Chapter 9
DESIGN, CONTEXT, AND THE COLORADO HIGHWAY

The precise science of engineering brought order to the chaos of Colorado's trails and early auto roads. The first wave of gold seekers followed existing native trails, or blazed new paths, with little consideration for configuration or design. A subsequent movement of settlers brought with them concepts of civilization and commerce that demanded better, safer roads in order to thrive. Within the first decade of Colorado's statehood, its elected leaders made their first attempts to improve the state's roads. However, from the 1870s to the early 20th century, commerce directed the layout of the state's rail lines and toll roads. A change came on the wheels of a horseless carriage. The self-reliance promised by the automobile ironically bound individuals together in demands for better highways. By the mid-1910s, both state and federal governments responded to those demands with the creation of the first standards regarding highway design, grade, and materials. Under the authority of state and federal agencies, highway design and standards evolved and improved throughout the century. Today, drivers across Colorado travel over a highway system that incorporates a variety of construction and design elements reflecting the period in which it was built and the economic and social character of the region it traverses.

9.1 Wagon Road Construction

Trails led gold seekers and settlers to Colorado. Countless wagon teams following the same general path left the prairie rutted and scarred. On the eastern prairies, early travelers faced the hazards of bogs and swollen rivers, as well as attack from outlaws and native tribes. Travel by wagon to the west was expensive and slow. However, on the plains they could go anywhere without any difficulty until they reached the gold camps of the Rocky Mountains. The design of the covered wagon meant it could cling to the steep side slopes of a mountain. In addition, there were no sufficient draft animals available to pull it over the seemingly endless summits. Overlooked in the haste of the Gold Rush was the time to build safe and suitable wagon roads.

The earliest roads were nothing more than wagon tracks with the largest stones removed. On the prairie, no one made the effort to keep them level transversely. Only when a wagon threatened

to tip over did most drivers think of returning to level ground. A trip west by wagon required the pioneers to get out and do some work on the road itself in order to get over it (Ridgeway, September 1932: 162).

Over the eastern plains, the first wagon roads were built quickly and were rough surfaced compared to the first unpaved automobile roads. Across the prairie, these trails were "little more than many pairs of ruts made by the wheels of heavy wagons" (Workers of the Writers' Program, 1987: 70). When a pair of ruts had been worn too deep for use, wagons straddled the old ruts and created new ones. The pioneers exerted little effort to level the roads, so their wagons were forced to climb or descend very steep slopes and to ford streams. In addition, strong rains and heavy snowfall made passage on the plains more difficult while heavy snowfalls in the mountain shut down the passage of both mail and passenger traffic. A number of different conveyances traveled over Colorado's first trails – from the cumbersome Spanish two-wheeled ox-driven *caretta* to the prairie schooners of the gold rush era (The Workers of the Writers' Program to Colorado: 71).

The Homestead Act of 1862 encouraged settlement of Colorado and other western territories. After the General Land Office completed land surveys in the early 1870s, small towns sprang up across Colorado. The space between most towns generally measured no more than 10 miles apart – the distance a team and wagon could travel from a nearby town and back in a day (Scott: Historic Trail Map of the Denver 1° X 2° Quadrangle, Central Colorado: 5).

9.2 Early Auto Highways 1900-1930

In 1908, James E. Owen, in an address before the Good Roads-Automobile Convention in Atlantic City, New Jersey, explained the transitional nature of the nation's roads from horse and carriage to horseless carriage:

> "Just consider what a road has to undergo. A heavy team comes tearing along with the horses' caulked feet, hammering and packing the stones for the heavy wheels to grind them to powder. Behind this comes a light buggy with a fast trotting horse and rubber tires, stirring up the loose material, then as a climax a six-ton motor car at 45 miles – excuse me, 21 miles [New Jersey speed limit]

> whizzes along throwing and hurling this loosened material into the gutter, or gently bedewing a strawberry patch with pure stone. Then what becomes of the road?" (AASHO, 1952: 105).

Since its beginnings, the State Department of Highways established and followed certain standards for all graded and surfaced roads. According to the department's first Chief Engineer James E. Maloney, the department's principles were "the outgrowth of our experience with the construction of different roads in different parts of the state." For graded and paved roads, the state demanded of a 60-foot-wide right-of-way in which to place a 24-foot-wide road. The spacious right-of-way allowed room for additional lanes and future surfacing. The department wanted standardization so that any grader or scraper could build roads that would be, in Maloney's words, "uniform, sightly, practical, and I believe, more economical." Conversely, the chief engineer warned that a crooked line of ditch and grade was "unsightly and unworkmanlike, indicating either carelessness or lack of skill" (Maloney, June 1918: 9).

With the federal government taking a greater hand in road construction nationwide, the highway engineers of Colorado and 47 other states followed a general Bureau of Public Roads (BPR) guide for surveys and plans. In surveying a potential road, a survey party comprised of a field engineer in charge, instrument man, rodman; two chainmen, one or more axemen and a camp man had to obtain the following information:

> "All fence and property lines, and intersecting roads. These should be carried back at least 300 feet. Telephone, telegraph and power lines – the number on several of the poles should be noted, and street or stream or electrical railroad lines crossing or parallel to surveys, if within 500 feet, culverts and siphons. The span, width of roadway, and character of all bridges, also diameter, length and kind of culverts – also the angle at which the stream crosses the road, the profile of the stream crossings and all information that can be had as to depth of foundation and area of drainage – also a profile up and downstream for 500 feet is to be taken when the bridge is on a stream that is liable to scour. Location and character of all material suitable for road surfacing or construction should be noted." (Colorado Highways Bulletin, June 1919: 21).

