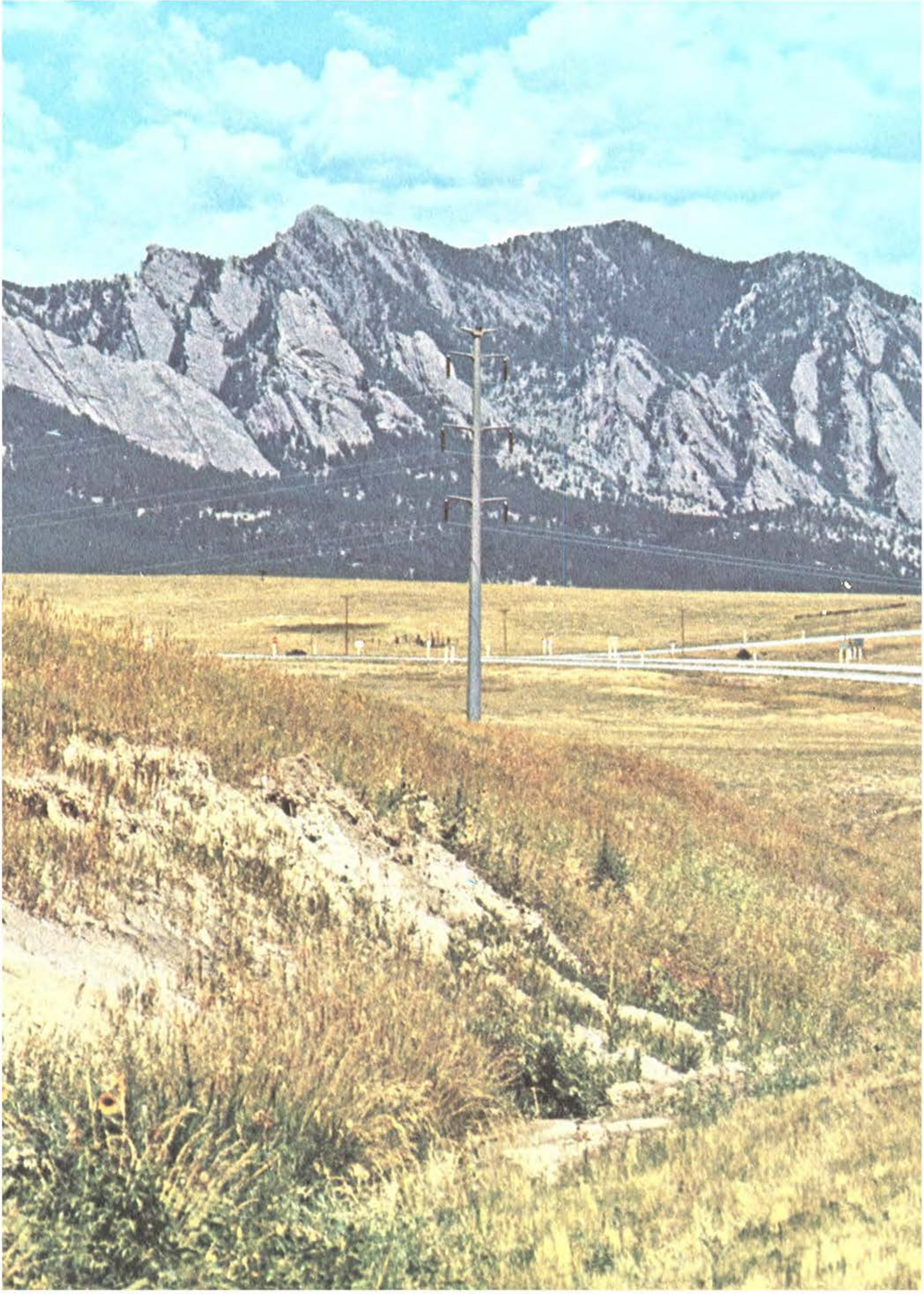
McELWAIN

NATIONAL FOREST LANDSCAPE MANAGEMENT

VOLUME 2 CHAPTER 2

UTILITIES

Forest Service
U.S. Department of Agriculture
Agriculture Handbook 478



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VOLUME 2 CHAPTER 2
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Forest Service
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July 1975

Foreword

Volume 1 National Forest Landscape Management, Volume 1, is a training document distributed throughout the National Forest System in April 1973. It is used as a basic text to illustrate the concepts, elements, and principles of our landscape management program. This program seeks to identify the visual characteristics of the landscape and analyze, in advance, the visual effects of resource management actions. Volume 1 was prepared by landscape architects, land management specialists, and research scientists from throughout the Forest Service over an extended period of time. It is available from the Superintendent of Documents, Washington, D.C., as Agriculture Handbook No. 434.

Volume 2 National Forest Landscape Management, Volume 2, will consist of several chapters (one of which you have before you), each dealing with the application of Volume 1 principles to a specific function or area of concern in the field of resource management. The effort to produce each chapter has been spearheaded by one Forest Service region, chosen for its experience and demonstrated expertise in the field, utilizing some contributions from other regions, research scientists, industry, and universities. These chapters will be published separately, as they are completed, for the purpose of prompt dissemination of what is, hopefully, very useful information.

When all chapters have been published and studied by all regions, and comments from other agencies and interested readers have been evaluated, we intend to revise and combine them into a single document—which will be Volume 2.
We hope you find this chapter thought-provoking and useful. Comments and suggestions are always welcome.

John R. McGuire

JOHN R. McGUIRE
Chief

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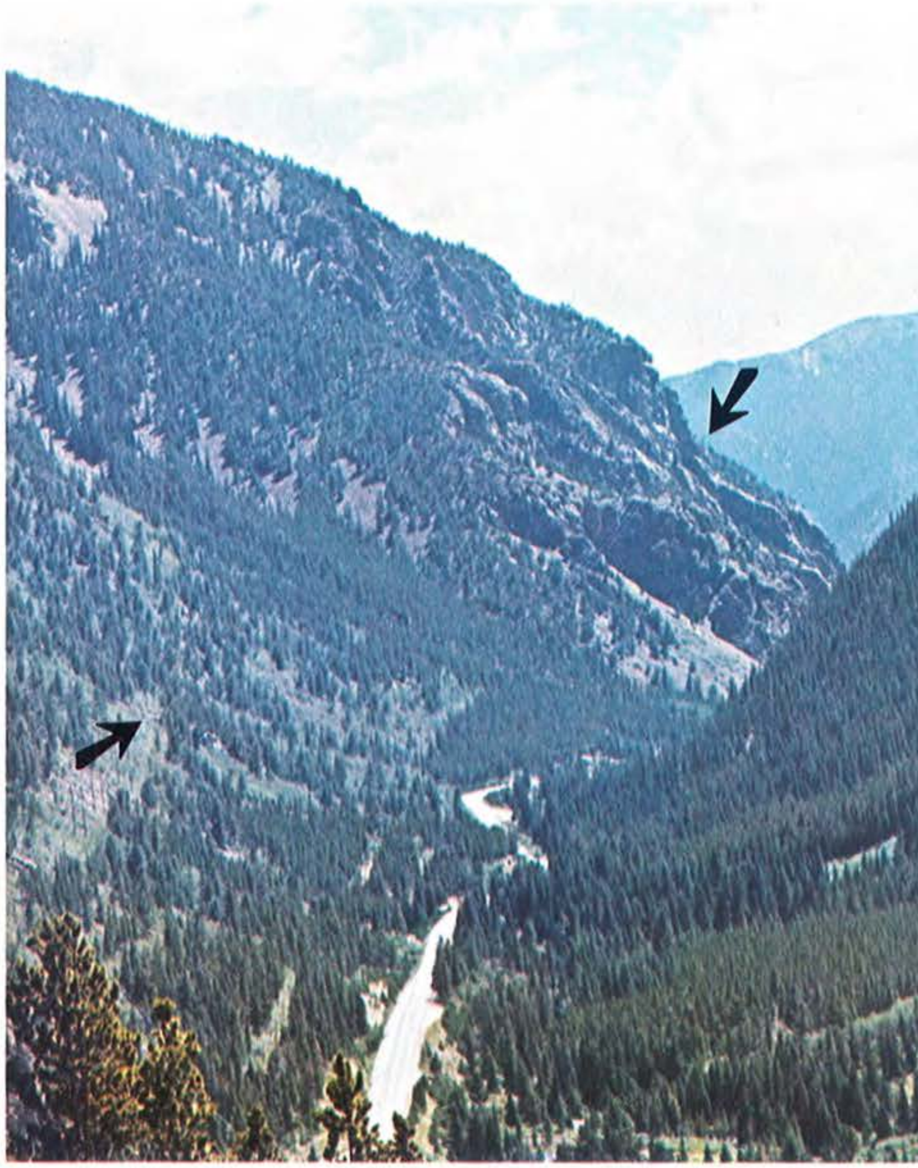

. . . Plan in full awareness of nature's forces, forms, and features—the sweep of the sun, the air currents, the peaks and hollows of the earth, rock and soil strata, vegetation, lakes and streams, watersheds and natural drainage ways —and this awareness should obviously entail planning in harmony with the elements of nature. If we disregard them we will engender countless unnecessary frictions and preclude those experiences of fitness and compatibility that can bring so much pleasure and satisfaction to our lives.

John O. Simonds
Landscape Architecture

Objective

The objective is to plan, design, and construct utilities in a manner that will visually harmonize them with or subordinate them to the landscape.

Utilities are basic ingredients of our way of life. Demands to better our lifestyle coupled with increases in the population will require more and better utilities. As utilities increase, impacts on the land increase.

This chapter provides a framework for communication among the utility companies with their technical experts, the land planning professionals, and the land managers to bring about a better understanding of utility requirements as well as the requirements of the land.

The following pages deal only briefly with the analyses and decisions that determine the need for a utility and its systemwide planning.* They concentrate, rather, on ideas and techniques for planning, designing, constructing, and maintaining needed utility services in ways that make the least visual impact on the environment.

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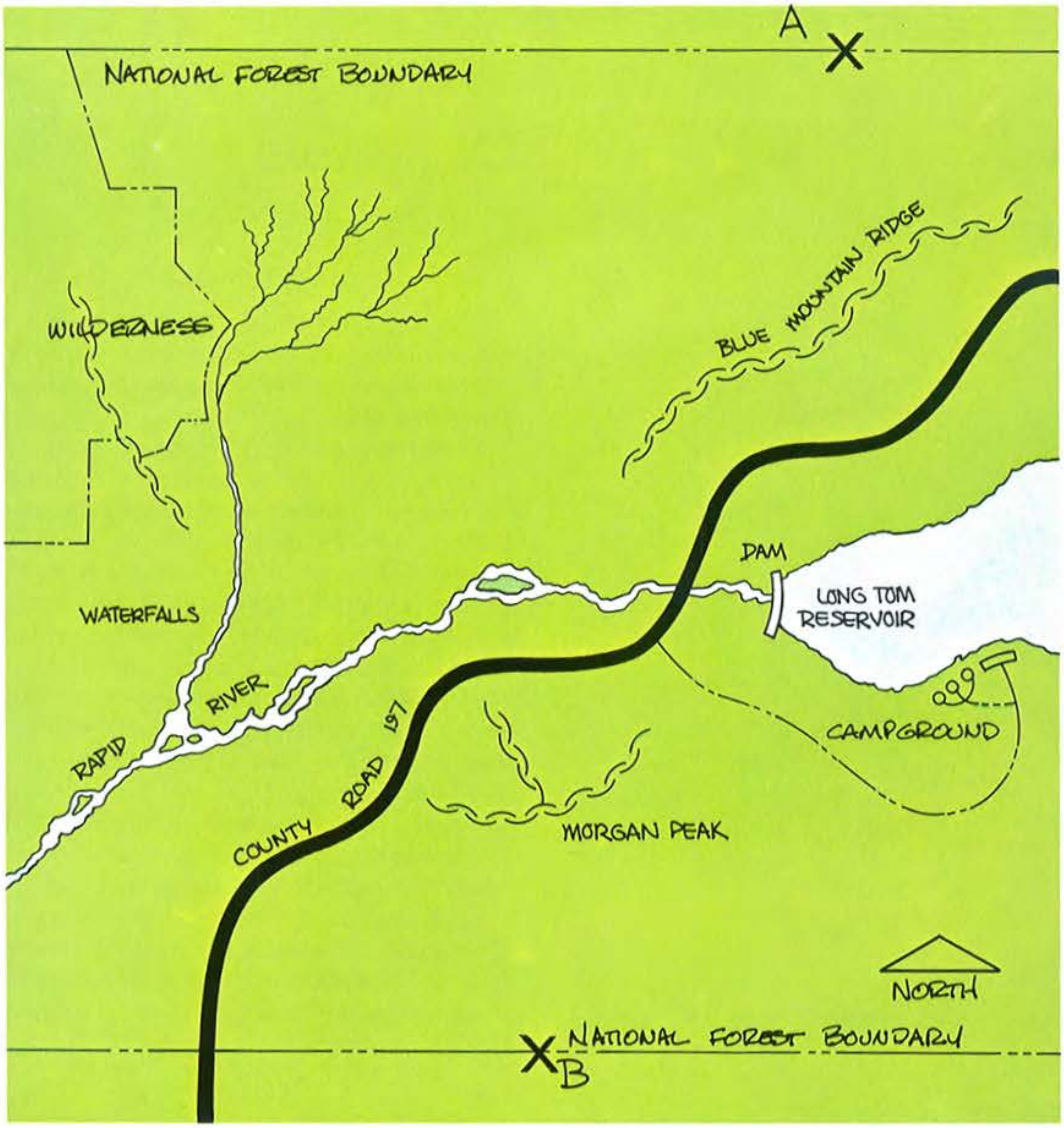
* For a more thorough discussion of systems planning, see Gary O. Robinette, *Energy and Environment*, Kendall/Hunt Publishing Company, Dubuque, Iowa, 1973.



Base Map

A transmission line (500kV) must be located from "A to B." It has been determined that the line is necessary for the public good and that this is the most feasible area between the generator and the consumer. The problem is now to determine the most appropriate corridor.

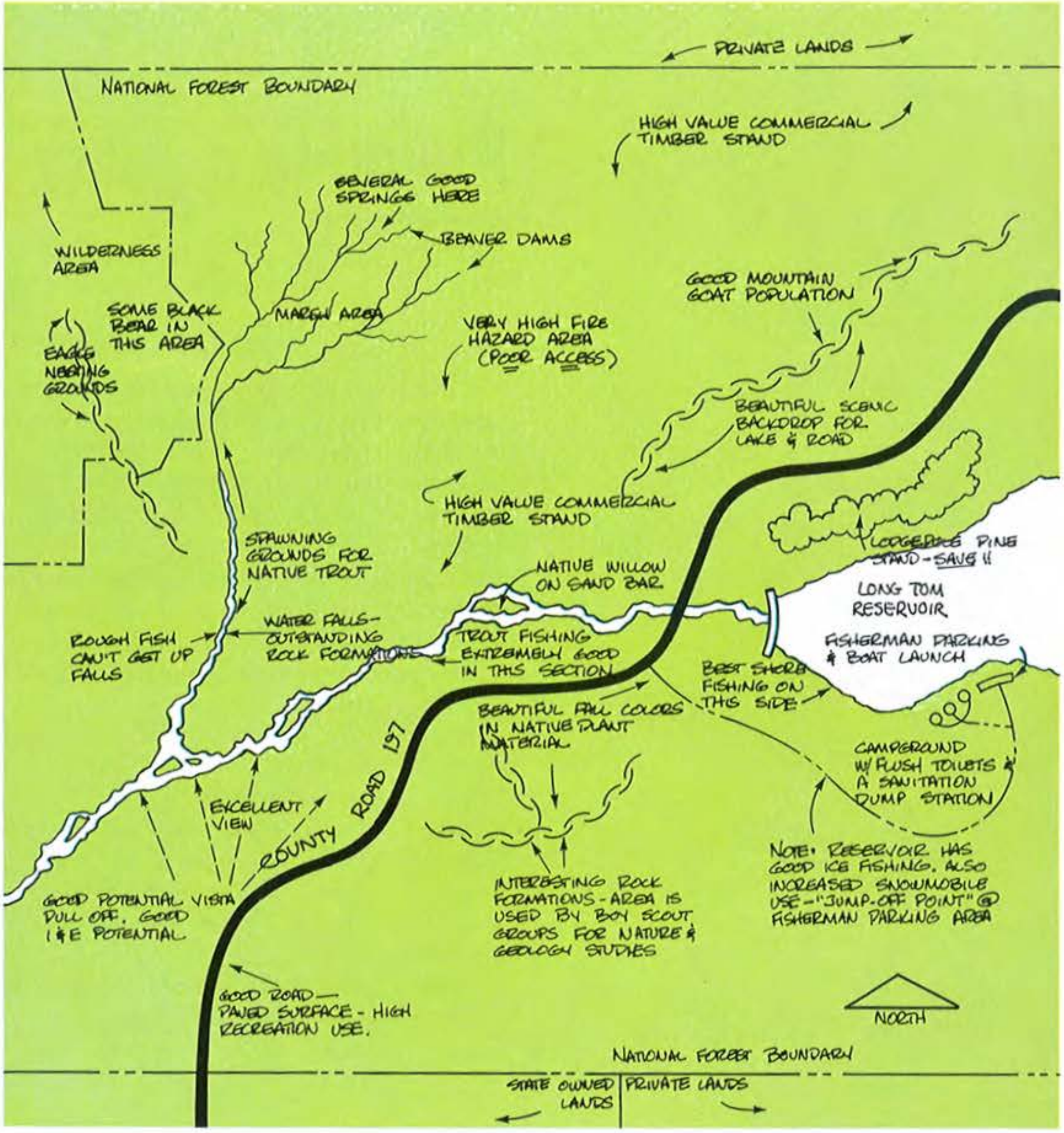
The series of sketches in this section illustrate a simplified process for utility corridor selection. It can be made as simple or as inclusive as each situation warrants. In complex situations involving fragile ecosystems, large utility structures, and an intensely concerned public, computers are often used to generate the necessary study maps from vast quantities of data. In less involved situations hand-drawn sketches may suffice.

Planning a utility system

Utility installations must be regarded as permanent fixtures that have lasting effects on land management. Therefore, the visual aspects of such installations must be considered in detail from the outset of project planning. This publication focuses only on the visual planning. But such planning, to be successful, must be reflected in every stage of development of a utility installation.

The landscape management principles set forth in *National Forest Landscape Management,* Volume 1, Agr. Handbook No. 434; *National Forest Landscape Management; The Visual Management System,* Volume 2, Chapter 1, Agr. Handbook No. 462; and in this publication (Chapter 2 of Volume 2), should be guides for visual analysis, planning, and design at each stage of project development.

This section of Chapter 2 outlines major steps in the overall planning of a utility system.



Area Analysis Map
(Field Inventory)

NEED ANALYSIS

The need analysis is basic to all utility planning. The first step in the planning is to clearly define the need to generate power, collect water, install a microwave system, store natural gas, or provide some other utility service.

A need analysis should encompass as large a geographical area as can be logically served from a central source. Within the bounds of reason, the need should be projected as far into the future as possible. This will enable the planners to provide for expansion of the system in an orderly and economical way. If possible, the need analysis should take into account the area's future needs for roads and other utilities. This may lead to the development of rights-of-way that can be used for more than one purpose.

The need analysis enables the planners to establish the:

- Size and nature of the demand for the utility service
- The physical components needed to provide and support the utility system
- The points of origin and use of the utility service.

ROUTE SELECTION

The points of origin and of use are the keys to utility planning. These set the parameters for route development.

To find the best route for any utility, all possible corridors must first be identified and analyzed. At the outset, studies should *not* be concerned with land ownership—the preliminary goal must be optimum corridor selection. Land use and other key constraints should be considered at a later stage of planning.

A *corridor analysis area* is the linear body of land of variable width (normally measured in miles) studied in a Corridor Analysis.

The *corridor analysis* is a study of the visual, environmental, physiographic and sociological characteristics of the land, considering the technical requirements of utilities, for the purpose of locating the most appropriate utility corridor.

The *corridor* is a linear strip of land which accommodates or is expected to accommodate a utility or all the utilities with similar orientation passing through a given land area. Its width can be variable and is normally measured in feet.

The *alignment* is the actual surveyed location of the utility line.

The corridor analysis must take into account all persons and agencies who own or administer land crossed by the alternative corridors.

Each alternate corridor must be analyzed from the standpoint of its environmental, socioeconomic, and engineering feasibility. The corridor selected should be the one that best satisfies three major criteria:

- The environmental and visual impact of the utility must be kept to the minimum.
- The corridor must create the best combination of socioeconomic benefits for the consumers, the utility company, the landowners, and the general public.
- Within the constraints of the land, the engineering and economics of the corridor must be feasible.

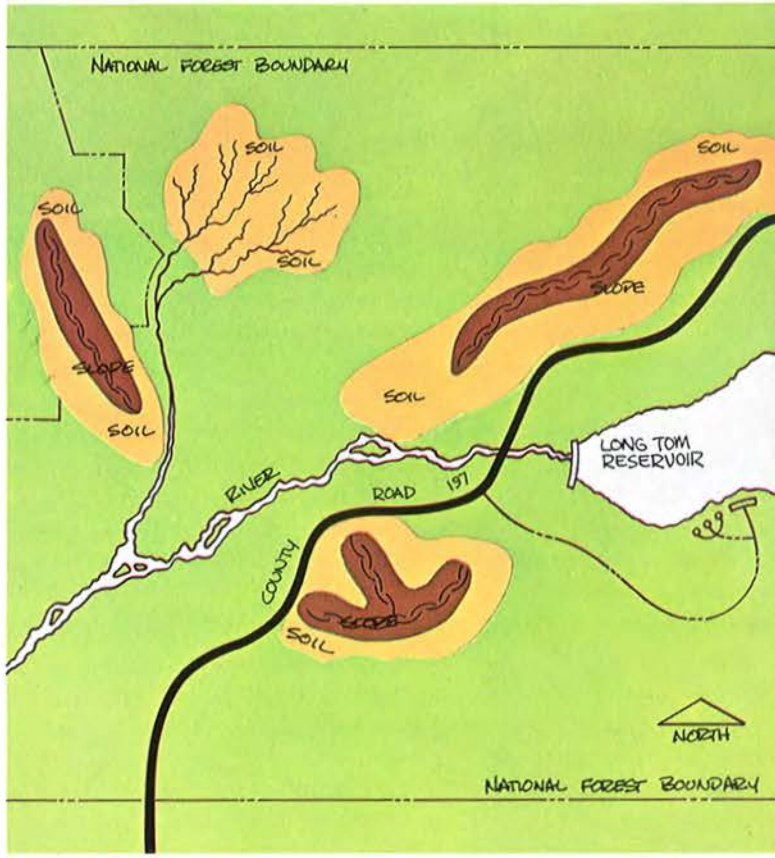
Thus, the corridor analysis is a composite of three special analyses:

- Environmental
- Socioeconomic
- Engineering.

All three analyses entail two phases:

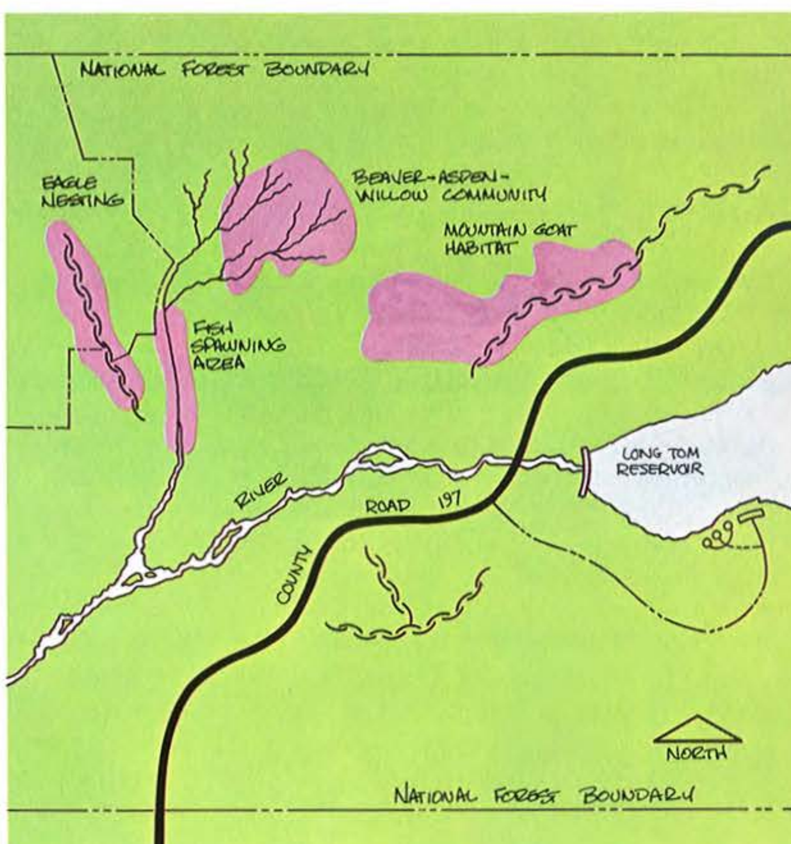
- The first phase is that of analyzing all corridors and selecting the one most feasible.
- The second phase is that of locating the utility within the selected corridor after a thorough analysis of all factors.

The intensity of the analyses usually depends on the conditions encountered; however, they should always be carried to a point that will ensure a well-planned utility that best satisfies the environmental, socioeconomic, and engineering criteria.



Physical Constraints

In this example, one needs to show only those soils and slopes which would be adversely affected by a transmission line or which would increase costs because of special precautions needed to prevent erosion, soil slippage, etc.



Ecological Constraints

ENVIRONMENTAL ANALYSIS

The environmental analysis helps to determine where the utility can be located with the least environmental impact. It takes into account all peripheral needs such as roads, auxiliary powerlines, water, and sewage.

The analysis is based on an inventory of broad ecosystems, topography, soils, hydrology, geology, vegetation, wildlife, climate, and other significant features of the area.

Ecosystems. The analysis seeks answers to such questions as: What effect will the utility have on the ecosystems involved? Will it change the character of the area to such an extent that it will be recognized as an obvious manmade change? Will it upset ecological balances such as those between plants and water, wildlife and food, soil and plant nutrients? If ecosystems are separated, changed, or disrupted, can the disturbance be tolerated or can adjustments be made that will minimize the ecological (and visual) impact of the utility system?

Topography. Topography is a crucial element in the location of utilities. Visually, it can be used to subordinate or hide manmade changes in the landscape.

Soils. Soils are especially important when the utility must be buried or roads must be built. They should be analyzed for stability and fertility and a revegetation program should be planned. Without such a plan, exposed subsoils and water erosion will have a negative visual impact because of color changes.

Hydrology. Hydrological conditions can strongly affect the visual impact of buried and surface utilities. The analysis evaluates the risks of cave-ins and of surface and subsurface erosion within the corridor.

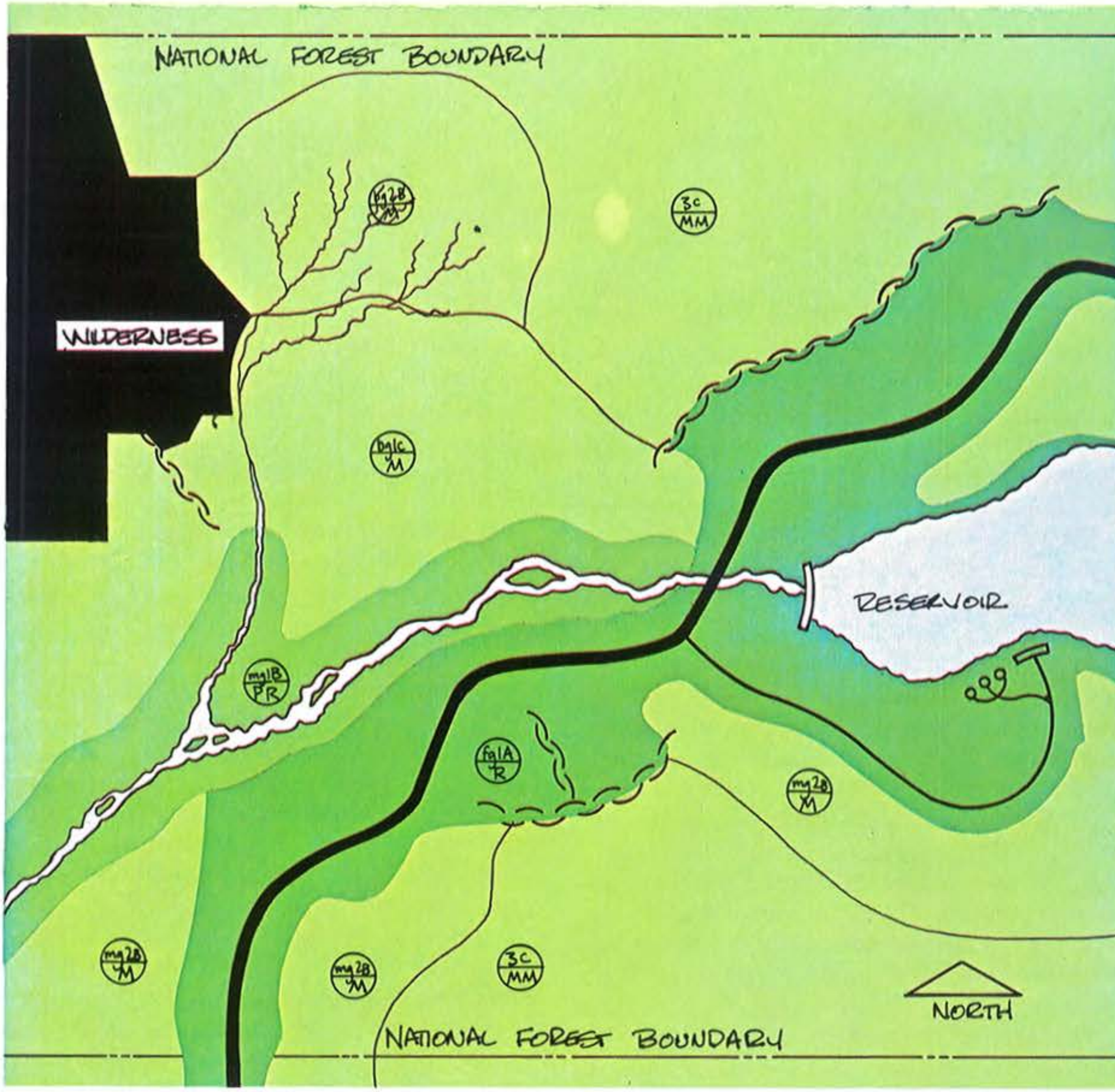
Geology. Surface and subsurface geology must be analyzed in detail. Costs and visual impacts of buried utilities can become very great when difficult geological formations are encountered. On the other hand, abovesurface systems can use geological features to advantage as visual backdrops for utility structures or as highpoints for spanning long distances.

Vegetation. The greatest visual impacts of utilities usually result from vegetative manipulation. The analysis is based on inventories of such factors as species of trees, age of trees, mixture of different species, even-aged or uneven-aged stands, ground cover, shrub and tree ratio, density of stands, natural openings, exposure of stands, windfirmness, disease conditions, potential for revegetation, suitability of trees for topping, vegetative edges along which utilities can be routed, and other relevant conditions of the area.

Wildlife. Although wildlife is covered in the ecosystem inventory, it should also be considered separately. Of major importance is an analysis of the impact the utility will have on habitat. Consideration must be given to all wildlife, cover, feeding habits, calving and nesting areas, and disruption of food sources, migration routes, or wintering habits. Endangered wildlife species must be noted and protected.

Climate. Climate can severely affect the reliability and serviceability of utility systems. The analysis must take into account such factors as snow accumulation, wind areas, ice storm hazards, high-volume rainfall areas, intensive freeze areas, and lightning hazards.

Unique features. The analysis takes into account all unique features within the corridor. Such features may be precious assets from the point of view of history, archeology, geology, hydrology, botany or horticulture, wildlife, or other disciplines.



Policy and Visual Considerations

If appropriate, different degrees of concern can be shown by darker shading. The darkest areas would be those which are most critical . . . subject to the most damage should a transmission line be constructed . . . or costing the most to cross because of the need for special towers, coloring, installation practices, etc. In this example only Retention (R) and Partial Retention (PR) Visual Quality Objective areas are shaded.
If agency policy prohibits transmission lines in Wilderness, the Wilderness could be colored black.

SOCIOECONOMIC ANALYSIS

This analysis encompasses the socioeconomic impact of the utility along its entire route—from its point of origin to the consumer.

To supply a utility as economically as possible and keep the visual and ecological impact to the minimum, it is necessary to gain the understanding and cooperation of everyone concerned:

- **The Supplier.** It is the supplier's responsibility to secure, store, and supply a certain utility to the consumer as economically as possible.
- **The Consumer.** Consumers (individuals, communities, industrial concerns) establish the need for a utility and agree to purchase the services from the supplier.
- **The Landowner.** Landowners (private, county, State, Federal) agree to have the utility cross or use their lands.
- **The Public.** The public views utility installations and judges them to be visually acceptable or unacceptable.

Although deeply concerned about what happens to the environment, our society cannot function without an ample supply of utility services. The cost of a utility must be related to the price that can reasonably be charged for services provided. Sometimes, however, over certain routes these charges would be relatively high because special design and construction methods would have to be used to preserve the visual integrity of the landscape. These situations should be identified as early as possible.

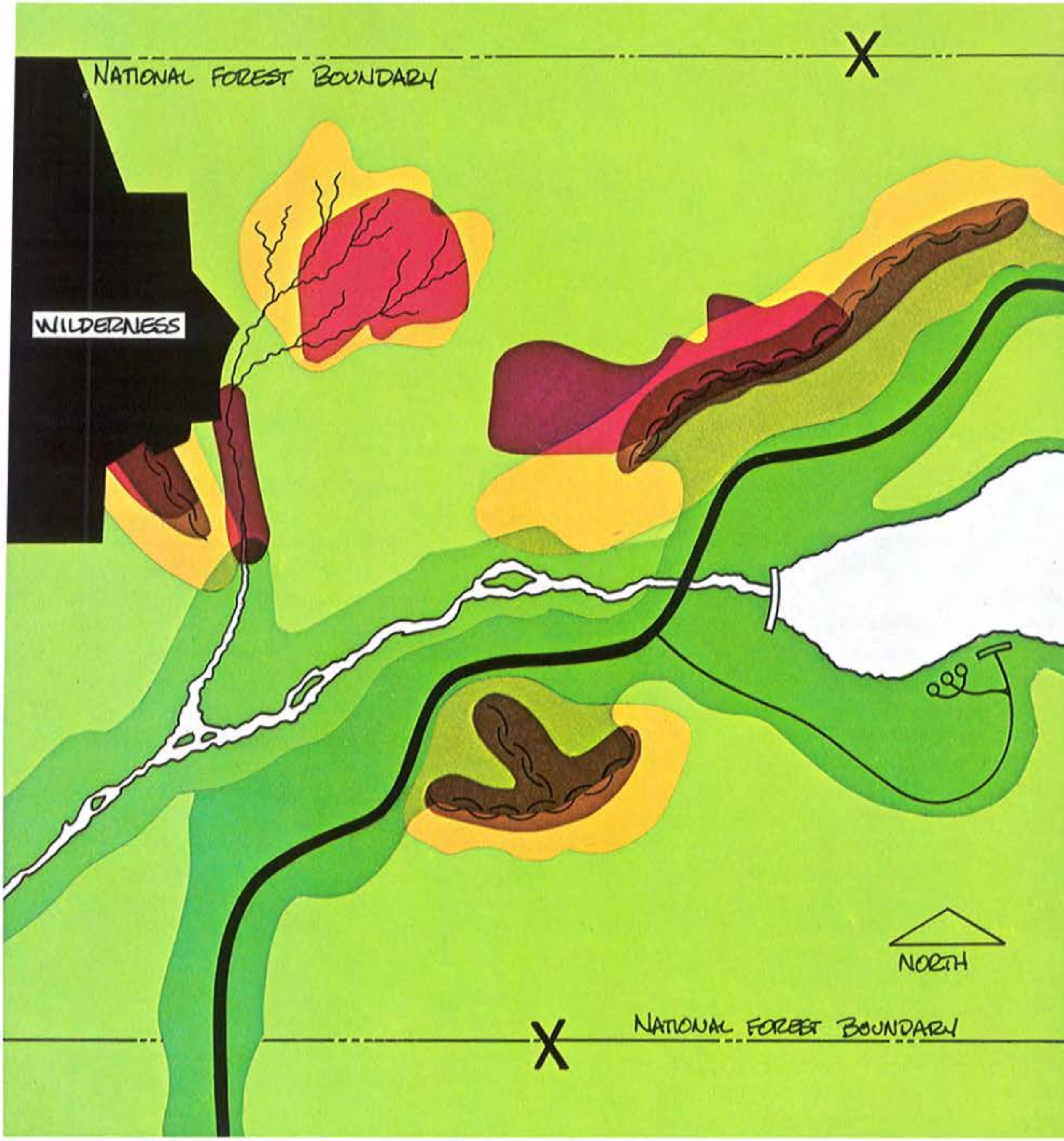
ENGINEERING ANALYSIS

This analysis seeks answers to such questions as: What components will be needed to make up a complete system? What kinds of structures will be needed? What are the best construction materials, methods, and equipment to use on the project? How will they be moved to the construction sites?

All of the equipment needed for excavation, for moving men and supplies, for inspection and maintenance, and for related purposes is collectively called the "construction train." The planning and operation of this "train" are crucial to the overall success of the project, particularly when special design and construction activities are required. The makeup and use of the train largely determines the amount and kind of space needed for the project and the extent of disturbance of soils and vegetation. Thus, the widths of corridors and access routes can be held to the minimum only through careful consideration of all necessary equipment, its direction of travel, its need to pass other equipment, periods when it is in use and when it is idle, and so forth.

The visual impact of the project can be assessed only after such information has been analyzed. Thus it is important that this analysis be completed as early as possible—while there is still time to make changes if the visual impact of the first approach will be unacceptable.

Such a situation can often be remedied in a variety of ways. For example: An alignment might be rerouted within the corridor. Vegetation might be retained for screening. The cleared part of the right-of-way might be narrowed. Structures might be painted an appropriate color. Soil disturbances might be minimized. Structures might be specifically designed for the area.



Total Land-Use Constraints

The darkest areas indicate where maximum impacts upon the land can be expected or where maximum costs can be incurred to ameliorate these impacts.

DESIGN

Final design of the utility is based on the findings of the environmental, socioeconomic, and engineering analyses. All facilities must be sited within the limits of the chosen corridor and be designed to make the best possible use of their particular sites.

The engineering design and landscape design must be accomplished together.

Some utilities and their specific engineering design parameters are discussed later in this chapter. This section addresses these design considerations:

- Visual impact
- Clearing of the right-of-way
- Utility crossings
- Structure design
- Color
- Support facilities.

Visual impact. In designing a utility, it is necessary to find answers to such questions as:

What visual quality objectives* have been assigned to the area to be involved?

From what vantage points can the utility be seen? From a major highway? Logging road? Airplane? Trail? Special-use area? Overlook?

How long can it be seen? (A 10–second glance from a car traveling at 60 miles per hour would be quite different from the view of a utility from a scenic overlook.)

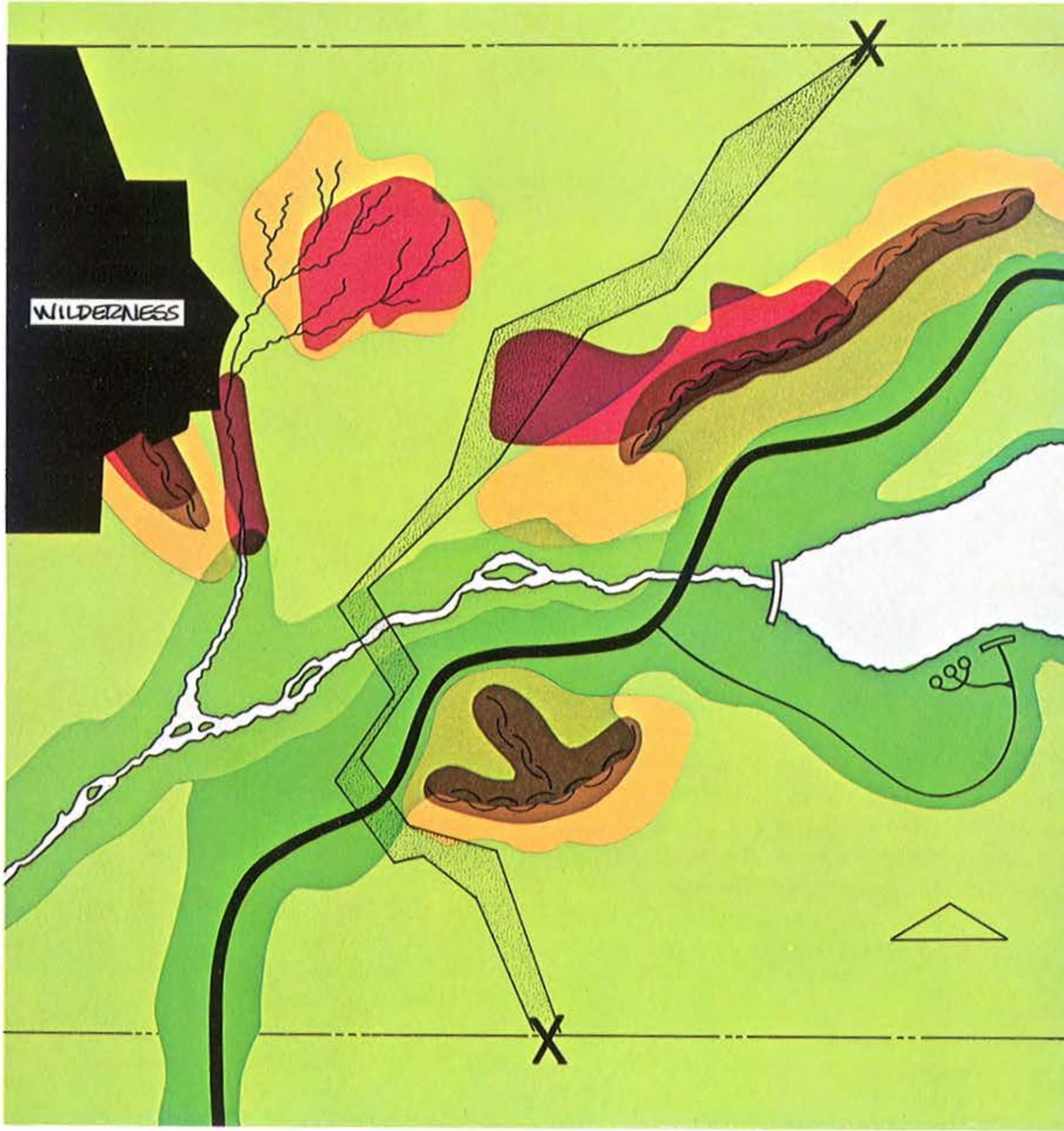
Which landscape features can be used to minimize the visual impact of the utility? Can skylining be avoided?

Clearing the right-of-way. Of all the elements of a lineal utilities system, site modifications along the right-of-way usually make the most noticeable visual impact on the landscape. Therefore, design of the right-of-way requires detailed consideration.

In many cases, wide access routes and large spaces must be opened during the construction stage to permit safe movement and staging of equipment and materials. Frequently, the width of access roads and extent of other spaces needed for these purposes far exceeds that permanently needed for maintenance of the installations. Therefore, plans and specifications for the project must require restoration of work spaces no longer required after construction has been completed.

In all cases, modifications of the natural setting must be held to the minimum required for safe, efficient construction, operation, and maintenance.

* 1974. National Forest Landscape Management. Vol. 2, Ch. 1 (The Visual Management System. U.S. Dept. Agric. Handbook 462, 47 p., illus.)



The Most Appropriate Corridor

By avoiding the darker areas and referring back to individual constraint studies for pertinent information, the most appropriate corridor can be selected.

Structures. If standard structures are used, their design should be adaptable for most sites without requiring extensive site modifications, especially grading.

Structures of different design should be used within a utilities system if this will soften their visual impact and help them blend with their particular surroundings. Certain structures may be specially designed to satisfy local architectural styles, their biotic environment or settings, or sociological desires.

However, special designs should be a last resort. They should be considered only after it has been determined that other alternatives would seriously impair the visual environment.

Utility crossings. Crossings at roads, railroads, rivers, and streams must be designed to minimize their visual impact. Toward this end, designers apply these basic criteria:

- When possible, crossings should be made at a right angle.
- Structures should be set as far back from the crossing as possible.
- In areas with tree and shrub cover, the right-of-way and structures should be screened from the crossing area.
- Wire with the least shine and gauge should be used to avoid reflection and glare.
- The site chosen for the crossing should be the one that will result in the least disturbance or alteration of the natural landscape.

Color. Colors for utility structures must be chosen after thorough analysis of site conditions. Structures that are colored to blend with their settings in direct sunlight may contrast with their settings in shade.

Natural surfaces are usually well textured and have shade and shadow effects that darken them; surfaces of utility structures are usually smooth and reflect light even if dull-finish paint is used. So, as a rule of thumb, structures that must blend with their surroundings should be painted somewhat darker than the appearance of the background.

Support facilities. When a system is planned and designed, an analysis must be made of what other utilities and services are needed to support the major system.

