

Multiple-Purpose Project
Little Blue River Basin
East Fork Little Blue River
Missouri

Blue Springs Lake

Operation and Maintenance Manual

Appendix IV

Construction Foundation Report

Volume One

AD-A228 611



**US Army Corps
of Engineers**

Kansas City District
Leaders in Customer Care

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The purpose of this report is to provide a record of foundation conditions encountered during construction and methods used to adapt to these conditions. This information is a part of the permanent collection of project engineering data required by ER 1110-1-1801, change 2, dated 1 April 1983.		

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 BLUE SPRINGS LAKE
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APPENDIX IV

CONSTRUCTION FOUNDATION REPORT



VOLUME ONE

September 1990

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 KANSAS CITY, MISSOURI

OPERATION AND MAINTENANCE MANUAL
BLUE SPRINGS LAKE
EAST FORK, LITTLE BLUE RIVER, MISSOURI

APPENDIX IV
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OPERATION & MAINTENANCE MANUAL
BLUE SPRINGS LAKE
EAST FORK, LITTLE BLUE RIVER, MISSOURI

APPENDIX IV
CONSTRUCTION FOUNDATION REPORT

CHAPTER 1

INTRODUCTION

1-01. Location and Description. Blue Springs Lake is located in Jackson County, Mo., on the East fork of the Little Blue River, 15 miles east-southeast of downtown Kansas City, Mo. A location and vicinity map is shown on Plate 1, and a general map of the damsite is shown on Plate 2. Drainage area above the dam is 32.8 square miles. At flood control pool, elevation 820.3 NGVD, the lake's surface covers 980 acres, and stores 15,700 acre feet of water. While at multipurpose pool, elevation 802 NGVD, there are 720 surface acres with a storage of 10,600 acre feet.

The primary purpose of the project is flood control. Secondary benefits are recreation and enhancement of fish and wildlife.

1-02. Construction Authority. Blue Springs Lake was authorized by the Flood Control Act of 1968 as a part of the Project for flood control and other purposes on the Little Blue River in the vicinity of Kansas City, Mo....substantially in accordance with the recommendations of the Chief of Engineers in House Document No. 169, Ninetieth Congress...."

The dam consists of the following:

a. A zoned, rolled earth and rock embankment approximately 2,500 feet in length. The crown of the dam is 30 feet wide at elevation 841.0 which is about 65 feet above the stream bed.

b. An uncontrolled limited service spillway is located near the left abutment. The spillway flowline is at elevation 827.6. It is 1,100 feet long and 300 feet wide. Spillway capacity is 24,600 cfs.

c. A controlled outlet works in the right abutment consists of an intake tower, service bridge, approach, and outlet channels, conduit and stilling basin. The outlet works has a rated capacity of 575 cfs with pool at elevation 820 NGVD, with a conduit length of 490 feet. Two 48-inch concrete sewers are placed immediately below the conduit.

d. The intake tower consists of an uncontrolled drop inlet for water release above multipurpose pool elevation of 802 NGVD, two 24-inch low flow knife gates, and a 4 by 5.5 foot gate for emergency release.

1-03. Purpose of Report. The purpose of this report is to provide a record of foundation conditions encountered during construction and methods used to adapt to these conditions. This information is a part of the permanent collection of project engineering data required by ER 1110-1-1801, change 2, dated 1 April 1983.

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1-04. Contract and Supervision. The contract, DACW41-182-C-0198 was awarded to Potashnick Engineering Company on 15 July 1982. The contract work included construction of approach structures; intake towers; service bridge; conduit consisting of flood control conduit and dual 48-inch sewers encased in concrete monoliths; stilling basin; approach, outlet and diversion channels; excavation of a diversion channel, cutoff trenches and the spillway; construction of two small diversion dikes and the dam embankment; foundation drilling and grouting; and electrical and mechanical equipment for the intake tower. Potashnick began work on 29 August 1982. The original completion date was 6 November 1985. Potashnick defaulted in August 1983 and subsequently filed for bankruptcy. The bonding company, Fireman's Fund, hired Holloway Construction Company of Wixom, Michigan, to complete the contract. Holloway began work in the summer of 1984, and the dam was completed in 1988. The grouting subcontractor was Boyles Brothers Drilling Company, Salt Lake City, Utah. Grouting began on 25 March 1983 and was completed on 26 August 1985.

The Resident Engineer for the project was Mr. Joseph L. Lilley. The Project Geologists were Mr. William F. Lowe, August 1982 to October 1984 and Mr. Clyde W. Huffman October 1984 to 1988. The Project Manager for Potashnick Engineering Co., was Mr. Doug Luna. Mr. Jack D'Haene was Project Manager for Holloway Construction Co. Boyles Brothers was the grouting subcontractor for both Potashnick and Holloway. Mr. Steve Hall was grouting Project Manager for the entire project.

1-05. Quality Control. The Quality Control staff consisted of the Project Managers and Office Engineers. The Office Engineers were Mr. James Schramm through 1985 and Mr. James Way through 1988.

CHAPTER 2

FOUNDATION EXPLORATIONS

2-01. Investigations prior to construction consisted of field reconnaissance, study of aerial photos, review of literature, drilling, pressure testing of bedrock, and sampling and testing of overburden and bedrock. A total of 306 borings and test pits were completed by Government drill crews prior to beginning of construction. A summary of drilling follows:

Prior to Construction			
<u>Type Core Holes</u>	<u>Number</u>	<u>Total Lineal Feet Drilled</u>	<u>Lineal Feet - Bedrock Core Only</u>
6-inch	3	107.5	104.5
4-inch	1	75.0	64.4
Nx	5	397.4	393.7
Nq	1	124.6	124.6
Drive Holes	138	3692.2	
Drive & 6-inch Core	9	444.2	338.3
Drive & 4-inch Core	1	89.4	81.4
Drive & Nx Core	6	411.9	375.1
Rock Bit & 6-inch Core	14	914.5	551.3
Rock Bit & 4-inch Core	1	100.0	72.1
Rock Bit & Nx Core	14	1118.1	909.9
Rock Bit & Nq Core	4	442.0	389.7
Auger 6-inch Core	4	312.0	281.0
Auger 4-inch Core	1	70.1	61.2
Auger Nx Core	2	104.5	77.7
Auger Nq Core	3	210.8	201.3
Undisturbed 6-inch Core	2	78.6	46.3
Auger/Drive	18	417.6	
Undisturbed	15	814.1	
Auger	38	493.7	
Hand Auger	19	209.3	
Test Pits	7		
TOTALS	306	10346.7	4072.5

Drive holes were made with 6-inch, and 4-inch drive barrels and varied sizes of split spoons. Undisturbed samples were taken with 5-inch and 3-inch Hvorslev thin wall samplers. Fourteen core holes were angled. Eight were on the left abutment and six on the right. Forty core holes were pressure tested. Eighty-seven holes were drilled during construction in addition to the cone penetration program to re-evaluate the foundation strengths. This evaluation was done to determine whether any strength gain had occurred in the foundation during the construction delay created by the original contractors' default. A summary follows:

2-02. During Construction.

<u>Type</u>	<u>Number</u>	<u>Total Lineal Feet</u>	<u>Lineal Feet of Bedrock Core</u>
Drive Holes	12	289.3	
Rock Bit & 6-inch Core	11	294.6	251.5
Rock Bit & 4-inch Core	11	878.2	444.2
Undisturbed & 6-inch Core	2	203.8	107.8
Undisturbed & 4-inch Core	5	445.4	127.2
Auger/Drive Undisturbed	15	1049.5	
Undisturbed	19	575.1	
Auger	2	106.4	
Hand Auger	4	9.0	
Rock Bit	6	566.6	
Cone Penetrometer	34	2368.0	
TOTALS	121	6785.9	930.7

CHAPTER 3

GEOLOGY

3-01. Regional Geology and Physiography. Blue Springs Lake is located at the southern edge of the dissected till plains section of the central lowland physiographic province. A mature drainage system has developed on what was probably an outwash plain deposited during the mid-Pleistocene by the Kansas ice sheet. Scattered till deposits and loess have been reported in the uplands, however, most have probably been eroded away by streams forming the present drainage system. Bedrock is middle Pennsylvanian and consists of alternating limestones and shales of the Kansas City group, underlain by the Pleasanton group which is a thick clastic sequence consisting of mudrocks, silty shales, sandstone, siltstones and some carbonaceous units with underclays.

3-02. Site Geology. The valley is surrounded by gently rolling uplands with moderate relief up to 120 feet. The floor is about 2200 feet wide along the dam axis. The east fork of the Little Blue River flows generally north in a meandering channel cut into the valley alluvium. The most prominent rock unit is the Bethany Falls limestone member of the Swope formation of the Kansas City group which forms the scarps along the valley walls. The uppermost rock unit at the site is the Wea Shale member of the Cherryvale formation. The lower valley walls are formed in the shales and siltstones of the Pleasanton group. The uppermost unit excavated on site is the Winterset limestone member of the Dennis formation.

3-03. Description of Overburden. Upland soils range from 0 to 19 feet in thickness and consist of fat clays with frequent lean clay interbeds. Valley side slopes are mantled with lean to occasional fat residual clays and colluvium. Valley alluvium ranges from 14 to 63 feet and consists primarily of soft, lean, silty clays and silts with occasional fat clays. The material responds quickly to drying conditions (sunlight and winds) and forms a thin dessicated crust which impedes drying at depth. Basal gravels are infrequent and range from 1 to 7 feet in thickness. The alluvium is deposited on shales and siltstone of the Pleasanton group.

3-04. Bedrock Stratigraphy. Bedrock at the damsite ranges from the Wea member of the Cherryvale formation of the Kansas City group to the upper 60 feet of the Pleasanton group. Other than some facies changes, no remarkable stratigraphic anomalies were observed. The most notable facies change was the maroon clay in the stratigraphic sequence along the right abutment normally occupied by the Critzer limestone. Bedrock units exposed at the damsite are described in descending order in the following paragraphs.

KANSAS CITY GROUP

Dennis Formation

Winterset Limestone Member is moderately hard, medium to thick bedded, finely crystalline, black chert nodules to bands in the upper half and light gray shale partings in the lower half. This is the uppermost rock unit excavated in the spillway and on site. Thickness excavated was approximately 13 feet.

Stark-Galesburg Shale Members are undifferentiated on-site. The upper or Stark Member is soft, platy to fissile, calcareous to carbonaceous, with occasional siltstone laminations in lower part. It is medium gray in the upper part, grading to dark gray to black in the lower portion. Occasionally it contains a band or thin bed of shaley limestone to limey shale. Contact with the Galesburg is not defined. The lower or Galesburg Member is soft, platy, silty, slightly calcareous, and dark gray; the lower part is soft to occasionally very soft, blocky, slightly silty, occasionally slickensided, and gray to greenish gray. The lower Galesburg transitions into the "peanut rock" zone of Bethany Falls and is not readily discernible.

Swope Formation

Bethany Falls Limestone Member is moderately hard, thin to massive bedded, dense to very finely crystalline, light gray with numerous undulating shale partings, stylolitic, (crenulations to .05 feet), with a nodular (peanut rock) zone in the top 2 to 5 feet. Joints are frequently solutioned, and open to clay filled, with occasional solutioning along bedding planes. It is light gray with dark gray shale. The upper 3 feet where rock is weathered appears to be granular and loosely cemented and is underlain by a 3-foot massive nodular appearing bed. The Bethany Falls is often found as very large slump blocks along the valley walls. The thickness on-site averages 22 feet.

Hushpuckney Shale Member. This shale is soft, gray, clayey to silty, and platy to fissile at top. The unit grades downward to a hard black fissile carbonaceous shale in the lower 1.0 foot. The lower fissile zone contains occasional phosphate nodules and small selenite crystals. Its thickness averages 2.5 feet.

Middle Creek Limestone Member is a limestone which is hard and thin bedded at the top, to thick bedded on the bottom. It is finely crystalline, gray brown, and fossiliferous; a shaley limestone, moderately hard to soft, gray, very fossiliferous, approximately 0.3 feet thick is in the center of the unit. The member averages 1.2 feet in thickness. It weathers to yellow-brown on exposed surfaces and joints.

Ladore Shale Formation. The Ladore is a soft, silty, platy shale which is calcareous in the upper part. It is gray to dark gray. Its contact with the Sniabar is frequently transitional and not well defined. Considerable alteration of the upper 0.5 feet of the Ladore occurs as a result of weathering. A consistent soft white chalky zone with soft limey concretions is present in weathered zones. Ramose Bryozoans are common in the upper part with Composita and Spirifer common in the lower part.

Hertha Formation

Sniabar Limestone Member. The Sniabar is a moderately hard to hard, light gray to tan, limestone with thin to massive bedding, and fine to medium crystallinity. It is shaley top and bottom, with occasional shale partings. It weathers on exposed surfaces to a coffee-colored brown; extreme weathering produces a yellow-orange, very soft material. Shale in the lower sections contains finely disseminated pyrite and occasional small 0.06-foot pyrite nodules. It is fossiliferous. The lower shale zone is laminated with phosphatic, taupe colored laminae to 0.02 feet thick. Dolomitic alteration

occurs in isolated instances with dolomite and barite crystals rare. Excessive solutioning in joints has deposited travertine up to 0.8 feet thick on joint faces.

Mound City Member is a shale which is soft, blocky, clayey, calcareous with occasional limey nodules and, slickensides in the upper part. It is light gray-green to light gray. It transitions into the Critzer and contact is often questionable. It contains finely disseminated pyrite and numerous pyrite nodules to 0.06 feet. Small horn corals are common.

Critzer Member is a soft platy shale which is clayey and slightly calcareous, with limestone nodules and partings. It is occasionally slickensided and is gray to gray-green. Recognition of the unit in outcrop is dependent on the more resistant limey nodules. A maroon clay replaces the lithology in the stratigraphic sequence on the right abutment.

PLEASANTON GROUP (UNDIFFERENTIATED)

Zone A is a shale which is interlaminated with siltstone and sandstone. It is soft, platy to silty, occasionally calcareous, dark gray to olive green with light gray or yellow siltstone and sandstone. The sandstones are soft to moderately hard, thin bedded, fine-grained and micaceous. There is a persistent zone of sandstone from 0.5 to 2.0 feet thick near the top of the zone. The sandstone weathers to a drab rusty brown and contains very hard, probably orthoquartzite, nodules. All massive shales or mudrocks in this zone slake or check rapidly. The bottom 6 to 8 feet of the zone is a dark blue-gray mudrock which is soft and blocky with phosphatic concretions. The joint infilling just below the Critzer limestone on the right abutment is limestone. The fissility in the upper 4 to 5 feet is very fine with micaceous partings. The thickness is 21.0 feet.

ZONE B is a sandstone which is hard to soft, medium to massive bedded, with shale partings. It is fine to very fine grained, silty micaceous, frequently calcareous, with occasional phosphate nodules. *Composita* and *Spirifers* are common at the base. It weathers to drab rusty brown. Facies changes include areas in which the upper 3 to 4 feet is hard with the lower 4 to 5 feet a soft siltstone. The thickness is 9.5 feet.

ZONE C is a shale and siltstone. The upper half is generally siltstone with occasional shale interbeds but sometimes it is all massive shale. It is moderately hard to soft, thin bedded, argillaceous, calcareous, pyritic, light to dark gray in the upper part; the lower half is soft, thick to medium bedded, occasionally fissile, non-calcareous, with occasional limestone nodules and thin beds. It is dark gray to nearly black, very fossiliferous with carbonaceous to thin coal beds at base. The joint system is very complex with no definite pattern. Joints generally trend NNW however they usually diverge abruptly into several smaller joints with random directional trends which have meandering or serpentine traces. Convergence of the smaller joints occurs to form larger joints which again trend NNW. Weathering is unique in that concretionary ovate spheroids occur (largest noted was 3.3 feet along the long axis), which may account for the random joint trace orientation. The thickness is approximately 60 feet.

ZONE D is an underclay and shale. The underclay is soft, light greenish gray, massive to thin bedded, and calcareous with sparse limestone nodules. The shale is soft, thin bedded with occasional thin interbeds of siltstone and micaceous sandstone. Limestone nodules are sparsely distributed throughout the zone.

ZONE E is sandstone. It is soft to moderately hard, thin bedded with occasional shale and siltstone partings to interbeds. It is very fine grained, micaceous with occasional limestone nodules, and disseminated carbonaceous particles. It is limey at the base, and is light gray to light greenish gray with dark gray laminae.

MARMATON GROUP

Holdenville Shale Member. This unit is a soft, thin bedded, fissile, clayey, calcareous shale with occasional limestone partings to thin beds. Occasional siltstone zones occur at the top. It is dark gray with light gray laminae and a red brown zone at the base.

Lenapah Member is interbedded shale, siltstone, and sandstone. The shale is soft, fissile to massive, clayey, non-calcareous, and varicolored, gray, green and red. The sandstone is greenish gray, moderately hard, massive, fine to medium grained, occasionally calcareous and micaceous. The siltstone is soft to moderately hard, non-calcareous, occasionally clayey, gray to greenish gray, reddish gray where clayey thin coal and underclay is at the top of the unit. The underclay is usually slickensided, and reddish gray to greenish gray.

3-05. Bedrock Structure, Jointing. Blue Springs Reservoir is located on the southeastern flank of the Forest City Basin, a synclinal structure about 260 miles long, north northeast by 140 miles wide east southeast. The regional dip of bedrock ranges from 10 to 20 feet per mile west northwest but local variations in dip and strike occur.

Jointing of beds may be very intense locally, due to dome related flexures. Primary joints are generally vertical and strike north 50° east, spaced 5 to 35 feet apart. Joints, especially in the Bethany Falls limestone are solution weathered and widened up to five feet near outcrops. Secondary joints are fine and generally vertical, strike N 75° W with intervals averaging two feet. Locally primary joints may be spaced as close as 0.1 feet and usually are hairline width.

Jointing in the Pleasanton Group is extremely complex and does not display the same predictable patterning described in the overlying units. Joints, especially in the Pleasanton C zone, trend generally to the northwest and appear in plan view to be a parallel series of closely spaced hairline fractures, separated by bands of discolored host rock. These joints parallel each other in straight lines for varying distances from 1 to 30 or 40 feet and then diverge abruptly into 2, 3, or more series of joints following serpentine or sinuous traces in random directions.

These serpentine joints may or may not reconverge into a brief, relatively straight line series of joints and then begin another cycle

of divergence/convergence. The Pleasanton A and B also display the patternless serpentine joint system. However convergence/divergence of joints was not noted.

3-06. Bedrock Weathering. The depth and degree of weathering varies considerably with rock type and thickness of cover. The two major limestone units in the abutments, the Bethany Falls and the Sniabar, were weathered from a few inches to several feet. Most severe weathering effects could be seen along valley walls and in areas where cover was sparse. The Sniabar however was found to be intensively weathered throughout its entire thickness in several spots which were uncovered in the spillway. In some cases virtually no cementation remained and the entire unit was soft and rust colored. Weathering to this extreme normally occurred near joints, and extended up to two feet laterally from water exposed joint faces. The transition from extremely weathered to apparently unweathered material also varied from gradual to abrupt. Weathering effects in the Bethany Falls were observed primarily along joints and outcrops. One signature weathering effect of the Bethany Falls can be easily observed throughout the area. The primary and secondary joint sets are nearly perpendicular and as weathering continues large blocks detach and creep downslope under gravitational forces. The peanut rock at the top of the Bethany Falls may be further evidence of weathering. There is conjecture that an unconformity exists between the overlying Stark-Galesburg and the Bethany Falls. If this is the case, there is probable reason to assume that the peanut rock is a product of weathering. Another possible product of weathering could be the Critzer limestone. This unit is a maroon clay on the right abutment. The Critzer overlies the Pleasanton A. The joints in the Pleasanton A are serpentine, much like the Pleasanton C. These joints are filled with a pink, hard, calcareous rock, which could possibly be formed by solution activity through the Critzer. If the joint infilling is from the Critzer, then the maroon clay may be the residue from the Critzer.

From an engineering point of view the most serious effects of weathering were seen throughout the Pleasanton group (see portions written for 3-11).

3-07. Solution Activity. Solution activity in the limestones on site was generally limited to travertine deposition on joint faces. Several open joints in the Sniabar Limestone on the right abutment had travertine or flowstone deposits. One joint face deposit was about 0.8 feet thick. Solution deposits were generally found near outcrops. Thin layers of travertine occurred in the Bethany Falls. Solutioning was not observed along bedding planes. Joints in the Bethany Falls near outcrops had been enlarged by solutioning; however, no significant deposition had occurred. The only noticeable joint on the site which did not contain clay or deposits was on the right abutment in the Sniabar Limestone. This joint, on the right abutment, widened into a solution cavity of indeterminate dimension which carried a large volume of water, especially after rains.

3-08. Groundwater. Groundwater occurs under three conditions: (1) Water-bearing alluvial sand and gravel, (2) Bedrock fractures usually in shallower limestone and shale, and (3) Porous sandstones usually of the Pleasanton and underlying Cherokee Groups. Yields from alluvial wells may vary considerably, with exception of those from Missouri River and Lower Blue River Alluviums. Due to extensive urban development and the presence of

numerous sewage lagoons, septic tanks and cesspools, water from the upper and middle Blue River alluviums and from the bedrock fracture zones may be highly polluted. Deep wells in the Pleasanton and lower sediments have varying yields, and are usually very mineralized and occasionally have artesian heads.

3-09. Engineering Characteristics of Overburden Materials. Overburden materials excavated from the cutoff trench and outlet works were thin layers of fat and lean clays mixed with colluvial detritus. Most of the material was stockpiled and used in the berm zone. Material from the cutoff trenches and outlet works were used in the random zone where possible with the bulk being used in the berm zone.

