

Environmental Constraints on the Vail Pass Project

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Environmental constraints to a large degree controlled both design and construction of the 22.5-km (14-mile) long segment of I-70 through Vail Pass in Colorado. An interdisciplinary team composed of engineers, ecologists, aquatic and wildlife biologists, and architectural and landscape consultants evaluated every aspect of the highway with regard to its environmental impact from the determination of the alignment to the color of the concrete structures. A variation of the Design Alternative Rating Evaluation system was used to quantify eight environmental factors, and these factors were then used to rank alternative alignments. After the alignment was selected, measures were taken to mitigate adverse environmental consequences associated with highway construction. In some instances, the amount of terrain disrupted was reduced by substituting a structure for a cut or a fill. In other cases, terrain was restored by landscaping methods. Environmental constraints imposed on the project design made it necessary to adopt innovative design concepts. The principal environmental constraints and the solutions that resulted from the use of innovative design concepts are examined.

The subjects to be discussed in this paper are the environmental and geologic constraints that to a large degree controlled both the design and the construction of the Vail Pass project. The two constraints are closely interrelated since a number of the anticipated environmental consequences stemmed from the geologic conditions, which are discussed in detail in another paper in this Record.

Prior to the studies reviewed in this paper, the so-called Red Buffalo route for the I-70 extension (see Figure 1) had been deemed unacceptable. The only feasible alternative locations were those that lay within the corridor of existing US-6, which crossed the Continental Divide at Vail Pass. These alternatives were some 14.5 km (9 miles) south of the proposed Red Buffalo route and were approximately 16 km (10 miles) longer between common points. By the time this decision was reached, the National Environmental Policy Act of 1969 was in effect and had been ruled applicable to the Vail Pass location for I-70. Consequently, the design was postponed and an environmental study was initiated.

It was obvious that the study would play no part in the selection of a route since only the Vail Pass corridor remained to be considered. Thus, the study became simply one of determining (a) the environmental consequences of constructing a four-lane highway through a narrow corridor along the general location of existing US-6 between East Vail on the west side and Wheeler Junction on the east and (b) measures that could be taken to mitigate these consequences.

The Colorado Division of Highways elected to contract for a study that would not only determine the environmental consequences of a highway but also identify and evaluate specific alternative locations within the corridor. This evaluation was to include the factors of cost and operation as well as environment. In addition, a major objective of the study was to develop preliminary design concepts to minimize any adverse effects ordinarily associated with heavy construction through mountain terrain.

ENVIRONMENTAL BACKGROUND

The area studied was approximately 22.5 km (14 miles) long—about 14.5 km (9 miles) on the west side of the summit and 8 km (5 miles) on the east side. On the

eastern slope, the location lies within the drainage of West Tenmile Creek. This stream meanders down a relatively flat drainage course bordered by extensive growths of willow trees and alpine meadows in the narrow bottom of the valley, which gives way quickly to steep, timber-covered mountain slopes (see Figure 2). West of the summit, the highway follows the course of Black Gore Creek, which twists and plunges down a steep drainage course at the bottom of a valley bordered on both sides by steep mountain slopes that are broken in places by precipitous cliffs. For the most part, the mountainsides are covered with light to moderate growths of timber.

The overriding problem on the west side of the summit, from a highway engineer's viewpoint, was the character of the geology. It was evident that any major roadway cuts could trigger earth slides and result in huge scars that would remain evident for generations (see Figure 3). Geology was thus a major factor in the environmental considerations.

ENVIRONMENTAL STUDIES

In environmental studies for the Colorado Division of Highways, approximately 40 factors were normally considered. Since no alternative corridor was under consideration in this case, it was apparent that a highway located anywhere within the corridor would serve equally well with respect to socioeconomic considerations. For this reason, all socioeconomic factors, except recreation, were eliminated. The proposed highway would serve an outstanding recreation area. At either end of the section are two major ski areas: Vail Village and Copper Mountain. The two drainage areas traversed by the highway serve the recreational activities of ski touring, snowmobiling, fishing, hiking, camping, and sightseeing. Except for a small community known as the Big Horn Subdivision at the western end, there were no problems associated with residential areas. For the most part, the problem became one of identifying and evaluating the adverse physical and ecological effects that might result from construction of a highway.

