COLORADO
Division of Reclamation, Mining and Safety
Department of Natural Resources

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November 10, 2022
Jason Carey
P.O. Box 248
Carbondale, CO 81623

Re: Roadside Portals Mine, C-1981-041, Response to Letter of Concerns

Dear Mr. Carey:

In response to your email sent to Mr. Brock Bowles of the Division on October 21, 2022, the Division has reviewed your October 27, 2016, letter associated with the Technical Revision application No. 69 ("TR-69") regarding concerns you had of your property and the Roadside Portals Mine. TR-69 was approved by the Division and upheld by the Mine Land Reclamation Board ("Board") on July 5, 2017. Since the approval of TR-69, the Division has conducted multiple site inspections on areas within the Roadside Mine, including issues presented in your October 27, 2016, letter. Please see the attached exhibits (Exhibits A, B, C, and D) for more details.

To date, the Division has not observed any mine-related subsidence during multiple site inspections of areas of the mine referred to as Tracts 70 and 71. The Division has determined that the surface features observed within the area of the mine, in your letter referred to as sinkholes, does not constitute underground mine subsidence, but rather small settling features that are the direct result of the collapse of soil structure and soil dissolution. See Exhibits A, B, C, and D. These sinkholes are the direct result of water applied to the soils in this area.

The Division inspected the area on July 9, 2019, with TC Waite, an expert in geologic hazards with the Division's IMP program and on July 20, 2021, with Jonathan White of the Colorado Geological Survey, an expert in geologic hazards and co-author of a CGS publication titled "Collapsible Soils in Colorado". In Jonathan White's report (See Exhibit A) Mr. White concludes "we find no real indications that the phenomenon seen at the subject site are anything other than collapse of soil structure and soil dissolution related to the introduction of flood irrigation to the ground surface and adverse wetting of the subsoils."

Please feel free to contact me at clayton.wein@state.co.us, or by phone at (303)-866-3567 x8185, if you have any questions or concerns.

Sincerely,

Clayton Wein

Clayton Wein
Environmental Protection Specialist
clayton.wein@state.co.us

cc: Jason Musick, Coal Regulatory Program Director
Travis Marshall, Senior Environmental Protection Specialist
Brock Bowles, Environmental protection Specialist
Scott Schultz, Assistant Attorney General

Exhibit A

Partial Phase III Bond Release No. 11

Proposed Decision
and
Findings of Compliance
for the

Roadside Portals

PERMIT NUMBER C-1981-041

COLORADO
Division of Reclamation, Mining and Safety
Department of Natural Resources

Virginia Brannon, Director

Prepared by
Clayton C. Wein
Environmental Protection Specialist

September 16, 2019

Introduction

This document is the proposed decision of the Colorado Division of Reclamation, Mining and Safety (the Division or CDRMS) in response to a request for a Partial Phase II and Partial Phase III bond release, (SL11) at the Roadside Portals, Division file number C-1981-041. The package contains four parts. These include: 1) procedures and summary of the bond release process; 2) criteria and schedule for bond release; 3) observations and findings of the Division regarding compliance with the bond release requirements of the Colorado Surface Coal Mining and Reclamation Act and regulations promulgated thereunder; and 4) the Division's proposed decision on the request for bond release.

Detailed information about the review process can be found in the Act and the Regulations of the Colorado Mined Land Reclamation Board for Coal Mining. All Rules referenced within this document are contained within the Regulations. Detailed information about the mining and reclamation operations can be found in the permit application on file at the Division offices, located at 1313 Sherman Street, Room 215, in Denver, Colorado.

The Roadside Portals is an underground mine which is permitted and operated by Snowcap Coal Company, Inc. The land requested for release is Federal, state and private. The coal ownership is federal and private. The inspections for which this bond release has been requested were conducted on June 27, 2018, August 16, 2018, November 28, 2018, and April 11, 2019.

I. PROCEDURES AND SUMMARY OF THE REVIEW PROCESS

Snowcap Coal Company, Inc. (SCC) applied for partial Phase II and partial Phase III bond release under the Colorado Surface Coal Mining and Reclamation Act following reclamation of the Roadside Portals. The mine is located in Mesa County, T10S, R98W, 6th PM Sections 26, 27, 28, 34, and 35; T10S, R98W, 6th PM and Portions of Section 2 T10S, R98W, 6th PM in Mesa County. The location of these sections is contained within the U.S. Geological Survey 7.5 minute Cameo and Palisade Quadrangle maps. The specific areas requested for final bond release in this SL11 application are located in; T10S, R98W, 6th PM Sections 26, 34 and 35; and T11S, R98W, 6th PM section 2.

This is the eleventh bond release request (SL-11) filed for the Roadside Portal Mines. A history of previous bond release applications are listed below:

- The initial (SL-01) application was withdrawn.
- The SL-02 application for Phase I bond release was approved October 27, 2003. Various reclaimed surface facility locations within the permit area were granted Phase I release based on proper completion of facilities removal, drainage control, and backfilling and grading by the SL-02 decision.
- The SL-03 application was approved October 31, 2007 and released from full liability areas overlying underground workings at the Roadside North and South Portals totaling 7,294 acres.
- The SL-04 application was approved January 26, 2009 and 18 acres were released from Phase I liability in the South Portal area and at the site of the former overland conveyor.
- The SL-05 application was approved November 5, 2009 and released 2.1 acres from full liability at the "Overland Conveyor" area located adjacent to the Union Pacific Railroad and south of I 9/10th road.
- The SL-06 application was approved December 14, 2010 and released 14.8 reclaimed acres from Phase I and II liability at an area referred to as the South Portal in T10S, R98W, Section 34.
- The SL-07 application was approved on April 26, 2011 and released 75.2 acres from Phase I, II, and III liability at the Unit Train Load Out facility.
- The SL-08 application was approved on November 14, 2015 and released 22.2 acres of Phase I liability, 136.5 acres of Phase II liability, and 128.0 acres of Phase III liability. The Division also released 744.0 acres of affected area (lands overlying underground coal mine workings).
- The SL-09 application was approved on November 23, 2016 and released 13.1 acres from Phase II liability, and 9.6 acres from Phase III liability.
- The SL-10 application was approved on July 24, 2017 and released 4.0 acres from Phase III liability.

An application for this partial Phase II and Partial Phase III bond release was received by the Division on May 24, 2018. The application was deemed complete on May 31, 2018, after the Division received proof of publication of the applicant's public notice. SCC published notice of the bond release application in *The Daily Sentinel* once weekly for four consecutive weeks, beginning April 27, 2018. SCC also notified land owners within and adjacent to the mine permit area, and other interested parties of the application for bond release, as required by Rule 3.03.2(1).

The Division scheduled and conducted a bond release inspection on June 27, 2018. The site inspection was conducted in accordance with Rule 3.03.2(2). The Division notified surface landowners, government agencies, the operator and subsurface landowners of the time and date of the bond release inspection via certified mail. Persons in attendance at the inspection included; Tonya Hammond and Greg Shurbet, representing SCC, Jim Stover, representing J.E. Stover and Associates, Christine Belka, representing OSMRE, and Clayton Wein and Daniel Hernandez, representing CDRMS, Brant Harrison, representing Kokopelli Farms, and Steve Erikson, representing himself as a landowner. Colorado Parks and Wildlife, and the Town of Palisade were notified of the date and time of the inspection, but no representatives from either party participated, or contacted the Division regarding the inspection.

A second bond release inspection was scheduled for August 16, 2018. This inspection was scheduled to inspect the areas requested for bond release on Mr. Rudy Fontanari's property. The inspection was three days and included GPS surveying of features on the Fontanari property. Clayton Wein, Daniel Hernandez and Brock Bowles represented the Division. David Fox, Ken Walter and James Beckwith were present on behalf of Fontanari (Fontanari Group). Tonya Hammond, Jim Stover, John Justus (SCC's attorney) and Karoline Henning (John Justus' Associate) represented SCC during the inspection.

Comments and a request for an informal conference were submitted by Mr. James Beckwith and were received by the Division on September 14, 2018. An informal conference was held on November 6, 2018 at the BLM Grand Junction Office. Following the informal conference, the Division inspected the Roadside Mine with SCC and Mr. Fontanari's representatives to determine the location and quantity of features requiring maintenance.

On November 28, 2018 the follow-up inspection to the informal conference was conducted and GPS coordinates were collected for identified features. Clayton Wein and Daniel Hernandez represented the Division. David Fox, Ken Walter and James Beckwith were present on behalf of Fontanari. Jim Stover and Tonya Hammond represented SCC.

On March 29, 2019, the Division was notified by SCC that the maintenance of the features identified on November 28, 2018 at the Roadside Mine had been completed. A follow-up inspection of the maintenance sites was conducted on April 11, 2019. Tonya Hammond of SCC and Clayton Wein from the Division were present for the inspection.

II. CRITERIA AND SCHEDULE FOR BOND RELEASE

PHASE II

Rule 3.03.1(2)(b) states, "Up to eighty-five percent of the applicable bond amount shall be released upon the establishment of vegetation which supports the approved post mining land use and which meets the approved success standard for cover... based on statistically valid data collected during a single year of the liability period". In regard to Phase II bond release, Rule 3.03.2(3)(b) also states, " No more than sixty (60) percent of the bond shall be released so long as the lands to which the release would be applicable are contributing suspended solids to streamflow or runoff outside the permit area in excess of premining levels as determined by baseline data or in excess of levels determined on adjacent nonmined areas". Criteria for Phase II bond release included the following:

1. Required topsoil replacement depth of a minimum of 6 inches;
2. Required vegetation cover standard; and
3. Establishment of vegetation in support of the approved post mining land uses of rangeland and wildlife habitat.

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PHASE III

Rule 3.03.1(2)(c) states that the final portion of performance bond, "shall be released when the permittee has successfully completed all surface coal mining reclamation operations in accordance with this approved reclamation plan, and the final inspection procedures of 3.03.2 have been satisfied. This shall not be before the expiration of the period specified for revegetation responsibility in 3.02.3." Rule 3.03.1(4) states, " No bond shall be fully released until all reclamation requirements of these Rules and the Act are fully met...". The same rule goes on to state, " No acreage shall be released from the permit area until all surface coal mining and reclamation operations on that acreage have been completed in accordance with the approved reclamation plan." Criteria for Phase III bond release included:

1. Meeting revegetation standards for species diversity, productivity and woody plant density;
2. Achievement of wildlife habitat and range land post-mining land use; and
3. Protection of hydrologic balance.

III. OBSERVATIONS AND FINDINGS

PHASE II

During the June 27, 2018 inspection, all 2.4 acres of land requested for release by SCC were inspected by CDRMS for Phase II criteria. The sites displayed sufficient vegetative cover to support the post-mining land use of rangeland and wildlife habitat. The sites were stable and there were no indications of erosional features. No off site impacts from the reclaimed areas were observed.

Topsoil depth replacement of a minimum of six inches was only required at the Conveyor Footprint. The other locations requested for Phase II release were disturbances created during the pre-law phase of the mine. Therefore, topsoil depth requirements do not apply to those areas. During the June 27, 2018 bond release inspection, a total of 6 topsoil depth measurements were taken at the Conveyor Footprint. All six of the samples yielded a depth of 6 inches of topsoil.

Table 1. SL-11 Application, Areas Requested For Phase II Release

Area	Description	Acres Req. for Phase II	Phase 1 Released with
#4	Conveyor Corridor	0.3 acres	SL-04 (2009)
#5	Substation A	0.2 acres	SL-04 (2009
#6	Light Use Road #1	1.9 acres	SL-04 (2009)
	Total	**2.4 acres**	

Summary and Conclusions

Based upon a review of the mine permit, the applicant's bond release application, and site inspections, the Division finds that Snowcap Coal Company, Inc. has replaced topsoil in accordance with the approved reclamation plan. Snowcap has established vegetation which supports the post mining land use of wildlife habitat and meets the approved success standard for vegetative cover. The 2.4 lands requested for Phase II release contributes runoff to the Colorado River. However, the Colorado River near Cameo has a drainage area over 5 million acres in size. The 2.4 acres requested for Phase II release does not measurably affect the quantity or quality of the water in the Colorado River.

PHASE III

The sites requested for Phase III release were inspected on June 27, 2018, including the North Decline, the Borrow Area, the Conveyor Corridor, Substation A, Substation B, and the Light Use Road #1. The sites were observed to be stable with established vegetation on them. There were no indications of erosional features. For more details please see the Division's June 27, 2018 Inspection Report. All of the sites were supporting the post-mining land use of rangeland and wildlife habitat. A second bond release inspection was conducted on August 14, 2018, by CDRMS. The inspection focused on the affected lands with no surface disturbance owned by Mr. Fontanari that were requested for Phase III release by SCC. The August 14th inspection was attended by representatives Tonya Hammond, Jim Stover, John Justus and Karoline Henning for SCC; Mr. Fontanari was represented by David Fox, Ken Walter and Jim Beckwith; and the Division was represented by Clayton Wein, Brock Bowles and Daniel Hernandez. During the inspection, features of the inspected land were recorded by the Division. The features recorded were of an unknown origin. After the Division completed its assessment of the data collected, five features were identified by the Division as needing maintenance repairs pursuant to C.R.S. 34-33-121(2)(h).

An objection and a request for an informal conference to the SL-11 bond release application was submitted by Mr. James Beckwith and was received by the Division on September 14, 2018. On November 6, 2018 an informal conference was held at the BLM Office in Grand Junction. After the November 6, 2018 Informal Conference, a subsequent inspection of the areas requested for release on Tract 70 and Tract 71 was conducted by the Division. The November 28th inspection included Tonya Hammond, Jim Stover and John Justus representing SCC; Mr. Fontanari was represented by David Fox, Ken Walter, Jim Beckwith and Trevor Gross; and the Division was represented by Clayton Wein and Daniel Hernandez. The November 28, 2018 inspection identified and marked locations with a GPS unit that potentially required maintenance within Tract 70 and Tract 71. A total of 19 locational features were identified during the inspection for potential maintenance repairs pursuant to C.R.S. 34-33-121(2)(h). Of the 19 repairs identified, 5 were features previously identified by the Division in the August 14, 2018 Inspection Report. All 19 of the locations identified were on lands within the affected area of the Roadside Mine. For more details, please see the Division's November 28, 2018 Inspection Report. SCC committed to conducting maintenance operations on the identified sites and completed the maintenance repairs on March 27, 2019. The Division conducted an inspection on April 1, 2019 to verify the maintenance repairs had been completed. All 19 of the locations had been repaired and were observed to be stable with no erosional concerns.

During Division's inspections conducted since April 2019, surface disturbances within portions of the SL-11 Phase III areas have occurred on lands within the affected area by the landowner. A portion of the North Decline above the western permanent diversion ditch has sloughed due to the landowner's activities. The slough was captured in the western permanent diversion ditch. The ditch has demonstrated in subsequent inspections to be stable and functional. Based on the Division's observations, the reclamation remains stable and the conditions of the permit, Rules and Act continue to be met by SCC. The surface disturbances continue to be as a result of Mr. Fontanari's activities and not those activities associated with SCC, with the exception of the maintenance work conducted by SCC in association with SL-11. Based on an July 9, 2019 inspection by the Division, the maintenance work conducted by SCC has been re-disturbed by Mr. Fontanari and will no longer by associated with SL-11 in terms of approval.

