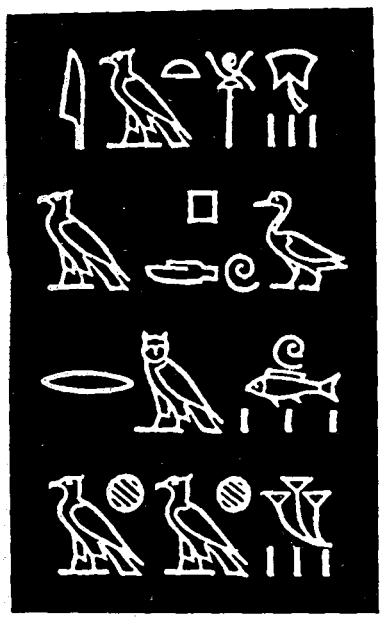


WILDLIFE MANAGEMENT TECHNIQUES MANUAL

FOURTH EDITION: REVISED

Edited by: SANFORD D. SCHEMNITZ
Professor, Department Head
New Mexico State University

Illustrated by: LARRY TOSCHIK
Phoenix, Arizona

THE WILDLIFE SOCIETY
WASHINGTON, D.C.

1980

This chapter is identified as APA 1048 in the Susitna Hydroelectric Project Document Index (1988), compiled by the Alaska Power Authority.

Chapter Twenty

Habitat Improvement Techniques

JIM YOAKUM

Wildlife Management Branch
U.S. Bureau of Land Management
Reno, Nevada

WILLIAM P. DASMANN (Retired)

Wildlife Management Branch
U.S. Forest Service
San Francisco, California

H. REED SANDERSON

Range and Wildlife Habitat Laboratory
U.S. Forest Service
La Grande, Oregon

CHARLES M. NIXON

Section of Wildlife Research
Illinois Natural History Survey
Urbana, Illinois

HEWLETTE S. CRAWFORD

Northeastern Forest Experiment Station
U.S. Forest Service
Orono, Maine

Introduction 330
Food and Cover Production 330
  Propagation 331
    Transplanting 331
    Direct Seeding 332
    Ten Basic Principles for Successful Plantings 338
  Regeneration 339
    Mechanical and Manual Methods 340
    Chemical Application 341
    Controlled Burning 341
  Rejuvenation 342
    Rejuvenating Bitterbrush 342
    Crushed Browse-Ways 343
  Release 343
    Browse 343
    Mechanical Methods 343
  Special Considerations 344
Cover Practices 344
  Hedgerows 344
  Brush Piles 345
  Natural and Artificial Roosts 345
  Nesting Cover 346
  Snags 346
Specialized Nest Structures 348
  Nest Boxes and Tires 351
  Platforms 355
  Baskets and Cones 361
  Burrows and Ledges 366
Water Developments 366
  Water Holes 366
  Springs and Seeps 366
  Reservoirs and Small Ponds 368
  Water Catchments 369
  Modified Water Developments and Safety Devices 372
Wetland Improvements 375
  Development of Water Areas 375
    Shallow Marshes 377
    Potholes, Sumps, Ponds 379
    Greentree Reservoirs 381
  Habitat Manipulation Practices 382
    Water Level Control 382
    Plantings for Food and Cover 383
    Resting Sites 384
    Nest Structures 385
    Man-made Islands 385
Constructing Water Control Devices 385
  Dikes and Embankments 385
  Spillways 387
  Level Ditching 388
  Plugs 389
Structural Improvements and Facilities 389
  Fences 389
  Interstate Highways 399
  Power Lines and Raptors 399
  Study Exclosures (Big Game) 400
Summary 402

INTRODUCTION

Wildlife management is the science and art of the interrelationships between wild animals, habitats, and man (Giles 1969b:1). Therefore, the maintenance or manipulation of habitats is a major component of the wildlife biologists' responsibilities. This responsibility cannot be slighted because wildlife habitats in North America are undergoing tremendous changes. These changes are primarily accomplished by man for man's needs: grazing rangelands for red meat; logging forests for building materials; or constructing towns, cities, and highways for concentrated human activities. Man's manipulation of the environment for his needs is the most prevalent factor affecting wildlife habitat and, consequently, wildlife populations. Often it is not the *act* of using natural resources, but the *way* man uses these resources that determines the total impact on wildlife.

There are many examples of how the manipulated environment can be beneficial or detrimental to wildlife. For example, logging dense old-growth forests may be disastrous to the spotted owl's nesting and feeding requirements, but could greatly increase preferred forage for elk. Wildlife biologists must recognize the factors that affect wildlife habitat, specifically those not designed or implemented for wildlife, and understand the habitat and animal interrelationships. The wildlife biologist has the responsibility to show how such practices can be modified to increase habitat diversity for the benefit of wildlife and man. These interrelationships are well documented by Thomas et al. (1976) for habitats in the Northwest and Holbrook (1974) for habitats in the South.

Wildlife habitat management is basically concerned with 2 major objectives: (1) to maintain quality habitat as it exists in a natural ecosystem; and (2) to provide quality habitat where it has deteriorated, or where a specific habitat component is lacking such as water, food, or shelter. The following basic principles should be included in planning and implementing habitat manipulation practices:

1. Projects must be justified according to biological needs based on intensive investigation.
2. Proposed practices must be evaluated for their effect on other natural resources and land uses.
3. Projects must be economically practical and should specify if the objective is to maintain, improve, or completely alter the existing habitat character.
4. Improvements must simulate natural conditions. Generally native flora and fauna should be perpetuated.
5. Manipulation projects must be designed to follow natural topographical features as opposed to geometrical squares or strips.
6. Projects must be evaluated at intervals to determine if the objectives have been accomplished.

Aldo Leopold's (1933) list of "axe, plow, cow, and fire" as major habitat management tools has expanded with new understandings and technological advances. All of the land-use tools available to the farmer, forester, and construction engineer have been used to manipulate wildlife habitat. However, all the habitat manipulation techniques cannot be described in 1 chapter; consequently, a guide for selection of projects and ways to "accomplish management goals" is presented. Each method must be judged critically for each site and for the goal to be accomplished.

Many of the methods discussed are from the following major periodicals: (a) *Western Browse Research* published annually by various western state wildlife agencies from 1955 to 1963; (b) *Game Range Restoration Studies* published annually by the Utah State Department of Fish and Game from 1956 to date; and (c) *Range Improvement Notes* published by the USDA Intermountain Forest and Range Experiment Station, Logan, Utah. By far the most important compendium on habitat manipulation is the *Wildlife Habitat Improvement Handbook* (U.S. Forest Service 1969). This handbook is the best available compilation of State, Federal, and private findings regarding food, cover, and water practices for the benefit of wildlife in North America. Consequently, we have incorporated much of the information in this chapter.

The *Wildlife Habitat Management Handbook* (U.S. Forest Service 1971), which has a "field reference" for popular game species (Byrd and Holbrook 1974), is also an excellent forest management guide for modifying silviculture practices to maintain or improve wildlife habitat. Although this handbook was developed for the southeastern United States, much of the information is applicable over a much wider area. Wildlife habitat managers in western North America would also do well to consult Vallentine's (1971) book *Range Development and Improvement,* because there is considerable information that can be used to develop habitat.

Other important sources of information are monographs and symposia on specific wildlife species, including those concerned with nongame species (U.S. Forest Service 1970, D. R. Smith 1975, U.S. Dept. Agric. 1976, U.S. Fish and Wildlife Service 1977b, DeGraff 1978).

This chapter concentrates on methods and techniques of habitat manipulation specifically designed to increase food, water, or cover for wildlife. The primary objectives are to provide the basic principles for the variety of techniques available. By being aware of these various procedures, the wildlife or resource manager has the basic tools to provide food, water, or shelter for wildlife.

FOOD AND COVER PRODUCTION

Here, the goal is to improve habitat by providing food and/or cover for a particular species, or group of species. In general, there are 3 major methods: Propagate "new" plants, release existing plants by destroying "undesirable" competing species, and protect existing habitat from such factors as nonprescribed livestock grazing, fire, or draining.

"Propagation" is the direct planting of desirable seeds or transplants; but it may also include the manipulation of residual cover to produce mixtures of species important to wildlife, such as even-aged forest management. "Release" encompasses such practices as mechanical crushing, controlled burning, and creating openings by mechanical or chemical means to favor increased production of desirable understory species. "Protection"

includes preserving those species producing food or cover important for wildlife.

Propagation

Although the art and science of plant propagation is very old, information on propagating wild plants is limited to relatively few species. However, there is considerable information on ornamental plant propagation that can be readily applied. The same scientific rules apply; the challenge is to apply these rules and the art of plant propagation to establish "new" plant species successfully for improved wildlife habitat.

Land reclamation efforts in the 1930's to revegetate wind- and water-eroded land and find suitable plants for windbreaks, waterways, and wildlife cover provide an information source which may require a diligent literature search for information on some plant species. More recent efforts to revegetate drastically disturbed areas as a result of surface mining provide valuable information on both plant propagation and site preparation.

The interested habitat manager would do well to consult further with the following major publications pertaining to the propagation of plants by Koller and Negbi (1961), Plummer et al. (1968), Gill and Healy (1974), U.S. Forest Service (1974), Hartmann and Kester (1975), Czapowskyj (1976), and U.S. Soil Conservation Service (1976).

Sources for nursery stock and seed are listed in such publications as *Source of Planting Stock and Seed of Conservation Plants Used in the Northeast* (Northeast Regional Technical Center 1971), *The Oregon Interagency Guide for Conservation and Forage Plantings* (Oregon Interagency n.d.), and *Provisional Tree and Shrub Seed Zones for the Great Plains* (Cunningham 1975).

The U.S. Soil Conservation Service maintains offices in most counties and is a good source of information for plant species best suited for a particular area. Such publications as *Grasses and Legumes for Soil Conservation in the Pacific Northwest and Great Basin States* (Hafenrichter et al. 1968), *Shrub Plantings for Soil Conservation and Wildlife Cover in the Northeast* (Edminster and May 1951), or *Plants Useful in Upland Wildlife Management* (McAtee 1941) also provide such information. The general rule is to use native trees, shrubs, and vines because they are adapted to the site and offer a better opportunity of surviving. Exotic species generally have poorer initial survival, frequently require more cultural treatment, often grow slowly, and may produce less seed.

The planting of food and cover species for wildlife is often expensive and results are not always predictable. Planting is no easy cure-all. From the standpoint of cost, there is no good substitute for natural regeneration of native species. Where possible, management should aim at maintenance or improvement of existing native species. Where it becomes necessary to introduce or restore species, this may be done by direct seeding or use of transplants (Plummer et al. 1955, Brown and Martinsen 1959, Holmgren and Basile 1959, Hubbard 1964, Plummer et al. 1966).

The most important considerations leading to a successful plantation are: site selection, site preparation, planting depth, and soil moisture. The best results may be expected on sites which are known to have supported the species concerned in the past. A knowledge of plant requirements is essential, including answers to the following questions: Should the soil be coarse or fine textured; should it be well-drained or poorly drained, acid or alkaline? At what depth should seed be planted?

An important cause of plantation failure is the competition for soil moisture given the transplants or seedlings by established vegetation. Whether planting is done on selected spots or over a broad acreage, care must be taken to eliminate or reduce competition by existing herbaceous and woody vegetation. With spot plantings, reduction of competition can be secured through either hand or mechanical scalping. For broad plantations, the best results follow the preparation of the site by regular farming methods. The objective is to plant in a clean, firm seedbed. This may involve plowing or disking as well as the drilling of seed.

TRANSPLANTING

Some native and exotic woody species suitable for habitat improvement can be obtained from commercial nurseries. Some will have to be found growing wild or propagated. Regardless of source, transplants must be kept moist until planted. Planting procedures should follow accepted nursery practices.

Elaborate facilities, although convenient, are not needed to propagate transplants. If a greenhouse is not available, cold frames or a plastic-covered greenhouse can be readily constructed. Milk cartons and coffee cans make convenient containers. However, one should become thoroughly familiar with propagation facilities and techniques before deciding on the course of action.

When a seed source is limited or not available, cuttings, layering, and suckers are appropriate methods for propagating transplants. Grafting also may be a useful means to establish a particularly desirable plant trait for a seed orchard or nursery.

The following discussion provides some general information on plant propagation techniques that could improve existing wildlife cover and/or food. Detailed instructions for these techniques are available from most state agricultural experiment stations and horticultural textbooks such as Hartmann and Kester (1975).

Cuttings are a portion of a leaf, stem, or root that has been removed from the parent plant and placed in a suitable rooting medium to form roots and shoots. Although some species are difficult to propagate by cuttings, other species root readily and only simple facilities are needed to achieve success. Tree species, which generally do not root from cuttings, may be stimulated to form root primordia by girdling the shoot 4 to 8 weeks before cutting (Hare 1977). For those species that root readily, cuttings are an inexpensive, rapid, and simple method of propagating many new plants in a limited space.

The following general factors must be considered when selecting cutting material:

1. Rooting ability varies greatly, even among individual plants. Botanical relationships give a general indication, and the rooting ability of some wild plants may be predetermined by reviewing the literature on related cultural species.
2. Stems with low-nitrogen and high-carbohydrate content are firm and stiff, and break with a snap, which can be confused with firmness due to tissue maturity. Succulent, rapidly growing plants should be avoided. Starch content, an indicator of nitrogen-carbohydrate ratio, can be determined by the iodine test: Immerse the ends of freshly cut stems in 0.2% iodine solution (potassium iodide) for 1 minute. The darkest stained cuttings have the highest starch content and are best suited for propagating. It may be desirable to fertilize selected wild stock plants to improve the rooting success of cuttings.
3. Usually cuttings taken from young plants root more readily than cuttings taken from older plants. In some cases, juvenile growth can be induced in mature plants (Hartmann and Kester 1975).

There are also some specific factors that should be considered, such as lateral versus terminal shoots: lateral shoots may produce horizontal spreading plants; terminal shoots may produce erect plants. Other factors are flowering versus vegetative shoots, cuttings from different parts of the shoot, or cuttings that retain part of the old wood, as well as the best time of the year to take cuttings from specific plant species. Because plant species respond differently to these specific factors, no generalized statements can be made to guide rooting success. Specific data on individual species must be obtained from the literature or through experience.

Layering stimulates root development on a stem while it is still attached to the parent plant. Basically, layering consists of covering a portion of a plant stem with a suitable rooting medium until it develops sufficient root mass. The disadvantages of layering are that it requires considerable hand labor, and the layered plants need individual attention. The advantages to the layering technique are that it can be used by an individual with little plant propagation experience and that larger plants can sometimes be produced in a shorter time than starting with cuttings.

Suckers are shoots produced from adventitious root buds and should not be confused with watersprouts that are produced from latent buds on the trunk or main branches of established plants. Suckers are usually removed in the dormant season by digging down and cutting the shoots from the parent plant. In cases where no roots are formed, suckers can be treated the same as cuttings.

Grafting is a specialized propagation technique of joining parts of plants together so they unite and continue to grow as 1 plant. Although grafting has only limited application for habitat improvement, it may be the best method to obtain transplants of species that do not readily reproduce by other means. Grafting may also be used to establish a more convenient parent stock with desirable fruiting or growth characteristics for later vegetative or seed production. Grafting can also be used to obtain desirable fruiting qualities on root stocks that are more tolerant of unfavorable soil conditions.

Regardless of the grafting method used, the following requirements must be met:

1. Scion (upper portion of the graft that develops stems or branches) and stock (lower portion of the graft that develops the root system) must be compatible. Generally only closely related plants are capable of uniting.
2. Cambial region of the 2 plant parts must be in intimate contact.
3. Stock and scion must be in the proper physiological stage. Depending on the grafting method, stock may be either active or dormant, but the scion must be dormant.
4. All cut surfaces must be covered with grafting wax to prevent drying.
5. Grafted plants must be given proper care. Shoots from below the graft must be removed to stimulate the scion growth. Also, shoots from the scion may need extra support to prevent breakage.

Smith (1973) recommended that clones of crab apples that produce large annual seed crops be located and protected as a source of scion wood for grafting on young, vigorous trees 7.6–10.2-cm dbh.

DIRECT SEEDING

The establishment and improvement of interspersed forage and cover species is a wildlife habitat improvement measure of broad application (Sampson et al. 1951, Plummer et al. 1955, Edmundson and Cornelius 1961). Frequently there are opportunities for forage or cover improvement by coordinating wildlife needs with other resource activities. It is important that such opportunities be recognized and used when available.

Some land management activities which offer opportunities to establish forage or cover at low costs are forestry (such as thinning, harvest, and postharvest treatments), utility transmission corridors, soil stabilization projects (such as after fires, road and ski-slope construction, and surface mining), range improvements (such as reseeding and brush control), and any other project that modifies the vegetative cover. It is often possible to choose species best suited for wildlife habitat requirements.

Coordination of this kind is an economical way to improve wildlife food and cover.

Sharecropping agreements with local farmers offer an opportunity to maintain unharvested grains for wildlife food and cover on lands in public ownership. In Illinois, sharecrop farmers use a crop rotation of corn or corn and soybeans, which may or may not be followed by small grain (wheat or oats); then 1–2 years of legumes and volunteer forbs. Farmers are not allowed to use herbicides or insecticides or to fall plow under these sharecropping agreements. Sharecropping is also a more economical and efficient method of maintaining unharvested croplands than developing food patches for wildlife. In most cases, it has been amply demonstrated that small plots (less than 2 ha) of unharvested grain are not effective in increasing the production of game species. Further, development costs for a grain planting

program have risen to such high levels that their use cannot be justified on the basis of the amount of game harvested (Ellis et al. 1969).

Food patches are certainly no substitute for management programs based on a thorough knowledge of wildlife ecology and the culture of native vegetation.

Wildlife management is, after all, applied ecology. To be cost effective it must be based on manipulation of natural successions. Cropping and fallowing lands, prescribed burning, and timber sales are all techniques designed to manipulate natural succession. While food plots have been used for many years in the East (Shomon et al. 1966), their effects on wildlife have not been well documented. Food plots should be only used in areas where sharecropping or burning is not feasible.

Seed Collection and Treatment

If seeds of native plants are not available commercially, it will be necessary to collect them, which requires specific information on time of seed ripeness and the proper method of handling, storing, and treating seed before planting. Such information is available in the following publications: *Collecting and Handling of Seeds of Wild Plants* (Mirov and Kraebel 1939) and *Seeds of Woody Plants in the United States* (U.S. Forest Service 1974). Specific information is occasionally available from regional botanical gardens such as Santa Barbara Botanical Gardens which specializes in native California plants (Emery 1964).

Many plant characteristics are genetic, such as growth form, seed production, and palatability. Therefore seed collections should be confined to plants that display characteristics desirable for propagation.

Seedbed Preparation

The first step ordinarily will be to get rid of woody vegetation by crushing and burning or other disposal. For some species, it is necessary to have a seedbed of exposed mineral soil for the seed to germinate and grow. Others do best on duff or litter. The type of equipment needed for seedbed preparation will vary with species to be planted, site and cover conditions. If domestic livestock are in the area, they will need to be fenced from the reseeded area until it is well established.

Fertilization

It is advisable to secure a soil test as a basis for deciding about the need for fertilizer. The County Agent can assist in getting the soil test, interpreting the results, and recommending the time of application.

Williams (1972) attempted to show how commercial fertilizers may be used to increase wildlife production by improving forage production and the nutritional quality of forage available to wild animals. The response to fertilizers varies greatly among plant species; however, nitrogen fertilizers have been used successfully to increase shrub and forb dry-matter production. Nitrogen fertilizers also have increased crude protein in plants. Sulphur and phosphorus applications have produced the best results for increasing legumes and other plants possessing nitrogen-fixing nodules on their roots. One of Williams' major summary points is that plants growing on soils of low fertility or soils having an improper nutrient balance have responded more to fertilizer applications than plants growing on fertile soils or soils having proper nutrient balance.

Barrett (1979), working on pronghorn winter range in Alberta, concluded that nitrogen and phosphorus fertilization on sagebrush-grassland steppes: (1) increased total forage production and hence protein production, and (2) that antelope use showed a definite preference for treated areas.

Equipment

There are several kinds of equipment commonly used for direct seeding. This equipment is described in the *Range Seeding Equipment Handbook* (U.S. Forest Service 1965) and information on new developments is generally available from the U.S. Forest Service Missoula Equipment Development Center (Fort Missoula, Missoula, Montana 59801). The commonly used equipment is briefly discussed below.

- Deep-furrow Drill

The deep-furrow drill provides a furrow 5.1–7.6 cm deep, spaced at 35.6-cm intervals. Wider spacing is achieved by removing drops. The 71-cm spacing is regarded the most practical for planting browse. Spacers in the seedbox can be quickly provided to permit seeding of different species in alternate rows. The drill is mounted on rubber tires and can be pulled by a light tractor or jeep. It was not designed for seeding rough rangelands. On more level lands, the drill does an excellent job of seeding as well as leaving a good seedbed for emergence. The machine can be hauled on a 1364-kg truck. Maneuvering ability of the drill limits its use. It is not a practical tool for seeding small openings.

- Hansen Browse Seeder

The Hansen browse seeder can be equipped with either 40.6- or 81-cm scalping wings. Whether equipped with 1 or 2 scalpers, the seeder can be pulled by a jeep or small tractor (either with wheels or tracks). The equipment is small enough to operate in small spaces as well as larger areas. Arrangements can be made to pull 2 drills at a time for large-scale seeding operations (Fig. 20.1). Successful plantings have been effectively made with a variety of shrubs, broadleaf herbs, and grasses (Plummer et al. 1968).

- Cutout Disk

The horse-drawn cutout disk used a decade ago has been satisfactorily used in rocky and partially brushy areas. This small disk pits the ground with many small impressions or gouges. The seed is broadcast either ahead of the disk or behind it. The gouges or impressions aid in retaining moisture in the soil. The disk is light in weight, compact, and rugged. It can be pulled by a single horse or by a team.

- Seed Dribbler

Observations have indicated that soils disturbed by crawler tractors are excellent seedbeds for browse, forb, and grass species. Some of the best stands are often obtained in these tracks. Because of the availability and

Fig. 20.1. Two Hansen browse seed drills hooked on a tandematic bar behind a tractor. The purpose of this arrangement was to drill over 1020 ha burned by wildfire on critical deer ranges. (U.S. Bureau of Land Management photo by Jim Yoakum.)

high cost of native browse, forb, and grass seed, it is important that a cost-efficient method be used in seedings. Consequently, the seed dribbler was constructed. This attachment dribbles seed onto the track-pad just as it breaks over the front idler. The seed drops off the pad and is imbedded in a compacted seedbed.

Seed dribblers are mounted on the deck of a D-8 or similar size tractor. The seed-drop mechanism has a direct drive from a rubber-tired wheel riding on the tracks of the tractor. The seeders may be mounted as a pair, one on each side of the tractor, and are adaptable to various types of seed. The hopper holds enough seed for approximately 1.5 hours of operation. With some modifications, it could be used to broadcast in front of plows or pipe harrows.

- Rotaseeder

The rotaseeder, a 1.78-m rototiller equipped with special slot cutting blades and a seed drill, has been used to seed ditch banks in the Midwest (Fig. 20.2). The blades cut narrow grooves in existing sods and when used with a chemical defoliant, can be used to seed areas subject to erosion.

Fig. 20.2. The rotaseeder features a 1.78-m series of blades that cut grooves and allow seed placement in established sods. (Illinois Department of Conservation photo by Larry M. David.)

- Broadcast Seeding

Seed can be broadcast by aerial, ground, or hand equipment. Aerial broadcasting is particularly useful on extensive areas following wildfires, on terrain too irregular, rocky, or steep for drills, or on areas covered with slash from tree or brush removal programs (including logging). Cyclone seeders can also be attached to

about any type of ground equipment: pickup trucks, jeeps, all-terrain-vehicles, or crawler tractors. Hand broadcasting is also an effective method of dispersing seed on small areas or selected sites. Excellent results have been obtained by seeding up to 32.4-ha areas with a 5-man crew using hand operated cyclone seeders. Two days were required to seed such areas with 10.7–13.4 kg of seed per ha. Many species of seed require covering after broadcasting by mechanical procedures such as harrowing, cabling, or chaining. However other species do not require covering and need only be seeded into the ashes after prescribed burning (Crawford and Bjugstad 1967).

- Seed Spots

Shrub seeds, such as bitterbrush, can be planted either by hand, by a modified corn planter, or by a "Schussler"[1] planter in areas 0.6–0.9 m in diameter that have been cleared and 1.27–2.5 cm of topsoil has been scraped away. Bitterbrush seed spots are particularly applicable following fire on terrain where large equipment cannot be used (Sanderson and Hubbard 1961).

- Seed Mixtures

On most lands, the use of "mixtures" of 2 or more adapted species is advisable. Crawford and Bjugstad (1967) successfully used grass and legume mixtures on mesic sites. In Utah, Plummer et al. (1968) recommended seed "mixtures" to include a minimum of 6 species each of grasses, forbs, and shrubs. Such mixtures are consistent with natural vegetative communities which most often have an endemic mixture of a variety of grasses, forbs, and shrubs. Soil and moisture conditions often change so markedly within short distances that there may be great variation in the success and productivity of a single species within a seeded area. If a species does poorly because of an unfavorable site condition, or is killed by rodents, insects, disease, or frost, one or more of the others may take its place. Another advantage of "mixtures" is that some species develop stands quickly and supply forage while slower developing species become established. "Mixtures" also produce vegetation with a more varied and often higher food value. The adaptation and relative values of 56 most promising species for seeding western rangelands with precipitation above 20.4 cm are shown in Table 20.1.

If adapted legumes are available, their use with grasses usually increases total production and improves the nutritive value of the forage for many species of wildlife. They also help increase soil nitrogen through the action of associated nodule bacteria which converts free nitrogen from the air into available soil nitrogen.

The introduction of dryland Nomad variety alfalfa was one of the most successful techniques accomplished on antelope ranges in southeastern Oregon (Kindschy 1974). In excess of 22,700 ha involving 36 separate seedings have been planted to date. The alfalfa was generally aerially seeded onto plowed sagebrush ranges following drilling to adapted grasses and shrubs. Recent analysis of the seedings disclosed that the majority have maintained alfalfa composition at a level of 10% of the vegetation present over a 6-year or longer period. The seedings have increased the forb composition from 2% in untreated areas to 7% in seeded areas. During August 1976 antelope census, more antelope does with fawns were observed in grass and forb seedings than on adjacent, shrub-dominated rangelands (Yoakum 1978).

Browse species can be mixed with grass and forb seeds and drilled or broadcasted concurrently. Over 30,375 ha of rangelands in Utah alone have been planted by such methods. On one 1,620 ha project in central Utah, there was a 7-fold increase in forage production 3 years after treatment. Forage increased from about 89 kg per ha to an average of nearly 623.5 kg per ha. Deer use averaged 1.6 deer-days per ha on the adjacent untreated lands and 34 deer-days of use per ha on the seeded areas 3 years after treatment—about a 20-fold increase. It was noted that deer were attracted to the seeded areas from adjacent untreated ranges. While the degree of deer use apparently had not damaged the forage plants at the time of inspection, such heavy use might prove deleterious if continued over many years. Average deer use of seeded range over the state of Utah is much less than reported here, but it appears possible to increase the carrying capacity on many thousand hectares of critical deer winter range by seeding and planting (Plummer et al. 1966).

Forage on seeded areas is generally available earlier in the growing season and is more palatable than on untreated ranges. An adequate supply of green forage on seeded areas during the critical early spring period, when fetuses are developing rapidly in pregnant does, is of special value. The improved forage reduces winter and early spring mortality and increases fawn survival. Seeded ranges have been especially helpful in keeping deer out of cultivated fields. Experience and knowledge gained from seeding projects to date indicate that the wildlife range manager obtains greatly increased livestock grazing capacities and watershed values—both of which greatly add to multiple-use values.

On reclaimed surface mining or strip mining areas, Riley (1963) successfully established 57 species of trees, grasses, legumes, and shrubs that enhance wildlife habitat. He tested these species on different soil types having critical site factors such as extreme acidity, high total salts, and compacted surface soil. Successful seedings grew on soils having a range of pH values from 3.4 to 7.2; most of the sites exhibited acid to extremely acid soil reaction. Many species of shrubs, grasses, and legumes displayed a tolerance to very acid soils, high concentrations of trace elements, sulfates, and soluble salts.

For reclaimed areas on which forest plantations presently grow, the technique of seeding strips of grass and legume through the plantations has proven highly beneficial to wildlife. Older deciduous forests often consist of hardwoods with a high percentage of black locust, often in a decadent condition. For such areas, a bulldozer can create seeding strips. Recommended minimum widths are no less than 15.2 m and a maximum of 30.5 m. On strips less than 15.2 m wide, black locust usually invades and closes the area within 5 years, often making treatment of such areas uneconomical. Seeded strips

[1]Bitterbrush seed planter designed by Mr. Howard Schussler and sold by Crookham Seed Company, Caldwell, Idaho.

Table 20.1. Adaptation and recommended use[1] of species for seeding in various precipitation and vegetation zones on lowland and mountain areas in the Intermountain region (Plummer et al. 1955).

GRASSES							
	Lowlands				Mountain lands		
Species	Below 20.3 cm precipitation	20.3–30.5 cm precipitation	Above 12 inches precipitation	Salty soils	Mountain brush[2]	Aspen[3]	Subalpine
Sand dropseed	C	C	.....	.....	.....	.....	.....
Bottlebrush squirreltail	C	C	.....	.....	.....	.....	.....
Indian ricegrass	C	C	C	.....	C	.....	.....
Russian wildrye	C	B	B	B	C	.....	.....
Crested wheatgrass (Standard)	B	A	A	.....	B	.....	.....
Crested wheatgrass (Fairway)	B	A	A	.....	A	C	.....
Bulbous bluegrass	.....	X	X	.....	X	.....	.....
Bluebunch wheatgrass	.....	B	B	.....	B	C	.....
Beardless wheatgrass	.....	B	B	.....	B	C	.....
Pubescent wheatgrass	.....	C[4]	A	.....	A	B	.....
Intermediate wheatgrass	.....	C[4]	A	.....	A	B	.....
Western wheatgrass	.....	C[4]	B	.....	C	C	.....
Beardless wildrye	.....	C[4]	B	C	C	C	.....
Big bluegrass	.....	C[4]	C	.....	C	.....	.....
Mountain rye	.....	.....	X	.....	X	.....	.....
Great Basin wildrye	.....	.....	B	.....	B	C	.....
Tall wheatgrass	.....	.....	B	A	B	C	.....
Tall fescue	.....	.....	.....	B[4]	.....	C	.....
Bulbous barley	.....	.....	.....	.....	B	C	.....
Blue wildrye	.....	.....	.....	.....	B	B	.....
Bearded wheatgrass	.....	.....	.....	.....	B	B	.....
Smooth brome (southern strain)	.....	.....	C[4]	.....	A	A	B
Smooth brome (northern strain)	.....	.....	.....	.....	C	A	A
Slender wheatgrass	.....	.....	.....	.....	B	B	C
Mountain brome	.....	.....	.....	.....	B	B	C
Meadow brome	.....	.....	.....	.....	B	B	B
Kentucky bluegrass	.....	.....	.....	.....	X	X	X
Tall Oatgrass	.....	.....	.....	.....	A	A	A
Orchardgrass	.....	.....	.....	.....	B	A	C
Reed canarygrass	.....	.....	.....	.....	B[4]	B	B[4]
Timothy	.....	.....	.....	.....	B[4]	A	B
Meadow foxtail	.....	.....	.....	.....	B[4]	A	B
Sheep fescue (Sulcata)	.....	.....	.....	.....	.....	C	C
Red fescue (sod-forming)	.....	.....	.....	.....	.....	C	C
Subalpine brome	.....	.....	.....	.....	.....	.....	B
Winter rye	.....	X	X	.....	X	.....	.....

Table 20.1. Continued.

Species	Lowlands				Mountain lands		
	Below 20.3 cm precipitation	20.3–30.5 cm precipitation	Above 12 inches precipitation	Salty soils	Mountain brush[2]	Aspen[3]	Subalpine
LEGUMES							
Alfalfa	.....	C[4]	B	.....	B	C	.....
Sicklepod milkvetch	.....	C[4]	B	.....	B	C	.....
Chickpea milkvetch	.....	C[4]	B	.....	B	B	C
Yellow sweetclover	.....	.....	X[4]	B[4]	X	C	.....
Strawberry clover	.....	.....	.....	X[4]	.....	.....	.....
Birdsfoot trefoil	.....	.....	.....	.....	C	C	.....
Mountain lupine	.....	.....	.....	.....	.....	C	B
Alsike clover	.....	.....	.....	.....	.....	C[4]	C[4]
OTHER BROADLEAF HERBS							
Summercypress	.....	.....	.....	X	.....	.....	.....
Fivehook bassia	.....	.....	.....	X	.....	.....	.....
Palmer penstemon	.....	X	X	.....	X	.....	.....
Wasatch penstemon	.....	.....	.....	.....	X	X	.....
Showy goldeneye	.....	.....	.....	.....	X	X	X
Common cowparsnip	.....	.....	.....	.....	C	C	C
Sweetanise	.....	.....	.....	.....	C[4]	C	C
SHRUBS							
Winterfat	C	C	C	.....	C	.....	.....
Fourwing saltbush	C[4]	C	C	.....	C	.....	.....
Antelope bitterbrush	.....	C	C	.....	C	C	.....
Oldman wormwood	.....	.....	X	.....	X	X	.....
Blueberry elder	.....	.....	X	.....	C	C	.....

[1]A—Proved to be productive and widely adapted for seeding throughout the zone or type.
B—Valuable over much of the zone or type, but value or adaptation either more restricted or not as well determined as species designated A.
C—Value or adaptation more restricted than those species designated B, but useful in some situations.
X—Recommended for special uses or conditions, usually as pure stands.
[2]Applicable also for seeding openings in the ponderosa pine zone.
[3]Applicable also for seeding openings in Douglas-fir and spruce timber.
[4]Adapted only to better than average sites in the zone or type.

through hardwood plantations, without black locust, have remained open for 6 years with practically no invasion by tree species. Large, nonforested areas supporting grasses and legumes can be improved for wildlife by planting strips not over 6.1 m wide with shrub species. Such woody plants, along with selected tree species, may be used around the perimeter of croplands, on slopes of strip-mine lands, or in abandoned fields.

The use of native grasses should also be considered in those areas where they will grow and where controlled burning or haying (in late summer) can be used to rejuvenate old sods annually or at 3- to 5-year intervals (burning). Use of such species as little bluestem on dry sites, Indian and switchgrass on sites with intermediate moisture, and big bluestem on moist sites offers a means of creating forage and nest cover at a reduced cost of

maintenance. These grasses should be sown in early summer on ground disked just before seeding to remove weed competition. Seeding rates of 2.7 to 3.6 kg/ha have proven successful. For the first few years, mowing may be necessary to control competition until the grasses achieve dominance on the site.

TEN BASIC PRINCIPLES FOR SUCCESSFUL PLANTINGS[2]

There are 10 fundamental principles for making ranges more productive by planting of browse, forbs, and grass. They are based on over 25 years of research and field-tested procedures developed at the Intermountain Forest and Range Experiment Station (Plummer et al. 1968). Recommendations usually cover broad areas and need to be modified to fit local conditions, availability of seeds, and facilities for doing the work. Such modifications will usually be satisfactory if they conform to the following principles:

1. *Reduce competition.*—Seedlings and suppressed plants must have moisture to develop. Established plants that use all or most of the available moisture must be greatly reduced before seedlings or transplants can develop into satisfactory wildlife cover or food.

2. *Determine when and where planting will improve the range.*—Where good forage plants are present, reduction of competition may be all that is necessary for the desired restoration. On western ranges, usually 1 shrub, on the average, to each 9.3 sq. m and 1 herb to each 0.93 sq. m is an approximate minimum. Sometimes, there is need to round out an existing forage resource by introduction of a scarce element. For example, there may be ample browse on a big game winter range, but a lack of grasses and broadleaf herbs. Departure of deer and elk from their native ranges to cultivated fields in late winter and early springtime in search of succulent plants is a particular problem in some states. A good balance of browse and herbaceous plants on the winter range may help to reduce such depredation. The establishment of early spring-growing herbaceous species, such as crested wheatgrass, Russian wildrye, intermediate wheatgrass, a range-type alfalfa, small burnet, and balsamroot can provide desirable succulent herbs on intermountain big game winter ranges.

3. *Annual precipitation should be adequate.*—Ordinarily, artificial seeding should not be undertaken on sites where precipitation is less than 25.4 cm. The amount of precipitation along with occurrence of indicator species are the important guides in selection of species to be used. Where precipitation is near the lower limits, species which may be successfully seeded are limited in the West to such plants as crested wheatgrass, Russian wildrye, and range alfalfa. As precipitation increases, the number of species that may be successfully established also increase.

4. *Terrain and soil should be suitable to support the desired forage species and to permit restoration treatments.*—Shallow, infertile soils naturally produce little forage and may not justify restoration. On such sites, using native species will usually result in better success at less cost than attempts to use exotic species. While some improvement is usually possible on unfavorable sites, similar effort on favorable tracts will usually be more effective and more productive. With improvement of forage on good sites, game animals may shift use to the better forage, and as a result, more severe sites will improve naturally. There will be instances, of course, where poor sites may require restoration treatment solely to fill a critical need such as control of soil erosion.

5. *Plant adapted species and strains.*—Returns on the investment for restoration and seeding depend on a lasting improvement. It is essential that the planted species be able to maintain themselves and, preferably, to spread by natural means. Sometimes it may be wise to include rapidly developing short-lived species to meet a planned objective, such as a nurse crop or a quick forage supply. Such species as mountain rye, small burnet, short-lived perennials, and yellow sweetclover, a biennial, are useful for this purpose. A low seeding rate of annual winter rye may achieve the same goal. Planting rates of transient species in the mix should not be so great as to offer serious competition to more desirable and persistent species. Usually 2.7–4.4 kg per ha is adequate for the short-lived perennials and sweetclover, and 13.4 kg of winter rye per ha is adequate. Slower developing but more persistent plants such as antelope bitterbrush, fourwing saltbush, balsamroot, crested wheatgrass, and bluebunch wheatgrass, will gradually replace the short-lived plants. Where there is no need for the rapid developing species, then only long-lived perennials should be used.

It is particularly important that adapted sources or strains be used. Ordinarily seed from plants growing on greatly different soils, or in different climatic zones, are much less preferable than seed from sites similar to that planned for treatment. For example, it has been observed that antelope bitterbrush seed collected from acid granitic soils may develop chlorotic plants on basic soils originating from limestone. Fourwing saltbush collected in the blackbrush type in southwestern Utah has failed to survive well in the higher elevation mountain brush type. Similarly, Indian ricegrass from salt desert shrub types has failed to survive on mountain brush and higher elevation juniper-pinyon range. It appears that sources from colder areas with greater precipitation can survive better in warmer and drier areas than the reverse. There may be exceptions, but these are rare.

6. *Plant mixtures, especially on variable sites.*—A major reason for using mixtures is to put different species in the site conditions where they are best suited. Site characteristics can change often and dramatically within a limited area. Another advantage of mixtures is that they provide a variety of forage. The total production of a well-chosen mixture is considerably greater than of single species stands. Where possible, seeds of

[2]Editor's Note: Although this section deals primarily with semiarid range, it has been included because the principles have wide utility, because more millions of hectares of land for which these principles apply are manipulated for wildlife than any other land type, and because of the need for making this information available to wildlifers and land managers in the U.S. and abroad where semiarid land management is critical.

slower growing shrubs and herbs should make up the initial seeding and fast growing, aggressive species introduced later. Thus, grasses drilled in alternate rows with shrubs permits better establishment of the slower establishing shrubs than when both seeds are planted in the same rows. Also, broadleaf herbs generally establish better if they can be similarly separated from the grass. Some species are better suited to specific sites, such as north versus south slopes or shady versus open areas. Therefore, it may be best to confine them to such sites. Of course, the practicability of separating species for localized conditions depends on the size of the area. Often it is not practical to segregate sites, so mixtures are used.

7. *Use sufficient seed to insure a stand.*—One reason to avoid heavy seeding is the unnecessary cost entailed. Stands are usually not materially improved by excessive seeding. Usually, 7.1–17.8 kg per ha of total mixture is adequate, depending on the sites involved and the method being used. Ordinarily, when drilling, 7.1–8.9 kg per ha are advised; in broadcasting 13.4–17.8 kg are recommended. With proper planting, 2.7–7.1 kg of shrub seed per ha is usually sufficient. Proper planting depths and spacing of seed by drilling is often far more effective than heavy broadcast seeding. However, there are many sites where, because of terrain and obstacles, broadcasting must be used in spite of its being more wasteful.

8. *Proper planting and coverage of seed is essential.*—Provision for some seed coverage must be made. Seeds placed under 0.64–1.9 cm of soil are usually satisfactorily covered. A few species with large seeds may emerge from depths deeper than 2.54 cm, but most are suppressed by excessive planting depths. Seeds which are very small should be sown no more than 0.64 cm deep. Establishment of seedlings from uncovered seed, as from broadcasting, requires unusual moisture conditions for successful establishment.

9. *Seed in late fall and early winter but transplant in early spring.*—Seeding in October, November, December, and even January is essential for those that need to lie over winter to break dormancy. With a few species, notably alfalfa, fourwing saltbush, and winterfat, spring planting is superior to fall. This results from their tendency to germinate during a warm period in winter or early spring only to succumb later as a result of freezing temperatures. The major advantages of late fall or winter seeding are: (1) inherent dormancy is overcome; (2) some stimulation is provided by the cold temperatures and seedlings are induced to more rapid growth; (3) a longer period of adequate moisture is available so that seedlings are larger and better able to withstand the drought and heat of summer; (4) many seed-collecting rodents tend to be inactive after late fall so seed loss from this factor is reduced.

There are exceptions to this rule. Native grasses, such as big and little bluestem, Indian and switch grasses, are warm weather grasses and should be sown in early summer.

Where rodent predation on seeds is a problem, as it is on fall-sown black walnut seed in eastern forests, spring sowing of seed may increase the chances of seedling establishment (Engle and Clark 1959). This problem of depredation is well documented in reports for birds (Goebel and Berry 1976) and small mammals (Everett et al. 1978). Sowing seed in the spring reduces the time that rodents have to find the seed before it germinates.

10. *Eliminate or reduce livestock and wildlife use.*—Young plants and seedlings do not develop well when cropped off or severely trampled by large or small animals. Livestock use of planted areas should be eliminated until the seeded stand is established. Control of game animals can be achieved by increasing the harvest during the hunting season. Mice, chipmunks, rabbits, kangaroo rats, and ground squirrels can also devastate plantings if control measures are not employed. Personnel in the Division of Animal Damage Control of the U.S. Fish and Wildlife Service, as well as county agricultural agents, can give up-to-date information on animal control methods (see Chapter 22).

