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GEOLOGICAL SURVEY

ENGINEERING GEOLOGY AS APPLIED TO HIGHWAY CONSTRUCTION

by

Leonard M Gard, Jr.

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

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ABSTRACT

A geologic study of the site for a relocated segment of State Highway 93 northwest of Denver, Colo., was made by the Engineering Geology Branch of the U. S. Geological Survey as a demonstration of the applicability of geologic mapping to problems of highway construction. The relocated segment provides access to the Rocky Flats plant of the Atomic Energy Commission.

The geologic conditions along five miles of the relocation route were examined. In most places apparently well-indurated sandstones of the Upper Cretaceous Fox Hills sandstone and Laramie formation can be excavated without using explosives. The intersection of a six foot thick coal seam in the roadbed in one proposed cut was predicted and removal and replacement with more suitable subgrade material was recommended Near Marshall the alignment crosses three northeast-trending normal faults which do not adversely affect the highway.

Clay minerals with expanding properties are present in some of the claystones of the Laramie, and special measures must be taken to ensure that ground water will not seep into them and cause swelling beneath the roadbed. Late Tertiary or Early Quaternary gravels cap pediments along the mountain front. Ground water issuing from seeps and springs found at the contact between these gravels and the underlying bedrock should be intercepted and removed from beneath the roadbed.

ENGINEERING GEOLOGY AS APPLIED TO HIGHWAY CONSTRUCTION

PART I

Background for Engineering Geology

"Engineering geology is not a branch of the science of geology; it is the application of all of the branches of the science to the practical problems of Engineering." (Burwell, 1950, p. 2.)

As all civil engineering structures are constructed on or in the earth's crust and often are composed of natural materials from the earth's crust it behooves those who design and build these structures to know as much as possible about these materials. The fundamental reasons for using geological information in engineering are to reduce costs and promote safety. Examples of these reasons may be found in many textbooks and papers on Engineering Geology. (Legget, 1939; Paige, 1950; Ries and Watson, 1936.)

The increased use that engineers are making of geology in the solution of a great variety of problems involves little essential change in the present techniques of the geologist. Naturally, the more well rounded and experienced the geologist is, the better equipped he is to assist in answering geological problems that arise in engineering practice. Because the fields of geology and engineering are both vast in scope, it is indeed a rare individual who is accomplished in both. It is necessary, however, that both geologists and engineers have sufficient knowledge of the other's field to appreciate their problems and to recognize how geology can assist in solving engineering problems.

Geologic reports written for the engineer must be written with clarity and simplicity if they are to be of any value. If the engineer cannot understand a geologic report he will not use it. The geologist who hides behind technical jargon and an aura of profound preoccupation will not be able to convey his ideas to the engineer and, as a resutl, engineers who come in contact with this type of geologist will lose confidence in geology.

Geology Applied to Highway Construction

Geologic information has been applied in highway construction for many years but only recently has it come into general acceptance by engineers. As early as 1889 a report on highway materials was written (Hill, 1889). Since that time the demand for more and better roads, stemming from the advent and improvement of the motor vehicle, has required more and better knowledge or earth materials. In 1937 two states each employed a geologist in the highway department (Horner and McNeal, 1950, p. 157). In 1951, according to a survey of state highway departments (Horner and Dobrovolny, 1952) 23 of the 48 state highway departments employed a total of 89 geologists of which Kansas uses 15 and Pennsylvania uses 10. Of the remaining 25 states, many use consulting geologists but do not employ geologists full time. From this it becomes apparent that the application of geological data to highway engineering is rapidly becoming accepted in state highway departments.

Huntting (1945, p. 272) has outlined some of the ways in which a geologist (and therefore geology) can be utilized in highway construction. These are:

"1. Locating suitable road-surfacing material pits and quarries,

2. Determining the suitability of various earth materials for surfacing, concrete construction, and other highway uses;

3. Sub-grade treatment and classification;

4. Frost heave problems;

5. Predicting the character of material to be excavated;

6. Preventing and correcting landslides;

7. Appraising the competency of materials for bridge foundations;

8. Judging the desirability of bridge sites and road sites with respect to possible changes of stream channels,

9. Investigating proposed tunnel sites;

10. Investigating and predicting sub-surface water conditions and locating underground water supplies;

11. Evaluating mineral lands to be bought or condemned for highway location; and

12. Acting as witness in litigation "

Descriptions of geological formations merely as sandstone, shale, limestone, granite and the like, are of little value to an engineer. He is mainly interested in the physical properties of a lithologic unit so that he may evaluate it to determine how it will react under certain conditions and what equipment will be needed to excavate it. The engineer divides materials to be excavated into to categories, "rock" and "common." "Rock" to an engineer is any material that is consolidated enough to require the use of explosives to reduce it to a size that can be readily handled by his equipment whereas "common" encompasses those materials that can be handled directly by his equipment.

By accurate mapping and the application of sound geological principles to the problems of highway construction, the geologist can aid the highway engineer by predicting materials to be encountered and their properties and can foresee problems that may arise due to geologic conditions.

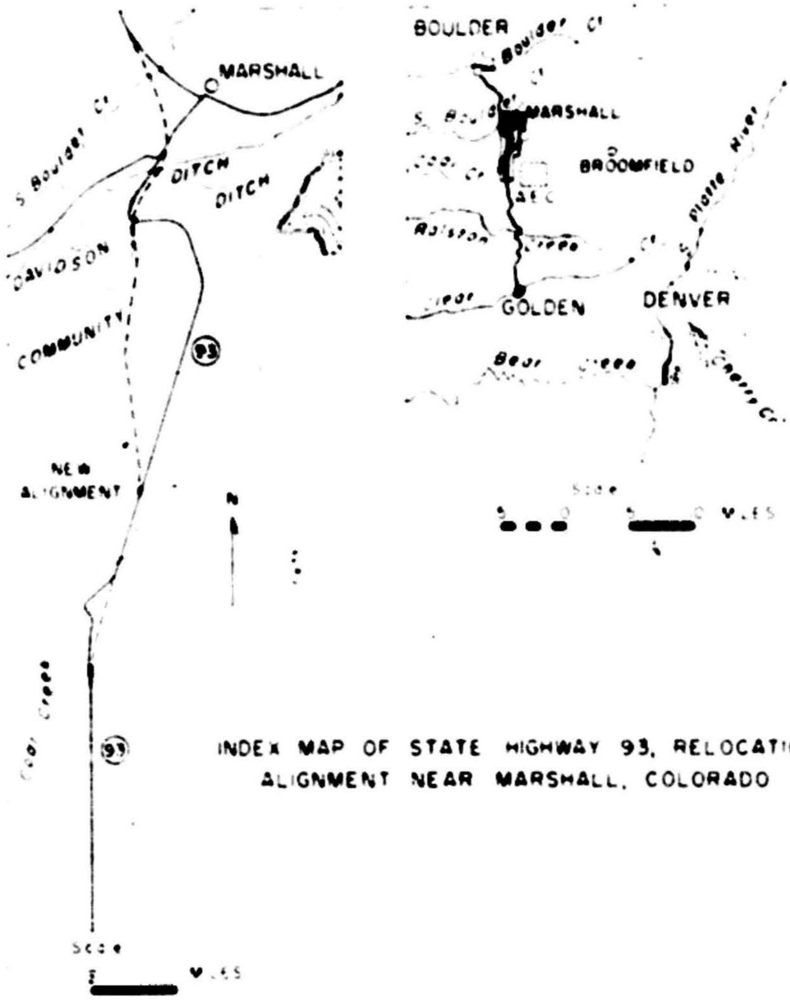
Part II of this paper is an example of a report on the engineering geology of a highway relocation In order to give the reader a better picture of the geologic setting, it contains more geologic background than is generally included in a report written for engineers.

PART II

Engineering Geology of the Relocation Alignment of State Highway 93 near Marshall, Colo.

Purpose of the investigation

The construction of the Atomic Energy Commission's Rocky Flats plant, northwest of Denver, has led to the improvement of part of State Highway 93 as an access road. In planning for the improvement of the north end of the road, the Colorado Department of Highways decided that a section of the road near the town of Marshall should be relocated to shorten it and to remove some steep grades and sharp curves. This relocation involved making a number of large cuts in bedrock. In the summer of 1953 the Engineering Geology Branch of the U. S. Geological Survey mapped a section of the relocation alignment as a demonstration of the applicability of geologic mapping to problems of highway construction. The purpose of the investigation was twofold; first, to provide geological data in a critical area, and second to demonstrate to the highway department the usefulness of geological data for good low cost highway design and the location of construction materials. The Colorado Department of Highways plans to hire a geologist and this survey would, in part, determine the type of work he will do and enable them to more correctly fit him into their organization As the request for this work was not made sufficiently far in advance to allow



INDEX MAP OF STATE HIGHWAY 93, RELOCATION ALIGNMENT NEAR MARSHALL, COLORADO

Figure 1

the geologic report to be completed prior to bidding for the contract, the highway department engineers of design, construction, and materials were taken on an inspection trip in the field and some of the more important recommendations were given them orally. Field mapping was done during July and August, 1953, and field checking was done at regular intervals as the construction took place.

Location

The project is located about 22 miles northwest of Denver and about four miles south of Boulder. It extends south from the town of Marshall to the Rocky Flats Atomic Energy Commission plant, a total length of about 5.2 miles.

Previous Geologic work

Early studies in the Denver Basin were made by Emmons, Cross, and Eldridge and the work published in U. S. Geological Survey Monograph 27 (1896). The structure of the Marshall area was mapped in 1935 as a thesis for the University of Colorado (J. F. Johnson, 1935). This previous work served to give a general picture of the geology of the area, but was of little assistance in the detailed mapping. Only a brief description of the general geology and structure will be given here For more detailed information, the reader is referred to the bibliography at the end of this thesis.

Acknowledgements

This opportunity is taken to acknowledge the guidance and supervision given by Ernest Dobrovolny of the U. S. Geological Survey and also the assistance and cooperation given by various members of the Colorado State Highway Department, especially for augering many of the test holes and the reproduction of Plates 10 through 63 of this paper.

Geology

The project is located on the west flank of the Denver Basin where sedimentary formations of Pennsylvanian through Paleocene age dip eastward into the Basin. This is on the western border of the Colorado Piedmont, a subdivision of the Great Plains Province. (Fenneman, 1931.) The geologic formations involved in the highway relocation are Pierre shale, Fox Hills sandstone, and Laramie formation, all of Upper Cretaceous age. These formations have been bevelled by several cycles of pedimentation. The bevelled surfaces are capped by late Tertiary or early Quaternary gravel. Later Quaternary terraces along the valleys of South Boulder and Coal Creeks are also capped by gravel.

Stratigraphy

Pierre shale. -- The Pierre shale is a gray-green to black marine shale. It is approximately 10,000 feet thick in this area (Lovering and Goddard, 1950, p. 39); but because it is soft and

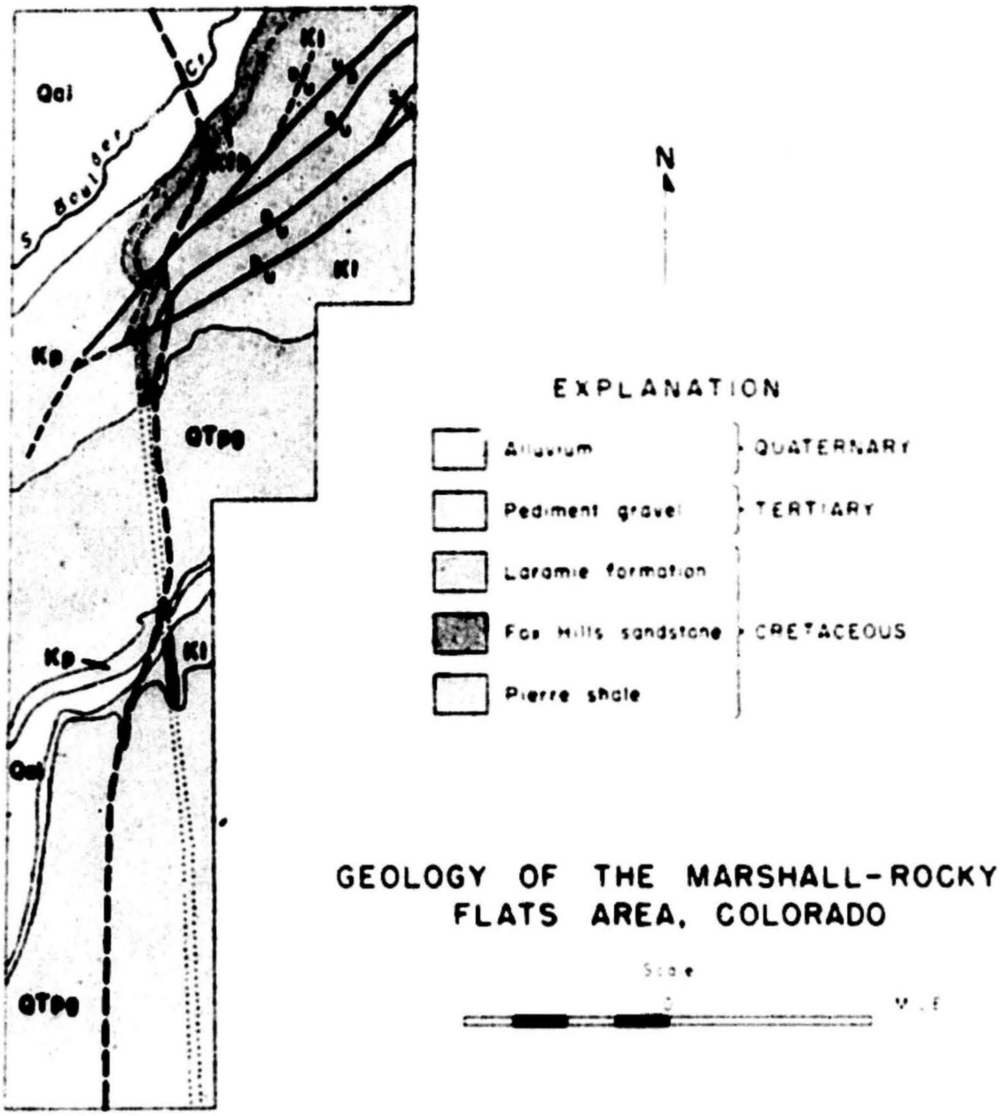


Plate 1. Geologic map of Marshall-Rocky Flats road relocation.

easily eroded, it is seldom exposed except in stream banks and man-made cuts. A nearly complete section of the Pierre is exposed in the Denver and Salt Lake Railroad cut seven miles north of Golden. (Moody, 1947.) The Pierre consists mainly of clayey shale with sandy lenses and a few thin bentonite seams. The upper half of the formation is more arenaceous than the lower half. Only the upper 800 feet of the formation was encountered in the highway relocation.

Fox Hills sandstone.-- The Pierre shale grades rapidly into the overlying Fox Hills sandstone which consists of buff to brown friable sandstone, siltstones, and sandy shale. Although the Fox Hills sandstone has been found to be as much as 550 feet thick, (Lavington and Thompson, p. 50, 1948) the maximum thickness measured in the vicinity of Marshall was 130 feet. Lovering and Goddard (op. cit., p. 40) have stated that, "The Fox Hills probably represents a near shore facies of the retreating Upper Cretaceous Sea."

Laramie formation.-- The Laramie formation, overlying the Fox Hills sandstone, is a series of alternating and lensing sandstones, siltstones, claystones, lignitic clays, and coals. This formation is of continental origin and has an average thickness of 600 feet (Lovering and Goddard, 1950, p. 40). Gude (1950, p. 1701) measured a thickness at Golden of 540 feet. This project involves only the lower 132 feet of the Laramie which is repeated by faulting several times along the alignment. Claystones predominate and contain the clay minerals kaolinite, illite, and montmorillonite (Gude, 1950). The sandstones are fine- to medium-grained and may grade laterally into siltstones in a short distance. The sandstones commonly lense with the claystones and marked changes in thickness are not unusual. The sandstones are friable and porous except locally where they are cemented with iron oxide.

Coal has been mined in the Marshall area since 1863. No mines are presently being operated but one was operated as recently as 1948. The area is dotted with abandoned mines, many of which were abandoned as early as 1881 (Emmons, Cross, and Eldridge, 1896, p. 347). At least one mine had caught fire prior to 1881 (op. cit., p. 348) and coal seams are still burning in at least three places.

There are at least four more or less continuous coal seams here, but only one of them is thick enough to be mined profitably. These coal beds are extremely useful locally for stratigraphic correlation of the Laramie

Correlation between various measured sections of the Laramie formation was found to be impossible because of the rapidly changing lithology. No correlation was made between the Laramie section in the Marshall area and the section measured at Coal Creek for the same reason. A composite section was made from auger hole information along the center line of the highway alignment (Fig. 2). Sometimes when it was not possible to correlate the geology between 100 foot stations on the profile due to the changing lithology, cross sections were made every 50 feet or less. (See Methods of Investigation, p. 15.)

Pediment gravel. -- Several gravel covered, partly dissected pediment surfaces of different levels exist at the edge of the Rocky Mountains in this area. At least three surfaces have been recognized by H. E. Malde, Geologist, U. S. Geological Survey. The highway alignment crosses only one, the Rocky Flats pediment, a bevelled bedrock surface capped by as much as 50 feet of gravel. Worcester (1939, p. 250) has called this feature a "pediment-topped, fan-topped pediment."

The age of both the bedrock cut surface and the gravel is in doubt. It has been implied indirectly (Wahlstrom, 1947) that the Rocky Flats surface could be no older than middle or late Pleistocene. However, according to Van Tuyl and Lovering (1935, p. 1327) the surface is the correlative of their Crodell berm and is late Pliocene in age. They correlate the Orodell berm with Worcester's (1931) upper Pliocene High Mesa Gravel. The surface relief of the pediment gravel is no more than five feet, although the underlying bevelled bedrock has as much as 50 feet of relief. The large amount of relief on the bedrock is due to resistant beds, such as the sandstone in the basal Laramie formation, withstanding pedimentation.

The valleys of South Boulder Creek and Coal Creek contain several gravel-capped terrace levels of Pleistocene age. Late Pleistocene gravel has filled channels in the Rocky Flats gravel. The Pliocene and Pleistocene gravels are similar and have not been considered separately in this report. Both gravels contain sandy and silty lenses. There is a definite decrease in the grain size of the gravel from the mountain front to the eastern edge of the pediment; however, as the highway alignment traverses the pediment in a north-south direction, the size of material encountered from place to place along the highway is about the same. The material ranges in size from clay-sized particles to boulders ten feet in diameter. Sub-angular to rounded fragments of quartzite, granite, gneiss, schist, and sandstone (usually Fountain and Dakota) are common.

Structure

The dominating regional structure is the east-dipping foothills monocline, which is broken at a number of places along the foothills by west-dipping, north-trending high angle reverse faults; northwest-trending normal faults, which die out in en echelon folds in the sedimentary rocks to the southeast; and northeast-trending faults, which are both normal and reverse. "The faulted monocline in reality represents the east limb of the great Front Range anticline formed during the Laramide revolution which culminated at the close of Denver time." (Van Tuyl et al, 1938, p. 24-25.) The sedimentary formations involved in this folding are Pennsylvanian through Paleocene (Reichert, p. 47, 1954) in age. Along the Front Range these formations generally dip eastward into the Denver Basin. The Upper Cretaceous formations in the project area generally strike nearly due north and dip eastward at 45 to 75 degrees, but at the north end of the project, near the town of Marshall, the strike of the Fox Hills, Laramie, and at least upper Pierre swings eastward to N 65° E and the dip decreases to 10° SE. Near Marshall the Fox Hills and Laramie are broken by a complex series of northeast-trending faults that have only 50 to 100 feet of displacement. Probably at least the upper part of the Pierre is also broken by these faults. However, no evidence was found to support this assumption. Most of the faults in the Marshall area are normal faults with the northwest sides downthrown. Mapping by the Fuels Branch of the U. S. Geological Survey in the Erie, Louisville, and Lafayette coal fields east and northeast of this area has revealed that the northeast-trending faults are far more common than was previously believed. Although most of these are normal faults with the northwest side down-thrown, some are reverse faults and some are hinge faults. Small horsts and grabens also complicate the structural picture.

Engineering Significance of the Geology

Methods of Investigation

Stratigraphic sections were measured and the geology was mapped by plane table. Because a large part of the area is covered by a mantle of soil and gravel, much of the geologic information found on plates 10 to 63 was determined from auger hole information.

For the benefit of the reader who is unfamiliar with the terminology and procedure used in highway surveying, the following description of the methods employed by highway engineers is included. The right of way and centerline of the relocation alignment of State Highway 93 had already been laid out by survey crews prior to the geological investigation. A stake of known elevation and location known as a station was placed every 50 feet along the centerline. These stakes were used in the plane table mapping as reference points and the centerline served as baseline. In laying out a highway centerline, these stations are always measured from one end of the project to the other. The stake 200 feet from the start of the project is known as station 2 + 00 (two plus zero zero). The next stake 250 feet from the start is station 2 + 50 (two plus fifty) and the next 3 + 00 (three plus zero zero) and so forth. Reference to right or left of the centerline is always made when facing in the direction of increasing station numbering and reference to direction along the alignment is referred to as "ahead" or "back."

The geology was mapped by plane table for purposes of constructing a structure contour map. Because of the abrupt changes in the lithology of the Laramie, the lack of good marker horizons, and the paucity of outcrops in many places, structure contouring was abandoned and the stratigraphy was determined along the right of way by test augering and test pitting.

A total footage of more than 728 feet was augered in 111 holes. The Highway Department made available a truck-mounted power auger, but the majority of the holes were augered by hand. The Highway Department provided a plan and profile_/ of the highway alignment on a

_/ A profile of the alignment is a drawing showing a vertical section of the highway alignment cut parallel to the alignment on the center line.

horizontal scale of 100 feet to the inch and a vertical scale of 10 feet to the inch. Cross sections made at right angles to the center line were provided at every 100 foot station and at some 50 foot stations at a scale of 5 feet to the inch. The geology was plotted on the cross sections from auger hole information and transferred to the center line profile. Thus with information at least every hundred feet along the center line profile, the geology could be interpolated between these points. By plotting the geology on the alignment profile and cross sections the contractor, resident engineer, and members of the Highway Department were provided with a geological picture superimposed on the plans with which they were familiar and would use during construction (see Plates 10 through 63).

By using information from the cross sections and the center line profile it is possible to construct a three dimensional picture of the geology at any given place along the right of way, thus enabling an accurate prediction to be made of the geologic materials that will be encountered during construction. Plate 6 is an isometric block diagram of the cut between stations 89+00 and 92+00 that was constructed in such a manner.

Geologic formations

Pierre shale. -- The Pierre shale is encountered in road cuts on both sides of Coal Creek. Prior to construction the Pierre-Fox Hills contact was determined to occur at station 141+45, where it crosses the proposed cut at an angle. This was confirmed when the cut was excavated in February 1954. On the south side of Coal Creek the investigation was assisted by test pits and trenches made by a cement company which was sampling and testing the Pierre shale. The Pierre shale usually is easily removed with power equipment and is classified as "common." No bentonite seams were observed to occur where the Pierre shale was to be exposed in road cuts. On the south side of Coal Creek a situation occurred that indicates some of the hazards of engineering geology. From all available data it appeared that the Pierre shale could readily be excavated with power equipment. The proposed cut was not investigated by augering to it's full depth because the available power auger was not capable of drilling to a depth of more than 20 feet. When the cut was excavated, an arenaceous zone in the upper Pierre shale was encountered that required blasting of some 3,000 cubic yards of material (Plate 7). This kind of experience tends to prevent the engineering geologist from becoming complacent and smug.

Fox Hills sandstone. -- The Fox Hills sandstone was encountered at two places in the project, on the north side of Coal Creek, as mentioned above, where it is in contact with the Pierre shale, and in the large cut made between stations ten and sixteen near Marshall (Plate 2). At the latter place a cut was made through a flat-topped ridge

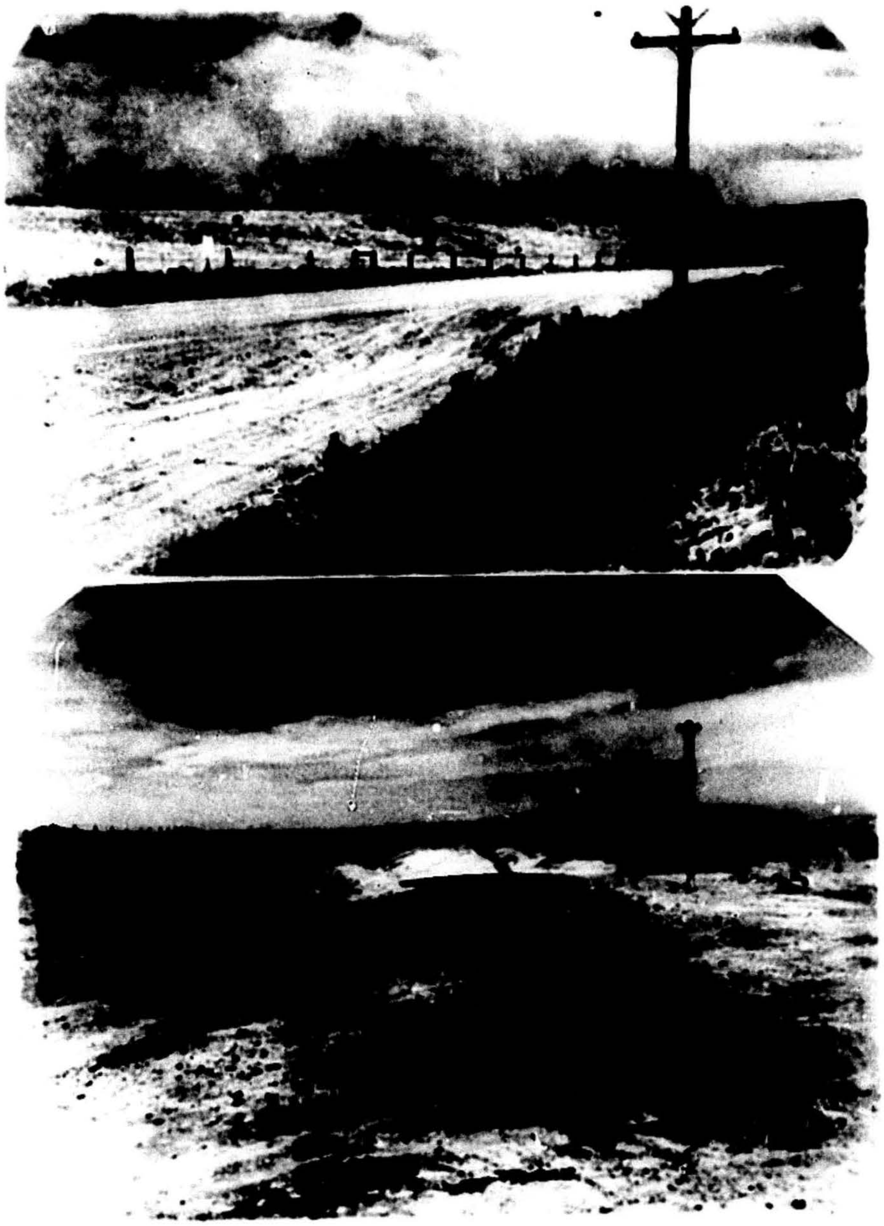


Plate 2. A. Looking back (north) from station 24. Before excavation of proposed cut at station 16.
B. After excavation of same cut. Gravel capped Pleistocene terrace on Fox Hills sandstone. Dark line on cut bank is lignite seam at base of Laramie dipping toward lower right corner of photo.

formed by the Fox Hills sandstone and the basal sandstone of the Laramie formation. This ridge, a Pleistocene terrace of South Boulder Creek, has a bevelled bedrock surface capped by five to eight feet of coarse gravel. Although the Fox Hills gives the appearance of being well indurated, it is friable and poorly cemented and was readily removed by power equipment. The Fox Hills is permeable, but, as it dips away from the road here, water percolating through this formation will not accumulate beneath the road.

Laramie formation. -- The majority of the project involves the Laramie formation. The base of the Laramie, a sandstone bed separated, in this area from the Fox Hills by a seam of lignitic shale, is exposed in the cut at station 15 nearMarshall. From this cut to station 33, the road rises in the Laramie section and crosses two thin coal seams at stations 22+50 and 26+50. From station 33 to station 52 the road lies on a sandstone member of the Laramie. Either one or both of the underlying thin coal seams have burned, causing minor collapse of the overlying shales and sandstone. The sandstone at the surface is well cemented by iron oxide, but the collapse has fractured it into pieces small enough to allow its removal with power equipment.

At station 52 the Laramie formation is broken by a normal fault striking N 55° E. The northwest side of the fault is downthrown which causes the geologic section to be repeated. In the ditch on the south side of the fault, the upper part of the basal Laramie sandstone again crops out. On this side of the fault, the upper part of this sandstone is cemented by iron oxide and had to be blasted before removal Ground water has deposited iron oxide in fractures and pervious bedding planes in some of the Laramie sandstones, which forms extremely hard zones that resist weathering A good example of this can be seen near station 58

South from the fault at station 52 the road again rises in the Laramie section and recrosses the two thin coal seams that were found at stations 22+50 and 26+50

The sandstone member that was so well cemented between stations 33 and 52 is less well cemented where it crops out at station 62 and could be broken loose with a ripper.

The presence of a six foot thick seam of coal in the proposed roadbed at station 64 was determined prior to construction There was no surface indication of this coal seam. Because of the unstable nature and low bearing strength of coal, it was recommended in the field that the coal be removed and replaced with a more suitable subgrade material.

At station 65 the highway crosses a normal fault that strikes northeast and is down-thrown on the northwest side (Plate 3). This fault has brought the six foot thick coal seam nearly in contact with the same sandstone bed that crops out at the surface between stations 33 and 52 and at station 62. The sandstone is stratigraphically nearly 55 feet below the coal. Local inhabitants indicated that the High View mine, which was on the northwest side of the fault, had been abandoned because the coal had been faulted out. A new mine, the Premier, was

Plate 3. Fault at station 65. Coal seam at left has been dragged up along fault in center of photo.

started on the south side of the fault, but also was abandoned when the coal was again offset by a fault that is believed to cross the highway alignment near station 68 (Plate 4). The faults that cross the highway alignment at stations 52, 65, and 68 will not have any adverse effect upon the highway. The fault at station 68 is in a gully and crosses beneath a fill. The faults at stations 52 and 65 cause the same iron oxide cemented sandstone to crop out at three different places along the realignment. The Laramie is present continuously in road cuts from station 15 to station 107 except between stations 91 and 102 where it is buried beneath pediment gravel.

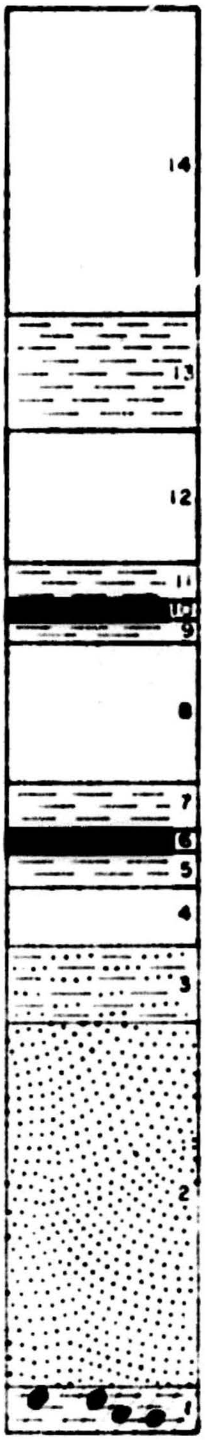
Figure 2 is a composite lithologic section of the Laramie formation measured along the right of way. It soon became apparent that the thicknesses and lithology of all units vary considerably over short distances. The lithologic units commonly are lenticular but no attempt was made to portray this in the column. Thicknesses shown in the column are the ones most closely approximating those shown on the profile.

<u>Pediment gravel</u>. -- The pediment and terrace gravels are classified as "common" excavation. The gravel capping the Rocky Flats pediment contains many badly decomposed fragments, which would prohibit its use as concrete aggregate or road metal. As little concrete was used on this project, the problem of locating a source of concrete aggregate did not arise.

Strati-graphic section	Unit No.	Description
covered		
	23	Shale, gray
	22	Sandstone, buff, fine grained
	21	Coal
	20	Lignite
	19	Coal
	18	Interbedded shale and sandstone
	17	Coal
	16	Lignite
	15	Interbedded shale and sandstone

Fig. 2. Composite lithologic section of Laramie formation measured along right of way. Scale 1 inch equals 10 feet.

Fig. 2 (Cont'd)



14	Sandstone, fine grained, gray to buff. Locally upper 2.0 to 5.0 feet iron cemented.
13	Shale, gray to buff
12	Sandstone, fine grained, light gray to buff.
11	Shale, buff
10	Coal
9	Shale, gray
8	Sandstone, buff
7	Shale, buff
6	Coal
5	Shale, gray, weak and incompetent
4	Sandstone, buff, fine grained
3	Shale, gray to buff, silty
2	Sandstone, massive, friable
1	Shale, lignit

Ground water conditions

Water entering and accumulating in permeable materials will in most cases cause considerable decrease in the stability of those materials. When this occurs in the sub-grade of a road it can decrease the stability of the sub-grade to such an extent that it will cause the pavement to fail under normal traffic loads. If montmorillonite clay minerals (Grim, 1953, p. 55) are present, the water will cause them to increase in volume which will cause rising and buckling of the pavement. In either case it is far more economical if these conditions can be anticipated and prevented during construction than to continually repair a road or attempt to rectify the condition after the road is completed.

A good example of the effect of clay expansion beneath a roadbed occurred about three miles east of Marshall on the Boulder-Denver Turnpike, which was completed in 1952, (Dobrovolny, 1953, p. 46). Here the Laramie formation dips gently toward the subgrade allowing ground water to move along a coal seam and saturate an underclay containing montmorillonite. The clay expanded causing one end of a concrete slab to rise eight-tenths of a foot. This, naturally, would have a disasterous effect upon vehicles using the highway, so the State Highway Department has had to raise the adjacent slab by mud-jacking to meet this rise. Mud-jacking is an expensive process. Had this situation been anticipated and drains installed during construction it would have been far less costly than it has been to correct. On the Marshall-Rocky Flats relocation alignment it was determined that all formations, fortunately, dip away from the road and this situation is

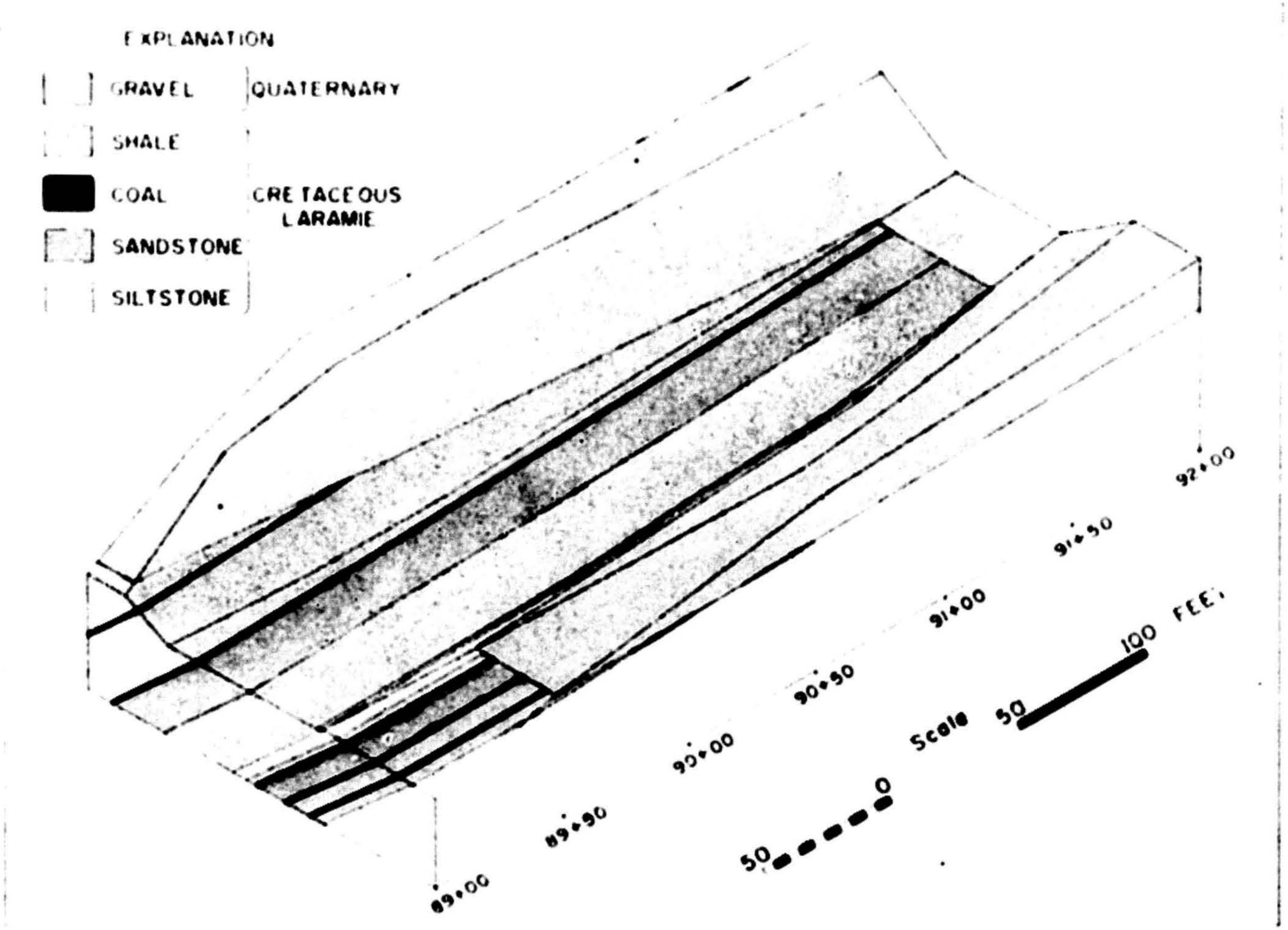
Plate 4. A. Looking back (north) from station 75 toward proposed cut from station 61 to 67. Center line of road lies to left of coal mine chute and tipple.
B. After construction of same cut. Thick coal seam (Fig. 2.) is seen behind cars. Same seam is seen above coal tipple on southeast side of fault. Collapsed tunnel indicates strike of seam. Another fault occurring in gully on near side of mine tipple has offset coal causing mines to be abandoned.

unlikely to occur because the more permeable lithologic units will tend to act as drains and lead water away from the road. However, the following ground water problem was present, but was not recognized by the Highway Engineers until it was pointed out to them in the geologic report.