Vegetation Success

The vegetative success standards for the Roadside Mine were last modified with Technical Revision No. 60 (TR-60). The standards from TR-60 were incorporated into the C-1981-041 permit with the approval of the revision in May of 2011. The standards are as follows:

1. Perennial Vegetation Average Ground Cover Success Standard - Achieve 90% of the perennial vegetation cover of the approved reference area.

2. Herbaceous Production Success Standard - Achieve 90% of the perennial herbaceous production of the approved reference area. Snowcap elects to use perennial herbaceous production due to annual and biennial species exhibiting 70% and 73% of the vegetation production of the Shadscale Reference Area in 2016 and 2017, respectively. This accepted alternative is stated under Section IV.A.3 (2nd Paragraph) in the Guideline Regarding Selected Coal Mine Bond Release Issues (CDMG, 1995).

3. Woody Plant Density Success Standard - Achieve woody plant density of 800 live shrubs per acre.

4. Total Perennial Cool-Season Grass Relative Cover Success Standard - Achieve total perennial cool-season grass species' relative cover of greater or equal to 0.5% with at least two species present in the reclamation (observed).

5. Total Perennial Warm-Season Grass Relative Cover Success Standard - Achieve total perennial warm-season grass species' relative cover of greater or equal to 0.5% with at least two species present in the reclamation (observed).

6. Total Perennial Forb and Sub-Shrub Relative Cover Success Standard - Achieve total perennial forb and suffrutescent (sub-shrub) species' relative cover greater than or equal to 0.5% with at least two species present in the reclamation (observed).

7. Relative Cover Density Standard- No reclaimed area shall have a single species that represents

greater than 70% relative cover, with the exception of annual grasses. The annual grass component shall not exceed 70% relative cover unless the annual grass component in the corresponding reference area also exceeds 70%. In such instances, the relative cover of the annual grass component of the reclaimed area shall not exceed the relative cover of the annual grass component in the reference area by more than 5%.

Vegetation sampling of the mine site was completed in 2016 and in 2017 by Cedar Creek Associates, Inc. Vegetation sampling in both years was compared to the Shadscale Reference Area. For both 2016 and 2017 vegetation sampling results concluded that the vegetation at the Roadside Mine was sufficient and met the standards outlined in the Roadside Mine's permit. The 2016 and 2017 vegetative data concluded the standards for Plant Cover, Diversity, Production and Woody Plant Species was greater than or equal to the standards outlined in the permit.

The total perennial herbaceous production in 2016 was 185.2 lbs/ac which exceeded the success criteria of greater than or equal to 156.5 lbs/ac. The total perennial herbaceous production in 2017 was 206.6 lbs/ac which exceeded the success criteria of greater than or equal to 146.8 lbs/ac. The reclamation production standard was demonstrated to have been met for both 2016 and 2017.

The woody plant density for 2016 was 1,066 live stems per acre which exceeded the standard of 800 live stems per acre. The woody plant density for 2017 was 1,506 live stems per acre which exceeded the standard of 800 live stems per acre.

The diversity standard has 4 criteria; a) the total perennial cool-season grasses standard must be greater oor equal to 0.5%, b) the total perennial warm-season grasses standard of greater or equal to 0.5%, c) the total perennial forbs and sub-shrubs standard must be greater than or equal to 0.5%, d) and the number of species with greater than or equal to 70% relative cover standard. The total perennial cool-season grasses surpasses the stardar in 2016 and 2017 with 2.7 % and 3.7% respectively. The total warm-season grasses surpassed the standard in both 2016 and 2017 with 4.9% and 3.0% respectively. The total forbs and sub-shrubs surpasses the standard in 2016 and 2017 with values of 9.2% and 11.2% respectively. The number of species with greater than 70% relative cover must be 0. In 2016 and 2017 the standard was met with a value of 0 for both years.

The reclamation diversity standards were demonstrated to have been met in both 2016 and 2017.

<u>Affected Lands Overlying Underground Workings</u>

The Division has completed its assessment of the lands on the Tract 70 Mesa, alleged by Mr. Fontanari to have been adversely impacted by mining subsidence. The Division has concluded that the surface features identified by Mr. Fontanari's consultants David Fox and Ken Walter, Mr. Fontanari's attorney Jim Beckwith, and Mr. Fontanari are not related to mining subsidence or mining related activities. Based on the characteristics observed at the site, the Division concludes that the surface features are the result of surface water applications to Hydrocompactive Soils. Hydrocompactive soils form in semi-arid climates and are composed of fine-grained, un-compacted sediments originating from colluvial and/or alluvial processes. Hydrocompactive soils are low density and contain low amounts of moisture. These soils are extremely sensitive to the introduction to water. The low density materials such as clays and silts form "tack-welds" that support the larger grained materials. The "tack-welds" that the soils are supported by can be easily dissolved into solution with the introduction of water. The voids left behind after the "tack-welds" are dissolved result in settling of the surface. Water entering hydrocompactive soils will follow the path of least resistance either by following void spaces or the dip of the deposit. The Roadside Mine is located in western Colorado, known to be a semi-arid arid climate. Palisade, CO receives approximately 10 inches of rainfall precipitation annually. The soils deposited on the site are derived from colluvium originating from the Grand Mesa and Alluvial material from the ancestral Rapid Creek. These soils ae fine grained, loamy silts and clay soils mixed with basaltic gravels, cobbles, and boulders. The Colorado Geologic Survey has mapped the permit area containing hydrocompactive soils. Please see the Division's Exhibit 1, attached to the end of this Findings, for a map showing the CGS mapped collapsible soils and the Roadside Mine permit area.

The water introduced to the Tract 70 Mesa from the landowner's water system has provided the necessary dissolution of the "tack-welds", resulting in the rapid settlement of the soils. The magnitude of the features observed during field inspections were isolated to the areas of the Tract 70 Mesa impacted by the landowner's water system. Water was observed to be flowing directly into the settled features and desiccation cracks (DRMS Coal July 2019 Partial Inspection Report). These pathways allow lateral "piping" to occur, resulting in the enlargement of the settled features. The Division also noted on the July 9th inspection that Mr. Fontanari's water system was applying water in ditches adjacent to SCC's maintenance repair work for this SL-11 bond release. The water from the ditches was flowing over the surface and onto SCC's maintenance repairs. Another set of ditches were observed to be dry during the inspection but had cut through a portion of the Line Object 9 maintenance repairs. The Division's Exhibit 2, attached to the end of this Findings, is an aerial photo showing the location of Mr. Fontanari's ditches to the maintenance repairs completed by SCC. Mining subsidence does not manifest itself at the surface this way.

In contrast, subsidence from room and pillar mining creates "troughs" on the surface. "Troughs" or surface depressions overlie areas of extracted coal and the highpoints in between "troughs" are located above the pillars that remain in place. Subsidence cracks occur at the surface at the boundary of the land over the collapsed workings and the land overlying the pillars due to tensional strain. Surface cracks from subsidence will outline the boundaries of subsidence troughs. Cracks observed on the surface of Tract 70 were not observed to be oriented in a manner outlining a surface depression. The Roadside Mine Permit includes a prediction of the maximum possible predicted subsidence and a subsidence monitoring program. The mine plan was designed to incorporate the subsidence predictions to minimize the impact to pre-existing structures and man-made features. Pre-existing man-made features on the Tract 70 Mesa included powerlines and a Ute Water line. The post-mining land use for Tract 70 is wildlife habitat and rangeland.

Table 2. SL-11 Application, Areas Requested For Final Bond Release

Area	Description	Acres Phase III	Phase II Released With
#1	North Decline	6.6 acres	SL-08 (2015)
#2	Borrow Area	1.1 acres	SL-08 (2015)
#3	Substation B	0.3 acres	SL-08 (2015)
#4	Conveyor Corridor	0.3 acres	SL-11 (2019)
#5	Substation A	0.2 acres	SL-11 (2019)
#6	Light Use Road #1	1.9 acres	SL-11 (2019)
#7	Affected Area	291.3 acres	No Surface Disturbance Associated
	Total	**301.7 acres**	

Summary and Conclusions

Based upon a review of the mine permit, the applicant's bond release application, and site inspections, the Division finds that Snowcap Coal Company, Inc. has successfully completed all surface coal mining reclamation operations in accordance with the approved reclamation plan and met all requirements of the Act and Rules on the 301.7 acres requested for final release in this SL-11 application.

IV. PROPOSED DECISION

Based on the observations above, the Division proposes to approve Snowcap Coal Company, Inc.'s request for a partial Phase II and partial Phase III bond release for the Roadside Portals. This proposed decision will release the applicant from liability for all reclamation work conducted on the 301.7 acres at the Roadside Portals Mine

PHASE III

The original performance bond for the Roadside Portals was $1,500,000.00. The Reclamation Liability prior to any bond release approvals was $3,264,149.00 (8/8/2002). A summary of bond releases previously approved by the Division is included in the following table:

Permitting Action	Description	Change to Reclamation Liability
SR1 Approved 7/27/2001	Reclamation Cost Liability Adjusted	$3,244,980.00
SL-1 12/14/2001 Withdrawn	NA	NA
SL-2 8/15/2003 Approved	Phase I release of 13 acres	$1,466,510.00
SL-3 10/31/2007 Approved	Liability release of 7,098, 2,140 affected acres, and 4.7 disturbed acres overlying underground workings	No $ released
SL-4 12/5/2008 Approved	Phase I 18.0 acres	$587,007.00
SL-5 9/9/2009 Approved	Phase II 2.1 acres Phase III 2.1 acres	$10,174.00

SL-6 11/4/2010 Approved	Phase II 14.8 aces Phase III 14.8 acres	$69,908.00
SL-7 3/21/2011 Approved	Phase I 75.2 acres Phase II 75.2 acres	$648,744.00
SL-8 10/8/2015 Partial Approval	Phase I 22.1 acres Phase II 136.5 acres Phase III 128.0 acres	$663,429.00
SL-9 11/23/2016 Partial Approval	Phase II 13.1 acres Phase III 9.6 acres	$97,202.20
SL-10 7/24/2017 Approved	Phase III 4.0	$22,121.80
SL-11 Approved with this Findings	Phase II 2.4 acres Phase III 10.4 aces of disturbance and 291.3 acres of affected land	$10,089.00

The remaining liability prior to approval of this SL11 application, is $49,631.54 and the current bond held by the Division is in the amount of $65,702.24. Snowcap Coal Company, Inc. has requested release of $10,089.00. Based on the observations in this Findings, and the updated reclamation task costs (Attachment No. 1), the Division proposes to release the full requested amount of $10,089.00. The remaining $55,613.24 of the bond is sufficient to assure completion of the remaining reclamation work at the site if the work had to be performed by the Division, including the cost of reestablishing vegetation on any revegetated areas, should those areas fail. The Division estimates its cost to complete remaining reclamation work at the site to be $39,010.00.

Reclamation work which remains to be done at the site are described in Attachment No. 1 of this Findings document.

Any person with a valid legal interest which might be adversely affected by this proposed decision may request a formal public hearing before the Mined Land Reclamation Board in accordance with Rule 3.03.2(6). Public notice of this proposed decision will be published twice in the *The Daily Sentinel* as soon as possible. Requests for public hearing must be submitted to the Division in writing within thirty days of the first publication in the *The Daily Sentinel*. If no hearing is requested within those thirty days, the Division's proposed decision will become final.

Exhibit 1

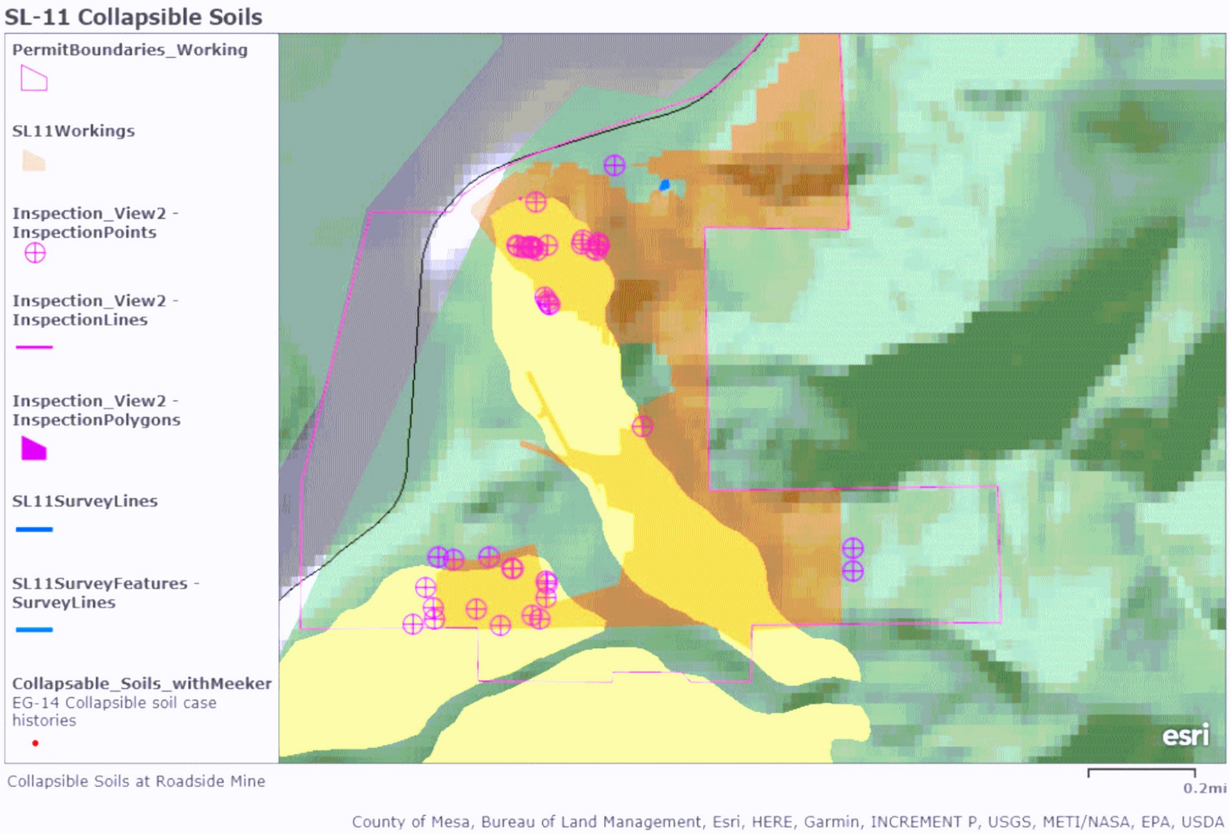

Exhibit 1 was created using GPS data collected during SL-11 bond release inspections and combining them with a Hydrocompactive soils layer from ARCOnline created by the Colorado Geological Survey. The yellow polygon is the mapped deposits of hydrocompactive soils. The Roadside Mine's permit boundary is a blue line. The GPS points collected during the Division's bond release inspections are the blue circles with crosshairs in them.

