AQUATIC HABITAT FEATURES

WETLANDS

Introduction

Wetlands on any disturbance make a unique and valuable contribution to plant diversity in a relatively unchanging terrestrial ecosystem (Munshower 1994). Unfortunately, adding impoundments and wetlands to reclaimed land may be restricted by state and federal law unless wetlands existed on the site prior to mining, or where they are designed to improve the land use.

An important factor in providing good wildlife habitat is the establishment of permanent, self-sustaining wetlands on reclamation, especially on larger sites (> 3-5 ha) where some sites may be far removed from accessible water (Green and Salter 1987). An exception to this is on ungulate winter range where water may encourage animals to remain throughout summer, resulting in overuse of the area.

A wetland complex allows diversity of habitat types all year from open water to marsh sites to upland habitats (Cole 1986). A complex is more valuable to waterfowl than a single area composed of a monotypic stand of vegetation.

Water holes frequently become a focus of wildlife activity in the semiarid West (Proctor et al. 1983a, 1983b). However, natural surface water is scarce in unglaciated regions, therefore human-created water developments can be particularly beneficial. Such water developments can extend the range of many species. Yoakum et al. (1980) described a case in which wildlife managers channeled the water from an artesian well to a small excavated basin, in an area devoid of water. Ultimately, the pond supported over 155 different species of wild mammals, birds, fishes, and amphibians. Creating additional water sources in Wyoming could similarly enhance the distribution, numbers, and diversity of wildlife (Proctor et al. 1983a, 1983b).

This section examines design considerations for wetlands, streams, final pit impoundments, and springs and seeps to benefit wildlife. Appendix B includes recommendations from a graduate research program (McKinstry 1993). McKinstry evaluated habitat attributes of wetlands constructed or enhanced by the AML Program in northeast Wyoming.

Wetland Habitat Functions

Wetland functions include (Green and Salter 1987; Hammer 1992):

1) Provides habitat and life support: includes all types of microbial, invertebrate and vertebrate animals, and microscopic and macroscopic plants; increases habitat edge;
2) Hydrologic modification: flood conveyance-wetlands slow and retain large amounts of water and in some instances, absorb floodwaters and release those waters slowly; storm surge abatement; base flow augmentation; ground water recharge and discharge - wetlands connect to groundwater systems as waters migrate and percolate into surrounding aquifers; however, groundwater recharge by wetlands is generally poorly understood; improves soil moisture;

3) Water quality changes: addition and/or removal of biological, chemical, and sedimentary substances; changes in dissolved oxygen, pH, and other biological or chemical influences on water;
4) Erosion protection: includes bank and shoreline stabilization; dissipation of wave energy; alterations in flow patterns, and velocity; provides opportunities for development of riparian communities
5) Open space and aesthetics: outdoor recreation - hunting, fishing, and observing and photographing animals; environmental education; research; scenic influences; and heritage preservation - historical and archeological sites;
6) Geochemical storage: includes carbon, sulfur, iron, manganese, and other sedimentary minerals

Mitigation of Natural Wetlands

Reclaimed wetlands should not depend on engineered structures which are prone to failure, excessive sediment accumulation, or which must be maintained. Generally, these must be excavated basins, or basins which have been incorporated into the recontouring plan. They can rely on either surface runoff or groundwater inflow. Other than the fact these will not generally have a dam or water level manipulation capabilities, general habitat features recommended from impoundments may be used to describe suitable enhancement features for wetlands.

Note: Impoundments cannot be used to mitigate loss of natural wetlands. A created wetland must mitigate for the loss of a wetland.

Site Selection Criteria

Criteria for selecting wetland sites include:

1) hydrology
   Important hydrology factors include: surface and groundwater location, quantity, and quality, along with surface and subsurface flow patterns, connections, and seasonal changes (Hammer 1992). Groundwater descriptions should include depth, quality, isolated or perched water tables, and flow patterns (Hammer 1992). Water tables should be above the surface of the wetland for part, but not all, of the growing season (Young 1983).
2) soils
   Wetland soils should be deep and poorly drained (Young 1983). Important soil attributes include: proportions of silt, sand, clay, gravel, and organic material, texture and particle size, permeability and drainage potential, erodibility, and chemistry (Hammer 1992). Soil types should hold water without excessive seepage. Clays and fine silts are better for holding water. Avoid sandy soils unless there is an underlying clay hardpan or fine silts. Some sites may require sealing with bentonite or other clays.
3) topography and drainage patterns
   Low-lying or poorly drained lands are often optimal for creating wetlands. Natural basins or swales along ephemeral drainages are often the best locations, especially where the surrounding vegetation is comprised of bluegrasses, sedges, asters, or other wet meadow flora, indicative of periodic flooding (Proctor et al. 1983a, 1983b). However, sites that

qualify as jurisdictional wetlands should be avoided. Using natural drainages lowers construction costs because less earth moving is necessary.

4) climate and weather

Direction and speed of prevailing winds can influence the choice of wetland orientation and perimeter planning because wave action impacts vegetation and shorelines (Hammer 1992).

5) geology

Geologic factors influence the amount and nature of sediment production (Hasfurther 1985), the water table, surface runoff, and whether bottom materials will hold water without leaking (Verry 1985).

6) biology

Proximity to existing wetlands can be important as a source of planting materials. Wildlife use patterns are an important factor in siting.

7) land ownership and use

Identify ownership, easements, rights-of-way, covenants, water rights, liens, and other encumbrances. In western regions, an outstanding water right can nullify a planned water source (Hammer 1992).

8) juxtaposition to other habitat features

Several small wetlands in close proximity can often be thought of as one large wetland complex (Williams 1985). Snags associated with wetlands can increase the number of bird species in the area (Williams 1985). For waterfowl, upland nesting cover is important.

9) regulations

Contact the State Engineers Office to comply with water statutes and the Army Corps of Engineers regarding Section 404.

10) equipment access

Sites should be accessible to heavy equipment as difficult access increases construction costs (Proctor et al. 1983a, 1983b).

11) potential construction cost

Mine operators are required to estimate construction and reclamation costs in the bonding section of each mine permit application. Costs are quite variable, depending on topography, geology, availability of equipment, pond size, etc. (Proctor et al. 1983a, 1983b).

Wetlands should be located where water conditions are relatively stable and where flash floods are minimized (but where annual recharge is possible) (Green and Salter 1987).

Sediment ponds are generally not recommended for wildlife habitat unless some of the design considerations for small wetlands are incorporated into the initial construction. Sediment ponds included for conversion must be appropriately designed. Typical sediment ponds are uniform, oval-shaped basins with small watershed areas, of limited potential for wildlife habitat. The potential benefit of rehabilitating sediment retention ponds varies greatly, depending on their design, degree of sediment loading, and presence of toxic effluents (Proctor et al. 1983a, 1983b). Dismantling and reclaiming sediment ponds is costly. For this reason, operators appear interested in developing a set of procedures to clean, modify, and retain sediment ponds as final ponds for wildlife and livestock use (Proctor 1983a, 1983b).

General Design Considerations for Wildlife Needs

The design must address structural features; basin morphology; soil handling; vegetation establishment; water quality and quantity; adjacent land uses; and state permitting regulations. Soil Conservation Service and State engineer personnel can assist with basin, dam, spillway, and water control structure designs.