For example, a microwave repeater station needs a road for access, electric power and a backup system, and sanitation facilities for persons working at the site. The visual impact of these support facilities must be considered along with that of the main utility. At times, the visual impact of the support facilities is decisive in selecting the specific location for the main utility.

CONSTRUCTION

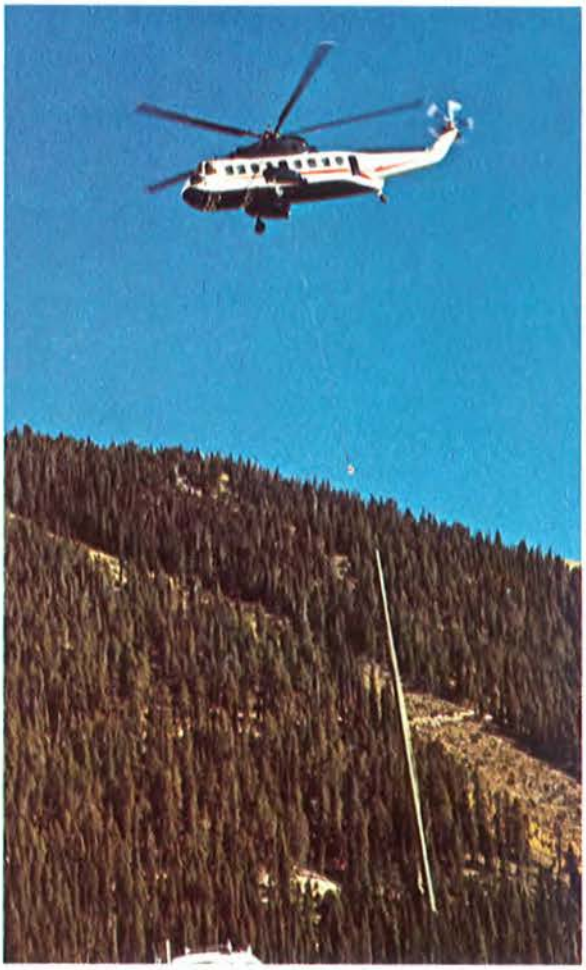
The construction phase must be planned in detail once the specific location of the utility has been chosen and the utility has been designed.

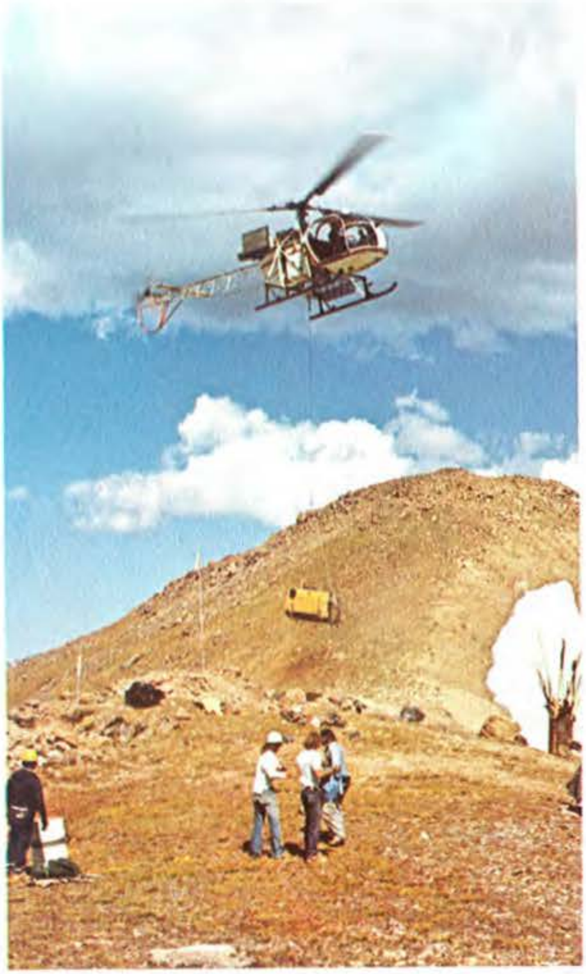
The "Engineering Analysis" (page 13) discusses construction considerations from the standpoints of the land base, construction equipment, construction train, and materials storage.

Construction methods must be suited for the utility as well as for the site and should be flexible enough to be changed if necessary.

A later section, giving "Examples of Utility Installations," describes standard as well as special methods of construction.

Everyone involved in construction should be informed of the land management goals to be achieved by the project. A dozer operator, for example, who understands why and how certain operations should take place can greatly reduce the impact of the dozer on the land.





MAINTENANCE

How the system is to be maintained must also be considered during the planning and design phase. The type of utility and its locality determine how maintenance should be planned and accomplished.

Modern technology allows continuous system monitoring. The monitoring method depends on the utility and when it was installed. Systems may be monitored by on-site inspections or from the air by observation or photography. Many utilities are monitored by computer systems.

Access routes, developed or undeveloped, must be designed for repair and emergency access. Right-of-way maintenance must be planned to protect the utility and keep its visual impact to the minimum.

Vegetation manipulation is important where wide rights-of-way are cleared for construction and must later be revegetated. Rights-of-way that were cleared completely in accord with the philosophy prevailing at the time they were installed must be looked at again and redesigned to allow plants (trees, shrubs, ground cover) to reestablish themselves so as to soften harsh visual impacts without endangering the utility.

Visual characteristics of utilities

Manmade objects in the natural landscape generally become focal points because of contrasting form, line, color, or texture.

Although manmade objects cannot duplicate nature, by taking advantage of nature's features and techniques developed by man, utilities can be planned and designed to complement their natural surroundings.

From the standpoint of visual impact, utilities can be classed as:

- **Site installations**—which are physically confined to compact areas
- **Lineal installations** (above, below, or on the earth's surface)—which extend across the countryside in relatively long, narrow ribbons.

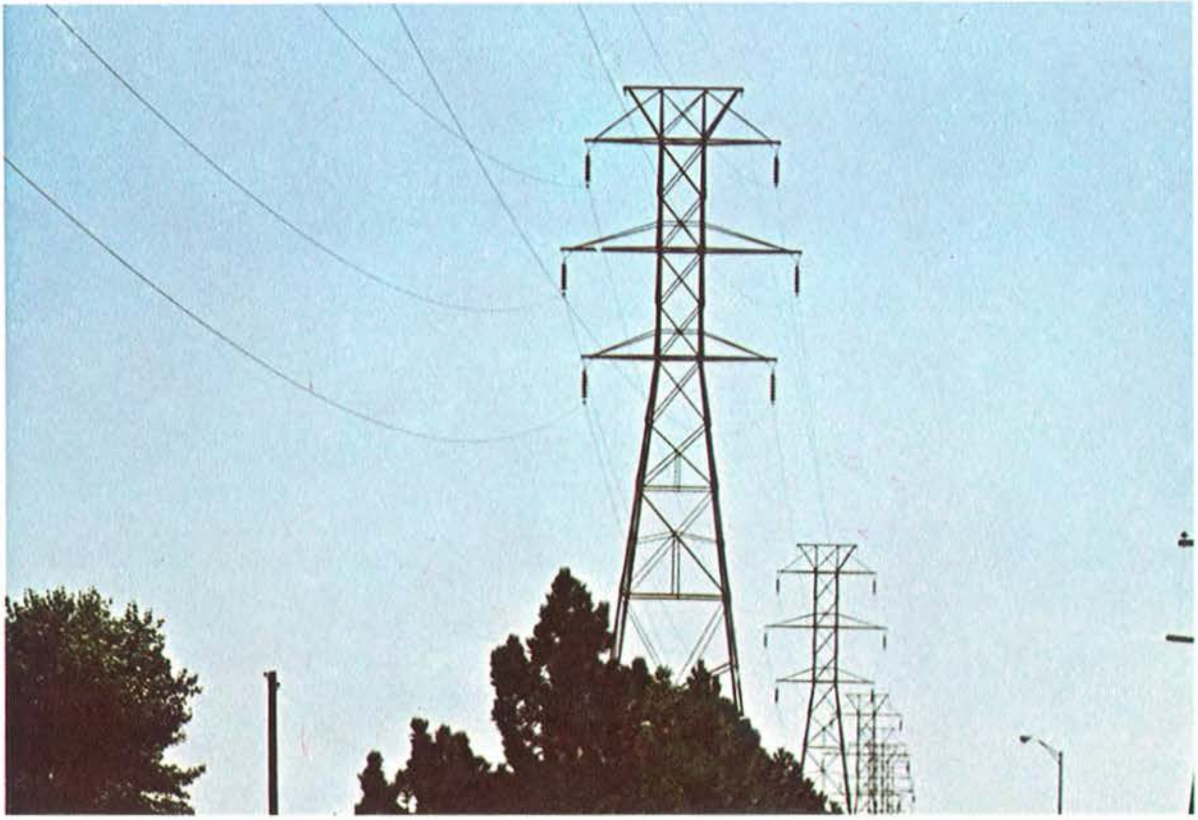
SITE INSTALLATIONS

The microwave repeater (left) is typical of a site installation. To fulfill its function, this one—like many others—had to be sited on a high point. Powerlines to the tower are relatively small and are partially buried. A narrow road through the trees provides access for maintenance purposes.

LINEAL INSTALLATIONS

The visual impacts of lineal installations can vary from major to minor. The three general types of lineal installations are:

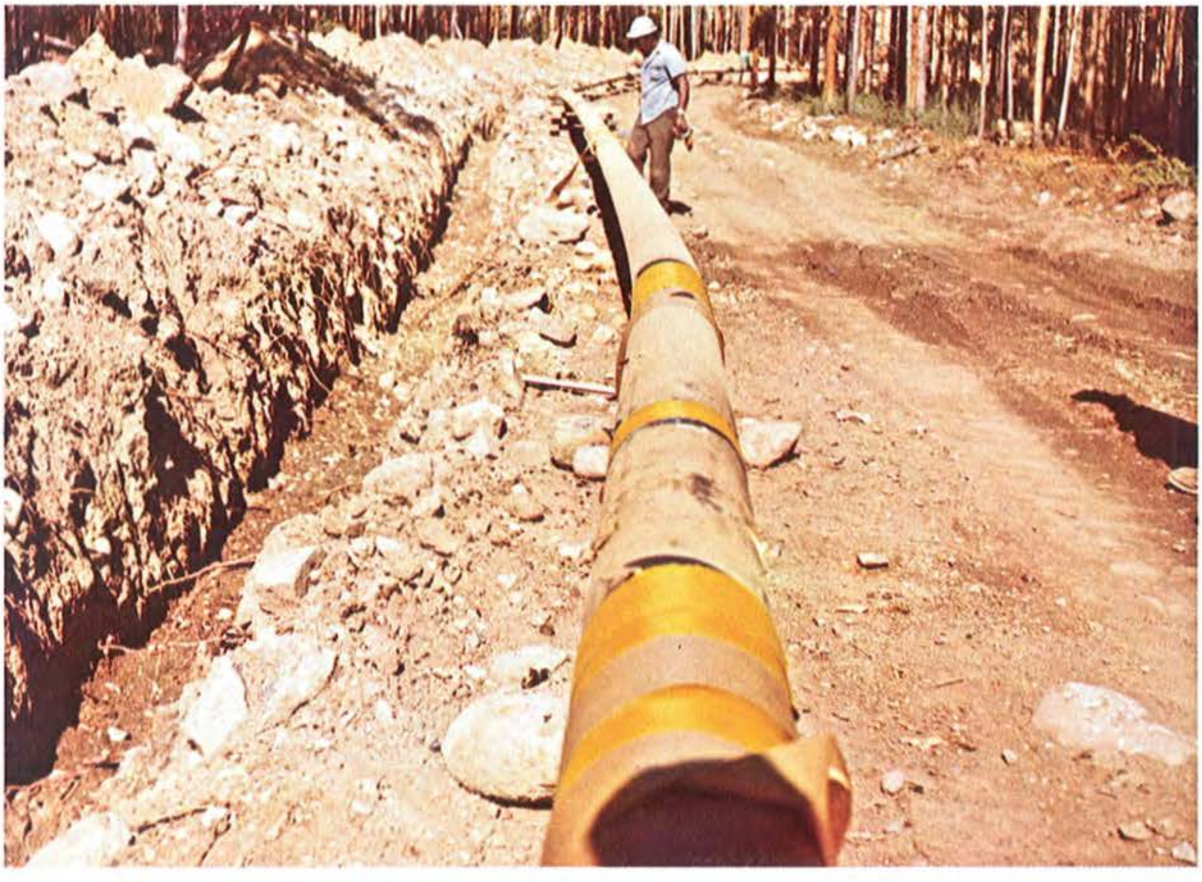
- Overhead systems
- Land surface systems
- Underground systems.



***Overhead systems** consist mainly of electric power and telephone lines.*

***Land surface systems** consist mainly of waterways, on-surface pipes, and access and maintenance roads.*

***Underground systems** consist mainly of pipe (for water, oil, gas, sewer, gasoline) and cable (for telephones and electric power).*



This utility installation was planned in coordination with natural forms. Advantage was taken of natural openings. The line followed an existing man-made line—the road on the left. The right-of-way was not clearcut—only danger trees were removed, thus retaining much of the natural texture. Structures were colored to blend.

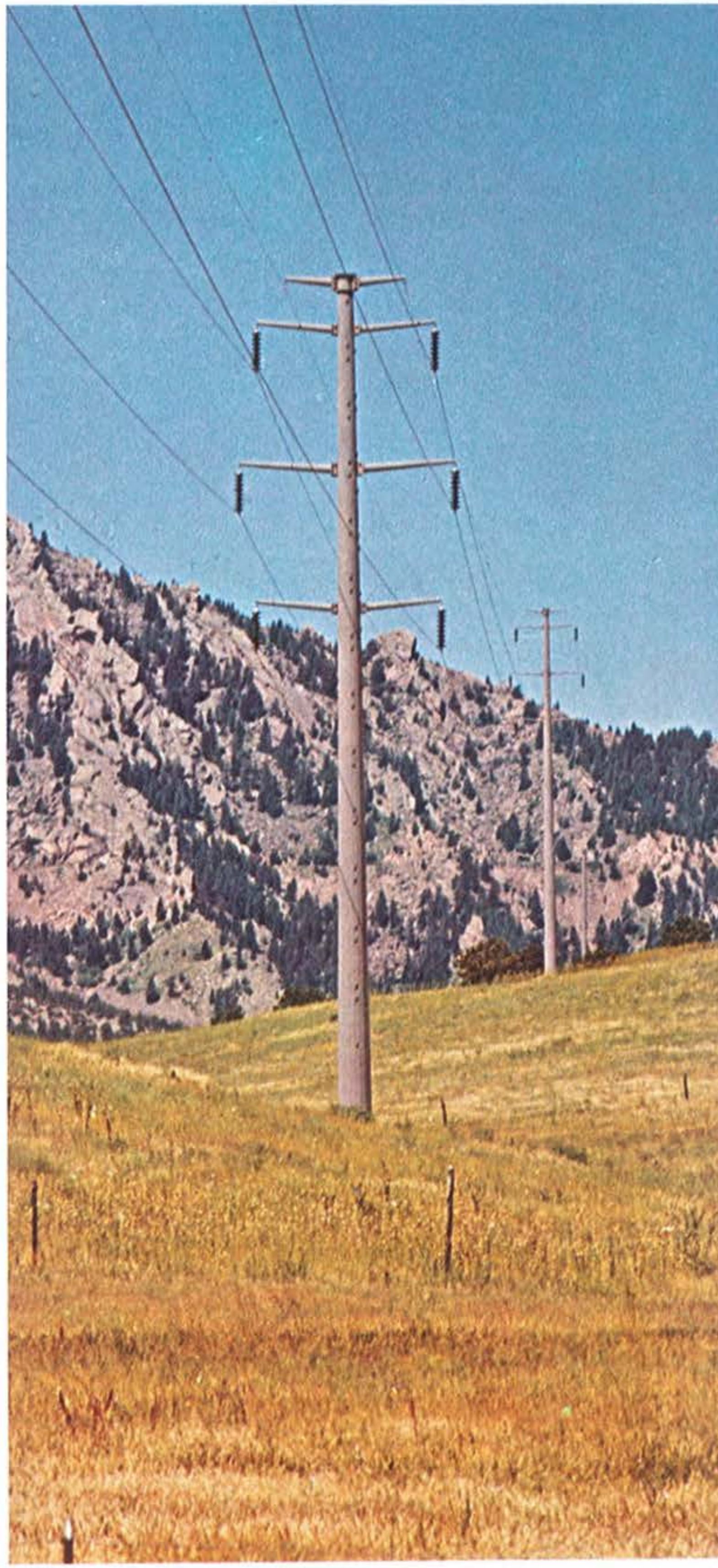
Visual dominance elements and utilities

Four visual elements compete for dominance in any landscape:

- Form
- Line
- Color
- Texture.

All four are usually present but exert differing degrees of visual influence, power, or dominance. In utility planning, these elements must be studied from two standpoints: that of the landscape and that of the utility itself.

To diminish the contrast between utilities and their surroundings, advantage must be taken of landscape features in the siting and design of all needed installations.

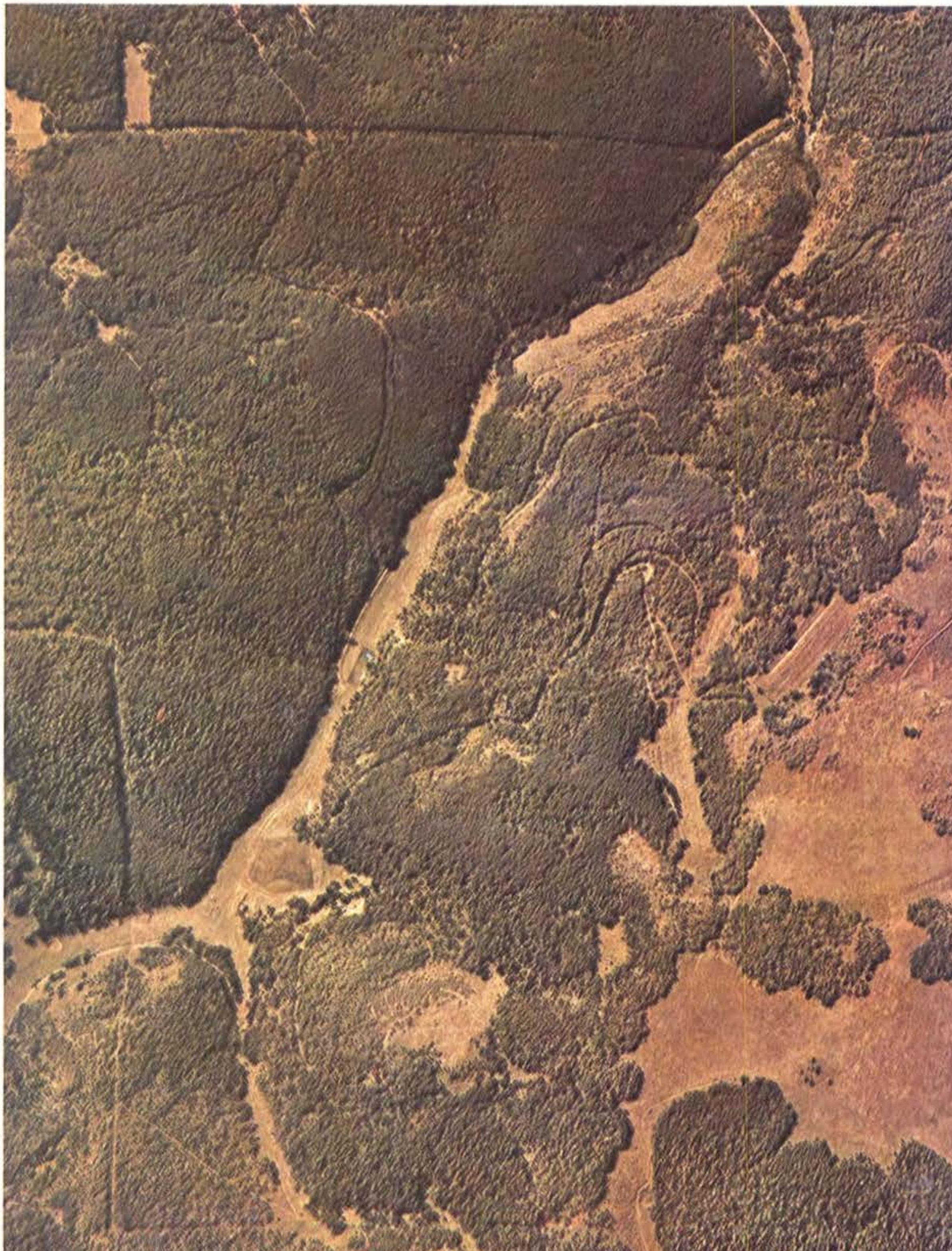


Simplicity of form.

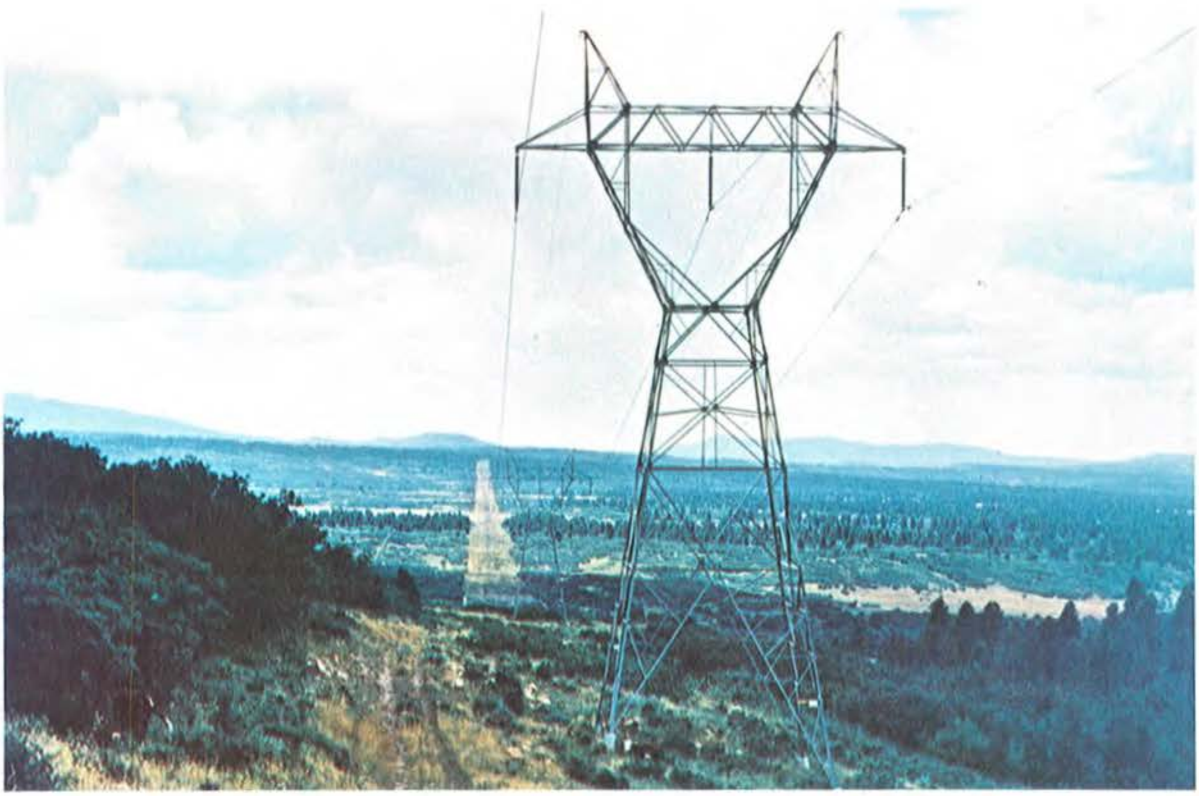
FORM

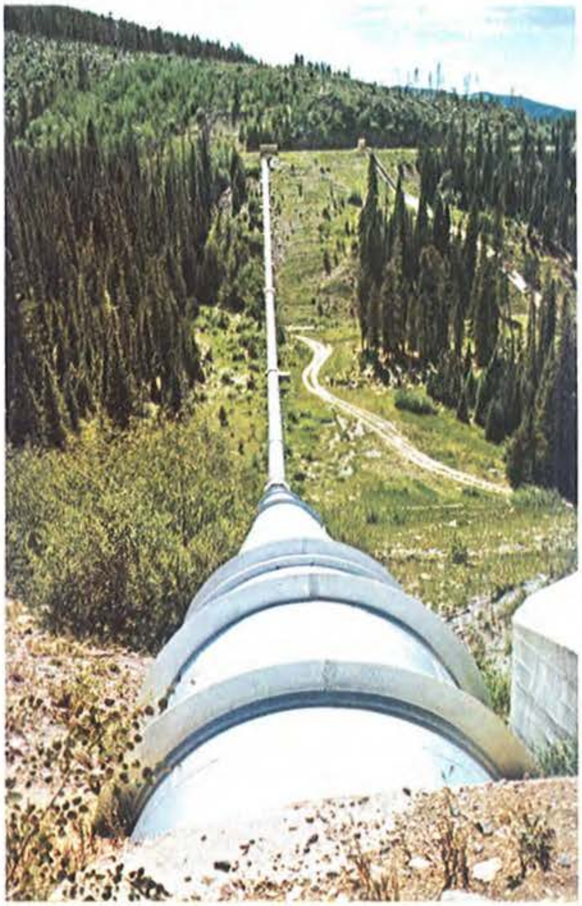
Landscape forms are determined by topography and vegetative pattern. If either of these is opposed by utility structures, as in the upper photo, the visual impact will be negative.

The forms of many utility structures are geometric, forceful, and large. They often contrast with and visually dominate the more subtle forms of the landscape. Right-of-way clearings (lower photo), access road construction, storage yards, and other utility support facilities create form in the landscape.



The manmade lines that oppose natural lines are obvious.





LINE

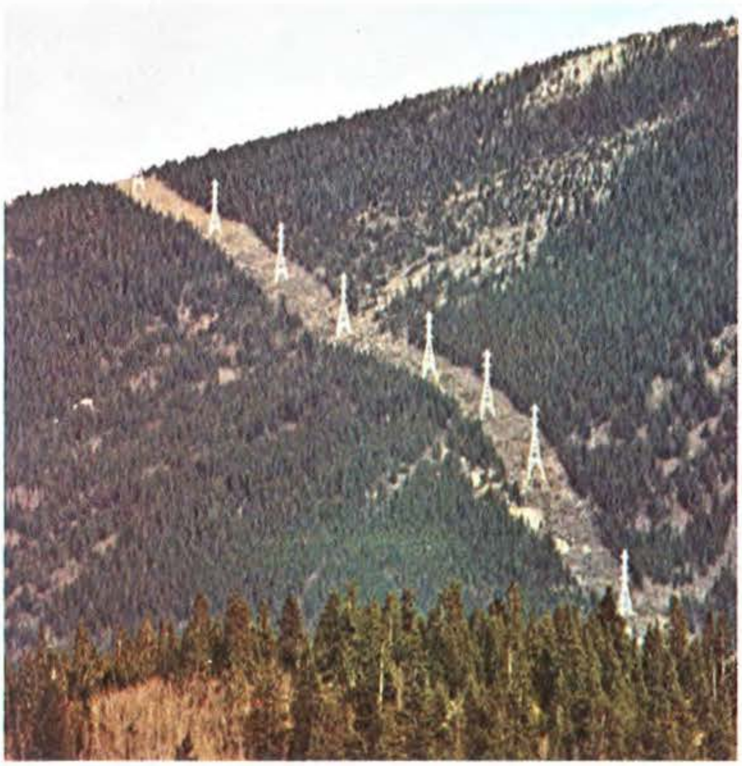
Line is anything that is arranged in a row or sequence. It can be the silhouette of a form, the edge of a meadow, a ridgeline, a tree trunk, a river, the path of an avalanche.

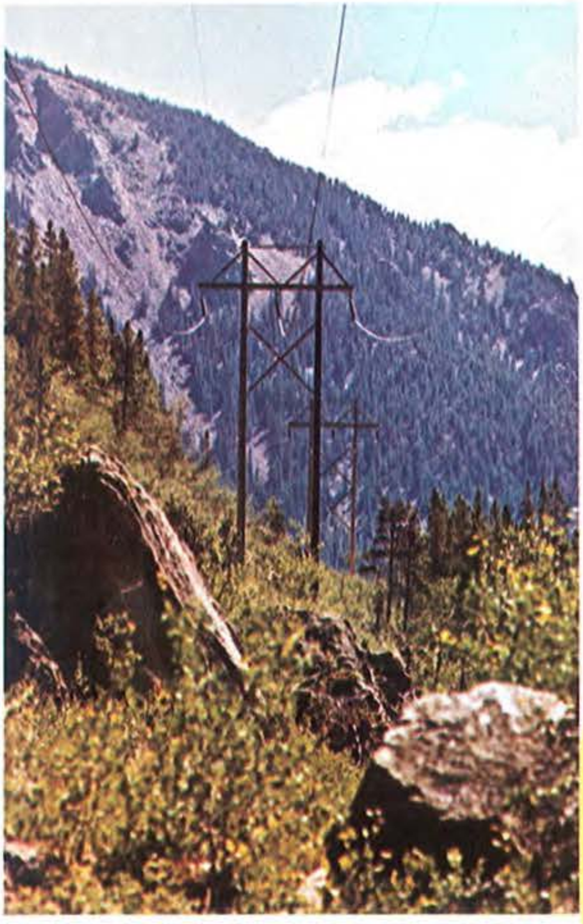
Clearcut rights-of-way, overhead powerlines, aboveground pipelines, and access roads are among the more common types of "lineal" utilities. Such installations create the least contrast with the landscape when they are sited and designed to take advantage of the natural lines of their surroundings.

The *forms* of the latticed towers shown here rapidly disappear with distance, but the *lineal* impact of the cleared right-of-way dominates the landscape as far as the eye can see.

The aboveground pipeline, the flume, the road, and the cleared right-of-way clash with their natural surroundings.

Two similar towers—except for color. The upper tower has been painted dark olive.





COLOR

Color enables us to distinguish among objects of identical form, line, and texture. It can also be used to subdue differences between manmade and natural objects.

To be successful, color selection for utilities must be based on a study of local conditions and of how the colored object will be seen from crucial points of view.

Foreground colors tend to be distinct. Background colors are usually muted blue-greens and grays.

The texture of a surface affects its color—the more texture, the darker the color tone.

Colors which blend well with the background may appear almost black when seen in the shade. If a shaded object is massive, it may be a major visual liability.

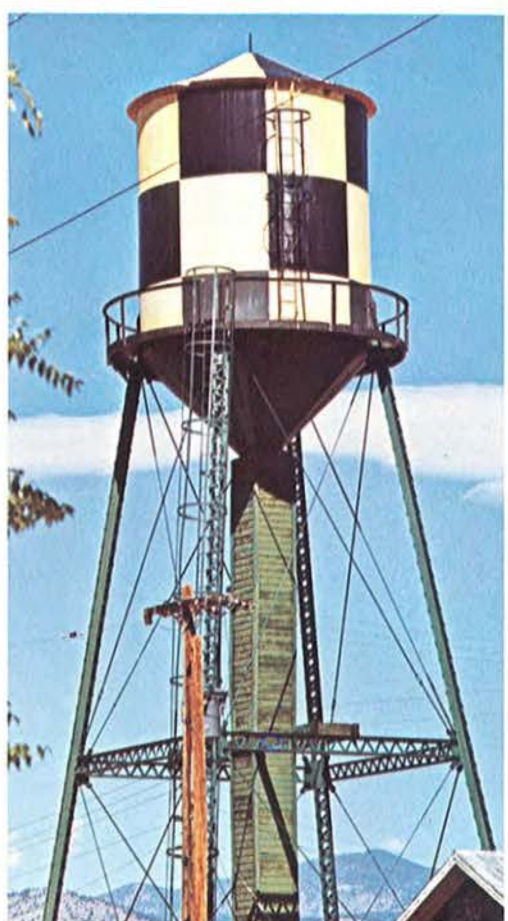
The light-colored towers (upper left) and cleared right-of-way contrast with their surroundings and become a distracting focal point.

Sunlight on a smooth surface lightens its color and creates reflection (upper right). In shade, colors appear dark, almost black (left). Bright reflection, especially from a massive object, can cause a negative visual impact.

These large, light-colored surfaces emit an undesirable brilliance.

These objects were carefully colored to blend with their surroundings. The picture at lower left shows a utilities structure in the sunlight; the picture at lower right shows the same object in the shade.

For safety, some utilities must contrast sharply with their surroundings. The colors of such installations are rigidly prescribed by law. Nevertheless, such utilities should be sited to the best feasible advantage.



The coarse, tree-studded texture of the mountainside was carefully observed during the design of this powerline—thus creating very little visual impact.

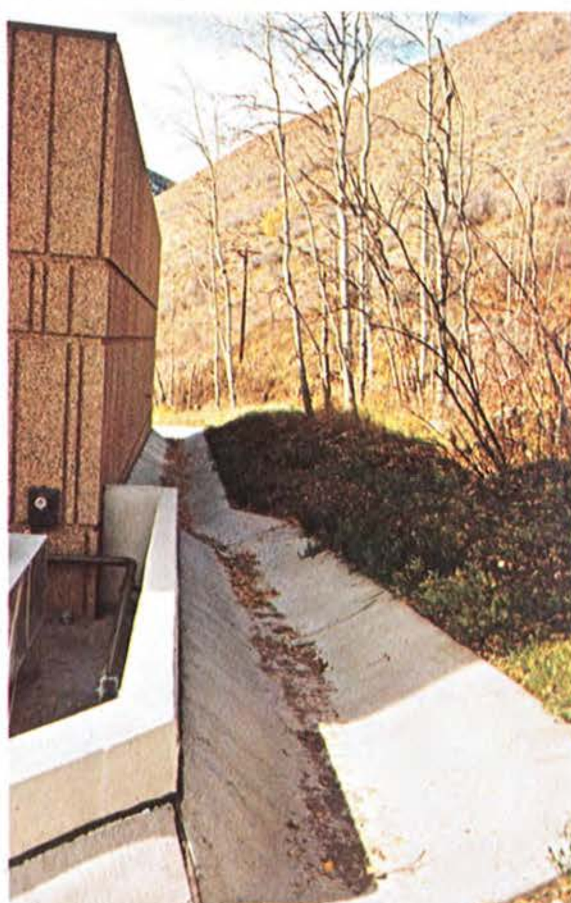
TEXTURE

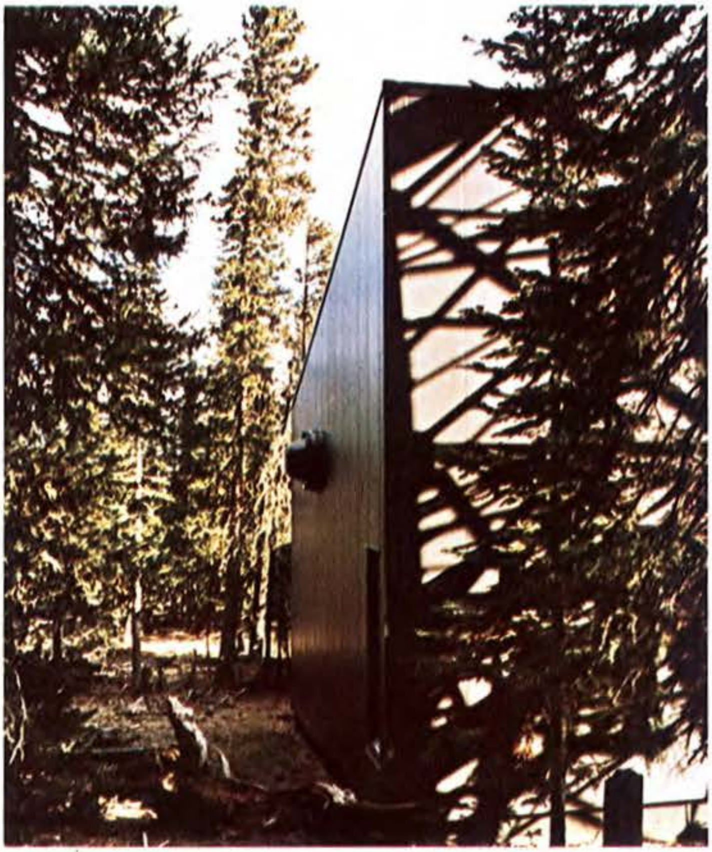
Textures in the landscape are determined by geology, soils, topography, and vegetation. The more variety there is in the landscape the easier it is to plan and design a utility that is visually subordinate to its natural surroundings.

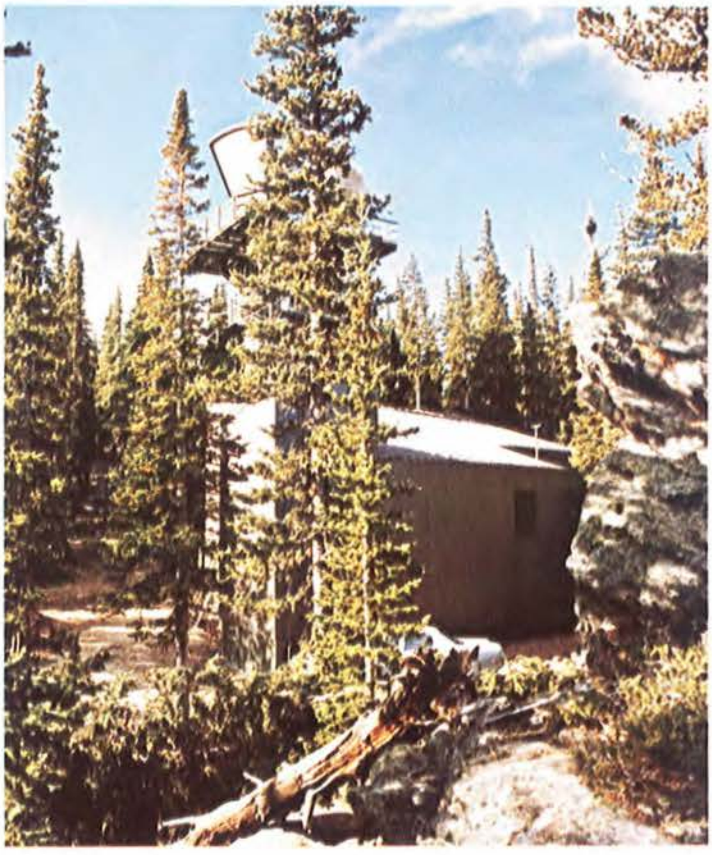
Natural textures can seldom be matched in utility structures. This makes it doubly important that a utility be designed and sited to minimize its visual impact.

Latticed towers, with their slender members and open texture (upper photo), tend to let the textures of the landscape "show through." They are therefore more appropriate under some circumstances than the simpler but more massive types.

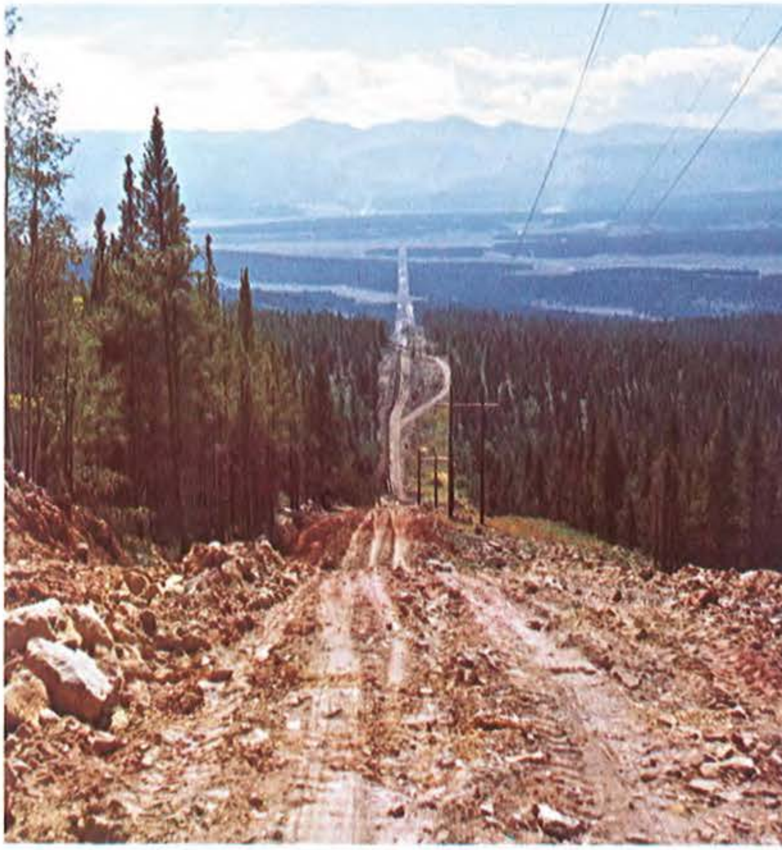
The textural pattern of precast concrete walls of a building (lower photo) can reflect the vertical patterns of the nearby trees which were carefully preserved during construction.



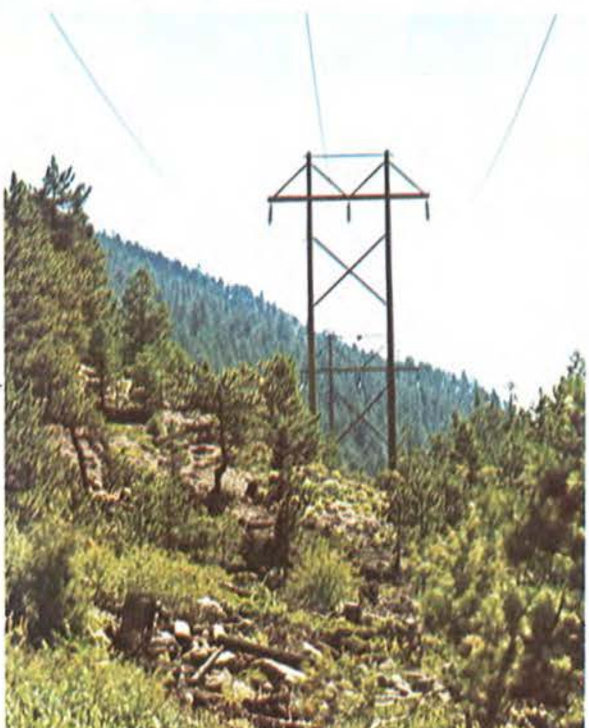




Several steps can be taken to overcome clashes between man-made and natural textures. Even a "standard" building can be situated so as to preserve trees and other vegetation close by the structure. This helps to confine reflection and screen the building from view. It also creates a shade-shadow effect—producing an appropriate texture on otherwise textureless surfaces.

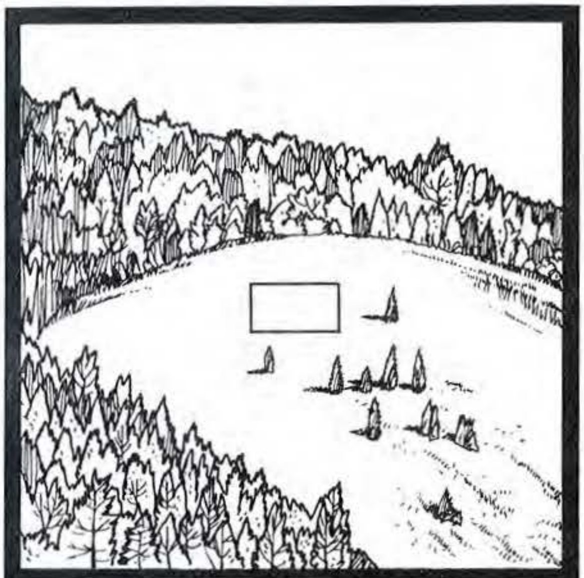


Textural change creates a contrast that is very visible (upper photo). Vegetative (textural) retention within a right-of-way will blend with the texture of the surrounding forest (lower photos).

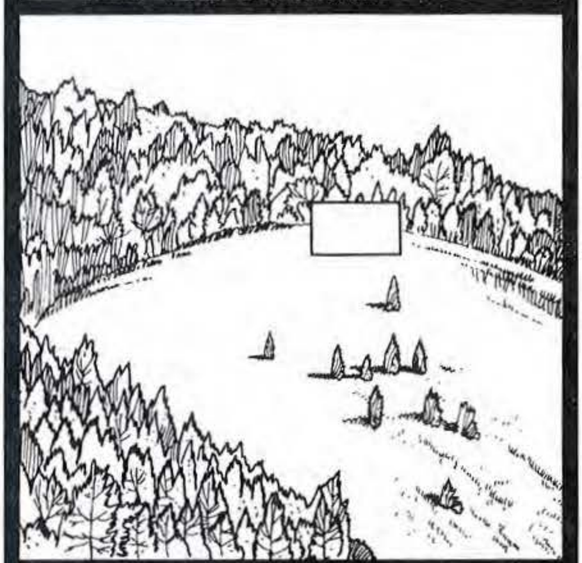


The microwave reflector on the mountain in the background serves this community. With the naked eye, the 24′ x 30′ reflector is hardly visible from the community because landscape management principles were followed:

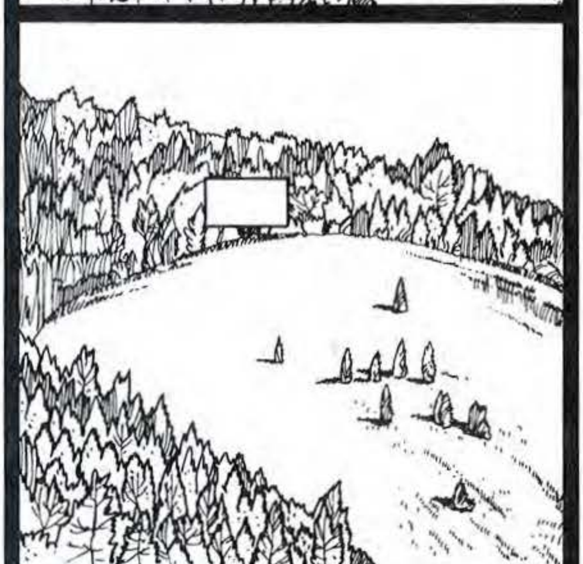
- **Line**—The reflector was located along a natural line formed by evergreen trees around a meadow. It was carefully placed to avoid "breaking" the skyline of treetops.
- **Form**—The evergreen trees are used as background. The form of the open area and the mountain is not disturbed by the structure.
- **Color**—The color is neutral (dark olive) and it blends well with the dark green background.
- **Texture**—The textural quality of the background evergreens could not be matched. The dark coloration of the reflector, therefore, must make up for this shortcoming.



