristics (such as above mentioned bedrock), and energy dissipated by the stream in transporting sediment. Sediments in the Green River at Ouray NWR originate primarily from the Upper Green and Yampa Rivers and the Uinta Basin itself. In addition to having limited channel migration, the Green River at Ouray NWR also appears to have had relatively constant bar locations in the last several decades, both before and after closure of Flaming Gorge Reservoir (Andrews and Nelson 1989). Alternating pool/bar configurations (Fig. 6) include both fixed bank and forced

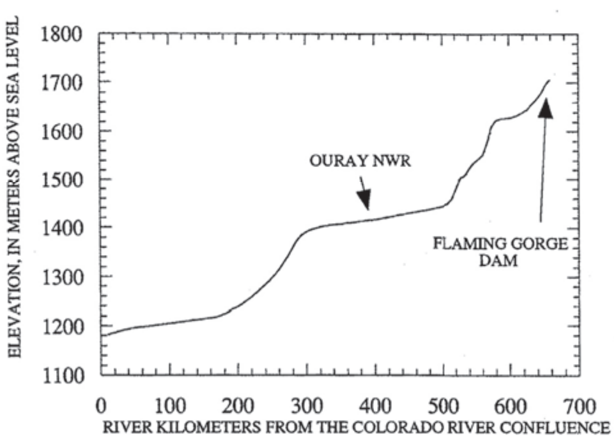

Figure 5. Longitudinal profile of the Green River between Flaming Gorge Reservoir and the confluence with the Colorado River (adapted from Schmidt 1994).

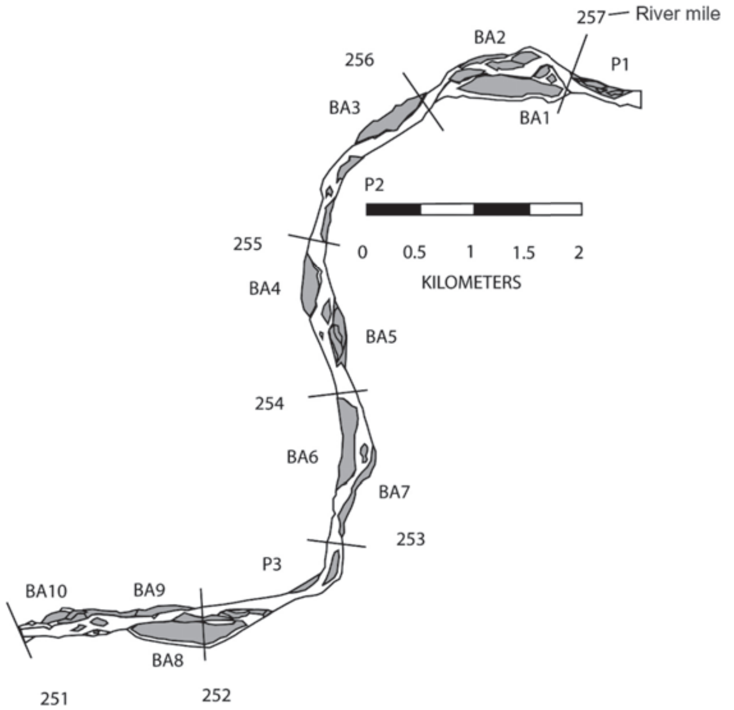

Figure 6. Map of bar locations of the the Green River next to Sheppard and Wyasket Bottoms, Ouray National Wildlife Refuge, Utah.

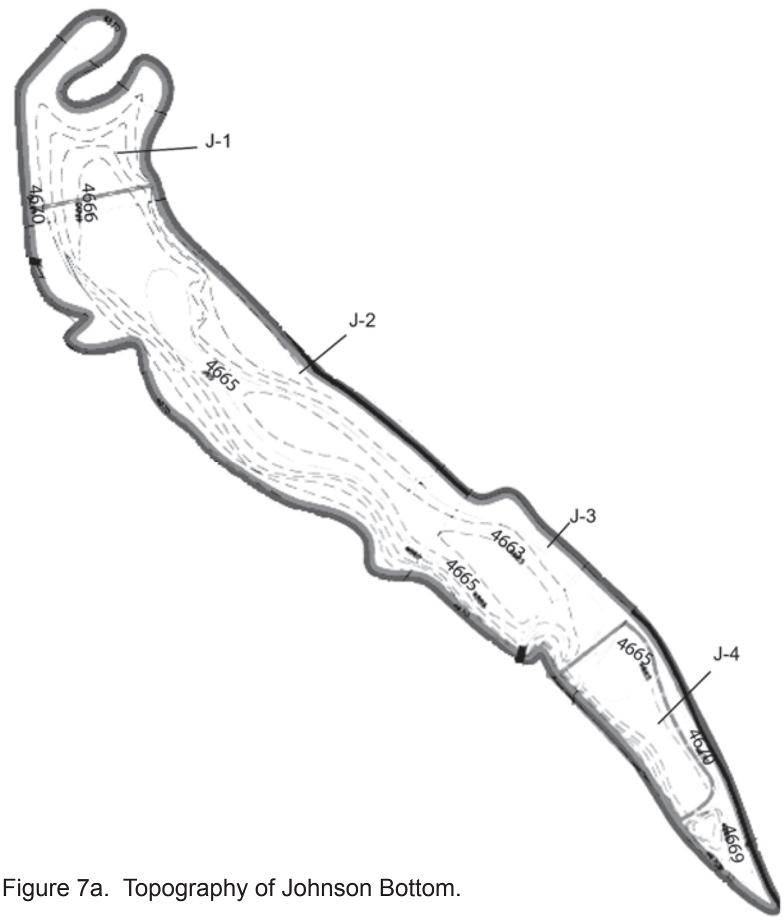

Figure 7a. Topography of Johnson Bottom.

point bars and are products of meandering flow (Ikeda 1989). In general, the Green River at Ouray NWR is, at high flow, a meandering, single-threaded channel between 2 well defined banks; at low flow it is multithreaded with flow divided by emergent midchannel bars (Rakowski 1997).

High magnitude, and highly variable, flood events on the Green River have created a complex of deposition/scour geomorphic surfaces in the Ouray NWR floodplain (see also Andrews 1986, Lyons et al. 1992). Topographic variation (Figs. 7a-e), soil type and distribution (Fig. 4), historic photographs (e.g., Fig. 8), and geomorphological patterns in similar river meander belts (Fig. 9) indicate where surfaces currently are distributed on the refuge (Fig. 10). Active point bars are immediately adjacent to inside bends of the present channel of the Green River and are predominated by sand waves capped by clay drapes (Fig. 11). Sand deposits on point bars increase in depth and width as the river approaches and departs the apex of inside bends. "Ridge-and-swale" topography is located behind active point bars and indicates progressive movement of point bars as the river has gradually moved in the direction of present point bar bends. Swales contain clay bottoms while ridges are predominantly sand. Most swales are < 5 feet lower than ridge tops and suggest relatively moderate dynamics of river movement and scouring/deposition at least in the last few decades.

Natural levees are accreted berms containing silty-clay soils along current and former channels where overbank flows slowed and deposited fine texture sediments. At Ouray NWR, natural levees seldom are more than 2-3 feet higher than river banks (Figs. 7a-e) and further indicate relatively moderate historic high flows of the Green River. Low areas behind natural levees are backswamp deposits containing clayey loams and clays. These backswamp areas represent the primary floodplain wetland "bottoms" on the refuge (Fig. 3). Remnant fans and terraces of eroded bluff material adjoin backswamps on upland sides of backswamps. Few

Figure 7b. topography of Leota Bottom.

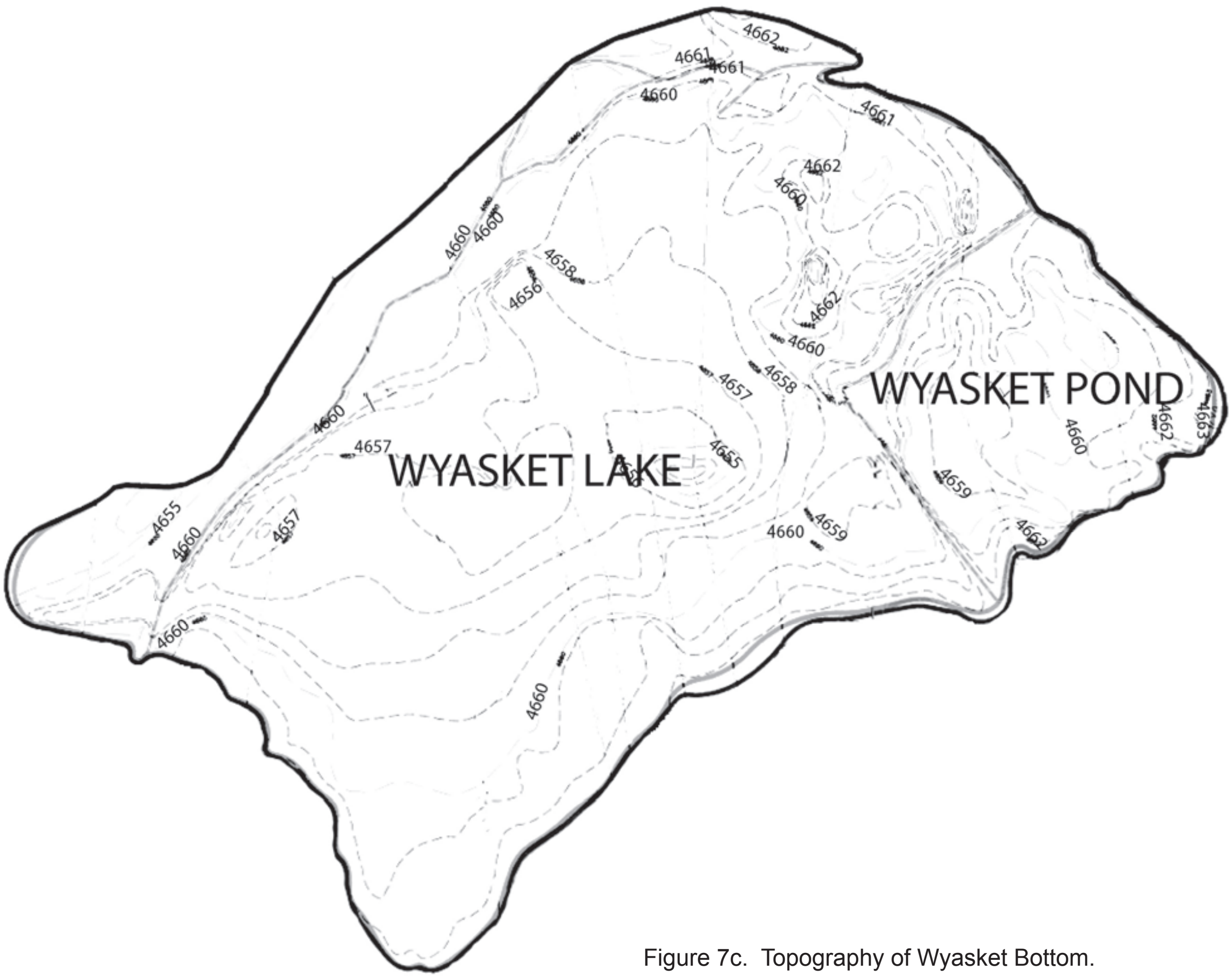

Figure 7c. Topography of Wyasket Bottom.

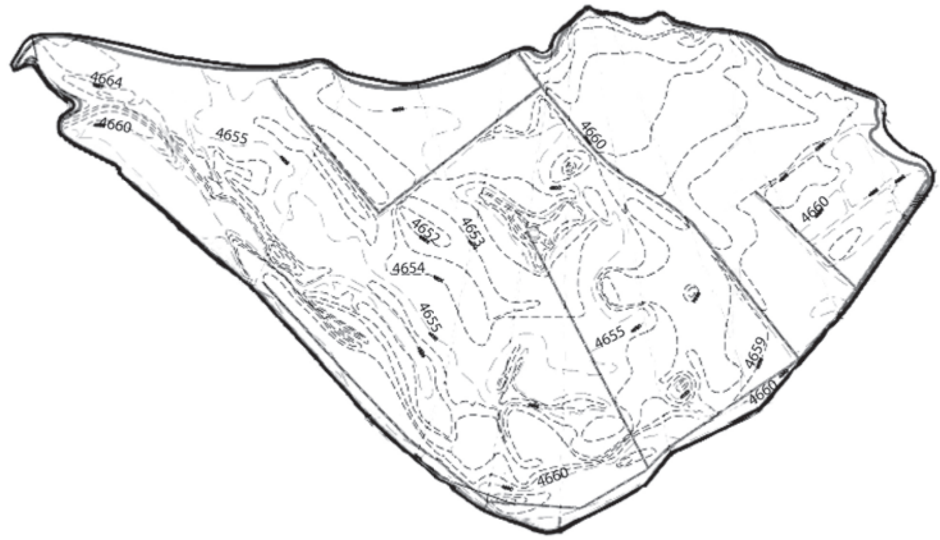

Figure 7e. Topography of Woods Bottom.

abandoned channels of the Green River are present on Ouray but many flow paths of recent flood events are evident as slight depression corridors across backswamp areas (Fig. 8). Collectively, the narrow width and shallow undulation of point bar ridge-and-swales, low natural levees, moderate flow paths across backswamp deposits, and few old abandoned channels suggest that the Green River at Ouray NWR has not experienced extremely high velocity flows, nor substantially changed its channel and bank configurations in the last several millennia.

OURAY CLIMATE AND GREEN RIVER HYDROLOGY

The southeastern Uinta Basin where Ouray NWR is located has a semiarid to arid continental climate. Days have wide variation in high and low temperatures and seasons are well defined. Winters are cold, however snowfall is relatively light (Table 2). Summers are mild and dry. The average length of the growing season is 113 days; the average date of the last killing frost in spring is 29 May and the average date of the first killing frost in fall is 19 September. Strong winds in spring and early summer cause high rates of evaporation and rapid drying of soils (Waltemeyer 1982). Likewise, high temperatures, wind, and limited rainfall cause evapotranspiration rates to be high in summer (Thomas 1962).

Because of relatively limited local precipitation and runoff, the hydrology of the Green River is controlled by spring snowmelt in the Rocky Mountains of Wyoming, Colorado, and Utah. Principal tributaries of the Green River near Ouray NWR include the Little Snake, Yampa, and White rivers in Colorado; Blacks Fork and Little Snake in Wyoming; and Duchesne, Price, and San Rafael rivers in Utah. Most of the water in the Green River at Ouray NWR originates in mountainous headwater regions, whereas most of the sediment is contributed by lower elevation semiarid regions, especially the Yampa River (Iorns et al. 1965). Snow melt and river flows in the Yampa

Table 2. Mean temperature and precipitation at Fort Duchesne, Uinta County, Utah.

Month	Temperature (ºF)	Precipitation (inches)
Jan	13.3	0.46
Feb	20.8	0.39
Mar	35.5	0.56
Apr	48.0	0.62
May	55.6	0.70
Jun	64.0	0.46
Jul	71.9	0.51
Aug	69.9	0.67
Sep	61.0	0.98
Oct	48.0	0.79
Nov	33.6	0.39
Dec	20.1	0.49

are earlier and of shorter duration (flashier) than the later more sustained flows from the Upper Green River watershed.

Annual discharge and peak yearly flows in the Green River are highly variable (Figs. 12, 13). Mean annual discharge of the Green River at Jensen, Utah about 37 miles upstream from Ouray NWR (arithmetic mean of all mean daily discharges) was 4360 cubic feet/second (cfs) from 1947 to 1962, prior to when Flaming Gorge Dam was closed. Historically, the Green River at Ouray began to rise in March, had a mean annual peak flow in late May (27 May for the 51 years of record at Jensen, UT), and declined significantly in July (Fig. 12). Prior to 1963, peak annual discharge at Jensen averaged 24,000 cfs and ranged from ca. 8000 cfs to 37,000 cfs among years. During the last 100 years, only 5 peak annual flows have occurred outside the months of May and June. One of these peaks occurred in February 1962, 1 in July 1959, and the other 3 peaks were in March and April. Generally, the higher the peak discharge, the later in the season the peak occurs. Base flows in the Green River at Ouray occur from September through March. At Jensen, UT the base flow from 1947 to 1963 was 1260 cfs. The historic ratio of mean peak discharge to mean base flow was 19.7 at the Jensen gage.

Figure 8. 1963 aerial photograph of Leota and Johnson Bottoms on Ouray National Wildlife Refuge, Utah.

The frequency of historic flows of the Green River at Jensen, UT varied from an almost annual return interval (1.01 with a probability of 0.99) of 7600 cfs to a 500-year flood event frequency at 48,300 cfs (Table 3). The historic mean annual peak discharge of 24,000 cfs occurred at a frequency of about 2.3 years with an annual probability of 0.43. From 1923-1962, the recurrence intervals of 1.25, 2, 5, and 10 years were associated with flows of 15,764 cfs, 21,967 cfs, 27,952 cfs, and 30,707 cfs, respectively (Table 4, Fig. 14). Flow duration curves of the Green River at Jensen, UT (Fig. 15) allow the average annual flow duration (days/yr) for discharges to be computed by multiplying the corresponding % exceedance from the duration curve (Fig. 15) by 365 days (FLO Engineering, Inc. 1996). Using this calculation, the mean annual discharge of 24,000 cfs historically was equaled or exceeded 1.3% of the time (about 5 days/yr). The duration of the pre-1963 base flow of 1260 at the Jensen gage was equaled or exceeded about 68% of the time.

Table 3. Green River flood frequency at Jensen, Utah prior to, and after, closure of Flaming Gorge Dam.

		Jensen Gage (cubic feet/second)	
Return period	Probability	1947-1962[a]	Post -1963
1.01	0.99	7600	5300
1.11	0.90	13800	9700
1.25	0.80	16500	11700
2.00	0.50	22500	16500
2.33	0.43	23900	1700
5.00	0.20	29400	22700
10.00	0.10	33400	26400
25.00	0.04	37700	30900
50.00	0.02	40500	34000
100.00	0.01	43100	37000
250.00	0.004	45500	39900
500.00	0.002	48300	43500
Mean Annual Peak		24000	17400
Mean Annual Flow		4360	4210
Mean Base Flow		1260	2560

[a] Includes 1895-1899 and 1904-1962.

Prior to construction of levees on Ouray NWR and closure of Flaming Gorge Dam, water from the Green River naturally began overtopping banks of the river and extensively flooded floodplain bottoms at Ouray NWR from 14,000 cfs to 18,600 cfs (Table 5). Some small, low areas on natural levees are overtopped at lower flows (the lowest entry elevation shown in Table 5), but areas flooded at these lower flows were small and isolated. Although the floodplain bottoms on Ouray NWR have different sizes and flood frequencies (Tables 5, 6), the recurrence intervals of initial flooding for all bottoms historically was from 1.2 to 1.7 years (Table 3). Johnson and Woods bottoms are smaller than other bottoms on Ouray NWR (FLO Engineering, Inc. 1997) and most areas in these bottoms are quickly filled once Green River flows overtop natural levees. In contrast, the large Wyasket Bottom begins to flood at about 19,000 cfs, but flows >22,000 cfs are required to fill it. Sheppard and Leota bottoms are completely inundated only during very high flood events. From 1947 to 1962, Green River discharges > 13,000 cfs (and thus some overbank flooding at Ouray NWR) occurred in 15 of 16 years and averaged 1.94 flood pulses/year, 37.8 total days of flooding, and 23.4 days/flood pulse (Table 7). At a discharge of 20,300 cfs (considered current "bankfull" discharge at Ouray) historic flows exceeded this level an average of 12 days/year with a return interval of about 2.4 years (FLO Engineering, Inc. 1996).