Proctor et al. (1983a and 1983b) provide several design recommendations for embankment ponds that can also provide general guidelines for wetlands. These include:

1) Where possible, perennial water sources should be used. Ponds should be designed to persist at least 20 years. The drainage area should be sufficiently large to ensure an adequate water supply.
2) Several small convoluted ponds are more desirable than one large, uniformly shaped pond, particularly if they are dispersed. Maximum distance between ponds in undulating prairie should be 1.2 to 1.6 km; in foothills or rolling terrain, the distance may be reduced to 0.6 to 1.2 km. Ponds should be clustered for waterfowl use, or uniformly dispersed for other animals such as big game.
3) Shoreline slope should be gentle for ready access by wildlife and for decreasing erosion.

Basin Design

The shape of the wetland should be based upon hydrogeologic and water-budget analyses, site characteristics, and the intended goals (Hollands 1990). For water-table dominated wetlands, the basin must be excavated into the water-table deep enough to attain the desired hydroperiod for the intended vegetation community. Wetland basin size and depth must also relate to the size of the contributing watershed to ensure a sufficient water budget.

Different authors recommend different designs, therefore the following are general guidelines only.

Basin Contours

A larger wetland should include shallow and steep gradients, ledges, trenches and potholes. Local irregularities included in the bottom contours increase interspersion of shoreline, shallow, and open water areas (Bale et al. 1987; Salter and Green 1987). Basin contours should establish approximately 25% temporary (<1 m deep), 50% seasonal and semi-permanent (1-2 m deep), and 25% permanent (>2 m deep) wetland zones in a concentric arrangement. Shorelines should not exceed 1:5 slope (a 1 m rise for each 5 m horizontal distance) to maintain substrate stability and establish productive shallow zones. Shallow gradient contours should approach a 1:30 slope to provide broad zones of temporary or seasonal water to enhance production and vegetation establishment. Shallow shorelines will eventually support wet meadow, emergent, and submersed aquatic vegetation. Depths up to 2.5 m are optimum for plant development. Steep-sloped shorelines inhibit emergent growth and maintains open water areas.

If a fishery is an objective, the Wyoming Game and Fish Department (1976) suggests that no more than 30 percent of the pond be less than 1 m deep. At least 25% of the basin should have a depth of 3.5-4.5 m or more to allow the fish to overwinter. Slopes can reach 3:1 or 1.5:1

for short intervals where drop-offs are desired for fish holding areas. Water depth needs to be adequate for the required life cycles of the stocked fish.

Deeper areas ensure surface water is available year-round (U.S. Soil Conservation Service 1971). Deep pools provide the last remnant of water when the rest of the water has dried up. During wetter months, the central pool should overflow into shallow habitat areas. Surface area/volume ration of the deep pool should be low to reduce evaporative losses. A moderate slope or ramp should enter some portion of the deep pool to allow wildlife access at all water levels (Proctor et al. 1983a, 1983b). Excavated material from deep pools can be included in constructing shoals or islands (Salter and Green 1987).

If waterfowl habitat is an objective, the wetland should have one-third open water and two-thirds marsh (Yoakum et al. 1980), and 50 to 75 percent of the wetland should be less than 0.6 m deep (Eng et al. (1979).

Basin Shape and Shoreline Configuration

On native sites, the existing topography often determines shape and orientation of created wetlands. However, on mine lands, topography can be altered to accommodate various shapes.

The following guidelines should be considered:

1) Shoreline curvature may be increased using a crescent, kidney, oakleaf, dog leg, or various other configurations as opposed to uniform circular or rectangular shapes. Irregular shorelines produce high ratios of shore length to open water (edge effect), maximizing the productive potential of a wetland and resulting in larger zones of emergent vegetation (Bale et al. 1987). Small bays, peninsulas, and shoals attract waterfowl and improve aesthetic qualities.
2) Broader basins can add more habitat diversity than long narrow wetlands by accommodating more varied contours.
3) Shallower zones should be situated parallel to prevailing winds to control shoreline erosion and protect shallow water communities from wave action. Waves will undercut the shore unless broken down by shallow water and vegetation. Peninsulas, besides increasing shoreline irregularity, also act as pond separators and reduce wave action (Bale et al. 1987).

Basin Capacity

Wetland basins should be designed to overspill during a normal spring runoff, and peak rainstorms. Concentric temporary and seasonal wetland zones should flood at maximum water levels. The contributing watershed and estimated runoff determine basin size. Local Soil Conservation Service personnel can recommend basin storage capacity. Minimum recommended surface area (acres) is estimated by dividing the storage capacity (acre-ft) by three.

Wetlands should be at least 0.2 ha, and preferably more than 0.4 ha (Green and Salter 1987).

Landscaping

If surface runoff and snowmelt are the primary water sources, the watershed must yield sufficient runoff to replenish the wetland annually (Proctor et al. 1983a, 1983b). Generally, 20.2 to 24.3 ha of watershed area are required for each acre-ft of pond storage in this region (U.S. Soil Conservation Service 1971).

On mined lands, reclamation efforts often create a moderate topography that may not yield sufficient runoff to support a wetland. If the reclaimed area is too flat, too high above groundwater, or the drainage area is inadequate, then the wetland could be built on suitable, adjacent lands.

The deep portion of the wetland can be excavated immediately upstream of the dam and the excavated material incorporated into the dam.

Substrate

Prior to compacting the wetland bottom, soil composition should be checked to ensure a minimum of 20% clay content or other impervious material. If soils are too porous, a sealer, such as bentonite, can be mixed into the soil with a disk (Proctor et al. 1983a, 1983b). A sheepsfoot roller will compact the wetland bottom.

Cap bottom materials with layer of topsoil (20 cm or more) and a thin layer (2 cm) of hay mulch for a growth medium for vegetation and to establish a natural detrital cycle (Salter and Green 1987). Salvage bottom substrates from wetlands or ponds that are destroyed elsewhere on the mine for use in the reclaimed wetland.

Retopsoiling

Topsoil and subsoil should be salvaged and stockpiled for reapplication to shorelines, islands, dikes, and other sites. Avoid prolonged storage to maintain viability of live seed and root stocks. All surfaces within the littoral zone should be dressed with salvaged topsoil to assist vegetation reestablishment and colonization by aquatic organisms.

Advantages of reusing wetland soils include (Hollands 1990):

1) organic soils generally maintain saturated conditions which helps wetland plants survive droughts; and
2) organic soils contain indigenous seed banks and root stock which ensures rapid revegetation with appropriate plants.

To the extent possible, minimize the volume of excavated materials and transport distances to reduce construction cost. Subsoil removed to form deeper contours can be incorporated directly into islands, dikes, peninsulas, and dams. After rough excavation, some of the abrupt contours can be left for diversity. Impoundment basins should be packed before replacing topsoil. Livestock access points should be graded relatively level and dressed with firm substrate. Islands and dikes should be stabilized with sod-forming grasses, as should the basin prior to flooding.

Earthen Islands

Islands add habitat diversity by increasing shoreline edge. Nesting and loafing waterfowl commonly utilize islands to avoid terrestrial predation and disturbance. Islands also increase the aesthetic appearance of waterbodies, and if placed properly, can provide a break to control wave action (Bales et al. 1987).

