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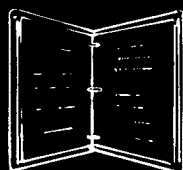
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**ENGINEERING
TECHNICAL
INFORMATION
SYSTEM**

FIELD NOTES • TECHNICAL REPORTS
DATA RETRIEVAL • MANAGEMENT
PROFESSIONAL DEVELOPMENT

VOLUME 11 NUMBER 7

Field



Notes

**TERRESTRIAL PHOTOGRAMMETRY-- TOOL
FOR ENGINEERING MEASUREMENTS**

**MONITORING CUT SLOPE EROSION BY
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CONSTRUCTION OF I-70 VAIL PASS**



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FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
Washington, D.C. 20013

TERRESTRIAL PHOTOGRAMMETRY--
A TOOL FOR ENGINEERING MEASUREMENTS

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ENGINEERS NEED MEASUREMENTS

Engineers and technicians use--and make--measurements. Practically all tasks of concern to an engineer, such as design, construction, maintenance, or management, require a measurement of some sort. The measure of size or shape, the amount of volume, or some base relationship is necessary for technical analysis.

PHOTOGRAMMETRY-A MEASUREMENT TOOL

Measurements made from aerial photographs (aerial photogrammetry) have been made for engineering purposes for many years in the Forest Service. Most Regions and many Forests have the ability and the experience to make measurements with aerial photogrammetry. Measurements of elevation and of X-Y coordinates by photogrammetry have been used to plan roads, measure earthwork, locate boundaries, and describe rights-of-way.

Most of us are creatures of habit. We all have job pressures. The opportunity to experiment with and learn about new techniques and tools is limited. Therefore, the true potential of photogrammetry as an engineering measurement tool has not really been fully explored, developed, or used in the Forest Service. Many measurement problems can be dealt with easily, inexpensively, and accurately through the use of photogrammetry. However, many engineers are not familiar with the potential of aerial photogrammetry, let alone terrestrial photogrammetry.

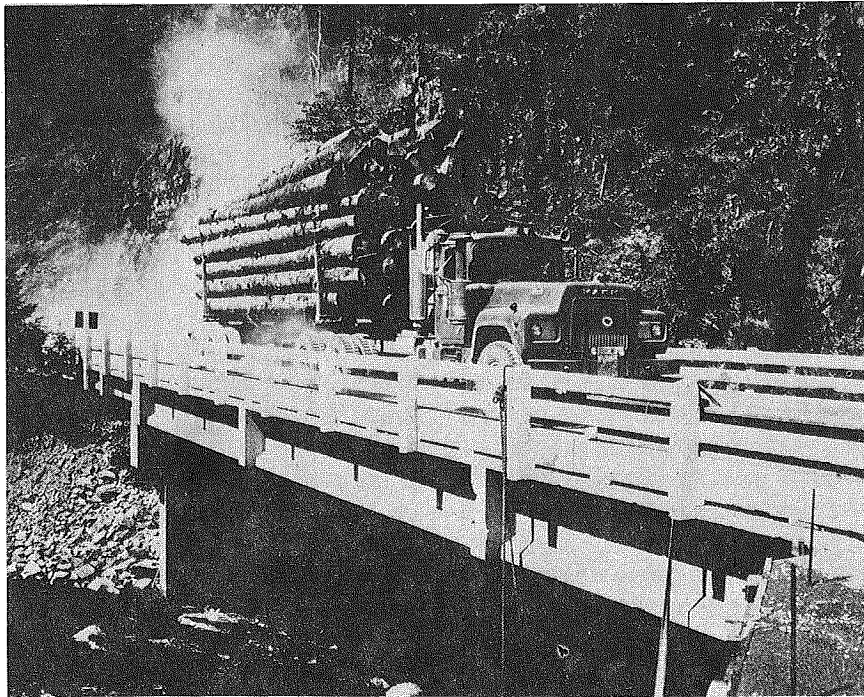
What is terrestrial photogrammetry? The major technical difference between aerial and terrestrial photogrammetry is that in the former the camera is in an airplane while in the latter the camera is on the ground. Different cameras are used, but the technical and theoretical applications of terrestrial photogrammetry are really not very different than those of aerial photogrammetry.

DIFFICULT MEASUREMENT JOBS

Have you ever had trouble in accurately measuring a quarry or borrow pit? Have you ever been asked to monitor the movement of a landslide? Maybe you have been asked to cross section a stream channel for erosion studies. A bridge inspection program might have required accurate measurement of bridge deflection under load (see figure). Maybe a gravel stockpile or even a log deck has been the target of your measurement needs. Or, perhaps, the problem of "cutting to fit" a cover for an awkwardly shaped opening has required that you describe the shape by dimensions.

PHOTOGRAMMETRY CAN HELP

These examples present a list of difficult measurement problems; they can readily be attacked--in many cases--using the tool of terrestrial photogrammetry. This technique offers a precise, low-cost graphic means of making accurate measurements. It will permit measurements in two or three dimensions of practically any surface or shape. In addition, photogrammetry allows noncontact measurements. This can be important if the object to be measured is fragile or hard to reach.



How can the bridge deflection be measured?

EQUIPMENT READILY AVAILABLE

Almost all Regions and several Forests have stereoplotting equipment. Therefore, the means of making measurements by the use of close-range photogrammetry is within the reach of many Forest Service units. In addition to the plotting equipment, all that is basically required is a high-quality camera. The camera should have a film-tensioning system and be of reasonably large format. The Hasselblad 500C meets these requirements. A camera of this type may be obtained for about \$1,500 to \$3,000. The price difference depends on extra lenses, film packs, and other available accessories. One drawback to this approach, however, is that this type of camera is not specifically designed for photogrammetry.