Historically, the Green River first began to enter floodplain bottoms on Ouray NWR at low elevation sites along natural levees at downstream ends of the bottoms and last at higher elevation point bar surfaces on inside bends of the river (Fig. 16). This pattern of flooding caused most flooding of Ouray NWR bottoms to occur as relatively slow "backwater" floods that entered floodplains at downstream ends of the bottom, usually at sites where fixed bank bars raised river flows. Higher velocity "headwater" floods that caused flood water to flow across bottoms only occurred when discharges were sufficient to rise above point bar elevations and allowed water to flow from upstream to downstream parts of the floodplain bottom. For example, at Leota, slow backwater floods entered the south part of the bottom near L7A (Fig. 7b) at flows of about 13-14,000 cfs at a return interval of about 1.1-1.2 years, whereas headwater floods that overtopped the inside bend point bar at L3 occurred only at flows > 27,000 cfs at a return interval of >5 years.

Backwater floods typically enter and exit floodplains at the

Table 4. Recurrence interval, in years, of peak discharge for the Green River near Jensen, Utah. Discharge in cubic meters/second (cubic feet/second in parentheses) for the periods before (1923 to 1962) and after (1963 to 1993) closure of Flaming Gorge Dam (from Schmidt 1994).

	Recurrence interval (years)			
Year	1.25	2	5	10
1923-1962	446.4 (15764)	622.1 (21967)	791.6 (27952)	896.6 (30707)
1963-1993	326.3 (11521)	463.0 (16347)	640.5 (22617)	753.3 (26598)

same general location and usually deposit fine texture sediments into floodplains; little scouring action occurs except for moderate exit channels. During backwater floods, the depth of water in floodplains is relatively shallow and has a lower hydraulic gradient (head) between the height of the flood water and the elevation of the "in-bank" river channel surface. Consequently, when backwater floods recede, the rate of fall typically is gradual and with a lower head, thus reducing the velocity of water draining from the floodplain bottoms and reducing scouring at exit sites. In contrast to backwater flood events, headwater floods enter at higher elevation upstream locations, exit at lower elevation downstream points, have high velocity flows that scour flow paths across floodplains, deposit coarse sands at high bank entry sites usually on point bars, and have greater depth and hydraulic gradients that cause extensive scouring at exit sites when floodwaters drain from floodplain bottoms. If headwater floods are prolonged and deep, some fine silts are deposited in deeper floodplain locations the farthest distance from higher velocity channel and flow path flows.

All Ouray NWR floodplain bottoms exhibit a similar pattern of floodwater entry and exit. In "S-shaped" meandering sand-based riffle(bar)/pool rivers such as the Green River at Ouray NWR it is typical for overbank flooding to occur first at downstream ends of floodplain bottoms (Fig. 16). These downstream locations usually correspond with gradually decreasing heights of natural levees and where fixed bank bars are present. Consequently,

Table 5. Discharge (cubic feet/second) and elevation (feet above mean sea level) when extensive overbank flooding occurs with no levees present in floodplain bottoms on Ouray National Wildlife Refuge, Utah[a]

Floodplain bottom	Discharge	Flooding elevation (Lowest Entry)	Lowest elevation in bottom
Johnson	18,400	4672 (4668)	4663
Leota	14,000	4666 (4664)	4658
Wyasket	16,000	4661 (4655)	4653
Sheppard	18,500	4660 (4657)	4652
Woods[b]	18,600	4657 (4657)	4650

[a] From FLO Engineering Inc. 1996, 1997.
[b] Excludes the small man-made ditch leading to woods which floods at 13,000 cubic feet/second.

Table 6. Area[a] of inundation versus discharge of floodplain bottoms on Ouray National Wildlife Refuge with levees, based on pre-and post-1963 hydrology[b]

Discharge[c]	Pre – 1963 return[d]	Post – 1963 return	Floodplain bottom				
			Johnson	Leota	Wyasket	Sheppard	Woods
13,000	1.0	1.1	250	-	-	-	350
18,600	1.5	2.6	280	-	500	-	490
20,300	1.9	3.4	300	-	530	245	500
22,700	2.1	5.0	400	775	1854	1400	570
26,400	4.5	10.0	420	1300	1880	1425	583
37,000	50.0	100.0	434	1650	2060	1440	600

[a] Acres.
[b] Modified from FLO Engineering, Inc. 1996.
[c] Cubic feet/second.
[d] In years.

these downstream sites have relatively flat low natural levee elevations and allow flood water to enter floodplains in a wide flow path. River flows accelerate at bends of a river and the increased energy and river current moves downward to scour the thalweg of the outside bend while simultaneously depositing coarse material on the inside of bends. Downward pressure of river flow at bends tends to create bluffs at bends and inhibits upward overbank flow at this location unless very large high velocity flows occur. Simultaneously, deposition of coarse material at the inside bend creates high elevation point bars which are not overtopped unless flows are very high. If high velocity flows occur, water typically crosses point bars first in the narrow "swale" locations and further scours the entry location.

After river flows exit bends of the river channel, the currents slow and move upward, and fine silts and clays are deposited in a gradually decreasing depth on natural river levees and in-channel bars as distance from the bend increases up to a point where flows accelerate at the entry of the next bend. In this flow pattern, the lowest bank location nd upward flow of water typically ccurs on the downstream part of ends on the bank side opposite rom the next bend (where point ar deposits start to accumulate oward the inside bend) (Fig. 16). As discharges increase, river levels ncrease and have multiple entry points into floodplains including ld scoured swales on the higher levation point bars. Often new iver "chutes" and "cutoffs" provide ntry spots at these higher flows nd allow river flow across the floodplain. If flood flows are large nd of high velocity for extended periods, these flow paths across he floodplain may scour shallow hannels or depressions (e.g., Fig.).

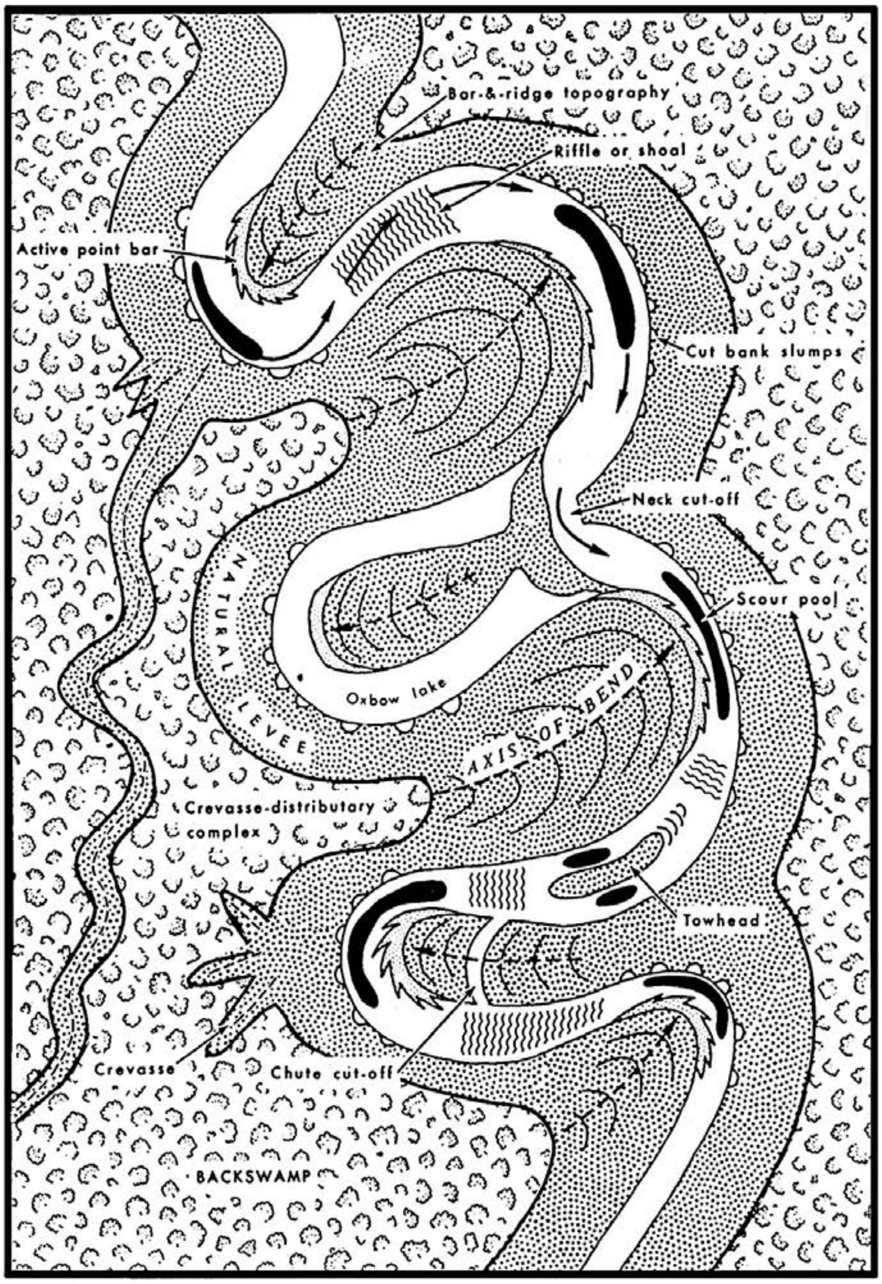

Figure 9. Topographic relationships of Holocene point-bar environments (from Saucier 1994).

Groundwater levels under Ouray NWR floodplains are influnced by geomorphic surfaces, soil ypes, and subsurface connectivity with the Green River. Where oils are relatively porous (coarse exture), groundwater moves etween floodplain soils and the Green River and consequently, roundwater, and perhaps even ome surface, water tables are nfluenced by stage of Green River flows. The degree and location of ubsurface connectivity between floodplain wetlands on Ouray NWR and the Green River has not een determined, however sites hat probably have the greatest onnection include sites immeditely behind point bars (Fig. 10)

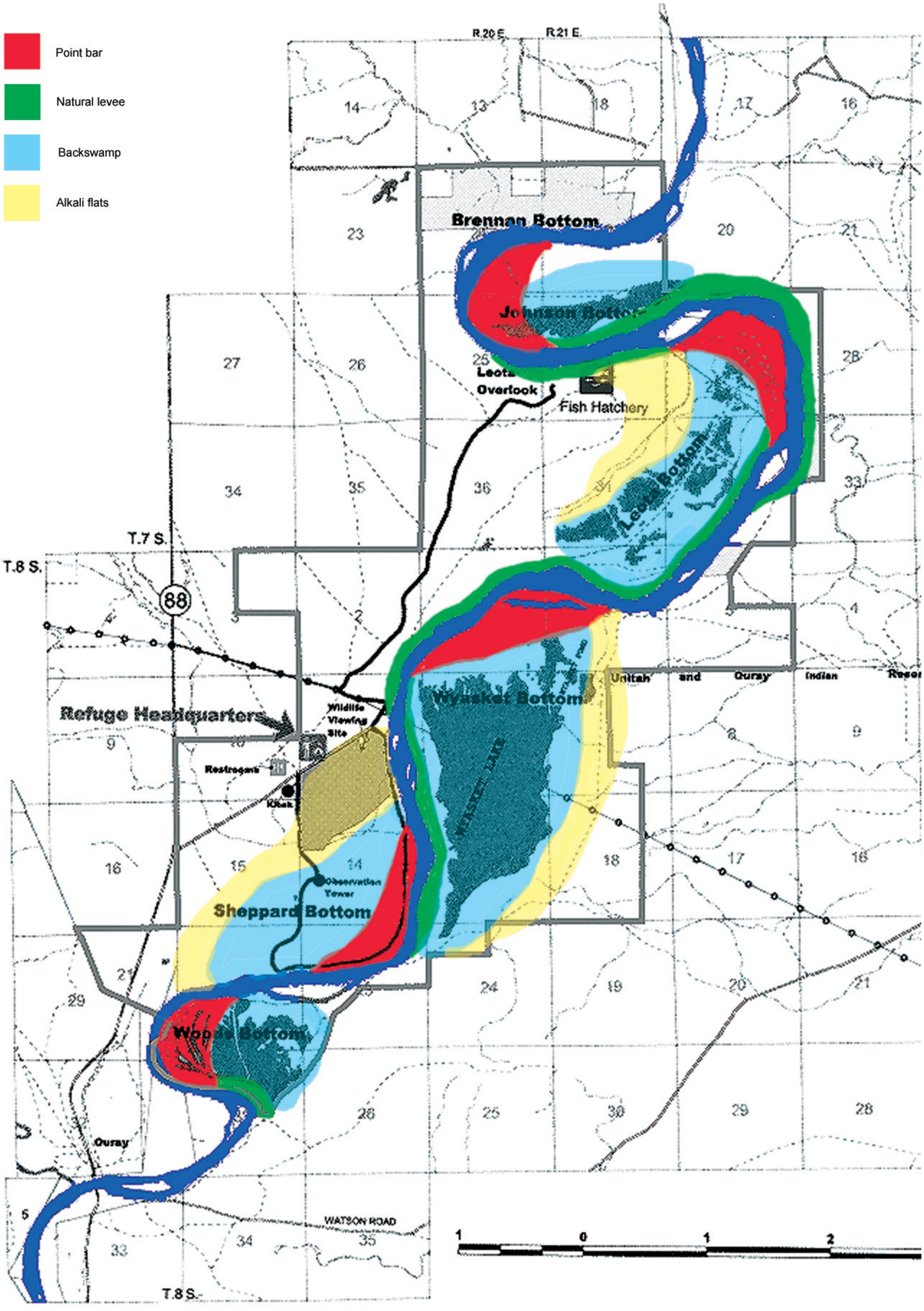

Figure 10. Geomorphic surfaces on Ouray National Wildlife Refuge, Utah.

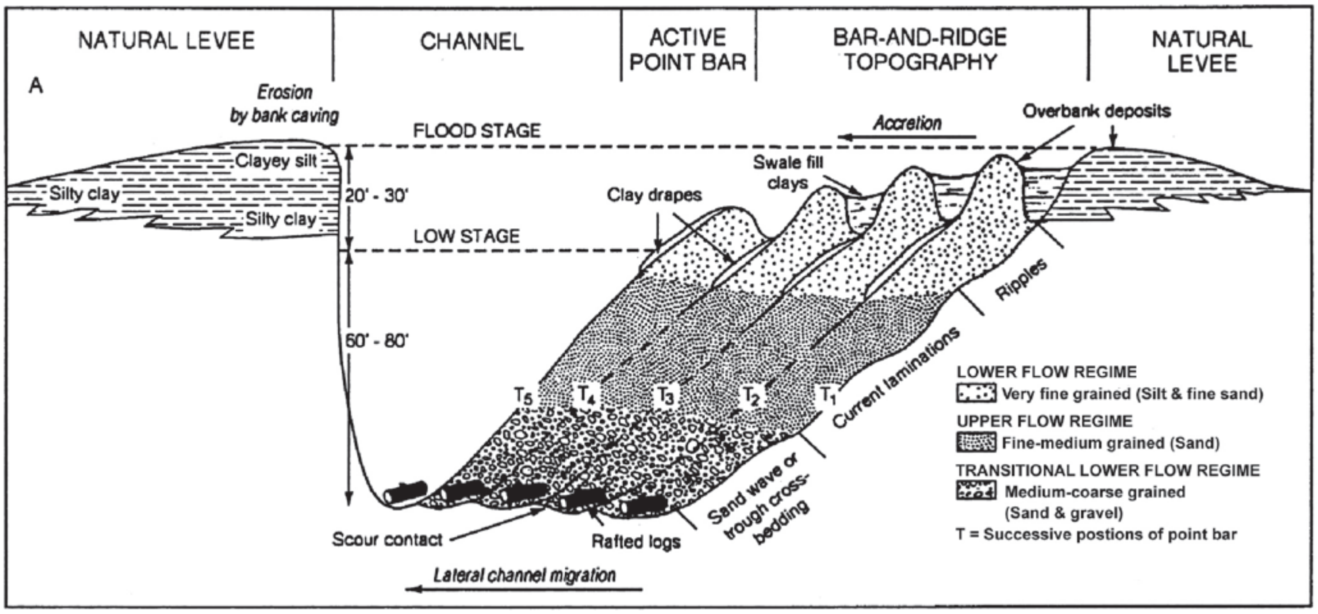

Figure 11. Topographic variation in relation to river processes that create meander belts in large sand bed rivers (from Saucier 1994).

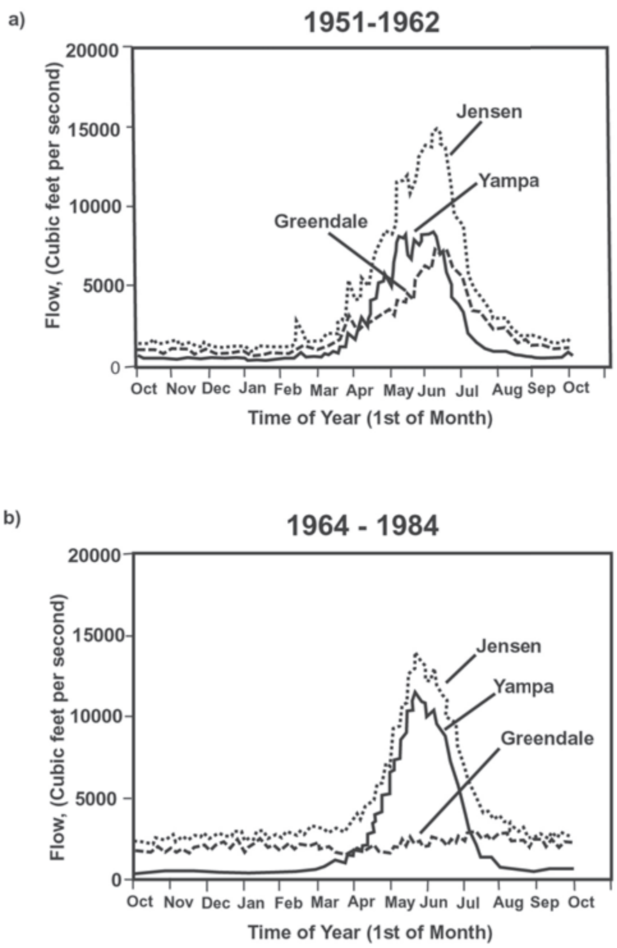

Figure 12. Green River basin flows at 3 gage stations above Ouray National Wildlife Refuge, Utah: a) prior to, and b) after closure of Flaming Gorge Dam in 1963.

where water can move through the sandy point bar areas into and out of backswamp depressions. In these wetland sites, some seasonal surface ponding of water may occur when the Green River is at a high stage, even if the river does not overflow natural levee banks and backflood these areas.