Exhibit 2

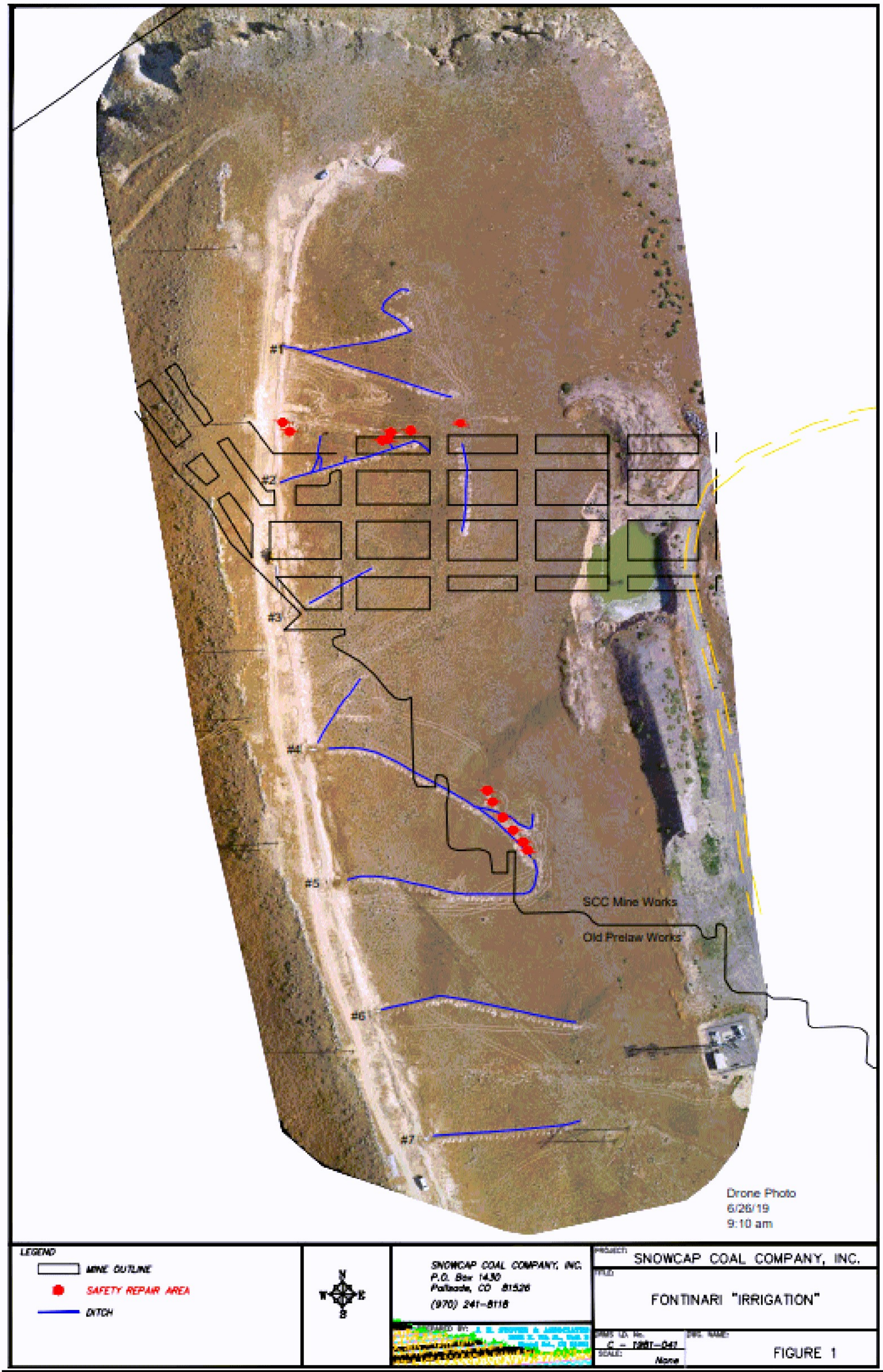

Exhibit 2 is a photograph taken by a drone of the Tract 70 Mesa. Mr. Fontanari's ditches can be observed to be in an irregular placement. SCC's repair locations can be seen as dots on the map. M. Fontanari's ditches can be seen adjacent to and in one case cutting through SCC's repairs.

Attachment 1 – Site Wide Reclamation Cost Estimate for Areas Left to be reclaimed at the Roadside Mine After SL-11

COST SUMMARY WORK

Task description: **SL 11 Site wide update**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	000	State:	Colorado	Abbreviation:	None
Date:	7/18/2019	County:	Mesa	Filename:	C041-000
User:	TNL				

Agency or organization name: DRMS

TASK LIST (DIRECT COSTS)

Task	Description	Form Used	Fleet Size	Task Hours	Cost
121	Plug and Seal Boreholes	BOREHOLE	1	0.00	$2,605
205	Mobilize Equipment for Remaining Reclamation	MOBILIZE	1	3.85	$7,519
207	Topsoil salvage from TR69	LOADER	1	2.83	$210
208	TR69 Topsoil salvage	GRADER	1	0.24	$42
209	excavate and backfill TR69 air shaft repair	SITEMAINT ENANCE	1	48.00	$10,379
213	TR69 Compacting fill in excavated hole	COMPACT	1	6.46	$1,505
214	TR69 replace topsoil	LOADER	1	1.74	$129
215	TR69 Topsoil replacement	GRADER	1	0.24	$40
216	TR69 Install concrete seal in excavated hole	MINESEAL	1	8.00	$1,481
217	Seed TR69 0.4 acre disturbance	REVEGE	1	3.40	$573
218	water truck for TR69 activity	MISCTRUK	1	22.00	$2,337
			SUBTOTALS:	**96.76**	**$26,820**

INDIRECT COSTS

OVERHEAD AND PROFIT:

Liability insurance:	2.02	Total =	$542
Performance bond:	1.05	Total =	$282
Job superintendent:	46.45	Total =	$3,223
Profit:	10.00	Total =	$2,682
		TOTAL O & P =	$6,729
		CONTRACT AMOUNT (direct + O & P) =	$33,549

LEGAL - ENGINEERING - PROJECT MANAGEMENT:

Financial warranty processing (legal/related costs):	$500	Total =	$500
Engineering work and/or contract/bid preparation:	8.59	Total =	$2,882
Reclamation management and/or administration:	6.20		$2,080

CONTINGENCY: 0.00 Total = $0

TOTAL INDIRECT COST = $12,190

TOTAL BOND AMOUNT (direct + indirect) = $39,010

BOREHOLE SEALING WORK

Task description: **Plug and Seal Boreholes**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #: 121 State: Colorado Abbreviation: None

Date: 7/18/2019 County: Mesa Filename: 121

User: TNL

Agency or organization name: DRMS

UNIT COSTS

Borehole Description	Sealing/Item Method	Diameter	Length	Quantity	Unit	Unit Cost	Total Cost
GVMS-01A	Portland cement grout - 8 in. (labor, equip, materials)	8	33	33.00	LF	$6.29	$207.64
GVMS-01B	Portland cement grout - 8 in. (labor, equip, materials)	8	33	33.00	LF	$6.29	$207.64
GVMS-02A	Portland cement grout - 8 in. (labor, equip, materials)	8	33	33.00	LF	$6.29	$207.64
GVMS-02B	Portland cement grout - 8 in. (labor, equip, materials)	8	33	33.00	LF	$6.29	$207.64
GVMS-03A	Portland cement grout - 8 in. (labor, equip, materials)	8	33	33.00	LF	$6.29	$207.64
GVMS-03B	Portland cement grout - 8 in. (labor, equip, materials)	8	33	33.00	LF	$6.29	$207.64
CRDA No. 1	Portland cement grout - 4 in. (labor, equip, materials)	6	90	90.00	LF	$5.00	$449.82
8" Bottom Plugs	PVC plug - 8 in. diameter borehole	6	NA	6.00	EA	$80.77	$484.64
Casing Removal	Exposed casing removal - Calculate Circumference in Linear Feet	7	33	33.00	LF	$3.26	$107.58
Hole Markers	Borehole location/identification marker (EA, material cost only)	NA	NA	7.00	EA	$32.00	$224.00

4" Bottom Plug	PVC plug - 4 in. diameter borehole	4	NA	1.00	EA	$32.62	$32.62
Outfall 002, Plug pipe	PVC plug - 6 in. diameter borehole	6	NA	1.00	EA	$58.97	$58.97
Cut Outfall 002 Pipe	Exposed casing removal - Calculate Circumference in Linear Feet	6"	NA	0.50	LF	$3.26	$1.63

Job Hours: **0.00** **Total Cost**: **$2,605.00**

EQUIPMENT MOBILIZATION/DEMOBILIZATION

Task description: **Mobilize Equipment for Remaining Reclamation**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #: 205
Date: 7/18/2019
User: TNL
State: Colorado
County: Mesa
Abbreviation: None
Filename: 205

Agency or organization name: DRMS

EQUIPMENT TRANSPORT RIG COST

Shift basis: 1 per day
Cost Data Source: CRG Data

Truck Tractor Description: GENERIC ON-HIGHWAY TRUCK TRACTOR, 6X4, DIESEL POWERED, 400 HP (2ND HALF, 2006)

Truck Trailer Description: GENERIC FOLDING GOOSENECK, DROP DECK EQUIPMENT TRAILER (25T, 50T, AND 100T)

Cost Breakdown:

Available Rig Capacities	0-25 Tons	26-50 Tons	51+ Tons
Ownership Cost/Hour:	$17.20	$29.63	$38.69
Operating Cost/Hour:	$26.56	$47.02	$55.69
Operator Cost/Hour:	$23.63	$23.63	$23.63
Helper Cost/Hour:	$0.00	$23.53	$23.53
Total Unit Cost/Hour:	$67.39	$123.81	$141.54

NON ROADABLE EQUIPMENT:

Machine Description	Weight/ Unit (TONS)	Owner ship Cost/hr/ unit	Haul Rig Cost/hr/unit	Fleet Size	Haul Trip Cost/hr/ fleet	Return Trip Cost/hr/ fleet	DOT Permit Cost/ fleet
ATLAS COPCO ROC D7-11,4.0 in.	11.00	$70.87	$67.39	1	$138.26	$67.39	$250.00
Drill/Broadcast Seeder with Tractor	25.00	$18.15	$67.39	1	$85.54	$67.39	$250.00
Cat D9T - 9SU	60.01	$121.49	$141.54	1	$263.03	$141.54	$250.00
CAT 14M	23.57	$64.10	$67.39	1	$131.49	$67.39	$250.00
Cat 324D L 9'-8" Stick	27.33	$46.78	$123.81	1	$170.59	$123.81	$250.00
CAT 914G	8.15	$16.09	$67.39	1	$83.48	$67.39	$250.00
CAT 825H	36.08	$113.26	$123.81	1	$237.07	$123.81	$250.00
				Subtotals:	**$1,109.46**	**$658.72**	**$1,750.00**

ROADABLE EQUIPMENT:

Machine Description	Total Cost/hr/ unit	Fleet Size	Haul Trip Cost/hr/ fleet	Return Trip Cost/hr/ fleet
Fuel Tanker, 6x4, 210 HP	$42.46	1	$42.46	$42.46
Lube Truck, 6x4, 250 HP	$50.41	1	$50.41	$50.41
Flatbed Truck, 6x4, 45K GVW	$48.50	1	$48.50	$48.50
Light Duty Pickup, 4x4, 1 T. Crew	$20.93	1	$20.93	$20.93
Water Tanker, 5,000 Gal.	$106.25	1	$106.25	$106.25
		Subtotals:	**$268.55**	**$268.55**

EQUIPMENT HAUL DISTANCE and Time

Nearest Major City or Town within project area region:	GRAND JUNCTION	
Total one-way travel distance:	25.00	miles
Average Travel Speed:	35.00	mph
Total Non-Roadable Mob/Demob Cost * ‘* two round trips with haul rig:	$7,135.43	
Total Roadable Mob/Demob Cost ** ** one round trip, no haul rig:	$383.64	

Transportation Cycle Time:

	Non-Roadable Equipment	Roadable Equipment
Haul Time (Hours):	0.71	0.71
Return Time (Hours):	0.71	0.71
Loading Time (Hours):	0.25	NA
Unloading Time (Hours):	0.25	NA
Subtotals:	1.93	1.43

JOB TIME AND COST

Total job time: **3.86** Hours

Total job cost: **$7,519**

WHEEL LOADER – LOAD AND CARRY WORK

Task description: **Topsoil salvage from TR69**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	207	State:	Colorado	Abbreviation:	None
Date:	8/13/2018	County:	Mesa	Filename:	207
User:	TNL				

Agency or organization name: DRMS

HOURLY EQUIPMENT COST

Basic Machine:	CAT 914G	Horsepower:	95
Attachment 1:	ROPS Cab	Shift Basis:	1 per day
		Data Source:	(CRG)

Cost Breakdown:

		Utilization %
Ownership Cost/Hour:	$16.09	NA
Operating Cost/Hour:	$22.05	100
Operator Cost/Hour:	$35.93	NA
Total Unit Cost/Hour:	$74.06	

Total Fleet Cost/Hour: $74.06

MATERIAL QUANTITIES

Initial volume:	325	CCY	Swell factor:	1.250
Loose volume:	**406**	LCY		

Source of estimated volume: TR69

Source of estimated swell factor: Cat Handbook

HOURLY PRODUCTION

Loader Cycle Time:

Unadjusted Basic Cycle Time (load, dump, maneuver): 0.450 minutes

Cycle Time Factors		Factor (min.)	Source
Material:	Bank or broken material 0.04	0.040	(Cat HB)
Stockpile:	No adjustment - factor not applicable 0.00	0.000	(Cat HB)
Truck Ownership:	Common ownership of trucks and loaders - 0.04	-0.040	(Cat HB)
Operation:	Constant operation -0.04	-0.040	(Cat HB)
Dump Target:	Nominal target 0.00	0.000	(Cat HB)
	Net Cycle Time Adjustment:	-0.040	minutes
	Adjusted Basic Cycle Time:	0.410	minutes

Rolling Resistance – Road Conditions

Haul:	Firm, smooth, rolling, dirt/lt. surfaced, watered, maintained 3.0
Return:	Firm, smooth, rolling, dirt/lt. surfaced, watered, maintained 3.0

Haul and Return Time

	Length (feet)	Grade Res. (%)	Rolling Res. (%)	Total Res. (%)	Travel Time (minutes)	Source
Haul Route:	150	3.00	3.00	6.00	0.1164	(Cat HB)
Return Route:	150	-3.00	3.00	0.00	0.0527	(Cat HB)

Total Travel Time:	0.1692	minutes
Total Cycle Time:	**0.5792**	minutes

Load Bucket Capacity

Rated Capacity:	1.80	LCY (heaped)
Bucket Fill Factor:	0.975	Loose material - mixed moist aggregates (95-100%) 0.975
Adjusted Capacity:	**1.76**	LCY

Job Condition Correction Factors

Site Altitude: 5100 feet

		Source
Altitude Adj:	0.95	(CAT HB)
Job Efficiency:	0.83	(1 shift/day)
Net Correction:	0.79	multiplier

Unadjusted Hourly Unit Production:	181.82	LCY/Hour
Adjusted Hourly Unit Production:	143.36	LCY/Hour
Adjusted Hourly Fleet Production:	**143.36**	LCY/Hour

JOB TIME AND COST

Fleet size:	1	Loader(s)	Total job time:	**2.83**	Hours
Unit cost:	$0.517	/LCY	Total job cost:	**$210**	

MOTOR GRADER WORK

Task description: **TR69 Topsoil salvage**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	208	State:	Colorado	Abbreviation:	None
Date:	8/13/2018	County:	Mesa	Filename:	208
User:	TNL				