Creation. Islands can be created by severing a peninsula from the mainland; dumping rock or earth fill; by modifying spoil piles in end pit lakes; or by excavating and mounding earth prior to flooding (Green and Salter 1987). Materials excavated from the wetland basin and incorporated into islands reduces the cost of removal. Materials for push-up islands are pushed up and compacted with a bulldozer or moved, dumped, and sloped with a scraper. Scrapers can compact and slope islands better which will reduce wave erosion (Payne 1992). At least 90 cm of freeboard reduces nest destruction from settling and periodic flooding.

Tips of peninsulas can be cut off, with minimal earth moving, into islands at least 4.6 to 6 m wide and projecting 46 to 60 cm above the anticipated high-water level (Payne 1992). However, cutoff islands are closer to the mainland and more susceptible to predators.

Construction is best in fall or winter. This allows time for sorting fine materials by wind and water without disturbing nesting waterfowl (Payne 1992).

Location. Islands on ponds over 10 ha should be closer to the leeward than the windward side of the mainland and at least 9 m from the mainland for maximum use by waterfowl (Eng et al. 1979; Ohlsson et al. 1982), in water 0.5 to 0.75 m deep (Hammond and Mann 1956; Jones 1975).

In larger waterbodies, place islands at least 30 to 50 m from and parallel to the mainland to avoid direct exposure to prevailing winds and wave action (Jones 1975).

If the island is not parallel to the prevailing wind, emergent vegetation (Green and Salter 1987) or riprap (Duebbert 1982) can protect against wave action or ice scouring.

Islands should be 60 to 150 m apart (Jones 1975; Giroux 1981; Duebbert 1982; Hoffman 1988). Islands separated from the mainland by a channel at least 9 m wide (Keith 1961), and 0.5 to 1.0 m deep (Keith 1961; Green and Salter 1987) reduce access by land predators. The distance from shore depends on each situation, other authors recommend a much greater distance between islands and the mainland. For example, McCarthy (1973) recommended long, narrow islands at least 15 m from the shore in impoundments larger than 0.8 ha. On large bodies of water, a minimum of 33 m between islands lessened territorial disputes among nesting Canada geese (Hook 1973).

Substrate. Almost any stable fill material is adequate for island construction. The islands should be capped with 20-40 cm of topsoil to provide a medium for suitable plant growth (Green and Salter 1987).

Mudflats, gravel bars, etc. provide habitat for small wading birds.

Size. Islands should be 0.5 to 5.0 ha (Duebbert 1982; Higgins 1986), although islands 100 sq meters or more seem adequate for use by most waterfowl (Green and Salter 1987). In larger waterbodies (> 20 ha), include several well-spaced small islands rather than one large island (Green and Salter 1987; Payne 1992).

Small islands might not be large enough to support many nests, but large islands might support too many predators (Payne 1992).

Shape. As island size increases, so should shoreline complexity (Green and Salter 1987). Islands greater than 1000 sq meters should include irregular shorelines, peninsulas, small bays, and shoals.

Tops of islands should be flat and average 1 m above spring water levels. Slopes should be 1:30 or less (Payne 1992). A horseshoe configuration with the open end oriented downwind will break wave intensity and provide a small, protected bay. Smaller islands can be rectangular for greater shoreline and ease of construction (Giroux 1981).

The leeward side of the island should have a flat, open shoreline for loafing and access for nesting (Payne 1992).

Height. The island should be high enough to prevent flooding and low enough to prevent wind erosion. After settling, the island should rise at least 0.6 m above the normal spring water level. Smith (1978) and Soots and Landin (1978) recommend a height of 1 to 3 m above high water.

Density. One island is recommended for each 1.6 ha of surface water (Wyoming Game and Fish Department 1976).

Revegetation. Trees and shrubs planted on the mainland upwind from islands create windbreaks (Ohlsson et al. 1982; Green and Salter 1987). However, these might provide perches or cover for raptors and crows that would prey on waterfowl (Payne 1992). Emergents planted around the island will reduce wave erosion. Avoid planting trees and tall-growing shrubs on islands intended for waterfowl because they provide perch sites for raptors and crows. However, if the islands have exposed surface areas greater than 25 sq meters, a few widely spaced, low shrubs provide protection for waterfowl nests.

The Alberta Fish and Wildlife Division (undated) recommended vegetating islands with alternating patches of native grass and legumes with dense shrubs such as willow, dogwood, or gooseberry planted on the windward side.

Water Quality

Water quality is critical to meeting the long-term goals of wetlands (Munshower 1994). If water quality cannot be met, the waterbody cannot be permitted. Studies and models may suggest what chemical characteristics the waterbody will have after reclamation, but the mining companies should be prepared to drain and fill the waterbody if the quality of the water does not meet standards of proposed use.

Man-made wetlands should periodically flush to prevent stagnation and conditions which may lead to wildlife disease problems. A dense stand of terrestrial and wetland vegetation at the incoming drainage will trap sediment, improve water quality, and extend the useful life of the wetland. Siphoning water to off-site containments for livestock watering will reduce shoreline degradation and sediment deposition. This practice also maintains water transparency which enhances aquatic plant growth.

Water Control Structures

Water levels and duration can be manipulated on wetlands by regulating water outflow and inflow from spring runoff. The ability to manipulate water regimes permits management of wetland vegetation and can enhance productivity. Building water control structures may not be practical in most reclaimed wetlands -- wetlands are to be self-sustaining, without engineered structures which are prone to failure, excessive sediment accumulation, or which must be maintained. Feasibility of water control structures must be considered prior to construction. Control structures provide a variety of management options to regulate and enhance aquatic plant

development. However, they require long-term maintenance and may not be permissible without a permanent maintenance and operation agreement. If water control structures are part of the reclamation plan, the local Soil Conservation Service can assist with the design.

Revegetation

Because plantings are expensive, they should be avoided if natural germination and succession are possible (Payne 1992). Generally, lands considered for seeding contain fewer than 15 percent desirable perennial species (Payne and Copes 1986), or are likely to be invaded by undesirable plants.

Before planting, sketch a base map of the wetland site, including depth contours, bottom types (muck, peat, clay, loam, sand, rock), and water clarity (Erickson 1964). The map will help determine species and quantity op planting stock needed and where to plant.

Wetland. Specific wetland variations and final land-use plans determine species selection (Nawrot and Warburton 1986).
When selecting wetland plants, consider the range of genetic tolerance of each species to different water levels, periods of inundation (hydroperiod), growth media, and other physical, chemical, and biotic factors (Haynes 1984; Hollands 1990).

Seeding or transplanting root stocks is the quickest way to establish aquatic vegetation. Submersed aquatic plants, algae, and benthic organisms can be established rapidly by inoculating the wetland with bottom sediments from other wetlands.

Replacing muck (organic surface material) on the newly created wetland can favor the establishment, growth, and initial survival of a diverse variety of native wetland species (Haynes 1984). Muck provides an improved growth medium and a source of seeds and propagules.

Emergent vegetation can be categorized into two groups (Bale et al. 1987):

1) draw-down shallow areas, 10 to 20 cm, which provide a habitat for microinvertebrates; and
2) more permanent and deeper shallow areas, 20 to 90 cm, which provide a habitat for perennial emergent vegetation.

Emergents require water depths less than 1 m to develop (Proctor et al. 1983a, 1983b). Sedges, spikerush, smartweed, rushes, and duckweed are the most likely pioneer species, but can be transplanted by rootstock, or the entire plant.