Had the rectangular reflector been placed like this, its geometric form would have contrasted sharply with the irregular, rounded ***form*** *of the opening.*



Had it been placed here, it would have interrupted the ***line*** *of the trees in the background.*

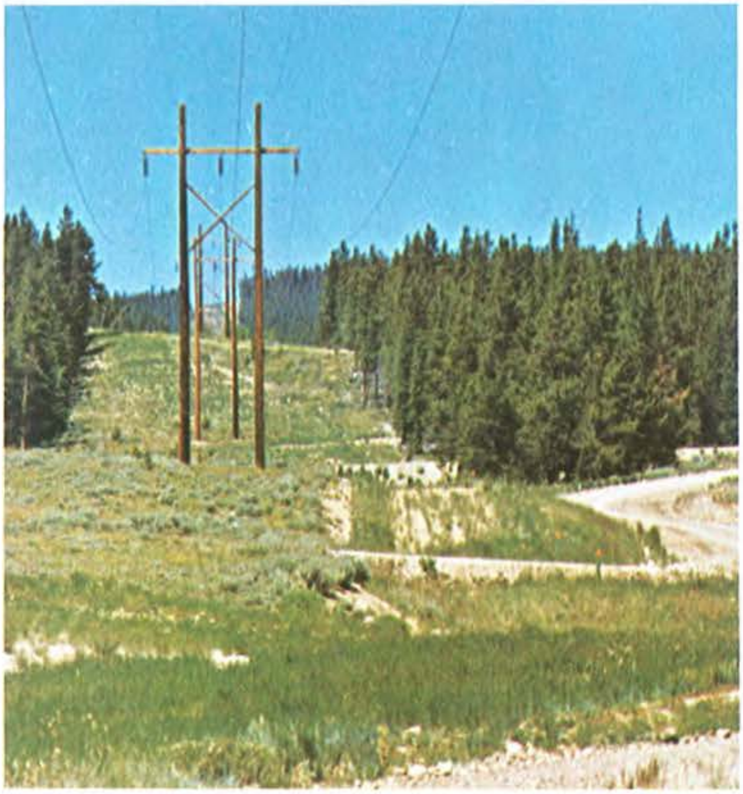


Here the placement is excellent for form and line, but the contrasting ***color*** *and lack of* ***texture*** *would have made the reflector an unwanted focal point.*

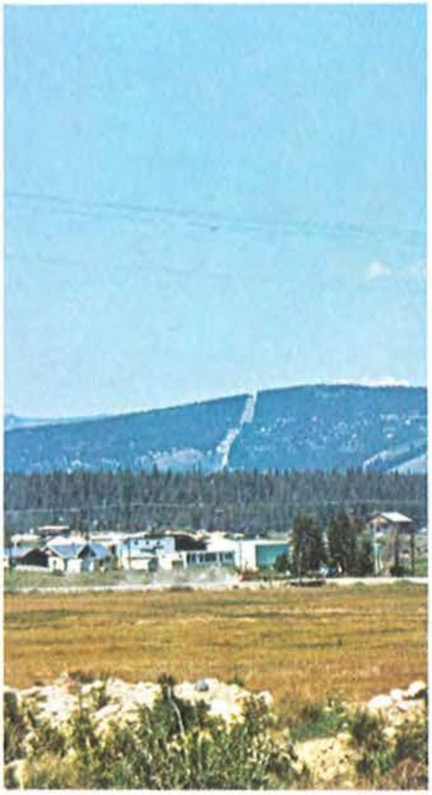
Visual impacts on the landscape

Visual impacts on the landscape result from:

- Vegetative manipulation
- Soil manipulation
- Introduction of structures.



1



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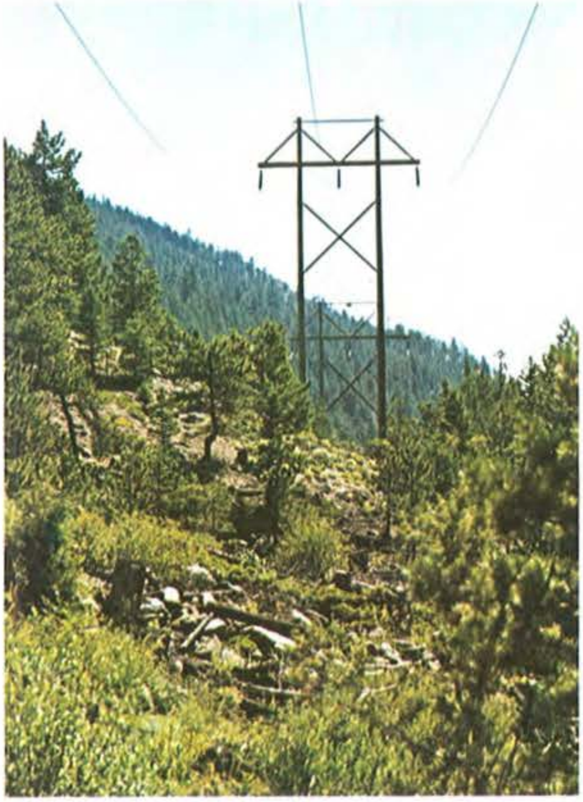

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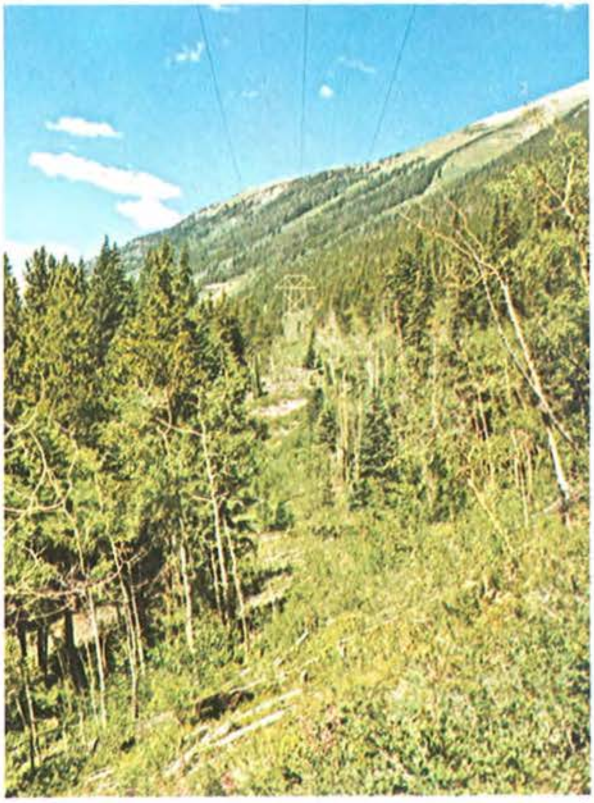


4

5

VEGETATIVE MANIPULATION

Vegetation can be removed, modified, or added. The visual impact depends on the form and scale of this change in relation to the surrounding landscape.

The results can be severe if all vegetation except ground cover is removed to the edge of the right-of-way (1 and 2).

Vegetation can also be used to blend, screen, or soften the impact of utilities on the landscape (3 and 4).

Vegetation introduced for soil stabilization or wildlife feeding on cleared rights-of-way can have varying visual effects, depending on the species selected (5 and 6).

Vegetative manipulation is one of the key elements to be studied at all stages of a utilities project (investigation, route and site selection, planning, design, construction, and maintenance).

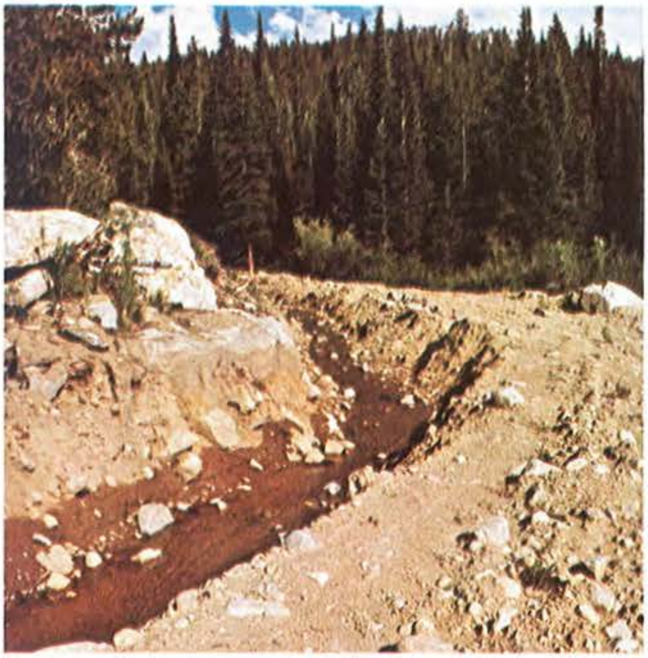
6

SOIL MANIPULATION

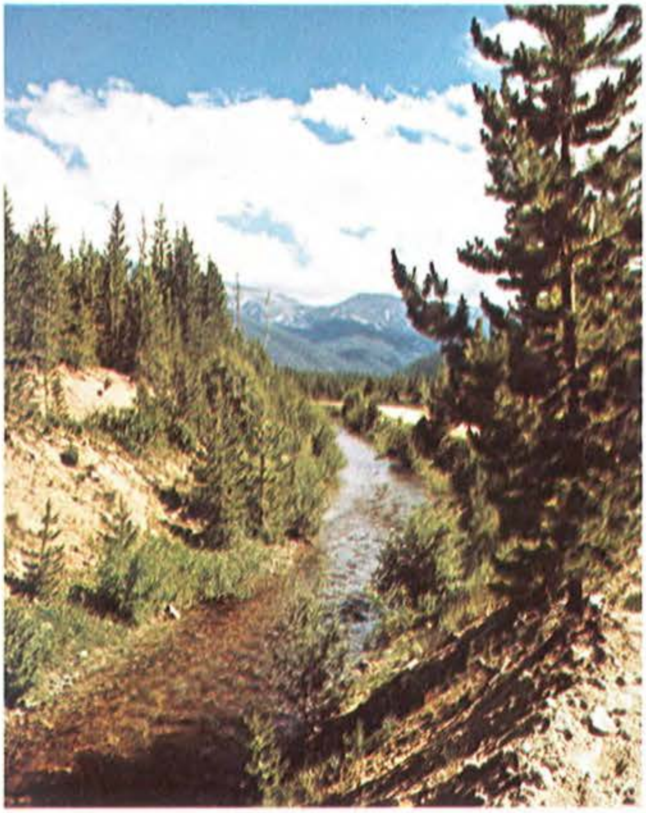
These pictures show some of the more common of the many ways that soil is manipulated during construction. Such manipulation should be held to the minimum and a rehabilitation plan should be prepared before construction begins.

The rehabilitation plan should be carried out in several steps:

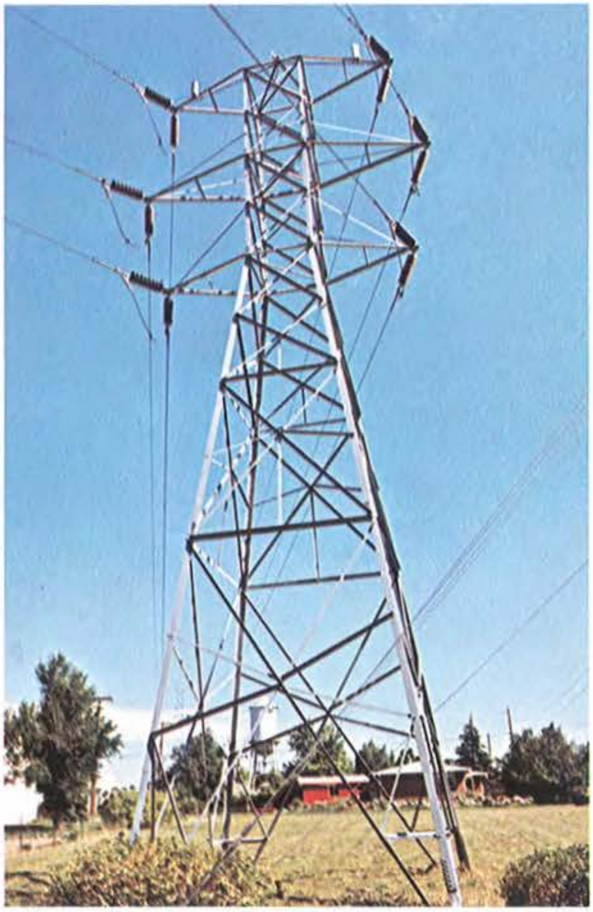
- Choose equipment that can do the job with least disturbance of the surrounding vegetation.
- Place (store) excavated soil so it will not interfere with the work or destroy adjacent areas.
- After placement of the utility, return the soil to the trench with proper compaction and fertilization of the topsoil.
- Seed or plant, as specified in the rehabilitation plan.

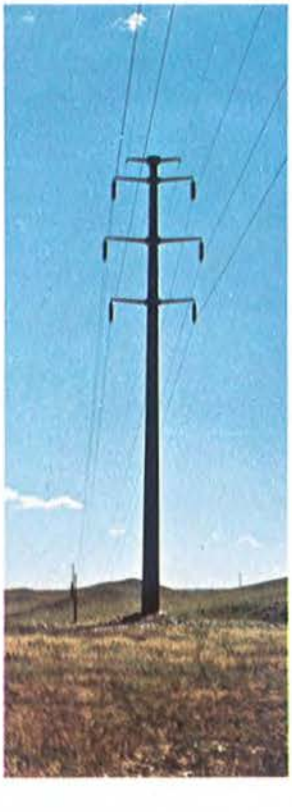


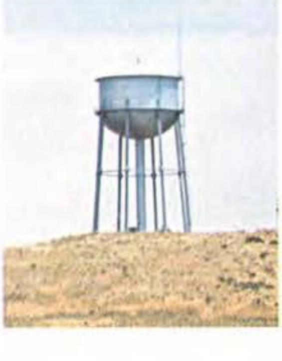
Poorly constructed ditch. With heavy runoff, the embankment could break and cause major erosion and resource damage.



Well-constructed ditch with adequate revegetation.



Raised tank.

Buried tank.

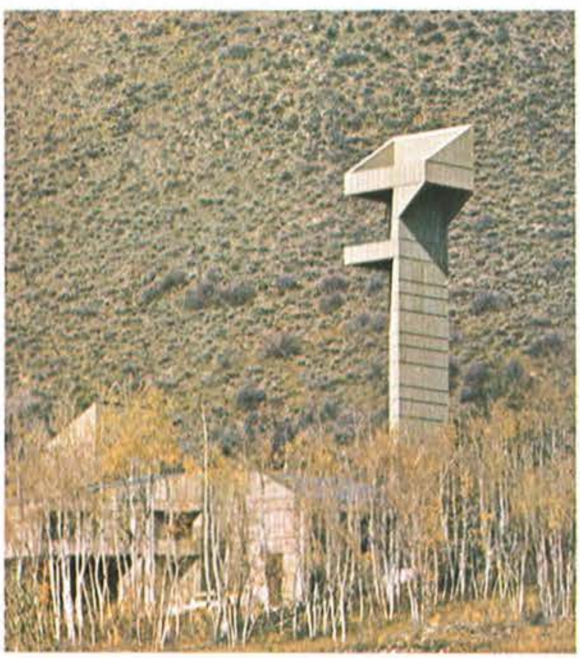
Both water tanks have approximately the same capacity.

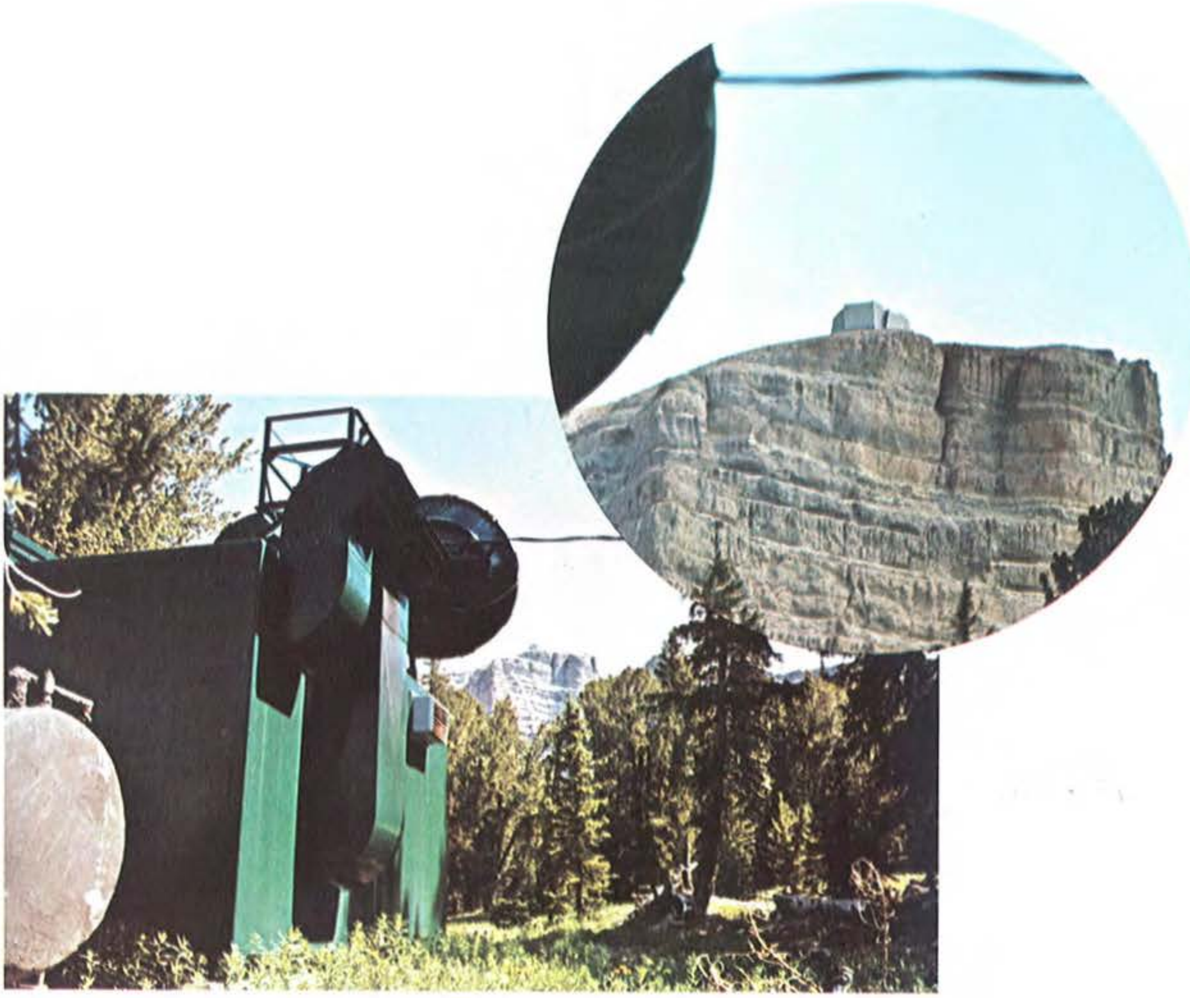
INTRODUCTION OF STRUCTURES

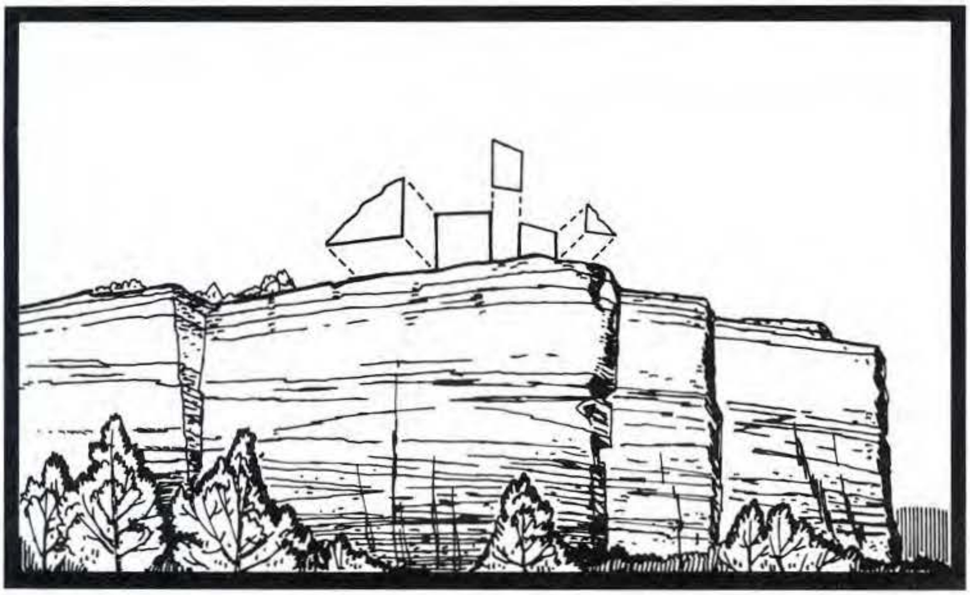
Utility structures can have a major visual impact on the landscape (left page). The variety of such structures is overwhelming.

Structure location, scale, design, and color are the key elements used to achieve the goals of landscape management. Just as important is the correlation of these elements with site conditions.

Through consideration of local conditions and proper design, a utility can be made to harmonize with its surroundings. An example is this microwave terminal or junction station (lower right) which was designed to blend with the architectural style of the local community.





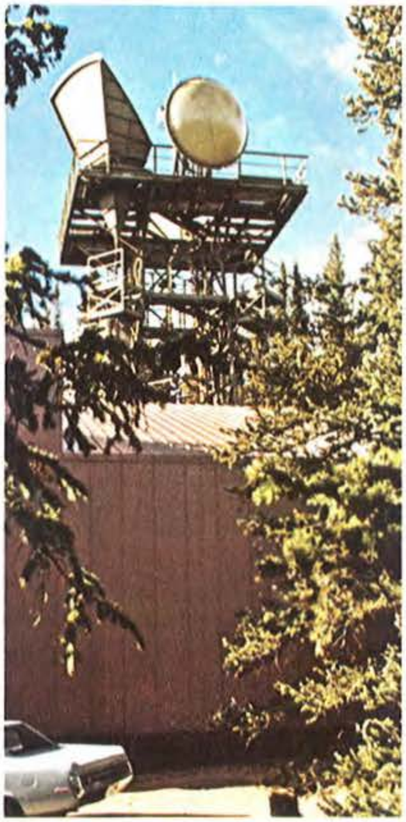


Three irregular-edged and appropriately painted screens were used to "blend" or camouflage two microwave reflectors on this Wyoming mountain-top many years ago. The effort was only partially effective because of the angle of the various panels to each other and the resulting shadow (color) patterns.

Some additional steps which might be taken in a similar situation are:

Gas

Electric



Microwave

Water

Examples of utility installations

This section discusses four specific utility installations: a natural gas pipeline, an electric transmission line, a microwave system, and a water collection and transportation system. It comments on the planning, design, visual considerations, installation, and rehabilitation techniques involved in each project.

Each project was planned on its own merits and was designed to suit local conditions. Each was planned as part of an overall system with complete interdisciplinary involvement and continuous coordination among all disciplines.

The treatments used in the four examples are for illustrative purposes only; circumstances will probably be different in most cases.

GASLINE

The gasline discussed here is a 10″ main that crosses mountainous terrain of high scenic value and very fragile ecosystems.

To develop the project, the gas company and the Forest Service assigned ecologists, soil scientists, geologists, hydrologists, landscape architects, archeologists, and engineers specializing in road and pipeline design, construction, and maintenance.

Initially, as many alternate routes as possible were identified and evaluated. Routes that were found not feasible were eliminated; the rest were studied in detail.

Because of the scenic value of the area to be crossed and the fragile ecosystems encountered, the route selected was the one that took advantage of as many existing rights-of-way as possible so as to hold landscape alteration to the minimum. Such rights-of-way were originally developed for roads, electric transmission and telephone lines, water mains, and a railroad.

Where a conflict between the landscape and the gasline was anticipated, special procedures were developed to minimize visual damage to ecosystems and the landscape.

Everyone involved in the work was continuously informed of all special procedures and their purpose. Continuous liaison between the gas company and the Forest Service assured smooth operation. When conflicts arose, field meetings were called at once to resolve them.

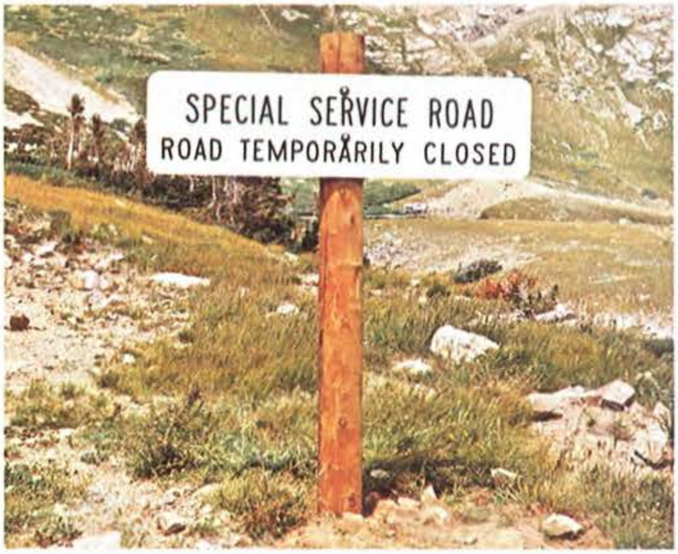
"Construction train" planning and scheduling became crucial because the gasline had to pass through many narrow areas.

This discussion focuses mainly on construction and testing equipment, procedures for installing a gasline, and special procedures developed for this project.

Through careful planning, the visual impacts of this gasline were held to a minimum. As with other utilities, painstaking route selection was the key to avoiding problems and taking advantage of all local opportunities. Although costly and time consuming, special procedures were developed for areas where normal pipe-installation procedures would have created unacceptable results visually or ecologically.

Interdisciplinary planning, on-the-ground discussions, and continuous coordination made it possible to complete this project successfully.

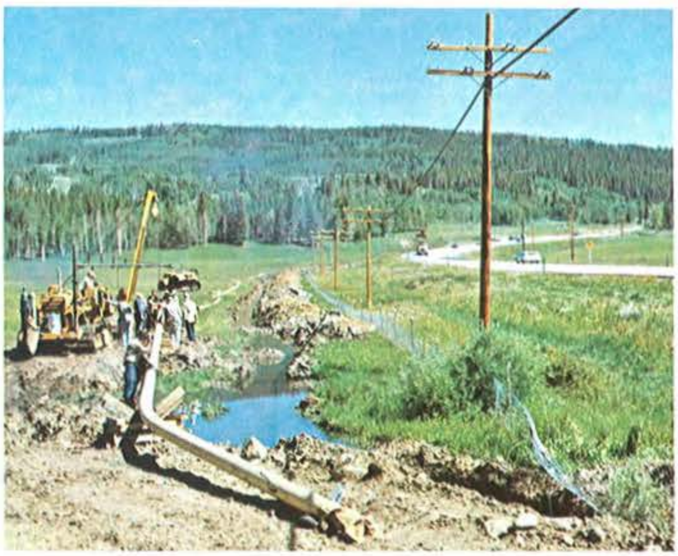
Much of the success of this project was due to continual coordination. Preconstruction on-site conferences to evaluate the situation were very successful. At these meetings problems were quickly recognized and resolved.



Traffic controls, right-of-way clearing, and disposal of trees were the first order of business after the line was surveyed on-the-ground.

Trees were cut into short lengths and stacked along the right-of-way. Small trees and branches were chipped or burned. Then the ground was leveled to accommodate construction equipment.

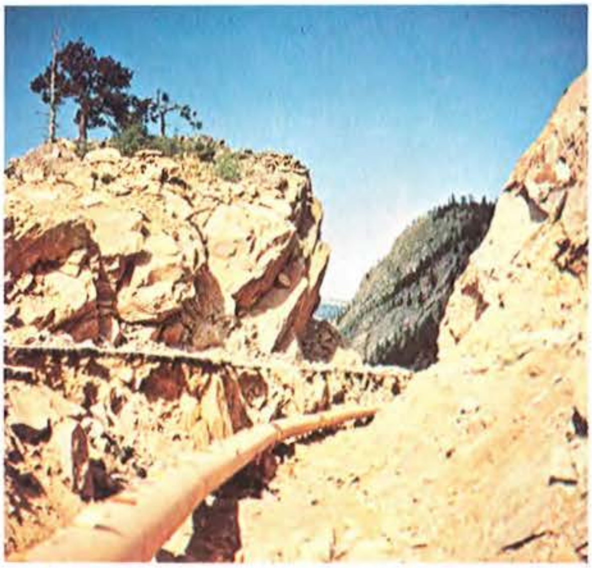
Pipe bending to meet horizontal and vertical alignment changes was used extensively on this job. In this way construction scars were held to a minimum and rehabilitation was made much easier.



A horizontal bend.

A vertical bend.

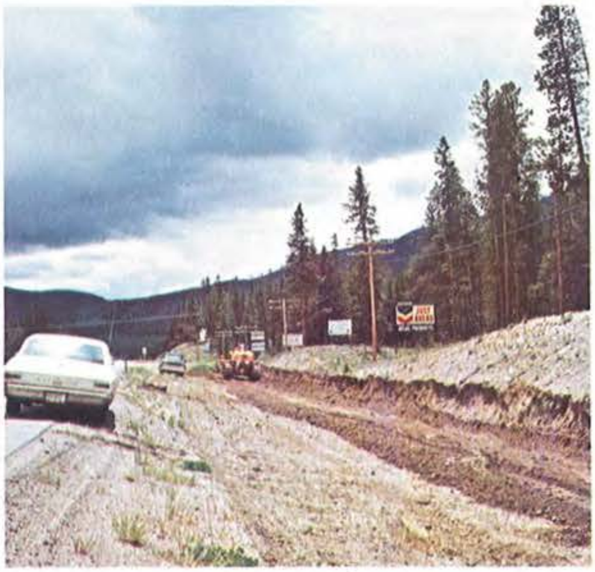
The gasline's 65-mile route across National Forest land encountered many different land forms. Planning had to account for these variables and for difficult weather conditions.



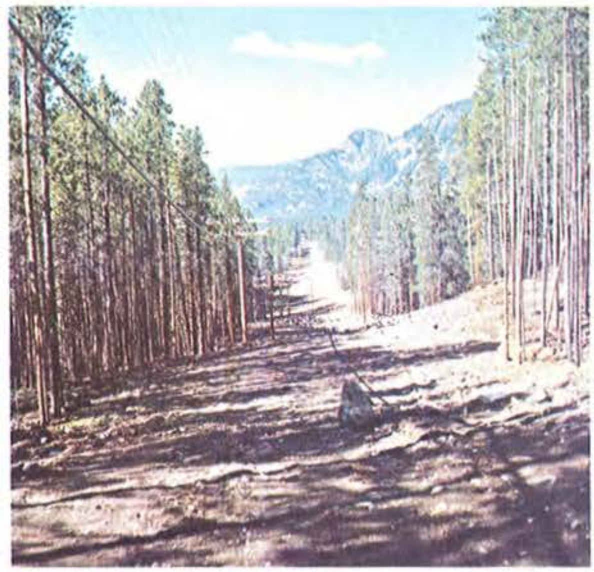
Rock blasting and pipe bending were required to install the gasline in this road shoulder.

Going from high country to a swamp, the pipe was pulled through rather than laid conventionally, thus keeping disturbance of the swamp to the minimum.

Crossing this meadow was difficult because of the high water table. The pipe was welded into one long section, the ditch temporarily drained, and the pipe quickly bedded into place.

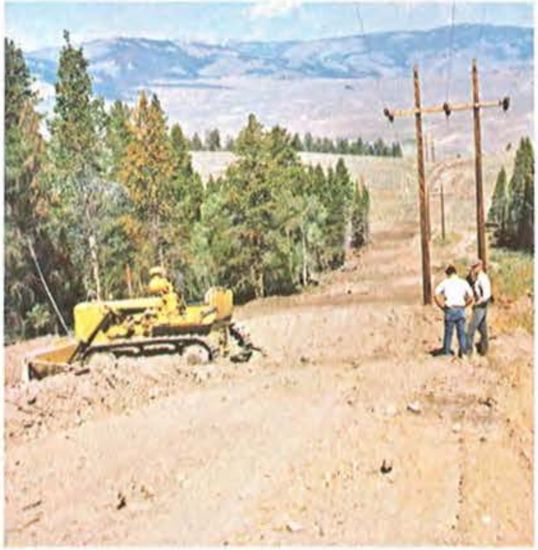


To eliminate additional scars on the landscape, existing rights-of-way such as this roadside were used to install the gasline.



Here an old telephone right-of-way was used for the gasline.

This picture was taken 3 years after the gasline was installed under the center of this road. The road serves a water collection system (the water main was installed to the left of the road shoulder).



Here the gasline was installed within the right-of-way of an existing electric transmission line. In such cases where rehabilitation was major and improvement of the existing right-of-way was involved, procedure was discussed in detail with the equipment operators.

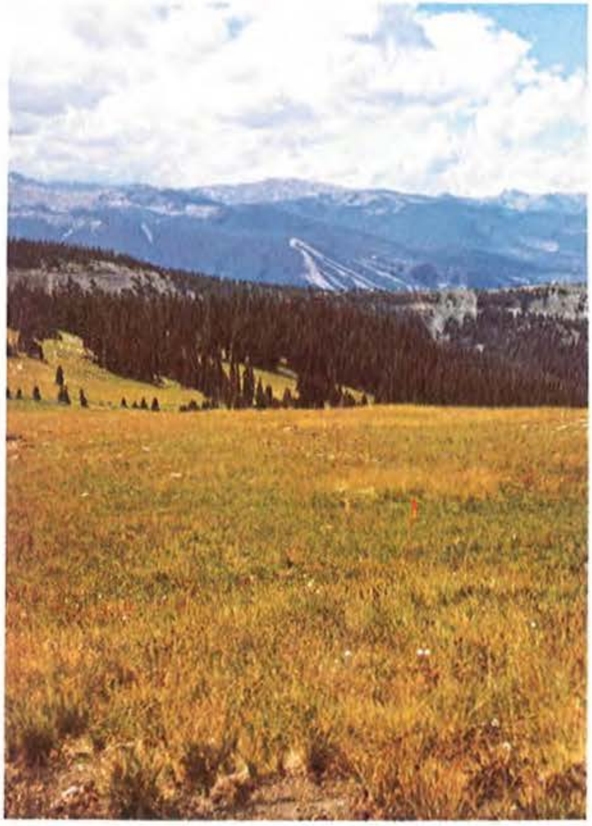
On side slopes under the powerline, the first step was to make an almost vertical cut into the slope. The excavated material was cast downhill. Then the pipe was brought in, assembled, and placed in the "V" notch of the cut. A dozer was used to bring the excavated material back up, place it over the pipe, and blend it with the upper edge of the cut, thus restoring the original contours of the land.

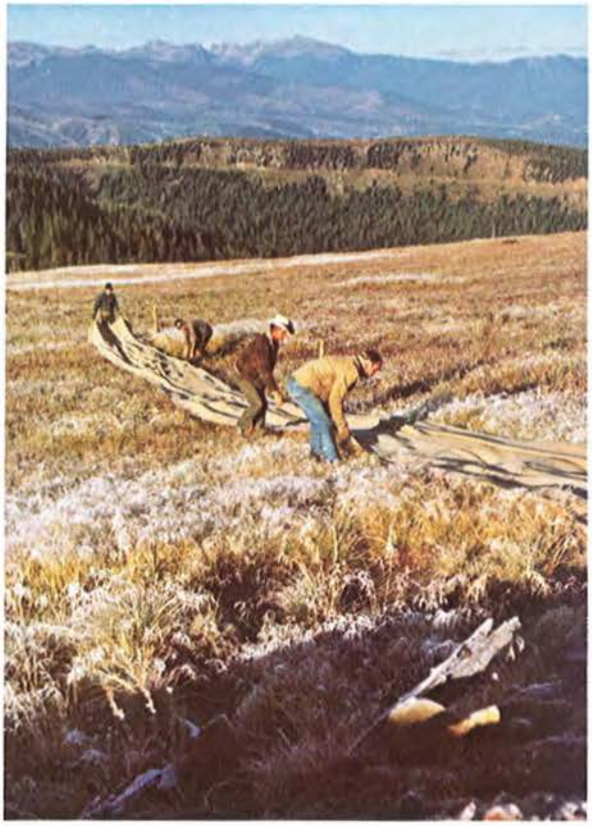
Rehabilitation by grooming, seeding, and fertilizing followed immediately.

To protect alpine and other fragile areas from "cat tracks," old tires and boards were used to cushion ground vegetation and soils.

In one area of extremely erodible soils, the gasline was installed aboveground. Here it was wrapped and painted green to blend with the alpine trees.

Visual impact was minimized in this difficult situation by burying the gas line in the roadbed and supporting it across this old railroad trestle.

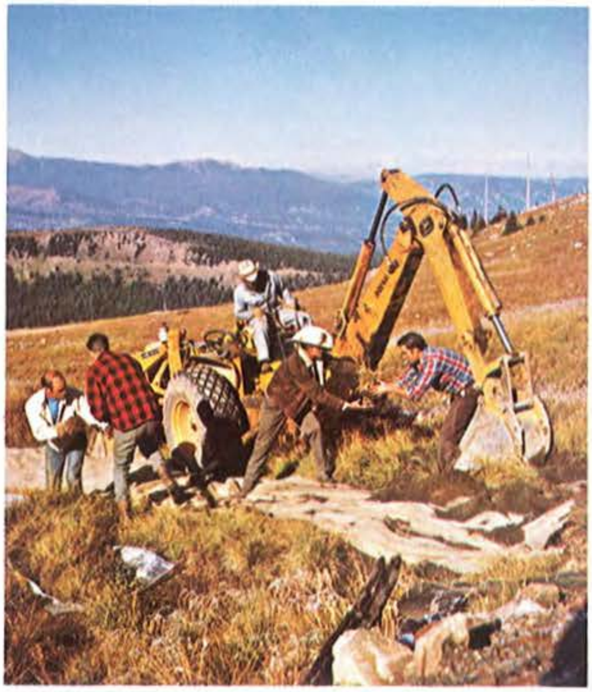




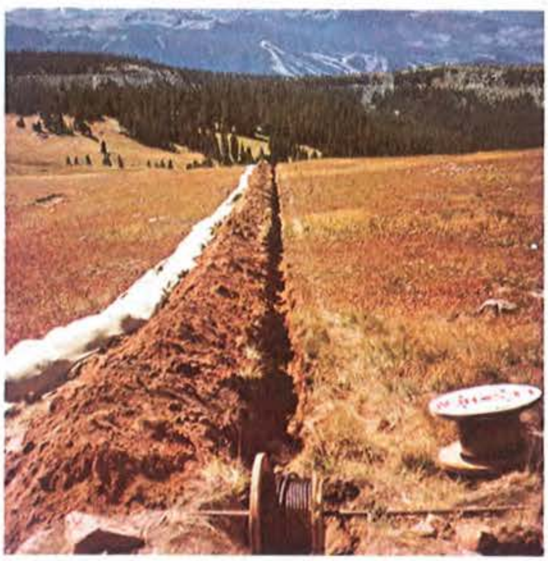
Above
A 1,250′ stretch of tundra had to be crossed on this project. Since normal procedures were not adequate, a special procedure was developed to minimize ecological damage and the visual impact of the unnatural line across the tundra.

Above right
Plastic and burlap were placed on the tundra to protect its fragile plants.

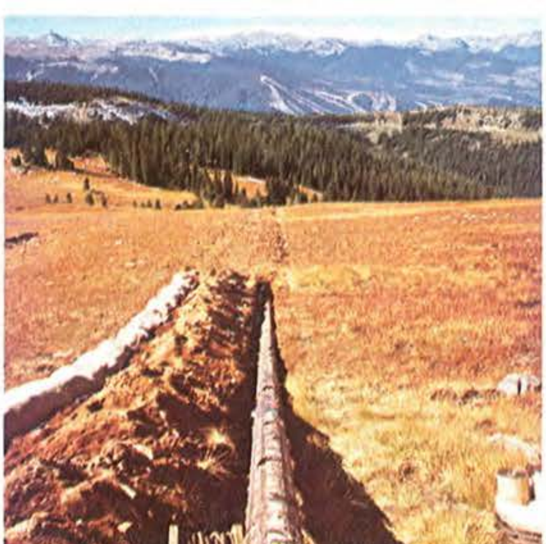
Right
Only one piece of equipment—a small, rubber-tired, lightweight backhoe—was allowed on the tundra.



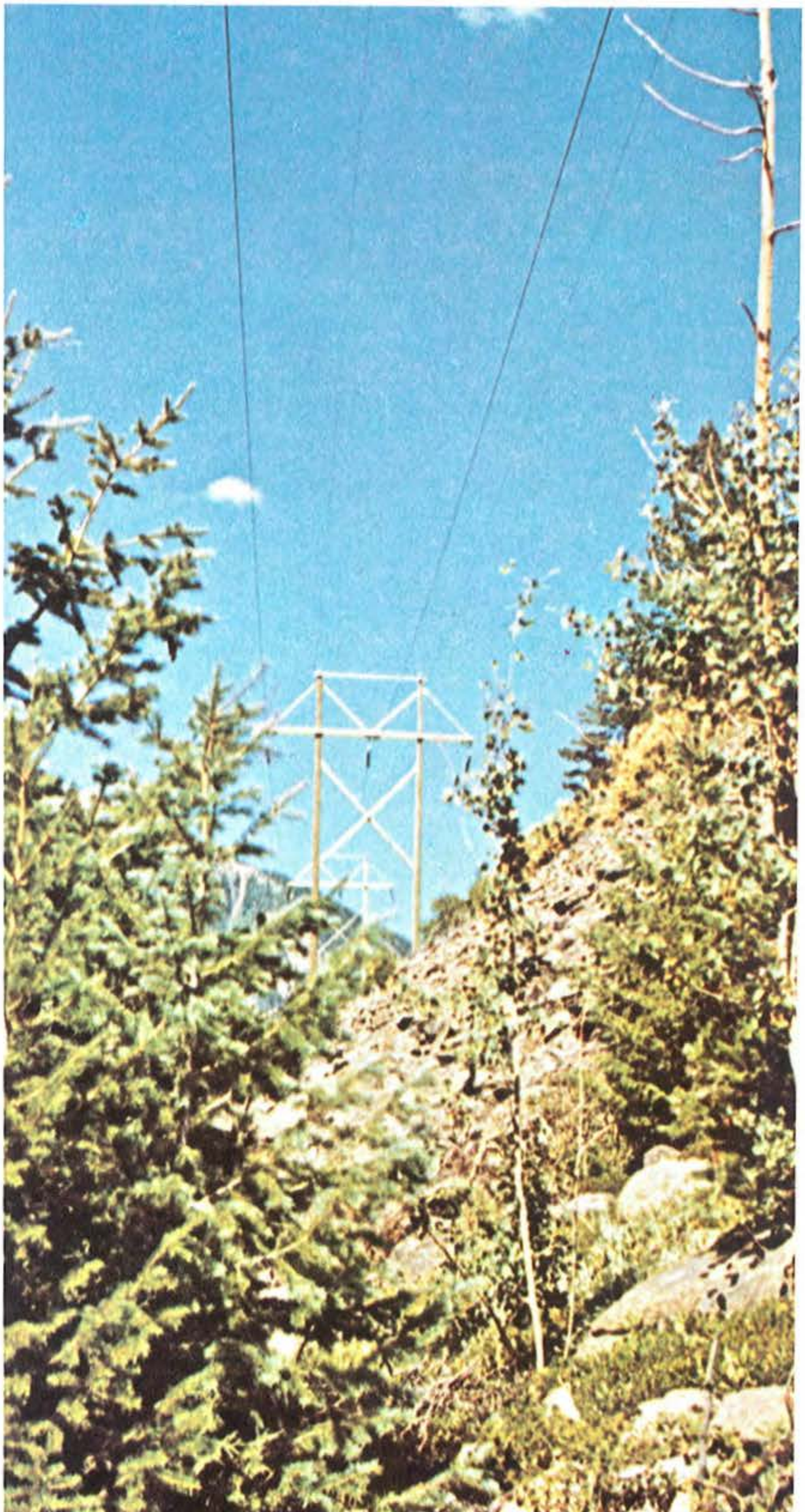
The top layer of tundra was excavated with a specially designed blade, placed on plastic by hand, covered with burlap, and watered.