3-10. Engineering Characteristics of Bedrock Materials.

a. During design investigations, significant stress release fracturing was found to exist low in both abutments in the Pleasanton Zone C. Fracturing was most intense in the left abutment where near vertical fractures were spaced as close as 2 inches or less. They were generally tight and disappeared with depth normally at bedding planes. There was concern that this might cause seepage problems, however the zone was subjected to extensive hydraulic pressure testing through drill holes and proved to be tight. Later grouting in the zone confirmed the tightness. As a result of the fracturing, it was deemed necessary to place a 3-foot thick impervious blanket from the core of the dam to the toe of the limestone/shale zone. This blanket extended from station 96+60 to elevation 823.6.

b. Less intense fracturing was found in the right abutment. It was felt that the fracturing resulted from local unusually high residual stresses.

3-11. Unusual or Unanticipated Geologic Conditions Encountered.

a. Seepage on Abutments: Water seeping downslope impeded placement on both abutments. Seepage was expected but not to the degree encountered. Contract requirements included the placement of a 3 feet thick impervious blanket (special backfill) to be placed on the upstream abutments to elevation 823.6. The contractor had planned to "wheel roll" the blanket for compaction, however, the amount of water flowing downslope required immediate action to prevent water from flowing under loose uncompacted fill. Consequently, most of the material was compacted quickly using hand operated gasoline engine driven tampers. Using these tampers permitted placement "in the dry" provided that earthmoving equipment and tamper operators were coordinated. Unfortunately, the coordination was frequently lacking and water created mud in the loose fill and could not be compacted. Most surfaces requiring special backfill were covered and uncovered several times before the job was complete. The most successful method employed to prepare rock surfaces for placement was to blow dry small areas with compressed air and place and tamp the fill immediately. Other methods were used to minimize flows. These included construction of sand bag revetments to collect water and diversion of ponded water through irrigation pipes to other areas; establishing small sumps and pumping water away from the slopes; digging a drainage ditch along the base of the Sniabar Limestone on the right abutment to divert seepage and surface runoff. One major water producing area was through joints in the Sniabar Limestone in the upstream wall of the right abutment cutoff trench. This was

a major seep which transported large volumes of water especially after rainfalls. Water from this source was deeply incising shales in the cutoff trench floor. Offset drilling and grouting was conducted to intercept and plug water conduits in the formation. Three holes were drilled between 46 feet and 66 feet upstream at stations 73+15, 73+30 and 73+45. Drilling fluid circulation was lost at station 73+30, 60 feet upstream and station 73+45, 66 feet upstream. These borings were pressure grouted and 113.5 cubic feet and 23 cubic feet, respectively, were pumped into them. The seepage was essentially stopped. Numerous joints and fractures in the Pleasanton B carried so much water that combinations of measures included sumps, dikes, compressed air and dry packing with cement.

b. Excess Seepage occurred in the right abutment cutoff trench between stations 76+00 and 76+30. This was the beginning and lowermost portion of the cutoff trench keyed into rock in the right abutment. The area had been prepared on 26 July 1985 with the intent of beginning placement of the core in the cutoff trench on 27 July 1985. Several joints were uncovered during the preparation, however they gave no indication of water passage (photos 84 and 85). On the morning placement was to begin, the joints had become water conduits and the cutoff trench was flooded. The situation was remedied by digging holes intercepting each joint upstream and downstream of the dam centerline (photos 86 and 87). Each hole was approximately 3 feet (along joint axis) by 2 feet by 3 feet deep. The intent was to fill each hole with an impervious material to impede the water flow at the base of the cutoff trench. Each hole was ultimately filled with 1 foot of sand at the bottom and topped with impervious clay after intercepted joints were dry packed with Portland cement. Additionally, a 2 foot sand drain was constructed upstream and parallel to the centerline to create a riverward flow for seepage (photos 89, 91, and 92). In order to keep the impervious core at a constant width of 25 feet, it was necessary to decrease the downstream width of the sand drain to 4 feet from station 76+03 to 76+25 (the point where sidewalls did not create lateral constraints). This upstream drain continued to station 77+18. Three sumps were located in the upstream drain to collect water and expedite pumping toward the river. One sump at station 76+30 and 20 feet upstream was packed in rock during grouting to assist in collecting and pumping water away from the grouters. A 12-inch perforated pipe was placed in the bottom (elevation 747.7) of the sump to permit pumping from the bottom while construction continued upslope. The sump around the pipe was filled with 3/8-inch crushed rock to the level of the sand drain and then covered with impervious fill. A second sump was created in the upstream sand drain, using perforated PVC pipe at station 76+60. The third sump, at station 77+18 (photo 109), was required to remove water produced by a thin gravel bed. Water levels stabilized in both pipes at approximately elevation 758.5. Pipes were continued upward to elevation 761.5 (level of impervious fill) and filled with lean concrete. The pipes were subsequently covered with impervious material and incorporated into the embankment.

c. Excess seepage also occurred in the left abutment at the beginning of the cutoff trench. This abutment cutoff trench, like the right abutment, was initially based in the Pleasanton "C" zone. The rock was intensely fractured and weathered. Several holes in this area, referred to as "root" holes, carried large volumes of water. In order to channelize this water to a central sump for pumping out of the zone of placement it was necessary to construct an upstream sand drain. This pervious drain was 2 feet thick and extended from station 96+65 to station 97+10. Elevation is 762 to 774 feet.

d. Extreme Weathering occurred in some rock units. The effects of the weathering in several instances required special preparation treatment prior to construction of the embankment.

(1) Pleasanton B zone in the left abutment. This unit is normally a hard, gray, crystalline calcareous sandstone. When it was exposed, it had deteriorated to the point of incompetence. Weathering was extreme along serpentine joints, incising the upper 2 feet to 3 feet to widths of 1.0 feet. Additionally, weathering occurred along bedding planes to the extent that the upper weathered thickness separated from the underlying strata. The sandstone here varies from 6 to 8 feet in thickness. The upper weathered zone was removed leaving near vertical faces three feet high from 18 feet downstream to 80 feet upstream. 1:1 slopes were constructed by line drilling using contractor equipment. Removal of the upper weathered portion revealed that the lower strata were still deeply incised; however, lower bedding planes, when present, were not weathered and the rock was considered competent. The open joints were gravity grouted and then filled with a 9 sack cement/sand slurry (photos 65, 66, and 70).

(2) The Pleasanton B zone in the right abutment was also extremely weathered and was removed 3 feet to 4 feet from the exposed face into the abutment. The serpentine joint pattern was evident, however, none of the joints had been excessively widened and treatment was dry packing with cement. Vertical surfaces were trimmed to 1:1 using pneumatic hammers with chisel bits.

(3) Pleasanton A zone left abutment: The lower 7 feet of this zone is a moderately hard dark gray shale, silty, micaceous with flattened ovate phosphatic concretions. The shale slakes rapidly upon exposure and must be kept moist to keep it intact. The floor of the cutoff trench could be scraped with a backhoe to smooth competent rock, however, the top 2 feet of the shale zone (elevation 803) was highly fractured in the cutoff trench sidewalls. Fracturing was across fine bedding planes and caused an appearance, in profile, of folding sharply to the east with fracture planes appearing to be bedding planes. There were no slickensides. The material was left in place and the embankment constructed against it (photos 73, 74, and 75). At station 98+61, elevation 805.2, the rock in the cutoff trench became a mudrock; soft, silty with yellow-brown silt laminae, olive drab and blocky. Efforts to excavate this material to correct configuration resulted in large blocks of material falling and creating slopes too steep to permit placement of the impervious core. Excavation continued to station 98+67, elevation 805 (base) to station 98+72, elevation 813 (top). Continued westward excavation was limited by the Sniabar limestone at station 99+20, elevation 825q. Rock conditions and geometric limitations favored construction of a concrete slope. concrete was placed in two pours, each approximately 4 feet in height. The concrete was tied into the slope using #10 rebars at 3 foot intervals. The rebar were set in holes drilled 2 feet into the basal blue-gray shale and grouted. Rebars extend 3 feet into the upper pour. A third pour without rebar began at station 98+70, elevation 813 and extended to station 98+77, elevation 816 (photos 80 and 81).

(4) The relic structure of an old slide was found in the downstream wall of the left abutment cutoff trench on 06/22/85 during excavation. A highly weathered bed of brown sandstone occurs in the

Pleasanton A at elevation 805.5. The bed is a drab rusty brown and is about 1 foot thick. The sandstone bed had been obscured in the downstream wall of the trench by rock debris. During preparation of the wall for placement of the pervious sand drain it was noted that the sandstone bed dropped approximately 2 feet and then rose eastward about 5 feet before it feathered out and became obscured in colluvium (photos 76 and 77). The structure gave the appearance of a normal fault. Investigation showed that the Pleasanton B underlying the apparent fault was undisturbed. Given the minor displacement, the lack of deep seated movement, the abrupt reverse dip and the location along the face of an old alluvial valley wall, it was concluded that this was the relic structure of an old slide which had bottomed near the top of the Pleasanton B sandstone. The structure was covered with the downstream pervious drain without excavating further.

(5) Pleasanton A zone on right abutment. This zone was severely weathered and fractured. Efforts to trim slopes to 1:1 resulted in the separation of large blocks up to 2.3 cubic yards in volume. Slopes in the cutoff trench floor were constructed using lean concrete. The walls, beginning at approximately station 74+30 (el. 798) to station 74+00 (el. 807) were nearly vertical to vertical, stepped and highly fractured (photos 110, 113, 114, 115, 116 and 117). Open fractures and joints were either clay packed or dry packed with portland cement prior to placement of backfill material (photo 121). Some of the vertical walls were as much as 4 feet high (photos 118, 119, 122, and 123). The lower 6 to 8 feet of the Pleasanton A is a dark blue gray, massive mudrock. The lower 0.5 feet of this facies was weathered to a greasy clay beginning about 40 feet upstream. This zone caused some concern regarding stability while excavating the right abutment to final grade. The clay zone which was saturated remained stable throughout construction.

CHAPTER 4

DESIGN CONSIDERATIONS

4-01. Design Consideration. The concrete conduit at Blue Springs includes two side by side, 48-inch, sewer pipes which enter just upstream of the tower and exit just upstream of the stilling basin.

Consideration and planning were also given to the shales subject to stress release phenomena. These are discussed in paragraph 3.10, Engineering Characteristics of Bedrock Materials, and 5.06, Foundation Preparation.

CHAPTER 5

EXCAVATION PROCEDURES FOR COMPONENT PARTS

5-01. Excavation Grades. Overburden side slopes in the cutoff trench and the outlet works were excavated 1:3. Bedrock slopes on abutments and the cutoff trenches were cut 1:1 where possible. Concrete was used in cutoff trenches where necessary. In the spillway, the Bethany Falls was vertical. The Stark Galesburg and Winterset were 1:1, the Sniabar 1:2.5, and all other units were 1:2.

5-02. Dewatering Provisions. Excavation and fill placement were performed in the dry. Seepage and run-off control required a great deal of additional effort to achieve conditions satisfactory for placement. The subject is more thoroughly covered in paragraph 3-11.

5-03. Overburden Excavation. Overburden excavated in the cutoff trench, outlet works and abutment foundations included silt, clay, and weathered shale. These materials were excavated with dozers, scrapers, front end loaders and backhoes. Wet areas were excavated with a drag line. A total of 363,500 cubic yards of overburden were removed.

5-04. Rock Excavation. The uppermost bedrock unit in all excavations was the Winterset limestone in the spillway. In the cutoff trenches the upper unit is the Bethany Falls limestone. Both cutoff trenches bottom in the Pleasanton Zone C. Limestone and sandstone bedrock units in the cutoff trenches were excavated by presplit drilling and blasting. Shale and siltstone units were excavated with backhoes and dozers. The uppermost rock unit excavated on the abutments and in the cutoff trenches was the Bethany Falls Limestone. The upper unit in the spillway was the Winterset Limestone. All rock in the spillway was presplit prior to blasting. 644,200 cubic yards of rock were excavated. Production blast holes were 3 1/2 inches in diameter and loaded with a detonating dynamite cartridge on the bottom and the balance of the charge was ammonium nitrate prells. Holes were loaded to various depths depending on the rock unit and then stemmed to the surface. Powder factors, burden, and spacing also varied accordingly.

The Contractor had difficulty in blasting the Bethany Falls and Winterset Limestones to meet contract specifications. The upstream limestone zone included limestones from the spillway and the cutoff trenches. The specifications required that the limestone be blasted to produce shot rock that was "reasonably well graded" with a maximum size of 36 inches and not more than 20 percent passing the 2-inch sieve. The Bethany Falls on site has only one massive bed. It averages 7 feet in thickness and its top is about 1.5 feet below the top of the unit after the "peanut rock" has been removed. The remainder of the 22 foot unit is medium to mostly thin bedded. In addition to bedding planes of weakness, the Bethany Falls is stylolitic. Numerous stylolites, each a plane of weakness, are present in the upper or massive part of the Bethany Falls. The original contractor shot the Bethany Falls and Winterset with very heavy loads in an effort to haul the limestone fill with scrapers. Unfortunately, the thin bedding along with heavy loading led to rock gradations totally out of specification limits. When gradation tests were taken on the embankment, over 60 percent of the rock passed the number 2 sieve. The Contractor experimented with new and different methods to

better control blast effects. One blasting agent tested had a burn rate of 9000 FPS, almost a deflagration agent. This agent produced rock in which 28.8 percent passed the number 2 sieve. It was finally determined that the 20 percent passing 2-inch was unrealistic and 30 percent prior to handling, placing, and raking was put in place of the 20 percent figure. It is probable that more than 40 percent would pass the 2-inch sieve after hauling, placing, and raking were done. Decking of charges was not done on this project.

5-05. Line Drilling and Presplitting.

a. Line drilling was done during only one segment of the construction operation and it was unplanned. The upper Pleasanton B zone had deteriorated in the left abutment to the extent that additional material had to be removed. This excavation left competent Pleasanton B with vertical faces to 3 feet. The required 1:1 slopes were constructed using line drilling methods. Presplitting was required for all slopes 1V on 1H or steeper in limestones and all rock in the spillway. Presplitting began on 22 October 1982 in the Bethany Falls Limestone on the left abutment at station 99+85. Holes were 3 inches in diameter, spaced 20 inches apart, and loaded with two strands of 200 grain primacord and stemmed with 3/8-inch crushed limestone. The same loading was used on all presplits; however, hole spacing was increased to 24 inches.

5-06. Foundation Preparation.

a. Cutoff Trench. A cutoff trench was excavated on the left abutment from station 96+70, elevation 760, to station 99+70, elevation 836, and the right abutment from station 76+25, elevation 760 to station 72+30, elevation 830. Overburden varied from 0 to 35 feet. Side slopes in the overburden were cut 1V on 3H and rock slopes were 1V on 1H. The floor of the cutoff trench was 31 feet wide. On the right abutment the trench begins at station 76+30, elevation 760, to station 75+40, elevation 722, where it ends abruptly due to interception of the conduit excavation. It begins again at station 74+87, elevation 768, to station 72+30, elevation 830. After completion of curtain grouting, shales were trimmed to final or Phase II grades and covered with burlap or burlene. The protective covering was necessary to prevent desiccation and subsequent slaking. Regardless of precautions, however, slaking did occur and in some cases undercutting occurred requiring the use of dental concrete. In some places, it became necessary to construct the entire cutoff trench floor with concrete (see 3-11). Concrete was placed in the right abutment from 74+00 to 74+04; 74+13 to 74+17; and station 73+18 to 73+21 to construct cutoff trench floors. In addition to concrete described in 3-11, a pour was made in the left abutment from station 98+82, elevation 815.7 to station 98+86, elevation 817.1. In addition to slope construction with lean concrete, dry pack, slush grout and concrete bulkheads were used to pack or seal off joints.

b. Excavation for Sewer/Outlet Works.

(1) The outlet works conduit placed on top of twin sewers ran generally parallel to the right abutment. This dual structure was encased within a trench cut into the Pleasanton C. The cuts were made with a Vermeer T800B trenching machine. There was concern that the trench walls would cave inwardly to the excavation. A test cut narrower than required to house the

structure was made in anticipation of the inward release of stress along vertical fractures. The test cut was 40 feet long and located along the conduit centerline from station 50+30 to 50+70. Its width was 30 feet and centered along the conduit centerline. An in-house instrumentation system was designed and fabricated to measure the anticipated lateral displacement due to stress release. This system consisted of rebars grouted at equally spaced intervals on each side of the test trench and parallel to the centerline at a distance greater than the trench width. Piano wire was secured to one rebar and suspended across the trench through a notch cut into the opposite rebar. A weight was attached to the loose end to keep the wire taut. A scale was attached to the notched rebar which permitted a direct reading of the amount of convergence by noting the vertical movement of the weight. Physical release did occur, however it was in the form of vertical displacement along bedding planes instead of the expected horizontal release. Number eight rebars grouted into two rows of vertical holes along each side of the cut were used throughout the length of the conduit for stabilization. The rows were spaced 5 feet apart with the first row located 1 foot from the face of the cut. The holes were 5 feet apart and staggered so that a vertical rebar was no more than 2 1/2 feet linearly from another along the entire conduit length. In addition, each exposed final sawed surface was treated with a coating of bituminous sealant (RC 800) within 4 hours to prevent surface desiccation and subsequent slaking. Bearing surfaces were covered with 6 inches of concrete within 24 hours of exposure and immediately after final preparation.

(2) During excavation for the intake tower foundation an open joint was exposed in the Pleasanton Zone C. The joint was open to 1 1/2 inches and filled with soft clay. The separation of the near vertical faces of the joint introduced the possibility that displacement may have taken place along a plane of weakness at some depth greater than the tower foundation. Because of the critical location of the joint in the tower foundation, it was considered essential to determine if movement had occurred. Two 36-inch holes were drilled vertically in an attempt to locate a plane of movement, if in fact one existed. The first hole, centered over the joint, traced the joint about 11 feet below the surface. The second hole was drilled about 5 feet from the first in a down dip direction. The joint was intercepted at about 18 feet down and terminated at 21.5 feet down on a thin near horizontal clay seam. At the terminus the joint was open 1/8-inch and flowing water. The clay seam was also 1/8-inch thick and continuous around the circumference of the hole. Additional 6-inch diameter core holes also intercepted the horizontal seam and led to the conclusion that this was a continuous seam. Direct shear tests along the recovered seams showed the strength to be well below the peak strength of the undisturbed shale. Sliding stability of the intake tower was analyzed and the results led to the conclusion that the tower foundation was safe. As a precautionary measure it was determined that sand drains would be installed downstream at depths to intercept the clay seam and provide a direct path for drainage into the sand blanket. Twenty-six, 4-inch diameter vertical sand drains were installed to provide these drainage paths.

(a) During design investigations, significant stress release fracturing was found to exist low in both abutments in the Pleasanton Zone C. Fracturing was most intense in the left abutment where near vertical fractures were spaced as close as 2 inches or less. They were generally tight and disappeared with depth normally at bedding planes. There was concern that

this might cause seepage problems, however the zone was subjected to extensive hydraulic pressure testing through drill holes and proved to be tight. Later grouting in the zone confirmed the tightness.

(b) Less intense fracturing was found in the right abutment. It was felt that the fracturing resulted from local unusually high residual stresses.

CHAPTER 6

FOUNDATION ANCHORS AND ROCK BOLTS

6-01. Foundation anchors and rock bolts were not used on this project. Number 8 rebars, however, used as rock dowels were used to stabilize Pleasanton "C" shale prior to sawing vertical cuts for the conduit/outlet works. See paragraph 5.06 b.1.

CHAPTER 7

CHARACTER OF FOUNDATION

7-01. Foundation Surface.

a. Valley Section. All of the embankment foundation was stripped of boulders, sod, roots, tree stumps, etc., disked at least 8 inches and compacted in accordance with the requirements for the zone in which the respective portion of the foundation was located. Because of depth to rock in the valley floor, a positive cutoff trench was not constructed. An inspection trench was excavated across the valley floor to permit inspection of the foundation character to assure that foundation materials were suitable.

b. Outlet Works. All outlet works structures are founded on the Pleasanton "C", an argillaceous shale. Backhoes, airspades, bulldozers, and a rock saw were used to remove and shape the foundation for the outlet works. (See 5-06(b)).

c. Abutment Foundations. Bedrock along the abutments required extensive treatment to trim to 1:1 slopes, curtail seepage, and keep foundation shales from slaking. Trimming was generally accomplished with a Cat 235 backhoe, however in certain areas, especially the Pleasanton "B" zone, extensive handwork was required. Slaking and short term weathering were exacerbated by the hiatus in construction time created by bankruptcy of the initial contractor. Provisions were made to cover the exposed rock until a new contractor could be found, however, protective materials placed on slopes were quickly eroded by run-off and in some cases deep incisions were made in foundation shales.

d. Cutoff Trenches. See Chapter 5.

7-02. Condition of Foundation Soil or Rock. The foundation, other than the abutments under the main embankment, consists of deep alluvial soils. These consist mainly of silty lean clays.

CHAPTER 8

FOUNDATION TREATMENT

8-01. Curtain Grouting. The grout curtain consists of a triple line on the left abutment from station 95+20 to station 101+00, and on the right abutment, a triple line stretches from station 76+30 to 73+50 with a single line continuing to station 65+00. The grout holes on the left abutment are oriented on a bearing of south 30° west and on the right abutment they are parallel to the dam centerline and into the abutment. All holes are 30° from vertical.

Line A is 5 feet downstream and line B is 5 feet upstream of line C which is on the dam centerline. Grouting was accomplished from the floor of the cutoff trench on bedrock through 2 3/4-inch diameter steel nipples 2 to 4 feet long and cemented into the floor of the cutoff trench. Grout was mixed in a double chamber mixer and agitator sump with a capacity of 20 cubic feet. Grout was pumped with a Moyno pump. Grout mixes ranged from 6:1 to 0.75:1 and contained 4 percent bentonite by weight. Grouting began 03/24/83 and was completed 08/26/85. Stop grouting methods were used. Holes were drilled to total depth, washed through the drill rods, pressure tested, and grouted through a packer which was set at successively shallower depths. Grout pressures were reduced accordingly with shallower depths. The amount of water and grout pressures used was only the amount required to balance the rock pressure at the packer depth. Water and grout pressure, packer depths, and numbers of sacks of cement injected are shown in the grout curtain profiles (plates 44 through 75).