Both the BPR and the Highway Commission followed a set of rules regarding grade limits and road curvature. Engineers knew that the grade could not exceed 6 percent, except for short

distances not exceeding 2,000 feet, where 7 percent would be favorable to avoid heavy work. Regarding road curvature, BPR philosophy maintained "A great many of the present curves on the roads are unnecessary and could be eliminated by a little grading work." However, where that was impossible, the BPR recommended a radius of not less than 100 feet. Unfortunately, in the tight spaces of the Rocky Mountains, a 100-foot radius was not possible economically. The BPR suggested a radius of no less than 40 feet on any mountain switchback or curve (Colorado Highways Bulletin, June 1919: 21).

The Bureau of Public Roads set the standard for Colorado's auto highways from the late 1910s forward. The pavement of the first Federal Aid concrete road laid in the state – Federal Aid Project No. 1 from Denver to Littleton – measured 16 feet wide, 5.5 inches thick at the edges and 6.5 inches at the center. Within five years of completion, BPR engineers noted that US 85 showed "more defects, especially in the corner cracks, than any other project" due to a lack of a sand cushion, the narrow width of the pavement, causing the load to come closer to the edges (Bureau of Public Roads, 1923).

Local representatives of the Bureau of Public Roads took a keen interest in the developments of the burgeoning highway departments in each state. In 1917, BPR's Acting District Engineer J.W. Johnson wrote to his boss, Thomas McDonald, the engineer in charge of federal road work for the BPR, that construction progress in Colorado was hindered by the state highway law that required a large portion of the state road fund be pro-rated to the counties and construction work in the individual counties be performed to their share of state funds. Johnson found that "the commission has been forced to submit a number of very small projects, several of them being concrete surfaced roads averaging from 2200 feet to a mile and a half . . . The character of the projects submitted could be very materially improved were it not for the fact that the State Highway Commissioner of the individual district apparently attempts to please everyone by the submission of a number of small projects rather than to submit a smaller number of projects and have them substantial in size and quality." (Bureau of Public Roads, 1919: 10). Johnson concluded: "If the Colorado Highway Commission would form a proper kind of an organization for carrying out the work and submit projects more from the point of view of improvement of

state highways, it is believed that a decided betterment would result." (Bureau of Public Roads, 1919: 11).

From the 1920s forward, federal aid paid for practically every concrete road in Colorado. These roads measured 18 feet wide, six inches at the sides and 7.5 inches at the center (Bureau of Public Roads, 1923). Because of BPR regulations, all pavements in Colorado were laid with traverse joints every 30 feet on a two-inch sand cushion wherever the soil had a large percentage of clay or adobe. Most of Colorado's soil is sandy loam. Colorado also used a 6-inch sand or gravel shoulder on the sides of the road, 4 feet in width. Before the Bureau of Public Roads instituted their statues, the State Highway Commission placed sand and gravel shoulders only two in depth. Once the state followed the federal agencies guidelines, the BPR gave Colorado's roads good marks. A 1923 BPR review noted "the pavements in Colorado are today in good shape. The only defects are minor in character, due to poor construction such as slight unevenness or roughness at the joints, or irregularities in the slab itself." (Bureau of Public Roads, 1923).

First World War technologies benefited the quality of road building across the United States and in Colorado after the war. Colorado contractor Edward Honnen told the Denver Post that machines built for war helped the state build better roads in peacetime:

> "When I took over my dad's company in 1920, there had been very little change in the tools from about 1860 to 1920. World War I had the greatest effect on the construction industry because they (the U.S. Army) developed a power unit. And from then on, we pulled wagons, we pulled plows, we pulled scrapers, we pulled everything" (The Denver Post, 1974: 14).

The reorganization of the State Highway Department in 1921 opened the increasingly distant lines of communication between headquarters and construction jobs in the field. The new department established an engineering division under supervision of an assistant highway engineer. Before creation of the engineer's division, communications between headquarters and the field was haphazard. In the remote areas of the state, crews relied on their own judgment to survey. Under the new system, highway location crews made initial surveys and were followed by other teams that conducted the final engineering surveys. Headquarters in Denver prepared

construction plans and specifications based on the two surveys to bring the prospective project to contract (Wiley, 1976: 17).

After 1921, the influence of the federal government took the dominant role in the Colorado and other states road construction. Road building between the two world wars took place within "the federal-aid structure of shared power, responsibilities and finances."(Seely, 1987: 67). The Federal Highway Act of 1921 (42 Stat. 212) retained the outstanding features of the Federal-Aid Road Act of 1916 and added the important requirement that the Secretary of Agriculture and the several State Highway Department should jointly designate a system of important interstate and intercounty roads, limited to 7 percent of the country's total road mileage, to constitute the federal-aid highway system on which all future federal appropriations were expended (Strobridge, 1962: 4).