The backhoe then dug the rest of the ditch. The pipe was welded together off the tundra. A winch at the upper end of the ditch pulled the pipe into place.



The backhoe was used to replace most of the soil. However, rocks and the top layer of tundra were carefully replaced by hand and the area was raked. Visually and ecologically the impact was held to a minimum.



ELECTRIC TRANSMISSION LINE

This powerline is being installed in phases; the first phase has been in place for 3 years. A 115-kV line, about 35 miles long, was constructed in the Rocky Mountains at elevations between 8,000′ and 13,000′.

The climate was extreme (high winds, icing, deep snow). Only about 3 months of the year were clear of snow and suitable for construction. The few existing access roads could not accommodate the heavy equipment needed for the project.

All necessary analyses were made during the planning stage. The corridor was selected and the transmission line was sited within the corridor. Staging areas were chosen and construction procedures were established.

Where the powerline crossed National Forest lands, planning and design were a coordinated effort of the power company and the Forest Service. Professionals in all relevant disciplines contributed to the planning and design. Since the line was to pass through a historic area, local residents helped in the planning.

Because of the problem of road access and of the danger of causing irreparable damage to the land, it was decided that helicopters would be used to haul and place materials and that the groundwork would be done by men and horses.

The right-of-way crossed stands of spruce and lodgepole pine, some mixed with aspen and ponderosa pine. Alpine fir was encountered just below the timberline. Much of the right-of-way had to be cleared within even-aged stands, thus making it very difficult to achieve a low degree of visual impact.

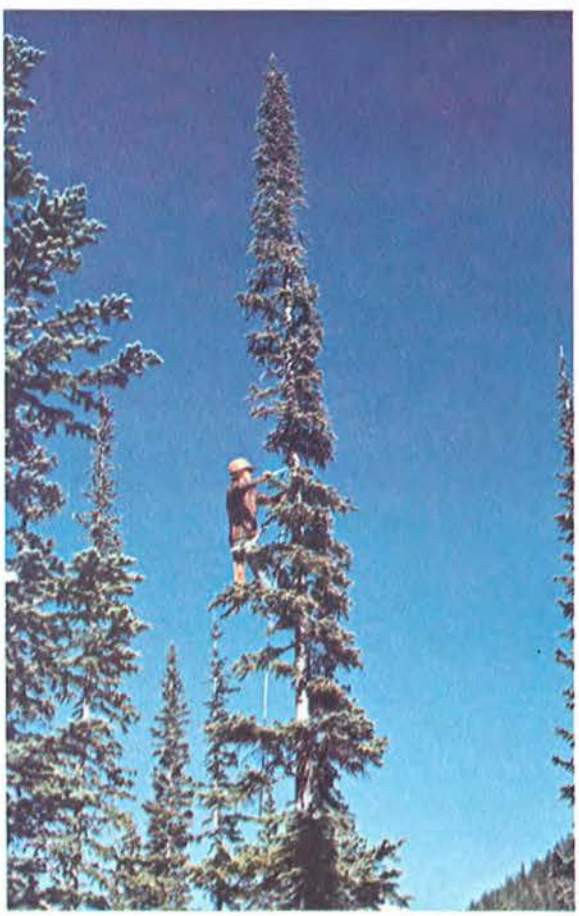
Selective clearing within the right-of-way and final surveying of the centerline and structure locations began after the centerline was designed and structure locations were pinpointed.

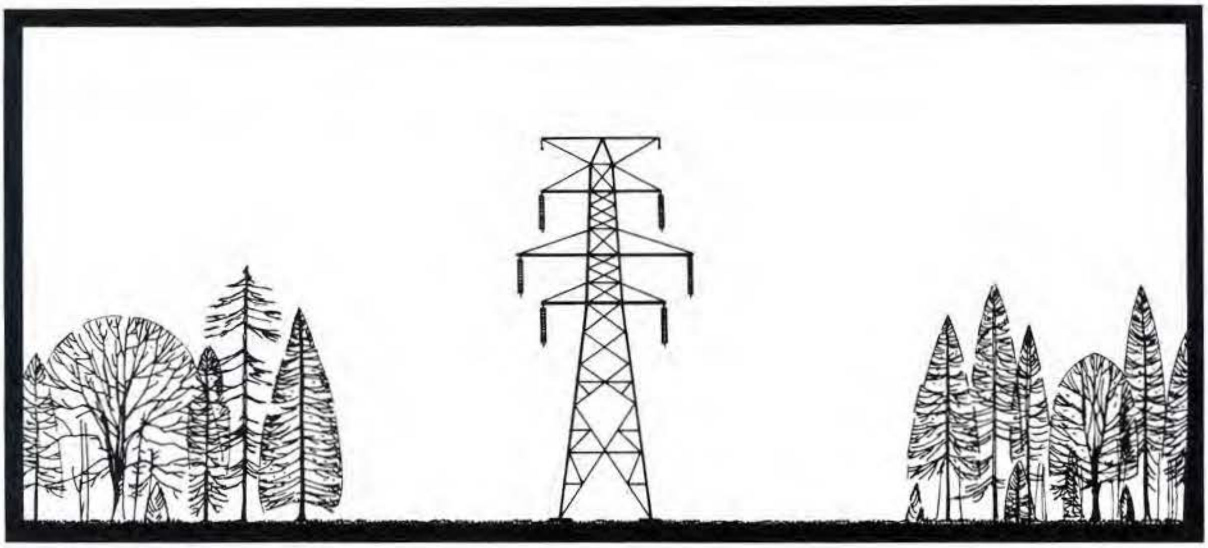
Through thoughtful planning, good design, and minimal construction impacts, an electric transmission line and its right-of-way can be made to blend gracefully with the natural landscape.

It should be reemphasized that the procedure described here was used for a 115-kV line. Larger or smaller lines probably will require different procedures.

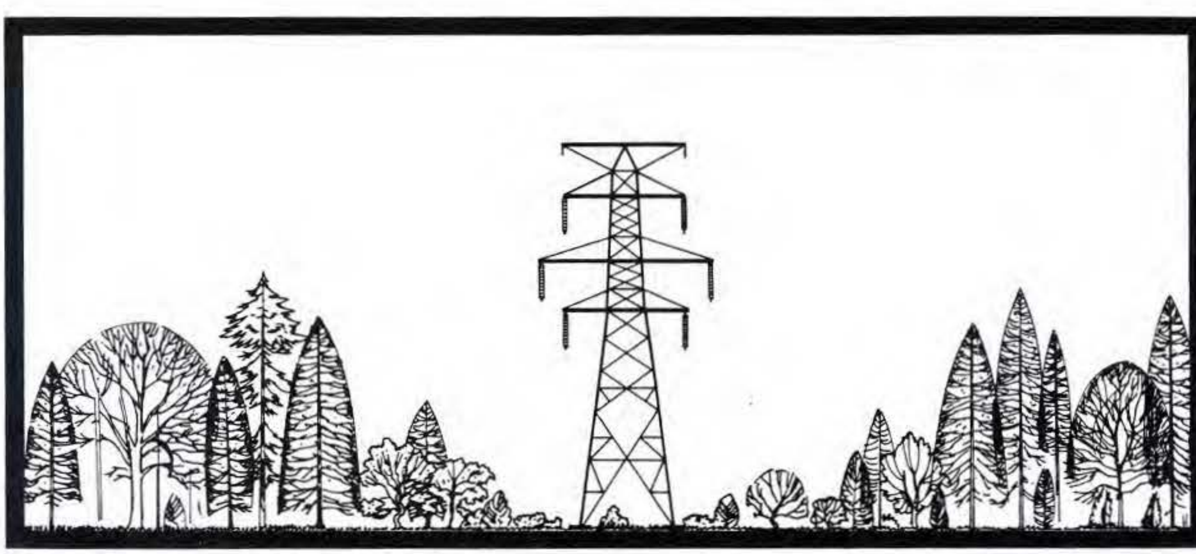
Right-of-way clearing for overhead powerlines. Right-of-way clearing procedures and techniques have changed drastically during the past 5 years. For many years, many companies and government agencies advocated clearcutting of the right-of-way as a safety measure since there was danger that the conductor would drop to the ground. During the past decade or two, use of aluminum conductors reinforced by steel strands has reduced the likelihood of this happening.

Because of the stronger conductors and the pressure to keep the visual impact of the powerline to a minimum, a method of selectively clearing the right-of-way has evolved. Fewer trees are removed and areas are cleared so as to blend with natural openings in the vicinity of the line. Tree-topping procedures provide required electrical clearances and minimize the visual impact of the right-of-way.

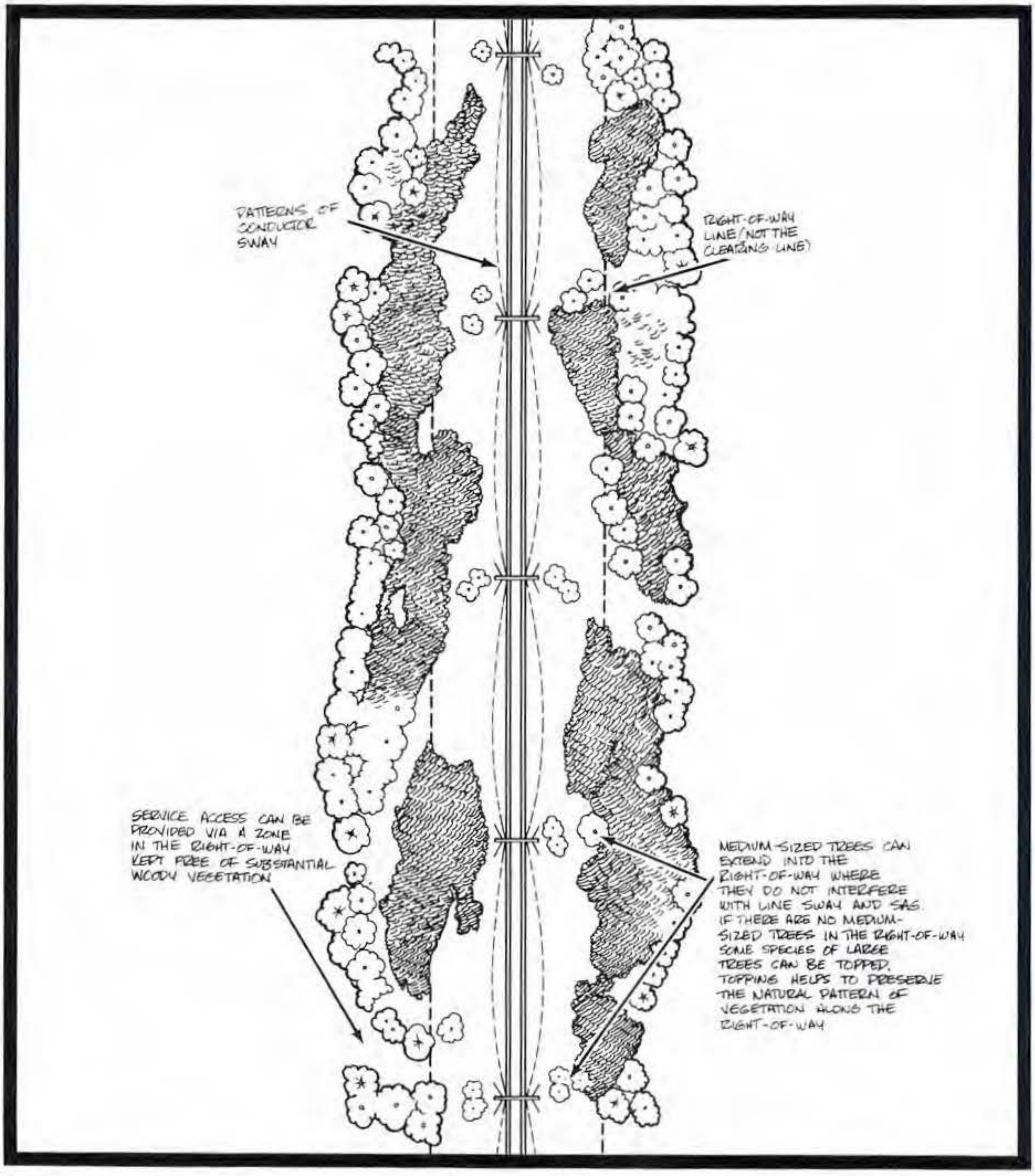




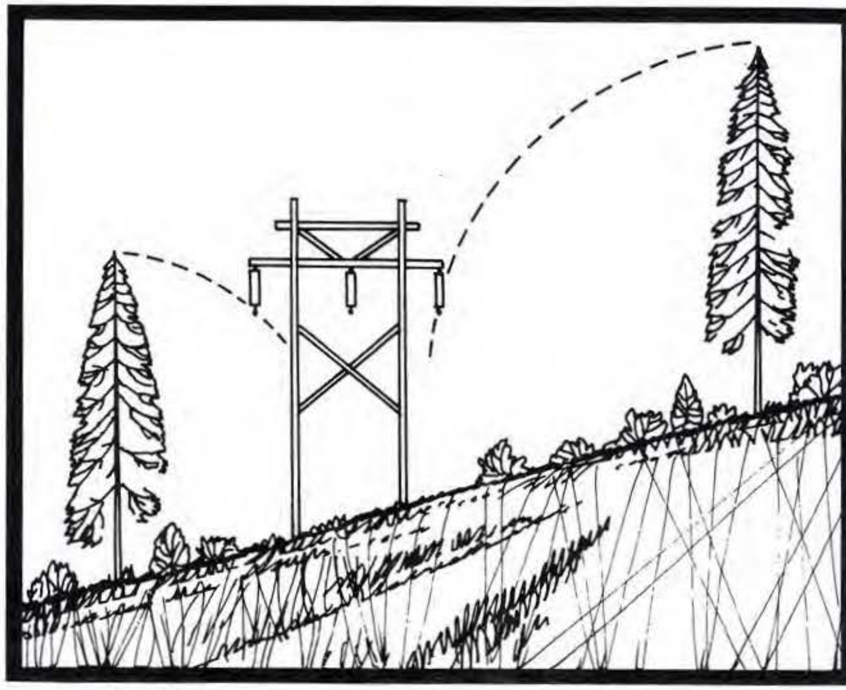
The old method of clearing the right-of-way.

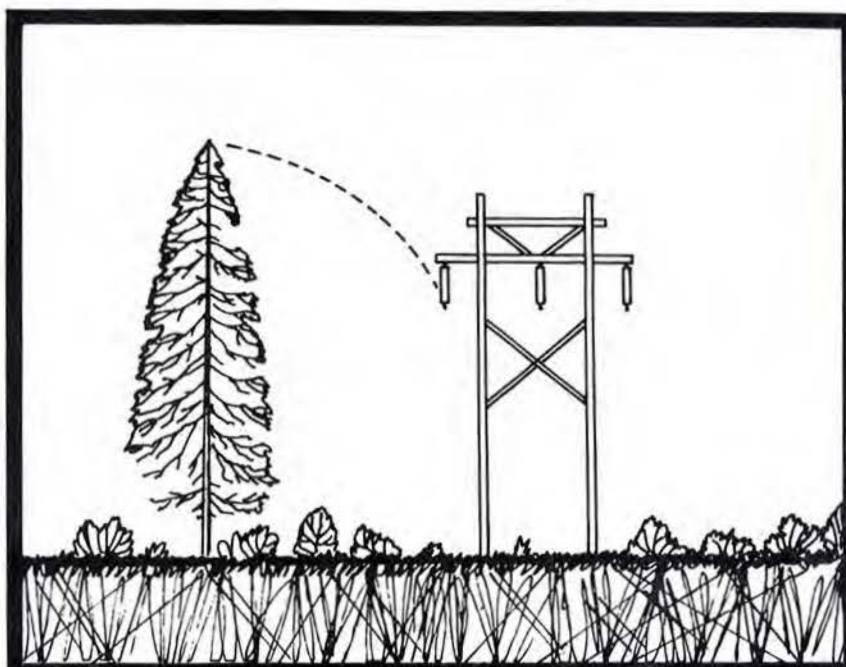


Tapered clearing softens the edges, thus reducing the visual impact of the right-of-way.



Right-of-way clearing pattern and sway factor.





Danger Trees

Trees that could damage the conductor—if they fell—should be marked as danger trees. All danger trees should be removed or topped. The health of a tree is a decisive factor in its designation as a danger tree.

Above left
Helicopters were used to bring in materials, tools, and personnel and to set poles and string the conductor.

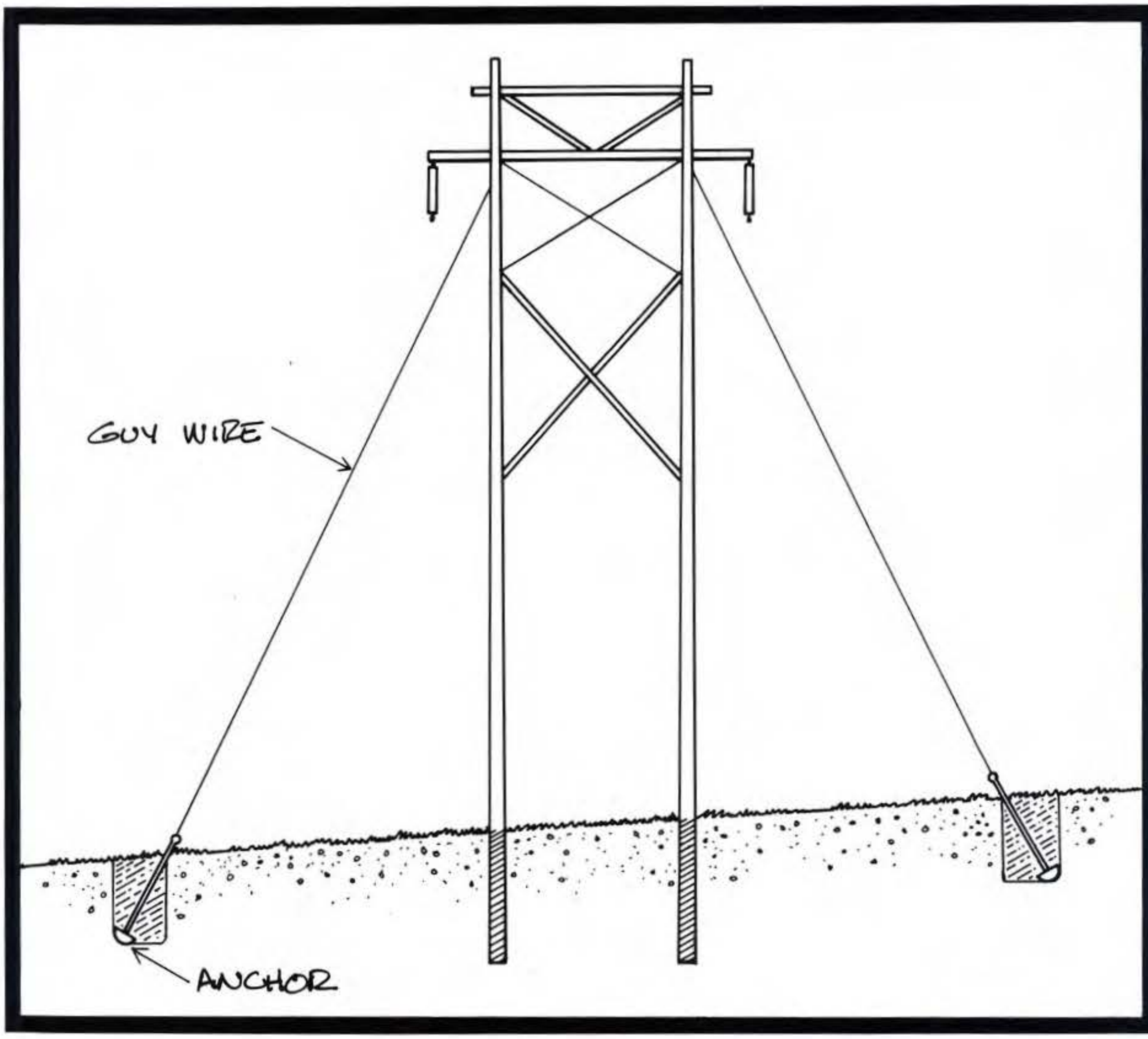
Top
The location of staging areas in relation to the construction site was very important because of the high cost of helicopter flying time.

The area had to be large enough to store materials, arrange them for helicopter lifting, and serve as a landing pad and fueling area.

All pole and anchor holes were dug by hand or with portable jackhammers.

Excavated materials were placed on burlap to protect surrounding land surfaces.

After an anchor was placed, soil and rock were manually compacted in the hole and the carefully maintained top tundra layer was replaced. No visible construction scar remained.

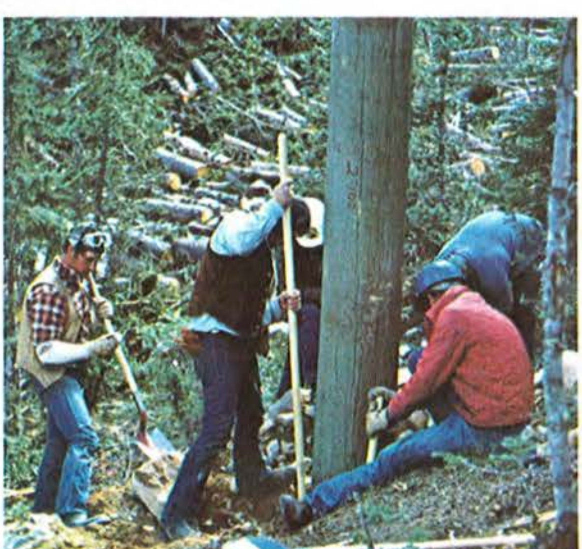


As many as 16 anchors were necessary for each set of poles above timberline (approximately 10,000′ elevation) to stabilize them from wind, snow, and ice loading wherever the line turned a corner.

Some anchors were embedded in rock.

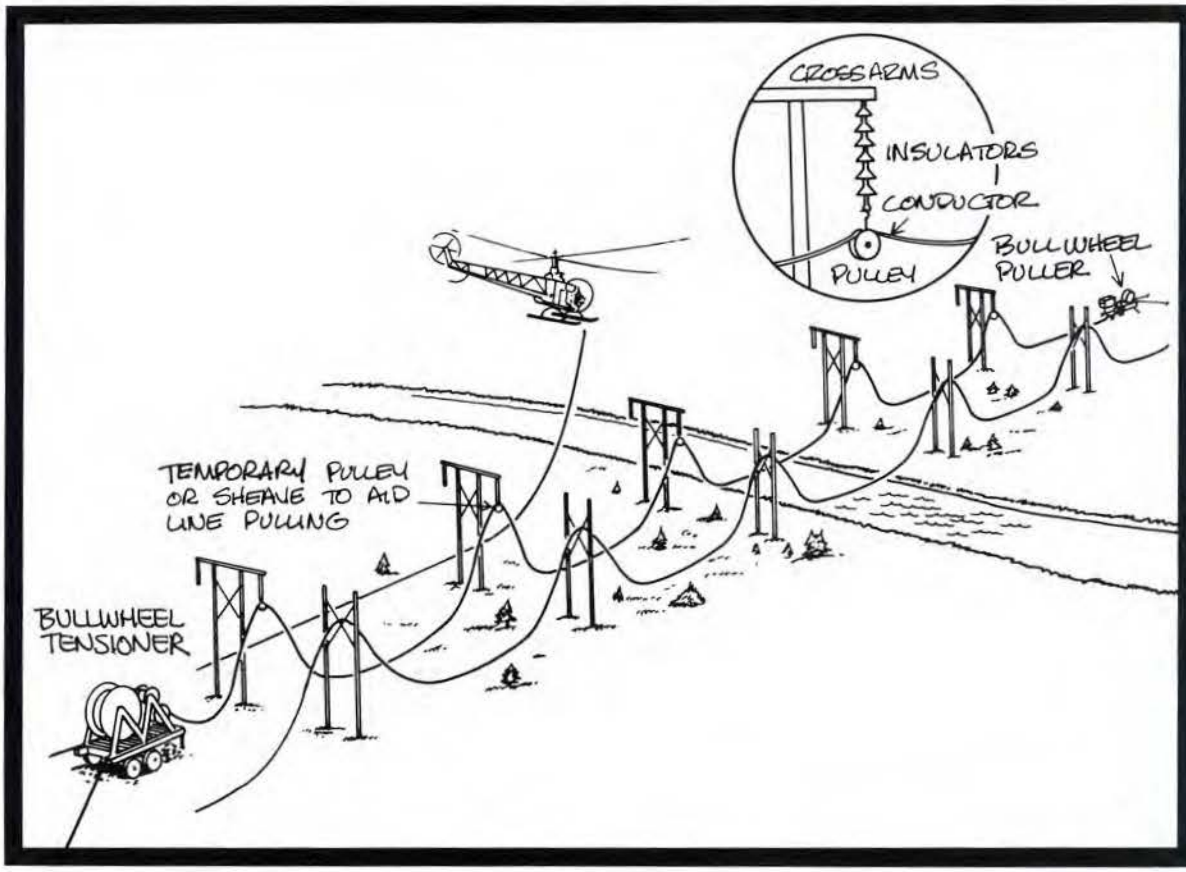
The poles were brought in by helicopter and lowered into the excavated holes.

When the pole was aligned vertically and tied to its anchors, the crew backfilled the hole and permanently secured the pole.



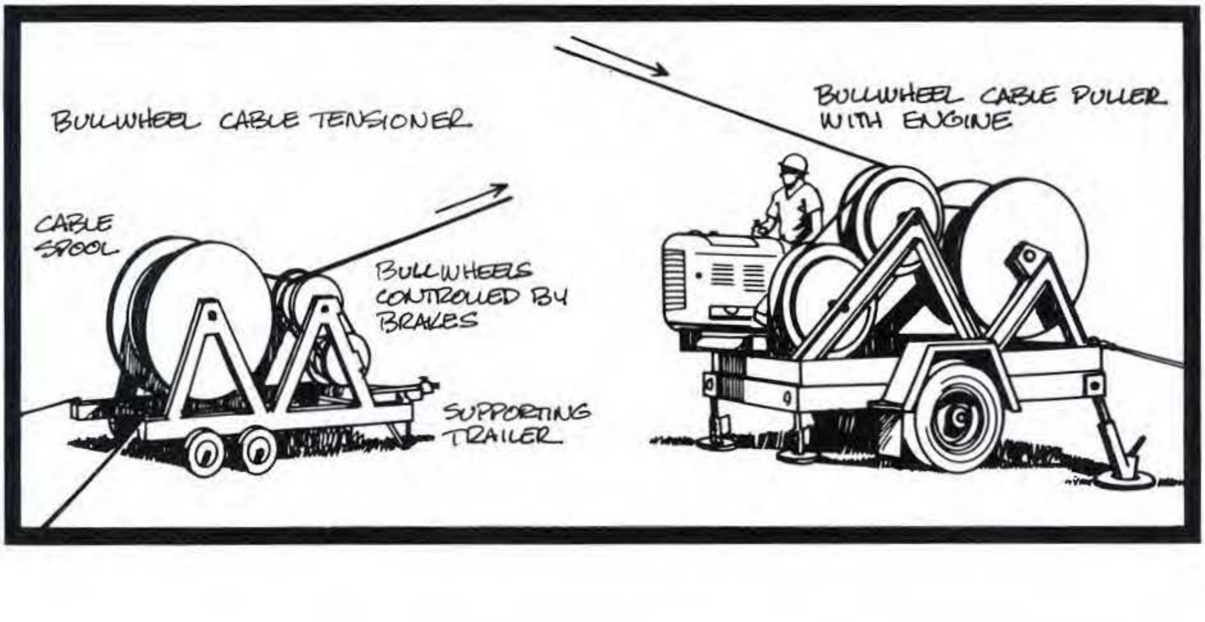
After the crossarms (if any) and permanent guys were attached, the nonspecular conductor was "pulled" by the tension-stringing method. The length of a "pull" depends on the situation—on this project, pulls ranged up to 5 miles in length.

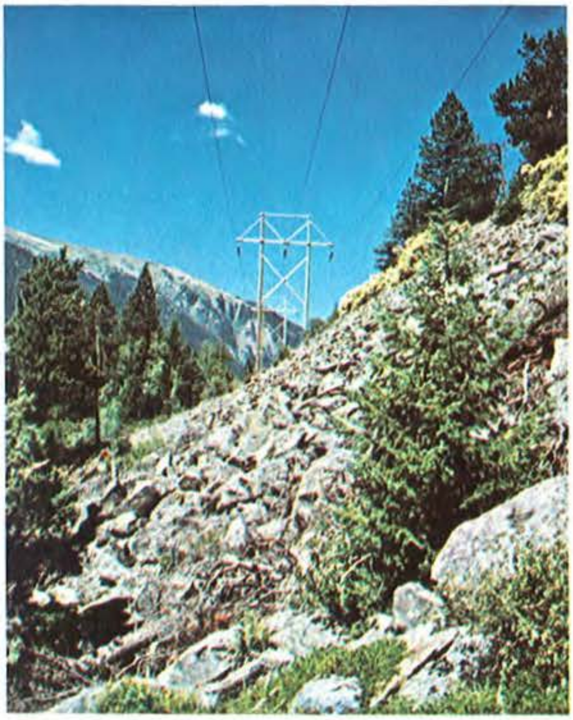
The "sock line" or pulling line is run out by helicopter or other method between the tensioner and the puller. It is laid upon the ground between trees and brush with little or no cutting necessary. A repeat trip is made as each cable is "pulled." In transmission line installation, the sock line is usually lightweight wire rope, for distribution lines it can often be nylon rope.



Tension stringing is also used in urban or suburban situations where powerlines must be installed over roads, telephone lines, or other powerlines without interrupting traffic or service.

Two main pieces of equipment are used in stringing the conductor: one pulls the conductor; the other keeps it under tension to keep it from being damaged by contact with the ground. In tension stringing, the conductor sags about 20 feet below normal. Trees that rise above this sagline should be marked for removal or topping. After the conductor is pulled and clipped in its final position, marked trees can be removed and the vegetative pattern of the right-of-way can be designed to achieve a tapered and scalloped effect that minimizes the visual impact of the right-of-way.

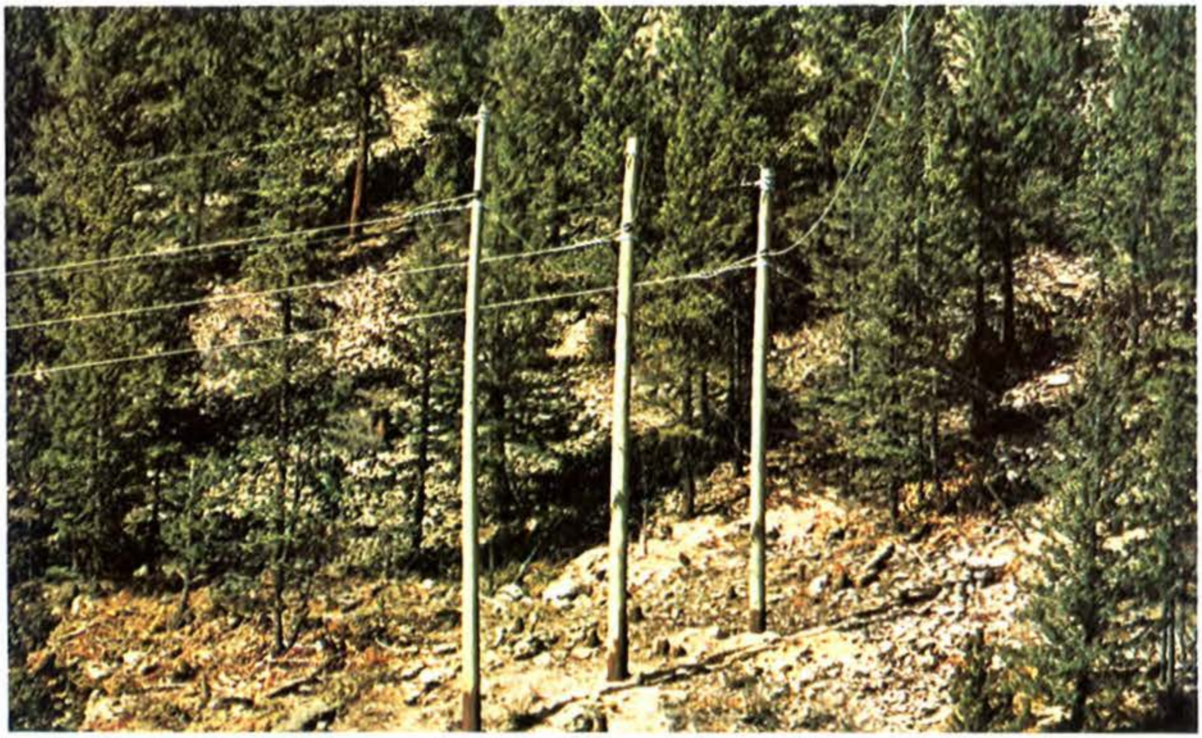




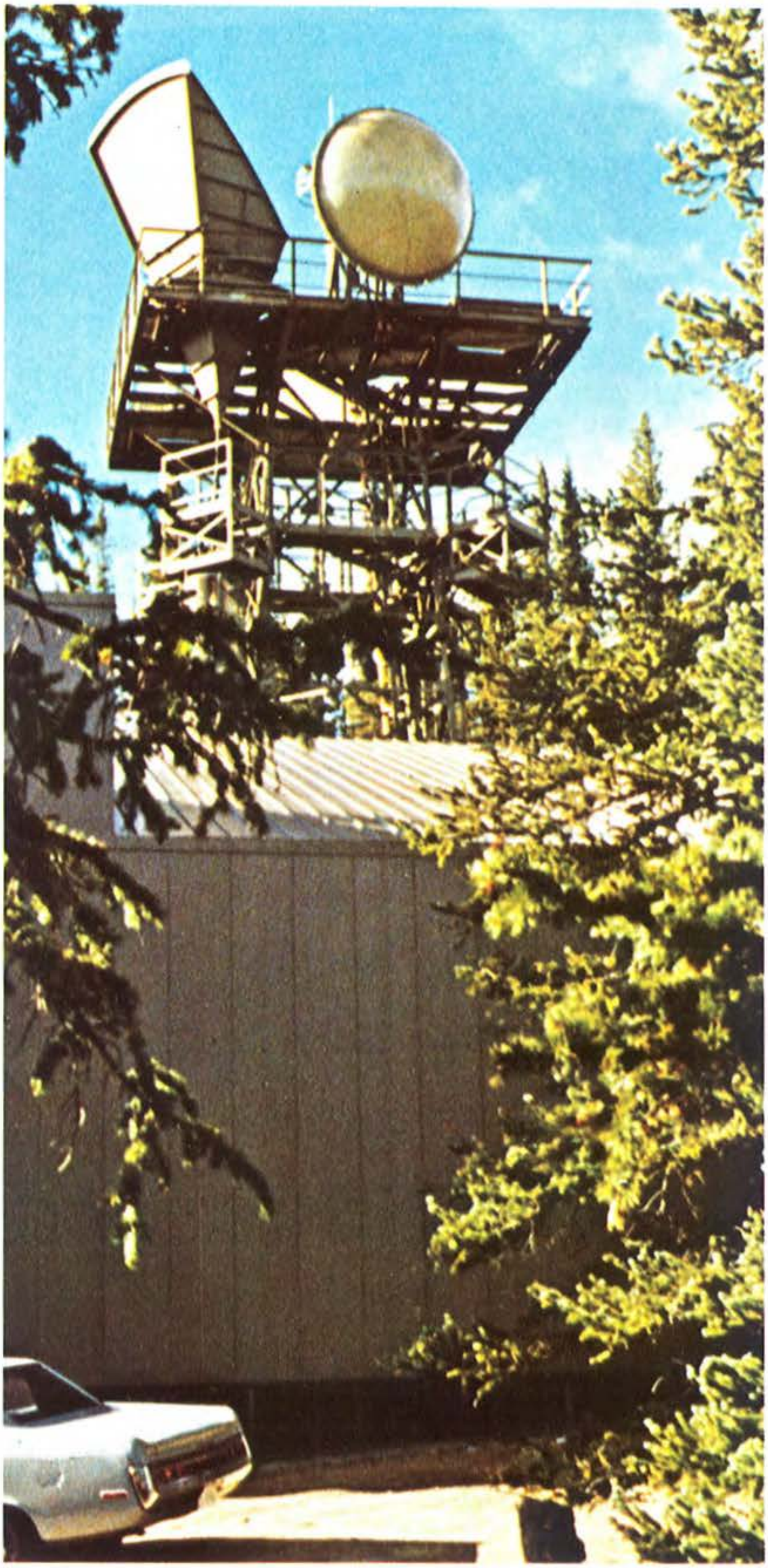
Here the line parallels a highway. Only danger trees were removed and the tree cover between the highway and the line was preserved, thus ensuring a minimum visual impact.

Visual impacts were reduced by many methods. The transmission line was placed across open spaces such as meadows, rock slides, and avalanche paths. In this way much tree clearing was avoided.

Topped trees survived well and are starting to take on the bushy appearance that was anticipated. Because of minimal ground disturbance, grasses, young aspen trees, shrubs, and small evergreens are filling in the right-of-way, minimizing the visual impact.



In this case, construction scars were covered by natural revegetation because care was taken not to disturb the construction site excessively. Three years elapsed between these two pictures.



MICROWAVE SYSTEM

To provide telecommunication services (including color TV and telephone) to some winter sports communities in the Rocky Mountains, a new system had to be planned—in this case a microwave system. The system had to cross mountainous terrain at elevations between 5,000′ and 13,000′ where climatic conditions are extreme and the ecosystems are very fragile.

Although microwave stations are not connected by landlines, each station must be sited and designed as part of an overall system. The system is a complex of telephone central offices, microwave repeaters, reflectors, and terminal or junction stations—all very accurately linked with one another by microwave paths. Road access and electric power supply are important factors in the design of the individual stations.

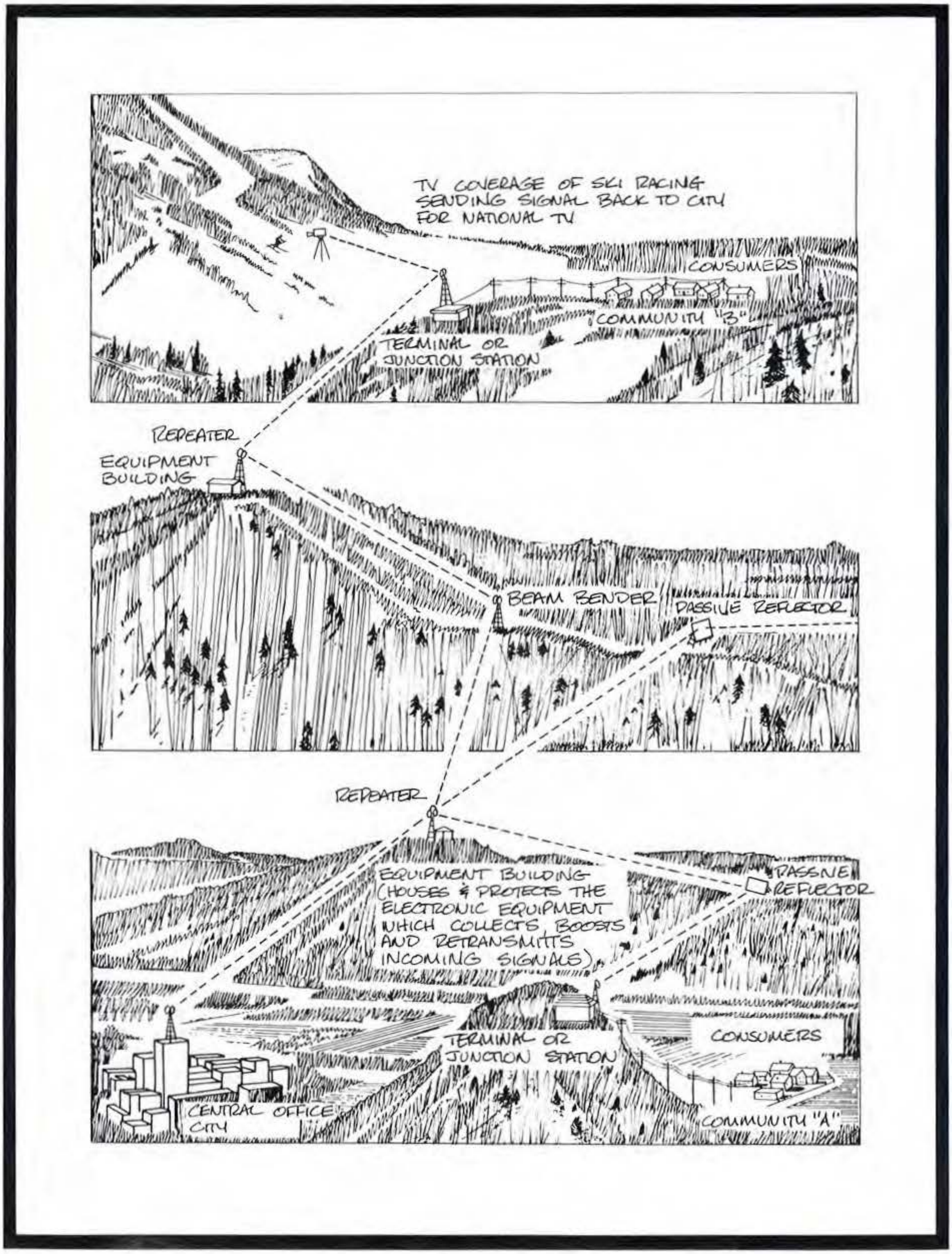
The success of this project was due to the intense cooperation of the telephone company, the Forest Service, and the architectural firm that designed a number of the structures. Personnel involved in project planning and design included foresters, landscape architects, architects, soil scientists, geologists, hydrologists, and mechanical and electronics engineers. Local governments and residents also participated significantly in the planning.

As the overall system was planned, alternate locations were selected for each installation. These locations were analyzed to determine: From what vantage points would each structure be seen? How long would it be seen and by how many people? How much access road would be needed? Where would the nearest source of electric power be? Would the site satisfy sanitation requirements?

Only after the overall system was planned and the station, repeater, and reflector sites were chosen did the design of individual installations begin.

Some sites had to be located at points where they could easily be seen. To harmonize these installations with their surroundings, special architectural treatment was called for. Because of this, a team of professionals gathered at the site to confer on the design of the terminal station and other facilities. This meeting resulted in:

- Overall design of the terminal station and tower with only details remaining to be worked out.
- An overall understanding of the many landscape, architectural, engineering, and legal requirements.
- A mutual understanding by the telephone company, the architect, and the Forest Service that allowed the remaining parts of the microwave system to be designed more efficiently.



A microwave system.

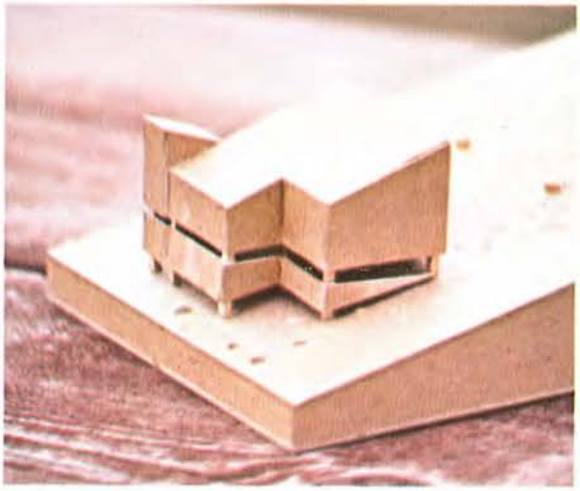
		Squaw Mountain				Santa Fe
		Site No. 1	Site No. 2	Site No. 3	Site No. 4	(South Peak Location)
	Apparent Tower Height[1]	85 feet	46 feet	75 feet	8 feet	100 feet
	Total Tower Height[2]	120 feet	103 feet	75 feet	63 feet	133 feet
	Travel Influence Zone	yes	yes	no	yes	Private outside N.F. boundary
Road Construction	Number Miles New	—	—	.5	.5	2.5 to 3.0
Road Construction	Number Miles Improved	.5	.3	—	.75	—
Road Construction	Cost in Thousands	5.0	3.0	7.5	15.0	37.5 to 45.0
Road Construction	Aesthetic Impact	Nil	Nil	Nil	Nil	Exposure on south side switch backs
Powerline	Number Miles	.9	1.1	.5	1.3	2.0 to 3.0
Powerline	Cost in Thousands	4.0	5.0	2.2	6.8	9.0 to 13.5
Powerline	Aesthetic Impact	Screening possible except near site	Screening possible; may cause problems	In open. Can see from lookout but screened from highway.	May cause problems from lookout but well screened from highway.	Difficult to do adequate job of screening
	Viewing Distance Squaw Pass Highway	West bound 1.2 miles. East bound .6 mile. About 85′ will be skylined 160–360′ above highway.	West bound 0.4 mile. East bound 0.0 mile. Good background to blend with.	West bound 1.7 miles. East bound 1.5 miles. Fully skylined. At Squaw Peak focal point.	West bound 0.4 mile. East bound 0.0 mile. Good screening and background west bound 360′ higher than highway.	West bound 10.0 miles. East bound 2.0 miles. Mountain acts as focal point. Level with or higher than highway. No screening possible. 2–6 miles airline distance.
	Viewing Distances Squaw Pass Lookout	¾ mile is about 1000′ lower. Back grounding possible.	1 mile is about 1000′ lower but not visible from lookout.	½ mile on opposite end of long ridge from lookout. Rocky outcrops will cut down on direct view.	⅞ mile 800′ lower but not visible from lookout.	2.5 miles about 1000′ lower. Back and foreground screening not possible. Most of structure will be above skyline.
	Maintenance Access	Good to Excellent	Good to Excellent	Fair to Poor	Good	Critical. May exceed two hour limitation.
M.T.R.[3]	Zuni	Yes	Yes	Yes	Yes	Yes
M.T.R.[3]	Idaho Springs	Yes, but not at desired location	Yes	Yes	Yes, but not at desired location	Yes
M.T.R.[3]	Mines Peak	Yes	Yes	Yes	Yes	Yes, with high tower height
	Building Site	Fairly level site of sufficient area. Some clearing necessary.	Only fair. Some excavation and clearing needed.	Expensive to develop. Solid rock. Minimum clearing.	Good building site. Relatively level. Some clearing necessary.	Fairly level. Light clearing.
	Remarks	Site could be developed into a small picnic site if needed.	About 600′ from existing Arapaho Springs Picnic Ground.	At an established electronic site.		

