LANDFORM DIVERSITY AND VERTICAL STRUCTURES

INTRODUCTION

Erosional landforms include badlands, gullies, headcuts, incised streambeds, rough breaks, cliffs, rimrocks, and diverse slopes. These important habitat features that were produced by millennia of geologic and erosional processes are difficult, if not impossible to restore during reclamation (Tessmann 1982a; Munshower 1994). For example, badlands and hogback ridges are supported by strata that are removed during mining, precluding reestablishment on reclaimed surfaces (Robison 1986). Regulations mandating erosionally stable, gentle slopes also preclude these features from being reclaimed.

Removal of such formations has typically been compensated by substituting other man-created features which do not adversely affect surface stability. Features such as cliffs and rimrocks provide necessary or important habitat for raptors and other wildlife, and can only be replaced with similar topography or features in reclamation.

This section presents some methods for improving landform diversity, reclaiming some of the unique landforms, and adding vertical structure. Some practices (e.g., developing highwall remnants) are not authorized by regulation, except to the extent that they approximate the original topography of the area and are erosionally stable. These restricted practices are discussed, bearing in mind that they cannot be implemented everywhere without additional regulation changes.

Landforms that increase topographic diversity can enhance aesthetics and assist recolonization by wildlife.

UNDULATIONS

Allowable Slopes

One of the primary goals in reclamation is erosion control. The use of machinery (draglines, scrapers, and dozers) is increasingly limited by slopes, especially as the slope approaches or exceeds 3:1 (Munshower 1994). For these reasons, 3:1 becomes a practical as well as a legal reclamation limit. This limit makes it difficult to reclaim broken, steeper topography that existed premining. Most stripmine grades are 5:1.

Grading to approximate original contour results in terrain that is fairly homogeneous in slope, soil types, and soil moisture content. Minor undulations provide some visual barriers for wildlife escape and increases interspersion and edge effect.

Swales, Hills, and Undulating Topography

Operators should leave small swales and minor hills with slopes approaching the legal limit (Tessmann 1985). Swales can be enclosed depressions or broad, vegetated waterways draining downward along gentle slopes.

Swales, hills, and undulating topography create different sun exposures; various air or wind flows; a variety of plant habitats; and varied elevation and topographic variety for viewing, hiding, and resting (Proctor et al. 1983a, 1983b).

Different sun exposures create variation in humidity, air, and soil temperatures (Proctor et al. 1983a, 1983b). Undulating topography provides a windbreak, which can be enhanced by vegetation providing shelter and habitat.

Benches and Terraces

Problems that can resulting from returning the land surface to AOC include over-long slopes, excessive compaction, poor drainage, and post-mining settling from standing water (Jackson 1991). Alternative slope designs such as incorporating benches, terraces and water diversions (based on the Universal Soil Loss equation and a Terrace Spacing Equation) have been recommended (Brenner 1985; Brenner and Steiner 1987).

ROCK AND BOULDER PILES

Rockpiles can fulfill various habitat functions including: perch sites; shelter; concealment, escape cover; nest sites; den sites; elements of topographic diversity; replacements for natural rock outcrops; and enhanced snow catchment, which increases soil moisture and vegetative development (Proctor et al. 1983a, 1983b; Tessmann 1985). Rock piles are most beneficial to small game and nongame animals, especially on young reclamation where cover is minimal, but can also enhance adjoining undisturbed areas (Proctor 1983a, 1983b). The absence of cover, its sparseness, or poor distribution can limit wildlife use in an area (Yoakum et al. 1980). Shrubs planted in conjunction with rock piles increase the cover value (Tessmann 1985). Shrub areas can be enlarged if piles are oriented across prevailing wind directions and somewhat elongated (Tessmann 1985).

Design criteria we investigated included:

1) optimal size
2) optimal shape
3) optimal density
4) best construction materials
5) juxtaposition with other habitat features
6) benefits derived from an association of complementary designs
7) aesthetic qualities

We could not locate sufficient information to fully address these topics. The following sections discuss results of several studies. This research provided some guidance in design, but generally lacked specific design criteria. However, our review should assist with designing effective rock piles for wildlife.

Generic Design

The first step is to excavate a basin where the rocks will be placed. After the rockpile is in place, the area around the base is backfilled to blend the rockpile in with the topography.