In 1923, the Highway Department authorized $70,000 toward erecting route markers in conjunction with introduction of a new highway numbering system. The department made an arrangement with the Mountain States Automobile Association to furnish the markers free. The department's maintenance division would install 1,500 signs in the first year. The new road signs required renumbering the state's highways, and the roads leading from adjoining states carrying heavy tourist traffic were marked first. Part of the $70,000 went toward the state's first traffic census. The census helped determine what kind of road to build in certain areas of the state by that area's traffic volume. The commission planned for 169 numbered highways, with the first 49 numbers reserved for interstate roads funded by the federal government. (Colorado Highways, June 1923: 13).

Plate 8. The federal government's heightened role in building the nation's highways demanded standardization of road signs and maps. The Rand McNally Map Company published this diagram a year after Colorado introduced its first road identification system in 1923. (1924 Rand McNally Roads of Colorado Map. Located in Denver Public Library, Western History Department).

By the start of the 1920s, screened or crushed gravel, stone and/or shale constituted most of Colorado's surfaced roads. The state constructed gravel roads in two courses, or layers. A 2.5-inch base of stone formed the bottom layer while three inches of gravel running to a feathered edge to the sides formed the top course. A road roller weighing 300 pounds compacted the material to a three-inch thickness (Colorado State Highway Commission, 1919: 14). As the 1920s progressed, the state built more concrete roads. An abundance of raw material and available labor convinced engineers to use the durable concrete at every opportunity. A 1923 Highway Department audit found that the cost of concrete paving in Colorado averaged $2.22 per square yard, lower than in 35 other states (Colorado Highways, October 1923: 11; December 1923: 16).

The heyday of concrete-highway construction in Colorado lasted from the late 1910s to the 1930s. During this period, builders used three standard mixes for construction: paving mix for concrete roads and Class A and Class B concrete. The paving mix consisted of one part cement, two parts fine aggregate (sand), and three parts coarse aggregate (gravel or crushed rock) added with enough clean water to form a stiff, workable substance. The Colorado Department of Highways used Class A and B concrete to form bridges, culverts, headwalls, and spillways. Class A concrete consisted of one part cement, two parts fine aggregate and four parts coarse aggregate with just enough water to make the concrete flow easily into place. Mixing Class B concrete required one part sand, 2½ parts fine aggregate and five parts of coarse aggregate together combined with enough water to form concrete with the same consistency as the paving mixture (Pierce, 1923: 5).

The vagrancies of Colorado's topography played a large role in the construction of its first concrete roads. Most of the state's sand and gravel could be found in creeks, riverbeds, and along valley slopes. Unfortunately, in most of Colorado's waterways, the heavy gravel remained in the bottom of the creek bed, and currents carried the sand hundreds of miles downstream. In eastern Colorado along the valleys of the Platte and Arkansas Rivers, good sand was obtainable, but there was little coarse gravel available. In the valleys of the Colorado River and its tributaries on the Western Slope, good gravel was available, but the sand was mixed with oil

shale or dirt. Faced with this situation, the State Highway Department soon established a laboratory to test samples well in advance of road construction (Pierce, 1923: 5-6).

Under the leadership of State Highway Engineer Charles Vail, asphalt was the material of choice to pave most of the state's roads during a 10-year period from the 1930s to the 1940s. Asphalt's popularity resulted from its durability and ease of placement. In the 19th century, bituminous materials for roads in the United States were limited primarily to the use of natural deposits and bitumens found in limestones and sandstones impregnated with asphalt. After 1900, discovery of additional crude petroleum sources and a heightened demand for fuels and lubricants resulted in construction of more asphalt roads. Since Vail's era, the Hot Mix Application process has served to blacktop Colorado's roads. The Hot Mix process required transporting, placing, and compacting hot asphalt over a road site to ensure a uniformly dense pavement layer (Baker, 1979: 515).

By the early 1920s, the Highway Department increasingly experimented with asphaltic materials. The Denver firm of Miller, Douglas & Haines poured the first mile of state-funded asphalt paving under a $36,618 contract to the Colorado Highway Department during August 1923. Crews spread a two-inch-thick asphalt top that covered a six-inch concrete base along the Victory Highway (now U.S. 40) near Fitzsimmons Hospital, east of Aurora (Colorado Highways, August 1923: 1).

A 5.3-mile project between Romero and Antonito in the San Luis Valley launched the department's first attempt at oil surfacing in 1928. Pople Brothers Construction of Trinidad won the contract supervised by Colorado Highway Department's resident engineer W.J. Walsh. After the contractor placed a gravel surface, crews started an oil distributor to spread three applications of about a half gallon per square yard. After each pass, crews used a double-disc harrow to work the oil into the gravel. The machinery bladed the oil back and forth until it thoroughly mixed and spread the material over the road. Cars could now drive over the road without getting splattered with fresh oil, as traffic compacted the mixture into place. Walsh later recalled that the road lasted for a number of years before resurfacing. This experiment on an isolated

Colorado road convinced the Highway Department to build fewer concrete and more asphalt-based roads (Wiley, 1976: 24).