[1] Tower height which cannot be screened as viewed from Squaw Pass Highway.

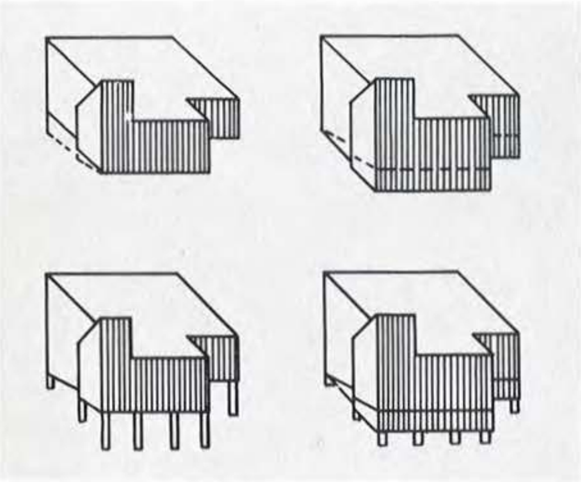
[2] All towers will support four horns and one parabolic antenna. Height includes distance to top of horns.

[3] Meet Transmission Requirements from these stations:
All sites flash tested, including Thorodin-Georgetown and Pence Mountain.

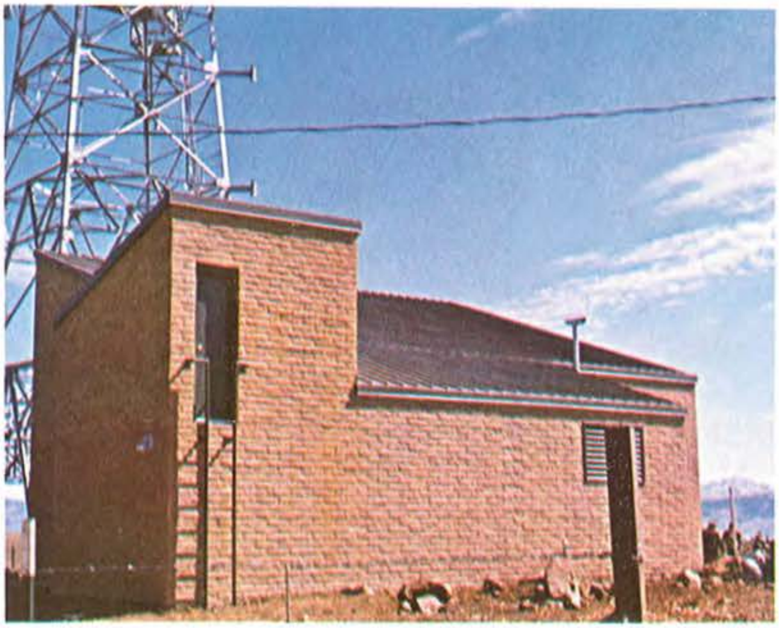
This table demonstrates the analysis of five alternative locations for one repeater with its associated equipment building, electric power supply, and access road for maintenance.



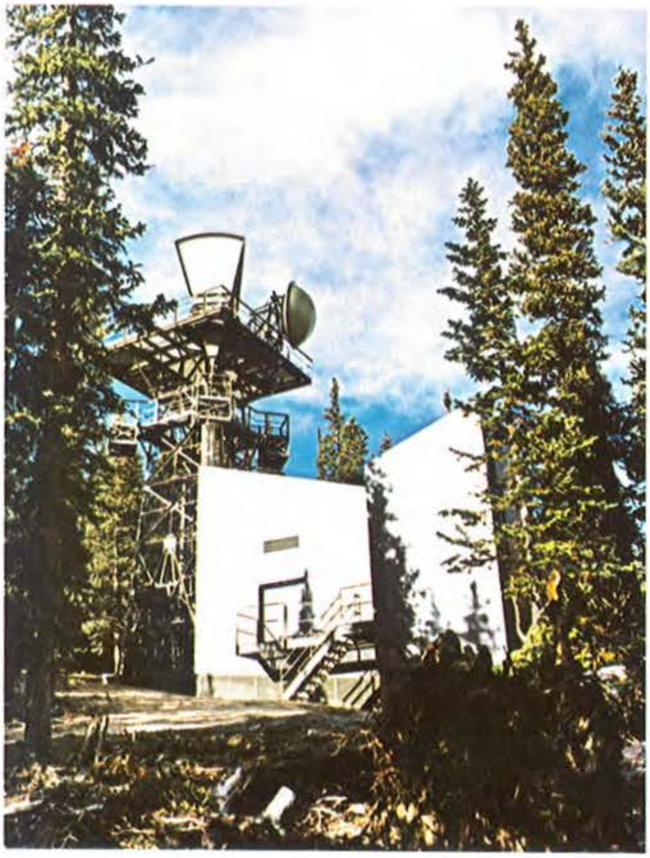
Each repeater requires a sizable building to protect its electronic equipment from extremes of temperature and humidity, weather, and vandalism. The architectural team created a design for a modular equipment building that could be easily adapted for local topographic and climatic conditions at many sites. Minimum excavation is required for this building. The building is prefabricated and assembled at the site. Built-in insulation satisfies the needs of the electronics equipment, and a durable exterior finish in a variety of colors satisfies maintenance requirements.

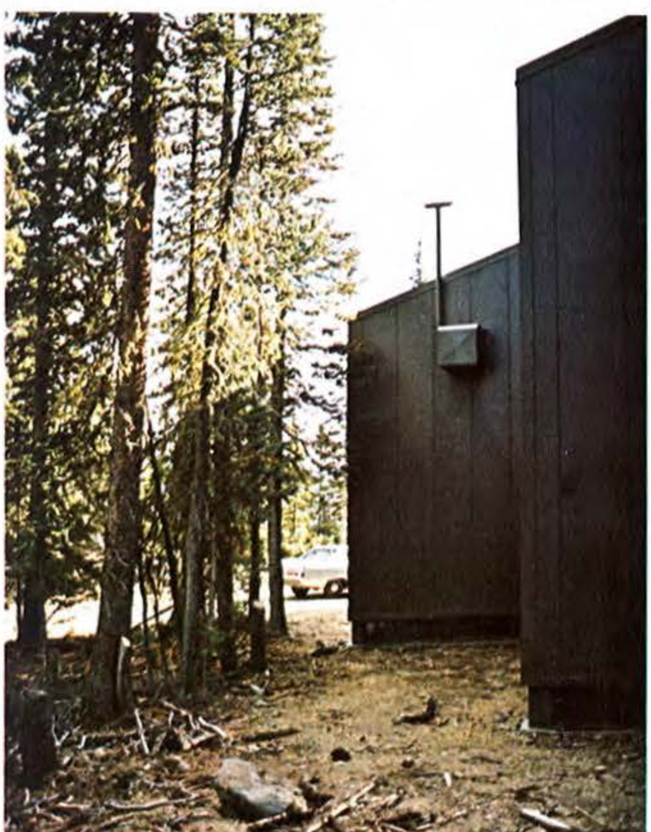


A model and architectural sketches were made to explore the problem of situating a standard building on a variety of slopes.



Local materials can be used on the exterior as appropriate. The high door provides access when winter snows block the normal route.





One of the disadvantages of a smooth manmade object, such as this enameled surface, is that it reflects light. On future projects efforts should be made to find building materials that satisfy all project requirements and have textures that tend to absorb rather than reflect light.

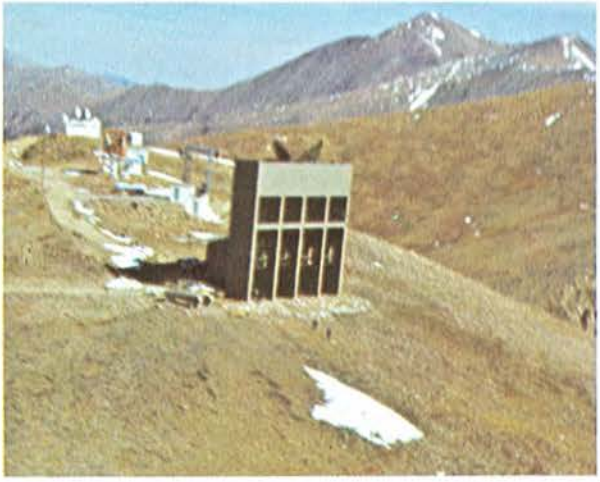
However, other methods can be used to confine reflections to the site. In this case, clearing around the building was held to a minimum. The trees that were left standing screened the building and created a continuous shade-shadow effect.

Another repeater had to be set on a bald mountaintop occupied by several less significant structures. This site is subject to severe ice storms and to winds exceeding 100 miles per hour.

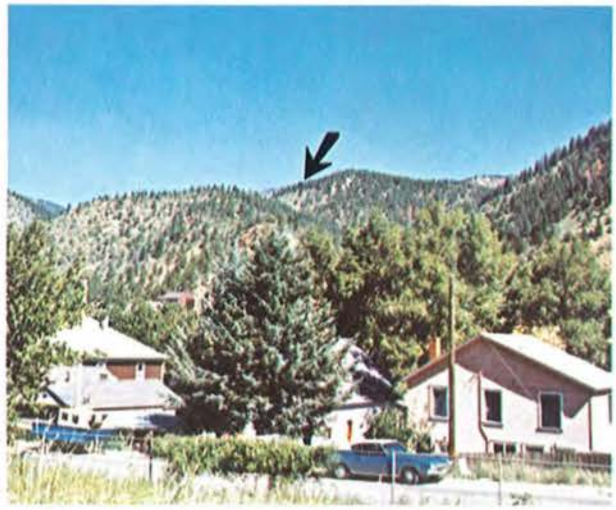
A conventional repeater design was rejected as being inharmonious with the site.

A unique structure was designed so that all four horn antennas could be mounted horizontally.
A model was then made of both the tower and its adjoining standard equipment building.

So that the visual impact could be studied, photographs of the model were superimposed on pictures of the site taken from all major vantage points.

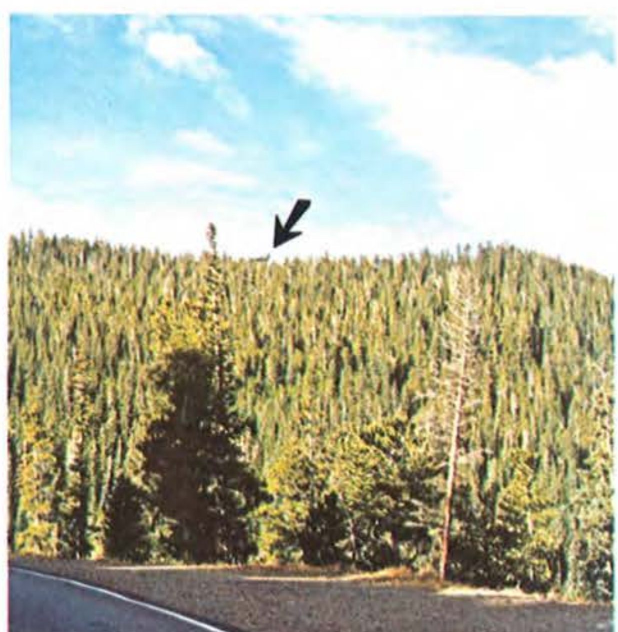


The actual structure under construction.

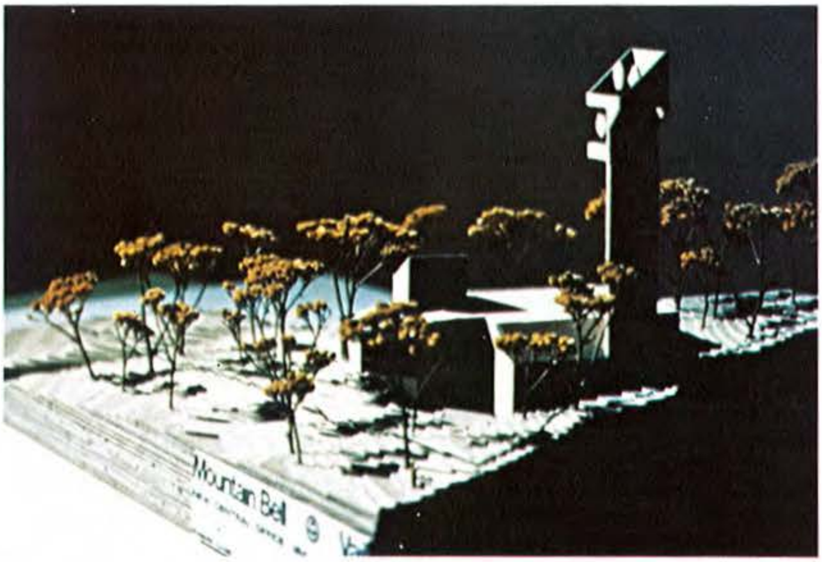


A large reflector was carefully sited just below the skyline and blended with its surroundings through the proper use of color. Construction scars were avoided through careful planning and design.

A telephoto view of the same scene.

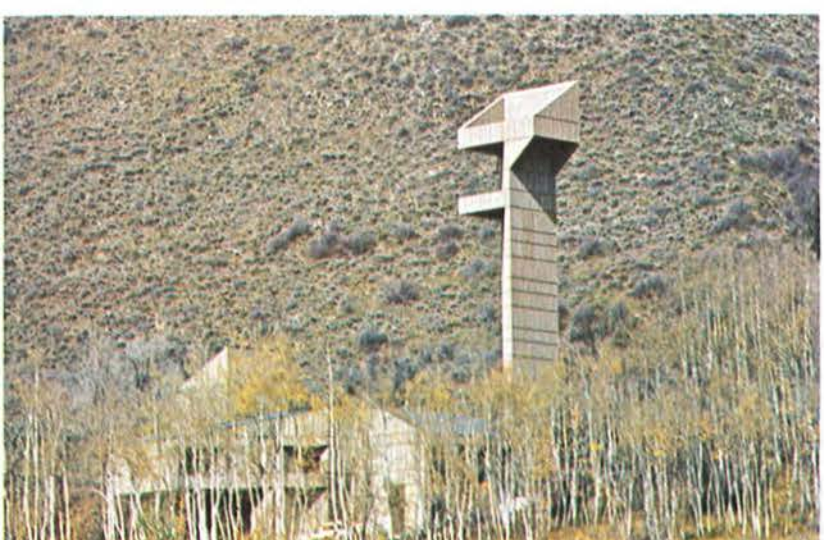


This repeater was placed where it is visible from a scenic road. However, it can be seen from only one point (a curve of the road) and the antennas are visible for only 15 seconds at normal car speed. Background blending and tree screening is so effective that most people will never notice the installation.

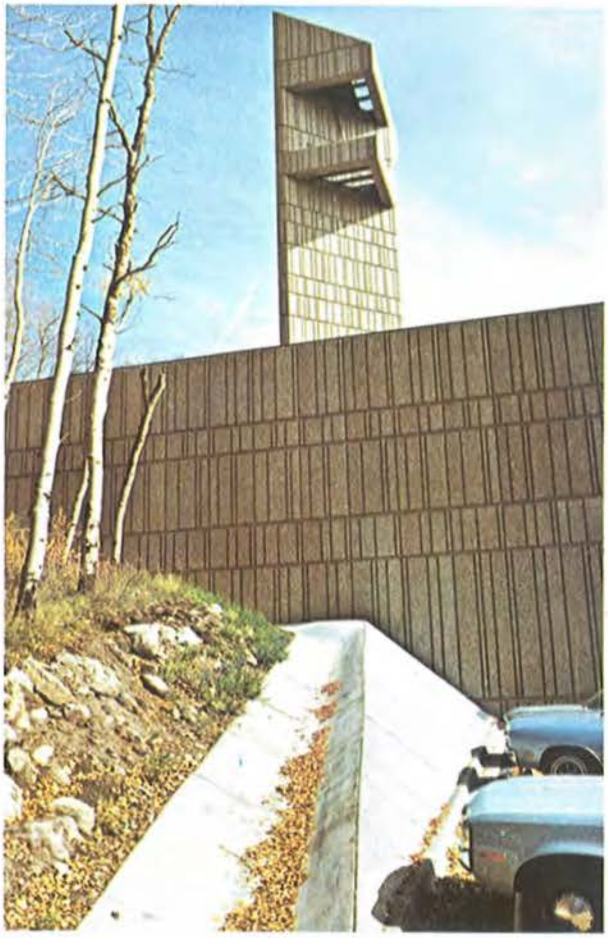


This terminal station was to be adjacent to an interstate highway and immediately across from a resort town that has a distinctive architectural style. A model was made in order to study site relationships and measure community support.

The completed structure is in a grove of aspen trees on gentle topography.

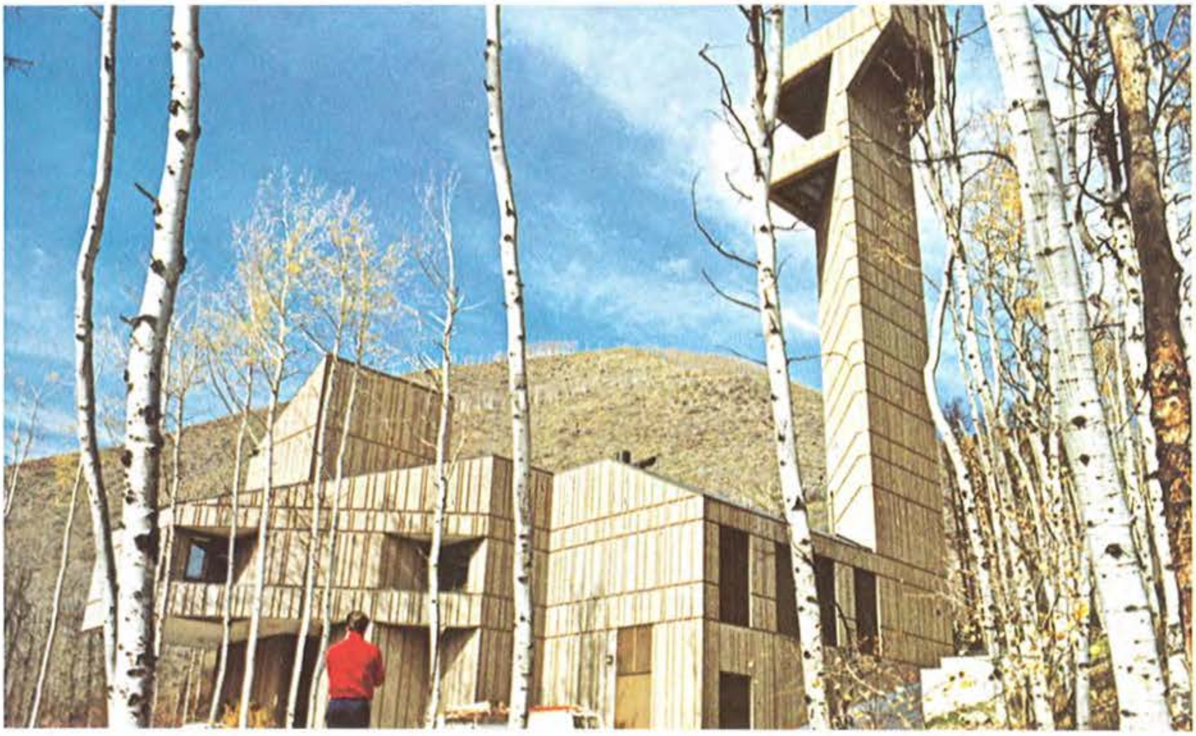


The goal was to blend the building with its surroundings through sound application of architectural style, color, texture, site planning, and design.

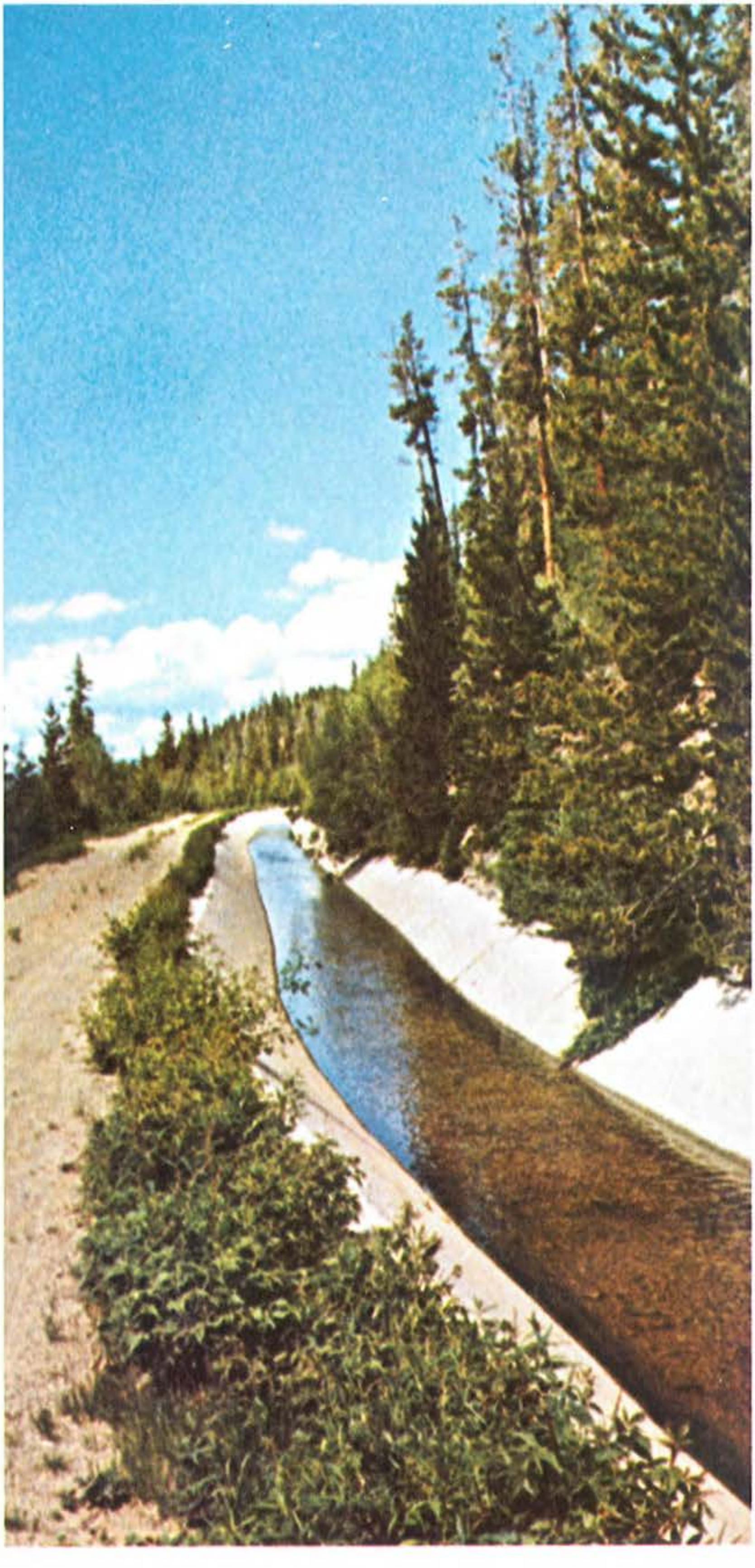


Excavation for the building and its support facilities was held to a minimum. Surface drainage was collected in a flume, guided around the building and parking lot, and . . .

. . . deposited in a natural drainage channel.



Architectural and construction personnel used special procedures to protect the site. For example, aspen trees were fenced during construction, and movements of heavy equipment were carefully planned to avoid damage. Depressed lines in the exposed aggregate wall panels give the building everchanging shade and shadow effects.



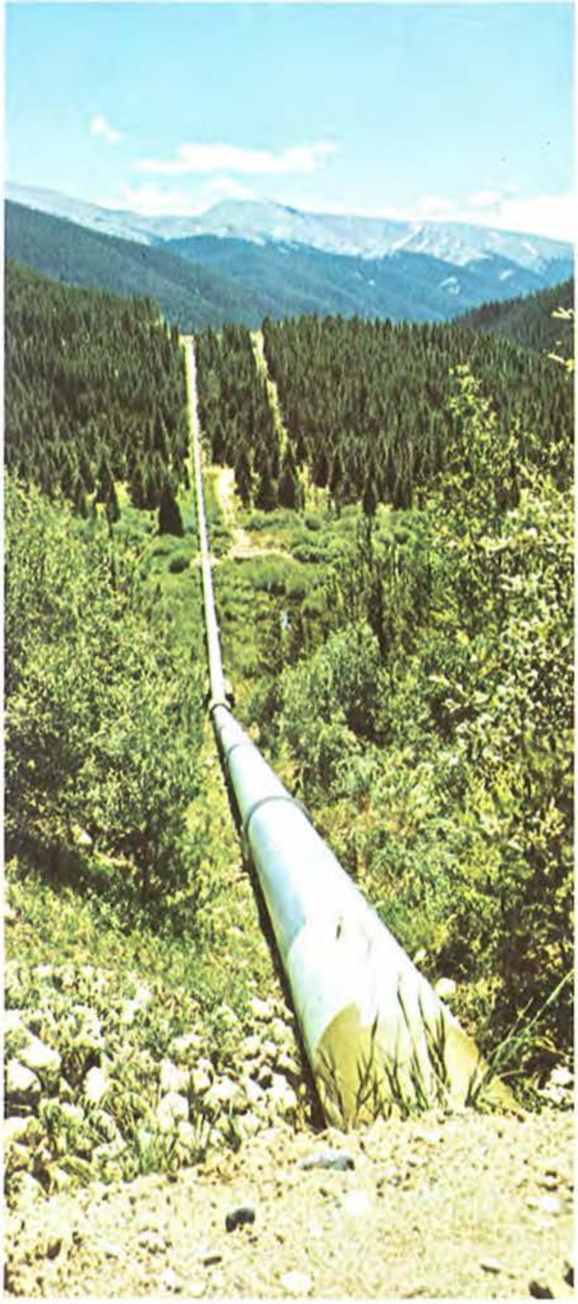
WATER-COLLECTION SYSTEM

The collection systems described here are in mountainous terrain and divert water from mountain streams by pipe (above and below ground) and canals (lined and unlined) to storage reservoirs. Most of the water is collected in spring and early summer.

Two visual impacts of such systems must be considered and analyzed:

- Visual impact of facilities and structures
- Visual impact of the stream after the water has been removed.

The type of facilities and their appearance vary with different areas and different water suppliers. Because continuous maintenance is needed, a complete road system is required, and this created another visual impact to be considered.



Visual Impact of Facilities and Structures

Visual impacts vary with the type of system being installed. Major water collection systems are unlike other utility systems in that they operate primarily by gravity. With proper rehabilitation plans, the only visual impacts from buried pipe should be those that occur during construction and those associated with access roads needed for maintenance. Ditches and exposed pipe often present major problems.

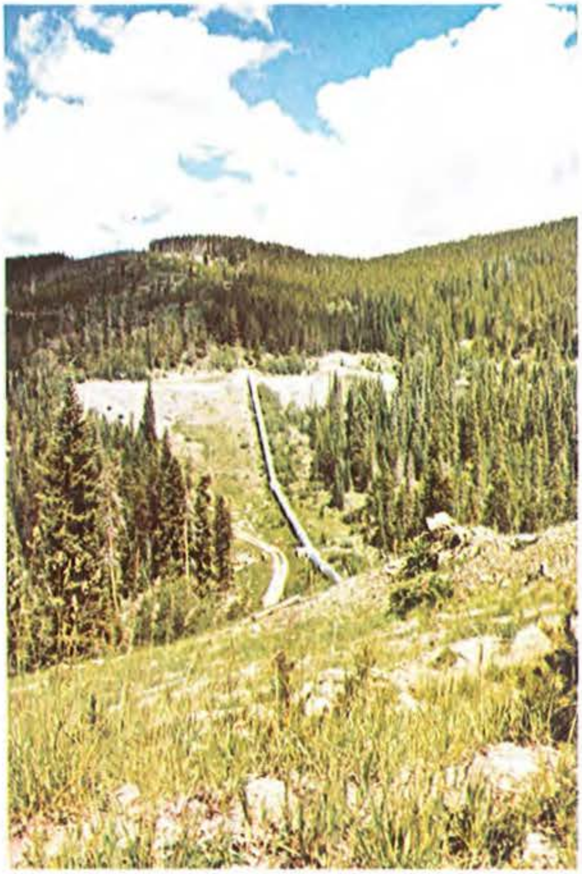
Existing and proposed buildings and aboveground pipes should be thoroughly examined and, if possible, eliminated. If they cannot be eliminated, their visual impact can be subdued by painting, additional planting, or new exterior finishes.

The elaborate road system needed to maintain a water collection system should be considered in the overall management of the land area. Carefully planned soil and vegetative rehabilitation can greatly reduce visual impact.

The digging of ditches and the installation of pipe usually require heavy equipment.

Even large pipe, metal or concrete, has properties that make it quite flexible for horizontal and . . .

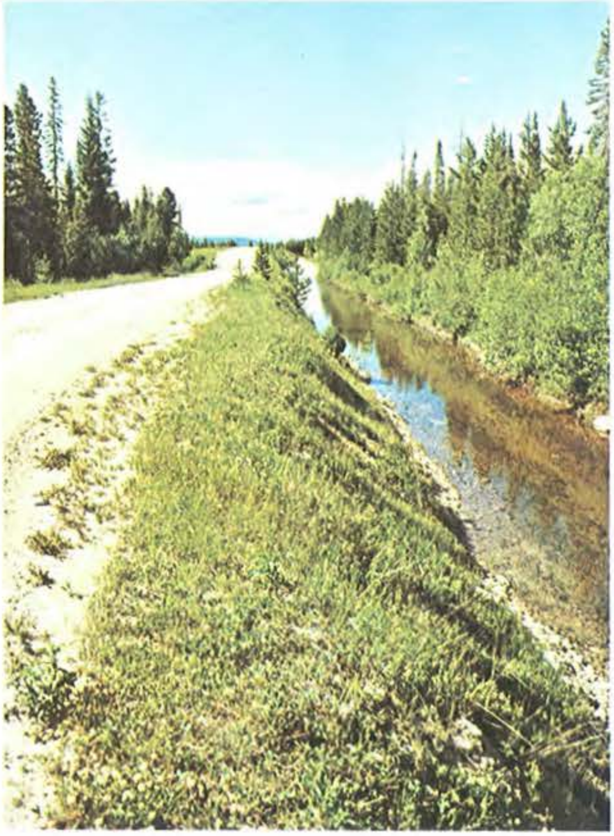
. . . .vertical curvature.



The relative visual impact of buried versus aboveground pipe is evident here. The left photo shows the installation of a buried pipe which is difficult to detect in the "after" photo to the right. The visual impact of the exposed pipe could be diminished by painting with a less dominant and reflective color.

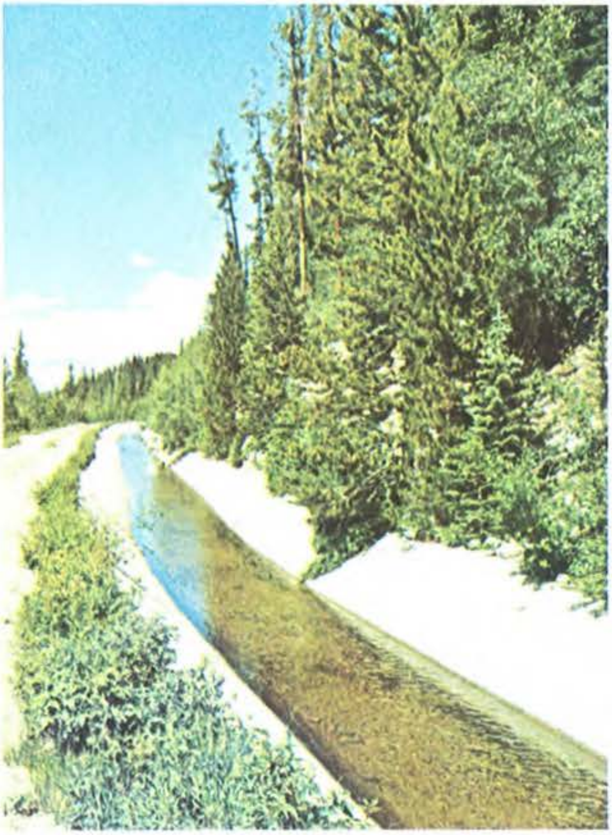
Inverted siphons are pipes (buried or aboveground) used to transport water across depressions. The pipe is full of water, and the inflow is higher in elevation than the outflow. As water is added, the inflow automatically forces the same amount of water to flow out of the other end.

When pipes are not used, water is carried from collection to storage points in . . .



open ditches (unlined), . . .

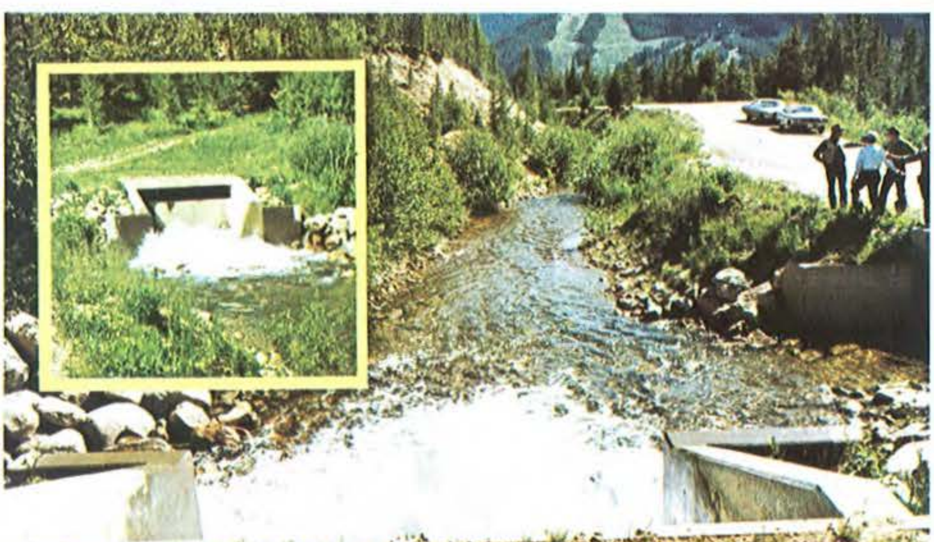
open ditches (lined), . . .



or covered ditches.

Other components of the water collection system are tunnels, gauging stations, weirs, and energy dissipaters.

At weirs, water volume, temperature, velocity, and turbidity, are measured.



If the water is dropped through a pipe to overcome steep grades, energy dissipaters are used before the water is released into the open ditch.

Diversion Structures

Water diversion structures have three basic components:

- Overflow spillway
- Water diversion gate
- Streamflow gate.

The size, color, and type of the structure determine how great the visual impact will be:

These three structures blend well with their natural settings.

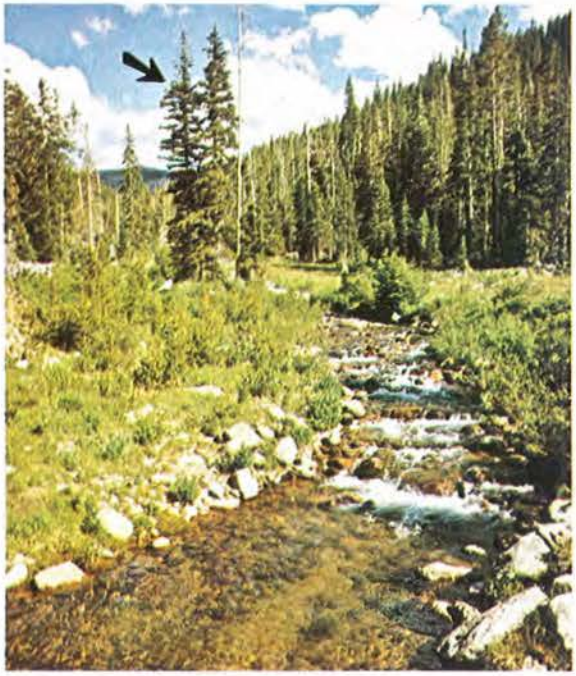
Visual Impact of the Stream After the Water Has Been Removed

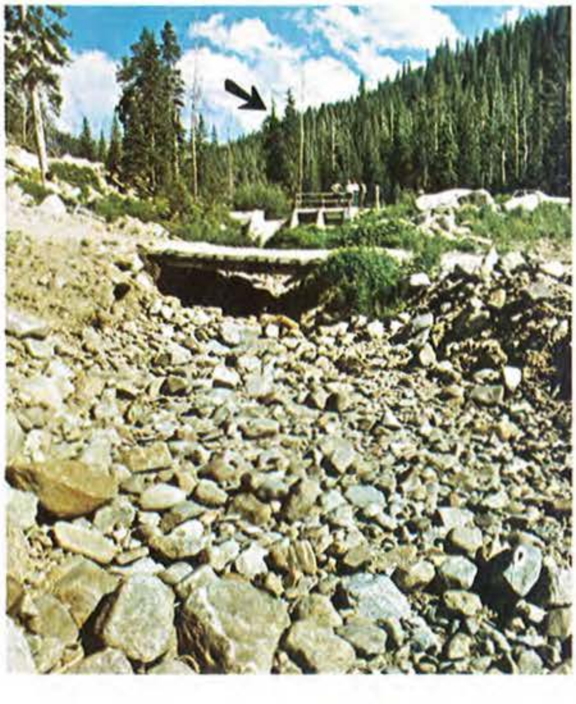
The amount of water needed to keep a stream visually acceptable must be determined case-by-case.

If a stream is dried up by the diversion or if too little water is released to sustain aquatic life while other streams have a normal seasonal flow, the dried-up or low-flow stream will have a negative visual impact.

Relationships of streambed configuration, wetted perimeter, and waterflow season determine whether the amount of water released in the streambed is visually acceptable.

If the lower release and reduction of peak flows continue over a long period, riparian vegetation will encroach on the stream and adjust to the lower water level.





The visual impact of water diversion, in this case a complete diversion, can be as drastic as shown in these two pictures. The twin trees in each photo (arrows) are the same. The photos were taken only minutes apart, one from above the diversion structure, the other from below it.

Technical aspects of utilities

This section discusses the basic technicalities of utility design and installation in common terms to provide a basis for communication between the land manager and the utility planner/designer.

Three considerations are common to all utility systems:

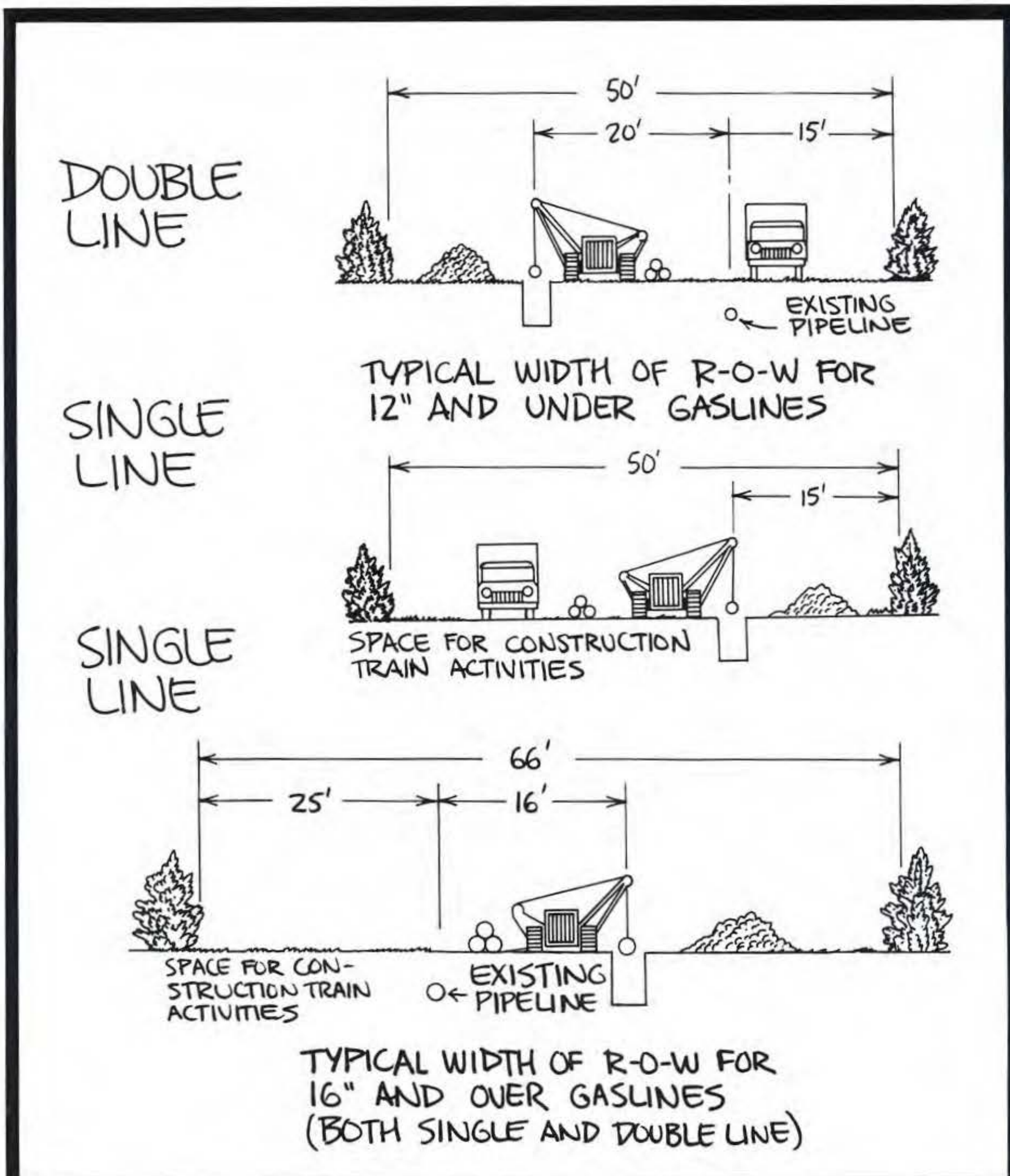
- Right-of-way sharing
- System planning for increasing capacity
- Multipurpose use of lands within the right-of-way.

Right-of-way sharing. Rising demand for agricultural, forest, and recreational uses of the land and society's growing needs for utilities make it impossible for all utilities to occupy separate rights-of-way. There are many existing examples of right-of-way sharing by utilities, but no single approach to the problem has been established. Standardization of spacing dimensions is difficult if not impossible because of differences in soils, hydrology, weather, vegetation, utility density, and types of utilities involved. The land manager can utilize local studies of utility compatability when preparing land-use plans. Highway rights-of-way, for example, often offer opportunities for dual use—especially for buried utility systems.

System planning for increasing capacity. All planning for utility systems should consider increased future need. This can be accomplished by providing for future installation of larger conductors, pipes, or ditches; by building a structure which will support additional conductors; or by reinsulating for higher voltage. Preplanning for parallel systems is also an alternative.

Multipurpose use of rights-of-way. Multiple use of the land within a right-of-way for agricultural, wildlife, tree farm, hiking, or other uses can usually benefit the installation as well as gain community support. Only uses that conflict with the utility, such as digging within the right-of-way for a buried line, should be automatically ruled out.

Initial consideration of the right-of-way for sharing, expansion, and multiple use is a must for all utilities.


DOUBLE LINE
50'
20'
15'
EXISTING PIPELINE
TYPICAL WIDTH OF R-O-W FOR 12" AND UNDER GASLINES
SINGLE LINE
50'
15'
SPACE FOR CONSTRUCTION TRAIN ACTIVITIES
SINGLE LINE
66'
25'
16'
SPACE FOR CONSTRUCTION TRAIN ACTIVITIES
EXISTING PIPELINE
TYPICAL WIDTH OF R-O-W FOR 16" AND OVER GASLINES (BOTH SINGLE AND DOUBLE LINE)

GASLINES

Gaslines that are likely to cross the National Forests can be classed as:

- Gathering lines
- Transmission lines
- Distribution lines.

The main difference in these is in purpose; only small differences occur in their installation, operation, and maintenance. Gathering lines collect natural gas from wells and carry it to stations where it is processed and compressed or, sometimes, carried directly to a transmission line. Transmission lines carry gas to metering or metering and regulating stations where it flows into distribution lines. Distribution lines carry gas to the consumers.

The gathering, transmission, and distribution of gas is regulated by State and Federal laws. At present, rules and regulations of the Office of Pipeline Safety, U.S. Department of Transportation, are the primary source of rules observed by the gas industry in the construction and maintenance of its facilities. Other rules stem from State public utility commissions and other State and Federal bodies.