8-02. Drainage Provisions. Foundation drainage in the cutoff trench is through a 6 foot wide downstream drain which is contiguous to the impervious core. The drain extends from the bottom of the impervious core to elevation 823.6 across the valley, abutment to abutment. It connects to a 3 foot horizontal drain which covers the embankment foundation downstream of the impervious core. The top and sides of the outlet works conduit, downstream of the impervious core are covered with a 3-foot layer of sand which also connects with the horizontal drain.

8-03. Foundation Compaction or Consolidation. See Chapter 5.

8-04. Dental Concrete and Gravity Grouting. See Chapter 7.

8-05. Six types of observation devices were placed in the embankment and foundation during construction. Sixty-six piezometers were installed. Nineteen of these were gas operated devices with 6 in foundation clays; 7 in foundation shales, and 6 in the impervious zone of the embankment. The remaining 47 instruments were open tube with 4 in the embankment, 31 in foundation clays, 12 in the foundation shales, limestones, siltstones, and sandstones. Fifteen settlement devices are all in foundation clays. Thirteen inclinometers were placed in the embankment at 77+00 and 94+00; both were 20 feet downstream. Ten alignment monuments are located 110 feet upstream and 11 are 142 feet downstream.

CHAPTER 9

POSSIBLE FUTURE PROBLEMS

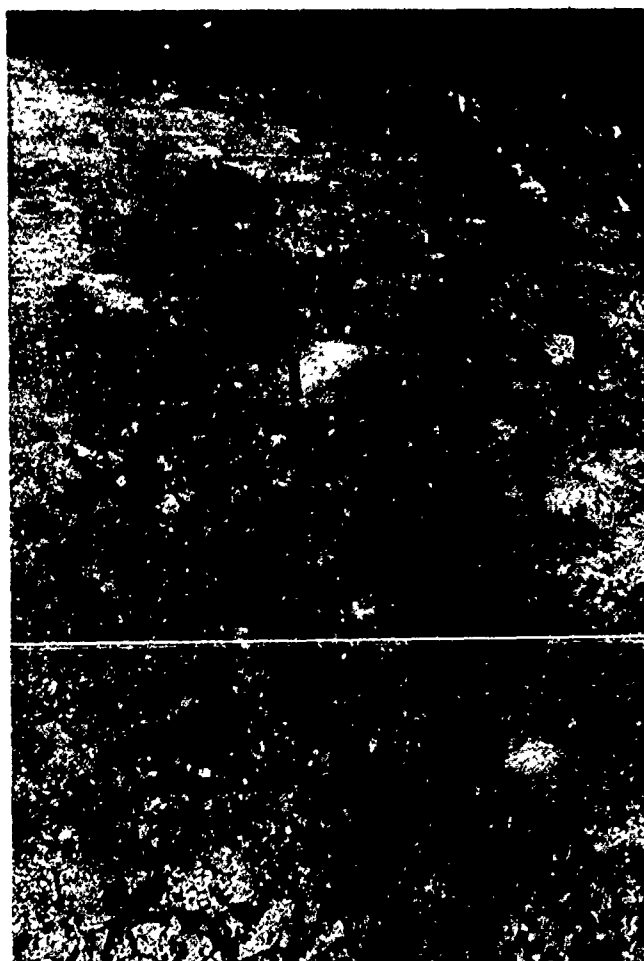
9-01. Conditions that Could Produce Problems. Seepage through both abutments can be expected due to the condition of bedrock. The dental treatment and tight quality assurance steps taken along with the downstream pervious drains and blanket should adequately control seepage. Shallow slides were observed in the valley walls prior to impoundment. It is expected that these will continue, especially when lake levels raise and lower quickly.

PHOTOGRAPHS

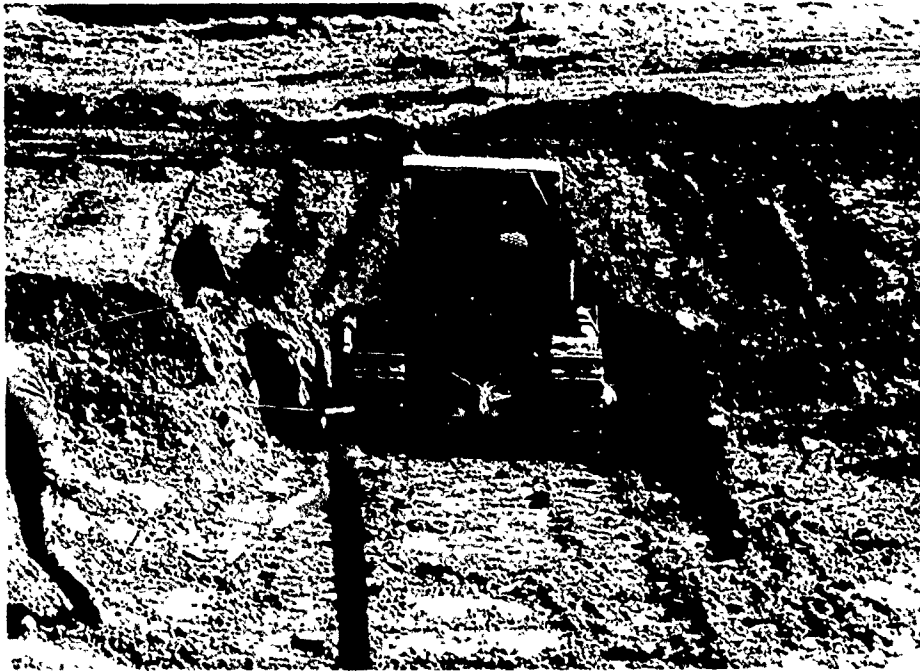
PHOTOGRAPHS



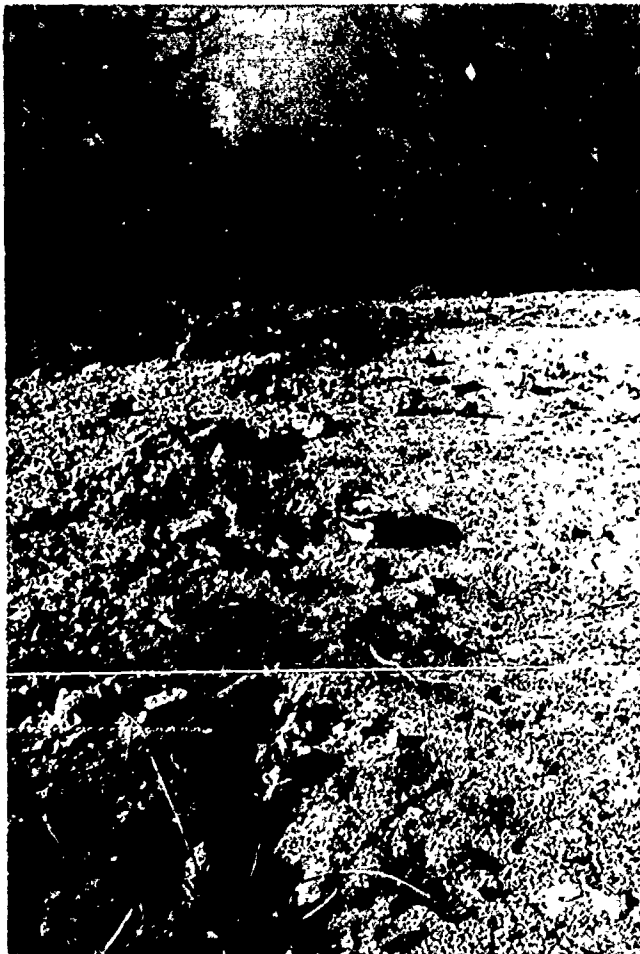
1. Blue Springs Lake, 2 November 1982, Neg. No. 45.
Right abutment. Top of Bethany Falls Limestone. Note clay filled joints. From Sta. 72+95 to 40 feet upstream, looking west.



2. Blue Springs Lake,
5 October 1982,
Neg. No. 33.
Left Abutment. Top
of Sniabar Limestone.
Open joint at Sta.
99+20, normal to dam
centerline, looking
north.



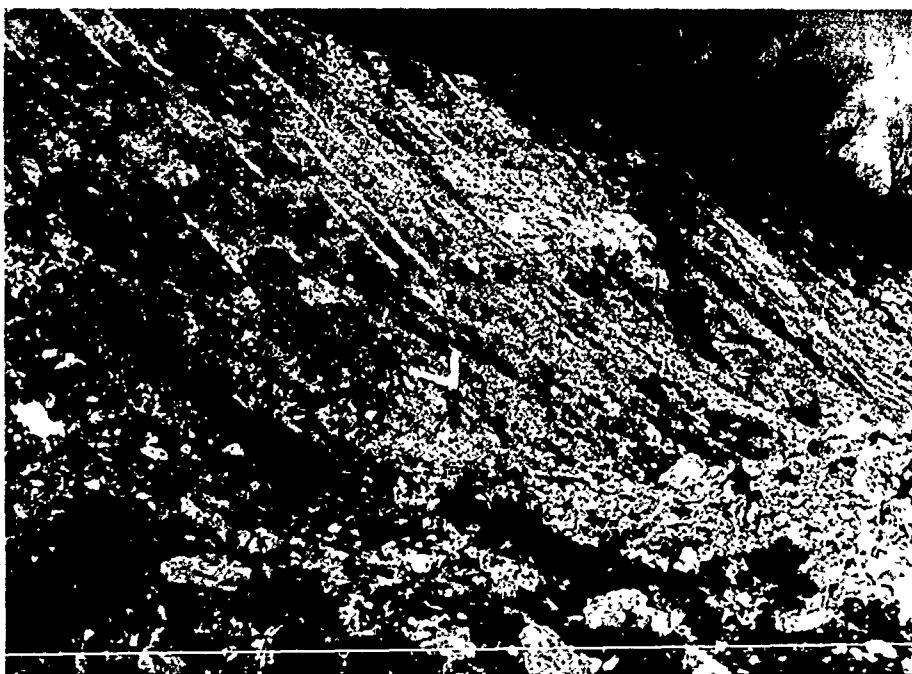
3. Blue Springs Lake, 14 October 1982, Neg. No. 37.
Left abutment. Sta. 99+00. Initial cutoff trench
excavation, looking west.



4. Blue Springs Lake,
16 November 1982,
Neg. No. 55.
Right abutment.
Presplit fracture
in top of Bethany
Falls Limestone.
Used one strand of
200 grain detonating
cord per hole, on 24
inch centers.



5. Blue Springs Lake, 15 November 1982, Neg. No. 52.
Dam foundation at station 92+00. Removing objectionable material, looking north.



6. Blue Springs Lake, 12 November 1982, Neg. No. 50.
Left abutment. Pre-split face of Bethany Falls Limestone, looking northwest.



7. Blue Springs Lake,
21 January 1983,
Neg. No. 76.
Right abutment. Top
of Sniabar Limestone.
From 30 feet downstream,
looking west.



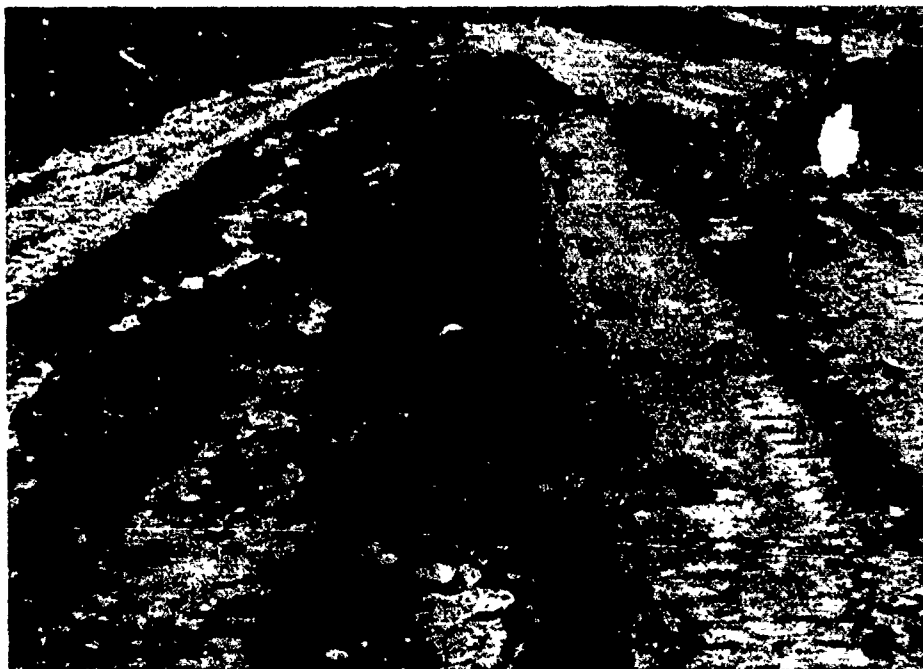
8. Blue Springs Lake,
18 January 1983,
Neg. No. 73.
Right abutment. Open
joint in Sniabar Limestone,
crosses cut off trench at
station 73+28, looking
south.



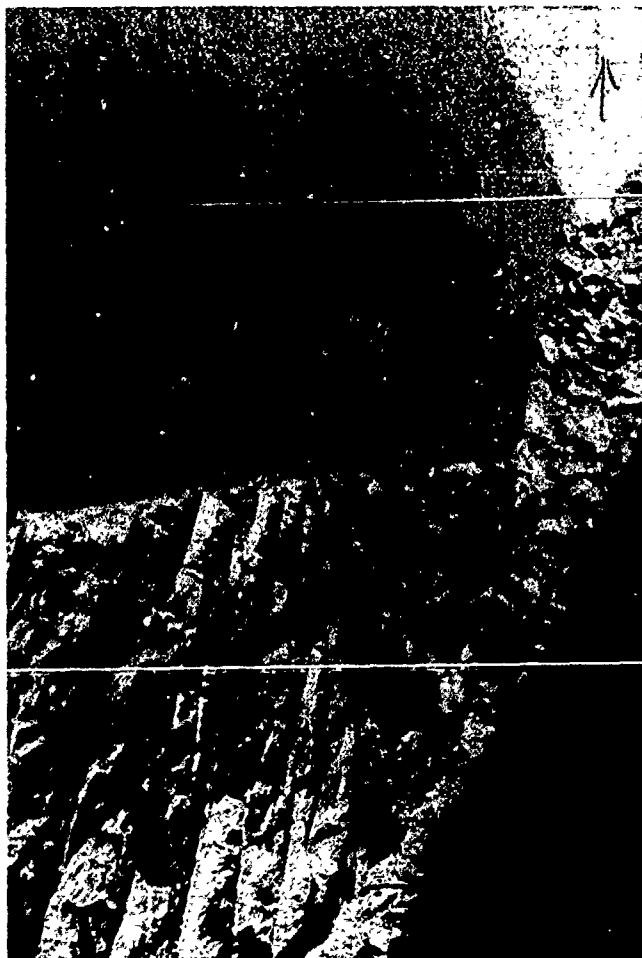
9. Blue Springs Lake,
22 March 1983,
Neg. No. 87.
Left abutment.
Artesian flow around
groutnipple at sta
96+20.



10. Blue Springs Lake, 15 March 1983, Neg. No. 84.
Left abutment. From station 95+20, looking west.



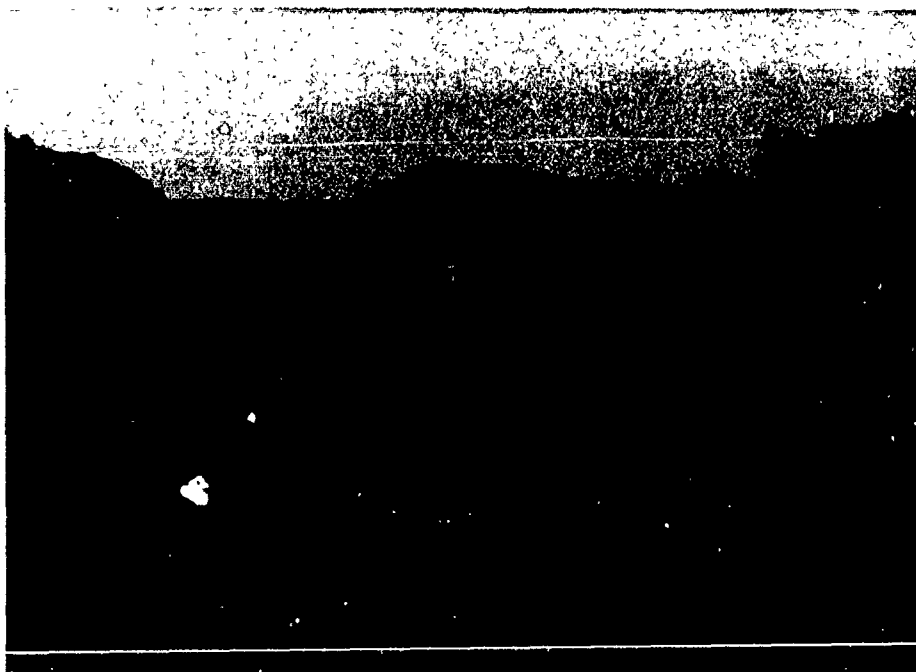
11. Blue Springs Lake, 4 May 1983, Neg. No. 100.
Sewer Test Cut #1.



12. Blue Springs Lake,
3 May 1983,
Neg. No. 90.
Sewer test cut #1
left side wall of cut.
Smooth surface at top
was cut with saw, lower
part was excavated with
backhoe. Looking down-
stream.



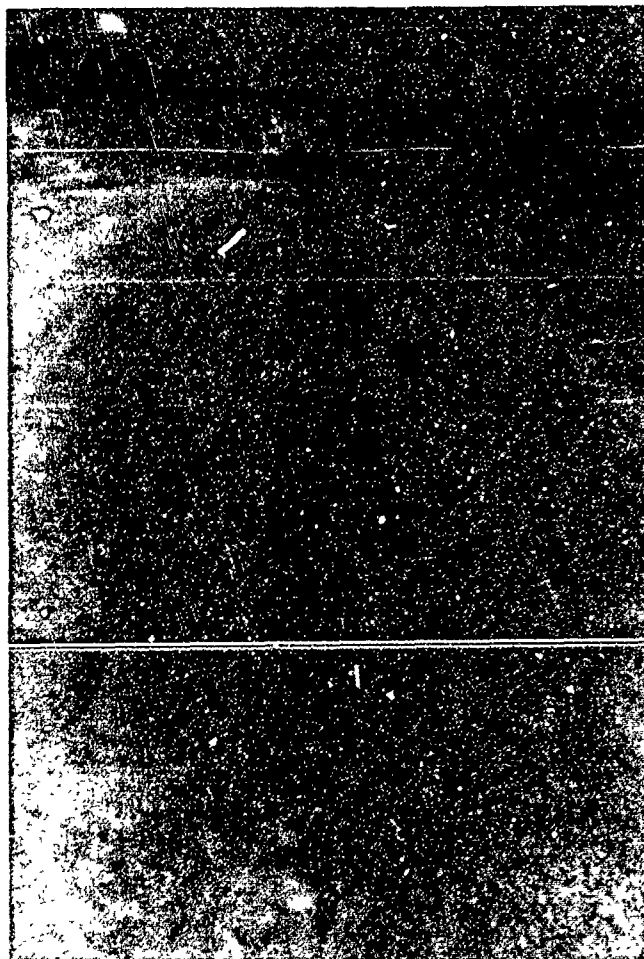
13. Blue Springs Lake, 3 May 1983, Neg. No. 95.
Sewer excavation test #1.
Vermeer T-800B saw was used for cutting sidewalls.



14. Blue Springs Lake, 2 May 1983, Neg. No. 114.
Right abutment. Cutoff trench.



15. Blue Springs Lake,
6 May 1983,
Neg. No. 103.
Joint which developed
on left side of sewer
cut #1.



16. Blue Springs Lake,
9 May 1983,
Neg. No. 122.
Outlet sewer excavation
wall between test cut
#1 and final cut.
Failure occurred during
final cut.



17. Blue Springs Lake, 7 May 1983, Neg. No. 117.
Outlet/Sewer excavation. Applying RC500 protective
coating to east side wall. Looking upstream.



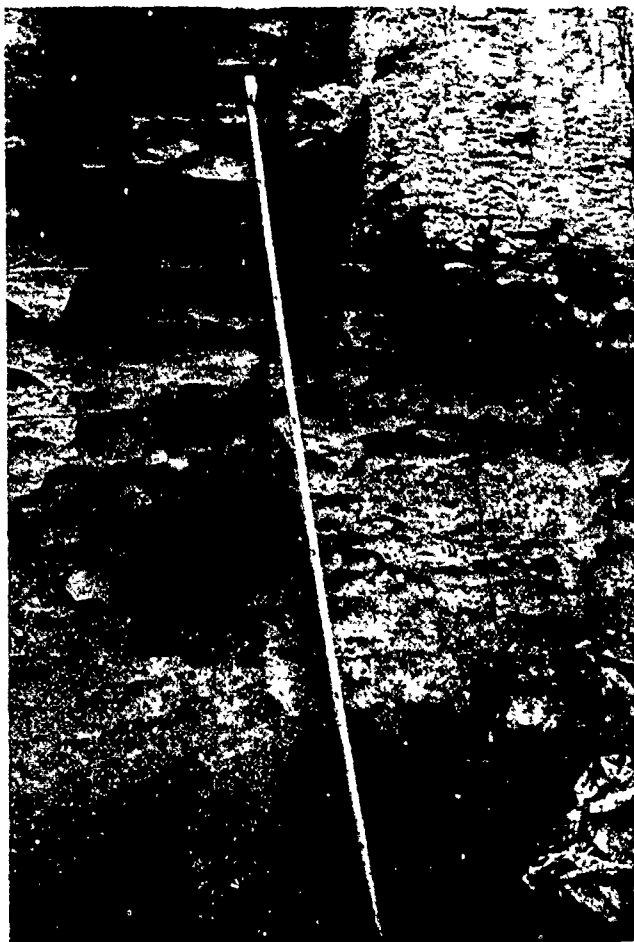
18. Blue Springs Lake, 5 July 1983, Neg. No. 131.
Tower excavation.