In 1970, the Colorado Division of Highways retained consultants to make a two-phase environmental study. The firm selected, now the Midwest District Office of International Engineering Company, organized a study team that consisted of staff engineers and geologists and several special consultants. This team collaborated with Charles S. Robinson, the consulting engineering geologist retained by the Colorado Division of Highways.

The first phase of the study was a general, overall environmental study to identify and evaluate the environmental factors that should be considered. This phase resulted in a report (1) that was used by the Colorado Division of Highways as the basis for their draft and final environmental impact statements. The second phase (2) evaluated various alignments within the limited corridor width and developed preliminary design concepts to serve as a guide during final design, emphasizing the development of concepts that would ameliorate damage to the terrain.

A perplexing problem arose when an attempt was made to quantify the various environmental factors involved in

Figure 1. Vail Pass I-70 location map showing rejected Red Buffalo route.

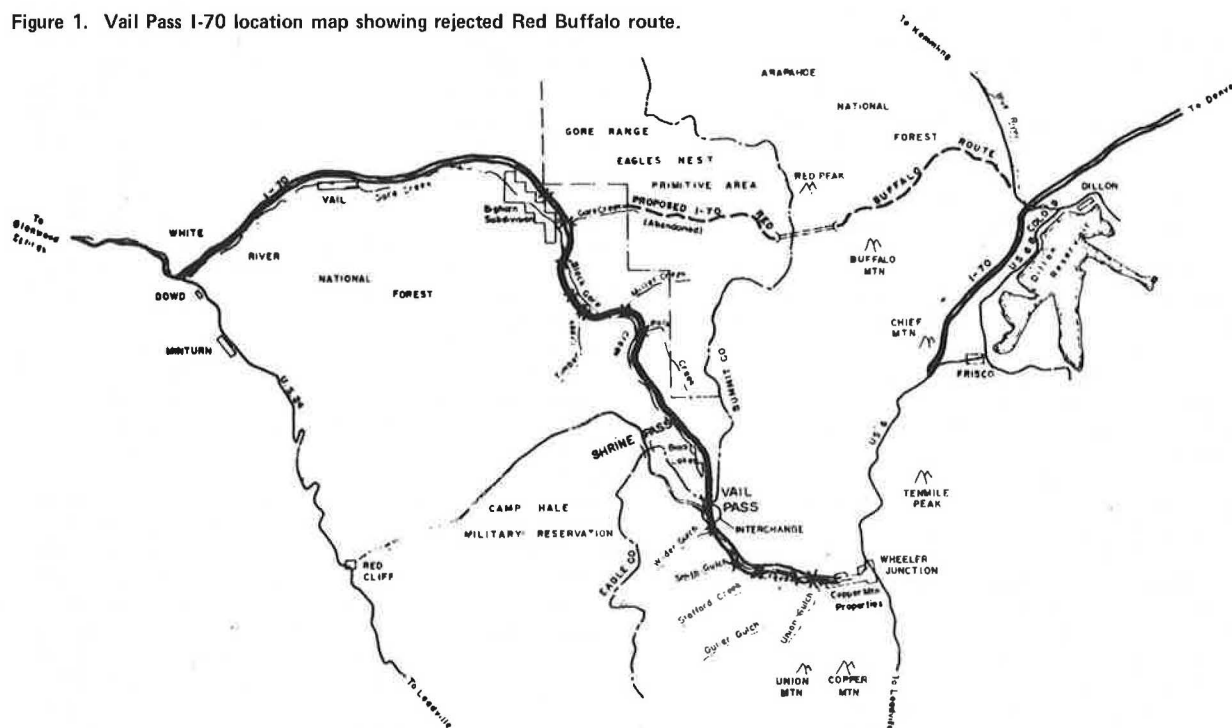


Figure 2. Typical timbered mountain slope.



Figure 3. Old construction scar along existing highway.



reaching a decision on which of several alternative alignments was preferable. The problem is an intriguing one: how to quantitatively compare a number of unrelated factors that are present in varying degrees in several alternatives. For example, how can it be determined whether the encroachment of a roadway fill into a fishing stream is preferable to the creation of a long-lasting, unsightly back-slope scar in the fragile alpine tundra of a mountainside?