Agency or organization name: DRMS

HOURLY EQUIPMENT COST

Basic Machine:	CAT 14M	Horsepower:	259
Ripper Attachment:	Multi-Shank Ripper	Shift Basis:	1 per day
		Data Source:	(CRG)

Cost Breakdown:

		Utilization %
Ownership Cost/Hour:	$64.10	NA
Operating Cost/Hour:	$56.17	100
Ripper Ownership Cost/Hour:	$4.44	NA
Ripper Operating Cost/Hour:	$3.92	100
Operator Cost/Hour:	$45.39	NA
Total Unit Cost/Hour:	$174.01	
Total Fleet Cost/Hour:	**$174.01**	

MATERIAL QUANTITIES

Total Area to be graded or ripped: 0.40 acres

Source of estimated acreage: TR69

HOURLY PRODUCTION

Average Grader Speed:	1.50	mph
Selected Application:	Finish grading (0-2.5 mph) - 1.5	
Selected Blade Angle:	30	degrees
Effective Blade Length:	12.10	feet
Width of blade overlap per pass:	2.00	feet
Net grading or ripping width per pass:	10.10	feet
Unadjusted Hourly Unit Production:	1.8364	acres/hour

Job Condition Correction Factors

Site Altitude: 5100 feet

		Source
Altitude Adj:	1.00	(CAT HB)
Job Efficiency:	0.90	(1sh/d, fav.)
Net Correction:	0.9000	multiplier

Adjusted Hourly Unit Production:	1.6527	acres/Hour
Adjusted Hourly Fleet Production:	**1.6527**	acres/Hour

JOB TIME AND COST

Fleet size: 1 Grader(s) Total job time: **0.24** Hours

Unit cost:	$105.29	per acre	Total job cost:	**$42**

SITE MAINTENANCE

Task description: **Excavate and backfill TR69 air shaft repair**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	209	State:	Colorado	Abbreviation:	None
Date:	8/13/2018	County:	Mesa	Filename:	209
User:	TNL				

Agency or organization name: DRMS

UNIT COSTS

Maintenance Item	Hours per Year	Menu Selection	Quantity	Unit	Unit Cost	Total Cost
Excavate old air shaft for repair	16.00	Cat 324D L 9'-8" Stick	16.00	EA	$142.16	$2,274.56
backfill and compact plugged air shaft	32.00	Cat 324D L 9'-8" Stick	32.00	EA	$142.16	$4,549.12
Excavation fron end loader support	16.00	CAT 914G	16.00	EA	$74.07	$1,185.12
backfill air shaft fron end loader support	32.00	CAT 914G	32.00	EA	$74.07	$2,370.24

Job Hours: **48.00** **Total Cost**: **$10,379.04**

COMPACTION WORK

Task description: **TR69 Compacting fill in excavated hole**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	213	State:	Colorado	Abbreviation:	None
Date:	8/13/2018	County:	Mesa	Filename:	213
User:	TNL				

Agency or organization name: DRMS

HOURLY EQUIPMENT COST

Basic Machine:	CAT 825H	Horsepower:	354
Compactor Type:	Soil - tamping foot	Shift Basis:	1 per day
		Data Source:	(CRG)

Cost Breakdown:

		Utilization %
Ownership Cost/Hour:	$113.26	NA
Operating Cost/Hour:	$88.24	100
Operator Cost/Hour:	$31.46	NA
Total Unit Cost/Hour:	$232.96	
Total Fleet Cost/Hour:	**$232.96**	

MATERIAL QUANTITIES

Loose volume:	1,100	LCY	Shrinkage factor:	0.875
Compacted volume:	**963**	CCY		

Source of estimated volume: TR69 SCC estimate
Source of estimated shrinkage factor: Cat Handbook

HOURLY PRODUCTION

Unadjusted hourly production = (W x S x L x C) / P

Compacted width per pass (W):	7.34	feet
Average Compactor Speed (S):	1.00	mph
Compacted thickness of each lift (L):	3.00	inches
Conversion Constant (C):	16.3	(5,280ft./12in./27cu.ft.)
Required number of machine passes (P):	2	passes
Unadjusted Hourly Unit Production:	179.46	CCY/hour

Job Condition Correction Factors

Site Altitude: 5,100 feet

		Source
Altitude Adj:	1.00	(CAT HB)
Job Efficiency:	0.83	(1 shift/day)
Net Correction:	0.8300	multiplier

Adjusted Hourly Unit Production:	148.95	CCY/Hour
Adjusted Hourly Fleet Production:	**148.95**	CCY/Hour

JOB TIME AND COST

Fleet size:	1	Compactor(s)	Total job time:	**6.46**	Hours
Unit cost:	$1.564	per CCY	Total job cost:	**$1,505**	

WHEEL LOADER – LOAD AND CARRY WORK

Task description: **TR69 replace topsoil**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	214	State:	Colorado	Abbreviation:	None
Date:	8/13/2018	County:	Mesa	Filename:	214
User:	TNL				

Agency or organization name: DRMS

HOURLY EQUIPMENT COST

Basic Machine:	CAT 914G	Horsepower:	95
Attachment 1:	ROPS Cab	Shift Basis:	1 per day
		Data Source:	(CRG)

Cost Breakdown:

		Utilization %
Ownership Cost/Hour:	$16.09	NA
Operating Cost/Hour:	$22.05	100
Operator Cost/Hour:	$35.93	NA
Total Unit Cost/Hour:	$74.06	

Total Fleet Cost/Hour: $74.06

MATERIAL QUANTITIES

Initial volume:	325	CCY	Swell factor:	1.000
Loose volume:	**325**	LCY		

Source of estimated volume: TR69 SCC estimate

Source of estimated swell factor: Cat Handbook

HOURLY PRODUCTION

Loader Cycle Time:

Unadjusted Basic Cycle Time (load, dump, maneuver): 0.450 minutes

Cycle Time Factors		Factor (min.)	Source
Material:	Mixed material 0.02	0.020	(Cat HB)
Stockpile:	No adjustment - factor not applicable 0.00	0.000	(Cat HB)
Truck Ownership:	Common ownership of trucks and loaders - 0.04	-0.040	(Cat HB)
Operation:	Constant operation -0.04	-0.040	(Cat HB)
Dump Target:	Nominal target 0.00	0.000	(Cat HB)
	Net Cycle Time Adjustment:	-0.060	minutes
	Adjusted Basic Cycle Time:	0.390	minutes

Rolling Resistance – Road Conditions

Haul:	Firm, smooth, rolling, dirt/lt. surfaced, watered, maintained 3.0
Return:	Firm, smooth, rolling, dirt/lt. surfaced, watered, maintained 3.0

Haul and Return Time

	Length (feet)	Grade Res. (%)	Rolling Res. (%)	Total Res. (%)	Travel Time (minutes)	Source
Haul Route:	100	0.00	3.00	3.00	0.0564	(Cat HB)
Return Route:	100	0.00	3.00	3.00	0.0564	(Cat HB)

Total Travel Time:	0.1128	minutes
Total Cycle Time:	**0.5028**	minutes

Load Bucket Capacity

Rated Capacity:	1.80	LCY (heaped)
Bucket Fill Factor:	1.100	Other - rock/dirt mixtures (100-120%) 1.100
Adjusted Capacity:	**1.98**	LCY

Job Condition Correction Factors
Site Altitude: 5100 feet

		Source
Altitude Adj:	0.95	(CAT HB)
Job Efficiency:	0.83	(1 shift/day)
Net Correction:	0.79	multiplier

Unadjusted Hourly Unit Production:	236.28	LCY/Hour
Adjusted Hourly Unit Production:	186.30	LCY/Hour
Adjusted Hourly Fleet Production:	**186.30**	LCY/Hour

JOB TIME AND COST

Fleet size:	1	Loader(s)	Total job time:	**1.74**	Hours
Unit cost:	$0.398	/LCY	Total job cost:	**$129**	

MOTOR GRADER WORK

Task description: **TR69 Topsoil replacement**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	215	State:	Colorado	Abbreviation:	None
Date:	7/18/2019	County:	Mesa	Filename:	215
User:	TNL				

Agency or organization name: DRMS

HOURLY EQUIPMENT COST

Basic Machine:	CAT 14M	Horsepower:	259
Ripper Attachment:		Shift Basis:	1 per day
		Data Source:	(CRG)

Cost Breakdown:

		Utilization %
Ownership Cost/Hour:	$64.10	NA
Operating Cost/Hour:	$56.17	100
Ripper Ownership Cost/Hour:	$0.00	NA
Ripper Operating Cost/Hour:	$0.00	
Operator Cost/Hour:	$45.39	NA
Total Unit Cost/Hour:	$165.66	
Total Fleet Cost/Hour:	**$165.66**	

MATERIAL QUANTITIES

Total Area to be graded or ripped: 0.40 acres

Source of estimated acreage: TR69

HOURLY PRODUCTION

Average Grader Speed:	1.50	mph
Selected Application:	Finish grading (0-2.5 mph) - 1.5	
Selected Blade Angle:	30	degrees
Effective Blade Length:	12.10	feet
Width of blade overlap per pass:	2.00	feet
Net grading or ripping width per pass:	10.10	feet
Unadjusted Hourly Unit Production:	1.8364	acres/hour

Job Condition Correction Factors

Site Altitude: 5100 feet

		Source
Altitude Adj:	1.00	(CAT HB)
Job Efficiency:	0.90	(1sh/d, fav.)
Net Correction:	0.9000	multiplier

Adjusted Hourly Unit Production:	1.6527	acres/Hour
Adjusted Hourly Fleet Production:	**1.6527**	acres/Hour

JOB TIME AND COST

Fleet size:	1	Grader(s)	Total job time:	**0.24**	Hours
Unit cost:	$100.23	per acre	Total job cost:	**$40**	

Task description: **TR69 Install concrete seal in excavated hole**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	216	State:	Colorado	Abbreviation:	None
Date:	8/13/2018	County:	Mesa	Filename:	216
User:	TNL				

Agency or organization name: DRMS

UNIT COSTS

Opening Description	Dimensions	Closure Method	Quantity	Unit	Unit Cost	Total Cost
pour concrete plug in excavated air shaft	15 CY	Shaft closure - concrete cap, poured-in-place (per Cubic Feet)	400.00	CF	$3.70	$1,481.48

Job Hours: **8.00** **Total Cost**: **$1,481.48**

REVEGETATION WORK

Task description: **Seed TR69 0.4 acre disturbance**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #: 217 State: Colorado Abbreviation: None
Date: 8/13/2018 County: Mesa Filename: 217
User: TNL

Agency or organization name: DRMS

FERTILIZING

Materials

Description	**Units / Acre**	**Unit**	**Cost / Unit**	**Cost /Acre**
8-32-16, 16-20-0	50.00	pound	$0.32	$15.75
			Total Fertilizer Materials Cost/Acre	**$15.75**

Application

Description	Cost /Acre
Truck whirlwind spreader (MEANS 32 01 90.13 0140)	$14.81
Total Fertilizer Application Cost/Acre	**$14.81**

TILLING

Description	Cost /Acre
Chisel plowing {DMG}	$94.63
Total Tilling Cost/Acre	**$94.63**

SEEDING

Seed Mix	Rate – PLS LBS / Acre	Seeds per SQ. FT	Cost /Acre
Alkali Sacaton	0.20	7.81	$5.70
Indian Ricegrass - Paloma	2.00	6.47	$22.25
Bluebunch Wheatgrass - Secar	2.00	6.43	$21.75
Russian Wildrye - Bozoisky	1.00	4.02	$6.48
Bottlebrush Squirreltail	0.50	2.20	$8.11
Galleta	2.00	7.30	$44.70
Slender Wheatgrass - San Luis	1.00	3.65	$4.25
Thickspike Wheatgrass - Critana	2.00	7.07	$13.75
Western Wheatgrass - Arriba	1.00	2.53	$6.50
Needle and Thread	1.00	2.64	$41.85
Saltbush, Four Wing	0.50	0.69	$6.25
Saltbush, Shadscale	3.00	4.48	$30.00
Winter Fat	2.00	5.10	$41.00
Penstemon, Palmer	0.25	5.53	$13.63
Primrose, Missouri Evening	0.50	2.03	$28.50
Greasewood, Black	1.00	140.45	$19.00
Kochia, Forage (Prostrate)	0.25	35.11	$2.24
Totals Seed Mix	20.20	243.50	**$315.96**

Application

Description	Cost /Acre
Drill Seeding (DRMS Survey Cost)	$232.00
Total Seed Application Cost/Acre	**$232.00**

MULCHING and MISCELLANEOUS

Materials

Description	Units / Acre	Unit	Cost / Unit	Cost /Acre

Hay, delivered {MEANS 31 25 14.16 1200}	2.00	TON	$295.00	$590.00
Total Mulch Materials Cost/Acre				**$590.00**

Application

Description	**Cost /Acre**
Crimping, with tractor {DMG survey data}	$70.17
Power mulcher (MEANS 32 91 13.16 0350)	$95.83
Total Mulch Application Cost/Acre	**$166.00**

NURSERY STOCK PLANTING

Common Name	**No / Acre**	**Type and Size**	**Planting Cost**	**Fertilizer Pellet Cost**	**Cost /Acre**
					$
Totals Nursery Stock Cost / Acre					**$0.00**

JOB TIME AND COST

No. of Acres:	0.4	Cost /Acre:	$1,429.15
Estimated Failure Rate:	0.3%	Cost /Acre*:	$1,429.15
*Selected Replanting Work Items:	FERTILIZING,TILLING,SEEDING,MULCHING		

Initial Job Cost:	**$571.66**
Reseeding Job Cost:	**$1.71**
Total Job Cost:	**$573**
Job Hours:	**3.40**

MISCELLANEOUS TRUCK WORK

Task description: **Water truck for TR69 activity**

Site: **Roadside Portals** Permit Action: SL11 Permit/Job#: C1981041

PROJECT IDENTIFICATION

Task #:	218	State:	Colorado	Abbreviation:	None
Date:	8/13/2018	County:	Mesa	Filename:	218
User:	TNL				

Agency or organization name: DRMS

HOURLY EQUIPMENT COST

Make and Model:	Water Tanker, 5,000 Gal.	Horsepower:	175
Attachment 1:		Shift Basis:	1 per day
Attachment 2:		Weight:	15.00
Labor Unit 1:	Tanker Driver - 1 rear axle		(US Tons)
Labor Unit 2:			

Cost Breakdown:

		Utilization %
Ownership Cost/Hour:	$27.40	NA
Operating Cost/Hour:	$39.99	100
Operator Cost/Hour:	$38.86	NA
Total Unit Cost/Hour:	$106.24	
Total Fleet Cost/Hour:	$106.24	

JOB TIME AND COST

Fleet size:	1	Truck(s)	Total job time:	**22.00**	Hours
Unit cost:	$106.24	/Hour	Total job cost:	**$2,337**	

Exhibit
B

COLORADO GEOLOGICAL SURVEY

1801 Moly Road
Golden, Colorado 80401
303-384-2655

Karen Berry
State Geologist

DATE: August 6, 2021

TO: Jason Musick, Jim Stark: Division of Reclamation, Mining and Safety (DRMS)

FROM: Jonathan L. White *Jonathan L. White*

SUBJECT: July 20, 2021 Site inspection of Roadside Mine (Snowcap Coal Company) surface collapse features near Cameo.