Regeneration

The acceptance of clear-cutting as a means of regenerating most of the forests of the United States, both soft and hardwood types, has created the opportunity for increasing forage yields at little direct costs to wildlife. The key to coordination of timber and wildlife lies in the long-term scheduling of timber harvests using *small* units of land (Roach 1974). Clear-cuts should be large enough so deer and other wildlife will not eat much of the tree reproduction, yet small enough so wildlife adapted to the old-growth forest, such as squirrels and wild turkeys, will not be seriously damaged by the practice. Narrow clear-cuts (<152.4 m wide) totaling about 8.1 ha in size seem to be a suitable compromise.

It should be remembered that nonyarding deer do not eat large quantities of woody browse but subsist mainly on mast, fungi, forbs, and grasses (Cushwa et al. 1970, Nixon et al. 1970). There are presently little data available on methods for increasing many of the forbs native to the eastern hardwoods. Crawford (1976) summarized the response of understory vegetation to overstory cutting in eastern hardwood stands.

For browse cutting, clear-cuts 1 and 1/2 times as wide as the uncut trees have been recommended. Rinaldi (1970) found that strip clear-cutting spruce-fir stands in patches 40.2 m wide yielded more forage for deer and hares than did strips cut 20.1 m or 60.4 m wide.

In the northeastern states, regular periodic winter-harvested strip clear-cuttings are encouraged in and adjacent to winter deer yards. Within the yards, strips of conifers 40.2 m wide are left along streams and lake shores for winter shelter for deer (Schemnitz 1974). In eastern Canada, Boer (1978) recommended cuts in strips or patches no wider than 60 m in deer wintering areas.

Many of the procedures used to release desirable browse plants from the competition of less desirable species are the same as those used for complete removal of existing vegetation. The results of such treatments depend upon the intensity of application. For example, chemical sprays may be used only to dessicate the crowns of woody species, or to kill the plants completely, depending on strength of the mix and the number of applications (Pechanec et al. 1954, Plummer et al. 1955).

There are 4 general methods of eliminating competition—mechanical and manual treatment, chemical sprays, and prescribed burning. Often these methods are used in combination to meet specific needs. Mechanical methods and hand methods are more expensive than either chemicals or burning, but have much wider application.

MECHANICAL AND MANUAL METHODS

The *Range Seeding Equipment Handbook* (U.S. Forest Service 1965) contains descriptions of equipment that may be used to treat areas for release from competition, together with the advantages and limitations of each method. Only a few of the more common procedures will be described briefly. Other important references on these practices include Plummer et al. (1955), Sampson and Jesperson (1963), Box and Powell (1965), Pechanec et al. (1965), Roby and Green (1976), and Green (1977).

Chaining

Chaining consists of dragging a heavy chain through vegetation to break off or uproot plants. The general procedure is for 2 tractors, 1 attached to each end of the chain, to travel on parallel courses 18.3–30.5 m apart. Additional disturbance can be gained with 1 tractor ahead of the other so the chain rides in a "J" configuration (Roby and Green 1976). The spacing is dependent upon density of vegetation, weight, and length of the anchor chain, size of tractor, bite of tracks, and slope. Ordinarily, tractors with a minimum of 110 horsepower on the draw bar are used. The chain size is dependent upon the degree of kill desired. For dense stands of target species with little desirable understory, a heavy anchor chain weighing about 45.4 kg per link achieves the best results. Dense young stands of trees or brush require a heavier chain than older stands because of the need to have the chain ride close to the ground. Links of 12.2–18.1 kg are used on areas where it is desired to leave a fairly dense residual stand of browse plants.

A better kill can be ensured by chaining when the soil moisture is at a minimum or when the first several cm of the soil are frozen. Chaining efficiently removes young, flexible trees. Chaining also can create a good seedbed for aerial broadcast seeding. In areas planned for twice-over chaining along with aerial seeding, the second pass should be timed so it will cover the seed. Properly planned chaining projects will leave fingers or islands of unchained trees to simulate natural openings in the landscape (Cain 1971).

Vegetative type manipulation projects such as chaining can change the aesthetic and biological values of an area. Consequently the manager should be well instructed in the principles and procedures for pretreatment, treatment, and posttreatment as described by Cain (1971). The habitat manager should likewise be concerned with and plan aesthetical values and designs into vegetative conversion projects.

Chaining projects in Nevada increased forage quality, quantity, and diversity for deer (Tueller and Monroe 1976). Deer utilization was 139% higher in treated area and a 7-fold increase in deer-days use per hectare was attributed to increase forage availability.

A "ball and chain" technique was developed to crush brush on steep sideslopes. The equipment consists of 45.7 m of chain and a 1.5-m-diameter steel buoy filled with water. Chain weight varies from 13.6 to 108.9 kg per m depending on the length of chain used and steepness of slope. Long chains should be of low weight per meter so the ball will drop down the slope far enough to work effectively (Roby and Green 1976).

Scalping

Scalping consists of scraping off the plants and part of the top layer of soil from planting sites. It is a simple and highly effective method of removing vegetation as well as most of the seed in the soil beneath it (Brown and Martinsen 1959, Holmgren and Basile 1959, Box and Powell 1965). The scalping of broad areas often leads to soil losses from erosion.

There are a number of methods for scalping. The simplest is with a hand hoe. The fastest and least expensive is with mechanical equipment. However, mechanical scalping is limited to terrain that can be negotiated by a tractor or jeep. A practical method for scalping and planting gentle slopes fairly free of rocks involves the use of a Hansen seeder equipped with a wide moldboard plow. Hand scalping is effective on steep slopes and rocky areas. Scalps 0.19 sq. m and at least 5.1 cm deep or deeper than the effective depth of the annual roots are cleared with a hoe. Heavier, narrower hoes are required for rocky, compact soils with perennial vegetation. In scalping, the material scraped off is piled on the lower side of the plot to form a catch basin. Care should be taken to avoid dirt spilling over the top of the blade back into the plot, since this may contaminate the seedbed with annual weed seeds. Sloughing of the soil into the scalp from its upper edge is common on slopes steeper than 50%. This sloughing can be minimized by gradually increasing the scalp in depth as the hoe is pulled downhill rather than by vertically chopping.

Conventional Tillage

Where soil and vegetative conditions permit, plowing is a desirable method to eliminate competitive vegetation (Pechanec et al. 1954, Plummer et al. 1955). Disk-type plows, such as a heavy offset disk or wheatland plow, are good for controlling nonsprouting species on soils with relatively few rocks. The brushland plow is best for rough, moderately rocky areas.

Plowing to a depth of 7.6 to 10.2 cm is recommended for most nonsprouting plants such as sagebrush. Depths of 10.2–15.2 cm are required to control plants which spread by underground root stocks or from the crown. A heavy-duty root plow is required to eliminate root-sprouting species.

The Holt plow is effective in reducing competition on slopes up to 40% where watershed measures are also needed. It will create a continuous furrow in either direction. This double disk furrower is attached to a crawler-type tractor by means of a specially built 3-point hitch. The depth and angle is controlled by a hydraulic

ram. The tractor must have more than 100 horsepower on the drawbar to handle the Holt plow effectively.

Chipping

Wood chipping machines are replacing some of the traditional cutting and hauling equipment for timber harvesting. Whole tree chippers used for clear-cutting will leave a postcutting site almost devoid of tree limbs. Because this technique is new, it deserves close observation to determine its appropriate value.

CHEMICAL APPLICATION

Herbicides offer possibilities for improving wildlife habitat (Crawford 1960, Krenz 1962, Sampson and Jesperson 1963, Halls and Crawford 1965, Kearl 1965, Oregon State University 1967). Selective spraying may be used to reduce stands of undesirable browse plants. Basal sprouting of browse species that have grown too high or dense for deer and elk can be stimulated by killing the aerial crowns with chemicals (Wilbert 1963, Mueggler 1966). The variable sensitivity of different species to the formulation, concentration, and time of application of herbicides should enable discriminating manipulation of the habitat, once these sensitivities are known. Unfortunately, not a great deal is currently known about this subject. Most big game ranges, for instance, support a mixture of shrub species that differ in sensitivity to chemicals. This often makes the effects of sprays unpredictable. It is known, for instance, that mixed stands of big sagebrush and bitterbrush may be sprayed with 2,4-D butyl or isopropyl ester at the standard sagebrush control rate without serious loss of bitterbrush, provided spraying is done while bitterbrush is still in bloom. On a California project, a 0.9-kg acid equivalent 2,4-D spray with diesel oil as a carrier, at a volume of 4.6 l per ha, resulted in 95% removal of sagebrush and 18% kill of the most severely hedged and decadent bitterbrush plants. The remaining bitterbrush plants, however, rapidly developed good form and vigor. Leader growth of treated plants was 1.1 times greater than that on controls 2 seasons after treatment even though crested wheatgrass was planted in the treated area. However, until more is known about selective sensitivities, caution is needed in application of chemical sprays on mixed browse stands. Opportunities to observe effects of forest or range management spraying on plants of various species should not be overlooked. The advantages of hand- or power-operated ground sprayers for control of individual undesirable species should be considered.

Pelletized picloram (4-amino-3,5,6-trichloropicolinic acid), a 10% acid formulation in an extruded clay pellet with low dermal toxicity, was effective in maintaining forest openings in northern Wisconsin (McCaffery et al. 1974a). Picloram pellets (30–50) applied by hand at the base of stems or suckers during the growing season, achieved adequate control of aspen, willows, fir, and alders at a cost of $23.47 to $46.93 per ha depending on labor costs and distance travelled to the work site. Because picloram also kills broadleafed forbs, broadcast applications are not recommended.

CONTROLLED BURNING

Controlled burning is one of the more economical procedures for removing a stand of vegetation for a prescribed purpose (Pechanec et al. 1954, Biswell and Gilman 1961, Hiehle 1961, Sampson and Jesperson 1963:27, Cushwa 1968) and is a valid habitat improvement technique (Beardahl and Sylvester 1974, Page 1975, Lovaas 1976). It can be used as a first step in seedbed preparation to reduce competing plant species, to create openings in dense stands of brush, or to create essential habitat for wildlife species that have adapted to fire climax vegetation such as the Kirtland's warbler (Radtke and Byelich 1963).

Investigators have reported direct, immediate stimulation of plant growth due to fire which results in greater forage yield. Soils are warmer on burned areas and spring growth starts earlier. On burned areas, soil fertility is usually increased. Plant vigor is promoted by removal of old shoots and foliage, and in many situations, burning of the mulch favors plant growth. Longer term increases in growth have been achieved by timing the fire to favor the species with highest yields, by removing undesirable, competing plants and by preparing seedbeds for successful reproduction. In addition to measurable increase in forage yield, greater forage availability was reported where unpalatable plants became palatable after burning, where physical barriers to utilization were burned, or where large plants were reduced in size by burning. Most prescribed fires lead to an increase in protein content and palatability of resprouting plants.

Fire has been a natural action changing vegetation through all biomes of North America for centuries. Fire is therefore a natural force in plant succession and has always been a factor in wildlife habitat manipulation. Uncontrolled, man-caused fires, which often have been devastating, are one of the biggest problems to wildlife. Such fires often have been started during the wrong seasons of the year and sometimes repetitively set, which in turn have created plant successional stages not always beneficial to endemic wildlife. Consequently, fire as a tool for habitat manipulation has been received with hostility at times during the twentieth century.

The Tall Timbers Research Station was organized in 1958 near Tallahassee, Florida, to explore the role of fire in land management. One of the station's primary interests is basic research regarding the influence of fire on the environment and the application of fire in land management. It further recognized the right of the public to be adequately and honestly informed as to the usefulness of fire in land management as well as to its destructiveness (Komarek 1962).

The Tall Timbers Station has held annual conferences on fire ecology since 1962. Most of these meetings have been held in Florida; however, some have been conducted in California, Montana, Canada, etc. Each conference has been summarized in a proceedings volume containing papers presented. An example would be Number 14, 1974, which was published in cooperation with the Inter-mountain Fire Research Council and totaled 675 pages in 3 parts: Fire Management Section; Fire Ecology Section; and Fire Use Section. Included are some of the most current papers on the values, procedures, and techniques of planning and implementing

prescribed burning. Each annual proceeding contains papers on the role of fire practices in relation to wildlife habitat management. The proceedings are concerned with fire ecology throughout the world as exemplified in the 1971 edition devoted to "Fire in Africa."

The following is a suggested outline for planning, execution, and evaluation for prescription burning (A. Becker, pers. comm.):

1. *Analyze Project*
   a. Ascertain present successional patterns for the area in question. Utilize historical references, photographs, fire history (long term), environmental influences and present vegetation patterns.
   b. Project where you wish to be. What vegetation composition do you wish to manage for (short term and long term)?
   c. Assess site potential. Soil, moisture, residual plants and/or seeds, etc.
   d. Evaluate projected fire effects on resources (vegetation, watershed, etc.). Utilize literature.
   e. Determine: Can fire meet management objectives?
2. *Prepare Prescription*
   a. Gather field data such as:
      Fuel loading (by size class)
      Depth and structure of fuels
      Fuel continuity
      Type of fuels (volatility)
      Slope
      Aspect
      Litter Depth
      Existing firebreaks
      Access
      Adjacent fuels
      Weather patterns
   b. Determine the projected fire intensity needed to meet objectives.
   c. Utilizing the above, fuel models[3] (if applicable) and/or expertise, formulate prescription and document. Acknowledge risk areas and mitigating measures. Prescription should include:
      Temperature
      Relative humidity
      Ignition points
      Wind speed and direction
      Fuel moisture
      Soil moisture
3. *Execute Burn*
   a. Follow prescription and burn plan. If changes are needed, document.
   b. Document fire behavior (flame length, rate of spread, etc.).
4. *Evaluate*
   a. Immediate followup: Map intensity of burn. Record amount of biomass left (by species such as sagebrush skeletons, etc.), amount of litter left, scorch height, etc.
   b. Document vegetation recovery, percent kill by species, sprouting, production changes.
   c. Insure proper management after burn. Document wildlife use, location, etc.

The wildlife habitat manager planning a controlled burn should review the reports by the Tall Timbers Research Station (Komarek 1962). We urge the manager to contact local authorities as to liability and seek expertise during the initial planning stages for a controlled burn.

[3]Most fuel models are averaged over a large area, and do provide good information. However, additional data gathered for each site will assist in more closely predicting fire effects for similar sites and altering prescriptions.

Rejuvenation

Many species of shrubs and trees can regenerate by sprouting from adventitious buds on the stem or from the root crown. The seed of chaparral species and other species are heat resistant and germinate in abundance after fire. When such species have grown too tall, dense, or decadent to produce available browse, it is possible to rejuvenate the stand by burning (Biswell et al. 1952, Hiehle 1961). With many species, it has been found that the sprouts and young plants are considerably higher in protein and other food values for several years after burning than in older growth stages. However, some species of shrubs and trees are killed by fire and may not reestablish on an area naturally for decades after a hot burn. These plants will, however, often respond by high production of adventitious growth to a rejuvenation treatment: crushing, cutting, or mowing. Chemical spraying that burns back the tops but does not kill the shrubs, has a similar effect on many kinds of woody plants. The root systems remain largely undamaged; the plants respond to the reduction of aerial growth by rapid and expansive root and leaf development. However, there is evidence that deer are reluctant to browse heavily on plants where a multitude of dead stems are intermingled with new growth. Dead stems may be a disadvantage if moderate to heavy browsing is needed to hold the growth at heights available for browsing. Crushing of brush either before or after burning results in better utilization of rejuvenated forage.

REJUVENATING BITTERBRUSH

Bitterbrush is an important browse species on mule deer winter ranges in several western regions. Many procedures have been used to rejuvenate tall, decadent stands of bitterbrush (Driscoll 1963, Ferguson and Basile 1966, Ferguson 1972). Results from railing or by crushing with a bulldozer, with blade 30.5 to 61 cm above the ground, indicate a great increase in growth the first year after treatment. This increase has been followed by a decline in growth the second and third year and by an actual loss of forage production. The evidence at hand indicates that dozing and railing cause severe mortality and diminishment of the total area of crown.

Rolling bitterbrush with a heavy log covered with rubber tires and pulled by a rubber-tired tractor shows promise for plant rejuvenation. Although there was little response the first year after rolling on a project in California, bitterbrush leader growth averaged 54% greater than that on the control area the second year, and

most of the treated plants showed excellent vigor. Only 2% of the rolled plants failed to resprout.

Roto-cutting bitterbrush in early spring with blade set 45.7 cm above the ground level resulted in a 47% increase in leader growth the same year on 1 project. Long-term results have not yet been evaluated. Pruning of stems from an average height of over 1.5 m to heights under 1.2 m coupled with removal of all shrub competition resulted, after 2 growing seasons, in an increase in leader growth 2.1 times greater than on an adjacent control area. Again, long-term evaluation has yet to be made (Schneegas and Zufelt 1965).

CRUSHED BROWSE-WAYS

Many chaparral-type brushfields are practically impenetrable to deer and offer little habitat to other wildlife. Such brush ranges can be improved for wildlife by creating interspersion of brush sprouts and herbaceous vegetation through development of small openings connected by lanes (Biswell et al. 1952, Hiehle 1961). The primary objectives of such work are the development of both food and access.

Release

On many sites, seed growth and production can be improved for some species by removing the surrounding competition. For example, Halls and Alcaniz (1968) found that seed yields for some understory plants were up to 32 times greater in openings compared to yields beneath a moderately stocked pine stand.

Small group selection cuts or row thinnings can be designed to admit more light, moisture, and nutrients to potential seed- or browse-producing understory species. In stands too young for commercial timber sales, individual stems of important seed and browse species can be released from surrounding competition using fire (such species as sassafras and flowering dogwood resprout vigorously after burning), herbicides, or cutting.

Release cutting of trees in older forest stands is best accomplished in conjunction with some type of commercial timber harvest. In the oak types, trees needing release should be selected in the fall during a good seeding year to insure that released trees will bear seed crops. Due to genetic factors, some oaks never bear much seed. In oak types, about 6.4 to 6.9 m^2 of basal area of seed producers should be reserved per ha (Shaw 1971).

In clear-cuts made in hardwood types, 0.5–0.9 m^2 per ha of basal area for seed-producing understory species, 5.1–12.7-cm dbh, should be reserved from cutting to insure that some seed is available for wildlife during the early years of regrowth after clear-cutting.

In addition, certain species important to wildlife, such as the hickories and American beech, are slow growers and are frequently overtopped by the vigorous growth of intolerant tree species that generally follow clear-cutting. If these slow-growing species are to reach seed-bearing size in these clear-cut stands, they must be released from competition. Nixon et al. (1975) recommended that 20–25 suppressed hickory poles greater than 15.2-cm dbh be left per ha after clear-cutting. Some of these stems may die after complete release but the remainder would have a good chance of reaching seed-bearing size. Similar recommendations have been made for beech and sugar maple in northern hardwood stands (B. A. Roach, pers. comm.).

Another method of increasing fruit production is to select trees, such as apple (wild or in abandoned orchards), wild cherry, hackberry, oak, or hickory, and apply one of the orchardist's methods for producing more fruit. This method involves measuring the diameter of the tree in cm at 1.37 m above ground. The diameter is divided by 2.78, and m are then substituted for cm. The resulting figure is the length of each side of a square from which all trees are to be removed except the fruit tree to be favored. Not only will this give the tree an opportunity to produce more fruit, but the interspaces are open for increased production of grasses, forbs, and shrubs (Shomon et al. 1966).

With many fruit-producing chaparral species in the West, such as manzanita, California redberry, and toyon, decadent stands can be renewed by mechanical crushing, chemical spraying, and especially by controlled burning.

BROWSE

Browse is defined as leaves, shoots, and twigs of shrubs and trees used as food. In some situations, such as a range recently burned by wildfire, there may be a need to plant desirable browse to introduce or restore a supply of forage. Elsewhere, increased food production may be a goal.

Twig growth has been found to be up to 7 times greater for browse plants growing in the open compared with those beneath trees (Halls and Alcaniz 1968). Creation of openings for browse production, like release cuttings, are best made in conjunction with a timber harvest. Browse manipulation practices can be grouped into the following categories:

1. Release through thinning to remove competition with less desirable species.
2. Rejuvenation through breaking, crushing, herbicide spraying, pruning, or burning rapidly regenerating species.
3. Planting to introduce seed stock.

MECHANICAL METHODS

Cabling

Cabling is suited to areas where it is planned to save residual stands of desirable shrubs and herbaceous cover and where the target species are not young and resilient (Plummer et al. 1955). Cabling is conducted essentially the same as the procedure described in chaining except a 45.7- to 61-m-long 3.8-cm cable is used in place of a chain.

Hula Dozer

This mechanical device is a 100 to 125 drawbar-horsepower crawler-type tractor with a "hula dozer" blade. The blade consists of hinged pusher bars and hydraulic tilting attachments. The pusher bar is used to

tip trees, while the corner of the blade is used to lift them from the ground. Hula dozing is economically advantageous in areas where target trees are clustered, and clusters are widely spaced, or where trees do not exceed 240 per ha. This method is used primarily where stands of browse plants are present, and it is desired to leave them undamaged.

Mechanical Thinning

Equipment used to precommercially thin coniferous forest species such as the Tomahawk and Hydroax may be used to release browse or seed-producing species. Other equipment that rolls, chops, or flails the vegetation also might prove useful depending on the objective of a particular project and the availability of equipment.

Special Considerations

Vegetative manipulation projects, such as chaining, burning, and spraying, are designed to alter the habitat structure—both plant species and shape. Therefore, depending on the individual involved, vegetative manipulation projects can be unsightly areas to observe. Consequently, project planners must be concerned with aesthetic values and plan projects to simulate natural openings in the landscape. Project planners should also be well instructed in the principles and procedures for pretreatment, treatment, and posttreatment as described by Cain (1971).

The size and pattern of food and cover treatments should be geared to the requirements of the target wildlife species involved and aesthetical values for ecological conditions. With nonmigratory deer, for instance, many small, treated spots or strips scattered over a large area will benefit more deer than a large, single project. There are several reasons for this. In the first place, the home ranges of bucks or doe-yearling-fawn family groups can be quite small. Only the deer whose home ranges impinge on or are immediately adjacent to the treated area will move into and use the new forage. In addition, deer often are reluctant to travel more than 61–91 m from cover and may use only the circumference of a large opening. Of prime importance, also, is the need to gear the amount of forage produced to the number of animals that will use it. If use is too light, the new sprouts and young plants may grow rapidly out of reach or become as dense as the original untreated stand. If, however, the treated areas are small enough so that moderately heavy browsing of forage holds plants in desirable forms, value will be prolonged over much longer periods. If deer respond to better forage conditions by increase in numbers, the frequency and size of treated areas can be increased. Treatments can be rotated so that no one area will be manipulated more often than once in 10–20 years. In any case, no more than 30% of the area should be treated to create better forage areas and the other 70% left in cover, with size of cover patches at least 16.2 ha or more (Taber and Dasmann 1958).

The prescribed treatments for key portions of migratory deer winter range will necessarily differ from those described above. Because heavy snows and other conditions force deer to concentrate during mid-winter, deer densities and hence food demands tend to be high in these areas. For this reason, it is essential that treatments be large enough to prevent decimation of new forage. Even here, the most productive patterns will be in extensive broad strips or openings interspersed with patches or strips of cover rather than in single large projects. Retention of cover should not be neglected in such projects and should be given special emphasis where winters are severe. In northern Maine, for instance, dense conifer winter cover for deer should be intermixed with open feeding areas not exceeding 91 m. in width.

This brief description of requirements for deer will show the need for analysis of the requirements of the wildlife species to be favored and the importance of tailoring the program to fit these requirements.

Finally, it should be pointed out that managing habitat for a single species of wildlife has essentially ended, at least on public lands in the United States. Today, the wildlife manager must strive to produce a mosiac pattern of different habitats providing niches for an array of wildlife species. A variety of techniques will be needed to do the job. We reiterate again that wildlife habitat management, to be successful, must be based on the manipulation of natural plant successions. Techniques that duplicate natural forces (such as fires that create openings) offer the cheapest and most effective means of providing wildlife with habitats they have adapted to through time. There will be situations where more artificial techniques such as planting will be required; but whenever practical, native species should have priority in any planting program.

COVER PRACTICES

Cover fulfills varied habitat requirements for wildlife. A hedgerow may provide escape cover for quail from predators, or the same shrubs may provide nesting cover for song birds. Cover can be provided by a variety of items; rock piles, ground burrows, brush piles, or trees (including cavities). The absence of cover, its sparceness, or its poor distribution can be the factor limiting the use of an area by wildlife. The habitat manager can improve wildlife numbers or area of use by improving cover quality or quantity. When manipulating food or water, wildlifers should be careful to assure enough cover of various kinds is left to meet wildlife needs.

Cover includes escape, nesting areas, and refuge from inclement or adverse weather. It most often consists of a form of vegetation—herbaceous, shrubs, or trees—that provides protection from hunters or predators, mechanical or thermal protection from winter storms or summer sun, or a combination of these factors which provide a secure nest site.

Hedgerows

In some areas, cover plantings are not necessary due to rapid natural revegetation. However, other regions may require the planting of cover such as hedgerows. Hedgerows provide desirable escape, refuge, and nesting cover, as well as travel lanes for many species of wildlife. Low, woody vegetation can be planted along

fence rows, in gullies, and along streams or around ponds, springs, food patches, and breeding grounds. Such plantings generally are established by transplanting seedlings or wildlings. Planting can be done by hand or with a mechanical planter depending upon the size of the project. Three to 4 rows of different size plants should be planted in a stairstep pattern so varied degrees of cover exist. For instance, rows of Russian olive, squawbush, and Siberian pea spaced appropriately will provide travel lanes, cover, and food for many wildlife species. Spacing of plants varies with species. The smaller plants are planted every 45.7 to 61 cm in rows 0.9 to 1.2 m apart. Larger plants are planted every 2.4 to 3.7 m in rows about 2.4 to 3.0 m apart. For most wildlife species, hedgerows 4.6 to 6.1 m wide are adequate. Row lengths vary, depending on the needs and available space. One strip to each 49.4 to 61.8 ha in open country appears adequate.

Hedgerows can also be established by plowing a strip where a hedgerow is desired, then lining or staggering fence posts about every 6.1 m down the strip. Wire or twine is strung between the posts for a bird perch. Droppings of birds that perch are laden with viable seed and will "plant" the prepared seedbed. These "plow-perch" plantings grow almost as fast as those produced from root stock.

Brush Piles

When cover is limited in wildlife habitat, brush piles may be provided. If possible, brush piles should be a by-product of other land treatments, rather than a specific practice. Timber harvest, timber stand improvement, pasture or cropland clearing, release cutting for trees or shrubs all provide woody limbs suitable for brush piles. Brush piles when correctly constructed and located provide nesting and protection cover as would a good stand of natural vegetation. Their values include (Warrick 1976):

1. Concealment cover from predators—an overhead canopy and surrounding brush hide nests from the view of predators.
2. Protection from predators—the tight network of strong twigs and small openings eliminate entry of many predators.
3. Protection from the elements—nests are sheltered from the cooling rains, wind, and excessive sunlight.
4. Harbor for various seeds to sprout in—the network of twigs and grass provide a medium for seed germination and young plant growth.

Spacing of brush piles will depend on the mobility of the species that are to use them. Brush piles for quail, for example, should be within 61 m of other escape cover and (for western quail) no more than 0.4 km from water. The carrying capacity of large clearings for many upland game birds can be increased by providing brush pile cover.

Top pruning of trees on scaled quail range not only provides slash that can be piled for cover but promotes a bushy tree growth that makes preferred loafing cover. Such piles should be about 1.5–1.8 m in diameter and about 0.9 m high. It is best to elevate the pile about 15.2 cm above the ground by using rocks or heavier limbs for support. Where large clearings (40.5 ha or more) are made on quail range, brush should be piled at an optimum rate of about 1 pile per hectare.

Long brush piles placed in the upper portion of broad arroyos or low profile ravines may be used to increase cottontail rabbit populations. For rabbits, the pile may be 7.6–15.2 m long, 1.5 m wide, and 1.2 m high (Shomon et al. 1966). Brush piles should be at least 3.7–4.6 m in diameter and 1.5 m high to provide rabbit cover for several years.

Both white-crowned and Harris' sparrows often are found in association with brush piles. In Kansas, Harris' sparrows often are found in winter wherever there are brush piles (R. Graber, pers. comm.).

Turkey nests have been found in slash piles, thickets, fallen tree tops or at the base of bushes and trees. There are indications that carefully located brush piles may provide nesting cover, and there may be advantages to simulate turkey nesting cover preferences by piling brush or slash at the bases of trees or around logs. Such brush piles should be within 0.8 km of water.

Use of slash remaining after a timber harvest offers a means of creating turkey nesting habitat adjacent to openings created by the logging operation. Openings are sought as feeding sites by hens with poults.

Brush or trees piled loosely in field corners or along fence rows may extend pheasant habitat. Grass, forbs, and vines will grow up through the brush and add density and permanence to the pile.

Javelina range may be extended by brush piles. A wooden platform about 0.9 m high supported by rocks or creosoted posts, with brush piled on top and on 2 sides, may be used for this species. The structure may be placed against a bank or overhanging cliff. Such javelina brush piles should be at least 1.8 × 1.8 m and located in an area protected from wind and near food.

Natural and Artificial Roosts

Some species of wildlife, such as quail and turkeys, require adequate perching or roosting sites. Where roosts are lacking, such cover can be provided through natural vegetation plantings or by artificial roosting structures.

Since 1958, the Rio Grande turkey has extended its range into the scrub mesquite prairie of west Texas, in part because of the installation of electric transmission poles that are used as roost sites (Kothmann and Litton 1975). Use by these turkeys suggests the installation of similar towers in other areas that lack roost sites but offer food supplies and adequate rainfall.

The California quail is an example of a species that needs at least a good roosting site per 12 ha for desirable habitat. The lack of adequate sites may be corrected by planting thick foliaged trees such as live oaks, olives, citrus, and juniper. Where it is not practical or feasible to plant trees, artificial quail roosts, e.g., brush piled on a wire-covered frame held off the ground by 4 posts, can be made with little cost and used as temporary roosts while waiting for permanent natural vegetation to grow (McMillan 1959). These roosts are constructed of pipe or wood and should be approximately 2.4 × 5 m in diame-

ter and installed 1.8 m above the ground when completed (MacGregor 1950, Fig. 20.3).

Another method to improve protective roosting sites for quail is to cut the limbs of large trees above the primary forks and pile these same limbs in the forks. This also causes the tree to bush out, which creates good dove nesting cover as well as quail roosting cover (Bauer 1963).

Eagles near Klamath Falls, Oregon, benefited from the construction of a huge artificial tree. The traditional roost was near a favored fishing lake. However, the few trees used for perching were blown down by a heavy wind. Recognizing their plight, an artificial tree was installed which has 3, 18.3-m poles placed in a tepee formation with 3, 6.1- to 9.1-m cross perch poles. Fast-growing poplars and elms were planted around the base of the artificial tree to provide eventually a more natural and permanent roosting site. Within less than a month, bald eagles used this new structure and have been using it each year since (Oregon State Game Commission 1972).

The extensive open grassland prairies of the West provide good food sources for raptors but frequently lack roost and nest sites. Olendorff and Stoddart (1974) noted that raptors readily used trees and buildings made by man, and, consequently, recommended planting trees to improve raptor habitat. They observed that trees planted near water are most frequently used. Until the natural trees are large enough for nest sites, it may be necessary to place an artificial nest structure (see "Specialized Nest Structures: Platforms" for further specifications).

Nesting Cover

Mixtures of brome grass and alfalfa, each applied at the rate of 8.9–10.7 kg/ha, have been found to produce suitable nesting cover for ring-necked pheasants and other grassland nesting avifauna along roadsides in otherwise intensively cultivated landscapes (Joselyn and Tate 1972). Such seedings, once established, have provided pheasants with 15 years of quality nest cover at an amortized cost of less than $24.70/ha (R. E. Warner, pers. comm.). Seedings are mowed once each growing season after August 1.

On Wisconsin upland sites, canary grass, Blackwell switchgrass, and brome grass produced the best nesting cover for grassland nesting species. On muck or peat soils, canary grass and timothy gave the best results (Frank and Woehler 1969). Plantings on upland soils were most successful when seeded in April or May with a nurse crop of oats; the oats were then harvested in late July or early August. They used 3.6–5.3 kg/ha of fine seeded grasses such as canary grass, and 5.3–7.1 kg/ha of the large seeded varieties such as brome grass. Oats were seeded at 42.8 l per ha. August seedings were most successful on muck soils because heavy weed competition occurred following spring planting. Forage sorghums and sorghum-sudan grass hybrids, established annually, provided good winter cover on Wisconsin upland sites. Such cover was useful on diverted acres or as interim winter cover until woody plantings furnished protective cover. For pure sorghum stands best results were obtained using 7.1–13.4 kg/ha. In seeding corn and sorghum-sudan mixtures, 0.1 l of Hi-Dan 35 seed were added to 17.6 l of seed corn. Corn planter boxes were kept about 1/2 full and 55–80 g of Hi-Dan were added to the plant boxes at regular intervals. As few as 4 rows received use by pheasants, but 0.4–1.2 ha were usually seeded (Frank and Woehler 1969). Cost of establishing nest cover ranged from $37 to $91/ha, including seed, fertilizer, site preparation, and planting. Winter cover costs averaged $59 to $89/ha, if such planting were renewed annually.

For prairie grouse, a successful seeding per ha of 1.8–2.7 kg of redtop, 0.45 kg of timothy and 0.45 kg of red clover, Korean lespedeza, and alsike clover, plus 0.45 kg of alfalfa when the pH of the soil is suitable, has provided attractive nest cover in Illinois (Sanderson et al. 1973).

Redtop seedings have been most attractive to nesting prairie chickens the second nest season after seeding and the second nest season after controlled burning of redtop sods 4 or more years old (Westemeier 1973). Nest cover for prairie chickens should be managed in 2.0–8.1-ha blocks, because most prairie chicken nests have been located near breaks in cover types.

If native grasses (bluestems, switchgrass, Indian grass, sideoats grama) are used for nest cover, they must be mowed, burned, or grazed frequently to break up the dense cover that will develop. The warm season grasses mature late and can be mowed for hay in late July or August after eggs are hatched and young are flying. These grasses should be rotation burned in early spring at 3- to 5-year intervals. This burning rotation benefited prairie chickens, sharp-tailed grouse, pheasants, upland plovers, and Hungarian partridge in North Dakota (Kirsch and Kruse 1973).

Additional suggestions for maintaining or improving nesting cover by Shomon et al. (1966) are as follows:

1. Maintain permanent, undisturbed cover along fences, ditch-banks, roadsides, railroad rights-of-way, and in waste areas (such as cattail sloughs) and odd corners, where possible.
2. Encourage farmers and ranchers to enter into 1 or more of the several government programs which provide financial aid for planting vegetation which is suitable for wildlife cover.
3. Work with state and local highway departments to discourage burning of cover along roadsides during the winter and spring; encourage the delay of mowing until after July 1; and encourage the planting of grasses and legumes for use by nesting pheasants.
4. Refrain from dryland fallowing operations between the period of April 15 and June 20 to enable ground-nesting birds to hatch in important stubble field nesting areas.
5. Use flushing devices on mowers to save nesting females during the first cutting of alfalfa.
6. Fence nesting cover to prevent grazing by livestock.
7. Plant shrubby thickets along gulleys and draws for use as cover.

Snags

Over 85 species of North American birds use cavities in dead or deteriorating trees (Scott et al. 1977). Thomas

Fig. 20.3. Installation of an artificial quail roost in southern California (photos by I. McMillan).

et al. (1976) observed that 24 mammal and 38 bird species used tree cavities for a mountain range in Oregon and Washington. Such trees are often called "snags." The removal of snags can reduce wildlife populations. For example, in Arizona the removal of snags reduced cavity-nesting bird populations by 50%. Much of this decline was in populations of violet-green swallows, pygmy nuthatches, and northern three-toed woodpeckers. Swallows alone dropped 90%, whereas a low woodpecker population was eliminated (Scott et al. 1977).

Foresters and recreation managers are now more aware of the economic and esthetic values of cavity-nesting birds. The majority of snag-dependent wildlife

species are insectivorous and fill a major role in the control of forest insect pests (Thomas et al. 1976). Recognizing these wildlife values, the U.S. Forest Service (1977) issued a new policy to "provide habitat needed to maintain viable, self-sustaining populations of cavity-nesting and snag-dependent wildlife species." An example of placing this policy into effect was the Arizona-New Mexico Forest Service Regional Office recommendation that 7 good quality snags per ha be retained within 152 m of forest openings and water, with 5 per ha over the remaining forest. Some agencies are now placing signs on snags and other valuable wildlife used trees identifying them as "Wildlife Trees" not to be harvested or cut down for firewood.

SPECIALIZED NEST STRUCTURES

Many species of wildlife that use tree cavities have declined due to the loss of primeval forests. Examples are the ivory-billed and red-cockaded woodpeckers which are presently on the endangered species list due mainly to the loss of habitat (Scott et al. 1977). There are many mammals that also rely heavily on tree cavities for part of their life cycle. For example, the best nest den sites for the eastern gray or fox squirrel are tree cavities with specific dimensions. For fox squirrels, cavity dimensions averaged 16 × 17.5 cm in diameter and 38.1–40.6 cm deep, measured from the top of the den entrance, with an entrance opening 6.1 cm × 9.4 cm in diameter (Baumgartner 1938). Blackgum, beech, maples, gums, basswood, and elms decay readily and form dens within a few years; oaks decay slowly and form dens in their later years. Sanderson (1975) recommended a mixture of trees that decay and form cavities at different rates.

Man should husband existing den or nest trees and should look to artificial structures only as a secondary technique after full evaluation of the need. It is more realistic and justifiable, in view of the many human and ecological values at stake, to make ample den or nest trees continuously available as a natural and vital component of the living forest.

At times, however, man-made structures must be used or a species will not survive. As an example, nest trees for double-crested cormorants have become scarce along the upper Mississippi River in Illinois and Wisconsin. In Illinois, an artificial nest tree was provided. A single 14.6-m utility pole was anchored adjacent to 2 existing natural nest trees about 1.6 km from shore and in water about 5.5 m deep. Twelve nesting platforms were attached to the pole using 6 cross arms spaced 0.9 m apart (Fig. 20.4). The nest platforms consisted of boxes 5.1 cm × 40.6 cm × 1.8 cm deep with 3, 7.6 × 40.6-cm slats on the bottom. The boxes were lined with 2.5-cm-mesh chicken wire (Kleen 1975). Another type of platform with 2 cormorant nests was built on the Agassiz National Wildlife Refuge in Minnesota (Fig. 20.12).

The U.S. Forest Service system of managing nesting trees for rare and endangered native wildlife such as the bald eagle, ivory-billed woodpecker, red-cockaded woodpecker, and osprey provides an example of how the important, but seldom understood, technique of nest tree protection is currently being practiced:

1. Maintain an inventory of all nest sites and identify in detail the location of each.
2. Check nests periodically and record a cumulative history of nest use.
3. Within 100 m of any nest tree, development activities will be limited to management measures beneficial to maintaining the nesting site.
4. A special buffer zone, 201 m in radius, will be established and marked on the ground around each nest site.
5. Timber cutting, timber stand improvement, prescribed burning, road construction, recreation construction, and other disturbing activities will not be allowed within the buffer zone during the period from November 1 to June 15.
6. All practices such as insecticide spraying, aquatic plant control, and the use of fish toxicants, will be critically evaluated regarding their effects on nesting sites within the forest and areas outside of the forest, but within 0.8 km of the forest's boundary.
7. Three to 5 old growth trees will be reserved as roosting and potential nest trees within the buffer zone surrounding the nest. For red-cockaded woodpeckers, an aggregate of cavity containing live pines, 25.4–63.5-cm dbh, 70–100 years old, are needed for each colony.
8. The location of all nests and their buffer zones will be shown in the forest's "Multiple Use Atlas." These special management considerations will stay in effect until it has been conclusively determined that the nesting site has been abandoned.

Artificial nest structures can substitute for a deficiency of natural sites in otherwise suitable habitat. Where primeval forests are primarily gone in the eastern United States, purple martins now depend almost entirely on man-made nesting structures (Allen and Nice 1952). Bird houses have been readily accepted by many natural cavity nesters, and increases in breeding density have resulted from providing such structures (Grenquist 1966, Strange et al. 1971, Hamerstrom et al. 1973). Nest boxes are useful for wood ducks and squirrels, as well as various nongame species, such as bluebirds, screech owls, kestrels, and barn owls. Nest baskets and platforms are readily used by waterfowl.

Bird houses have been built by man all over the world for eons. Sometimes this was merely the placing of a large gourd with a small hole in a nearby tree. At other times it would be the elaborate construction of a 18-compartment complex for the gregarious purple martin. The practice continues today as attested by the variety of different bird house designs and styles (Fig. 20.5). Detailed plans for these structures are often available from the National Audubon Society, local bird clubs, Cooperative Extension Service (McDowell 1972), and other sources (Shomon et al. 1966).