19. Blue Springs Lake,
5 July 1983,
Neg. No. 134.
Tower excavation. Right
half of floor from station
47+57.4 to station 47+28.5.
Looking upstream.



20. Blue Springs Lake,
5 July 1983,
Neg. No. 133.
Tower excavation. Left
half of floor from station
47+57.4 to station 47+28.5.
Looking upstream.



21. Blue Springs Lake,
7 July 1983,
Neg. No. 139.
Tower excavation.
Detail showing high
angle joints in
Pleasanton "C" shale,
station 47+65.



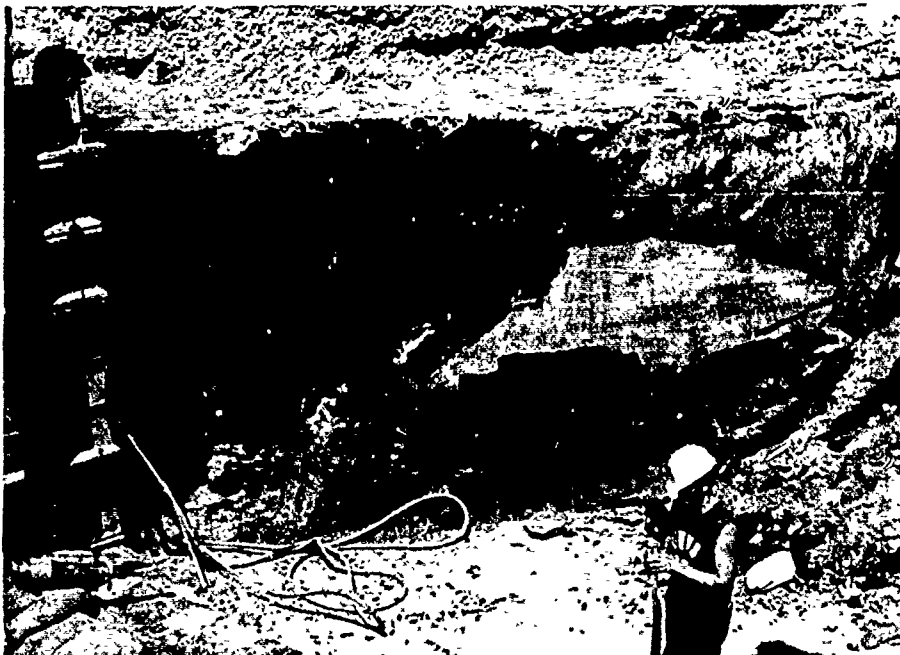
22. Blue Springs Lake,
7 July 1983,
Neg. No. 138.
Tower Excavation.
Installing dowels.



23. Blue Springs Lake, 19 July 1983, Neg. No. 151.
Sewer excavation. Cracks in north wall. Cracks
developed in about 2½ weeks in unpinned and unprotected
Pleasanton Shale. Looking south.



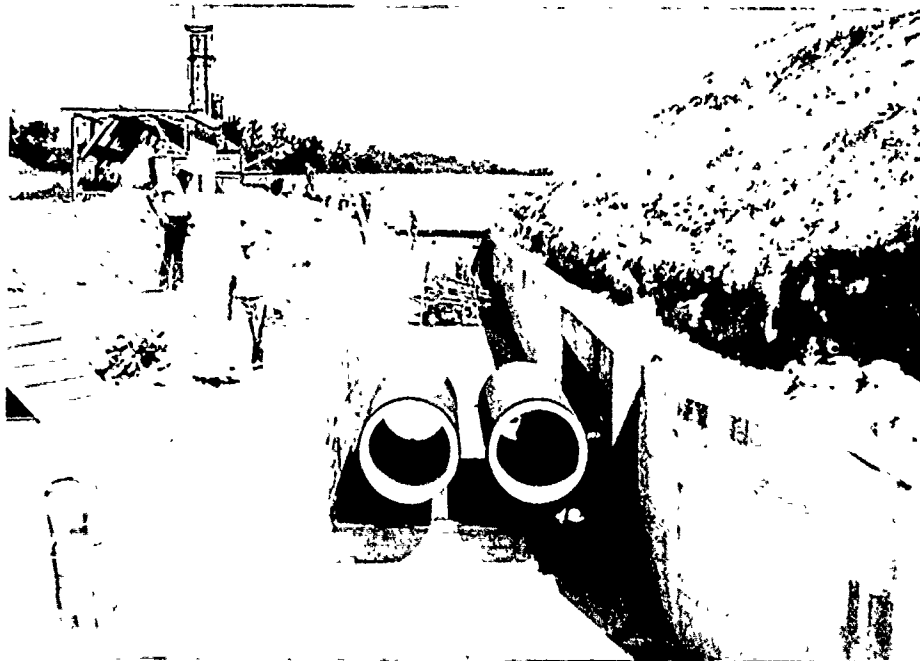
24. Blue springs Lake,
11 July 83,
Neg. No. 147.
Tower excavation.
Open joint in floor
bearing surface from
station 47+57.1 to
station 47+73.4.
Looking downstream.



25. Blue Springs Lake, 11 July 1983, Neg. No. 145.
Tower excavation. Left special surface from station
47+57.4 to station 47+73.4. Looking west.



26. Blue Springs Lake, 11 July 1983, Neg. No. 146.
Tower excavation. Right special surface from station
47+57.4 to station 47+73.4. Looking east.



27. Blue Springs Lake, 1 August 1983, Neg. No. 157.
Outlet works excavation. Sewer pipe installation.
Looking downstream from station 47+70.



28. Blue Springs Lake, 4 August 1983, Neg. No. 167.
Sewer excavation. Joint in bearing surface,
from station 51+08 to station 50+99, bearing N56°W.
Looking upstream.



29. Blue Springs Lake,
8 Aug 1983,
Neg. No. 168.
Sewer excavation.
From station 51+10 to
station 51+42, contin-
uation of joint shown
in photograph No. 28.



30. Blue Springs Lake,
9 August 1983,
Neg. No. 169.
Sewer/Outlet works
excavation. Top
left bearing surface.
Slab detached along
joint. Probably being
held in place by grouted
rebars. From station
51+50 looking downstream.



31. Blue Springs Lake, 13 August 1983, Neg. No. 185.
Left abutment cutoff trench. Downstream side wall
at station 96+66, then 13 feet downstream to a root
hole producing water at rate of 10 GPM.



32. Blue Springs Lake, 12 August 1983, Neg. No. 183.
Left abutment cutoff trench from station 96+50 to
station 97+50. Looking west.



33. Blue Springs Lake, 12 August 1983, Neg. No. 182.
Left abutment cutoff trench, bottom of trench.
From station 96+75 to station 97+00.



34. Blue Springs Lake, 13 August 1983, Neg. No. 186.
Left abutment cutoff trench. Foundation clean up
at station 97+10, prior to start of pervious placement.



35. Blue Springs Lake, 15 August 1983, Neg. No. 189.
Left abutment cutoff trench. Placement of upstream
sand drain at station 96+90.



36. Blue Springs Lake, 23 August 1983, Neg. No. 203.
Left abutment cutoff trench. From station 96+00
to station 97+50.

37. Blue Springs Lake,
10 April 1984,
Neg. No. 246.
Drilling test cores in
outlet works lean
concrete. Left side
wall 16 inches down
from top, drilled on
concrete pour joint,
station 50+42.04.



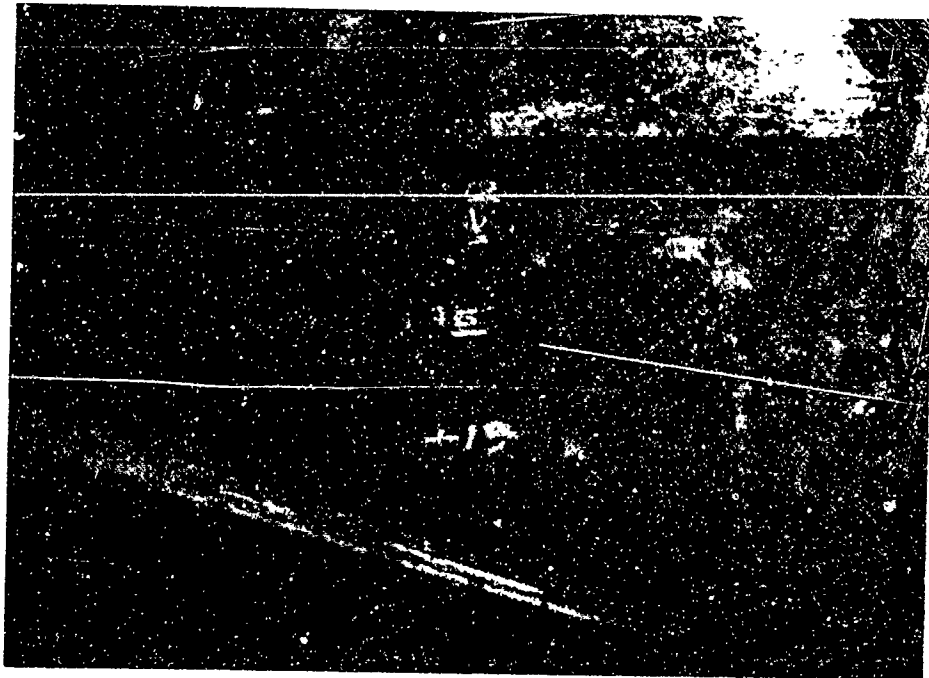
38. Blue Springs Lake, 10 April 1984, Neg. No. 247.
Test cores from drilling in outlet works as shown
in Photo No. 37.



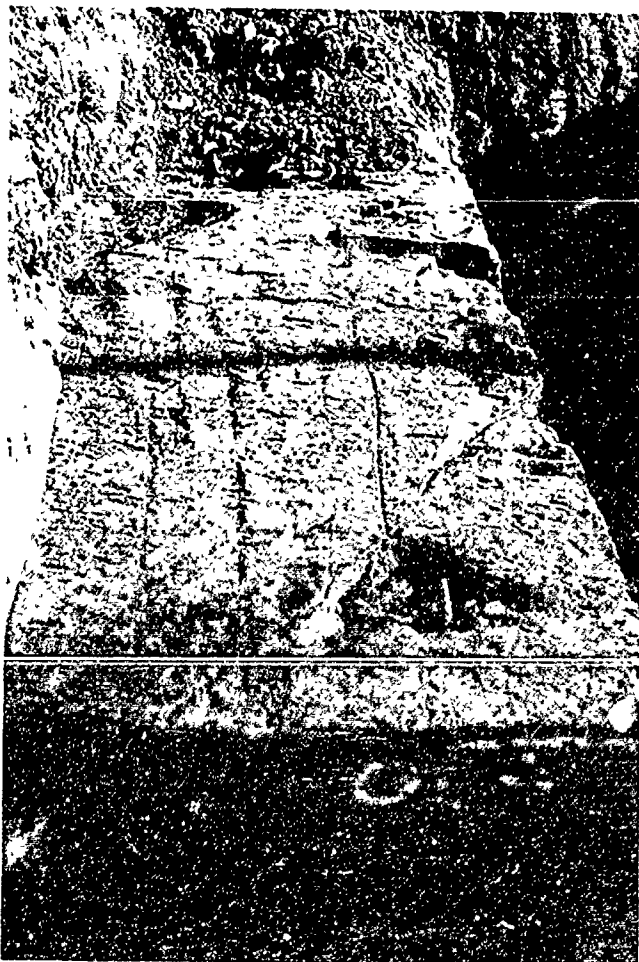
39. Blue Springs Lake, 14 June 1984, Neg. No. 256.
Sewer/Outlet works excavation. Top right surface,
looking upstream from station 103+23 to station 103+10.



40. Blue Springs Lake, 14 June 1984, Neg. No. 258.
Sewer/Outlet works excavation. Top left surface,
looking upstream from station 103+23 to station 103+10.



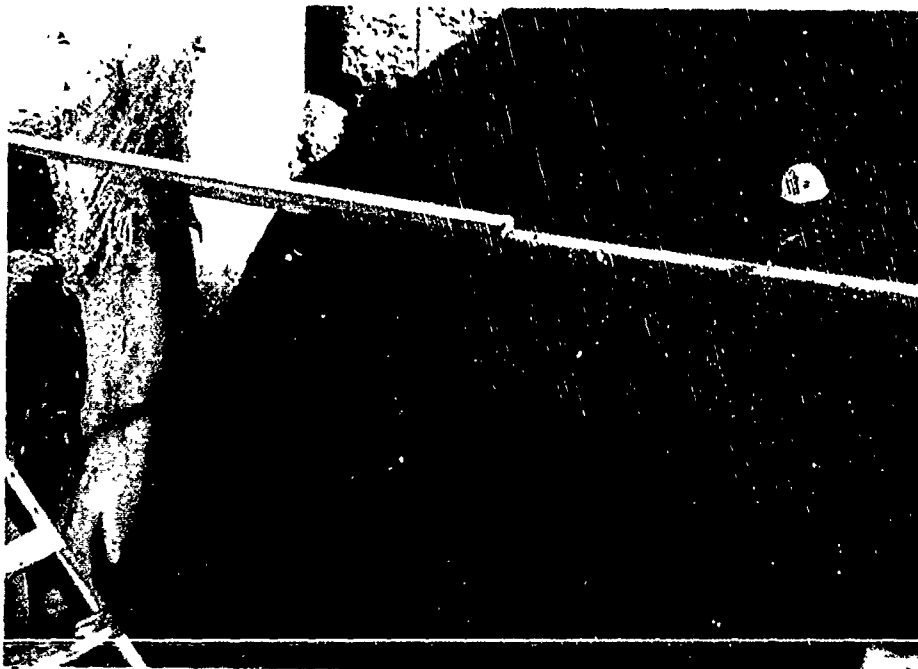
41. Blue Springs Lake, 14 June 1984, Neg. No. 259.
Sewer/Outlet works excavation. Floor looking
upstream from station 103+23 to station 103+10.



42. Blue Springs Lake,
18 June 1984,
Neg. No. 264.
Sewer/Outlet works
excavation. Top
left bench from
station 103+30 to
station 103+4, looking
downstream.



43. Blue Springs Lake,
18 June 1984,
Neg. No. 265.
Sewer/Outlet works
excavation. Top right
bench from station
103+40 to station
103+25, looking
downstream.



44. Blue Springs Lake, 18 June 1984, Neg. No. 268.
Sewer/Outlet works excavation. Joint in floor from
station 103+25 to station 103+40.



45. Blue Springs Lake,
19 June 1984,
Neg. No. 269.
Sewer/Outlet works
excavation. Top left
bench from station
103+60 to station
103+45, looking upstream.



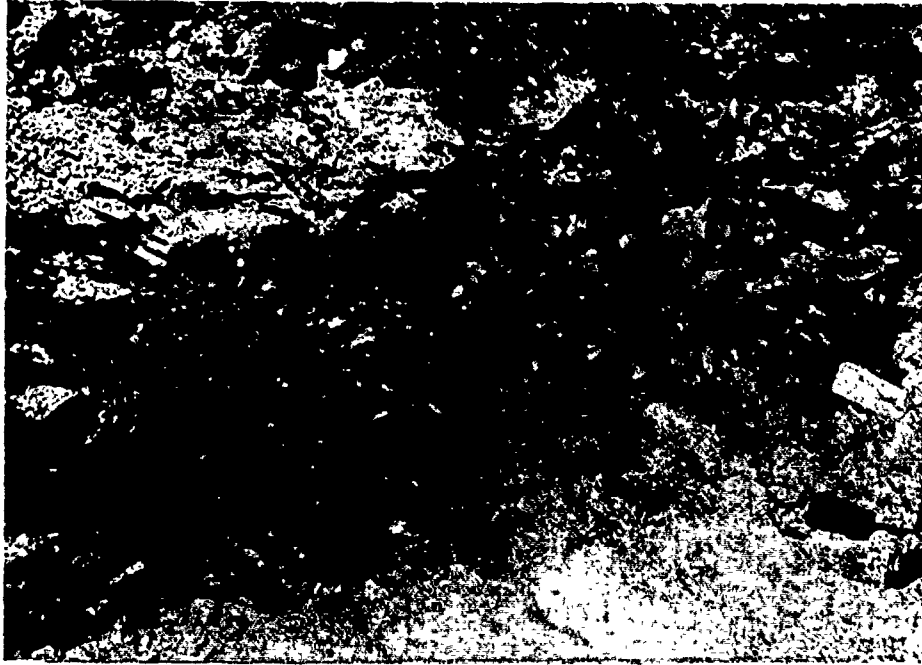
46. Blue Springs Lake,
19 June 1984,
Neg. No. 270.
Sewer/Outlet works
excavation. Top right
bench from station
103+60 to station
103+45, looking upstream.



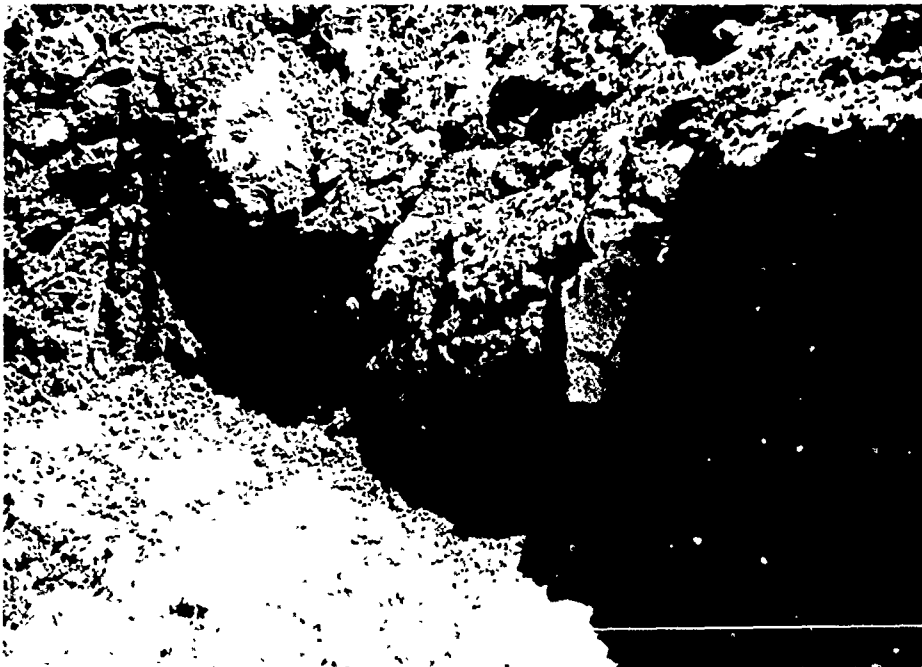
47. Blue Springs Lake,
20 June 1984,
Neg. No. 274.
Sewer/Outlet works
excavation. From
station 103+60 to
station 103+75, top
left, looking down-
stream.



48. Blue Springs Lake,
20 June 1984,
Neg. No. 276.
Sewer/Outlet works
excavation. From
station 103+60 to
station 103+75, looking
downstream.



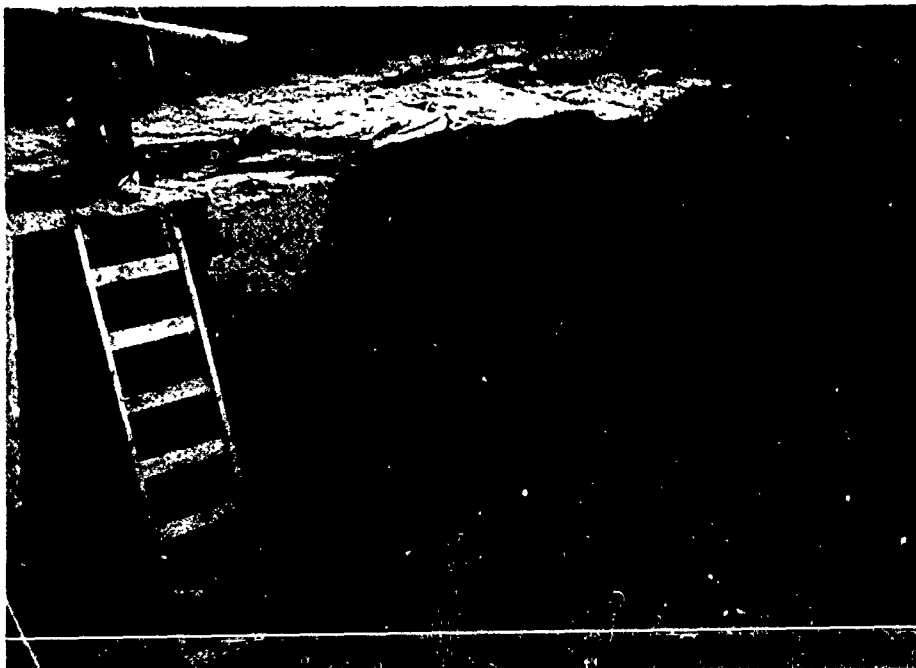
49. Blue Springs Lake, 25 June 1984, Neg. No. 280.
Sewer/Outlet works excavation. Left side wall from
station 103+75 to station 103+95, looking downstream.