There is little surface runoff from the pediment gravel. Water falling on the surface percolates down through the gravel until it reaches the bedrock surface. Because so much of the bedrock underlying the gravel is impervious (i.e. Pierre shale and shales of the Fox Hills sandstone and Laramie formation), the water migrates along the gravel-bedrock contact until it appears at the edge of the pediment in the form of springs and seeps. The bevelled bedrock surface as well as the gravel surface has a gentle dip to the northeast; therefore most of the water appears on the north and east edges of the pediments and terraces. The amount of water will fluctuate with the season, spring and summer having the maximum amounts.

Every place where the grade line of the road intersects the gravel-bedrock contact represents a potential source of trouble (Plates 5, 6). Near station 180, test pits were dug in the gravel by a cement company to test overburden thickness. The gravel here was nine feet thick. Many of these pits filled with water overnight to depths of as much as seven feet.

Plate 5. A. Looking ahead (south) from station 82 toward proposed cut at station 90. Note springs in gully below edge of pediment. B. After excavation of same cut. Note pediment gravel-bedrock (Laramie) contact in left cut bank. Bedrock dips 45° to left (east).



BLOCK DIAGRAM OF ROAD CUT FROM STATION 89+00 TO STATION 92+00

Plate 6

Water, migrating along the gravel-bedrock contact, reaching a pervious bedrock formation may percolate into this formation and seep out on the ground surface at some point on the edge of the pediment below the base of the gravel. An example is seen near station 90. The water seeps from the gravel-bedrock contact into a pervious sandstone of the Laramie formation and appears at the ground surface as a spring in a gully near the road. From the geological investigation it appeared that a lateral drain placed beneath the road, where the grade line intersects the gravel-bedrock contact, would intercept the ground water seeping into the sub-grade and also a large part of the water moving through the sandstone so that it would not come to the surface beneath the fill. The spring itself would be depleted and any water issuing from it would be intercepted by a ditch, thus protecting the fill from saturation.

Landslides

Many small landslides are to be seen on the edges of the pediments in this area They are of two types. The smaller slides generally involve only the surficial rubble that mantles the slopes bordering the pediments. In the larger slides bedrock also has been involved. They are lubricated by water from the seeps and springs that issue from the gravel-bedrock contact. An example of one of these large slides is south of the project where the road to Golden descends the pediment edge on the north side of Ralston Creek.

Plate 7. A. Looking back (north) from station 180 before excavation of cuts from station 166 to 183. Note Pleistocene terraces in valley of Coal Creek in middle distance
B. After excavation of same cuts. Foreground cut in Pierre shale capped by pediment gravel. Cut with trucks in arenaceous zone of Pierre shale capped by terrace gravel.

As the road descends into Ralston Creek Valley it traverses the surface of a large slide in the Laramie formation.

A slide occurred in a cut in the Pierre shale on the Marshall-Eldorado Springs road in the spring of 1953. An irrigation ditch just above the cut bank apparently supplied water which saturated the Pierre shale. When the cut was subsequently steepened by regrading, the stability of the material was upset and the slide occurred.

The relocated highway alignment will not be affected by major landslides.

Recommendations

Station 10/50 and 17/50 -- The contact between the capping gravel and the underlying Fox Hills sandstone will be intersected above the grade line and any water that might issue at the base of the gravel will effectively be carried in the ditches. Shaly zones are not anticipated in this cut, however, if they do exist, water deleterious to the road may be carried above the sandstone-shale contact and should be intercepted.

As the Fox Hills sandstone is evenly fine-grained and in this cut homogeneous, it may be considered to be isotropic in the sense that it will work the same in all directions. If shaly partings are present, they will alter this property to the extent that separation will take place more easily at the contact of sandstone with shale. The upper

5.0 feet or so are weathered which means the upper part will be removed with greater ease than the lower part. If the unweathered part of the sandstone is blasted, the material will pot out.

Surface observations reveal no cementation along the proposed center-line cut and it is believed that all of the material that will be removed will be "common excavation."

Station 23 to 28. -- Excavation will encounter sandstone, shale, and coal. Within a given unit the properties will, of course, be isotropic, but since the units alternate in lithology, i.e., sandstone, shale, and coal, separation will take place along the planes distinquishing one kind of rock from another. Even though the sandstones may be hard, the entire cut is considered to be "common excavation" because of the alternation of thin layers of hard and soft rock.

Coal and particularly the underclay are weak and incompetent and if allowed to become wet will expand. As these rocks dip slightly to the left and the cut will be daylighted_/ on the right it is assumed that moisture will not reach them. On the basis of existing knowledge, no sub-surface drainage is recommended.

_/ In this instance, the term "daylight" means making the cut slope horizontal on one side of a road cut. This is often done in road cuts on side slopes where there is a small amount of material to be removed. The material is used for fill elsewhere.

Station 35 to 49. -- All excavation will be in fine-grained sandstone. Along some portions of the center line the upper 2 to 4 feet have been iron cemented. The iron cemented part will work more or less as a unit. The sandstone below the cemented part will be harder to remove than the Fox Hills sandstone. Locally, however, it was possible to penetrate it two to three feet with a post hole auger.

All of the sandstone that has been iron cemented is "rock excavation." Approximately 4 feet below the top of the sandstone the material is considered to be "common excavation." It was not possible to verify this belief, but observations made at the surface indicate that such an interpretation is rational.

The surface of the sandstone is irregular because underlying coal seams have been burned out, causing collapse of the sandstone.

Station 49 to 52+12. -- Excavation will be in part in the same sandstone that is present from station 35 to 49. It will also include a shale below that sandstone. As it was possible to penetrate the sandstone at station 52+12 to a depth of 12 feet with an auger, it is not very hard. The materials are considered to be "common excavation" except for the small quantity of iron cemented sandstone that will be removed from the top part of the cut on both the right and left side.

On the basis of present knowledge, drains are not recommended.'

Station 52+12 and 53+00. -- Geology is not shown on the profile between station 52+12 and 53+00. This is because the precise location of a fault which passes through center-line was not definitely established. Beds adjacent to the fault are somewhat distorted and without additional investigation cannot be accurately delineated. Materials that will be excavated are sandstone and shale. As the sandstone does not appear to be well cemented, all of the materials that will be moved are classified as "common excavation."

<u>Station 61 to 67.</u> -- The sequence of rocks that will be encountered is represented on the attached natural scale profile (Plate 21). The sandstone shown at the surface at station 65 ≁ 50 has been cemented by silica. The distribution of silicification in this sandstone is imperfectly understood, but it is believed to pervade so much of it that the entire unit is classified as "rock excavation." All other rock units shown above grade line will be "common excavation."

The beds at station 61 ≁ 50 and at 65 ≁ 00 have been distorted because of collapse resulting from mining or burning of the underlying coal. For that reason, and also because faults of small displacement may be present, some of the contacts as shown may be in error.

<u>Station 75 to 81 ≁ 50.</u> -- The cut will be in weak and incompetent shales, sandstones, lignites, and coal. They represent a part of the geologic column that was established by augering because they are everywhere concealed by a thin mantle of colluvium. All material in this cut is "common excavation."

The rocks dip to the left. Because the rocks contain clay minerals that expand upon wetting and because aquifers in the form of sandstones are present, drains are recommended. As the only entrance of water to the roadway is from right to left in conformity with the structure, subsurface drains are suggested for the right shoulder only. They should extend throughout the length of the cut on the right side. To be certain of intercepting all the water, stub drains are suggested for the right side of stations 76/50, 77/00, and 80/75. These should connect with the right longitudinal drain.

Stations 89 to 96. -- The upper part of the excavation will be in Tertiary(?) gravel and the lower part will be in weak sandstones and shales of the Laramie formation. All material in this cut will be "common excavation."

Adequate control data for determining the precise elevation of the contact between the gravel and the Laramie formation at the grade line was not secured. However, the deviation from the point shown will be relatively small and will affect the hydrology problem only in location. Water in small quantities will be encountered at about station 91/50. It should be intercepted by drains before it reaches the grade line. Recognizing that the location may have to be altered, the following is suggested. A lateral drain should be placed at station 92/00. This lateral which will intercept most of the water should connect with longitudinal drains on each shoulder of the road. The longitudinal drains should extend from station 92/00 to station 90/50 where they may empty into the ditch line.

Station 100+00 to 107+00. -- The overlying materials are Tertiary to Pleistocene gravels and the underlying material is shale of the Laramie formation. In this place the gravel is underlain by fine sand. All material in this cut will be "common excavation."

Penetration by auger to a depth of twenty feet at station 104 and 106 has proved conclusively that the lower part of the gravel, all of the sand, and the top of the shale are water saturated. The top of the shale has been altered because of this almost continual saturation. A zone of accumulations of secondary lime exists in and on top of the shale. Two alternate suggestions are offered for interception of sub-surface water.

The first suggestion is: a lateral drain should be installed at about station 102+00. This lateral should be connected with longitudinals in each shoulder of the road. The longitudinal drains should extend to about station 107+00. A second lateral, also connecting with the longitudinals, might be placed at station 104+00.

The alternate suggestion is: excavate the ditches to a greater depth than now planned and have ditches serve as drains. In this place it is possible to eliminate sub-surface drains because the source of the water is mainly overflow in the gravel from the valley at station 98+00. If this suggestion is followed, it is recommended that the ditches only be cut about two feet lower than is now planned. This area between the road shoulders should not be cut lower than now planned. To cut lower than now designed and then backfill to grade will produce a contact along which water will move..

If the suggestion that the ditches serve as drains is followed, the outer sides of the ditches will be almost permanently moist and during rainy seasons may be saturated.

The determination of which of the two alternative methods should be used will be based on a comparison of (1) cost of moving larger quantities in excavating deeper ditches and (2) cost of installing standard sub-surface interception drains.

Station 120 to 125. -- Excavation will be entirely in gravel. As the base of the gravel will not be cut, drains are not recommended.

Station 138 to 144. -- Excavation will be in gravel, Pierre shale, and Fox Hills sandstone. All materials are classified as "common excavation."

As the Fox Hills sandstone is porous probably it will carry any water that might be present in the gravels. Drains are not recommended on the basis of existing information.

Station 156 to 173. -- Excavation will be in gravel and Pierre shale and is classified as "common excavation."

As contact between the gravel and the Pierre shale will be above the grade line, surface ditches will be adequate to carry any water that issues from the contact. Very little water is expected because the catchment area is so small.

On the left side of the cut between station 168 and 171, a sand composes the lower part of the gravel. The expectable yardage is estimated to be approximately 2,000 yards. Additional testing will be necessary to determine its specific use, if any.

Station 178 to 186. -- Part of the excavation will be in gravel and part in Pierre shale. These materials are classified as "common excavation."

About sixty feet to the left of station 186 a pit excavated to a depth of 9 feet has, after opening, filled with water to within 2.3 feet of the surface. Because of channeling on top of the Pierre shale the gravel may not carry quite so much water at station 180 where the grade line intersects the contact. However, as the Pierre shale contains expansive clay minerals, even a small addition of water will cause swelling. Therefore, drains should be installed to keep the sub-grade dry. A lateral drain should be installed on the right at station 180/50 and connected with a longitudinal extending to about 179/00. As the left side of the cut will be daylighted the opening of the lateral may be in the left ditch.

Station 201 to 205. -- The contact between the gravel and the Pierre shale is well exposed in the ditch line of the existing road. The materials are classified as "common excavation."

A lateral drain is recommended at about station 204 to 205 connected with longitudinals extending to about 204.

PART III

Conclusions

Many phases of geology are called upon in the solution of engineering problems. Among the phases used in this investigation were: structural geology, sedimentology, stratigraphy, geomorphology, lithology, and hydrology.

Rarely will any one project be able to utilize more than a few of the geological services listed by Huntting (1945, p. 272). As a result of this investigation, geologic information will contribute to an overall reduction in costs by providing a basis for:

1. Predicting the material to be excavated thus preventing any serious error in bidding. Knowledge of the geology will eliminate much of the risk involved in bidding for either the State or the contractor.
2. Predicting where ground water problems will be encountered and recommending possible solutions to the problem. This will contribute to the length of life of the road and thus reduce maintenance costs.
3. Predicting sub-grade stability which will also reduce maintenance costs.
4. Predicting the presence or absence of potential or actual landslides.
5. In conjunction with No. 1 above, determining the type of material that will be used in fills.

The works of the engineer are becoming increasingly larger and more complex and therefore he is obliged to call upon more and more types of technical assistance in planning and construction. Geology is one of the valuable tools that can materially aid in the solution of many engineering problems.

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Explanation of Plates 10 through 63

Plates 10 through 21 are copies of the State Highway Commission's plan and profile sheets reduced to 1 inch equals 200 feet horizontal scale and one inch equals 20 feet vertical scale. The upper half of each sheet shows the plan of the highway alignment. No geology is shown on the plan. For the geologic map the reader is referred to Plate 1.

The lower half of each sheet shows the profile of the highway center line with the geology added. Along the bottom of the profile every fifth station is numbered and on either end of the profile the altitude above sea level is shown.

The following conventional engineering signs and symbols are the only ones essential to a basic understanding of the plan and profile.

Plan Symbols

Center line ———┼———┼———

Right of way line ——— — — — ———

County line ——— – ——— – ——— –

Township or range line — — — —

Section line ———————————

Quarter section line ——— ——— ———

Barbed wire fence ——•——•——

Telephone line ⌽ ⌽ ⌽

Power line ♦ ♦ ♦ ♦

Present road ==============

Profile Symbols

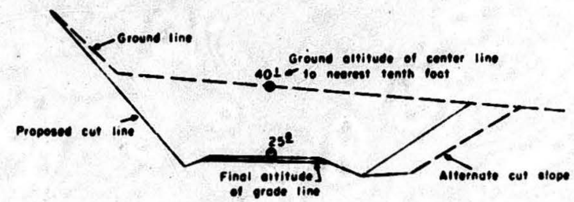
Ground line — — — — — — —

Highway grade (center line) ————————

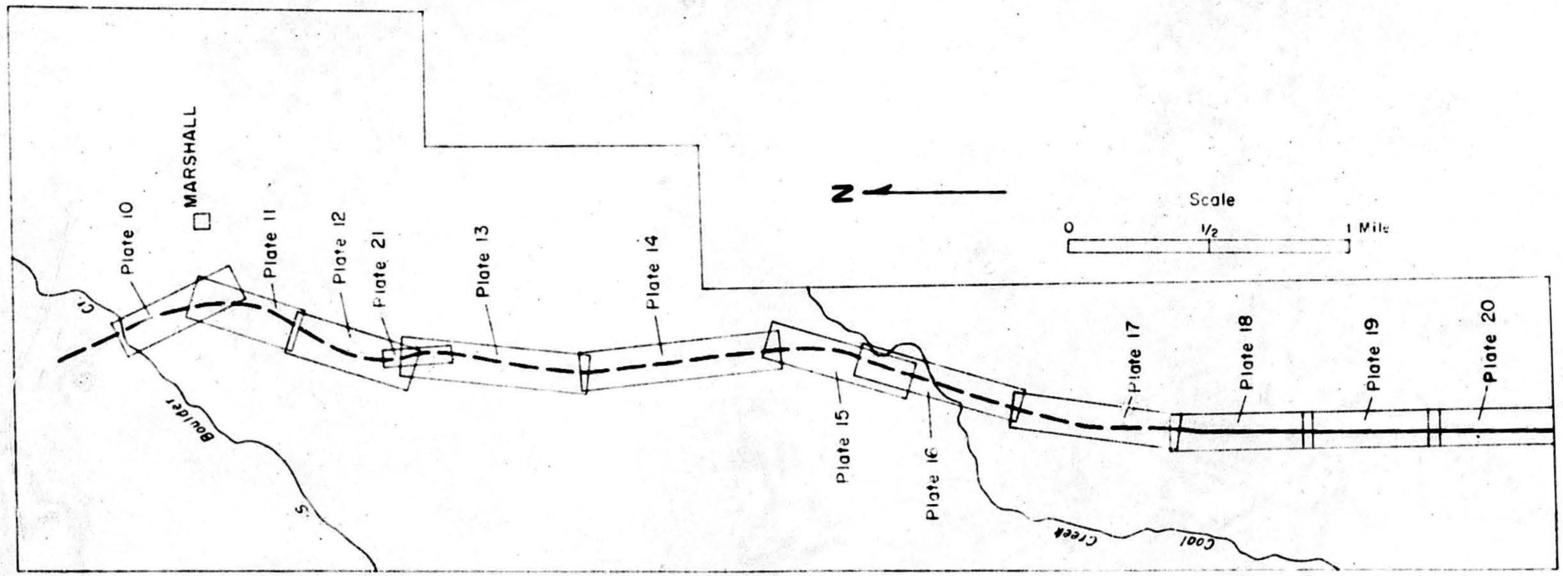
Plates 22 through 63 show reductions of the cross sections made by the state highway engineers at every 50 & 100 foot stations. The geology has been added to the more important of these cross sections. The scale is one inch equals ten feet both horizontally and vertically.

The following conventional engineering signs and symbols are the only ones necessary to a basic understanding of the cross sections. Cross sections are always made looking "ahead" (see p.   ) along the center line.

Cross Section Symbols



LOCATION OF PLATES 10 THROUGH 21 ON HIGHWAY ALIGNMENT



FED. ROAD DIV. NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO.	AA-13 UNIT 1	1	

Rev. – 8-21-53 – Index of Sheets – J.C.R.

COLORADO
DEPARTMENT OF HIGHWAYS

PLAN AND PROFILE OF PROPOSED
FEDERAL AID PROJECT NO. AA-13 UNIT 1
STATE HIGHWAY NO. 93
BOULDER AND JEFFERSON COUNTIES

INDEX OF SHEETS

TABULATION OF LENGTH AND DESIGN DATA

STATION	ROADWAY Lin. Ft.	BRIDGES Lin. Ft.	BRIDGES NO WORK Lin. Ft.	BRIDGES Loading
BOULDER COUNTY				
0+00 BEGIN AA-13 UNIT No. 1				
	13,194.4			
131+94.4 Bk. = Equation 129+31.6 Ah.				
	2,849.0			
157+80.6 Bridge 158+33.0		52.5		H-20-S16-44
	58.0			
158+91.0 Bk. = Equation 159+00.0 Ah.				
	979.8			
168+79.8 County Line				
JEFFERSON COUNTY				
	3,702.6			
205+82.4 Bk. = Equation 208+52.5 Ah.				
	5,032.5			
258+85 Bridge 259+28			43.0	H-18-44
	1,372.0			
273+00 END AA-13 UNIT No. 1 – BEG. AA-13 UNIT No. 2				
TOTALS	27,188.3	52.5	43.0	

SUMMARY

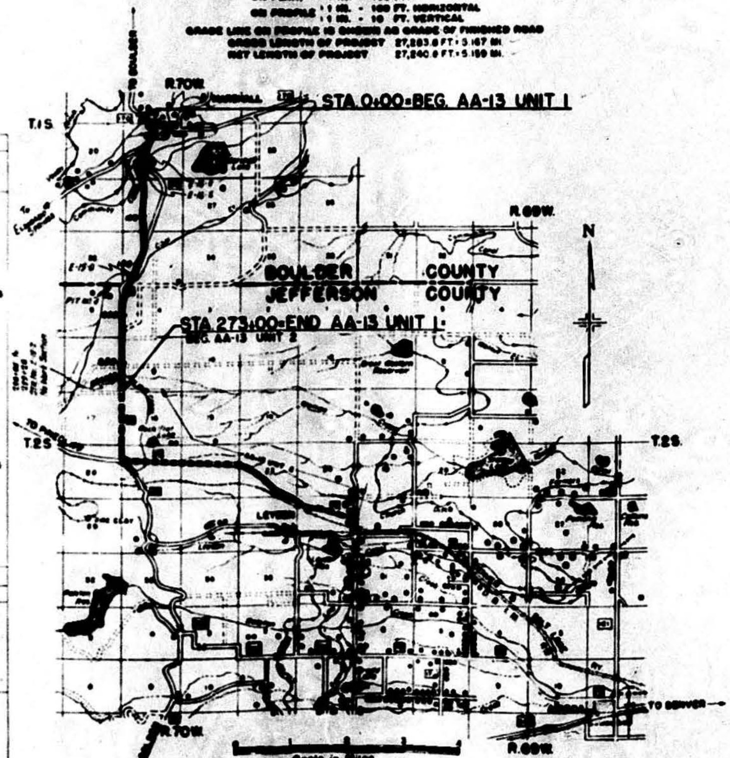
	LIN. FT.	MILES
AA-13 UNIT No. 1 - ROADWAY - BOULDER COUNTY	17,081.2	3.235
AA-13 UNIT No. 1 - BRIDGES - BOULDER COUNTY	52.5	0.010
AA-13 UNIT No. 1 - ROADWAY - JEFFERSON COUNTY	10,107.1	1.914
NO WORK SECTION	43.0	0.008
TOTAL AA-13 UNIT No. 1 - GROSS LENGTH	27,283.8	5.167
TOTAL AA-13 UNIT No. 1 - NET LENGTH	27,240.8	5.159

DESIGN DATA

MAXIMUM DEGREE OF CURVE	5°00'
MAXIMUM GRADE	7.00%
MINIMUM NPSD - horizontal	465'
MINIMUM NPSD - vertical	460'
MAXIMUM DESIGN SPEED	50 M.P.H.

SCALES OF ORIGINAL TRACINGS

ON PLAN, 1 IN. = 100 FT.
ON PROFILE: 1 IN. = 100 FT. HORIZONTAL
1 IN. = 10 FT. VERTICAL
GRADE LINE ON PROFILE IS SHOWN AS GRADE OF FINISHED ROAD
GROSS LENGTH OF PROJECT 27,283.8 FT. = 5.167 MI.
NET LENGTH OF PROJECT 27,240.8 FT. = 5.159 MI.



CONVENTIONAL SIGNS

CENTER LINE OF SURVEY
RIGHT OF WAY LINE
COUNTY LINE
TOWNSHIP OR RANGE LINE
SECTION LINE
QUARTER SECTION LINE
RAILROAD
BARBED WIRE FENCE
SNOW FENCE
TELEPH. & TELEG. LINE
POWER LINE
PRESENT ROAD (PLAN SHEETS)

NOTICE TO BIDDERS

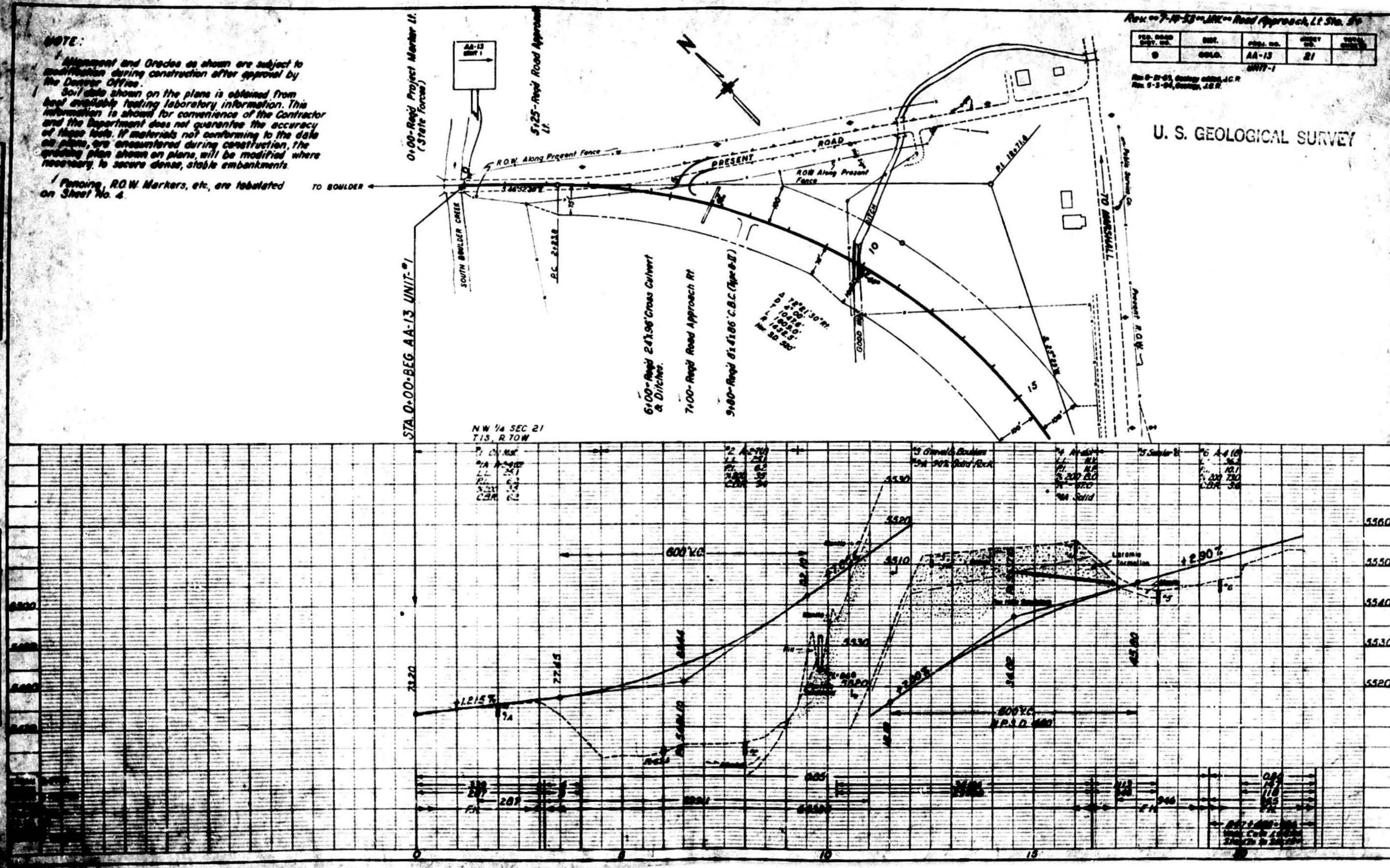
It is recommended that bidders on this Project go over the plan details with one of the following field representatives of this Department.
Glen McEldreney, Construction Engineer, Denver, Colorado.
Paul R. Morley, Resident Engineer, Denver, Colorado.

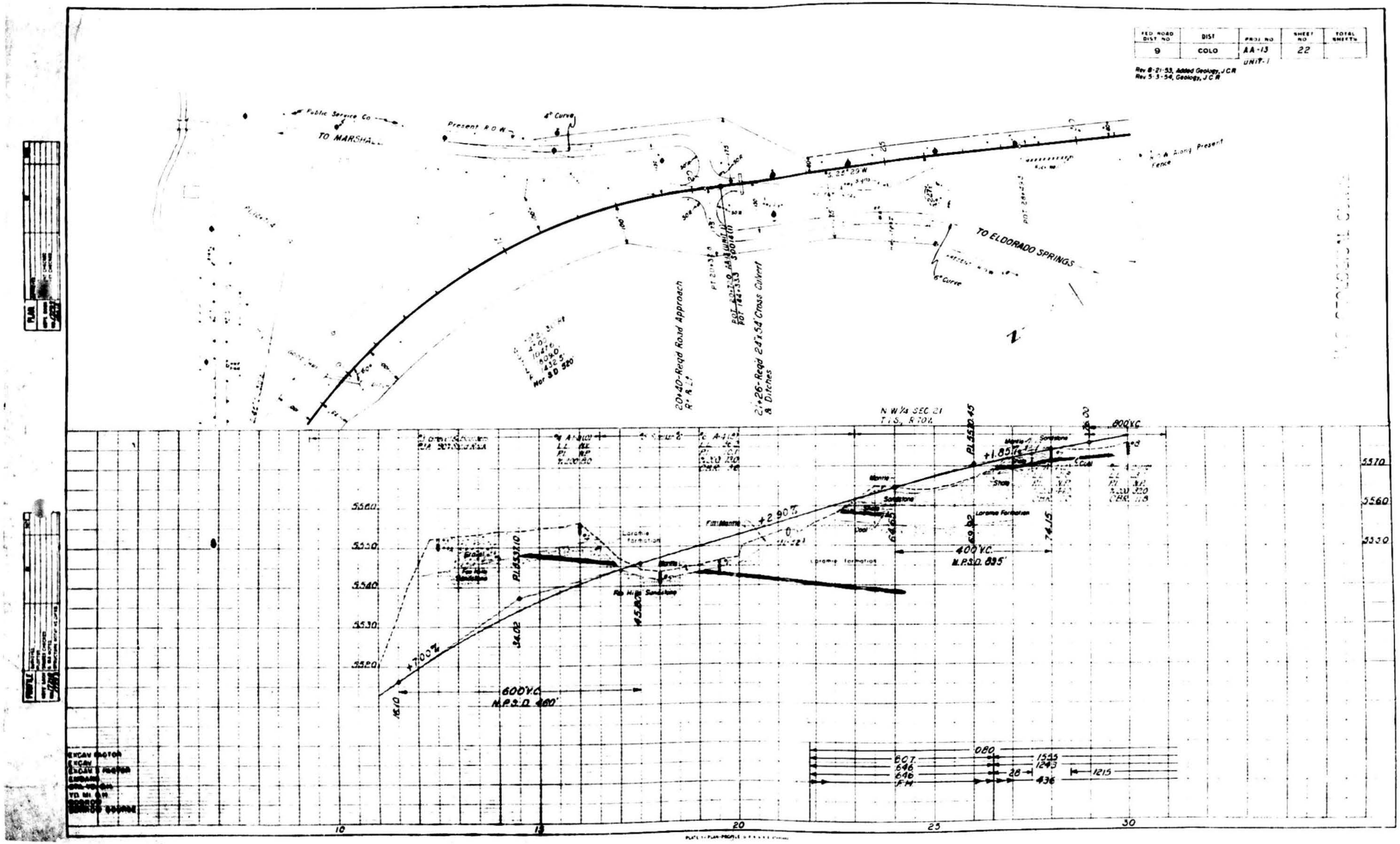
COLORADO DEPARTMENT OF HIGHWAYS

APPROVED: *Mark U. Watrous* 7-3-53
CHIEF ENGINEER DATE

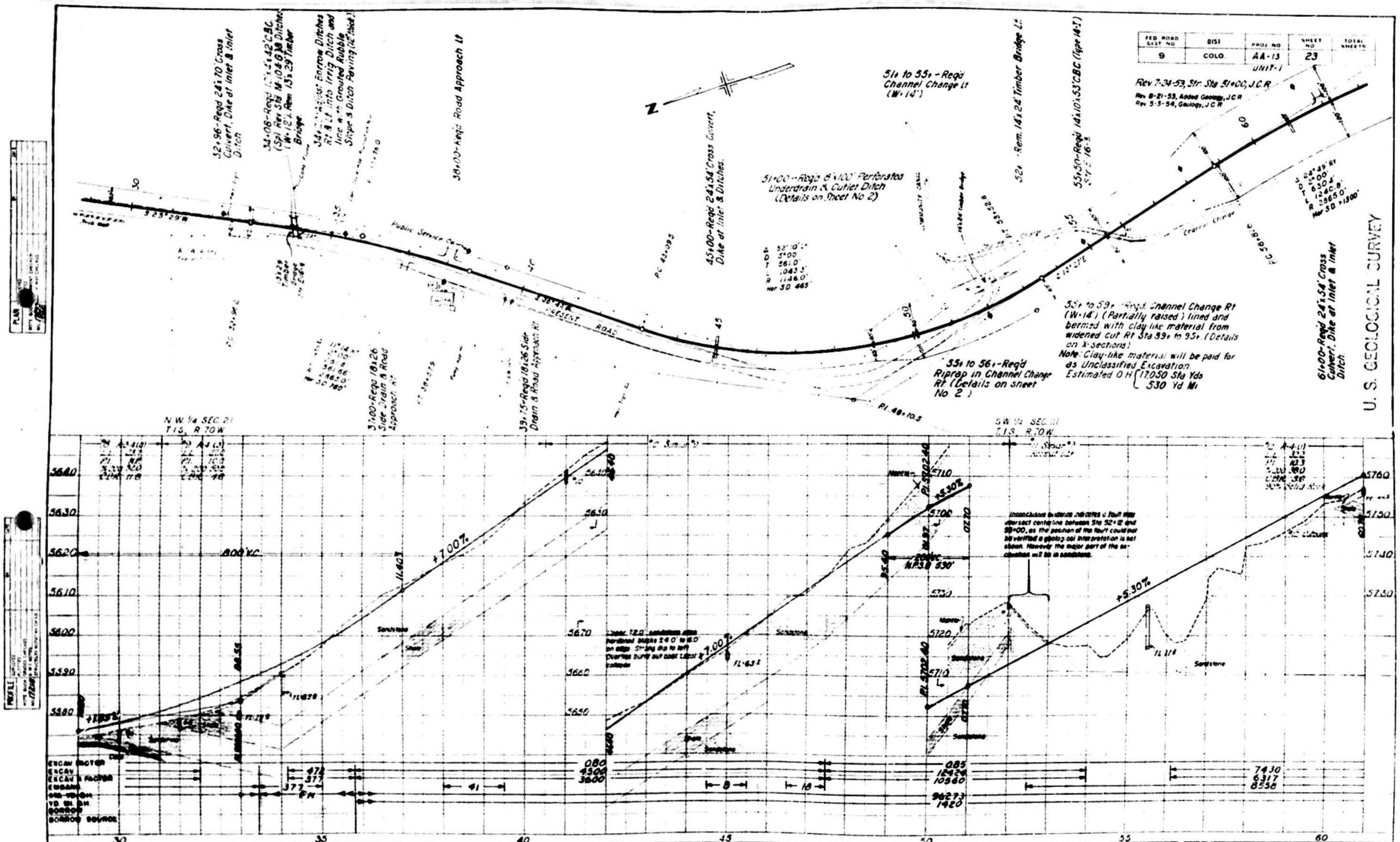
DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