HISTORIC VEGETATION, FISH AND WILDLIFE COMMUNITIES, AND ECOLOGICAL PROCESSES

The types and distribution of historic vegetation communities at Ouray NWR can be determined using a combination of historic and contemporary information. Contemporary vegetation present in relatively unmodified locations of different geomorphological, soil, topography, and flood frequency settings (e.g., USFWS 2000, Crowl and Goeking 2002) provide an initial basis for determining which species typically occur at different sites. For example, cattail is found only on backswamp deposits and swales in point bars, in low elevations typically <4660 feet above mean sea level (amsl), in Green River and Wyasket soils, and in the 1-2 year floodplain. These contemporary data can be compared with historic accounts (e.g., Powell 1875, Dale 1918, Reagan 1934), botanical collections (e.g., Graham 1937), and notes from early soil mapping (Wilson et al. 1959) to confirm and extrapolate historic plant occurrence

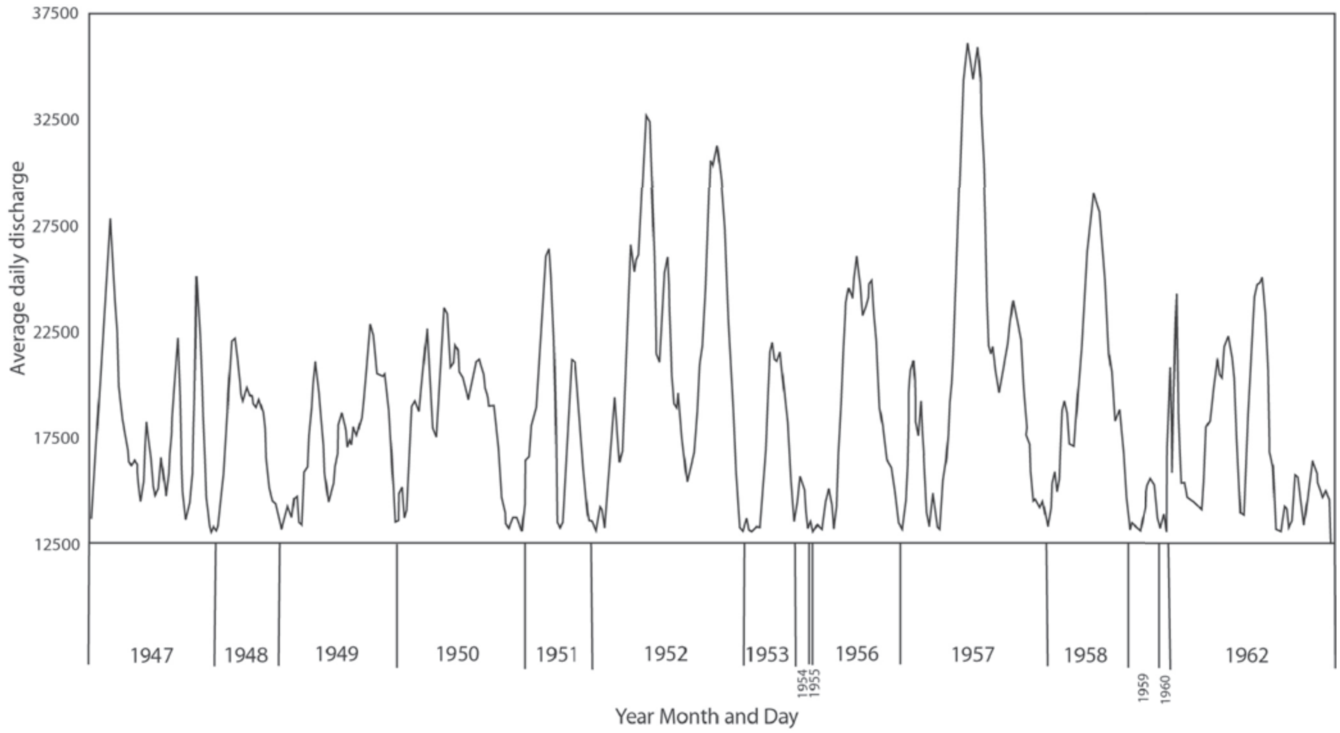

Figure 13. Green River average discharge 1947-1962 at Jensen, Utah.

and distribution. Historic and current surveys of animals associated with different vegetation communities provide a basis for determining species occurrence and resource use among habitat types. Other ecological information identifies the basic ecological processes, both abiotic and biotic, that control these ecosystems. Collectively, historic and contemporary information suggest a gradation of vegetation types and ecological processes from high elevation upland benches to the present river channel at Ouray NWR (Fig. 17).

Upland Grasslands, Clay Bluffs, Semi-Desert Shrublands

The high elevation upland benches formed by the Uinta Formation contain grassland plant and animal communities; low shrubs also are present in many locations and add structural and resource diversity. Soils on upland benches typically are Badland, Rock outcrop, and Cadrina-Casmos types (Table 1, Fig. 17) and support desert-type plant species including wheatgrass, purple three-awn, saltgrass, wildrye, bucksheath, milk vetch, ricegrass, rabbitfoot grass, alkali sacaton, and needle-and-thread grass (Table 8). Horsebrush and tall tumble mustard are common low shrubs. Clay bluffs support almost no vegetation and typically are barren highly dissected and eroded bluffs. Terrace fan remnants

Table 7. Mean number of flood (>13,000 cubic feet second) pulses, number of total days of flooding /year, and mean number of days/flood pulse of the Green River at Jensen, Utah 1947-1962.

Year	# Pulses	Total days	x̄ Days pulses
1947	1	60	60.0
1948	2	32	16.0
1949	3	55	18.3
1950	2	62	31.0
1951	3	32	10.7
1952	2	74	37.0
1953	4	24	6.0
1954	1	7	7.0
1955	1	1	1.0
1956	3	43	14.3
1957	1	75	75.0
1958	1	40	40.0
1959	1	14	14.0
1960	1	4	4.0
1961	0	0	-
1962	5	81	16.2
x̄ Total	1.94	37.8	23.4

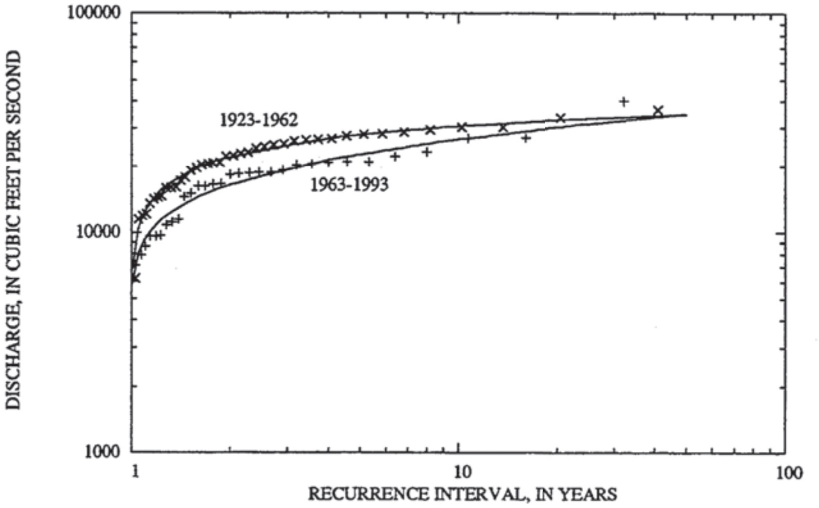

Figure 14. Recurrence interval of instantaneous peak flow for the Green River near Jensen, Utah (from Schmidt 1994).

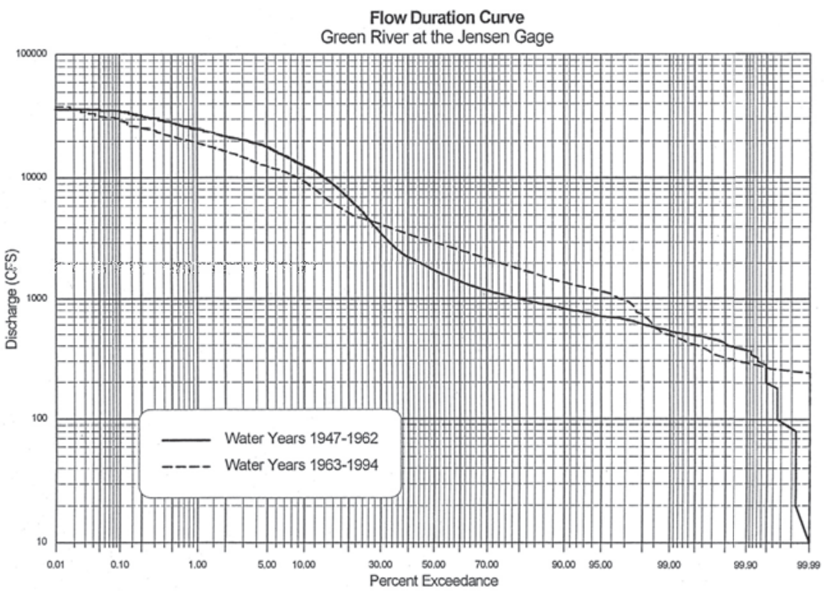

Figure 15. Pre- and Post- 1963 flow duration curves for the Jensen, Utah gage (from FLO Engineering, Inc. 1996).

that contain material eroded from upland benches have semidesert shrubland communities at upper elevations near bluffs and transition to alkali flats at lower elevations adjacent to alluvial floodplains. Common shrubs on terrace fans include greasewood, horsebrush, saltbush, hopsage, and tall tumble and tansy mustard. Many grassland birds are present in uplands and shrublands including several species of sparrows, western meadowlark, snow bunting, sage thrasher, sage grouse, and birds-of-prey (Table 9). Badgers, marmot, prairie dog, antelope squirrel, Ord's Kangaroo rat, white- and black-tailed jack-rabbit, desert cottontail, mule deer, and pronghorn are common mammals in these habitats. Common reptiles included fence, side-blotched, and horned lizards along with whiptail and gopher snakes (Table 9).

The ecological processes that sustain grassland and shrubland communities on upland benches and terraces are driven by local precipitation, occasional fire, and soils. The arid conditions of the region, coupled with high elevations that do not flood from the Green River create an environment that is water limited, especially on upland benches. Small amounts of precipitation occur in most months, with modest snow packs contributing to groundwater levels in winter and early spring preceding growing seasons. Grasses that occur on benches occur in clumps interspersed with bare soil and with scattered shrubs where soil moisture is higher. Periodic fire and moderate levels of grazing by native herbivores recycle nutrients in these communities.

Downslope remnant fans and terraces receive modest runoff and sediments from upland benches and bluffs depending on the topographic slope and magnitude of individual and annual precipitation events. Increased soil moisture on terraces compared to uplands allow shrubs to become established on terrace fans and they increase in abundance from top to bottom of slopes. Historically, fires periodically recycled nutrients, however, primary productivity is relatively low compared to other habitats in the region.

Alkali Flats

Alkali flats occur between the bottom slopes of shrubland terraces and upland sides of floodplain wetlands. Water flows into and through alkali flats from upland slope runoff and groundwater seeping from terraces and benches. Seasonal presence of surface water in alkali flats depends on magnitude of annual precipitation, especially snowmelt, in the local area and seasonal temperature. Runoff and seepage water typically occurs on alkali flats in spring. As this water evaporates in depressions, salt

accumulates on soil surfaces and creates alkaline soil conditions. During very high flood events on the Green River, alkali flats may be shallowly flooded for short periods. Alkali flats typically have Stygee and Turzo soils; the amount of loam and sand depends on source of eroded material and topography. Common plants in alkali flats include black greasewood, alkali sacaton, bottlebrush, squirreltail, shadscale, saltbush, dock, Indian ricegrass, galleta, seepweed, globemallow, and winterfat (Table 8). On some locations, l predominantly saltgrass occurs. alkali flats include species from upland, semidesert, and wetland communities depending on the season and wetness of the site (Table 9). During high flood events on the Green River, alkali flats attract large numbers of shorebirds, gulls, swallows, wading birds, and waterfowl.

Backswamp Floodplain Wetlands

Backswamp wetlands are present in all of the floodplain bottoms on Ouray NWR (Fig. 17), however, each bottom has slightly different water regimes and dynamics depending on topography of the bottom and frequency of inundation from the Green River. The depth, duration, and extent of flooding in these wetlands historically was driven primarily by flood pulses of the Green River and were highly variable among years; the norm being a relatively short pulse (1-2 weeks) of flood entry followed by gradual drying through summer and fall. Some depressions in floodplains behind point bars also may have been influenced by high Green River levels in spring, if subsurface connections of groundwater occurred. Consequently, most of the area (excepting deeper depressions) in floodplain wetlands at Ouray NWR had seasonal or semipermanent water regimes in most years.

Plant and animal communities in floodplain wetlands reflect seasonal and annual dynamics of flooding, especially timing, depth, duration, and extent of flooding. Primary and secondary productivity and biodiversity of these wetlands is high (e.g., Crowl et al. 2002), but is annually variable and

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Floods introduce sediments and nutrients to these wetland during backwater flood events, but may scour and remove bottom sediments and nutrients during headwater floods. Seasonal drying of these wetlands sustains productivity by recycling vegetation and nutrients.

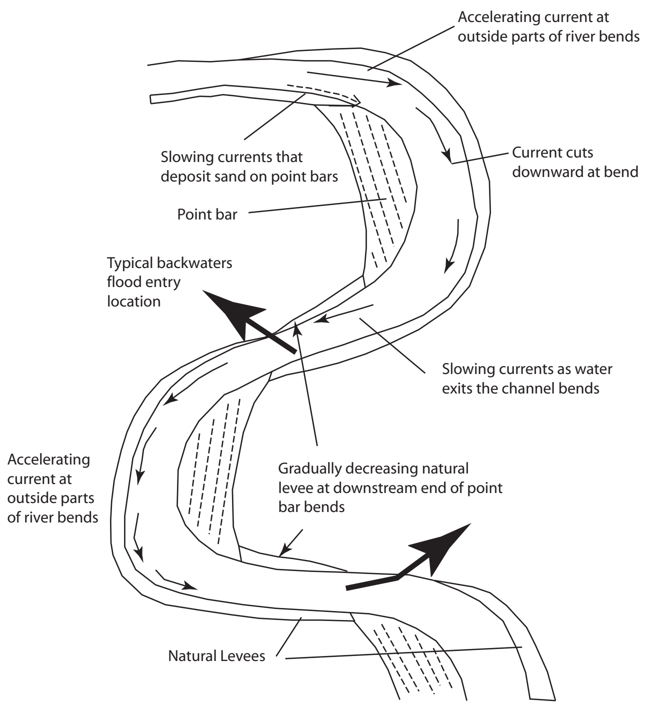

Figure 16. Schematic of typical geomorphic surfaces, river flows, and flood entry locations on sand bed rivers that have "S"-shaped channel configurations.

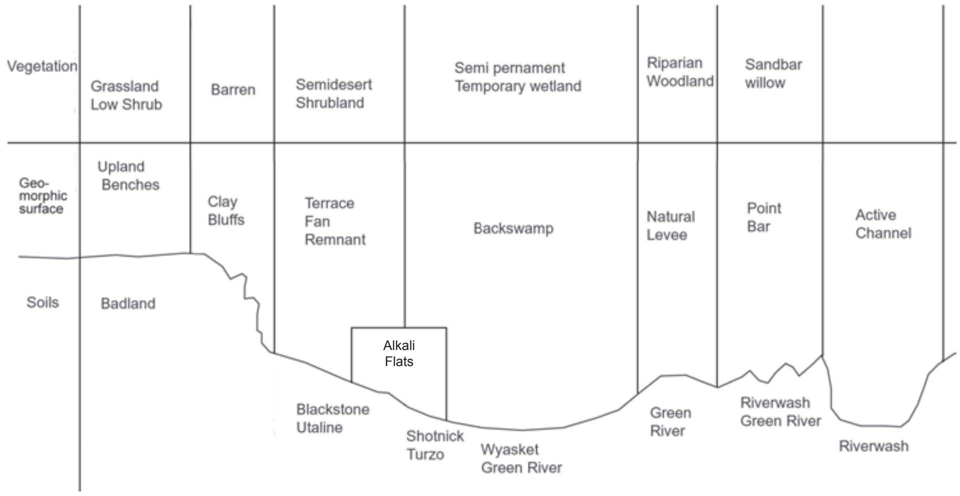

Figure 17. Cross-section of habitats on Ouray National Wildlife Refuge, Utah, indicating vegetation type, geomorphic surface, and soils.

Most floodplain bottoms on Ouray NWR have low depressions in the middle of the bottoms that slope upward toward natural levees and point bar deposits next to the Green River. When extensive flooding occurs, water may be up to 7-9 feet deep in these locations (Table 5). Woods and Johnson bottoms each contain a single relatively deep "bowl-shaped" depression in the middle of the bottom while other bottoms have more gently sloping topography that contain large shallow flats (Wyasket), multiple shallow depressions of moderate size (Leota), or only a few small shallow depressions surrounded by wide higher elevation flats (Sheppard) (Figs. 7, 18).

Depressions in floodplain wetlands on Ouray NWR hold water for the longest periods following inundation from flood waters and vegetation in these locations reflects more permanent water regimes. Many robust emergents such as cattail and bulrush occur in these depressions and if water permanence is prolonged (such as in very high flows or successive years of high river stages) dense mats of submerged aquatic vegetation also are present (Table 8). Flats and shallow areas in floodplains have shorter duration flooding and contain vegetation typically found in seasonally and temporarily flooded locations including a wide diversity of annual and perennial herbaceous plants (Table 8). Common species in seasonally-flooded areas include smartweed, spikerush, dock, sedges, wiregrass, and salt heliotrope. Flooding at the highest elevations in floodplains typically is of very short duration (perhaps only a few days) and vegetation at these sites represents a transition from wetland to upland species. This transition zone may move to lower elevations during dry (low or no flood events) periods and then retreat to higher elevations in wet periods.

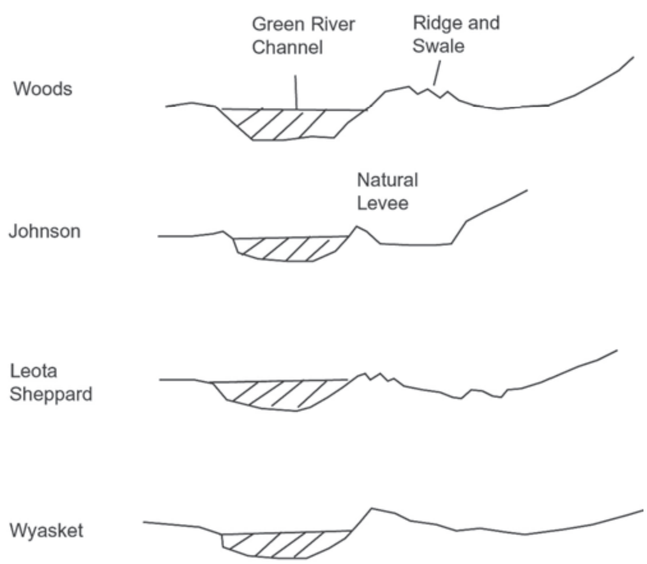

Figure 18. Cross-section of elevation and topography of floodplain "bottoms" on Ouray National Wildlife Refuge, Utah.

During wet periods with extended flooding many species of fish and more aquatic-dependent birds, mammals, and amphibians use floodplain wetlands. During wet years many waterbirds nest in or near these bottoms including migrant redhead, lesser scaup, gadwall, cinnamon teal, shoveler, ruddy duck, canvasback, western and eared grebe, coots, rails, moorhen, ibis, yellow-headed and red-winged blackbird, and marsh wrens (Sangster 1976, USFWS 2000). In contrast, during dry years or times of low, short duration Green River floods, floodplain wetlands historically held surface water only during spring and summer, if at all. Some waterbirds may attempt to breed during dry years, but nest success is relatively low compared to wet periods and most species and individuals move elsewhere for breeding (Sangster 1976). Natural summer drying of floodplain wetlands provide abundant and concentrated prey (e.g., invertebrates, amphibians, fish) for many birds such as pelicans, cormorants, gulls, herons, egrets, ibis, and shorebirds and also for mammals including otter, raccoon, fox, and coyote.