At the request of the DRMS, the Colorado Geological Survey (CGS) conducted a cursory surface inspection of the Roadside Mine at the Interstate-70 Cameo exit (Exit 46) on Tuesday, July 20, 2021. Prior to the CGS site visit, we received a copy of a site inspection report of the mesa surface by DRMS dated July 9 and July 11, 2019. Jason Musick and the operator's representative, Tonya Hammond, accompanied me to point out areas of interest on the mesa above.

The site is an unnamed mesa south of Cameo. Lidar was flown for this site in 2015 and the bare-earth hillshade image (Figure 1) generated from the 1-m resolution digital elevation model (DEM) was examined. The model revealed that at the time of the lidar survey, irrigation operations of the mesa surface had not yet occurred. There was no evidence in the DEM of ground disturbances such as the clearing of surface boulders to the mesa sides and excavation of irrigation pipelines and ditches within the cleared areas. Our understanding is that this mesa surface had never been historically irrigated until after 2015. Historical Google Earth (GE) photos of the mesa indicate that water lines were trenched and irrigation took place in 2019 (Figure 2). We also found no ground morphology in the lidar hillshade image that would suggest pre-existing subsidence deformation at the ground surface that could be attributed to mine subsidence.

The mesa is capped with unmapped older Pleistocene-aged debris/alluvial-fan deposits that were sourced from drainage basins to the south up onto the north flank of Grand Mesa, including the paleo Rapid Creek basin. These deposits are not ancient riverine gravel terraces of the Colorado River, which has more colorful pebbles and cobbles that originated from the Colorado Mountains within the river basin. Colorado River gravel contains many rock types, the rocks are smoothed and well rounded, water sorted, and typically densely packed and clast supported with a clean sand matrix.

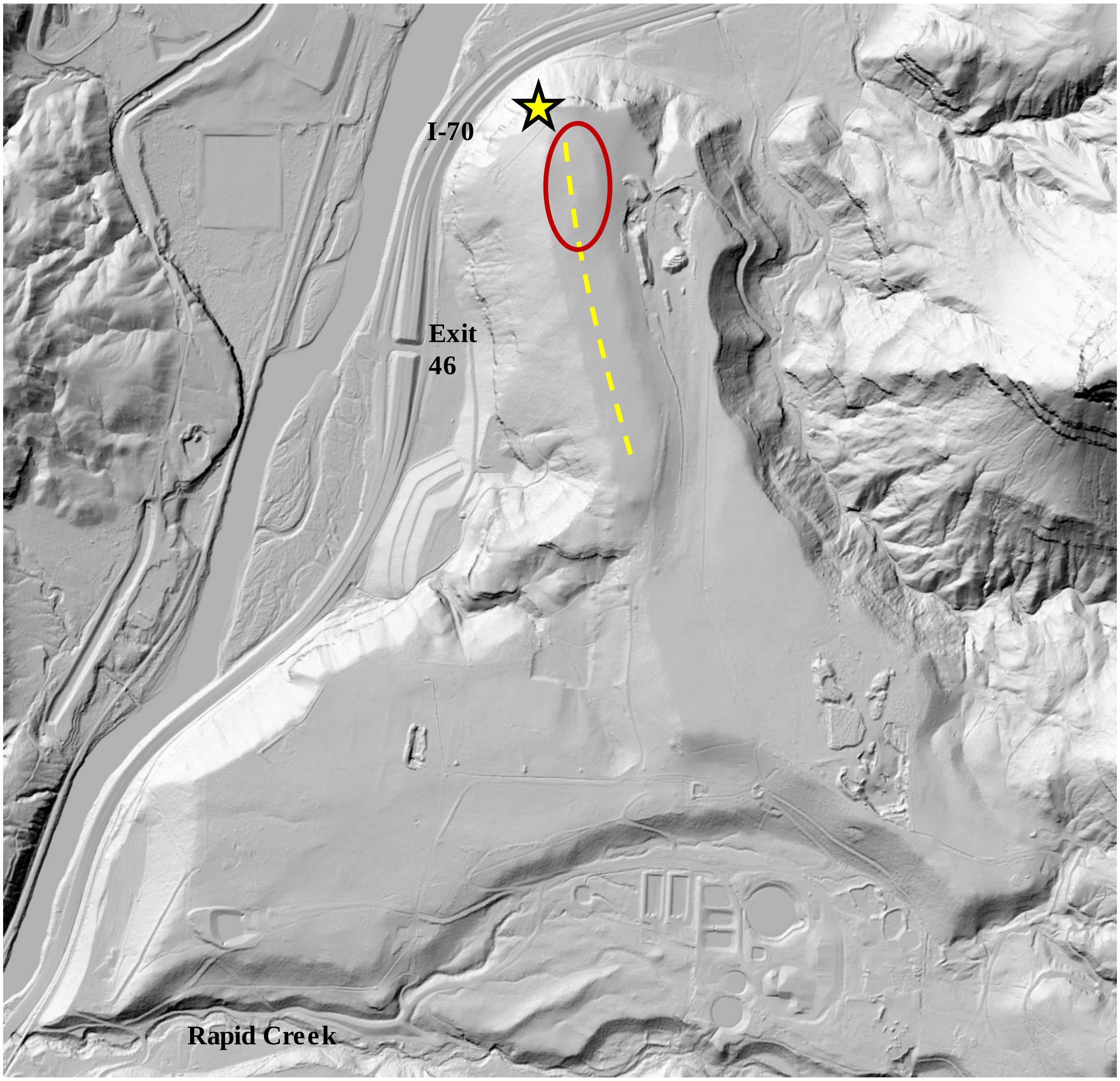

Figure 1. Lidar bare-earth hillshade image. Long linear gravel capped mesa is shown by yellow dashed line. Area of soil dissolution and piping voids approximated by red-lined oval. Location of star is where CDOT mitigated rockfall hazards related to water seepage and flow by scaling and construction of rockfall fence.

Debris fans, deposited during episodic flash floods and debris flows, are typically unsorted, very rocky (up to boulder sizes), and composed predominantly of volcanic rocks from Grand Mesa. Much of the surface boulders have a calcic crust related to a soil K horizon that has developed in the deposit. Gravel quarry exposures on the property indicate the deposit has a fine-grained (mud) matrix with both matrix supported and clast supported zones; an indication of rapid deposition of debris and (or) hyperconcentrated rocky mud flows. Trenches and open excavations at the gravel pits reveal that the debris-flow deposits are perhaps over 30 feet in thickness and overlie the bedrock sandstone of the coal bearing Williams Fork Formation. The top of the gravel may be variably mantled with a thin deposit of reworked reddish loess (wind-blown deposits of fine-grained silt and clay).

Figure 2. Oblique GE image of linear gravel-capped mesa remnant. Note lateral irrigation ditches on surface. Area of piping/soil dissolution approximated by yellow oval.

During the inspection, several small soil piping-type sinkholes and soil cracks were observed in clay and silt soil that contained dispersed angular to subrounded rocks up to boulder sizes. Most were clustered in the approximate oval area shown in the figures. DRMS and the mine representative stated that the mine workings were about 500' below the ground surface where the bulk of soil piping had occurred along the long linear mesa (shown as yellow-dashed line in Figure 1) with the lateral ditches running through it (seen in Figure 2 GE photo). This linear mesa remnant had the rockfall problems addressed by CDOT at its furthest point.

While there is no geotechnical testing available such as swell-consolidation testing or surface plate-load tests under saturated conditions to verify collapse potential of the underlying unconsolidated gravel and mud deposits, potential settlement of dry sediments and soil dissolution is quite common in arid to semi-arid climates of Colorado when water is first introduced.

There is an early reference cited in the CGS publication, *Collapsible Soils in Colorado* (EG-14) that specifically mentions the hazards of "sinking ground" when ground of western Colorado is first cleared and irrigated for agricultural use (Paddock and Whipple, 1910, *Fruit-growing in arid regions: An account of approved fruit growing practices in the inter-mountain country of western United States: New York, The Macmillan Company, 395 p.)*. Paddock and Whipple described soil cracks and fissures when soils subside. The mechanisms of collapsible-soil settlement are twofold. One is the mechanical densification of a unit volume of soil that has become wetted. As the soil saturates, the binding agents that support the soil grains weaken, shear, and collapse, causing the soil grains to re-orient into a denser configuration that results in less pore space and less volume, which manifests itself as settlement or subsidence at the ground surface. The second is soil dissolution and piping of dispersive fine-grained soils, which typically forms small sinkholes and other pseudokarst landforms. Fresh water disperses clay particles and the then cloudy water, with a suspension of very fine clay particles, flows into fissures, cracks, and open pore spaces as ground water.

In conclusion, we find no real indications that the phenomenon seen at the subject site are anything other than collapse of soil structure and soil dissolution related to the introduction of flood irrigation to the ground surface and adverse wetting of the subsoils. If you have any questions, please contact me at jwhite@mines.edu or my cell at (720) 272-9947.

Cc: Karen Berry, via e-mail attachment (Director, Colorado Geological Survey)

Exhibit C

Jan 12 2017

Collapsible Soils

Geologic Hazards

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At the end of the 19th and beginning of the 20th Century, some of the first settlers of the plateau region of western Colorado along the Colorado River, and the Uncompahgre and Paonia river basins, looked to fruit crops for their livelihood. The semi-arid but moderate climate was well suited for fruit orchards once irrigation canal systems could be constructed.

But serious problems occurred when certain lands were first broken out for agriculture and wetted by irrigation. They sank, so much in places (up to four feet!) that irrigation-canal flow directions were reversed, ponding occurred, and whole orchards, newly planted with fruit trees imported by rail and wagon at considerable expense, were lost. While not understood, fruit growers and agriculturists began to recognize the hazards of *sinking ground*. Horticulturists with the Colorado Agricultural College and Experimental Station (the predecessor of Colorado State University) made one of the first references to collapsible soil in their 1910 publication, Fruit-Growing in Arid Regions: An Account of Approved Fruit-Growing Practices in the Inter-Mountain Country of Western United States (pdf download). They warned about sinking ground and in their chapter, *Preparation of Land for Planting*, made one of the first recommendations for mitigation of the hazard. They stated that when breaking out new land for fruit orchards, the fields should be flood irrigated for a suitable time to induce soil collapse, before final grading of the orchard field, irrigation channels excavation, and planting the fruit tree seedlings.

Piping-void surface collapse near Loutsenhizer Arroyo east of Olathe.

So, what are these soils? Why do they collapse? The reference cited above briefly stated that, "The tendency to settle appears to be due to the porous conditions of the subsoil." Such soil properties are diametrically opposite from the better-known swelling problems that are found in the "fat" plastic clay soils of the Front Range. Collapsible soils are generally dry, low density, silty soils with high void space or air gaps between the soil grains where the soil particle binding agents are highly sensitive to water. These micro-pores can sometimes be seen by the naked eye. When exposed to and weakened by water, the binding agents break, soften, or dissolve such that the soil grains shear against each other and re-orient in tighter, denser, configurations. This reconfiguration causes a net volume decrease in the soil mass that, in turn, results in settlement of the ground surface. This condition can occur just by the weight of the soil itself, called the overburden, or the weight of a structure, such as a home foundation or dam abutment.

The binding agents of the collapsible soil structure can be very strong while the soil is in a dry state, and may possess high

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Damage to foundation and mortared brick walls from settlement of collapsible soils. Building in Montrose was demolished shortly after photo was taken. [Photo credit: Buckhorn Geotech]

bearing capacities able to support heavy structures. When water is introduced, the soil fabric's skeletal structure quickly weakens and fails. Collapse rate is also dependent on saturation rate of the soil. Because the introduction of water causes this collapse, the terms hydrocompactive and hydrocompressible are also used to describe these soils.

There are other types of soil collapse. One is piping and formation of soil caverns in dispersive and erodible soils, caused by active suspension and removal of soil particles by flowing water. Another is soil with a high evaporite-mineral or gypsum content, where actual dissolving of mineral grains and the cementation matrix (soil mass loss) can result in volume loss and settlement at the surface.

Continued settlement in collapsible soil dropped new town home driveway to a level where vehicles are unable to enter garage. Note leveling slab of concrete on garage floor from previous repair.

Structures and underground utilities founded on these types of soils can suffer from distress because of differential settlement. Because of the differential between two rates of settlement, strain can build until the structure bends, distorts, or breaks. The shifting and settling of the structure can be seen in a number of ways: 1) settlement, cracking, and tilting of concrete slabs and foundations; 2) displacement and cracking in door jams, window frames, and interior walls; and 3) offset cracking and separation in rigid walls such brick, cinderblock, and mortared rock. The damage can be similar to that caused by expansive or swelling soil. In fact, where both types of soils occur, usually in complex interlaying, it becomes difficult to initially determine what soil property is

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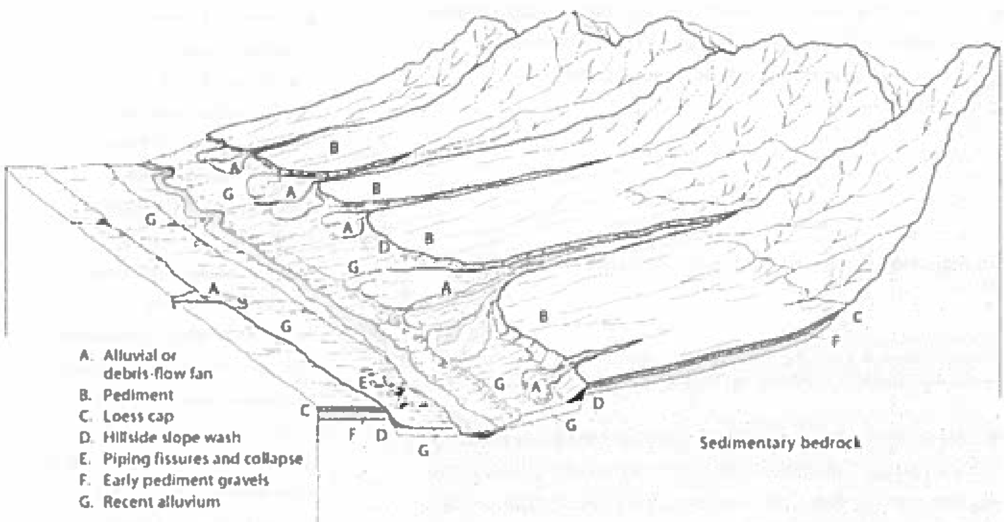
the cause of damage.

So, why do these soils form and where are the locations? The soils are derived from a number of different types of sediment deposition, but the key is really geology, climate, and resultant geomorphology.

Many regions of Colorado, outside of the crystalline rocks that form the major mountains, are underlain by poorly indurated (soft), clay and silt rich, sedimentary bedrock. The bedrock weathers easily and forms residual soils and is susceptible to rapid erosion.

It has been shown that semiarid areas are more prone to high sediment yields (expressed as tons of soil per acre lost by erosion, per year), which is to say that deposition of new sediments eroded from poorly vegetated hillsides is quick. Semi-arid regions have less vegetation and sufficient runoff of intense thunderstorms to transport large amounts of sediment. Sediment yields peak within the range of 12–20 inches (0.3-0.5m in annual precipitation that is typical for most of western Colorado, the intermontane valleys, and the high prairies next to the Front Range.