The first generation of highway road builders knew the importance of drainage in maintaining roads. Roy J. Randall, supervisor of Federal Aid Projects for the Bureau of Public Roads (BPR) wrote in 1922, "The most important factors to be considered in the improvement of highways are foundation and drainage" (Randall, 1922: 1).

Across rural Colorado, bridges, culverts, and siphons were necessary where there was a natural cross-drainage, such as streams, swales, and arroyos. On long grades of highway, engineers placed culverts at proper intervals to carry drainage across and away from the roadway, prevent overflow and wash in the side ditches. As the Highway Department graded the state's first earth roads for the automobile, engineers paid attention to maintaining clean, free-flowing gutters or side ditches, adequate culverts in sufficient numbers and unobstructed free-flowing outlets. The Bureau of Public Roads warned that these ditches "must not be so deep as to be a menace to travel" (Whittaker, February 1919: 13, 21; Randall, 1922: 1).

Throughout the irrigated agriculture lands of northeastern Colorado, highway builders dug side ditches along roads like the Omaha-Lincoln-Denver Highway (now US 6) that were deep enough to transport storm water and carry moisture from the crown to the shoulder. (Randall, 1922: 1).

By the early 1920s, there were a number of different types of culverts beneath the nation's roads. These included cast iron, corrugated metal, reinforced concrete boxes and pipes, vitrified tile, and wooden boxes. Among early 20th century engineers and road builders, the cast-iron culvert was considered the standard of excellence. During the early years of highway construction, engineers avoided using cast-iron because of its excessive weight and cost (Randall, 1922: 1,12).

Subsequent to the introduction of federal standards by the late 1910s, the Bureau of Public Roads attempted to codify culvert construction nationwide. The BPR recommended placing culverts low enough to allow water to enter and yet not be so low as to become filled with sediment. The

culvert also needed protection from above through sufficient cover to prevent road traffic from breaking them. All culverts meeting federal regulations required headwalls at the ends to hold the earthfill in place. Additionally, the culverts had to be easily identifiable. Randall recommended one further construction tip: "the best economy lies in using the most permanent structure at the first installation" (Randall, 1922: 12).

Because of Colorado's variations in topography and subsoil, there remain a number of different kinds of culverts. The State Highway Department's "Standard Specifications for Road and Bridge Construction" (1930) required all non-cast or built-in-place culverts to lie in a trench excavated to the depth and grade established by the project engineer. Concrete in substructures were placed so that all construction joints were horizontal unless otherwise shown on the plans, and in locations difficult to detect in the finished structure. State specifications also reminded engineers to watch for placing construction joints through parallel wingwalls or any surfaces designed for additional architectural treatment. Trenches for pipes had to be completely filled and the pipe covered to a depth of one foot. At that point, crews would place and properly compact materials before the construction of the embankment over the culvert (Colorado Department of Highways, 1930(b), 152-4).

Today's standard "multiple-type" culvert was first used during the building of the Mount Vernon Highway in 1937. The multiple-type culvert consists of thick, corrugated iron plates that are curved, punched, and galvanized. The plates were delivered to the job unassembled. Workers on site bolted the pieces together to fit the design specified by the engineer. On the Mount Vernon Highway (US 6) there were four culverts installed with the longest measuring 338 feet. The amount of earth required covering the culverts averaged 68.5 feet (Tracy, November 10, 1937: 10-11).

Snow is the biggest natural obstacle to safe passage along Colorado's mountain highways. Before mechanical snow plows, men began shoveling passes in May so that traffic could move through the mountains around the middle of June. In 1923, a rotary plow designed by State Highway Engineer L.D. Blauvelt cleared Berthoud Pass in less than 72 hours. Crews nicknamed the machinery the "Bull of the Woods" to honor Major Blauvelt. In 1927, the maintenance

department mounted a rotary plow on a four-wheel drive Coleman truck with a separate engine to drive the rotary head. The rotary plows demonstrated their worth during the winter of 1928-29, as they kept an important route between over the Continental Divide – Tennessee Pass along US 24 – open all winter. It marked the first time any vehicular mountain pass in Colorado remained open to traffic year round. By 1939, state maintenance crews kept all major passes over the mountains open throughout the winter (Wiley, 1976: 22).

From 1905 to 1920s, the state extensively used concrete in bridges because it held up under traffic and resisted flood more than truss bridges. The Luten arch bridges were the forerunner of other concrete bridge types. The Luten arch was dependent on steel reinforcement allowing relatively thin concrete sections at the midspan. In 1921, the Highway Department built a segmentally reinforced concrete bridge just south of Boone on US Highway 50. Subsequent floods destroyed almost all of the trusses in Pueblo County, but the concrete bridge remained structurally intact (Christensen, et. al., 1987: 51).

9.3 New Deal/New Roads, 1930-1945

Remaining Depression-era federal work programs continue to benefit modern drivers. Under the Works Progress Administration (WPA) of the mid-1930s, over 2,000 miles of Colorado roads were improved and more than 600 highway bridges were completed. Rural areas benefited the most from construction of all-weather roads along with grading, and graveling, and bridge building. WPA workers commonly constructed coursed-stone-roadway bridges. The Douglas Crossing Bridge over Two Butte Creek remains an example of this type. Completed by an eight-man crew in 1936, the Douglas Crossing Bridge needed a large volume of stone for its six 14-foot-span semicircular arches (Christensen, et. al., 1987: 53).