Tessmann (1985) encourages rockpile designs which benefit a variety of species. He recommends a core of one to three large (1 to 4 m in diameter) boulders abutted with smaller ones up to 1 m in diameter. When available, rocks should be competent, erosionally resistant material. It may be convenient to stockpile such boulders as they are encountered during overburden removal. If intended strictly for raptor nests and perches, piles should include one to three vertically oriented boulders as large as equipment can handle. Two or three boulders propped together form a more stable nest substrate than a single boulder (R. Phillips, pers. comm. to S. Tessmann).

In general, heights should be 1 to 4 m (the taller piles would be intended as raptor perches and nest sites). The length should be 4 to 10 m (or longer to form a windbreak).

Rock piles can be constructed on south and southwest slopes to increase moisture accumulation, thereby enhancing plant growth on these otherwise xeric, erodible, and less diverse sites (Tessmann 1985; Shelley 1992). Rock outcrops in native habitat are often associated with hilly, dissected topography (Shelley 1992).

Achievable densities of rock piles can be limited by availability of suitable materials. Assuming material is not limiting, rock piles should at least approximate the density of natural outcrops prior to mining. Additional piles should be planned to mitigate the loss of topographic diversity and nest and den sites.

Proctor et al. (1983a, 1983b) believe several smaller rock piles interspersed throughout reclamation are more beneficial than one large pile. Boulders should be sufficiently large to provide a maze of internal spaces. They recommend dimensions exceeding 4 m in length, 4 m in width, and 2 m in height; and a stable interior environment. The more irregular the configuration (the greater the "edge" effect), the more benefit to wildlife. Rocks and boulders do not have to be neatly arranged -- several truck loads randomly piled will suffice. [**Note**: aesthetics have recently become a concern. Compliance inspectors and others may be more receptive if piles are neatly arranged and blend with topography.] Rock piles require no maintenance and may reduce the disposal cost of large boulders unearthed during overburden removal.

Raptors

Rockpiles constructed primarily for raptor nest and perch sites should be placed near, but not on hilltops, on the slope protected from prevailing winds (R. Phillips, pers. comm., in Tessmann 1985). On steeper slopes some taller rockpiles and a few trees and shrubs slightly below the leeward crest of a hill or bluff will provide alternative nest, perch, and roosting sites protected from the wind.

Art Anderson (U.S. Biological Survey, pers. comm.) feels a complex of rock piles is beneficial when raptor mitigation is the goal. These complexes will increase prey base diversity. In addition to availability of suitable nest sites, prey abundance affects raptor use and reproductive success within an area.

Sometimes man-made or relocated inactive nests are placed on rockpiles to induce nesting away from mining disturbance. Nests should be anchored so they do not blow off. An important consideration when building rockpiles for nest sites is to make the nest site inaccessible to terrestrial predators.

A platform placed next to a rockpile might encourage raptors to use the rockpile later, after the platform has broken down (Art Anderson, U.S. Biological Survey, pers. comm.).

Songbirds

Shelley (1992) determined rockpiles increase bird density (significantly), diversity, and richness. For areas designed solely to enhance songbird habitat, he recommended a rock pile height no greater than the average maximum height of vegetation (shrubs), or about 1.2 m. Rockpile density is increased by constructing more, smaller rockpiles rather than a few larger rockpiles. However, nesting raptors require taller rockpiles and mammals may find more den sites in large, complex rock piles. Rock outcrops in native habitat (Powder River Basin) were typically small (height 1 m); very numerous (20 to 38 per 3 ha); very close in proximity (5 to 25 m); and usually located on or near ridgetops (Shelley 1992). Shelley's data suggested sites with greater numbers of rock outcrops per 3 ha, placed close together (clustered), and of consistent height attracted a greater abundance of birds. Shelley recommended distances of 7 to 15 m between rockpiles within the rockpile clusters (if material allows). When vegetation structural diversity was low, bird density and diversity increased on sites with rockpiles. When vegetation structural diversity was high, rock piles lost some of their effect on songbirds.

Rumble (1987) determined natural scoria outcrop habitats supported higher species richness, total population density, density of lark sparrows (Chondestres grammacus), and density of rock wrens (Salpinctes obsoletus) than surrounding sagebrush/grassland steppe. Western meadowlarks (Sturnella neglecta) and vesper sparrows were more abundant in sagebrush/grassland habitats lacking scoria outcrops. The unique plant community and structural diversity provided by the scoria outcrops were correlated with higher avian use. His study plots sampled the full range of outcrop configuration in the area (few to many and small to large).