Numerous studies and case history compilations that include soil engineering properties (see map below) have shown that certain types of recent sediment deposits and soils can be susceptible to collapse. Those soils include windblown deposits of dust, silt, and fine sand called loess, hillside gravity deposits called colluvium, rapid deposition of unsorted waterborne material (mud and debris) in alluvial/debris flow alluvial fans and hillside slope wash, and recent overbank deposits called alluvium (silt and clay laid along tributary streams and gently sloped mud flats) (see block diagram, below). With few exceptions, soil collapse appears to occur in areas that have less than 20 inches (0.5m) of annual precipitation.



The common characteristic of these soils is recent and rapid deposition, depositional dynamics that result in an inherently unstable internal structure. The generally dry environmental conditions of the area cause these deposits to quickly desiccate (dry out) in their original condition, without the benefit of further re-working or packing of the sediment grains by water. Local ground-water levels generally never rise into these mantles of soil so they never become saturated. Only through human development and land use do local ground-water levels rise. The soils are introduced to moisture, through combinations of field irrigation, lawn and landscaping irrigation, capillary action under impervious slabs, leaking or broken water and sewer utilities, and altered drainage.

The most important thing to remember is that collapsible soils are dry in their natural state, and it is important that they remain so where structures have already been constructed without mitigation. Water and drainage management is always important for new-site development but is even more so with maintenance of existing structures. Certain restrictions for lawn-irrigation systems are also recommended. To reduce possible water introduction into the subsoil, xeriscape landscaping, requiring lower water usage, is suggested.

There are available engineering techniques to mitigate collapsible soils. They are grouped broadly into 1) ground modifications that mitigate the collapse potential of the soil, 2) structural reinforcement techniques, and 3) deeper foundations to transfer building loads through the collapsible soil horizon to a competent soil or rock layer below.

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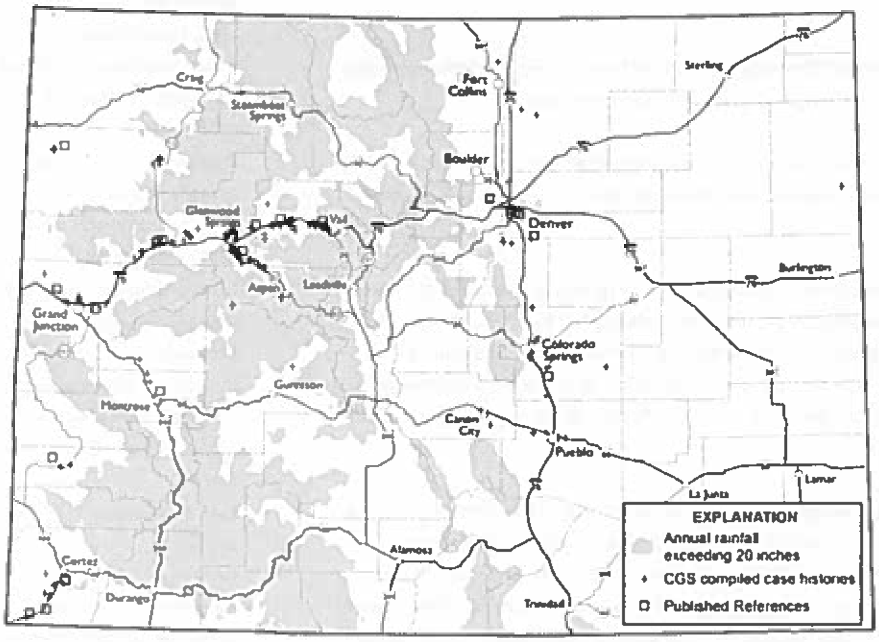

Collapsible soil case histories in Colorado. [Precipitation Data from USDA-NRCS, National Cartography And Geospatial Center, Ft. Worth, Texas, 1999]

The CGS has been studying collapsible soils in Colorado for a number of years and has compiled case histories in Colorado on sites studied by the CGS, cited in published references, or supplied by other government agencies and private consulting firms. The data have been analyzed with respect to local geology, geomorphology (landforms), soil formation, and climate.

Further Resources:

The CGS published both a regional susceptibility map and state-wide report on susceptibility of collapsible soils in Colorado in 2002.

Citation: White, Jonathan L. "MS-34 Collapsible Soils and Evaporite Karst Hazards Map of the Roaring Fork River Corridor, Garfield, Eagle, and Pitkin Counties, Colorado." Soil and Karst Hazards. Map Series 34. Denver, CO: Colorado Geological Survey, Department of Natural Resources, 2002.

This map identifies locations that may be susceptible to collapsible soils and subsidence related to dissolution of evaporite minerals. Meant as a guide for landowners, planners, municipal and county land-use regulators, and the geotechnical and civil engineering community, the map is a tool for formulating appropriate and proper types of investigation in the Roaring Fork River Corridor. 1 color plate (1:50,000).

Citation: White, Jonathan L. "MS-47 Collapsible Soil Susceptibility Map of the Colorado River Corridor in the Vicinity of Rifle, Garfield County, Colorado." Soil and Karst Hazards. Map Series 47. Denver, CO: Colorado Geological Survey, Department of Natural Resources, 2008.

This map identifies locations that may be susceptible to collapsible soils within the broad, semi-arid valley from the towns of New Castle to Parachute (formerly Grand Valley) along the Colorado River. Collapsible soils are dry, low-density, high-porosity soils that can spontaneously compact when they become wet. Also known as hydrocompaction, this phenomenon manifests itself as ground settlement and has been responsible for damage and distress for structures in the towns of New Castle, Silt, Rifle, and Parachute within the Corridor. Digital zip download.

Jonathan White, Senior Engineering Geologist (emeritus staff)

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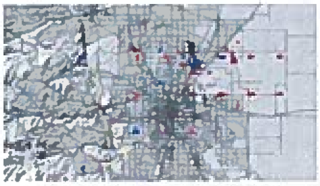

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Exhibit D

3. WHAT ARE COLLAPSIBLE SOILS?

Collapsible soils are known as hydrocompactive, hydrocompressive, metastable, low-density, and water-sensitive soils. Most collapsible soils are dry, fine-grained soils with a honeycomb skeletal fabric of open pores that are visible both microscopically and macroscopically (visible to the eye). The soil-binding agents are relatively strong in a low-moisture state and are able to support not only the load of the overburden pressures, but also additional loads, such as buildings or embankments. However, upon wetting, a water-content threshold is reached at which the soil-binding agents weaken. The same stresses that the soil had previously accommodated now cause the soil grains to shear against each other and pack into a denser configuration that reduces the void space. The result is settlement at the ground surface, as conceptualized in the illustration shown in **figure 3-1**. The process that leads to soil collapse includes three necessary components, as described by Barden and others (1973): (1) soil composed of an open, potentially unstable structure; (2) an applied stress component that is large enough to develop a metastable condition, and (3) a suitably strong soil-binding agent to hold and stabilize the soil-grain contacts in their original metastable orientation. This process pertains to classical mechanical collapse of soils upon wetting (i.e., hydrocompaction). Soil collapse through dispersion, piping erosion, and soil-mass loss by dissolution are discussed later in the chapter.

CLASSICAL MECHANICAL COLLAPSE

Hydrocompactive soil was defined as "unsaturated soil that goes through a radical rearrangement of particles and great loss of volume upon wetting with or without additional loading" in early work by Sultan (1969). The common features of collapsible soils are (1) open structure, (2) high void ratio, (3) low dry density, (4) high porosity, (5) geologically young or recently altered deposits, (6) high sensitivity, and (7) low interparticle bond strength (Rogers, 1995).

Soil structure is the sum of various factors, including the degree and type of aggregations, the particle gradation, the porosity, and the geometric arrangement or soil fabric of the individual soil grains. In collapsible soils, an open skeletal fabric is pronounced, and the grain-to-grain contacts are tenuous. The void space between soil grains of silt or clay can typically be seen only with a microscope. Collins and McGown (1974) reviewed some of the early soil-mechanics work in which clay-soil microfabric was first described as a "honeycomb" or "house of cards" structure. They discussed at length how agglomerations or aggregations of clay platelets act as individual units or grains within the microfabric of the soil. This porous microfabric can be best seen in scanning electron microscope (SEM) images. **Figure 3-2** shows SEM images of collapsible soils from southwestern Colorado (Luehring, 1988).

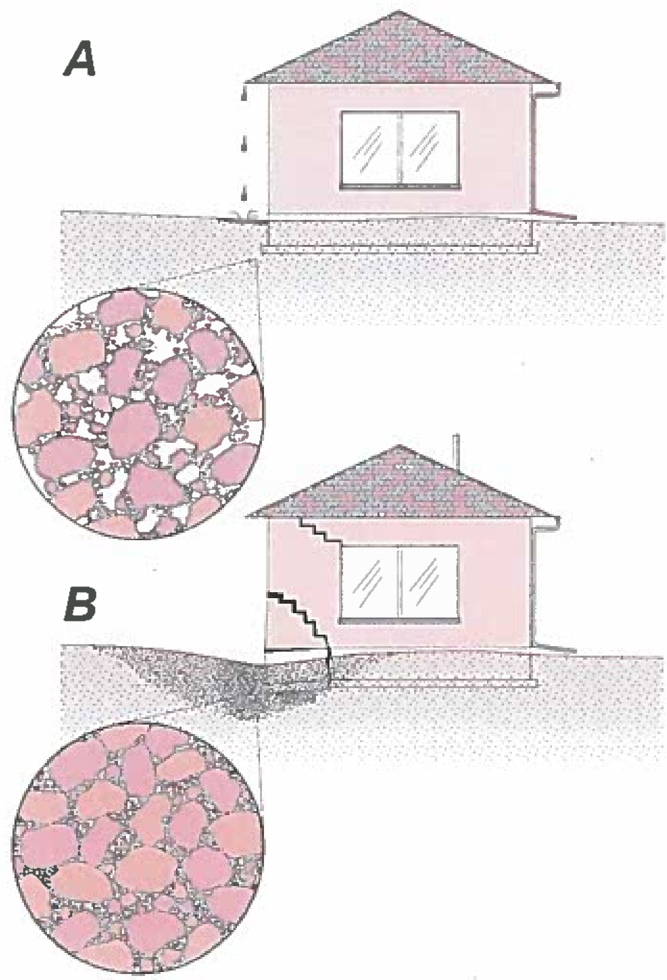
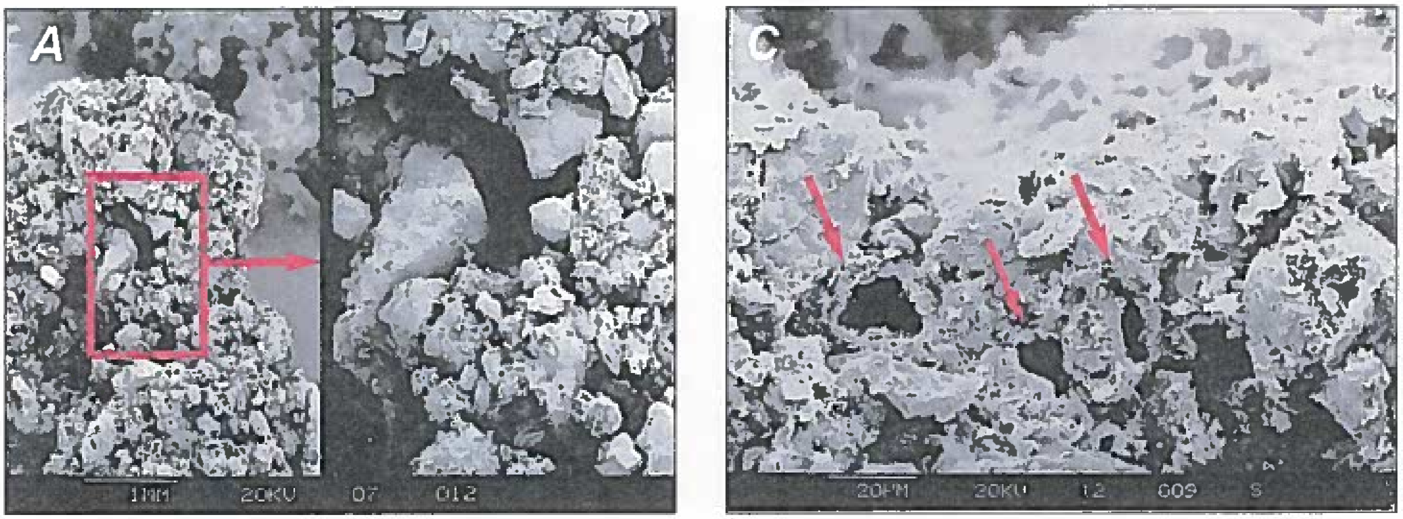


Figure 3-1 ***A*****, Wetting of high-void-space hydrocompactive soil has caused;** ***B*****, collapse and densification of the soil fabric, ground settlement, and distress to the structure.**



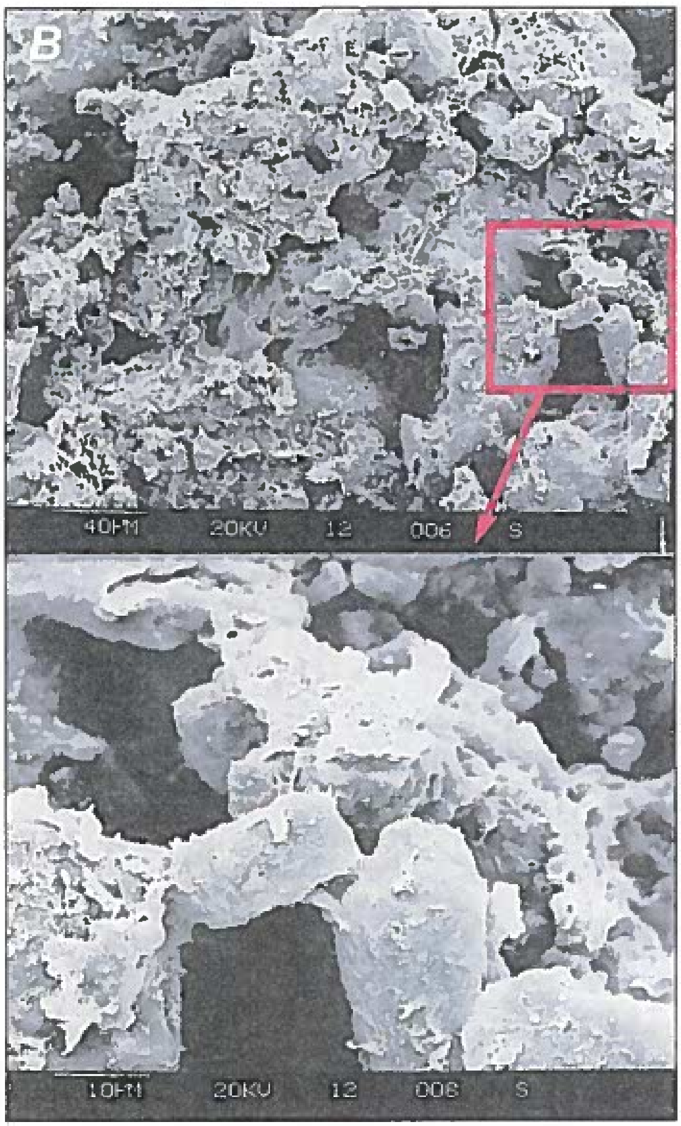


Figure 3-2. SEM images of collapsible clayey-silt soil. *A* and *B*, Void space is abundant between discrete soil grains. *C*, Clay-encrusted "shells" (arrows) line void pockets, and fragile bonds bridge between grains. Scale bar for *A (left)* is in millimeters. Scale bars for *B* and *C* are in micrometers (1 μm = 0.0001 cm). By comparison, 1/32nd of an inch is 795 μm, and the no. 200 sieve openings (upper gradational boundary of silt) are 75 μm. Boxes indicate close-up views shown by arrows. Images courtesy of R. Luehring.