Nevertheless, as noted in the following article, good results can be obtained by using nonphotogrammetric cameras.

There are several cameras and camera systems on the market specifically designed for terrestrial work. Probably the least expensive camera of this type is the Wild P-32, which is in the \$5,000 price class. This camera mounts on a T-2 theodolite, a provision that allows all camera axes to be set to zero. This feature helps to set up the subsequent stereoplotter operations. More sophisticated (and more expensive) systems are available from Kelsh, Wild, Zena, and other manufacturers. For most expected applications in the Forest Service, the lower-priced systems offer good potential for achieving photogrammetric measurements at reasonable cost.

Almost any stereoplotter can be used for terrestrial work. The Forest Service has many Kelshes, Topocarts, B-8s, C-8s, and even Stereomicrometers that are suitable as plotting instruments for many applications.

USE SURPRISINGLY SIMPLE

Field operations for terrestrial work are very simple. Control points need to be established the same as for aerial applications. This can be done by leveling between targets at the top and bottom of the camera scene. Another way is to measure a baseline parallel with the camera base. The ends of the baseline are marked with targets that appear in the photo scene.

A camera baseline parallel with the object to be measured is established. The distance between camera stations on the base (usually 1 - 4 m) is carefully measured and exposures are taken from each camera station. Further operations are performed in the photo lab and in the plotter.

PLOTTER HINTS

In photogrammetry, the focal length of the camera must be known. If a nonphotogrammetric camera is used, the focal length can be determined by photographing an object of known length at a known distance. The image size is measured on the negative. Effective focal length can be computed from the known dimensions.

Cameras with short (65-mm or less) focal lengths normally are used for terrestrial work. The wide angle of the short focal length will provide greater model coverage. Such a wide angle might be necessary for the placement of the photographs in projection plotters such as the Kelsh. In the Kelsh the model base needs to be greater than about 1 foot (0.3 m). For use in most plotters (except analytical or universal plotters such as the C-8), the photos must be enlarged to an equivalent 6- or 8.25-inch (15.2-cm or 20.955-cm) focal length.

If the camera has no fiducial marking systems, the photo center can be established at the intersection of diagonal lines connecting in each corner. This will locate the photo center with enough accuracy for most applications.

Depending on the focal length and focus characteristics of the camera, the photo scale can be as large as 1:10, or perhaps even larger. The "base height" ratio (photo base to object) should generally be between 0.07 and 0.25.

Engineers familiar with aerial photogrammetry should have little difficulty relating to terrestrial applications. The following article, "Monitoring Cut Slope Erosion by Close Range Photogrammetry," relates experience with this technique. A difficult measurement task was successfully accomplished using terrestrial photogrammetry.

MONITORING CUT SLOPE EROSION
BY CLOSE-RANGE PHOTOGRAMMETRY

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INTRODUCTION

A method using close-range photogrammetry has been field tested. It is currently being used to measure the amount of erosion from road cuts and other surfaces. Additional uses, such as measuring quarries, channel erosion, slides, and slide movement, appear to be possible and practical.

HORSE CREEK STUDY AREA

Evaluations of various types of road construction and erosion control techniques are being conducted on the Horse Creek area in the Nezperce National Forest in north-central Idaho. This area has been established as a large-scale watershed laboratory. Research is being conducted there on the soil and hydrologic impacts of different kinds of road construction and timber harvesting practices.

The watershed has been monitored for many years. Base values for water quality and natural sediment production have been established. A number of subdrainages, in which a variety of road construction techniques are currently being applied, have been monitored. This will enable studies of the erosion and sedimentation caused by road construction and timber harvest practices.

EROSION MEASUREMENTS

To meet the objectives of this study, measurements of actual erosion are needed to study erosion rates, mechanisms, and the transportability of eroded materials. A variety of techniques to make these measurements were considered. In the past, measurements of slope erosion have been made by establishing permanent reference pins in the slope. Wires were stretched from these pins and direct measurements were made to the slope from the reference wire. This procedure has obvious drawbacks in terms of reliability and accuracy. Also, the slope is disturbed during the measurement process.

Another method has been to trap sediments from the slope, which also has drawbacks in terms of accuracy and reliability.

One logical solution to this measurement problem is the use of close-range photogrammetry. To develop field procedures for performing these measurements by stereo-photogrammetry, a special terrestrial camera that mounts on a theodolite was obtained. It was determined that measurement accuracies of about 10 mm would be satisfactory. Through several trials, the final field procedures for the stereo-photography process were established. A variety of photo bases (distances between camera stations) was tried. The most satisfactory photo base was 2 m; with this base the measurement accuracies were met with ease.

CAMERA SYSTEM

As many as 50 sites must be measured. The camera system that was used in establishing the field procedure was cumbersome. It required two setups per site, and the use of special glass plates rather than film. A more efficient method for acquiring field photography was necessary. To solve this problem, two electrically driven, high-quality cameras were mounted on a 2-m bar and attached to a tripod (figure 1). These cameras do not possess calibrated lenses and have no fiducial marking systems, as do special terrestrial cameras. They do, however, have a film tensioning system that assures flat film during exposure.



Figure 1.--Electrically driven cameras on 2-m mounting bar.

To test the relative accuracy of these cameras against the special camera, a flat surface was photographed. The surface was measured photogrammetrically in the first-order stereoplotting instrument. A series of measurements were taken in a stereo model that was only relatively oriented. By using a regular aerial triangulation adjustment program, a mathematically flat plane was passed through the series of measurements. The deviation of the model from flatness was determined. By this test, it was found that the model was indeed "flat," at least within 3 - 5 mm. This met the measurement precision criteria previously established.