9.3.1 Blacktopping Colorado: Vail's Vision in Asphalt

State Highway Engineer Charles Vail's decision to asphalt the state's roads did not come without controversy. During the mid to late 1930s, it was Department of Highways policy to coat as many main roads as possible with a slow-curing oil containing a low asphaltic content. Asphalt oil acted as a binder that held together particles of sand and rock. When the oil is rich with asphalt, the surface of the road cures and dries rapidly, becoming very hard. The department told

crews to spread a comparatively thin oil mat of less than half the amount required by federal specifications. Some critics of the department complained this policy resulted in inferior roads and precluded the possibility of obtaining federal aid for oiling (University of Denver, 1940: 14-5)[Figure 9].

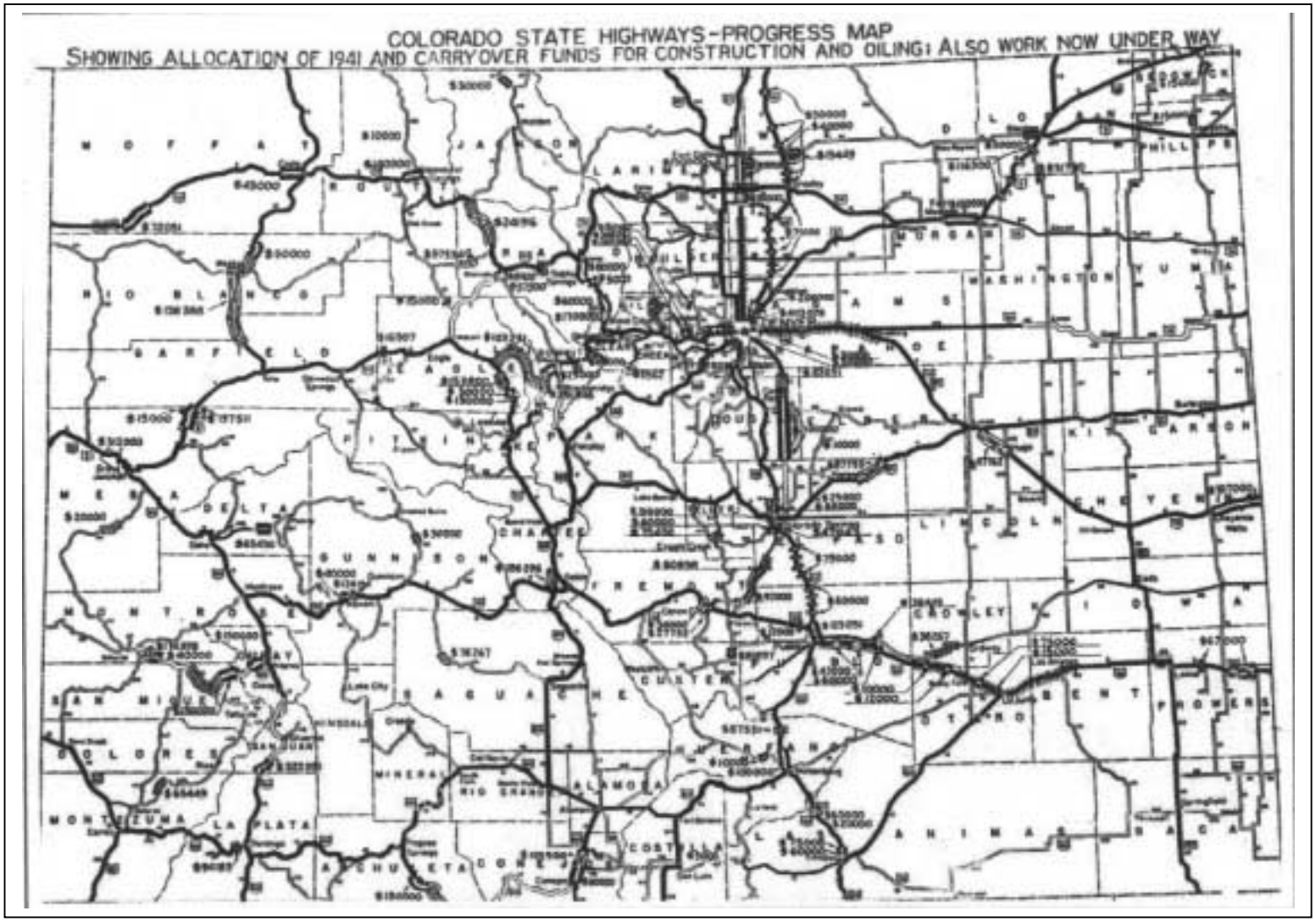

Figure 9. The 1941 progress map pays tribute to State Highway Engineer Charles Vail's determination to oil the state's highways (Rocky Mountain Contractor, May 14, 1941: 6).