The shallower areas provide for short-term inundation, allowing cycles of vegetative growth and decomposition (Bale et al. 1987). The 20 to 90 cm depths provides an emergent vegetation zone. Varying the shoreline slopes below the water horizon will vary the width of the emergent vegetation zone. Variations in thickness and density increase the ponds value to wildlife and enhances aesthetics.

Nawrot and Warburton (1986) recommend using perennial species which produce rhizomatous or tuberous rootstocks as these provide the most successful vegetative establishment. Rhizomes can be placed directly into favorable subsurface zones when seeding establishment at the surface is precluded due to high temperature, salinity, or droughty conditions. Nurse crops or establishment of a temporary cover of clover, grasses, and/or broadleaf herbaceous species may enhance conditions.

Planting stock collected locally or obtained from commercial sources is recommended (Nawrot and Warburton 1986). The advantage of using local stock is increased viability due to

better ecotypic adaptation within a given species and fewer deleterious effects associated with shipping and handling. Rhizomes are usually collected by hand because of accessibility and substrate conditions, although low ground pressure equipment can occasionally be utilized where feasible to increase rates of collection. Harvesting rhizomes should be based on a sustained yield to retain a source of available local stock.

Collect rhizomes and tubers in late fall after shoot growth has stopped, or in early spring before extensive new growth begins (Nawrot and Warburton 1986). Lengths of tubers containing 2 to 3 nodes/rhizome should be cut after removing all vegetative growth. Until they are planted, they can be stored in a moist medium (peat, sand). If storing fall-collected rhizomes overwinter, treat with dilute bleach solution (0.5% sodium hypochlorite) to reduce danger of fungal injury, and then maintain at 35 to 40 degrees F. Injury and mortality during storage is reduced by collecting in the spring rather than the fall.

Rhizomatous species do well when planted in the spring, although some species (e.g., threesquare bulrush (Scirpus americanus) may do well when planted during summer (Nawrot and Warburton 1986). Late winter seeding over frozen slurry substrate allows areas to be planted that are otherwise inaccessible during early spring thaw.

Propagules should be spaced to allow for lateral spread of rhizomes within each stand (Nawrot and Warburton 1986). Depending on species, 30-150 cm intervals are recommended. Wider intervals are adequate for rapidly spreading species such as threesquare bulrush. Less prolific (e.g., hardstem bulrush (S. acutus) rhizomes should be spaced at 30- to 90-cm intervals. Clustered planting arrangements of perennials, providing both species diversity and spatial diversity, best simulates natural wetland habitat. Excessively dense plantings (yielding 100% cover) in seasonally inundated zones reduces a wetland's value as waterfowl habitat; 50% overall cover is desirable.

Riparian. Riparian vegetation communities occur adjacent to lakes, ponds, wetlands, streams, rivers, and seeps in moist or saturated soils. Riparian vegetation intercepts overland drainage, dissipates flood energy, binds the soil (reduces soil erosion and stabilizes streambanks), traps sediments and nutrients, provides food and cover for wildlife, and moderates water temperatures in the stream through shading (Green and Salter 1987; Platts et al. 1987).

Riparian zones are preferred habitat because they contain (Kovalchik and Elmore 1992):

1) easily accessible water
2) more favorable terrain
3) hiding cover
4) soft soil
5) more favorable microclimate
6) an abundant supply of lush palatable forage

Riparian habitats in arid regions can be developed more quickly by transplanting rooted cottonwood cuttings (Miller and Pope 1984).

The water table should be less than 60 cm below the ground for riparian species (Swenson 1988).

Upland. Uplands associated with wetlands are generally managed for nesting cover and pasture for waterfowl, but upland wildlife also benefit (Payne 1992).

Upland cover should at least equal the total wetland area (Olson 1990). Good upland cover is important throughout the watershed. However, a concentric zone equal to the impoundment areas should receive additional protection from grazing. Seeded areas should be permanently fenced and grazing excluded the first two years to aid vegetation establishment. Afterward, periodic moderate grazing within the fenced area will maintain vigor and production. Fences should be located at least 8 m and preferably 12 m or more back from the waterline (Mathiak 1965). Open shoreline segments should always be fenced to protect them from livestock grazing and trampling. Good livestock management can maintain nesting habitat near wetlands. Late summer or fall grazing is recommended to avoid disturbing nesting waterfowl and other wetland birds. Livestock should be excluded from nesting areas during April 1 through June 30. Livestock should also be removed when proper utilization is attained, before vegetation exhibits signs of trampling or overuse.

Dense residual cover is necessary for protection and nesting by some species of waterfowl. Upland waterfowl nesting sites and islands should be seeded with species that establish dense nesting cover, including wheatgrasses, yellow sweet clover, and alfalfa. Mulching hay with ripened seed heads into established grass stands can also convert them into dense nesting cover. Shrubs and trees add cover, improving wildlife habitat. Seeding and transplanting herbaceous and woody plants are encouraged, but trees should never be planted on a dam because roots weaken the structure and can lead to failure. Well-dispersed clumps of shrub seedlings improve habitat diversity within upland grass meadows.

Adjoining upland cover such as shelterbelts, hedgerows, woodlots, heavy grass-covered areas, or shrubby patches provide travel lanes to water. However, predation may increase along these corridors. Hedgerows and shelterbelts also provide visual barriers which can reduce disturbance related to frequent human activity.

Some species found in Wyoming wetlands include the following grasses and grasslike plants (Young 1983): Nebraska sedge (Carex nebrascensis), tufted hairgrass (Deschampsia cespitosa), bluejoint reedgrass (Calamagrostis canadensis), northern reedgrass (C. inexpansa), and mountain bromegrass (Bromus marginata). Common forbs are: arrowgrass (Triglochin palustris), columbine (Aquilegia spp.), horsetails (Equisetum spp.), monkshood (Aconitum spp.), pale agoseris (Agoseris glauca), waterleaf (Hydrophyllum spp.), and waterhemlock (Circuta spp.). Dominant woody vegetation is bog kalmia (Kalmia polifolia), currant (Ribes spp.), rose (Rosa spp.), and willows.

General Waterfowl Habitat Requirements

Waterfowl must access a variety of seasonal habitat components for reproduction, feeding, staging, molting, and brood rearing. For example, dabbling ducks require shallow wetland areas in spring for mating; dense upland cover for nesting in late spring; shallow wetlands interspersed with emergent shoreline vegetation and open water for brood rearing; and large areas of open water for molting and staging. These habitat types all provide seasonal food sources.

Upland nesting cover next to or near water is preferred by dabbling ducks, grassland birds, and other upland wildlife (Payne 1992). Ducks generally nest within 400 m of water (Moyle 1964), but if suitable cover exists, most can be accommodated within 100 m (Atlantic Waterfowl Council 1972).

Characteristics of a pond considered to be of value to waterfowl include (Hinkle et al. 1981; Bale et al. 1987): shoreline slopes and pond depths which provide ideal open water to perennial emergent vegetation ratios (e.g., 50 to 75% of the pond with less than 0.6 m of water (Proctor et al. 1983a, 1983b); resting and loafing areas (open, gentle shorelines); reduced sedimentation; irregular shorelines; permanent water supply (in balance with the watershed); improved water quality; islands and peninsulas; draw-down shallows; pond sizes primarily from 0.4 to 4 ha with lush shorelines of emergent vegetation; marshy zones; and the proximity of ponds to one another. A slightly deeper pond in the beginning can compensate for some sedimentation of the new wetland (Steve Tessmann, Wyoming Game and Fish Department, pers. comm.).