Porosity or void space can also be macroscopic, visible as tiny pores in the soil sample (**figure 3-3**). These macroscopic voids can be primary, that is, formed as the geologically recent sediment was deposited. Primary voids represent either large air bubbles entrained in a "frothy" muddy debris flow that quickly consolidated or sites previously holding organic matter that has decomposed. Secondary voids form later from animal burrows, vegetation roots, or selective dissolution and removal of soluble soil constituents in the soil.

Soil that contains high percentages of gravel- and cobble-sized rock fragments can also be collapsible; such soil is termed "collapsible gravel." During the deposition, the larger rocks are dispersed in and supported by the finer-grained soil matrix, which exhibits the collapsible-soil structure. The larger rocks are not touching each other as they would, for example, in a tightly packed gravel. Typical gradations for collapsible gravels are provided by Rollins and others (1994).

One of the criteria for collapsible soils is the presence of strong, but sensitive, soil-binding or cementing agents to hold the soil fabric in its initially open configuration, which becomes unstable upon wetting and then fails such that the soil structure loses void space (Barden and others, 1973). There are several types of water-sensitive, soil-fabric binding agents that have been found to soften, disperse, reduce bond pressures, or dissolve when wetted (Jennings and Knight, 1957; Bull, 1964; Dudley, 1970; Barden and others, 1973; Clemence and Finbarr, 1981). The major ones are:

- capillary tension—also called soil suction, which when high improves soil shear strength at lower moisture contents because the water meniscus that bridges soil particles becomes smaller and holds the soil grains tighter as the soil dries after its initial deposition,
- silt bridges (also utilizing capillary tension),
- clay bonds (clay bridges of clay agglomera tions and flocculated clay that buttress silt and sand grains), and
- chemical precipitate—either carbonate or sulfate (gypsum)—as a cementing agent.

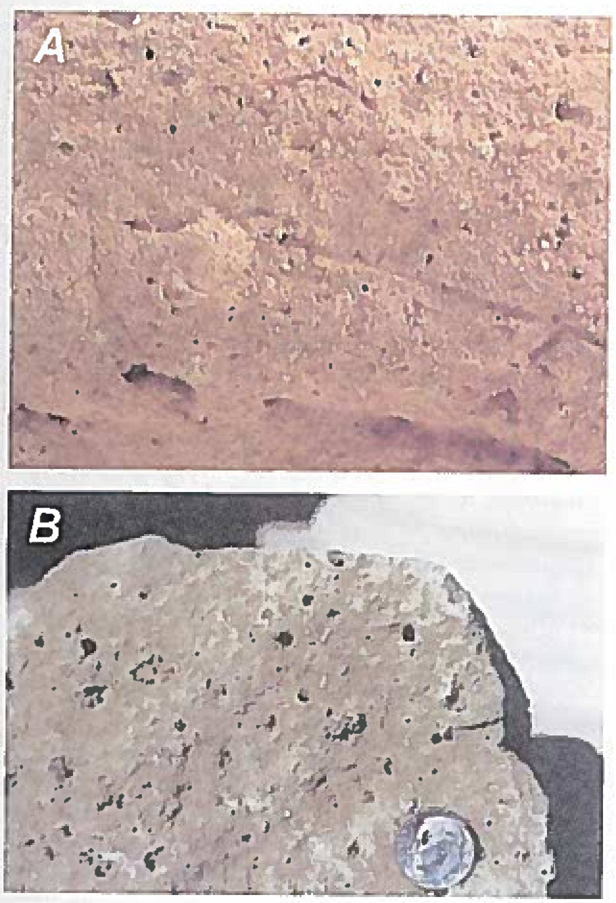


Figure 3-3. Visible, macroscopic voids in collapsible soils. *A*, A sandy-silt soil in which the primary voids were created at the time of deposition. *B*, A more clayey soil with secondary voids formed by microdissolution and biogenic activity.

The soil-binding agents can be quite strong, but weaken quickly in the presence of water. Houston and others (1988) and Beckwith and Hansen (1989) described the agglomeration of sand, silt, and clay grains as being "tack-welded" in the loose honeycombed state by the various binding agents. Upon wetting, the "tack-welds" fail quickly, clay agglomerations disperse, and grains shift so quickly that the honeycomb soil fabric "collapses"; hence the term "collapsible soil" describes any soil that is vulnerable to this process. Figure 3-1 illustrates this phenomenon at the microscopic level as well as how the phenomenon is manifested at the ground surface as subsidence and settlement. This condition is diametrically different from normal soil consolidation in the engineering sense. For clay- or silt-rich soils, consolidation implies expulsion of water and lowering of the soils' intergranular pore pressure. Collapsible soils, on the other hand, absorb water as they settle and compact, which is why "hydro-" (denoting water) is used as a prefix in the terms "hydrocompaction" and "hydrocompression." Chapter 4 provides information on engineering properties.

Hydrocompaction results in a conical-shaped zone of subsidence in the soil layer (fig. 3-1*B*). The perimeter of the settlement depression may show arcuate ground cracks, which define the wetting front where the compacted and subsiding soil has pulled away from the unaltered ground surface **(figure 3-4)**. These depressions can capture additional runoff that can cause further wetting and progressive subsidence. This mechanism is the predominant means of soil collapse for most low-plasticity soils with higher silt and sand content that are formed in eolian, alluvial-fan, and hillside colluvial environments..

OTHER METHODS OF SOIL COLLAPSE

Dispersion and Piping Collapse

In another type of soil collapse, soil mass can be lost by processes that physically remove sediment grains, primarily through dispersion and piping erosion. Overbank alluvial soils with high percentages of clay and silt and high salt contents can be dispersive and prone to piping. In many arid locations covered with recently-deposited clayey-silt alluvium, pedogenic gypsum soil horizons and heavy concentrations of gypsum and (or) other salts may occur. Such soils are commonly dissected by U-shaped gullies and arroyos typical of erosion in arid environments.

Dispersiveness is the property that causes colloidal suspension of clay particles in the presence of fresh water. The soil mass and volume reduce as soil disperses, particle by particle, in the water, which causes the water to become cloudy. Dispersion is also

Figure 3-4. Ground settlement during a soil-flooding test near Rifle. Hydrocompaction has created arcuate, concentric ground cracks in the 10-ft-high test embankment adjacent to the pond (see arrow). Note collapse features in floor of pond due to piping erosion. Photo courtesy of R. Barrett and CDOT.

referred to as colloidal erodibility. Dispersion of clay and silt particles widens soil fissures and creates subsurface channels called pipes. Dispersive soils can appear dense and have a high clay content; they do not necessarily have the appearance of a loose, highly erodible soil.

Piping erosion (i.e., formation of subsurface soil pipes) results when water is able to flow through sediments in subsurface channels. Piping passageways can begin at holes or fissures formed from several methods: the decay of plant roots, animal burrows, eluviation (i.e., the passage of silt and clay grains suspended in water through the interstices or connected pore spaces of a soil), dissolution of soluble constituents of the soil, desiccation cracks from swelling and shrinking of clay-rich soil, and subsidence cracks. Because the ground surface is often relatively impermeable, runoff is directed down these vertical macropores (cracks), and erosion is transferred underground where large pipes and wide fissures form. Piping is a common type of erosion of clay- and silt-rich soils in dry lands (Parker and Higgins, 1990) and thus is widespread in the Eastern Plains, Colorado Piedmont, and Western Slope plateau regions of Colorado.

Parker and Jenne (1967) described soil pipes in association with soil stress cracks or fissures formed from subsidence related to both hydrocompaction and ground-water removal that is common in Arizona, Nevada, and California. Parker and Higgins (1990) made the following generalizations about places where soil dispersion and formation of soil pipes may occur: (1) there is enough water to fill soil cracks and flow through the soil pipes, (2) the soil has shrink-swell clay-mineral constituents (e.g., higher smectite clay percentages), (3) the soil is generally dry or desiccates thoroughly on a seasonal basis, and (4) there is a topographically low outlet or discharge point for the water flow, such as an arroyo, ditch, or cut slope. Parker and Higgins also wrote that rates of piping erosion are enhanced by high percentages of exchangeable sodium ions and instability of the clay-agglomerated soil grains (on the micro level) and minimal vegetation cover and low slopes (on the macro level), which could increase infiltration and flows toward areas of shallow subsidence. These soils are generally unsaturated, fine grained (clay and silt), and low density, and they have moderate to good shear and bearing strengths when in a dry state. Soil collapse occurs by soil-mass loss (i.e., enlargement of subsurface pipes and voids and subsidence and failure of the bridged material into the void).

After connected pipes form an outlet at an arroyo, further piping erosion can also occur by corrasion (i.e., tunnel scour), which is the frictional wearing away of soil by the mechanical action of turbulent water with suspended sediment (Parker and Higgins, 1990). This action accelerates the enlargement of pipes and voids and can overtake dispersion as the primary erosive tool. These pipes and subsurface voids can be quite extensive, even cave-like, and can widen and migrate laterally through the subsurface over time, with no surface expression. At some point, failure of the soil bridges above the voids and fissures leads to the spontaneous appearance of modest-sized sinkholes and troughs. Livestock and farm equipment have been reported to fall into voids when soil bridges at the surface failed abruptly. **Figure 3-5** illustrates the complexity of forms of structural failure that can occur (Parker and Jenne, 1967).

The landforms resulting from soil dispersion and piping are called "pseudokarst" **(figure 3-6)**. This term, coined at the beginning of the twentieth century, is a variation of "karst," a term derived from the geographical name of part of Slovenia in southern Europe that contains terrain characterized by open voids, caverns, subterranean flows, sinkholes, etc., formed by the dissolution of limestone. Whereas true karst features result from the molecule-by-molecule dissolution of soluble rock, pseudokarst features are primarily a result of grain-by-grain removal of soil or poorly cemented bedrock constituents (clay, silt, and very fine grained sand particles) by suspension in moving water.

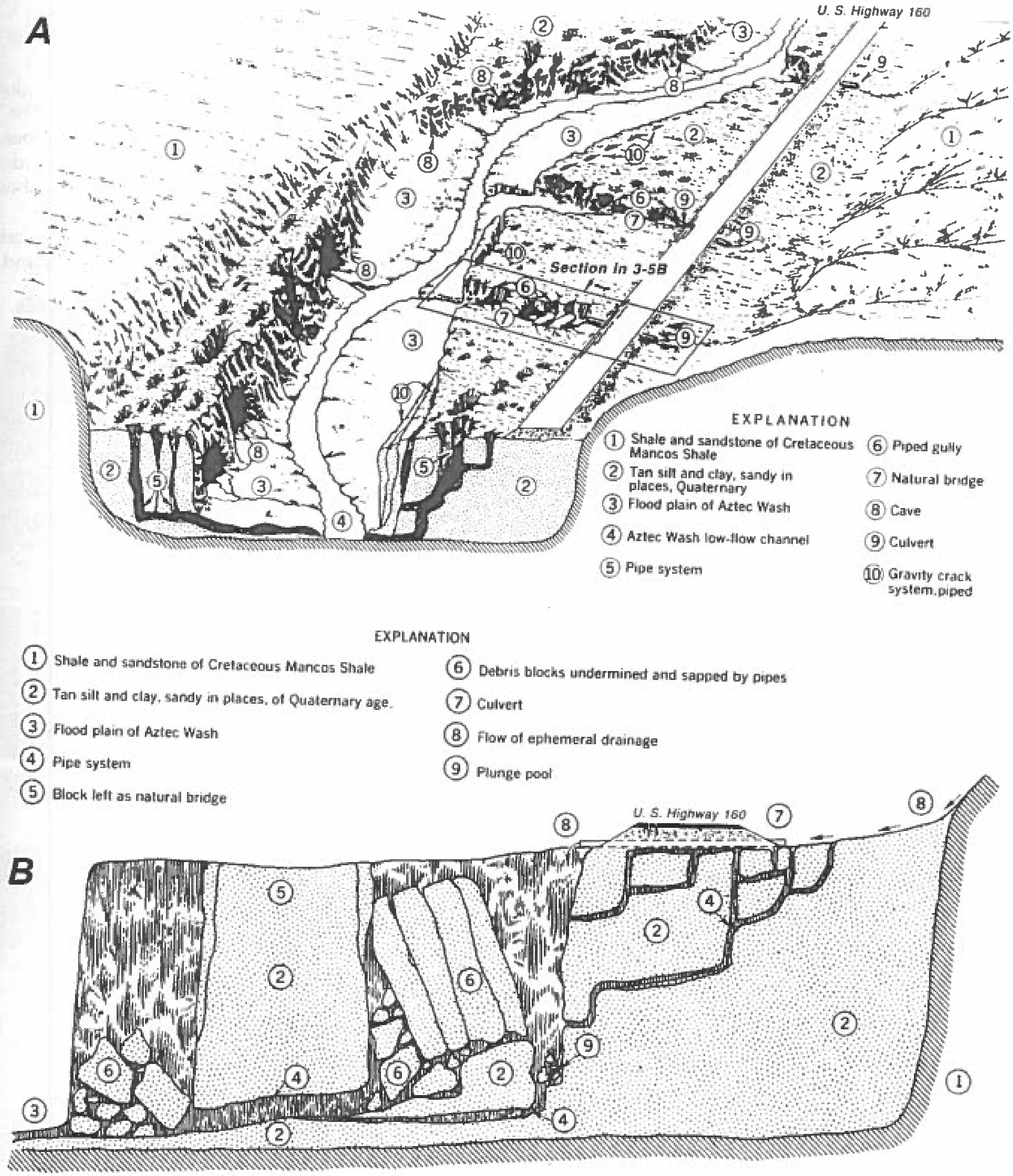


Figure 3-5. ***A*, Terrain resulting from piping dissolution of geologically recent alluvial sediments and the creation of pseudokarst morphology in an example along U.S. Highway 160 at Aztec Wash in southwest Colorado. *B*, Cross section through the terrain. Illustration from Parker and Jenne (1967).**

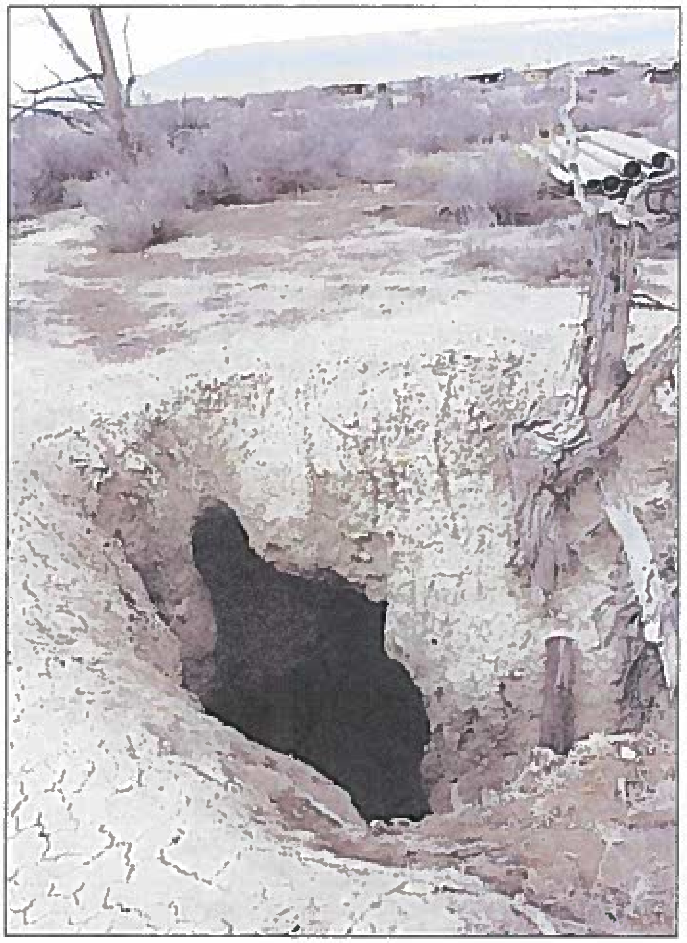


Figure 3-6. Sinkhole and cavern formation due to soil dispersion, piping, and void collapse along Loutsenhizer Arroyo, north of Montrose.