The study team reviewed several methods of quantification that have been developed in recent years. The one selected is referred to as the Decision Alternative Ration Evaluation (DARE) system (3, 4). The DARE system describes a problem of selecting a site for solid

waste disposal. The factors involved are, of course, different from those involved in selecting a highway location, but the principle is nonetheless applicable. The DARE system was used to quantify eight environmental factors and thus obtain a ranking of alternative alignments that established an environmental order of preference.

The study team consisted of specialists in the fields of botany, biology, geology, architecture, and highway engineering. Ecologists spent considerable time in the field taking an inventory of the trees in the area, which were predominantly aspen, lodgepole pine, and Engelmann spruce. They identified and delineated the location of the various types of trees as well as other forms of ground cover, mainly shrubs and grasses. Aquatic biologists made extensive studies of both Black Gore Creek and West Tenmile Creek by counting the fish and collecting data on their food sources along the banks of the streams. The fish count was taken by a small crew that waded up selected sections of each stream and, using electrodes, stunned and netted practically every fish in those sections. They measured and weighed each fish and in some instances sampled the stomach contents. In addition, counts were made of the number of fishermen using the various sections of the streams. A wildlife biologist observed the species of animal and bird life in the area and the ground cover that afforded them food and protection. Geologists studied existing geologic data and made field reconnaissance studies. Architects and landscape architects reviewed tentative plans in order to evaluate from an aesthetic viewpoint not only the proposed bridges but the highway as well. They concentrated on the way the alignment would blend with the ground forms and the scale effect of a four-lane highway within the restrictive corridor. They also analyzed the impact of the highway on recreational activities in the area.

PRINCIPAL CONSTRAINTS AND SOLUTIONS

The environmental constraints imposed on the design and construction that are most apparent to motorists are those related to the terrain itself. Since the final location generally parallels the two streams that flow in either direction from the summit, care obviously had to be taken to blend the alignment into the land forms as far from the streams as practicable. Considerable effort was expended in projecting the alignment on topographic maps.

In general, the alignment followed the contours of the mountainsides, crossing the contours as required to obtain the desired gradients, which in some instances were as high as 7 percent. This effort generated an alignment highly curvilinear in plan with no tangents longer than 20 stations in the entire 22.5-km (14-mile) section. Fitting the alignment to the topography served to minimize cuts and fills and resulted in an aesthetically pleasing alignment.

Associated with this constraint were those represented by the two streams and the trees and other vegetation, plus the critical factor, the geologic composition of the terrain in and adjacent to the construction area. All of these constraints influenced the location and alignment to some degree. With only one notable exception, encroachment on the two mountain streams was avoided. In some instances, this was achieved by constructing an elevated structure to carry the roadway above terrain adjacent to the stream. In other instances, the base width of the roadway fill was reduced by using retaining walls.

In one section, geologic constraints dictated a major

encroachment on a stream, Black Gore Creek, on the western side of the pass. In that section (in the vicinity of station 425), in-place instrumentation indicated that the slopes on both sides of the creek were moving slowly, which suggested that roadway excavation on either slope might trigger a major landslide that would leave a defacing scar on the mountainside. Rather than run such a risk, it was decided to buttress both sides by constructing a large embankment over the stream and reconstructing a streambed at a higher elevation along the intersection of the newly placed embankment and the natural slope along the right bank of the creek. Before the embankment was placed, the stream was temporarily enclosed in a culvert pipe. The pipe was placed directly in the existing streambed, where the water flowed until the embankment was completed and the new channel constructed. The water was then diverted into the new channel, and the roadway was constructed on top of the embankment.

Design and construction were also influenced by a number of recreational considerations. The aquatic studies had indicated that neither West Tenmile Creek nor Black Gore Creek was a significant fishery. Both, however, support populations of small, beautifully colored brook and native (cutthroat) trout. Black Gore Creek is a particularly scenic example of a small mountain trout stream with tumbling waters and deep forest cover. Both streams are fast, clear, cascade types generally deficient in pool areas. This lotic environment, combined with cold temperatures and low productivity, limits the size of fish. The small size of the fish and the difficult access are probably responsible for the small numbers of fishermen at these locations. On Black Gore Creek, however, there are two small, man-made lakes that attract a number of campers to their shores, people who do fish in the lakes during the warm-weather months. It was considered necessary to maintain access to these lakes and to avoid any damage to the downstream reaches of the creek that might hamper fish from reaching the lakes.