Table 1. Plant species beneficial to waterfowl (Evans and Kerbs 1977; Payne 1992).

Brood Cover:
- Bulrushes (Scirpus species)
- Cattail (Typha spp.)
- Sedges (Carex spp.)
- Whitetop (Scolochloa festucacea)
- Burreed (Sparganium spp.)
- Rush (Juncus spp.)

Nesting/Escape Cover:
- Reed canarygrass (Phalaris arundinacea)
- Redtop (Agrostis alba)
- Garrison creeping foxtail (Alopecurus arundinacea)
- Barnyard grass (Echinochloa crusgalli)
- Switchgrass (Panicum virgatum)
- Orchardgrass (Dactylis glomerata)
- Bulrushes (Scirpus species)
- Cattail (Typha species)
- Wheatgrasses (Agropyron species)
- Alfalfa (Medicago sativa)
- Sweetclover (Melilotus officinalis)
- Smooth Brome (Bromus inermis)
- Retired cropland/ungrazed or moderately grazed areas with residual vegetation

Food Species:

Flooded Areas-
- Pondweeds (Potamogeton spp.)
  - (Sago pondweed preferred-(Potamogeton pectinatus)
- Wild Millet (Echinochloa crusgalli)
- Sedges (Carex spp.)
- Smartweed (Polygonum spp.)
- Alkali bulrush (Scirpus maritimus)
- Widgeongrass (Ruppia maritima)

Table 1. Continued.

Duckweed (Lemna spp.)
Coontail (Ceratophyllum spp.)
Spike Rush (Eleocharis spp.)
Muskgrass (Chara spp)
Dryland Areas-
Corn (Zea mays)
Wheat (Triticum aestivum)
Barley (Hordeum vulgare)
Proso millet (Panicum miliaceum)
Foxtail millet (Setaria italica)
Cereal rye (Secale cerceale)
Clover (Trifolium species)
Oats (Avena sativa)

Construction

September through December are preferred months for wetland construction when soils have dried sufficiently for efficient handling of heavy equipment. Small projects can be constructed with tractors and other equipment commonly available on mines. Larger projects require more extensive commitments of equipment, labor, and materials. Excavation and contour development can be accomplished with bulldozers, scrapers, bobcats, backhoes, or front-end loaders. When basin subsoils contain moderate to high portions of gravel, sand, or other coarse material, a 15-cm clay seal must be applied to control seepage.

A wetland plan should include a cross-sectional view of the basin and an aerial view including shoreline configuration, islands, upland cover areas, fencing, topsoil stockpile sites, water control structures, access routes, observation points, and other features.

Post-Construction Management

Water Level Manipulations

Periodic drawdowns and reflooding are necessary to maintain vigor and productivity of aquatic vegetation (Addy and MacNamara 1948; Linde 1969; Weller 1978). Flexibility to manipulate water levels should be incorporated where feasible in wetland creation. Drawdowns 1) expose bottom sediments to aerobic decomposition, releasing bound nutrients; 2) break seed dormancy of certain aquatic plants; 3) enhance access to waterfowl foods, and; 4) stimulate production of aquatic invertebrates. However, consistently high or stable water levels impede new wetland plant establishment and may lead to over-mature, decadent vegetation of little value for wildlife. Wetland plant density and diversity decline with prolonged flooding.

Natural wetlands are subject to seasonal fluctuations from spring runoff through the summer period due to evaporation, seepage, and plant transpiration. Water control structures can be built into man-made wetlands to simulate natural fluctuation. However, they require maintenance and may not be practical. Ideally, man-made wetlands should have two drainage outlets: an emergency overspill to prevent flood waters from overtopping the dam and a valve-controlled drain to adjust water levels. The valve outlet should be situated where it can completely drain temporary, seasonal, semi-permanent, and permanent open water areas. The Soil Conservation Service can assist with outlet specifications.

Prescribed water management regimes may not be practical on mined lands, but a discussion is included for cases where a permanent operation agreement can be negotiated. Controlled water level manipulations require a perennial water source and cannot be implemented on impoundments within ephemeral or intermittent drainages. In Wyoming, prescribed drawdowns should occur after spring migration but prior to fall frosts, and should be timed to stimulate aquatic plant germination and seed production. These periods depend on local growing season length. Assuming an adequate water supply throughout the growing season, controlled drawdowns should be initiated in early to mid-July, allowing sufficient time for reflooding by mid- to late September. This stimulates germination and plant reestablishment, yet restores water levels for fall migrating waterfowl. Drawdowns can be implemented annually or on multi-year intervals depending on the management goals for vegetation.

During spring runoff, concentric temporary and seasonal wetland zones are rapidly inundated. Regulated drawdowns gradually expose the substrate within these outer zones, permitting germination of new aquatic vegetation. Slow drawdowns, produce denser, more diverse vegetation without impacting wildlife use. Periodic rainstorms create slight fluctuations which benefit aquatic plant establishment. The outlet should be closed by mid- to late September to permit refilling before migrating waterfowl arrive.

Optimum productivity is achieved by implementing yearly drawdowns which expose temporary and seasonal wetland fringes, and by completely draining the wetland every 5-7 years. Structural maintenance can be accomplished when the wetland is emptied.

Adequate water quality is important to prevent stagnation, disease outbreaks, and algae blooms. Maintain periodic exchange through all shallow wetland areas, particularly during ice-free periods.

Management of Adjacent Land Uses

Created wetlands should be developed only where adjoining land uses are compatible. Toxic runoff from herbicides, pesticides, and fertilizers, overgrazing, and intensive agricultural practices may retard habitat development. Management of adjacent lands includes controlling livestock access, irrigation, farm runoff, and integrating agricultural activities.

Mitigation of Saturated or Subsaturated Wetland Types

Subirrigated sites are found within every major resource area in Wyoming (Young 1983). Subirrigated sites are located adjacent to wetlands, in lowland valleys, and on mountain rangelands where water is likely to concentrate and spread (Plummer et al. 1968; Young 1983).

Wet meadows are important because the produce succulent forage throughout the growing season for ungulates.

Wet meadows depend on a high water table and typically have free water covering at least a portion of the surface (Melton et al. 1983). Soils are deep, characterized by a fluctuating water table, and are nonsaline and nonalkaline (Young 1983). Broadleaf sedges and rushes are common and willow communities may be present. Hydrophilic grasses and narrow-leaved sedges dominate on drier sites. Major grasses and grasslike plants vary slightly between northern and southern areas (Young 1983). Nebraska sedge, basin wildrye (Elymus cinereus), and tufted hairgrass are common in northern climates and higher altitudes. Southern plains are dominated by big bluestem (Andropogon gerardi), indiangrass (Sorghastrum nutans), little bluestem (Schizachyrium scoparium), and prairie cordgrass (Spartina gracilis). Forbs include: American licorice (Glycyrrhiza lepidota), iris (Iris spp.), clovers (Melilotus spp.), flax (Linum spp.), fleabane (Erigeron spp.), and western yarrow (Achillea millefolium).