The very popular and helpful pamphlet *Homes for Birds* published by the U.S. Fish and Wildlife Service (Kalmbach et al. 1969) provides many excellent examples for constructing bird houses. The authors stress that the bird house should be designed and constructed according to the needs of the target species. These specifi-

D.C. CORMORANT NEST STRUCTURE

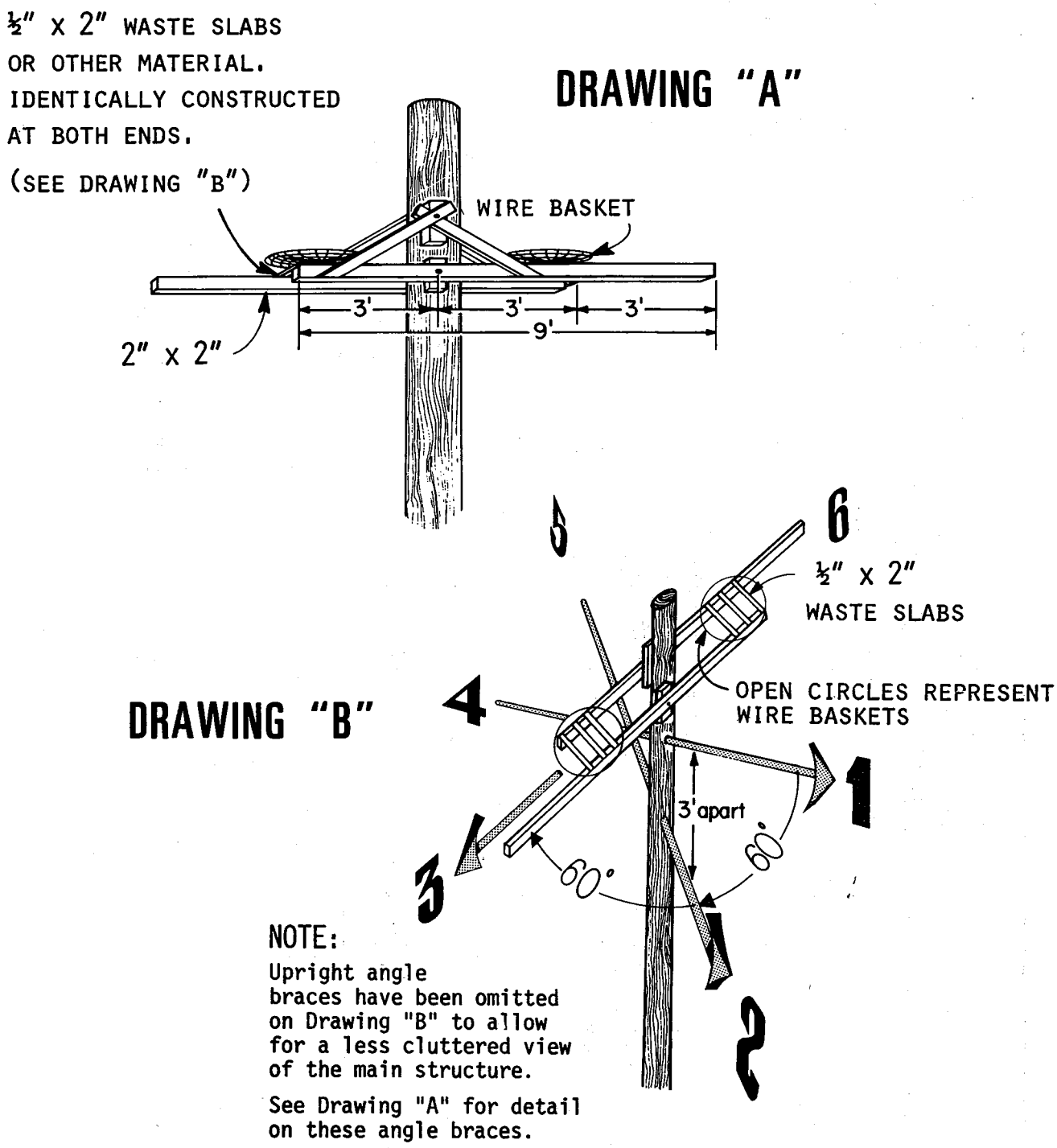
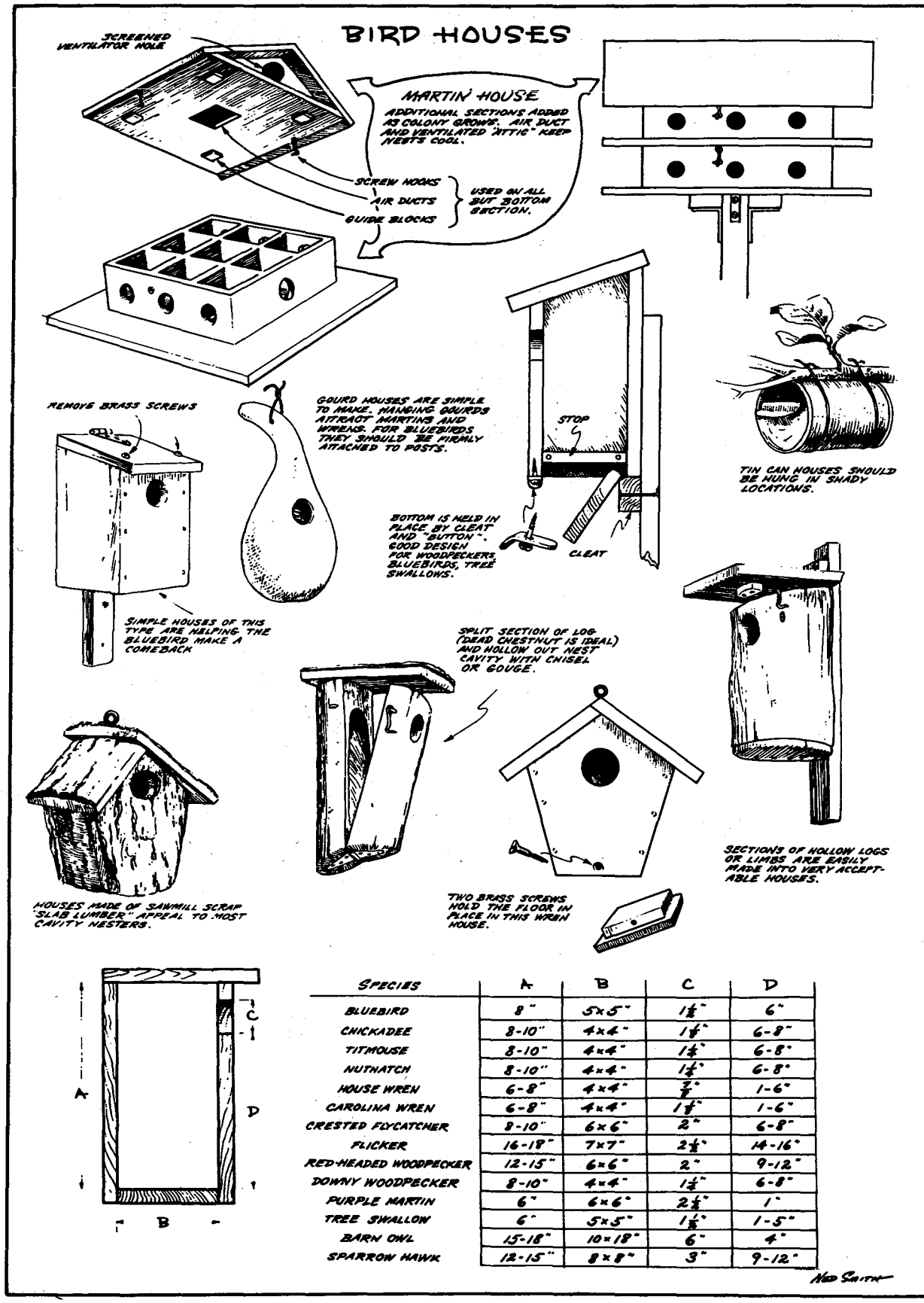


Fig. 20.4. Nest tree for double-crested cormorants. The crossarms and nest baskets are attached to a 14.6 m telephone pole as shown in Drawing "A." Crossarms spiral up the pole 60 degrees apart as shown in Drawing "B." The numbers in Drawing "B" refer to crossarms. (Illinois Natural History Survey drawing by Lloyd Lemere.)



Species	A	B	C	D
Bluebird	8"	5×5"	1½"	6"
Chickadee	8-10"	4×4"	1⅛"	6-8"
Titmouse	8-10"	4×4"	1¼"	6-8"
Nuthatch	8-10"	4×4"	1¼"	6-8"
House Wren	6-8"	4×4"	1⅛"	1-6"
Carolina Wren	6-8"	4×4"	1⅛"	1-6"
Crested Flycatcher	8-10"	6×6"	2"	6-8"
Flicker	16-18"	7×7"	2½"	14-16"
Red-headed Woodpecker	12-15"	6×6"	2"	9-12"
Downy Woodpecker	8-10"	4×4"	1¼"	6-8"
Purple Martin	6"	6×6"	2½"	1"
Tree Swallow	6"	5×5"	1½"	1-5"
Barn Owl	15-18"	10×18"	6"	4"
Sparrow Hawk	12-15"	8×8"	3"	9-12"

Fig. 20.5. There are many styles or varieties of bird houses. The 1 main criteria for design is to build the nest facility to the size and needs of the target species (Shomon et al. 1966).

cations vary greatly and can make the difference in the success or failure of a newly constructed bird house producing nestlings. Table 20.2 provides the various specifications for 26 different birds.

In the U.S.S.R. and some eastern European countries, increasing emphasis is being placed on the role of forest birds in preventing irruptions of harmful forest insects. While the role of birds is generally considered prophylactic and contributive as a component in integrated pest control (Khramtsov and Timchenko 1976), certain species are believed to depress insect numbers during high insect populations (Blagosklonov 1977). Research efforts in attracting birds for insect utilization have significantly increased (Kuteev 1977). Blagosklonov (1977) discussed the results of an evaluation of artificial nesting structures, differing in construction material, dimensions, construction form and color. Evaluation criteria were based on the habitat requirements of 5 bird species important as insect predators.

Where intensive forest management has eliminated dead and dying trees, the placing of artificial bird nest boxes can be a beneficial wildlife management technique (Bruns 1960, Franz 1961, Williamson 1970, Beebe 1974). The installation of bird nest boxes can increase bird abundance which in turn can be an important factor on the control of insects injurious to forests.

Nest Boxes and Tires

Nest boxes must be properly designed, located, erected, and maintained for beneficial results. They must also be durable, predator proof, weather tight, lightweight and economical to build. The boxes also must meet the biological needs of the target species.

WOOD DUCK

No one type of nest box or placement meets all the requirements imposed by the diversity of habitat and predators. Consequently, each nest box program needs to be designed for local conditions. However, certain generalizations are warranted (Bellrose 1976):

Table 20.2. Dimensions of nesting boxes for various species of birds that regularly use them, and the height at which they should be placed above the ground (Kalmbach et al. 1969).

Species	Floor of Cavity	Depth of Cavity	Entrance above Floor	Diameter of Entrance	Height above Ground[1]
	Inches	Inches	Inches	Inches	Feet
Bluebird	5×5	8	6	1½	5–10
Robin	6×8	8	(2)	(2)	6–15
Chickadee	4×4	8–10	6–8	1⅛	6–15
Titmouse	4×4	8–10	6–8	1¼	6–15
Nuthatch	4×4	8–10	6–8	1¼	12–20
House wren	4×4	6–8	1–6	1-1¼	6–10
Bewick's wren	4×4	6–8	1–6	1-1¼	6–10
Carolina wren	4×4	6–8	1–6	1½	6–10
Violet-green swallow	5×5	6	1–5	1½	10–15
Tree swallow	5×5	6	1–5	1½	10–15
Barn swallow	6×6	6	(2)	(2)	8–12
Purple martin	6×6	6	1	2½	15–20
Prothonotary warbler	6×6	6	4	1½	2–4
Starling	6×6	16–18	14–16	2	10–25
Phoebe	6×6	6	(2)	(2)	8–12
Crested flycatcher	6×6	8–10	6–8	2	8–20
Flicker	7×7	16–18	14–16	2½	6–20
Golden-fronted woodpecker	6×6	12–15	9–12	2	12–20
Red-headed woodpecker	6×6	12–15	9–12	2	12–20
Downy woodpecker	4×4	9–12	6–8	1¼	6–20
Hairy woodpecker	6×6	12–15	9–12	1½	12–20
Screech owl	8×8	12–15	9–12	3	10–30
Saw-whet owl	6×6	10–12	8–10	2½	12–20
Barn owl	10×18	15–18	4	6	12–18
Sparrow hawk	8×8	12–15	9–12	3	10–30
Wood duck	10×18	10–24	12–16	4	10–20

[1]Many experiments show that boxes at moderate heights mostly within reach of a man on the ground are readily accepted by many birds.

[2]One or more sides open.

1. Initially, wooden boxes are more acceptable to wood ducks than metal boxes. But metal boxes have a higher nest success rate and in a few years may have a higher occupancy rate than wooden boxes. However, wood ducks need to be conditioned to using metal boxes by prior use of wooden boxes. For wooden boxes, rough-cut lumber is best. Smooth lumber can be used if a "ladder" of 0.64-cm mesh hardware cloth is attached inside so the day-old ducklings can climb out. Vertical metal boxes should be provided with either a hardware cloth "ladder" inside or with a car undercoat material sprayed or troweled inside to permit ducklings to exit.

2. Nest boxes should be made as predator-proof as possible or mounted in such a way to prevent predators from entering. Both wooden and metal boxes should have elliptical, raccoon-proof entrances, or be protected with inverted metal cones, or be attached to a steel pipe.

3. All nest boxes must be provided with 7.6–10.2 cm of sawdust, wood chips, or shavings to form a nest base and cover the first few eggs.

4. Groups of 4 to 8 nest boxes per ha ultimately have the highest use because of successful nesters and the associated young birds' homing behavior. However, grouped boxes have higher predator exposure and must have adequate protection.

5. Wood ducks use nest boxes on poles in water at a higher rate than those in woods. In woods, the nearer the water the better; up to 0.4 km is good, 0.8 km satisfactory, and 1.6 km a possibility for nesting. The more open and parklike the woods, the better for wood ducks and, unfortunately, for starlings. Dense woodland deters starlings more than wood ducks. Houses in trees should be placed 3.7 to 6.1 m above the ground where the canopy is open and does not overhang the entrance.

A design for both wooden and metal nest boxes for wood ducks is shown in Figs. 20.6 and 20.7.

Where starlings are a problem, a horizontal nest box can be substituted for the vertical box (McGilvrey and Uhler 1971). This nest box is constructed of galvanized duct pipe 30.5 cm in diameter and 61 cm long with 2.5-cm-thick wooden ends. The back is solid and the front has a 10.2 × 27.9-cm semicircular opening. Cylinders are mounted on steel fence posts over water and equipped with 61–91 cm lengths of aluminum downspout sleeves (7.6-cm diameter) to act as predator guards. A shallow partition may be placed in the center of the cylinder to prevent eggs or ducklings from moving forward and becoming chilled.

Cylinder structures should be used in combination with the metal or wooden vertical boxes to allow wood ducks gradually to accept the horizontal cylinders. It should be possible to switch the nesting population of an area from vertical boxes to cylinders over a 5–6 year period. Kestrels, tree swallows, grackles, purple martins, and great crested flycatchers have also nested in these cylinders (Heusmann et al. 1977).

The British Columbia Fish and Game Branch erected 30 wood nest boxes for buffleheads. Most were used by starlings and tree swallows from the start. However, 6 were used by buffleheads on 3 consecutive years. Reports indicate that buffleheads also used nest boxes in Alberta and California (Erskine 1971). Norman and Riggert (1977) reported 36% of nest boxes examined were used by ducks in Australia.

SQUIRRELS

The nest box designed by Barkalow and Soots (1965) has been slightly modified to provide a more durable and maintenance-free structure. See Fig. 20.8 for design specifications. The use of rot resistant or treated wood enhances durability of nest boxes; however, creosote treated wood should be avoided. The wooden nest boxes should be fastened to the tree with nonferrous nails.

The dimensions of this box also meet the specifications of nest boxes for kestrels and screech owls. Other species of wildlife known to use squirrel nest boxes for shelter or nurseries include flickers, nuthatches, red-bellied woodpeckers, starlings, flying squirrels, and tree frogs.

Tire nests have also been utilized for nesting by eastern gray squirrels (Burger 1969). The construction details are shown in Fig. 20.9. Tire nests should be hung over a branch at least 4.6 m from the ground with the open throat towards the tree trunk.

Nesting structures for squirrels should be erected at densities of 5–7.4 per ha in areas producing 45.4 kg or more mast per ha (Sanderson 1975). They are most effective in hardwood stands between 30 and 60 years when mast crops are abundant, but tree cavities suitable for sheltering squirrels are scarce. Nesting structures should not be placed in trees already containing tree cavities; squirrels will not readily accept artificial nesting structures if natural cavities are available in the same tree.

BLUEBIRDS, SWALLOWS

During the past 40 years, eastern bluebird populations appear to have plummeted as much as 90% (Zeleny 1977). The western bluebird and the mountain bluebird of the Rocky Mountain region have suffered less, but gradually they are experiencing similar declines. The loss is due in part to decreased old, decadent cavity trees needed for nesting and competition with starlings and house sparrows for limited nest sites.

Today's bluebirds are taking more readily to artificial nest boxes due to the scarcity of natural nest sites. During the past 5 years, nearly 1,000 bluebirds were raised in 85 nest boxes along a "bluebird trail" 11.3 km from Washington, D.C. (Zeleny 1977). Canada boasts a 3,218-km "bluebird trail" through the prairie regions of Manitoba and Saskatchewan. Some 8,000 nest boxes were installed which produced more than 8,000 young bluebirds and 15,000 young tree swallows in 1976.

Bluebirds prefer open areas with scattered trees. Nest boxes may be constructed of almost any type of wood. They should be placed 0.9–1.5 m off the ground. Fence posts make good sites. Boxes should be spaced at least 100 m apart to eliminate fighting among highly territorial males. Figure 20.10 provides detailed plans for constructing a top-opening bluebird nest box.

Tree swallows also readily use nest boxes of the same specifications. Ponds and marshy areas are ideal locations to place nesting boxes. Backyards are another good place as swallows readily adapt to human activity and are welcomed for their habit of consuming numerous mosquitos. Nest boxes should be spaced 22.9–30.5 m apart on poles about 1.2 to 2.7 m above the ground. Fig-

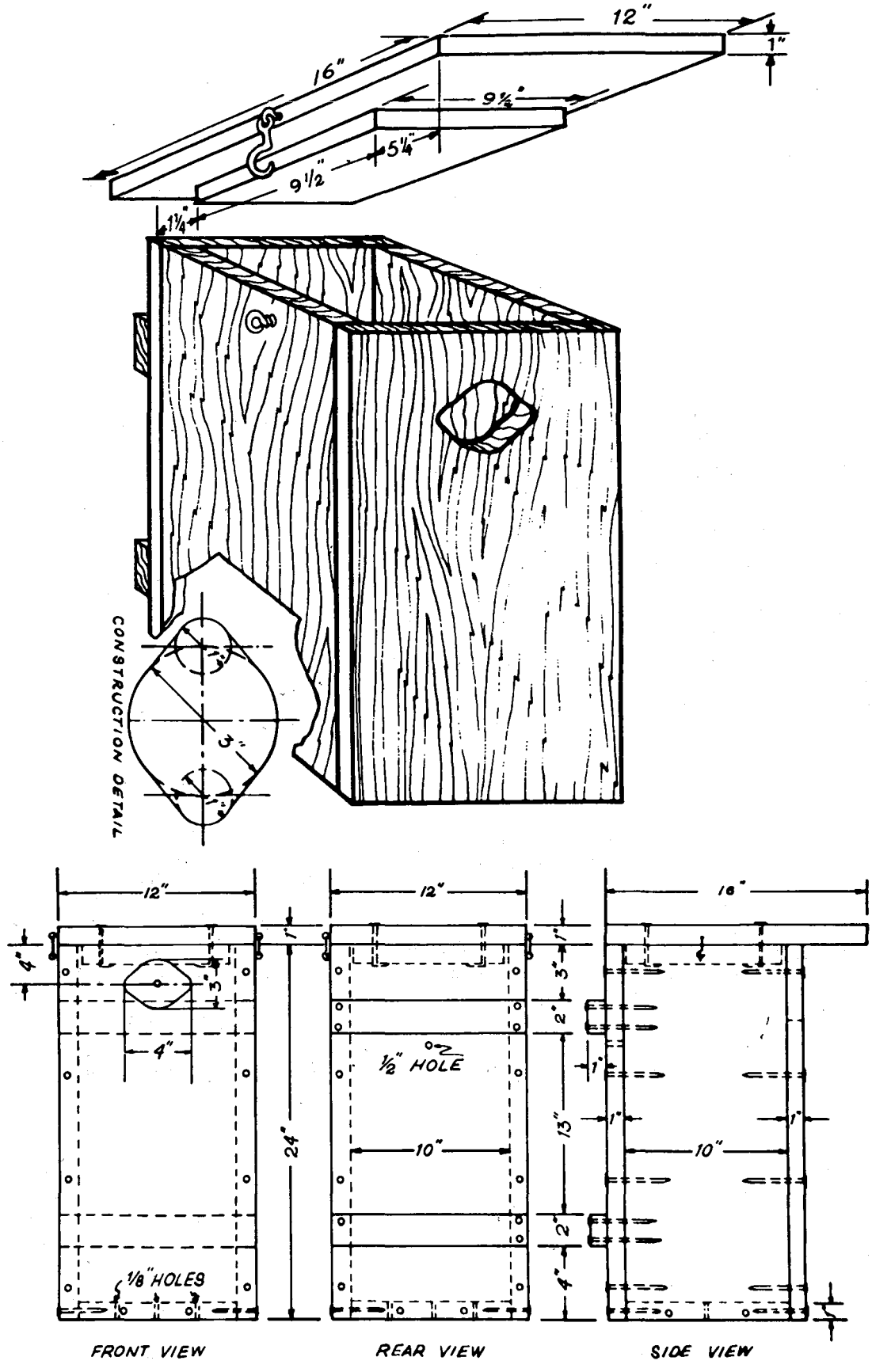


Fig. 20.6. Plans for a wooden nest box for wood ducks (Bellrose and Crompton 1972).

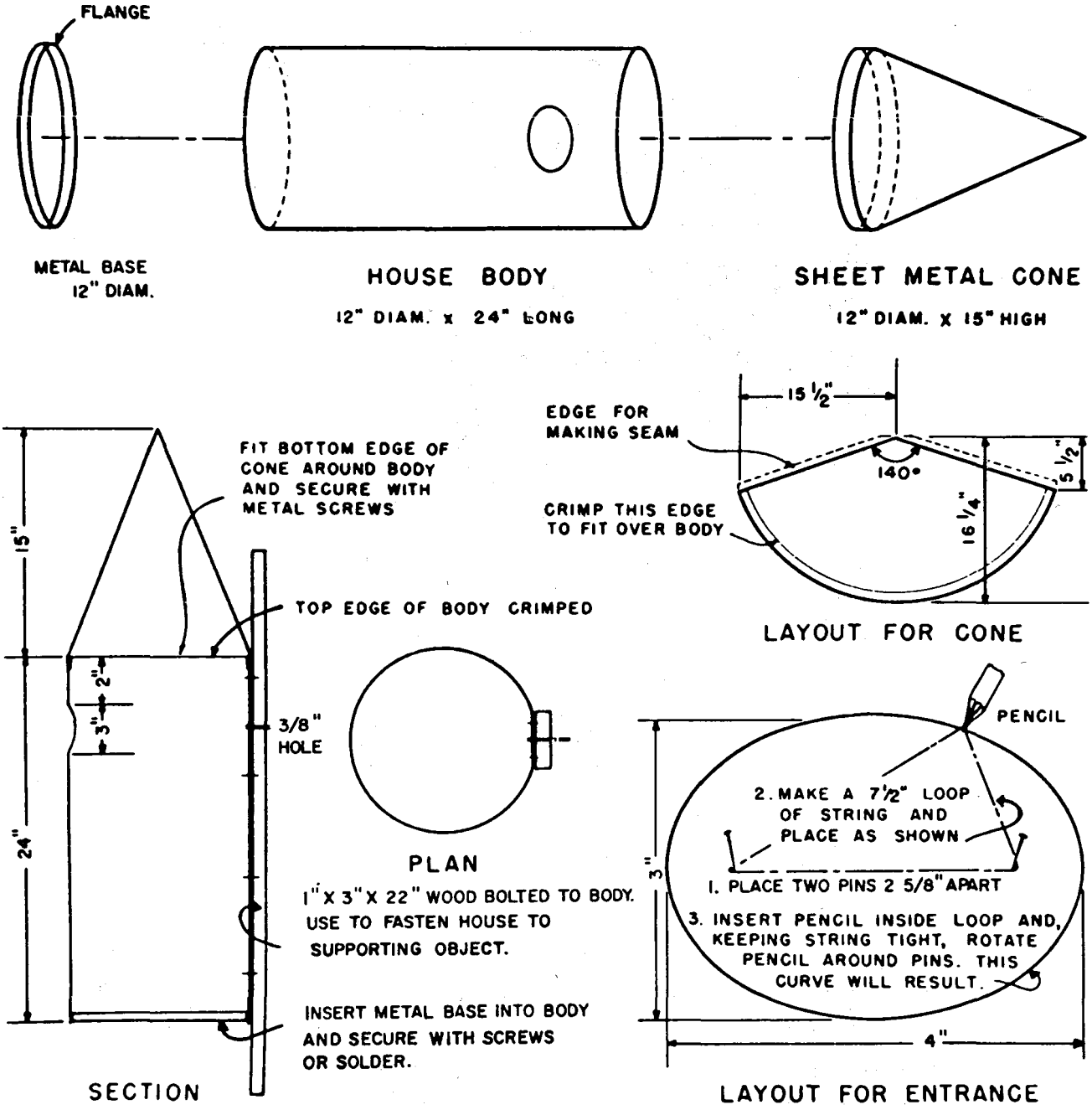


Fig. 20.7. Plans for metal nest facility for wood ducks (Bellrose and Crompton 1972).

ures 20.5 and 20.10 list specifications to follow. Be sure the box opening is small enough to prevent cowbirds and starlings from entering (Ebert and Francis 1978).

KESTRELS

The commensal value of nest structures for wildlife is well illustrated with nest boxes for kestrels. Hamerstrom et al. (1973) noted that only 3 pairs of nesting kestrels were located over a 20-year period on a 20,243-ha study area in central Wisconsin. Fifty nest boxes were put up from 1968 through 1972. These boxes successfully produced 8 to 12 broods per year, totaling 204 birds, or 1,600% increase in kestrels compared to natural production in the same study area. This study documents well that for some areas, the limiting factor controlling cavity-nesting birds is the paucity of nest sites, and that man-made structures can fulfill this habitat requirement, thereby increasing wildlife populations.

Figure 20.11 provides a good diagram for construction detail of a kestrel nest box. It is recommended that the box not be painted or sprayed. Also, no entrance perch is required, as kestrels do not need them and a perch attracts starlings.

Kestrel nest boxes can be placed in towns and urban communities, but they are most successful in rural areas. Place the nest box on a lone tree or post in or on the edge of a field. Kestrels generally nest 6.1–7.6 m from the

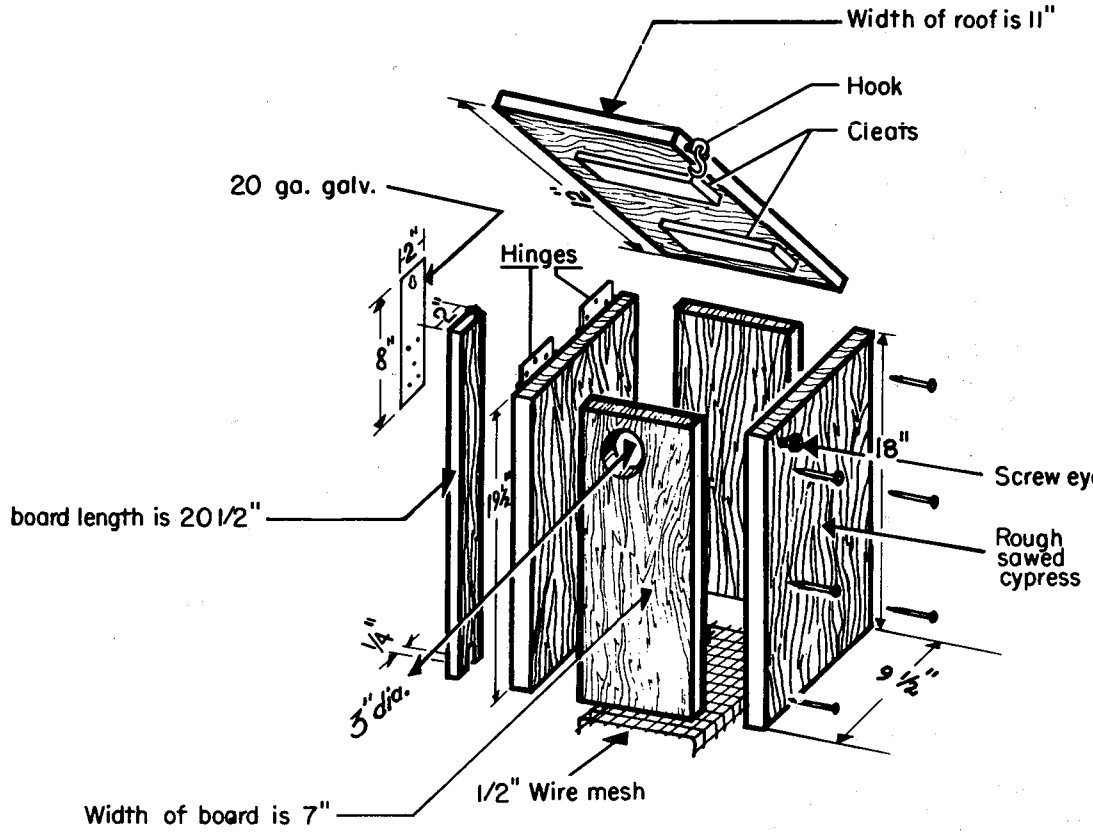


Fig. 20.8. Plan for wood nest box for tree squirrels (modified from Barkalow and Soots 1965).

ground and the nest usually faces south or east. They apparently prefer a clear flyway, so the space in front should be free of shrubs, limbs, or obstructions. Another favored site is old barns or buildings. Place 7.6 cm of coarse sawdust or wood chips in the bottom. This should be cleaned out and new material replaced annually following the nesting season.

Kestrel nest boxes have proven so successful and easy to install during the past decade, they are now located across the country in both Canada and the United States. This is another wildlife habitat improvement technique popular as a conservation project for youth and education groups.

MICE

Natural control of harmful insects is receiving increased emphasis to help offset massive chemical spray projects. H. R. Smith (1975) recommended the use of nest boxes to increase populations of deermice to prey upon larvae and pupae of the gypsy moth in young, even-aged hardwood stands. These nest boxes followed the design of Nicholson (1941) and were 12.7-cm cubes of 9.5-mm (3/8-inch) exterior plywood with a hinged lid and a 2.5-cm hole for an opening. Cotton bedding was supplied and replaced as it became fouled.

Platforms

WATERFOWL

Structures, such as illustrated in Figs. 20.12 and 20.13, have been constructed for the benefit of geese in the West (Saake 1968, Grieb 1970). Their value is especially great in areas where predation by feral dogs is a problem. Many construction variations may be employed; such as, 4 bales of hay instead of the tire, 1 stout pole instead of 4, and a large metal washtub instead of the wooden platform. The single pole specification is better than 4 steel posts in regions where ice movement is a problem.

Canada geese also will nest on floating nest structures constructed of a 20.3- × 55.9-cm canoe-like platform which supports a 48.3- × 66-cm nest box, an anchor, and an equalizer (Will and Crawford 1970). To give extra buoyancy to the platform, a sheet of Dyfoam 5.1 cm thick is encased with lumber. Splash shields are a necessity during high winds to keep the nest and eggs dry: 1 shield to the side of the nest box and an additional V-shaped shield to the bow of the platform. A dark-colored preservative should be applied to the nest box and box splash shield, not only to preserve the wood, but to camouflage the newly cut lumber. Prairie hay or coarse wood shavings should be packed tightly into the

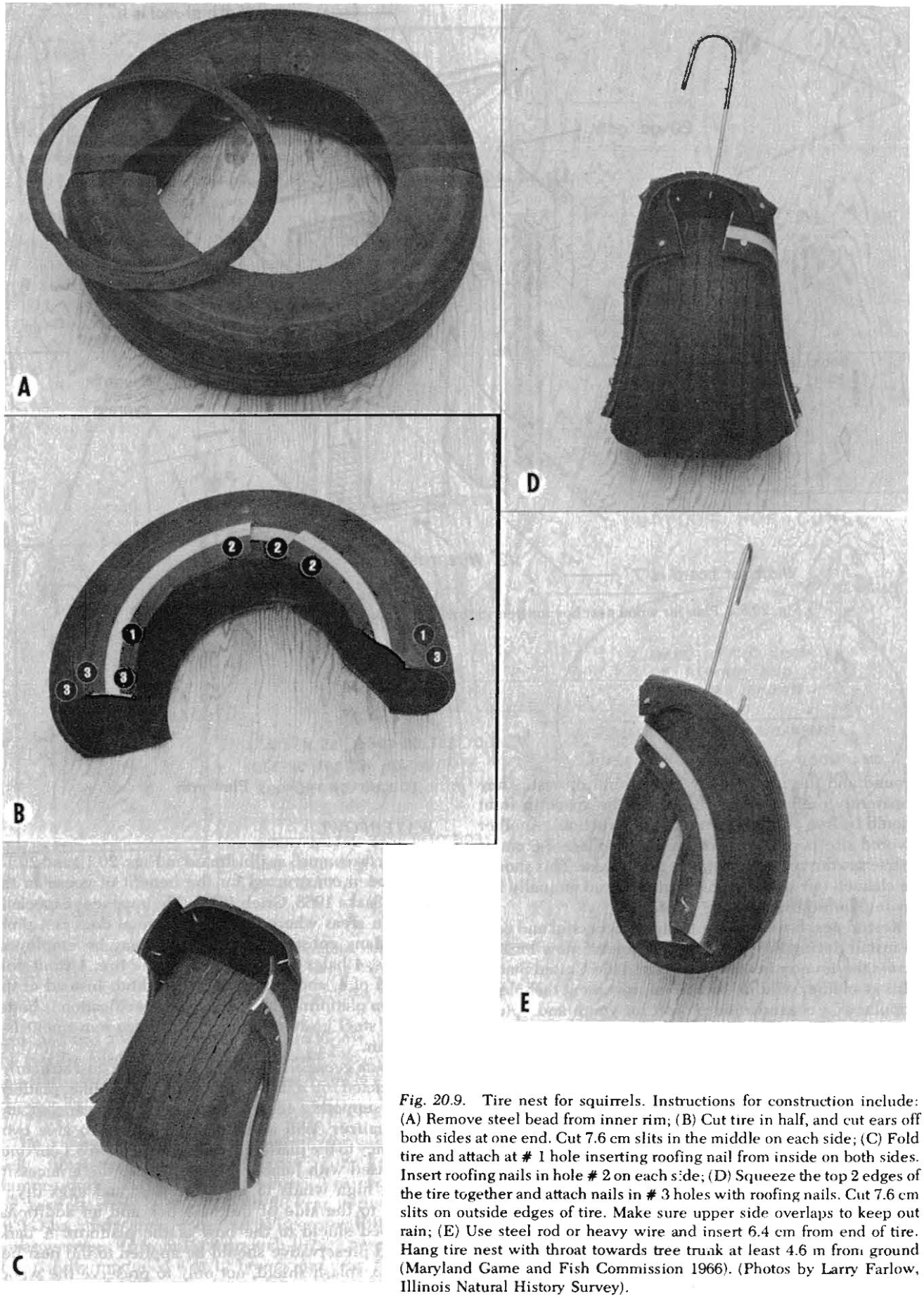
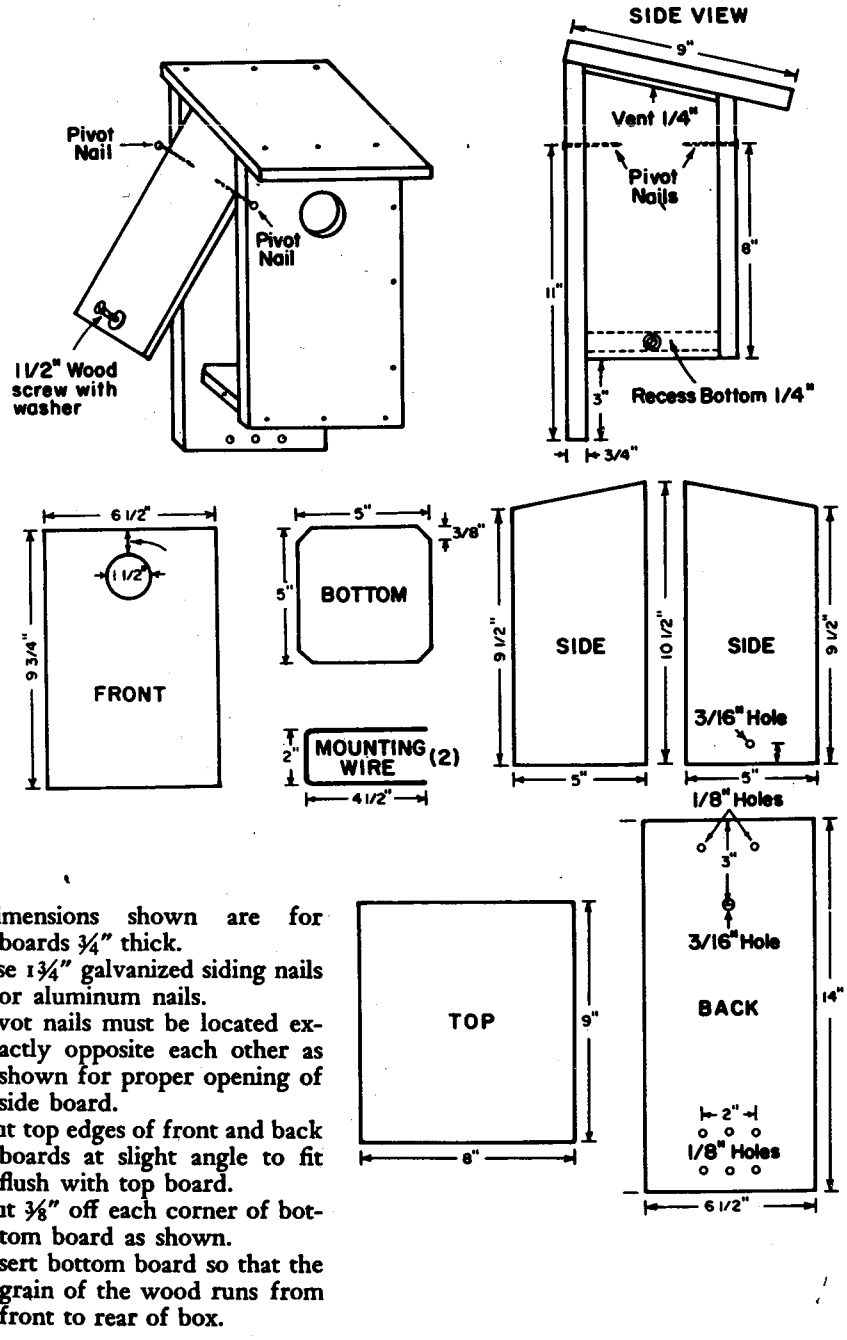


Fig. 20.9. Tire nest for squirrels. Instructions for construction include: (A) Remove steel bead from inner rim; (B) Cut tire in half, and cut ears off both sides at one end. Cut 7.6 cm slits in the middle on each side; (C) Fold tire and attach at # 1 hole inserting roofing nail from inside on both sides. Insert roofing nails in hole # 2 on each side; (D) Squeeze the top 2 edges of the tire together and attach nails in # 3 holes with roofing nails. Cut 7.6 cm slits on outside edges of tire. Make sure upper side overlaps to keep out rain; (E) Use steel rod or heavy wire and insert 6.4 cm from end of tire. Hang tire nest with throat towards tree trunk at least 4.6 m from ground (Maryland Game and Fish Commission 1966). (Photos by Larry Farlow, Illinois Natural History Survey).



Dimensions shown are for boards ¾" thick.
Use 1¾" galvanized siding nails or aluminum nails.
Pivot nails must be located exactly opposite each other as shown for proper opening of side board.
Cut top edges of front and back boards at slight angle to fit flush with top board.
Cut ⅜" off each corner of bottom board as shown.
Insert bottom board so that the grain of the wood runs from front to rear of box.

Fig. 20.10. Plans for a side-opening bluebird nest box (Zeleny 1976).

nest box to provide nesting material. The structures are easily stored by removing the nest box and splash shield.

In early experiments with floating structures, high winds dragged the anchor if it was attached directly to the floating structure. To prevent this, an equalizer was placed between the anchor and the structure, where it rode broadside against the wind. Structures anchored in this manner were not moved by winds exceeding 128 kph.

Forty-five kg of large rocks placed in a basket made from a 76.2- × 91.4-cm section of V-mesh wire laced together with galvanized wire has proved to be a satisfactory anchor. A new anchor was recently developed using heavy plastic bags obtained from the Ralston Purina Company, St. Louis, Missouri. Two bags, one inside the other, are large and durable enough to hold 49.9 kg of fine sand. Just before the anchor is dropped into the water, a number of small holes are punched into the bag to allow trapped air to escape.

For best acceptability, floating structures should be made available to Canada geese as soon as water areas are completely free from ice.

RAPTORS

Artificial nest structures for birds of prey is another example of habitat improvement practices which have greatly accelerated during the past decades. References documenting successes for various raptors include: eagles (Dunstan and Borth 1970, Olendorff and Stoddart 1974, Nelson and Nelson 1976, Postupalsky 1978); ospreys (Kahl 1972, Rhodes 1972, 1977, Postupalsky and Stackpole 1974, Postupalsky 1978); great gray owl (Nero et al. 1974); great horned owl (Scott 1970, Doty and Fritzell 1974); kestrels (Hamerstrom et al. 1973); ferruginous hawks (Olendorff and Kochert 1977); and prairie falcon (Brown 1976, Fyfe and Armbruster 1977, Olendorff and Kochert 1977, Postovit and Crawford 1978).

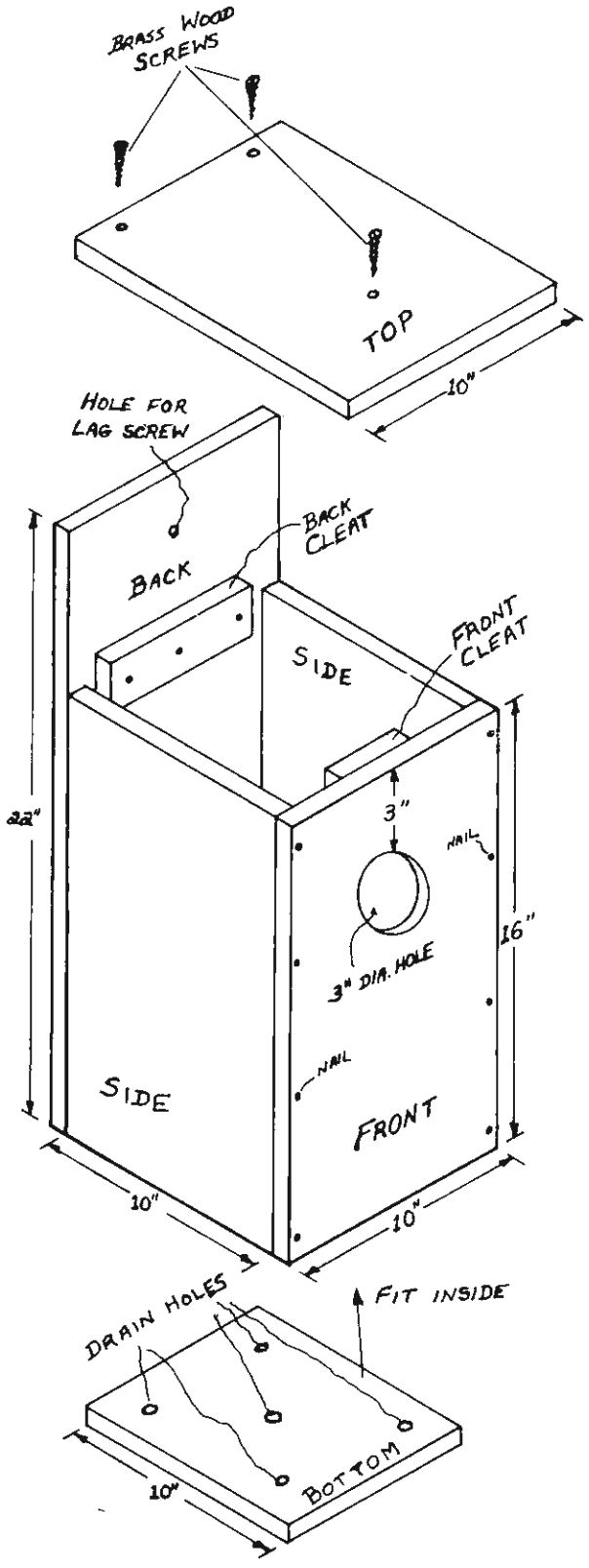


Fig. 20.11. Plans for a kestrel nest box.