Based on his research, Rumble (1987) prescribed clumped arrangements of approximately 9 rock piles/ha taller than 1 m, and varying up to 2 m high. The minimum area of a cluster of outcrops should occupy is approximately 1 ha. Shrubs should be planted in and around piles to establish diverse habitat complexes (Biggins et al. 1985).

Mines in Wyoming utilize dozers, loaders, and haultrucks to isolate, stockpile, and transport materials to the site (1.5 to 4 hours for each site). Dozers, scrapers, or front end loaders are required for foundation preparation, placement, and arrangement of materials (1 to 3 hours). Special revegetation procedures (e.g., transplants, tubelings, shrub patches, etc.) will take 2 to 8 man-hours and several equipment hours.

Cost includes isolating materials from overburden, stockpiling, transportation to reclaimed surfaces, bed preparation, placement, and arrangement of boulders, topsoiling and special revegetation procedures. Costs range from about $350 to $1800/rock pile (based on an average of 10-15 rocks/pile for the latter). Costs will vary considerably from mine to mine, and from site to site. Creating rockpiles is less expensive than creating rock outcrops (discussed later).

Small Mammals

Optimum locations for mammal use include bottoms, draws, and protected hillsides (Tessmann 1985; Green and Salter 1987). Coarse rocks that provide space and openings within a pile should be used.

Predators

If rock piles are intended as denning sites, they should be large enough to provide a stable interior. Larger boulders will create a maze of spaces within the pile that should be acceptable to predators as resting or denning sites.

Vegetation Features

Precipitation runoff, snow catchment, and lowered evaporation create more favorable soil moisture around rockpiles. Consequently, they provide good sites for shrub and tree establishment. Species found around natural rock outcrops (juniper, currant (Ribes spp.), Woods rose, etc.) should be planted and protected from herbivorous animals. Shrub survival can be increased by (Biggins et al. 1985):
1) removing large pieces of soil or fractured rock adhering to rock structures before transplanting;
2) avoiding sites which totally shield the plant from sunlight or precipitation; and
3) avoiding sites which can develop into miniature water channels or sedimentation zones.

Many shrubs and tree species commonly associated with natural rockpiles and outcrops are difficult to reestablish (Clark and DePuit 1981; Eddleman 1982). Most of these species have significant value for wildlife.

Biggins et al. (1983) evaluated the condensation function of constructed rock outcrops. Most rock outcrops were constructed on southeasterly exposures within the study site. Deciduous shrub survival was significantly higher near rocks. The effect became more conspicuous with time; survival increased from 2.5 times greater in spring 1981 to nearly 4 times greater by spring 1982. Most species fared better near rocks, but timing of mortality varied. Currant and chokecherry rapidly declined below the level needed for reliable statistical inference, however a trend for increased survival near rocks was apparent. Sumac responded most conspicuously to conditions near rocks; both plant survival and vigor were better. Pine reacted more slowly, but exhibited significantly higher mortality away from rocks by spring 1982. Junipers planted on southeast sides of rocks or interior positions between several rocks survived better than those exposed to the northwest. Prevailing winds accentuated mortality, presumptively due to winter dehydration. Summer mortality may increase in hotter and drier southeast exposures. Shrub vigor near rocks is undoubtedly linked to enhanced moisture from precipitation runoff, wind protection, shading, snowdrift accumulation, mulch effects or even a "heat pump" effect (Stark 1982).

ROCK OUTCROPS OR RIMROCKS

Design

These formations include rock-capped ridges or exposed linear rock ledges which are surface expressions of subterranean formations (Munshower 1994). They cannot be duplicated by standard reclamation methods, but can be mimicked with man-made structures. Rock can be pushed together in a wall-like formation, and anchored in a trench along the contour of an unfinished slope (Munshower 1994). Subsoil and topsoil is placed over these ledges, leaving the rock-face exposed to resemble native rock ledges. If not sufficiently anchored, the soil/subsoil dressing will rapidly erode from between the rocks. The practice of embedding rocks and back-filling around them offers the dual advantage of enhancing appearance and providing stable burrowing sites (Biggins et al. 1983). Black Thunder and Belle Ayr Mines in the Powder River Basin have constructed rock outcrops.