APPROVED:
DISTRICT ENGINEER DATE

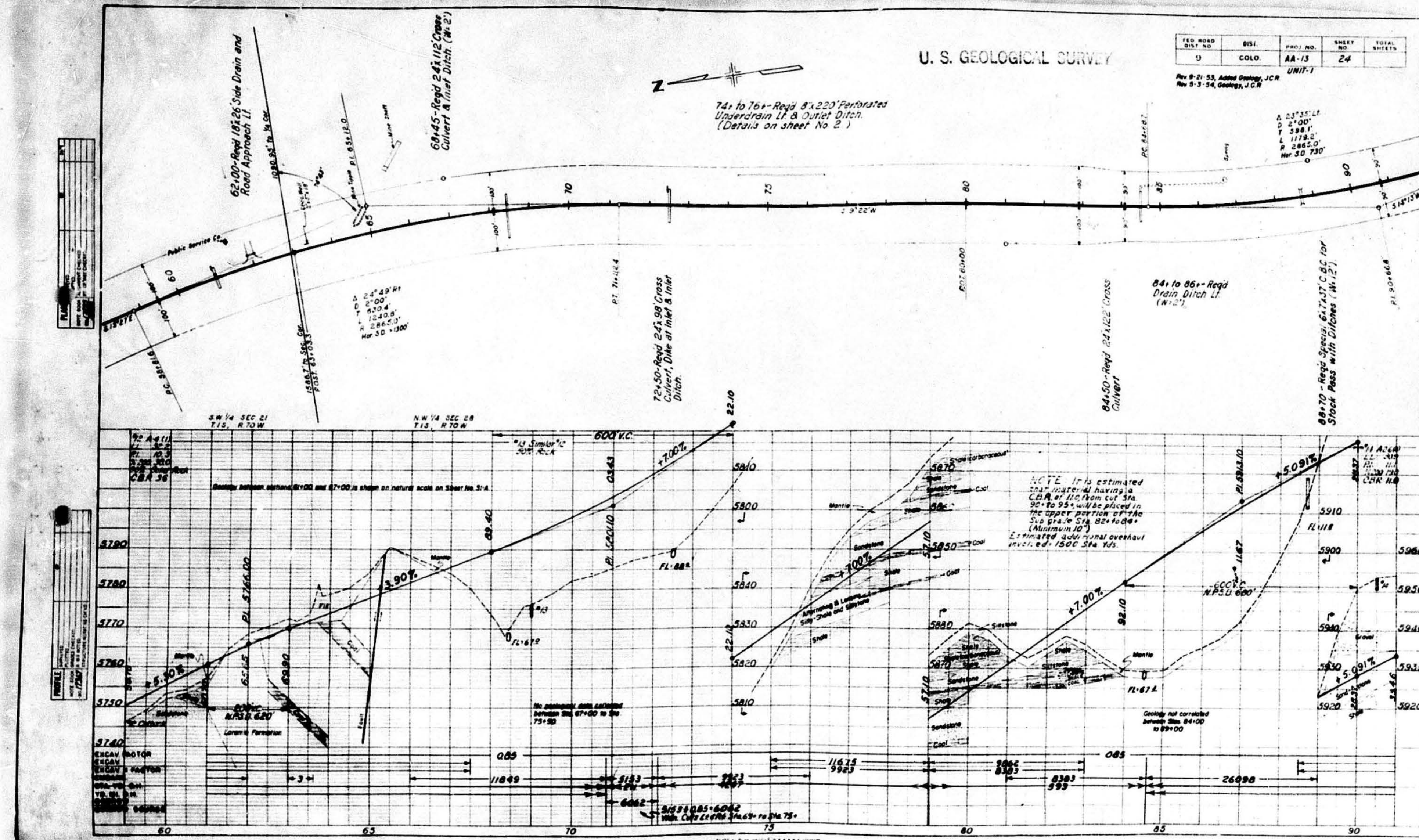

NOTE:
Alignment and Grades as shown are subject to modification during construction after approval by the Denver Office.
Soil data shown on the plans is obtained from best available testing laboratory information. This information is shown for convenience of the Contractor and the Department does not guarantee the accuracy of these tests. If materials not conforming to the data on plans, are encountered during construction, the grading plan shown on plans, will be modified where necessary to secure dense, stable embankments.
Fencing, R.O.W. Markers, etc., are tabulated on Sheet No. 4.
TO BOULDER
SOUTH BOULDER CREEK
0+00-Req'd Project Marker Lt. (State Forces)
5+25-Req'd Road Approach Lt.
R.O.W. Along Present Fence
PRESENT ROAD
ROW Along Present Fence
6+00-Req'd 24"x96" Cross Culvert & Ditches.
7+00-Req'd Road Approach Rt
9+80-Req'd 6'x4'x86' C.B.C. (Type B-II)
STA. 0+00-BEG. AA-13 UNIT-#1
NW 1/4 SEC 21
T 1 S, R 70 W
TO MARSHALL
Present R.O.W.
U. S. GEOLOGICAL SURVEY
Rev. 7-10-53 Road Approach, Lt Sta. 5+
AA-13
UNIT-1
21
600' V.C.
800' V.C.
+1.215%
+2.90%
Laramie Formation
5560
5550
5540
5530
5520
0
5
10
15
20

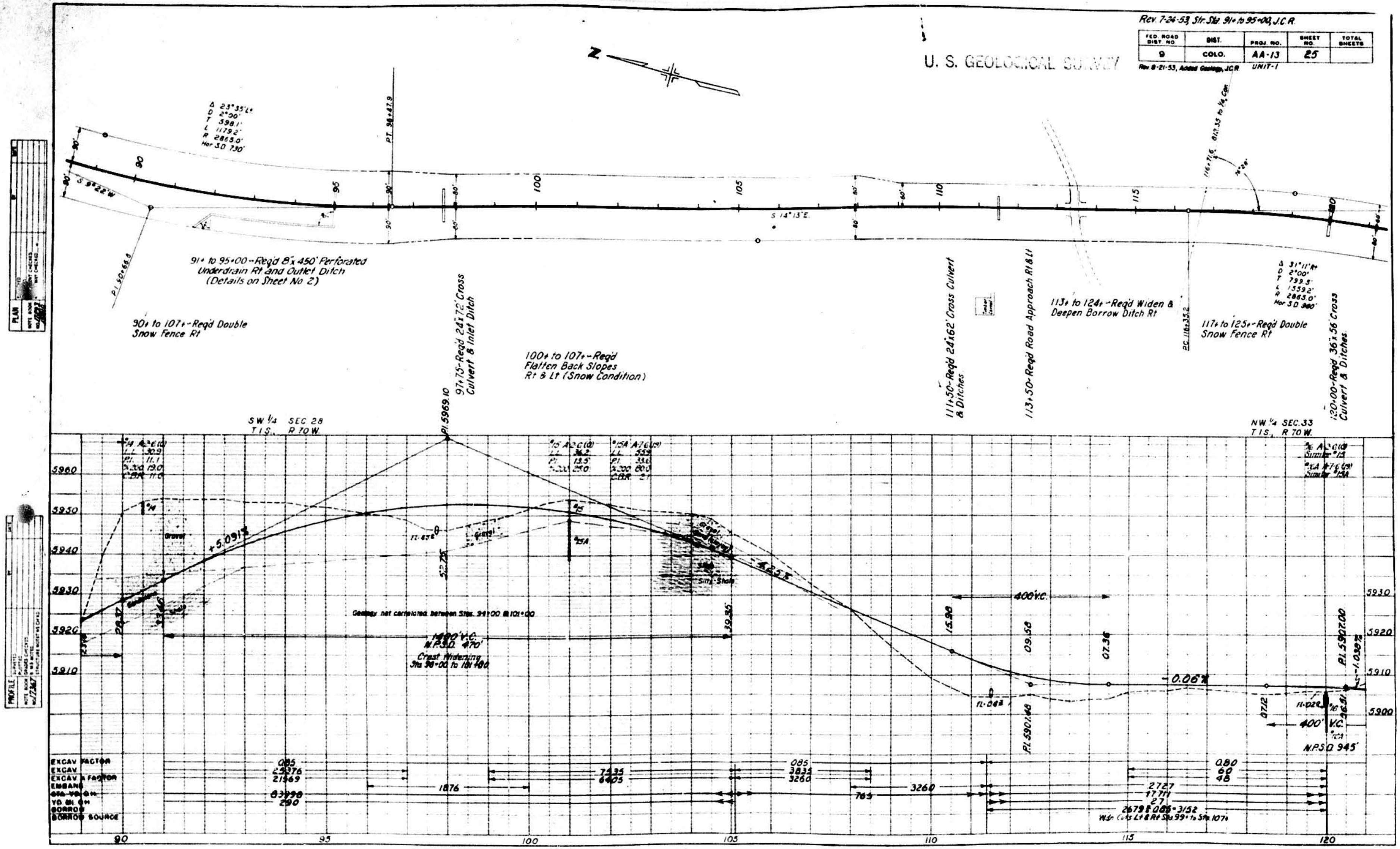


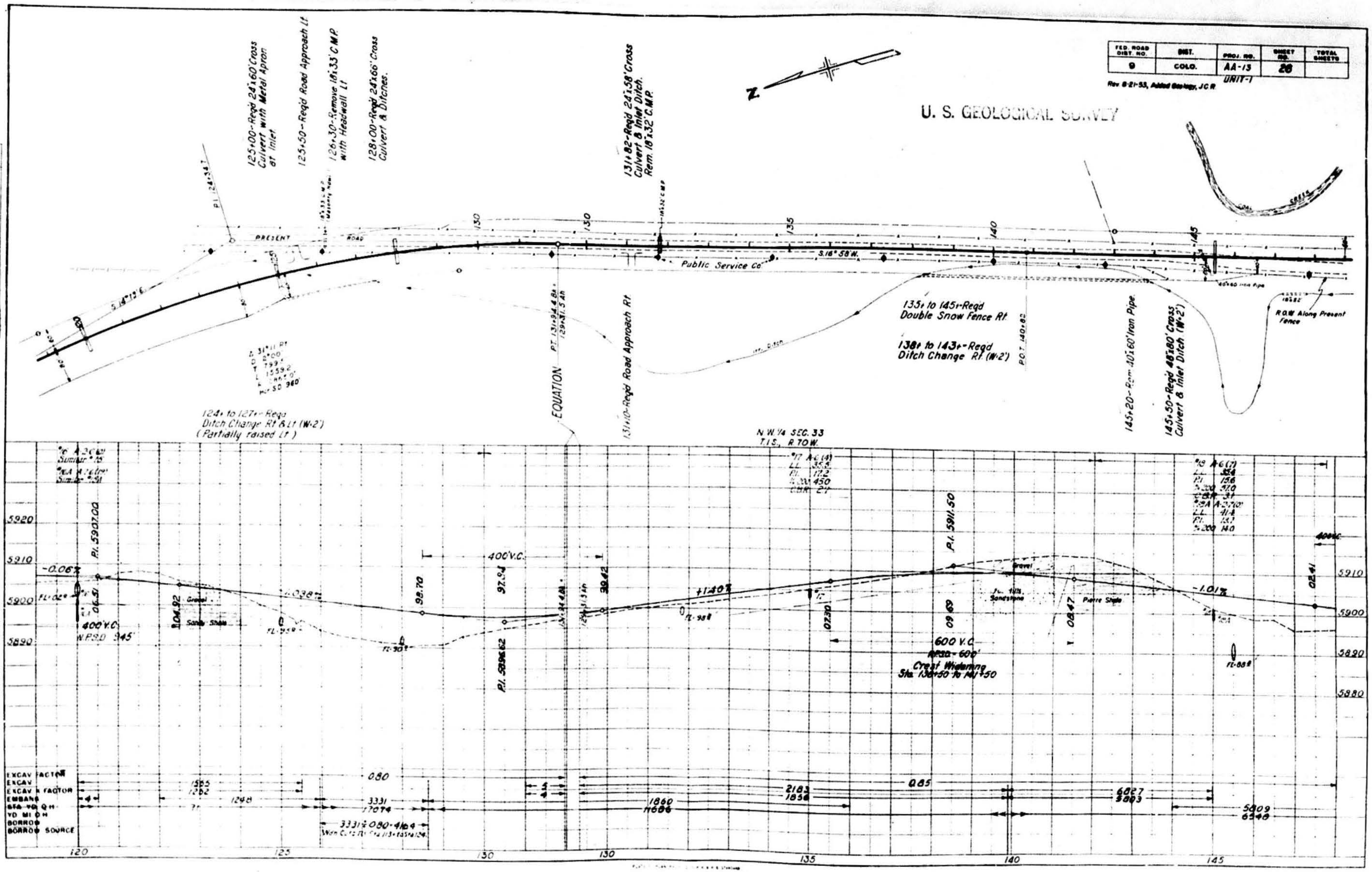
FED ROAD DIST NO
9
DIST
COLO
PROJ NO
AA-13
UNIT-1
SHEET NO
22
TOTAL SHEETS
Rev 8-21-53, Added Geology, J.C.R
Rev 5-3-54, Geology, J.C.R
Public Service Co
TO MARSHALL
Present R.O.W.
4° Curve
TO ELDORADO SPRINGS
6° Curve
20+40-Reqd Road Approach
21+26-Reqd 24"x54" Cross Culvert & Ditches
N.W.1/4 SEC. 21
Laramie Formation
Fox Hills Sandstone
Shale
Coal
Sandstone
+7.00%
+2.90%
+1.85%
600'V.C.
M.P.S.D. 460'
400'V.C.
M.P.S.D. 835'
800'V.C.
5570
5560
5550
5540
5530
5520
10
15
20
25
30
PLAN
PROFILE

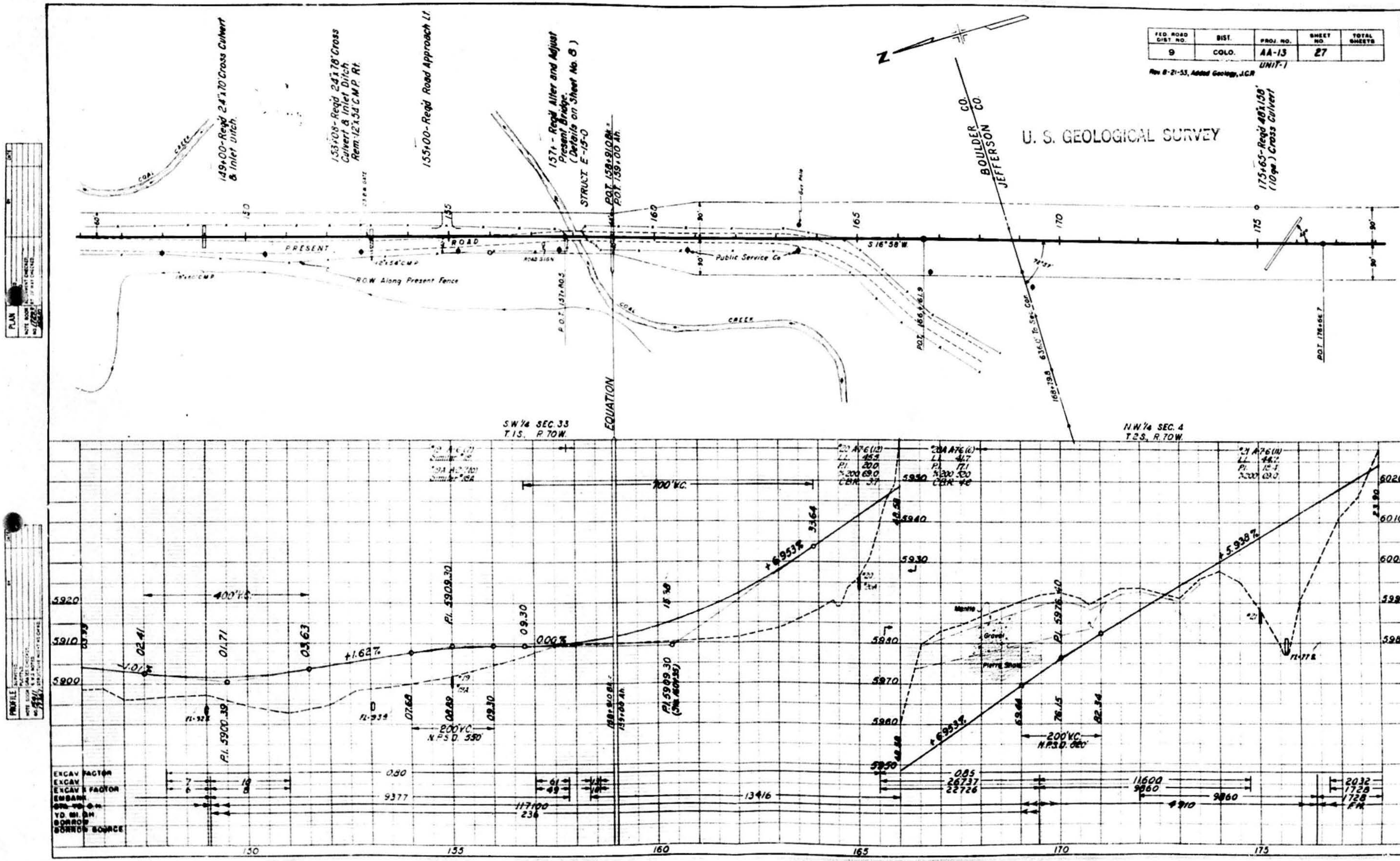


FED. ROAD DIST. NO. 9
DIST. COLO.
PROJ. NO. AA-13 UNIT-1
SHEET NO. 23
TOTAL SHEETS
Rev. 7-24-53, Str. Sta 51+00, J.C.R.
Rev 8-21-53, Added Geology, J.C.R.
Rev 5-3-54, Geology, J.C.R.
32+96 - Req'd 24"x70' Cross Culvert, Dike at Inlet & Inlet Ditch
34+06 - Req'd 13'x4'x42' CBC (Spl. Rev. Std. M-104 & 38 Ditches (W=12'), Rem 13'x29' Timber Bridge
34+ - Adjust Borrow Ditches Rt & Lt into Irrig. Ditch and line with Grouted Rubble Slope & Ditch Paving (12" thick)
38+00 - Req'd Road Approach Lt
45+00 - Req'd 24"x54' Cross Culvert, Dike at Inlet & Ditches.
51+00 - Req'd 8"x100' Perforated Underdrain & Cutlet Ditch (Details on Sheet No 2)
51+ to 55+ - Req'd Channel Change Lt (W=14')
52+ - Rem. 14'x24' Timber Bridge Lt
55+50 - Req'd 14'x10'x53' CBC (Type 14-T)
55+ to 56+ - Req'd Riprap in Channel Change Rt (Details on sheet No. 2)
55+ to 59+ - Req'd Channel Change Rt (W=14') (Partially raised) lined and bermed with clay-like material from widened cut Rt Sta 59+ to 95+. (Details on X-Sections)
Note: Clay-like material will be paid for as Unclassified Excavation.
Estimated O.H. 17,050 Sta Yds, 530 Yd Mi
61+00 - Req'd 24"x54' Cross Culvert, Dike at Inlet & Inlet Ditch.
37+00 - Req'd 18"x26' Side Drain & Road Approach Rt
39+75 - Req'd 18"x26' Side Drain & Road Approach Rt
Public Service Co.
PRESENT ROAD
Channel Change
PC 43+09.5
PI 48+10.5
Δ 32°10' Lt, D 5°00', T 561.0', L 1043.3', R 1146.0', Hor SD 465'
Δ 24°49' Rt, D 3°00', T 630.4', L 1240.8', R 2565.0', Hor SD 1300'
N.W. 1/4 SEC. 21 T.1 S., R. 70 W.
SW. 1/4 SEC. 21 T.1 S., R. 70 W.
U. S. GEOLOGICAL SURVEY
PLAN
PROFILE
5640, 5630, 5620, 5610, 5600, 5590, 5580
5670, 5660, 5650
5760, 5750, 5740, 5730, 5720, 5710
800' VC
+7.00%
+5.30%
PI 5702.40
400' VC
Sandstone
Shale
Inconclusive evidence indicates a fault may intersect centerline between Sta 52+12 and 58+00, as the position of the fault could not be verified a geological interpretation is not shown. However the major part of the excavation will be in sandstone.
EXCAV. FACTOR
EXCAV.
EXCAV. & FACTOR
EMBANK.
YD. BI. MI.
BORROW
BORROW SOURCE
0.80, 4500, 3600
0.85, 12424, 10560
7430, 6317, 8556
96273, 1420
472, 377, 377
41, 8, 18
30, 35, 40, 45, 50, 55, 60

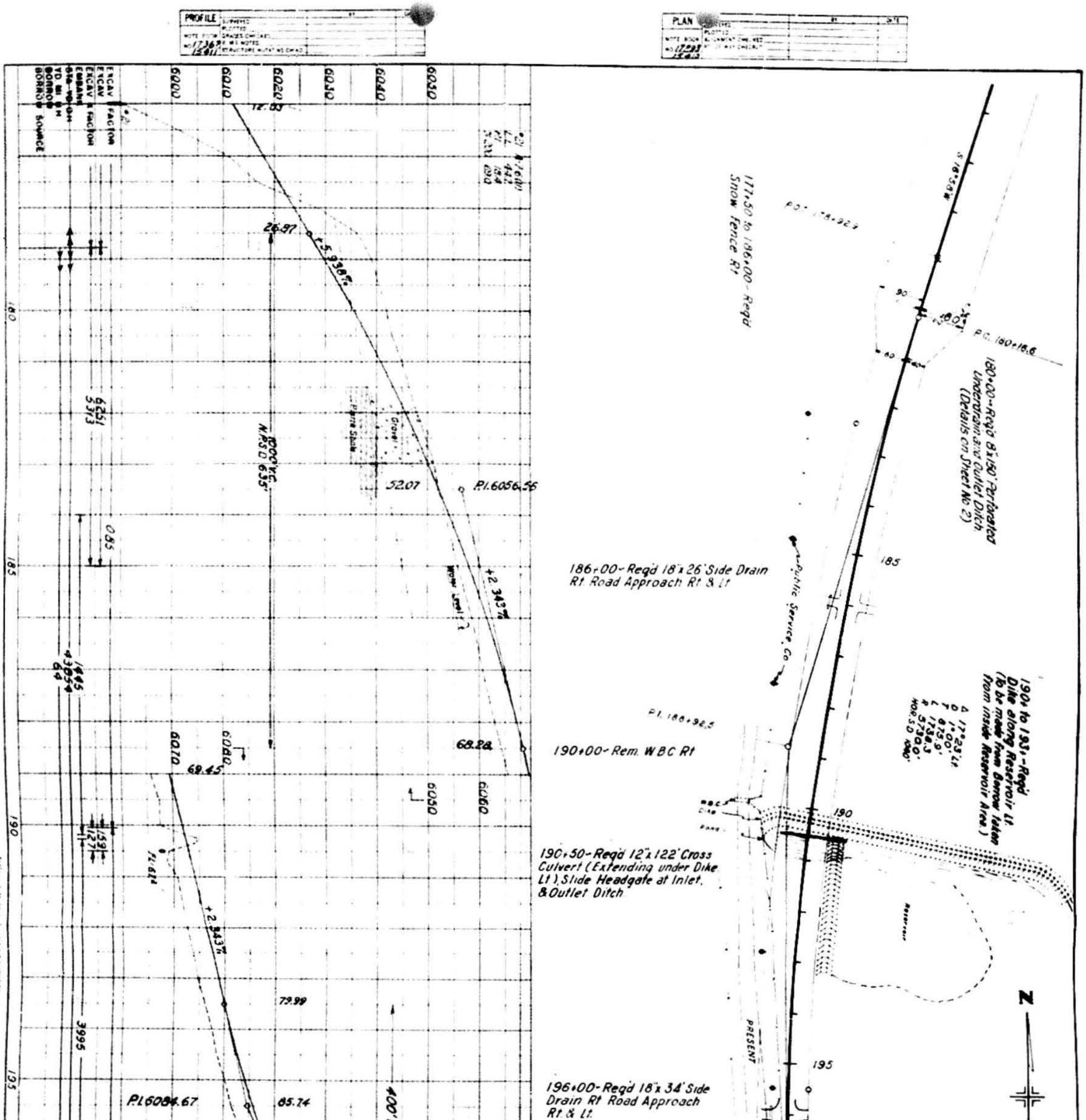

U. S. GEOLOGICAL SURVEY
FED. ROAD DIST. NO. 9
DIST. COLO.
PROJ. NO. AA-13 UNIT-1
SHEET NO. 24
TOTAL SHEETS
Rev 9-21-53, Added Geology, J.C.R.
Rev 5-3-54, Geology, J.C.R.
62+00-Reqd 18"x26' Side Drain and Road Approach Lt.
68+45-Reqd 24"x112' Cross Culvert & Inlet Ditch. (W=2')
74+ to 76+-Reqd 8"x220' Perforated Underdrain Lt. & Outlet Ditch. (Details on sheet No. 2)
Public Service Co.
Δ 24°49' Rt
D 2°00'
T 630.4'
L 1240.8'
R 2865.0'
Hor SD 1300'
Δ 23°35' Lt
D 2°00'
T 598.1'
L 1179.2'
R 2865.0'
Hor SD 730'
72+50-Reqd 24"x98' Cross Culvert, Dike at Inlet & Inlet Ditch.
84+50-Reqd 24"x122' Cross Culvert
84+ to 86+-Reqd Drain Ditch Lt. (W=2')
88+70-Reqd Special 6'x7'x37' C.B.C. for Stock Pass with Ditches (W=12')
S.W. 1/4 SEC 21 T1S, R70W
N.W. 1/4 SEC 28 T1S, R70W
600' V.C.
+7.00%
+3.90%
+5.30%
+5.091%
Geology between stations 61+00 and 67+00 is shown on natural scale on Sheet No. 51-A.
No geologic data collected between Sta. 67+00 to Sta. 75+50
Laramie Formation
Sandstone
Shale
Coal
Mantle
Fault
Alternating & Lenses of Silty Shale and Siltstone
Shale (carbonaceous)
Siltstone
Gravel
NOTE: It is estimated that material having a C.B.R. of 11.0 from cut Sta. 90+ to 95+ will be placed in the upper portion of the Sub grade Sta. 82+ to 84+ (Minimum 10"). Estimated additional overhaul involved: 1500 Sta. Yds.
Geology not correlated between Sta. 84+00 to 89+00
600' V.C.
N.P.S.D. 680'
5153+085=6062
Wdn. Cuts Lt. & Rt. Sta. 69+ to Sta. 75+
11849
11675
9923
9862
8383
8383
593
26098
085
PROFILE
PLAN
60
65
70
75
80
85
90


Rev. 7-24-53, Str. Sta. 91+ to 95+00, J.C.R.
FED. ROAD DIST. NO. 9 | DIST. COLO. | PROJ. NO. AA-13 | SHEET NO. 25 | TOTAL SHEETS
UNIT-1
Rev 8-21-53, Added Geology, J.C.R.
U. S. GEOLOGICAL SURVEY
Δ 23°35' Lt
D 2°00'
T 598.1'
L 1179.2'
R 2865.0'
Hor S.D. 730'
PT 96+47.9
S 9°22' W
S 14°13' E
P.I. 90+66.8
91+ to 95+00 - Req'd 8" x 450' Perforated Underdrain Rt and Outlet Ditch (Details on Sheet No 2)
90+ to 107+ - Req'd Double Snow Fence Rt
97+75 - Req'd 24" x 72' Cross Culvert & Inlet Ditch
100+ to 107+ - Req'd Flatten Back Slopes Rt & Lt (Snow Condition)
111+50 - Req'd 24" x 62' Cross Culvert & Ditches
113+50 - Req'd Road Approach Rt & Lt
113+ to 124+ - Req'd Widen & Deepen Borrow Ditch Rt
PC 116+35.2
117+ to 125+ - Req'd Double Snow Fence Rt
120+00 - Req'd 36" x 56' Cross Culvert & Ditches
Δ 31°11' Rt
D 2°00'
T 799.5'
L 1559.2'
R 2865.0'
Hor S.D. 980'
SW 1/4 SEC. 28 T.1 S., R.70 W.
NW 1/4 SEC. 33 T.1 S., R.70 W.
P.I. 5969.10
+5.091%
-4.25%
-0.06%
-1.09%
1400' V.C. N.P.S.D. 470'
Crest Widening Sta. 96+00 to 101+00
Geology not correlated between Stas. 94+00 & 101+00
400' V.C.
400' V.C. N.P.S.D. 945'
P.I. 5901.48
P.I. 5907.00
Gravel
Sandstone
Shale
Silty Shale
EXCAV FACTOR
EXCAV
EXCAV x FACTOR
EMBANK
STA. YD. O.H.
YD. BI. O.H.
BORROW
BORROW SOURCE
Wstr Cuts Lt & Rt Sta. 99+ to Sta. 107+
PLAN
PROFILE

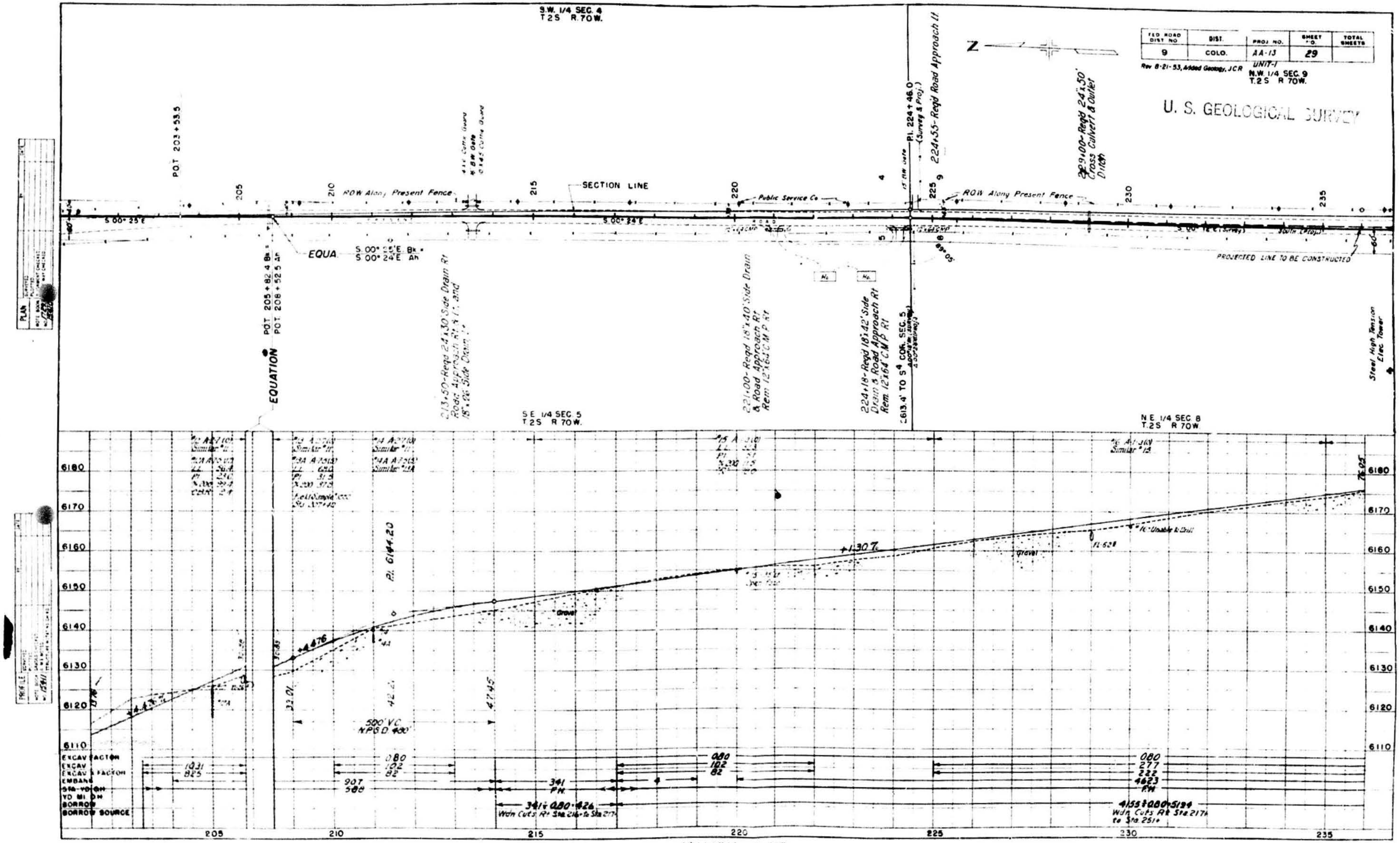

FED. ROAD DIST. NO. 9
DIST. COLO.
PROJ. NO. AA-13
SHEET NO. 28
TOTAL SHEETS
UNIT-1
Rev 8-21-53, Added Geology, J.C.R.
U. S. GEOLOGICAL SURVEY
125+00-Reqd 24"x60' Cross Culvert with Metal Apron at Inlet
125+50-Reqd Road Approach Lt
126+30-Remove 18"x33' C.M.P. with Headwall Lt
128+00-Reqd 24"x66' Cross Culvert & Ditches.
131+82-Reqd 24"x58' Cross Culvert & Inlet Ditch. Rem. 18"x32' C.M.P.
PRESENT ROAD
Public Service Co.
S.16° 58' W.
135+ to 145+-Reqd Double Snow Fence Rt.
138+ to 143+-Reqd Ditch Change Rt. (W-2')
145+20-Rem. 40"x60' Iron Pipe
145+50-Reqd 48"x80' Cross Culvert & Inlet Ditch (W-2')
R.O.W. Along Present Fence
EQUATION
131+10-Reqd Road Approach Rt
124+ to 127+-Reqd Ditch Change Rt & Lt (W-2') (Partially raised Lt)
N.W. 1/4 SEC. 33 T.1S., R.70W.
P.I. 5907.00
400' V.C.
P.I. 5896.62
P.I. 5911.50
600 V.C.
Crest Widening Sta. 138+50 to 141+50
-0.06%
-1.038%
+1.40%
-1.01%
Gravel
Sandy Shale
Sandstone
Pierre Shale
5920
5910
5900
5890
5880
EXCAV FACTOR
EXCAV
EXCAV & FACTOR
EMBANK
STA YD O.H.
YD MI O.H.
BORROW
BORROW SOURCE
0.80
0.85
3331
1860
2183
6827
5809
120
125
130
135
140
145



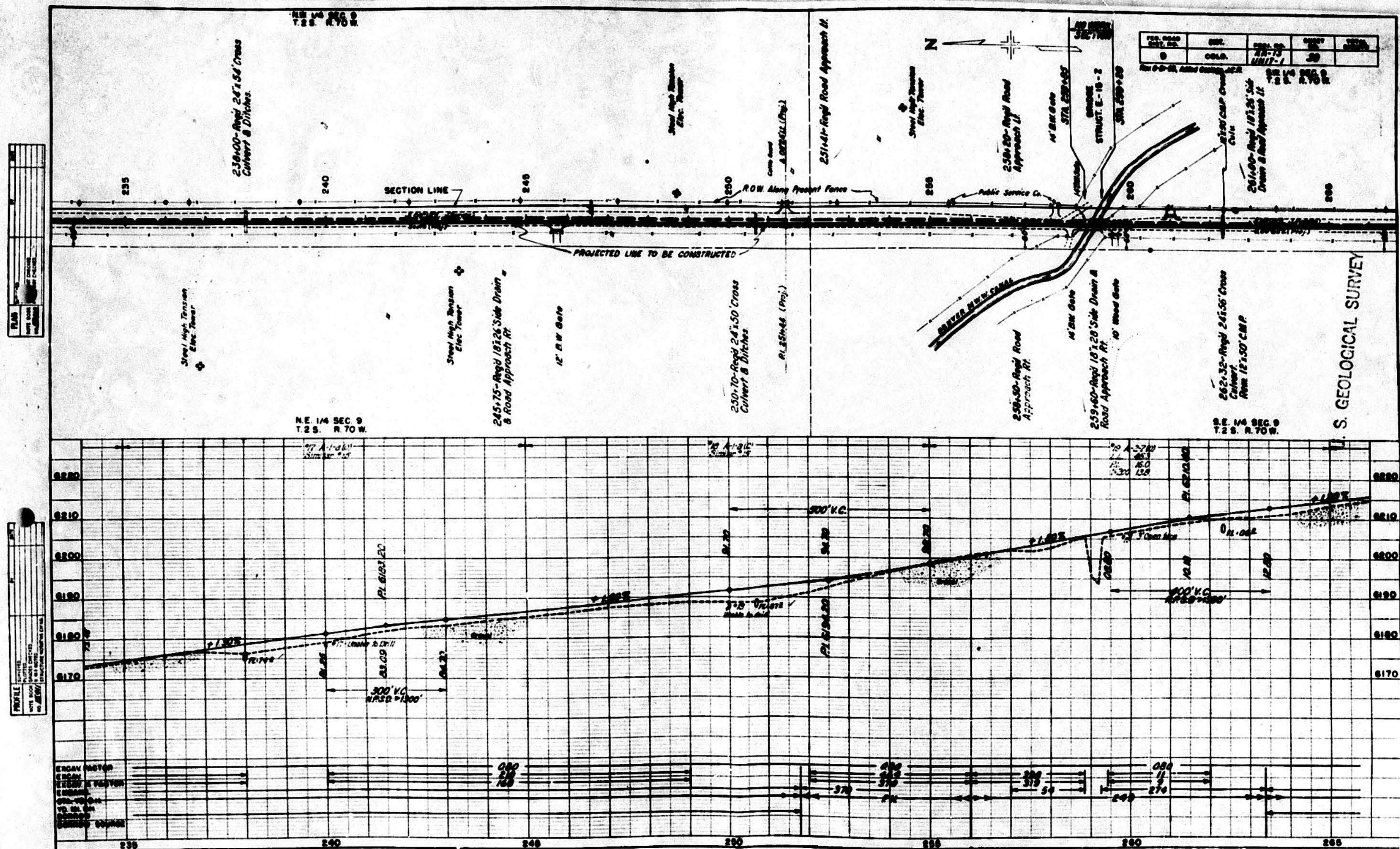
FED. ROAD DIST. NO. 9
DIST. COLO.
PROJ. NO. AA-13
SHEET NO. 27
TOTAL SHEETS
UNIT-1
Rev 8-21-53, Added Geology, J.C.R.
U. S. GEOLOGICAL SURVEY
149+00-Reqd 24"x70' Cross Culvert & Inlet Ditch.
153+08-Reqd 24"x78' Cross Culvert & Inlet Ditch. Rem. 12"x54' C.M.P. Rt.
155+00-Reqd Road Approach Lt.
157+ - Reqd Alter and Adjust Present Bridge. (Details on Sheet No. 8)
STRUCT. E-15-O
P.O.T. 158+91.0 Bk.
P.O.T. 159+00 Ah.
BOULDER CO.
JEFFERSON CO.
175+65-Reqd 48"x158' (10 ga.) Cross Culvert
PRESENT ROAD
COAL CREEK
R.O.W. Along Present Fence
Public Service Co.
S 16°58' W.
EQUATION
S.W.1/4 SEC. 33 T.1S., R.70W.
N.W.1/4 SEC. 4 T.2S., R.70W.
400' V.C.
700' V.C.
200' V.C. N.P.S.D. 550'
200' V.C. N.P.S.D. 660'
P.I. 5900.39
P.I. 5909.30
P.I. 5909.30 (Sta. 160+35)
P.I. 5976.40
+1.62%
0.00%
+6.953%
+5.938%
Mantle
Gravel
Pierre Shale
EXCAV FACTOR
EXCAV
EXCAV FACTOR
EMBANK
YD. ST. HAUL
BORROW
BORROW SOURCE
PLAN
PROFILE