Working in Colorado on the open grasslands, Olendorff and Stoddart (1974) found raptors using windmill structures as nest sites. They also noted that the absence of quality nest sites was a limiting factor to raptor density. Consequently they recommended the construction of artificial nest platforms (Fig. 20.14). A major objective is to build the artificial nest structure first and then immediately plant trees. Later when the trees mature, transfer the nest platform to the trees which results in a more natural nest location. Alterations of this basic design might include eliminating the shading device, placing the nest platform atop the pole, and constructing the fence only where cattle are grazed or when necessary to protect newly planted trees. Nest structures such as these can serve a number of birds of prey including eagles, osprey, ferruginous hawks, and great horned owls. They can also serve as perching or roosting sites.

Nelson and Nelson (1976) proposed a habitat improvement technique developed to accommodate eagle and other raptor nests on power lines. During 1973, 32 raptor nests were observed on a power line between Twin Falls, Idaho, and Hells Canyon, Oregon. These nests can be a problem to the power company when nest materials contact the wires and cause power outage. To remedy this problem, the platform was placed on the power pole chosen by the raptor (see Fig. 20.15). These nest platforms were designed to (1) provide shade for the young birds, (2) provide a large platform for nest construction, and (3) provide a base for the nest to reduce dangling sticks from contacting the wire. These power line platforms have been used successfully by golden eagles, ospreys, ferruginous hawks, red-tailed hawks, and ravens.

Ospreys near Eagle Lake in northeastern California have experienced major problems including the loss or deterioration of nest sites. State and federal agency personnel joined efforts and developed 2 techniques to improve nest sites, especially for these raptors (Kahl 1972). One practice required the topping of 15 large trees along the lake shores (Fig. 20.16). These trees ranged from 22.8 to 38.1 m in height and from 1.2- to 1.8-m dbh. To provide a good foundation for potential nests and reduce windstorm losses, 30.5-cm spikes were driven into the outer edges of the topped trees and a 61-cm-diameter platform was nailed on the topped tree. Osprey acceptance was especially good, and within a month a pair built their nest.

The second technique was to erect poles 7.6 m high and from 0.9-m to 1.5-m dbh near deteriorated snags used for nest sites. A 61-cm diameter nest box was nailed on top of each pole to anchor and protect it from windstorm damage. These structures were also readily accepted by the ospreys (Fig. 20.16).

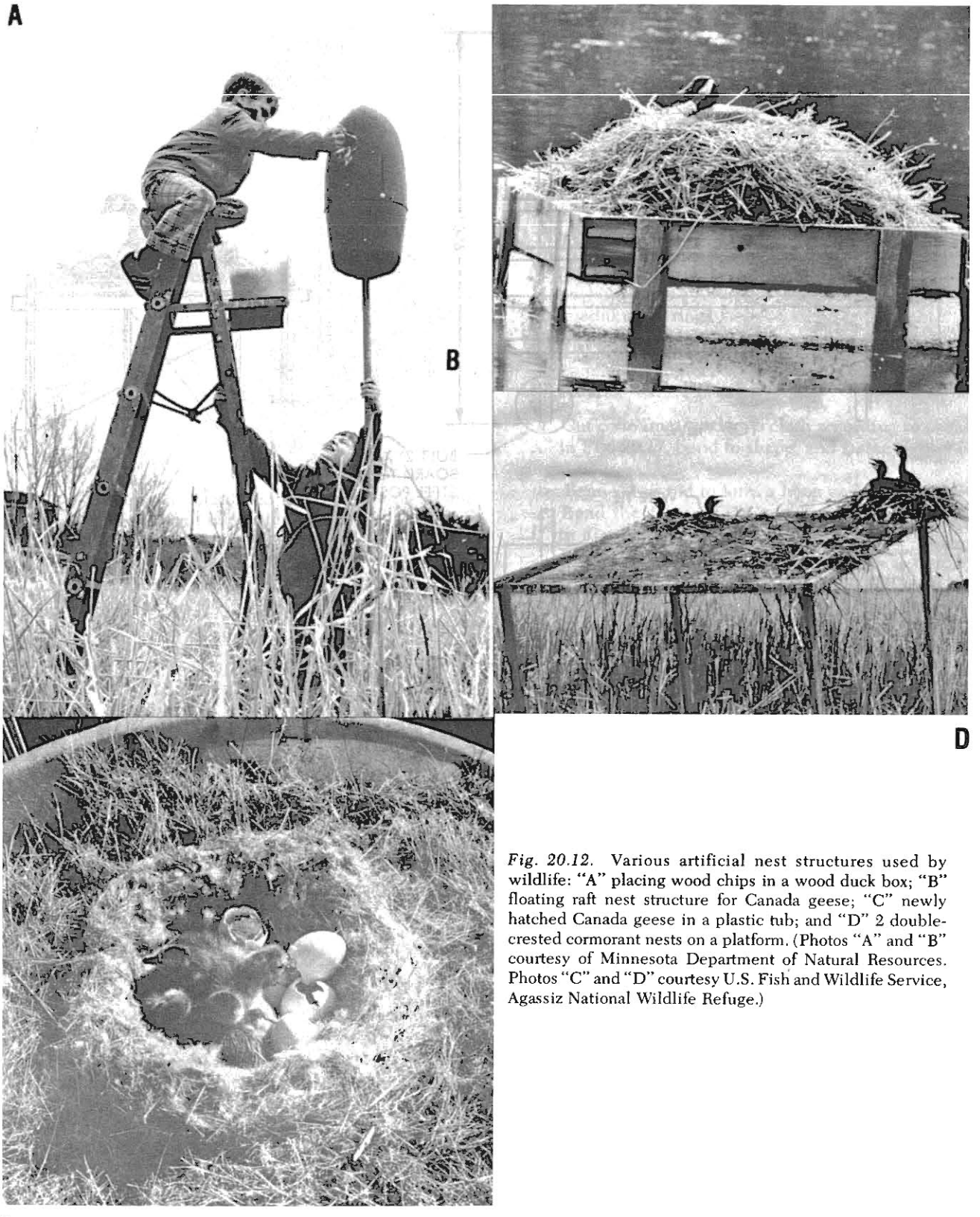


Fig. 20.12. Various artificial nest structures used by wildlife: "A" placing wood chips in a wood duck box; "B" floating raft nest structure for Canada geese; "C" newly hatched Canada geese in a plastic tub; and "D" 2 double-crested cormorant nests on a platform. (Photos "A" and "B" courtesy of Minnesota Department of Natural Resources. Photos "C" and "D" courtesy U.S. Fish and Wildlife Service, Agassiz National Wildlife Refuge.)

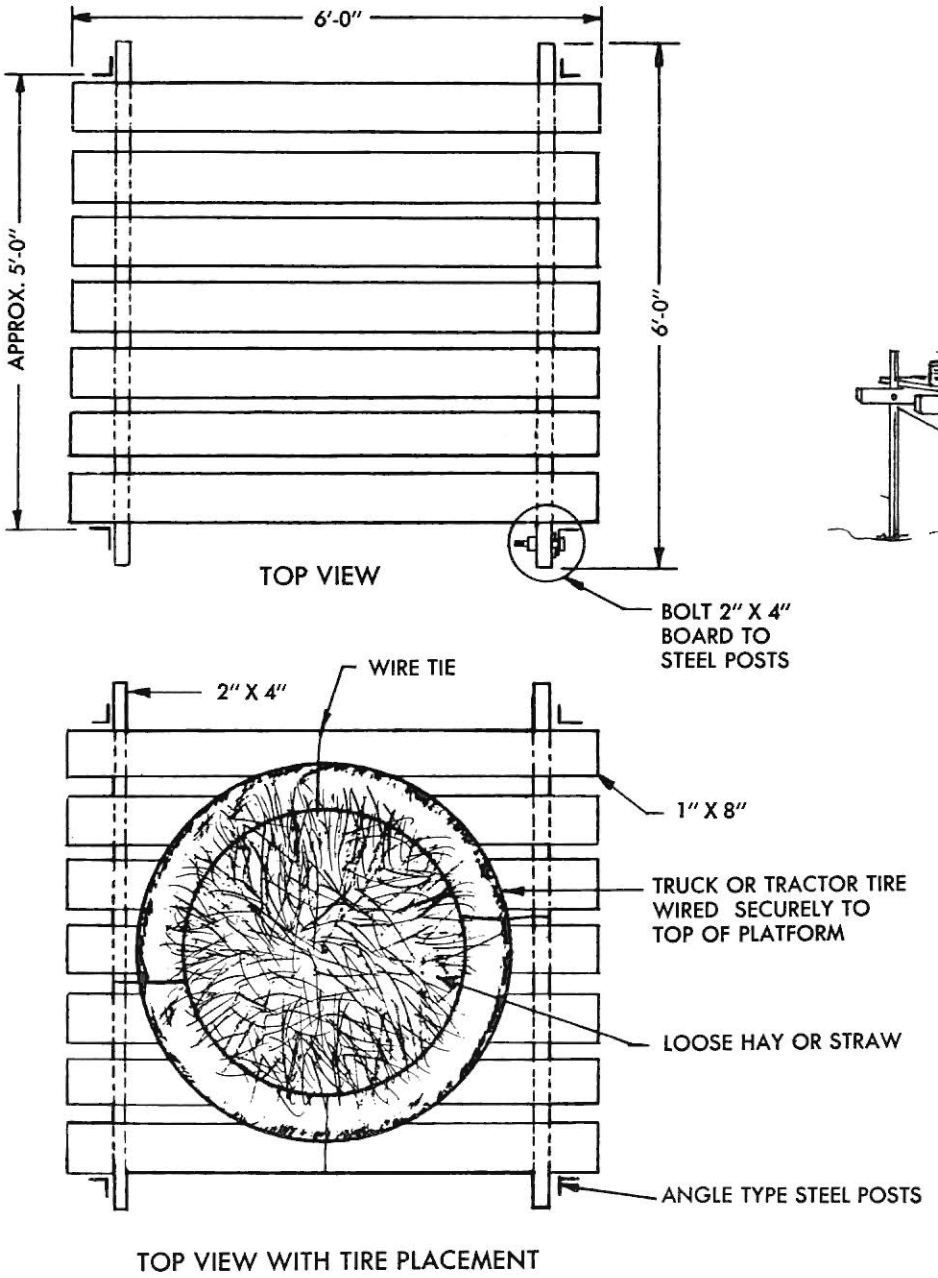


Fig. 20.13. Diagrammatic plans for constructing a goose nesting platform. (Nevada State Office, U.S. Bureau of Land Management.)

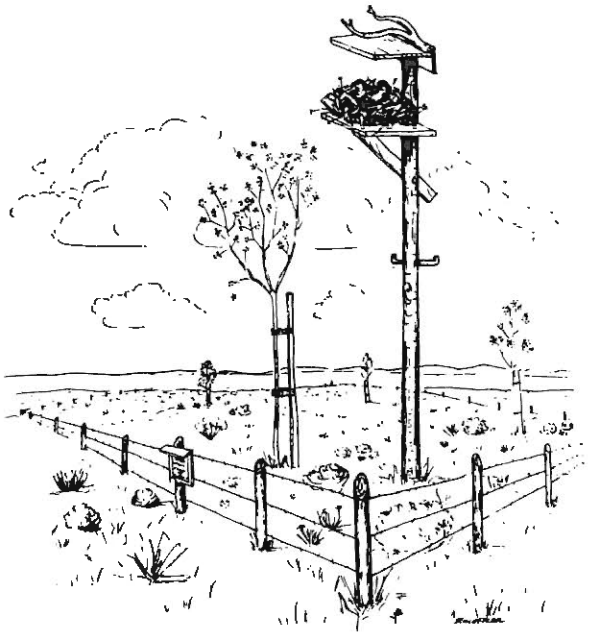


Fig. 20.14. Plans for an artificial nest structure for raptors (modified from Olendorff and Stoddart 1974).

WATERFOWL

The following specifications have been used in the construction of durable and economic nest baskets for use of waterfowl. Materials needed include:

4 black metal rods, 53.3 cm × 0.6 cm (¼ inch)
1 black metal rod, 2.1 m × 0.6 cm
1 sheet of 0.6-cm (¼-inch) hardware cloth, 91.4 cm × 91.4 cm
1 I.D. (inside diameter) galvanized pipe, 45.7 cm × 3.2 cm (1 ¼ inch)
1 machine bolt and nut, 9.5 mm (⅜ inch) × 2.54 cm
12 medium pig rings
1 I.D. galvanized pipe, 3.1 m × 2.54 cm

Recommended procedures for construction of nest baskets are:

a. Cut cone from hardware cloth according to pattern "A" in Fig. 20.17, bend to shape, and fasten with 4 pig rings.

b. Bend 2.1-m rod to form a hoop and weld.

c. Bend the 4 braces (53.3 cm) according to pattern "B" in Fig. 20.17.

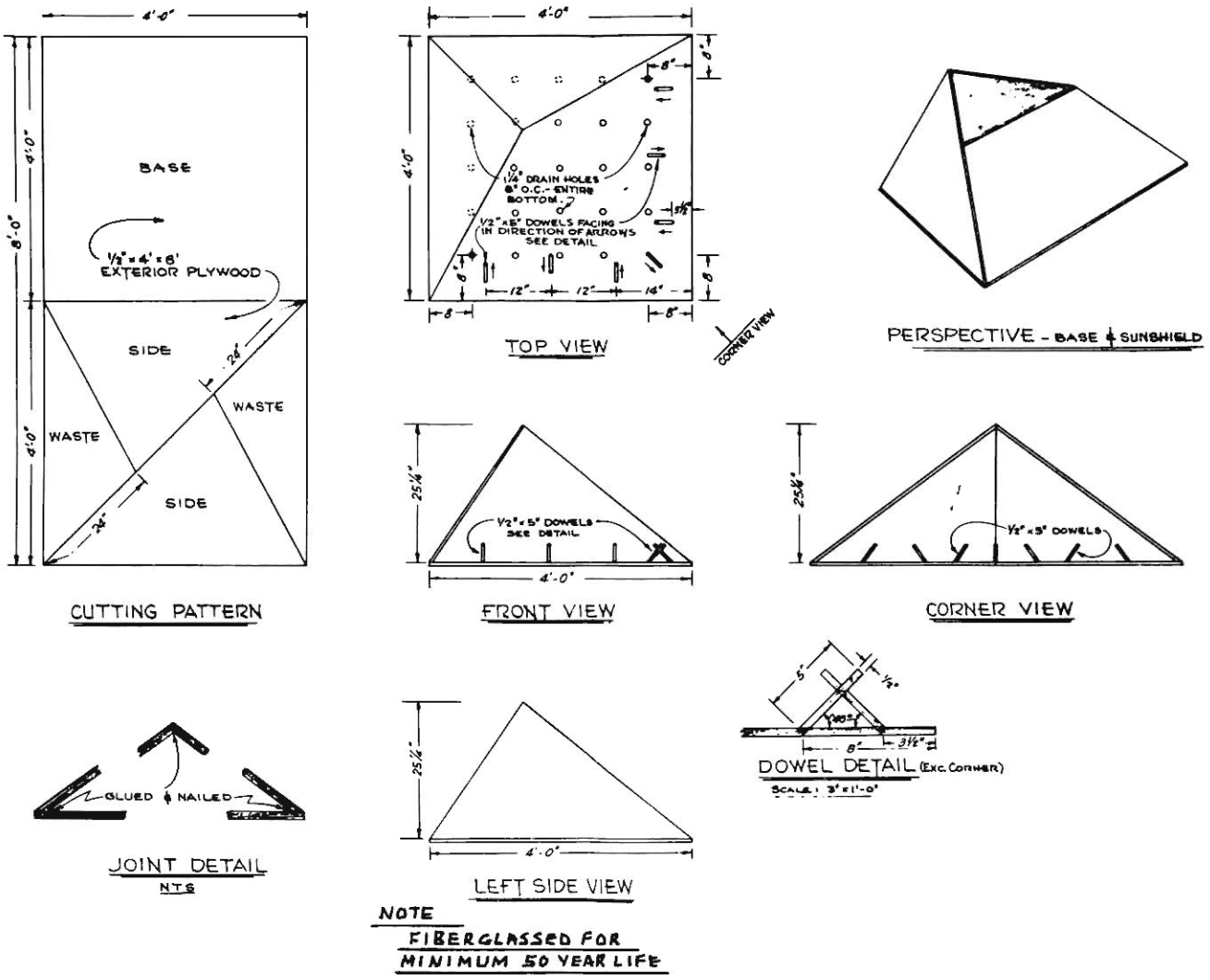
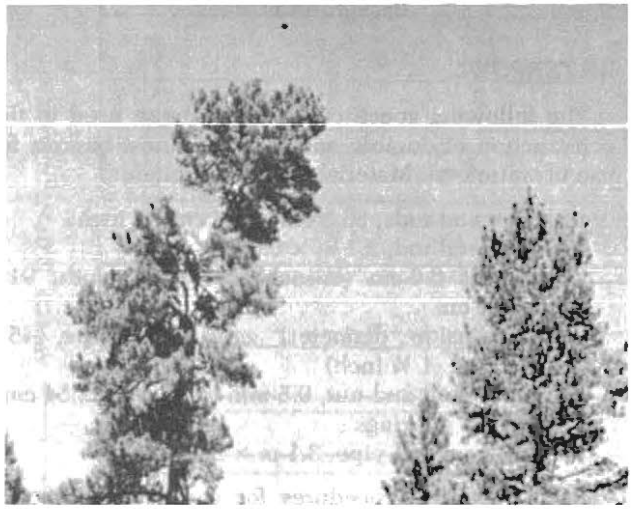


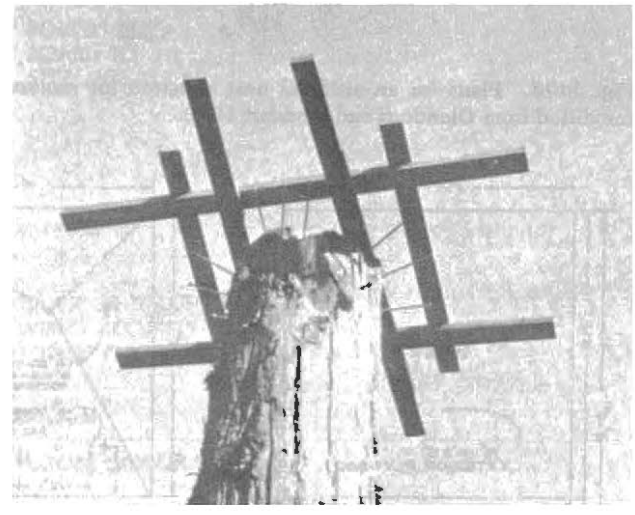
Fig. 20.15. Plans for a raptor nest platform for placement on power lines (Nelson and Nelson 1976).



A. Topping a pine tree.

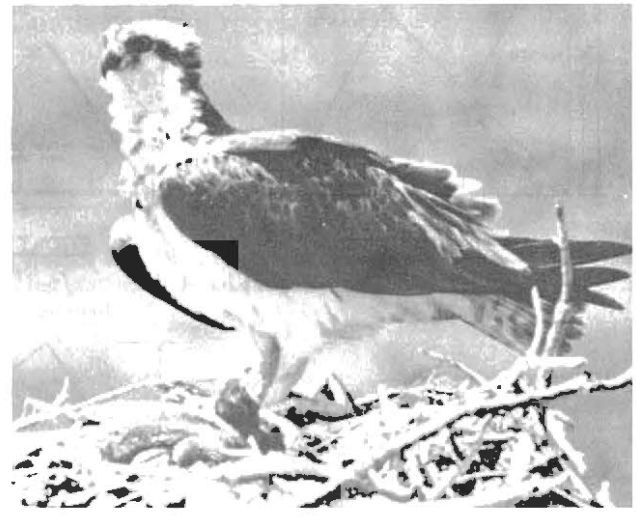
B. Topped tree ready for platform.

C. Erecting a cedar pole.



D. Platform placed on topped tree or cedar pole.

E. Cedar pole without nest placed by a deteriorating snag.



F. Adult osprey with chick.

Fig. 20.16. Constructing artificial platforms for osprey (after Kahl 1972).

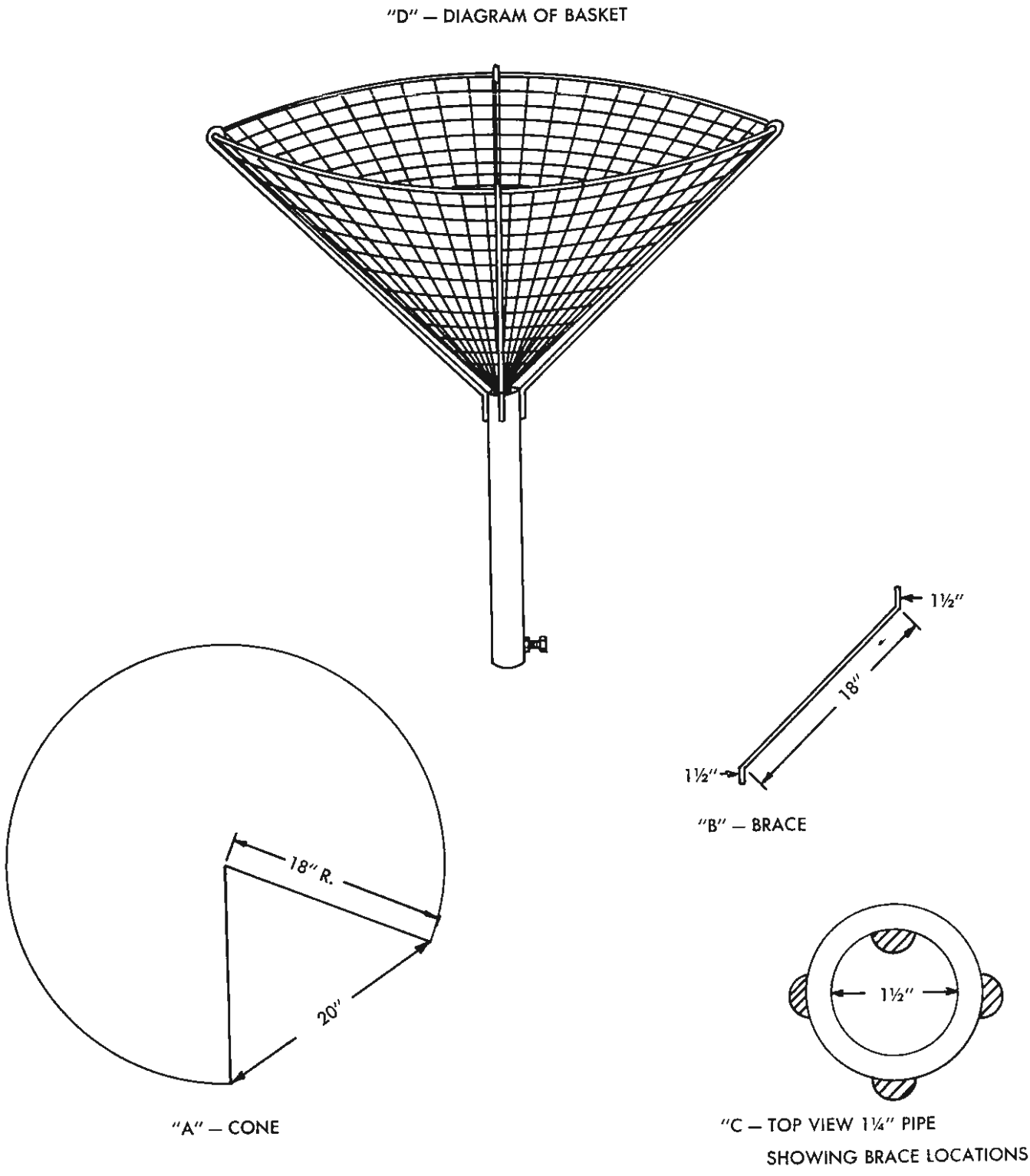


Fig. 20.17. Patterns for construction of waterfowl nest baskets.

1) Bend short hook in 1 end to fasten over hoop.
2) Bend other end of rod and place flat against pipe for welding.

d. Drill 1 hole, 11 mm (7/16 inch), in 3.2-cm (1 ¼-inch) I.D. pipe, 5.1 cm from end. This will be referred to as the bottom of the pipe.

e. Weld nut to pipe over hole and insert 9.5-mm (⅜-inch) machine bolt as set screw.

f. Weld braces to top end of 3.2-cm I.D. pipe according to pattern "C" in Fig. 20.17 (1 brace is welded inside to serve as a stopper in case the set screw loosens, allowing the basket to slip on the pipe stand).

g. Hook braces to hoop and weld in place.

h. Place hardware cloth cone inside of hoop according to the diagram of the basket. Attach to braces and hoop with pig rings.

i. Spray the hardware cloth with light brown or olive color paint to reduce reflection.

j. The constructed basket is attached to the 2.54-cm I.D. galvanized pipe at the time nesting structure is erected.

Procedures for placing nesting material in basket include the following:

a. Fill the baskets with a desirable nesting material prior to being erected. Suitable material may be flax straw, sedge, grass, or upland "wild" hay.

b. Place a large handful of nesting material in the bottom of the basket.

c. Line the inside of the basket with nesting material and secure it in place with stovepipe wire woven loosely through the straw and hardware cloth.

d. Completely fill the basket with loose nesting material, leaving a slight depression in the middle of the basket to simulate a nest.

e. Replenish the supply of nesting material as needed.

Care should be exercised to insure proper procedures for erecting the nest baskets. General guidelines to consider are:

a. Baskets should be erected in a minimum of 30.5 cm of water on a 2.54-cm I.D. galvanized pipe. Length of pipe will vary with type of soil. In many types of lake bottoms, it may be necessary to lengthen the stand-pipe by attaching it to a pole and push the pole further into the muck.

b. The rim of the basket should be 76.2 cm above the normal water level.

c. Baskets should be erected in sheltered areas to reduce damage from ice.

d. Baskets should be located as close as possible to emergent vegetation.

e. Baskets should be erected in diamond-shaped clusters of 4 with 1 cluster per 1.6 km of shoreline. Spacing of the nest baskets is shown in Fig. 20.18.

f. Baskets should be checked for ice damage immediately after spring breakup.

RAPTORS

Sykes and Chandler (1974) reported on use of artificial nest structures by Everglade kites. The structure consists of a shallow basket attached to a 1.5-m-long shaft of thin-walled metal tubing, 7.8 cm in diameter and open at the bottom end. The basket is similar in shape and construction as the structure used for waterfowl (above and Fig. 20.17) except this structure has a tubular outer ring, 1.27 cm in diameter, with 6 concentric and 15 radial strips, each 1.27 cm wide and riveted together,

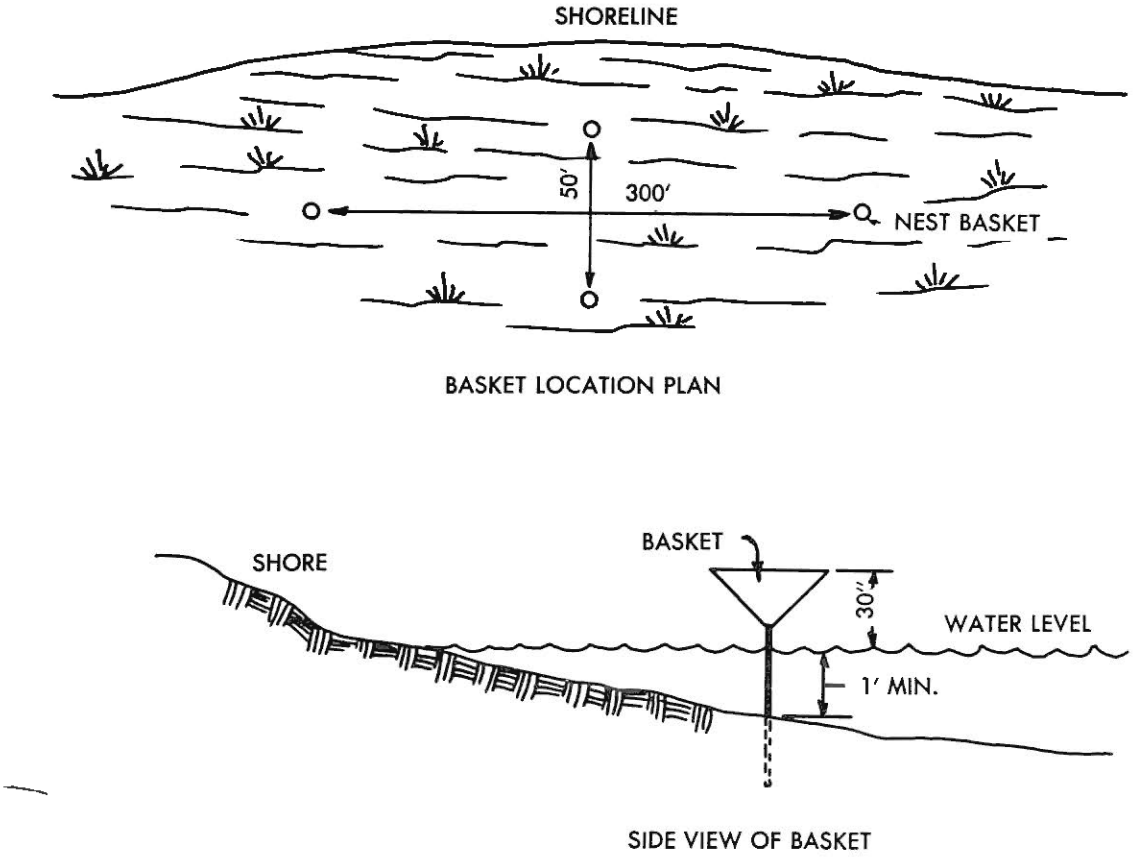


Fig. 20.18. Diagram of cluster placement of waterfowl nest baskets.

forming the nest. The basket measures 55.9-cm inside diameter and 7.6 cm in depth. It is supported on the bottom by 3 braces, which are woven into the basket and are attached by rivets to the main support tubing. Stainless steel, aluminum, or galvanized sheet metal all produce a reusable structure. Care should be taken to place the structure close to and at the same height above water as the existing nests. Young fledged in the artificial structures after eggs were transferred from natural nests to the artificial structures (Sykes and Chandler 1974). Perhaps egg transfer will not be necessary once a population adapts to artificial structures.

DOVES

Mourning doves generally build a loose, flimsy platform of twigs for a nest. Many are destroyed by heavy winds and rains. Artificial wire cone nest structures improve nestling survival (Cowan 1959). These wire cones are made of 6.4-mm (¼-inch) or 9.5-mm (⅜-inch) mesh hardware cloth. They are easy to construct and install (Fig. 20.19).

The best location usually is along limbs where branches are forked and where there is moderate shade. Most doves seem to prefer a height of 1.8 to 4.4 m above

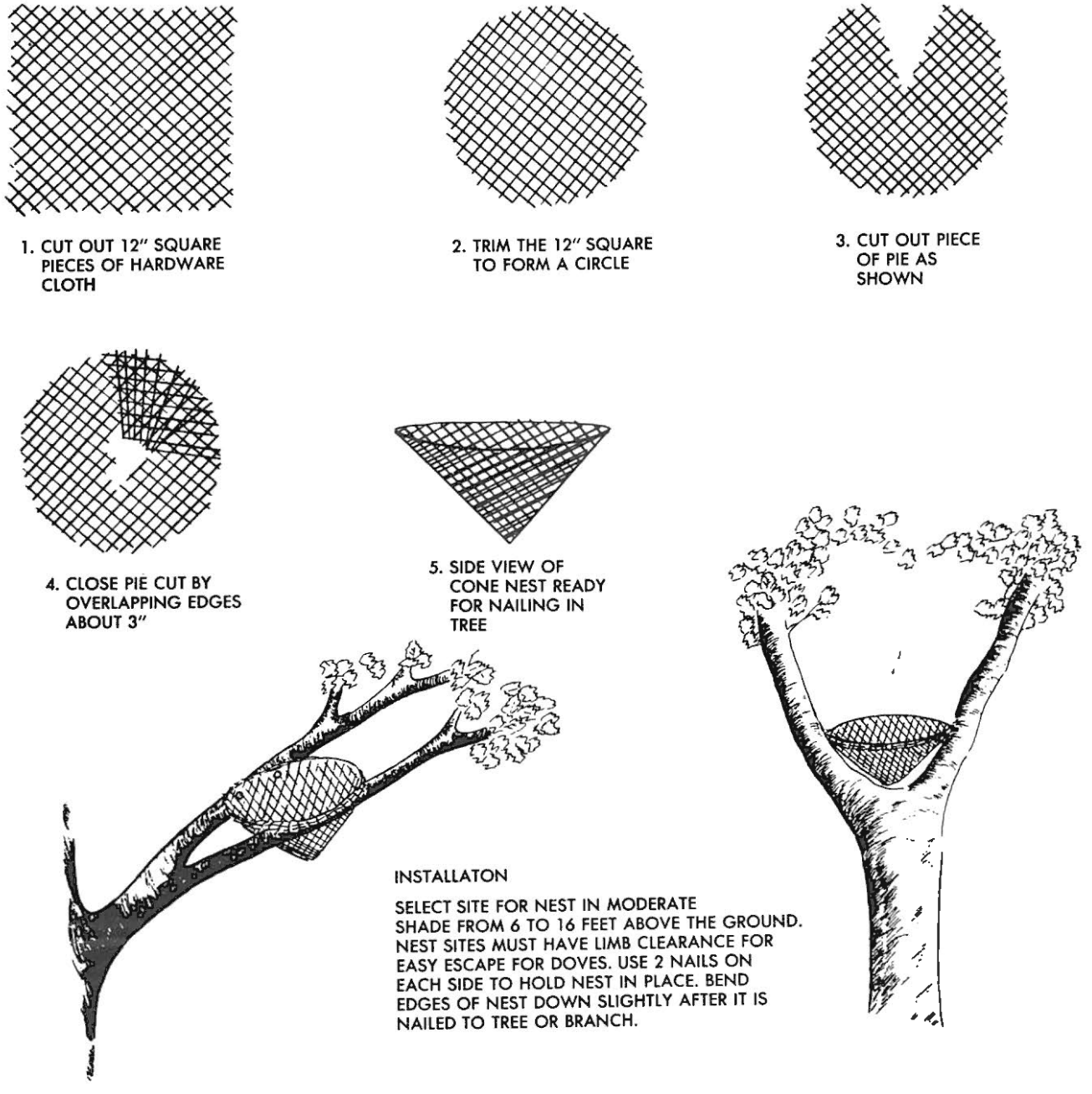


Fig. 20.19. Construction and installation of wire nest cones for mourning doves (Cowan 1959).

the ground for their nests. Sites must command good visibility and have enough clearance of brushy limb growth so the birds can escape danger easily. After the nest cone is properly secured, bend the outer rough edges down slightly to form a smooth place for the birds to alight. Best results in the Central Valley of California were obtained by installing the wire cones in late February, March, and April before most doves selected their nesting territories.

Periodic checks should be made to see that the wire cones remain securely fastened and that they are not obstructed by new branches. Clean out old nest material from the cones each year.

Burrows and Ledges

BURROWING OWLS

Burrowing owls appear to be declining throughout much of their historical range. Apparently there are 2 principle factors for this decline: (1) loss of burrow sites as a result of widespread burrowing mammal control, and (2) direct loss of habitat to urban, industrial and agriculture development (Zam 1974). To counteract this problem, Collins and Landry (1977) developed artificial burrows. The owls occupied 20 of 30 sites the first year of installation. The artificial nest chambers were 30.5 × 30.5 × 20.3 cm deep with a 10.2 × 10.2-cm tunnel connecting the chamber to the burrow entrance. The tunnel was approximately 1.8 m long with 1 right-angle turn about 1.2 m from the entrance. The sides and top of the nest chamber and tunnel were constructed of warp-resistant, exterior plywood with natural dirt base. Apparently the dimensions are not critical. One turn in the tunnel seems necessary to maintain the nest chamber in darkness. The artificial burrow should be buried 15.2 cm to provide thermal stability in the nest chamber (Collins and Landry 1977).

FALCONS

Working in the grassland prairies of Colorado, Fyfe and Armbruster (1977) found good populations of prey species but a lack of nest sites for prairie falcons. To create more nest locations, artificial sites were made by digging holes in cliffs and constructing ledges. Care was taken to select sites based on the following criteria: (a) site location near suitable habitat for prey species, (b) freedom from excessive human activity, (c) a minimum cliff face height of 7 m, (d) a relatively permanent or solid substrate of clay, conglomerate, or sandstone, and (e) freedom from excessive erosion, such as serious undercutting and slumping along river channels. Artificial nest holes or ledges had the minimum dimensions of 30 cm deep × 60 cm long × 30 cm high. Several methods of digging holes were used, including dynamite, but hand digging was the most efficient.

Prairie falcons readily accepted these new artificial sites. In 1970, 5 sites were completed and 4 were used that year. Since then, the Canadian Wildlife Service and the Saskatchewan Falconry Association have made over 200 similar artificial sites and one-fourth have been occupied.

WATER DEVELOPMENTS

The amount, availability, and presence of water throughout the year can be improved for purposes of increasing wildlife numbers or expanding the use of habitat. Water can be "removed" to reduce animal numbers and feeding in areas where they are undesired. Frequently water is developed for various other uses than specifically for wildlife. For one 11-year rangeland rehabilitation program in a 96- by 282-km area of southeastern Oregon, 1,600 water developments were completed primarily for the needs of domestic livestock (Heady and Bartolome 1977). When these uses are properly planned, water also can provide benefits to wildlife. Consequently, the habitat manager should be familiar with the various techniques for development of water including natural springs, seeps, and water holes; and man-made structures such as reservoirs, "guzzlers," and wells.

Water Holes

Water holes are open water storage basins, either natural or artificial. Water is such a basic requirement to wildlife in some areas that water holes are often the hub of wildlife activities; therefore, they should be designed and maintained to be usable for all species of wild animals.

Natural water holes are often found in playas and rocky areas where runoff waters are accumulated in a depression. At times such holes can be improved by deepening the catchment or by trenching runoff waters directly to the basin. In the Southwest, cement embankments have been added to large, flat rock surfaces, thereby channeling water to a nearby hole. Storage has been increased by raising the lowest level of the basin's edge.

Man-made structures can be adapted to provide water holes for wildlife. Examples are the side basins on pipelines as illustrated in Fig. 20.20. One such pipeline development in Nevada provided 3 new water holes along a 24-km stretch which formerly had no natural waters for chukar partridge (U.S. Bureau of Land Management 1964). Similar structures have been used in New Mexico (Bird 1977).

Springs and Seeps

No 2 springs are alike as to developmental needs; however, there are several different planning techniques that can be applied. Before a spring or seep is developed, the reliability and quantity of its flow should be checked. Generally, it is necessary to install a protective box to catch and store the water. Sometimes it is advisable to provide large capacity storage at sites where waterflow is intermittent so that stored water will be available after the spring or seep quits flowing. These waters should be dug out of firm ground, hardpan, or rock to obtain maximum flow. The source, whether one or several, should be conducted to a collection basin and thence piped to a trough. It is usually necessary and desirable to fence the water source and collection basin from human or livestock use.

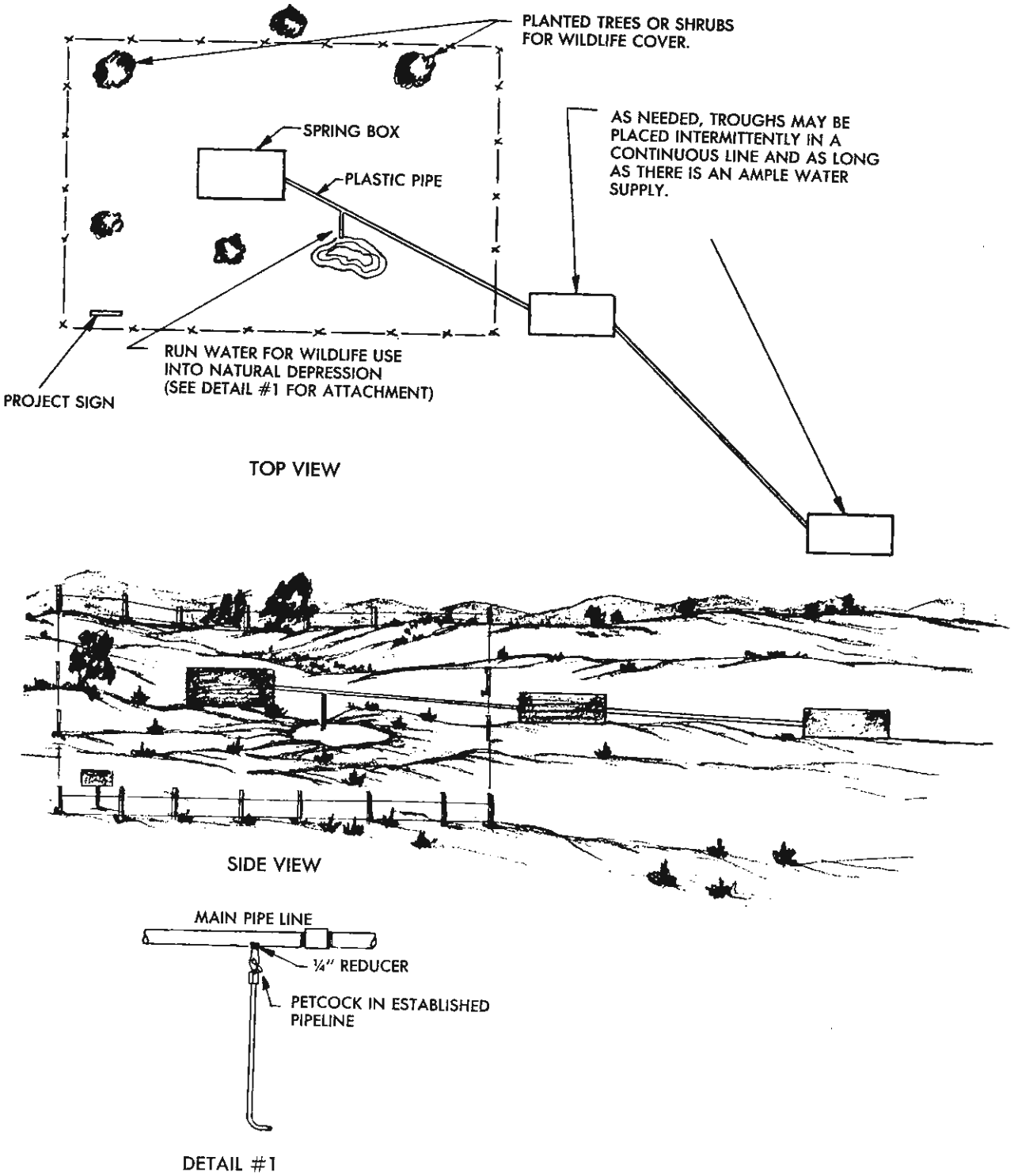


Fig. 20.20. Water developments for many uses can be modified for the benefit of wildlife. This drawing of a spring improvement for livestock in Nevada included a side basin installation for chukars. (Nevada State Office, U.S. Bureau of Land Management.)