INPLACE SPOIL RIDGES

Mines with premine landforms of breaks or gumbo knobs, might modify some spoil piles to approximate these forms (Munshower 1994). This practice may not be appropriate where thin overburden conditions exist, as it will detract from topographic diversity elsewhere on the mine (Steve Tessmann, Wyoming Game and Fish Department, pers. comm.). Although natural breaks are sparsely vegetated with hardy grasses, forbs, shrubs, and an occasional clump of trees, they can provide critical food and cover resources to several classes of wildlife during winter months (Munshower 1994). Several characteristics of these features may require exemptions -- leaving spoil piles, leaving steeper slopes, and omitting topsoil from them. Clay or silty clay spoils increase erosion resistance, and a cap of consolidated erosion-resistant material can be placed on top (after reducing the peaked ridge top) in order to slow soil movement (Munshower 1994). Seed should be collected from premining rough breaks to increase revegetation success on these unique sites.

Munshower (1994) suggests implementing this practice on an experimental basis. Western Energy Mine in the Northern Great Plains has retained a short stretch of spoil ridges to replace rough break habitat, but data on resultant use by wildlife was not given.

MODIFIED HIGHWALLS (Oversteepened Slopes)

Highwalls and steep slopes are a byproduct of site operations. Stabilization and development of these into AOC features for wildlife can provide biological and aesthetic benefits. In many regions, rimrocks may be one of the only sources of cover during winter storms (Proctor et al. 1983a, 1983b).

Highwall remnants can be successfully modified to simulate natural rimrocks or cliffs if the final highwall is cut through competent, erosionally resistant materials (Green and Salter 1987; Ward 1987). However, retaining highwall segments is currently prohibited by SMCRA. A 1988 regulatory proposal developed by the Wyoming Mining Association would have provided for establishment of bluff features,but was disapproved by the Office of Surface Mining. This does not mean bluff creation is disallowed in all cases. When bluff features were components of the original topography, closely resembling features can be developed from competent highwall segments in accordance with the requirement to restore approximate original contours (AOC).

Appropriately designed bluff features provide (Tessmann 1982a; Wyoming Mining Association 1988):

1) improved topographic diversity
2) terrestrial habitat that was originally provided by rimrocks, gullies, steep slopes, etc.
3) enhanced vegetative diversity
4) shelter
5) shade
6) nesting, denning, perching, or loafing sites
7) escape corridors
8) visual barriers
9) reduced reclamation costs
10) the potential for increased minable reserves and taxes to the State

Many complex questions enter the decision to develop a highwall remnant on a particular site including (Ward 1987):

1) AOC criteria
2) engineering
3) stability
4) drainage
5) ecosystem integrity, environmental quality, and aesthetics
6) land use
7) landowner preference
8) public safety
9) long-term sustainability

The biologist must consider which species are targeted. In some situations, developing a highwall may benefit some species, but could adversely affect others. Therefore, benefit/costs to all wildlife species in the area must be assessed. If a particular wildlife species is targeted for the AOC design, additional features which benefit other wildlife without adversely affecting the targeted species should be considered (Ward 1987).

Substrate

The potential for developing a highwall to benefit wildlife is influenced by its geologic composition. Preferable substrate includes competent igneous, metamorphic, or sedimentary rocks (Green and Salter 1987). Nesting raptors heavily utilize sandstone and limestone cliffs because erosion has created an abundance of ledges and potholes (Enderson 1964; Edwards 1968; Smith and Murphy 1973). Because sandstone and limestone are easily modified, highwalls made of these materials may represent optimum sites for reclamation for raptors. Ground-nesting ferruginous hawks (Buteo regalis) may use highwalls of unconsolidated material, if it is stable enough for reclamation standards (Weston 1969; Snow 1974). Unconsolidated benches might provide substrate for badgers (Taxidea taxus), or foxes (Maser et al. 1979; Chapman and Feldhamer 1982). Near water, such embankments could also benefit swallows or belted kingfishers (Megaceryle alcyon) (Maser et al. 1979).

Length

Highwalls developed into several smaller sections of less than 400 m (Green and Salter 1987), rather than one long wall, and a convoluted configuration reduce direct lines of site. This may reduce intra- and interspecific conflicts among raptor species and allow multiple raptor nests in an area (Murphy et al. 1969; Olendorff 1972; Smith and Murphy 1973; Lockhart et al. 1980).

Broken bluff topography is simulated by series of short highwall sections. Mule deer prefer this type of broken topography (Hamlin 1978), and it does not constitute a movement barrier to other species.