Table 8. Common plant species present on Ouray National Wildlife Refuge, Utah. Data from Folks 1963, Goodrich and Neese 1986, Laison 1993, USFWS 2000.

Common Name	Scientific Name
Grasses	
Crested Wheatgrass	*Agropyron cristatum*
Western Wheatgrass	*Agropyron smithii*
Slender Wheatgrass	*Agropyron trachycaulum*
Creeping Bentgrass	*Agrostis stolonifera*
Purple Three-awn	*Aristida purpurea*
American Sloughgrass	*Beckmannia syzigachne*
Cheatgrass	*Bromus tectorum*
Inland Saltgrass	*Distichlis spicata*
Barnyard Grass	*Echinochloa crusgalli*
Nodding Wildrye	*Elymus canadensis*
Low Creeping Wildrye	*Elymus simplex*
Sixweeks Fescue	*Festuca octoflora*
Galleta	*Hilaria jamesii*
Foxtail Barley	*Hordeum jubatum*
Scratchgrass	*Muhlenbergia asperifolia*
Indian Ricegrass	*Oryzopsis hymenoides*
Old Witchgrass	*Panicum capillare*
Common Reed	*Phragmites australis*
Sandberg Bluegrass	*Poa secunda*
Rabbitfoot Grass	*Polypogon monspeliensis*
Squirreltail	*Sitanion hystrix*
Alkali Sacaton	*Sporobolus airoides*
Sand Dropseed	*Sporobolus cryptandrus*
Needle-and-Thread Grass	*Stipa comata*
Forbs and Weeds	
Lowland Purslane	*Sesuvium sessile*
Redroot Amaranth	*Amaranthus retroflexus*
Springparsley	*Cymopterus acaulis*
Onion Springparsley	*Cymopterus bulbosus*
Uintah Basin Springparsley	*Cymopterus duchesnensis*
Purple Springparsley	*Cymopterus purpurascens*
Hemp Dogbane	*Apocynum cannabinum*
Pallid Milkweed	*Asclepias cryptoceras*
Labriform Milkweed	*Asclepias labriformis*
Showy Milkweed	*Asclepias speciosa*
Bur Ragweed	*Ambrosia tomentosa*
Leafy Aster	*Aster frondosus*
Nodding Beggarticks	*Bidens cernua*
Russian Knapweed	*Centaurea repens*
Douglas Chaenactis	*Chaenactis douglasii*
False Yarrow	*Chaenactis stevioides*
Creeping Thistle	*Cirsium arvense*
Bull Thistle	*Cirsium vulgare*
Dandelion Hawksbeard	*Crepis runcinata glauca*
Enceliopis	*Enceliopsis nutans*
Fleabane	*Erigeron bellidiastrum typicus*
Low Fleabane	*Erigeron pumilus*
Lowland Cudweed	*Gnaphalium palustre*
Curlycup Gumweed	*Grindelia squarrosa*
Broom Snakeweed	*Gutierrezia sarothrae*
Orange Sneezeweed	*Helenium autumnale*
Wild Sunflower	*Helianthus annuus*
Sunflower	*Helianthus petiolaris*
Showy Goldeneye	*Heliomeris multiflora*
Fineleaf Hymenopappus	*Hymenopappus filifolius luteus*
Poverty Sumpweed	*Iva axillaris*
Chicory Lettuce	*Lactuca tatarica*
Heath Aster	*Leucelene ericoides*
Skeleton Plant	*Lygodesmia grandiflora*
Purple Aster	*Machaeranthera canescens*
Discoid Tansyaster	*Machaeranthera grindelioides*
Desert Dandelion	*Malacothrix sonchoide*
	Platyschkuhria integrifolia
	Prenanthella exigua
Canada Goldenrod	*Solidago canadensis*
Missouri Goldenrod	*Solidago missouriensis*
Western Goldenrod	*Solidago occidentalis*
Field Sowthistle	*Sonchus arvensis*
Prickly Sowthistle	*Sonchus asper*
Wirelettuce	*Stephanomeria paucifloria*
Wirelettuce	*Stephanomeria runcinata*
Nuttall Horsebrush	*Tetradymia nuttallii*
Cottonthorn Horsebrush	*Tetradymia spinosa*
Towndsendia	*Townsendia grandiflora*
Towndsendia	*Townsendia incana*
Yellow Salsify	*Tragopogon dubius*
Rough Cocklebur	*Xanthium strumarium*
Desert Daisy	*Xylorhiza venusta*
Cryptantha	*Cryptantha ambigua*
Yellow Cryptantha	*Cryptantha flava*
Cryptantha	*Cryptantha paradoxa*
Desert Stickseed	*Lappula redowskii*
Persoon	*Tiquilia nuttallii*
Beauty Rockcress	*Arabis pulchra*
Rough Wallflower	*Erysimum asperum*
Prairie Pepperweed	*Lepidium densiflorum*
Giant Whitetop	*Lepidium latifolium*
Mountain Pepperweed	*Lepidium montanum*
African Mustard	*Malcolmia africana*
Common Twinpod	*Physaria acutifolia*
Blunt-leaf Yellowcress	*Rorippa curvipes*
Marsh Yellowcress	*Rorippa islandica*
Cress	*Rorippa lyrata*
Flaxleafed Plainsmustard	*Schoencrambe linifolia*
Tall Tumble Mustard	*Sisymbrium altissimum*
	Thelypodiopsis elegans
Yellow Bee-plant	*Cleome lutea*
Rocky Mountain Bee-plant	*Cleome serrulata*
Fendler Sandwort	*Arenaria fendleri eastwoodiae*
	Chenopodium atrovirens
Fremont Goosefoot	*Chenopodium fremontii*
Oakleaf Goosefoot	*Chenopodium glaucum*
Green Molly	*Kochia americana*
Kochia Weed	*Kochia scoparia*
Povertyweed	*Monolepis nuttalliana*
Russian Thistle	*Salsola iberica*
Halogeton	*Halogeton glomeratus*
Field Bindweed	*Convolvulus arvensis*
Dodder	*Cuscuta spp.*
Spurge	*Euphorbia albomarginata*
Fendler Euphorbia	*Euphorbia fendleri*
Locoweed	*Astragalus amphioxys*
Cicada Milkvetch	*Astragalus chamaeleuce*
Lesser Rushy Milkvetch	*Astragalus convallarius*
Duchesne Milkvetch	*Astragalus duchesnensis*
Yellow Milkvetch	*Astragalus flavus*
Geyer Milkvetch	*Astragalus geyeri*
	Astragalus hamiltonii
Woolly Locoweed	*Astragalus mollissimus*
Draba Milkvetch	*Astragalus spatulatus*
American Wild Licorice	*Glycyrrhiza lepidota*
Dwarf Lupine	*Lupinus pusillus*
Yellow Sweetclover	*Melilotus officinalis*
Silvery Sophora	*Sophora stenophylla*
Tall Centaury	*Mentaurium exaltatum*
	Nama densum
Scorpionweed	*Phacelia crenulata*
Scorpionweed	*Phacelia ivesiana*
Geyer Onion	*Allium geyeri*
Wild Onion	*Allium textile*
Asparagus	*Asparagus officinalis*
Sego Lily	*Calochortus nuttallii*
False Solomon's Seal	*Smilacina stellata*
Whitestem Mentzelia	*Mentzelia albicaulis*
Brushy Mentzelia	*Mentzelia dispersa*
Wingseed Mentzelia	*Mentzelia pterosperma*
Purple Ammannia	*Ammannia robusta*
Alkali-mallow	*Malvella leprosa*
Scarlet Globemallow	*Sphaeralcea coccinea*

Table 8, cont'd.

Common Name	Scientific Name
Nelson Globemallow	*Sphaeralcea parvifolia*
Sandverbena	*Abronia elliptica*
Narrowleaf Umbrellawort	*Mirabilis linearis*
	Tripterocalyx micranthus
Barestem Camissonia	*Camissonia scapoidea*
Small-flowered Gaura	*Gaura parviflora*
Tufted Evening-primrose	*Oenothera caespitosa*
Evening-primrose	*Oenothera elata*
Pale Evening-primrose	*Oenothera pallida*
Plantain	*Plantago asiatica*
Broadleaf Plantain	*Plantago major*
Woolly Plantain	*Plantago patagonica*
Ballhead Gilia	*Gilia congesta*
Gilia	*Gilia leptomeria*
Gilia	*Gilia polycladon*
Dwarf Gilia	*Gilia pumila*
Common Prickly Phlox	*Lepodactylon pungens*
Hood Phlox	*Phlox hoodii*
Wild Sweet William	*Phlox longifolia*
	Eriogonum batemanii
	Nodding Eriogonum
	Eriogonum cernuum
Big Wild Buckwheat	*Eriogonum corymbosum*
	Eriogonum flexum
Gordon's Umbrella Plant	*Eriogonum gordonii*
	Eriogonum hookeri
Desert Trumpet Eriogonum	*Eriogonum inflatum*
Slenderbush Eriogonum	*Eriogonum microthecum*
	Eriogonum salsuginosum
Shockley Wild Buckwheat	*Eriogonum shockleyi*
Green Eriogonum	*Eriogonum viridulum*
Western Virgin-bower	*Clematis ligusticifolia*
Nuttall Larkspur	*Delphinium nuttallianum*
Biennial Cinquefoil	*Potentilla biennis*
Brook Cinquefoil	*Potentilla rivalis*
Desert Paintbrush	*Castilleja chromosa*
Marsh Paintbrush	*Castilleja exilis*
Black Nightshade	*Solanum nigrum*
Prostrate Verbena	*Verbena bracteata*
Aquatic and Wetland Plants	
Narrowleaf Water-plantain	*Alisma gramineum*
Bur-head	*Echinodorus berteroi*
Upright Burhead	*Echinodorus rostratus*
Arrowhead	*Sagittaria cuneata*
Salt Heliotrope	*Heliotropium curassavicum*
Saltmarsh Sandspurry	*Spergularia marina*
	Chara spp
Awned Flatsedge	*Cyperus aristatus*
Needle Spikerush	*Eleocharis acicularis*
Common Spikerush	*Eleocharis palustris*
Dwarf Spikerush	*Eleocharis parvula*
Hardstem Bulrush	*Scirpus acutus*
Alkali Bulrush	*Scirpus maritimus*
Bulrush	*Scirpus saximontanus*
Softstem Bulrush	*Scirpus validus*
Smooth Scouring-rush	*Equisetum laevigatum*
Alpine Rush	*Juncus alpinus*
Wiregrass	*Juncus arcticus*
Toad Rush	*Juncus bufonius*
Torrey Rush	*Juncus torreyi*
Marsh Hedgenettle	*Stachys palustris pilosa*
Water Smartweed	*Polygonum amphibium*
Dooryard-grass	*Polygonum aviculare*
Pale Smartweed	*Polygonum lapathifolium*
Curly Dock	*Rumex crispus*
Canaigre	*Rumex hymenosepalus*
Golden Dock	*Rumex maritimus*
Bitter Dock	*Rumex obtusifolius*
Western Dock	*Rumex occidentalis*
Longleaf Pondweed	*Potamogeton nodosus*
Sago Pondweed	*Potamogeton pectinatus*
Hairleaf Water-buttercup	*Ranunculus aquatilis*
Rocky Mtn. Buttercup	*Ranunculus cymbalaria*
Pennsylvania Buttercup	*Ranunculus pennsylvanicus*
Meadowrue	*Thalictrum spp*
Hedge Hyssop	*Gratiola neglecta*
Mudwort	*Limosella aquatica*
Water Speedwell	*Veronica anagallis-aquatica*
Common Cattail	*Typha latifolia*
Fogfruit	*Phyla cuneifolia*
Woody Plants	
Squaw Bush	*Rhus trilobata*
Biennial Wormwood	*Artemisia biennis*
Tarragon	*Artemisia dracunculus*
Prairie Sage	*Artemisia ludoviciana var. ludoviciana*
Black Sagebrush	*Artemisia nova*
Bud Sagebrush	*Artemisia spinescens*
Big Sagebrush	*Artemisia tridentata*
Mohave Brickellbush	*Brickellia oblongifolia*
Rubber Rabbitbrush	*Chrysothamnus nauseosus*
Low Rabbitbrush	*Chrysothamnus viscidiflorus*
Silverscale	*Atriplex argentea*
Fourwing Saltbush	*Atriplex canescens*
Shadscale	*Atriplex confertifolia*
Mat Saltbush	*Atriplex corrugata*
Castle Valley Saltbush	*Atriplex gardneri cuneata*
	Atriplex heterosperma
Fivehook Bassia	*Bassia hyssopifolia*
Winterfat	*Ceratoides lanata*
Spiny Hopsage	*Grayia spinosa*
Black Greasewood	*Sarcobatus vermiculatus*
Russian-olive	*Elaeagnus angustifolia*
Silver Buffaloberry	*Shepherdia argentea*
Torrey Mormon Tea	*Ephedra torreyana*
Woods Rose	*Rosa woodsii*
Fremont Cottonwood	*Populus fremontii*
Peach-leaf Willow	*Salix amygdaloides*
Narrow-leaf Willow	*Salix exigua*
Whiplash Willow	*Salix lasiandra*
Tamarisk	*Tamarix ramosissima*
Cactus	
Ball Cactus	*Coryphantha vivipara*
Plains Pricklypear	*Opuntia polyacantha*
Uintah Basin Hookless Cactus	*Sclerocactus glaucus*

Birds (*Indicates confirmed nester on the Refuge.)

Loons	
Common Loon	*Gavia immer*
Grebes	
Pied-billed Grebe*	*Podilymbus podiceps*
Horned Grebe	*Podiceps auritus*
Eared Grebe*	*Podiceps nigricollis*
Western Grebe*	*Aechmophorus occidentalis*
Pelicans	
American White Pelican	*Pelecanus erythrorhynchos*
Cormorants	
Double-crested Cormorant*	*Phalacrocorax auritus*
Bitterns, Herons, and Egrets	
American Bittern	*Botaurus lentiginosus*
Least Bittern	*Ixobrychus exilis*
Great Blue Heron*	*Ardea herodias*
Great Egret	*Ardea alba*
Snowy Egret*	*Egretta thula*
Little Blue Heron	*Egretta caerulea*
Green Heron	*Butorides virescens*
Black-crowned Night-Heron*	*Nycticorax nycticorax*
Ibises and Spoonbills	
White-faced Ibis*	*Plegadis chihi*
New World Vultures	
Turkey Vulture*	*Cathartes aura*
Swans, Geese, and Ducks	
Greater White-fronted Goose	*Anser albifrons*
Snow Goose	*Chen caerulescens*
Canada Goose*	*Branta canadensis*
Trumpeter Swan	*Cygnus buccinator*
Tundra Swan	*Cygnus columbianus*
Wood Duck	*Aix sponsa*
Gadwall*	*Anas strepera*
American Wigeon*	*Anas americana*
Mallard*	*Anas platyrhynchos*
Blue-winged Teal*	*Anas discors*
Cinnamon Teal*	*Anas cyanoptera*
Northern Shoveler*	*Anas clypeata*
Northern Pintail*	*Anas acuta*
Green-winged Teal*	*Anas crecca*
Canvasback*	*Aythya valisineria*
Redhead*	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Greater Scaup	*Aythya marila*
Lesser Scaup	*Aythya affinis*
Bufflehead	*Bucephala albeola*
Common Goldeneye	*Bucephala clangula*
Barrow's Goldeneye	*Bucephala islandica*
Hooded Merganser	*Lophodytes cucullatus*
Common Merganser*	*Mergus merganser*
Red-breasted Merganser	*Mergus serrator*
Ruddy Duck*	*Oxyura jamaicensis*
Osprey, Kites, Hawks, and Eagles	
Osprey	*Pandion haliaetus*
Bald Eagle	*Haliaeetus leucocephalus*
Northern Harrier*	*Circus cyaneus*
Sharp-shinned Hawk	*Accipiter striatus*
Cooper's Hawk	*Accipiter cooperii*
Northern Goshawk	*Accipiter gentilis*
Swainson's Hawk*	*Buteo swainsoni*
Red-tailed Hawk*	*Buteo jamaicensis*
Ferruginous Hawk	*Buteo regalis*
Rough-legged Hawk	*Buteo lagopus*
Golden Eagle*	*Aquila chrysaetos*
Falcons and Caracaras	
American Kestrel*	*Falco sparverius*
Merlin	*Falco columbarius*
Peregrine Falcon	*Falco peregrinus*
Prairie Falcon*	*Falco mexicanus*
Gallinaceous Birds	
Ring-necked Pheasant* Introduced	*Phasianus colchicus*
Sage Grouse	*Centrocercus urophasianus*
Rails	
Virginia Rail*	*Rallus limicola*
Sora*	*Porzana carolina*
Common Moorhen	*Gallinula chloropus*
American Coot	*Fulica americana*
Cranes	
Sandhill Crane	*Grus canadensis*
Whooping Crane	*Grus americana*
Plovers	
American Golden-Plover	*Pluvialis dominica*
Snowy Plover	*Charadrius alexandrinus*
Semipalmated Plover	*Charadrius semipalmatus*
Killdeer*	*Charadrius vociferus*
Stilts and Avocets	
Black-necked Stilt*	*Himantopus mexicanus*
American Avocet*	*Recurvirostra americana*
Sandpipers and Phalaropes	
Greater Yellowlegs	*Tringa melanoleuca*
Lesser Yellowlegs	*Tringa flavipes*
Solitary Sandpiper	*Tringa solitaria*
Willet	*Catoptrophorus semipalmatus*
Spotted Sandpiper*	*Actitis macularia*
Long-billed Curlew*	*Numenius americanus*
Marbled Godwit	*Limosa fedoa*
Western Sandpiper	*Calidris mauri*
Least Sandpiper	*Calidris minutilla*
Baird's Sandpiper	*Calidris bairdii*
Dunlin	*Calidris alpina*
Short-billed Dowitcher	*Limnodromus griseus*
Long-billed Dowitcher	*Limnodromus scolopaceus*
Common Snipe*	*Gallinago gallinago*
Wilson's Phalarope*	*Phalaropus tricolor*
Red-necked Phalarope	*Phalaropus lobatus*
Skuas, Jaegers, Gulls, and Terns	
Franklin's Gull	*Larus pipixcan*
Bonaparte's Gull	*Larus philadelphia*
Ring-billed Gull	*Larus delawarensis*
California Gull	*Larus californicus*
Herring Gull	*Larus argentatus*
Caspian Tern	*Sterna caspia*
Common Tern	*Sterna hirundo*
Forster's Tern*	*Sterna forsteri*
Black Tern*	*Chlidonias niger*
Pigeons and Doves	
Rock Dove Introduced	*Columba livia*
Band-tailed Pigeon	*Columba fasciata*
Mourning Dove*	*Zenaida macroura*
Cuckoos and Anis	
Yellow-billed Cuckoo*	*Coccyzus americanus*

Table 9, cont'd.