In the central and western U.S., many springs are found in canyon bottoms and when developed often become a maintenance problem due to storm flood damage. Flood damage can be reduced for canyon bottom projects by burying a short length of perforated asphalt soil pipe in packed gravel at the water source from which the water is piped to a basin out of the canyon bottom. This technique allows storm water to flow over the buried source of spring water without damage to the development work (Weaver et al. 1959).

For wildlife water developments, plastic pipe is usually preferred to galvanized iron pipe since it is lighter and easier to transport and lay. 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.

The development of a spring is not just a simple matter of collecting a maximum flow of water and making it available. The development should be planned to achieve a purpose with a minimum of detrimental effects. Spring developments planned primarily for wildlife use, as well as those planned for other purposes, should do the following:

1. Provide at least 1 escape route to and from the water. Take advantage of the natural terrain and vegetation where possible.
2. Provide an alternate escape route where feasible.
3. Fence water developments from livestock. Fences can serve the purposes of preserving the water source and protecting food and cover needed for small species of wildlife. Protective fences should be negotiable by wildlife except where trampling or wallowing by big game will damage the spring source. Fence posts should be pointed to discourage perching by avian predators.
4. Provide safety from wildlife drowning by construction of gentle basin slopes or ramps in tanks (see Figs. 20.27, 28, 29.)
5. Maintain or provide adequate cover around the watering area, either by saving the natural cover or by plantings and brush piles.
6. Provide, where applicable, an information sign to inform the public as to the purpose of the development.
7. Provide water developments of sufficient capacity to supply water at all seasons of the year during which it is needed for wild animals.
8. Provide public access to water by piping it outside of fenced water developments. Where shy animals are involved, pipe water for human consumption some distance from wildlife water. For example, it is recommended that sustained camping be discouraged within 0.8-km radius of water used by desert bighorn sheep.

Many habitats in the Southwest have no form of permanent water. Such areas provide minimal use for bighorn sheep (McQuivey 1978) and other wildlife. Recognizing this limiting habitat component, the California and Nevada Wildlife Agencies have been working for years to improve intermittent springs and seeps. Sometimes these waters provide such low quantities that they are measured as "teaspoons" per hour compared to the more common measurement of "gallons" per hour. Often, seeps can be detected only by moist soil. Even with such little natural water, some of these seeps have been developed to fill a 18.9-l (5-gallon) or 37.8-l (10-gallon) container. Bighorns have been seen to wait their turn for such available drinking water (C. Hansen pers. comm.). Figure 20.21 illustrates desert bighorn sheep using a spring development.

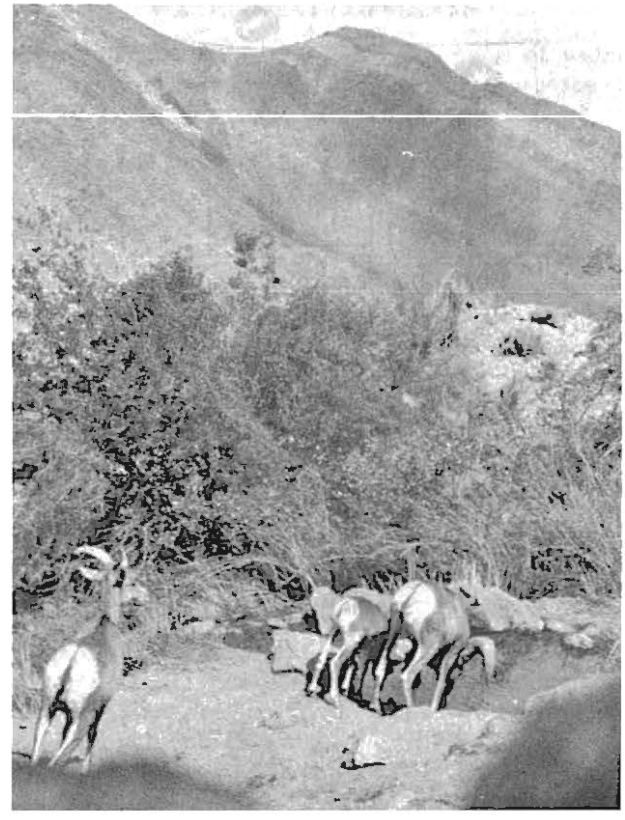


Fig. 20.21. **Desert bighorn sheep at a developed spring on the Desert National Game Range in Nevada. (U.S. Fish and Wildlife Service photo by O. Deming.)**

Reservoirs and Small Ponds

The term "reservoir" as used here refers to water impounded behind a dam. It may be formed by building a dam directly across a drainage or by enclosing a depression to one side of a drainage and constructing a diversion ditch into the resulting basin. Reservoirs should be designed to provide maximum storage with a minimum of surface area to reduce evaporation loss. The following are major points to consider in the selection of reservoir sites:

1. The most suitable soils for dams are clays with a fair proportion of sand and gravel (1 part clay to 2 or 3 parts grit). Soils with a high proportion of clay crack badly upon drying and are apt to slip when wet.
2. The watershed above the dam should be large enough to provide sufficient water to fill the reservoir, but not so large that excessive flows will damage the spillway or wash out the dam.
3. The most economical site is one along a natural drainage where the channel is narrow, relatively deep, and the bottom is easily made watertight. The channel grade immediately above the dam should be as flat as possible.
4. Wildlife should have easy access to the water.
5. The dam should be located, if possible, to take advantage of natural spillway sites. Otherwise, an adequate spillway must be incorporated into the development.

The dam site should be surveyed and staked prior to construction. If there is any question as to the suitability of material for dam construction, an examination should be made by a soil scientist. Trees and shrubs should be cleared from the dam site and flooded basin. The foundation area of the dam should be plowed or scarified in the direction of the main axis of the dam so there will be

a good bond between the foundation and the fill material. On sites where stability and permeability of the foundation material is questionable, a narrow core trench should be dug lengthwise to the dam, then refilled and packed with damp clay soil. Where suitable material is available above the dam, it should be obtained there so the borrow pit will become part of the reservoir and add depth to the impoundment. General specifications for the construction of dams should include these items:

1. The base thickness of the dam must be equal to or greater than 4½ times the height plus the crest thickness. The slopes of the dam should be 2½:1 on the upstream face and 2:1 on the downstream face.
2. Minimum width of the top of all dams should be 3.1 m.
3. The fill of the dam should be carried at least 10% higher than the required height to allow for settling.
4. Freeboard (depth from the top of the dam to the high-water mark when the spillway is carrying the estimated peak runoff) should not be less than 61 cm. The spillway should be designed to handle double the largest known volume of runoff and should be constructed at a level which will prevent the water from ever rising higher than within 61 cm of the top of the dam. A natural spillway is preferred. It should have a broad, relatively flat cross section, take the water out well above the fill, and re-enter the main channel some distance downstream from the fill. When a spillway is built, it should be wide, flat-bottomed, and protected from washing by riprapping (facing with rocks). The entrance should be wide and smooth and the grade of the spillway channel mild so the water will flow through without cutting (Hamilton and Jepson 1940).

New reservoirs usually do not hold water satisfactorily for several months. It may be necessary to spread bentonite over the bottom and sides of the basin and face of the dam to "seal" the impoundment so it will hold water. Samples of soil from the reservoir, the dam material, and the bentonite can be laboratory tested to determine how much bentonite should be applied. Another method of sealing reservoirs to prevent excessive loss of water is to line the basin with polyethylene (U.S. Bureau of Land Management 1966). After the basin has been made, it is covered with plastic sheets, then 15.2 to 20.3 cm of dirt rolled evenly over the plastic. Where there is the possibility of damage to the plastic by animals, 30.5 cm of soil must be placed over the liner.

While working in the Southwest, biologists for the U.S. Fish and Wildlife Service found that water-cut canyons offer suitable sites for small concrete dams and reservoirs to provide water for desert bighorn sheep (Halloran and Deming 1956). These small reservoirs were most effective where canyons narrowed down with steep, vertical sides of bedrock. Such arroyos make good construction sites, particularly on east or north facing drainages which provide protection from the sun and reduce evaporation. Dams should be firmly keyed into the bedrock on both sides and bottom. A pipe outlet should be incorporated into the dam. Water loss will be prevented if rock formations are checked from cracks and fissures. Rock sealing is, at times, an important phase of sound construction. Commercial sealers can be quickly applied to the dam after completion. Usually, such canyon dams should be under 12.2 m long and not over 3 or 3.7 m high. During the first several years after construction, the small ponds formed behind the dams will provide water for wildlife. After the reservoir becomes filled with gravel and sand washed in by rain floods, the water soaking into the gravel and sand is stored and protected from excessive evaporation. The stored water is piped through the dam to natural rock basins below or to cement troughs constructed away from the main water course (U.S. Bureau of Land Management 1964).

Small ponds can often be constructed quickly and efficiently for wildlife needs. Their small size and strategic distribution provide not only an animal's water requirements but add new diversity to habitats. One example is an area that was devoid of natural surface waters. Then an unsuccessful agricultural experiment left an uncapped artesian well. Wildlife managers channeled water from the well to a small excavated pond which now services over 155 different species of wild mammals, birds, fishes, and amphibians. It can be said that in this case, man created a new environmental niche which in turn provided a richer habitat for endemic wildlife.

Water Catchments

During the past 2 decades, there have been several types of self-filling watering devices designed for the use of wildlife. Probably the greatest numbers have been constructed for primary use by quail. However, many of these structures have been built specifically to benefit other wild animals, including antelope, bighorn sheep, deer, sage grouse, and turkeys. The California Department of Fish and Game (Glading 1947, Leopold 1977) constructed over 2,000 catchments for quail between 1943 and 1974. Since so many of these devices were installed for upland game birds (Galliformes) they have been referred to as "Gallinaceous Guzzlers" or recently, just "Guzzlers."

GUZZLERS

The guzzler is a permanent, self-filling water catchment similar to a cistern. The whole structure is so simple there is very little that can get out of order, and so a minimum of maintenance is required. Essentially, the guzzler installation consists of a watertight tank set in the ground which is filled by a rain-collecting apron. This apron collects rainwater and drains it into a tank where it is stored for use by wildlife. Where the device is intended for watering birds or small animals, they may enter the covered tank through an open end and walk down a sloping ramp to the water level. If the birds and other animals drink directly from the storage tank, all floating valves or other mechanical devices that are subject to failure are eliminated (see Fig. 20.22).

The most important step in the installation of a guzzler is locating an adequate site for its placement. A guzzler should not be placed in a wash or gully where it may collect silt or sand, or be damaged by flood waters.

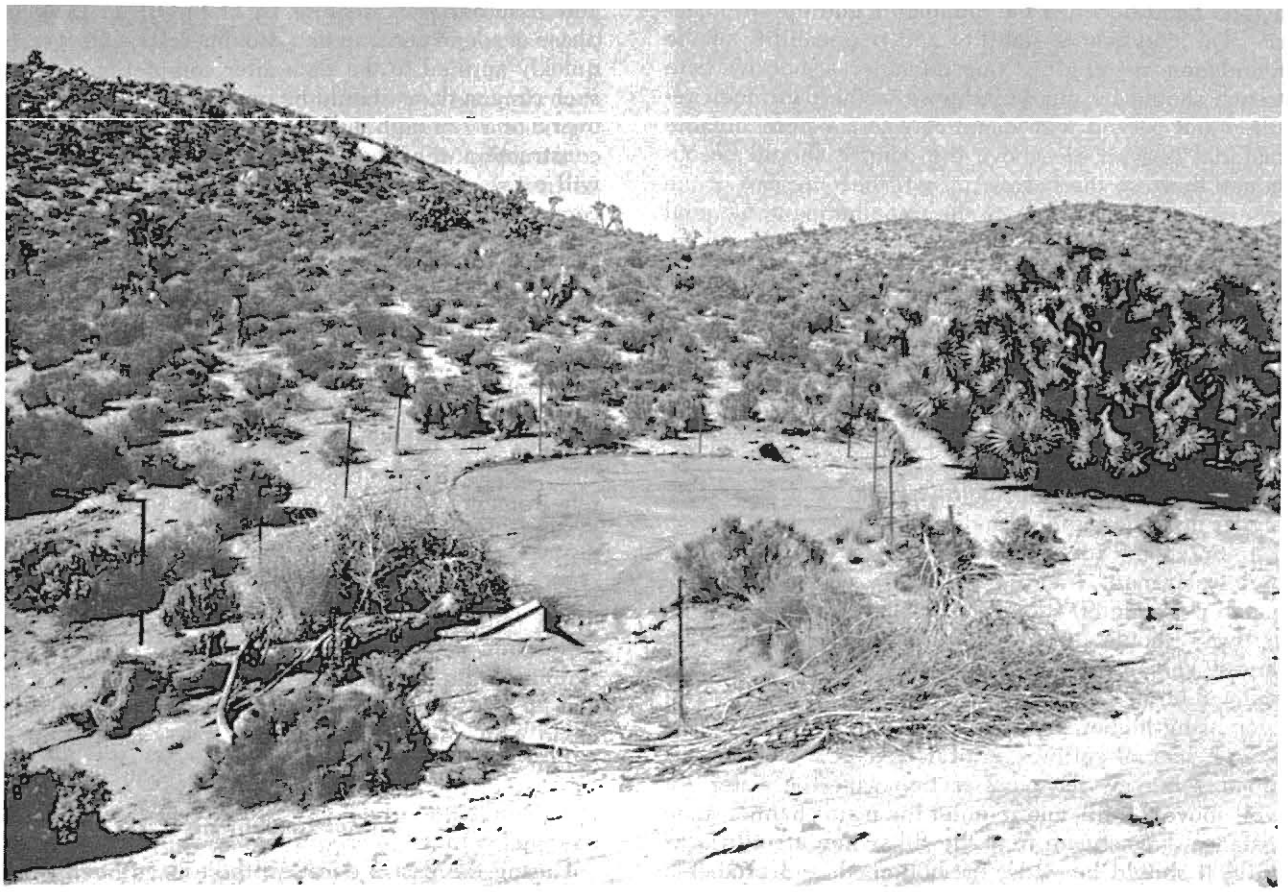


Fig. 20.22. Water catchments for small wildlife species have been constructed in the western states. They have been an important factor in increasing suitable habitat (U.S. Bureau of Land Management photo by Ed Smith).

The size of the water-collecting apron should be proportioned so that the cistern will need no water source other than rainfall to fill it. Since the cost of digging the hole for the cistern is one of the largest expenditures, a site should be chosen where digging is comparatively easy. The tank should be placed with its open end away from the prevailing wind and, if possible, facing in a northerly direction in order that a minimum of sunlight will enter the tank. Such placement will cut down the growth of algae, temperature of water, and evaporation.

The cisterns used for guzzlers usually are made of either concrete or plastic. Occasionally steel tanks are used. The plastic guzzler is a prefabricated tank constructed of fiber glass impregnated with a plastic resin. If the construction site is a long distance from a source of washed aggregate, or if labor costs are high, the plastic guzzlers offer savings in transportation and labor costs.

With concrete guzzlers, only washed gravel aggregates should be used for construction; otherwise the concrete may start to disintegrate after 5 or 10 years. Tanks made of steel are used for guzzlers in some areas and are reported as giving satisfactory service.

Collecting aprons have been made of many materials. Concrete sealed with bitumul, galvanized metal sheet roofing, glass mat and bitumul, rubber or plastic sheets, asphalt, and plywood have all been used successfully. From the standpoint of maintenance costs, however, durable materials such as concrete or metal have proven most satisfactory.

The size of the water collecting apron or surface needed to fill a guzzler will depend on the size of guzzler and the minimum annual rainfall that can be expected at the construction site. Actually, the size of the needed interception area will prove surprisingly small because nearly 100% of the rainfall is collected. Calculation of the potential yield of the rainfall collection surface can be determined by the following formula:

Surface area in square meters of apron × 9.9 = liters per cm of rainfall. It is important that calculations be made on the basis of the minimum of precipitation expected, rather than the average or maximum, to prevent guzzler failing during drought years. Table 20.3 gives the size of aprons in square feet needed to fill 2271 l, 2649.5 l, 3046.5 l tanks at different minimum rainfall rates.

General instructions for installation of a concrete guzzler are summarized as follows:

1. Select the site and clear the apron. Lay out the excavation site for the guzzler. To square the outline, measure diagonally from each rear corner to opposite front corner and adjust stakes until these distances are equal. Excavate the rear portion to required depth and slope ramp at front to ground level. Line excavation with laminated Kraft paper.

2. Assemble reusable plywood forms for inner walls and hang in position with 10.2-cm clearance between forms and walls and floor. Level the forms and pour

Table 20.3. Size of apron needed for 600, 700, and 900 gal "guzzlers."

Minimum Annual Rainfall (inches)	Square Feet of Collecting Surface Required			Apron Dimension in Feet Square			Circular		
	600g.	700g.	900g.	600g.	700g.	900g.	600g.	700g.	900g.
1	965	1,127	1,453	31	34	38	36	38	43
2	482	563	726	22	24	27	25	27	31
3	322	376	485	18	19	22	20	22	25
4	242	282	365	16	17	19	18	19	22
5	192	225	290	14	15	17	16	17	19
6	162	189	243	13	14	15	15	16	18
7	138	161	208	12	13	14	13	14	16
8	121	141	182	11	12	14	12	13	15
9	107	125	161	11	12	13	12	13	14
10	97	113	146	10	11	12	11	12	14
11	87	102	132	9	10	11	10	11	13
12	80	94	121	9	10	11	10	11	12

concrete between forms and walls of excavation. Tamp and vibrate walls. Pour enough concrete to complete floor and ramp. Trowel smooth, allowing 1.3-cm clearance between edge of form and ramp.

3. Remove wall from carriers, assemble reusable roof forms, place in position and cover with 3 thicknesses of Kraft paper. Place dishpan in position for manhole. Cover roof with 7.6 cm of concrete, place 7.6 cm of concrete inside the dishpan. Insert a loop of heavy wire or 0.6-cm reinforcing rod at center of manhole cover to serve as a handle. Provide a 15.2-cm curb at front end of guzzler roof. Pour a 7.6-cm skirt 0.9 m wide in front of guzzler ramp and provide a 15.2-cm trash wall.

4. Outline apron. Excavate a settling basin 45.7 cm in diameter and 20.3 cm deep in front of skirt. Cover entire apron and basin with Kraft paper and pour concrete 7.6 cm thick. Trowel smooth and provide a 15.2-cm trash wall around circumference of apron. Provide a hole of 7.6-cm diameter through trash wall for screened inlet to guzzler. Make holes for 1.3-cm-diameter iron coyote guard at 10.2-cm intervals across front of guzzler. Cover all fresh concrete with paper to ensure proper curing.

5. Allow to set for 24 hr, remove paper and forms, wash inside of guzzler with cement and water. Apply asphalt emulsion to apron. Install coyote guards. Cover roof with 25.4 cm of dirt to stabilize temperature within cistern. If domestic livestock graze the area, fence the entire guzzler against stock so there will be no chance of damage to apron, tank, or lid. When guzzler is constructed after the rainy season, it is best to fill it with water to aid in curing concrete and to develop bird or animal acceptance.

Although incorporating the same general principles as the concrete guzzler described above, the quail guzzler illustrated in Fig. 20.22 is dissimilar in many respects. This illustrates the flexibility and diversity of design that has been characteristic of guzzler development in various regions. The iron roof should have a gentle slope of around 5% for best performance and should be relatively smooth to prevent water from standing on surface. Runoff is caught at the bottom of the aprons and carried in pipes to the storage container.

In some localities the storage tank has been closed at all ends, or a storage bag is used, and the water piped by gravity flow to a small trough (Lauritizen and Thayer 1966). Here the flow is regulated by a float valve. Where such a valve is in use, a regular schedule of maintenance is needed to keep the valve functioning during the season when water is needed. Possibly the greatest value of this design facility is that it directly allows wildlife to use the water in the storage tank. This eliminates additional construction and maintenance costs experienced with additional items such as troughs and float valves.

Although most guzzlers have been constructed for game bird use, their values to big game were well analyzed by Roberts (1977). He researched the literature thoroughly to identify the needs and values for antelope, bighorn sheep, deer, and elk. Roberts' final comment was that water catchment devices for big game are a practical means of increasing wildlife habitat and distribution in arid areas.

Figure 20.23 portrays a guzzler adapted for bighorn sheep. Similar structures have been designed for and used by deer. The catchment provides for a precipitation collecting apron and underground storage tanks. From the storage tanks the water proceeds to a trough with a control valve. The project is designed to use water more efficiently through excess surface exposure causing high evaportation. However, it can require a higher maintenance frequency schedule and has a more limited use value for other species of wildlife.

The installation of precipitation catchment facilities on ranges lacking adequate water has been successful for pronghorns (June 1965, Sundstrom 1968). Figure 20.24 provides specifications for the catchment used. At first, a fence was constructed to control livestock use; however, this was later dismantled when its need was no longer justified. This construction type of catchment was installed in a variety of habitats and was used by deer, elk, sage grouse, doves, rabbits, ground squirrels,

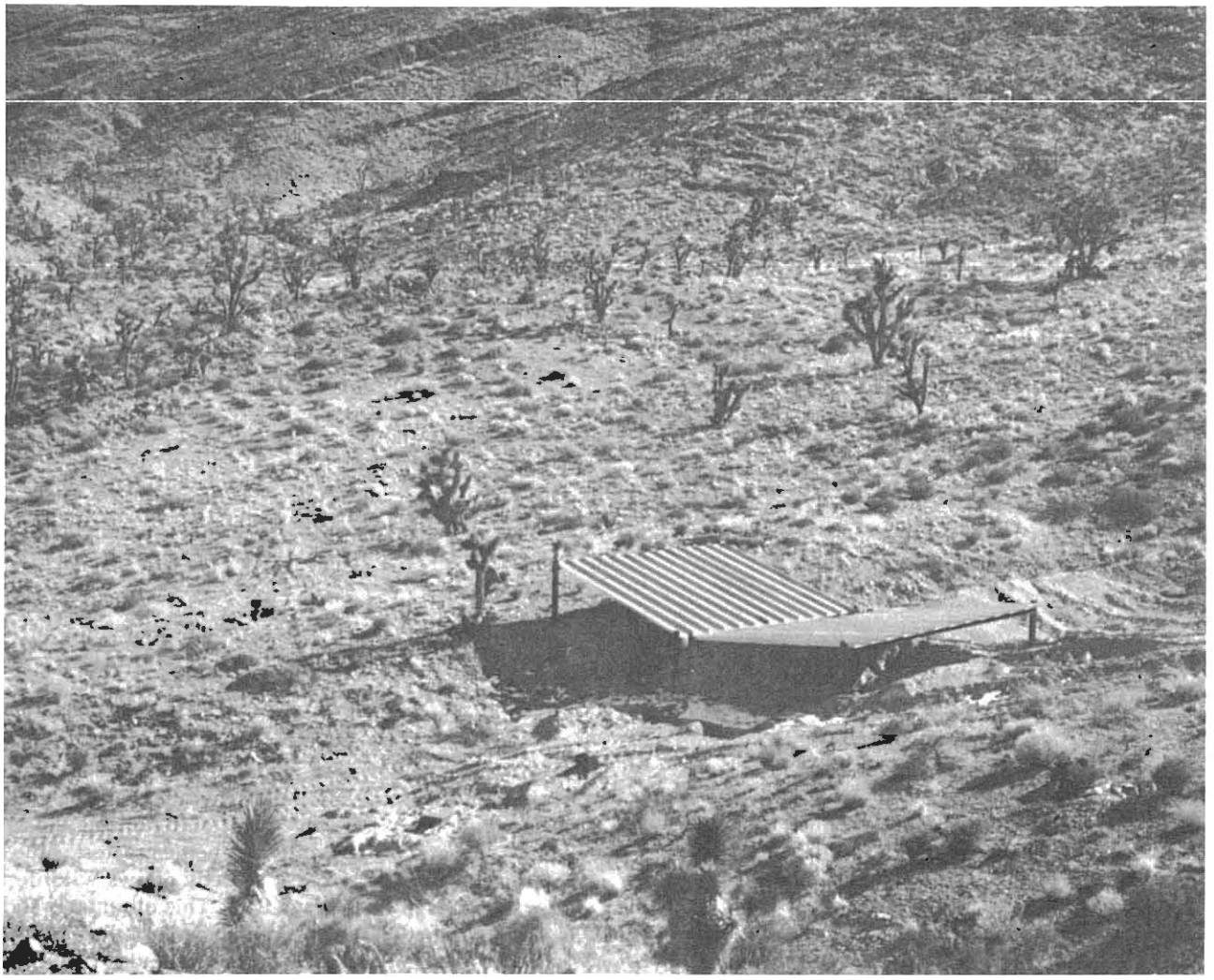


Fig. 20.23. A water catchment constructed in the Southwest on a critical summer range inhabited by desert bighorn sheep. (U.S. Bureau of Land Management photo by Jim Yoakum.)

and many other species of wildlife. Possibly its greatest value is that it provides ready access of water to a tremendous variety of wildlife. Not only was the water used for drinking, but it was used frequently for bathing by songbirds, thereby qualifying as a genuine multiple-use improvement!

DUGOUTS

As cattlemen moved into the West, they constructed large earthen catchment basins to collect water for livestock. These excavations were commonly called "dugouts" by early pioneers and "charcos" by early settlers along the Mexican border. Lately, government agencies have been constructing many of these charco pits on public lands. Deer and antelope frequently make use of such improvements and rely heavily upon their use during critical dry summer months. Bighorn sheep are not frequent users of these projects but do benefit occasionally during seasonal movements to and from their ranges in rocky, mountainous terrain.

Dugouts may be located in almost any type of topography. They are, however, most satisfactory and commonly used in areas of comparatively flat but well-drained terrain. Flat slopes facilitate maximum storage with minimum excavation. A natural pothole or intermittent lake bed is often a good location for a dugout. Dugouts should not be located in wet or muddy areas because of the difficulty for large animals to get to the water.

Fig. 20.25 shows a small rectangular dugout with specifications. For larger dugouts the length, width, or depth may be increased, but the side slopes should be about the same. All sides should be sloped sufficiently to prevent sloughing (usually 2:1 or flatter) and 1 or more relatively flat side slopes (4:1 or flatter) should be provided for livestock or big game entrances (U.S. Bureau of Land Management 1964).

Modified Water Developments and Safety Devices

The habitat manager may construct water developments, such as tanks, troughs, or wells strictly for the

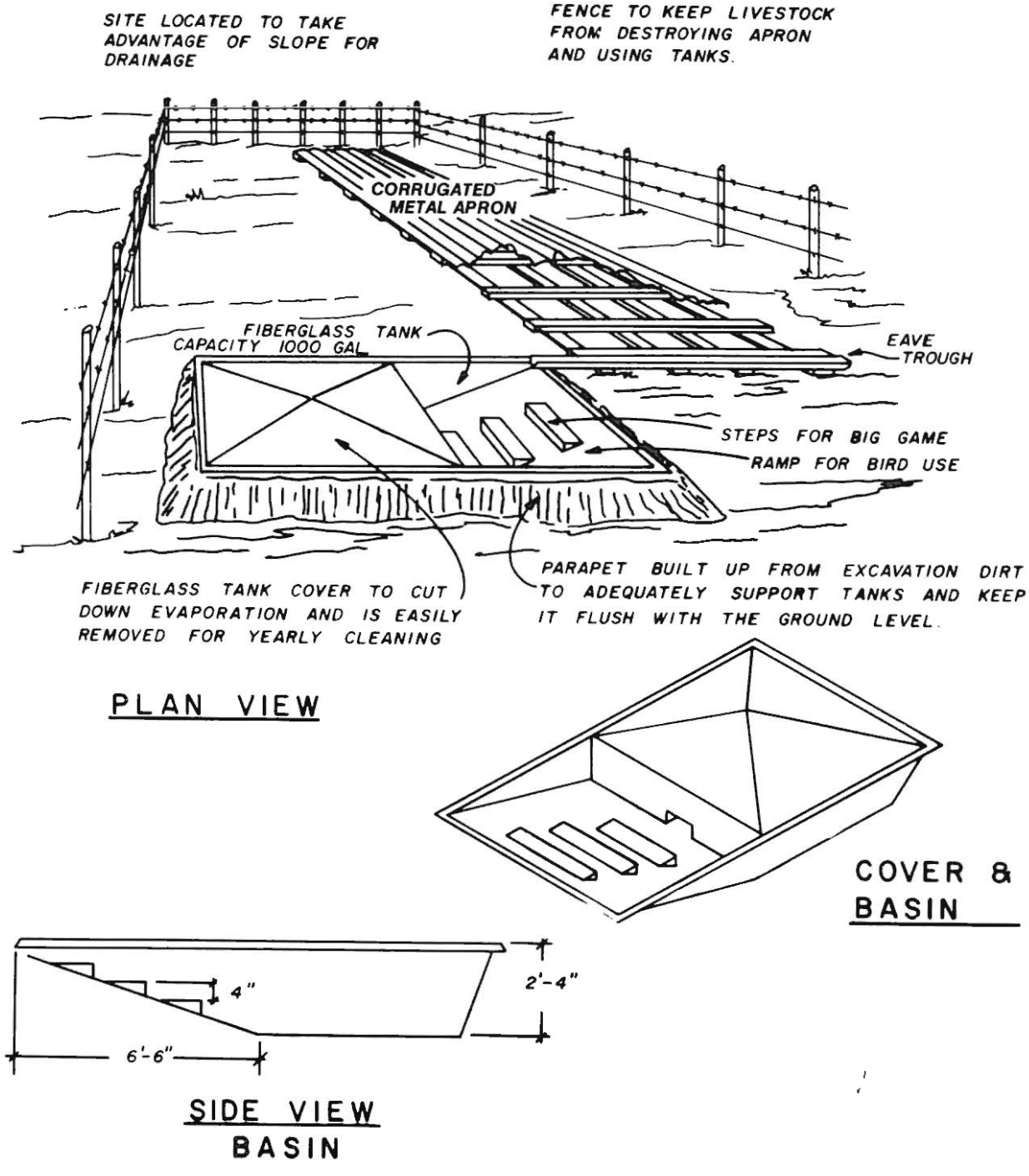


Fig. 20.24. A water catchment designed for antelope use on the Red Desert of Wyoming (adapted from June 1965).

benefit of wildlife. More commonly, water developments will be constructed for other purposes, i.e., for livestock, campground water storage, and fire suppression. Often a slight modification or addition to such developments can be made that will make water available to wildlife. Managers desiring additional information on specifications, plans and construction details for water improvements will find the following sources of value: *Range Improvement Standards Handbook* (U.S. Forest Service 1960), *Engineering Handbook and Construction Manual* (U.S. Bureau of Land Management 1967), and Vallentine's (1971) book: *Range Development and Improvement.*

Where water is scarce in dry environs, wildlife often readily seek and use man-made water improvements. Some of these are designed without proper considerations for wildlife use and, consequently, can become a problem by entrapment and drowning. This is especially true for young animals. The hazard of drowning can be reduced by floats, ramps, or ladders that allow avenues of escape. The best design will incorporate such escape facilities as a part of the improvement.

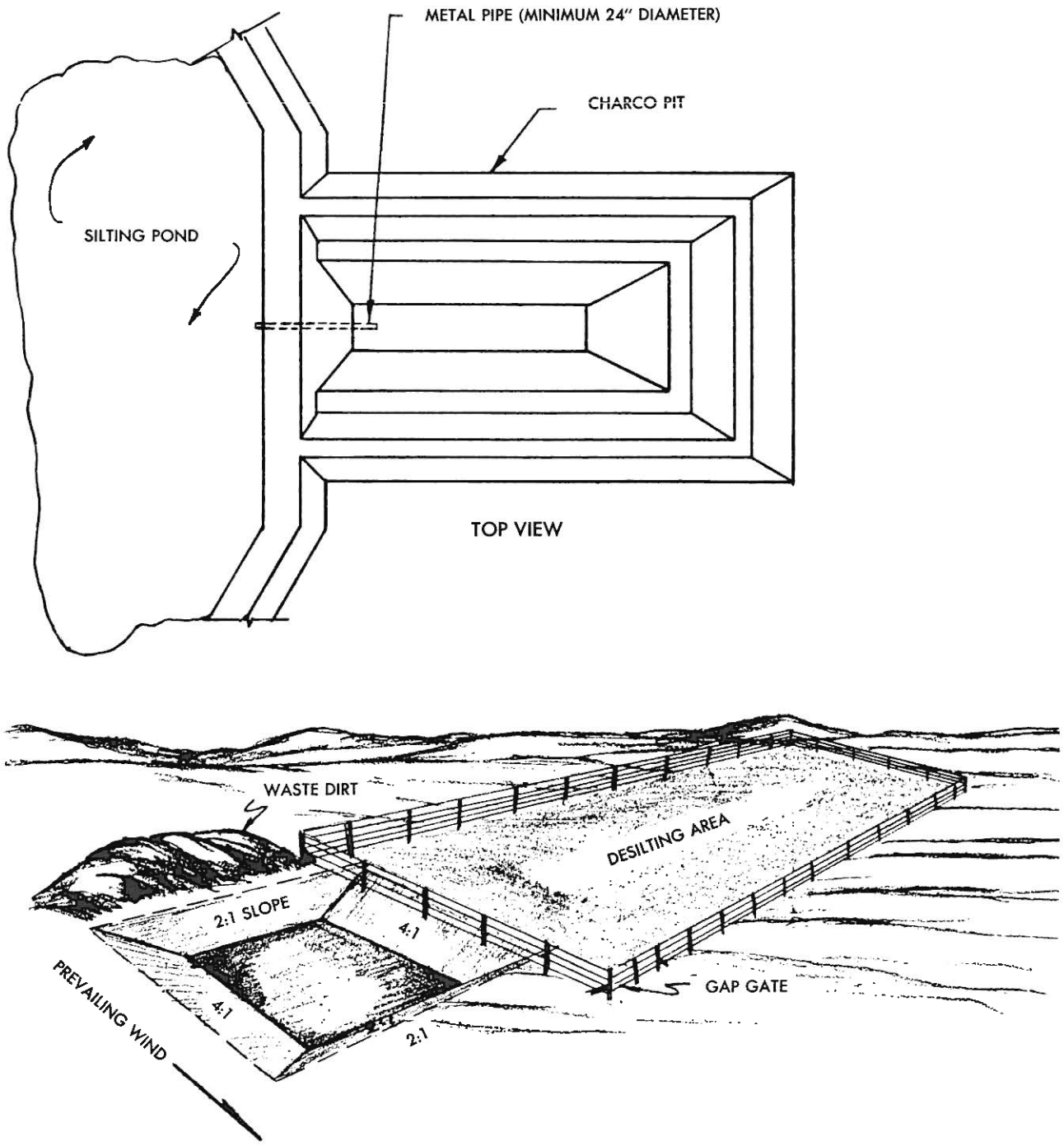


Fig. 20.25. Schematic sketch of a "dugout" or charco pit used in the west for providing water on the ranges for livestock and wildlife. Nevada State Office, U.S. Bureau of Land Management.)

Where this has not been done, it becomes necessary to improvise. Any float, ramp, or ladder placed in a water development should be relatively maintenance free and designed so that it neither interferes with nor can be damaged by livestock. Wilson and Hannans (1977) surveyed the subject of water development for livestock and listed the following guidelines:

1. Rarely are livestock water developments located in areas where terrain and cover conditions promote maximum utilization by wildlife; therefore, separate watering facilities for wildlife should be provided in association with the livestock development.

2. Fencing the wildlife water facility in a manner allowing wildlife use, but excluding livestock, is nearly always necessary to preserve water quality and insure growth of protective cover.

3. Water should be available in all water developments at all times, except in those areas where freezing during the winter could result in damage to the project.

4. Wherever ground-level wildlife drinking facilities are not provided in association with other water developments, the height of livestock troughs or other containers must not exceed 50.8 cm (Fig. 20.26).

5. Consider installing safety barricades in all livestock watering developments to prevent accidental entry and possible drowning (Fig. 20.27).

6. Consider installation of concrete blocks and/or rocks to form escape ramps on all livestock water developments where water depth exceeds 50.8 cm (Fig. 20.27).

7. When the lip of water troughs prohibits small wildlife from the water, construct wildlife ladders which allow the animals access. These ladders can be constructed of expanded metal or rebar and hardware cloth and should be protected by posts or protective fencing (Fig. 20.28).

8. An alternate method of providing small animal access to the water from outside the trough is to construct concrete ramps or rock ramps topped with cement (Fig. 20.28).

9. Large troughs posing survival problems inside the facility need escape ladders. These escape ladders must be constructed to intercept the line of travel around the edge of the tank. They should be attached to the structure by a hinge or bracket. Wildlife escape ladders should have a minimum slope of 30 degrees, but the incline should not exceed 45 degrees. A minimum of 1 ladder should be installed per 9.14 linear m of trough perimeter (Fig. 20.29).

In many livestock rangelands, large open water storage tanks are used which are out of reach for many species of wildlife (except birds and bats). For these developments, a floating wildlife platform should be installed. Figures. 20.30 and 20.31 provide examples of floating ramps.

WETLAND IMPROVEMENTS

Development of Water Areas

Techniques for improving wetlands will vary and are dependent to a large degree on the prior structural development of the area, water quality, water level management, soil, climate, topography, and plant succession. Sometimes wetlands can be manipulated by use of biological and physical forces to develop an improved environment for wildlife.

A biological need should be established before any plans for wetland improvements are made. The chief use or uses of the area should be the prime consideration in judging its potential development, although these uses are also largely determined by the location of the area and physical characteristics. Some areas may best be developed primarily for waterfowl, others for muskrat or other fur production. There will be other areas where these 2 features can be combined. The habitat manager can often use various practices to create interspersion of open water with marshland, interlace ditches and high spoil lands, plant vegetation for food and cover, and thereby create wetlands favorable to ducks and geese, beaver, muskrats, mink and warmwater fishes. For the habitat manager seriously concerned with techniques of preserving, managing, or manipulating wetlands, we recommend the *Techniques Handbook of Waterfowl Habitat Development and Management* published by the Atlantic Waterfowl Council (1972). A sizable portion of this book is devoted to making preliminary evaluations prior to development in order to establish need. There are also sections on improvement techniques, many of which are incorporated in this Chapter.