FIELD CONTROL

In a typical case, the object distance (camera to cutslope) is 5 - 8 m. By photographing the sloping cut surface, the net model area appears as a wedge-shaped figure. Dimensions range from 5 - 7 m on the bottom, 8 - 17 m on the top, and 1 - 9 m high (figure 2).

In photogrammetry, the stereo models must be controlled. At least one distance and three elevations must be known for points in the model.

To provide field control for the stereo models, the following scheme was employed. A baseline, which runs through the camera station, was laid out. A perpendicular was erected from this baseline through the center of the model. Two control lines parallel to the baseline were established in the model: at the top, out of the cut zone; and in the bottom, along the ditch line. Distances between targets on these control lines were measured. The distance from the camera stations to points at the top, center, and bottom of the model were also measured (figure 3). These targets enabled the scaling, leveling, and twist of the model to be adequately controlled. The points so established were permanently monumented targets.

STEREO MEASUREMENT

Erosion measurement utilizes a series of stereo models taken at yearly intervals. The first year provides the base or "no erosion" situation. It was expected that the change in the surface could be measured by "contouring"--or, more properly, profiling--a series of equally spaced lines along the cut slope. Thus, the profiles from year to year would be compared. The area between the two profiles could be measured, and the average end-area method could be applied in computing the net volume change of the surface. To test the feasibility of this system, an attempt was made to profile, then to exactly reprofile, an unchanged surface. In attempting to do this, the difficulty of "precision" profiling became apparent. It is very difficult for the plotter operator to follow a previous path exactly with his measuring mark due to the extreme convergence angle of the measuring mark. This convergence is caused by the short object distance.

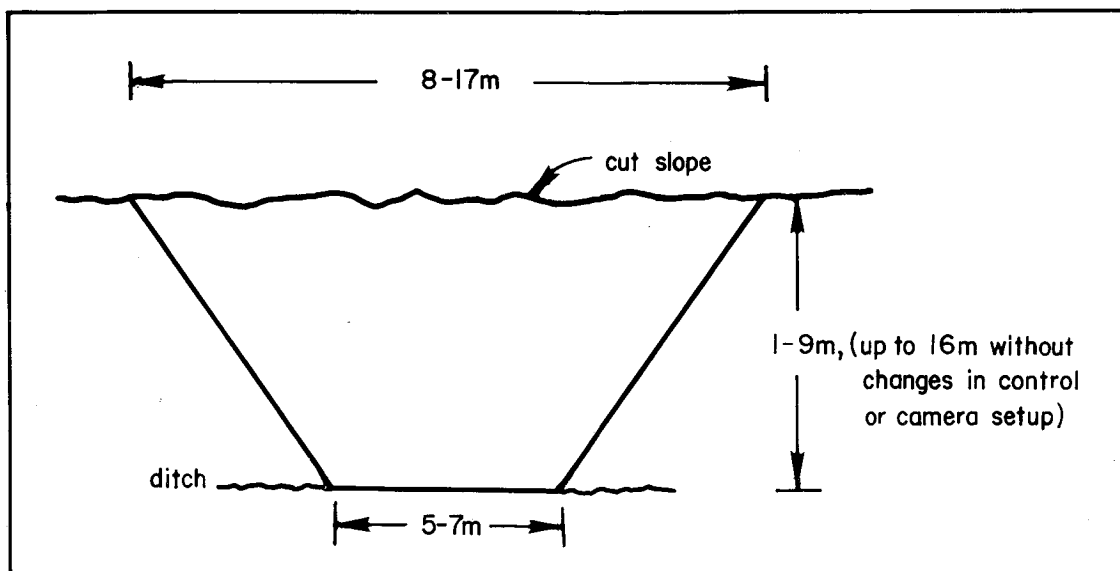


Figure 2.--Typical stereo model.