Common diameters for gaslines are 2″, 3″, 4″, 6″, 8″, 10″, 12″, 14″, 16″, 20″, and 24″. Larger sizes are rare, but quite possible.

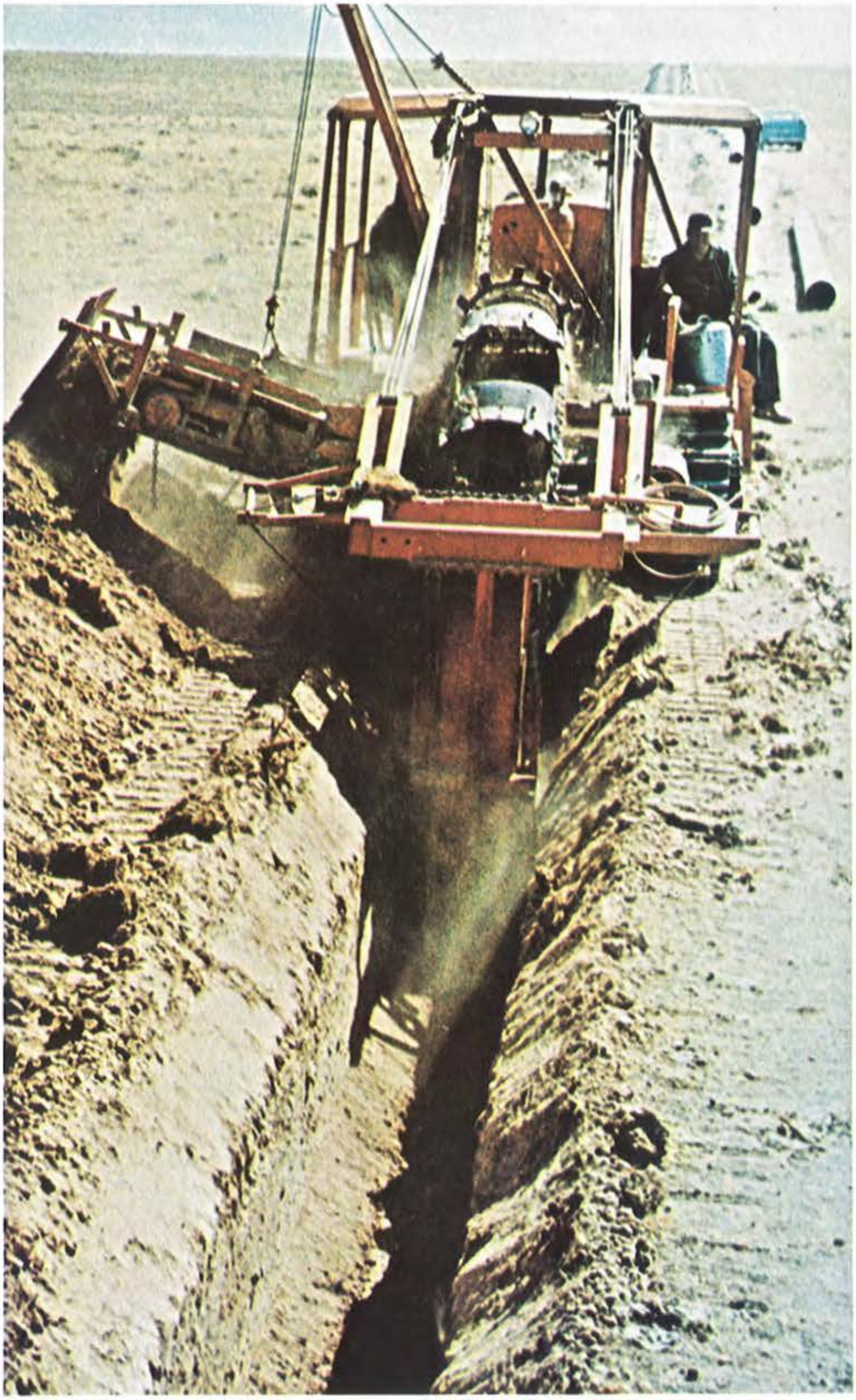
Gas companies require rights-of-way in which to install, operate, and maintain their gaslines. Practical widths of rights-of-way for transmission lines are 50′ for lines 12″ and smaller and 66′ for lines 16″ and larger. If conditions are favorable, a 2″ or 3″ line (more apt to be for distribution than for transmission) can be installed in a right-of-way only 20′ wide. A wider right-of-way may be needed during construction of special jobs (for example, a river crossing), but it can be narrowed to normal width after construction.

A gasline can share a right-of-way with most other utilities; however, a right-of-way suited for a gasline may not be suited for other utilities. Gravity strongly affects the flow in waterlines, and these tend to follow contours; an overhead powerline might easily span a deep gully that a gasline would have to go around.

It is becoming common to transmit direct current over long distances. However, it is not feasible for a gasline to share a right-of-way with a DC powerline, since the metal of the gasline cannot be protected against corrosion caused by induced direct current. Transmission lines for alternating current do not cause the severe corrosion of gaslines caused by nearby DC powerlines. However, AC transmission lines of high voltage or in areas with moist soils sometimes induce a current that can cause severe arching across insulated gasline joints or when flanges are separated.

Gasline construction starts with clearing of the right-of-way. This work is usually done with bulldozers. Trenching and pipe stringing begin as soon as an ample amount of right-of-way has been cleared.

The next step is to position pipe on skids alongside the trench and begin welding. Generally, some or all of the welds are checked by X-ray to make sure that the welding is of the required quality. Following the welders at a convenient distance, a coating and wrapping machine cleans the pipe and applies a protective coating and outer wrap. If mill-wrapped pipe (pipe coated and wrapped before delivery to the job) is used, it is only necessary to coat and wrap the welded joints. This is done by hand. The coating and wrapping protects the gasline from corrosion. A high-voltage device called a "jeep" tests the coating to make sure there are no "holidays" (breaks in the electric insulation of the wrapping). After this check is made, a side-boom tractor lowers the gasline into the trench.



The trench for the gasline is dug with a backhoe or a trenching machine.

A bending shoe is used to bend pipe as needed to follow contours and turns in the right-of-way. The maximum permissible bend of this type is 1½° per length divided by the diameter in feet (a 40′ length of 24″ pipe would have a maximum bend of 30°). Sharper bends can be made with factory fittings (45° and 90° ells).

In some soils—especially rocky soil—it may be necessary to use sand or clean dirt for padding around the gasoline. Often it is only necessary to pick out the rocks from the soil before backfilling the trench.

A bulldozer or an auger backfiller does the backfilling, and the soil over the trench is left slightly raised to prevent moisture from eroding the trench.

With the gasline in the ground, cleanup of the right-of-way and pressure testing can begin. Air, gas, and water are used to pressure-test the gasline. Short lines are tested as a unit; long lines are tested in sections.

After testing, the line is cleaned. Short lines can be cleaned by purging (blowing high-pressure gas through them). Long lines are cleaned by blowing a scraper-type device (called a "pig") through them with air pressure to remove dirt, mill scale, small animals, and other debris that may have been left in the pipe during construction.

Cleanup of a right-of-way includes placing markers to warn of the gasline's presence and seeding the right-of-way with suitable grasses. Where the gasline crosses a paved road, paving is permanently patched. Waterbars are installed where needed to prevent erosion of the right-of-way.

Valves divide long gaslines into sections. Distances between valves vary but, to conform with U.S. Department of Transportation rules, cannot exceed 20 miles. The valves are in the gasline, but their stems and gearing extend aboveground.

Other aboveground installations that may be part of a gasline system are metering stations, regulator stations, compressor stations, and gas processing stations.

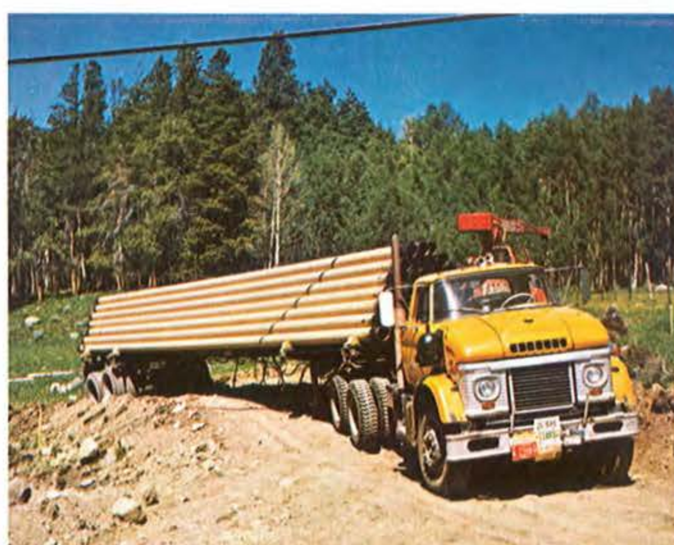
Processing stations may be combined with large compressor stations, but sometimes they are simply dehydrators installed on individual gas wells. Compressor stations can vary in size from a small skid-mounted, unhoused field unit to a multiunit station that provides living quarters for station personnel.

Metering and regulating stations usually mark points of sale of gas from transmission companies to distribution companies or from distribution companies to consumers. Sometimes the two functions are combined at a common station. In any case, aboveground piping is normally exposed, but instruments and equipment are housed.

Unmanned compressor, regulator, and meter stations are checked frequently; for this reason they should be readily accessible all year round. Such stations are often operated remotely by microwave- or telephone-carried commands and thus require antennas, poles, lines, and so forth. Station buildings are generally utilitarian in design. Prefabricated metal buildings are quite functional and are in common use.

Ditch digging and other construction or testing equipment for a gasline is large and must be accommodated in the right-of-way and specially designated areas.

Strategic locations are set aside to unload and store pipe and equipment.

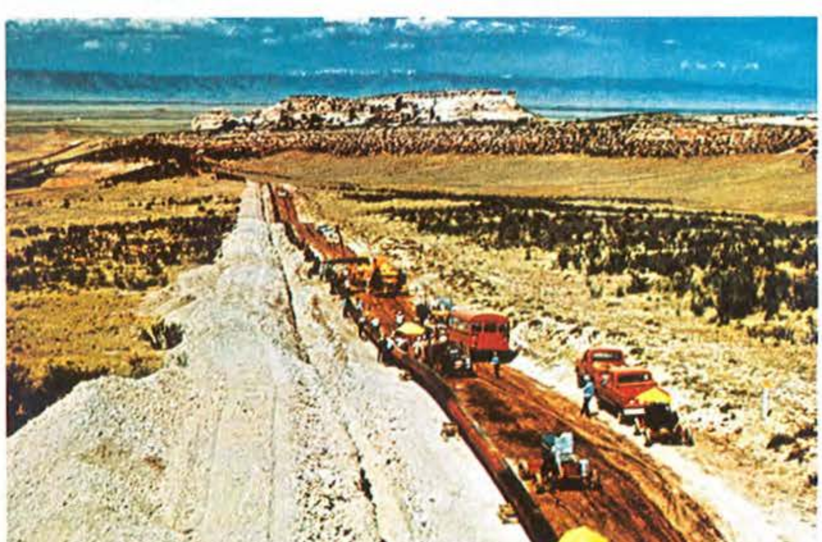


Roads leading to the storage area must be constructed to support heavy trucks and other equipment.

Through rocky areas, blasting may be necessary. In general, the gasline will have 2' to 4' of cover.

Rock drills are used here to prepare the rock for blasting.

As soon as the ditch is dug, the pipe is "strung out" beside it.

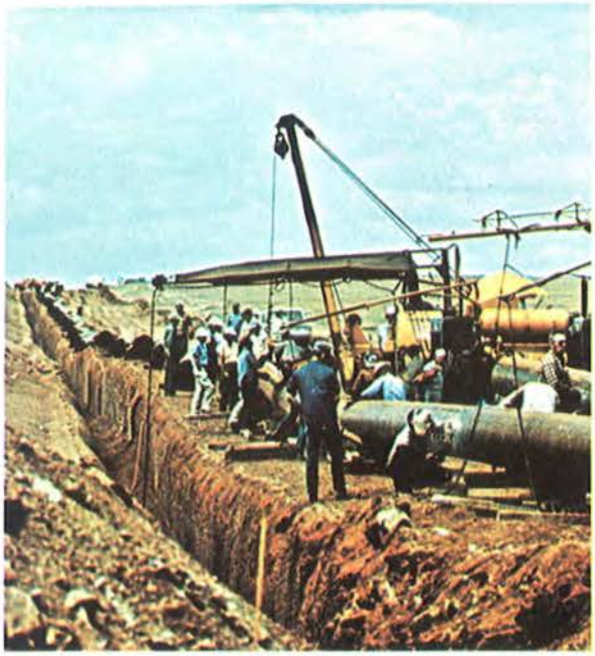


Right-of-way sharing with another pipeline. Spoil has been deposited to the left of the ditch; the original pipeline is buried to the right of the vehicles.

After the ditch is dug, the pipe is welded and the weld buffed, X-rayed, and wrapped.

A portable X-ray machine checks the welded joint.

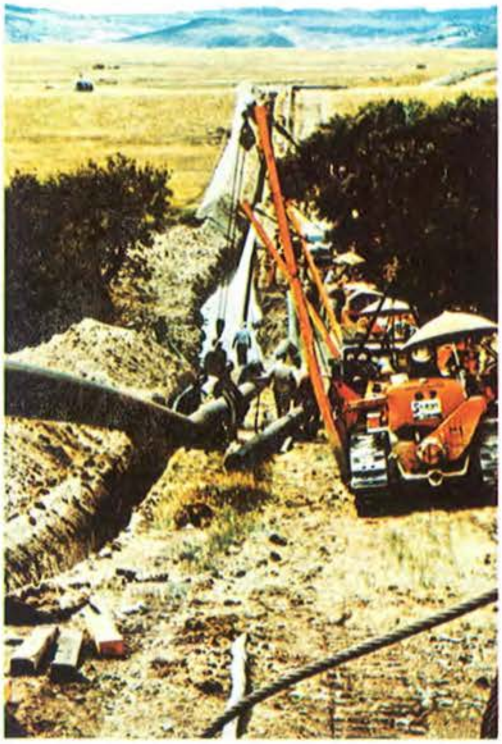
The pipe is wrapped to protect it from corrosion.

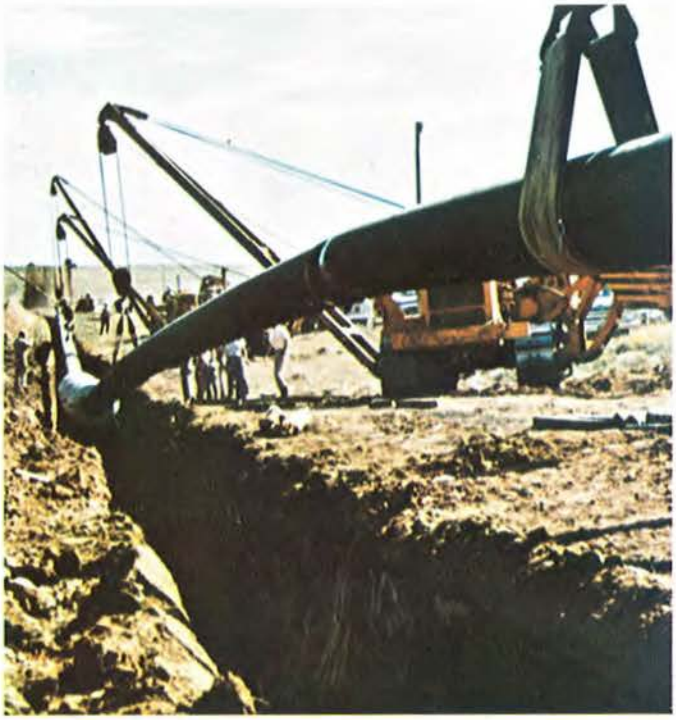


Several welders may work simultaneously on a large pipe.

This machine is tape-coating a 24" pipe.

Asphalt, fiberglass, and tarpaper outer wrap is being applied to a 20" pipe. The next morning, after the coating sets, the pipe is lowered into the trench.





Above
A 16" gasline crosses a small stream. Note the 30' gap in the trees and the extra width of the trench at the stream.

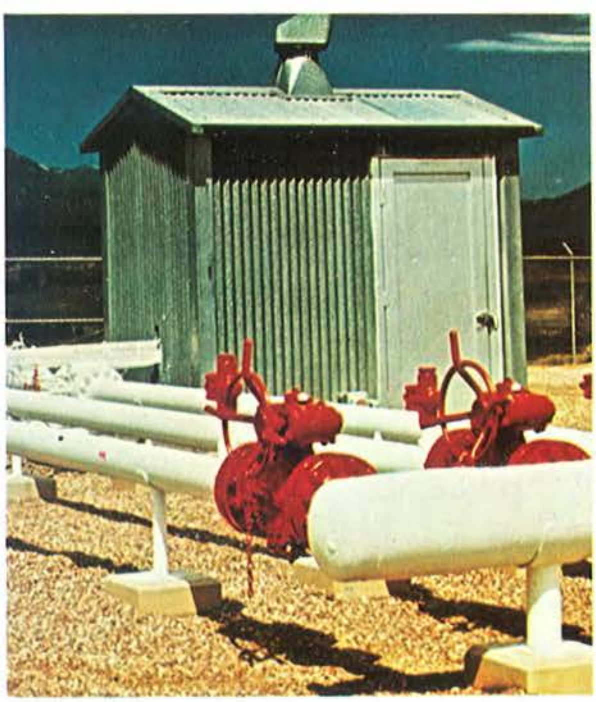
Above right
A 20" pipe is being installed. Note the concrete weight at the stream crossing. This weight holds the pipe in place (prevents floating) and protects the wrapping from water, ice, and gravel scouring.

Right
Here an auger-type machine is being used to backfill the ditch.

Right
Large portable air compressors are used for pressure-testing gaslines.

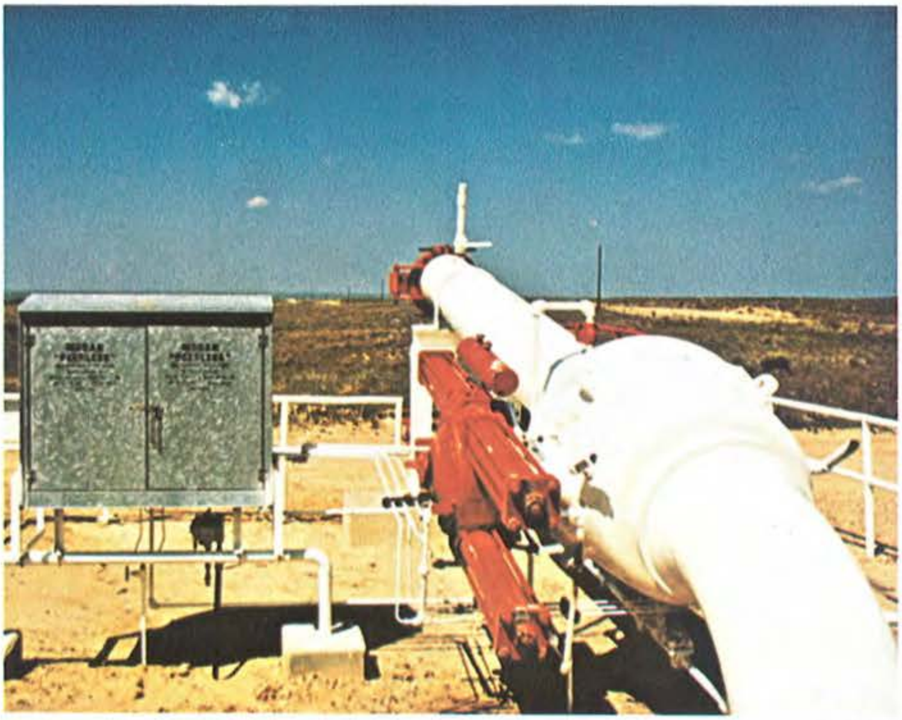
Below left
At a point of sale, such as at this typical 6′ x 6′ meter station, the station would commonly be measuring the flow through these three 4″ orifice "runs" as the gas is sold to three different customers.

Below right
The building at this compressor station houses two 4,000-hp-engine compressor units that provide pressure to impel the gas through the pipeline.



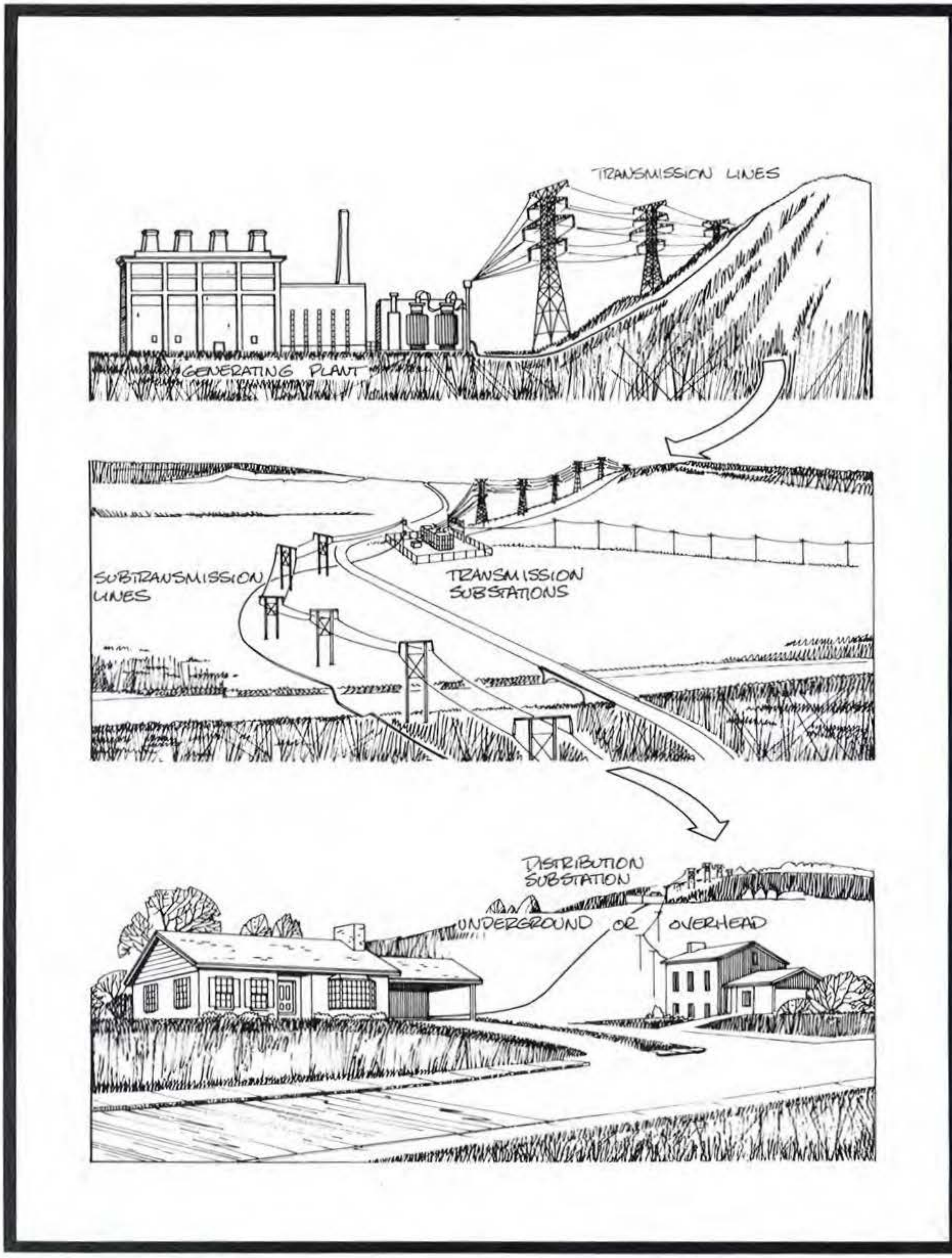
This skid-mounted gas compressor will be installed on a concrete pad to provide pressure for a small gasline.

This "heater-separator" unit is on a gas well in irrigated farmland.



Automatic controls for this sphere launcher are in the metal "doghouse." The unit drops spheres into the gasline to aid in removing liquids from the gas. Such units are used primarily in gathering systems.

A 3" gasline has been carefully installed through this forest. The right-of-way has been cleaned up but not yet seeded.



Electric power transmission system.

ELECTRIC POWERLINES

Federal and State laws govern the design of most electric powerlines. One of the most widely used sets of design criteria is the 1973 edition of the National Electrical Safety Code (NESC), which has been accepted by many States as the design manual for transmission and distribution lines. NESC sets forth minimum clearances that must be observed in the plans and specifications for towers, conductors, and other components of an overhead powerline.

Multiple use of rights-of-way. Because of the tremendous growth of the electrical loads throughout the United States, it is becoming more and more necessary for private and public power companies to jointly plan integrated systems so that duplication of facilities is eliminated.

At present, many rights-of-way are being used jointly for such utilities as gas, power, and water so that multiple use has been achieved, thus reducing the number of corridors. The degree of right conveyed to any permittee or grantee on public lands is limited to the area actually occupied by its improvements, plus the right-of-way needed to build, operate, and maintain those improvements. If addition of other improvements does not interfere with the original or succeeding occupancy, more than one use can be made of the right-of-way.

Overhead Lines

Overhead powerlines are of two main types:

- Distribution lines
- Transmission lines.

Distribution line voltages may range from 110 volts to 34,500 volts (34.5 kV). The lines are normally strung on single poles that support as few as two or as many as four conductors per circuit. Pole heights vary from 30′ to 60′. Span lengths vary from 150′ to 450′, depending on pole height, terrain, conductor size, and voltage. Conductor sizes vary from #8 AWG to 795 kcmil ACSR. When terrain allows, long spans can be supported on multipole structures.

Transmission line voltages may range from 44 kV to 760 kV. Lines that carry voltages above 230 kV are called EHV (extra high voltage) lines.

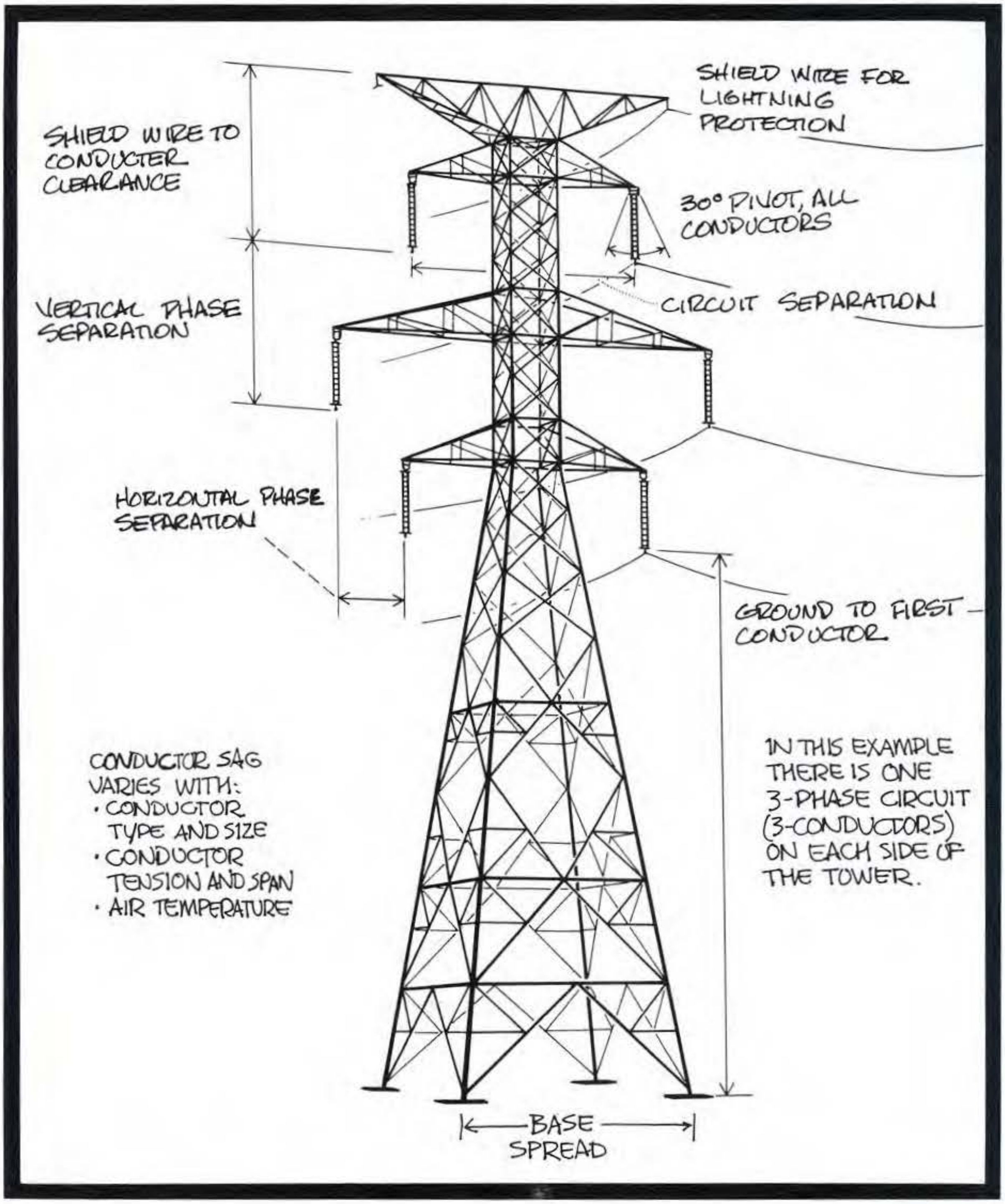
Lines that carry voltages such as 44 kV and 69kV are normally strung on single poles; however, in mountainous terrain, two-pole H-frames are sometimes used. Single-circuit lines of 115 kV or 230 kV are normally strung on two-pole H-frames. Across open grazing or agricultural lands, lines of all other voltages are normally strung on latticed steel towers. Lines of 115 kV, 230 kV, and 345 kV that run through or near urban residential or commercial areas are often being strung on single-shaft tubular steel poles.

Conductor sizes vary from #2 AWG ACSR to 2,000 kcmil ACSR or larger. EHV lines may have several conductors per phase (called "bundling"). Most bundled lines have two or three conductors per phase, but some lines have four conductors per phase.

Span lengths vary from 350′ to 1,800′ and, on mountainous terrain, to as much as 4,000′ or 5,000′. For such long spans, specially designed towers and tower heights are used to withstand extremes of temperature, ice, snow, and wind velocity.

Supporting structures. The structures that support overhead lines are usually selected on the basis of the number of circuits supported, location of the lines, and economics. Only during the past few years have single-shaft steel poles been used for distribution and transmission lines. This was brought about by the shortage of good wood poles, particularly in lengths needed for transmission lines.

Steel poles can be installed by a variety of methods; some are mounted on caisson-type foundations and base plates; and, depending on the soils at the site, some are embedded directly and back-filled. To protect the steel from corrosion the poles can be galvanized or painted with zinc-rich coatings that also enhance their esthetic qualities.



Elements of a typical latticed tower.

Wood poles afford the most economical construction for transmission and distribution lines. Such poles can now be treated by a variety of methods that give them a color acceptable in most surroundings. Wood poles and structures are also suited for helicopter-assisted construction if their length and weight do not exceed the lifting capacity of the helicopter. When helicopters are to be used at high elevations, special consideration must be given to weights and construction techniques in the design of powerlines.

As noted, latticed steel towers are often used to support transmission lines of all types. The power industry has historically used galvanized latticed towers because of economics and the availability of designs. Although critics tend to disapprove of this type of structure on esthetic grounds, some recent uses of painted latticed towers have achieved an excellent blending with the environment. New technology of paint and paint systems now allows for the painting of all wood and steel structures. If justified from the standpoint of landscape management or for other reasons, different tower designs can be used on the same powerline.

Most transmission line designers provide for the number of circuits necessary for transmitting the load, each circuit requiring at least three conductors, and always provide one or two shield wires for lighting protection. During the past few years, a method has been perfected for the airblast abrading of the surface of aluminum conductors so that the conductors do not reflect light. Such conductors are called "nonspecular" conductors. The shield or overhead ground wires are normally made of galvanized stranded steel which dulls quickly after stringing so that the wires do not reflect light.

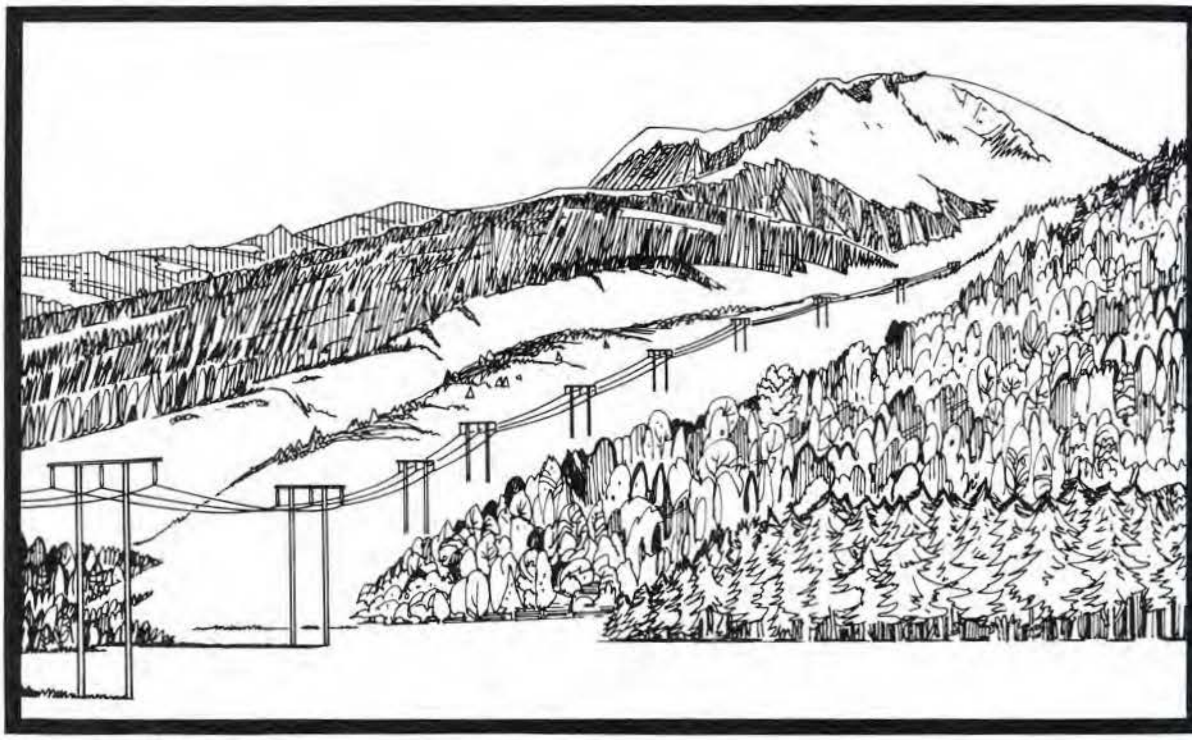
As voltage increases, so must the phase spacing between conductors and the clearance to ground at the midpoint of the span. High-voltage and extra-high-voltage (EHV) lines require very large, high towers and, because of the expense, spans are increased to achieve some economy in material and labor.

The separation between parallel lines depends on voltage, tower height, sag of the conductors, and the terrain. For example, in heavily populated areas, clearances are increased for protection of the public; in remote areas, clearances can be reduced somewhat because people seldom come near the lines.

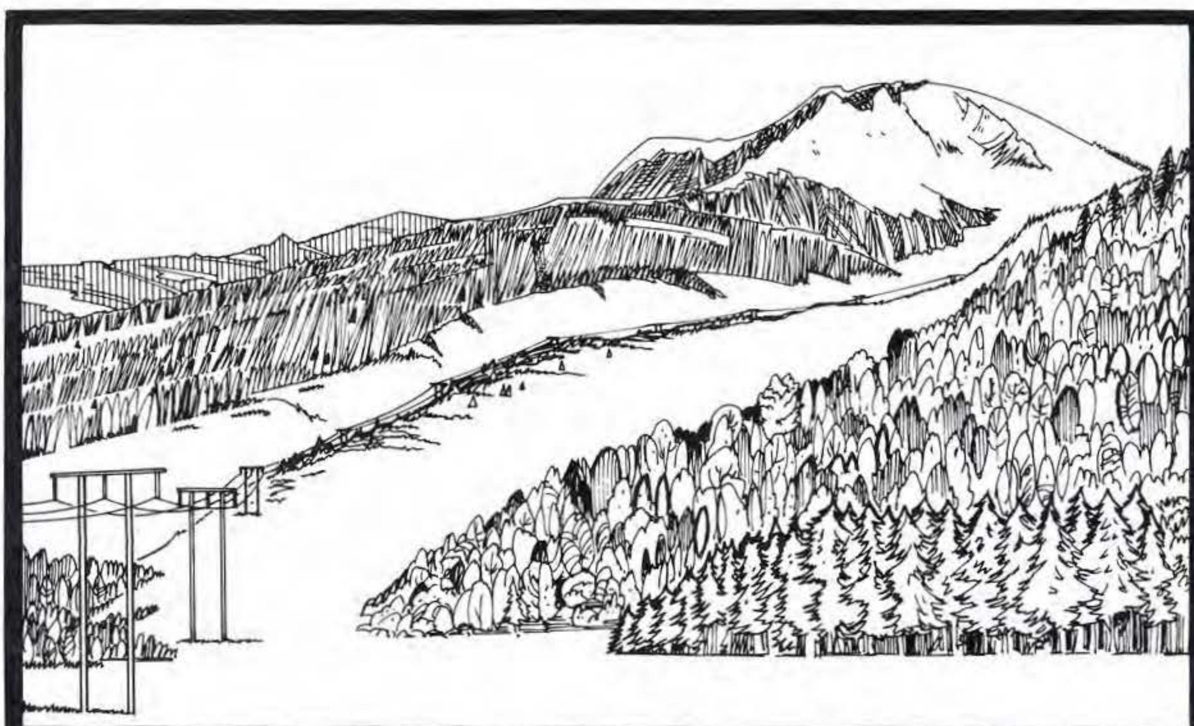
There can be no set rule, but these generalizations can normally be used for parallel lines of the same voltages:

Voltage	**Minimum separation**
115 kV	50′
230 kV	75′
345 kV	100′
500 kV	130′
760 kV	200′

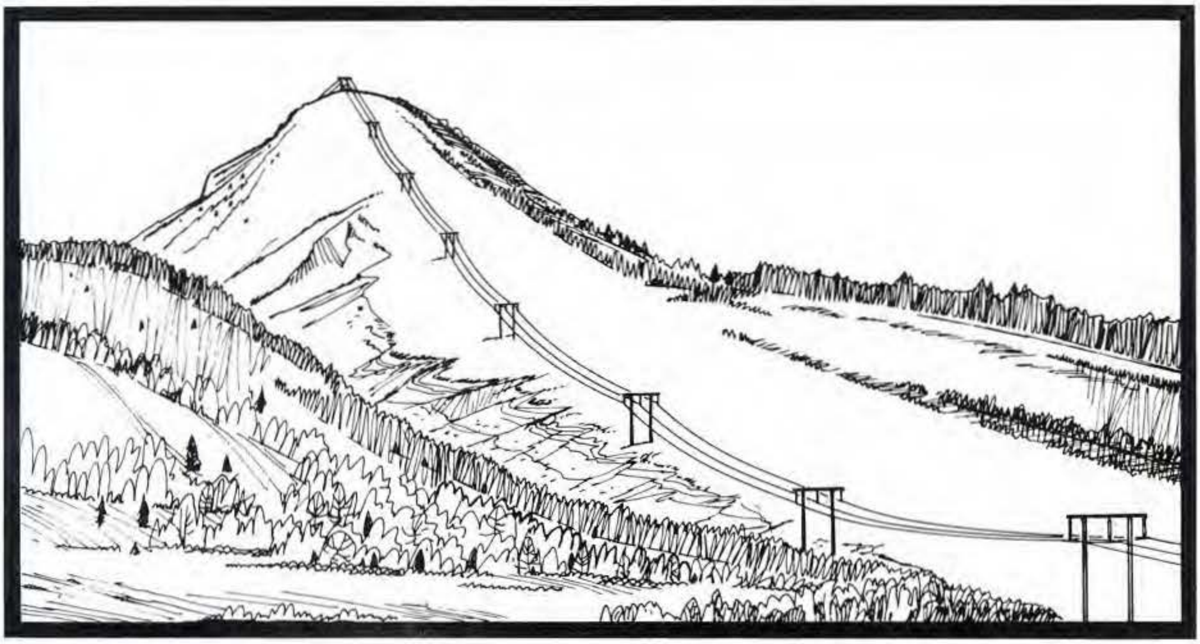
Methods for the clearing of the right-of-way for an overhead powerline are discussed on page 64 and illustrated on the following pages.



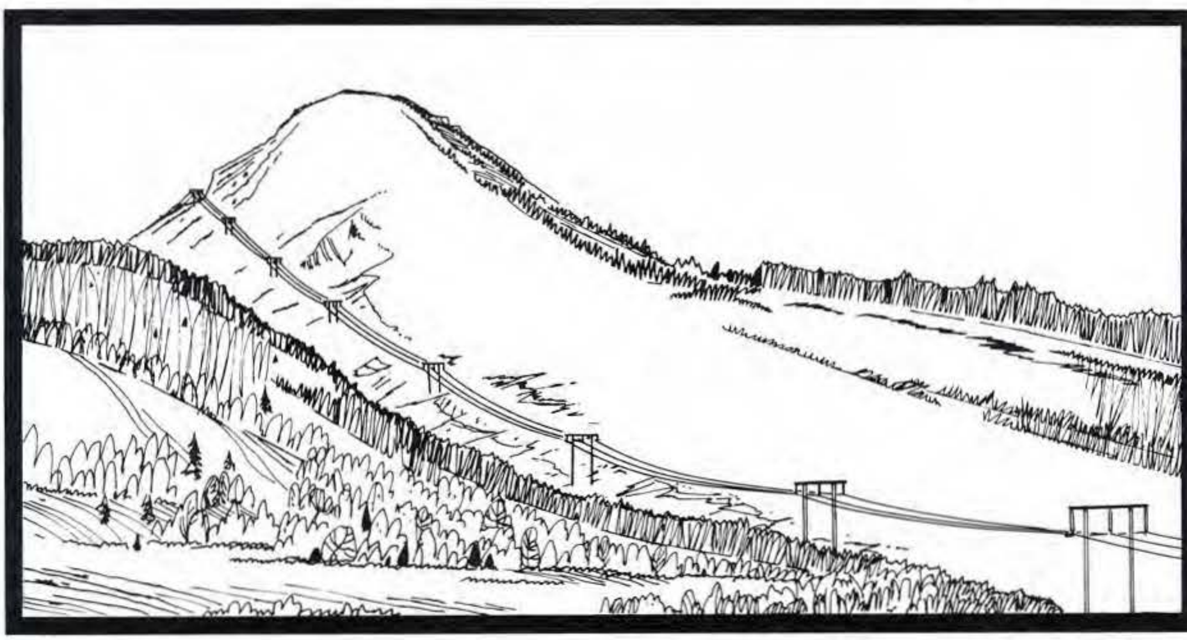
Utility in full view.



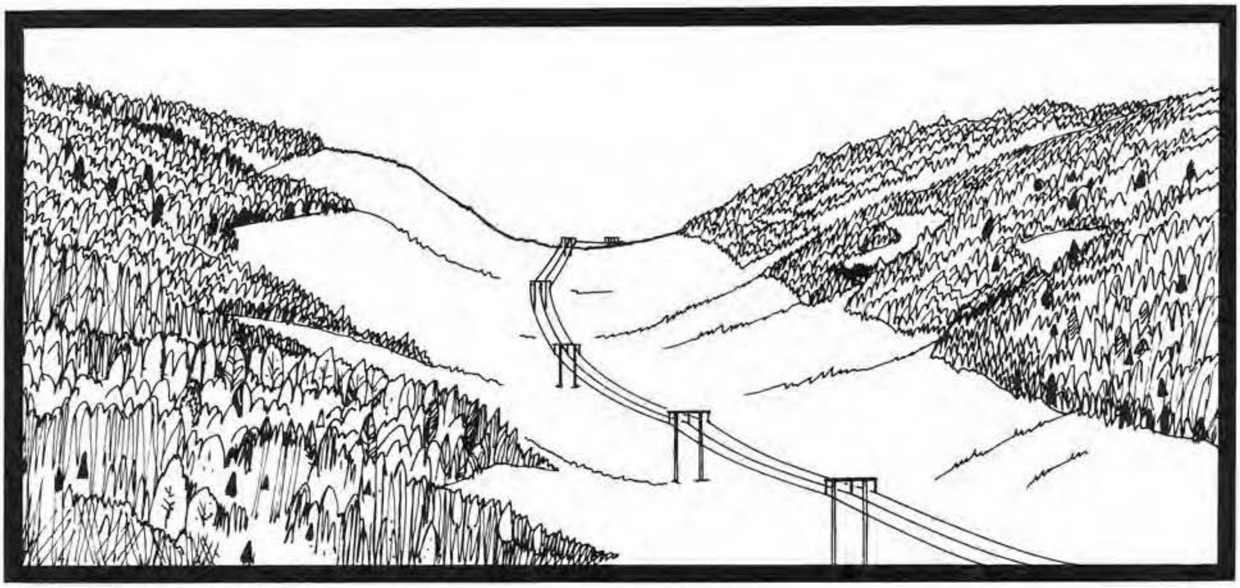
Utility located behind a hill. Topography must be considered in the location of utilities. Natural topographic lines should be followed in order to soften the visual impact of structures and of disturbances of soils and vegetation.