Height

Most cliff nesting raptors will utilize vertical faces over 3 m high (Smith and Murphy 1973; Snow 1973; Maser et al. 1979) as long as suitable nest sites (ledges) are available. The minimum height preferred by golden eagles (Aquila chrysaetos) and prairie falcons (Falco mexicanus) is about 7 m (Edwards 1968; Smith and Murphy 1973; Siebert et al. 1976; Lockhart et al. 1980). A varied height (within limits set by safety and stability) is recommended (Green and Salter 1987). Beyond 10 to 15 m, safety might become a concern even though higher walls might attract more breeding raptors (Tessmann 1982a). One highwall segment approved for experimental variance was 12 m high (Fala 1982). An optimum height for reclamation might be 10 m, for both stability and to attract a wide range of wildlife species (Maser et al. 1979).

Aspect

An undulating profile can provide a wide range of exposures or aspects from which raptors can choose. Golden eagles, prairie falcons, and great horned owls (Bubo virginianus) exhibit some degree of selection for particular aspects (Enderson 1964; Murphy et al. 1969; Smith and Murphy 1973; Mosher and White 1976; Siebert et al. 1976). Generally, southern, southeastern, and southwestern exposures are preferred and highwall segments with these aspects should receive a higher priority for retention and development. In addition, big game and nongame birds may be able to use southern aspects for feeding and resting during winter, because southern aspects retain less snow.

Golden eagles and prairie falcons prefer cliffs with a broad, unobstructed view (Edwards 1968; Boeker and Ray 1971). Highwall segments intended for raptors should therefore be developed with this in mind.

Opposing Slopes

Provide open areas next to the cliff face by partially recontouring adjacent and opposing slopes (Green and Salter 1987).

Ledges

Most cliff-nesting raptors nest on ledges (Call 1978). Golden eagles and prairie falcons prefer high ledges on the cliff face (Ogden and Hornocker 1977; Lockhart et al. 1980). Ledges should be excavated on the upper third of the modified highwall, preferably underneath overhangs for protection (Snow 1973; Ogden and Hornocker 1977; Evans 1982). A wide variety of ledges would maximize raptor nesting potential, small mammal travel lanes and vegetation development (Tessmann 1982a). Green and Salter (1987) recommended ledges 0.5 to 2.0 m in width, and up to 10 m in length. The ledges should be at least 7 m high, of relatively permanent or solid substrate, and free from excessive erosion (Fyfe and Armbruster 1977).

Boyce et al. (1980) describe the design, placement, and construction of an artificial ledge for prairie falcons.

Holes

Prairie falcons, American kestrels (Falco sparverius), great horned owls, common barn owls (Tyto alba), and ravens (Corvus corax) all show an affinity for potholes and caves as nest sites (Dixon and Bond 1937; Enderson 1964; Edwards 1968; Murphy et al. 1969). A variety of holes blasted, drilled, or hand-dug into the highwall face would provide bird nesting and roosting sites, and mammal shelter and dens (Tessmann 1982a). Dimensions recommended by Green and Salter (1987) of 0.5 to 2 m in diameter and 0.5 to 2 m in depth should be suitable for these species. If holes of varied size and spacing are included, the birds are given several choices which allows them to partition the resource (Steve Tessmann, Wyoming Game and Fish Department, pers. comm.).

Boyce et al. (1982) describe design and effectiveness of an excavated cavity for peregrine falcon, and Fyfe and Armbruster (1977) describe design, placement, and effectiveness of an excavated cavity for prairie falcon. Call (1979) describes cavities, ledges, and burrows, for several raptor species.

Developed highwalls that can be manipulated to hold a series of narrow, deep crevices may be more valuable to a wide range of mammal and bird species. Fissures less than 15 cm in width are preferred by bat species (Barbour and Davis 1969; Maser et al. 1979) and small rodents (Maser et al. 1979). Deep crevices with wider opening (30 cm or more) are preferred by various small mammalian predators (Maser et al. 1979).

Access Corridors

Access corridors provided every 100-400 m along a highwall allows wildlife to ascend or descend without travelling around the site (Green and Salter 1987). Access can be created by dumping overburden or rock rubble up to the top of the highwall, or by converting access roads or corridors.

Talus Slopes

A wide variety of small mammals and reptiles utilize talus slopes for cover and denning (Rose 1976; Maser et al. 1979; Chapman and Feldhamer 1982). Size of the rock pieces should be at least 0.5-1.5 cu meters and the piles should be a minimum of 2-3 m thick, but should include a variety of depths to provide diverse habitat (Green and Salter 1987). Tessmann (1982a) recommended depositing broken talus slopes of various sizes along the base of the highwall. These should not reach raptor nest ledges to minimize access by predators. Talus slopes enhance access by such species as woodrats, allowing them to utilize more of the habitat (Fala 1982).