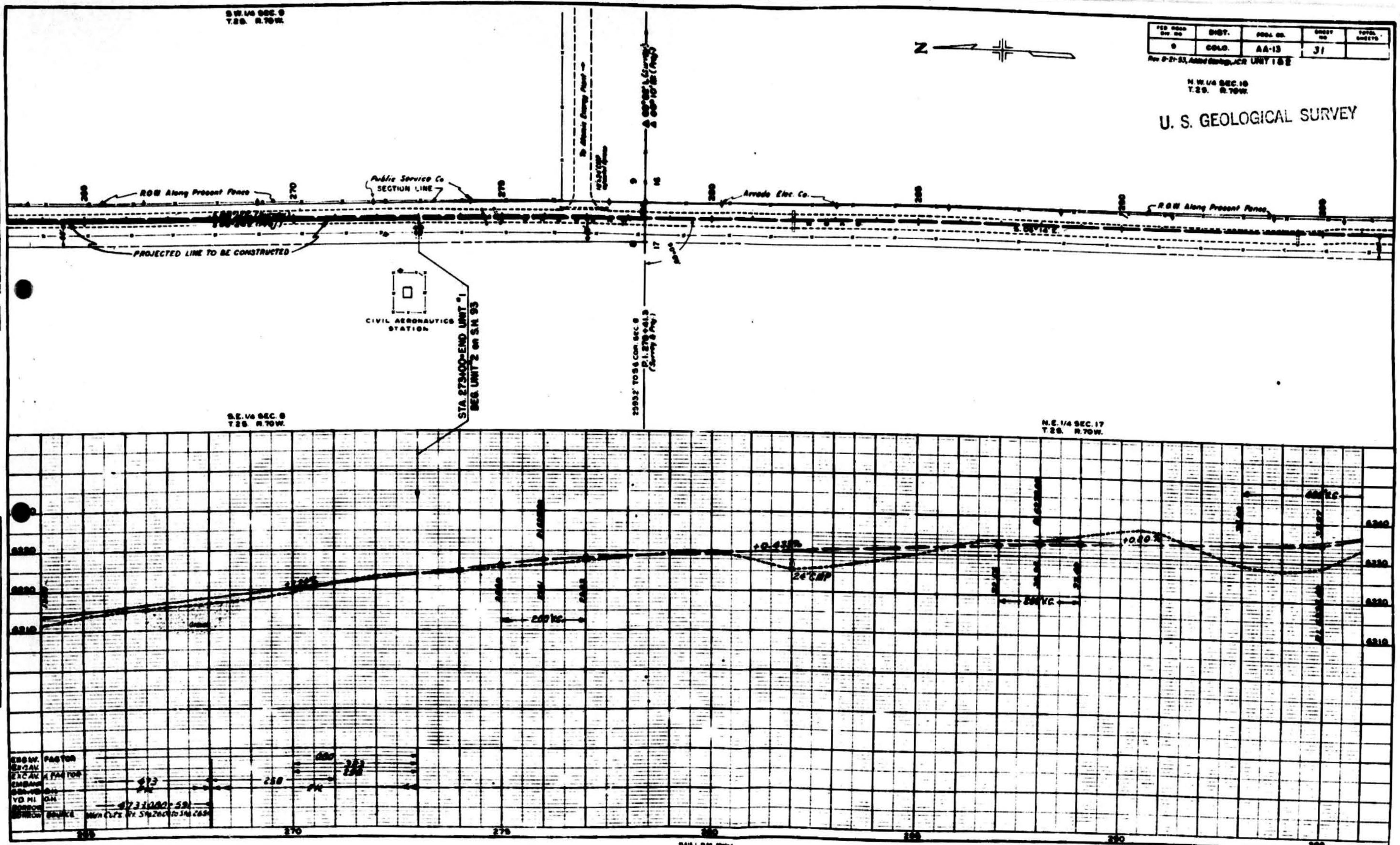


PROFILE
PLAN
177+50 to 186+00-Reqd Snow Fence Rt
180+00-Reqd 8"x150' Perforated Underdrain and Outlet Ditch (Details on Sheet No 2)
186+00-Reqd 18"x26' Side Drain Rt Road Approach Rt & Lt
Public Service Co
190+00-Rem. WBC Rt
190 to 193-Reqd Dike along Reservoir Lt. (To be made from Borrow taken from inside Reservoir Area.)
190+50-Reqd 12"x122' Cross Culvert (Extending under Dike Lt), Slide Headgate at Inlet, & Outlet Ditch
196+00-Reqd 18"x34' Side Drain Rt Road Approach Rt & Lt
197+50-Reqd 84"x58' Cross Culvert for Stock Pass, with mitered Ends (Sl 2:1), Grouted Rubble Headwalls, & Ditches (Details on sheet No 2)
FORCE ACCOUNT
197+50-Placing 6" Asphaltic Mat in bottom of C.M.P. Stock Pass
205+75-Reqd 24"x58' Cross Culvert, Dike at Inlet & Ditches
EQUATION
P.O.T. 205+62.4 Bk
P.O.T. 208+52.5 Ah
ROW Along Present Fence
PRESENT ROAD
P.I. 6056.56
P.I. 6084.67
400' V.C.
1000' V.C.
+2.343%
+4.476%
U. S. GEOLOGICAL SURVEY
Rev 7-24-53 Sta 180+00 J.C.R.
FED. ROAD DIST NO | DIST | PROJ NO | SHEET NO | TOTAL SHEETS
9 | COLO | AA-13 | 28 |
UNIT 1
S.W.1/4 SEC 4 T.2S, R 70W
S.E.1/4 SEC 5 T.2S, R 70W
Rev 8-2-53, Added Geology J.C.R.



S.W. 1/4 SEC. 4
T.2S R.70W.
FED. ROAD DIST. NO. 9
DIST. COLO.
PROJ. NO. AA-13
SHEET NO. 29
TOTAL SHEETS
Rev 8-21-53, Added Geology, JCR
UNIT-1
N.W. 1/4 SEC. 9
T.2S R 70W.
U. S. GEOLOGICAL SURVEY
POT 203+53.5
ROW Along Present Fence
SECTION LINE
Public Service Co.
ROW Along Present Fence
S.00° 25' E
S.00° 24' E
EQUA.
S.00° 25' E. Bk.
S.00° 24' E. Ah.
PROJECTED LINE TO BE CONSTRUCTED
POT 205+82.4 Bk.
POT 208+52.5 Ah.
EQUATION
213+50-Reqd 24' x 30' Side Drain Rt Road Approach Rt. and 18" x 26' Side Drain
221+00-Reqd 18" x 40' Side Drain & Road Approach Rt Rem 12" x 64' C.M.P. Rt
224+18-Reqd 18" x 42' Side Drain & Road Approach Rt Rem 12" x 64' C.M.P. Rt
613.4' TO S 1/4 COR. SEC. 5
P.I. 224+46.0 (Survey & Proj.)
224+55-Reqd Road Approach Lt
229+00-Reqd 24" x 50' Cross Culvert & Outlet Ditch
Steel High Tension Elec. Tower
S.E. 1/4 SEC. 5
T.2S R 70W.
N.E. 1/4 SEC. 8
T.2S R 70W.
P.I. 6144.20
+4.476
+1.307
500' V.C.
Gravel
EXCAV. FACTOR
EXCAV.
EXCAV. FACTOR
EMBANK.
STA. YD. OH
YD. MI. OH
BORROW
BORROW SOURCE
Wdn. Cuts Rt. Sta. 216+ to Sta. 217
Wdn. Cuts Rt. Sta. 217+ to Sta. 251+
205
210
215
220
225
230
235
6110
6120
6130
6140
6150
6160
6170
6180


N.W. 1/4 SEC. 9
T. 2 S. R. 70 W.
238+00—Reqd 24"x 54' Cross Culvert & Ditches.
SECTION LINE
R.O.W. Along Present Fence
PROJECTED LINE TO BE CONSTRUCTED
Public Service Co.
Steel High Tension Elec. Tower
245+75—Reqd 18"x 26' Side Drain & Road Approach Rt.
12' B.W. Gate
250+70—Reqd 24"x 50' Cross Culvert & Ditches.
251+41—Reqd Road Approach Lt.
256+20—Reqd Road Approach Lt.
256+50—Reqd Road Approach Rt.
259+60—Reqd 18"x 28' Side Drain & Road Approach Rt.
14' B.W. Gate
10' Wood Gate
BRIDGE STRUCT. E-16-Z
261+00—Reqd 18"x 26' Side Drain & Road Approach Lt.
262+32—Reqd 24"x 56' Cross Culvert
N.E. 1/4 SEC. 9
T. 2 S. R. 70 W.
S.E. 1/4 SEC. 9
T. 2 S. R. 70 W.
S.W. 1/4 SEC. 9
T. 2 S. R. 70 W.
COLO.
30
N
U. S. GEOLOGICAL SURVEY
300' V.C.
N.P.S.D. = 1300'
P.I. 6183.20
P.I. 6194.20
P.I. 6210.40
6170
6180
6190
6200
6210
6220
235
240
245
250
255
260
265
PLAN
PROFILE



U. S. GEOLOGICAL SURVEY
COLO.
AA-13
31
UNIT 1 & 2
S.W. 1/4 SEC. 8 T.2S. R.70W.
N.W. 1/4 SEC. 16 T.2S. R.70W.
R.O.W. Along Present Fence
Public Service Co
SECTION LINE
Arvada Elec. Co.
PROJECTED LINE TO BE CONSTRUCTED
CIVIL AERONAUTICS STATION
STA. 273+00=END UNIT 1 BEG. UNIT 2 on S.H. 93
S.E. 1/4 SEC. 8 T.2S. R.70W.
N.E. 1/4 SEC. 17 T.2S. R.70W.
24" CMP
200' V.C.
270
280
290

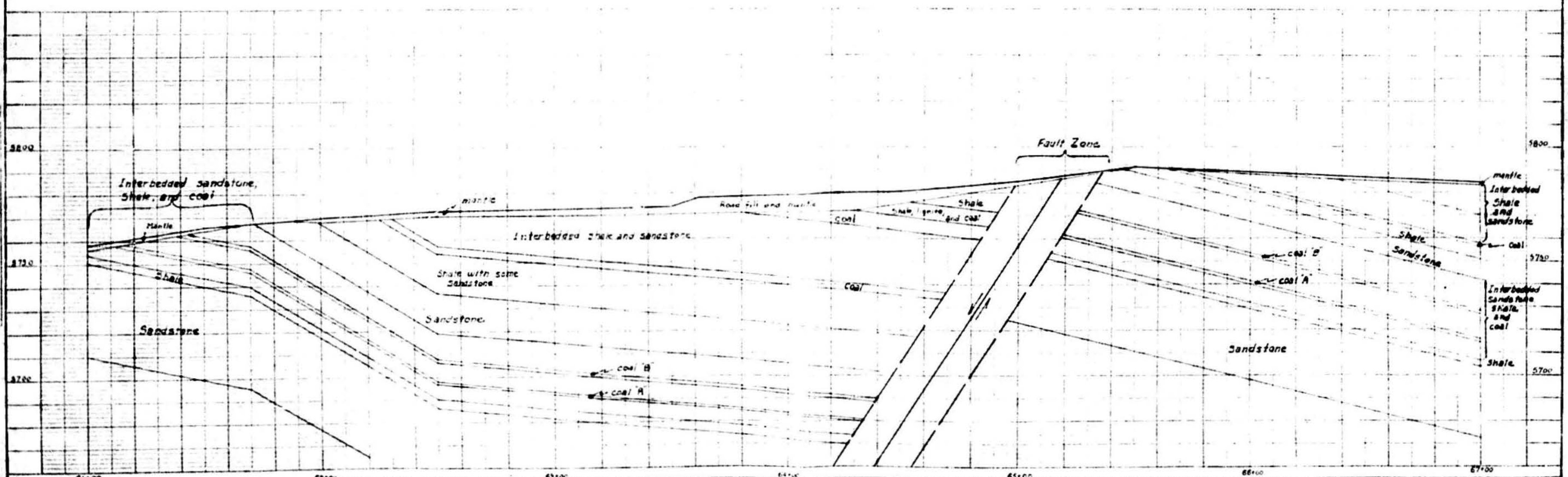
FED. ROAD DIV. NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-1$ UNIT I	31a	

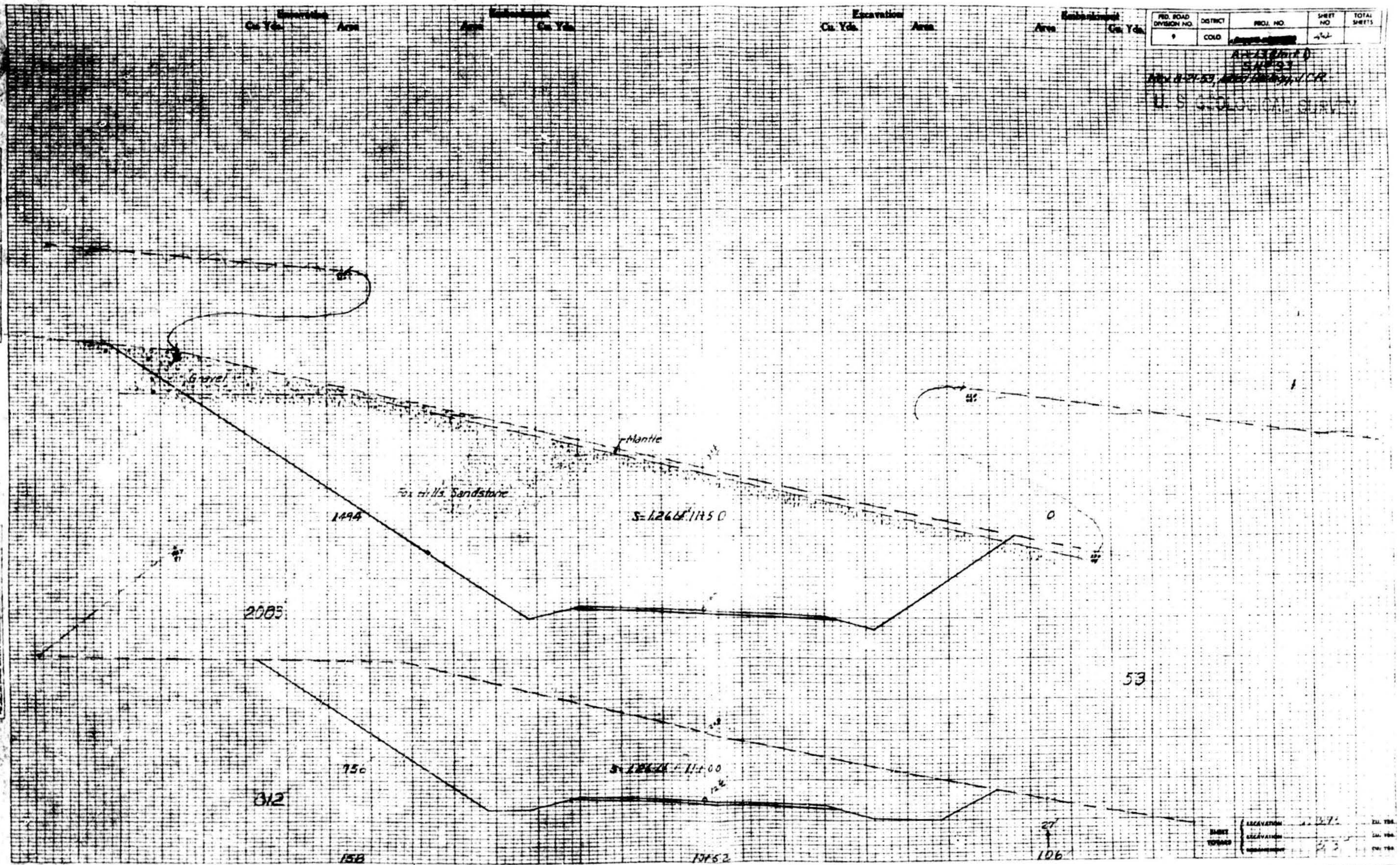
Added Sheet 8-21-53, J.C.R.
Rev. 5-3-54, Geology, J.C.R.

U. S. GEOLOGICAL SURVEY

Geologic Profile between Stations 61+00 and 67+00

Horizontal and Vertical scales 1 inch = 20 feet





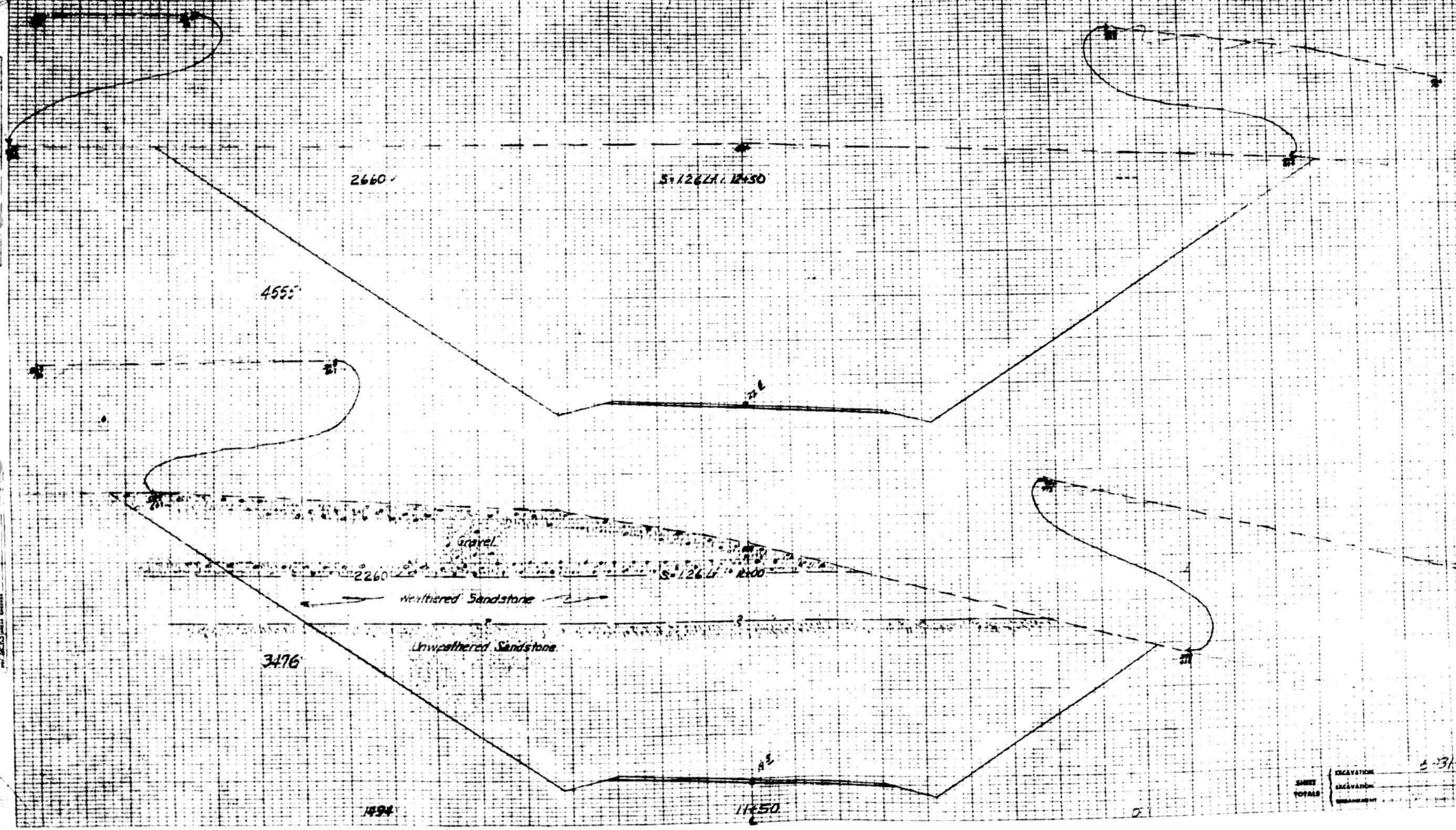
Excavation
Cu. Yds.
Area
Area
Cu. Yds.
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Area
Cu. Yds.
FED. ROAD DIVISION NO.
DISTRICT
PROJ. NO.
SHEET NO.
TOTAL SHEETS
9
COLO
Gravel
Mantle
Fox Hills Sandstone
1494
0
2085
53
750
312
158
27
106

FED ROAD DIVISION NO	DISTRICT	PROJ. NO	SHEET NO	TOTAL SHEETS
9	COLO	AF-13 (Unit I	4?	

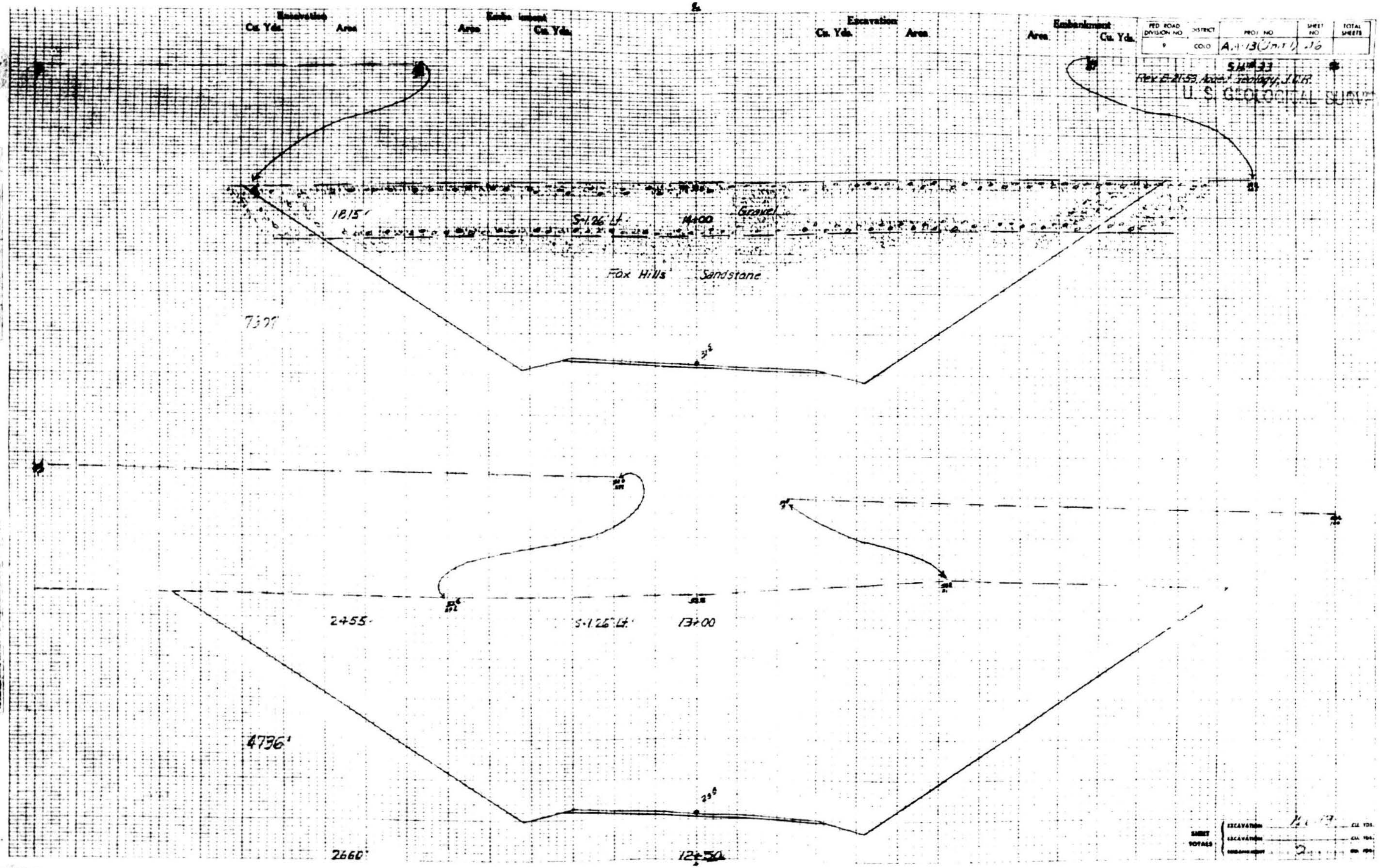
SH 93

Rev 5-21-53, Added Geology, J.C.R.

Excavation		Embankment		Excavation		Embankment	
Cu. Yds.	Area	Area	Cu. Yds.	Cu. Yds.	Area	Area	Cu. Yds.



SHEET TOTALS: EXCAVATION ___ CU. YDS.; EXCAVATION ___ CU. YDS.; EMBANKMENT ___ CU. YDS.

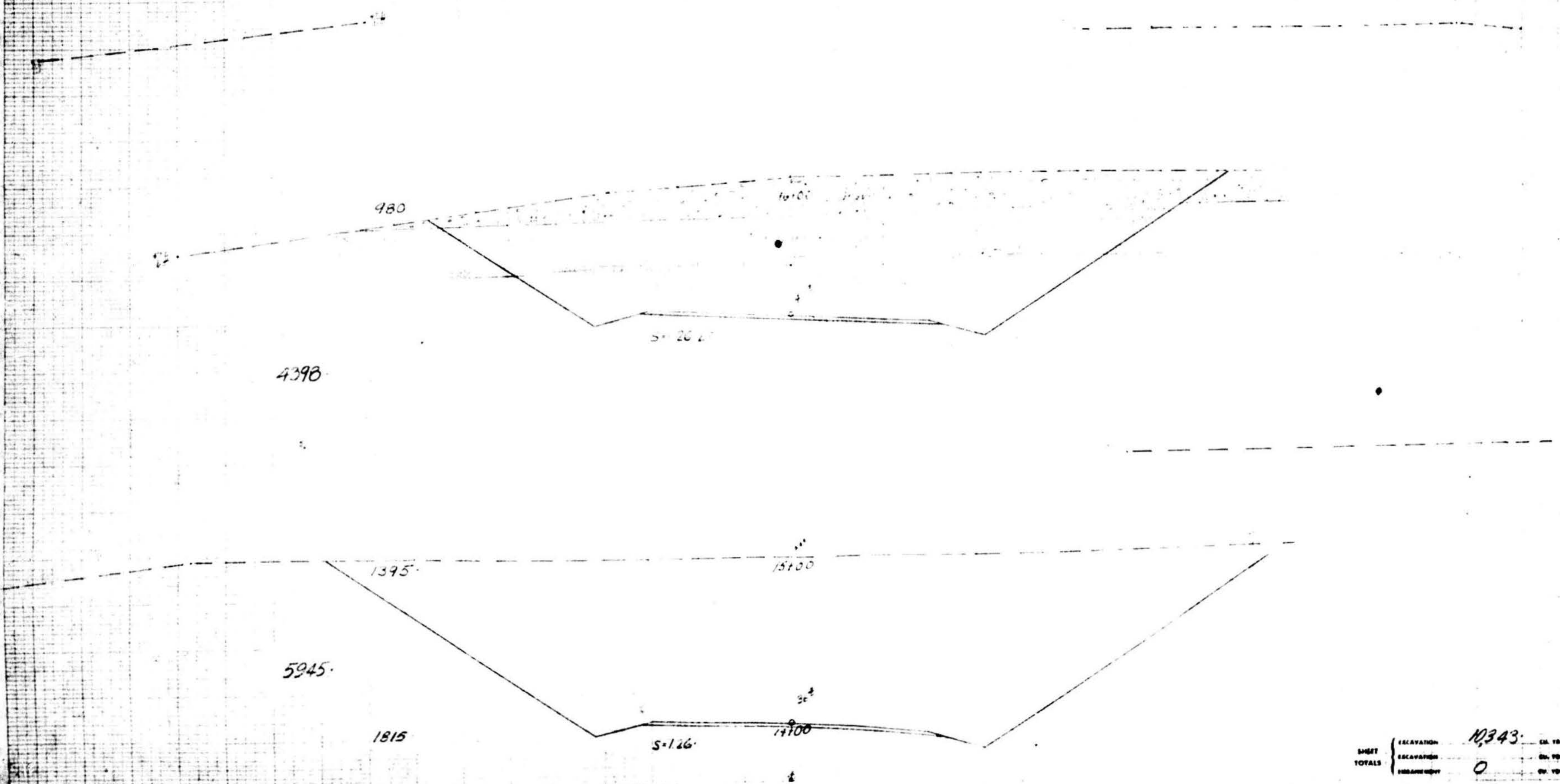

Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED ROAD DIVISION NO
DISTRICT
PROJ NO
SHEET NO
TOTAL SHEETS
9
COLO
A.-1-13(Unit 1)
16
1815'
S-1.26 Lt.
14+00
Gravel
Fox Hills Sandstone
7377
2455
S-1.26 Lt.
13+00
4736'
2660'
12+50
EXCAVATION
EMBANKMENT
SHEET TOTALS

Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.	Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	[redacted]	47	

AA-13(Unit 1)
SH#93

Rev 2-3-55 Adopt Geology J.C.R.
Rev 5-3-54 Geology J.C.R.



SHEET TOTALS		
EXCAVATION	10,343	CU. YDS.
EXCAVATION		CU. YDS.
EMBANKMENT	0	CU. YDS.

Excavation Cu. Yds.	Area	Embankment Area	Cu. Yds.	Excavation Cu. Yds.	Area	Embankment Area	Cu. Yds.

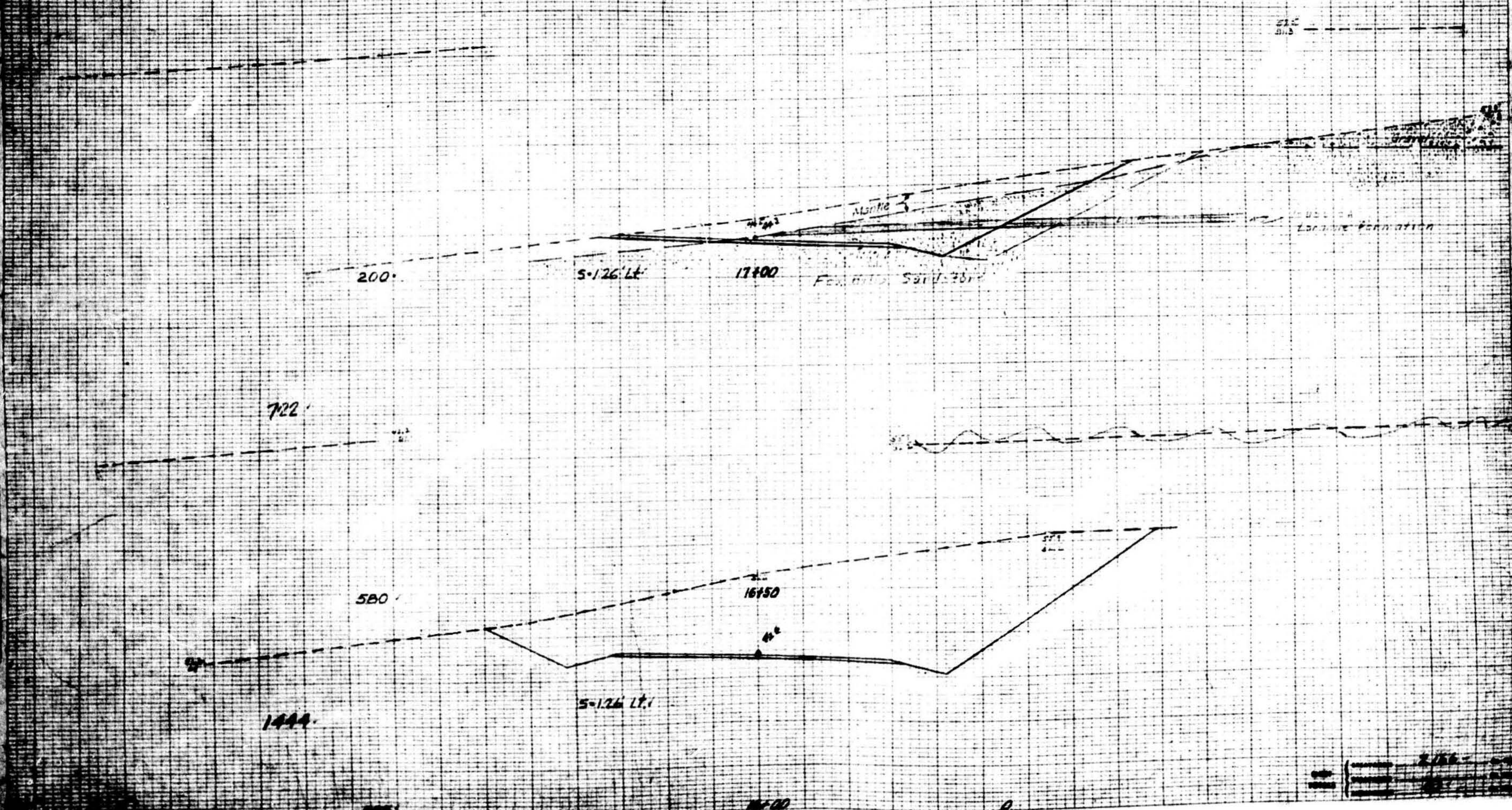
FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO.	AA-13(Unit 1)	48	

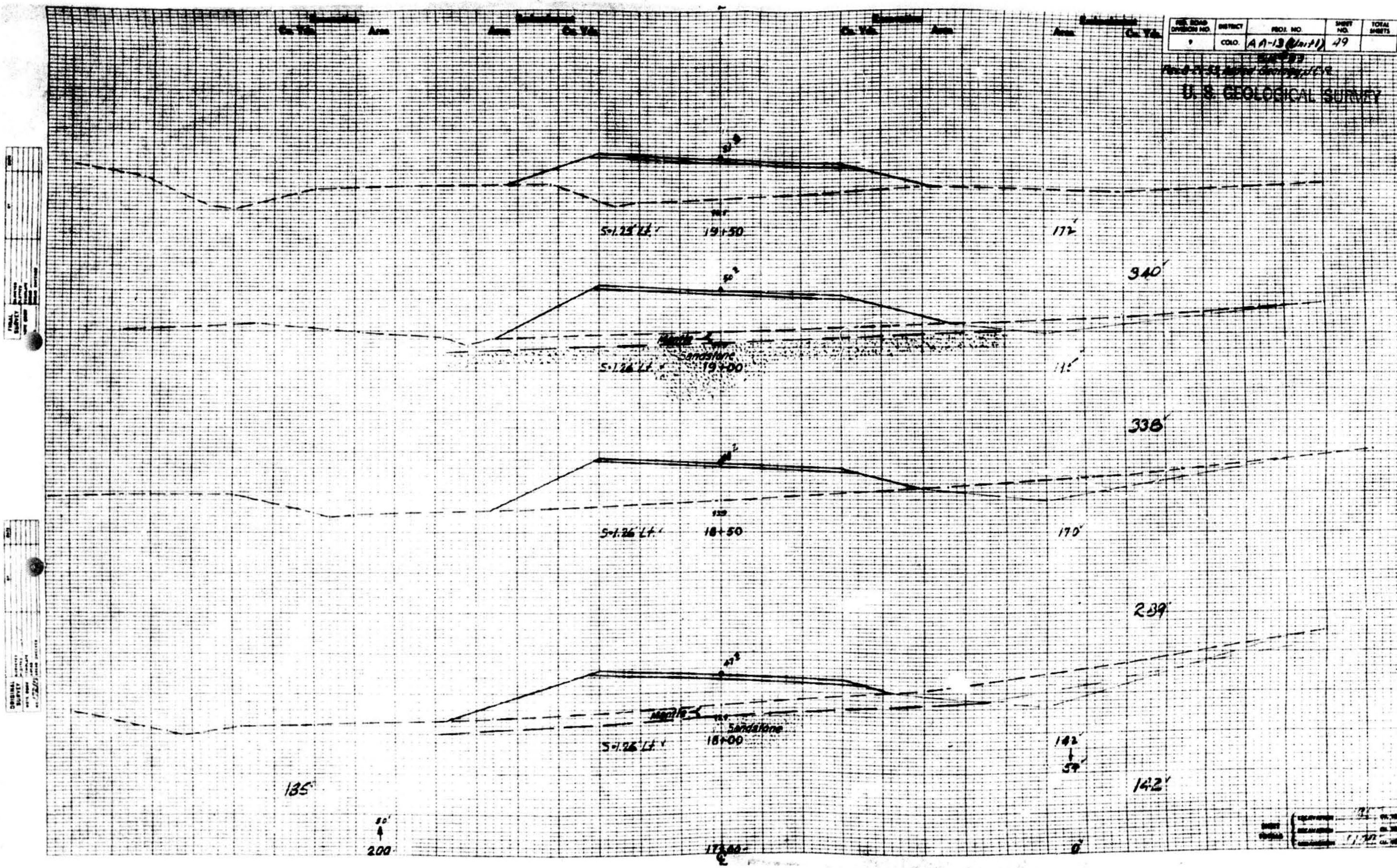
SH 93

Rev. 8-21-53, Added Geology, J.C.R.