Typical Owls	
Western Screech-Owl	*Otis kennicottii*
Eastern Screech-Owl	*Otus asio*
Great Horned Owl*	*Bubo virginianus*
Burrowing Owl*	*Athene cunicularia*
Long-eared Owl	*Asio otus*
Short-eared Owl	*Asio flammeus*
Northern Saw-whet Owl	*Aegolius acadicus*
Nightjars	
Common Nighthawk*	*Chordeiles minor*
Common Poorwill	*Phalaenoptilus nuttallii*
Swifts	
White-throated Swift	*Aeronautes saxatalis*
Hummingbirds	
Black-chinned Hummingbird	*Archilochus alexandri*
Broad-tailed Hummingbird	*Selasphorus platycercus*
Rufous Hummingbird	*Selasphorus rufus*
Kingfishers	
Belted Kingfisher	*Ceryle alcyon*
Woodpeckers	
Lewis' Woodpecker*	*Melanerpes lewis*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Downy Woodpecker*	*Picoides pubescens*
Hairy Woodpecker*	*Picoides villosus*
Northern Flicker*	*Colaptes auratus*
Tyrant Flycatchers	
Western Wood-Pewee	*Contopus sordidulus*
Willow Flycatcher	*Empidonax traillii*
Say's Phoebe*	*Sayornis saya*
Vermilion Flycatcher	*Pyrocephalus rubinus*
Ash-throated Flycatcher	*Myiarchus cinerascens*
Western Kingbird*	*Tyrannus verticalis*
Eastern Kingbird	*Tyrannus tyrannus*
Shrikes	
Loggerhead Shrike*	*Lanius ludovicianus*
Northern Shrike	*Lanius excubitor*
Vireos	
Warbling Vireo*	*Vireo gilvus*
Crows, Jays, and Magpies	
Pinyon Jay	*Gymnorhinus cyanocephalus*
Black-billed Magpie*	*Pica pica*
American Crow	*Corvus brachyrhynchos*
Common Raven	*Corvus corax*
Larks	
Horned Lark*	*Eremophila alpestris*
Swallows	
Purple Martin	*Progne subis*
Tree Swallow	*Tachycineta bicolor*
Violet-green Swallow	*Tachycineta thalassina*
Northern Rough-winged Swallow*	*Stelgidopteryx serripennis*
Bank Swallow	*Riparia riparia*
Cliff Swallow*	*Petrochelidon pyrrhonota*
Barn Swallow*	*Hirundo rustica*
Titmice and Chickadees	
Black-capped Chickadee*	*Poecile atricapillus*
Mountain Chickadee	*Poecile gambeli*
Nuthatches	
Red-breasted Nuthatch	*Sitta canadensis*
White-breasted Nuthatch	*Sitta carolinensis*
Creepers	
Brown Creeper	*Certhia americana*
Wrens	
Rock Wren*	*Salpinctes obsoletus*
Bewick's Wren	*Thryomanes bewickii*
House Wren*	*Troglodytes aedon*
Marsh Wren*	*Cistothorus palustris*
Kinglets	
Golden-crowned Kinglet	*Regulus satrapa*
Ruby-crowned Kinglet	*Regulus calendula*
Old World Warblers	
Blue-gray Gnatcatcher	*Polioptila caerulea*
Thrushes	
Western Bluebird	*Sialia mexicana*
Mountain Bluebird	*Sialia currucoides*
Townsend's Solitaire	*Myadestes townsendi*
Swainson's Thrush	*Catharus ustulatus*
American Robin*	*Turdus migratorius*
Mimic Thrushes	
Gray Catbird	*Dumetella carolinensis*
Northern Mockingbird*	*Mimus polyglottos*
Sage Thrasher	*Oreoscoptes montanus*
Starlings	
European Starling*	*Sturnus vulgaris*
Wagtails and Pipits	
American (Water) Pipit	*Anthus rubescens*
Waxwings	
Bohemian Waxwing	*Bombycilla garrulus*
Cedar Waxwing	*Bombycilla cedrorum*
Wood Warblers	
Orange-crowned Warbler	*Vermivora celata*
Virginia's Warbler	*Vermivora virginiae*
Yellow Warbler*	*Dendroica petechia*
Yellow-rumped Warbler	*Dendroica coronata*
Black-throated Gray Warbler	*Dendroica nigrescens*
Townsend's Warbler	*Dendroica townsendi*
American Redstart	*Setophaga ruticilla*
MacGillivray's Warbler	*Oporornis tolmiei*
Common Yellowthroat	*Geothlypis trichas*
Wilson's Warbler	*Wilsonia pusilla*
Yellow-breasted Chat*	*Icteria virens*
Sparrows and Towhees	
Green-tailed Towhee	*Pipilo chlorurus*
Spotted Towhee*	*Pipilo maculatus*
American Tree Sparrow	*Spizella arborea*
Brewer's Sparrow	*Spizella breweri*
Vesper Sparrow	*Pooecetes gramineus*
Lark Sparrow	*Chondestes grammacus*
Sage Sparrow	*Amphispiza belli*
Lark Bunting	*Calamospiza melanocorys*
Savannah Sparrow	*Passerculus sandwichensis*
Fox Sparrow	*Passerelia iliaca*
Song Sparrow	*Melospiza melodia*
Lincoln's Sparrow	*Melospiza lincolnii*
White-throated Sparrow	*Zonotrichia albicollis*
Harris' Sparrow	*Zonotrichia querula*
White-crowned Sparrow	*Zonotrichia leucophrys*

Table 9, cont'd.

Dark-eyed Junco	*Junco hyemalis*
Snow Bunting	*Plectrophenax nivalis*
Cardinals, Grosbeaks, and Allies	
Black-headed Grosbeak	*Pheucticus melanocephalus*
Blue Grosbeak	*Guiraca caerulea*
Lazuli Bunting	*Passerina amoena*
Blackbirds and Orioles	
Red-winged Blackbird*	*Agelaius phoeniceus*
Western Meadowlark*	*Surnella neglecta*
Yellow-headed Blackbird*	*Xanthocephalus xanthocephalus*
Brewer's Blackbird*	*Euphagus cyanocephalus*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird*	*Molothrus ater*
Baltimore Oriole	*Icterus galbula*
Finches	
House Finch	*Carpodacus mexicanus*
Pine Siskin	*Carduelis pinus*
Lesser Goldfinch	*Carduelis psaltria*
American Goldfinch*	*Carduelis tristis*
Evening Grosbeak	*Coccothraustes vespertinus*
Rosy Finch	*Leucosticte arctoa*
Old World Sparrows	
House Sparrow* Introduced	*Passer domesticus*

Mammals

Bears	
Black Bear	*Ursus americanus*
Raccoons	
Raccoon	*Procyon lotor*
Otters, Badgers, and Skunks	
Northern River Otter	*Lutra canadensis*
American Badger	*Taxidea taxus*
Striped Skunk	*Mephitis mephitus*
Dogs and Foxes	
Coyote	*Canis latrans*
Red Fox	*Vulpes vulpes*
Kit Fox	*Vulpes macrotis*
Cats	
Mountain Lion	*Felis concolor*
Lynx	*Lynx canadensi*
Bobcat	*Lynx rufus*
Squirrels	
Yellow-bellied Marmot	*Marmota flaviventris*
White-tailed Prairie Dog	*Cynomys leucurus*
White-tailed Antelope Squirrel	*Ammospermophilus leucurus*
Least Chipmunk	*Tamias minimus*
Kangaroo Rat	
Ord's Kangaroo Rat	*Dipodimys ordii*
Beaver	
American Beaver	*Castor canadensis*
Mice	
Deer Mouse	*Peromyscus maniculatis*
White-footed Mouse	*Peromyscus leucopus*
Vole	
Meadow Vole	*Microtus pennsylvanicus*
Muskrat	
Muskrat	*Ondatra zibethicus*
Porcupine	
Porcupine	*Erithizon dorsatum*
Hares and Rabbits	
White-tailed Jackrabbit	*Lepus townsendii*
Black-tailed Jackrabbit	*Lepus californicus*
Desert Cottontail	*Sylvilagus audubonii*
Deer	
American Elk	*Cervus elaphus*
Mule Deer	*Odocoileus hemionus*
Moose	*Alces alces*
Pronghorn	
Pronghorn	*Antilocapra americana*
Bison	
American Bison	*Bos bison*

Reptiles and Amphibians:

Reptiles:

Fence Lizard	
Eastern Fence Lizard	*Sceloporous undulatus*
Side-Blotched Lizard	
Side-blotched Lizard	*Uta stansburiana*
Horned Lizard	
Short-horned Lizard	*Phrynosoma douglassii*
Whiptail	
Western Whiptail	*Cnemidophorus tigris*
Garter Snake	
Wandering Garter Snake	*Thamnophis elegans vagrans*
Racer	
Yellow-bellied Racer	*Coluber constrictor*
Green Snake	
Smooth Green Snake	*Opheodrys vernalis*
Gopher Snake	
Great Basin Gopher Snake	*Pituophis melanoleucus*
Rattlesnake	
Western Rattlesnake	*Crotalus viridis*

Amphibians:

Toads	
Woodhouse's Toad	*Bufo woodhousei*
Rocky Mountain Toad	*Bufo woodhousei woodhousei*
Chorus Frog	
Boreal Chorus Frog	*Pseudacris triseriata maculata*
Leopard Frog	
Northern Leopard Frog	*Rana pipiens*

Fish:

Trouts	
Rainbow Trout*	*Oncorhynchus mykiss*
Brown Trout*	*Salmo trutta*

Pikes	
Northern Pike*	*Esox lucius*
Carps and Minnows	
Common Carp*	*Cyprinus carpio*
Utah Chub*	*Gila atraria*
Roundtail Chub	*Gila robusta*
Bonytail	*Gila elegans*
Humpback Chub	*Gila cypha*
Sand Shiner*	*Notropis stramineus*
Fathead Minnow*	*Pimephales promelas*
Colorado Pikeminnow	*Ptychocheilus lucius*
Speckled Dace	*Rhinichthys osculus*
Redside Shiner*	*Richardsonius balteatus*
Red Shiner*	*Notropis lutrensis*
Suckers	
White Sucker*	*Catostomus commersoni*
Bluehead Sucker	*Catostomus discobolus*
Flannelmouth Sucker	*Catostomus latipinnis*
Razorback Sucker	*Xyrauchen texanus*
Bullhead Catfishes	
Black Bullhead*	*Ictalurus melas*
Channel Catfish*	*Ictalurus punctatus*
Livebearers	
Mosquitofish*	*Gambusia affinis*
Sunfishes	
Green Sunfish*	*Lepomis cyanellus*
Bluegill*	*Lepomis macrochirus*
Smallmouth Bass*	*Micropterus dolomieui*
Black Crappie*	*Pomoxis nigromaculatus*
Perches	
Yellow Perch*	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*
Sculpins	
Mottled Sculpin	*Cottus bairdi*
Sticklebacks	
Brook stickleback	*Culaea inconstans*

***Indicates species is not native to this area.**

Several native fish species in the Green River move into floodplain wetlands on the ascending limb of flood pulses and use resources in these sites for reproductive and survival purposes, depending on the species (e.g, Wydoski and Wick 1998, Modde 1997, Modde et al. 2001). For example, larval razorback suckers move into floodplain wetlands during flood events, become entrained in deeper wetland depressions and bottoms when river levels recede in summer, exploit abundant wetland invertebrate foods that allow juveniles to grow rapidly during summer to the following spring, and, if wetlands remain flooded through the subsequent winter and spring, the young then move back into the Green River during flood events the following year(s). Survival of larvae and juveniles depends on extended flooding and retention of water in the bottoms for at least a year after flooding. Historically, at least some deeper depressions in floodplains on Ouray NWR periodically were flooded extensively enough to retain surface water through the following spring (e.g., the deeper bottoms at Johnson and Woods), however, many floodplain areas dried prior to the following spring and limited recruitment of these species. Analyses of long-term river level data (Figs.12, 13) suggests that year-long (perhaps several successive years) inundation of at least some of the deeper depressions in at least Woods and Johnson Bottoms historically occurred about every 5-7 years.

Because of seasonal dynamics, many animals use semipermanent and seasonal floodplain wetlands on Ouray NWR to exploit rich food supplies that become available during seasonal inundation or drying. For example, large numbers of waterfowl and shorebirds are present at Ouray during spring migration (Sangster 1976) where they obtain important resources used during subsequent migration and breeding. Some species of waterfowl, shorebirds, and wading birds successfully bred in these wetland during wetter periods, but rapid seasonal drying precludes significant recruitment in most years. In contrast, short duration water regimes are ideal for amphibians that time breeding to coincide with short periods of inundation in these seasonal basins that do not support populations of their predators such as fish, waterbirds, and aquatic mammals. Seasonal water regimes also are necessary to maintain productivity and nutrient recycling in semi-arid wetlands (e.g., van der Valk and Davis 1978).

Natural Levee

Natural levees along the Green River at Ouray NWR are relatively low and wide. Floodwaters overtop natural levees first at low spots and seldom overtop all natural levee areas except during high flow events. Consequently, soils on natural levees are only occasionally inundated and contain rich alluvial silts with moderate amounts of sand. Historically, dense stands of cottonwood were present on natural levees with an underlying shrub layer comprised mainly of sumac, rose, and buffaloberry (Table 8). A dense herbaceous layer is common under shrubs and includes goosefoot, buttercup, bee plant, gooseberry, cinquefoil, licorice, poison ivy, water hemlock, milkweed, sneezeweed, sunflower, sumpweed, goldenrod, and cocklebur.

During high flow events, fine texture sediments are deposited on natural levees. This periodic changing and exposure of surface sediments provided new substrates for cottonwood to germinate, and also replenishes groundwater levels required by new seedlings to survive (Cooper et al. 1999). New sediments also provided ideal soil surfaces for germination of shrubs and perennials and maintain a dynamic balance of nutrients and regeneration of plant communities.

Riparian corridors on natural levees attract and support an abundance of animal species (Table 9). These woodlands offer abundant food supplies (e.g., arboreal arthropods, seeds, fruits), escape and thermal cover and shade, close proximity to predictable (river) and seasonal (floodplain wetland) water sources, and corridors for migration and local movement. Over 100 species of birds use these riparian areas during migration, breeding, and wintering. Many reptiles, especially lizards and snakes are present in these sites, as are numerous mammals, both small (mice) and large (elk).

Point Bar Ridge-and-Swale

Point bars on inside bends of the Green River contain complex topography of sandy higher ridges and silt- and clay-capped swales. Ridges represent different ages of sand deposits as the river has migrated over time. Ridges next to the river are often relatively barren with only scattered willows present. Older ridges may have a thin veneer of silt on top of deep deposits of sand and support a more diverse vegetation community including species commonly found on natural levees. At these locations, willow is intermixed with scattered cottonwood, rose, tumble mustard, sunflower, bee plant, sneezeweed, and saltbush. Swales typically have a clay layer on top of underlying silt and sand and this relatively impermeable clay layer allows surface water to "pond" for short periods, depending on depth and topography of the swale. Most swales are seasonally flooded and contain a mix of species including species present on natural levees and wetlands depending on duration of flooding. Because of greater and extended soil moisture, cottonwood is commonly found on the edges of older swales, with a mix of perennial and emergent herbaceous plants occurring in the bottoms of swales.

Point bar ridges are not flooded except during very high flow events of the Green River. In contrast, swales may be inundated regularly, depending on their proximity to the river and topography. During high flow events, coarse sandy sediments are deposited on ridges; swales receive a combination of both coarse and fine sediments. Changes in soil surfaces create new conditions that may either enhance or retard new germination of woody and herbaceous vegetation. Where silt is deposited, soil conditions may be suitable for cottonwood to germinate, but new deposits of sand may retard growth or survival of cottonwood and replace it with willow.

Animals that inhabit point bars typically are those species that spend most of their time in adjacent riparian or wetland areas (Table 9). Dense stand of willow on point bar ridges offer escape and thermal/shade cover and have moderate, but very seasonal, populations of insects used by many birds and reptiles. Only a few species of birds nest in willow-dominated point bar areas. Wetland-associated species of birds, mammals, and amphibians commonly use swales, but they typically are only seasonal visitors following flood events and seasonal inundation.

CHANGES IN THE OURAY ECOSYSTEM

Major changes have occurred in the hydrology, river geomorphology, topography, and plant and animal communities at Ouray NWR since it was established in 1960. Each of these changes has affected basic ecological processes that control ecosystem functions and values and the distribution and abundance of plant and animal species.

HYDROLOGY AND RIVER GEOMORPHOLOGY

Perhaps the most basic and important alteration to the Ouray NWR ecosystem has been a marked reduction in the frequency, magnitude, and duration of flooding from the Green River after Flaming Gorge Reservoir was built and its dam closed in November 1962 (FLO Engineering, Inc. 1996). Mean annual discharge at the Jensen, Utah gage decreased from 4360 cfs prior to closure of Flaming Gorge Dam to 4210 cfs after 1963. In contrast, base flow of the Green River at Jensen increased from 1260 cfs during 1947-63 to 2560 cfs after 1963 because of more regular releases of water from Flaming Gorge for hydro-power generation. During this same time, mean annual peak flow in the Green River at Jensen decreased from 24,000 cfs prior to 1963 to 17,400 cfs after 1963. The ratio of mean peak discharge to mean base flow decreased from 19.7 pre-1963 to 6.8 post-1963. Prior to closure of Flaming Gorge Dam, the average monthly temperature of water in the Green River below the damsite ranged from 0-19.5^0 C compared to 3.5-10^0 C after closure (Bolke and Waddell 1975).

The total amount of water released from Flaming Gorge Reservoir is not different now from total annual river discharges prior to closure of the dam, but the timing is altered such that spring flood peaks now are lower (on average), shorter duration, and less frequent (Figs. 12,13). Historic flows that would result in 2-, 5-, and 10-year flood recurrences at Ouray NWR now have been reduced 26%, 19%, and 13%, respectively, from the period prior to dam closure (Table 4, Fig 14). The mean peak flow of 24,000 at the Jensen gage prior to dam closure historically occurred about every 2.4 years; now that same flow occurs on average every 8+ years (Table 3).

The duration of flood events also has changed significantly at Ouray NWR. Prior to 1963, the mean peak of 24,000 cfs was exceeded on average about 5 days/year. Now, that same discharge is equaled or exceeded only about 1 day/year (Figs. 14,15). The current mean flood peak of 17,400 cfs now is exceeded an average of about 6 days/year, where in the past this discharge was exceeded on average of 15-16 days/year. Consequently, flood events at Ouray NWR now are narrower "spikes" of high flow compared to more prolonged "pulses" of flow prior to closure of Flaming Gorge Dam. Prior to 1963, some overbank flooding of the Green River into at least some areas of flood-plain bottoms on Ouray NWR occurred almost every

Flaming Gorge Dam on the Green River north of Ouray National Wildlife Refuge, Utah.

year. Now, substantial overbank flooding occurs on average only about 2 of every 5 years.

Because most sediments carried by the Green River at Ouray originate from low elevation areas below Flaming Gorge and from the Yampa River, the total sediment loading in the Green River has not changed significantly since dam closure (FLO Engineering, 1996). However, lower peak discharges and shorter duration high flows have reduced mean annual sediment discharge near Jensen, Utah by up to 54% (Andrews 1986). Currently, sediment transported into the Green River between the Yampa River and the southern end of Ouray NWR is about equal to the amount of sediment transported out of that reach (Andrews 1986).