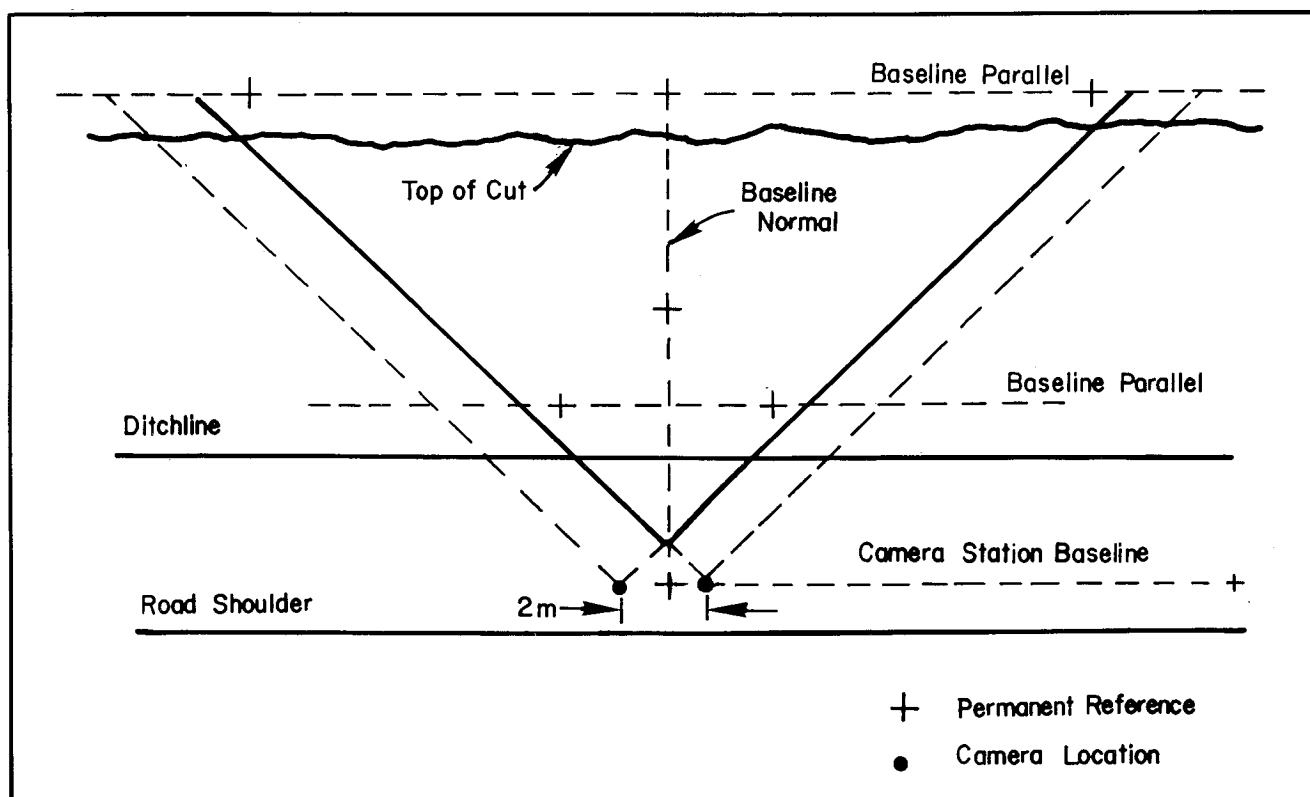


Figure 3.--Plan view of control.

Due to these problems, the method of measuring erosion by profiles was abandoned. Instead, the digital approach was selected. In this process, a computer program sums a large number of volume elements. The total volume of the figure bounded by the camera plane, the cut slope, and the model limits are computed. The length of each volume element is measured photogrammetrically. The size of each element corresponds to a uniform grid placed in the model. In following years, the same area is digitized on the same grid. A subtractive program computes the amount of change, comparing volume of the first year against volume of the figure at succeeding years. This program measures positive and negative volume change.

The digital technique is proving very satisfactory. It allows rapid processing of data. Work on this project is proceeding, with actual digitizing being performed on analytical stereoplotters at the Forest Service Geometronics Service Center in Salt Lake City, Utah.

SUMMARY

For this measurement problem, close-range photogrammetry clearly offers significant advantages. It is reliable, accurate, and precise. It is repeatable, and most important, provides a noncontact means of making measurements. In addition, a comparatively large sample area can be measured in a narrow timespan. This allows studies of slopes that have experienced the same weather conditions.

After the initial investment is made in acquiring field control, future measurements can be made at relatively low cost. The use of a high-quality camera permits stereo measurements to be made within specified accuracy limits. The digital approach offers the most practical way of measuring volume change.

Additional information regarding costs, necessary field control, adaptation to specific needs, and other possible uses can be obtained from the authors.

AIR VENT SIZING FOR REGULATED DAM OUTLET WORKS--
A PROGRAM FOR THE HEWLETT-PACKARD 67 HAND CALCULATOR

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The determination of air requirements and the sizing of vent pipes to prevent cavitation in regulated dam outlets has been complicated by conflicting test data. Recent work by Dr. Henry Falvey of the Bureau of Reclamation has clarified much of the confusion and forms the basis for some of the relationships in this program. The work done by Dr. Falvey should be published in the near future.

This program is actually two three-card programs--one for the condition where the controls are at the inlet end and one where the controls are within the length of the outlet conduit. The programs are so similar that a single description is adequate for both.

The first card calculates the flow upstream of and through the valve, assuming no reduction due to downstream conditions. It calculates the maximum possible gravity flow downstream from the valve, assuming the conduit just flows full, but not under pressure. If the upstream flow is greater than that calculated for the downstream portion, the program displays a series of 2s to indicate that the second card (for pressure flow in the entire system) is to be inserted next. If the flow calculated for the downstream portion is greater, the program displays a series of 3s to indicate that the third card (for pressure flow upstream, if applicable, and gravity flow downstream) is to be inserted next.

If the lower portion of the conduit flows under pressure, the Froude number is determined for the flow under the gate, and air requirements are determined from the equation developed from the Kalinske and Robertson tests:

$$\beta = 0.0066 (F - 1)^{1.4}$$

where β is the ratio of the quantity of air to the quantity of water, and F is the Froude number. The program then calculates the diameter of the air vent pipe required to keep the air velocity at 100 feet per second (1829 meters per minute). This limitation is

imposed to keep noise levels to a point where exposure time is not limited or protective gear required.

If the lower portion of the conduit flows by gravity, the assumption is made that the air velocity at the discharge end is the same as the water velocity (due to the drag), and the β ratio is taken as the ratio of the cross-sectional areas of air to water at the discharge end. While this assumption might not be true in a strict sense, it represents the maximum expected value. Obviously, for very shallow depths of water, this assumed condition is not likely; but, it is not likely that the system would often operate in this range. To prevent unsteady flow, the maximum water depth should not exceed three quarters of the diameter of the pipe.

