INTERIM REPORT

ON

BENTONITE SEDIMENT SEALING ACTIVITIES

IN

TRANS-MOUNTAIN DIVERSION SYSTEM

OF

THE TWIN LAKES RESERVOIR AND CANAL COMPANY

NEAR

ASPEN, COLORADO

by
R. D. Dirmeyer, Jr.

Prepared for
Agricultural Research Service
U. S. Department of Agriculture

under terms of
ARS Contract No. 12-14-100-507(41)
CSU Research Foundation Project 108

Colorado State University Experiment Station
Civil Engineering Section
Fort Collins, Colorado

April 1958

CER58RDD15

Preliminary Report -- Subject to Revision

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PREFACE

This report is one of five separate interim reports to be prepared by July 1958. Each report is to cover one of the five sites that are now being studied as part of the present sediment sealing research program at Colorado State University. Each report is of a preliminary nature -- subject to revision -- and contains:

1. A complete tabulation of all available data, including an inventory and preliminary discussion of evaluation results;

2. Tentative plans for future investigation and evaluation work.

Even though this interim report pertains to one site only, it will be helpful to consider how the investigations at this site fit into the overall research program of sediment sealing activities at the University. For this reason a very brief summary of the entire program is outlinedin the following paragraphs of this PREFACE.

Research investigations -- relating to the development of low-cost methods of sealing irrigation canals with water-borne bentonite or colloidal clay -- have been carried on at Colorado State University in Fort Collins since July 1953. The work has been accomplished through the Experiment Station and the Research Foundation.

Because of the practical objectives of the research project investigations, the field trial type of development work has been emphasized. This emphasis is also related to the major source of the project research funds. During the early work from July 1953 to January 1957, almost

all of the research studies were financed by operating groups, such as the Bureau of Reclamation and private irrigation companies and districts. Important help was also received from companies with a direct commercial interest, such as bentonite, chemical and mixing equipment companies.

In January 1957, a contract -- relating to the sediment sealing investigations -- was entered into between the U. S. Department of Agriculture and the University. Important provisions of this contract work are outlined below:

1. It provides a major amount of supplemental research funds for the canal sealing investigations at the University.

2. Administration of the contract funds is carried out by the Agricultural Research Service through its Western Soil and Water Management Research Branch.

3. It is effective for the period of January 14, 1957 to January 14, 1960.

4. It provides for detailed investigations at not less than three and not more than six field installations.

Experiment Station funds were allotted to the research project in July 1956 for the purpose of supplementing the contract funds and other co-operator funds to be utilized in the restricted program as outlined in the ARS contract.

In arranging the contract program, field trial sites were needed where the irrigation district or company could be expected to actively push

and finance the development work. For this reason priority was given to those sites involving organizations that were:

1. Already co-operating in the sediment sealing investigations at the University;

2. Willing to finance completely the installation costs of a sedimenting trial in their canal system;

3. Willing to finance supplementally the University evaluation costs not fully covered in the joint ARS contract and Experiment Station budget.

In addition to the above selection factors, it was also necessary to pick sites that were representative of:

1. The sedimenting installations or investigations previously made in the States of Colorado, Nebraska, Wyoming, South Dakota, Arizona and California;

2. The kinds of pervious materials and operating conditions commonly found in irrigation canals.

To date, five sites have been selected for the contract program and are listed in the tabulation on the following page according to the dominant pervious or leaky material found at each site.

The interim reports for each evaluation site are being prepared at the request of Mr. Lloyd E. Myers, Jr., who is the officially designated contract representative for the Agricultural Research Service of the U. S. Department of Agriculture. A copy of each report is also being sent to each of the other co-operators in the present sediment sealing research program at the University.