The channel morphology of the Green River at Ouray NWR has become narrower, and perhaps more incised, since closure of Flaming Gorge Dam. Most channel narrowing was completed by 1974 (Lyons et al. 1992), but complete adjustments to reduced flows, decreased sediment discharge, and fewer shorter flood peaks may require a century or more before stabilization occurs (Andrews 1986). In general, the river stretch at Ouray NWR now has a smaller channel width-depth ratio, enlarged sand bars, more bars attached to channel banks, dense vegetation on many in-stream bars, and reduced scouring and movement of sediments (FLO Engineering, Inc. 1996). Invasion of saltcedar also has exacerbated channel narrowing because it has colonized bank and bar deposits causing additional deposition of sediments by vertical accretion (Friedman et al. 1996). Reduced scouring flows now may be insufficient to remove young saltcedar which stabilizes deposits, adds channel "roughness" that slows water velocities, and causes additional sediment deposition. These events create further elevated saltcedar-covered bank deposits that are inset between older natural levees dominated by cottonwood and the river channel.

TOPOGRAPHY

The local topography and hydrology of Ouray NWR has been altered greatly with construction of roads, levees, water control structures, spillways, ditches, building compounds, ponds, and facilities of the Ouray National Fish Hatchery. Each development has altered overland flow of water in, out, and through the various floodplain bottoms of Ouray and ultimately changed vegetation composition and system processes. Specific changes that have occurred in each bottom are describe below:

Johnson Bottom

After Ouray NWR was established, levees were constructed perpendicular to the length of Johnson Bottom and old natural and man-made levees along the Green River were raised and lengthened. This development divided Johnson Bottom into 4 separate "ponds" (Fig. 7) that were managed for more permanent water regimes and waterfowl production. Culverts with rudimentary water control structures were placed between cross levees, a gravity flow inlet was constructed at the upper end of the J-1 unit, and an outlet structure was built in J-4. Water flowed into Johnson Bottom through the inlet structure at Green River flows > 3000 cfs. A pump station was constructed along the Green River to pump water into this bottom and an electric line was built to operate this pump. Several small islands were built in the ponds for waterfowl nesting sites. Over time the interior levees of Johnson Bottom deteriorated, the inlet ditch at J-1 silted in and was inoperable at the flows it was originally designed for, and changes in river flows and bar locations made pumping water from the Green River inefficient. Subsequently, the electric line into the pump station was removed in 1988. A 200 foot portion of the levee along the southeast corner of J-4 was removed in 1998 and this breach site allowed the Green River to flow into Johnson Bottom at discharges >13,000 cfs. A new drain structure/fish kettle was built in the southeast corner of J-3 in 1999. In 2000-2002, most of the old interior cross levees and some islands in Johnson Bottom were removed.

Leota Bottom

Leota Bottom is the most altered and developed of the floodplain areas on Ouray NWR. Since the refuge was established Leota Bottom has been developed into 11 separate "units" each with levees and water-control structures. The 11 wetland units have been managed for varying water levels and frequencies ranged from nearly permanent regimes to seasonal flooding. Some low-level levees were built along the Green River prior to refuge establishment to restrict Green River flooding, and to facilitate agricultural production, in this bottom. Ouray NWR enhanced these old "protective" levees and also built new ones along the Green River for similar purposes of restricting flood flows into Leota; these levees do not control extent or depth of flooding in the wetland

West side of Johnson Bottom, point bar surface.

Johnson Bottom river bar/channel geomorphology.

Green River channel dynamics creating ridge-and-swale surfaces.

Fish hatchery located between Green River and Leota Bottom.

Alkali flat habitat on the west side of Leota Bottom

Leota Bottom L10

South end of Leota Bottom along river cottonwood corridor.

Sheppard Bottom semi-permanent wetland.

units. Interior cross levees were built to divide the wetland units to regulate timing, depth, and extent of flooding. The Ouray National Fish Hatchery is located in the northern part of Leota Bottom and consists of leveed ponds, drainage ditches, pumps, and pipelines to supply water to hatchery ponds.

Draining and flooding wetland units in Leota Bottom are facilitated by a ditch that runs through the center of the bottom and an interconnected system of water-control structures. Green River water can be pumped or gravity fed into Leota Bottom through an inlet structure in L-2. This inlet is operational at Green River flows > 7500 cfs. A new inlet structure was built in L-10 in 1996 to make gravity flow into the area easier. Pelican Lake water can be gravity fed via pipeline into L-10. In 1998, short portions of the levee along the Green River adjacent to L7 (350 foot upper river) and L7A (600 foot lower spillway) were removed (breached) to allow flood flows of 15-20,000 cfs to enter Leota Bottom. A new drain structure/fish kettle was constructed at the south end of the bottom in 1999. Spillways were built between L-1/L-2, L-2/L-4, L1/L3, L4/L6, and L6/L8 in 1999 to facilitate movement of water between wetland units during flood periods. Likewise, a portion of the cross levee between L7 and L7A was removed in 2001 to allow flood water coming into Leota at the L7 upper river breach site to flow through units L7 and L7A and exit at the lower spillway breach site in L7A.

Levee breaches at L7 and L7A have changed elevation (and thus impacted levels at which the Green River enters and exits Leota) since their construction as deposition and scouring have occurred (FLO Engineering, Inc. 1999). In 1998, peak flows of the Green River were high and floodwater drained quickly in Leota (declines of several thousand cubic feet/second and 1-2 feet/day) and caused large changes in the hydraulic gradient between the flooded bottoms and the Green River. This rapid fall of the river caused extensive scouring at the L7A outlet with 2-3 foot down cutting over a 20 foot wide area. In contrast, in 1997, longer sustained connection of the Green River with Leota induced 2-3 foot deposition of sediments at the L7 inlet breach. Protective geowebbing material has been placed along a concrete pad at the L7A outlet breach, however some erosion and deposition continues at breach sites.

Wyasket Bottom and Wyasket Pond

Wyasket Bottom is a large undeveloped floodplain area except for the ca. 250-acre Wyasket Pond that is surrounded by a man-made levee. Levees around Wyasket Pond were built by a private landowner prior to establishment of Ouray NWR to prevent Green River flooding into this area. After the refuge was established, the old protection levees around Wyasket Pond were refurbished and included water-control structures to purposefully flood this pond annually. An inlet ditch was dug from Wyasket Pond to the Green River to allow Green River water to be pumped into the pond during low flows and gravity-flowed into the pond at Green River flows >5000 cfs. In 1986, this inlet structure was replaced to allow more efficient gravity flow into the area. Water also can be diverted to Wyasket Lake through the Wyasket Pond inlet structure, but this practice was discontinued in the late 1990s because of reoccurring botulism outbreaks in Wyasket Lake during natural drawdowns of ponded water in this area during summer. Wyasket Bottom does not have a constructed outlet location and water trapped in this bottom evaporates and creates stagnant pools that are anoxic. The pump station on the inlet structure into Wyasket Pond has not been used since 1991 and water levels have not been maintained in Wyasket Pond since 2000.

Sheppard Bottom Area

After the refuge was established, Sheppard Bottom was developed into 5 separate wetland units with interconnected inlet and outlet structures. Water for flooding Sheppard Bottom historically was provided via a gravity flow inlet and pump station along the Green River. Originally, the Ouray National Fish Hatchery was located in the northeast corner of Sheppard Bottom. The inlet structure was rebuilt and the pump station abandoned in 2000. Water gravity flows into a series of canals that move water into Sheppard units at Green River flows >5000 cfs, however, flows >10,000 cfs are needed to provide flows sufficient to flood all Sheppard units.

Historically, agricultural irrigation runoff and seep/spring water draining from the Roadside Draw flowed into Sheppard Bottom. Small levees were built in the Roadside Draw area to impound water for waterfowl production in the 1970s. In the l980s, water in the Roadside Draw ponds were determined to contain high selenium concentrations that posed health risks to wildlife (Fig. 19). Consequently, the Roadside Ponds were retired from impoundment use in 1996. To offset loss of the Roadside Ponds, 5 independently controlled moist-soil impoundments were constructed in 1997 adjacent to the north part of Sheppard Bottom Unit S-4. These moist-soil

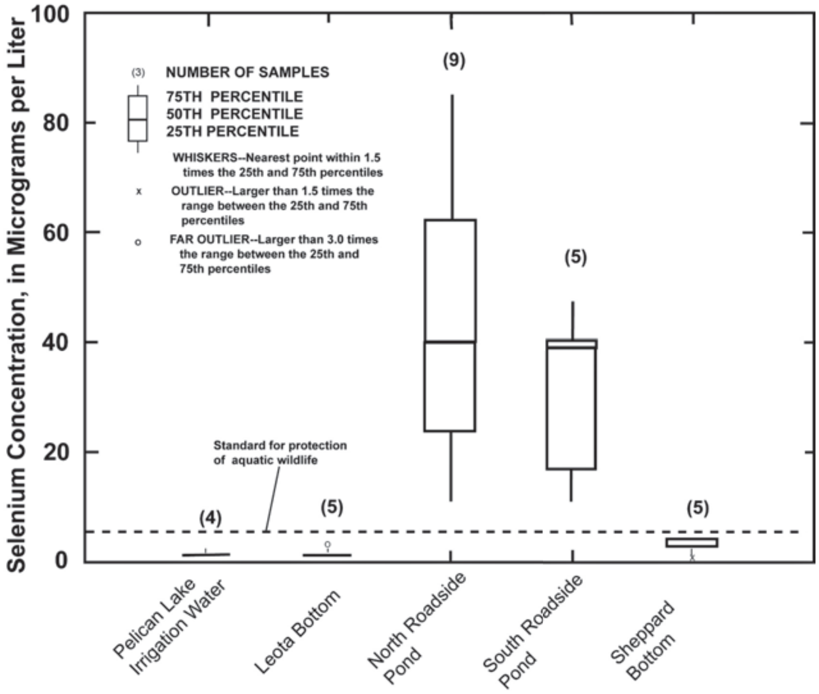

Figure 19. Selenium concentration in areas of Ouray National Wildlife Refuge, Utah, during 1988 and 1989 (from Stephens et al. 1992).

impoundments receive water from a newly constructed pipeline coming from Pelican Lake. Each impoundment has separate inlet and outlet structures that connect with a drain canal that empties into the S-1 Sheppard Bottom Unit. Green River water also can be backed into these units from the Sheppard Bottom inlet during high flows. In 2002, part of the protective levee on the south end of S-3 was removed as was the cross-levee between S-3 and S-5. Also, a ca. 50 foot wide drain canal was built in the southeast corner of S-3 to the Green River. Removing levees and construction of the drain canal allowed selenium-laden water to drain from Sheppard Bottom into the Green River and also allowed the Green River to flood this area during high flows and further dissipate and dilute selenium concentrations (Fig. 20).

About 150 acres of Sheppard Bottom are in farm fields. These fields typically are cropped each year on a rotation basis for alfalfa, small grains such as barley, and row crops including grain sorghum.

Woods Bottom

Levees were constructed in Woods Bottom beginning in the 1960s to create 2 impoundments: a diked backside unit and a larger main unit (Fig. 3) Water from the Green River is diverted into Woods Bottom by gravity flow through an inlet structure and ditch on the north side of the bottom at Green River flows of >10,000 cfs and from water backing into the bottom through the drain structure on the south side of the main unit. No pumpsites were developed in this bottom. Woods Bottom was the first bottom on Ouray NWR to be developed and managed to benefit native endangered fishes. The drain structure on the southeast corner of the bottom was modified in 1993 with a fish kettle to process fish and a bottom elevation to allow the Green River to back into the bottom at about 4000 cfs. In 1997, a 100 foot wide section of the south levee of the backside unit along the Green River was removed to allow overbank flooding at about 13,000 cfs. Since that time, part of the natural levee along the Green River at the southeastern part of Woods Bottom was scoured and now the 100 foot wide constructed breach operates more as an outlet than an inlet for flood flows.

VEGETATION AND ANIMAL COMMUNITIES

The general location of habitat types (i.e., upland grassland, floodplain wetland, etc.) have not changed much since Ouray NWR was established, however, species composition of some areas are different than in the past and invasive species have become widely distributed over the refuge.

The major changes in distribution and species composition of native habitats on Ouray NWR are within riparian woodland and floodplain wetland habitats. Reductions in flooding frequency and intensity have reduced scouring of natural levees and point bar areas that is needed to provide new exposed surfaces for wind-blown seeds of cottonwood to land and germinate. Typically, newly scoured areas contain fine-textured alluvium that is saturated by spring floods and provides adequate soil moisture needed for late-summer cottonwood seedling survival (Cooper et al. 1999). Reduced flooding and lower flows of the Green River reduced soil moisture and also have allowed many river bars to become densely vegetated with willow and saltcedar which further slows river flows and reduces scouring action. The combination of reduced flows and floods, willow-dominated bars, and

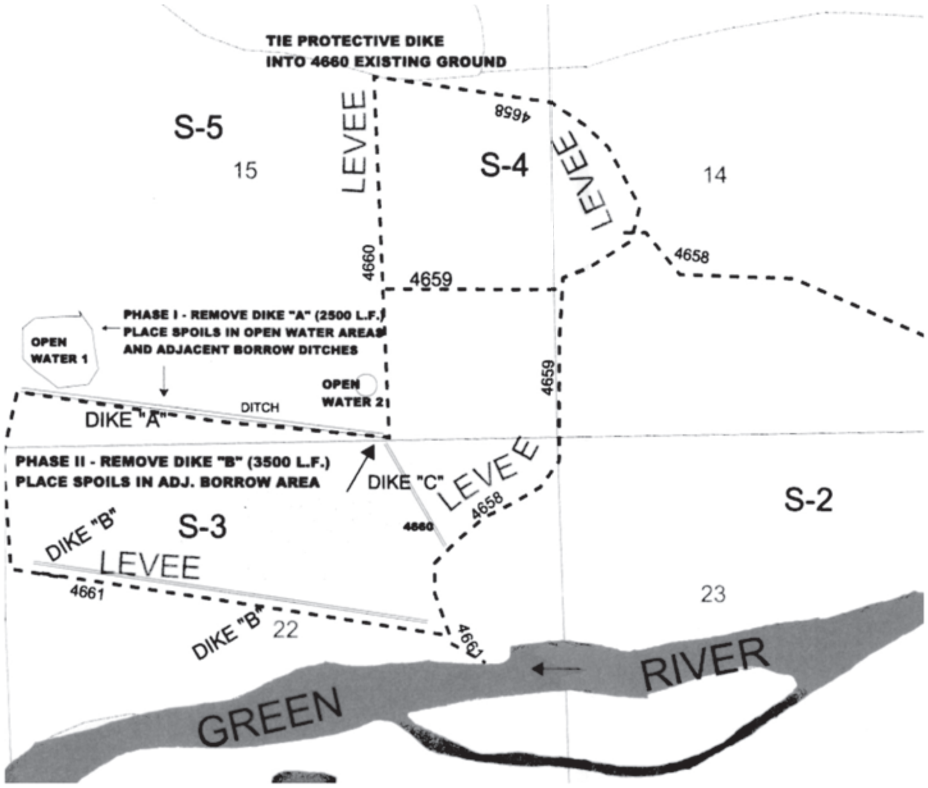

Figure 20. Structure modifications to Sheppard Bottom for dilution of selenium concentrations.

saltcedar invasion have caused additional accretion of natural levees and river bank areas, caused denser stands of vegetation that shades cottonwood seedlings, increased competition for water and light, and increased the depth to which cottonwood roots must grow to get adequate water to support tree growth and survival. In these situations, regeneration, growth, and survival of cottonwood is reduced. In contrast, saltcedar has a higher drought resistance than cottonwood, grows quickly, and has greater root elongation in response to declining water tables or depth to groundwater (e.g., Horton and Clark 2001 and references within). Consequently, saltcedar is out competing cottonwood in many areas of Ouray NWR and is gradually replacing and reducing cottonwood-dominated riparian areas. Reduced cottonwood stands on the refuge are potentially impacting the diverse animal community that relies on these areas including species of special concern such as the yellow-billed cuckoo, common yellowthroat, Lewis' woodpecker, blue grosbeak, Swainson's hawk, and smooth green snake.

Historically, most wetlands in floodplains along the Green River near Ouray were seasonally inundated and recharged, but did not retain water year round except in depressions and following years of exceptionally high flood events. Wetland vegetation in floodplains ranged from annual grasses and herbaceous species at higher elevations at the edges of floodplains to water tolerant macrophytes and submergents in low depressions (Fig. 17). As floodplains were leveed and managed for extended water regimes for breeding waterfowl, wetland vegetation shifted to water tolerant communities dominated by dense stands of cattail and bulrush (Sangster 1976). Wetland units on Ouray periodically were drained and disturbed (e.g., by disking) to control dense monotypic stands of emergent vegetation. Despite periodic disturbance, robust emergents have become more dominant than during historic conditions. In recent years, management has attempted to use more seasonal flooding to encourage moist-soil vegetation and to control dense stands of emergents.

More permanent water regimes and dense emergent vegetation in floodplain wetlands may have increased the number of waterbirds nesting on Ouray NWR compared to historic periods, but the more prolonged inundation also reduced vegetation and food resources used by migrant waterbird species. Long-term surveys of nesting waterbirds on Ouray do not indicate increasing populations nor high recruitment. Surveys of migrant waterbirds are incomplete, but suggest reduced numbers during periods when Ouray wetlands were permanently flooded. Extended water regimes also increased muskrat and beaver populations on Ouray NWR. These mammals have caused delays in drainage of some units by obstructing flows through water-control structures and increased herbivory both in the wetlands and on cottonwood saplings along the Green River. This increased herbivory on cottonwood saplings may be further suppressing cottonwood abundance in the Green and Yampa river floodplains (e.g., Breck et al. 2003).

Levee construction on Ouray NWR has reduced the frequency of overbank flooding of the Green

River into floodplain wetlands and restricted access to these sites by river fishes. Restricted access to floodplains and increases in nonnative fishes in the Colorado and Green River system have caused reductions in the state and federally endangered bonytail, Colorado pikeminnow, humpback chub, and razorback sucker (e.g., Modde et al. 1996). Other species of special status on Ouray NWR that rely on floodplain wetlands include bald eagle, peregrine falcon, roundtail chub, black tern, American white pelican, northern river otter, long-billed curlew, and Caspian tern.

In addition to saltcedar, other nonnative plants that have invaded large areas of Ouray NWR include tall whitetop, Russian-olive, and Russian knapweed The exact area of coverage of these species is not entirely known and apparently is expanding (Fig. 21) Many chemical and mechanical techniques have been used to control nonnative plants including disking, burning, cutting, and application of herbicides, especially Round-up, Arsenal, and 2,4-D amine (USFWS 2000, Gardner 2002).