Certain assumptions are made to simplify the program (most can be changed if conditions warrant): entrance and trash rack losses are combined and are represented as 1.8 times the velocity head for full pipe flow; the specific roughness coefficient* is the same for the full length of the outlet conduit and for the vent pipe; air weighs 0.06 pound per cubic foot (0.9614 kilograms per cubic centimeter) and can be changed for lower altitudes; temperature and vapor pressure effects are neglected, because the limit imposed on the air velocity makes the pressure loss in the vent pipe extremely small in most cases; and the conduit flows at normal depth if it flows partially full.

The determination of the Froude number, $F = \frac{V}{(yg)^{1/2}}$, is based on commonly accepted valve loss coefficients and the assumption that the losses are expansion losses. From this, the ratio of the contracted velocity to the pipe velocity is found. These same valve

**The specific roughness coefficient is a term used in the Harris method for determining the friction factor for turbulent flow in a pipe of any diameter. The method is similar to Moody's but has the advantage of a physical representation that the designer can grasp. Due to the effect of particle distribution and varying size, the particle diameter selected in the Moody system probably does not exist. The Harris method says that in turbulent flow,*

$$f = \frac{f_1 - 0.0061}{D^{1/3}}$$

where f_1 is the specific roughness coefficient or the friction factor of a 1-foot (0.3048-m) diameter pipe, and D is the pipe diameter expressed in feet.

loss coefficients are used to determine an equation from which the program calculates the loss for any valve opening. This portion of the program would have to be modified for application to butterfly or plug valves, but would be suitable for square gates if the percent opening were accurate.

In the event the discharge conduit is not circular, the assumption of a pipe of equal hydraulic radius should result in a solution within the accuracy of the state of the art.

The listing and documentation for the programs can be obtained from the author at the R-2 Regional Office, 11177 West 8th Avenue, Box 25127, Lakewood, Colorado 80225.

U.S. FOREST SERVICE INVOLVEMENT IN THE CONSTRUCTION
OF I-70 VAIL PASS, COLORADO

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INTRODUCTION

This material, developed from a paper given by the author at the 58th Annual Meeting of the Transportation Research Board,* serves as an introduction to the liaison functions very often required of the Forest Service. While this discussion is about an Interstate Highway Project, most of the points made apply to other types of projects.

The Vail Pass segment of Interstate Highway 70 was constructed across the Gore Range on the White River National Forest in Colorado; at an elevation of 10,600 feet (3,230.88 m), it is within the sub-alpine ecosystem. The goal of the project was to construct the highway in a manner that would be as unobtrusive as possible. As the land management agency, the Forest Service had responsibility to ensure that the construction would neither disrupt nor destroy the land's resources.

The Forest Service carried out this responsibility by issuing environmental constraint stipulations for the construction, by reviewing the construction plans and specifications in relation to these stipulations, and by periodically reviewing the construction work. A Forest Service Liaison Officer (GS-12 Civil Engineer) was assigned to the project, and with the help of specialists, expressed Forest Service concerns. This team assisted the Colorado Department of Highways in minimizing or eliminating the adverse environmental impacts caused by the construction of a highway built to Interstate System standards.

For many of the sensitive environmental problems generated by the highway construction, unique and innovative solutions were found and applied through the cooperative efforts of many different professionals and agencies. The result is an interstate highway that is compatible with the surrounding mountain environment.

*Washington, D.C., January 18, 1979.

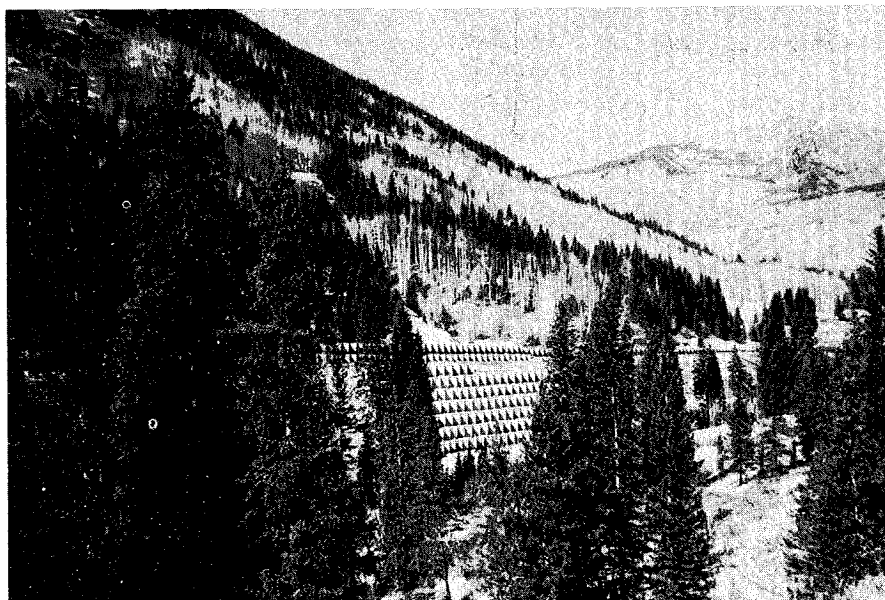


Figure 1.--Reinforced earth retaining walls near proposed game crossing bridge illustrate the use of new structural applications.

FOREST SERVICE RESPONSIBILITY

The Forest Service is responsible for management of the National Forests; this includes authorizing occupancy of land and construction activities. A right-of-way or easement is granted after the work is completed according to the plans and specifications.