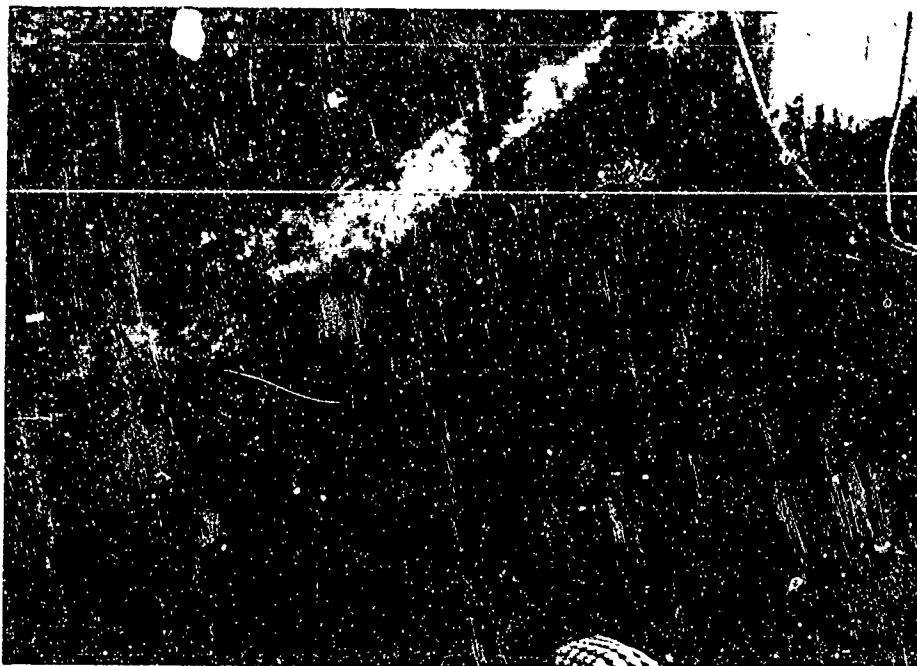
50. Blue Springs Lake, 25 June 1984, Neg. No. 281.
Sewer/Outlet works excavation. Right side wall from
station 103+75 to station 103+95, looking downstream.



51. Blue Springs Lake, 25 June 1984, Neg. No. 282.
Sewer/Outlet works excavation. Floor from station
103+75 to station 103+95, looking downstream.



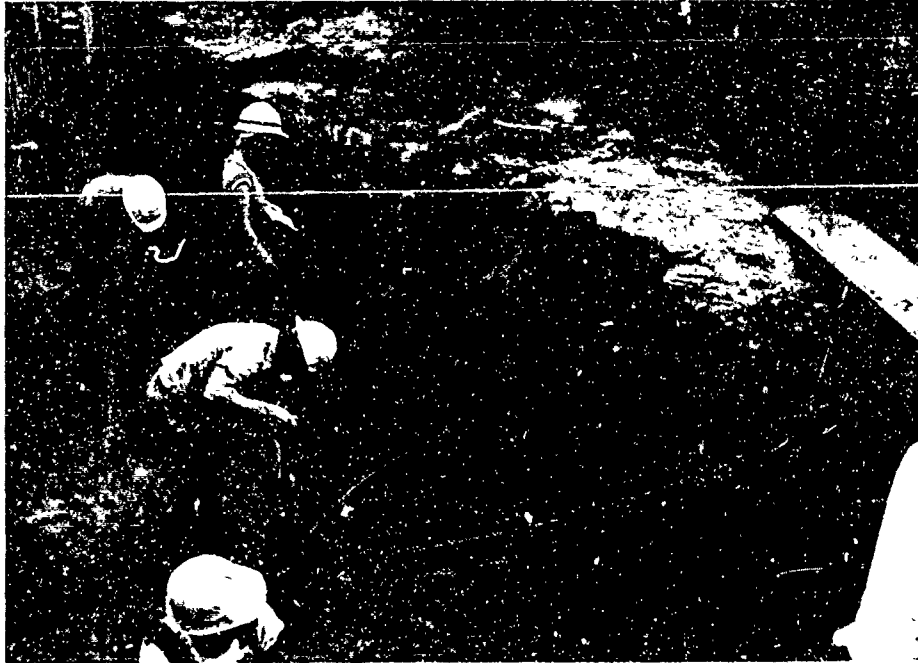
52. Blue Springs Lake, 23 June 1984, Neg. No. 285.
Sewer/Outlet works excavation. Right side wall from
station 96+85 to station 97+09, looking upstream.



53. Blue Springs Lake, 28 June 1984, Neg. No. 288.
Sewer/Outlet works excavation. Left side wall from
station 97+09 to station 96+93, looking downstream.



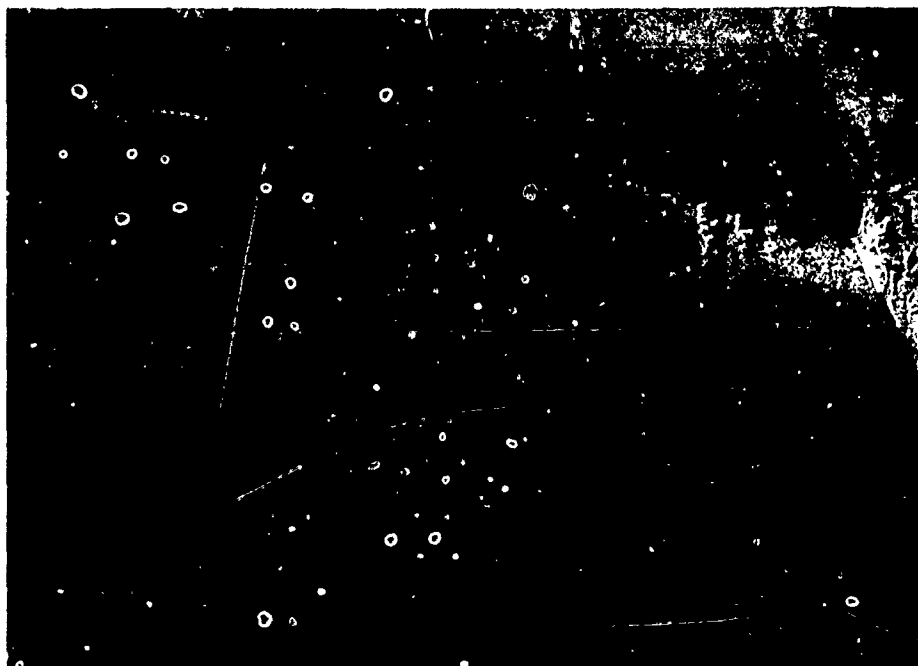
54. Blue Springs Lake, 3 July 1984, Neg. No. 293.
Sewer/Outlet works excavation. Left wall from
station 96+70 to station 96+55, looking downstream.



55. Blue Springs Lake, 3 July 1984, Neg. No. 295.
Sewer/Outlet works excavation. Right wall from
station 96+70 to station 96+55, looking downstream.



56. Blue Springs Lake, 26 July 1984, Neg. No. 305.
Ogee section, outlet works, looking upstream.



57. Blue Springs Lake, 26 July 1984, Neg. No. 304.
Ogee section, outlet works, looking upstream.



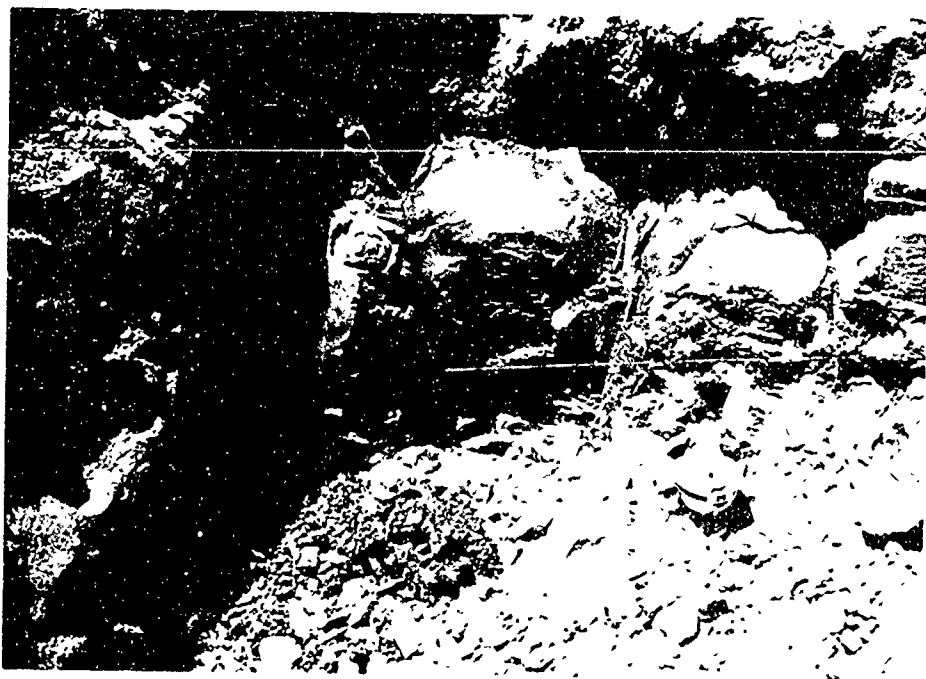
58. Blue Springs Lake,
30 July 1984,
Neg. No. 307.
Joint zone in outlet
works at station
53+25, looking east.



59. Blue Springs Lake,
30 July 1984,
Neg. No. 308.
Stilling basin, east
side from station
53+53 to station 53+00,
looking upstream.



60. Blue Springs Lake,
30 July 1984,
Neg. No. 309.
Stilling basin, west
side from station
53+53 to station 53+00,
looking upstream.



61. Blue Springs Lake, 30 July 1984, Neg. No. 306.
Outlet works. Nodular Pleasanton Zone "C" at station
53+40, looking northwest.



62. Blue Springs Lake, 24 October, 1984, Neg. No. 345.
Shale floor west of conduit. Pleasanton Zone "C"
from station 49+14 to station 49+78.5, looking north.



63. Blue Springs Lake, 6 November 1984, Neg. No. 361.
Left abutment, cutoff trench at station 97+90. Lean
concrete was placed to build slope. This material
was later removed when extremely weathered material
further west was uncovered. Looking west.



64. Blue Springs Lake, 7 November 1984, Neg. No. 362.
Joints in downstream wall of left abutment cutoff
trench at station 98+00, looking north.



65. Blue Springs Lake, 13 November 1984, Neg. No. 376.
Continuation of joints shown in Photo No. 64. Joints
were filled with grout prior to placement of downstream
sand filter.



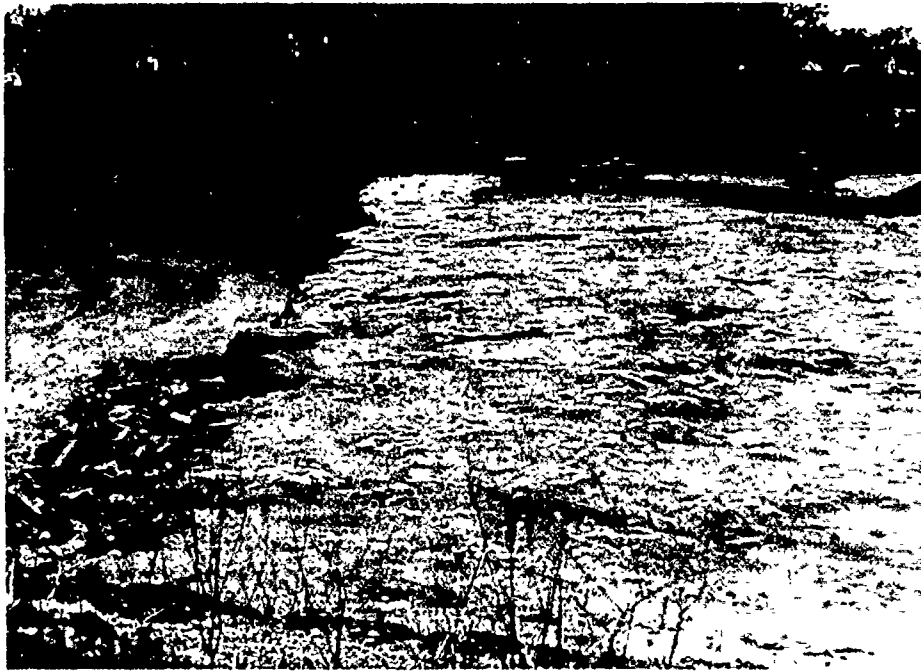
66. Blue Springs Lake, 26 November 1984, Neg. No. 396.
Backhoe removing rock along right abutment, east
of conduit, which separated as a result of stress
release. Loosened zone ran from station 48+65 to
station 49+09 center line of conduit.



67. Blue Springs Lake, 22 July 1985, Neg. No. 495.
Contact of Sniabar Limestone and Mound City Shale,
Station 73+75 upstream wall. A major seep was corrected
by offset drilling and grouting.



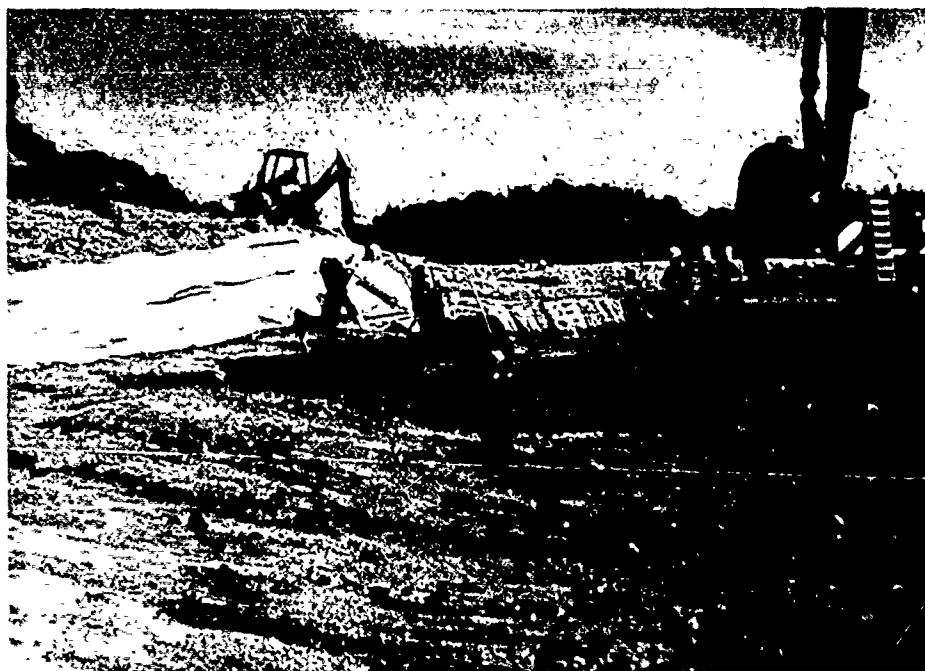
68. Blue Springs Lake, 16 April 1985, Neg. No. 407.
Sandbag revetment on right abutment. Ponded water
was diverted downstream through an irrigation pipe.
Note deep incising in cover materials down into
foundation rock. From station 75+30 looking east.



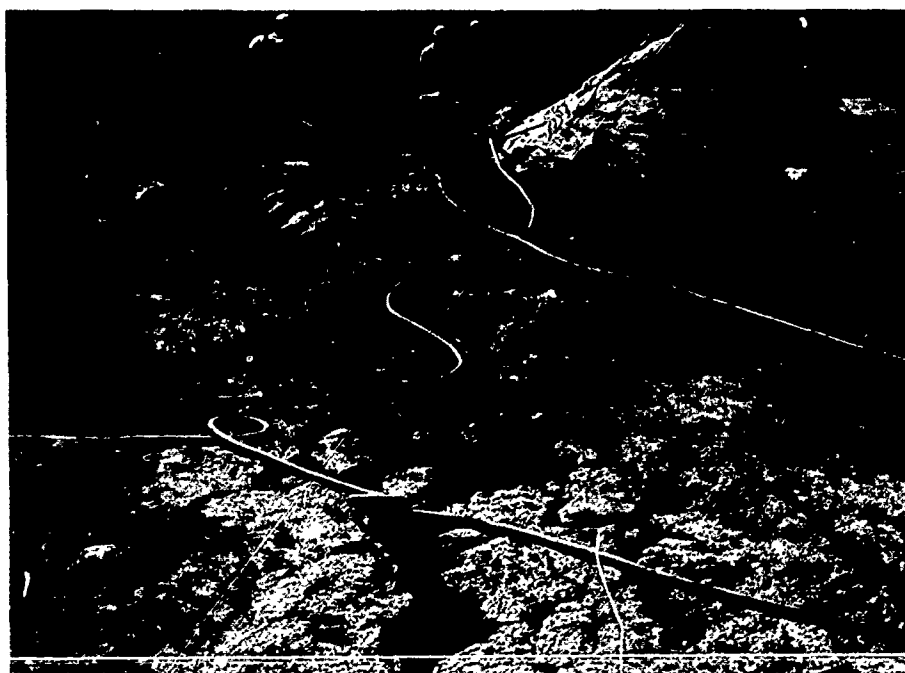
69. Blue Springs Lake, 24 April 1985, Neg. No. 408.
Top of Bethany Falls Limestone in spillway. From
dam center line station 103+00, looking west.



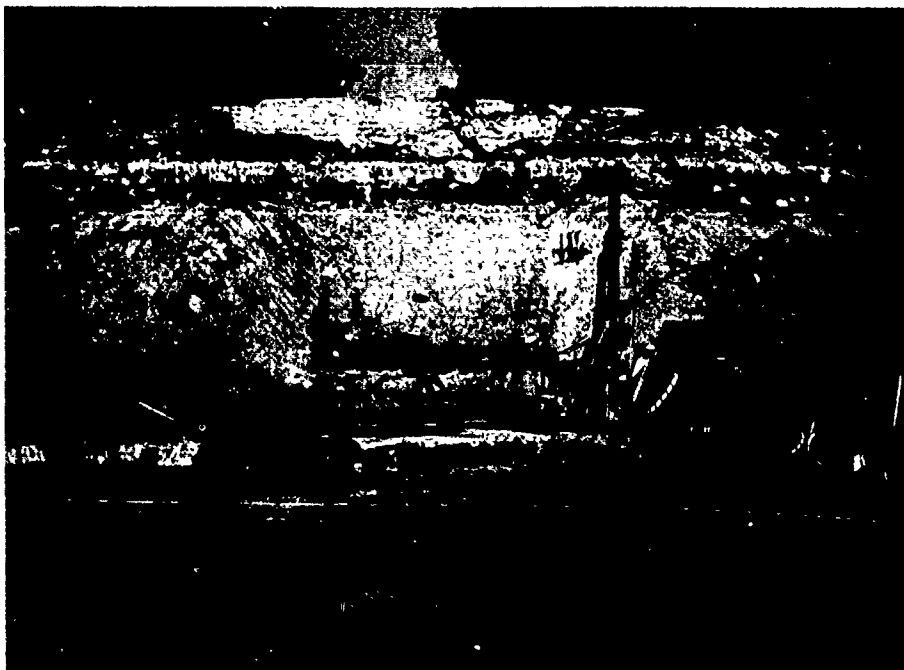
70. Blue Springs Lake, 29 April 1985, Neg. No. 416.
Pleasanton "B" Zone prior to placement of downstream
sand drain. At station 97+84 and 78 feet downstream,
left abutment, looking west.



71. Blue Springs Lake, 3 May 1985, Neg. No. 420.
Left abutment. Jack Hammers being used to trim
Pleasanton "B" Sandstone to proper slope. Station
98+00 looking downstream.



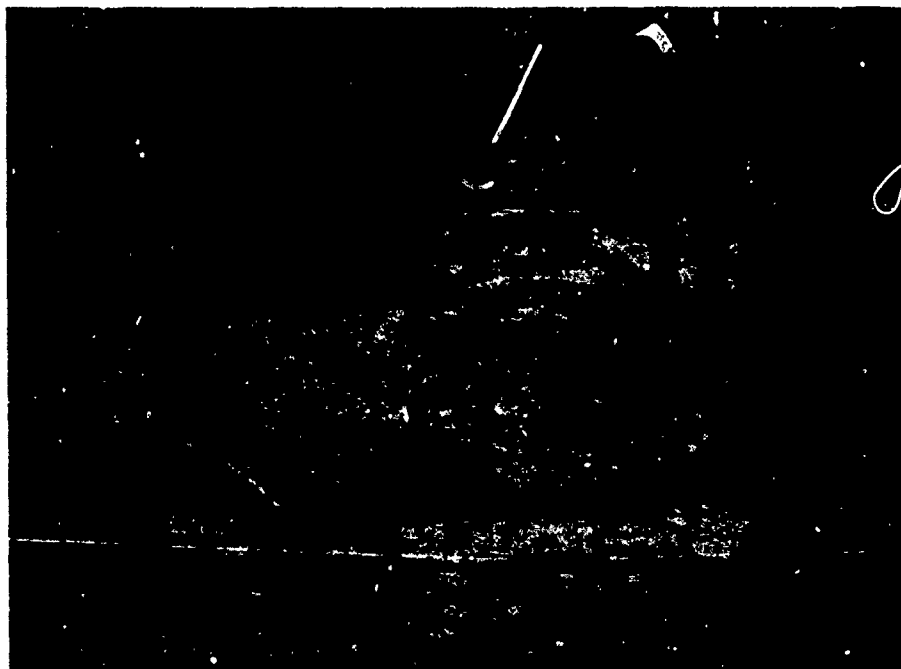
72. Blue Springs Lake, 3 May 1985, Neg. No. 423.
Left abutment cutoff trench, joints in Pleasanton
"B" Zone after top 2 to 2.5 feet were removed. Joints
were filled with cement sand slurry. From 34 feet
downstream of station 98+10, looking upstream.



73. Blue Springs Lake, 4 May 1985, Neg. No. 422.
Left abutment cutoff trench. Line drilling to
trim Pleasanton "B" Sandstone to proper slope.
From station 97+50 looking west.