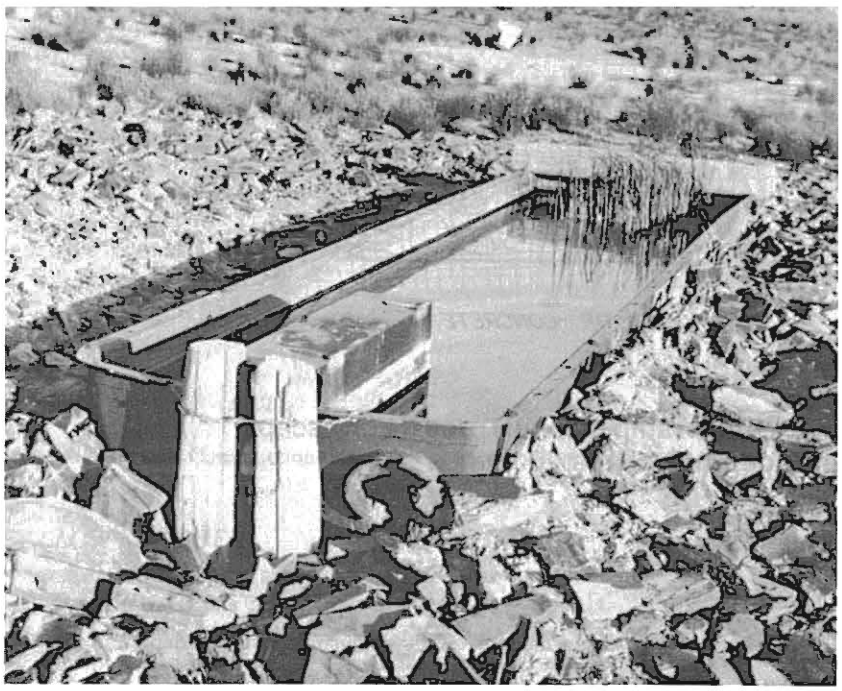
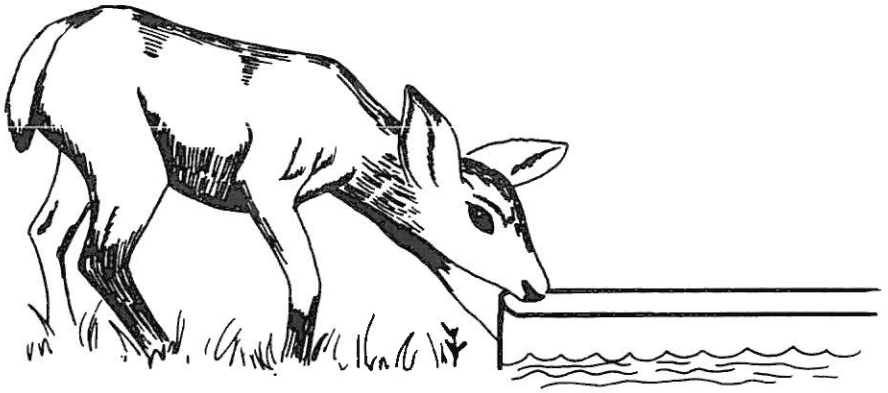
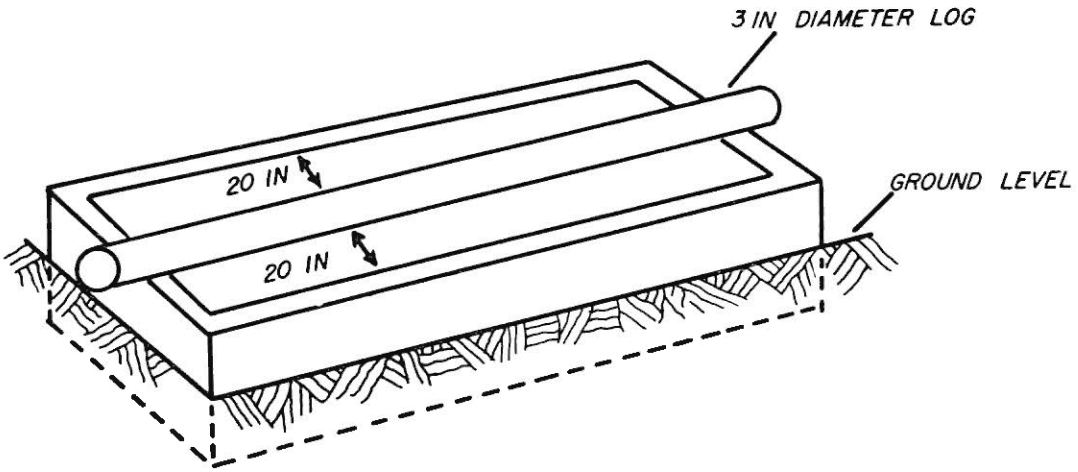


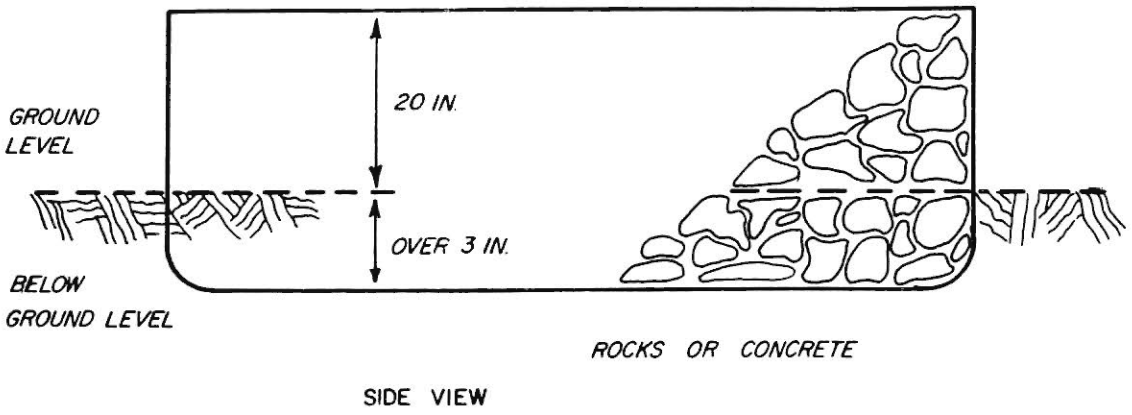
Fig. 20.26. A water trough financed for livestock use; however, a wildlife habitat manager added the following specifications for wildlife requirements: (1) that the trough be placed low to the ground for easy wildlife access; (2) that water be available for wildlife during critical dry seasons even though livestock are not in area, and (3) that an escape ramp (right distance end covered in part by vegetation) be installed for small wildlife. (U.S. Bureau of Land Management photo by Jim Yoakum.)



A. When trough height is 20 in or less wildlife have better access to water



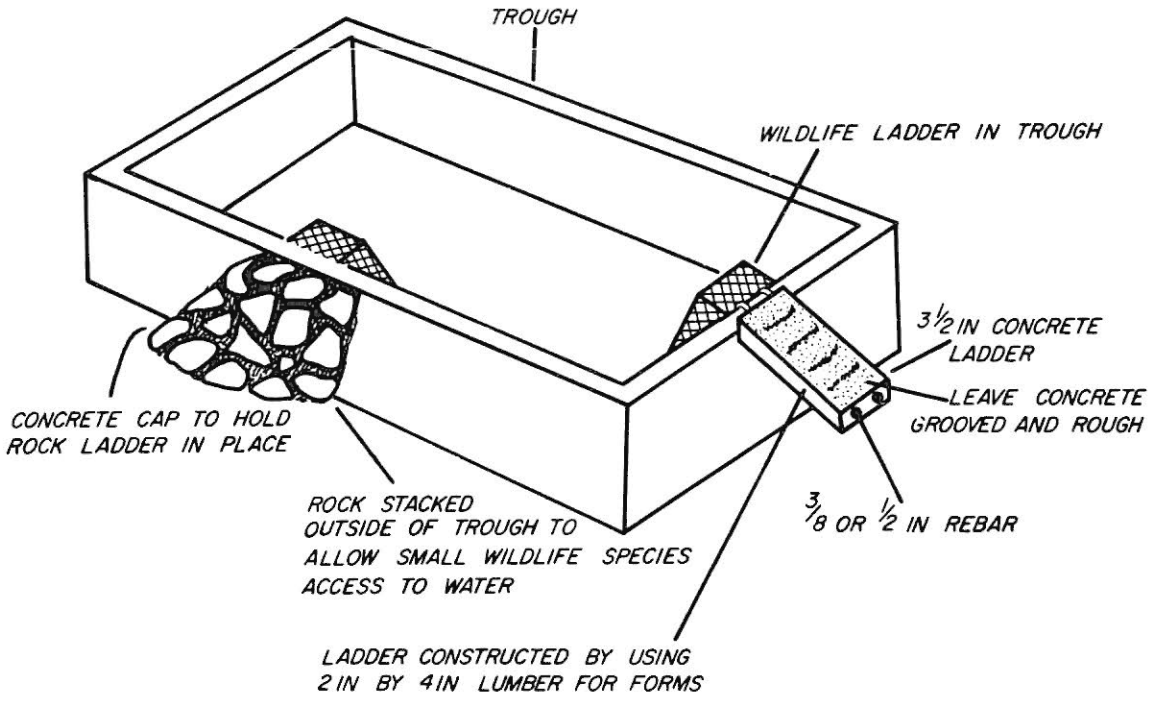
B. Possible barricade development depending on livestock trough configuration



C. Placing of rocks, concrete blocks or other ramp facilities provide on escape route for wildlife where the water depth exceeds 20 inches

Fig. 20.27. Design modifications beneficial to wildlife for water troughs constructed for domestic livestock (adapted from Wilson and Hannans 1977).

A. Concrete ramps or rock ramps capped by concrete into livestock trough



B. Details for a triangular shaped wildlife ladder

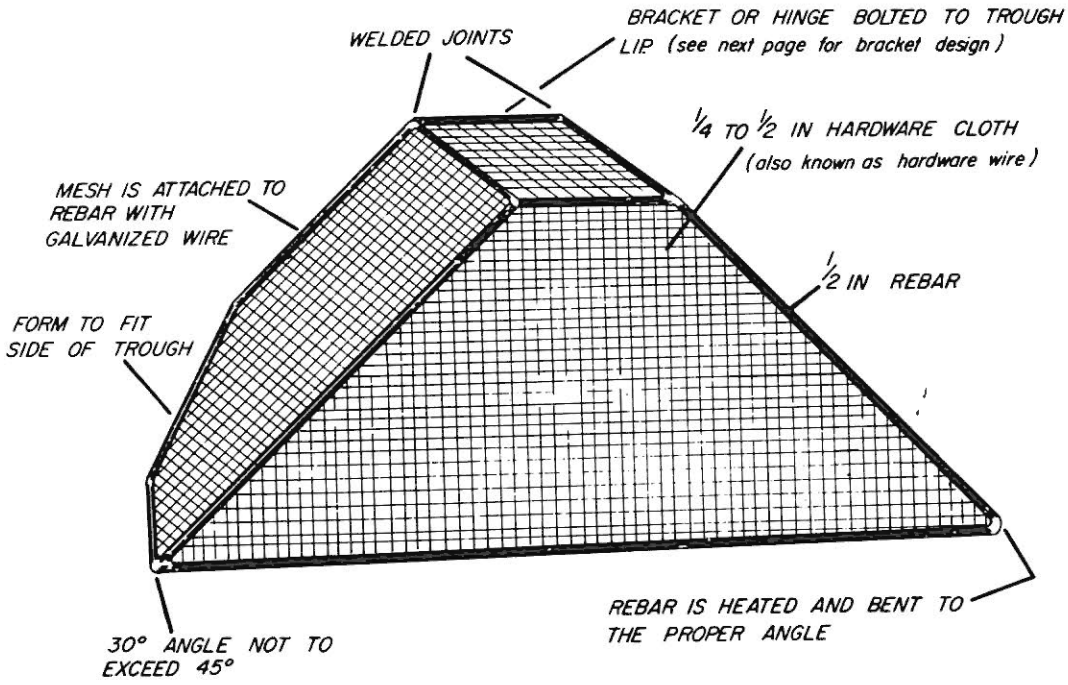


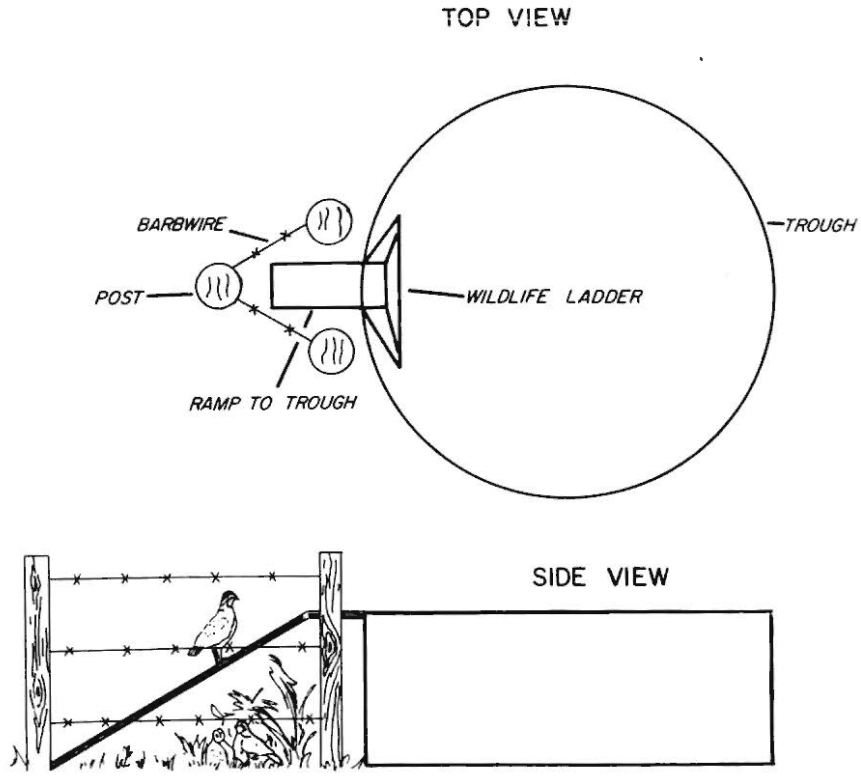
Fig. 20.28. Construction details for adapting a livestock water trough for wildlife use (Wilson and Hannans 1977).

SHALLOW MARSHES

Marshes provide nest sites, cover, and food for waterfowl and for muskrats and other furbearing mammals, such as mink and otter. Herons, cranes, rails, plovers, and sandpipers are the chief bird families that require marshes. Many forms of reptiles, amphibians, and fish complete the vertebrate fauna. A marsh should have open water areas if it is large, or an adjacent pond, if small, for maximum wildlife value.

Artificial impoundment is a common practice used to improve existing marshes or to create new ones. The objective is not merely to flood an area, but to control

A. Fencing and post arrangement to protect wildlife ramp leading into a livestock watering facility.



B. Details for constructing a wildlife ladder.

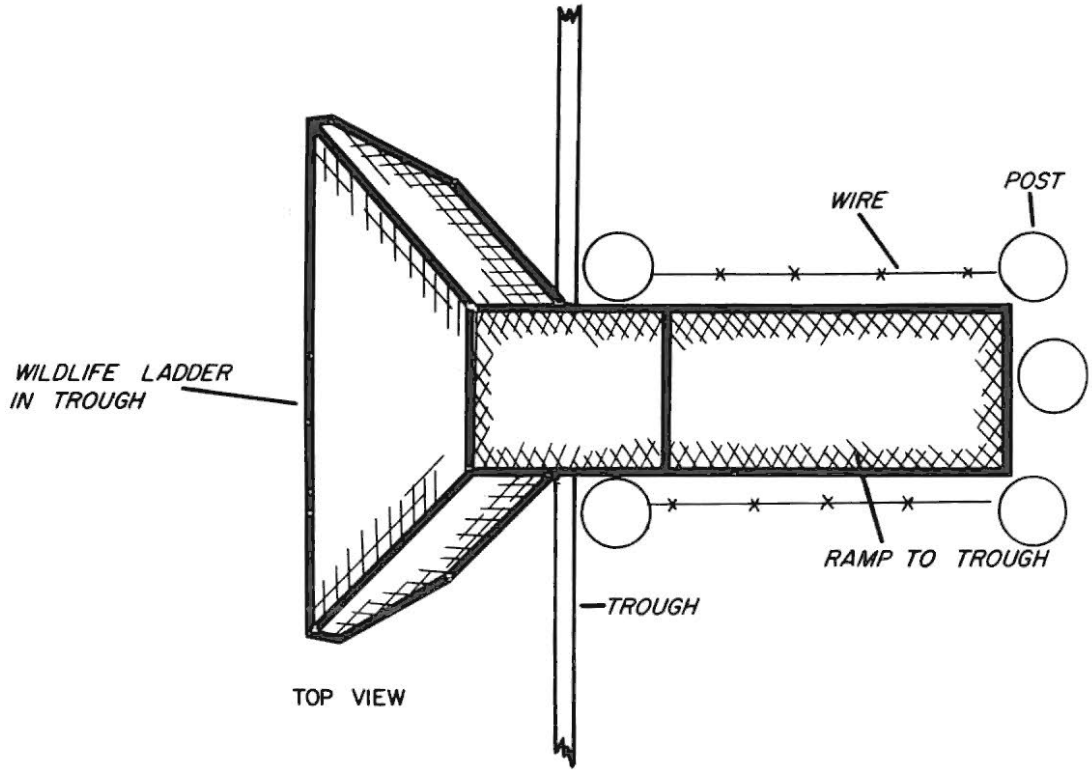


Fig. 20.29. Plans for modifying a livestock water trough by providing both an outside and inside wildlife ladder (Wilson and Hannans 1977).

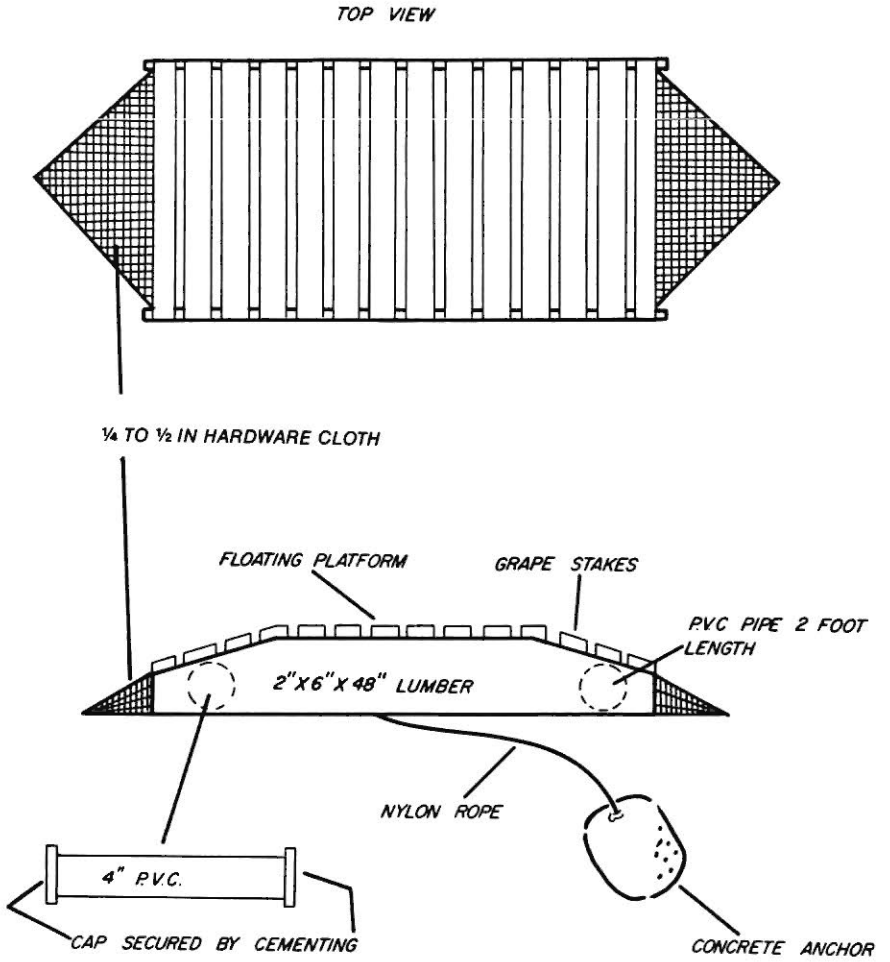


Fig. 20.30. Floating wildlife platform recommended for large open water storage tanks (Wilson and Hannans 1977).

water levels after impoundment as a method of managing food and cover conditions. Stoplog controls should be designed so that water level can be manipulated, including complete drawdown when needed. In most instances the average water depth should be 45.7 to 61 cm depending on site condition and amount of edge.

Ditching marshes increases the variety of habitat for furbearers as well as waterfowl. Deeper water in ditches helps animals find food and cover during dry periods. The spoil banks, on the other hand, offer dry resting sites, feeding areas, and shelter during flood periods. Ditches also facilitate access for hunters, trappers and maintenance crews.

Dredging has been found superior to blasting as a method of ditch construction. Blasted ditches tend to be shallower and loosened muck along the edges of the ditch is highly susceptible to wave and wind erosion. The lack of high spoilbanks desired for waterfowl nest sites and muskrat dens further reduces the value of blasting.

In constructing improvements in shallow marshes, the use of scoops, draglines, bulldozers, or combinations of the 3, are recommended so that the material removed may be piled along the edges. The high areas should be planted to a grass-brush cover.

POTHOLES, SUMPS, PONDS

Potholes may be defined as small, shallow, open water retention areas or basins with surface areas usually under 1.6 ha in size. These areas, when developed in conjunction with large, permanent water areas, can be a particularly valuable tool in waterfowl management. The purpose of making potholes is to create or increase water area lost to geological change and plant succession. An ideal wetland for waterfowl has one-third open water and two-thirds marsh.

Draglines and bulldozers have been used in construction of potholes, but they are of most use when ditching, damming, and diking are required. The use of a blasting agent is the most expeditious and economical method to employ in creating new small potholes. Recent experience has shown ammonium nitrate to be a very effective agent. It is less expensive and safer than dynamite. Best results are obtained with commercially prepackaged ammonium nitrate fuel oil charges (U.S. Forest Service 1969). In pastured areas potholes should be fenced. Fences should be located at least 7.6 m and preferably 12.2 m or more back from the waterline (Mathiak 1965).

Beavers, when skillfully managed, can create much desirable habitat. Their ponds in intermediate stages of

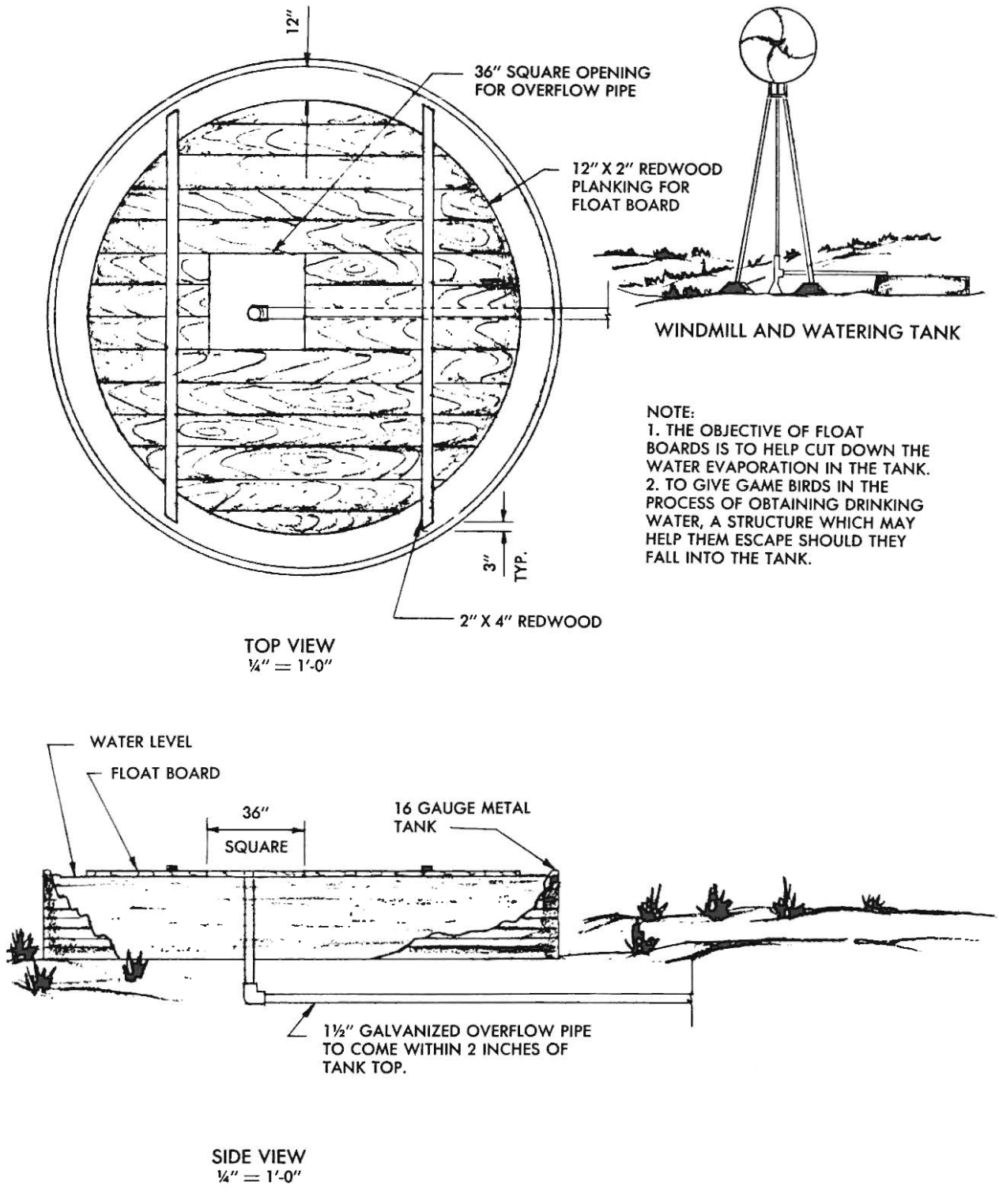


Fig. 20.31. The simple round float board illustrated in these drawings has saved hundreds of wild birds by providing an area for them to drink at round water troughs. One such trough without the board flat contained 13 sage grouse carcasses, however, after the "wildlife saver" had been installed, no further mortalities were observed (Nevada State Office, U.S. Bureau of Land Management).

development are major attractions, not only for waterfowl, but also for other wildlife. But the typical beaver impoundment is a changing affair that evolves through several stages. For this reason, the manager should not be as concerned with maintenance of individual ponds as he is with rotation of favorable habitat elements within the entire area of beaver influence.

During the past 25 years, the states of Maine and New Hampshire have developed and refined beaver management techniques as part of their waterfowl manage-

ment programs. Hundreds of hectares of selected beaver-created impoundments, including problem flowages which otherwise might have to be destroyed, are preserved annually through a program of beaver population control and stabilization of water levels.[4]

The life expectancy of a beaver-created impoundment is determined by the available food supply and the number of beaver utilizing the food. From a food supply standpoint, a beaver flowage in which the beaver population is maintained at low numbers (2–3 beaver) will remain active for a much longer period of time than if the same flowage were occupied by a full colony (10–12) of beaver. Beaver populations in desirable flowages can be managed by annual trapping, live trapping and transfer, and beaver sterilization techniques.

New Hampshire has developed a "beaver pipe" (Laramie 1978) or water level stabilization device which can be used in alleviating flooding conditions caused by beaver building dams in culverts or flooding valuable timber, fields, or roadways. A "beaver pipe" is a 7.3-m-long, 30.5-cm-sq wooden tube with 1 solid end and a bottom of 5.1 × 10.2-cm wire mesh. For ease of handling, a "beaver pipe" is constructed in 2 sections which are joined together at the installation site. When pushed through or set on top of a beaver dam (wire side down with the solid end extending out into the pond) and secured by steel posts, water flows freely through the bottom of the pipe out over the dam. The pipe can be set at almost any level and the beavers' efforts to stop the flow are usually futile. Experience has shown a minimum of 0.6 m of water must exist between the bottom of the upstream end of the pipe and floor of the pond for the pipe to work efficiently.

In the case of a plugged culvert, the dam is removed and a heavy wire mesh fence (15.2 × 15.2-cm #6 concrete reinforcing wire) is installed around the mouth of the culvert and secured with steel posts. When the beaver build a dam on the fence, a "beaver pipe" can then be placed through the fence to keep the water at a desired level (Fig. 20.32).

For beaver flowages where no culvert is involved (a situation where the water level must be maintained or lowered) installation of a "beaver pipe or pipes" alone will do the job. A single "beaver pipe" can handle the normal runoff from a 8.7-sq-km drainage area and installations have been made utilizing up to 3 pipes (Fig. 20.33). Beaver flowages with drainage areas exceeding 26–28.8 sq km are not feasible to manage using "beaver pipes."

The State of Maine in turn has developed a water level control pipe (Boettger and Smart 1968) constructed from aluminum culvert stock which they use to achieve and maintain optimum water levels in beaver flowages and prevent damage through excessive flooding.

GREENTREE RESERVOIRS

Greentree reservoirs are bottomland hardwood areas shallowly flooded for short periods during the dormant growth period for the purpose of attracting waterfowl.

[4]Material provided by Harold Nevers, New Hampshire Fish and Game Department, Concord.

Fig. 20.32. Wire mesh fence to protect culvert from flooding with a "beaver pipe" (H. Nevers, N. Hampshire Fish and Game Department).

Fig. 20.33. Water level can be maintained or lowered in a beaver flowage by installing a "beaver pipe" (H. Nevers, N. Hampshire Fish and Game Department).

Short-term flooding makes possible attractive feeding conditions on mast from various oaks (pin, willow, Nuttall, and cherrybark) supplemented by understory food plants, such as wild millet and smartweed. Flooding may be scheduled so as not to adversely affect tree growth or plant succession.

Acorns are the staple wildlife food item for which such areas are managed. Ducks (mallards and wood ducks) are the principal target species; but greentree reservoirs are also good for turkey, squirrel, deer, quail, raccoon, other furbearers, and many species of nongame mammals, birds, reptiles, amphibians, and fish.

Water depth of 30.5 to 45.7 cm is considered most suitable for "puddle duck" feeding. It is not necessary that the ground be completely flooded; narrow ridges may remain dry and still be utilized by waterfowl.

The selection of a site for a greentree reservoir should be based on 3 main considerations:

1. The area should be flat and contain impervious clay soils and be close to a low gradient stream to prevent excessive diking cost.
2. There must be mast-bearing oak timber that can be flooded and is adapted to flooding. The opportunity for this appears to be largely limited to broad, geologically old-age valleys such as those of the south central and southeastern United States.
3. There must be an ample and dependable water supply which can be removed from the area before tree growth starts in the spring.

In the operation of a greentree reservoir, it is desirable to begin flooding sufficiently early in the fall to attract early flights of waterfowl. Drainage of flooded areas should be accomplished during late March to mid-April to prevent loss or damage to timber stands.

An open marsh constitutes an ideal supplement to a greentree reservoir. Such marshes add to the variety of habitat conditions and probably increase nesting and brood rearing values. Marshes may be improved by the methods suggested in the "Shallow Marshes" section of this chapter. Technical engineering guidance and planning are needed for all proposed greentree reservoirs. A detailed plan of the area to be flooded should be made prior to construction including proposed water levels, soil samples, and location and design of levees and diversion channels or dams. Engineering features that should be included in the plan include:

Levees

a. Levees should be wide enough for small vehicles, a minimum of 1.2 m wide at top.

b. Levees should have a 3 to 1 slope downstream, 4 to 1 slope upstream.

c. Levees should be seeded or sodded to permanent vegetative cover including wildlife food plants.

Borrow Areas

Areas where soil is taken should be outside the greentree reservoir, preferably on high ground where the spillway will be located. Taking soil from within the greentree reservoir creates a deep water hazard for hunters.

Spillways and Drainage

a. The borrow area, if properly located, may be incorporated into the spillway. The spillway should flow onto undisturbed earth.

b. When a system of levees is needed to make flooding possible or to divide large areas into management units, the spillway may be incorporated into the structures.

c. Spillways built into levees must be stabilized by using soil, cement, concrete, or paving material.

d. Flooding of the feeding range may be accomplished by several methods, all of which require use of low contour levees with control structures.

Retention of Rainfall or Flood Waters

This method is best adapted to flat bottoms with low gradient. It requires minimum investment and is economical to operate. This method depends on rainfall for flooding at the proper season. Since soils on these sites generally are heavy clay and difficult to drain, sites should be chosen which will allow draining the impoundment early in the spring to guard against loss of tree growth.

Diversion of Inflowing Streams

This method may be used where small streams enter terraces and well-drained bottomlands. It consists of a gate-type structure in the stream to permit diversion of the stream-flow into the diked area at the proper time. Initial cost is largely governed by the size of the diversion structure and extent of facilitating levees. Flooding by this method, however, is not dependent on rainfall.

Pumping

Pumping is used where groundwater is readily available and where other water sources are unreliable. Flooding, of course, is completely controlled, but requires a relatively fixed annual cost for pumping. Pumping costs usually range from \$2.03 to \$4.05 per 1000 m^3.

Habitat Manipulation Practices

WATER LEVEL CONTROL

Production of submerged aquatic vegetation will generally require stable water levels. Actual depths will depend upon topography, clarity of the water, plants used, and species of wildlife involved. Operating depths will usually vary from 0.5 to 3.7 m with the optimum being about 1.2 or 1.5 m. Water levels of 0.3 or 0.6 m during the production season for submerged aquatics proved most beneficial to waterfowl on the Montezuma National Wildlife Refuge. Depths greater than this were of little value to dabbling ducks. Water levels should be managed so as not to allow freezing to occur in the bottom soils. It should be pointed out, too, that where sufficient water level control is possible to permit growth of wet-soil plants, food production usually exceeds that of

submerged aquatics. In all improvement projects, means should be incorporated in the control structures to allow maximum flexibility in manipulating water levels.

For management of emergent vegetation, the drawdown practice of water level controls is used in areas where waters are acid, turbid and light penetration is inhibited, and also where soils are of low quality. Perennial and annual food plants may be managed by drawdown dependent upon whether the objective is to encourage permanent muskrat populations, or to provide needed habitat requirements for waterfowl. Drawdown should be as late as possible yet still early enough to allow seed production for such fast growing aquatics as wild millet, rice cutgrass, and annual smartweeds which may become established on moist mud flats. The drawdown date will vary according to latitude. In the Middle Atlantic states, June 20 is the approximate drawdown date. Reflooding is usually done by September 1 in order to serve early migrating waterfowl.

If the impoundment is in an estuarine area, tide gates should be in operation during the period of drawdown to prevent ingress of saline waters. For most marshland plants drawdown is to meadow level in order to furnish subirrigation waters. For millet, the water level should be raised above meadow level after the growing millet has attained a height of 15.2 cm or more. As the millet grows, water levels can be raised accordingly, but in no case should the water be allowed to flood over the top of the growing plants. Preventing overflooding has the advantage of inhibiting the growth of undesirable and perennial plants.

Reservoir drawdown is an effective method of manipulating cover around waterfowl impoundments. Species composition of cover can be controlled by time and length of drawdowns. If the soil remains wet, cattail and bulrush are favored. If it is allowed to dry, sedges and such species as woolgrass are likely to invade. Late spring and early summer drawdowns favor submerged plants; mid and late summer drawdowns favor weedy growth. In some regions, willow and red-osier dogwood may invade rapidly where the drawdown is sustained for 2 years or more. Drawdowns also improve the growth of submerged aquatic plants once the area is reflooded because of both physical and chemical improvement of soils.

In Ohio, drawdowns during May in a managed marsh were the most successful in producing plant successions beneficial to waterfowl (Meeks 1969). Semiaquatic species such as rice cutgrass and nodding smartweed were abundant after May drawdowns. In addition, drawdowns in May did not impair duck nesting and did not limit muskrats to single litters as occurred following drawdowns in March, April, or June.

Although water drawdowns are a valuable tool in marsh management, they must be used with care, and should be predicated on knowledge of physical and biological characteristics of the marsh. Bottom topography, soils characteristics, existing plant communities, current waterfowl use and productivity, and seasonal water supplies all are important factors that will affect the decision to use drawdown as a habitat manipulation technique.

PLANTINGS FOR FOOD AND COVER

Efforts to propagate plants for waterfowl food should be undertaken only after thorough survey of existing conditions. The important native species first must be identified and inventoried. Consideration needs to be given to the distribution and environmental requirements of all the important duck food plants that are, or should be, present on the area. Planting, the last step in the program, is done only when it is known that important species are missing and that conditions for their introduction are right. A very important first step in providing food plants for waterfowl is covered in this Chapter under "Shallow Marshes." This is to create the kind of shallow, marshy-edged type of impoundment that encourages the favored flora. A constant, stabilized water level is very important for growth and reproduction of most aquatic life, whether it be plant or animal. This is especially true during late spring and summer.

Artificial introductions are of most value to small areas where the site can be managed and controlled intensively. Planting of large marshes, river bottoms, or extensive impoundments is frequently very costly. When starting a planting program, small plantings should be made, thereby determining the adaptability of test species for the site.

To realize best results from the planting program, the work must be conducted at the proper period of the year, usually during spring or early summer months. Second, the planting site must be of a nature that promotes growth. If the site is already supporting a cover, there is little reason to expect planting success, as the plants growing on the site will be much more adapted than introduced species (Singleton 1965).

The job of the habitat manager is similar to that of the farmer as he implements the principles and practices of crop production. In order to insure successful growth, the crop producer first removes all competing growth from the land and tills the soil in an effort to create conditions favorable to the growth and production of the target crop. Recommended sources of good information pertaining to plantings, especially for waterfowl, include the following: for the Gulf states (Singleton 1965); for the eastern states (Atlantic Waterfowl Council 1972); for the Pacific Northwest (Scheffer and Hotchkiss 1945); for the Great Lakes areas (Pirnie 1935); for the Pacific Southwest (Miller and Arend 1960, George 1963); and in general for North America (Addy and MacNamara 1948).

For immediate reference, the following are some of the more important food plants for waterfowl and suggested techniques for planting them:

Pondweed

Pondweeds can best be introduced into new waters by transplanting of the rootstock early in the spring season. Whole plants should be pulled or dug, the roots balled with mud, and immediately transplanted. Soft, muddy bottoms make the most satisfactory growth sites.

Smartweed

Smartweed is best propagated by transplanting rootstocks. Successful establishment has also been ac-

complished by 30.5-cm long stem cuttings. About one-half of each cutting should be stuck into mud bottoms in shallow water. Rootstocks or cuttings should be transplanted during late winter or early spring.

Duck Potato

This species may be established by transplanting the entire plants in the spring or early summer. The transplants should be set in water equally as deep as that from which they were collected. Soft, muddy bottoms make the best growth sites.

Spike Sedges

Rootstalk or entire plants can be propagated. All transplanting should be completed in the spring or early summer months.

Duckweeds

Transplant the entire plant. This is done simply by collecting the floating plants in a bucket or basket and then scattering the material in the site to be planted. Duckweed makes its best growth in sites having emergent vegetation which will protect the duckweed from excessive wind or wave action.

Coontail

New plants grow from fragments of coontail stems. The stem fragments may be planted at any time during the growing season and can be transported whenever it may be gathered, either from the masses of live plants in the fall or by rakes and drags used on the bottom in winter or spring. They may be planted in packages or merely pushed by hand into the soft soil.

Grasses

There are hundreds of grasses, both natural and domesticated grains, used by waterfowl in North America. Two native species commonly planted are wildrice and wild millet. Wildrice is broadcasted and requires no covering, for each good seed sinks at once and becomes embedded in the bottom soils. Best planting sites are those that have shallow, fresh, nonstagnant water, mud bottoms, and are open to the sunlight. A great deal of wildrice seed has been wasted in water too deep for the young plants to reach the surface or on sludge bottom into which the seed worked down too deep by means of its tiny slanting barbs.

Wild millet, or watergrass, will not sprout if the water depth exceeds 15.2 cm. Usually no seedbed preparation is necessary if the wetlands are newly formed on agricultural land or on annual grassland. The seed can be broadcast and the pond flooded. The same treatment can be given bare pond bottoms. However, a seedbed must be prepared if the bottom is covered with cattails, tules, and saltgrass, or rushes and spikerushes, since millet cannot compete with these plants. In such cases the soil must be plowed or disced 2 or 3 times and then harrowed to break the sod. The seed may be planted by a field broadcaster, airplane application, or by use of grain drills. When using drills, plant the seed no more than 0.6 cm deep since deeper plantings often fail to germinate. The usual planting rate is 22.4 to 33.6 kg of seed per ha. May and June plantings produce the best yield. Millet germinates rapidly when soaked and must not be left dry afterwards or the germ will die (Miller and Arend 1960).

Alkali Bulrush

For many of the southwestern salt wetlands, alkali bulrush may be established. Generally seedbed preparation is not needed unless competition is severe with other plants such as cattails, tules, and saltgrasses. Spring seedings are recommended at a rate of 33.6 kg per ha. Seed may be aerially broadcast (seed should be presoaked for 5 days) for large areas or a standard 20 × 6 grain drill used for operations smaller than 10 ha. If drilled, be sure not to cover the seed more than 1.27 cm otherwise germination will be retarded or lost. Very small areas (of less than 0.4 ha) can be hand transplanted by digging up the entire plant, including rhizomes and tubers.

Proper water management is exceedingly important to establish this species. First, as much of the field as possible should be preflooded to a depth of 2.5 to 7.6 cm. After seeding, the water should be held at this 2.5- to 7.6-cm level for 2 to 3 weeks, then the water should be drawn down to a mud flat stage for 2 or 3 days. This allows the seedlings to emerge and firm their rudimentary root systems. The wetland should then be reflooded to the original depth (2.5 to 7.6 cm) and maintained at this depth until the plants have full mature seed heads. After this plant has become established, it may be flooded to almost any depth without adverse effects (George 1963).

RESTING SITES

Often it is necessary to create loafing islands or nesting sites on wetland development projects for waterfowl. Brood-rearing territories can be increased on improved marshlands exceeding 0.8 ha by partitioning the tract. Partitions are made by ridging or building chains of islands across the project. Ridges and islands can be constructed with a bulldozer or dragline during dry periods or by depositing rocks and boulders on the ice in winter. Snow fences strung across potholes is another practice to serve as temporary partitions (Atlantic Waterfowl Council 1972).

Floating "islands" can be anchored in shallow low water ponds. Metal barrels are sometimes attached underneath to adjust the height of flotation. The "islands" can be constructed from green logs with rough mitred corners made by a chain saw and held together with lag screws. Each "island" should be landscaped with grass or willows to provide shade and protection from predators (Shomon et al. 1966). Loafing and resting places may also be made by anchoring a couple of logs or 1.2 × 1.2-m rafts in open water, or by stacking rocks, old straw or hay bales in shallow water.

NEST STRUCTURES

For suggested techniques on nest boxes, nest platforms and cones, see "Nesting Cover" and "Specialized Nest Structures" in this Chapter.

MAN-MADE ISLANDS

During the past hundred years, over 2,000 man-made islands have been constructed throughout U.S. Coastal, Great lakes, and riverine waterways. These islands have created new habitats for many species of wildlife, especially colonial birds. Landin (1978) provided an evaluation of these structures and listed some 50 references documenting the use of man-made islands by wildlife.

Most man-made islands are constructed with dredged materials. They vary greatly in size and characteristics and range in age from newly formed to 50 years. Commencing in 1976, the Dredged Material Research Program's Habitat Development Project located at the U.S. Army Engineers Waterways Experimental Station, Vicksburg, Mississippi, initiated studies of these structures. Most results published to date relate plant succession to bird utilization of islands. One report (Soots and Landin 1978), provides helpful information pertaining to the development of avian habitat through dredged material islands.

Small man-made islands were attractive, relatively safe nesting sites for mallards and Canada geese in prairie wetlands (Johnson et al. 1978).

Constructing Water Control Devices

There are various development structures used to control water to improve wetlands for wildlife. A general list of techniques is presented here with references on construction methods and specifications. The importance of working with expert engineers in developing construction requirements cannot be overemphasized.

DIKES AND EMBANKMENTS

All discussions relating to earthen water impounding embankments are limited to fills 3 m high or less. If higher embankments are required, detailed soil studies must be undertaken in order to design and construct a safe structure for the most reasonable cost.

For a well-documented review of principles and methods of making dikes or impoundments, see the excellent *Techniques Handbook of Waterfowl Habitat Development and Management* compiled by the Atlantic Waterfowl Council (1972). The material presented here was obtained from that book. The handbook describes the following types of embankments:

Simple Embankments

Simple embankments are those consisting of reasonably uniform material throughout. They are generally located in marsh or swamp areas where on-the-site soils must be used. They generally involve the least expenditures for construction and in many instances are the only feasible type to use (Fig. 20.34).

Core Type Embankments

Core type embankments are those whose central portion or core is constructed of selected soil, usually the least pervious material. The outer surface is comprised of on-the-site, more pervious soils. This type of embankment seldom is used on low-head fills unless the supply of less pervious materials is readily available or unless the soils of different permeability are separated naturally by distinct layers, readily available to the earth-moving equipment being used. However, on-the-site soils can be so poor that stability of the embankment will be questioned by competent engineers. In such cases it may be economically sound to haul the core material from some distant borrow pit (Fig. 20.35).

Diaphragm Type Embankments

Diaphragm embankments are those which incorporate a relatively thin section of concrete, steel, or wood to form a barrier to percolating water. The "full diaphragm" type has the barrier extended from the level of the impounded water down to a seal in an impervious foundation. A "partial diaphragm" or cutoff wall type is one which does not meet the conditions of the full type (Fig. 20.36).