LIST OF RESEARCH SITES

Pervious Material	Canal Site
Fractured rock to coarse rock talus	Connection Canal -- 7700' section Trans-Mountain Diversion System near Aspen, Colorado The Twin Lakes Reservoir and Canal Company, Ordway, Colorado
Sandy to gravelly alluvial material	West side supply ditch -- 1 mi. sec. Experimental Farm near Center, Colorado Adolph Coors Company, Golden, Colorado
Dune sand with alluvial clay to sand	Coachella Canal -- Reach No. 2 -- 8 mile section -- near Holtville, California Imperial Irrigation District, Imperial, California
Dune sand	Lateral 1 -- 1st 6 miles -- near Torrington, Wyoming North Platte Project (USBR) Pathfinder Irrigation District, Mitchell, Nebraska
Loessial soil -- wind - deposited clayey silt	Lateral 19.3 -- 1st 4.4 miles -- near Bertrand, Nebraska E-65 Main Lateral System The Central Nebraska Public Power and Irrigation District, Holdrege, Nebraska

The major co-operator at each site is underlined.

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INTRODUCTION

The Twin Lakes Reservoir and Canal Company has been involved in co-operative activities with the Sediment Sealing Research Project at Colorado State University since January 1956. The actual bentonite sedimenting work of procedure development and installation has been carried on in the west portal canals of the Company's Trans-Mountain Diversion System during the past two summers of 1956 and 1957.

The Trans-Mountain System collects snow-melt water from an alpine area on the west side of the continental divide. The area is southeast of Aspen, Colorado and in the vicinity of Independence Pass. The water yield of this high altitude collection canal system is carried in a tunnel through the continental divide and is then stored in Twin Lakes Reservoir, south of Leadville, Colorado and near the town of Twin Lakes, Colorado.

The Trans-Mountain water is released from Twin Lakes Reservoir into the Arkansas River. The Company also has water rights in the Arkansas River. The irrigated area served by the Company is east of Pueblo, Colorado and in the vicinity of Ordway, Colorado.

The canal sealing problems of the west portal collection canals relate to the coarse rocky nature of most of the canal bed materials. The dominant canal bed materials are (1) a closely fractured granite bedrock, and (2) a loose talus or rock slide material.

As a result of the dominance of pervious canal bed materials, loss of water through canal seepage has been a serious problem --

a problem that has varied significantly with the operating conditions in the canals.

Under peak flow conditions during the maximum snow-melt and run-off period, significantly large quantities of canal seepage water have, in the past, been irretrievably lost to the Company. Extensive seepage areas would appear below most of the west portal canals almost immediately after the high flows of water were turned into the canals. While other sources of water feed the seepage areas, in many instances, the most evident major source was canal seepage. The access road into the west portal area also was damaged by the over-abundance of seepage water during the main run-off period.

On the other extreme, the low flows of water during the early spring, late summer, and fall would not carry through the canals. Thus, while the total amount of seepage loss water involved was, perhaps, not large, being able to carry and maintain small flows of water through the canals does have other compensations. Carrying the small flows in the canals -- during the winter and under the snow cover -- provides a pilot bore that greatly expedites the snow removal and canal opening problems in the spring. A quick opening of the canals is especially important if the snow-melt comes fast.

During the summer of 1955, the Company started a major improvement program in the Trans-Mountain System. The improvements -- designed to increase the water yield of the system -- have included:

1. Cleaning, enlargement, and partial realinement of canals -- approximately 6.5 miles of canals, ranging in capacity, after new

construction, from 80 to 350 cfs.

2. Construction of canal bank roads since they were not included in the original construction -- provides access for power equipment needed for operations such as canal lining or sealing, and removal of snow, rock and mud.

3. Installation of corrugated metal pipe in unstable areas -- serious mud flow problems have been encountered in a few restricted areas on the New York-Tabor Gulch collection canal.

4. Development of appropriate low-cost methods of sediment sealing the remainder of the west portal canals -- mostly in open rocky material that is fairly stable but quite pervious.

The report is concerned only with the last item -- the sediment sealing activities -- listed in (4) above.

PEOPLE INVOLVED IN DEVELOPMENT WORK

The bentonite sedimenting work has been accomplished under the general supervision of Mr. Wallace A. Doe, General Manager-Engineer for the Company, and under the direct supervision of Mr. Harry Peters, Superintendent of the Trans-Mountain Diversion System. Mr. P. R. McOllough was Resident Engineer on the job during the 1956 summer season. The Company's Board of Directors has also been actively interested in the work and, on several occasions, has reviewed the progress of work at the canal locations.