Talus should be either metamorphic or igneous rocks or competent sedimentary rocks because softer rock will erode easily and fill interstitial spaces (Green and Salter 1987).

Vegetation Elements

Highwalls near undisturbed conifers or deciduous shrubs are good candidates for development as wildlife habitat. Otherwise, these species should be planted (Tessmann 1982a). Both red-tailed hawks (Buteo jamaicensis) and great horned owls prefer nest sites with numerous perch or hooting sites within a 2- to 3-km radius (Baumgartner 1939; Fitch et al. 1946; Call 1978). Shrub availability near topographic relief increases the value of the site to big game and numerous nongame bird species (Maser et al. 1979; Fala 1982; Tessmann 1982a).

Rimrocks often accumulate moisture from snow drifts. The increased moisture, along with variations in soil conditions, provide conditions for important shrubs used as winter forage (Proctor et al. 1983a, 1983b; Munshower 1994). These include currant, bitterbrush, and mountain mahogany. Steep slopes often support shrubs that are utilized by deer or pronghorns when climatic conditions are most severe, and other food is inaccessible under snow.

Water

If feasible, provide a water source within 300 m of the cliff face to provide drinking water for a variety of species as well as hunting areas for raptors (Green and Salter 1987). If small waterbodies are developed in the final pit at the base of a highwall, they should abut talus rather than the highwall to prevent undercutting of the cliff face.

BRUSH PILES

Brush piles are a useful interim feature when cover is limited. Brush piles should be a by-product of other land treatments, rather than a compulsory or specific practice (Yoakum et al. 1980). Properly constructed and located, they afford nesting sites and cover for wildlife. These structures are particularly beneficial where small mammal and bird habitats are limited, such as recently constructed wetlands or young reclamation (Proctor et al. 1983a, 1983b). With very little maintenance, brush piles will benefit wildlife for several years. They eventually decompose, however shelter is provided until natural vegetative features develop.

Any trees and larger shrubs that were removed and stockpiled prior to topsoil stripping can be used for brush piles. Use only woody vegetation large enough to persist for a considerable time after reclamation is complete (Tessmann 1985).

Because brush piles are intended primarily for small mammal use, they should be placed on protected hillsides and along bottoms (Tessmann 1985). They should also be incorporated into shrub and tree plots or riparian zones.

Brush piles can be designed to provide the following specific uses (Warrick 1976):

1) concealment from predators -- an overhead canopy and surrounding brush screen nests from predators.
2) protection from predators -- the tight network of strong twigs and small openings preclude entry of many predators.
3) thermal shelter -- shelter from the cooling rains, wind, and excessive sunlight.

4) a conducive site for various plants to germinate -- the network of twigs and grass provide a protected growth medium.

Brush piles should be constructed over a log or large rock to provide 20 to 30 cm of clearance for a crawl space (Tessmann 1985).

Mature sagebrush, greasewood, or trees of any species are suitable for brushpiles, which should be oriented perpendicular to prevailing winds. They may be anchored with cable laid over the tops and secured by stakes. Several small brush piles are more beneficial for small mammals and birds than a single large one (Proctor 1983a, 1983b).

Brush piles should be at least 4 to 4.5 m in diameter and 1 to 2 m high to persist for several years (Yoakum et al. 1980; Tessmann 1985). A good strategy for rabbits is to place long narrow brush piles in the upper portion of broad arroyos or shallow ravines. Such piles may be 8 to 15 m long, 1.5 m wide, and 1.2 m high (Shomon et al. 1966). Other species often associated with brush piles include white-crowned (Zonotrichia leucophyrys) and Harris' sparrows (Z. querula) (Yoakum et al. 1980).

Turkey nesting cover can be enhanced by piling brush or slash at the base of trees or around logs. These should be within 0.8 km of water (Yoakum et al. 1980).

The following general guidelines will assist construction of brush piles for duck nesting sites at created wetlands or impoundments (Warrick 1976; Proctor et al. 1983a, 1983b):

1) Ideally, locate them on nest islands.
2) Select locations protected from erosion and prevailing winds.
3) Collect brush with twigs of 0.6 to 5 cm diameter and stems which are 30 to 120 cm long, and a native grass bundle.
4) Dig a bowl shaped depression 15 cm deep and 30 diameter in the soil.
5) Build a dome-shaped canopy 45 to 60 cm long over the depression and embed it 20 cm into the soil, at a 60 degree repose. Leave a 15 x 15 cm opening at ground level.
6) Layer native grass throughout the inside of the canopy and depression.
7) Weave additional twigs into the canopy and cover the entire pile with dense brush. Be sure the 15 x 15 cm entrance remains clear of debris.
8) Weight the brush at one end or push butts into the soil to anchor the pile.
9) Complete work prior to spring arrival of migratory species.