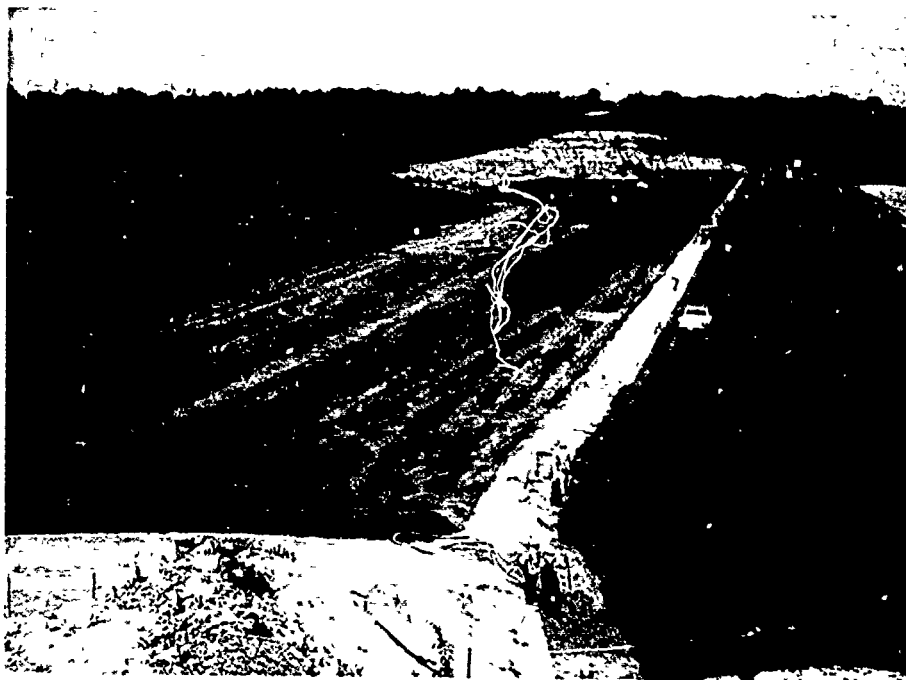
74. Blue Springs Lake, 16 May 1985, Neg. No. 435.
Conduit trench. Placement of downstream sand
drain. From 270 feet downstream of conduit head
wall; looking upstream. Burlap on shale slopes
is for protection against drying.



75. Blue Springs Lake, 16 May 1985, Neg. No. 437.
Floor of conduit trench. Shows converging/diverging
patterns of joints in Pleasanton "C" Shale. 250'
downstream looking west.



76. Blue Springs Lake, 20 May 1985, Neg. No. 440.
Left abutment cutoff trench. From station 98+00
looking downstream. View of floor after cement
sand slurry. Note results of line drilling on face
of Pleasanton "B" Sandstone.



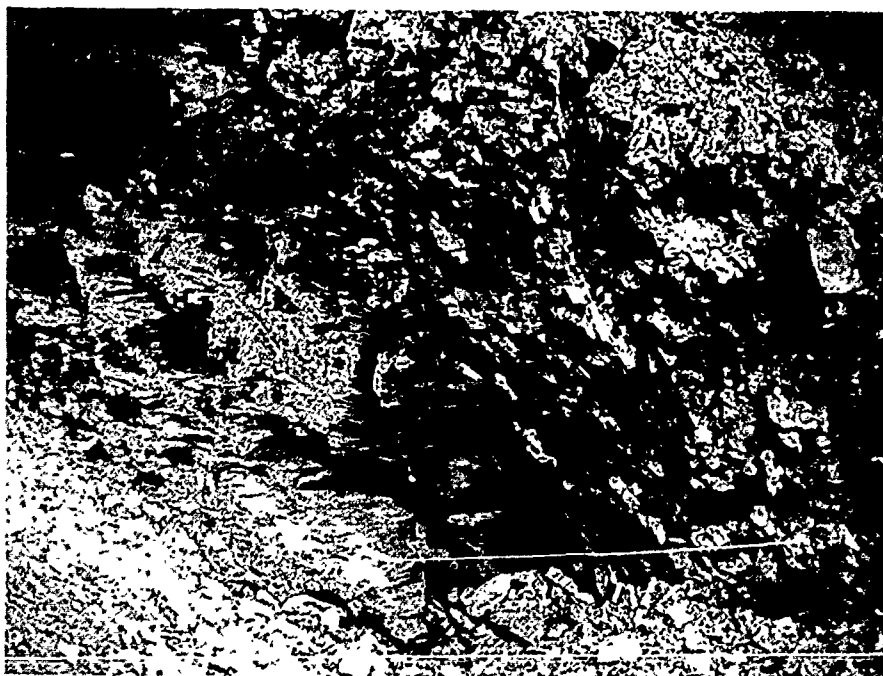
77. Blue Springs Lake, 21 May 1985, Neg. No. 441.
From left abutment station 99+00, looking east.



78. Blue Springs Lake, 21 May 1985, Neg. No. 442.
From left abutment station 99+00, looking east.



79. Blue Springs Lake, 29 May 1985, Neg. No. 448.
Left abutment cutoff trench. Gray shale is base
of Pleasanton "A" Zone. Condition of shale on
side slopes shows intense fracturing. Gray portion
of shale was shaped to final configuration using a Caterpillar
235 back hoe. From station 98+00 to station 98+60, looking west.



80. Blue Springs Lake, 1 June 1985, Neg. No. 452.
Left abutment downstream wall of cutoff trench
showing fractured zone at station 98+40.



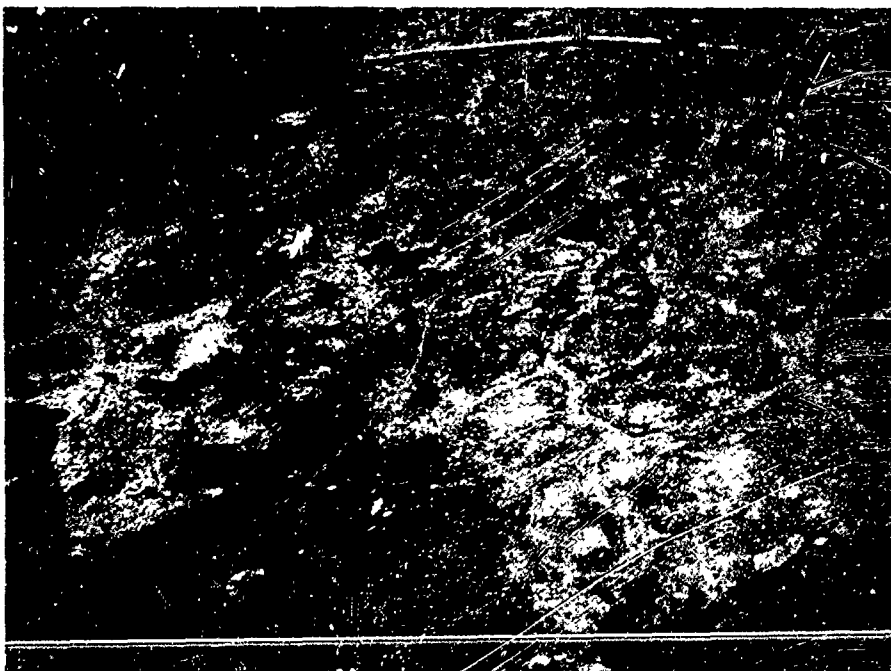
81. Blue Springs Lake, 29 May 1985, Neg. No. 449.
Left abutment cutoff trench. Upstream wall station 98+40.



82. Blue Springs Lake, 22 June 1985, Neg. No. 450.
Apparent fault in downstream wall of le. cutoff trench, station 98+45. Marker bed is 1 foot thick sandstone in Pleasanton "A". Probably toe of old slide.



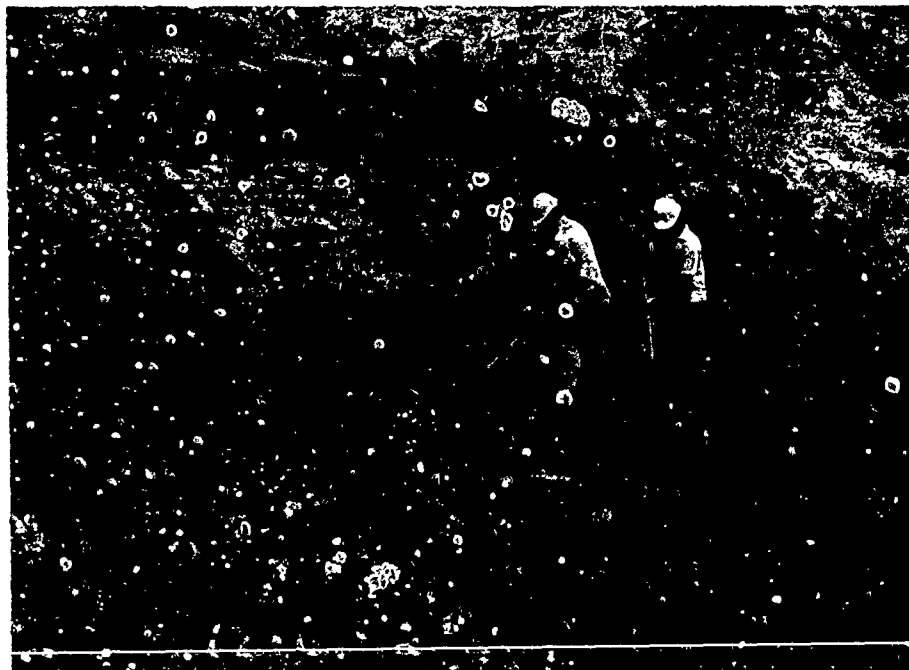
83. Blue Springs Lake, 22 June 1985, Neg. No. 461.
Apparent fault in downstream wall of left abutment
cutoff trench station 98+45. Relic toe of slide.



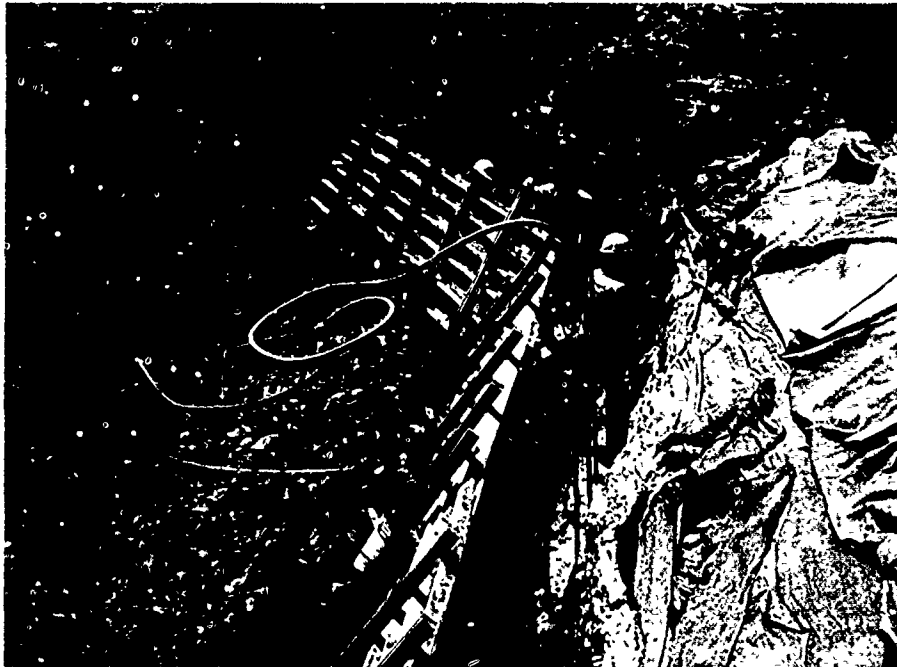
84. Blue Springs Lake, 27 June 1985, Neg. No. 468.
Left abutment, floor of cutoff trench, station
98+30. Serpentine jointing in Pleasanton "B"
Sandstone. Joints are tight but show signs of
previous water flow.



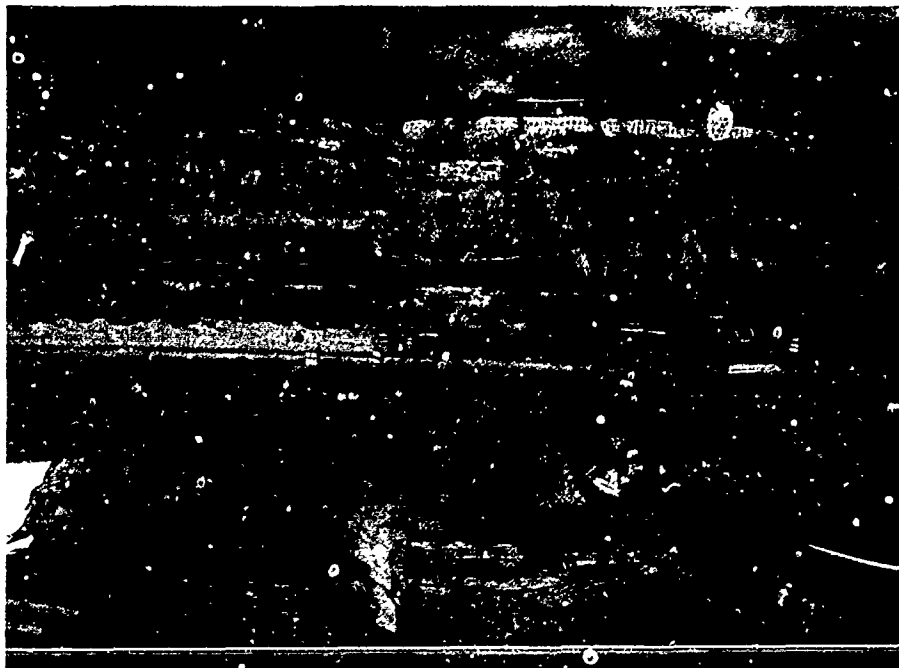
85. Blue Springs Lake, 2 July 1985, Neg. No. 473.
Left abutment cutoff trench at station 98+50.
Fractured appearance in upstream wall.



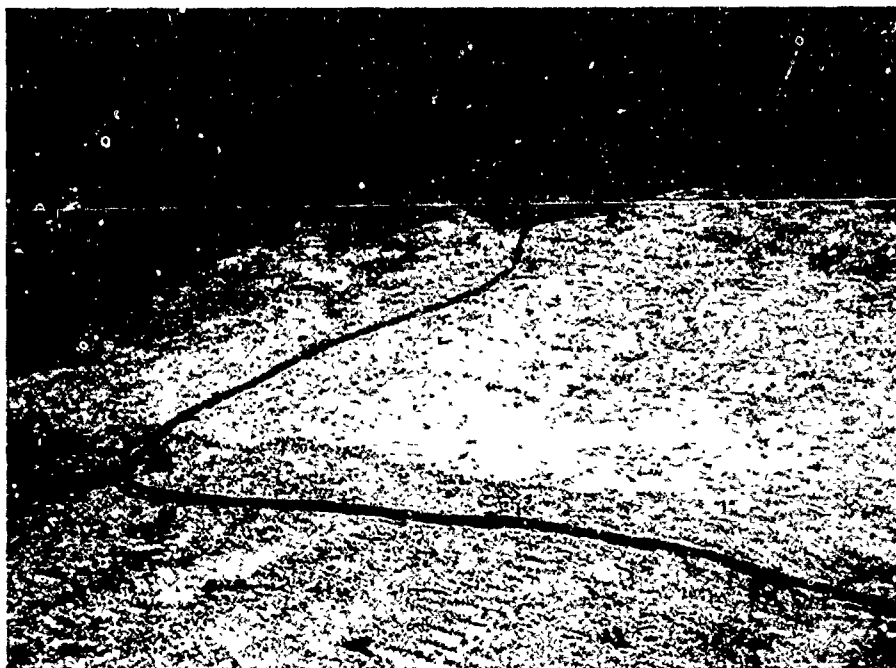
86. Blue Springs Lake, 12 July 1985, Neg. No. 477.
Left abutment cutoff trench at station 98+65.
Pleasanton "A" could not be trimmed to correct
slope. Concrete was used to form slope.



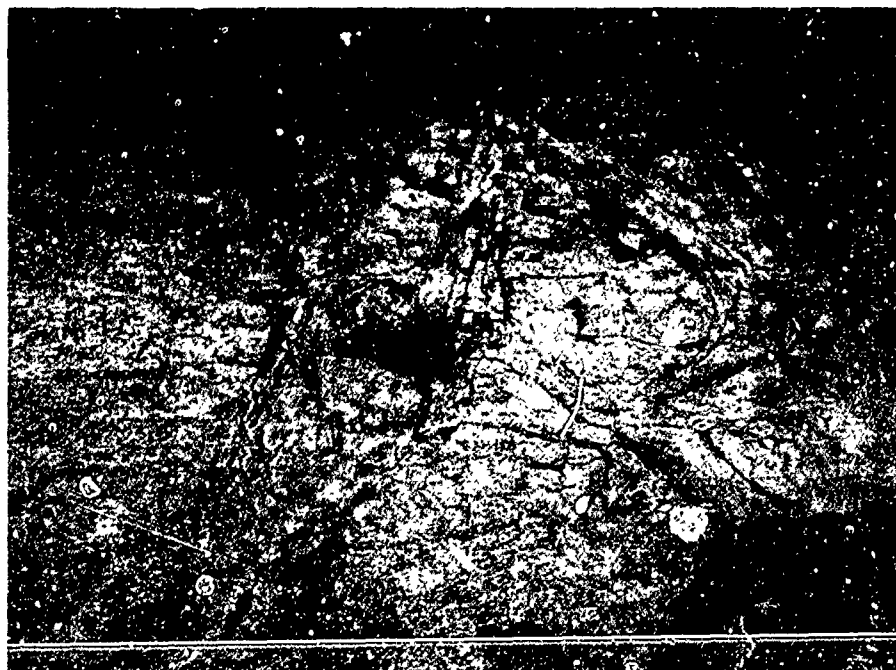
87. Blue Springs Lake, 16 July 1985, Neg. No. 489.
Left abutment cutoff trench, station 98+65. Concrete
forms constructed to form cutoff trench floor and
slope.



88. Blue Springs Lake, 26 July 1985, Neg. No. 501.
Right abutment cutoff trench, station 76+30.
Beginn ng of impervious placement in abutment.



89. Blue Springs Lake, 24 July 1985, Neg. No. 498.
Shale floor in right abutment cutoff trench.
Beginning in weathered Pleasanton "C" Zone at
station 76+30.



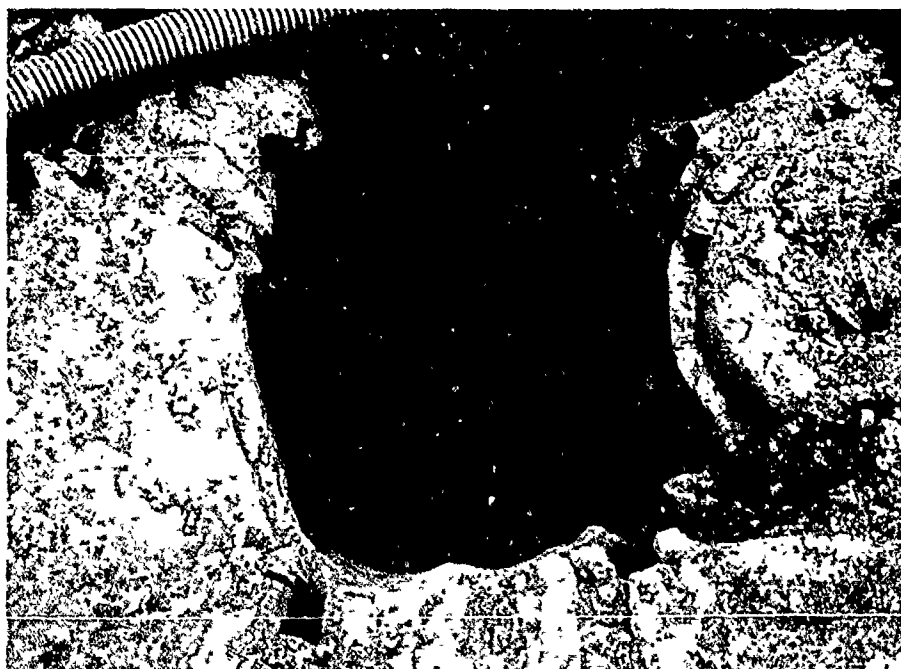
90. Blue Springs Lake, 1 August 1985, Neg. No. 512.
Joints in Pleasanton "C" Shales. Right abutment,
cutoff trench floor, station 76+20.



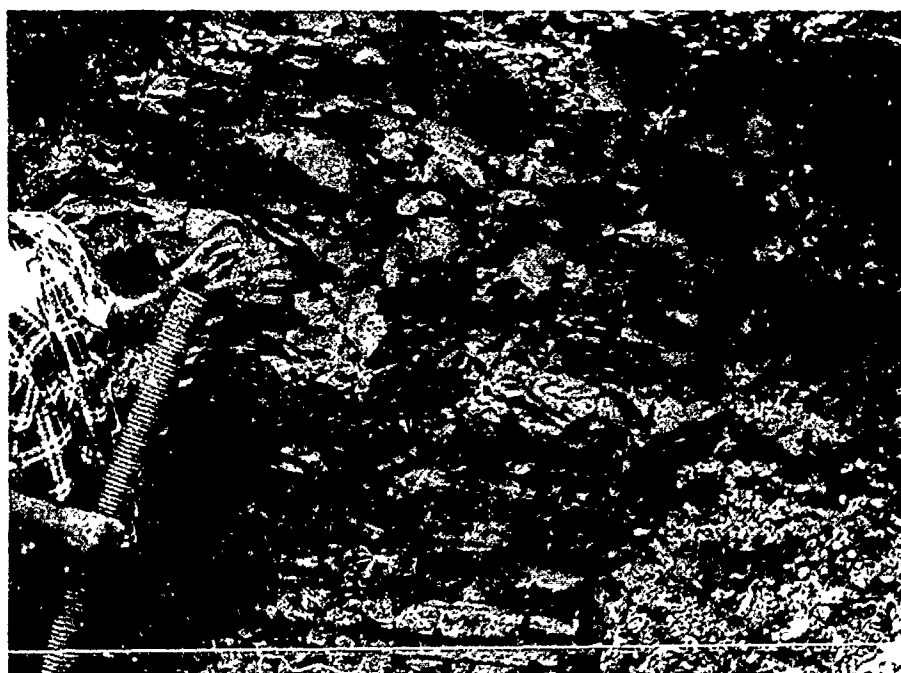
91. Blue Springs Lake, 1 August 1985, Neg. No. 513.
Joints in Pleasanton "C" Shale, right abutment,
cutoff trench floor, station 76+20.



92. Blue Springs Lake, 29 July 1985, Neg. No. 502.
Pits jackhammered into Pleasanton "C" Shale
intercepting joints in cutoff trench floor, from
station 76+00 to station 76+30. Pits were filled
with 1.0 ft. of sand and covered with impervious
material.