The environmental study identified a number of birds and animals that inhabit the area. It was obvious that, with the construction of a four-lane highway, the killing of wildlife on the highway would increase. A single-span structure was constructed at station 436 to accommodate the crossing of deer, and a passageway was provided beneath all four lanes so that deer and other animals could gain access to the creek.

Early in the studies, there was some concern about the beavers that inhabit both streams. It was feared that the construction activities would drive the beavers out of their ponds and in some instances destroy the beaver dams. The wildlife biologist on the study team advised that, although construction noises would drive the beavers out, they would simply move to a nearby side drainage and construct their dams and ponds in new locations.

Trees and shrubs represented environmental constraints only to a limited degree. In selecting the location, the willows along West Tenmile Creek were avoided as much as possible. It was decided that the Engelmann spruce was to be favored over the lodgepole pine and the aspen, the other two predominating species. But, because of the preponderance of trees in the project area, no part of the final location was predicated on avoiding any particular group of trees.

On the west side of the summit, in the narrow confines of the canyon, avoiding encroachment on Black Gore Creek was a problem in several locations. If normal cut-and-fill construction had been attempted, embankment fill slopes would have tumbled down the mountainside and blocked the creek in several places. At some locations, the obvious answer was an elevated

structure to carry the roadway over the terrain.

Twenty-one highway bridges in the project were designed so that they could be erected without falsework to minimize construction damage to the terrain. Eight of these were post-tensioned concrete segmental bridges (see Figure 4), 11 were welded steel box-girder bridges (see Figure 5), and 2 were poured-in-place concrete structures.

Figure 4. Precast concrete segmental box-girder bridge.



Figure 5. Typical welded box-girder bridge.



Figure 6. Terraced retaining wall.



In other places, a more economical solution was a retaining wall that would limit the base of the roadway embankment and confine all embankment materials on the hillside above the creek. In many places, the height of the required wall was so great that a concrete cantilever retaining wall would have been uneconomical as well as aesthetically unacceptable. The designers, therefore, set out to create another type of retaining wall that would be economical to construct and architecturally acceptable. The scheme devised consisted of a wall of any height and length composed of two basic precast concrete elements that could be easily fabricated and erected. The two basic elements were a precast concrete L-shaped piece, called a tieback, and a 12.7-cm (5-in) thick curved concrete precast facing panel. Units were assembled in the field to provide a wall of any desired height consisting of a series of tiers, each 2.4 m (8 ft) in height, with each succeeding upper tier set back a minimum of 1.2 m (4 ft) from the lower. Each setback provided a terrace that was topsoiled and planted with vegetation.

After the award of the first contract on the project, the Reinforced Earth Company requested consideration of a system of concrete-faced reinforced earth retaining walls as an alternative to the precast concrete walls. Predesigning the facing panels of the normal reinforced earth retaining walls resulted in an appearance that was nearly identical to that of the precast concrete walls (see Figure 6). Bids were taken on both types of walls on subsequent contracts, and the final overall project contains a number of walls of each type that are difficult to distinguish from each other unless examined closely. In two locations, the horizontal distance between the edge of the roadway and the edge of the creek was so limited that the setback type of wall was impractical. In these cases, the conventional reinforced earth wall with flat concrete facing panels was stipulated.

Another environmental consideration was the natural coloring of the rock formations. The natural slopes and cliffs in the area are composed of a reddish material known locally as maroon sandstone. Bridges and retaining walls of the conventional concrete gray would have introduced an undesirable contrast into the landscape. Therefore, in an effort to match the sandstone, varying percentages of iron oxide in the concrete mix were specified.

Normally, air pollution and noise represent environmental constraints, but this was not the case on the Vail Pass project. It was reasoned that the construction of the Vail Pass segment to Interstate standards would actually improve the air quality in the project area. The rationale for this position was that, since the Interstate highway had been constructed to a point near each end of the Vail Pass project and since there was no feasible alternate route, the increasing traffic would force itself through the 22.5-km (14-mile) bottleneck of the existing two-lane highway under conditions of increasing congestion and slow speed. Since the four-lane highway would accommodate the anticipated traffic at speeds up to 96.6 km/h (60 mph), fewer pollutants would be left in the area along the roadway.