SNAGS

Snags are erected on reclaimed lands to replace those lost as a result of mining and to provide additional nest, den, and perch sites until planted trees reach sufficient height to provide these functions (Tessmann 1985). Because they will eventually fall, snags should not be considered permanent reclamation structures. However, they are a valuable interim feature while permanent reclamation matures. Depending on the type of habitat surrounding snags, birds such as mountain bluebirds (Sialia currucoides), flickers (Colaptes auratus), nuthatches (Sitta spp.), and woodpeckers will use the snag for cavity nesting and as a food source; kestrels will nest in cavities constructed by other species; and wild turkeys and bald eagles (Haliaeetus leucocephalus) will use snags as roost sites (Oneale n.d.; Melton et al. 1983). Red-tailed hawks, great gray owls (Strix nebulosa), and bald eagles hunt from and often nest in the top of large snags. Bats roost under loose bark of some snags. Other wildlife uses of snags include perching, food caching, and ritualistic mating behaviors.

Snag height and diameter will depend on the trees removed and salvaged prior to mining. Cottonwood trees make some of the better snags because of their generally large diameter, well-developed crown with robust lateral branches, and more hollow den sites than most other species (Tessmann 1985).

Reclamation plans to benefit birds should include the development of fast growing Populus deltoides and Acer negundo with planned girdling of the trees when trunk diameter reaches 20 cm (Burley and Hopkins 1984). Snags should be at least 20 cm diameter at breast height (DBH) and at least 5 m in height. Embedding the base sufficiently deep will support the upper part against strong winds; it may be necessary to shore the base with rocks or cement.

Snags should be erected in conjunction with live trees for best wildlife use; otherwise place along bottoms and on protected slopes (Tessmann 1985). For raptor use, place the snags near, but not on hilltops, on the aspect most protected from prevailing winds (R. Phillips, pers. comm. to S. Tessmann). The density of snags will depend on size and number of trees removed and saved prior to mining and the intended purpose of the snags. Planned snag locations should be placed in clusters of 5 to 10 trunks per ha within tree stands, or along riparian areas (Burley and Hopkins 1984; Tessmann 1985). If possible, created snags should be associated with a stand of shorter trees within 100 m of an opening (Oneale n.d.).

Snags situated close to water are used disproportionately greater than those farther away (Melton et al. 1983). Dead shrubs or trees immediately adjacent to or protruding over water are preferred by many avian species for resting and hunting or fishing.

Many cavity nesting birds are territorial and will not allow other conspecifics to nest or feed close to their nesting and feeding territory (Oneale n.d.). If potential snags are in short supply, they should be spread over as wide an area as possible to provide a greater number of nesting and feeding territories.

Downfall and stumps also provide immediate landform diversity as well as cover for small mammals and birds (Green and Salter 1987). Downed logs and stumps should be oriented at right angles across the slope of the land. Logs with diameter greater than 50 cm are best for cover. Logs in varying states of decay are recommended.

SPECIALIZED NEST STRUCTURES

Platforms

Raptors

Platforms are often used to lure raptors that habitually nest on highwalls to another part of their territory away from disturbance. When deterrents are also employed at the highwall, the platform is more likely to be used. The use of deterrents requires close coordination with the U.S. Fish and Wildlife Service and their concurrence.

Platforms are also used to: relocate young to an alternative site where they can be raised in a more secure location, and to increase numbers of nesting sites in areas where a lack of natural sites is considered limiting.

Artificial nest structures such as towers with nest platforms, nest platforms on existing power poles, or nests and nest baskets, have been successfully used to increase raptor nesting densities and productivity (Call 1979; Olendorff et al. 1980). Olendorff et al. (1980) reviews a variety of raptor nest structures.

Well-built platforms probably will not require a lot of maintenance, but they should not be considered permanent features (although they can last a very long time). Eventually, artificial structures should be augmented with more long-lasting features such as trees, rockpiles, cliffs, or, where allowed, modified highwalls with nest cavities and ledges.