Subirrigated ecosystems are less hydric than wetland sites, thus willows do not usually dominate these sites unless they have been disturbed (Young 1983). Shrubs commonly found in the higher precipitation zones are: chokecherry, rose, shrubby cinquefoil (Potentilla fruticosa), and willow. At lower elevations, buffaloberry (Shepherdia argentea), hawthorn (Crategus spp.), and rubber rabbitbrush become more important. Thistle (Cirsium spp.), Kentucky bluegrass, and willows begin to invade misused sites.

Production is usually greater than on dryland sites, but less than on wetlands (Young 1983).

Small dams with water-control structures and spreader ditches maintain water levels in meadows to ensure retention of green succulents into late summer. If succulent vegetation is inadequate, clovers and vetches can be plowed and reseeded. A strip of sage planted on the edges of meadows and drainages enhances diversity (Braun et al. 1977).

Wet meadows can also be developed on alluvial fill along water courses where the slope gradient and stream velocity are decreased (Eckert 1983). As sediment deposits, vegetation develops from the edges and more sediment is trapped, until the basin is filled and completely vegetated with a mesic plant community (Robertson and Kennedy 1954).

Shrub Meadows

Shrub meadows can be established in association with lowland grasslands or riparian meadows (Green and Salter 1987). Shrubs should be well-dispersed and/or in small clumps (about 10 sq meters) for adequate cover. No more than 25% of the community should be occupied by shrubs at maturity. Shrub meadows are recommended for damp to water-saturated soils around waterbodies, along streams, and in depressions.

Large Final Pit Impoundments

A waiver to AOC is required to not backfill the final pit. Final pit impoundments can provide sport fisheries, wildlife habitat, and public recreation. Final pit impoundments can provide potential sites for lake and pond development if water quality remains acceptable, if an adequate inflow of ground and/or surface water is received, and if the depression holds water (Munshower 1994). Spoil ridges can be used to create islands in final pit impoundments.

Runoff from the reclaimed watershed should provide sufficient water to replenish annual water losses from the reservoir, and one or more inlet streams and one outlet channel should be present (Green and Salter 1987). The pond should be planned for the average annual runoff expected: 12 to 32 ha/acre foot of pond storage are generally required for our region (USDA 1971). Final cut lakes and ponds supplied by aquifers probably require considerably less surface drainage area, depending on the aquifer (Proctor et al. 1983a, 1983b).

Other considerations include: the reservoir should aesthetically blend into the surrounding; animals and people should have easy access to the water; hazards must be eliminated; and an alternative plan must be provided if the water quality or quantity turns out to be inadequate (generally the alternative is backfilling and revegetation) (Munshower 1994).

Impoundments with fish must be managed to for at least the first few years. Ponds greater than 0.8 ha are not as difficult to manage as smaller ones (SCS 1971).

Substrate

At least 20% of the substrate mix should be fine clays or other non-porous material to retain water. This will help prevent shoreline saturation and sloughing of the outslopes of the lake. Some substrate compaction may be necessary. To provide a growing substrate for plants, topsoil and hay mulches should be applied to the bottom where operating water depths will be less than 3 m. The pH range of the substrate materials should be 5.5-7.5.

Water Quality

Fish will be influenced by: water temperature; dissolved oxygen; pH; turbidity; nutrient levels; concentration of metals; and permanent toxic materials (Proctor et al. 1983a, 1983b). Year-round water characteristics should be assessed before impoundment construction.

Depth

At least 25% and preferably 75% or more of the basin should be more than 3 m deep (USDA 1971; Green and Salter 1987). If ponds are designed exclusively for fish and fishing, some shores should slope abruptly to a 1-m depth (Proctor et al. 1983a, 1983b). This decreases the number of fish lost to wading birds, discourages growth of emergent aquatics and pond weeds, and makes fishing easier (USDA 1971).

Fish Habitat

The Wyoming Game and Fish Department should be consulted for appropriate fish stocking.

Fish and aquatic invertebrates should be placed in the lake as soon as possible after accumulation of adequate water (Munshower 1994).

Fish habitat can be improved by placing shelters in lakes. Brush can be tied together and weighted to sink (Everhart and Youngs 1981). More complicated shelters with frames and brush can also be built. The shelters often concentrate fish for better availability by anglers.

Spawning areas in lakes can be constructed by dumping quantities of large rocks at selected sites (Everhart and Youngs 1981). They should be placed at a depth where they will not be uncovered by normal lake fluctuations. Other spawning devices are cut brush along shores, spawning slabs, and floating boards for those species that lay their eggs underneath floating logs or other debris.

STREAM RESTORATION

Perennial Streams

Channel Types and Morphology

A natural stable channel will have ongoing cycles of degradation and deposition; however, sediment transport through a given reach will be greatly reduced when compared to an unstable channel (Bale et al. 1987). Stable channels decrease sediment deposition and increase water quality to ponds located downstream.

Basic channel patterns include (Leopold and Wolman 1957; Schumm and Meyer 1979):

1) Straight channel; straight thalweg (deepest part of channel); channel relatively stable.
2) Straight channel; sinuous thalweg; channel generally stable, but thalweg shift and bar migration occur.
3) Meandering
    a. Uniform channel width, small point bars. Channel is stable but neck cutoffs occur.
    b. Channel wider at bends, large point bars. Chute and neck cutoffs and meander shift produce a relatively unstable channel.
4) Meander - braided transition; large point bars with frequent chute cut-offs; unstable channel with sinuous thalweg.
5) Braided channel; unstable channel with multiple thalweg and numerous bars and islands.

Channel Design Concepts

For maximum wildlife use, a watercourse should have a shallow gradient (less than 11%) and a sinuous channel to slow water velocities (Green and Salter 1987). Through natural erosion processes, sinuous channels eventually provide a variety of bank heights and shapes. Pools constructed at bends provide deep water areas for fish and aquatic mammals. Extended bends in flatland areas create oxbow lakes and wetlands.

Design recommendations include (Green and Salter 1987):

1) width and depth must be sufficient to handle a maximum discharge equivalent to two consecutive 1:10 year flood events.
2) bends should be separated by distances 5-7 times the stream width.
3) pools on bends should be 0.5-1.0 m deeper than the channel bottom, and should be excavated when the channel is dry or during low water.

<u>meanders</u>. Meandering channels consist of alternating S-shaped bends, not necessarily controlled by terrain (Moore et al. 1976). Meandering streams are characterized by a series of pools and crossings. The main current of the channel flows from outside of one bend, across the channel, to

the outside of the next bend. In the pools, the channel cross-section is triangular, becoming deeper along the outside of the curve. The crossing area shape is more rectangular and shallow. Most authors designate streams with a stream length one and one half times as long as the corresponding valley length to be meandering streams.

Meanders are initiated by continually changing gravel bars, deeps, and shallows (Moore et al. 1976). The current is deflected from one bank to the other. Uneven bank sloughing, trees, and large obstructions also initiate the instability. The deflected current erodes the bank for a distance until the current shifts to the opposite bank further downstream, where erosion continues, and the process is perpetuated.

Meandering stream sections are considered reasonably stable (Hasfurther 1985). Meanders can be used to reduce stream velocities and increase habitat diversity in the stream channel (Green and Salter 1987). They are best located in flat terrain and the stream cross-section should be uniform within the meander.