The following personnel of the Sediment Sealing Research Project at the University have assisted in the development activities: the writer, as project leader, in setting up the sedimenting procedures and evaluation methods; Mr. D. L. Bonder, as project hydraulic engineer in accomplishing the initial water loss measurements; and Mr. R. T. Shen, as assistant research engineer in assisting in the water loss measurements and laboratory evaluations of potential sedimenting agents.

Several members of the Civil Engineering Department of the University's College of Engineering have been consulted at various times concerning specific problems at the canal locations.

PRELIMINARY PLANNING ACTIVITIES

As a follow-up to correspondence starting in the fall of 1955 and at the request of Mr. Doe, General Manger-Engineer, a trip was made to the Company office in Ordway, Colorado on January 17 and 18, 1956. As a result of detailed discussions with Mr. Doe and the Company's Board of Directors, a preliminary plan was prepared. A copy of this original tentative plan was included in a report to the Company, a copy of which is attached to this report as Enclosure 1 of the Appendix.

In this first report to the Company, the research and development or "trial and error" nature of the proposed work was carefully emphasized. The "failure" possibilities in this type of development work should be definitely recognized so that a few such stumbling blocks can be accommodated without stopping or appreciably retarding the development work.

Because of the coarse rocky nature of the dominant canal bed materials, it was assumed that a modified sedimenting procedure would be required. Thus, the preliminary plans and cost estimates in the attached report recommended the use of supplemental sediments, such as sawdust, or local clays and silts, in addition to the high-swell type of bentonite sediment. The estimated total cost, including the costs of development, materials, equipment, and labor, was $25,000.

The purchase of 500 tons of high-swell bentonite was recommended in the preliminary report. Since the west portal development work was scheduled to start around June 1, 1956, laboratory testing of several potential bentonite sediments was started immediately after the January 17 and 18, 1956 trip. This initial testing included samples of two Colorado bentonites and five commercial Wyoming bentonites. The results of the testing are attached as Enclosure 2 of the Appendix.

As a follow-up to the initial sample testing, a general request for price quotations on 500 tons of bentonite -- of a specified quality -- was prepared. The request was sent to eleven bentonite companies -- including both Wyoming and Colorado producers. A copy of the request for quotations, including bentonite specifications, is attached as Enclosure 3 of the Appendix.

During the week of March 18-23, 1956, a number of bentonite deposits in southern Colorado were sampled. The samples were subsequently tested in the project laboratory at the University. Conclusions and recommendations, based on this and the initial sample testing, were

outlined in a letter to Mr. Doe, dated April 7, 1956. A copy of this letter is attached as Enclosure 4 of the Appendix.

The conclusions and recommendations of the April 7, 1956 letter are briefly summarized below:

1. High-swell bentonite -- Recommended that the low quotation of $22.31/ton (FOB Aspen, Colorado) by the American Colloid Company at Osage, Wyoming be accepted.

2. Supplemental sediment -- Recommended that 300 tons of the Lamberg bentonite, mined near Howard, Colorado, be purchased -- final price was $16.75/ton delivered at the west portal area.

On May 24 to 27, 1956, the west portal area of the Company's Trans-Mountain Diversion System was visited. A report pertaining to this trip was forwarded to Mr. Doe on May 29, 1956. A copy of the report is attached as Enclosure 5 of the Appendix.

The conclusions and recommendations of the May 28, 1956 report are briefly summarized below:

1. Site for initial trial work -- Recommended that the preliminary research and development work be confined to the Connection Canal between Tunnel No. 2 and Lincoln Gulch Dam.

2. Seepage loss studies -- Recommended that detailed seepage loss measurements be made on both the Connection Canal and the Collection Canal -- water measuring stations were located.

3. Sedimenting procedure -- Recommended that the initial trial work in worst seepage areas include, in the order mentioned: (a) sawdust, (b) Colorado bentonite, and (c) Wyoming bentonite.