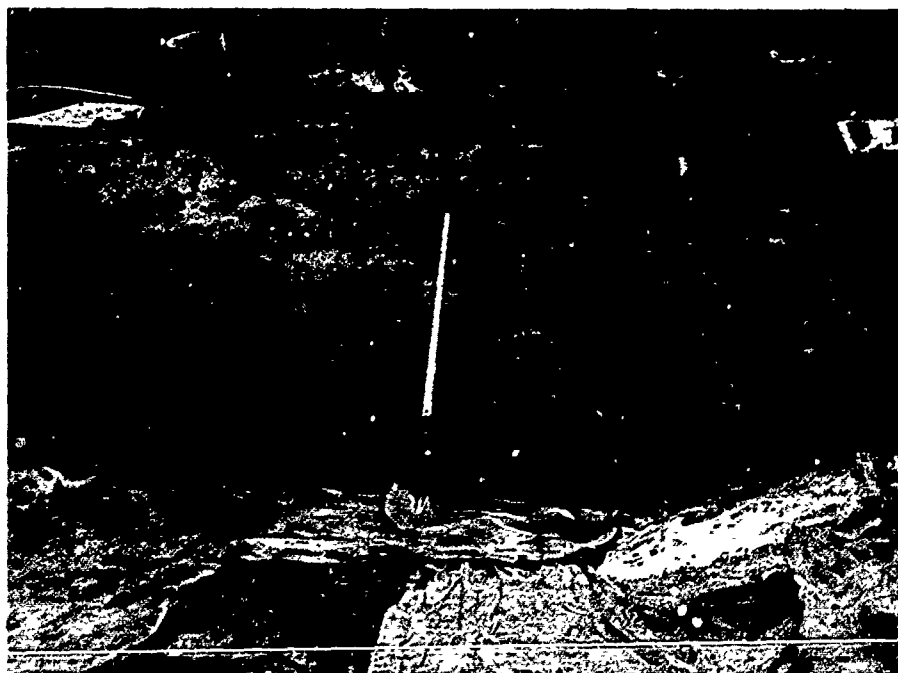
93. Blue Springs Lake, 29 July 1985, Neg. No. 504.
Close up view for detail of one of the pits shown
in Photo No. 92. Looking down.



94. Blue Springs Lake, 2 August 1985, Neg. No. 518.
Right abutment cutoff trench. Upstream sump at
station 76+30. Note the spheroidal structures in
Pleasanton "C" Shale.



95. Blue Springs Lake, 2 August 1985, Neg. No. 521.
Right abutment cutoff trench. Perforated PVC pipe
placed in sump at station 76+30.



96. Blue Springs Lake, 5 August 1985, Neg. No. 524.
Contact of weathered Pleasanton "C" Shale and
alluvium. Right abutment cutoff trench at station
76+50. Looking upstream.



97. Blue Springs Lake, 12 August 1985, Neg. No. 536.
Right abutment upstream sand drain at station 76+30.



98. Blue Springs Lake, 12 August 1985, Neg. No. 538.
Perforated PVC pipe placed in upstream sand drain
at station 76+60.



99. Blue Springs Lake, 2 September 1985, Neg. No. 544.
Left abutment, 45 feet upstream of cutoff trench.
From station 98+40 to station 98+60. Extensive
excavation was required to remove roots and weathered
Pleasanton "A" Shale.



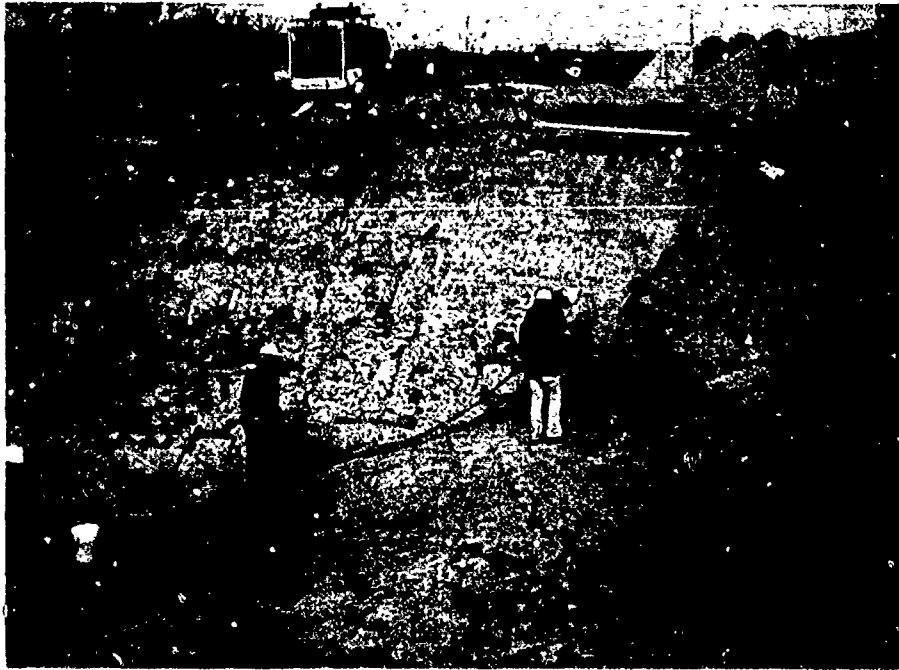
100. Blue Springs Lake, 17 September 1985, Neg. No. 546.
Left abutment cutoff trench. Pleasanton "A" Shale
Zone which could not be trimmed to correct slope.
Lean concrete was used to form slope on upstream
side. From station 98+50 looking west.



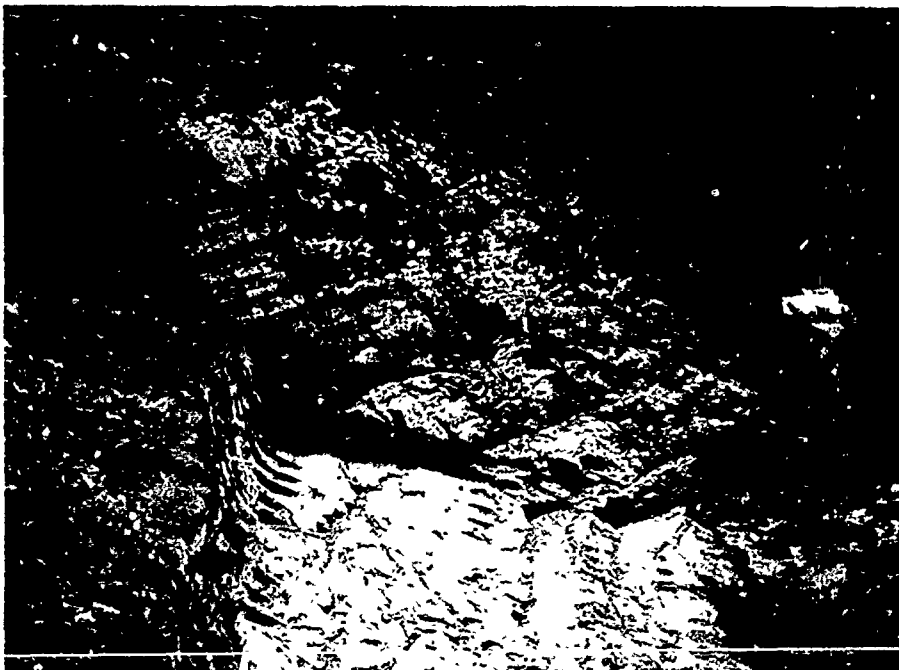
101. Blue Springs Lake, 17 September 1985, Neg. No. 547.
Left abutment cutoff trench, downstream section.
Detail as shown in Photo No. 100.



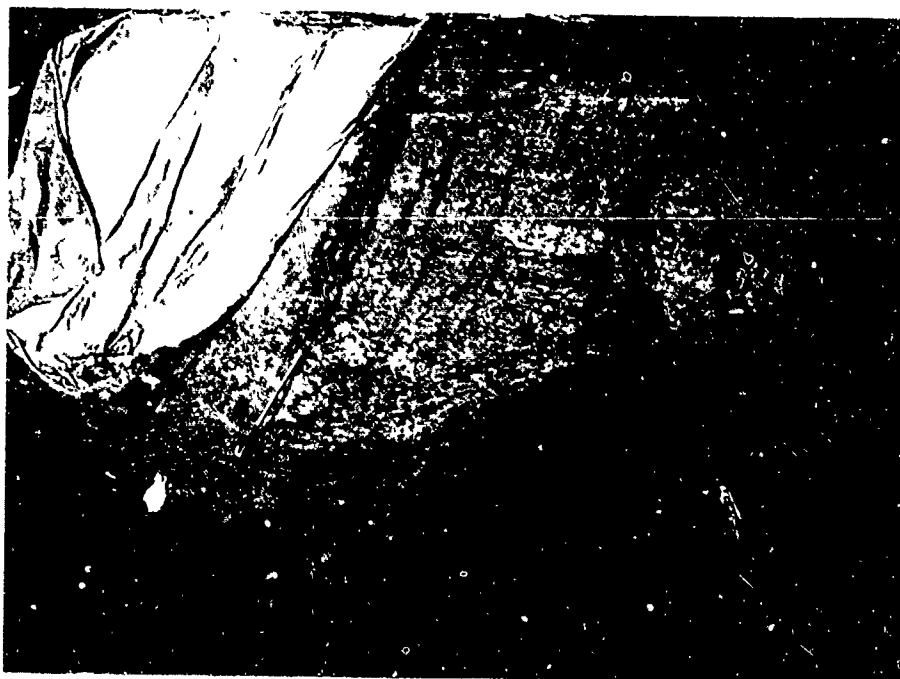
102. Blue Springs Lake, 17 September 1985, Neg. No. 548.
Left abutment cutoff trench. From station 98+70
and 20 feet downstream. Looking upstream.



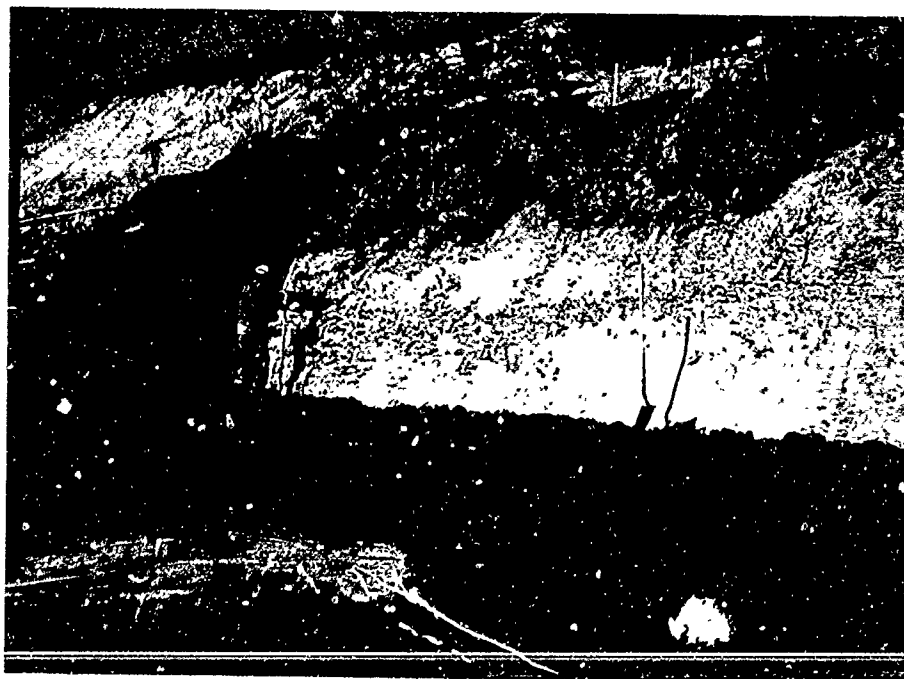
103. Blue Springs Lake, 30 October 1985, Neg. No. 564.
Right abutment cutoff trench. Downstream wall from
station 75+70 to station 76+00. From station 75+75,
50 feet upstream, looking north.



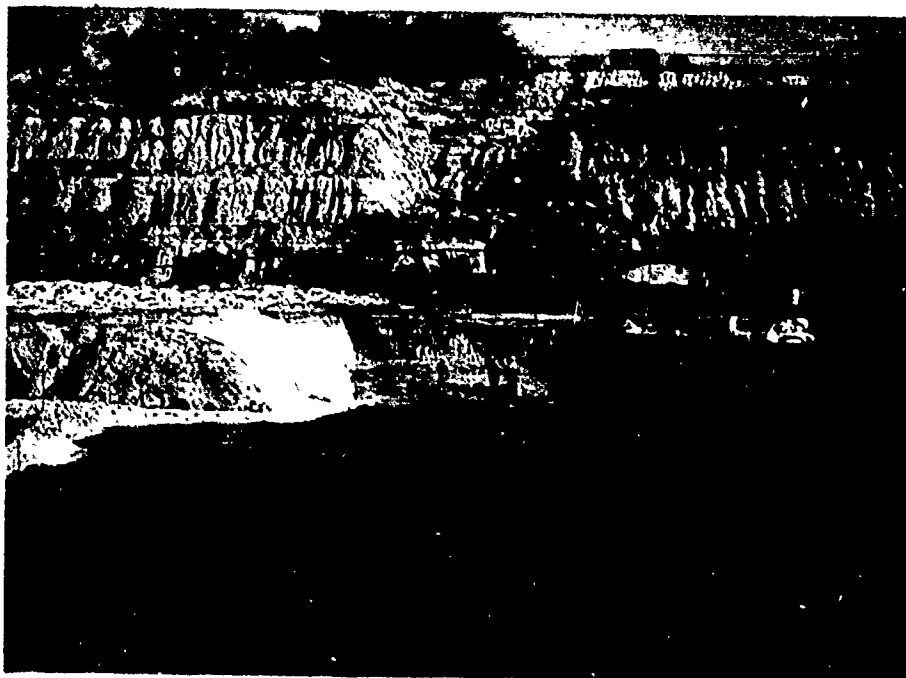
104. Blue Springs Lake, 30 October 1985, Neg. No. 565.
Right abutment cutoff trench upstream wall at
station 75+70. From 30 feet downstream, looking south.



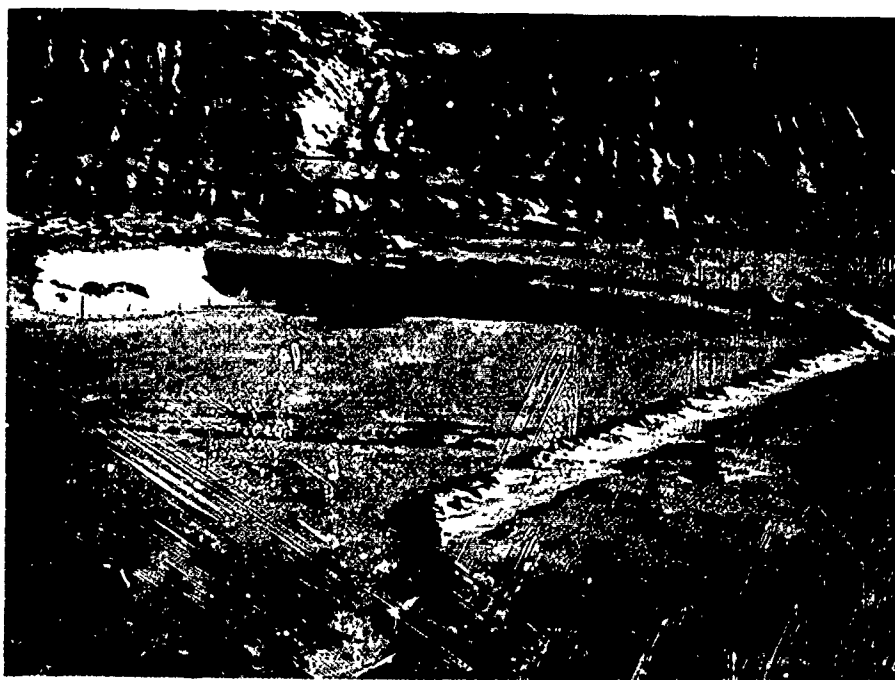
105. Blue Springs Lake, 7 November 1985, Neg. No. 579. Right abutment cutoff trench from station 75+60 to station 75+70. Joint is at station 75+60 and is tight. From station 75+60 and 30 feet upstream, looking downstream.



106. Blue Springs Lake, 7 November 1985, Neg. No. 583. Backfill operations east of intake tower from station 46+85 to station 47+29, looking northeast.



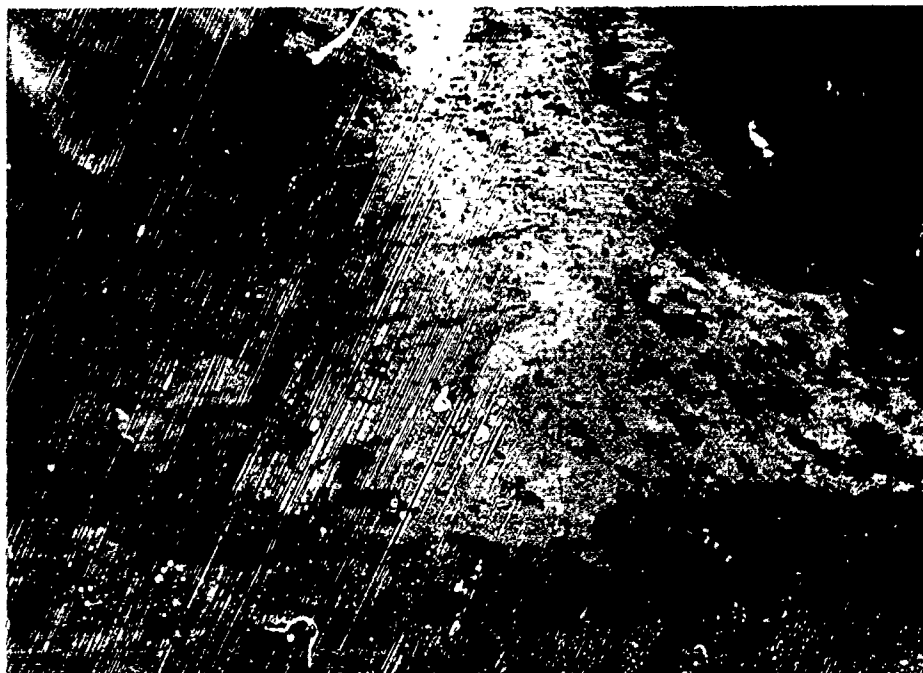
107. Blue Springs Lake, 2 November 1985, Neg. No. 581.
Right abutment, looking east.



108. Blue Springs Lake, 4 December 1985, Neg. No. 591.
Right abutment, looking east. View of same area
as shown in Photo No. 107.



109. Blue Springs Lake, 17 April 1986, Neg. No. 604.
Right abutment. From station 47+90 on center
line of conduit, looking downstream. Top of
cleaned slope is at station 74+60.



110. Blue Springs Lake, 17 April 1986, Neg. No. 608.
Right abutment. From station 74+70 on center
line of dam, looking upstream. View of Pleasanton
"C" Zone.



111. Blue Springs Lake, 17 April 1986, Neg. No. 609.
Right abutment. See Photo No. 110 for details.



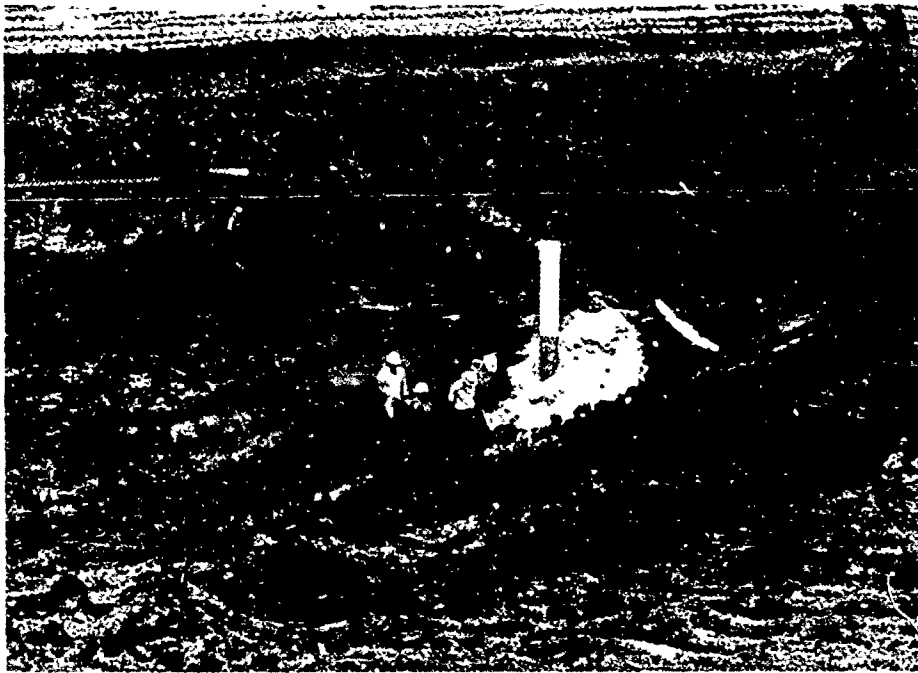
112. Blue Springs Lake, 26 April 1986, Neg. No. 613.
Right abutment. Cutoff trench from station 75+60
to station 75+48.5. From 25 feet downstream of
station 76+10, looking east, viewing downstream section.