Meander radius of curvature should be less than 100 m in order to achieve distinct pool and point bar particle size distributions like those which occur in natural stream channels (Milne 1982), and to provide sufficient fine soil for riparian vegetation along the channel (Vinson 1988).

Newly designed and constructed stream channels have an early period of self-adjustment before they become hydrologically stabilized with controlled sediment deposition and transport (Hasfurther 1985).

oxbows. can be constructed in conjunction with meanders, or by extending streambank channels on the outside edge of bends (Green and Salter 1987). Oxbows are also best constructed on flat terrain and on streams with low water velocities. Construct shallow sills at both the inlet and outlet channels and dredge deeper areas in the central oxbow area.

An oxbow may be cut off from the main flow by construction of a levee (Nelson et al. 1978). A shallow impoundment may be developed by incorporating a water outlet structure in the oxbow. Where the main stream channel is characterized by shifting streambed material, isolated oxbows can provide necessary stabilized habitat for fish production.

pools, riffles, and sequencing. Straight streams typically have an undulating bed which alternates between pools and riffles (Moore et al. 1976). Pools and riffles are typically spaced 5-7 channel widths apart (Leopold and Wolman 1960).

Pools hold deep, slow moving water at low flows, while riffles are both faster and shallower. Pools are scoured and maintained at high flows, and riffles collect coarse bed material.

Riparian Vegetation

Green and Salter (1987) recommend:

1) selecting good turf-forming species along streambanks that are able to withstand a wide range of moisture conditions and short-term flooding.
2) transplanting clumps of aquatic plants such as bulrushes, cattails and sedges (root clumps at least 0.25 cu meter in size) along streambanks in slow-moving areas of streams. Rocks or metal staples will anchoring clumps securely with until roots are established.

3) planting shrubs using fresh cuttings of willows and alders (treat stems with rooting hormone) or transplants of established plants. Shrubs stabilize cutbanks and establish plant cover in stream depositional areas.
4) planting trees 2-5 m away from the streambank to prevent excessive shading of the stream.
5) planting sod-forming grasses such as red fescue (Festuca rubra) or flood tolerant grasses such as reed canarygrass immediately adjacent to the water's edge to stabilize the shoreline or streambank.

Spacing between plants will vary with need and cost. For quick control of an eroding bank, a 1-m spacing may be required immediately adjacent to the bank (Melton 1983). Farther back, spacing can gradually increase. Terrain features such as hummocks and depressions, and organic residue such as stumps and cull logs protect new plants from drying out, trampling damage, sun scald, browsing, etc. Natural looking, random spacing in clumps at flow stress points along streambanks prove cost effective and produce an aesthetic spatial array of vegetation types with maximum wildlife benefits.

Stream Improvements

The following is a very brief description of some of the stream improvement or instream devices. For a more detailed description and evaluation of the structures, see Wesche (1985).

channel blocks. Channel blocks can be used to consolidate braided channels.

checkdams. Checkdams are small dams constructed in a gully or other small watercourse. They decrease streamflow velocity and promote deposition of sediment (Bituminous Coal Research, Inc. 1974). They can be placed in straight runs to create shallow upstream pools and downstream scour pools (Green and Salter 1987). Checkdams should extend 0.25 m above the streambed and should only be installed in low velocity streams (< 3 cu m/s). Checkdams are constructed with rock, concrete, gabions, or logs, with bracing extending at least 2 m into the streambank.

cover logs. Cover logs can be designed to provide overhead fish cover in stream sections with adequate water depth.

modified root wads. When securely anchored in deep pools, modified root wads can provide excellent fish cover.

single log deflectors. Deflectors are used to (Wesche 1985): direct current to key locations such as bank covers; assist in the development of meander patterns within the confining banks of channelized reaches; deepen and narrow channels; scour pools, increase water velocities; remove silt from spawning gravels and critical areas for benthic invertebrate production; protect stream banks from erosion; and enhance pool-riffle ratios.

A log deflector and cover log are often combined to provide pool habitat and cover within wide, shallow, low gradient sections of a stream.

double log deflectors. Double log deflectors increase current velocity in order to scour pools and create stream bank undercuts.

single, double, and triple log dams or weirs. The use of various small dams creates plunge pools or deeper water in shallow, low-gradient streams dominated by long homogenous riffles. In steeper gradients, log dams create resting and feeding areas for fish.

wedge dams. Wedge dams create plunge pools or deeper water in shallow sections of streams that are extensively dominated by long riffle areas. In steeper gradient streams, wedge dams break the gradient, providing resting and feeding areas for fish.

"K" dams. The purpose and design of the "K" dam are similar to the wedge dam. One log is used to span the entire stream, with braces placed on the lower side at approximately 45 degrees to the main log.

overhanging banks. Overhanging banks provide cover for fish and aquatic mammals. Overhanging banks can be constructed on the outside bends of stream channels using log or plank platforms to support overhanging ledges of topsoil (Green and Salter 1987). For stabilization, plant grass and sedge groundcovers and shrubs such as willows or alders on the platform.

tree revetments. Tree revetments are used to protect degrading and slumping stream banks.

barrier trees. Barrier trees are laid within the riparian zone parallel to the bank to reduce livestock grazing and trampling.

riprap, gabions, and other erosion control. These are used to stabilize streambanks until bank vegetation is well established (Green and Salter 1987). These methods are best used in combination with revegetation so a soil cap on these structures should be provided.

Rip-rap of sufficient size, shape and weight should withstand expected water flows (Green and Salter 1987). Large enough spaces left between stones prevent clogging with silt. Rip-rap should extend at least 40 cm below the low water line.

Moderate to large-sized rock material (10-30 cm diameter) in gabions and wire mesh with openings small enough to retain rock material are recommended (Green and Salter 1987). To avoid snagging, lids of gabions should close in the downstream direction. Debris should be removed periodically.

Wood cribbing will probably rot quickly when exposed to air, and needs to be maintained periodically (Green and Salter 1987).

Erosion fabrics are useful for trapping sediments, thus promoting plant growth, but they must be securely anchored with staples or rock (Green and Salter 1987).

rock deflectors, jetties, wing deflectors. These are used to direct flow into meandering patterns and increase flow velocity to maintain a deep channel. They are more stable than log deflectors in large streams.

rock dams. Rock dams are similar in design and function to the different types of log dams.

rock or concrete ledges. These provide similar benefits as checkdams, but do not impound water upstream (Green and Salter 1987). Rock or concrete slabs are embedded in the streambed and the scour pool and upstream edges are rip-rapped to reduce erosion.

boulder placement. Large boulders in streams create pools, reduce current velocities, increase fish shelter, establish feeding positions, and provide rearing habitat. Boulders should be at least 1 cu meter; located on firm substrates to minimize bottom scour; and should not be placed in areas where water currents will be deflected onto soft streambank material (Green and Salter 1987).

Intermittent and Ephemeral Streams

Most of the streams in our region are ephemeral. They only flow during periods of snowmelt or heavy precipitation (Ferreira 1981). Mean annual runoff reflects strong evapotranspirative demands, and is less than 15 mm in most small basins of the region.

Intermittent or ephemeral streams can be used for containing water as a water source for water. Water retention structures can be constructed along these drainages where they would benefit wildlife.