Dissolution of Soluble Constituents

The third type of soil collapse is soil-mass loss by dissolution. Dissolution of soluble soil constituents results in soil-mass loss and settlement of ground surfaces. In Colorado this type of dissolution occurs where evaporite bedrock is exposed near the surface and where soils contain significant percentages of pedogenic gypsum, either dispersed in the soil or as discrete Bk-By soil horizons. Any exposure to water can cause dissolution of the gypsum. This process, although not triggering rapid collapse, can cause long-term subsidence and settlement at the surface. Soil scientists are aware of the problems with these types of soils (Nettleton and others, 1982), and well-known occurrences exist in the Colorado Four Corners region (Doug Ramsey, personal communs., 2001, 2004). The Soil Survey of Aspen-Gypsum Area, which describes a region where Eagle Valley Evaporite bedrock is widespread and exposed at the surface, also cautions about building on potentially settling gypsiferous soils (Alstatt and Moreland, 1992). A more in-depth description of the environments where these soils are found is included in Chapter 5.

DAMAGE THAT RESULTS FROM SOIL COLLAPSE

All types of collapse, regardless of genesis, result in subsidence and settlement of the ground. Severe subsidence could cause adverse land impacts; if the strain of differential settlement exceeds the strength of a structure foundation, utility line, or pavement, then structural distress and damage might occur. Examples of land impacts and structural damage are shown in **figure 3-7.**

Figure 3-7. ***A*, Typical damage to foundation walls and brickwork from settlement is visible on a school in Canon City.**

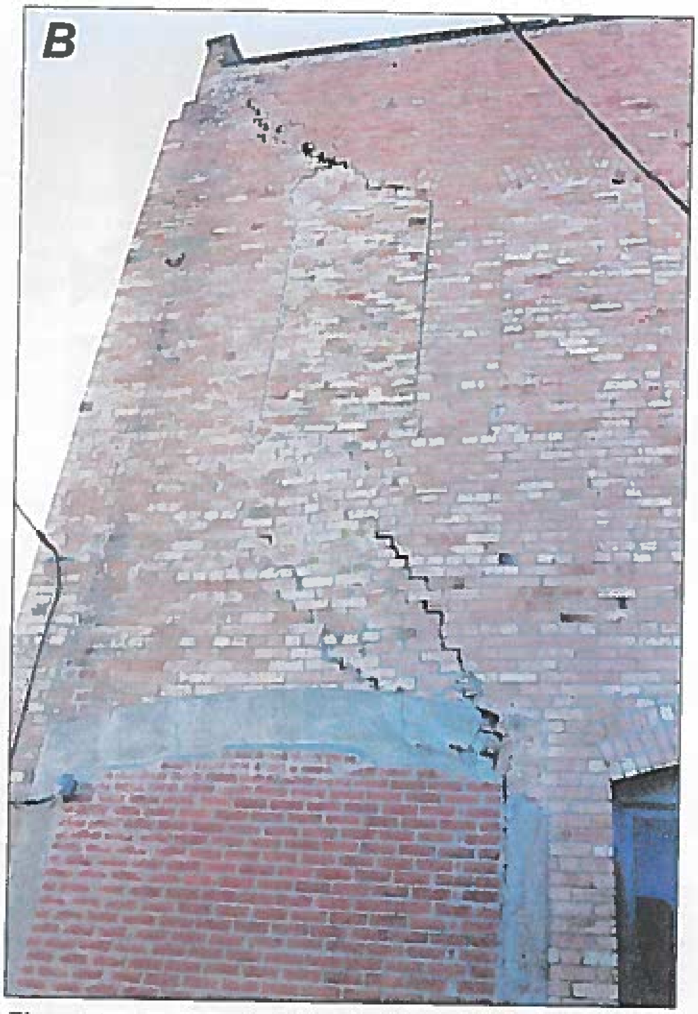


Figure 3-7. *B*, Extensive settlement-caused brickwork damage mars a downtown building in Montrose.

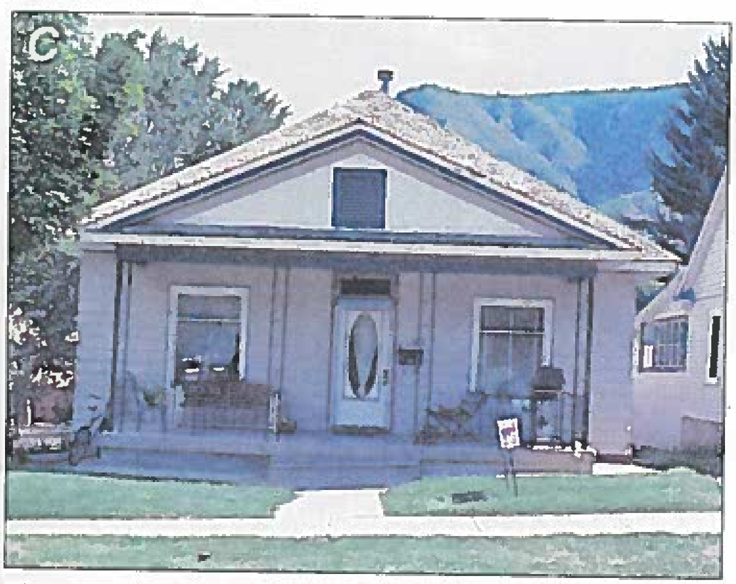


Figure 3-7. *C*, Settlement has damaged the porch and doorway of a home in Glenwood Springs.

Figure 3-7. *D*, Pseudokarst collapse from dispersion and piping erosion has caused this agricultural field to be abandoned near Olathe. The plateau in the background is Grand Mesa.

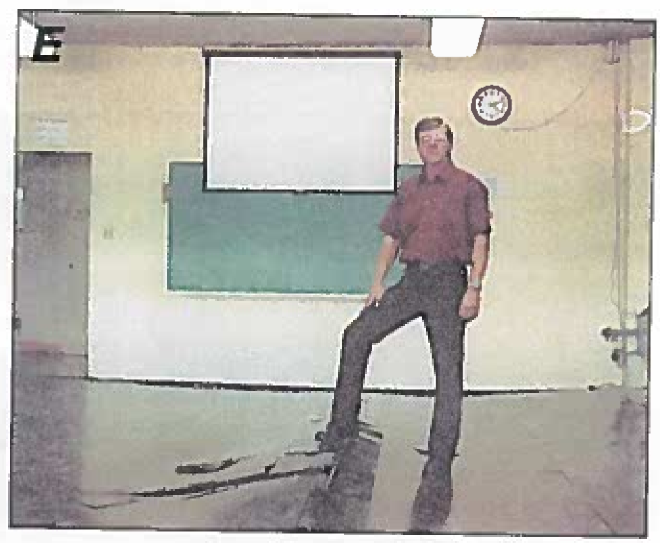


Figure 3-7. *E*, The wood flooring in a school in Montrose has buckled because of compression due to settlement of the underlying concrete slab-on-grade. Photo courtesy of Tom Griepentrog, Buckhorn Geotech.

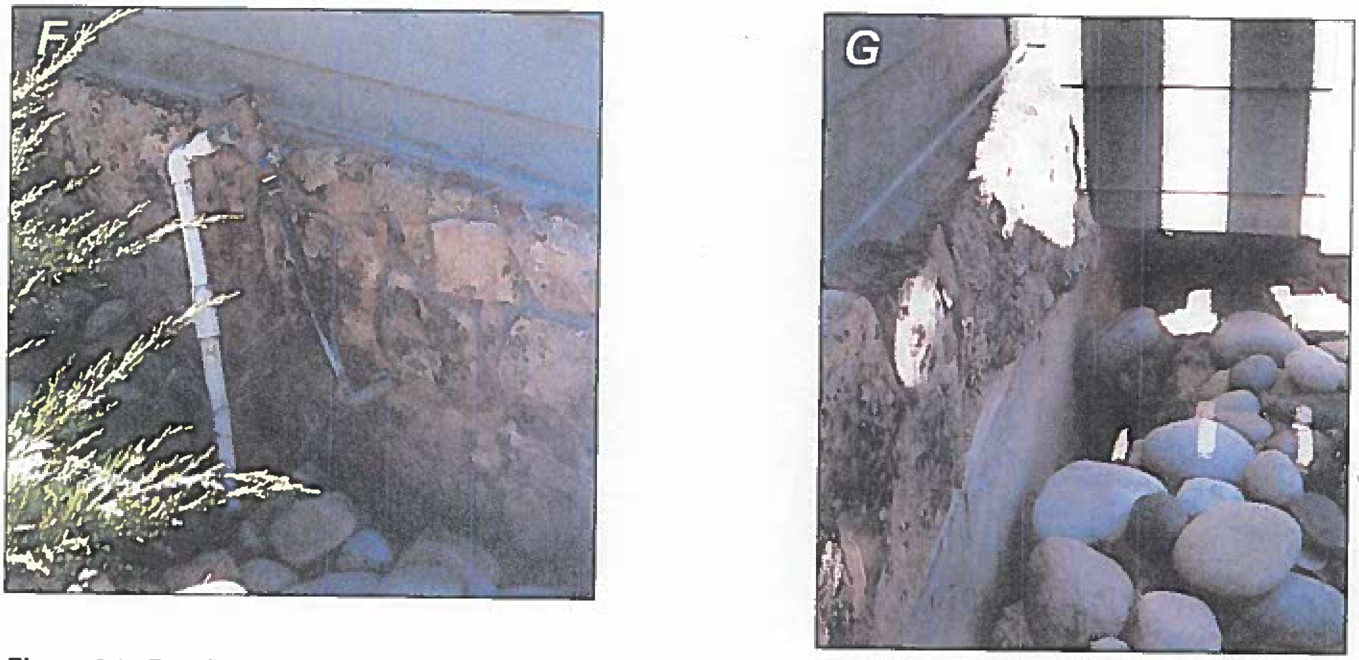
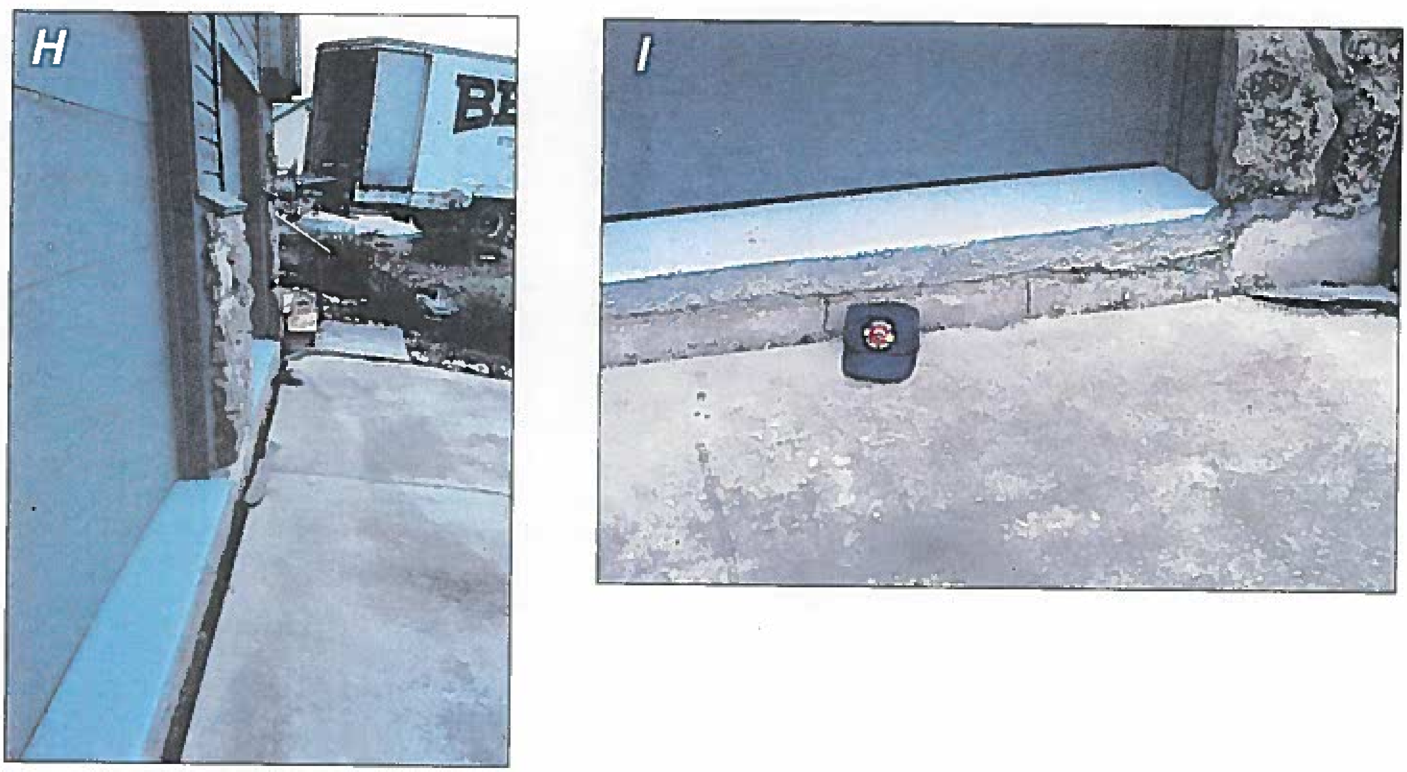


Figure 3-7. *F* **and G, Large wetting events such as broken water mains will cause widespread settlements, ultimately putting the soil of the surrounding area into tension (which is why arcuate cracks form around wetting ponds). In these two photographs, soil is being pulled down and away from the foundation walls. Note the gap along the foundation wall and the distress of the water line into the home. Dangerous conditions occur if natural gas or buried power lines are pulled to the point of rupture.**



H **and** ***I*****, Large-scale settlement due to a water main break in road (off picture) has pulled this driveway down and away from the residence. This residence was previously underpinned, and a new leveling concrete pad was poured in the garage. The pipe piles were of inadequate depth, and deeper wetting of the collapsible soils caused further distress to the structure. (In** ***I*****, a baseball hat shows the scale).**