Nests should be well anchored to the platform to withstand strong Wyoming winds. Call and Tigner (n.d.) recommended constructing artificial nesting structures on platforms with branches extending above the nests to hold nest material on the structures, prevent the young from falling off, and possibly deter aerial predators.

Compacted nest materials will prevent raptor chicks from entangling their feet or legs in the branches (Postovit and Postovit 1987). Nest platforms should provide shade for young birds; a windbreak; and a large platform for nest construction (Yoakum et al. 1980; Art Anderson, US Biological Survey, pers. comm.).

Man-made platforms have been built by rockpiles in order to attract ferruginous hawks to accept reclamation rockpiles (Parrish et al. 1994). Ferruginous hawks are attracted to platforms (Howard and Hilliard 1980; Schmutz et al. 1984) and often have higher productivity than that of natural-nesting pairs on the ground because of reduced ground predation.

A primary objective when using artificial nest structures is to plant trees immediately (Yoakum et al. 1980; Art Anderson, U.S. Biological Survey, pers. comm.). As the trees mature, the nest platform can be transferred to the trees, resulting in a more natural nest location.

Some North American raptors that have used artificial nest structures as part of habitat management projects and information on construction, placement, and maintenance are given in: Ellis and Kellett (1970); Nero et al. (1974); Olendorff and Stoddard (1974); Bohm (1977); Fyfe and Armbruster (1977); Craig and Andersen (1978); Call (1979); Howard and Hilliard (1980); Olendorff et al. (1981); and Henderson (1984).

Waterfowl

Canada geese platforms have many design variations from bales of hay to a tire; one to four poles; and a large metal washtub instead of a wooden platform (Yoakum et al. 1980). Canada geese will also nest on floating structures, consisting of a canoe-like platform supporting a nest box, anchor, and equalizer (Will and Crawford 1970). The equalizer, which is placed broadside against the wind, and between the anchor and the structure, keeps the floating structure from being dragged in high winds (Yoakum et al. 1980). Splash shields may be necessary during high winds to keep eggs dry. One shield to the side of the nest box and an additional V-shaped shield at the bow of the platform are recommended. To preserve the wood and camouflage newly cut lumber, a dark-colored preservative should be applied to the nest box and box splash shield. Nesting material can consist of hay or coarse wood shavings, tightly packed into the nest box. The structures can be stored by removing the nest box and splash shield.

Specifications for baskets and cones for waterfowl are found in Yoakum et al. (1980).

Nest Boxes

For best results, nest boxes must be properly designed, located, erected, and maintained (Yoakum et al. 1980); be durable, predator proof, weather tight, lightweight and economical to build; and most important, meet the needs of the target species. Kalmbach et al. (1969) provided dimensions of nesting boxes of various species of birds that regularly use them, and the height at which they should be placed above the ground. Boxes at moderate heights, within reach of a person on the ground, are readily accepted by many birds (Yoakum et al. 1980). Yoakum et al. (1980) provide several designs of nest boxes for wood ducks, tree squirrels, bluebirds, and kestrels.

Kestrels successfully use nest boxes, and their production can be greatly increased when compared to natural production in the same area (Hamerstrom et al. 1973), especially where suitable nest sites are lacking. The box should not be painted or sprayed, and no entrance perch is required, as starlings are attracted to them, and kestrels do not need them (Yoakum et al. 1980). Placement is best on a lone tree or post in or on the edge of a field; facing south or east; with a clear flyway (no obstruction in front); and about 6.1-7.6 m off the ground (Yoakum et al. 1980). About 7-8 cm of coarse sawdust or wood chips should be placed in the bottom before the breeding season. This material needs to be cleaned out and replaced annually following the nesting season. Because the nestboxes require maintenance, this technique is probably going to be used only for those kestrels impacted by mining.

Bluebirds prefer open areas with scattered trees. Nest boxes can be placed on fence posts and should be spaced at least 100 m apart to reduce fighting among highly territorial males (Yoakum et al. 1980).

For Canada geese, round bales of hay should be tightly wrapped with wire and located 20-50 m offshore in water no more than 1 m deep (Green and Salter 1987). Bales at least 90 m apart and separated by emergent vegetation or shoreline projections are recommended where possible. One hectare of wetland is required for each nesting bale.

Information on nestbox construction and maintenance for American kestrels are found in Henderson and Holt (1962); Hamerstrom et al. (1973); Heintzelman (1971); Yoakum et al. (1980); and Henderson (1984). For common barn owls, see Marti et al. 1979; Bunn et al. (1982); and Colvin (1983).