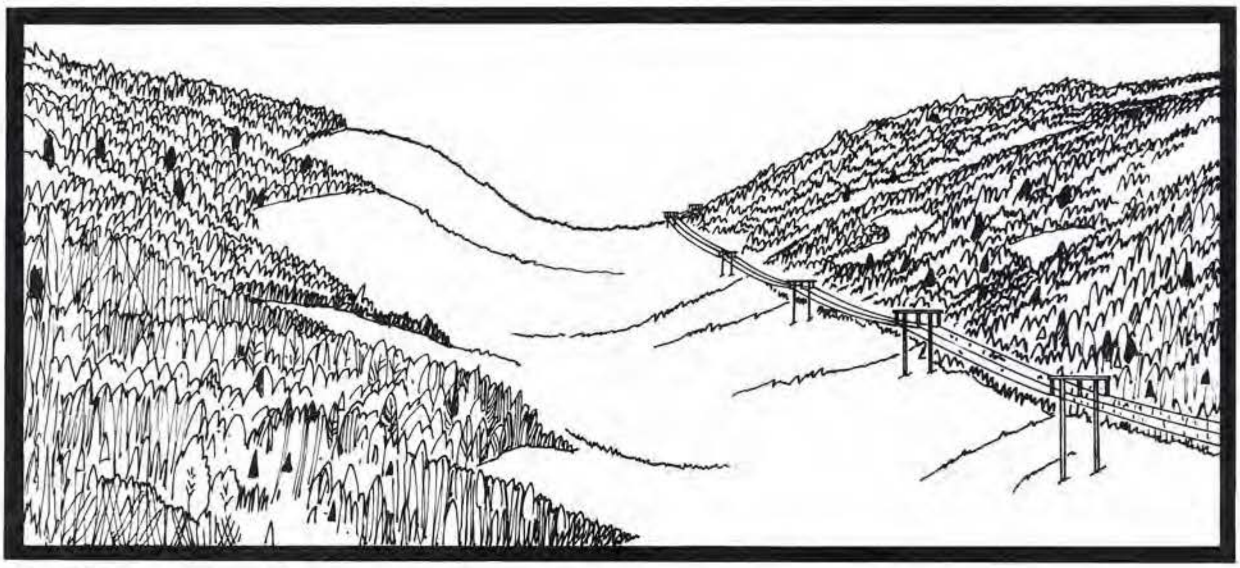
Natural topographic lines must not be opposed. If they are, the focus will be on the utility, and the visual impact will be negative.



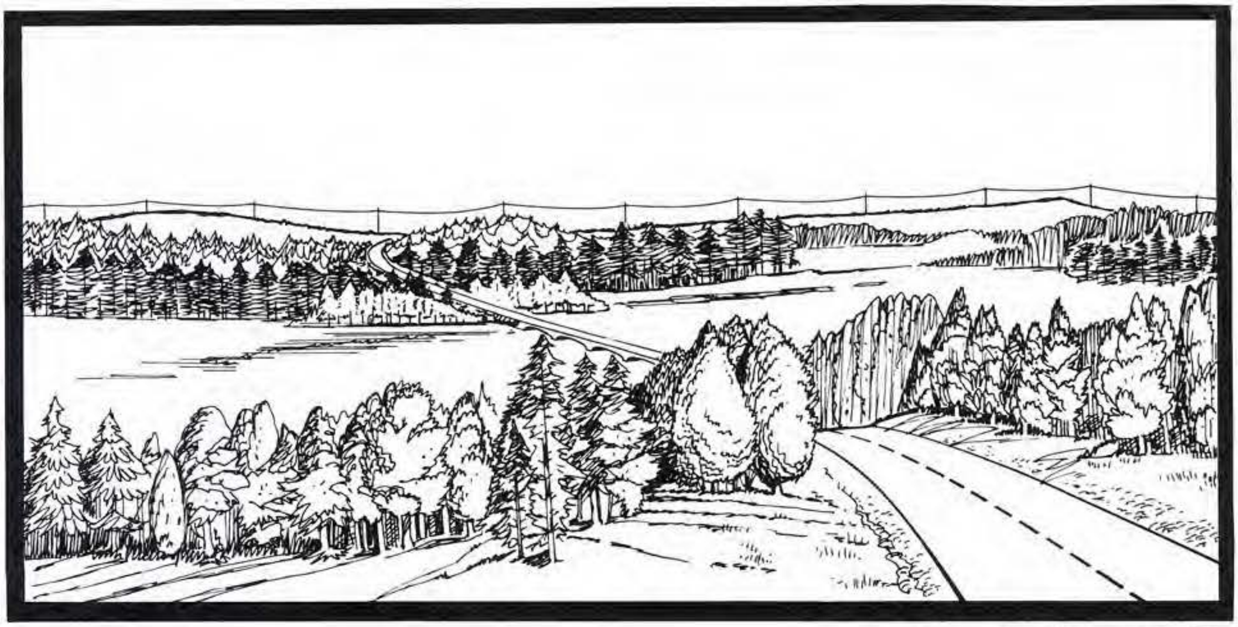
The visual impact of a utility can be greatly reduced by following natural lines and locating the utility away from natural features, such as this knob, that would draw attention to it.



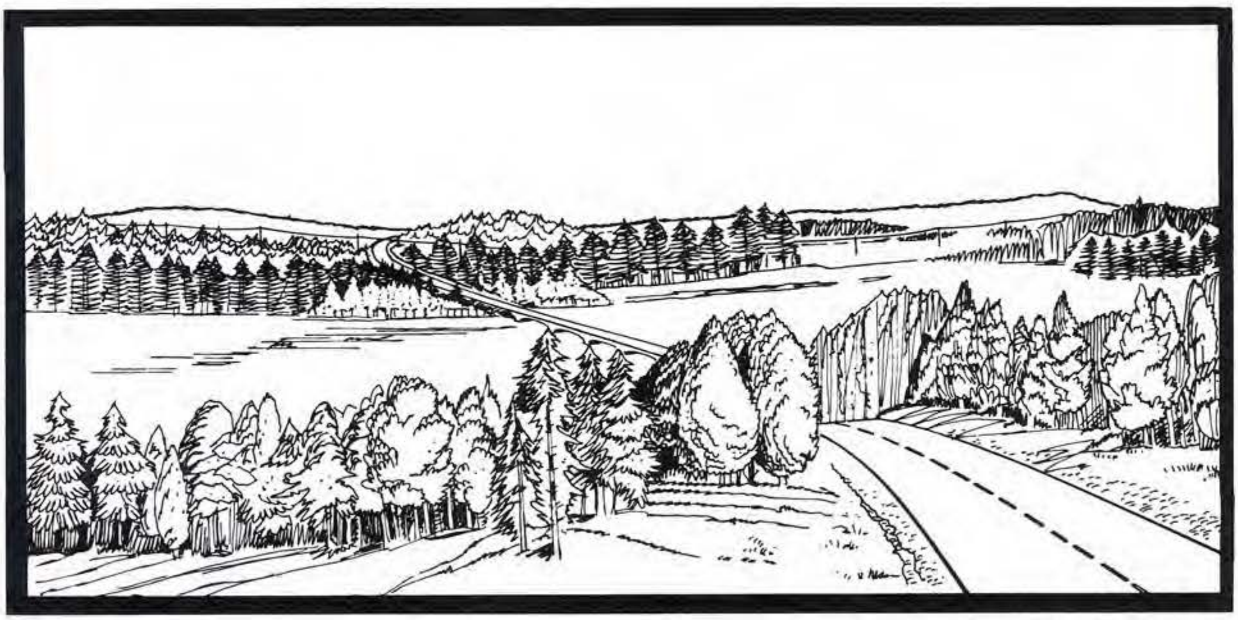
In a valley or draw, attention is usually attracted to the center—any utility in the center will be a focal point and it will usually have a negative visual impact.



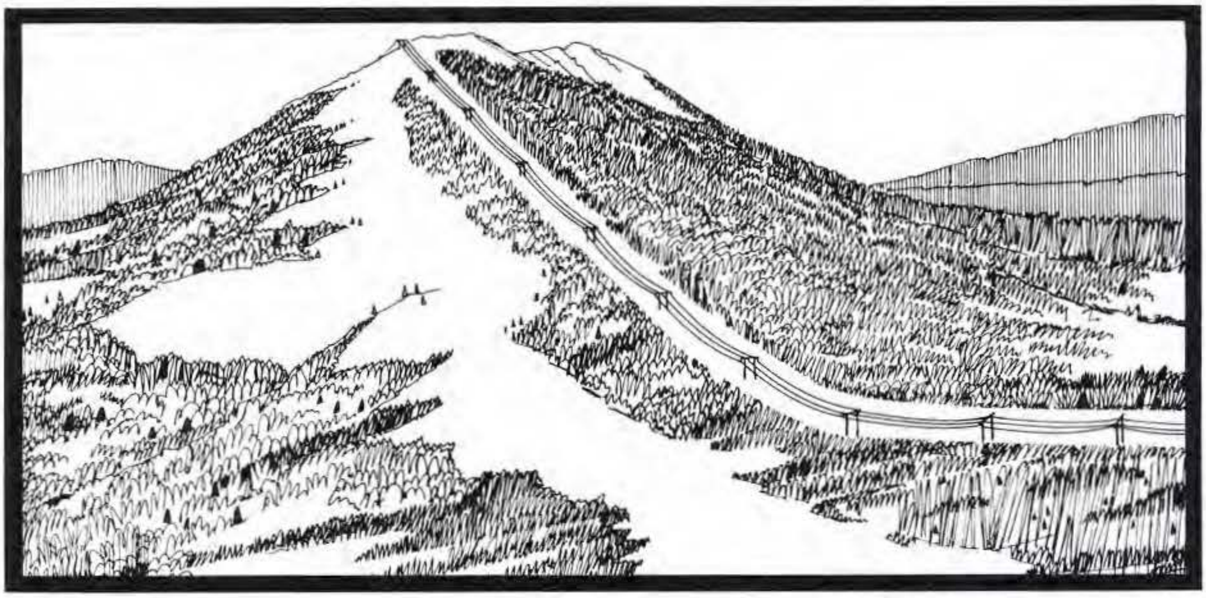
The utility should be sited on one edge of the valley or draw where natural lines created by topographic change, geology, and vegetation help to minimize the visual impact of the utility.



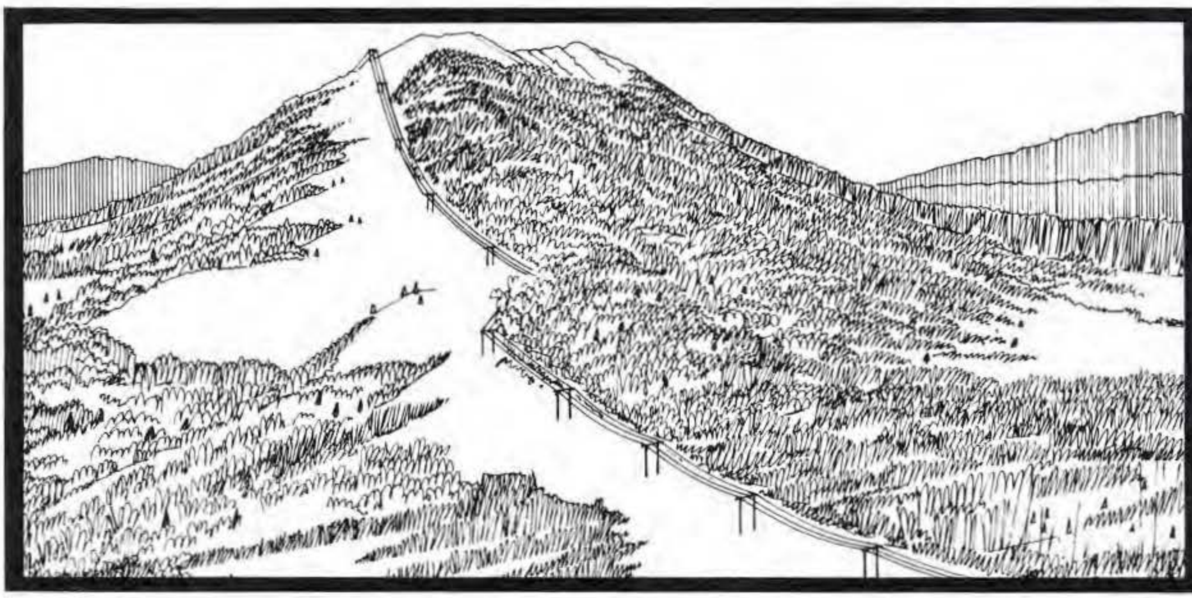
Skylining of utilities makes them very visible and, therefore, undesirable in landscape management.

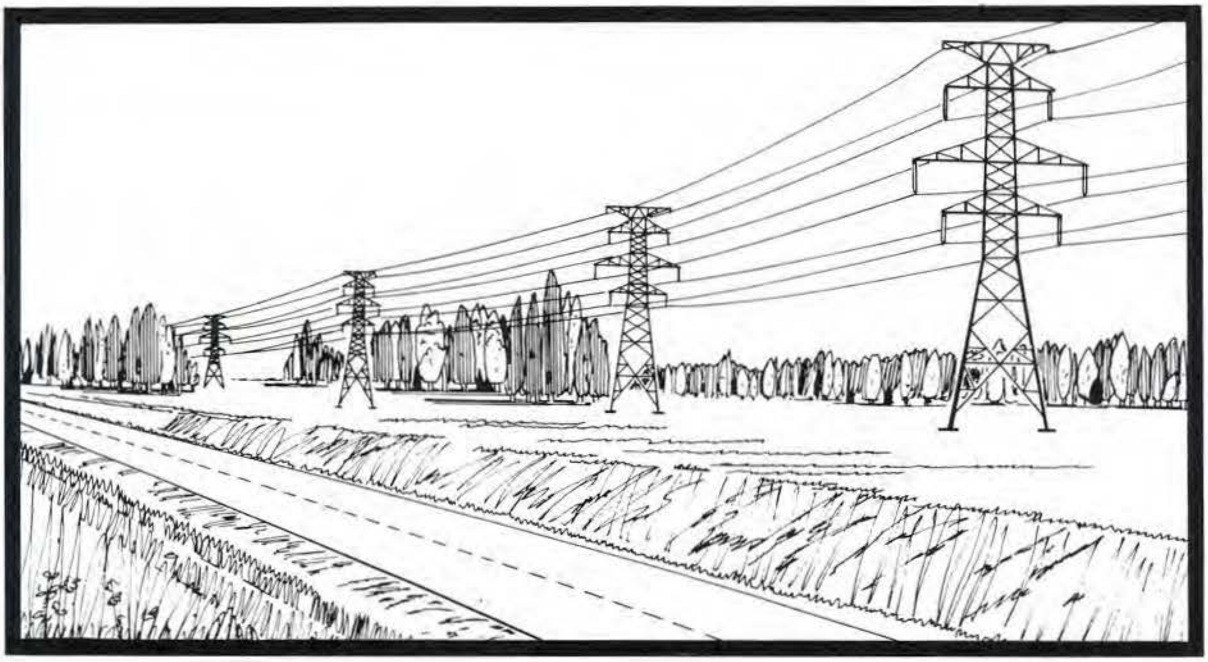


Lowering the utility to eliminate skylining and taking advantage of topographic and vegetative changes will usually reduce visual impact of the utility.

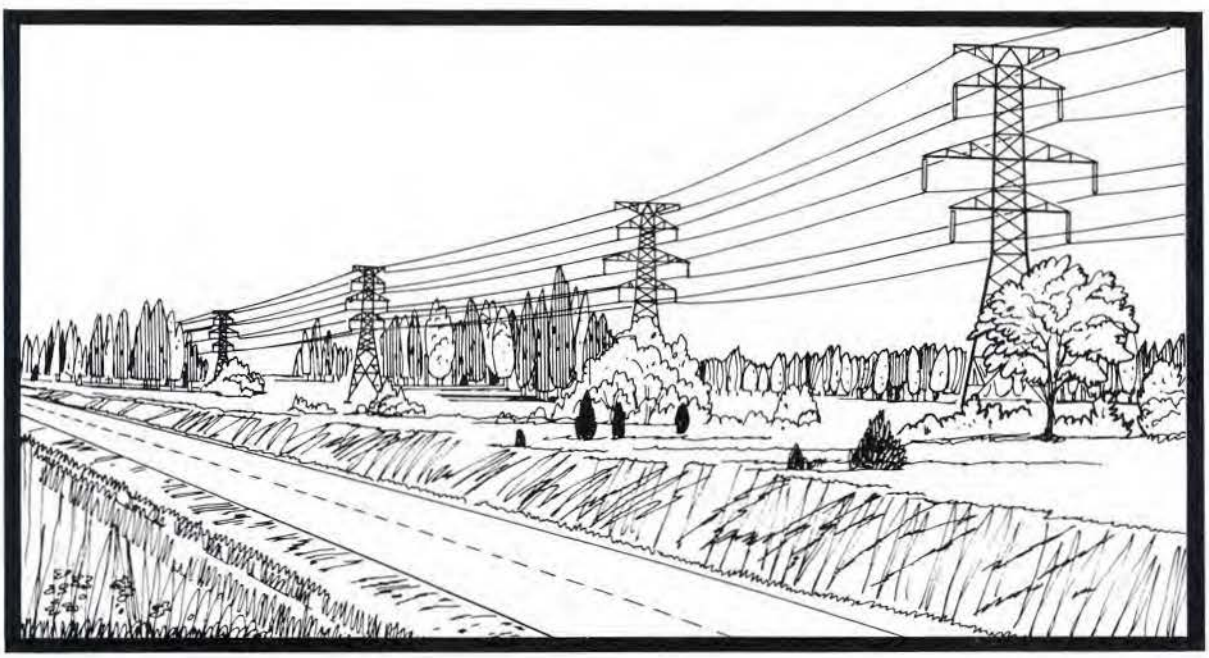


In the vegetation inventory and analysis, vegetative edges should be noted and considered for a utility location. As shown above, vegetative manipulation can have a negative visual impact if not planned well.



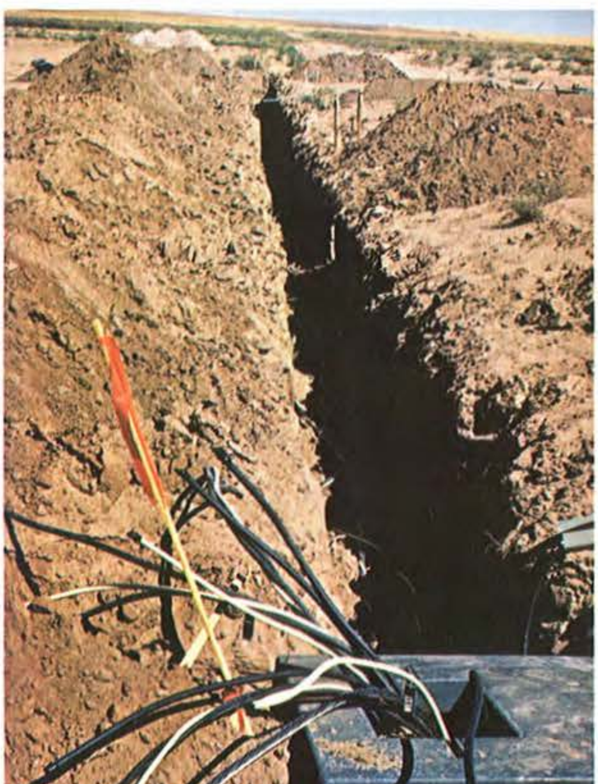


By leaving or adding vegetation, partial screening can soften the visual impact of a utility, especially along a road.



This telephone cable is passing into the feed chute of a vibrating plowshare being drawn by a tractor.

Aboveground facilities such as this padmount transformer and secondary pedestal are necessary, even for underground systems.



This concrete transformer pad is at the end of a distribution trench.

The tooth at the bottom of this plowshare is pushed through the soil by the tractor.

Construction requirements. When lines cross open grazing and agricultural lands, conventional construction methods are used. Such methods involve the use of trucks, diggers, cranes, cats, and other tracked vehicles.

As the terrain changes from flat or rolling to mountainous, and the ecological and visual impact becomes more critical, it becomes necessary to change the construction methods from conventional to a combination of conventional and special methods including helicopter-assisted construction. In any project, consideration must be given to methods of stringing conductors, moving men and equipment, placing concrete, and supporting structures.

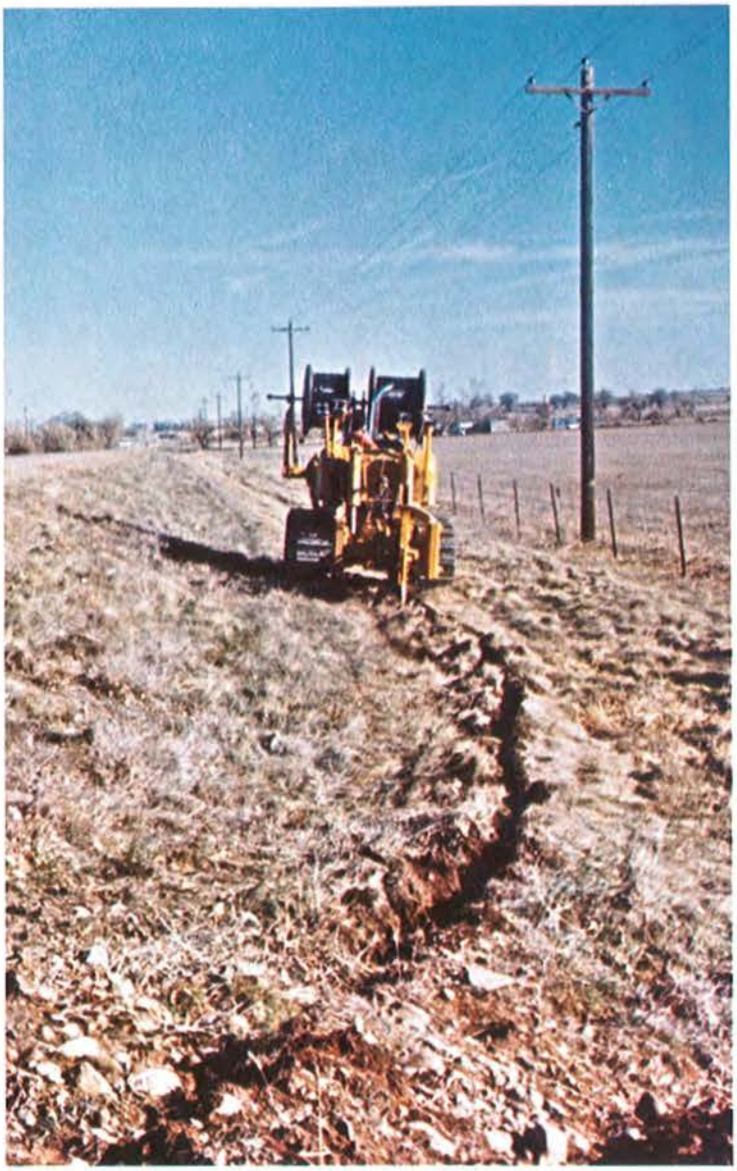
As voltages increase, the size and weight of materials and equipment also increase, thus presenting difficult problems for the engineer, the contractor, and the land manager. In most cases, the agency issuing the construction permit must fully understand construction methods and equipment in order to ensure a mutually acceptable project. Only thorough, coordinated planning prior to construction will produce an environmentally satisfactory installation.

Underground Cables

The methodology and environmental impact of burying cable by the plow-in or trenching methods are much the same for telephone lines as for powerlines.

If high-voltage powerline cables are buried, the method is much more complicated and expensive. The cost-benefit factor plays a major part in the feasibility determination.

Most underground distribution (low-voltage) cables are installed by "plowing-in" or trenching. These methods are applicable to all standard distribution voltages. Plowing-in is the underground installation of cable by means of a plowshare (or tooth) that rips through the earth. The cable is placed at a predetermined depth by passing through an enclosed guide (called a "feed chute") which is integral with or attached directly behind the plowshare. When required, the plowshare is vibrated to reduce the drawbar pull and provide slack in the cable and a bedding around the cable. Plowing-in is a one-step operation and is often less expensive than conventional trenching which requires three steps (opening the trench, laying the cable, and backfilling).



Plows that install primary voltage cables are usually mounted on tractors large enough to ensure adequate depth of burial.

The tractor may carry the cable reel if a single cable is being installed or may draw a trailer that carries several cable reels when two or more cables are installed simultaneously.

This telephone cable is being installed by a vibrating plowshare drawn by a tractor that also carries its own supply of cable.

In some areas, ordinances and land use permits require new distribution lines to be underground. Underground cables can be less costly than overhead lines when extensive right-of-way clearing is required but may be many times more expensive than overhead lines in rocky areas or hilly terrain or when higher voltages are involved.

Locating circuits underground may be desirable in areas where snow loading, lightning, wind, and narrow rights-of-way adversely affect the reliability of overhead lines. Underground cables are less subject to storm damage but involve a much longer outage time to locate the damage and repair the cable should failure occur. It is very difficult to locate and repair a faulted cable under many feet of snow and in frozen ground.

High underground costs are caused by:

- Number of taps, transformers, and splices
- Soil conditions (which may vary from sandy loam to solid granite)
- Number of substructures, fences, streams or lakes, and road crossings that are in the cable route
- Tree and brush clearing required for accessibility
- Slope of the terrain and weather conditions
- Resurfacing and seeding requirements.

When contracting for cable plowing, the utility company normally provides the cable, splices, splice boxes, and warning markers and performs the splicing.

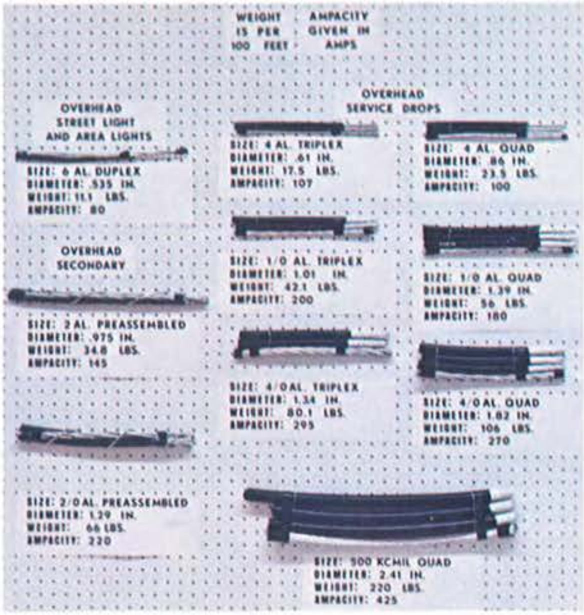
If the thermal resistivity of the soil is high, trenching and backfilling rather than plowing can be used for draining heat away from the cable. If numerous substructures exist, the trenching method is the only practical means of installing a cable.

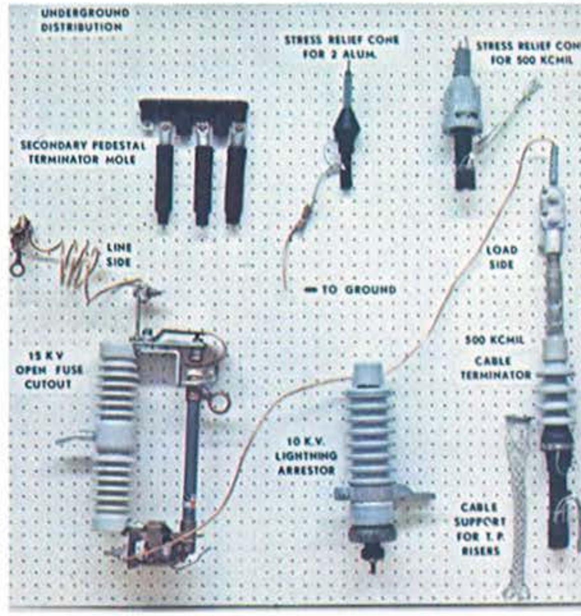
Most installations have been made along road shoulders, in dirt roads, or over cleared rights-of-way through forests. However, to provide 3–phase service to one community, it was necessary to cross 3,000′ of lake. The cable was plowed-in down to the shore area, and a trench was opened the remaining distance to the water. The lake-crossing cables were attached to a boat and simultaneously pulled slowly across the lake. As the cables were payed off their reels, inflated tire tubes were placed under the cables at 50′ intervals. With the cable in position across the lake, the tire tubes were removed, and the cable settled to the bottom of the lake. PVC pipe was fed over the cables to protect them from boats and boat anchors. The pipe extended 100′ into the lake to a point where the depth was about 50′. The pipe and cable were placed in the trench before splicing the lake-crossing cables to the plowed-in cables.

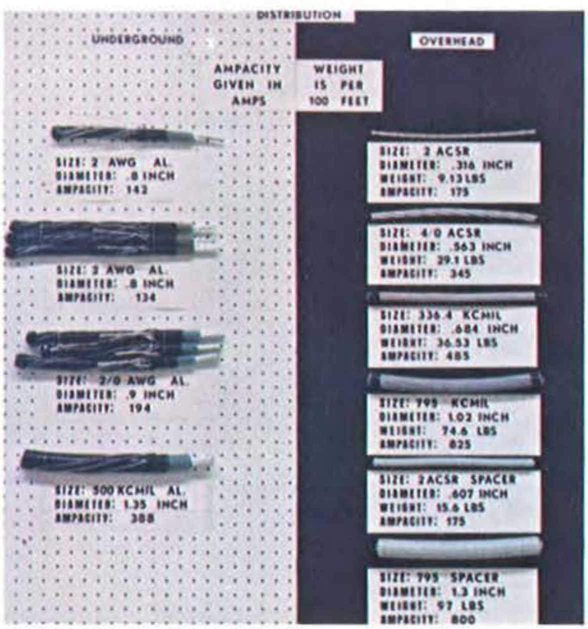
Two types of plow-in cable are typically used:

- *Standard PE-CONC cable* consists of stranded aluminum conductor, extruded polyethylene conductor shield, polyethylene insulation, extruded polyethylene insulation shield, and concentric tinned copper neutral wires. When there is a need for additional protection, a high-density polyethylene is used.
- *XLPE-CONC* is similar to the above but the insulation and extruded shields are cross-linked polyethylene and have slightly higher operating temperature ratings.

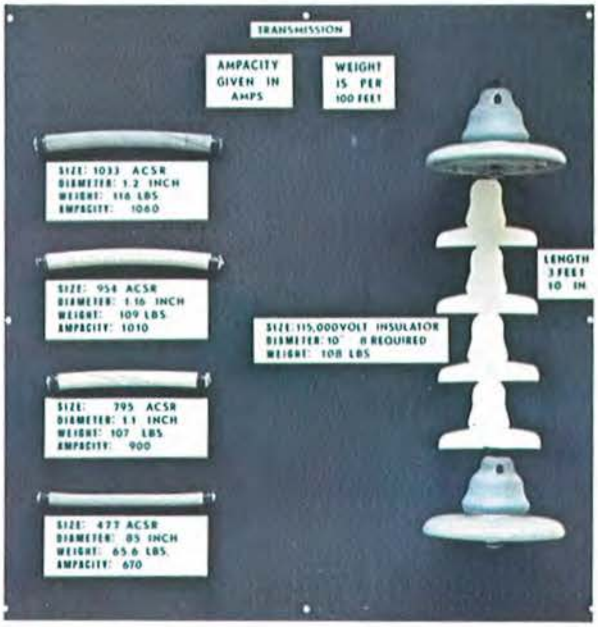
On several occasions after cables have been plowed-in, they have been uncovered and examined. It was noted that the vibrating plow tends to settle "fines" around the cable and prevents tension in the buried cable.

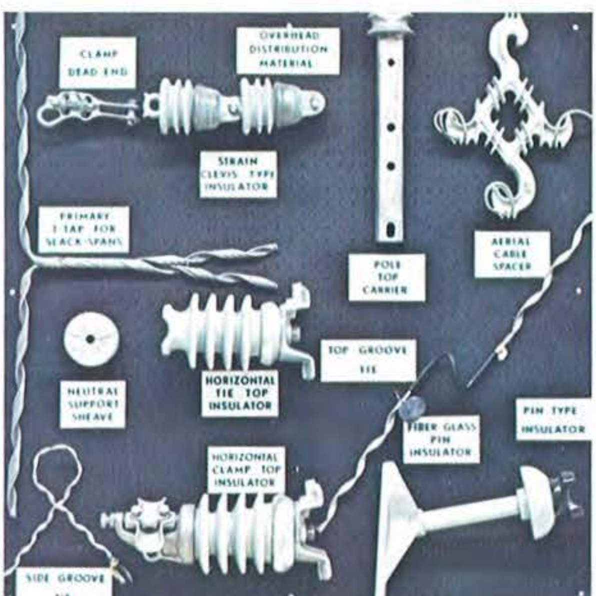

WEIGHT IS PER 100 FEET
AMPACITY GIVEN IN AMPS
OVERHEAD SERVICE DROPS
OVERHEAD STREET LIGHT AND AREA LIGHTS
SIZE: 6 AL. DUPLEX DIAMETER: .535 IN. WEIGHT: 11.1 LBS. AMPACITY: 80
SIZE: 4 AL. TRIPLEX DIAMETER: .61 IN. WEIGHT: 17.5 LBS. AMPACITY: 107
SIZE: 4 AL. QUAD DIAMETER: .86 IN. WEIGHT: 23.5 LBS. AMPACITY: 100
OVERHEAD SECONDARY
SIZE: 1/0 AL. TRIPLEX DIAMETER: 1.01 IN. WEIGHT: 42.1 LBS. AMPACITY: 200
SIZE: 1/0 AL. QUAD DIAMETER: 1.39 IN. WEIGHT: 56 LBS. AMPACITY: 180
SIZE: 2 AL. PREASSEMBLED DIAMETER: .975 IN. WEIGHT: 34.8 LBS. AMPACITY: 145
SIZE: 4/0 AL. TRIPLEX DIAMETER: 1.34 IN. WEIGHT: 80.1 LBS. AMPACITY: 295
SIZE: 4/0 AL. QUAD DIAMETER: 1.82 IN. WEIGHT: 106 LBS. AMPACITY: 270
SIZE: 2/0 AL. PREASSEMBLED DIAMETER: 1.29 IN. WEIGHT: 66 LBS. AMPACITY: 220
SIZE: 500 KCMIL QUAD DIAMETER: 2.41 IN. WEIGHT: 220 LBS. AMPACITY: 425


UNDERGROUND DISTRIBUTION
STRESS RELIEF CONE FOR 2 ALUM.
STRESS RELIEF CONE FOR 500 KCMIL
SECONDARY PEDESTAL TERMINATOR MOLE
LINE SIDE
LOAD SIDE
TO GROUND
15 K V OPEN FUSE CUTOUT
500 KCMIL CABLE TERMINATOR
10 K.V. LIGHTNING ARRESTOR
CABLE SUPPORT FOR T. P. RISERS


DISTRIBUTION
UNDERGROUND
OVERHEAD
AMPACITY GIVEN IN AMPS
WEIGHT IS PER 100 FEET
SIZE: 2 AWG AL. DIAMETER: .8 INCH AMPACITY: 142
SIZE: 2 ACSR DIAMETER: .316 INCH WEIGHT: 9.13 LBS AMPACITY: 175
SIZE: 2 AWG AL. DIAMETER: .8 INCH AMPACITY: 134
SIZE: 4/0 ACSR DIAMETER: .563 INCH WEIGHT: 29.1 LBS AMPACITY: 345
SIZE: 336.4 KCMIL DIAMETER: .684 INCH WEIGHT: 36.53 LBS AMPACITY: 485
SIZE: 2/0 AWG AL. DIAMETER: .9 INCH AMPACITY: 194
SIZE: 795 KCMIL DIAMETER: 1.02 INCH WEIGHT: 74.6 LBS AMPACITY: 825
SIZE: 500 KCMIL AL. DIAMETER: 1.35 INCH AMPACITY: 388
SIZE: 2ACSR SPACER DIAMETER: .607 INCH WEIGHT: 15.6 LBS AMPACITY: 175
SIZE: 795 SPACER DIAMETER: 1.3 INCH WEIGHT: 97 LBS AMPACITY: 800


UNDERGROUND DISTRIBUTION
500 KCMIL SPLICE
DIRECT BURY SPLICES
2 ALUM. SPLICE
LOADBREAK FEEDTHROUGH BUSHING
2 ALUM. Y SPLICE
STANDOFF INSULATOR
RTE LOADBREAK TERMINATOR
PROTECTIVE CAP





The location of cable faults in remote areas is expected to be time consuming because present fault-location techniques require special equipment and experienced personnel.

Compared to overhead distribution lines, underground cable construction in forested areas appears to offer the following advantages:

- Substantial improvement in appearance because of the relatively inconspicuous structures involved
- Probability of improvement in continuity of service due to relative immunity from snow, lightning, fire, automobiles, and vandalism
- Greater safety to the public in areas where depth of snow sometimes seriously impairs ground clearances of overhead lines
- Lowered fire hazard.

If the incidence of faults proves to be greater than anticipated due to floods, washouts, or landslides, the long restoration times associated with directly buried cables could reduce the continuity of service and increase operating costs. This would be particularly true in areas of exceptionally precipitous or rugged terrain, subject to heavy snow cover, or located far from the nearest operating headquarters.

This problem can be overcome through the use of "loop" distribution systems rather than "radial" systems. Loop systems are used and recommended by most utilities where a high degree of reliability is required. If one section of a loop faults, the power can be maintained to all except the faulted section.

Soils, geology, and hydrology of an area considered for underground cable must be thoroughly inventoried and analyzed before the cable is installed.

MICROWAVE SYSTEMS
Reliability

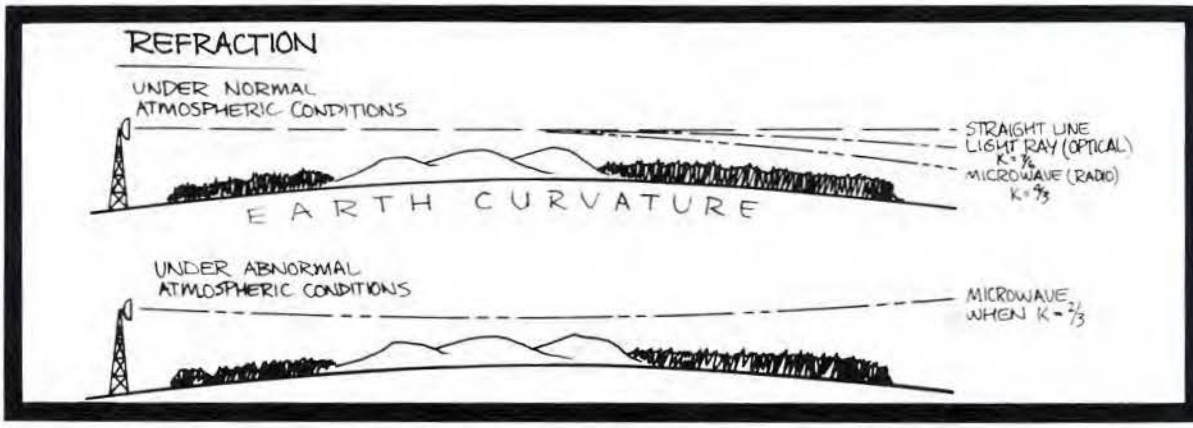
Reliability and economy are the main reasons why microwave radio is sometimes preferred to landline facilities for communication services such as telephone, TV, and telegraph.

Landlines (open wire, overhead or underground cable) are subject to a variety of natural hazards. Open wire and overhead cables are often downed by icing, heavy snows, or high winds. Underground cables are sometimes disrupted by washouts, landslides, "gully washers," or long, heavy rainfall. More often, in the case of underground cable, natural hazards take a back seat to manmade hazards. Cable cuts caused by excavation for roads, pipelines, and so forth are a constant danger.

A well-designed microwave system, with adequate standby power reserves, is relatively free from the whims of nature. Over the long term, a microwave system costs less to repair and maintain than its landline counterparts.

Microwave Paths

Electromagnetic radiation in the microwave frequency range involves principles and methods similar to those of light transmission. Thus, a "microwave beam" is often compared to a light beam. A microwave beam is subject to the effects or refraction, diffraction, reflection, and heavy rainfall.

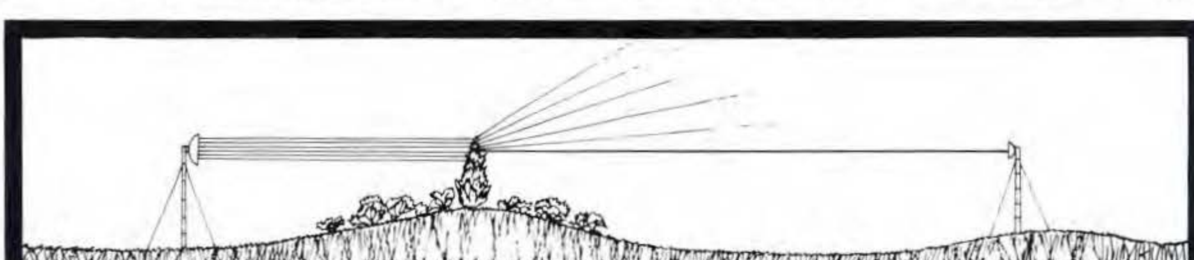


Refraction. The beam tends to follow a straight line in the horizontal (azimuthal) plane. But due to changes in the dielectric constant of the atmosphere, the beam is seldom precisely straight in the vertical plane.

The dielectric constant is a function of barometric pressure, temperature, and amount of water vapor in the atmosphere. Variations in the constant usually cause the beam to refract (bend) slightly downward, thereby extending the radio horizon beyond the optical horizon. The refraction (beam bending) is measured in relation to the curvature of the earth's surface and is called K (effective earth radius/true earth radius).

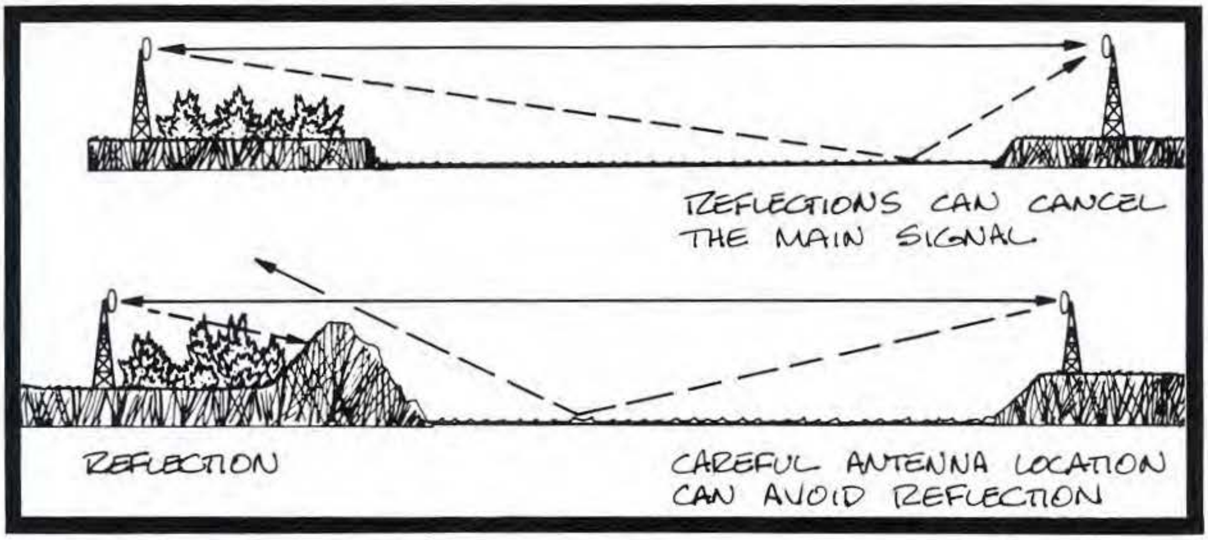
Certain atmospheric conditions cause inverse bending. When the dielectric constant of the atmosphere increases with height (it normally decreases), the microwave beam bends upward. $K = 2/3$ is an example of this condition. This reduces the path clearance and may even obstruct the beam. This explains why antenna heights (and hence, tower heights) may seem excessive to the layman, who may be able to sight along the path and see the next station while standing at the base of the tower.

Diffraction. Diffraction occurs when the beam grazes an obstacle; the grazing redi-



rects part of the beam and results in a loss of radio energy reaching the receiving antenna. The amount of energy lost depends on the type of surface over which diffraction occurs and to what degree it intercepts the beam.

To minimize diffraction losses, microwave path clearances are designed to avoid grazing under the most adverse conditions of K. Clearance requirements also apply to the sides of the beam.