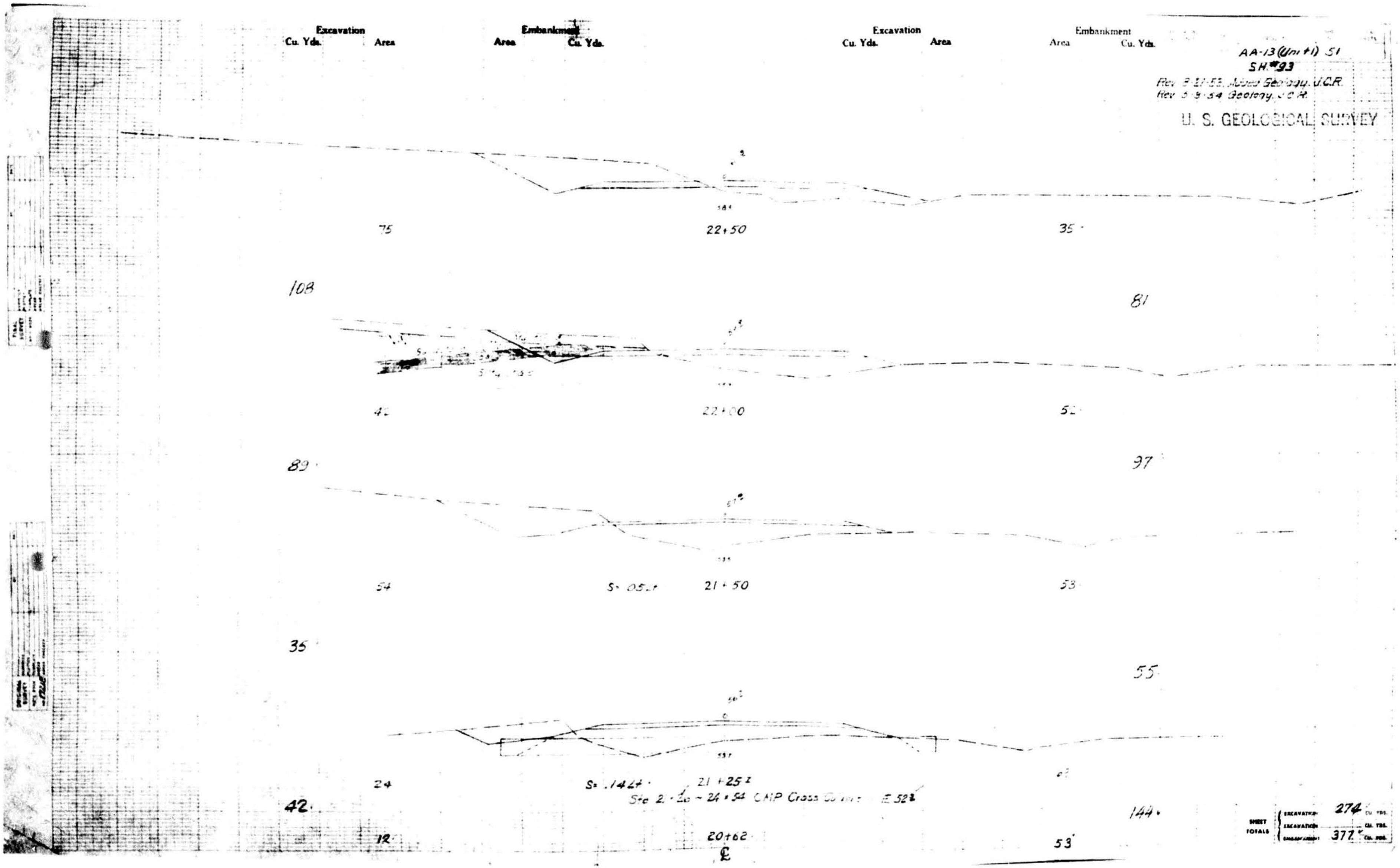
Rev. 5-3-54, Geology, J.C.R.

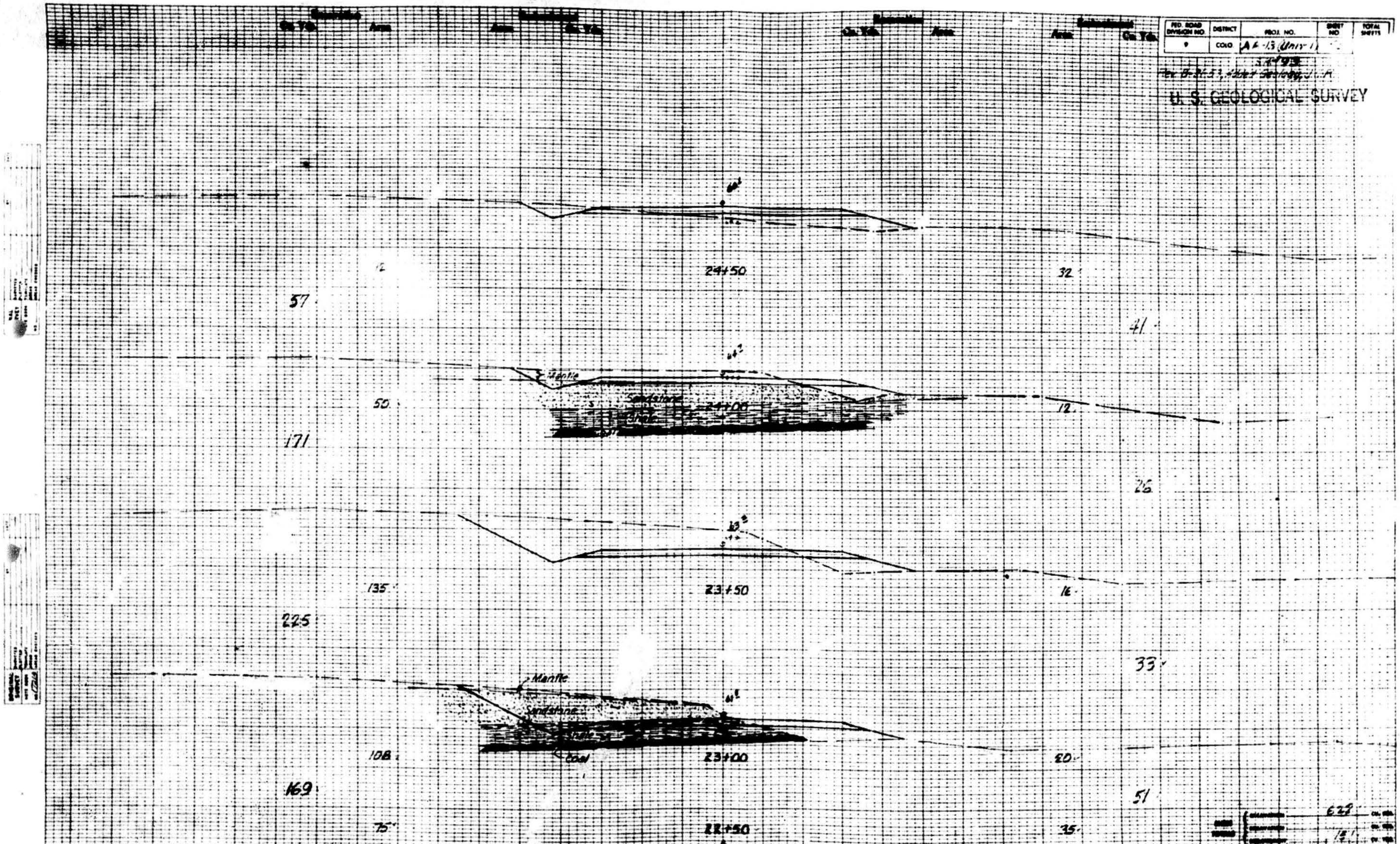
U. S. GEOLOGICAL SURVEY





FED. ROAD DIVISION NO.
DISTRICT
PROJ. NO.
SHEET NO.
TOTAL SHEETS
9
COLO.
AA-13 (Unit 1)
49
U. S. GEOLOGICAL SURVEY
Cu. Yds.
Area
S=1.25' Lt.
19+50
172
340
Mantle
Sandstone
S=1.26' Lt.
19+00
338
S=1.26' Lt.
18+50
170
239
Mantle
Sandstone
S=1.26' Lt.
18+00
142
54
142
135
80
200
0


Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
AA-13 (Unit 1) 51
SH. #93
Rev 8-21-53. Added Geology. J.C.R.
Rev 5-9-54 Geology. J.C.R.
U. S. GEOLOGICAL SURVEY
75
22+50
35
108
81
22+00
89
97
54
21+50
53
35
55
24
21+25
42
144
12
20+62
53
SHEET TOTALS
EXCAVATION 274 CU. YDS.
EXCAVATION CU. YDS.
EMBANKMENT 377 CU. YDS.

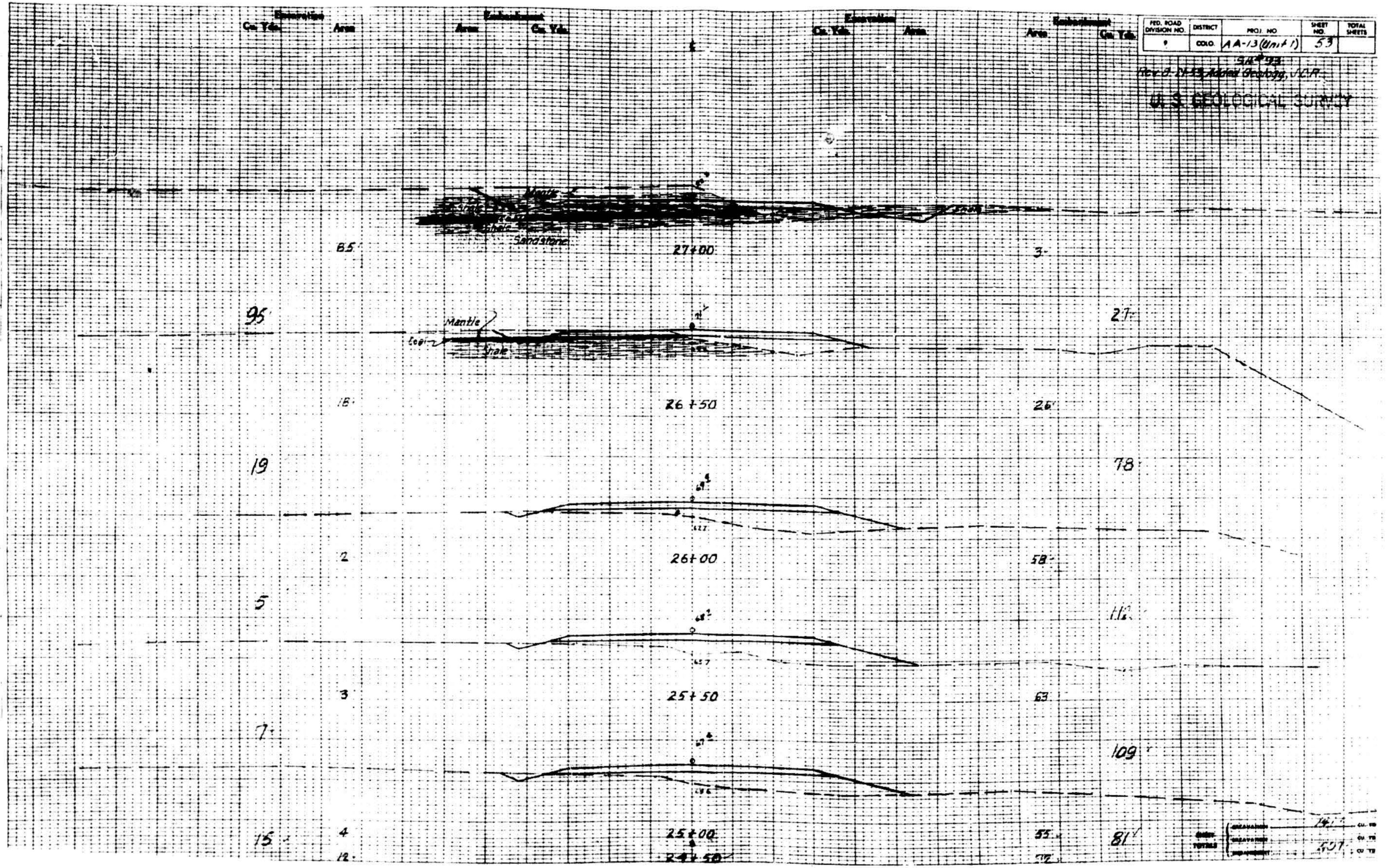


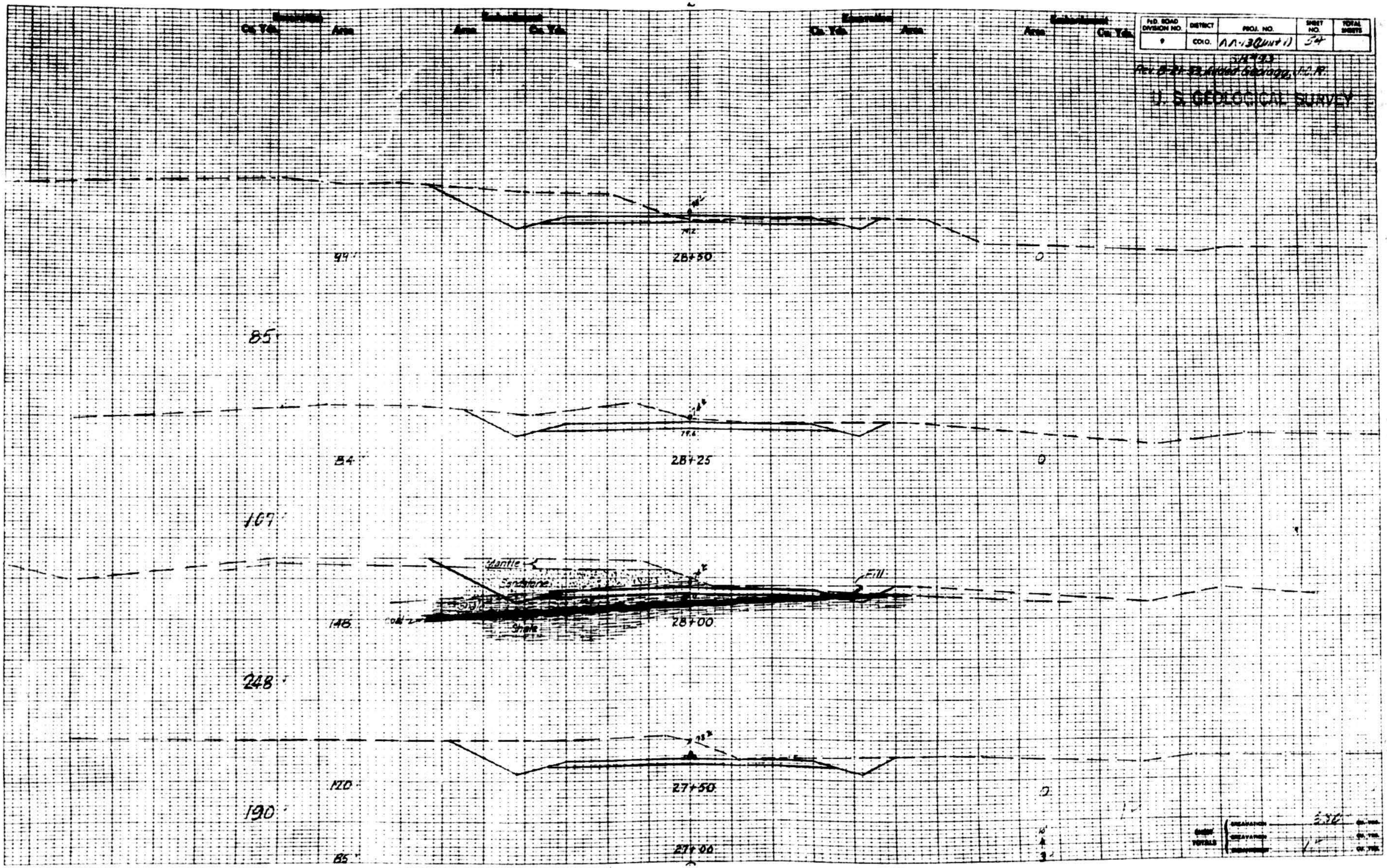
Cu. Yds.
Area
Area
Cu. Yds.
Cu. Yds.
Area
Area
Cu. Yds.
FED. ROAD DIVISION NO.
DISTRICT
PROJ. NO.
SHEET NO.
TOTAL SHEETS
9
COLO
AF-13 (Unit 1)
U. S. GEOLOGICAL SURVEY
24+50
57
32
41
Mantle
Sandstone
Shale
50
24+00
12
171
26
135
23+50
16
225
33
Mantle
Sandstone
Shale
Coal
108
23+00
20
169
51
75
22+50
35
628

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO	SHEET NO.	TOTAL SHEETS
9	COLO.	AA-13 (Unit 1)	53	

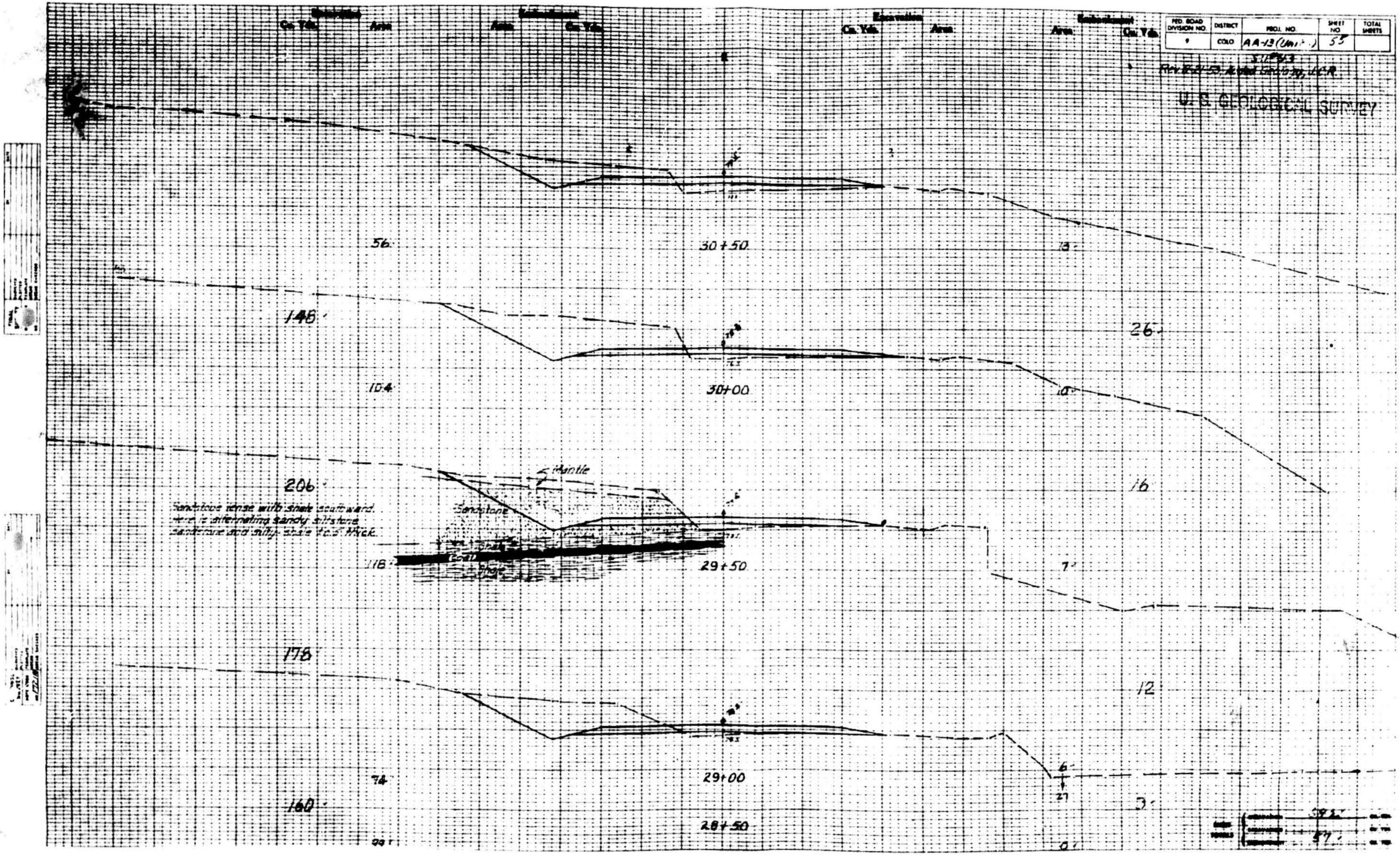
SH #93

U.S. GEOLOGICAL SURVEY

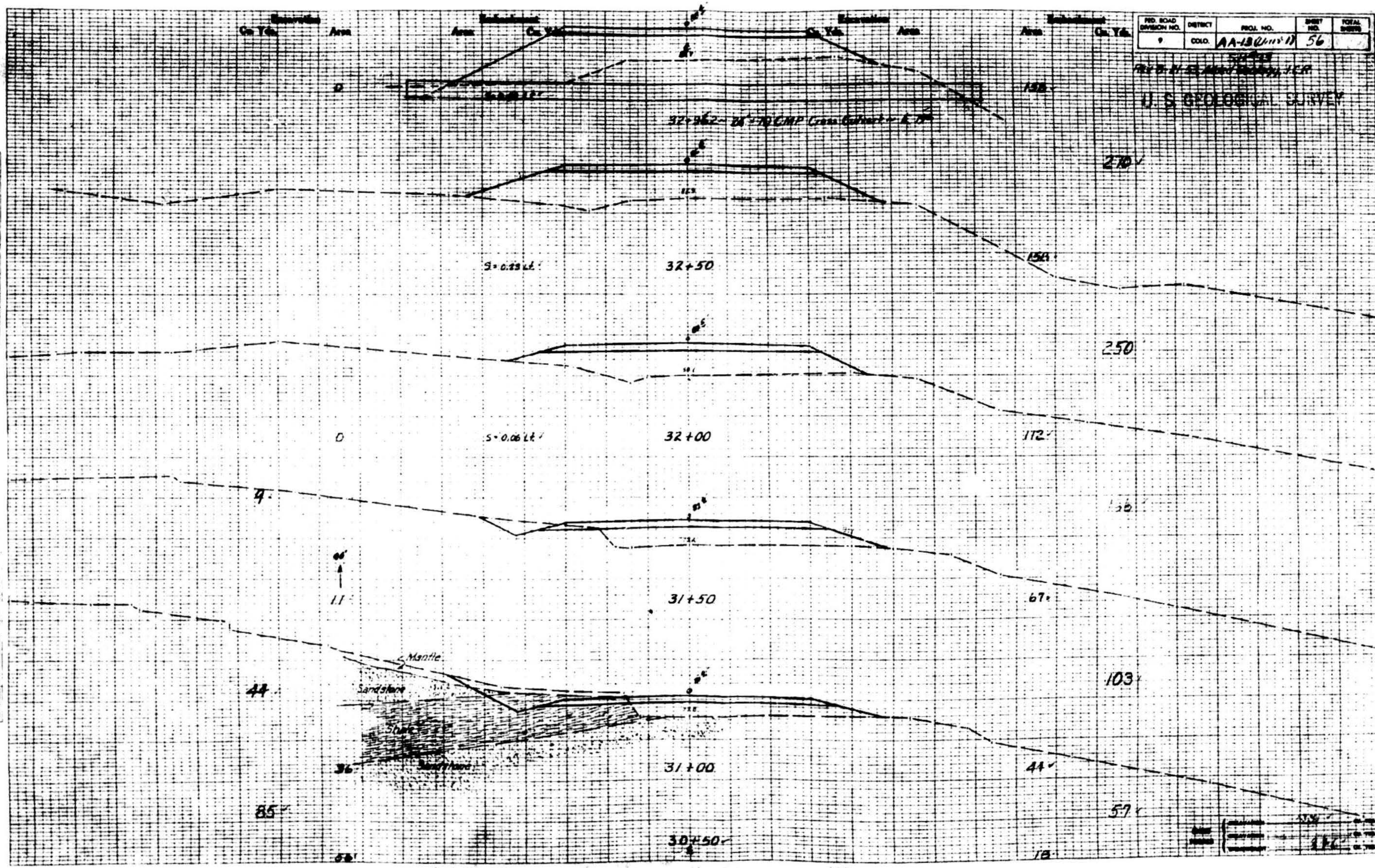




Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED. ROAD DIVISION NO.
9
DISTRICT
COLO.
PROJ. NO.
SHEET NO.
54
TOTAL SHEETS
U. S. GEOLOGICAL SURVEY
99
28+50
0
85
84
28+25
0
107
Mantle
Sandstone
Fill
Shale
148
28+00
248
120
27+50
0
190
27+00
85
SHEET TOTALS
EXCAVATION
EXCAVATION
EMBANKMENT
CU. YDS.
CU. YDS.
CU. YDS.

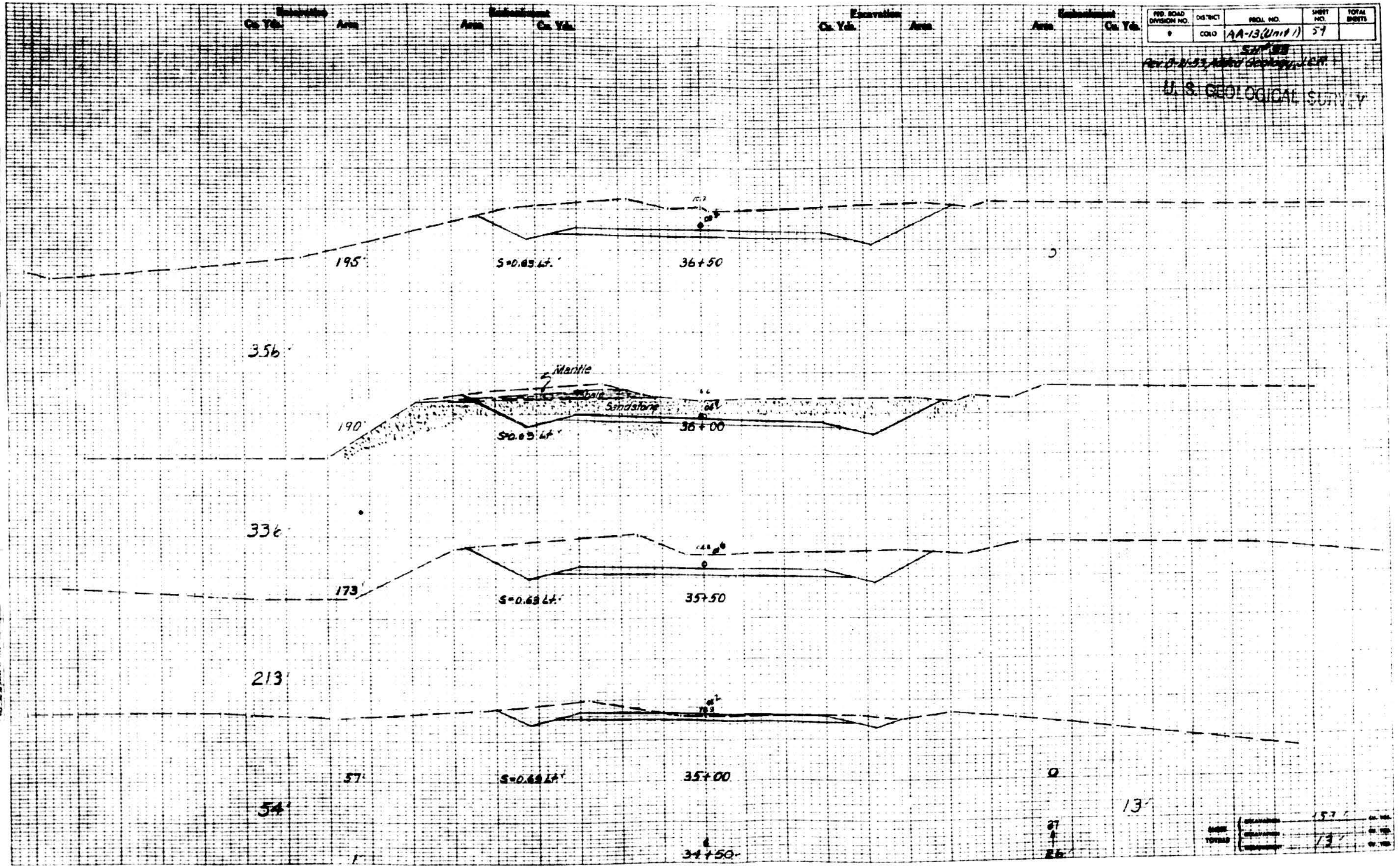


Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED. ROAD DIVISION NO.
DISTRICT
PROJ. NO.
SHEET NO.
TOTAL SHEETS
9
COLO
AA-13
55
U. S. GEOLOGICAL SURVEY
56
30+50
13
148
26
104
30+00
10
206
Mantle
Sandstone
Shale
Coal
Shale
16
118
29+50
7
178
12
74
29+00
6
27
160
3
28+50
0



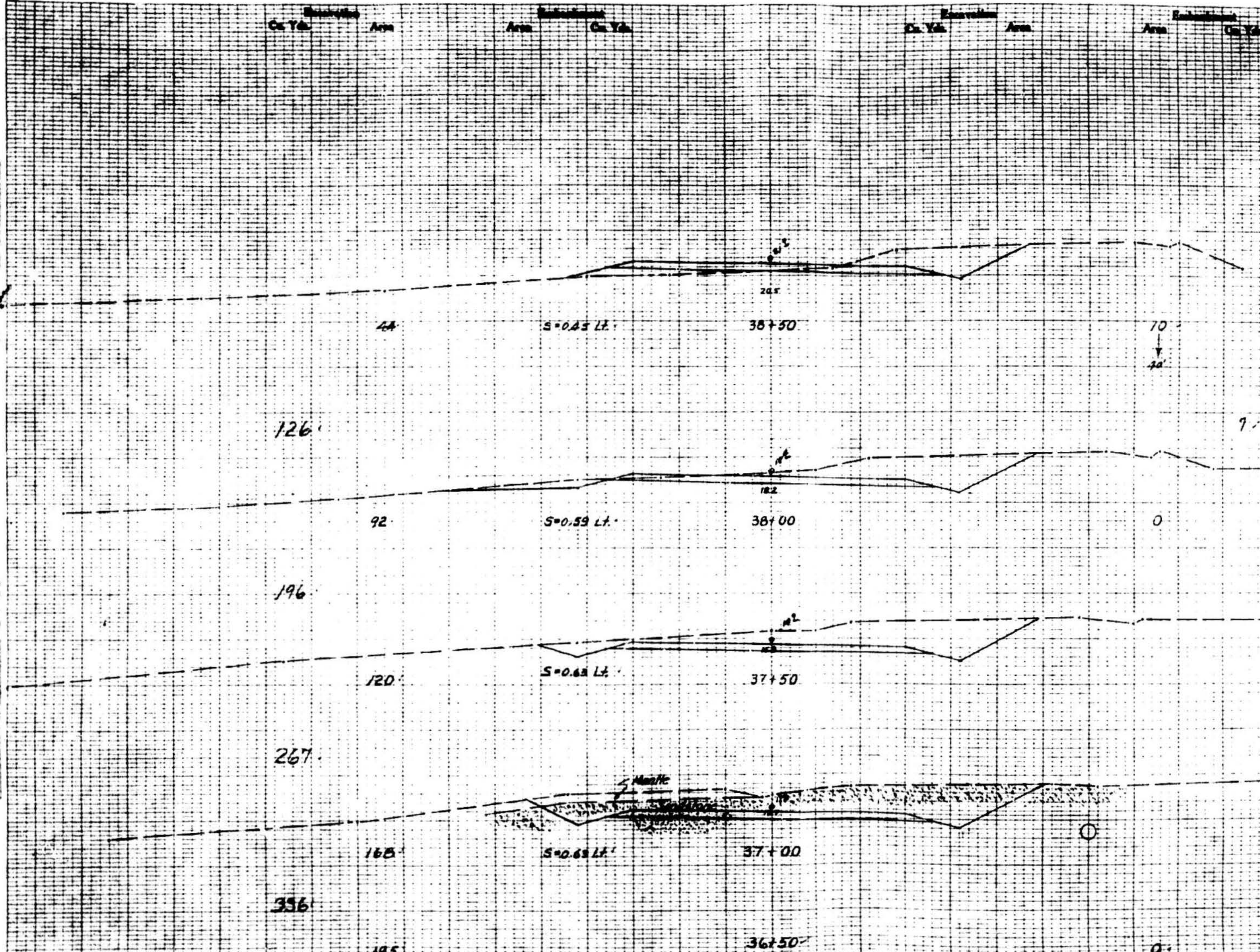
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED. ROAD DIVISION NO.
9
DISTRICT
COLO.
PROJ. NO.
SHEET NO.
56
TOTAL SHEETS
U. S. GEOLOGICAL SURVEY
32+50
32+00
31+50
31+00
270
250
112
150
103
67
44
85
57
Mantle
Sandstone
Shale

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	54	



FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 [illegible]	60	

Geology, UCR

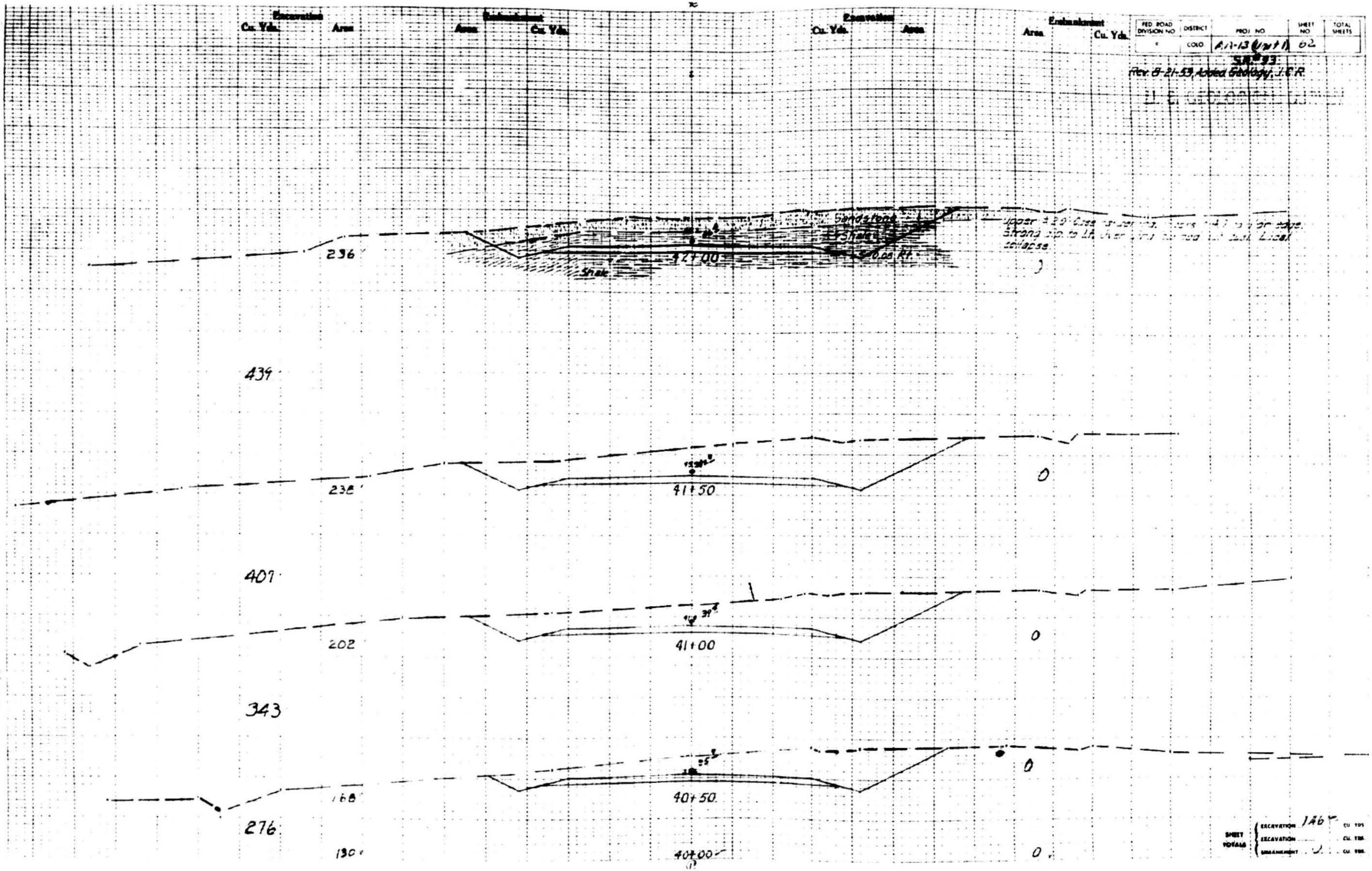


SHEET TOTALS
EXCAVATION 42.5 CU. YDS.
EXCAVATION CU. YDS.
EMBANKMENT 7 CU. YDS.