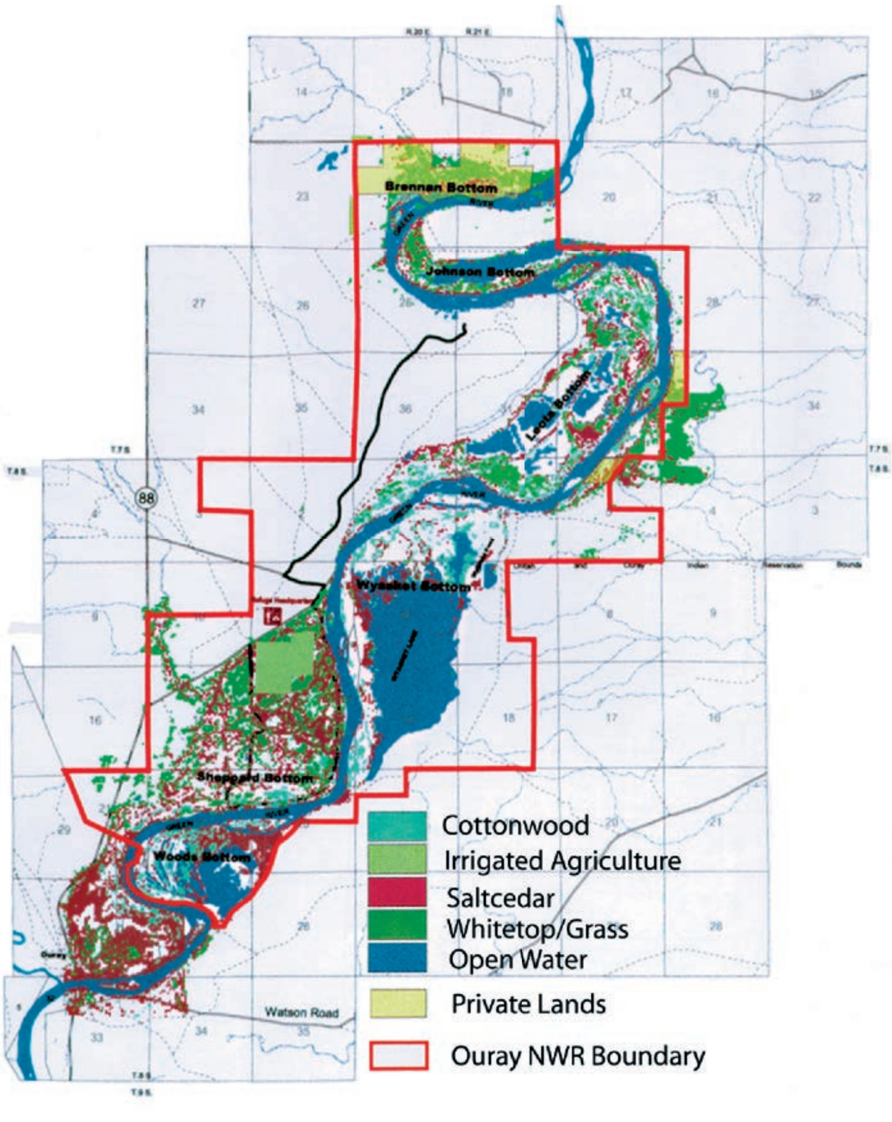

Figure 21. Distribution of saltcedar and tall whitetop on Ouray National Wildlife Refuge, Utah, during 2000.

ECOSYSTEM RESTORATION OPTIONS

GUIDING PRINCIPLES

Many areas of Ouray NWR retain at least parts of historic community structure and ecological processes despite considerable alterations to the hydrologic condition of the Green River, extensive development in some floodplain bottoms, and invasion of nonnative plants. Floodplain wetlands comprise the largest, but also the most altered, habitat type on Ouray NWR. In contrast, most upland grasslands are relatively unchanged from when the refuge was first established. Restoration of degraded floodplain habitats on Ouray NWR will require that each bottom be carefully evaluated to: 1) understand geomorphic surfaces; 2) realistically assess opportunities to emulate ecological processes especially flooding frequency, duration, and extent; and 3) determine relative costs and benefits of management actions. We offer certain ecological principles that can help guide decisions about restoration activities.

What is the appropriate conservation objective?

The type and magnitude of alteration to structure (e.g., vegetation composition) and ecological processes (e.g., frequency of overbank flooding) of habitats should determine what type of conservation action is appropriate for individual sites on Ouray NWR. If an area has minimal degradations to historic structure and processes, then protection of the site and its habitat(s) is needed (Fig. 22). An example of low degradation on Ouray NWR is upland grasslands. In contrast, if either structure or processes are highly degraded then a combination of enhancement and restoration is needed. Riparian woodlands on Ouray are an example of this type of degradation where structure (i.e., cottonwood trees) is mostly intact, but significant alterations to flood frequency have reduced scouring actions and exposed soil surfaces needed for germination and survival of cottonwood. In this case, structural parts of the riparian woodland need enhancement (e.g., control of saltcedar) and processes need restoration (e.g., some means to create bare soils where good groundwater is present). In the most severe cases of degradation, many floodplain wetlands on Ouray NWR have greatly altered structure (extensive cross levees) and processes (reduced flood frequency) and restoration efforts will be more difficult, if they are possible at all.

The various floodplain bottoms on Ouray NWR have different degrees of alteration to process and structure (Fig. 22). Wyasket Bottom has the least amount of degradation and Leota and Sheppard Bottoms have the most altered conditions. Most of Wyasket Bottom has minor structural alteration because no levees were built in this area, except for the old Wyasket Pond levees. Although Green River flows and flooding are altered from pre-Flaming

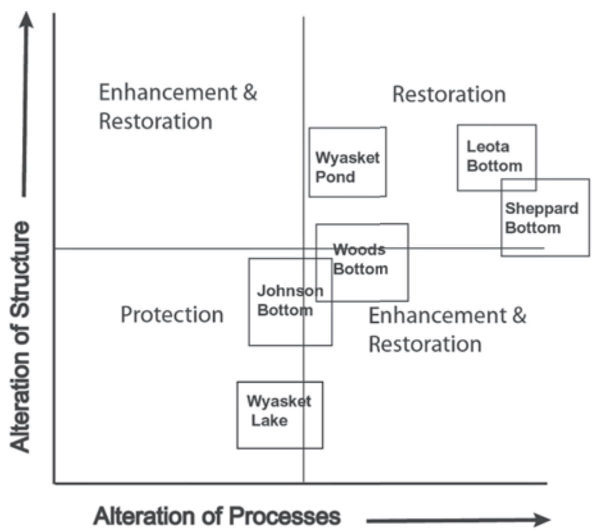

Figure 22. Model of conservation actions most appropriate for floodplain "bottoms" on Ouray National Wildlife Refuge, Utah.

Gorge Reservoir periods, periodic overbank flooding does occur in Wyasket Bottom and its large area allows both sheet and flood water to flow across it unimpeded. Consequently, protection of the Wyasket Bottom area with no, or limited, future development seems most appropriate.

In contrast to Wyasket Lake, the Wyasket Pond area has greatly altered structure because of the old levee surrounding it and construction of inlet canals to allow flooding of the area at low water levels of the Green River. Because Wyasket Pond is located on a higher point bar area, it historically (pre-levee) was not flooded as often or as long as lower backswamp areas. Consequently, it needs restoration of both structure (i.e., removing levees) and processes (i.e., shorter duration and less frequent flooding). Because Leota and Sheppard bottoms also have high alteration in both structure and processes, complete restoration may not be possible, or desirable, because of the significant infrastructure in these areas, potential contamination from selenium, and a desire to provide complexes of floodplain wetlands with different water regimes.

Woods and Johnson Bottom have medium levels of alteration to structure and processes. Johnson is somewhat less altered than Woods Bottom because interior cross-dikes have been removed in Johnson Bottom. For these bottoms, enhancement of processes (restoring overbank flooding at pre-1963 recurrence intervals) and restoration of structure (e.g., partial levee removal) seems most appropriate.

Structure and function

Restoration must seek to repair both the structure and functions of habitats. Functions of habitats are created and maintained by both structural and process elements of ecosystems. For example, nursery sites for razorback suckers require periodic river flooding of floodplain wetlands that contain dense stands of emergent and submergent vegetation (Modde 1997). Restoring only structure or process without the other will not replicate natural ecosystem functions and values and will require greater management intensity to maintain the site. In the above example, reintroducing regular spring flooding without creating annually dynamic water regimes including periodic dry years that sustain floodplain wetland communities may allow fish to enter floodplains, but will not provide high primary and secondary productivity needed for growth and survival of young. Conversely, manipulating water levels to sustain plant and invertebrate productivity without reintroducing flood flows will not provide access for entrainment and subsequent growth and recruitment of native fishes.

On Ouray NWR it will not be possible to completely restore all structure and processes to every site. Any return to historic structure and process usually is better than the currently degraded condition. However, some sites may be so altered that either structure or processes can not be restored and these areas may be permanently shifted to another condition. In these "irreversible" areas, managers must understand the "new" condition and not try to manage the site for "old" habitats or processes that can not be reinstated or sustained without extremely intensive management.

Like-for-like

True restoration of ecosystems involves trying to reestablish vegetation communities and processes that previously were present on a site. In this report we use the mid-1900s period prior to construction of Flaming Gorge Reservoir as the baseline for determining types, distribution, and abundance of habitats historically present on Ouray NWR and as a model for restoration. Modeling historic distribution of habitats depends on understanding the distribution of habitats relative to soils, geomorphic setting, topography, and hydrologic regime. This "base" information provides the first-level criteria for deciding what habitat type(s) should be restored at specific locations and also how basic processes (e.g., overbank flooding) operate and should be restored, or replicated, if possible.

Wyasket Pond provides an example of using base abiotic information to make sustainable habitat restoration decisions. Wyasket Pond historically was a higher elevation point bar surface with interspersed riparian woodland habitat on ridges and herbaceous seasonal wetland in swales (Fig. 23). The point bar surface at Wyasket Pond graded into alluvial and upland terrace that contained finer alluvial sediments and upland grassland and semi-desert shrubs. These soils were conducive to crop production and in the mid-1900s a protective levee was built in this area by a private landowner to exclude flood waters from the Green River. After Ouray NWR was established, managers reversed use of the Wyasket Pond levee from an exclusion purpose to an inclusion purpose used to impound water. Clearly, this change created a different wetland condition than historically occurred on the site and management of Wyasket Pond has traditionally been difficult and intensive, because

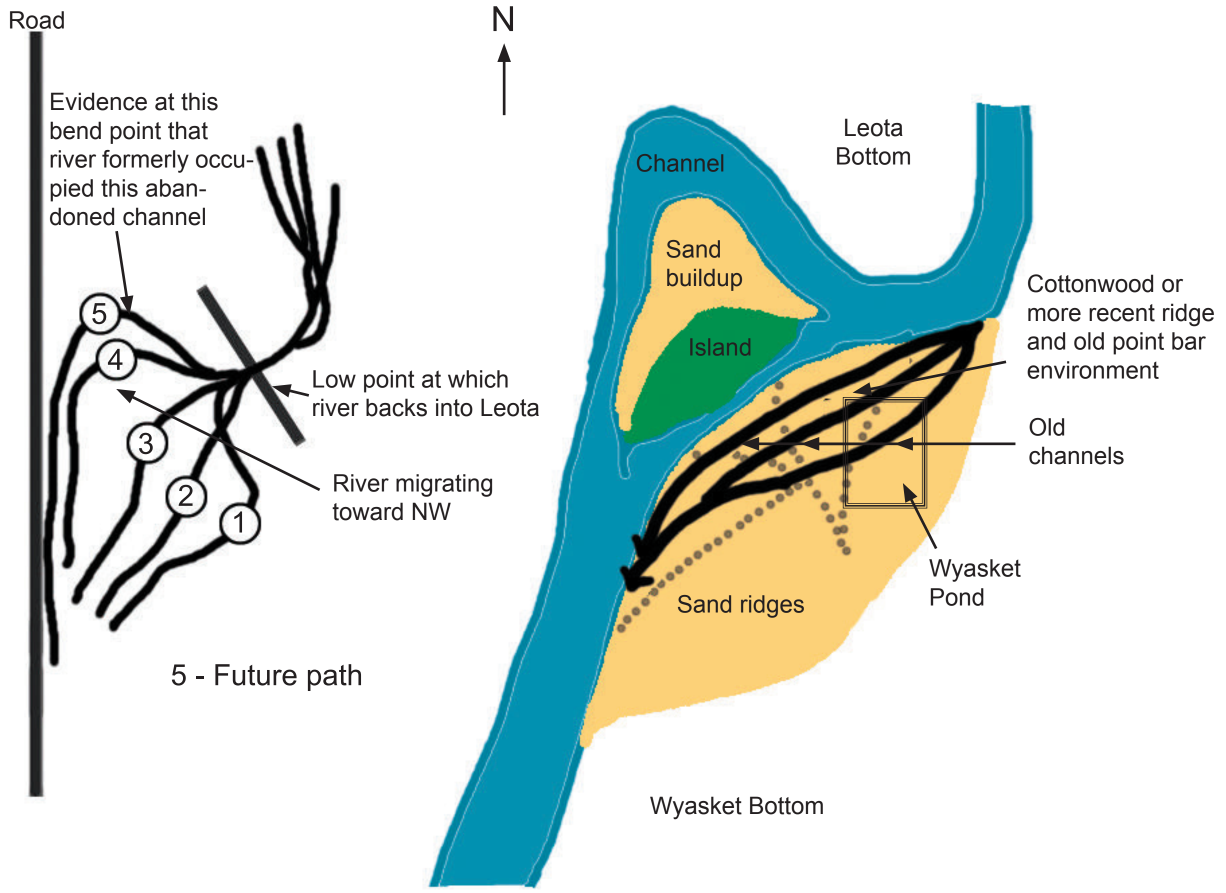

Figure 23. Green River channel migration (1= oldest, 4= current, 5 = projected future path) that formed point bar ridge and swale complex at the north end of Wyasket Bottom. Location of Wyasket Pond includes former channel paths and sand-based ridges and swales.

soils are sandy and topography is heterogenous. Impounding water for extended periods in Wyasket Pond was desired to attract and increase breeding waterfowl on the site, but this required regular pumping and construction of a low elevation inlet to deliver water to the pond each year. Over time, dense emergent stands of cattail and bulrush dominated the area and created an artificial wetland condition. Dense monotypic stands of emergents gradually reduced the use of this area by breeding waterfowl and regular mechanical disturbance and nest structures were required to improve the attractiveness of the area for breeding ducks and geese.

Restoring Wyasket Pond to a more natural condition that is suited for the soils, topography, and geomorphology of the site will require restoring structure (i.e., a complex of ridge-and-swale riparian forest and seasonal wetland) and processes (i.e., irregular, short duration, flooding). If this is done, then a like-for-like restoration will be accomplished.

As previously indicated, some sites on Ouray NWR may have highly altered conditions and warrant management that attempts to create a slightly different habitat type than what was historically present. This creation does not emulate historic site-specific conditions, but may help restore "landscape mosaics" that have been reduced or eliminated on the area. For example, low elevations in some floodplain bottoms were inundated for extended periods by flood waters of the Green River. During wetter periods these low "spots" may have held surface water for 1-3 years, but then dried in subsequent years. These long-term dynamics recycled nutrients and maintained system productivity during dry periods and then provided periodic nursery sites for native fish such as razorback suckers, breeding sites for birds that nest over water, brood sites for waterfowl, and sites for growth and survival of amphibians in wet times. Because of changes in Green River flood frequency and magnitude, and construction of levees in bottoms, these low elevation wetland sites became drier and shifted wetland communities to seasonal or semipermanent water regimes. While it may not be possible to restore Green River flows, it may be possible to use the alterations (e.g., levees) to emulate periodic extended inundation in some impoundments and thereby restore some elements of historic landscapes at Ouray NWR.

River ecology and floodplain connectivity

Attempts to restore hydrological processes on Ouray NWR will be compromised because of alterations to Green River flows following closure of Flaming Gorge Dam. While it may be possible to alter future releases from Flaming Gorge Reservoir to more closely emulate seasonally- and annually-dynamic flows and flood pulses, many competing uses and objectives will influence decisions and changes are not likely to occur soon. Conservation interests should continue to advocate changes in releases from Flaming Gorge to more closely emulate natural dynamics. In the near future, some management opportunities may be possible on Ouray NWR to help restore seasonal flood patterns. These management actions must understand and replicate basic hydraulic patterns and geomorphology of the Green River channel and floodplain system and include natural patterns and locations of connectivity between the river and floodplain.

In general, it is desirable to improve the connectivity between the Green River and Ouray NWR floodplain bottoms during spring flood pulses. Historically, some parts of most, but not all, floodplain bottoms on Ouray NWR flooded at recurrence intervals of 1.5-2.5 years. From 1923-1962, a 2-year recurrence flow was 21,967 cfs but since 1963 a 2-year recurrence interval is only 16,347 cfs. Consequently, if a recurrence interval of 2 years was desired on Ouray NWR, entry points on natural or man-made levees would need to be provided at elevations that allowed flows of >16,000 cfs to enter floodplain bottoms.

At Ouray NWR, overbank flooding historically occurred first at low elevation sites along natural levees at downstream ends of floodplain bottoms and last at higher elevation point bar surfaces on inside bends of the Green River (Fig. 16). Consequently, most flooding of Ouray bottoms was from slow "backwaters" that deposited some fine sediments in bottoms and had limited scouring at entry and exit points. Backwater floods typically occurred in some areas of Johnson, Leota, and Woods Bottoms almost every year. Higher floods were needed to back water into Sheppard and Wyasket Bottoms because these areas had higher elevations and more pronounced natural levees. Headwater floods that crossed point bars into Ouray bottoms historically occurred only at flows >27,000 cfs at a return interval of >5 years. A similar recurrence interval now is >23,000 cfs.

The above geomorphological patterns and hydrological data for Ouray NWR suggest that altering existing natural or man-made levees to restore backwater flood connectivity to floodplain bottoms should occur at low downstream ends of bottoms to allow flows of 14-16,000 cfs to enter Johnson, Woods, and Leota bottoms and 17-20,000 cfs to enter Wyasket and Sheppard bottoms. Lowering entry points on levees at upper ends of bottoms or across point bar surfaces generally is not desirable at elevations that allow flooding <23,000 cfs. Artificially lowering entry sites at upper ends of bottoms or at locations that cause flooding <14,000 cfs will create more headwater type flooding that: 1) deposits coarse texture sediments at entry sites and 2) increases scouring at unarmored exit locations. In contrast, constructing entry sites at the downstream end of bottoms >16,000 cfs will create slow sluggish backwater flooding that: 1) reduce scouring of natural levees and exit sites, 2) deposits moderate amounts of silt at entry sites that may enhance cottonwood regeneration and 3) periodically deposit thin veneers of silt in floodplain wetlands that sustains wetland productivity.

Flood flows across Ouray NWR floodplains generally occurred at wide slow sheetflow that gradually rose and fell. Structural developments that impede sheetflow across bottoms or that accelerate rates of rise and fall should be removed where possible.

Practicality and management intensity

Decisions about restoring native ecosystems on Ouray NWR must understand the relative "costs" and constraints of restoring and maintaining a site in relation to the degree of ecosystem degradations (Fig. 22). Certain structural alterations may be reversible, while others are not. For example, some interior cross-levees in floodplain bottoms may be easily removed and not compromise management of other units (e.g., the levee between L7 and L7A in Leota Bottom) while others can not be removed because of interconnected water movement, concerns about selenium contamination, etc. In general, intensity and expense of restoration and management will be greatest in the areas that have the most severe degradations (e.g., Leota, Sheppard - Fig. 22). Also, restoring Green River flows and overbank flooding of Ouray NWR bottoms will be difficult, if not impossible. Consequently, other more practical modifications will be needed, especially those modifications that do not require intensive management.