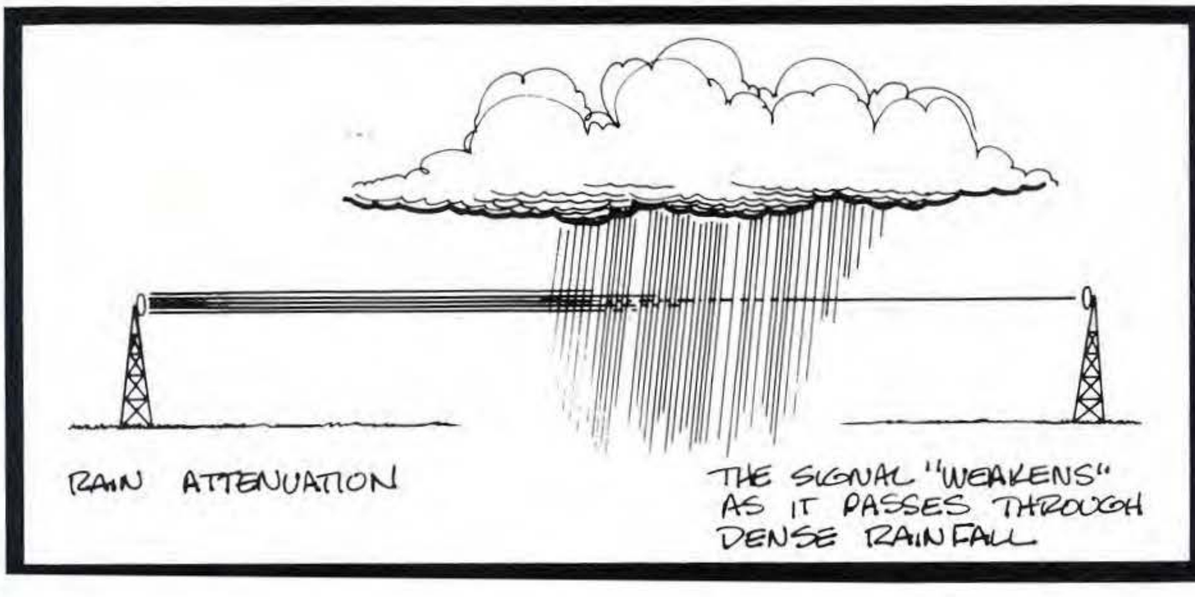


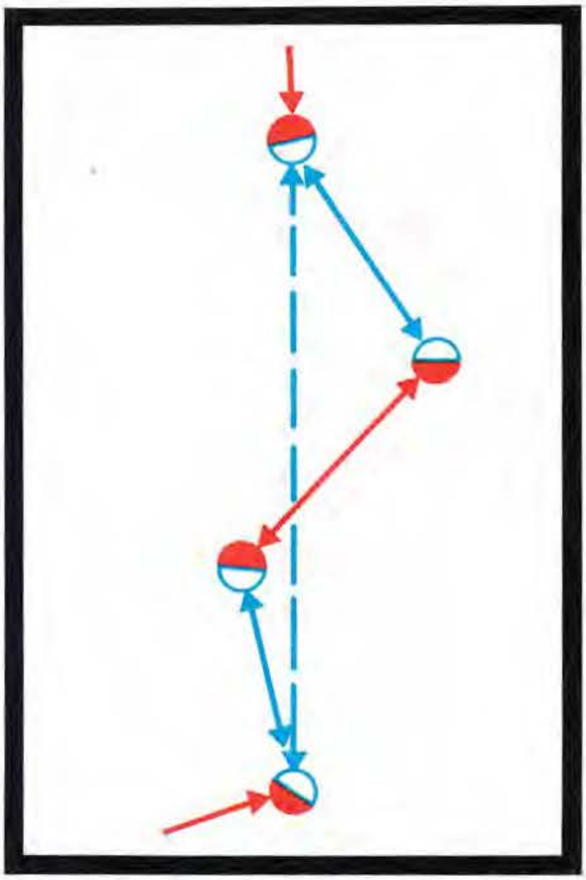
Reflection. Reception of a reflected beam is undesirable. Reflections occur at one or more points along the beam path. Strong reflections may be caused by relatively smooth surfaces (such as lakes, salt flats, or deserts) and may cancel the direct signal.

Such situations may be avoided through careful specification of the heights of the transmitting and receiving antennas so that reflection points can be "seen" from only one end of the path under normal conditions of K.

Rain attenuation. Attenuation (weakening) of a microwave signal due to rainfall occurs at all microwave frequencies, but the effect is negligible at frequencies below 8 GHz. Above 10 GHz, attenuation becomes significant and is important in determining path lengths and overall system reliability. As a rule, at frequencies above 10 GHz, short paths are recommended in areas of heavy rainfall. Rainfall intensity, not total annual rainfall, is the major consideration.

A well-engineered microwave path is one in which, after the variables have been taken into account, all obstructions have been adequately cleared, thus allowing transmission through "free space" and ensuring that the strongest possible signal is received.





In a microwave system each station receives a signal in the lower portion of its assigned frequency band (the green lines) and retransmits it in the upper portion (the red lines). Thus, the signal proceeds cross-country by an alternating pair of frequencies. Repeaters or passive reflectors may be used between stations but they do not affect the signal's frequency.
Under some conditions the signal will tend to "leap frog" (the green dashed line) and cause intra-system interference. Careful alignment, antenna design, terrain obstruction, etc. are used to prevent this.

Interference and Frequency Coordination

Within the United States, the Federal Communications Commission (FCC) controls the radio frequency spectrum and assigns radio channels to the various services within designated frequency bands. The FCC requires that all licensees and applicants for licenses cooperate in the selection and use of frequencies to ensure the most effective and efficient use of the spectrum. This includes reasonable efforts to avoid blocking the growth of systems that are likely to need greater capacity in the foreseeable future.

The effects of interference vary with the nature of the desired signal and the interfering signal. Generally, paralleling systems cannot be fully developed within the same frequency band. System design, providing angular separation between the microwave paths involved, can overcome most problems of this nature. At certain angles, careful equipment selection, especially of antennas, may provide a workable solution for systems that converge or diverge at one point.

For shared-band operation, ample terrain shielding or distance separation is required between terrestrial (microwave) stations and ground stations of satellite systems. This is because a ground station transmits (up link) an extremely powerful signal and receives (down link) an extremely weak signal. This creates a strong potential for interference into or from terrestrial systems operating in the same band(s). System design must also consider the probability of interference between satellite and terrestrial systems due to "hydrometeoric scatter."

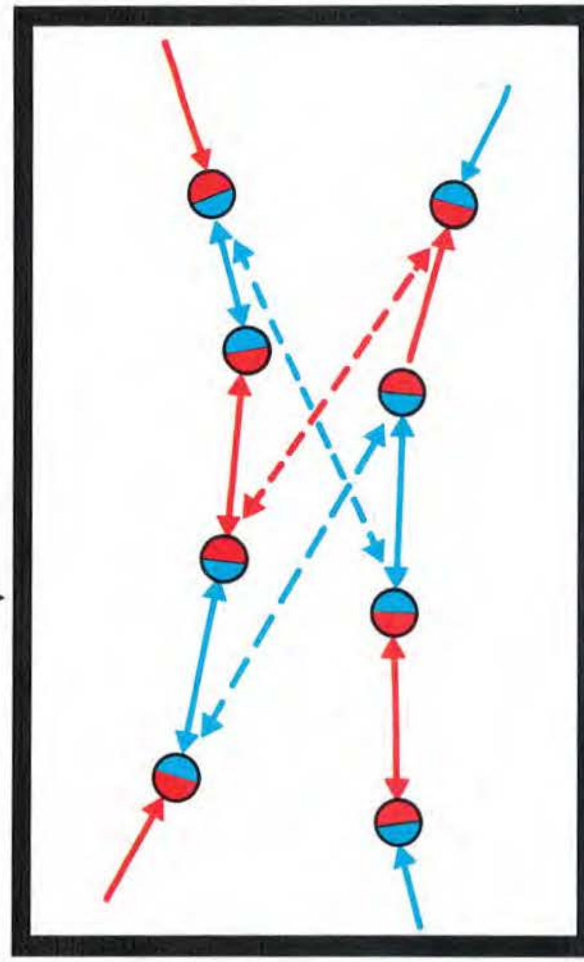
Terrrain shielding may also become a design consideration if there is the possibility of interference from a radar station. Radars (weather, military, civil aviation, and so forth) present special interference problems since they typically radiate high energy levels in a 360° arc. Although shared-band operation is not a factor, the power in the primary frequency of a radar transmitter may overload or desensitize a microwave receiver, and a harmonic of the primary frequency of a radar transmitter may fall within the band used by a microwave system.

Sites

Selection of a site for a microwave station is largely determined by the terrain between that site and the next stations in the microwave system. The "ideal" site would have:

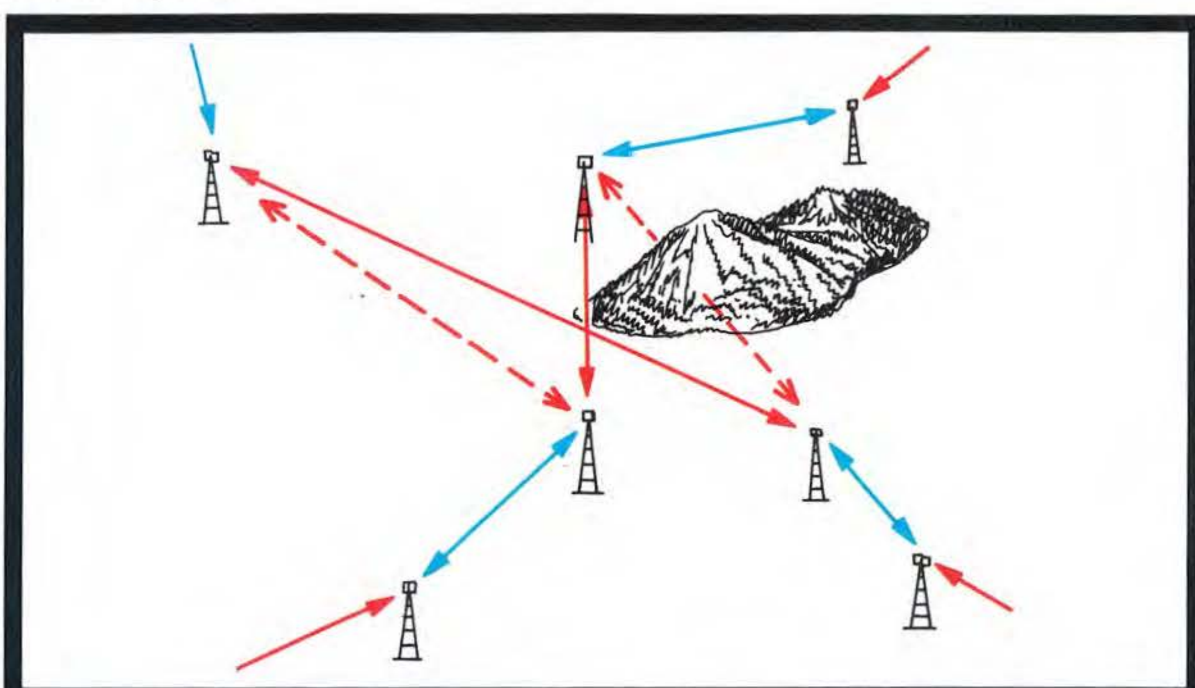
- Sufficient elevation above surrounding terrain to allow minimal antenna heights
- Level ground with suitable soil conditions
- Easy access from existing roads or highways
- Proximity to AC powerlines.

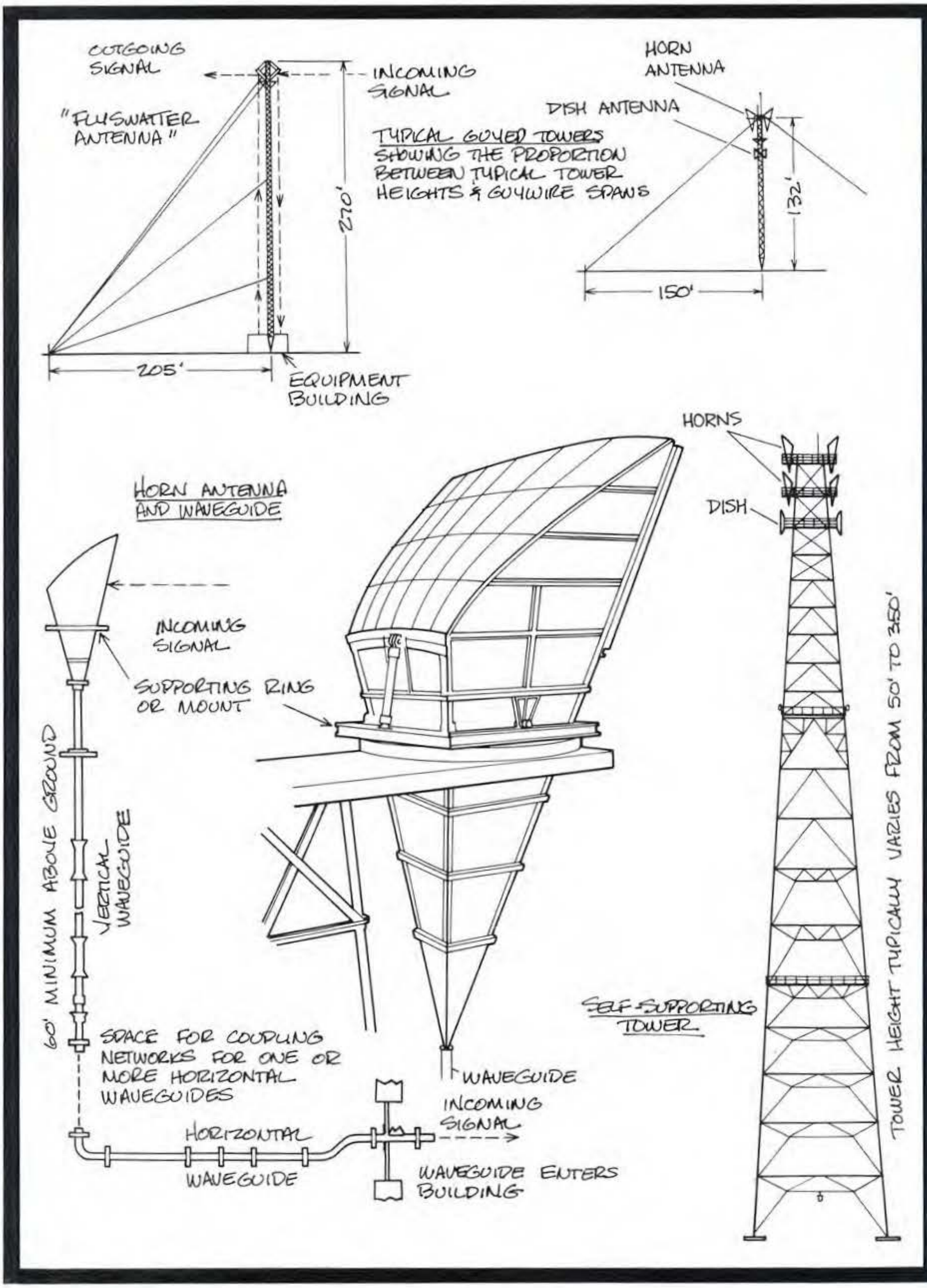
Realistically, the choice of a site is the result of a number of compromises or "tradeoffs" among these ideals and considerations of environmental impact and potential sources of radio interference.



Two paralleling systems in the same frequency band tend to produce inter-system interference (dashed lines) in much the same way.

When two systems utilizing the same frequency bands cross, inter-system interference can be expected (dashed lines). This can be prevented by taking advantage of topography (such as the hill), by using a more perpendicular crossing, by careful antenna selection, or a combination of these.





Examples of microwave towers and antennas.

Antennas

Microwave antennas are highly directional in that they focus the radio energy into a narrow beam. A transmitting antenna may be compared to a searchlight, a receiving antenna to a telescope; in either case, effectiveness is increased by the concentration of radiation. "Gain" is the ability of an antenna to concentrate radiation in a given direction.

Gain is the ratio of the power radiated in one direction by a standard reference antenna; it is usually measured in decibels (dB). The gain of an antenna is directly related to its effective area (size) and operating frequency (wavelength).

A wide variety of antenna types and sizes (commonly ranging from 4′ to 16′ in diameter or aperture) is available to the microwave engineer. Each type has special advantages, and the design goal is to hold equipment to the minimum needed for overall system requirements, including capacity for growth. Good characteristics in relation to off-axis radiation discrimination and polarization discrimination are especially important for purposes of frequency coordination.

Some microwave systems use separate antennas for transmitting and receiving over the same path; but in many cases, one antenna can perform both functions. Some antennas can operate in widely separated frequency bands. An antenna of the horn reflector type can accommodate an exceptionally broad range of frequency bands.

Most microwave antennas now in use are of the direct-radiating type. Periscope antennas ("fly swatters"), widely used in the past, have recently fallen into disfavor for use in frequency-congested areas because of poor off-axis radiation discrimination characteristics.

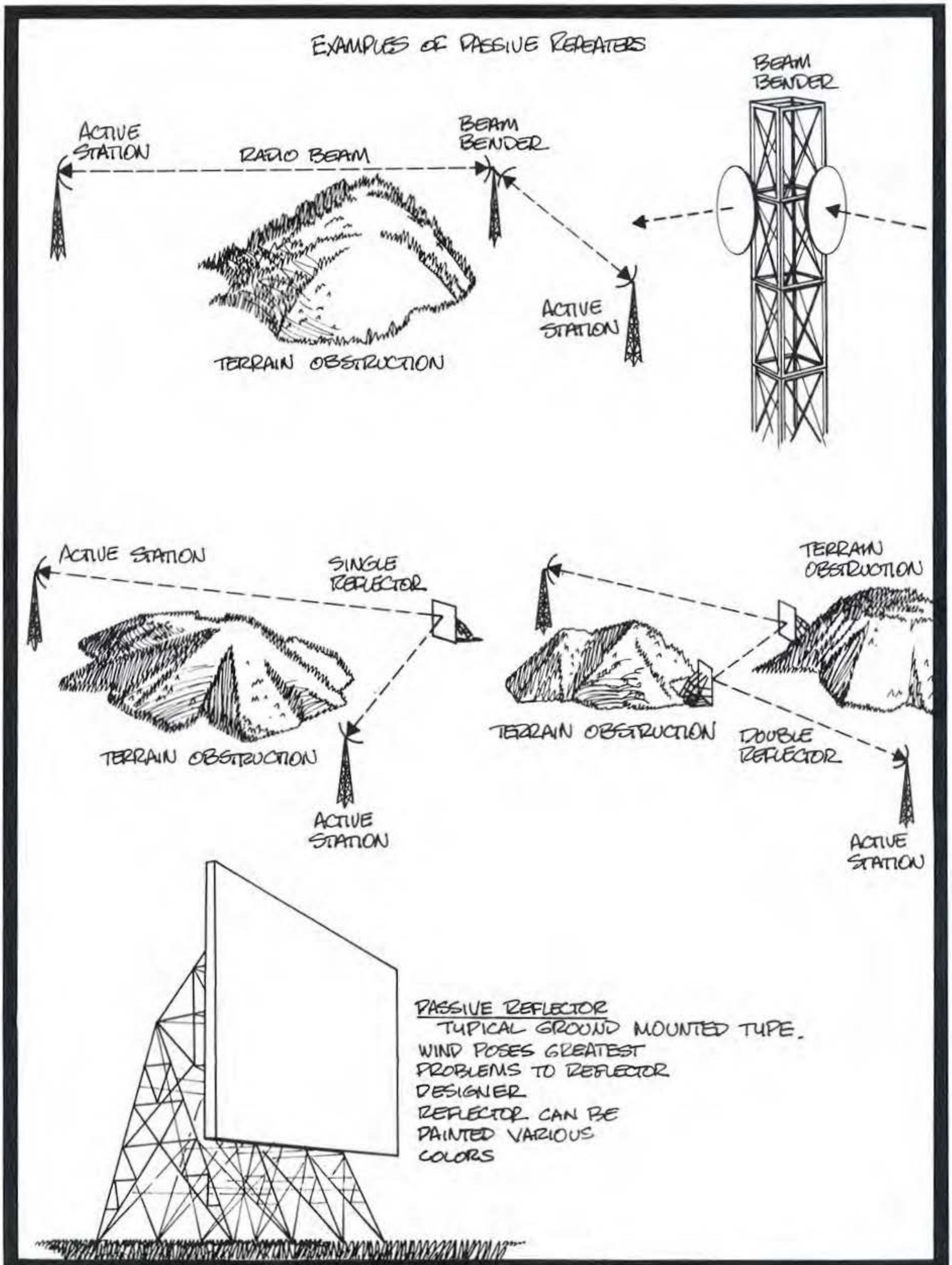
Antenna Support Structures

Problems associated with antenna support structures (towers) have a significant, at times dominant, effect in the design of a microwave system. One primary consideration, in this time of ecological awareness, is the environmental impact, mainly the "visibility factor," of towers. This consideration is crucial in both rural and urban areas.

Tower heights depend basically on propagation requirements, that is, the antennas must be high enough to permit the microwave beam to adequately clear all obstructions on the radio path. Consistent with this need, minimal antenna mounting heights are generally selected. Certain antennas, such as the horn reflector type, must be mounted at least 60′ above ground in order to realize their full capabilities for use in multichannel, high-capacity microwave systems. This limitation is imposed by the vertical spacing requirements of the coupling networks that are an integral part of the antenna system.

There are two common tower types: self-supporting and guyed. The advantages and disadvantages of each type must be weighed along with the environmental and economical considerations. Some factors that influence the selection of a specific tower design are soil conditions, wind and/or ice loading, dimensions of site, and ultimate use (capacity to mount additional antennas for predicted growth or extension of facilities). Occasionally, antennas may be roof-mounted on structurally adequate buildings.

Normally, towers and reflectors can be painted to blend with the environment. The exceptions are structures that exceed limitations imposed by governmental regulations (FAA and FCC) regarding hazards to air navigation. Such structures must be obstruction marked and lighted. Depending on proximity to airports or airlines, structures less than 200′ in overall height are generally exempt from the obstruction marking and lighting requirements.



Examples of passive repeaters.

Passive Repeaters

Passive repeaters redirect microwave beams around or over natural or manmade obstructions. There are two types of passive repeater: one is the "beam bender," a back-to-back configuration of direct-radiating antennas; the other more common type is a reflector (sometimes called a "billboard" or "radio mirror"). Double reflectors are used when the change in beam direction is to be less than about 50°. Since reflectors do not require AC power and are essentially maintenance free, they may be used at remote and relatively inaccessible sites.

Reflectors vary considerably in size; standard dimensions range from 8′ x 10′ to 40′ x 60′. The required dimensions are determined by such factors as frequency of operation, distance from end (active) stations, angle between the incident and the reflected microwave beam, antenna gain and transmitter power at end stations, and circuit loading and channel noise requirements.

Reflectors require path clearances much like those needed for direct-radiating antennas. They may be painted and, *if possible*, should be sited so they do not stand out on the horizon. Sharply rising, sparsely foliated terrain behind the reflector may cause transmission problems. Use of a larger reflector will reduce this possibility.

Buildings

The main purpose of microwave equipment buildings is to house transmitters, receivers, and emergency power systems and to provide a conditioned climate for that equipment.

Equipment buildings must be as close to the base of the tower as possible. For this reason, placement of the building is determined by location of the associated microwave tower.

Equipment buildings range in size from very small equipment huts to large buildings. In some cases, small buildings can be made inconspicuous using adequate ground cover and landscaping.

Today some manufacturers are marketing equipment buildings factory-made in a variety of colors and shipped ready for installation. The outer skins of these buildings vary in composition and design ranging from fiberglass to aluminum or steel. Such nondeteriorating surface materials reduce total maintenance needs and improve long-range appearance. Such buildings must be sturdy enough to withstand occasional heavy structural loads caused by wind or snow.

Generally all sites are enclosed by security fencing. Federal Communication Commission rules require transmitters to be secured from unauthorized access and use. All such fencing should be of nonreflecting (such as a galvanized) material. In some cases, green vinyl-coated fences should be considered.

Modern radio equipment is very sensitive to temperature, and therefore temperature extremes must be provided for. At high elevations, heaters and fuel reserves are required. Conversely, at lower elevations, air conditioning is often required, so adequate commercial power must be provided. In areas of high visibility or noticeability, painting fuel reserve tanks a dull blending color or partial burial of tanks might be considered as alternatives. Safe storage of fuel should be of topmost concern because of the hazard of forest fires.


N317Y

AC Power

Commercial AC power is normally required at most transmitter sites. Due to the remote location of many microwave installations, it is usually necessary to install a commercial powerline from the nearest possible source. Buried powerlines can sometimes be used, but exorbitant costs in some areas, and potential environmental damage in others, prevent widespread use. For the most remote sites, limited use is now being made of solar cells and butane-powered thermal converters to power these stations. However, technology has not yet advanced to the point where these or similar techniques are satisfactory for most installations because of their limited generating capacity.

Emergency power at radio sites, during commercial power failures, requires use of combustion engine driven generators. The generators are normally housed in the equipment building and are muffled to prevent disturbing the surrounding area. These generators are seldom run except when needed for routine maintenance checks.

Helicopters

Helicopters provide an efficient means of year-round access to remote towers. When possible, enough area should be cleared for a landing site when the radio station is developed. Occasionally, a natural clearing suitable for use as a helicopter pad is available near a site. Minimum development might include removal of brush and large rocks.

Shorter construction intervals may be realized when helicopters are used. This is of major importance at high elevations, where building periods are short due to weather extremes.

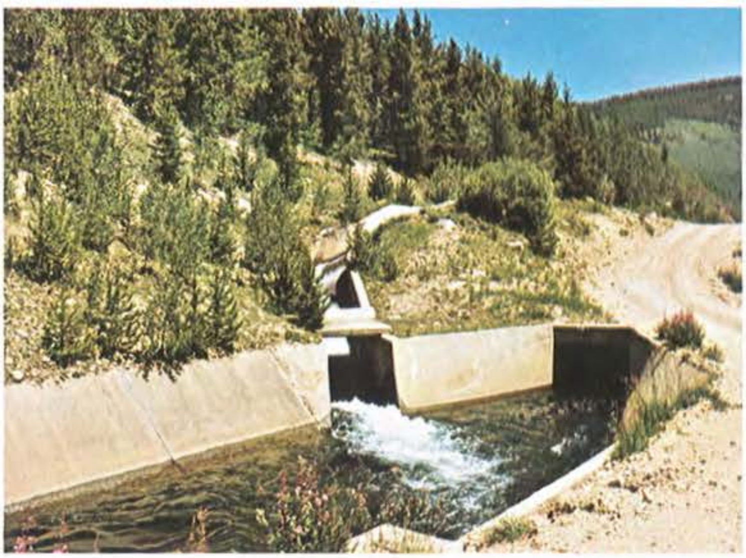
The use of helicopters for the transportation of maintenance personnel can reduce downtime in case of system failure. In most situations, helicopters can be used year-round since they are not subject to the normal road and weather restrictions of ground vehicles.

Contractors

Maximum environmental damage usually occurs during initial establishment of sites and access roads. Guidelines should be made available to contractors, and a definite effort should be made to confirm that they are being followed. Construction and installation should be closely monitored to ensure that proper care is taken by all contractors, suppliers, and associated personnel.

Work should be planned as far ahead as possible to allow orderly construction of buildings and towers and installation of equipment. Priority should be given to projects in areas that have very short building periods, due to weather conditions. This becomes even more important at elevations around timberline. Revegetation at this elevation is usually difficult due to cold temperatures and a short growing season.

Unlined ditch.



Open drop structure.

Lined ditch.

WATER-COLLECTION SYSTEMS

Above-surface Conductors—Ditches

Gradients should be determined so as to limit velocities on unlined ditches to the velocity that will cause minimum erosion to the ditch bottom and side slopes. These velocities vary from about 1 foot per second to about 5 feet per second, depending on the type of soil through which the ditch passes.

In unlined ditches, the most efficient, practical shape is the half hexagon, which gives the smallest wetted perimeter. In most cases the terrain and soils in which the ditch is constructed determine the gradient and shape of the ditch and, sometimes, a less than optimum shape may be used. Most side slopes should be 1½ to 1, but flatter slopes are sometimes desirable.

If drop structures are required, they should be designed to minimize erosion of the canal bottom and side slopes.

Ditches should be lined if the gradient and resulting velocities exceed the ability of the soil to prevent scouring or bottom degradation.

The degree of ditch curvature is a function of topography in most instances. In general, alignment of ditches, a change in canal cross section, or change in canal slope is a function of measurement of flow. Lift structure or pump station design is a function of what is needed to provide the energy required to lift the water the required distance.

Buried Conductors—Water Conduits

Location and rights-of-way requirements. Buried conductors are normally gravity systems laid on a flow line grade that follows the natural contours of the land. A deviation from this alignment is the inverted siphon used in crossing valleys.

Road requirements. Access roads are necessary for the construction, operation, and maintenance of buried conductors. The roads must be adequate to permit the transport of the heavy construction equipment, sections of conduit, and other materials to the site. In many cases, a temporary roadway will suffice for construction purposes and a smaller access road will suffice for maintenance.

Since electric power is not available to remotely regulate water flows, access roads are required for operation of the system. Roads are also needed for maintenance of the system, including trash removal from screens and gates and control of beavers, muskrats, and other rodents.

The minimum width of the right-of-way for the conduit and the access road is usually 100′; however, requirements may vary depending on terrain.

The size of the stream or river and water detention requirements determine the amount of land needed for diversion structures and reservoirs.

Use of water system rights-of-way for other utilities is feasible—to within about 10′ of the actual water facility. Adjoining utilities must be accurately located and marked to prevent future problems.

Glossary of technical terms

GENERAL

Alignment—The specific, surveyed location or route of a utility line.

Corridor—A linear strip of land which accommodates or is expected to accommodate a utility or all the utilities with similar orientation passing through a given land area. Its width can be variable and is normally measured in feet.

Corridor analysis—A study of the visual, environmental, physiographic and sociological characteristics of the land, considering the technical requirements of utilities, for the purpose of locating the most appropriate utility corridor.

Corridor analysis area—The linear body of land of variable width (normally measured in miles) studied in a Corridor Analysis.

Right-of-way (abbreviated: ROW; plural: rights-of-way)—An accurately located strip of land with defined width, point of beginning, and point of ending. The area within which the user has authority to conduct the operations approved or granted by the land owner in an authorizing document such as a permit, easement, lease, license, memorandum of understanding, etc.

System examination—An examination and report, by the applicant, defining the present system, the proposed system and its supporting facilities, all anticipated future expansion, and alternatives to the proposal.

ELECTRICAL

ACSR—Aluminum conductor steel reinforced.

Alive; live; energized—Electrically connected to a source of potential difference or electrically charged so as to have a potential different from that of the earth. The term "live" is sometimes used in place of the term "current-carrying," where the intent is clear, to avoid repetitions of the longer term.

AWG—American wire gauge.

Bonding—The electrical interconnection of conductive parts; for example, cable sheaths, armors, or enclosures designed to maintain a common electrical potential.

Brand—A mark on the pole indicating when it was cut, treated, and installed and the company's name.

Cable—A conductor with insulation, a stranded conductor with or without insulation and other coverings (single-conductor cable), or a combination of conductors insulated from one another (multiple-conductor cable).

Cable sheath—A conductive protective covering applied to cables.

Circuit—A conductor or system of conductors through which an electric current is intended to flow.

Circuit breaker—A mechanical switching device, capable of making, carrying, and breaking currents under normal circuit conditions, and also of making, carrying for a specified time, and breaking currents under specified abnormal conditions such as those of short circuits.

Conductor—A material, usually in the form of a wire, cable, or bus bar, suitable for carrying an electric current.

- **Grounding conductor**—A conductor used to connect the equipment or the wiring system with a grounding electrode or electrodes.
- **Lateral line**—a short branch of an electric line constructed at an angle to the main system line.
- **Line conductor**—One of the wires or cables carrying electric current, supported by poles, towers, or other structures, but not including vertical or lateral connecting wires.
- **Vertical construction**—The method of attaching conductors to insulators mounted on and perpendicular to the side of the pole or other support used for electric line construction, where the

conductors have a stacked vertical effect. Eliminates the use of conventional cross-arms.

Deenergized (dead)—Free from any electric connection to a source of potential difference and from electric charge; not having a potential different from that of the earth.

Disconnecting or isolating switch; disconnector; isolator—A mechanical switching device used for changing the connections in a circuit or for isolating a circuit or equipment from a source of power.

Effectively grounded — Permanently connected to earth through a ground connection or connections of sufficiently low impedence and having sufficient current-carrying capacity to prevent the building up of voltages that may result in undue hazard to connected equipment or to persons.

EHV—Extra high voltage.

Electric supply lines—Those conductors used to transmit electric energy and their necessary supporting or containing structures. Single lines of more than 400 volts to ground are always supply lines within the meaning of the rules, and those of less than 400 volts may be considered as supply lines, if so run and operated throughout.

Energized—See **Alive.**

Ground men; grunts—Men working on the ground, digging holes and moving materials.

Grounded—Connected to earth or to some extended conducting body which serves instead of the earth whether the connection is intentional or accidental.

Grounded conductor—A conductor which is intentionally grounded, either solidly or through a current-limiting device.

Grounded system—A system of conductors in which at least one conductor or point (usually the middle wire or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a current-limiting device.

Guarded—Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers or casings, barrier rails or screens, mats or platforms to remove the liability of dangerous contact or approach by persons or objects to a point of danger.

Insulated—Separated from other conducting surfaces by a dielectric substance or air-space permanently offering a high resistance to the passage of current and to disruptive discharge through the substance or space.

Joint use—Simultaneous use by two or more kinds of untilities.

kcmil—1,000 circular mills.

kV—Kilovolt (1,000 volts).

Lightning arrester—A protective device for limiting surge voltage on equipment by discharging or bypassing surge current; it prevents continued flow of follow current to ground and is capable of repeating these functions as specified.

Linemen—Men qualified to climb the poles.

Live; alive; energized—See **Alive.**

Nonspecular—Nonreflective. A nonspecular surface (for example, an airblast-abraded conductor) does not shine.

Open wire—A conductor or pair of conductors separately supported above the surface of the ground.

Puller—Usually a trailer-mounted rig with a donkey engine and a number of drums to pull the conductor.

Pulling tension—The longitudinal force exerted on a cable during installation.

Sag:

Apparent sag at any point—The departure of the wire at the particular point in the span from the straight line between the two points of support of the span, at 60° F, with no wind loading.

Apparent sag of a span—The maximum departure of the wire in a given span from the straight line between the two points of support of the span, at 60°F, with no wind loading.

Final unloaded sag—The sag of a conductor after it has been subjected for an appreciable period to the loading prescribed for the loading district in which it is situated, or equivalent loading, and the loading removed.

Initial unloaded sag—The sag of a conductor prior to the application of any external load.

Maximum total sag—The total sag at the mid-point of the straight line joining the two points of support of the conductor.

Total sag—The distance measured vertically from any point of a conductor to the straight line joining its two points of support, under conditions of ice loading equivalent to the total resultant loading for the district in which it is located.

Sock line—A rope used to pull the conductor. This rope is pulled through the pulleys or sheaves first, followed by the conductor.

Span length—The horizontal distance between two adjacent supporting points of a conductor.

Strings—Refers to insulators, which could be from 2 to 30 insulators. Each single insulator is 6″ in length.

Tension:

Final unloaded conductor tension—The longitudial tension in a conductor after the conductor has been stretched by the application for an appreciable period, and subsequent release, of the loading of ice and wind, and temperature decrease, assumed for the loading district in which the conductor is strung (or equivalent loading).

Initial conductor tension—The longitudinal tension in a conductor prior to the application of any external load.

Tensioner—A device that keeps tension on the conductor as it is pulled into place.

Transformer vault—An isolated enclosure either above or below ground with fire-resistant walls, ceiling, and floor, in which transformers and related equipment are installed and which is not continuously attended during operation.

Vault—An enclosure above or below ground, which personnel may enter, used for the purpose of installing, operating, or maintaining either equipment or cable or both, which need not be of a submersible design.

Voltage—The effective (rms) potential difference between any two conductors or between a conductor and ground. Voltages are expressed in nominal values. The nominal voltage of a system or circuit is the value assigned to a system or circuit of a given voltage class for the purpose of convenient designation. The operating voltage of the system may vary above or below this value.

Voltage of a circuit not effectively grounded—The highest nominal voltage between any two conductors. If one circuit is directly connected to and supplied from another circuit of higher voltage (as in the case of an autotransformer), both are considered as of the higher voltage, unless the circuit of lower voltage is effectively grounded, in which case its voltage is not determined by the circuit of higher voltage. Direct connection implies electric connection as distinguished from connection merely through electromagnetic or electrostatic induction.

Wire gages—The American Wire Gage (AWG), otherwise known as Brown & Sharpe (B&S), is the standard gage for copper, aluminum, and other conductors, excepting steel, for which the Steel Wire Gage (Stl. WG) is used.

TELEPHONE ENGINEERING

Anchor—A buried steel rod affixed to an anchoring device.

Single eye—An anchor having a single eye at the top of the rod for the purpose of attaching one guy.

Double eye—an anchor having a double eye at the top of the rod for the purpose of attaching two guys.

Triple eye—an anchor having a triple eye at the top of the rod for the purpose of attaching three guys.

Arm:

Buck—A power company crossarm parallel to the line of poles. This arm is usually the lowest power company arm on the pole and is used to attach power service drops branching off approximately perpendicular to the line of poles.

Cable—A short wooden arm attached to a pole perpendicular to the lead for the purpose of supporting cable at one or both ends, resulting in adequate climbing space between the cable.

Cable extension—A wooden or metal arm attached to a pole perpendicular to the lead for the purpose of supporting a cable several feet from the pole.

Cross—A wooden arm attached to a pole perpendicular to the lead for the purpose of supporting open wire circuits.

Guard—A wooden arm attached to a pole parallel to the lead and immediately above the top cable for the purpose of supplying an insulated position upon which workmen may stand.

Cable—One or more insulated pairs of wire surrounded by sheath.

Aerial—Cable supported by poles.

Burial—Cable buried in the ground. This cable, in addition to the lead sheath, has a wrapping of jute and sometimes steel armor.

Coaxial—A cable consisting of a few paired or quadded conductors and usually eight coaxial tubes. The tubes consist of a single inner conductor surrounded by a single coaxial copper sheath.

Gage—A number which designates the physical diameter of each wire in a cable.

Rack—A physical support for cable located in manholes and in central office vaults.

Toll—Cable of any type used to connect metropolitan areas.

Trunk—A cable used to connect central offices with a metropolitan area.

Central office—A building containing telephone switching equipment for the purpose of connecting telephone subscribers to the telephone network.

Climbing space—Legally required clear vertical space at a pole, completely free of all conductor plant, to provide a safe climbing space.

Conductor—A wire capable of carrying electric currents.

Conduit—A pipe used for the purpose of containing cable, usually made of clay or plastic and either round or square with 3" to 4" inside dimensions.

Depth of setting—The depth at which the butt of a pole is set in the ground.

Dip—An underground dip of a cable between two poles, usually placed to avoid placing aerial cable over a very busy street or where an aerial span between the two poles is not possible or practical.

District—an area comprising several central office areas in which the engineers of a particular district are responsible for all engineering work.

Drop wire—Paired, rubber-insulated, fabric-covered wire used to connect a residence telephone with a cable terminal.

Easement—A permanent legal grant to a public utility for the purpose of placing and maintaining plant on private property.

Electrolysis—An electrochemical process by which the lead sheaths of underground cables are slowly eroded due to soil, moisture, and earth currents.

Exchange—A metropolitan area or portion thereof served by one or more central offices in which any subscriber may be connected with any other subscriber without a toll charge.

Exposure—A condition in which telephone plant is exposed in the proximity of power plant to power voltages which are dangerous to the public or the telephone plant or both.

Eye-bolt method—A method of attaching a guy or a messenger to a pole by use of a long bolt running through the pole and having an eye on one or both ends.

Grade—The distance above ground at which an item of plant is attached to a pole.

Grade clamp—A clamp rigidly connecting a cable to its messenger; used on steep grades to prevent the cable from slipping downhill.

Guy—Strand used to balance the horizontal forces on a pole.

Anchor—Guy running from an anchor in the ground upwards diagonally to the cable or wire grade on the pole.

Pole to pole—A guy extending from one pole to another.

H-fixture—A combination of two poles set a few feet apart and secured together with horizontal members, in line with the lead for the purpose of supporting aerial load coil cases or perpendicular to the lead for supporting special long-span construction to cross rivers or other obstacles.

Height—The height in feet above ground at which an anchor guy is attached to a pole.

High tension—High-voltage power circuits.

Joint pole—A pole jointly owned by two or more utilities.

Joint-use contract—A contract existing between the telephone company and other utilities in this area covering the joint use of poles.

Lateral—(*a*) A cable extending from a manhole to a pole. (*b*) A pipe extending from a manhole to a pole.

Lead—Tangent of a pole line—horizontal direction from one pole to another.

Line pole—A pole located in the line of a major pole lead.

Lines—A term used to denote the number of working pairs in a cable as differentiated from the number of total pairs. See also *Pair*.

Loading—The introduction of loading coils into a cable pair circuit at uniform intervals for the purpose of improving the transmission.

Long-span construction — Special construction for aerial cable plant used for span lengths longer than normal under conditions where the weight of cable to be supported results in strand tensions greater than those allowable for a single messenger.

Low tension—Low-voltage power circuits.

Manhole—An underground concrete room inserted in a conduit structure at frequent intervals for the purpose of permitting sections of underground cable to be spliced together and for the purpose of splicing side lead cables to main cables.

Messenger—A strand used for supporting aerial cable.

Neutral space—The space between telephone lines and powerlines on the same pole; required to provide proper clearances.

Open wire—Bare wire, copper or steel, supported on poles by the use of crossarms and insulators for establishing a toll or exchange lead of a few numbers of circuits.

Pair—(*a*) Two conductors associated together as a circuit. (*b*) Two insulated wires twisted together to form a pair.

Permit—Written authority granted by a municipality, county, State, or property owner authorizing the construction of telephone equipment on public or private property.

Plant—All telephone installations and in-place equipment.

Pole class—A number which designates the strength of a pole.

Pole height—The length of a pole.

Pull—A number expressing the relationship of the tension in a wire or cable lead to the unbalanced horizontal force produced by a corner in the wire or cable lead at a pole.

Sag—The vertical sag in feet or inches from a straight line passing through the point of support of a cable on two adjacent poles to the lowest point of the cable in the span between the two poles.

Service pole—A pole set exclusively to support drop wire and not line conductors or cable. It may be solely or jointly used.

Sheath—The lead, polyethylene, neoprene, or fabric outer covering of a cable.

Span—The distance between two adjacent poles in an aerial plant lead.

Span, slack—A short cable span that cannot be anchored and accordingly is placed at a reduced messenger tension.

Splice—A means of twisting individual wires of sections of cable together, properly insulating the twisted joints and enclosing all of the twisted joints in a gastight and watertight lead sheath, or splice case.

Strand—Wire rope varying in sizes up to ½″ in diameter. When used to support cable, it is called a messenger and, when used to balance horizontal stresses on poles, it is called a guy.

Stub, pole—A pole set exclusively for guying.

Terminal—An item of plant to bring cable pairs from inside the sheath to an outside position where they are available and maintain watertight integrity of the cable plant.

Tie—A physical dimension in feet, used to define the legal location of an item of plant, such as the distance of a pole from a street corner.

Treated—A term applied to poles which have been treated with creosote, a wood preservative.

Wrap method—A method of attaching a guy or a messenger to a pole by wrapping the guy or messenger around the pole.

MICROWAVE

Down link—The radio path from a space station (satellite) to an associated ground station.

FAA—Federal Aviation Administration.

FCC—Federal Communications Commission.

Flash test—A test to determine the visibility of one site from another by use of mirrors or lights.

Frequency band—A specified range of frequencies, e.g., the 4 GHz common carrier frequency band extends from 3.7 GHz to 4.2 GHz.

Harmonic—A (usually undesirable) side effect of frequency generation. Harmonics appear as multiples (2X, 3X, etc.) of the primary frequency at considerably lower energy levels.

Hz (hertz)—The basic unit of frequency, equivalent to one cycle per second. Commonly encountered terms are kHz—kiloHertz (one thousand hertz or 10^3); MHz—megaHertz (one million hertz or 10^6); GHz—gigaHertz (one billion hertz or 10^9). Use of the terms is quite flexible, e.g., 2,110,000 kHz may also be expressed as 2,110 MHz or 2.11 GHz.

Microwave frequencies—As defined by the FCC, this term refers to frequencies of 890 MHz and above.

Off-axis radiation discrimination—A characteristic of a directional antenna which is a function of its ability to suppress or attenuate radiation outside the main lobe (beam) of radiation.

Polarization discrimination—The ability of an antenna (and associated feed devices) to suppress radiation in an unwanted polarization plane. Most microwave systems employ linear polarization, i.e., the electric or "E" field of the microwave beam is either in the vertical or the horizontal plane.

Primary frequency—The authorized frequency generated by a given radio transmitter. It is a function of transmitter design.

Radio frequency spectrum—As commonly defined, electromagnetic energy with wavelengths ranging from 100 kilometers (3 kHz) to 1 millimeter (300 GHz). By international agreement, the spectrum is divided into bands allocated for various radio services.

Satellite system—A microwave system which employs ground stations and space stations (satellites) in orbit about the earth. Most, if not all, communications satellite systems have their space stations in geostationary orbit above the earth's equator.

Shared-band operation—Operation of two or more microwave systems within the same frequency band in a particular geographic area.

Terrestrial system—A microwave system for communications between stations located at fixed points on the earth's surface.

Up link—The radio path from a ground station to an associated space station (satellite).

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