Although the need for complete, detailed investigations of the properties of soils and subsurface conditions is less on the low-head fills, on-site inspections must be

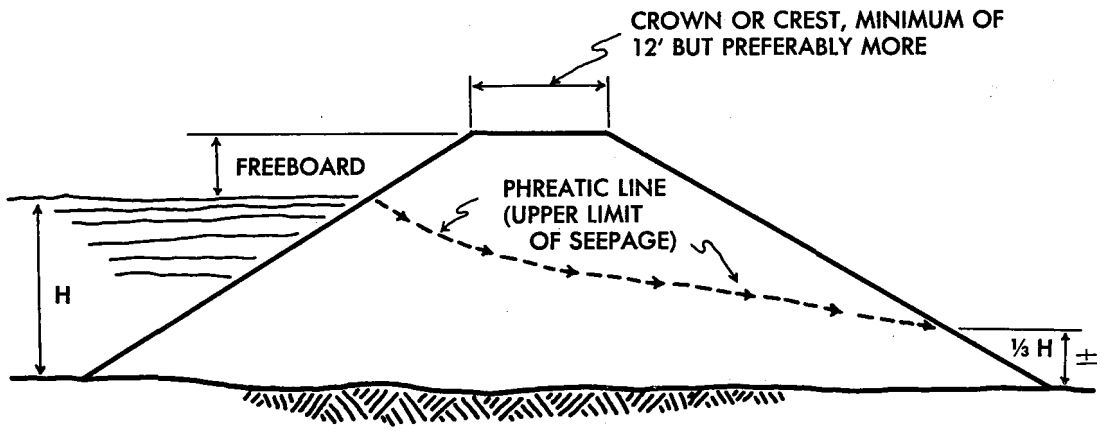


Fig. 20.34. Plans for construction of a homogenous fill typical dike (Atlantic Waterfowl Council 1972).

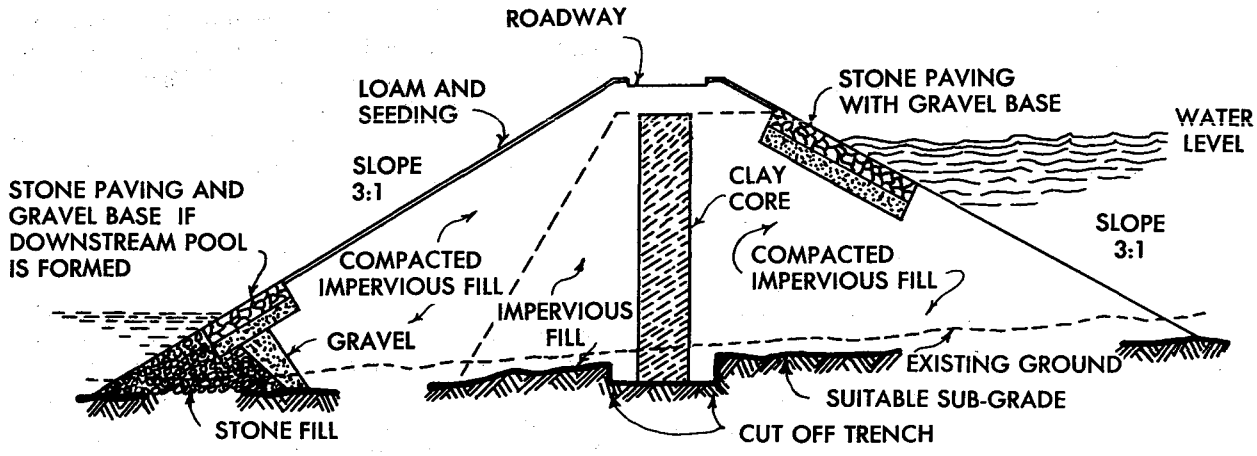


Fig. 20.35. Plans for construction of a typical clay core dam (Atlantic Waterfowl Council 1972).

made and "rule-of-thumb" criteria based on experience, must be used in designing the embankment and selecting the type of earth moving equipment for the job.

All earthen embankments should meet the following recommended criteria:

The dam shall be designed so that destruction through erosion is prevented. In order to meet this condition: (1) the spillway should have sufficient capacity to safely pass the expected peak flow for the drainage area, and (2) freeboard should prevent overtopping by wave action at maximum high water. The final top elevation of the embankment, after settlement, in areas of runoff water should be designed by adding to the maximum high-water elevation (resulting from flood flows) an amount at least equal to the wave height plus wave run up the slope. These amounts are determined by standard construction formulas. In areas of deep frost, an additional amount must be added to allow for damage from frost action. The elevation so determined considers overtopping by water originating upstream from the embankment.

For construction of sites in tidewater areas, overtopping by storm waters from outside the impoundment should be given consideration. The type of management within the impounded area, type of material available, and the cost of construction will have to be weighed to determine whether or not embankments in these locations will be constructed to exclude such storm waters. If it is decided not to exclude them, provisions must be made in spillway and control structure sizes to admit the storm water into the impoundment in such quantities that the water surface elevation within the impoundment rises at approximately the same rate as the water outside. Then, when overtopping occurs, dike erosion will be reduced to the minimum.

For some wildlife management purposes, extremely low fills may be desirable to temporarily impound shallow water. Under these conditions, a comparison of construction plus annual maintenance costs must be made between dikes which would allow for overtopping and those which would prevent overtopping.

The foundation should be able to support the load imposed by the embankment and live loads placed on it. Foundation soils will usually be stable enough to support the load of the embankment and live loads for low-head fills. In some areas, however, the soils may be highly plastic so special precautions must be taken to insure stability. If such soils are not too deep they can be removed and replaced with more stable material. In other areas, however, it may not be feasible to remove and replace them and some method of treating them in order to realize stability will have to be devised. Rows of sheet piling or round piling can be used, but the cost per meter of dike is high. If extensive areas of such unsuitable foundation soils are encountered, it may be wise to abandon the site.

The resistance of the embankment and foundation to the passage of water is dependent on the impervious-

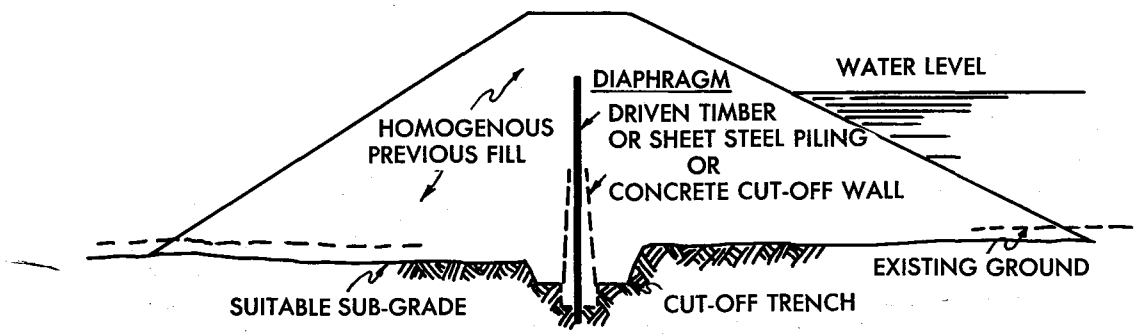


Fig. 20.36. Plans for construction of a typical diaphragm embankment (Atlantic Waterfowl Council 1972).

ness and compaction of the material used. Loss of water is not dangerous if the supply retained in the impoundment is sufficient for operational needs and the seepage of water does not cause flotation of soils. Care must be taken to establish the minimum slopes and top width of dike which will provide this embankment safety and bury the seep line. A 3.5 or 4 to 1 slope is considered the minimum for maintenance because tractor mowing equipment usually cannot safely operate on steeper slopes. Any embankment used for travel or maintenance mowing should have a minimum 2.4 m crown width with 3.1 m preferable.

The sites for habitat impoundment projects cannot always be limited to those having suitable foundation and fill materials. It is frequently necessary to compensate for poor onsite material by safe design and construction of the embankment. However, under such conditions, the initial construction cost and future annual maintenance costs will increase proportionately with the decrease in soil stability. In all cases, the typical section (slopes, crown width and freeboard) should be such as to keep the impoundment seep water line within the fill. Wet spots on the downstream slope of any embankment could indicate the seepage line is not covered and remedial action should be taken. The type of embankment will be governed by the depth of water to be impounded, the materials available, and costs of both initial construction and later maintenance. All of these factors are interrelated but any one of them can outweigh the others on the specific project.

SPILLWAYS

Spillways are provided in major wetland developments to release surplus or floodwater which cannot be contained in the impoundment basin. Inadequate design of the spillway structure may result in failure of the retaining dam and possible downstream damage. The spillway design should be considered in relation to the management potential of the marsh and to drawdown or stable pool operation. A spillway design of maximum flexibility of water levels will, in most cases, be the best suited to the management of a wetland impoundment. Flexibility should be carefully judged against its benefits as related to structural costs. Standard types of spillways include the following:

Free Overfall or Straight Drop

This type is used most frequently in the Northeast in low-head design, common to most large shallow area impoundments. It is necessary to provide artificial protection below the spill crest, as scouring and structural damage is likely to occur. A concrete or plank apron combined with cutoff walls is, therefore, an integral part of the free overfall design. The free overfall spillway of reinforced concrete or wood planking is usually designed for fixed water level impoundments. In low-head waterfowl impoundments, the design is usually modified to provide for drawdown or limited increase in storage capacity.

The reinforced concrete spillway is usually the most satisfactory design. The initial cost of concrete design is higher than log cribbing or Wakefield piling, but maintenance of the structure is minimized since concrete longevity is much greater than other materials. The location of the impoundment site and availability of material may warrant use of material other than concrete. The spillway should be designed for access so structural maintenance can be performed.

Ogee

The ogee spillway, usually designed of reinforced concrete, has a weir that is ogee or (S) shaped in profile. The flow is over the crest and along the profile of the structure with minimum interference and therefore attains near maximum discharge efficiency. In many low-head designs for waterfowl, storage of water is important and discharge efficiency is not a factor limiting design. The ease of construction and cost-related considerations may limit construction of ogee spillway design. In cases where ogee designs are contemplated for waterfowl impoundments, consideration should be given to incorporating drawdown features. This may involve drop boards, gates, or valves, so that water levels may be dropped below normal operational levels. Drawdown features should be considered even where management planning is based on stable pools. The installation cost of a drawdown feature may well pay for itself by improving the future maintenance of the prime structure.

Natural

This spillway is one that provides for impoundment runoff over natural undisturbed ground. A spillway of this type is unusual in a large fresh water impoundment design. The possibility of locating a natural spillway with runoff capacity, soil type, and vegetative cover that will meet design criteria is unlikely. If a design can take advantage of such a spillway, substantial savings in development cost may result. It should be noted that maintenance of this type spillway may in some instances be rather high. The obvious disadvantage is that unless this type is supplemented with gates or other mechanical devices, it is not possible to provide for drawdown or drainage.

Pipe or Culvert

A culvert spillway is a simple type spillway with the inlet opening placed either vertically or inclined upstream, with a uniform profile grade. The approach to the conduit may have flared or tapered sidewalls with a level or sloping floor. Conduits are usually metal, with a bituminous coating, and may have paved inverts. Concrete or fiberglass conduits have been used some. In low-head design, this type spillway is adaptable for either part or full capacity operation. Construction is simple and economical.

There are disadvantages, however, in the use of culvert-type spillways in managed wetland impoundments. The capacity does not increase greatly with increased head, and there are limitations imposed in drawdown unless a gate valve is incorporated.

Log Crib

The log crib spillway used in wetland impoundment is limited to locations where the use of permanent materials would be too costly. Logs should be selected that have uniform taper and are highly resistant to deterioration. Logs treated with preservatives such as coal tar, creosote, or pentachlorophenol solution are desirable where longevity is important. The abutments and spillway are usually faced with 7.6 cm treated planking. The maintenance of this type spillway is often very high in relation to cost of a more permanent type installation.

Because standard design plans are not often used in these structures, it is important that a plan be designed to meet local needs. The plan should be based on competent engineering standards. In general log spillways are constructed of toe piling driven on the upstream face of a bed log with the spillway having a maximum incline of 30°. All bark should be peeled from logs not completely underwater. It may be desirable to include a stoplog section if drawdown is a consideration in the impoundment.

Drop Inlet

A drop inlet is one in which the water enters over a horizontal positioned lip, drops through a vertical box or shaft, and is discharged through a pipe or conduit. In waterfowl impoundments, a concrete drop inlet in conjunction with reinforced metal pipe may be suited to small drainage areas. The most usual design is a monolithically reinforced concrete box, with stoplog slots on the upstream side. Provisions may be made for trash screens to prevent pipe constriction. Emergency spillways are incorporated in the design.

Stop Planks

Stop planks provide a means of adding flexibility to an ungated spillway. These are planks spanning horizontally between grooved recesses in supporting piers. Stop planks may be removed during floods to pass excess waters or when partial or complete drawdown of the pond is desirable. This type control is the most economical and provides adequate area to pass debris. The passage space should be a minimum of 1.2 m wide on larger dam structures. A lifting type device may be desirable if the stop planks are to be removed frequently since manual removal may entail considerable time and work. If water loss is to be minimized, stop planks should be planed on all 4 sides and free from warp. Leaks between planks can be easily sealed by placing soft coal ashes in small quantities (handful) immediately upstream and over the leak. Dry cinders are best as they float more quickly into the leak. Planks should be naturally resistant or specially treated, and a minimum width of 5.1 cm.

Gates

Gates are used in spillways where higher frequency and greater control of drawdown may be desirable. Lift gates span horizontally between guide grooves in supporting piers. Gates are usually cast iron or steel and raised or lowered by an overhead hoist device. Radial gates are usually constructed of steel (prefabricated). Water thrust operates the radial type of gate which may be set at a predetermined level so as to operate automatically. Cost of the installation of radial gates may be appreciably higher than lift gates, stoplogs, or drop inlet installations. If continual drawdown in the impoundment is contemplated, gate installation should be considered.

LEVEL DITCHING

Level ditching means constructing upgraded ditches on lands having a high water table. These ditches are installed to improve water distribution, provide open water for waterfowl, furnish nesting sites, and aid in increasing or maintaining aquatic food and cover plants for waterfowl and furbearers (Mathiak and Linde 1956). This practice is applicable on wetlands where soils are suitable for ditch construction and require a minimum of maintenance for a long period of time. Suitable soils include peats, muck, clays, and silt. Sands, sandy loam, and clay high in salt content generally are not suitable. Generally, ditching is applied to marshes exceeding 0.8 ha.

It is helpful to consult with soil scientists, hydrologists and agricultural engineers for planning level ditching. On large wet areas, an aerial photo or topographic map is useful in locating natural drainage patterns and in laying out ditch systems. A sufficient number of levels should be run to determine the general slope of the wet area. Where slopes exceed 0.5% the ditches must be laid out on the contour level. The ditching pattern is designed to avoid interception of natural channels except where desirable for circulating systems. Usually blocks are left between level ditches and the natural channels, but these are designed to allow flood or high tide flows into the ditches or else water circulation is regulated by means of control devices. As a rule, level ditches are installed at approximate right angles to natural channels.

Level ditches are generally constructed with a dragline or with ditching dynamite. Occasionally a backhoe or a bogharrow may be used. In the use of ditching dynamite, the supervision of a licensed and experienced explosive expert is recommended. When a dragline is employed for ditching, spoil material is stacked 3 m from the ditch edge in piles alternated from side to side at 15.2 m intervals. This spoil serves an important function in providing nesting areas. The breaks between piles are said to reduce nest predation. In small marshes ditching usually is done in straight lines or, where there is a slope, on the contour. Whether straight or curved, these ditches must not have a fall. On flat marshes exceeding 4 ha, the ditch is constructed in zigzag pattern, with each reach about 30.5 m long. Such a design reduces influences of wave action during high winds. Multiple ditches are laid out with parallel reaches 61 to 121.9 m apart.

Minimum dimensions recommended for level ditches are 1.2 m depth and 3.7 m top width. Such ditches provide, at intervals given above, about 275.5 square m of open water per ha.

PLUGS

Plugs are usually recommended for marshes where diking is not a feasible management tool due to either improper physical conditions of the area (size, location, water, or terrain) or economic reasons.

Plugs can prevent the fluctuation of water levels in existing water areas or increase the water area in the marsh. Various types of plugs as defined by the Atlantic Waterfowl Council (1972) include the following:

Nonspilling earth plugs are usually used to repair marsh damage caused by mosquito or other marsh drainage projects. The same principles are used as in building a dike across a tidal creek. The plug must be keyed in to both sides of the ditch and a good bond must be made between the fill material and the bottom of the ditch.

Nonspilling wooden plugs serve the same purpose as the earth plug type. Wakefield piling of creosoted lumber is used. Care must be taken to use piling long enough to prevent undercutting and the wing walls must be of sufficient length to prevent water from cutting around the end of the plug.

Spilling gut plugs are designed to reduce water fluctuations due to tidal action and thereby to make more food available to waterfowl for longer periods. The most common material used in this type of construction is creosoted lumber.

STRUCTURAL IMPROVEMENTS AND FACILITIES

Modern society creates a variety of structural improvements and facilities that affect wildlife populations. Most of these are built for other than wildlife management objectives, e.g., fences to control domestic livestock, bypasses for vehicular access on highways, etc. Since these structures are being built continually and design specifications can adversely or beneficially affect wildlife populations, techniques are provided stating how they can best be implemented with considerations for wildlife. Then too, there are certain practices needed in wildlife management, such as fences to control wildlife access.

Fences

Most fences are constructed today to control domestic livestock. However, fences are also constructed to restrict vehicular access on highways and other reasons. Fences have had their most serious impact on big game; consequently, techniques are listed on how best to construct fences to (1) allow wildlife movement through fences built to control livestock, and (2) design specifications that will control wildlife access.

LIVESTOCK FENCES AND PRONGHORNS

Fences constructed to control domestic livestock often have been documented as a problem to the free movement of antelope on western rangelands. Caton (1877) first noted this problem a century ago. More recently, wildlifers report (Martinka 1967, Sundstrom 1970, Oakley 1973) that fences can be major obstacles where antelope mobility is restricted to procure food and water, or escape deep snows.

During the 1960's, there was an accelerated increase in livestock fences constructed on western private and public rangelands. The effects of these fences was the subject for an in-depth research project conducted in Wyoming during 1963 and 1964. Results from this research provided scientifically designed and tested data regarding the interrelationships between pronghorns and livestock fences. However, the true importance of fencing to antelope mortality was not well accepted into the 1970's; consequently, a regional workshop pertaining to the problem was conducted during March 1974, in Cheyenne, Wyoming. Some 150 people representing state, federal, and private workers met to establish guidelines for the construction of fences in relation to the pronghorn's welfare (U.S. Bureau of Land Management 1974).

There are 2 major interagency conferences that periodically meet to exchange information and provide recommendations on pronghorn management. Relative to fences, each of these conferences documented their findings and recommendations in the following publications: Interstate Antelope Conference (1962) and Antelope States Workshop (1974).

It can, therefore, be stated that the controversy between livestock fences and antelope has been a long one with many studies and recommendations. Recognizing these interrelationship problems, the following are basic principles that should be considered during the planning of all fences in pronghorn habitat:

1. Any fence has the potential of becoming a problem to antelope welfare if the fence restricts access to food and water or causes physical injury through entanglement. These potential biological problems should be recognized during the initial planning justification for all fences in pronghorn habitat.
2. How the fence is specifically designed will determine the true effects the fence will have on the antelope population. A fence can be designed to allow no antelope movement; it can be designed to allow limited antelope movement; or it can be designed to allow easy movement for most antelope.
3. The design of the fence should allow for movement of all antelope age groups in order to maintain healthy populations. This is particularly important for fawns.
4. Fences that are constructed on migration routes or seasonal movement areas can be especially deleterious. Antelope traditionally need to have freedom of access from areas with deep snows. Likewise they need unrestricted access for seasonal movements to obtain water and preferred forage. They also need unrestricted routes to seek traditional fawning grounds.
5. Keep fenced areas as large as possible to allow antelope to obtain basic habitat requirements. Pronghorns maintain best populations on ranges where there is an abundance of forage and water with no undue movement restrictions.
6. Existing or planned fences constructed through traditional antelope migration routes or important seasonal movement areas should contain an alternative to use "lay-down panels" during time of antelope use. The choice of such an alternative decision means that these

panels must be properly maintained; otherwise, they may be ineffective and could be even disastrous to a population if not functioning during a crisis (e.g., extreme early season deep snowfall).

7. Although a number of devices known as "antelope passes" have been recently developed, they are a mitigating alternative and have limited value in providing movements for all aged pronghorns. This mitigating alternative needs to be recognized in the initial planning and justification of the fence project.

Net or Woven Wire Fences

Antelope workers are adamant in their professional opinion that net or woven wire fences are a serious restriction to movement of pronghorns. Such fences can be the primary cause of death for individual animals when deprived of access to waters or forage, or restricting herds when inclement weather conditions result directly in mortality. Therefore, it is strongly recommended that no woven wire fences be constructed in antelope habitat. This is especially true for the so called "wolf-proof" fences on domestic sheep ranges in New Mexico and Texas. These fences are constructed of woven wire (of which 15.2 to 45.7 cm is buried underground) and topped with 2 to 4 stands of barbed wire. Fence heights average 1.4 to 1.8 m. The objective is not to allow coyote access under, through, or over such fences. They also are 100% effective in preventing pronghorn access.

Barbed Wire Fences

1. The bottom wire should be at least 40.6 cm from the ground.

2. Because antelope generally go under barbed wire fences and the barbs can cause injury, it is recommended that this wire be smooth.

3. No stays should be placed between fence posts to provide a more flexible fence for antelope attempting to go between wires.

4. Spillett et al. (1967) documented that 81 cm high fences contained most livestock on rangelands. It is therefore recommended that this fence height be constructed on antelope rangelands. Antelope can and do jump fences in some areas, and the lower the top wire the better. This would also hold true for other wildlife such as deer, elk, and moose.

5. Based on findings of the "Regional Fencing Workshop" (U.S. Bureau of Land Management 1974), the following specifications for barbed wire fences on livestock ranges (see Fig. 20.37.) are provided:

Type 1: Ranges occupied by cattle only
3 strands of wire spaced at intervals of:
—bottom wire 40.6 cm from ground (smooth wire only)
—next wire (barbed) up 27.9 cm
—top wire (barbed) up 27.9 cm more for a total wire height of 96.4 cm from ground

Type II: Ranges occupied by domestic sheep only
4 strands of wire spaced at intervals of:
—bottom wire 25.4 cm from ground (smooth wire only)
—2nd wire (barbed) up 17.8 cm
—3rd wire (barbed) up 17.8 cm
—4th wire (barbed) up 20.3 cm for a total of 81 cm from ground

Type III: Ranges occupied by domestic sheep and cattle
4 strands of wire spaced at intervals of:
—bottom wire 25.4 cm up from ground (smooth wire only)
—2nd wire (barbed) up 22.9 cm
—3rd wire (barbed) up 22.9 cm
—4th wire (barbed) up 25.4 cm for a total of 96.6 cm from ground

Antelope workers would be quick to evaluate these fence specifications and to note that types II and III could provide limitations to easy movement of certain antelope age groups.

Antelope Passes

Standard cattleguards will allow the movement of adult antelope. Fawns, however, have difficulty in crossing them. They must be placed where antelope can readily locate them. Advantages have been realized by placing cattleguards in fence corners. The fences then act to "drift" the antelope to the pass opening. In long sections of fences, it is helpful to build a jog in the fence line for placement of the cattleguard. Care needs to be taken in locating the placement site to minimize the cattleguards filling with debris and silt.

Structures described as "antelope passes" were developed and tested in the Wyoming sheep-antelope-fence study (Spillett et al. 1967). Unfortunately few of these structures have been tested under range conditions. More recently, Mapston and ZoBell (1972) field tested one such structure in Wyoming. Their conclusion was that antelope passes are used but they have limited value in relation to properly planned and fully implemented range fences such as Type I in Fig. 20.37. Figure 20.38 depicts a 4–5 month fawn pronghorn negotiating one of these facilities. Figure 20.39 provides detailed plans for constructing antelope passes. After studying the effects of passes on antelope movements under field conditions, Mapston and ZoBell (1972) provided guidelines as to when they are advantageous and where they have limited values. Antelope passes can facilitate antelope movement through fences, but only when properly located and installed. For maximum effectiveness, passes should be placed in fence corners or offsets (see Fig. 20.40) and supporting fence post braces kept to a minimum. Although antelope have an innate jumping ability, it takes considerable time in certain areas for pronghorns to learn to use passes. The authors emphasized that passes have limitations and should not be viewed as a substitute for fences that permit ready passage of pronghorns. The manager responsible for making the decision as to whether a livestock fence should or should not be constructed should also consider the fence's effect.

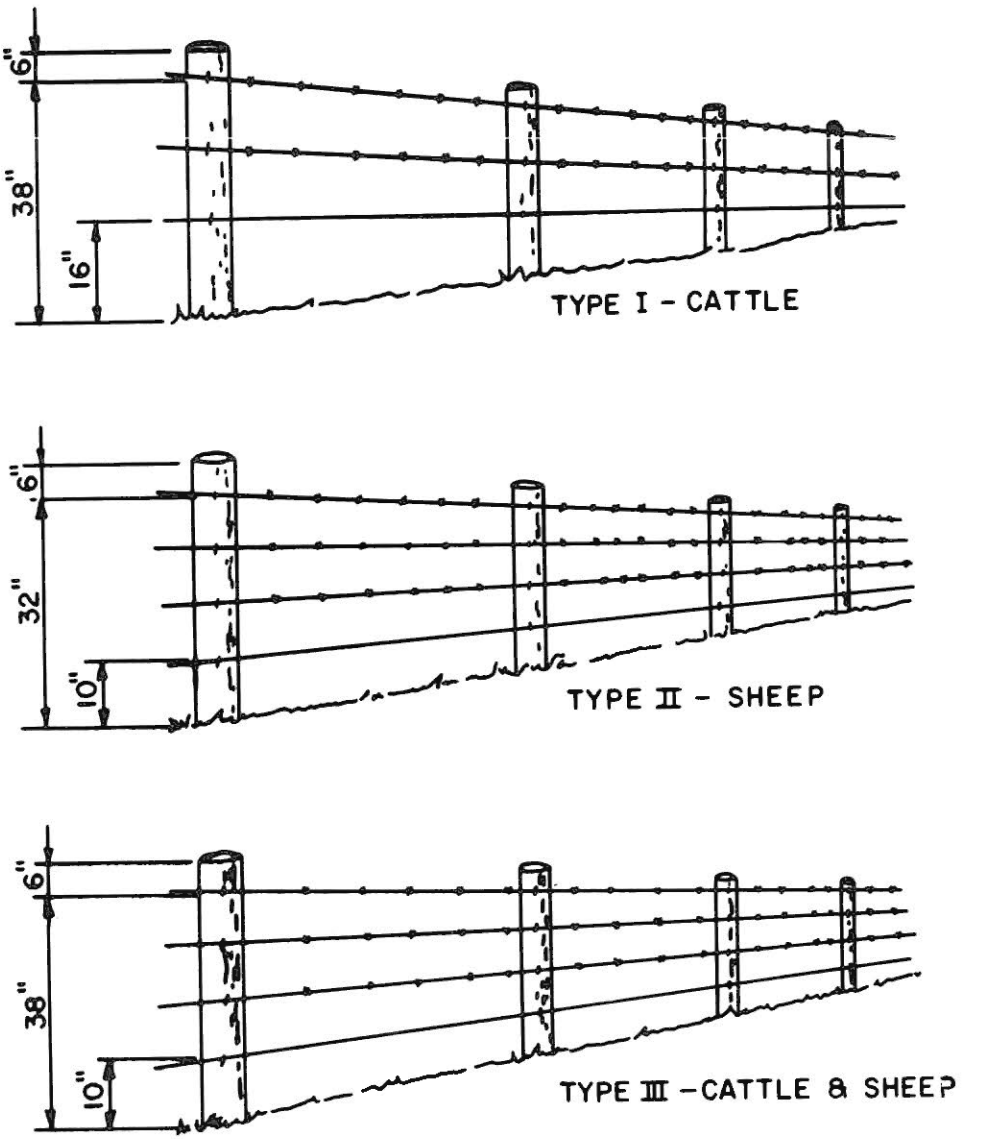


Fig. 20.37. Details of specifications for livestock fences constructed on antelope ranges as recommended by the Regional Fencing Workshop (U.S. Bureau of Land Management 1974).

Fig. 20.38. A 4-5 month fawn pronghorn leaps through a break in a livestock fence known as an "antelope pass" (U.S. Bureau of Land Management photo by Ray Mapston).

LIVESTOCK FENCES AND DEER

The interrelationships of domestic livestock fences and native deer have not raised the political furor that it has for the American pronghorn. However, throughout North America where livestock fences have been built, they have undoubtedly caused a far greater mortality problem to deer than they have to antelope. Deer are more subject to being victimized on an individual basis whereas antelope at times are entrapped in large winter concentrations. Then too, deer are frequently caught in fences in isolated areas not readily witnessed, whereas antelope mortalities in wide open country are easy to observe.

Deer characteristically jump over fences and this often leads to their demise. While the adult deer is jumping, its hind feet can become entangled between the top 2 wires of range fences. Such a case generally results in eventual death. A case investigated in north-

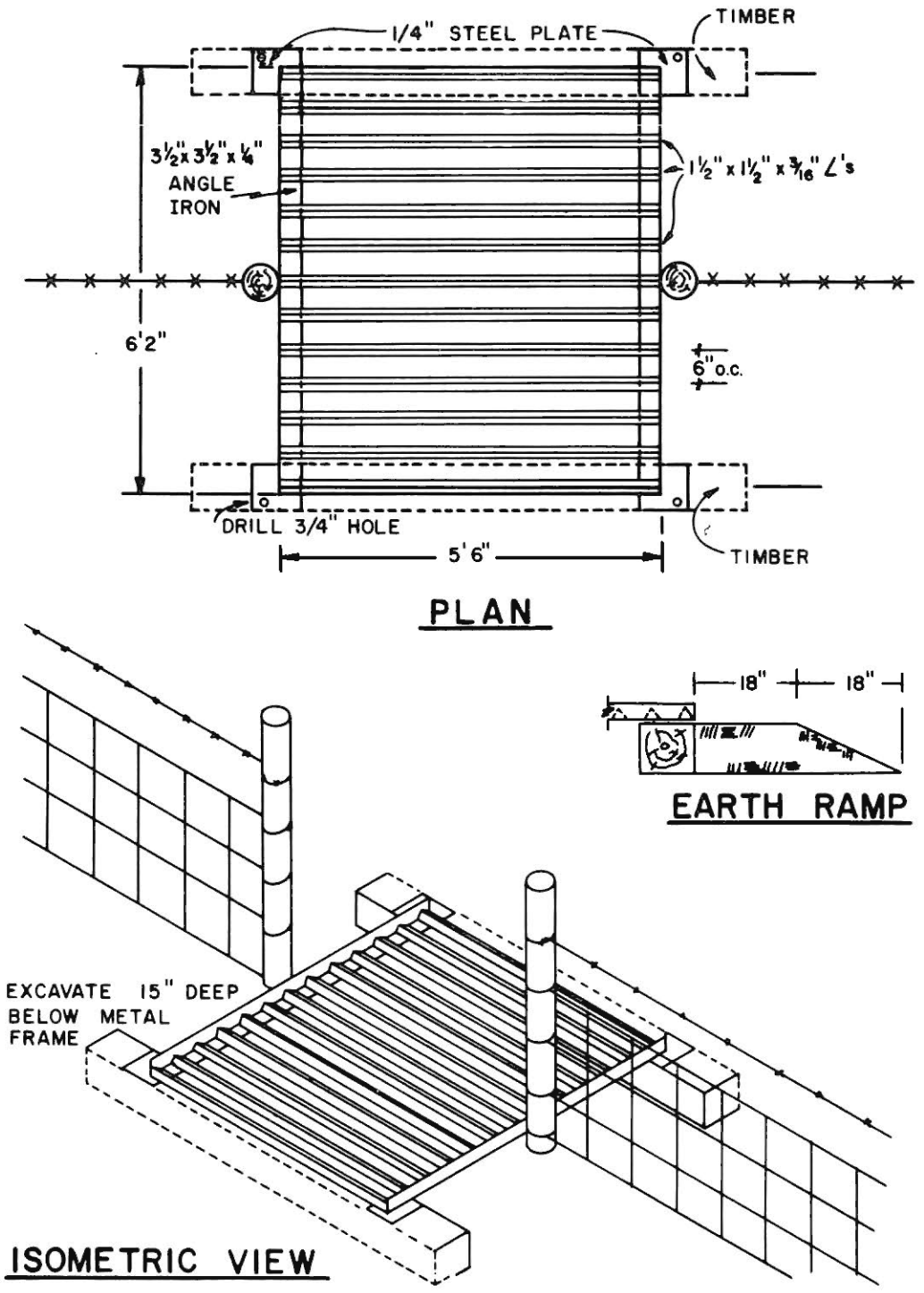


Fig. 20.39. Antelope pass specifications and recommended method of installation (Mapston and ZoBell 1972).

west Colorado disclosed a major deer death loss due to a combination 81-cm net wire and 2-stranded barbed wire fence. The 1.6-km-long fence was placed across a traditional migration route. For years the winter snows were not deep and no problems were recorded. Then during 1974, heavy snows fell. The deer migrated through the area as they normally did. However, the short yearling class of deer did not have the ability to negotiate the fence with a result of 12 perishing in the fence and some 50 others succumbing through entrapment.

Guidelines for Barbed Wire Fences

Nevada has experienced many cases where deer have become entangled in barbed wire fences. Recognizing this problem, state and federal wildlife managers designed a barbed wire fence best adapted for deer ranges. It stresses 2 major points: (1) keep the bottom wire up to allow movement of fawns, and (2) keep the top wire down to allow ease for jumping over. Figure 20.41 provides a schematic drawing for this specially designed

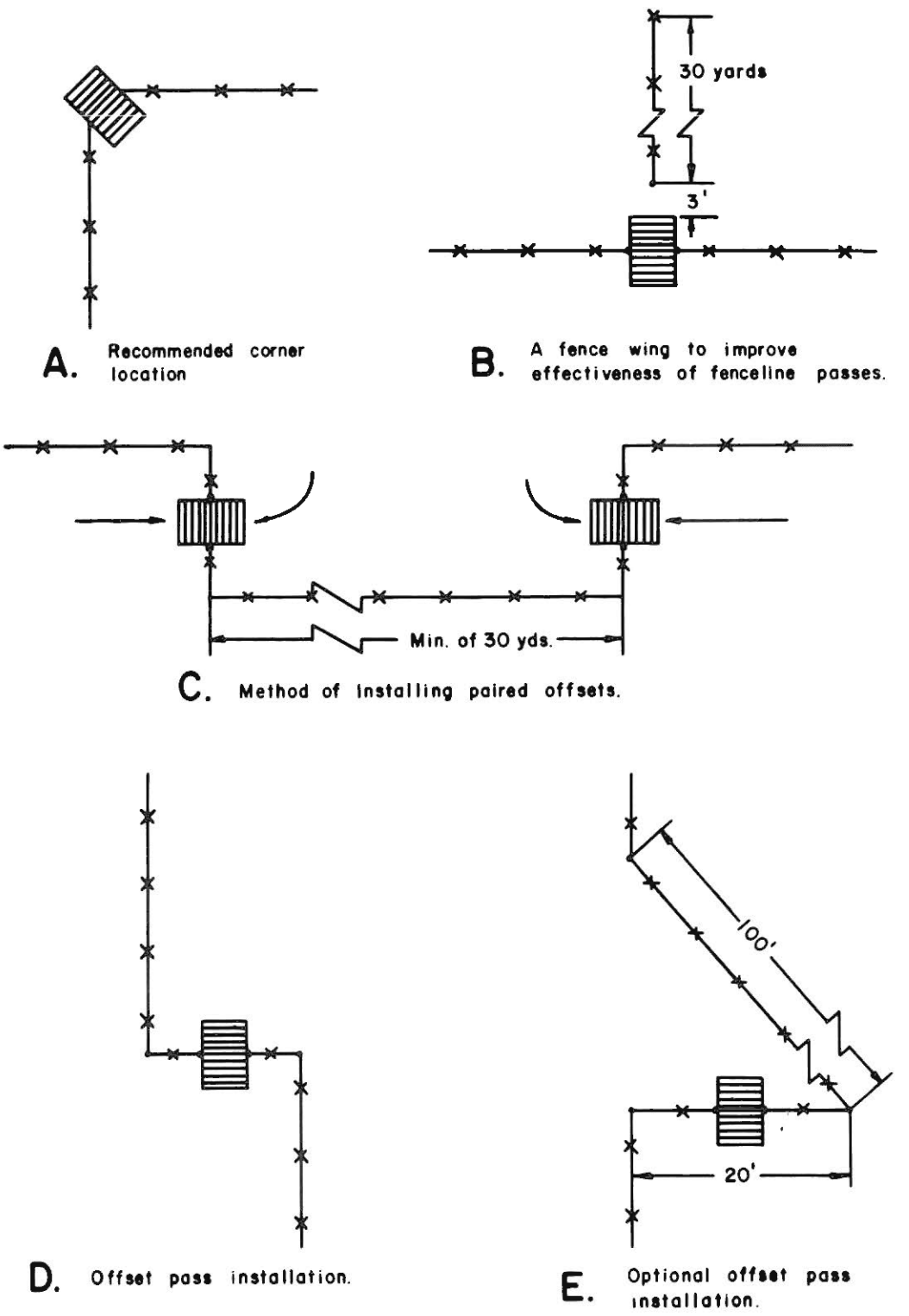


Fig. 20.40. Recommended methods for installing antelope passes (Mapston and ZoBell 1972).

deer fence. Note these specifications designed for deer requirements:

1. Bottom wire up 40.6 cm from ground—thus allowing for movement of fawns.

2. Only 3 strands of wire required. Fences were constructed on large open rangelands where livestock were not restricted. Under these circumstances, 3 wires are all that were needed to control cattle.

3. Top wire is smooth and 91.4 cm from ground, thus allowing deer greater ease in jumping over the fence.

4. Stays are placed between fence posts. Since deer frequently become entangled when the top 2 wires twist

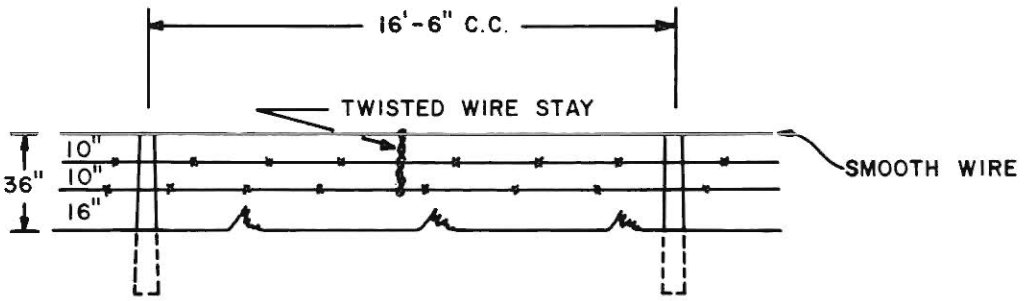


Fig. 20.41. Recommended specifications for construction of a barbed wire fence for cattle control allowing deer access.

around the legs, the stays make a more rigid fence, thereby allowing the animal a better chance to wiggle out of the fence.

Managers should recognize that these fence specifications are adequate to control livestock for open range conditions. Where livestock concentrate around water or adjacent fields of lush, preferred forage, these specifications will be minimal and not always adequate; however, most range fences do not face these problems and therefore the specifications can be applied in more cases than not. Because deer characteristically jump over fences and frequently become entangled in the top wire, a smooth wire would decrease physical injuries.

Two fences were tested with these specifications in Nevada for the past 6 years. In each case, the fence adequately controlled livestock and decreased the incidence of deer entrapment. Based upon information gained from this field management study, other fences with these specifications to control livestock on important deer ranges have been constructed on western rangelands by the U.S. Bureau of Land Management.

FENCES FOR CONTROLLING DEER

Properly constructed fences can provide good protection against deer depredations to various agricultural crops, high concentration winter ranges, and areas of timber reproduction (Longhurst et al. 1962). Although the initial cost of installation of fencing for depredation controls is often high and continued maintenance is necessary, the expense can, in many cases, be justified.

Fences can provide economic protection against damage that deer can cause to high-value crops. Deer control fences are also being constructed for the purpose of rotating deer use of forage in range pastures on critical winter ranges in California, Colorado, and Washington. Under most circumstances the upright style of fence has proven most satisfactory, but under some conditions the slanting fence is cheaper to construct and is advantageous because of its lower height. Specifications for both fence types are presented here as adapted from Longhurst et al. (1962). The use of electrical fences has been a third technique used to a limited degree in deer habitat control.

Upright

While a height of 1.8 m is usually adequate for upright fences on level ground, a 2.4-m fence may be necessary against larger deer (Fig. 20.42). Deer normally will not jump a 1.8-m fence for food, but if pressed they can jump a 2.4-m fence on level ground. When fences are located on sloping ground, it may be necessary to build them 3 m or 3.3 m high to guard against deer jumping from above.

Woven mesh wire is preferable for the full height of the fence; if economy is necessary, 2 or more strands of 9- or 10-guage smooth wire can be stretched at 10.2- to 15.2-cm spacings above a 1.5-m mesh wire. There is no advantage in using barbed wire for this purpose, and it is more costly. Welded mesh wire is less expensive than woven, but it is too rigid to conform readily to irregularities in the ground surface and is most useful on even ground. Wire lighter than 12½ gauge is not recommended. Vertical stays should not be over 15.2 to 20.3 cm apart, and line wires not over 10.2 to 15.2 cm apart. Because deer will crawl under a fence when possible, mesh wire should be secured and kept close to ground level. An extra strand of barbed wire stretched along the ground will help prevent them from crawling under. In any depressions between posts, wire should be staked firmly to the ground or depressions should be filled with materials which will not deteriorate or wash away. A 0.9–1.2-m piece of angle-iron post makes a good permanent stake to hold wire close to the ground.

Wooden or steel posts may be used, the choice depending on availability and costs. Wooden posts are usually somewhat cheaper, with sawed ones being more expensive than split posts. Their dimensions at the ends should not be less than 10.2 to 12.7 cm across. If fences are to be moved from time to time, steel posts are preferable because of the greater ease with which they can be installed and removed. Steel posts can be purchased in 3 types: T-shaped, channel, and angle. The T-type is more rigid and is perhaps preferable, with channel next and angle last in order of strength; prices also decrease in that order. Posts should generally be set about 3 to 3.7 m apart, but extra posts may be necessary to hold the wire to the contour of uneven ground. When building with steel posts it is often advisable to intersperse them with wooden posts in order to strengthen the fence—1 wooden post for every 3 to 5 steel posts is the approximate ratio. Proper bracing along fence lines is important to give sufficient strength. Wooden corner posts should be at least 15.2 cm across the ends and are preferable to steel posts unless the latter are in concrete and are well braced.