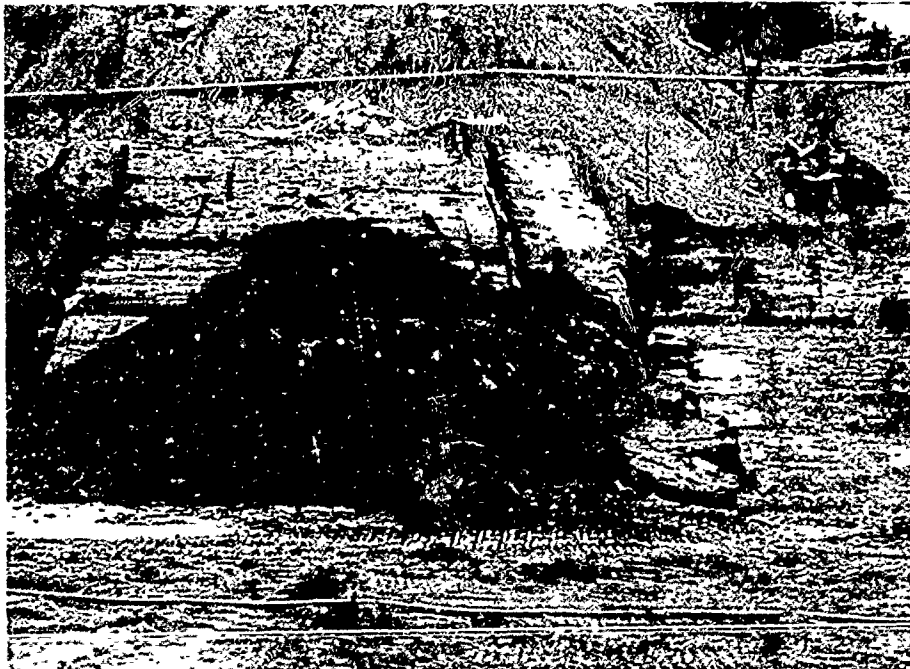
113. Blue Springs Lake, 26 April 1986, Neg. No. 614.
Right abutment. View of cutoff trench from station
75+60 to station 75+48.5. From 25 feet downstream
of station 76+10, looking east, viewing upstream section.



114. Blue Springs Lake, 30 April 1986, Neg. No. 617.
Right abutment. Cutoff trench, from 25 feet
upstream at station 75+40, looking northwest.



115. Blue Springs Lake, 6 May 1986, Neg. No. 621.
Sump placed at 19.6 feet upstream of station
77+18 at end of upstream sand drain.



116. Blue Springs Lake, 27 June 1986, Neg. No. 657.
Right abutment, cutoff trench. Downstream side
from station 74+50 to station 74+30. From center
line of dam at station 75+00, looking east, viewing
Pleasanton "A" Zone.



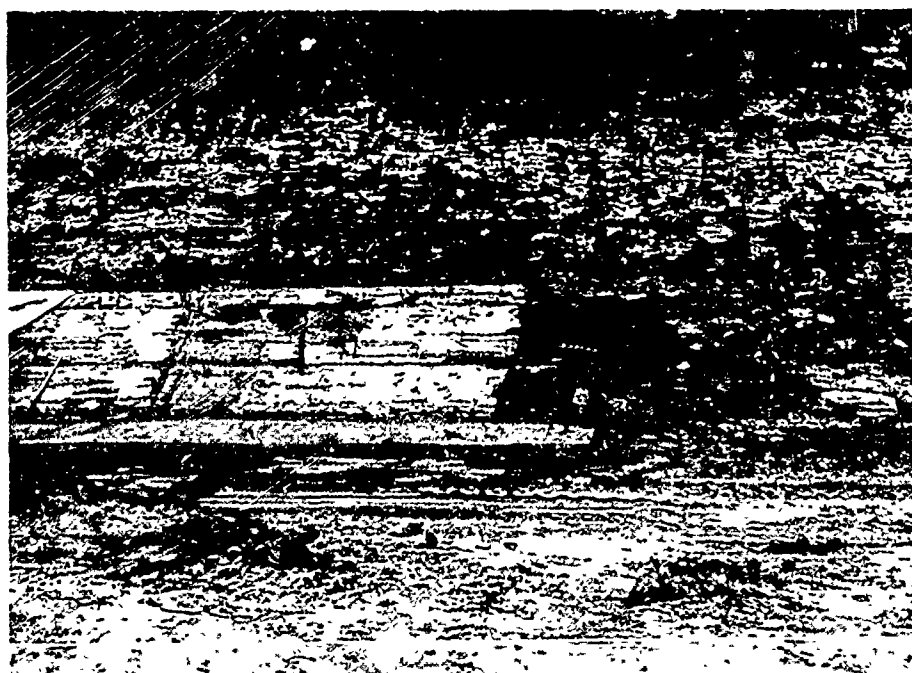
117. Blue Springs Lake, 27 June 1986, Neg. No. 650.
Right abutment, cutoff trench. View of upstream
side. Details as in Photo No. 116.



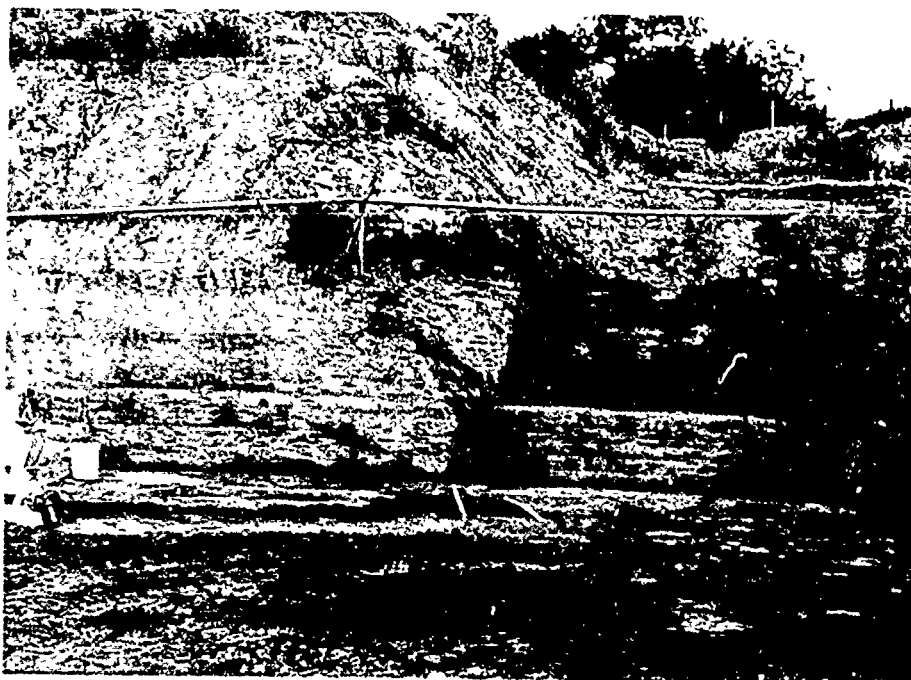
118. Blue Springs Lake, 28 June 1986, Neg. No. 659.
Right abutment, cutoff trench. View of downstream
wall from center line at station 74+70, looking
northeast.



119. Blue Springs Lake, 28 June 1986, Neg. No. 660.
Right abutment, cutoff trench. View of upstream
wall from center line at station 74+70 looking
southeast. Wall was cleaned from El. 786.2 to
El. 792.0.



120. Blue Springs Lake, 29 June 1986, Neg. No. 661.
Right abutment from 80 feet upstream of station
75+10, looking east.



121. Blue Springs Lake, 24 July 1986, Neg. No. 671.
Right abutment, cutoff trench. Downstream section,
from center line of dam at station 75+00 looking
east. Lower bench El. 795, from station 74+30 to
station 74+17.



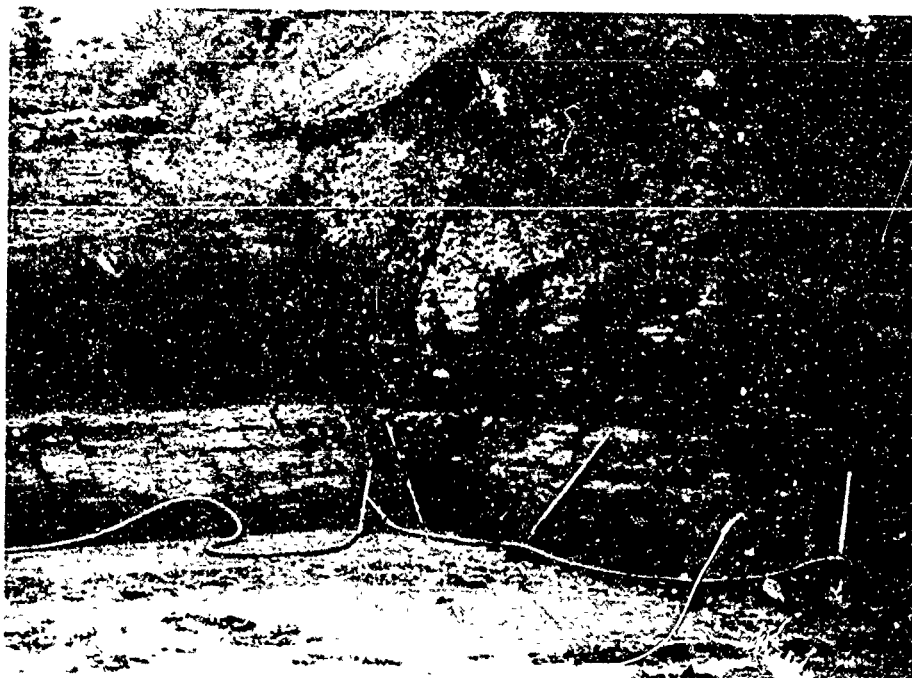
122. Blue Springs Lake, 24 July 1986, Neg. No. 672.
Right abutment, cutoff trench. Upstream section,
from center line of dam at station 75+00 looking
east. Lower bench El. 795 from station 74+30 to
station 74+17.



123. Blue Springs Lake, 13 August 1986, Neg. No. 677.
Right abutment, cutoff trench. View of center
section from station 74+17 to station 74+07 and
from El. 799.3 to El. 807.0. From center line
of dam at station 74+70, looking east.



124. Blue Springs Lake, 13 August 1986, Neg. No. 678.
Right abutment, cutoff trench, downstream wall.
Details as in Photo No. 123.



125. Blue Springs Lake, 13 August 1986, Neg. No. 676.
Right abutment, cutoff trench, upstream wall.
Details as in Photo No. 123.



126. Blue Springs Lake, 19 August 1986, Neg. No. 679.
Right abutment, cutoff trench. Slope constructed
with concrete from station 74+10 to station 74+07
and from El. 802 to El. 805. From station 74+50
looking east.



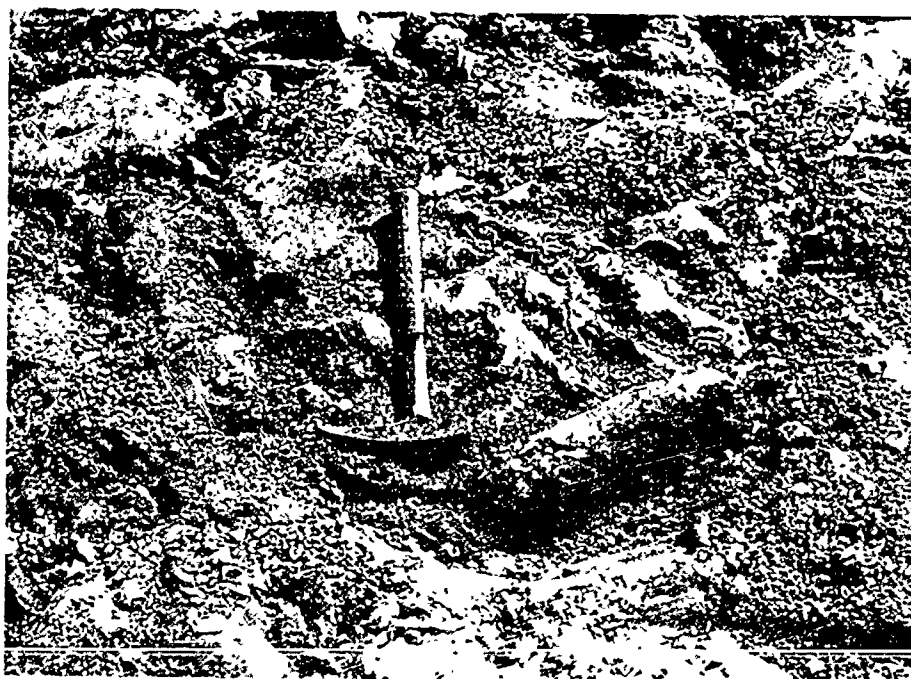
127. Blue Springs Lake, 19 August 1986, Neg. No. 680.
Right abutment, cutoff trench at station 74+15.
View of downstream wall after open fractures and
joints were dry packed. The head of rock-hammer is
at El. 802.5 at station 74+20.



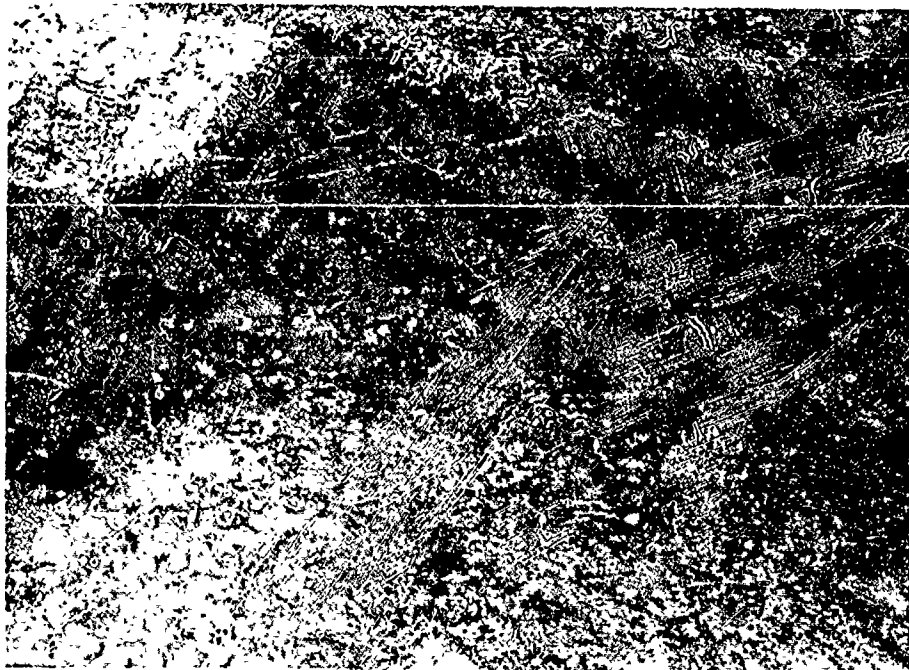
128. Blue Springs Lake, 19 August 1986, Neg. No. 681.
Right abutment, cutoff trench. View of downstream
wall from station 74+30 to station 74+10. The head
of rock-hammer is at El. 802.5 from station 74+50
and 20 feet downstream, looking east.



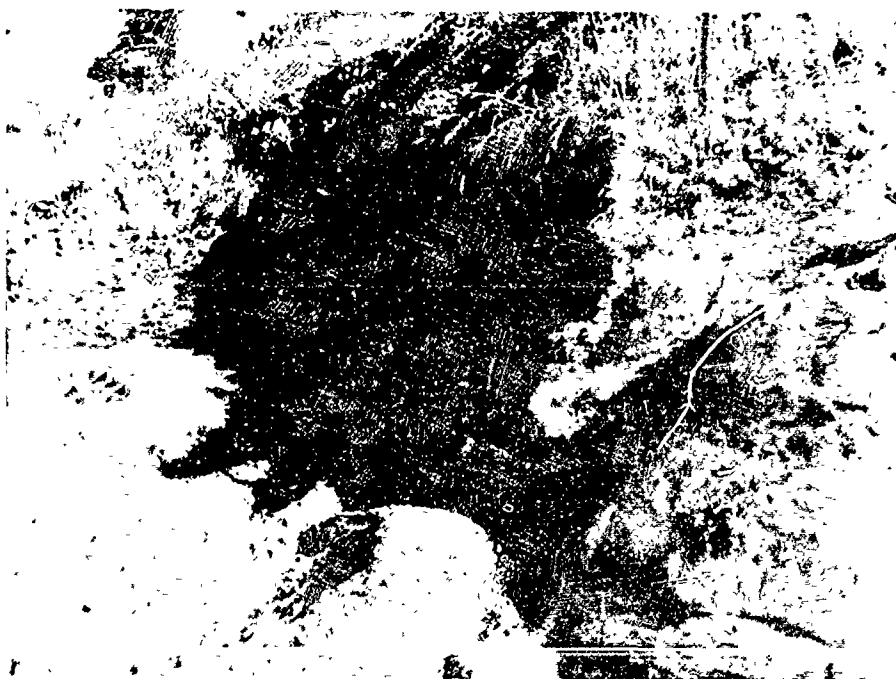
129. Blue Springs Lake, 19 August 1986, Neg. No. 682.
Right abutment, cutoff trench. View of downstream
wall from station 74+40 to station 74+25. From station
74+50 and 20 feet downstream, looking northeast.



130. Blue Springs Lake, 21 August 1986, Neg. No. 683.
Right abutment, cutoff trench. Detail of maroon
clay in stratigraphic sequence of Critzer Limestone.
Highly slickensided. Station 73+85 and El. 810.



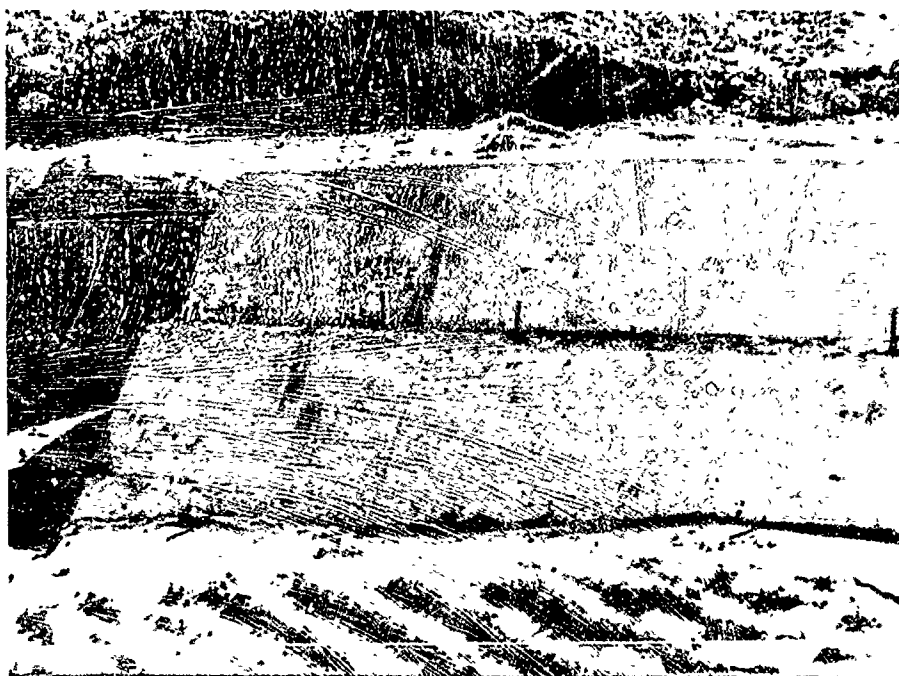
131. Blue Springs Lake, 22 August 1986, Neg. No. 685.
 Right abutment. View of cutoff trench from station
 74+05 to station 73+85 and from El. 805 to El. 810.
 Note maroon clay in upper right. Floor is Pleasanton
 "A", joint infilling is impure limestone.



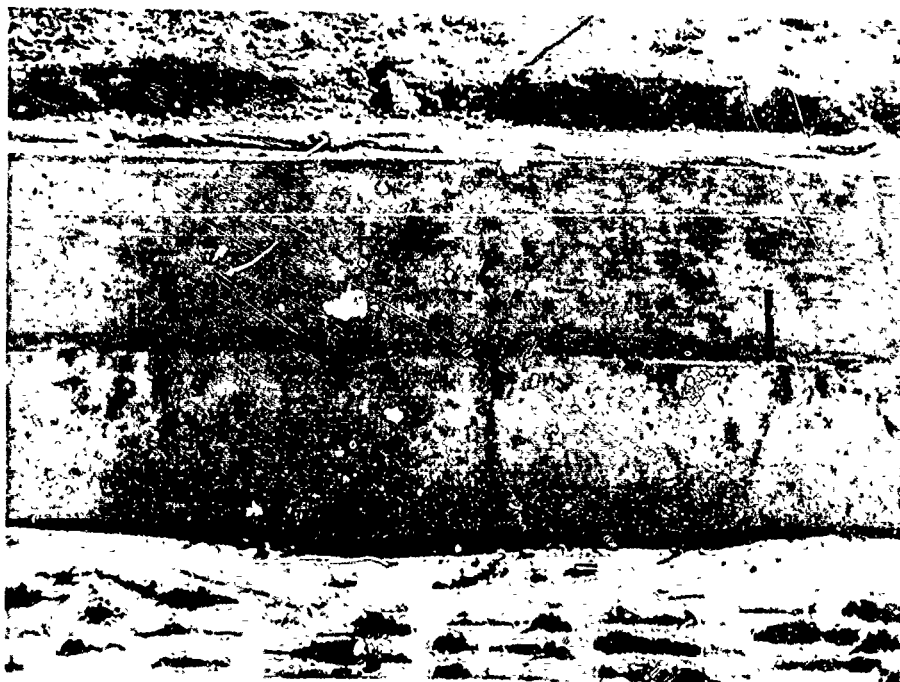
132. Blue Springs Lake, 5 August 1987, Neg. No. 692.
 Right abutment at station 74+00 looking downstream.
 Note Sniabar Limestone.



133. Blue Springs Lake, 5 August 1987, Neg. No. 693.
Right abutment. From station 73+90 looking
upstream. Note Sniabar Limestone.



134. Blue Springs Lake, 5 August 1987, Neg. No. 695.
Right abutment cutoff trench. View of downstream
section of concrete used to construct slope at
station 73+40.



135. Blue Springs Lake, 5 August 1987, Neg. No. 696.
Right abutment, cutoff trench. View of center
section of concrete used to construct slope at
station 73+40.



136. Blue Springs Lake, 5 August 1987, Neg. No. 697.
Right abutment, cutoff trench. View of upstream
section of concrete used to construct slope at
station 73+40.