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO.	A.A-13 (Unit 1)	62	

S.H. #93

Rev. 8-21-53, Added Geology, J.E.R.



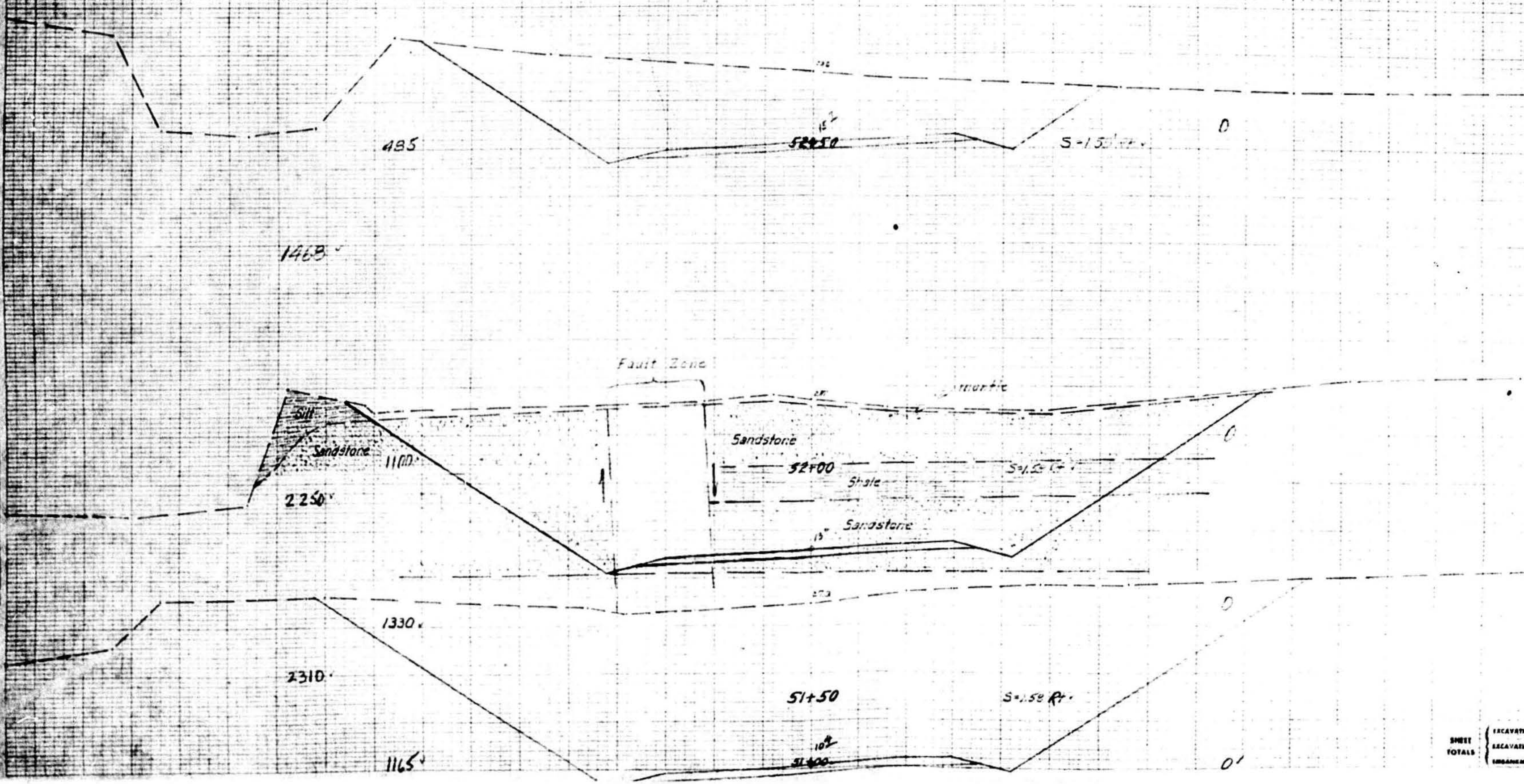
SHEET TOTALS	EXCAVATION	1267	CU. YDS.
	EXCAVATION		CU. YDS.
	EMBANKMENT	0	CU. YDS.

Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.	Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.

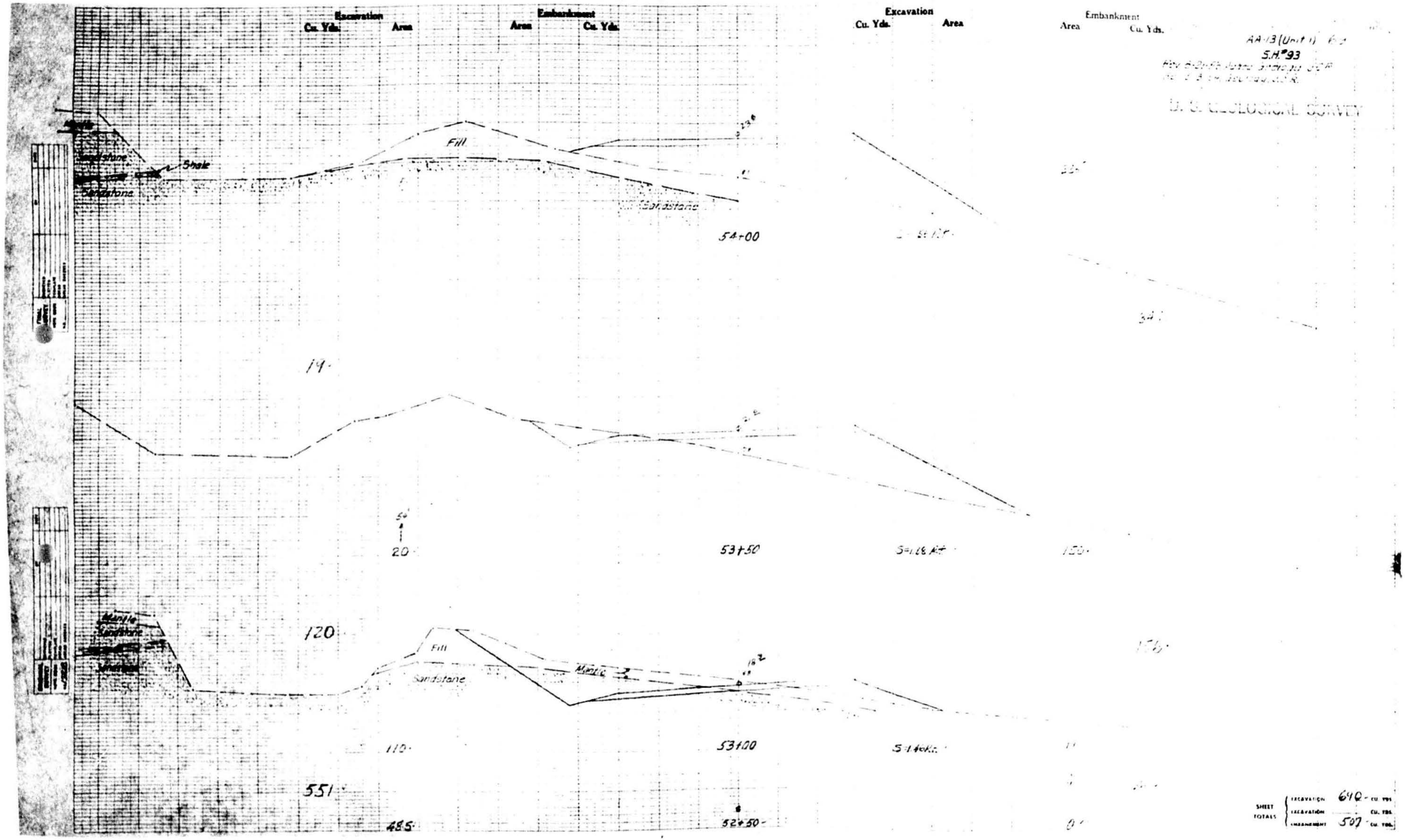
FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	68	

SH 93

Rev. 8-21-53, Added Geology, J.C.R.
Rev. 5-3-54, Geology, J.C.R.



SHEET TOTALS
EXCAVATION 6028 CU. YDS.
EXCAVATION CU. YDS.
EMBANKMENT 0 CU. YDS.



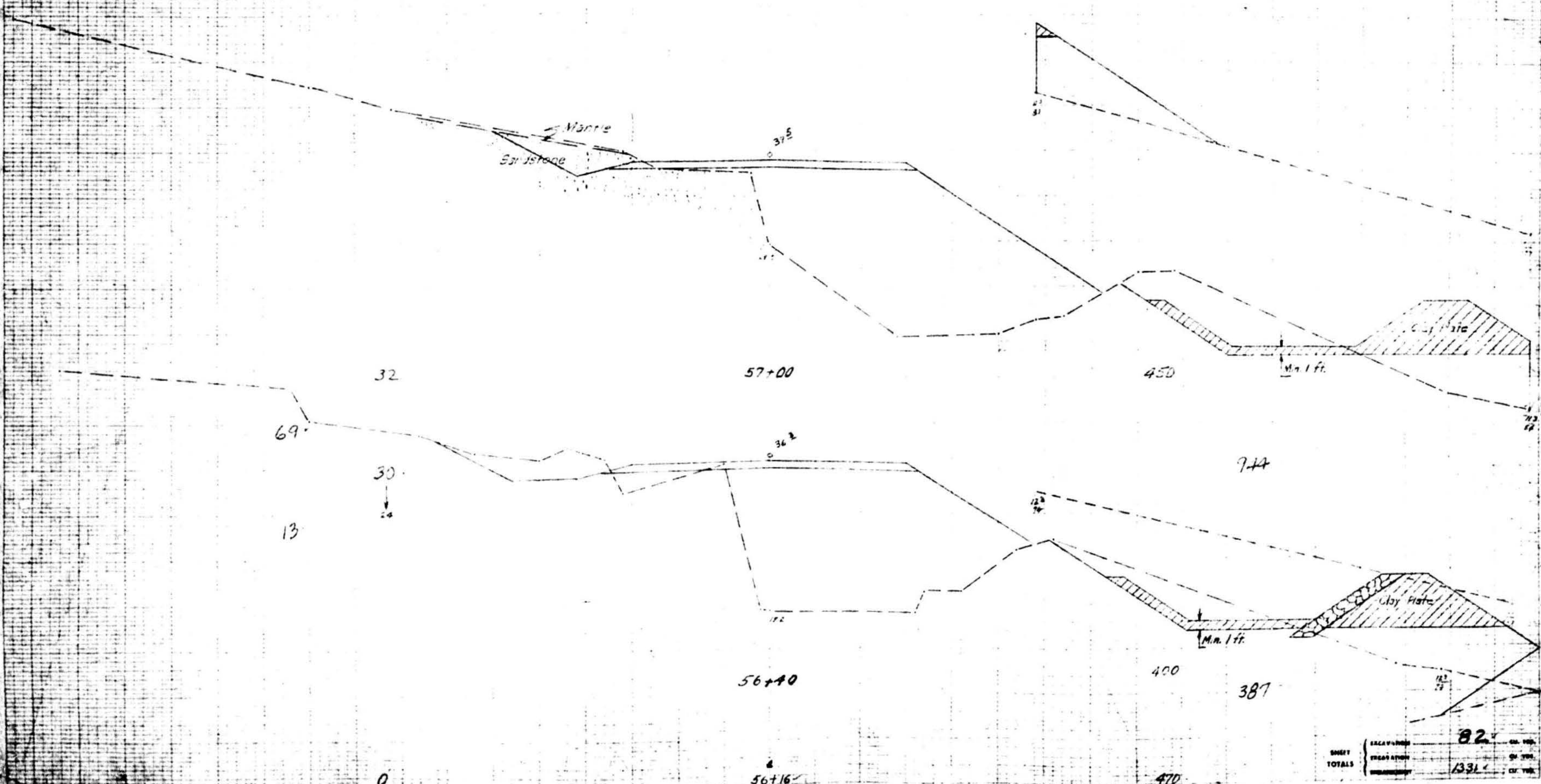
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
AA-13 (Unit 1)
S.H. #93
U. S. GEOLOGICAL SURVEY
Mantle
Sandstone
Shale
Sandstone
Fill
Sandstone
54+00
19
53+50
20
Mantle
Sandstone
Sandstone
120
Fill
Mantle
Sandstone
53+00
110
551
485
52+50
SHEET TOTALS
EXCAVATION 690 CU. YDS.
EXCAVATION CU. YDS.
EMBANKMENT 507 CU. YDS.

Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.		Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	73	

SH. # 93

Rev. 8-21-53, Added Geology, J.C.R.
Rev. 5-3-54, Geology, J.C.R.



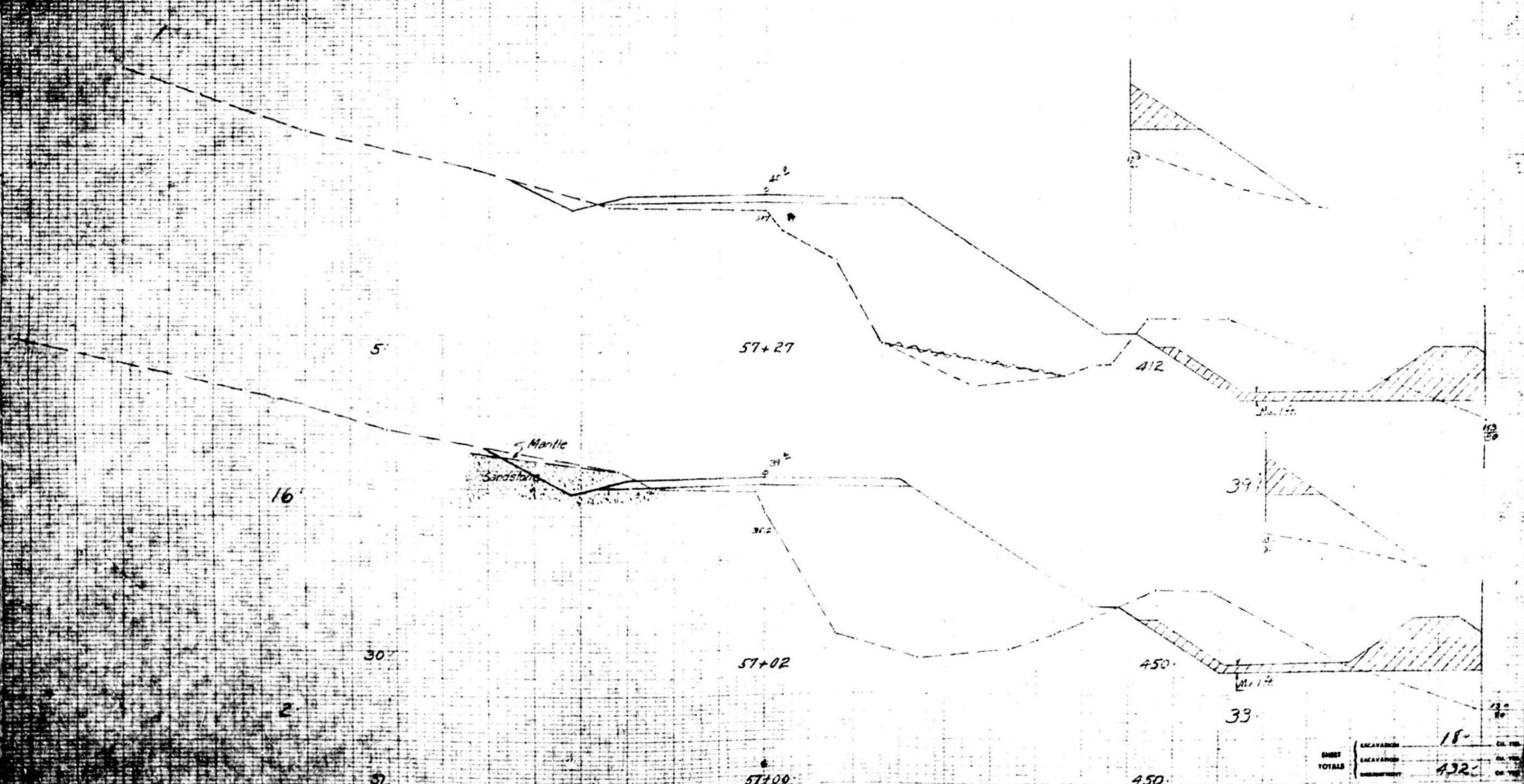
Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.	Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO.	AA-13 (Unit 1)	14	

SH#93

Rev 6-2?-55 Added Geology, J.C.R.

Rev 5-3-54 Geology, J.C.R.



SHEET TOTALS		
EXCAVATION	18	CU. YDS.
EXCAVATION		CU. YDS.
EMBANKMENT	432	CU. YDS.

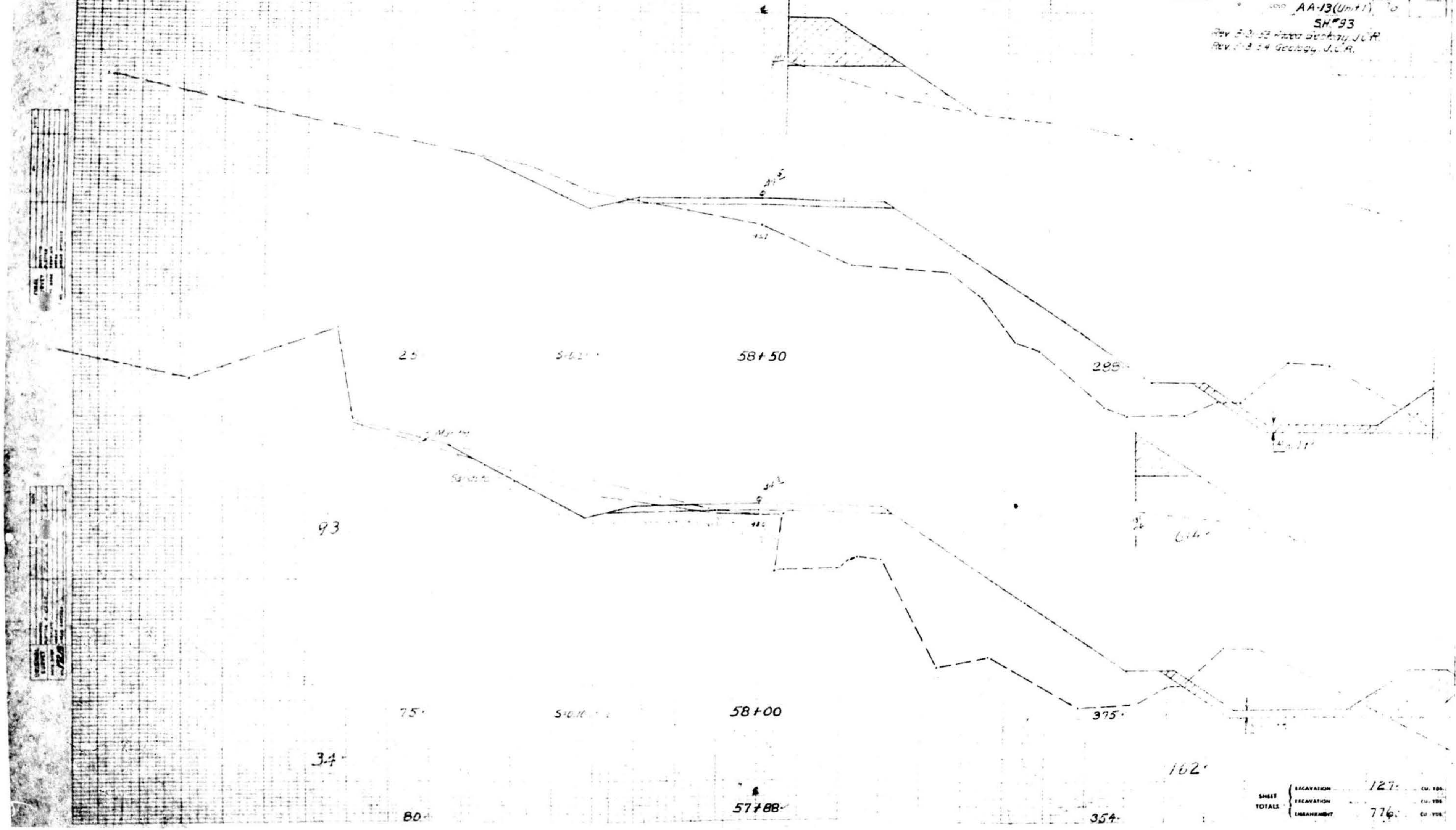
Excavation		Embankment		Excavation		Embankment	
Cu. Yds.	Area	Area	Cu. Yds.	Cu. Yds.	Area	Area	Cu. Yds.

FED. ROAD DIVISION NO. 9 | DISTRICT COLO | PROJ. NO. AA-13(Unit 1) | SHEET NO. | TOTAL SHEETS

SH. #93

Rev. 5-3-53 Added Geology J.C.R.

Rev. 5-3-54 Geology J.C.R.



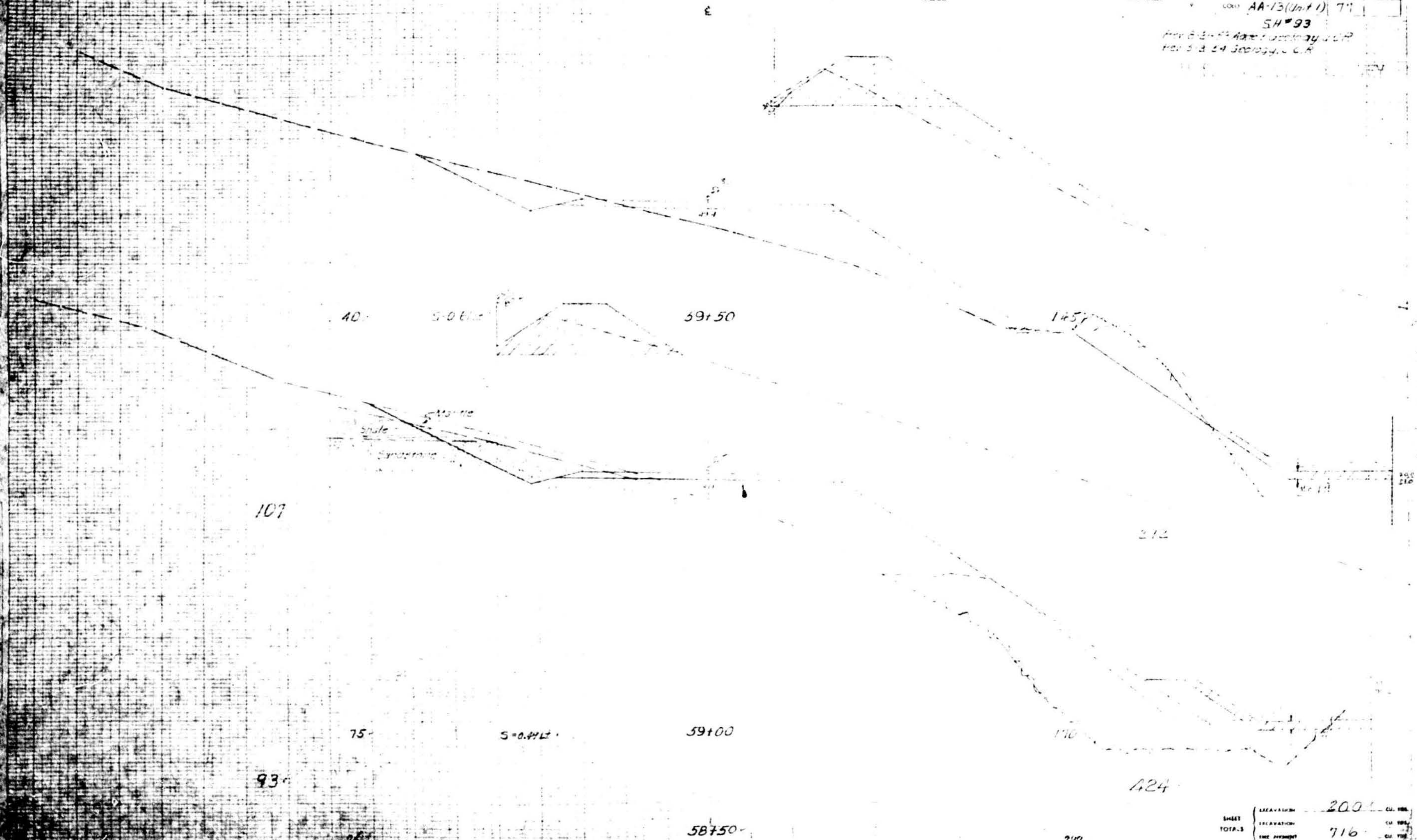
SHEET TOTALS	EXCAVATION	127.	CU. YDS.
	EXCAVATION		CU. YDS.
	EMBANKMENT	776.	CU. YDS.

Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.	℄	Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.

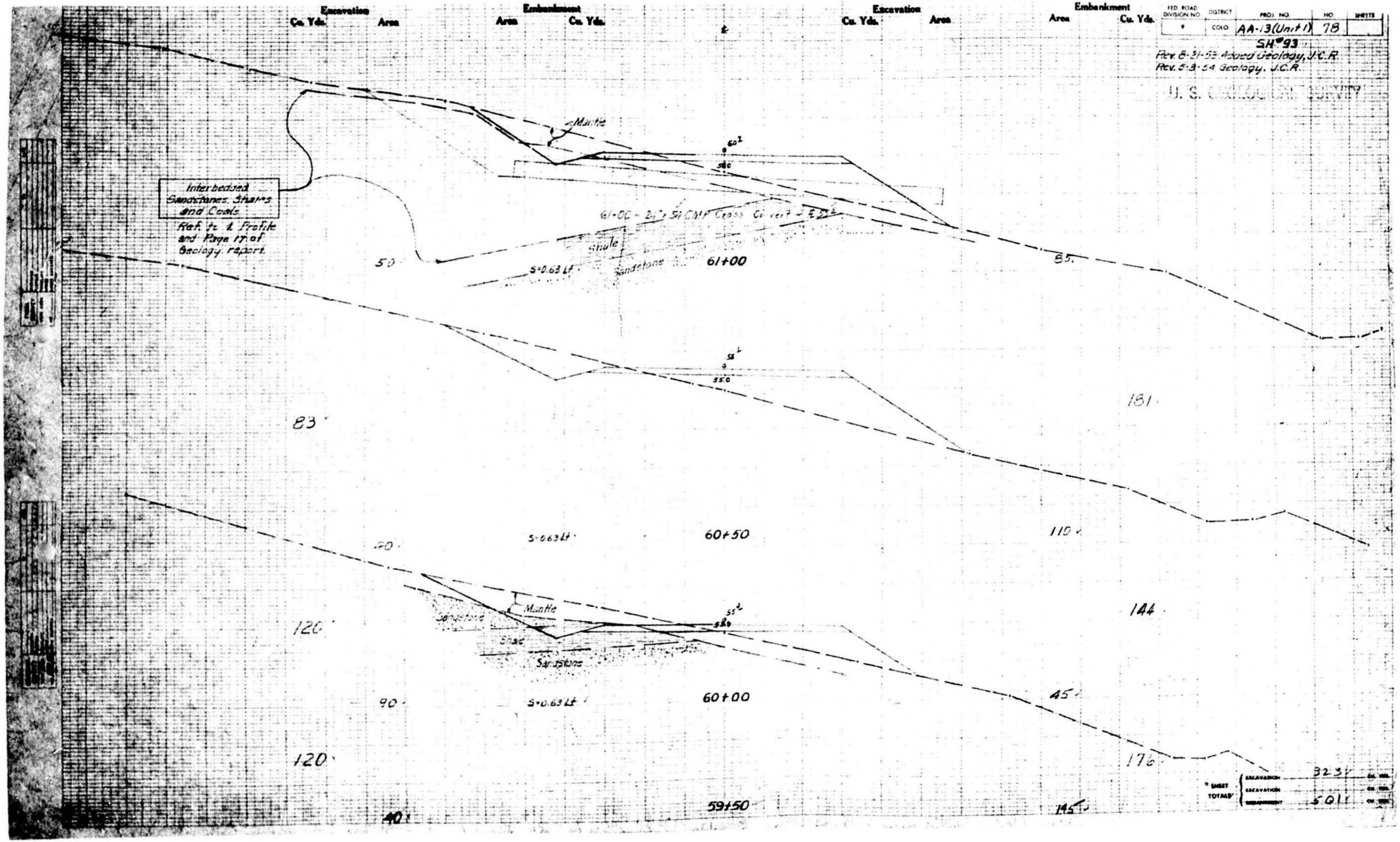
Fed. Road Division No.	State	Proj. No.	Sheet No.	Total Sheets
	COLO.	AA-13 (Unit 1)	77	

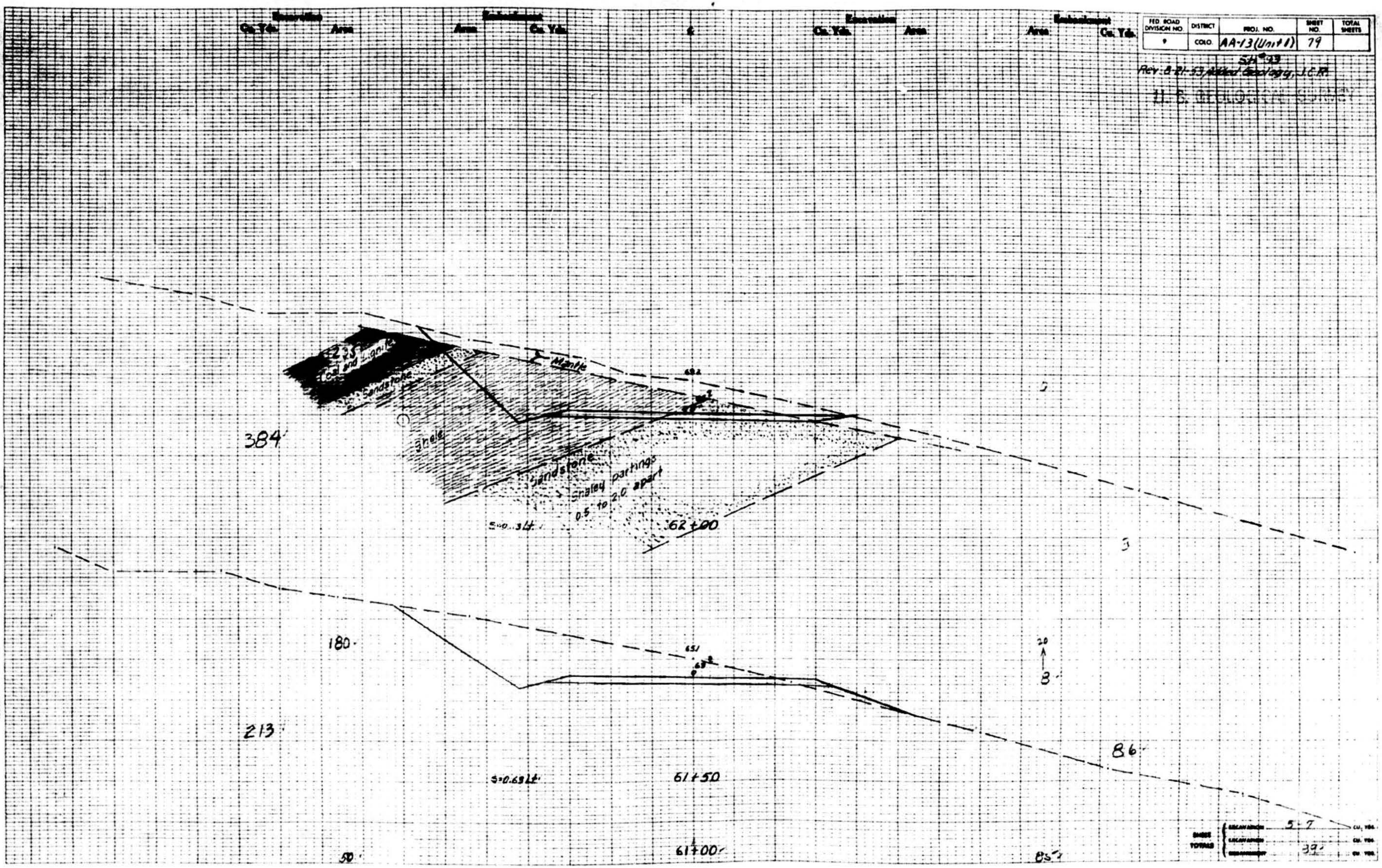
SH #93

Rev 5-3-54 Geology, C.R.

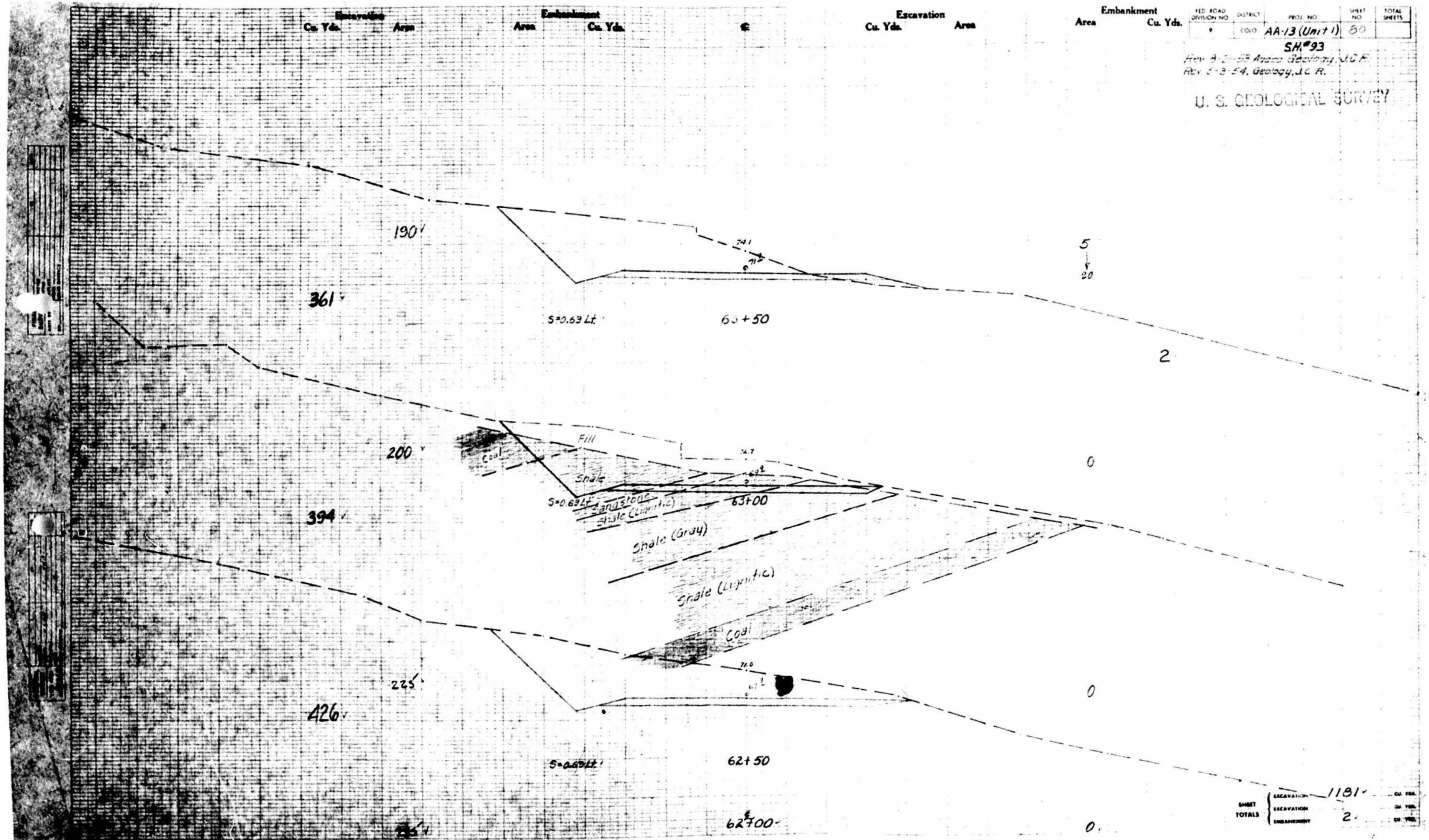


SHEET TOTALS			
	EXCAVATION	200	CU. YDS.
	EXCAVATION		CU. YDS.
	EMBANKMENT	716	CU. YDS.


Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED. ROAD DIVISION NO.
DISTRICT
PROJ. NO.
NO.
SHEETS
9
COLO.
AA-13(Unit 1)
78
SH#93
Rev. 8-31-53 Added Geology, J.C.R.
Rev. 5-3-54 Geology, J.C.R.
U. S. GEOLOGICAL SURVEY
Mantle
Interbedded Sandstones, Shales and Coals
Ref. to ℄ Profile and Page 17 of Geology report.
61+00 - 24" x 54' CMP Cross Culvert
Shale
Sandstone
50
S=0.63 Lt
61+00
85
83
181
90
S=0.63 Lt
60+50
110
120
144
Mantle
Sandstone
Shale
Sandstone
90
S=0.63 Lt
60+00
45
120
176
40
59+50
145
SHEET TOTALS
EXCAVATION
EXCAVATION
EMBANKMENT
323
501
CU. YDS.



Excavation Cu. Yds. Area
Embankment Area Cu. Yds.
℄
Excavation Cu. Yds. Area
Embankment Area Cu. Yds.
FED ROAD DIVISION NO. 9
DISTRICT COLO.
PROJ. NO. AA-13(Unit 1)
SHEET NO. 79
TOTAL SHEETS
SH 33
Rev. 8-21-53, Added Geology, J.C.R.
U. S. GEOLOGICAL SURVEY
Coal and Lignite
Sandstone
Mantle
Shale
Sandstone
Shaley partings 0.5' to 2.0' apart
384
62+00
180
213
61+50
61+00
86
50
85
SHEET TOTALS
5-7 CU. YDS.
39 CU. YDS.

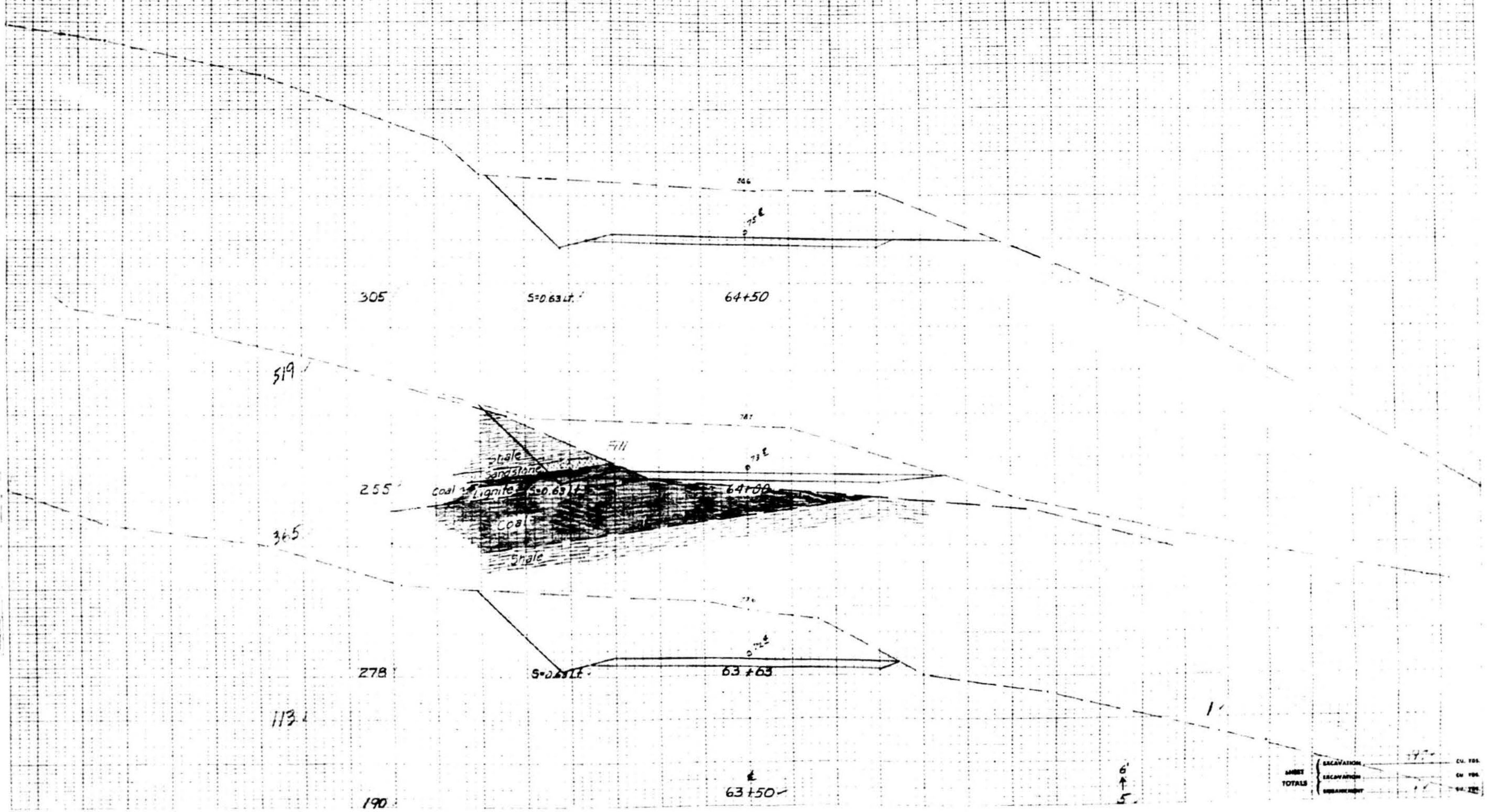

Excavation
Embankment
Cu. Yds.
Area
Area
Cu. Yds.
℄
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED ROAD DIVISION NO
DISTRICT
PROJ NO
SHEET NO
TOTAL SHEETS
9
COLO
AA-13 (Unit 1)
80
SH.#93
Rev 3-2-53 Added Geology, J.C.R.
Rev 5-3-54, Geology, J.C.R.
U. S. GEOLOGICAL SURVEY
190
361
5
20
S=0.63 Lt.
63+50
2
200
Fill
Coal
Shale
Sandstone
Shale (Lignitic)
S=0.63 Lt.
63+00
394
Shale (Gray)
Shale (Lignitic)
Coal
0
225
426
0
S=0.63 Lt.
62+50
62+00
0.
SHEET TOTALS
EXCAVATION
EXCAVATION
EMBANKMENT
1181
2
CU. YDS.
CU. YDS.
CU. YDS.

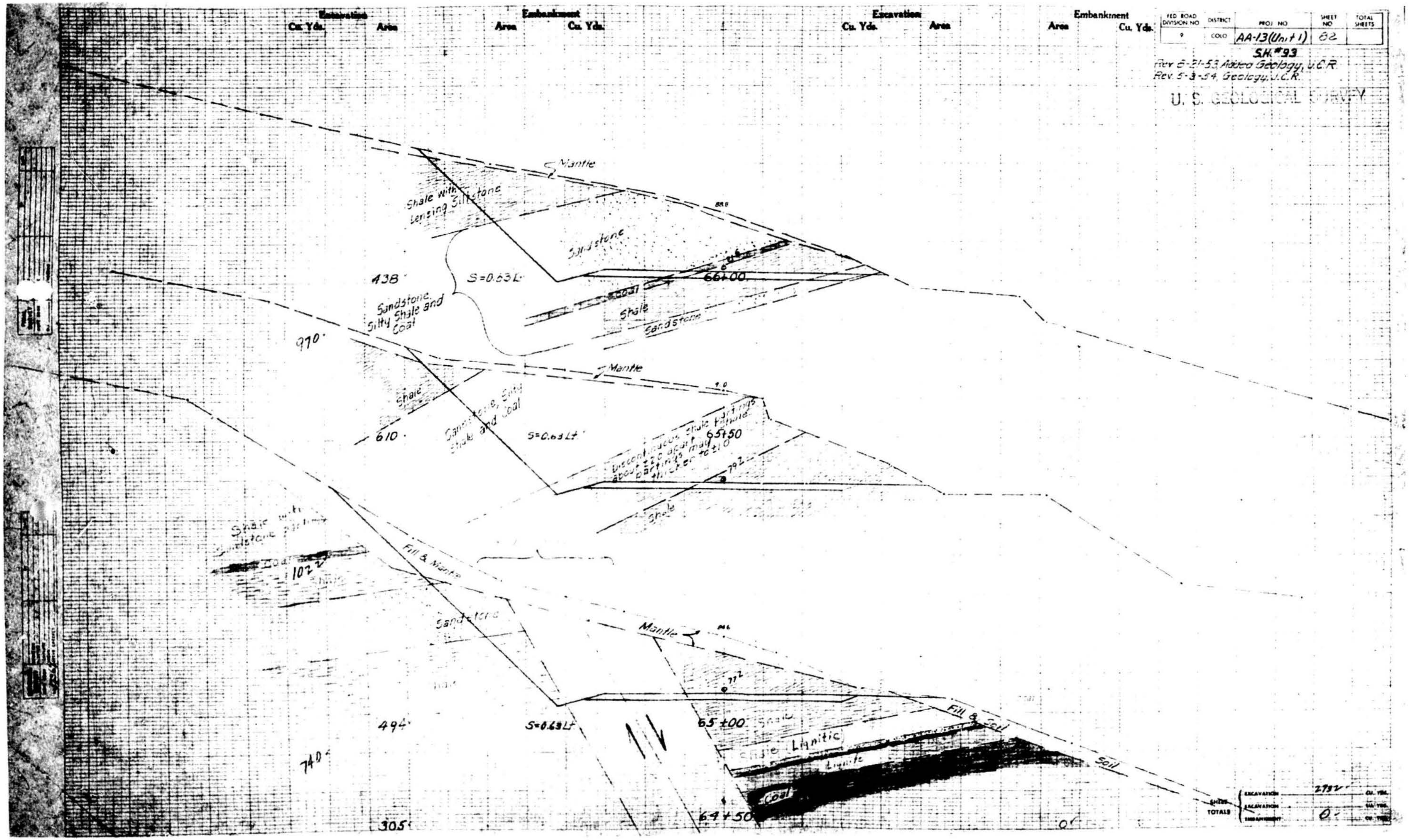
FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	81	

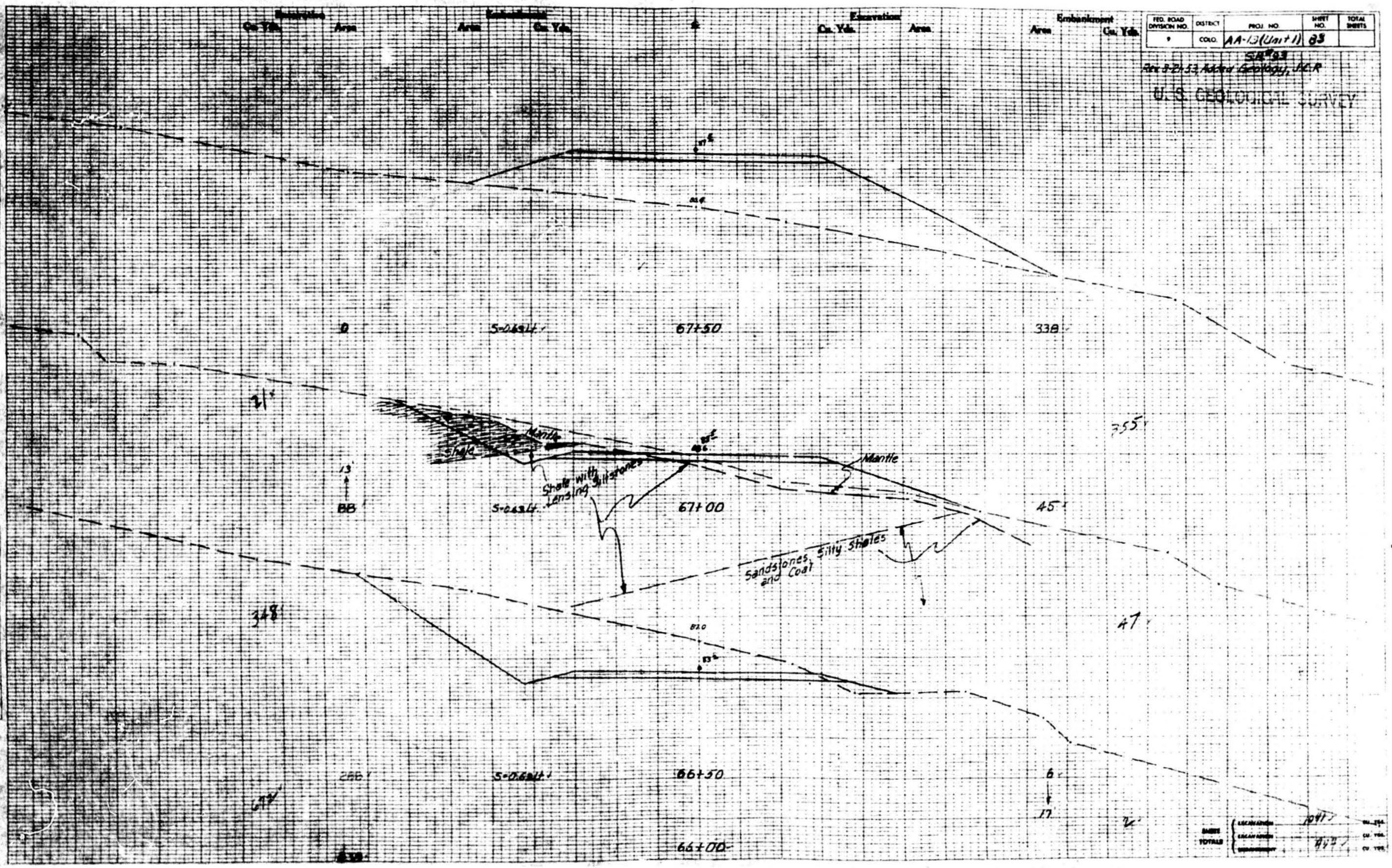
S.H. 93

Rev. 2-21-53, Added Geology; J.C.R.

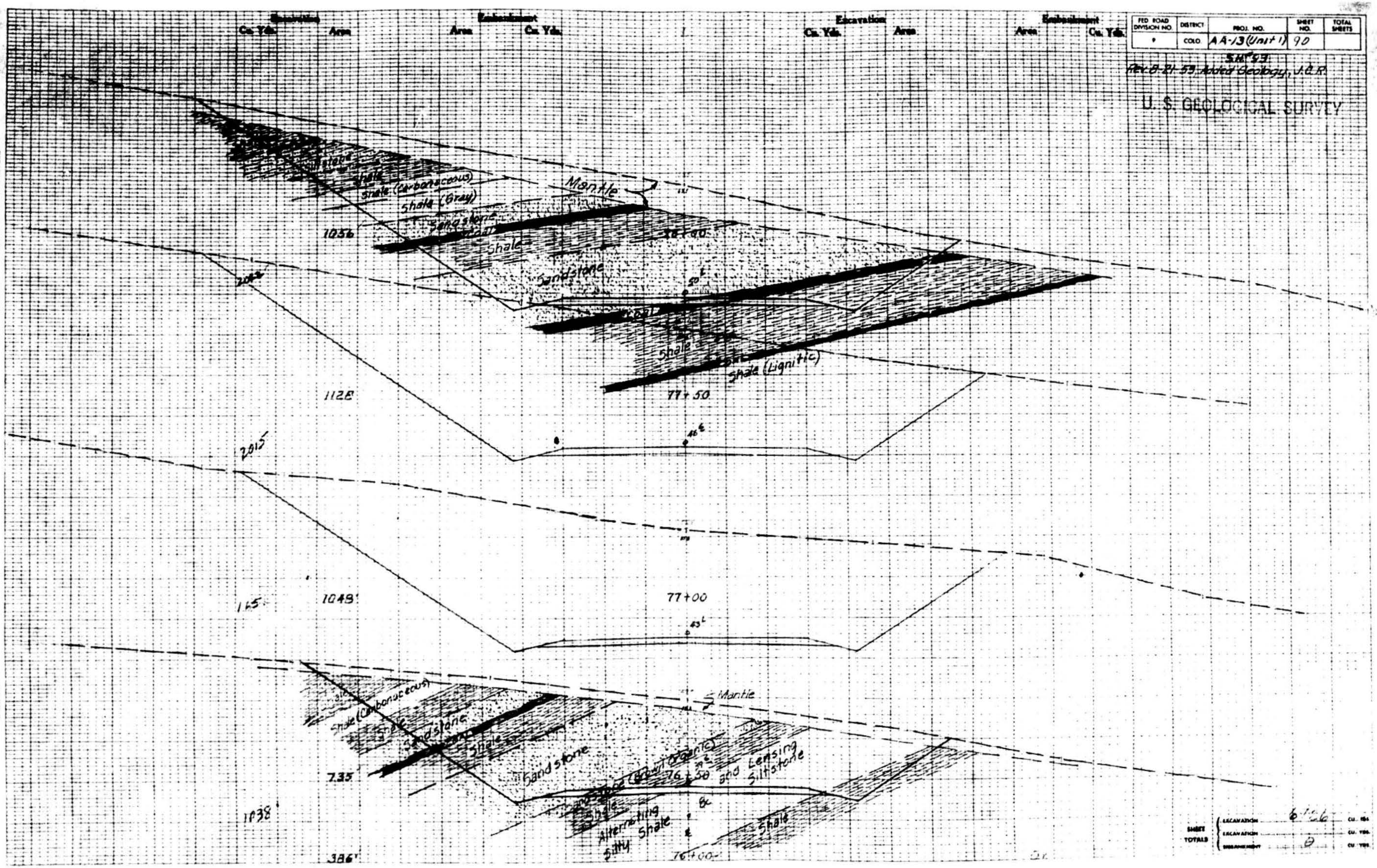
Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.	℄	Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.



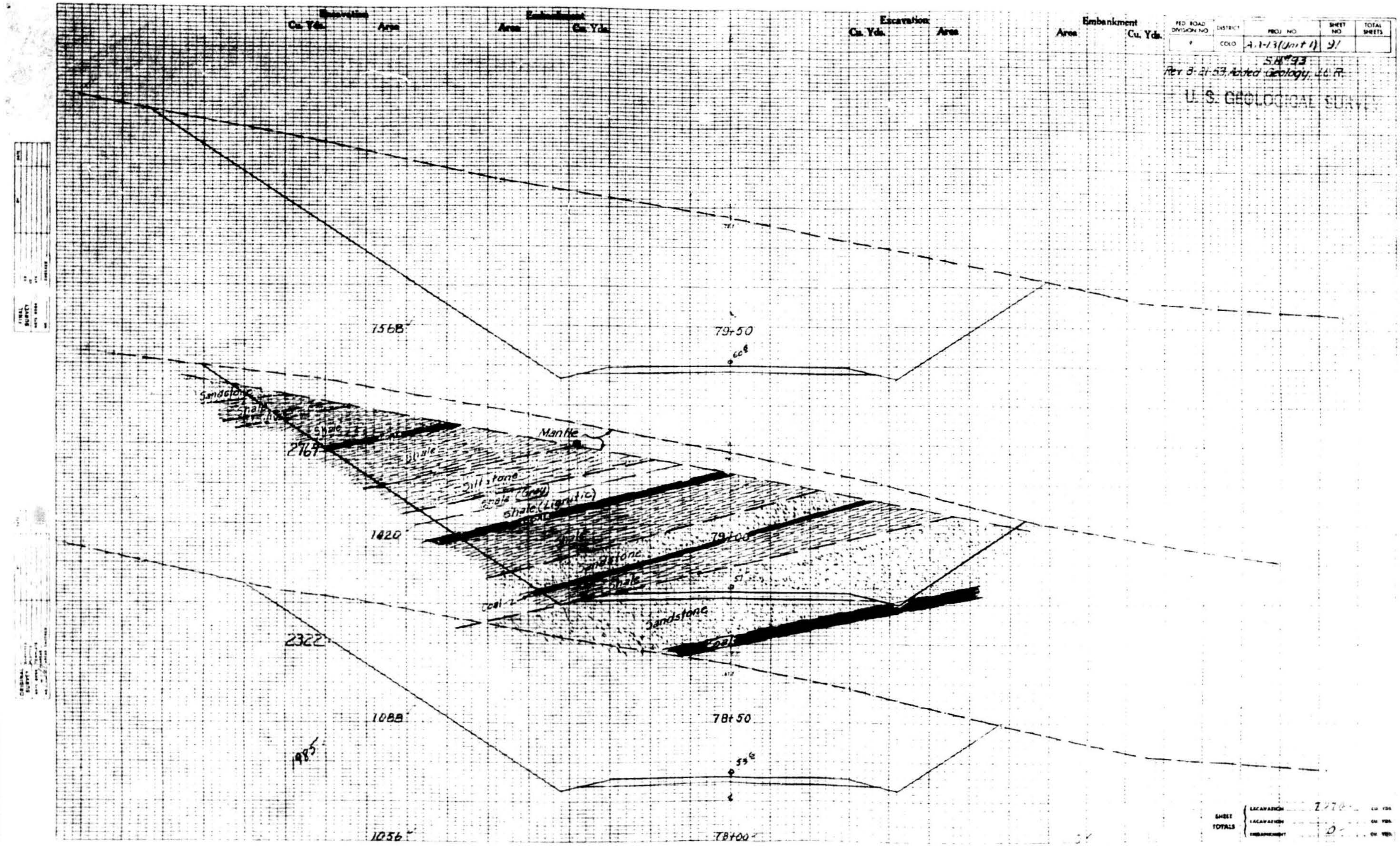

Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED ROAD DIVISION NO
DISTRICT
PROJ NO
SHEET NO
TOTAL SHEETS
9
COLO
AA-13(Unit 1)
82
SH.#93
Rev. 8-21-53 Added Geology, U.C.R.
Rev. 5-3-54, Geology, U.C.R.
U. S. GEOLOGICAL SURVEY
Mantle
Shale with Lensing Siltstone
Sandstone
438
S=0.63 Lt
66+00
Sandstone, Silty Shale and Coal
Shale
Sandstone
970
Mantle
Shale
Sandstone, Silty Shale and Coal
610
S=0.63 Lt
65+50
Discontinuous shale partings about 2 ft apart. Partings may thicken to ±1.0
792
Shale
Shale with Sandstone partings
Coal
1022
Fill & Mantle
Sandstone
Mantle
772
Fill & Soil
494
S=0.63 Lt
65+00
Shale
Shale Lignitic
Lignite
Soil
740
Coal
305
64+50
SHEET TOTALS
EXCAVATION
2792
CU. YDS.
EMBANKMENT
0
CU. YDS.



Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED. ROAD DIVISION NO.
DISTRICT
PROJ. NO.
SHEET NO.
TOTAL SHEETS
9
COLO.
AA-13(Unit 1)
83
Rev 8-21-53, Added Geology, JCR
U.S. GEOLOGICAL SURVEY
0
S=0.634
67+50
338
21
355
Shale
Mantle
Shale with Lensing Siltstones
Mantle
13
BB
S=0.634
67+00
45
Sandstones, Silty Shales and Coal
348
47
820
266
S=0.634
66+50
6
17
67
66+00
SHEET TOTALS
EXCAVATION
EMBANKMENT
1041
447
CU. YDS.



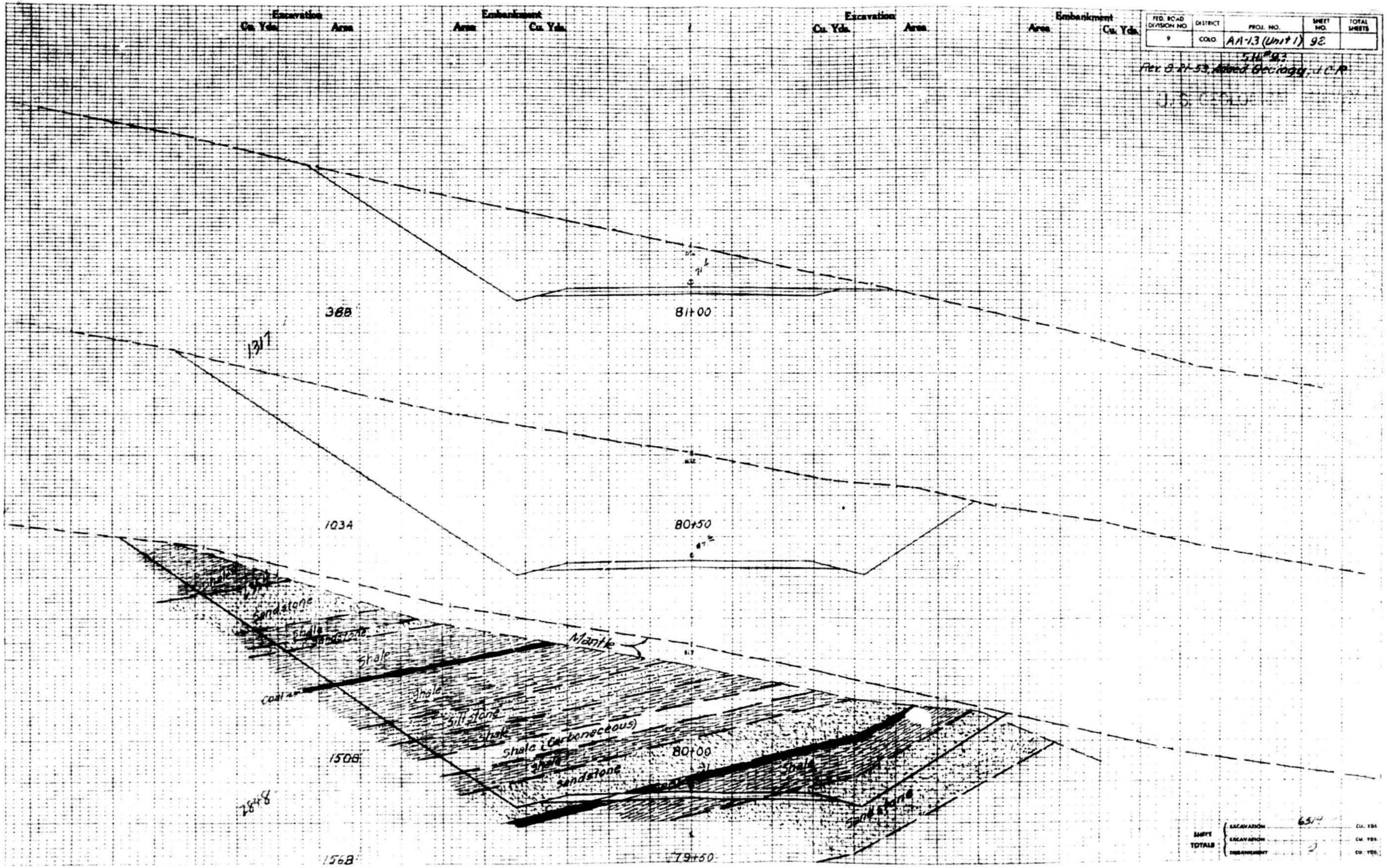
Excavation
Embankment
Excavation
Embankment
Cu. Yds.
Area
Area
Cu. Yds.
Cu. Yds.
Area
Area
Cu. Yds.
FED ROAD DIVISION NO. 9
DISTRICT COLO
PROJ. NO. AA-13 (Unit 1)
SHEET NO. 90
TOTAL SHEETS
S.H. 93
Rev. 8-21-59, Added Geology, J.C.R.
U. S. GEOLOGICAL SURVEY
Siltstone
Shale
Shale (Carbonaceous)
Shale (Gray)
Mantle
Sandstone
Shale
Sandstone
Shale
Shale (Lignitic)
1036
78+00
50
2012
1128
77+50
2015
1049
77+00
Mantle
Shale (Carbonaceous)
Sandstone
Shale
Sandstone
Shale
Alternating Silty Shale and Lensing Siltstone
76+50
Shale
735
1038
386
76+00
SHEET TOTALS
EXCAVATION
EXCAVATION
EMBANKMENT
CU. YDS.
CU. YDS.
CU. YDS.

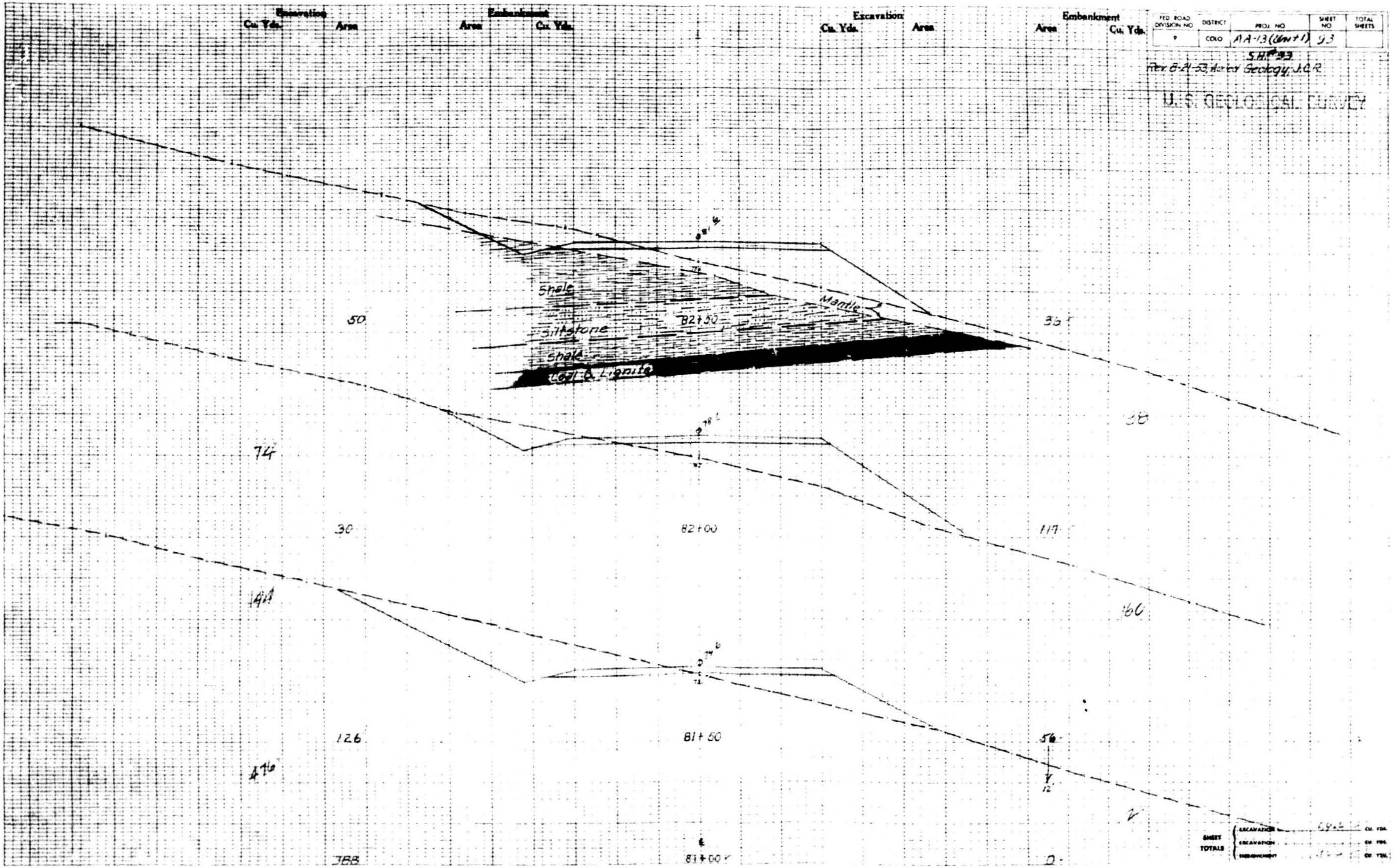

Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED. ROAD DIVISION NO.
DISTRICT
COLO
PROJ. NO.
A.A-13(Unit 1)
SHEET NO.
91
TOTAL SHEETS
S.H. 93
Rev 3-21-53 Added Geology
U. S. GEOLOGICAL SURVEY
7568
79+50
Sandstone
Shale
Mantle
2164
Shale
Siltstone
Shale (Grey)
Shale (Lignitic)
1820
79+00
Siltstone
Shale
Coal-2
Sandstone
Coal
2322
1088
78+50
1985
1056
78+00
SHEET TOTALS
EXCAVATION
EMBANKMENT

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO.	AN-13 (Unit 1)	92	

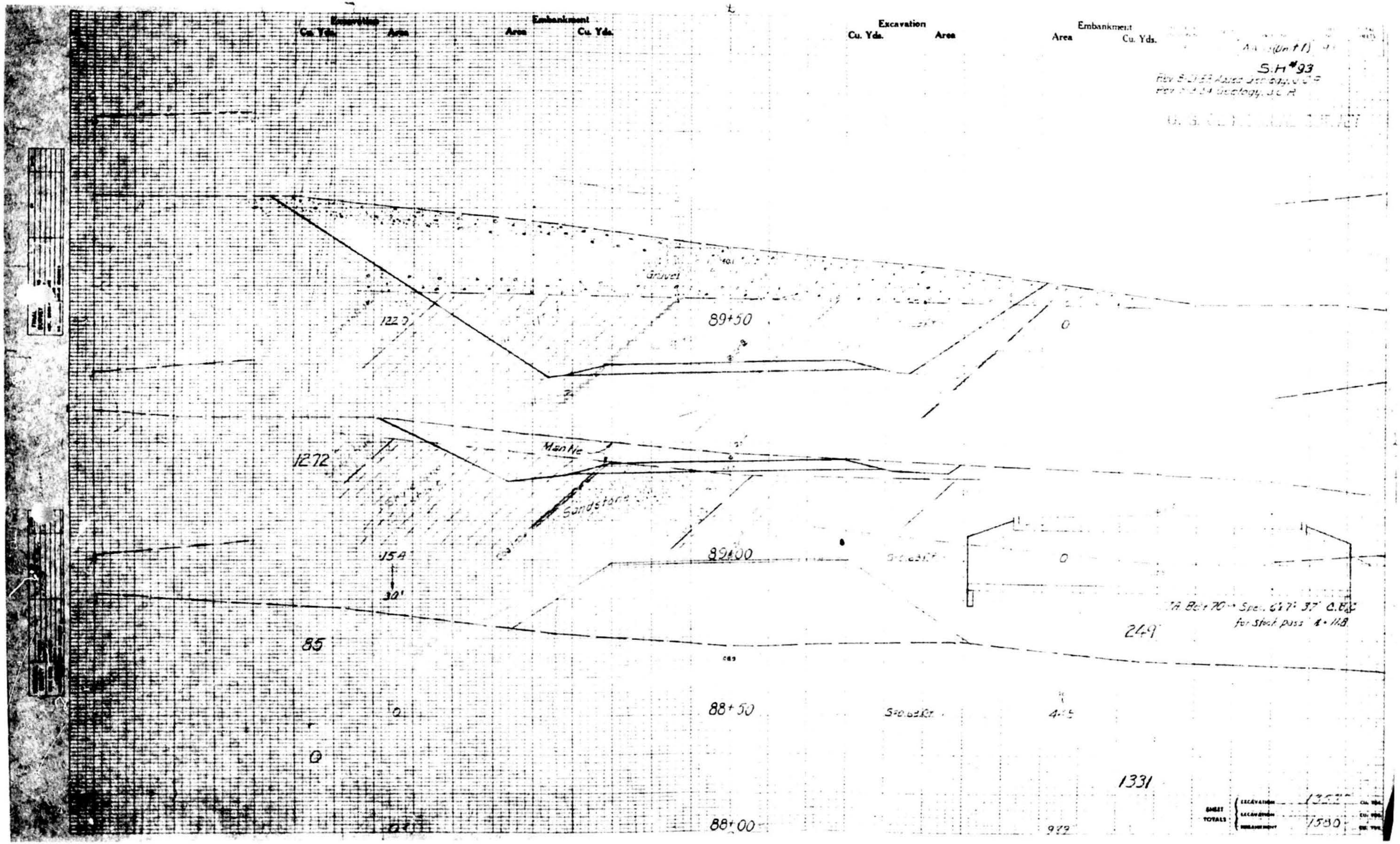
Rev. 8-21-53, Added Geology, J.C.P.

J. S. C.





FED ROAD DIVISION NO 9
DISTRICT COLO
PROJ. NO AA-13 (Unit 1)
SHEET NO 93
TOTAL SHEETS
S.H. #93
Rev 8-21-53, Added Geology, J.C.R.
U.S. GEOLOGICAL SURVEY
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Shale
Siltstone
Shale
Coal & Lignite
Mantle
50
82+50
35
74
38
30
82+00
117
144
160
126
81+50
56
388
81+00
0
SHEET TOTALS
EXCAVATION
EXCAVATION
EMBANKMENT
CU. YDS.


Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
S.H #93
Gravel
122.0
89+50
0
1272
Sandstone
154
30'
89+00
0
249
85
88+50
0
1331
88+00
EXCAVATION
EMBANKMENT
SHEET TOTALS
Cu. Yds.