Noise was of minimal consideration since most of the project is located in an unpopulated area within the national forest. The only residents are located in the Big Horn Subdivision at the western end of the project, and in that area the I-70 location is well above the valley bottom where the residences are located.

Another factor that influenced design and construction was the fact that the area along the highway is used for cross-country skiing in the wintertime and backpacking, hiking, and camping in the warmer months. The construction of the highway has done nothing to inhibit these

activities. In fact, one feature that is still in the planning stage will serve to benefit them: A rest area located adjacent to the interchange at the top of the pass will provide toilet facilities and parking space at a strategic access point for snowmobiling and cross-country skiing and a trail head for hikers and backpackers. Also included in the architecturally attractive building that will house the toilet facilities will be a sizeable shelter room complete with seats and a large fireplace. The primary source of heat proposed for the buildings is to be solar energy. When excavations for the rest area were in progress, remains of ancient Indian campgrounds were found. An archaeological team recovered a number of Indian artifacts that date back 5000 years or more. It is the intent of the state to put these artifacts on display in the rest-area building as an added attraction.

CONCLUSIONS

The environmental restraints imposed on the design of the Vail Pass project necessitated the development of designs that would ameliorate the adverse environmental consequences so frequently associated with heavy construction. This became a challenge to all members of the team involved in the design and construction efforts. The measures taken on the project generally mitigated the disruption of the terrain in two ways: In some in-

stances the design simply reduced the area affected by substituting a structure for a cut or a fill, and in other cases the terrain was restored by landscaping measures. With the passage of time, the massive construction should have less and less effect.

The measures taken were costly; how costly is hard to assess accurately. It will always be a matter of conjecture whether or not the additional expense was warranted. In my opinion, the extraordinary scenic qualities of the terrain justified the extraordinary measures taken to preserve them.

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Geologic Constraints on the Vail Pass Project

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The complexity of the geology in the Vail Pass area of Colorado and the many engineering problems it presented in the design and construction of I-70 are discussed. Precambrian igneous and metamorphic rocks and Pennsylvanian-Permian sedimentary rocks had been extensively folded and faulted. Glacial and stream erosion and deposition had modified the topography. Large, complex landslides that had developed in bedrock and surficial deposits and that could not be avoided by changes in highway alignment were the major geologic constraints. The engineering solution to the geologic problems and the integration of the engineering solutions with other environmental factors resulted in minimal environmental impact. The Vail Pass route of I-70 can serve as an example of the value of defining the geologic environment in an environmentally complex area and incorporating environmental constraints into the design and construction of a major highway to minimize environmental impact.

The geology of an area and the geologic processes operative within it determine the environment. The modification of this environment for any purpose must consider geology and geologic processes. Minimal environmental impact will occur when engineering design and construction practices are integrated with the geology and the geologic processes of an area. At Vail Pass every effort was made to integrate geology and geologic processes into the design and construction of I-70 in order to ensure a safe highway and minimize environmental impact and highway maintenance.

GENERAL GEOLOGY

I-70 across Vail Pass crosses terrain typical of the geology of the high mountains of Colorado (see Figure 1). The route follows the valleys of Black Gore Creek, which flows north from Vail Pass, and the west fork of Tenmile Creek, which flows south from Vail Pass. These streams flow along the west flank of the Gore Range, a northwest-trending mountain range bordered on the east by the Blue River. The Gore Range is an uplifted block of granite and metamorphic rocks, flanked on either side by sedimentary rocks—chiefly beds of sandstone, siltstone, shale, and some limestone. Figure 2 shows a generalized stratigraphic section of Vail Pass. Figure 3 shows a generalized geologic map of the area.

After the uplift of the Gore Range, the area was subjected to glaciation and stream erosion. The deposits related to the glaciation, erosion, and weathering of the rocks are unconsolidated and locally, after their original deposition, slid to form extensive landslide areas. As a result of the extensive faulting of surficial materials and most of the areas of landsliding, the bedrock—with a few notable exceptions—is relatively stable. Construction across these deposits, however, could easily have caused new landslides or activated old landslides.

Previous geologic work done in the area was mostly