Channel Design Concepts

Drainage networks develop in response to surface runoff, geologic structure, lithology, relief, vegetation, soils, climate and anthropogenic activities (Jensen 1994). Reclaimed landscapes will undergo adjustment processes to the surrounding undisturbed landscape regardless of the methods used to design the reclaimed environment. The design should follow the natural landscape as closely as possible, but for landscapes to form and mature, adjustments and erosion must and will occur.

Water flow in natural channels may be perennial, intermittent, or ephemeral. Perennial streams carry some flow at all times. During low flows, intermittent streams have dry reaches alternating with flowing ones along the stream length (Leopold and Miller 1956). Ephemeral streams carry water only during storms and are generally smaller but are much more numerous than perennial ones.

Initially, infiltration on a reclaimed landscape is lower than surrounding, undisturbed landscapes (Stiller et al. 1980). Runoff will be higher and drainage density will eventually increase which may lead to increased flood peaks (Stiller et al 1980; Lowham and Smith 1993).

Channels of ephemeral streams range from tiny rills to deep trenches (Leopold and Miller 1956).

Hillslope design will determine overland flow which dominates first order hydrologic regimes (Jensen 1994). Toy et al. 1987 recommended the landform design should disperse overland flow (Toy et al. 1987) to prevent erosion, which can lead to gullying before vegetation is established. Deep ripping or pitting can help relieve the problem (Jensen 1994). Jensen (1994) recommended a concave slope since the steepest portion is in the upper reaches where the power of water is at a minimum and therefore less erosive. Complex slopes where the upper reaches are convex, the center is uniform, and the lower reaches are concave occur most frequently in nature (Toy et al. 1987).

If water transport is the design goal, then short, moderate slopes with a concave-up profile should be designed (Toy and Hadley 1987). But if water storage is the objective, then the basin should be enlarged and rough, broken profiles should be reclaimed (Jensen 1994).

Ephemeral stream channels gradually lose water by percolation into the stream bed (Leopold and Miller 1956). Runoff can be accumulated in depressions. These pools can be improved by deepening the catchment or by trenching runoff waters directly to the basin (Yoakum et al. 1980). By raising the lowest edge of the basin's edge, storage can be increased.

Water can be conserved for wildlife (see "guzzlers" below) or distributed to aid vegetation establishment. Waterspreading and water harvesting techniques divert runoff from natural channels or gullies through a system of dams, dikes, or ditches, and spreads it over relatively flat areas. Water can also be diverted to establish or maintain wet meadows.

Water harvesting is the practice of using the landscape to collect and accumulate runoff water of acceptable quality (U.S. Forest Service 1979). The water is concentrated in a plant-growing zone. Water harvesting is useful in areas that receive less than 38 cm of annual precipitation and in any area where rainfall is the major limiting problem associated with revegetation. Both snow and rain are trapped, resulting in two to three times more plant growth biomass than where these harvesting methods are not used.

The area of land for collecting water varies, depending on rainfall amount, intensity, and timing; soil infiltration; and slope (U.S. Forest Service 1979).

Water Retention Structures

Guzzlers are long-lasting, self-filling water catchments similar to a cistern. They can be constructed on ephemeral drainages, except where silt or sand may accumulate, or where they could be damaged by flood waters (Yoakum et al. 1980). The whole structure is simple minimal maintenance is required. Guzzlers should be designed to be used by as many different species of wildlife as possible (Rutherford and Snyder 1983). A rain-collecting apron fills a watertight tank set in the ground. The water-collecting apron should be proportioned so that the cistern will need no water source other than rainfall to fill it (Yoakum et al. 1980). By placing the open end away from prevailing winds and facing it north, sunlight entering the tank is minimized. Algae growth, water temperature, and evaporation are all reduced by placing the open end away from prevailing winds and facing it north to minimize entering sunlight. The size of the apron is based on the minimum expected precipitation, rather than average or maximum, to prevent water failure during drought years. See Yoakum et al. (1980) for general installation instructions of a concrete guzzler. Concrete or metal guzzlers are more economical from a maintenance cost standpoint. See Rutherford and Snyder (1983) for a practical design for multi-purpose watering.

Most guzzlers have been constructed for game birds, but big game also benefit (Humphrey and Shaw 1957; Roberts 1977). Water catchment devices for big game are a practical way to increase wildlife habitat and distribution in arid areas. Water can be sent to a trough with a control valve, but this may require more maintenance and has limited value for other species of wildlife (Yoakum et al. 1980). Troughs should be low to the ground (50 cm or less) for easy wildlife access and an escape ramp (rocks, concrete blocks, etc.) or ladder should be installed for small wildlife where water depth exceeds 50 cm (Wilson and Hannans 1977; Yoakum et al. 1980).

The area should be fenced to exclude livestock (Rutherford and Snyder 1983). Where possible, place the water source in association with feeding and escape cover.

Note: the water will freeze in winter and be unavailable for drinking (Rutherford and Snyder 1983).

Riparian Vegetation

Riparian vegetation along ephemeral or intermittent streams should be tolerant of periods of dryness.

Green and Salter (1987) recommend:

1) reseed intermittent, gently sloping streams with sedges or grasses [e.g., reed canarygrass (Phalaris arundinacea L.), timothy (Phleum pratense L.), or red fescue (Festuca rubra L.)] to reduce water velocity and erosion.
2) provide bank cover in seasonal or permanent streams by seeding grasses and sedges, clump planting aquatic plants, and transplanting trees and shrubs.

SPRINGS AND SEEPS

Before developing a spring or seep, the reliability and quantity of the flow needs to be checked (Yoakum et al. 1980). Generally a storage box is necessary to catch and store water; where flow is intermittent, a larger capacity box will store water after the flow stops.

Plastic sheeting overlaid with coarse gravel and perforated pipe will collect and concentrate the flow of springs and seeps into a single stream that will not readily freeze and will be available year long (Rutherford and Snyder 1983). A small pit placed a short distance below the source will concentrate reserves and stimulate green, lush vegetation for wildlife.

Yoakum et al. (1980) recommended the following when developing a spring primarily for wildlife use:

1) provide at least one escape route to and from the water, taking advantage of the natural terrain and vegetation where possible.
2) provide an alternative escape route where feasible.
3) fence water developments from livestock and human use (Yoakum et al. 1980). Protective fences should be negotiable by wildlife, except where big game will damage the spring source by wallowing or trampling. Fence posts should be pointed to discourage perching by avian predators.
4) construct gentle basin slopes or ramps in tanks to reduce wildlife drowning.
5) maintain or provide adequate cover around the watering area.
6) provide, where applicable, an information sign informing the public as to the purpose of the development.
7) provide water developments of sufficient capacity to supply water at all times of the year during which it is needed.

If pipe is used, plastic pipe is usually preferred to galvanized iron pipe since it is lighter and easier to transport and lay (Yoakum et al. 1980). The pipe should be buried deep enough to escape damage by freezing, trampling by livestock, or washing out during floods. The pipe should also be laid to grade, in order to avoid air blocks.

SUGGESTED REFERENCES

Gore (1985) The Restoration of Rivers and Streams; Atlantic Waterfowl Council (1972) Techniques Handbook of Waterfowl Habitat Development and Management; Payne (1992) Techniques for Wildlife Habitat Management of Wetlands; and Hammer (1992) Creating Freshwater Wetlands.