RESTORATION DECISIONS ON OURAY NWR

The specific goals and priorities for restoring and managing habitats on Ouray NWR will depend on many biological, social, and economic factors. This report does not attempt to prioritize habitat restoration opportunities, but does offer suggestions on how certain restoration and enhancement of habitats on Ouray NWR can help restore and sustain the ecological integrity of the area and region. Important general goals for restoration on Ouray NWR are to:

1. Maintain a complex of habitat types on Ouray that match historic distributions related to soils, geomorphological surface, topography, and hydrological regime.
2. Improve the connectivity between the Green River and floodplain wetlands.
3. Emulate natural hydrological regimes in floodplain wetlands where possible.
4. Enhance riparian woodlands to provide a corridor of cottonwood-dominated forest along the Green River.
5. Enlarge the size of habitat "patches" where possible and reduce compartmentalization and/or restrictions to surface water flows into and across floodplains.

Specific recommendations for each habitat type and area are provided below:

Upland grassland, clay bluffs, semi-desert shrublands

The high elevation benches and terraces that border the Green River floodplain contain unique assemblages of plants and animals that add diversity, buffers, and continuity to floodplain habitats at lower elevations on Ouray NWR. Most upland, bluff, and shrubland areas are relatively unchanged from the mid-1900s and should be protected. Plant communities on these sites are adapted to older eroded soil types and limited soil moisture. Annual primary production in these communities is low and sustained by low-levels of herbivory and occasional fire. Recommendations include:

- Protect uplands, bluffs, and shrublands from development and unusual erosion. Roads, trails, and human access should be limited in these areas and soils should not be mechanically disturbed.
- Sustain grass-dominated communities with moderate levels of herbivory from native mammals and periodic fire.

Alkali flats

Alkali flats are bands of habitat between shrublands and floodplain wetlands that have high evapotranspiration rates. Runoff water and groundwater seeps provide seasonal surface moisture and short-duration shallow flooding that supports diverse grass and herbaceous plants adapted to more saline conditions. The key to sustaining alkali flats is maintaining seasonal sheet water flow into and across these areas. Historically, alkali flats were occasionally (20-30-year flood events) flooded for short periods during very high flow events of the Green River. Most alkali flats on Ouray NWR are not highly degraded, but in some places sheetflow to, and across, these flats is interrupted by roads, levees, and culverts that concentrate and divert flows laterally. Alterations to the hydrology of the Green River and levees in and around floodplain bottoms have virtually eliminated floodwater inundation of alkali flats. Recommendations include:

- Protect undisturbed alkali flats from additional development where possible.
- Improve surface water sheetflow across alkali flats by removing unnecessary roads and ditches.
- Where roads cross alkali flats, construct multiple culverts and/or low spillways to allow water to cross flats in many locations and flow into floodplain wetlands.
- If roads must cross alkali flats they should be low wide berms to allow the rare, but important, high flood waters of the Green River to flow into alkali flat areas.

Riparian woodland

Most of the historic riparian woodland areas on Ouray NWR are still present, but patch size is diminished and the species composition is gradually changing as cottonwood is being replaced by saltcedar. River processes that perpetuated cottonwood included periodic high flows that scoured point bars and deposited a thin veneer of silt on natural levees and ridges. These newly exposed substrates, adequate soil moisture, and light allow cottonwood seedlings to germinate and survive. In the absence of any of these 3 conditions, germination and survival of cottonwood is compromised and is subject to increased competition from saltcedar. Changes in flow of the Green River and levees constructed along the river have reduced overbank flooding at higher elevation natural levee and point bar locations. Interestingly, some areas within levees especially in Sheppard and Leota bottoms have many young cottonwood along higher elevation contours that have been periodically disturbed in attempts to control saltcedar or from road and levee construction. Recommendations include:

- Improve frequency of overbank flooding of the Green River at appropriate sites and elevations (see discussion of floodplain bottoms below).
- Evaluate cottonwood and saltcedar response to mechanical soil disturbance on point bar ridges inside protection levees in Sheppard and Leota bottoms.
- Protect existing stands of cottonwood-dominated stands of riparian forest.

Wyasket Bottom and Wyasket Pond

With the exception of the old Wyasket Pond site, this floodplain bottom is less disturbed and degraded than other bottoms on Ouray NWR. Green River water begins to flow into Wyasket Bottom at about 19,000 cfs but most of the area is not flooded until the river discharge exceeds 22,000 cfs (Tables 5, 6). Although flood frequency at Ouray has changed since Flaming Gorge Reservoir was built, a 16-17,000 cfs flow still occurs about every 2-3 years and a 22,000 cfs flow occurs about every 5 years. Consequently, although less frequent, Wyasket Bottom continues to flood at regular intervals and retains many historic processes and water flow patterns that are not restricted by roads, levees, ditches, and water control structures. In contrast, Wyasket Pond is ringed with levees and is at a higher elevation old point bar location that historically was not flooded except at high flows. Recommendations include:

- Protect Wyasket Bottom by retaining its topography and water flow patterns, eliminating roads and ditches where possible, and not developing the area further.
- Remove all levees and water-control structures in the old Wyasket Pond area and restore the ridge-and-swale topography and plant communities to this site by re-creating and connecting depressions and ridges.
- Abandon the inlet structure and ditch that provided water to Wyasket Pond at flows of > 4000 cfs.
- Evaluate mechanical soil disturbance on point bar ridges on the north side of Wyasket Bottom and the former Wyasket Pond area to encourage cottonwood regeneration.

Johnson Bottom

The structure and processes of floodplain wetlands in Johnson Bottom have been partly restored in recent years by removing internal levees and by the construction of a 200 foot levee breach at the southeast corner of J-4. Low portions of this bottom historically flooded about every 1.5 years at Green River discharges >18,000 cfs. Presently, some Green River water flows through the breach at discharges >13,000 cfs at a recurrence interval of about 1.5 years. Construction of the fish kettle and modified water-control structure allows water to be retained in Johnson Bottom for extended periods, perhaps longer than historic regimes. Given past development for fisheries concerns, this bottom now can be managed for prolonged flooding, however, care will be needed to sustain the long-term plant communities and primary and secondary productivity of this area. Recommendations include:

- Promote slow backwater flooding of Johnson Bottom by widening the current 200 foot breach and by constructing at least one additional breach (of at least 200 foot) along the Green River at J-4 to allow flood water to enter Johnson Bottom in a wider flow pattern. Wider and multiple breaches are desirable to allow more natural water flows into floodplains and to reduce excessive scouring and/or deposition of silt that occurs at constricted inlets and outlets.
- Do not construct breaches at the upstream end of Johnson Bottom - such a breach would cross a point-bar surface and cause excessive deposition of silt and sand into Johnson Bottom.
- Abandon and fill the old inlet ditch and structure at J-1.
- Manage Johnson Bottom for dynamic water regimes including regular seasonal, and periodic annual, drying. Do not continuously flood Johnson Bottom for more than 2-3 years.

Woods Bottom

Woods Bottom has been modified similar to Johnson Bottom in that an area in the southern part of the Main Unit now has a fish kettle and modified outlet water-control structure. Woods Bottom also has a short levee breach in the Backside Unit. These modifications have attempted to provide more regular flooding of the bottom to enhance entrainment and recruitment of native fishes. The levee breach allows flood water to enter the western diked part of Woods Bottom, however this water can not inundate the entire bottom because the internal levee between the Backside and Main units restricts flow throughout the area except at very high flows. Restoration of more natural flood flows into and through Woods is needed and future management should seek to maintain natural wetland vegetation communities and dynamics. Recommendations include:

- The upstream inlet and interior drain canals in Woods Bottom are in unnatural locations and tend to silt in during flood flows and are difficult and costly to maintain. The inlet structure should be maintained to provide management flexibility during low flow periods, however, the interior drains should be filled because their excavations may perforate bottom seals of the wetland and reduce water holding capability. Future habitat management plans should address when and how the inlet structure should be operated.
- Remove all interior levees in Woods Bottom to facilitate sheetflow of water across the floodplain wetlands. This removal includes both the long internal levee that separates the Backside and Main units and the short levee spur into the east central part of the bottom that led to an old abandoned gas well site.
- Construct a new levee breach at least 400 foot wide at the southern part of the Main Unit of Woods Bottom immediately west of the fish-kettle/outlet structure to allow slow backwater flooding.
- Manage Woods Bottom for long-term dynamic water regimes to sustain plant and animal communities and long-term productivity. Do not continuously flood Woods Bottom for more than 2-3 years, and then periodically dry the bottom.

Leota Bottom

Although Leota Bottom is highly modified because of the extensive levees, ditches, and water control structures, opportunities exist to enhance the connectivity between the Green River and Leota Bottom and also use remaining infrastructure to provide diverse and dynamic floodplain wetland types that have been lost throughout the Green River floodplain ecosystem. Historically, some backwater flooding into low elevations at the south end of Leota occurred almost every year at Green River discharges >14,000 cfs. Changes in river flows have reduced this flooding frequency, however, the levee breaches at L7 and L7A allow water to flow into and out of Leota at ca. 15,000 cfs. The breach at L7A is more appropriately located to allow backwater to flow into Leota than is the L7 breach site, however, the entry flow at L7A is compromised by its narrow width and by the modified outlet structure and fish kettle at this location. Future management of Leota should seek to simultaneously enhance backwater flooding into this bottom, reduce constrictions or diversions of flood water across the bottom, and maintain many units in an intensive wetland management. Recommendations include:

- Remove levees along the river-side of Leota and cross levees that impede sheetflow of water across the bottom. Specific levees that could be removed without sacrificing significant area of managed wetland include levees between and on the north sides of L1 and L2, the levee between L7 and L7A, and the levee between L8 and L9. Removing these levees would create a more natural flow corridor both for backwater flooding and occasional headwater floods along the east side of Leota and still allow intensive management of wetlands in the western side of the bottom.
- Widen the levee breach at L7A and armor it to prevent excessive scouring.
- Do not construct levee breaches or low elevation river entry spillways along point bar locations at the upper part of Leota in L1, L2, and L3. Even though the frequency of high Green River flows is reduced from historic patterns, causing more regular river entry at these locations at relatively low flows (i.e., < 20,000 cfs) of the Green River would increase sediment deposition in Leota and possibly cause unnatural flows across the bottom that could increase velocity and

scouring at exit locations at lower ends of the bottom.

- Manage all areas above 4663 feet amsl for riparian woodland. These areas are remnant natural levees and point bar deposits that historically supported cottonwood and include almost all of L1, L2, and eastern parts of L3, L5, and L7. Cross levees between L3 and L5 and between L5 and L7 could be shortened to those areas < 4663 feet amsl without sacrificing wetland area.
- Manage the low elevations of L3, L5, and L7/L7A as semipermanent wetlands with occasional drying of the units to emulate natural floodplain wetland plant community dynamics.
- Manage L4, L6, L8, L9, and L10 as seasonal floodplain wetlands with shorter duration flooding regimes and regular drawdowns to create a mosaic of moist-soil and herbaceous vegetation. Where possible enhance sheet water flow from uplands and alkali flats on the western edge of Leota into these units.

Sheppard Bottom

Historically, most of Sheppard Bottom was seasonally flooded wetland with periodic extended inundation in low depressions during high flow events. With intensive development and construction of inlet structures that allow water to flow into Sheppard at flows >5000 cfs, this area now is flooded longer, deeper, and more regularly than at historic times. Also, the protective levees along the Green River restrict overbank flooding into the area except at high flows. Removing levees in S3 and S5 and part of the protective levee at the south end of S3 now provide an opportunity for more regular overbank flooding. Inadvertently, however, the narrow drain canal constructed in the southeast corner of S3 now also allows the Green River to flow into this area at flows >10,000 cfs and has caused high velocity flows through the canal which has caused head cutting in the canal near the exit point at the Green River and conversely carried coarse sediments further into S3 and caused excessive sedimentation where the canal enters floodplain flats in S3. If head cutting continues, the Green River will flow up the drain canal more frequently and cause continued sedimentation problems and unnatural inundation of parts of S3. Recommendations include:

- Isolate the drain canal in S3 from the Sheppard Bottom floodplain which is connected to the Green River. Options include raising the bank of the drain canal, placing pipes and structures between the floodplain and canal, or closing the drain canal and placing a pipe structure at the former exit point. Engineering analyses should be done to determine which options will be most efficient and effective.
- As with other floodplain bottoms, do not construct levee breaches at the upstream ends of Sheppard Bottom or across old point bar deposits. A natural low-natural levee point is on the south side of S1 and is an appropriate site for a 200-400 foot wide levee breach to emulate natural flooding entry and exit patterns in this portion of Sheppard Bottom.
- Manage S1, S2, and S4 as a complex of seasonal and semipermanent wetlands, rotating flooding and drying schedules so that no unit has prolonged inundation for more than 2-3 years. Much of Sheppard Bottom historically had short duration seasonal flooding, and restoring this water regime would more closely emulate natural hydrologic regime, reduce monocultures of robust emergents, and provide critical moist-soil type foods and habitats for migrating waterbirds.
- Manage higher elevations along the Green River as riparian woodland. Evaluate mechanical disturbance to increase cottonwood, and decrease saltcedar, germination and survival in these spots.
- Continue to manage the higher elevation crop fields in Sheppard for grains and forage for geese, sandhill cranes, and ungulates. While artificial, these fields provide valuable forage that replaces the greatly reduced browse naturally occurring along the higher elevation “edges” of wetlands in the Green River floodplain corridor.

Parker moist-soil impoundments

These moist- soil impoundments were constructed at higher elevations adjacent to S4 of Sheppard Bottom to replace wetlands lost when the Roadside Ponds units were retired because of selenium contamination. Because the Parker impoundments are at higher elevation and receive water only from Pelican Lake, they should continue to be managed as seasonally flooded units to produce herbaceous vegetation and other moist-soil foods. These units should not be flooded for extended periods and periodically should be kept dry to prevent encroachment of robust emergents and invasive woody vegetation.

MONITORING AND EVALUATION

Habitat restoration projects should be accompanied by an active monitoring and evaluation program to document biotic and abiotic responses to the project and to improve understanding of the ecosystem. At Ouray, 4 restoration and management issues have considerable uncertainty and will require careful monitoring and evaluation. These issues include: 1) long-term impacts of levee breaches, 2) mechanical disturbance to increase cottonwood germination and survival, 3) intensive management of wetland impoundments, and 4) location and degree of subsurface groundwater connection between the Green River and floodplain wetlands.

Impacts of breaching levees

Initial observations of levee breaches have indicated the potential for significant erosion and/or sedimentation at breach sites depending on the location of the breach and the magnitude of overbank flows from the Green River (FLO Engineering Inc. 1999). Levee breaches on Ouray NWR to date have been narrow and have concentrated water flowing in and out of the floodplain bottoms. Furthermore, exit sites have been modified with fish kettles in Woods, Johnson, and Leota bottoms and these structures further confine flows. If river levels are high and flood flows across bottoms are fast, the potential for erosion and scouring increases. Also, if floodwaters drop quickly, water in the floodplains exits the breach site rapidly and causes excessive scouring. Armoring breach sites seems to reduce erosion, however, very high flows have not occurred since breach sites were constructed and damage potential is unknown. It appears that widening breaches and constructing multiple breaches in close proximity to each other at the downstream ends of bottoms will more closely emulate natural overbank back flooding patterns, but this approach also needs evaluation. Also, armoring wider and multiple areas will increase costs of construction substantially.

If breaches are constructed in upstream locations, significant sedimentation occurs and could quickly change elevations where flood waters can enter bottoms and also partly fill floodplain wetlands with coarse texture sediments. Where breaches or inlets are present in these upstream locations, sedimentation should be monitored carefully, and if excessive deposition occurs, these breaches and inlets should be closed. Large sediment deposits also can occur at narrow breach sites or ditches. For example, the drain canal constructed to facilitate drainage of S3 and S5 in Sheppard Bottom inadvertently served as an inlet (breach) for flood flows in 2003 and caused head cutting of the canal at the exit point where it connects with the Green River and conversely significant sedimentation where the canal connects with the floodplain. These changes ultimately may create unnatural flood entry and exit flows and compromise drainage from S3 and S5 where residual selenium concentration occurs. Sedimentation and head cutting in this canal should be carefully monitored and the canal should ultimately be redesigned. (see recommendations for Sheppard Bottom).

Cottonwood regeneration

Observations of good cottonwood regeneration inside floodplain impoundments on natural levee and point bar surfaces that have had soil disturbance suggests that periodic disturbance might be useful to increase cottonwood germination and survival in similar areas. Experimental soil disturbance coupled with active monitoring is needed. Higher elevation point bar deposits exist in impoundments in Leota and Sheppard bottoms and in inside bends in Wyasket and Woods bottoms and these sites seem appropriate for restoration of riparian woodland, not herbaceous wetland communities. Targeting point bar sites for some mechanical manipulations, followed by careful evaluation of plant communities, could provide valuable information on cottonwood restoration techniques. Also, the recommended restoration of ridges and swales in the Wyasket Pond area after levees have been removed might be an opportunity to evaluate cottonwood response to disturbance. Any disturbance must be careful not to encourage expansion of saltcedar, consequently, monitoring and evaluation is critical.

The condition of existing stands of cottonwood forest on Ouray should be continually monitored to evaluate survival, regeneration, and competition with saltcedar. Not only should the trees themselves be evaluated, but the abiotic conditions that sustain them should also be monitored. These conditions include soil moisture, frequency of inundation, flood duration, and soil disturbance. Also, occurrence of other ground, shrub, and tree species should be documented.

Wetland vegetation dynamics

Past management of floodplain wetlands at Ouray has tended to inundate wetland units for more prolonged periods than occurred naturally. This management encouraged establishment of dense stands of robust emergents such as cattail and has required regular disturbance to restore more desirable wetland plant communities and open water/vegetation interspersion. Disturbances included draining the impoundments for several years, fire, chemical application, and mechanical means. Prior to development, the floodplain bottoms on Ouray NWR had variable topography that included some deeper areas that held water for longer periods, including year round surface water following high flood events. However, historically most of the floodplain bottoms dried in summer following the periodic overbank flooding and these areas supported primarily herbaceous vegetation communities that are adapted to semipermanent and seasonal hydrology.

Future wetland management on Ouray will try to balance needs of: 1) native fishes that require extended inundation of floodplain wetlands and 2) migrant waterbirds that depend on foods and other resources in seasonally-flooded wetlands. Recommendations in this report suggest managing floodplain wetlands as a complex where intensive management of impoundments for seasonal-type flooding occurs in Sheppard Bottom and the west part of Leota Bottom, extended flooding is manipulated in Johnson and Woods bottoms, and natural overbank flooding and drainage is allowed to occur in Wyasket Bottom and the east part of Leota. This diversity of flooding regimes and management effort provides an excellent opportunity to design an experimental matrix of flooding regimes and to monitor wetland responses including both biotic and abiotic conditions.

Groundwater connectivity

Groundwater connectivity between floodplain wetlands and rivers is common in sand-based river systems such as the Green River. Generally, however, the magnitude and relative influence of these connections are poorly understood despite their potential importance in understanding and managing water levels in floodplain wetlands. It seems probable that the most subsurface connectivity at Ouray NWR may occur in floodplain backswamp deposits immediately adjacent to point bar deposits, but careful monitoring of seasonal and annual groundwater levels is needed to determine the degree of influence. Pesiometers that remotely measure and record groundwater levels could be placed at many locations in the floodplain bottoms of Ouray to determine inputs and drainage. These pesiometers should be maintained for several years to capture both high and low flow years in the Green River.

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