A 1941 study classified the kinds of materials and total number of state highway miles:

Unimproved (projected, primitive, and bladed)	2,034 miles
Graded and drained	1,256 miles
Gravel surfaced	4,688 miles
Low-type Bituminous (oil)	3,764 miles
Paved (concrete, brick, etc.)	626 miles
Total	**12,368 miles**

(Colorado Department of Highways, 1941).

9.3.2 Guardrails and Safety

As traffic in Colorado increased by the late 1930s, state highway engineers paid greater attention to safety. This was especially true for roads constructed through the Rockies. Six major highway projects constructed during this period (Big Thompson Canyon-North St. Vrain, the Mt. Vernon-Floyd Hill Highway on U.S. Highway 40 between Denver and Idaho Springs, U.S. Highway 24 west of Colorado Springs to Leadville, U.S. Highway 50 west from Canon City to Salida, and U.S. Highway 160 west from Walsenburg to southwestern Colorado) reflected those concerns. Each design featured wider roadways and curves, longer sight distances, and easy grades rarely exceeding five or six percent. A 1938 study by the Colorado Highway Patrol uncovered the "increasing danger" of fast highways unprotected on curves and high embankments (Rocky Mountain Contractor, May 10, 1939: 11). In the late 1930s, the department installed semi-rigid guardrails to prevent cars from going over steep embankments. Earlier forms of guardrail did not "give" on impact, resulting in serious injuries or death. The state design required installation of a series of rigid posts, with protruding eight-inch, strong springs supporting an outside steel rail or beam. First used along the Mount Vernon Canyon road, this design deflected cars back onto the road and away from the supporting posts (Williams, 1937(b): 17). The regional trade publication, Rocky Mountain Contractor, praised the guardrails 'as modernly streamlined with (its) curved convex beam surface gleaming" as it offered drivers an unobstructed view of the state's "scenic beauty" (Rocky Mountain Contractor, May 10, 1939: 11).

9.3.3 A Road Crew's Work is Never Done: Highway Maintenance

Colorado's heavy snows, scant humidity, hot summers, and continual use by motorists demanded that the state set aside much of each year's highway budget toward maintenance. As early as 1922, C.T. Brock, assistant superintendent of maintenance in Division 1 (Denver), stated that maintenance was "the most important function of the Highway Department" (Brock, 1922: 6). In dry weather, Colorado's sand-clay roads needed continual dragging, as they soon rutted and turned impassable. A tractor and a grader moving at a rate of one mile a day kept roads smooth. A crown of too much loose sand or gravel quickly turned the road into a washboard. In wintertime, crews dumped loose gravel from the side of the road back onto the crown to further harden the surface (Brock, 1922: 6; Taylor, 1923: 8-9).

Repairs to the state's concrete roads offered their own set of problems. In the early 1930s, the maintenance division devised their own system to bring worn concrete slabs up to grade. The method for maintaining undergrade depressions required pressure pumping mud and cement underneath the slabs. Crews drilled two-inch-diameter holes in the center of the most depressed section. Selected loam material (in the ratio of two parts to one part cement) and water brought the material to a "soup" consistency. The mixture was then forced through a hose leading to the point of application. Crews drilled holes at six-foot intervals, starting at the center of the most depressed portion of the slab. The Highway Department claimed this method filled nearly 85 per cent of the depression beneath a selected slab (Williams, 1937(b): 18).

The wave of asphalt sweeping over Colorado's roads during the 1930s still required the state to perform upkeep. Douglas N. Stewart, superintendent of maintenance, stated that maintaining oil-surfaced roads required "constant vigilance" (Rocky Mountain Contractor, October 13, 1937: 8). Small holes caused by oversized gravel, friction, or water, caused potholes to expand across the road's surface at a relentless pace. Crews fixed these ruts with pre-mix asphalt to maintain a smooth road surface.

9.4 The Interstate Era, 1945-2000

Anticipating a post-war public demand for a national highway system, the Federal Highway Act of 1944 authorized construction of road network connecting the nation's big cities. Under the legislation, all designs minimally featured four-lane divided highways, expanding to six to eight in and near large metropolitan areas. In 1947, Congress approved final planning for the National System of Interstate and Defense Highways. Colorado's allotted mileage included Interstate 25 between Cheyenne and Raton Pass, Interstate 80 South (now I-76) from Denver to the Nebraska line at Julesburg, and Interstate 70 from Denver to the Kansas border (Christensen, et. al 1987: 53).

Since 1954, the American Association of State Highway and Transportation Officials (AASHTO) in Washington, D.C. has published *A Policy on Geometric Design of Highways and Streets,* better known as the Green Book. The Green Book addresses every element of the nation's road design from city curbs, residential cul-de-sacs, posted speeds on the interstate, design of rest areas, commercial intersections, and recreational roads (Marriott, 1998: 69). Similar to the other 49 states, Colorado adheres to the guidelines set for in the Green Book. However, the Green Book only recommends guidelines to the states and local governments for design of roadways; no state is forced to adopt AASHTO's rules. The Federal Highway Administration (FHWA) adopted the Green Book as the standard for all federal roads and construction projects. Projects not a part of the National Highway System (NHS) do not have to follow the Green Book, however, because of the expense of developing and enacting their own guidelines, most state and local governments follow AASHTO regulation regarding non-NHS construction (Marriott, 1998: 71).