During the periods of May 27 to June 1, 1956 and June 11 to 15, 1956, Mr. D. L. Bender initiated the seepage loss measurements mentioned in (2) above. Mr. P. R. McOllough assisted in the water measurements during the week of June 11th and then, after June 15th, continued alone on the water measuring work. The results of this initial measuring work were outlined in a report by Mr. McOllough, dated October 12, 1956, and titled, "Report of Water Measuring, Bentonite Sedimenting, and Canal Construction at the Twin Lakes Trans-Mountain Diversion System during 1956 Summer Season". Those portions of the above report that pertain to this initial "Water Measuring Phase" are attached as Enclosure 6 of the Appendix.

In this initial water measuring work during the main snow-melt and run-off period, it was possible to measure the peak flows of most of the canals and creeks entering Lincoln Gulch Reservoir. It was not possible, however, during this particular period, to determine accurately the seepage loss or flow shrinkage in the various major sections of canal in the west portal system.

The loss measurements were upset by a complex interaction of several characteristic conditions of the snow-melt period. Several of the most obvious distracting conditions are listed below:

1. Fluctuating flow -- Reflecting the variable rates and quantities of snow-melt in the upstream area, the stage of canal flow -- and the flows into and out of canal bank storage -- are almost constantly changing.

2. High groundwater level -- During the snow-melt period -- especially when the snow in the immediate vicinity of the west portal canals is melting -- the ground is essentially saturated and the canals act as drains.

Thus, for practical purposes it can be assumed that during the snow-melt period the seepage losses in any given section of the west portal canal system are quire variable and essentially indeterminate.

In summation, as result of the preliminary planning activities it was concluded that:

1. Where -- The initial sediment sealing development work in the west portal area would be accomplished in the Connection Canal.

2. When -- The major development and trial work would be accomplished after the main snow-melt period and after the canal flows had stabilized to a relatively small but steady flow. Groundwater inflow would not be a significant problem at that time.

3. Materials -- The following sedimenting materials would be used (a) 500 tons of high-swell bentonite from Osage, Wyoming, (b) 300 tons of supplemental sediment or low-swell bentonite from near Howard, Colorado, and (c) wet sawdust from waste pile at saw mill site in west portal area.

4. Procedure -- A ponding method of sedimenting would be used with trial mixing and application methods to include (a) blanketing of worst areas, and (b) mixing methods designed to produce lumpy mixes and utilizing locally available equipment.

5. Evaluation -- Inflow-outflow water measurements would be obtained immediately before, during, and after sedimenting by using weirs mounted in the ponding dams at the two ends of the Connection Canal.

DEVELOPMENT AND EVALUATION ACTIVITIES -- SUMMER 1956

During the period of July 23 to August 1, 1956, a trip was made to the west portal area to assist in the initial bentonite sedimenting trials. The results of this trip -- and in addition, those of the subsequent development work during the remainder of the summer -- are summarized in a report that was forwarded to Mr. Doe on October 17, 1956. A copy of this report is attached as Enclosure 7 of the Appendix.

The 1956 summer work was also detailed in the October 12, 1956 report by Mr. P. R. McCllough. Those portions of the latter report that relate to the "Bentonite Sedimenting Phase" are attached as Enclosure 8 of the Appendix.

Briefly summarized, the procedure development work during the summer of 1956 included the following:

1. Preliminary preparations -- These included (a) hauling of 500 tons of high-swell bentonite from railroad siding in Aspen to stockpile area at Lincoln Gulch Reservoir, (b) delivery of 300 tons of low-swell bentonite at west portal stockpile area, (c) construction of temporary check structure at lower end of Connection Canal, and (d) installation of 5' rectangular weir blades in check structures at upper and lower ends of Connection Canal.

2. Water measuring -- Starting toward the end of July when the flows were small, water loss measurements were accomplished (a) prior to first sedimenting trials, (b) after first sedimenting trials,

(c) before second sedimenting trials, and (d) after second sedimenting trials. Detailed records of this water measuring are included in Enclosure 8 of the Appendix.

3. Procedure development work -- These activities were accomplished during the periods of (a) July 28th to August 5th, and (b) August 24th to September 1st. The step-by-step details of the work are outlined in Enclosure 8, but in general two methods of bentonite mixing and placement were used: (a) blanketing of most obvious seepage loss areas with Colorado bentonite, and (b) wash-out of temporary dams of Wyoming bentonite -- placed so that major seepage loss areas were subjected to treatment with lumpy bentonite sediment sealing mixtures.