During the course of legally transferring National Forest lands to the Colorado Department of Highways for construction of the highway, there were three sets of stipulations or construction requirements agreed upon and implemented. The first set--rather broad in scope--was written into the Easement Deed between the Department of Agriculture and the Department of Transportation. The second set of more specific requirements was written into the Memorandum of Understanding between the Colorado Department of Highways and the Forest Service. The third set consisted of construction clauses included with the Interim Letter of Consent (for construction), which was issued by the Forest Service to the Colorado Department of Highways as a stipulation. These requirements were still more specific, but their exact meaning needed interpretation. The Interim Letter of Consent is no longer used. It has been replaced by a Letter of Consent which accomplishes the same end.

EASEMENT DEED

The authorization for the transfer of lands to a State for construction of an interstate highway was established by an Act of Congress

dated August 27, 1958. Briefly, this states that if the Department of Transportation deems it necessary for an interstate highway to cross Federal lands, the Secretary of the Department of Transportation must request an easement from the agency responsible for managing the lands. The Department of Transportation grants the right-of-way to the State after the easement is issued.

The granting of the easement to the Department of Transportation carries with it certain considerations, obligations, and responsibilities. The Easement Deed contains 11 stipulations agreed upon by the two agencies. These stipulations must be executed by the State highway agency involved before the Easement Deed is consummated. Implementation of the stipulations becomes the responsibility not only of the State highway agency involved but also of both the Department of Transportation, working through the Federal Highway Administration, and the Department of Agriculture, working through the Forest Service.

Examples of the stipulations are:

1. The State and the Forest Service will determine the need for archeological surveys.
2. The easement will be used only for interstate highway construction in accordance with the approved plans.
3. The highway will be built to interstate standards.
4. The plans and specifications will be reviewed by the Forest Service and, if necessary, changes will be made to protect National Forest interests.
5. The final plans and specifications must be approved by the Forest Service before construction.
6. Erosion must be prevented during construction, and construction scars must be revegetated when the work is completed.

MEMORANDUM OF UNDERSTANDING

Under the law a further delegation of responsibility is given to the Regional Foresters of the Forest Service. A Memorandum of Understanding must be executed between the Forest Service and the State highway agency responsible for construction of the highway. This was done in June 1970.

This Memorandum established procedures and responsibilities from the inception of Federal-aid highway construction or reconstruction through the location and planning stages, the environmental impact statements, on-the-ground surveys and joint reviews, preconstruction

meetings, and construction activities. The Memorandum of Understanding includes the procedures for coordinating the transfer of National Forest lands to the State for the construction of an interstate highway. The memorandum elaborates on the stipulations already established by the Department of Transportation/Department of Agriculture Easement Deed. The Memorandum recognizes the need for cooperation to solve the problems of building a highway to the demanding standards of the Interstate System through the mountainous terrain of Colorado. Some features recognized by this memorandum are:

1. The need for joint cooperation in locating the highway to satisfy the objectives of both agencies.
2. Forest Service review of the Division of Highways preliminary plans and specifications.
3. A joint office review to resolve any differences or to make changes in the plans and specifications.
4. The recognition of Forest Service land management concerns:
 - a. Locations of detours and construction standards for haul roads.
 - b. Air and water pollution and erosion control.
 - c. Aesthetic features in harmony with the surrounding terrain.
 - d. Restoration of the disturbed areas.

In 1957 when the Interstate Highway System was expanded, it was decided to extend Interstate 70 westward across the Colorado Rockies, generally following the route of U.S. Highway 6. Two alternative corridors were tentatively selected for the Vail Pass segment where it crossed the Gore Range in Colorado. These corridors were the Red Buffalo route and the Vail Pass route. Because the Red Buffalo route crossed through the southern tip of the Gore Range-Eagles Nest Primitive Area (now the Eagles Nest Wilderness), the Secretary of Agriculture determined in May 1968 that this route was not in the public interest; thus, the Vail Pass corridor was selected. Construction of this 17.3-mile (27.84-km) segment of Interstate 70 began in September 1973.

The magnitude of the problem of fitting an interstate highway into the selected corridor became evident during the location phase of the project. The mountainous terrain in the corridor was steep and unstable. The route paralleled streams from which communities took their water supplies, and the corridor passed through the fragile subalpine ecosystem of Vail Pass. The growing season was short and the weather unpredictable; construction operations would be limited

to summer. Due to these restrictions, it was necessary to establish criteria to implement the conditions of the Memorandum of Understanding.

Opinions varied on interpretation of the Memorandum and how to accomplish its goal. Many agencies, including the Colorado Division of Wildlife, Federal Highway Administration, Geological Survey, Colorado Department of Public Health, and Environmental Protection Agency, were involved in reaching final procedural decisions. Innovative ideas were expressed and welcomed, and the final decisions were agreed to and incorporated into the construction.

FOREST SERVICE STIPULATIONS

Before construction of any segment of the highway over Vail Pass commenced, the Forest Service gave the State an Interim Letter of Consent agreeing to the use of the land for the construction. The Interim Letter of Consent included a standard stipulation, which was a requirement of Department of Agriculture regulations and was implied in the stipulations of the Easement Deed between the Department of Transportation and the Department of Agriculture. Special clauses or requirements can also be included in the stipulation for specific items unique to the project, but these must be approved first by the Chief of the Forest Service.

The stipulation included in the Interim Letter of Consent was broad in scope, but covered most of the environmental concerns. Briefly, some standard requirements and conditions to be met in the stipulation were to:

1. Prepare, before any construction begins, a fire protection plan, a clearing plan that includes disposal of merchantable timber, a landscape and erosion control plan, and a construction plan that specifies restrictions and delineates methods of construction to avoid environmental damage.