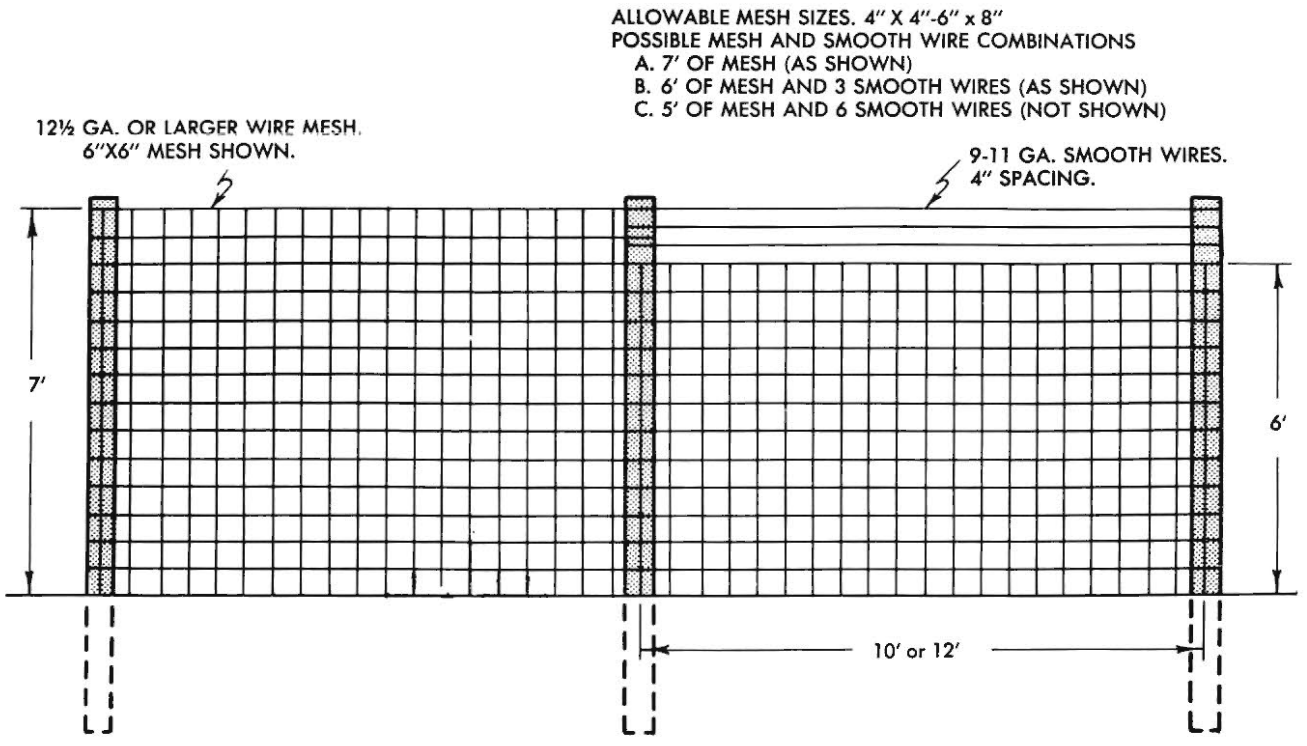


Fig. 20.42. Drawing showing 2 methods of using wire, either mesh above or combinations of mesh and smooth, to construct an upright fence for controlling deer damage (Longhurst et al. 1962).

With upright fences the gate height should be approximately equal to fence height. Weight should be kept to a minimum. A light wooden frame over which mesh wire is stretched is often satisfactory. If factory-made aluminum gates are used, metal extensions may be bolted or welded on and mesh wire stretched over them. It is always advisable to sink a metal or treated wooden base frame in the ground below the gate to give a uniform surface and to prevent deer from working under the gate.

In Colorado, a 3-m-high upright fence was constructed to control deer movements on a rotational basis for a key winter range. The fence was effective in controlling both deer and elk movements. The fence was also effective in increasing plant diversity and abundance through controlled use of big game foraging (J. Clark, pers. comm.).

Overhanging or Slanting

This type of fencing is less expensive to construct than upright fencing because fewer and shorter posts are needed and lighter gauge wire can be used. Slanting fences are particularly suitable for temporary fencing, as the few posts can easily be removed and the wire more readily rolled. This type of fencing is also suitable for locations where an upright fence would be unsightly or otherwise unsuitable.

Slanting fences are believed to be effective because they act primarily as a psychological barrier to deer. Deer usually first try to crawl under such a fence and then, finding this impossible and with the wire extended above them, they are discouraged from jumping. For this reason slanting fences are effective in 1 direction only. Overhanging woven wire mesh fences are not recommended in heavy snowfall areas since the fence is subject to being crushed by the settling snow pack. Under such circumstances the fence can be modified by using smooth wires stretched horizontally at 10.2-cm spacings.

The basic design for the slanting fence consists of approximately 1.8 m of mesh wire supported by a guy wire stretched between widely spaced posts (Fig. 20.43). The high side of the fence is the side away from the area to be protected.

For temporary installations, light chicken wire or stucco mesh may be used. For permanent installation, wire no lighter than 12½ gauge is advisable. If woven wire is used, vertical stays should not be over 15.2 to 20.3 cm apart and horizontal line wires should not be over 10.2 to 15.2 cm apart with 1.8-m steel posts recommended and spaced up to 9 to 12 m apart.

A hinged gate is needed if there will be considerable traffic. Adequate side wings should be provided (Fig. 20.44). If little traffic is expected, a panel consisting of a light wooden frame with wire mesh stretched over it is often satisfactory. For easy access where no gate is needed, a stile is simple to construct.

The California Department of Fish and Game (Blaisdell and Hubbard 1956) used this type fence to control deer use of game range vegetation study plots. They found slanting fences (also termed outrigger type deer fence) controlled deer entry whereas regular barbed wire was inadequate. The authors suggest that this fence technique could have values for protecting haystacks, orchards, gardens, and other places where extensive

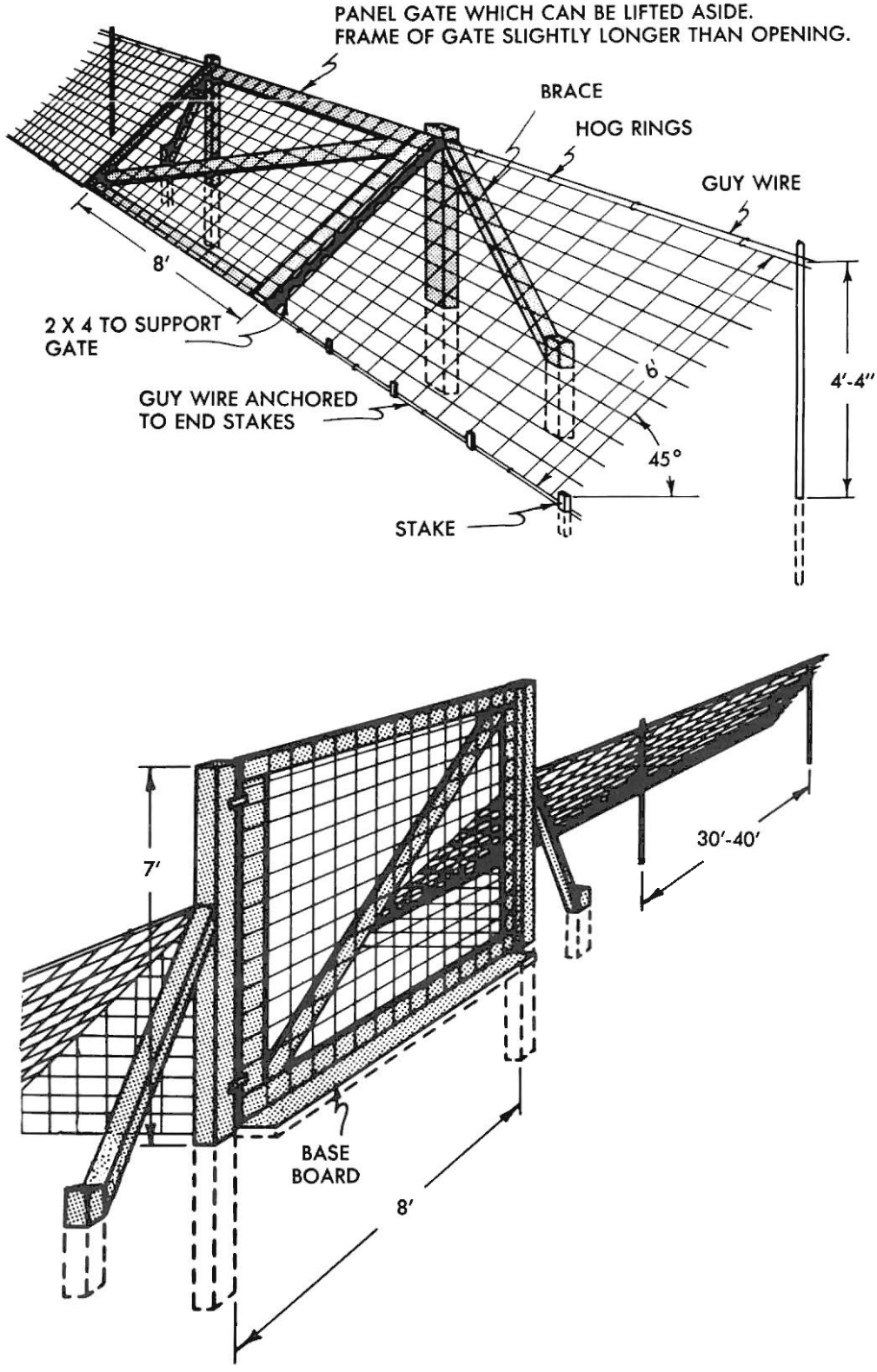


Fig. 20.43. Typical slanting deer fencing with examples of placing the gates either slanting or vertical (Longhurst et al. 1962).

fencing is not needed. Fig. 20.45 depicts an outrigger fence on site to control deer access on key winter ranges near Bishop, California.

Working in South Dakota, Messner et al. (1973) modified the slanting fence described by Longhurst et al. (1962) with several major improvements (Fig. 20.46). These changes included less mesh wire and shorter posts, both contributing to a less expensive structure. The authors also credit their design as blending well into forest and meadow environments and capable of

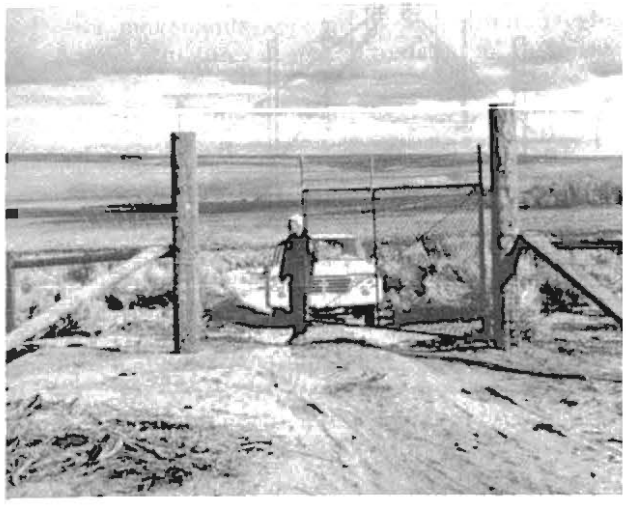


Fig. 20.44. Hinged gate for an upright deer control fence (U.S. Bureau of Land Management photo by Jim Yoakum).

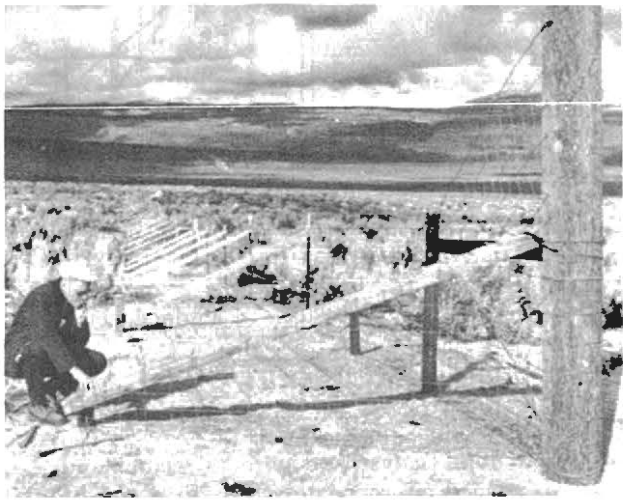


Fig. 20.45. "Outrigger" fence used to control deer movement on rangelands in California (U.S. Bureau of Land Management photo by Jim Yoakum).

withstanding greater snow loads than other designed slanting deer fences. During 5 years of testing, white-tailed deer and livestock were successfully excluded by this slanting fence.

Electric

Experience has shown that electric fences can be used for deer control. The standard electric fence design used for livestock, however has proven unsatisfactory at times for big game control in parts of the West and Southwest. This is generally during the dry season when lack of moisture in the ground prevents good grounding of current. Researchers in California found that the use of 2 rows of posts and ground wires with leads deeply imbedded in the ground worked best (Longhurst et al. 1962). Fig. 20.47 depicts how the double electric wire fences were used in California.

Managers in Virginia had better experiences with electric fences controlling deer damage to agricultural crops. Here too, the conventional 1-wire fence used to control livestock was not effective for deer. However, with new designs specific for deer management, the electric fence proved effective in reducing deer foraging (Myers 1977). Myer's recommendations for electric fence are:

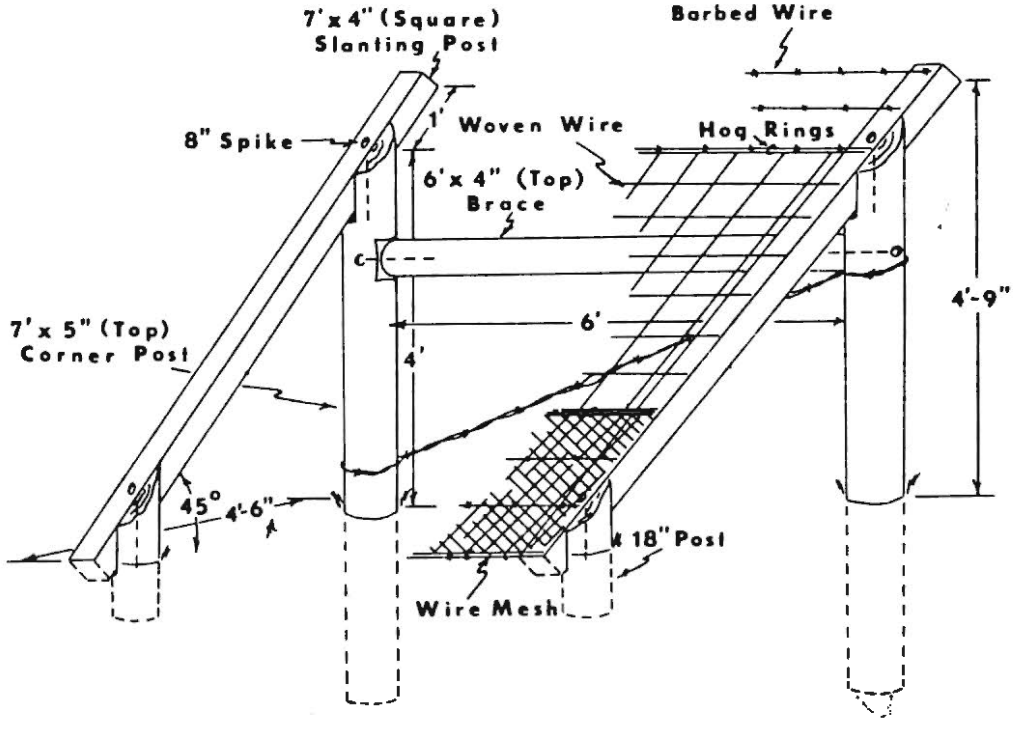


Fig. 20.46. Modification of slanting fence developed in South Dakota (Messner et al. 1973).

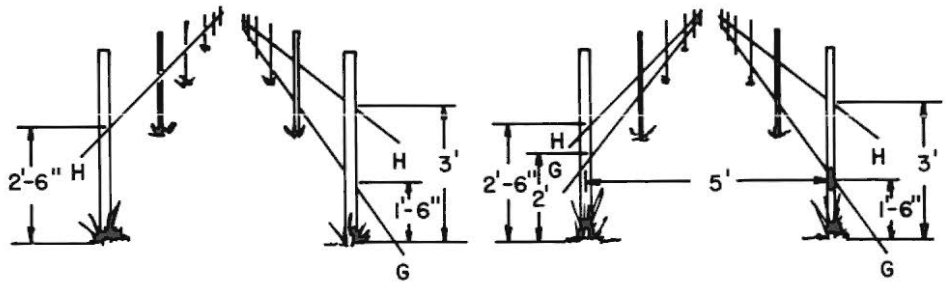


Fig. 20.47. Plans for double electric fence to control deer (Longhurst et al. 1962).

In construction, three strands of 12 or 14-gauge, smooth type, galvanized wire is recommended. Posts spaced approximately 9 m apart can be of either metal or wood with 1.5 m extending above ground level. Corner posts need to be braced properly and all posts must be placed deep enough in the soil to hold wires securely. Measuring from the ground, the bottom wire is attached 45.7 cm up on the post. The second wire is spaced 45.7 cm up from the bottom wire, and the third wire another 45.7 cm higher. This results in a fence that is 137.2 cm high from ground level to the top wire. Either plastic or porcelain insulators can be used. The porcelain insulator is recommended, as the wire can be wrapped around the insulator when needed and does not cut through to cause shorting out when pressure is applied. All three wires are charged with a controller (or box) that operates from 110 volts which must be properly grounded. An electric fence tester is also recommended for checking the fence to assure that it is operating properly. The ground underneath the fence has to be mowed and maintained to prevent electrical short circuits or grounds caused by growing vegetation. Spring type gate hooks can be used for access into the fenced area. It is also recommended that the fence be set away from the area to be cultivated to allow for the operation of equipment.

Gates

Sometimes it is desirable to permit deer to move through a deer-proof fence in 1 direction only. An example would be when a deer has entered a highway and needs to get back through the right-of-way fences. To meet this situation a "1-way deer gate" (Fig. 20.48) was developed and tested in Colorado (Reed 1971). The rationale for this gate is that deer would jump through heavy brush. When tested in the field, several 1-way gates on a major highway were used by deer a total of 146 times during the 1976 spring and fall migration.

The 1-way deer gate is now being used in various parts of the country. Its value has been varied depending on where the installations were made. One point is apparent to date—the device does have some limited value in meeting its objectives; however, in other areas it has received very little use and should be so realized when planning.

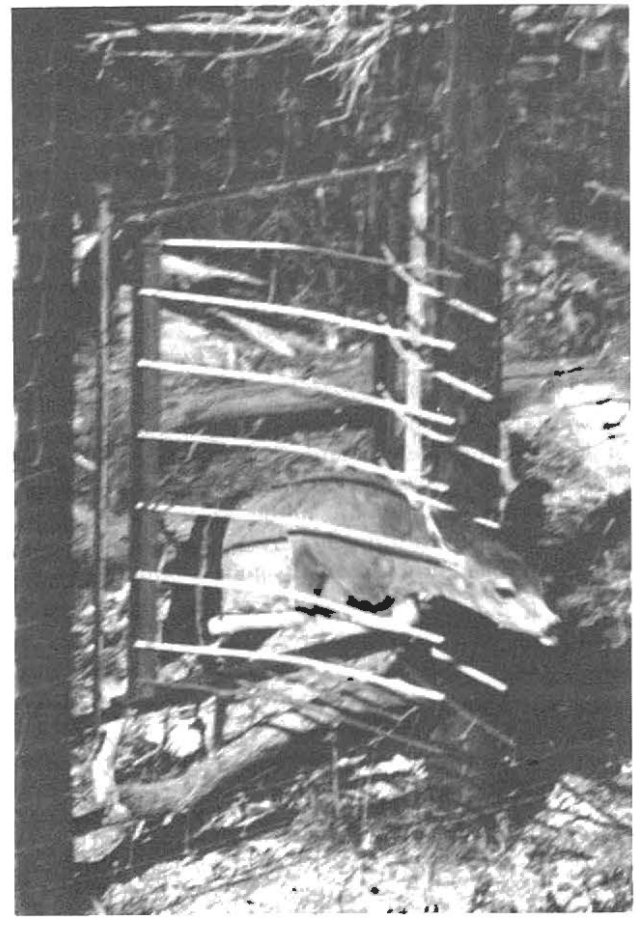


Fig. 20.48. A mule deer passes through a 1-way deer gate constructed in Colorado (Photo by Dale F. Reed).

Guards

At times it is necessary to allow easy access of vehicles through deer-proof fences. This has resulted in recommended deer guards similar to cattle guards constructed on range fences for years. Deer guards are similar to the cattle guards in structure, but generally are longer to limit deer crossing (Longhurst et al. 1962). Working in Colorado, Reed et al. (1975) tested deer use of 3.7-, 5.5-, and 7.3-m guards. Their findings substantiated that little advantage was gained by extending the length of guards for deer; when these animals were motivated, they walked, trotted, or bounded across the guards. Conse-

quently, the use of modified deer-cattle guards to control deer movements appears to have limited value, based upon structures designed to date.

Interstate Highways

Movement of big game over country roads and low standard highways has not been a serious problem. Normally, barbed wire fences previously described are used on most rights-of-way. Leedy et al. (1975) published 2 lengthy volumes containing extensive literature reviews on highway-wildlife relationships and suggested research and management approaches to protect and enhance environmental quality for wildlife habitats. These reports are especially timely because currently there over 10 million hectares in highway rights-of-way. The authors cited various reports on practices including fencing, underpasses, traffic warning signs for animals, and other measures.

FENCES

With the creation of the federal interstate highway system, a serious problem has developed. Highway construction is cutting across important big game migratory and access routes. It is important to maintain these big game travel routes, yet the human hazard caused by animals seeking to cross high-speed highways also must be given consideration. When fences are constructed to reduce hazard to life and property on super-highways, alternate methods of allowing game to cross need to be devised. Otherwise, highway fences can have a serious detrimental effect on big game. In some instances, migratory habits may be impeded sufficiently to eliminate a complete big game herd. Mitigation of wildlife losses due to fence barriers must be done through state wildlife agencies. The following approaches to the problem should be considered:

Traversable game fences are described in this section in "Guidelines for Barbed Wire Fences." These fences will hold livestock but will allow game relatively free crossing. They should be used only in areas of light automobile traffic and in stretches where there are no center or island fences. They should be wide enough to allow game to make crossings without entrapment.

There are many areas where game normally winter or summer adjacent to interstate highways. While highways present no barriers to wildlife, the 2.4-m high woven wire fences used in some areas not only block game from crossing the right-of-way, but commonly entrap animals that manage to get inside. Also, in narrow canyons, interstate highways sometimes abandon the separate opposite lanes of traffic and place roadways adjacent to one another, separated by a chain-link fence to reduce collisions and headlight glare. The fence may or may not have a space at the bottom and may exceed the maximum height game animals can jump. This type of fence not only creates an unnatural barrier to wildlife, but a hazard to the driving public as well, because it holds animals in the traffic zone. For such cases as this, the manager may consider the "1-way deer gate" referred to under "Gates." Where chain link fences are used, a 10.2 cm space should be left on the bottom to allow small animals to cross. The maximum height should not exceed 1.0 m where consistent with highway needs.

Regelin et al. (1977) experimented with snowfences to relocate snowdrifts to influence forage availability. Snowfences reduced snow depths in shrub stands so that deer could use them and created drifts deep enough to protect overused and newly seeded areas from grazing by deer.

OVERPASSES

Underpasses and overpasses will need either natural terrain or else wing fences to guide and funnel migrating animals to them. Research in Colorado showed that underpass openings 4.3 m square with dirt floors were accepted by mule deer (Reed et al. 1975). Small skylights or artificial lights were not necessary for deer to use the underpass. Overpass use by game shows a marked reduction as the structures increase in length or decrease in width. Fenced wings to guide big game to these structures have been used with some success, but more study is needed to discover ways of improving their effectiveness.

Power Lines and Raptors

The problem of hundreds of raptors being electrocuted by electric distribution lines became a national conservation issue in the 1970's (Olendorff and Kochert 1977). The problem is greatest in the western United States. Nelson and Nelson (1976) documented that for 1974, over 300 eagles were electrocuted in the U.S. The count showed 98% were young birds just learning to fly. The young birds lacked skill necessary to land smoothly on power lines and were electrocuted.

Efforts to decrease this mortality problem were accelerated in the last decade. State and federal wildlife agencies pooled their biological knowledge with power company's engineering technical skills. The result was the development of several guidelines on how best to construct power lines to minimize electrocution of raptors. These are well documented and available through the U.S. Rural Electrification Administration (1972) and the Raptor Research Foundation (n.d.). Since there are many different power line designs and corrective measures need to be specific to the problem line, the manager should consult with these sources or other specialists.

Two examples of habitat improvements recently developed to enhance power lines for raptors are nesting platforms and wood perches. Nesting platforms are discussed in detail under "Specialized Nest Structures." Figure 20.15 is an example. Wooden perches are structures added 0.9 m above power lines. These have been well used as preferred landing sites by eagles and other raptors (Nelson and Nelson 1976). Figure 20.49 depicts how these perches are mounted. It is estimated that 95% of raptor electrocutions can be prevented by correcting 2% of power line poles. The authors also stated that power line poles properly constructed are a means of improving raptor habitat, for they are often constructed in vast open areas of the West, lacking cliffs or trees. Consequently, the raptors use power line poles for hunting, feeding, and nesting sites.

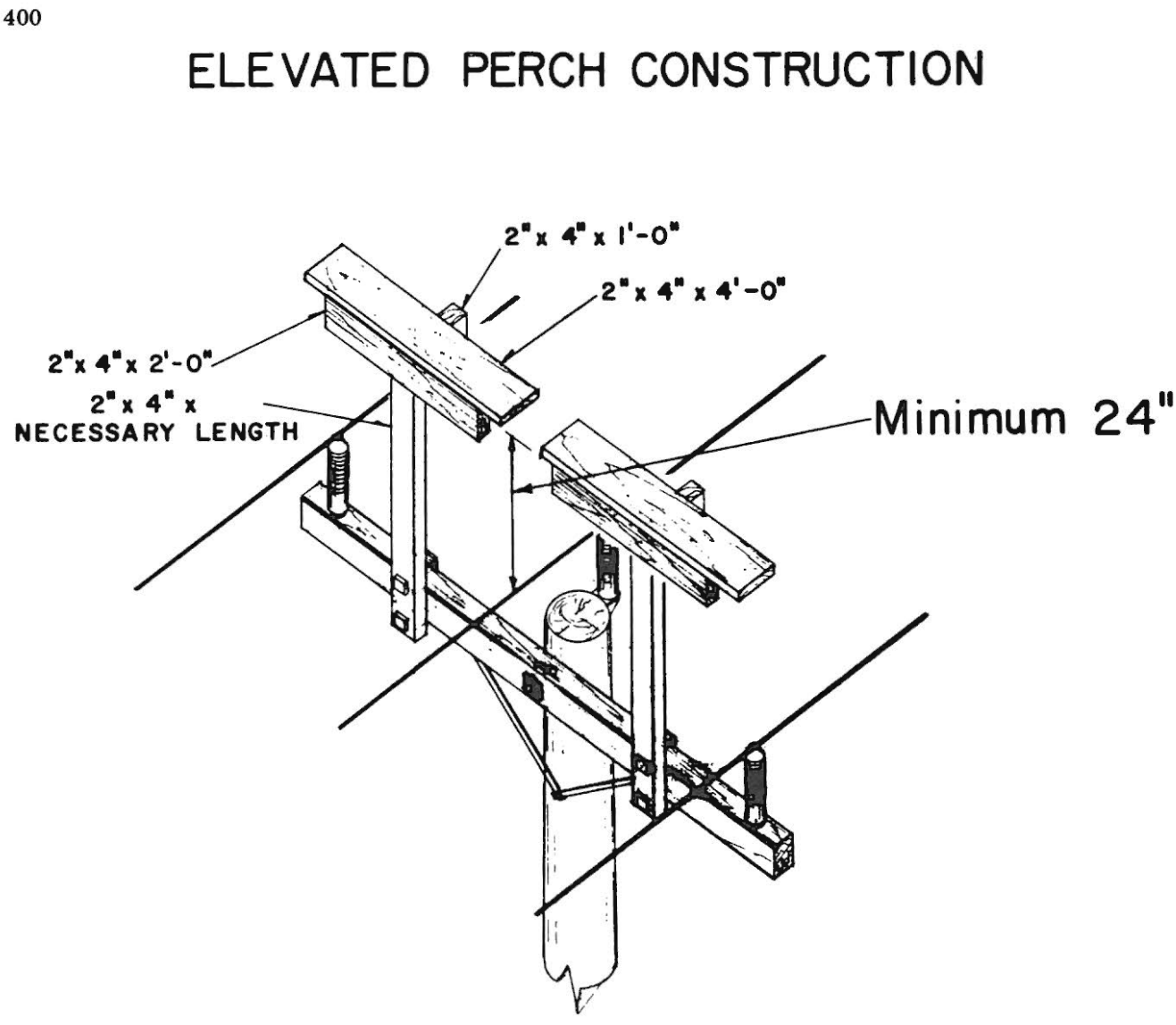


Fig. 20.49. Plans for perches on power lines to help reduce cases of raptor electrocutions (Nelson and Nelson 1976).

Study Exclosures (Big Game)

Exclosures are constructed for a number of purposes, but are mainly used to exclude or control livestock or big game use within the fenced area. These exclosures provide a basis for comparison of grazing or browsing with that on adjacent open range. Exclosures also serve as a method to determine proportionate use on ranges grazed by both big game and livestock.

Permanent exclosures should not be less than 0.4 ha in size—1 to 2 ha are frequently more desirable. Extra strong construction is needed on all parts of the fence to withstand heavy pressure by animals against these small, fenced areas of better forage. Gates should not be constructed in exclosure fences. Stiles, steps, or ladders will provide access to the plot.

Three-way exclosures are often used to compare big game and livestock use of vegetation in an area (Fig. 20.50 and 51). These exclosures are constructed with 2 fenced plots and 1 unfenced or open adjacent control plot. They are generally not less than 0.4 ha each. One fenced exclosure (a) is game and livestock-proof; the second livestock-proof (b) but readily accessible to game. The third plot, (c) or control, is established on open range nearby. This unfenced control plot (c) should be an equal-sized area marked on the ground. The following specifications apply to the fenced plots.

A 2.1-m high fence usually is adequate to exclude both elk and deer. However, if the exclosure is so located, or of such a size that it forms a barrier to concentrated game movements, the fence should be at least 2.4 m high. If areas subject to drifting snows cannot be entirely avoided, it is necessary to construct a higher fence through the drift zone. Fences should not be located on steep ground unless necessary. This will minimize the influence of water drainage from outside the plot.

A square exclosure with wire fence 2.1 m high with 64 m on all sides, will enclose about 0.4 ha and will require the following materials:

20 corner wooden posts	15.2-cm diameter at small end and 3 m long, peeled and penetrated
48 steel line posts	"T" stud, 3 m long

16 line wooden posts,	15.2-cm diameter at small end and 3.0 m long, peeled and penetrated
8 braces, horizontal	12.7-cm diameter at small end and 2.4 m long
8 braces, diagonal	12.7-cm diameter at small end and 3.1 m long
2 spools, barbed wire	80-rod (401.6 m) spool
No. 9 smooth wire, galvanized	91.4 m
9.1 kg staples	3.8 cm
1.8 kg nails	40 d.
hog wire	1.1 m, galvanized, 256 m
Rabbit-proof wire	5.1 × 10.2 cm, galvanized, 256 m
200 hog rings	Heavy duty, galvanized

The livestock-proof plot (b) will be enclosed with 1.0-m fencing; 4-m spacing between posts (64 m to a side). On livestock range, 4 barbed wires shall be spaced 12.7, 28, 45.7 and 66.1 cm from the ground with a smooth wire on top, 25.4 cm above the top strand of barbed wire.

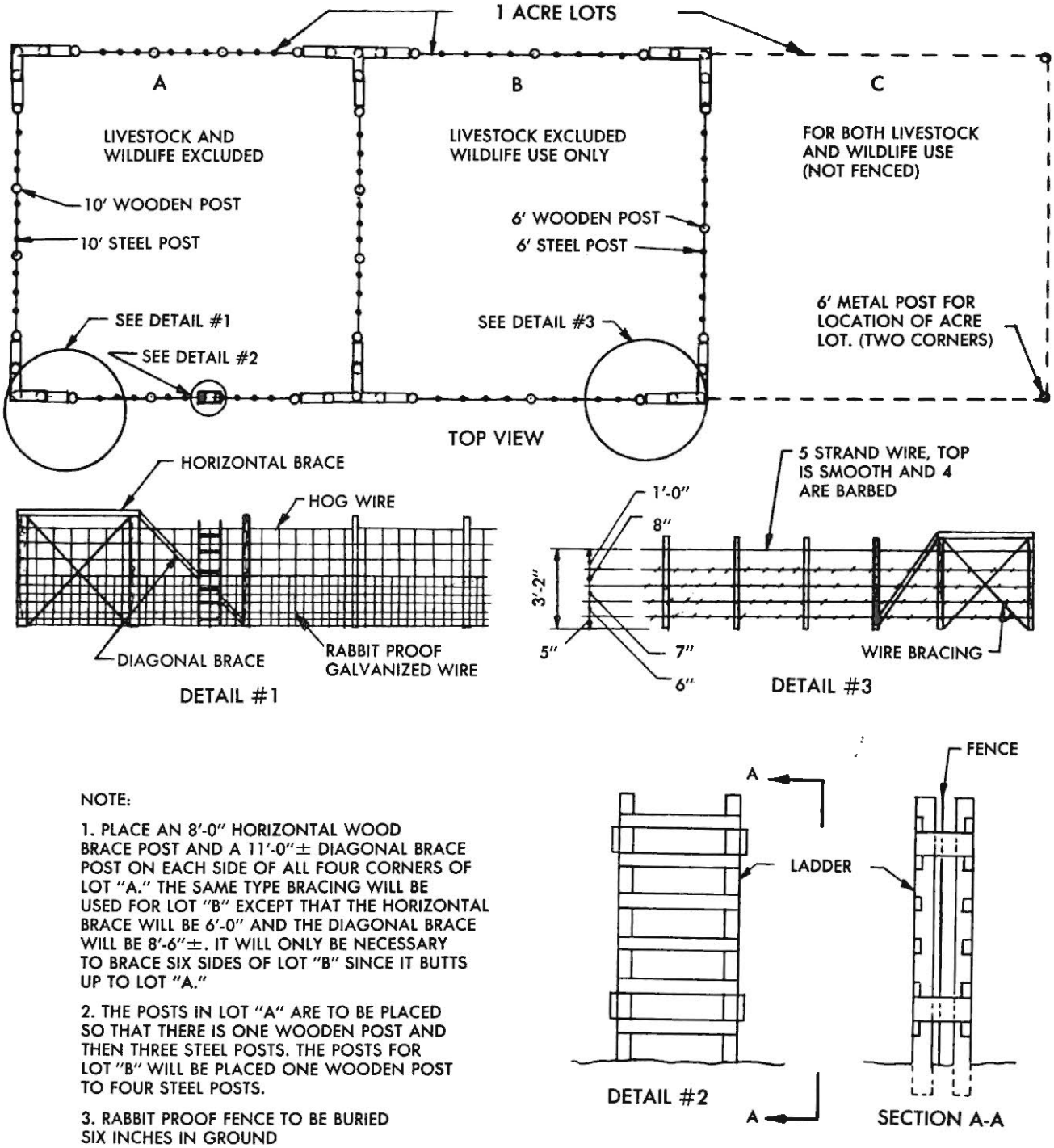


Fig. 20.50. Plans and specifications for the installation of a 3-way wildlife-livestock exclosure.

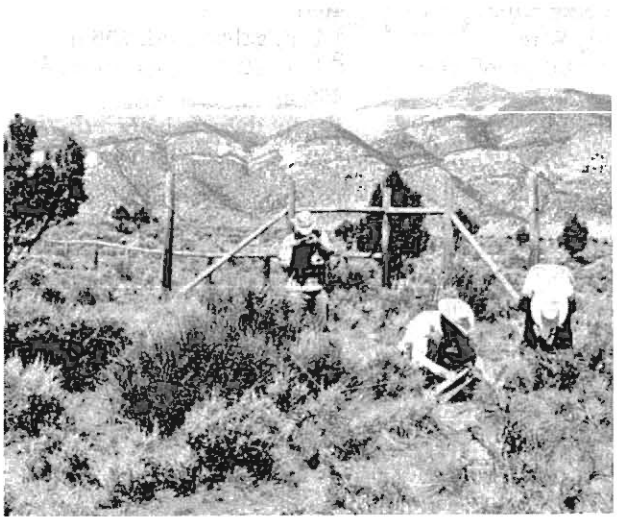


Fig. 20.51. Collecting forage production data on a 3-way Wildlife lifestock exclosure (U.S. Bureau of Land Management photo by Jim Yoakum).

The following is a bill of materials for a livestock-proof plot having 1 side in common with a game and livestock-proof exclosure:

8 corner wooden posts	15.2-cm diameter and 1.8 m long, peeled and penetrated
6 brace posts	15.2-cm diameter and 1.8 m long
6 wood line posts	15.2-cm diameter and 1.8 m long
36 steel line posts	"T" stud, 1.8 m long
2 spools barbed wire	Standard (12-½ gauge, 2 points), 80-rod (401.6 m) spools
2.3 kg staples	3.8 cm
0.9 kg nails	40 penny
No. 9 soft smooth wire, galvanized	24.4 m

A ladder should be constructed in 1 corner of the plot with the high fence to facilitate workers access in and out.

Consideration should be given to the construction of a large attractive sign denoting: (1) name of exclosure plot; (2) brief statement on purpose of plot; and (3) a list of cooperating agencies responsible for construction.

Plot (c) should have 2 steel 1.8-m stakes placed at the 2 exterior corners for location purposes. In some areas, it may be desirable to construct buck pole fences or worm fences around exclosures.

SUMMARY

This chapter on wildlife habitat improvements has set forth numerous ideas and suggestions on how to manipulate food, water, cover, and living space for the benefit of wildlife. Techniques will, of course, vary throughout the regions of North America; however, below is a list of the main principles and methods:

1. Develop "edge" because many wildlife species are a product of the places where 2 habitats meet. Examples are the borders of woods, fields, ponds, orchards, meadows, rivers, potholes, marshes, brushlands, clearings, and swamps.
2. Maintain mast trees. For oaks, 112 kg of mast per ha is needed to sustain reasonable wildlife densities or 5.7–6.9 m^2 of basal area per ha for trees old enough to produce seed (25.4 + cm dbh). For hickory and beech 0.7–1.4 m^2 per ha has been recommended.
3. Encourage fruit trees; also woody cover in hedgerows and fence rows.
4. Discourage fall plowing of harvested grain crops. Encourage sharecropping agreements.
5. Favor trees and shrubs with high wildlife values, especially heavy seed-, berry-, and fruit-producing species like autumn olive, Russian olive, dogwood, and thornapple.
6. Erect wood duck nest boxes in suitable sites, 5–9 per ha.
7. Erect 2–3 squirrel nest structures per ha in forests and woodlots lacking tree cavities but having a minimum of 5–7 mast-producing trees per ha.
8. Erect nest structures for kestrels on barns and trees near open fields, for screech owls erect nest structures in parks or forest edges.
9. Favor tall trees, especially clumps of trees, for eagles, ospreys, other hawks, and heron nest sites in areas where these species are nesting.
10. Save 5 to 9 den trees per ha in wooded areas for cavity nesting birds and mammals such as woodpeckers, squirrels, and raccoons.
11. Construct brush piles where needed for protection and nesting sites.
12. Leave nesting cover undisturbed wherever practical, i.e., plow land before nesting; mow after nesting is over.
13. Allow natural succession to revegetate areas not suited for farming or plant them to trees, shrubs, and permanent cover crops to intersperse cover types.
14. Maintain existing low-growing shrubs for natural food and cover.
15. Establish living hedges around field boundaries to reduce soil erosion and provide nesting cover, travel lanes, and food. Use native plants when possible.
16. Establish windbreaks along roads, around homesites, and between fields and crop strips.
17. Establish and maintain openings in woodlands and brushfields. Coordinate with other resource activities when possible: tree harvesting, range improvement, and fire control. Use prescribed burning, selective spraying, or sharecropping as often as possible.
18. Seed roadside ditches and waterways with suitable grasses and legumes for nesting cover in intensively cultivated areas. Maintain seedings by mowing in late summer after nesting is completed.
19. Encourage sedges and rushes in marshes and sloughs.
20. Encourage the use of native plants for highway borders, median strips, and interchanges, as well as fence corners. In the Midwest native grass plantings can be maintained by spring burns at 3–5 year intervals.

21. Keep certain fields open on old farmland by mowing hayfields or keeping certain areas in cultivation.

22. Vary cover as much as possible. The more varied the cover, the more wildlife.

23. Mix small plantings (0.4 ha) of evergreens with hardwoods for cover; do not plant in extensive solid blocks and reserve the bottoms for hardwoods.

24. Control excessive weed growth in canals, streams, lakes, and ponds.

25. Provide floating logs or rafts as loafing sites for waterfowl.

26. Establish water holes at springs or in seepage areas.

27. Provide potholes and other small open-water areas for nesting or resting waterfowl.

28. Develop ponds and lakes for waterfowl, water birds, and aquatic mammals.

29. Protect forests, marshes, swales, and fields from uncontrolled fires. However, consider a "let burn" program. Fire is a natural force in many ecosystems and can provide benefits for man and wildlife.

30. Avoid burning when vegetative habitat is critical for nesting cover or food for young wildlife. In some areas cool, late season burns can be used to rejuvenate herbaceous species needed for wildlife food and cover. Depending on successional trends and wildlife needs, burns should be used on a 3–5 year rotation.

31. Perpetuate sand and small, natural gravel along roads and trails to supply birds with grit.

32. In February–March, place mourning dove nest cones 1.8–4.9 m above ground in suitable trees.

33. Fence woodlots and planted areas against uncontrolled grazing to protect food and cover.

34. Stabilize streambanks with shrub and conifer plantings. Fence livestock and wildlife away from eroded streambanks where their use restricts recovery of vegetation.

35. Reserve undisturbed buffer strips of riparian vegetation alone streams to provide shade, insect food for fish, and dens for mammals.

36. Control water levels in marshes to favor habitat for waterfowl and other water birds.