Even though the bentonite mixing methods were quite crude and undoubtedly could be improved, excellent sealing results were obtained. The results of the water loss evaulations are summarized in the table below:

Date	Average Inflow	Av. Loss before 1st Sed.	Av. Loss after 1st Sed.	Av. Loss before 2nd Sed.	Av. Loss after 2nd Sed.
July 27	10.68 cfs	4.71 cfs			
" 28	10.88	5.10			
" 29	12.05	4.92			
" 30	12.25	4.23			
" 31	12.03	3.26			
1st run -- bentonite placement started July 28, 1956 -- main mixing in canal started August 1, 1956 and completed August 4, 1956.					
August 5	9.87 cfs		2.45 cfs		
" 23	7.57			1.20 cfs	
" 24	7.50			1.20	
2nd run -- bentonite placement started August 25, 1956 -- mixing in canal completed September 2, 1956.					
Sept. 3	4.15 cfs				0.97 cfs
" 4	3.93				0.83

On November 8, 1956, Mr. Doe released a statement to the Company's Directors and Stockholders that outlines the results of the bentonite sediment sealing activities at the end of the first season. A copy of this statement is attached as Enclosure 9 of the Appendix.

DEVELOPMENT AND EVALUATION ACTIVITIES -- SUMMER 1957

During 1957, one trip was made to the Company office in Ordway, Colorado and three trips to the west portal area -- for the purposes as indicated in the table below:

Dates	Destination	Purpose
May 7 and 8	Ordway, Colorado	Preliminary planning of summer bentonite sedimenting and evaluation activities.
June 11 and 12	West Portal Area	Final planning of summer evaluation activities and water measuring during peak flow conditions.
Aug. 19 to 23	" " "	Water measuring during low flow conditions and testing of air jet mixer.
Sept. 23 to 26	" " "	Water measuring during low flow conditions.

Plans were made to (a) continue evaluation of sealing effects of the 1956 bentonite work in the Connection Canal, and (b) complete bentonite sediment sealing of the Collection Canal. The latter canal sealing plans, however, were disrupted and suspended in the early part of the summer because of a serious wash-out and canal break at the upper end of the Collection Canal near New York Gulch. The repair of this canal

break was a major work project for the west portal construction crew during the 1957 summer season. The water loss measurements on the Connection Canal were carried out as planned.

The water loss measurements made during the August 19 to 23 trip are attached as Enclosure 10 of the Appendix. During that time, with an inflow of about 4.2 cfs, the loss in the Connection Canal ranged from 1.2 to 1.5 cfs. At a larger inflow of about 20 cfs, the loss ranged from 1.0 to 3.2 cfs.

During the period of September 24 to 26, a recorder was set-up at each of the upper and lower weir stations on the Connection Canal. The canal flow had tapered off to a smaller but much steadier flow than was found during the August water measurements. The range of water flow and loss during this period was as tabulated below:

Upper		Lower		Apparent
Min	Max	Min	Max	Loss
6.45 cfs	6.75 cfs	3.68 cfs	3.80 cfs	2.80 cfs

After the recorders were removed, weir gauge readings were made, once daily, until October 5, 1957. The results of the readings by Mr. Peters are listed below:

	Upper Weir			Lower Weir			Approx.
Date	Time	Gauge	CFS	Time	Gauge	CFS	Loss
9-28	8:15A	.62	6.3	8:00A	.40	3.3	3.0
9-29	8:20A	.55	5.3	8:10A	.34	2.6	2.7
10-1	8:40A	.54	5.1	8:30A	.35	2.7	2.4
10-2	8:15A	.55	5.3	8:00A	.35	2.7	2.6
10-3	8:30A	.53	5.0	8:15A	.33	2.5	2.5
10-4	8:50A	.49	4.5	8:40A	.32	2.4	2.1
10-5	9:15A	.50	4.6	9:00A	.31	2.3	2.3

It will be noted that the indicated losses during the 1957 season have increased to some extent from those for the 1956 season. While the sealing effect has undoubtedly deteriorated to some extent, it should also be realized that the 1956 measurements were made with less ponding depth than the 1957 measurements. The 1956 measurements were made with a 5-foot weir with a pond depth of around 1 foot.