In the first years of interstate construction all 48 states were happy to follow the rules laid down by Washington. The interstates that cross Colorado today share the following characteristics to interstates nationwide:

Highways would have to meet the projected traffic numbers for 1975. Traffic lanes would be at least 12-feet wide and shoulders 10-feet wide. In rural areas the median strips dividing oncoming traffic would be at least 36-feet wide, while in urban areas the strips would be as

narrow as 16-feet wide. The roads were engineered for speeds of 70 miles per hour and feature grades not greater than three percent. No railroad crossings or grade-level intersections interfered with traffic, and overpasses had to stand at least 14 feet above the road. Access to take flight on these new roads was strictly limited to entrances and exits (Lewis, 1997: 140).

The hallmark of the Federal Interstate Highway System is homogenization. This sameness went beyond the same fast-food restaurants and motels at the next exit. The interstate system standardized construction and safety standards nationwide. Since the federal government funded 90 percent of interstate construction, they held the authority to determine the rules of the road.

In 1956, the Bureau of Public Roads established for interstate construction standards it had worked out with the American Association of State Highway Officials (AASHO). Colorado was one of only a handful of states with a basic highway design manual, let alone a design standard for superhighways. In August 1957, the AASHO also established the tri-color federal shield designating the nation's interstates and reversed the numbers of the interstate routes originally established in 1926. AASHO first decided that north-south roads would ascend numerically in odd numbers from Route 1 on the East Coast and 101 on the West. Roads running east-west descended numerically in even numbers from Route 2 in the North to Route 90 in the South. From the late 1950s, Interstate 95 has been the east coast's main thoroughfare from Florida to Maine while bumper-to-bumper traffic clogs Interstate 5 around Los Angeles. At the nation's northern border runs Interstate 10, while across the southern United States, the primary highway is Interstate 90 (Lewis, 1997: 136-7).

Historian Tom Lewis commented on the uniformity of the interstate noted in his 1997 book, Divided Highways:

> "The Bureau of Public Roads and the American Association of State Highway Officials issued specifications for construction that left little leeway for interpretation. Engineers simply applied the rules to the task at hand, be it Interstate 10 through Santa Monica, California, or Interstate 94 through Dickinson, North Dakota. They simply repeated the tasks in small increments of usually five, ten, twenty, or thirty miles many times over: surveying, walking the line, grading the land, laying the substrate, laying the asphalt or concrete, painting the lines, erecting the signs, holding the ribbon-cutting ceremony, and moving on" (Lewis, 1997: 253).

In spite of the direction of the "unseen hand" of the federal government, Colorado's highway engineers did experiment with different materials and environmentally friendly designs after World War II. In the early 1950s, the State Highway Department conducted experiments with "rubber roads." Engineers studied placement of one-mile sections between Blakeland and Castle Rock and south of Pueblo for five years. It was the first attempt with rubber on any highway in the West. The process required two-percent basic rubber blended with penetration asphalt at the refinery and laid in a special section on each highway. The rubberized section bore no distinguishing physical characteristics, but engineers were intrigued by its propensity for greater resiliency and resistance to skidding. However, the state chose not to continue laying rubber by the late 1950s (Colorado Department of Highways, 1954: 54).

9.4.1 Post-War Safety Standards and Design

Retaining walls are an important element in Colorado highway design. In the mountains, walls made of wood, rock, metal and preformed concrete protect drivers from rock fall or tumbling off the side of the road.

By the early 1970s, AASHO added the word "Transportation" to its name and became the American Association of State Highway and Transportation Officials (AASHTO). However, AASHTO regulations regarding highway design remained the same. According to AASHTO, retaining walls should be located no closer than 10 feet from the edge of the pavement and preferably at least two feet from the outer edge of the shoulder, whichever is greater. Where walls are located the same distance from the edge of the pavement as from the bottom of slopes,

the effective shoulder width is less and appears narrower. Where the top of a retaining wall is at the level of a frontage road or ramp, the face of parapet, or rail preferably, should be at least four feet from the edge of the traveled way. Where a retaining wall is adjacent to an auxiliary lane or ramp, the wall should provide ramp shoulder lateral clearance of at least four feet between the edge of traveled way and the face of the wall. Where walls are located near the traveled way, the contour of the lower portion should appear as a slope-faced barrier, to effectively redirect errant drivers and minimize damage to the vehicle. Along Interstate 70 through the Rocky Mountains, particular attention was paid toward aesthetics. Concrete walls used textured forms to complement the surrounding scenery between Vail and Glenwood Springs. The environmental sensitivity of retaining structures along 12 miles of I-70 through Glenwood Canyon brought state highway engineers international plaudits (AASHTO, 1973, 386-7; Rocky Mountain News, October 15, 1992: 10).

Curbs are a related element of highway design. Curbs border all types of highways to control drainage, deter vehicles from leaving the pavement at hazardous points, protect pedestrians, delineate the edge of pavement, present a more finished appearance, and assist in the orderly development of the roadside. There are two general classes of curbs: barrier and mountable. Barrier curbs are relatively high, steep-faced and designed to inhibit, or at least discourage, vehicles from leaving the roadway. A typical barrier curb features a vertical face, a half-inch radius and a height of at least six inches. Barrier curbs are not used in highways designed for speeds in excess of 50 mph, because when struck at high speeds, drivers risk losing control of their automobiles.