2. Comply with recommendations of the Colorado Division of Wildlife and Forest Service for wildlife and fish management to:

- a. Avoid damage to fish habitat.
- b. Protect live streams from soil deposits.
- c. Install temporary bridges for hauling material across live streams.
- d. Prohibit mechanized equipment operation in live streams.
- e. Not allow oil or greasy substances to be washed into a live stream.

- f. Permit no construction activity within 25 feet (7.6 m) of the edge of a major stream.
 - g. Set up a cooperative agreement with the Geological Survey to monitor the water quality in the streams.
3. Provide standard highway signs to identify Forest Service boundaries and features.
4. Permanently monument the right-of-way.
5. Establish or restore public land monuments disturbed or destroyed during construction.

COOPERATION OF AGENCIES

One unique aspect of the Vail Pass Project was the opportunity for many Government agencies to provide input into the project plans. When discussions began, ideas were argued zealously. Later, as rapport and trust developed, the pros and cons of each idea were considered objectively and decisions were made that were generally agreeable to everyone. Many sound, innovative ideas evolved from this approach.

LANDSCAPE AND EROSION CONTROL MANUAL

International Engineering Company, a private consulting firm, prepared the Landscape and Erosion Control Manual for the State. Input for the manual came from several sources, including the Forest Service. The manual addressed specific environmental problems associated with Vail Pass. It provided concepts to be followed for landscaping and erosion control. It emphasized the molding of landforms, such as slope rounding, staggered benches, undulated slopes and accentuated draws or ridges. It addressed leaving rock in place to blend with the natural surroundings, and specified methods for erosion control and treatment of sediment-laden water.

Although the information contained in the manual was conceptual, it stimulated innovative thinking to develop procedures to mitigate particular problems. The Landscape and Erosion Control Manual became an integral guideline for the environmental work. The State used the manual's concepts to develop contract specifications.

The manual was a useful tool; a similar approach is recommended for any project where environmental problems are critical.

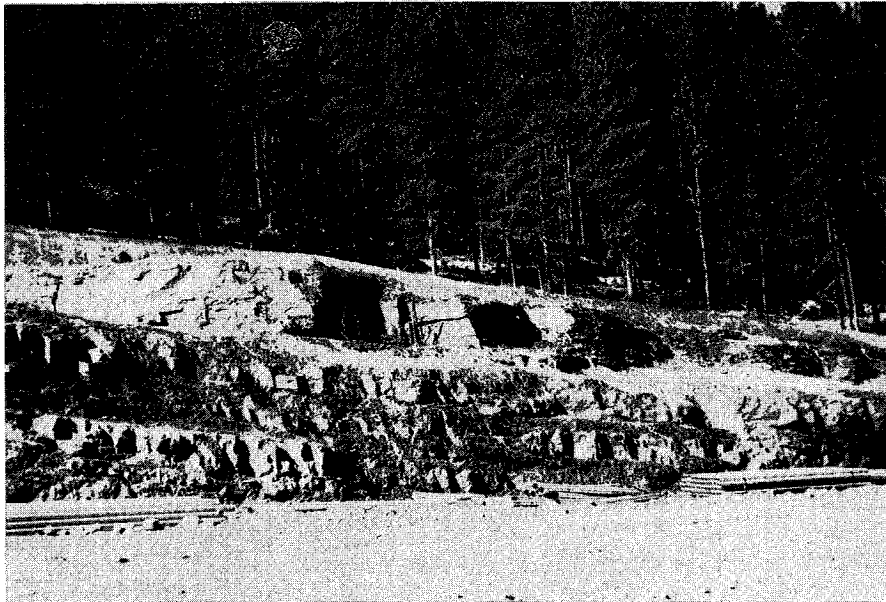


Figure 2.--Section of irregular rock cut sculpturing just above Timber Creek. Trees visible below top ledge had just been watered as specified in Landscape and Erosion Control Manual.

SPECIFICATIONS

The Colorado Department of Highways wrote special specification provisions, with assistance from the Forest Service, to cover the stipulation in the Interim Letter of Consent. The sources of information for the specifications included the Landscape and Erosion Control Manual, specialists' proposals tempered by engineering concerns, and engineers who are cognizant of the problems involved and who know how to cope with them.

Planning, Memoranda of Understanding, and stipulations would have been fruitless without the specifications to give to the contractor. The specifications had to be written carefully to avoid confusion and to indicate precisely what was required. A great deal of time was spent in making the specifications as clear as possible. As the project progressed, alterations were made to the specifications due to unforeseen misinterpretations. Furthermore, specifications were modified to fit the different locales.

DESK REVIEW OF PLANS

A desk review of plans was an essential part of the development of the Memorandum of Understanding. It was important for the Forest Service to provide an experienced engineer who could interpret the plans and specifications, and understand what was proposed. Cross-sections were not included with the preliminary plans, so it was

necessary to interpret the extent and locations of cuts and fills from the plan and profile sheets. The sheet plans included topography and the boundaries of existing vegetation. By extrapolating from profile elevations, it was possible to determine the size of cuts and fills. With this knowledge, erosion treatments could be made for a particular area, and landscaping could be planned conceptually before seeing the area. For specific questions regarding cuts or fills, cross-sections were available at the desk review. In one instance, the cross-sections showed that long sliver fills were planned. The length of the sliver fills was shortened considerably by placing low timber-crib retaining walls where the natural ground line approached the face of the fill. A desk review of the plans with all interested parties is highly recommended; the reviewers must have a background in engineering to respond intelligently to the plans.

FIELD REVIEW

A field review must be made with the plans in hand. Not every inch of the project must be covered, but critical areas should be seen on the ground to visualize the appearance of the final product.