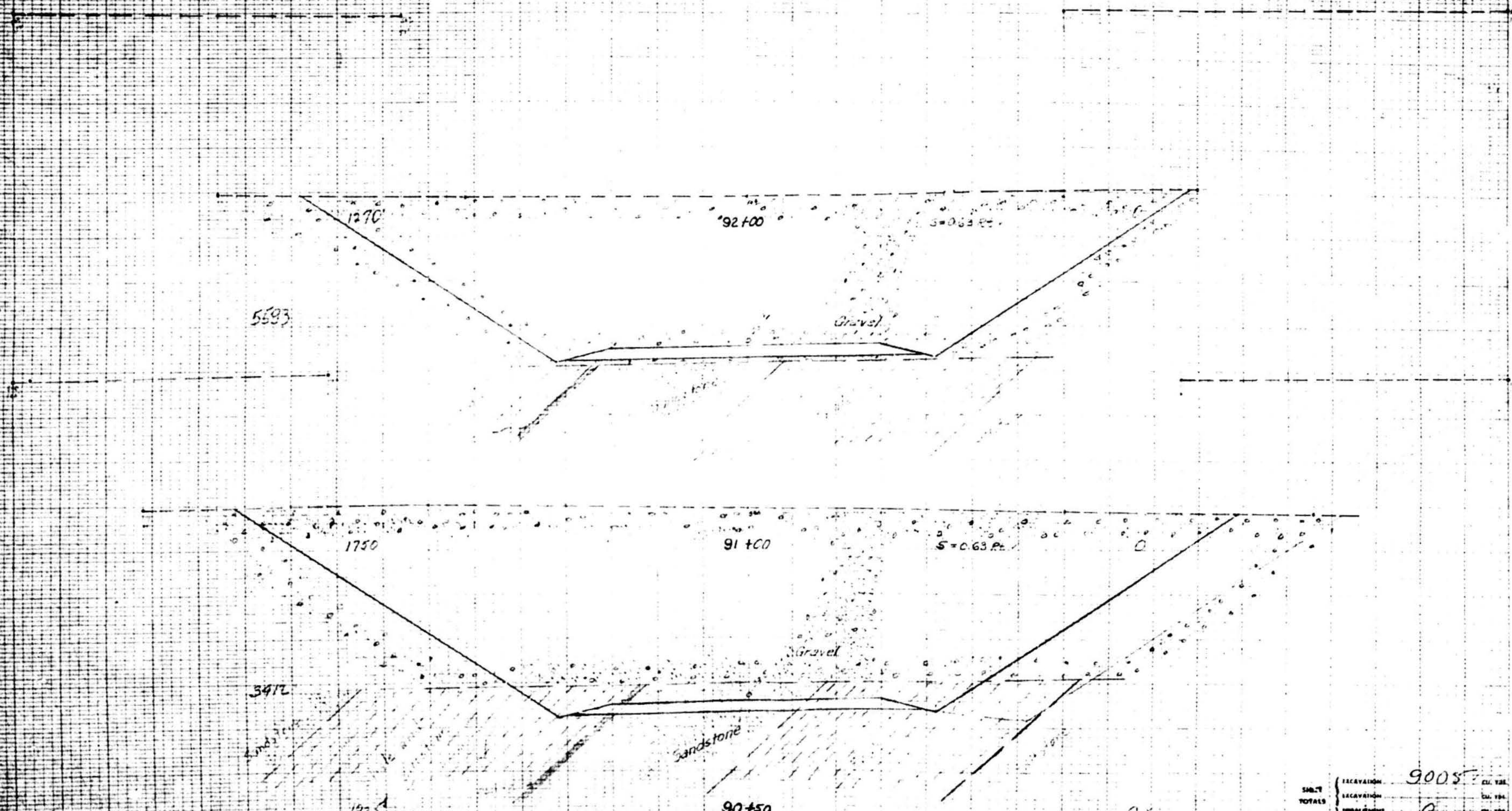
Excavation Cu. Yds.	Area	Embankment Area	Cu. Yds.	Excavation Cu. Yds.	Area	Embankment Area	Cu. Yds.

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	101	

SH#93

Rev. 8-21-53 Added Geology, J.C.R.
Rev. 5-3-54 Geology, J.C.R.

U. S. GEOLOGICAL SURVEY



SHEET TOTALS			
	EXCAVATION	9005	CU. YDS.
	EXCAVATION		CU. YDS.
	EMBANKMENT	0	CU. YDS.

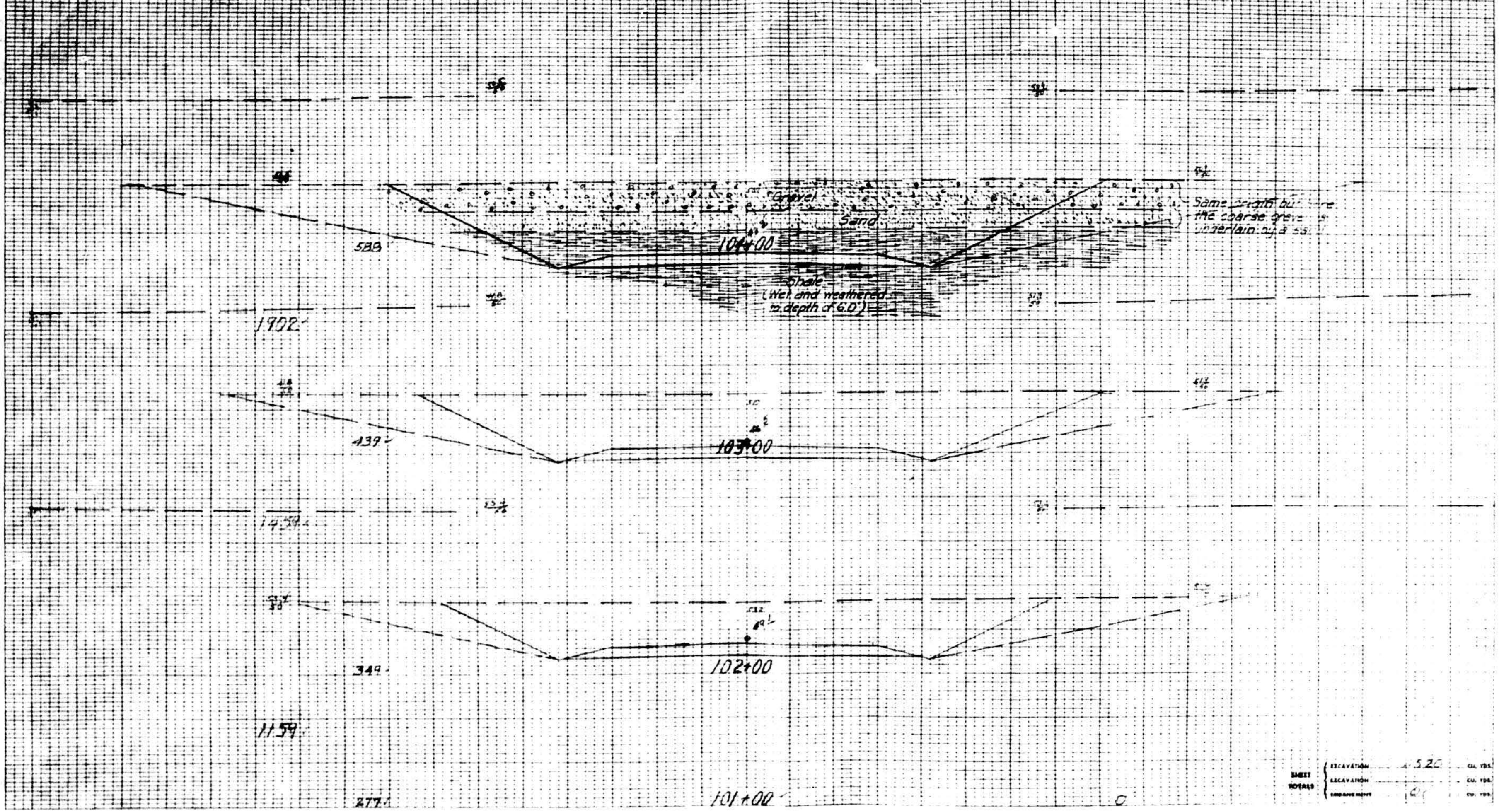
FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO.	A11-13(Unit 1)	105	

SH 93

Rev. 8-21-53 Added Geology, J.C.R.

U. S. GEOLOGICAL SURVEY

Excavation		Embankment		Excavation		Embankment	
Cu. Yds.	Area	Area	Cu. Yds.	Cu. Yds.	Area	Area	Cu. Yds.



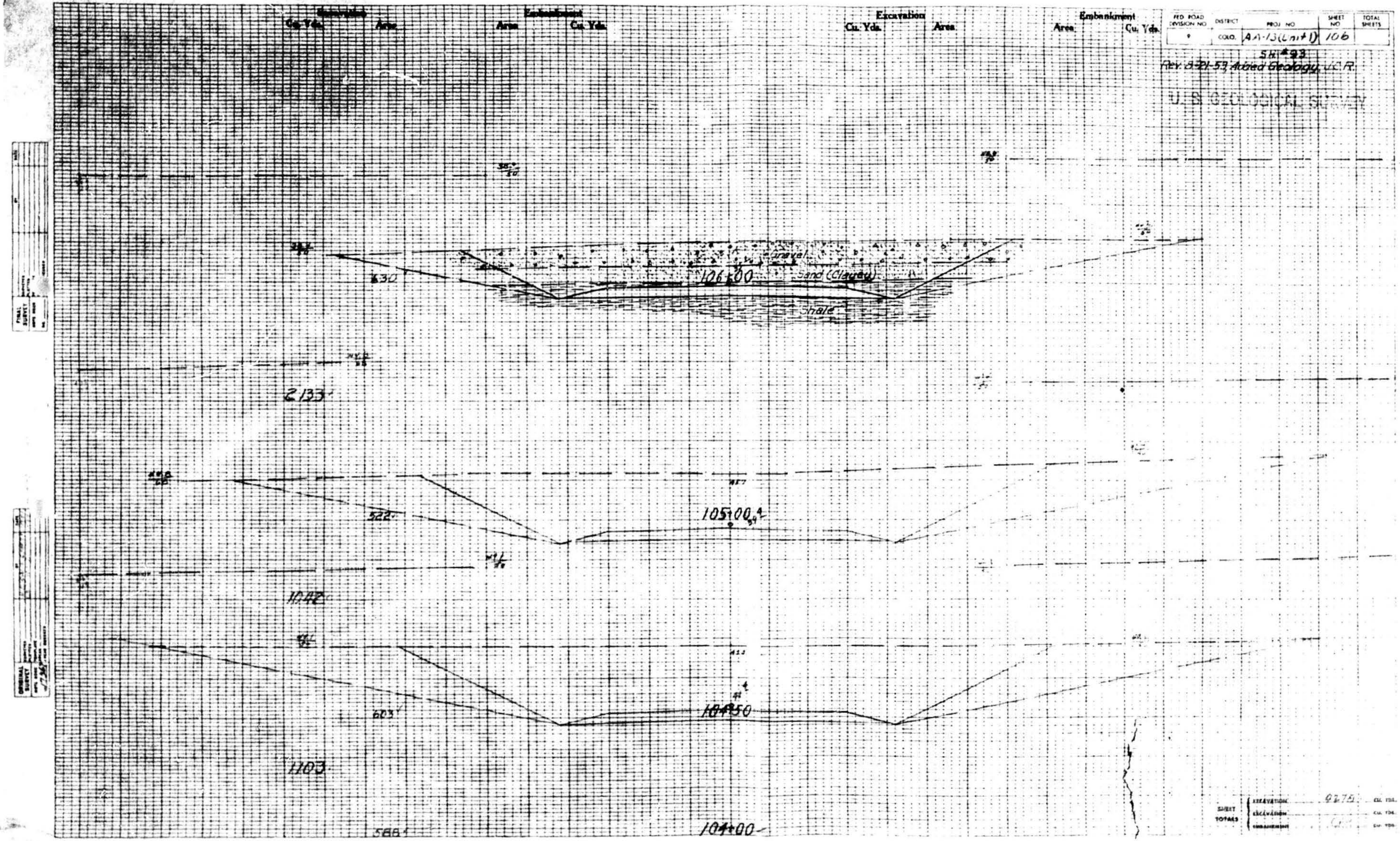
SHEET TOTALS
EXCAVATION
EXCAVATION
EMBANKMENT
CU. YDS.

FED ROAD DIVISION NO	DISTRICT	PROJ NO	SHEET NO	TOTAL SHEETS
9	COLO.	AA-13(Unit 1)	106	

SH. #93

Rev. 8-21-53 Added Geology, J.C.R.

U. S. GEOLOGICAL SURVEY

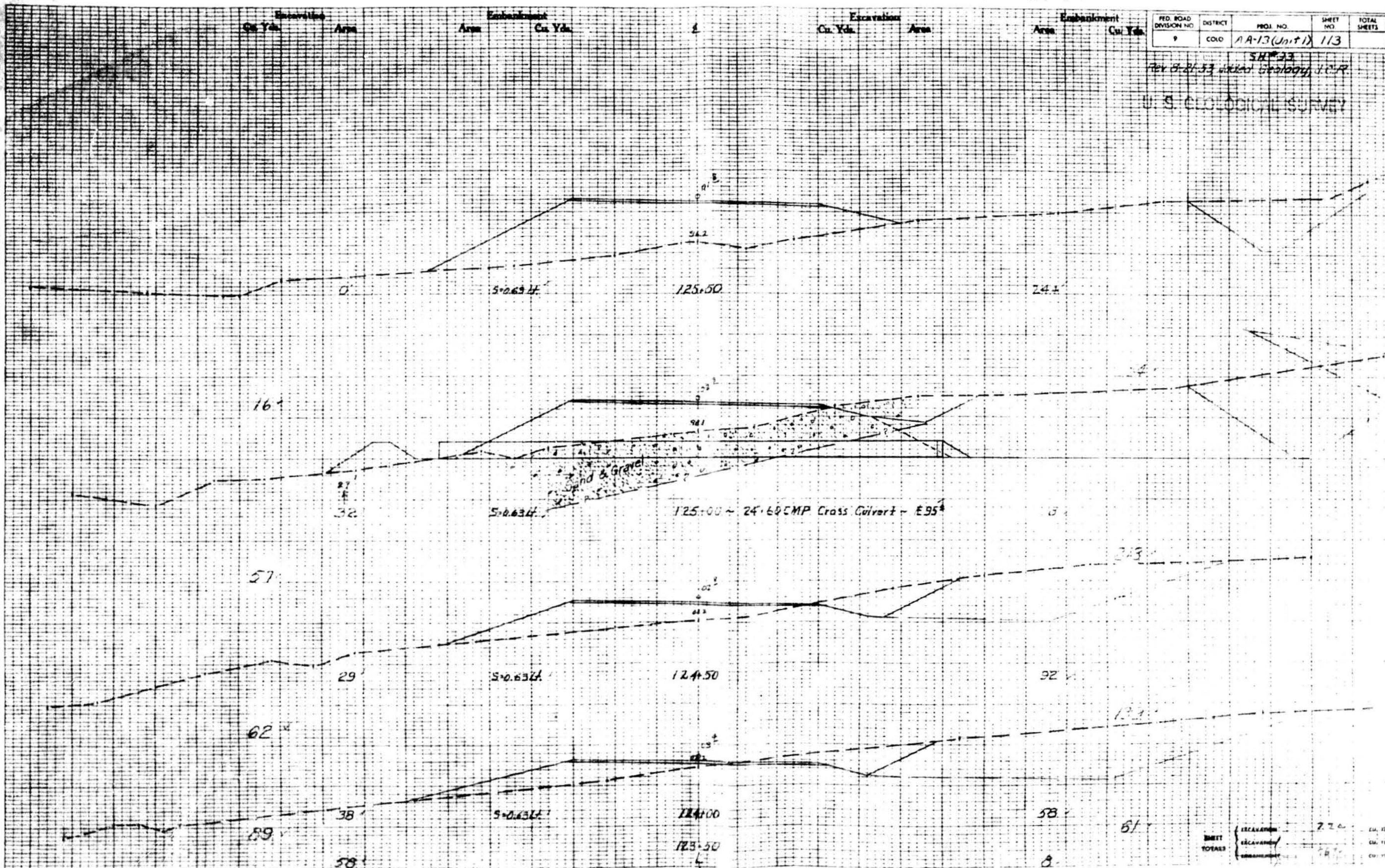


FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13(Unit 1)	113	

SH #33

Rev 8-21-53 added Geology, J.C.R.

U. S. GEOLOGICAL SURVEY



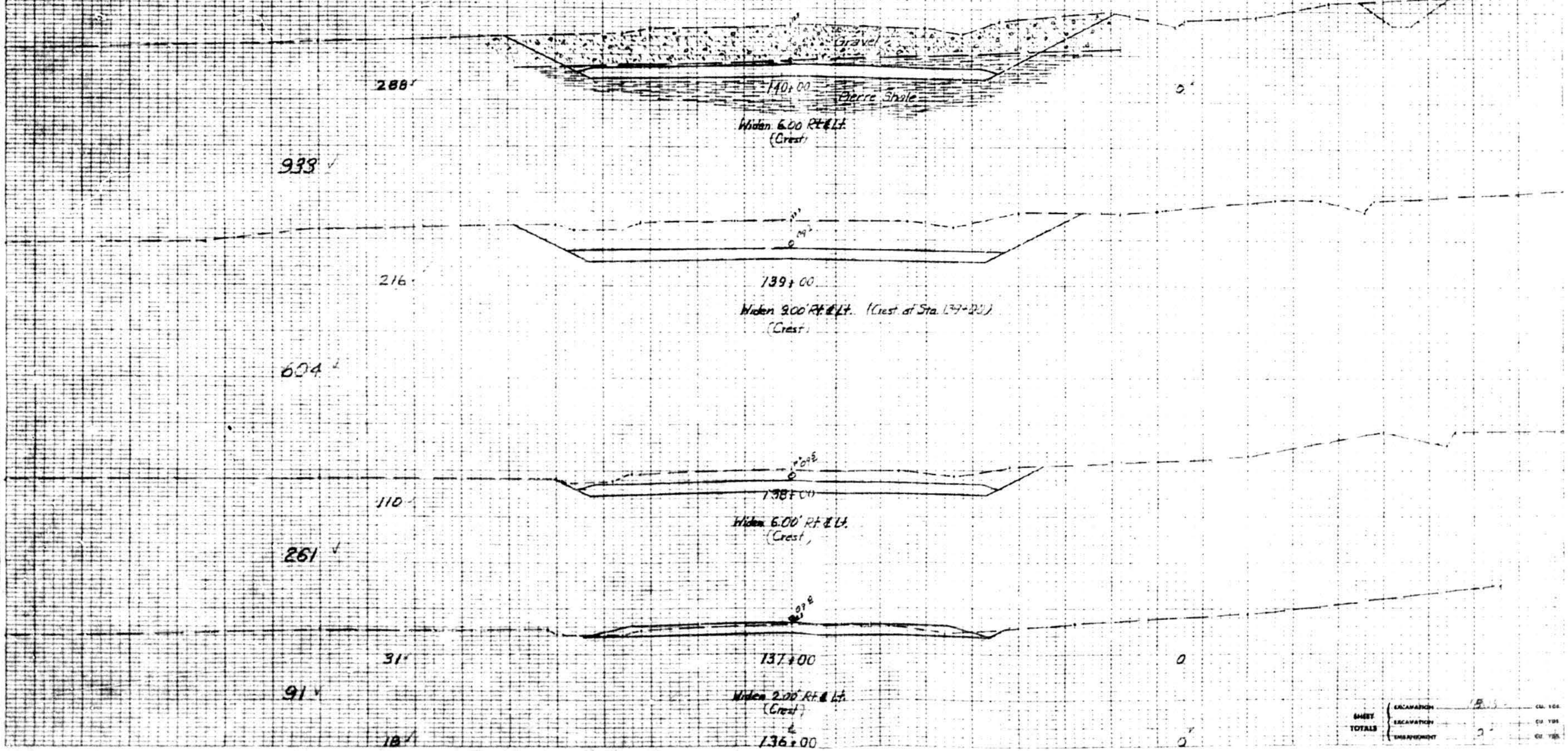
Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.	Excavation Cu. Yds.	Excavation Area	Embankment Area	Embankment Cu. Yds.

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	118	

SH #93

Rev. 8-21-53, Road Geology, J.B.R.

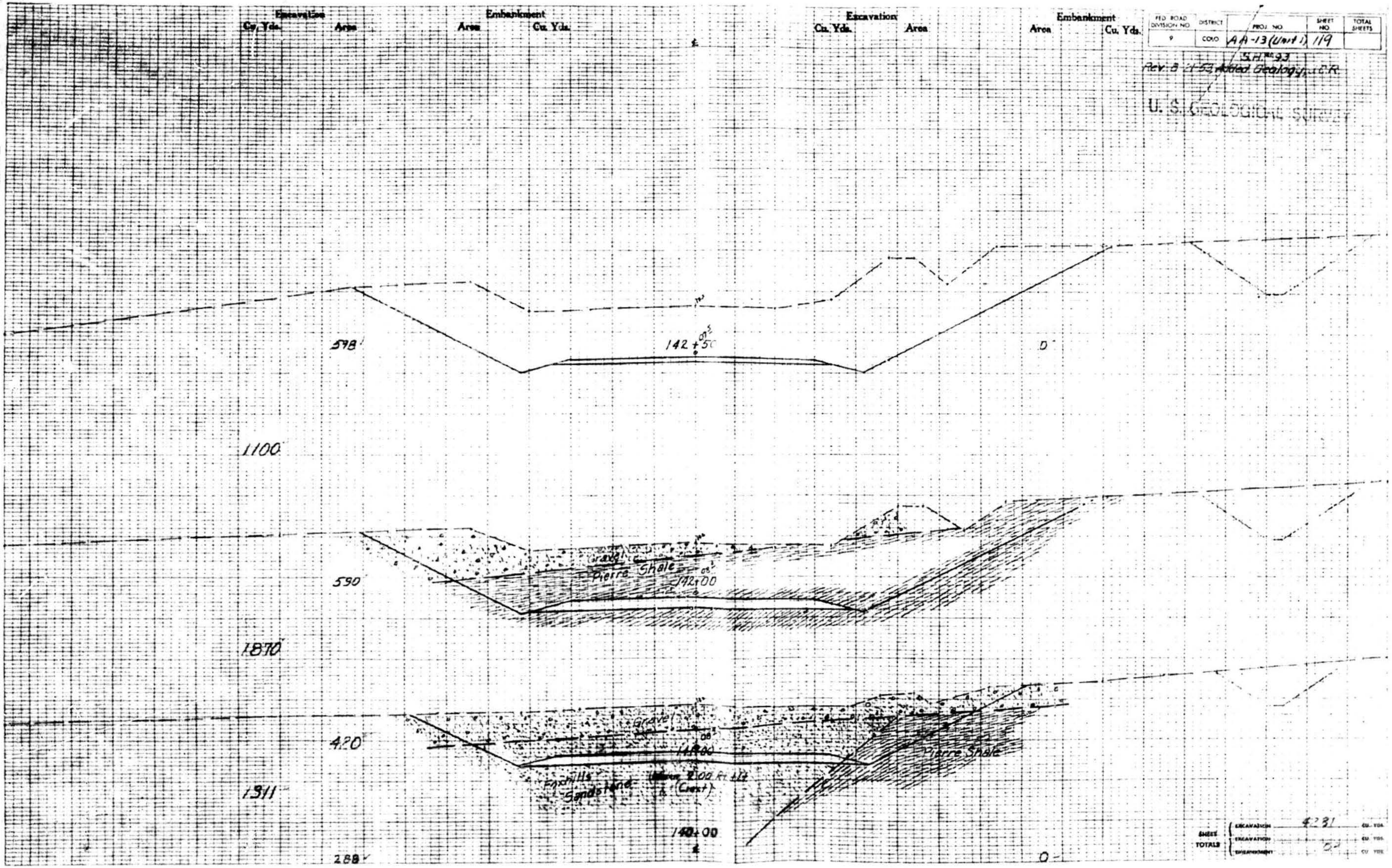
U. S. GEOLOGICAL SURVEY

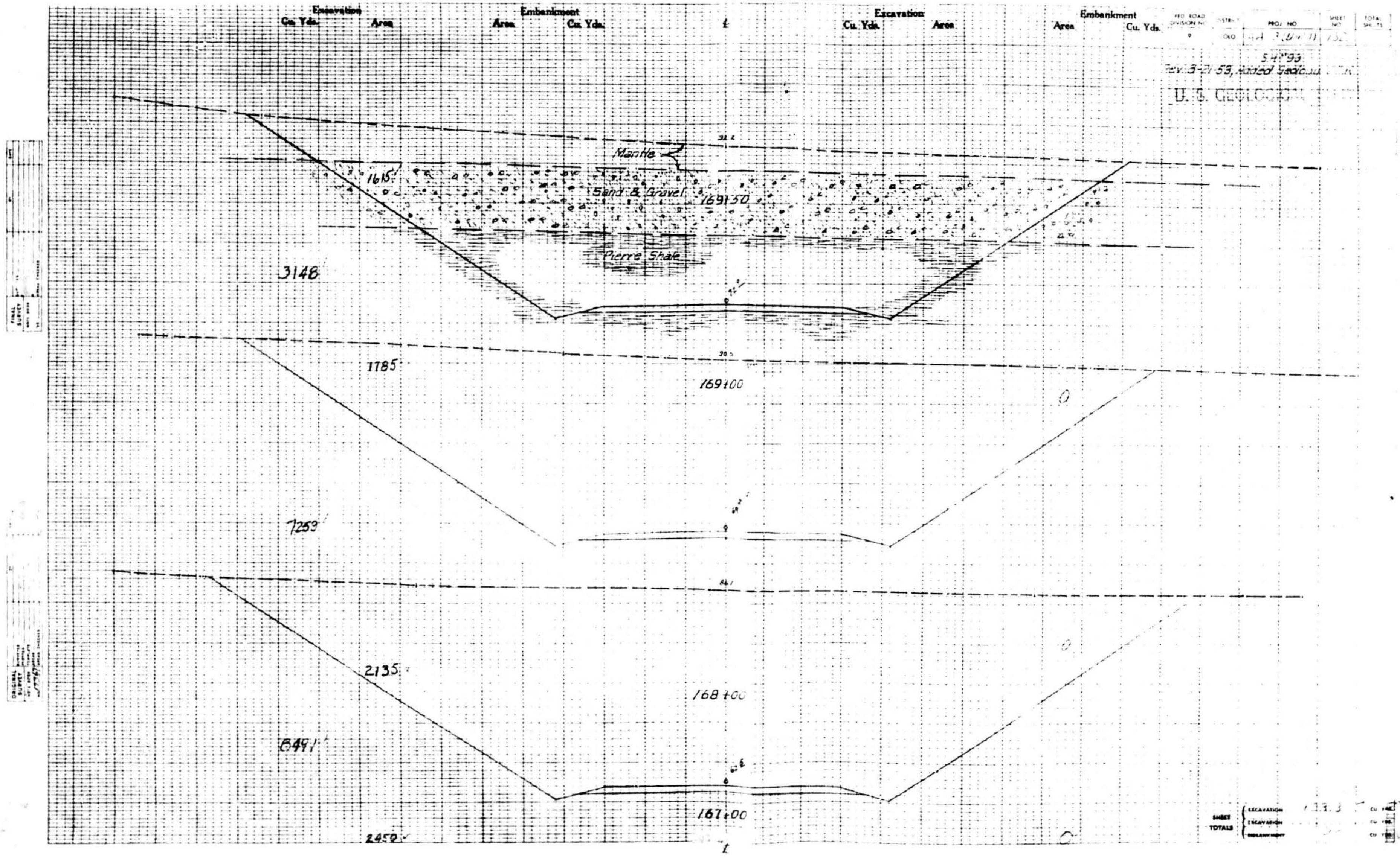


FED ROAD DIVISION NO	DISTRICT	PROJ NO	SHEET NO	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	119	

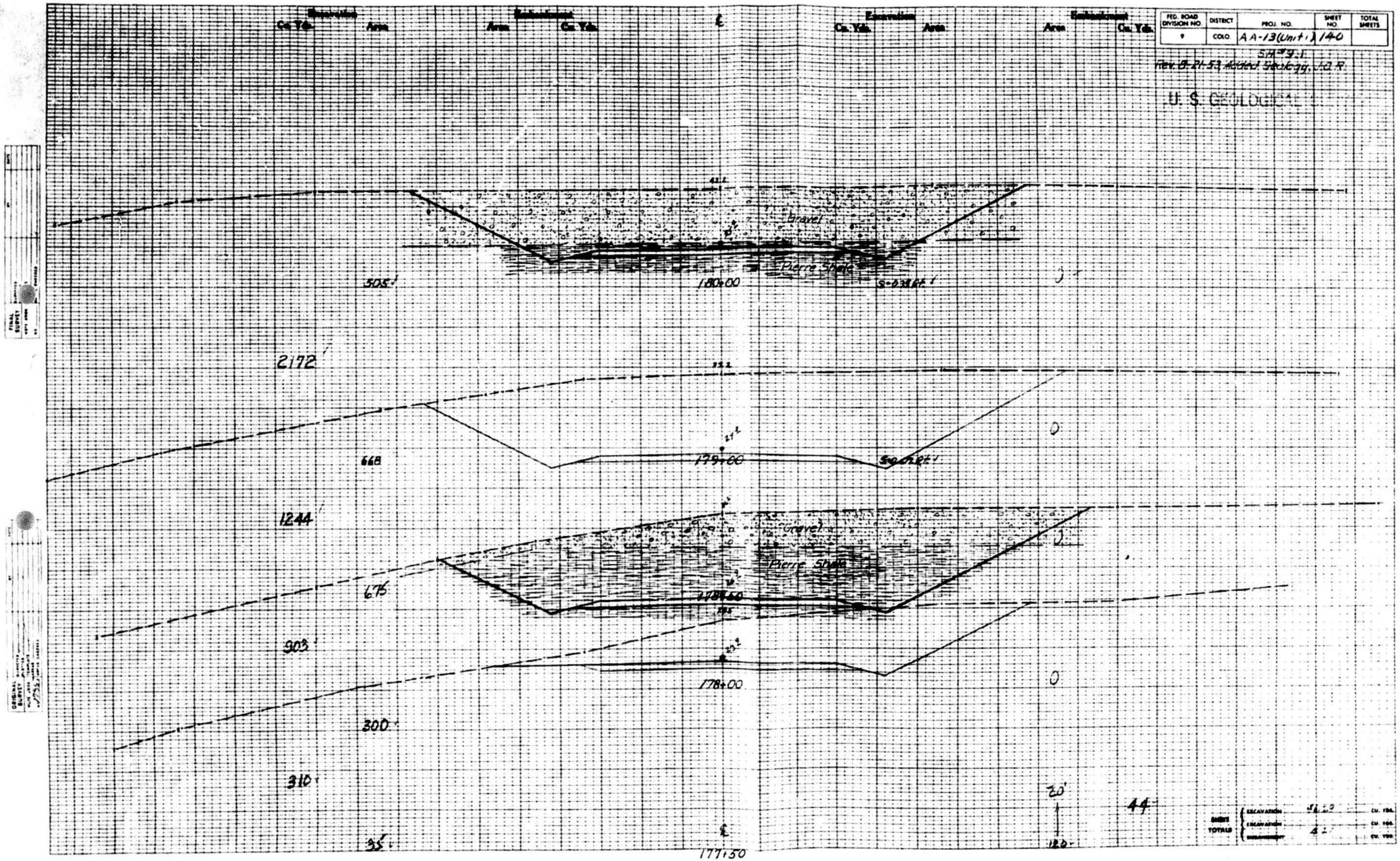
S.H. No 93

Rev. 8-21-53 Added Geology J.C.R.

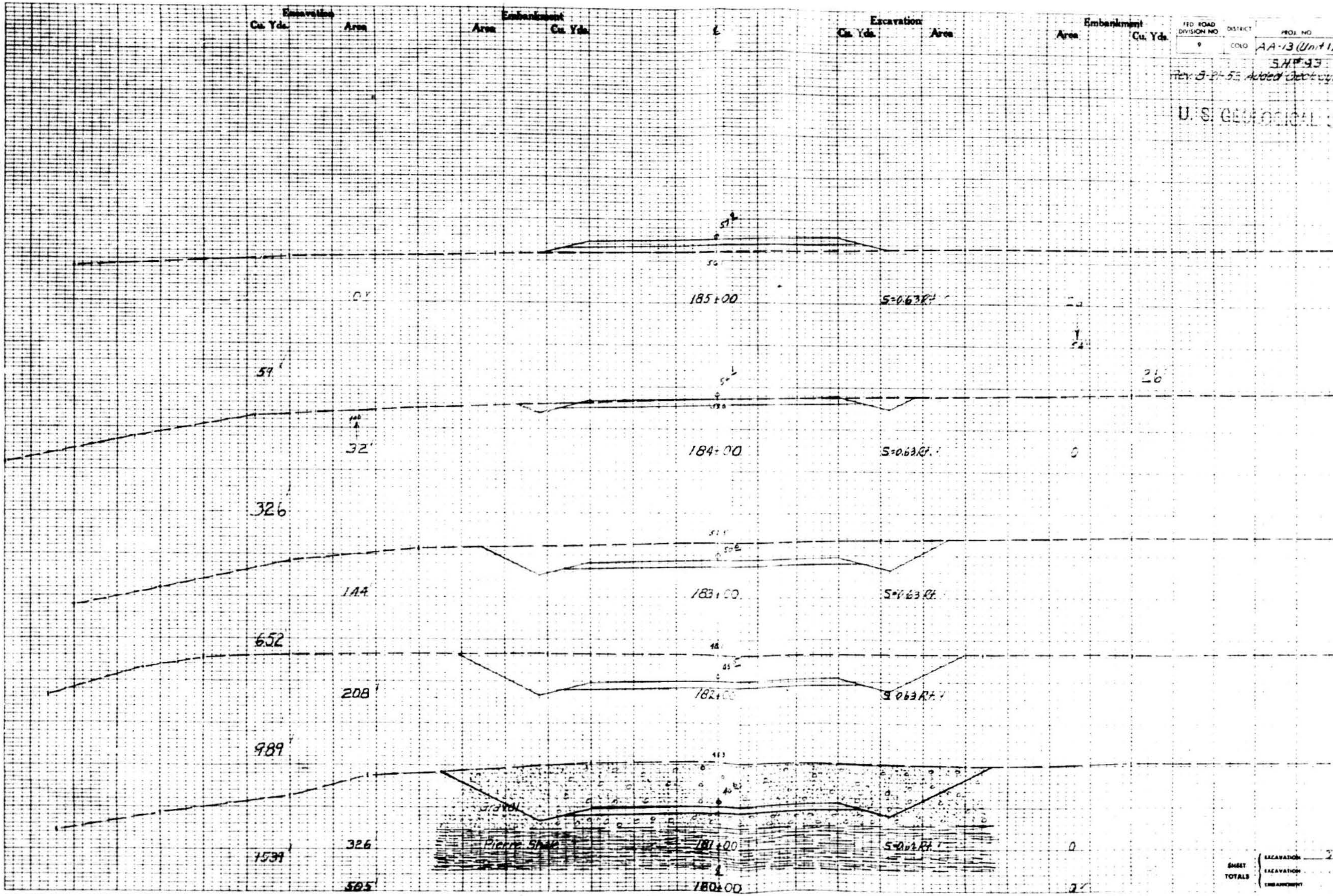




Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
℄
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED ROAD DIVISION NO
9
COLO
PROJ NO
SHEET NO
TOTAL SHEETS
U. S. GEOLOG
Mantle
1615
Sand & Gravel
169+50
Pierre Shale
3148
1785
169+00
0
7253
2135
168+00
0
8491
167+00
2459
EXCAVATION
EXCAVATION
EMBANKMENT
SHEET TOTALS
FINAL SURVEY
ORIGINAL SURVEY



Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
Excavation
Cu. Yds.
Area
Embankment
Area
Cu. Yds.
FED. ROAD DIVISION NO. 9
DISTRICT COLO.
PROJ. NO. AA-13(Unit 1)
SHEET NO. 140
TOTAL SHEETS
SH #9.1
Rev. 8-21-53 Added Geology, J.O.R.
U. S. GEOLOGICAL
Gravel
Pierre Shale
505
180+00
2172
668
179+00
0
1244
Gravel
Pierre Shale
675
178+50
903
178+00
0
300
310
20'
44
35
177+50
SHEET TOTALS
EXCAVATION
EMBANKMENT
CU. YDS.



FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	141	

S.H. # 93

Rev. 3-2-53 Added Geology J.C.R.

U. S. GEOLOGICAL S...

SHEET TOTALS: EXCAVATION ___ CU. YDS. / EXCAVATION ___ CU. YDS. / EMBANKMENT ___ CU. YDS.

FED. ROAD DIVISION NO.	DISTRICT	PROJ. NO.	SHEET NO.	TOTAL SHEETS
9	COLO	AA-13 (Unit 1)	146	

SHT 43

Rev. 8-21-53 Added Geology, U.C.R.

U. S. GEOLOGICAL SURVEY