The design of mountable curbs allowed vehicles to clear with varying degrees of ease. The height of the mountable curb should not exceed more than four inches high. When placed on the outer edge of a shoulder the mountable curbs also help to control drainage, improve delineation, and reduce erosion. Nationally, both types of curbs are made of either Portland cement or asphalt or granite (AASHTO, 1973: 356-9). In Colorado, older highways like US 6, between Brush and Sterling, retain both asphalt and timber curbing.

In 1979, a resurfacing project on US 160 between Durango west to the town of Hesperus employed a new recycling process for a portion of the work. Crews lifted the existing bituminous mat and reprocessed the roadway through a hot plant with additives and additional material and then re-laid the mat. The Division of Highways expressed their pleasure over the results in their 1981 Annual Report: "In a time of declining revenues and resources, pavement recycling will become more prevalent. This project helped develop the technology and experience necessary to make such recycling work on a continuing basis." (Colorado Division of Highways, Annual Highway & Transportation Report, 1981: 55).

The completion of Vail Pass in 1979 on Interstate 70 came with a set of engineering features unlike any other mountain highway in the state. A precast retaining wall system controlled erosion, while slope stabilization and revegatation methods successfully protect the surrounding environment. Another innovation involved construction of twin bridges utilizing segmental construction. The segmental bridges were built in relatively short sections involving repetitive sequences of operations. The segments are precast permitting their placement as soon as piers are completed, thereby shortening construction time. In order to conform as much as possible with the surrounding environment, trees were left in place beneath the structures and engineers designed special underpasses to accommodate game animals (Christensen, et. al., 1987: 57).

9.4.2 The Triumph of Design: I-70 Through Glenwood Canyon

The debate over building a 12-mile section of Interstate 70 through the Glenwood Canyon took the better part of two decades. A number of groups fought the road on the grounds that a major interstate would have destroyed the canyon's beauty. The disputed stretch was in a 2,000-foot-deep Colorado River gorge. Completed in 1992, engineers developed a variety of features that attempted to minimally impact the canyon's wild splendor. Many sections featured prestressed concrete slabs cantilevering six feet over the retaining walls. A number of the 39 bridges along the route were prefabricated superstructures, including several segmental box-girder bridges that were trucked in rather than constructed on site. Perhaps the most difficult element of the project, the $103 million Hanging Lake Tunnel, challenged four construction companies to build two 3,880-foot long tunnels to facilitate traffic movement and protect the Hanging Lake Park area from the highway. At the portals of both tunnels, heated water from nearby springs controlled

winter icing (Christensen, et. al. 1987: 57). On the project was completed, the *Rocky Mountain News* noted that 265 engineers worked 800,000 hours, or the equivalent of 91 work years, "to pioneer the techniques that will win awards for years to come" (Rocky Mountain News, October 15, 1992: 10).

Completion of the last mile of I-76 northwest of Denver signaled the end of the interstate era in 1993. The Colorado Department of Transportation kept busy with maintenance and construction small stretches of highway for the rest of the 1990s. However, a series of potholes forming on the state's most traveled highway signaled the start of the next important chapter in the Colorado's highway history.

On May 5, 1996, a three-foot hole, nearly 18-inches deep, opened in the center lane of the Interstate 25 bridge carrying traffic southbound traffic over Yale Avenue. A few days previous, another pothole dropped fist-sized rocks of concrete on to the highway below. Repair crews tamped quick-setting concrete into the holes, and CDOT completely rebuilt the Yale Avenue bridge in 1997 (Colorado Department of Transportation, 2002).

The potholes symbolized only one of many transportation headaches on I-25 from Southeast Denver to Douglas County. By the late 1990s, CDOT sought help from metro Denver's Regional Transportation District (RTD) to stem the rising tide of traffic through this corridor. In 1999, voter approval of a $1.67 billion reconstruction project through this corridor gave the green light to CDOT and RTD to improve 17 miles of two interstate highways in metro area and add 19 miles of light rail transit line. Under the Transportation Expansion (T-REX) project, both organizations aim to increase transit options, enhance safety for motorists and replace aging infrastructure. CDOT's planned highway improvements include:

- Four through lanes in each direction on I-25 from Logan Street to I-225
- Five through lanes in each direction on I-25 from I-225 south to the C-470/E-470 interchange
- Three through lanes in each direction on I-225 from I-25 to Parker Road in Aurora

CDOT will also improve inside and outside shoulders, replace bridges, interchanges and drainage and upgrade acceleration/deceleration lanes or collector/distributor roads between the interstate and local roads (Colorado Department of Transportation, 2002).

Annually, the Colorado Department of Transportation expends a good deal of money and attention toward problems beyond a 17-mile corridor south of Denver. Year-round heavy traffic, and winter ice and snow, will always demand maintenance of the state's roads. According to the FY2000 budget, CDOT apportioned $124.5 million, or $960.3 of its total funding (roughly 13 percent) toward maintenance (Colorado Department of Transportation, 2000(a): 32).