This phase required that a Forest Service engineer be a member of the team. At the time of the field review, hydrologists and landscape architects were asked to contribute their ideas. On Vail Pass field reviews a geologist often had to identify potential problems due to the unstable conditions brought about by a north-south fault paralleling the highway location.

During the construction phase of the project, periodic field reviews were continued due to changing field conditions. Latent problems developed that could not be foreseen during the initial design. Sometimes there was excess material for disposal; at other times additional borrow had to be obtained. Topsoil for revegetation was scarce, and topsoil had to be identified and saved. Decisions for these problems had to be made on-the-ground immediately so the contractor's progress was not impeded. Most decisions were made following a multidisciplinary review tempered by engineering constraints. Therefore, a background in engineering aided the decision-making process.

PRECONSTRUCTION CONFERENCE

The Memorandum of Understanding stipulated that the Forest Service participate in the preconstruction conference held with the contractor. Much of the conference pertained directly to the construction itself; however, it afforded an opportunity to discuss Forest Service concerns as expressed in the specifications written by the State.

The specifications were unfamiliar to the contractors. Usually, it was necessary to emphasize and explain their purpose and what final result was expected.

There were questions concerning fire control, such as: "Who should be contacted in case of fire, when and how to burn during the clearing operation, and what fire equipment should be on hand at all times within the construction area?"

It was necessary to point out to the contractor the role of each agency during construction. The contractor was to deal with the State Project Engineer who, in turn, responded to Forest Service concerns and requests. During construction the contractor occasionally responded directly to the Forest Service Liaison Officer; these responses were limited to emergency situations when the Project Engineer was unavailable, and only to problems involving aesthetics, pollution control, water quality, or erosion control. Every request was later coordinated with the Project Engineer. These situations are usually unavoidable, but precautions should be taken to limit their occurrence.

During the preconstruction conference, the contractor was responsible for furnishing an erosion control and water quality plan for his project. The plan was discussed and changed to fit the actual needs more closely. The contractor designated one person to assume the responsibility for implementation of the plan. The specifications stated that in case of an emergency regarding water quality, the contractor would furnish equipment and men immediately to correct the problem.

The preconstruction conference also provided an opportunity to emphasize the resource protection requirements and the methods to be employed. In addition, the representatives of the various agencies afforded it a chance to become acquainted with the contractor.

USE OF SPECIALISTS

Forest Service specialists were consulted during the planning and construction phases of the project. Primarily, these specialists were hydrologists, landscape architects, and geologists, but the advice of foresters and range conservationists was also sought. Although specialists were consulted and their opinions evaluated, the Forest Service Liaison Officer made all modifications recommended to the State Project Engineer.

Landscape architects must have input into the initial design of the project. The Colorado Department of Highways recognizes this and now makes the landscape concept a part of their plans, with the understanding that these plans will be flexible as the project evolves.

While the use of specialists is recommended, sound engineering judgment must be used to determine the feasibility of their proposals.

LIAISON OFFICER

The Forest Service assigned a civil engineer as Liaison Officer to the Interstate 70 Project. He was responsible for reviewing all plans and specifications, attending the desk review of the plans, attending the preconstruction conferences, receiving and reviewing the opinions of the Forest Service specialists and passing the applicable ideas on to the State, and keeping the land managers (District Rangers and Forest Supervisor) informed of what was happening. He also passed the land managers' concerns on to the State. In turn, he received correspondence that pertained to the Forest Service from the State. In this way, the State had to deal with only one Forest Service representative.

The Liaison Officer acted as an inspector for procedures taken to mitigate the environmental impacts. He had to be aware of Forest Service concerns and apply his knowledge of engineering and resource management to the project. He spent 3 or 4 days a week at the construction sites. As many as a dozen subprojects were under construction at one time, leaving little time to seek the help of specialists for each problem. Most problems required an immediate response and little time was available for consultation with land managers; the Liaison Officer had to respond to the State using the broad objectives set forth by the land managers.

With more than two or three subprojects in progress simultaneously, the Liaison Officer was often hard-pressed to accomplish his assignment alone. Therefore, assistants sometimes helped monitor the construction. Fully trained assistants should be used as monitors, although on this project some untrained people were assigned.

Because road construction is primarily an engineering function, the Liaison Officer must have an engineering background to interpret the plans and specifications properly and to respond intelligently to other agency representatives. Only a trained engineer could identify those mitigating measures that were feasible. He also needed a background in the principles of hydrology and geology or geological engineering.

The use of a Liaison Officer must be an integral part of any project like Vail Pass. This individual should be an engineer, preferably a civil or geological engineer, and should have assistants who are preferably trained in engineering, hydrology, and landscaping.

SUMMARY

A key element to a successful project is early planning and preparation before the project is designed. This will lead to fewer misunderstandings.

Another important element is the cooperation and coordination between the interested parties. All efforts should be directed toward accomplishing a final product. Everyone has something to contribute; everyone should contribute. This cannot be accomplished if one agency feels it has the final control and is jealous of ideas supported by another agency. A project like this is too large and complicated for one agency or one person to have all the answers.

The goal of the Vail Pass Project was to construct an interstate highway across a major mountain range that would be compatible with the mountain environment. This goal was accomplished through the cooperation and coordination of many individuals and government entities. The highway speaks for itself. Not all of the operation was smooth. There were arguments and frustrations from which innovative ideas and a rapport emerged that can be used for future projects. Certainly not all the things tried on Vail Pass were successful, but overall there would be little I would recommend changing.

The Forest Service has officially commended the Colorado State Highway Department for their cooperative efforts to mitigate environmental concerns in a very sensitive corridor of public lands.

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