During 1957, the upper weir crest setting was the same for the August and September water measurements. The weir crest was about 2.2 feet above the bottom of the weir pool -- two check boards plus 4 inches of weir blade. One bay of the three-bay check structure at the outlet of Tunnel 1 was used for the weir set-up.

The lower weir crest setting was not the same for the August and September measurements. During the August measurements, the weir crest was about 2 feet above the bottom of the weir pool. During the September measurements, the weir crest was one check board higher or about 3 feet above the bottom of the weir pool. The center bay of a temporary timber check was utilized for the weir set-up. The timber structure was set in against the upstream edge of the concrete transition of the drop structure into Lincoln Gulch Reservoir.

Identical 4-foot weir blades were used in the upper and lower weir set-ups. The weirs were operated under contracted conditions. The blades were filed to a dull knife-edge.

The accuracy of the weir measurements is estimated to be $\pm$ 10% -- because of the following factors:

1. Some inflow of groundwater into the Connection Canal -- probably very minor amounts during August and September readings.

2. Weir structures were not completely water-proofed -- despite concentrated efforts, the leakages through and around the structures could be stopped only temporarily. It was estimated that the lower structure was leaking slightly more water than the upper structure.

Because of the canal wash-out previously mentioned, the procedure development activities were cut to a minimum during the summer of 1957. However, some work was accomplished, such as listed below:

1. Priming method -- After completion of the enlargement work in the Collection Canal from Tabor Gulch to Lincoln Gulch Reservoir and toward the end of the summer of 1957, it was found that the low flows -- less than 10 cfs -- would not carry through to the reservoir. Various combinations of sediments were tried in attempts to seal the canal. The best combination seemed to be one involving a mixture, in equal parts, of (a) wet sawdust, (b) Colorado bentonite, and (c) Wyoming bentonite. The mixture was hand shoveled into the head end of the canal flow at Tabor Gulch. The resulting muddy water mixture and the subsequent follow-up flows of clear water carried through the canal. Inflow-outflow measurements of the flow were not made.

2. Air jet method -- In an attempt to develop a simple method of transporting relatively unswelled and just slightly wet granules of bentonite directly into very pervious canal bed zones, a preliminary trial with a cone jet mixer was completed. Compressed air was used

instead of water in an attempt to blow the dry granulated type of bentonite into the ponded water directly above the very pervious zones to be sealed. It was found that the bentonite could be handled in this manner with the equipment; however, it was obvious that larger, more convenient equipment was needed. A new mixer and air-slide hopper has been constructed and will be tested during the coming summer.

It is anticipated that the first method above could be used as a "priming and puddling" type of operation in the newly enlarged and unsealed sections of canal, and the second method as a follow-up method to seal off the pervious zones not sealed in the first priming operation.

In a recent discussion, Mr. Doe stated that during the past winter it has been possible to maintain small flows of water through the Connection Canal. He attributed this to being able to maintain a full water depth in a checked-up pond in the canal with a small flow of water. With an insulating cover of snow, the water does not freeze completely to the bottom. If this pilot bore stays open through the rest of the winter, it should simplify the canal opening procedures in the coming spring period. With a flow of water established under the snow cover and even though the snow-melt water seems very cold, it is surprising how fast it will melt the snow out of the canal.

TENTATIVE CONCLUSIONS

As a result of the recent sediment sealing activities of the past two summers in the west portal area of the Twin Lakes Trans-Mountain Diversion System, several tentative conclusions can be stated. Final conclusions cannot be offered at this time since the development work -- and especially the evaluation work -- is only partially complete. The west portal work will probably be continued, as a minimum, through the next two summers of 1988 and 1989. The tentative conclusions, based on results of work to date, are listed below:

1. Problem -- The major problems of sediment sealing in the west portal canals relate to the following:

a. Character of pervious materials -- The fractured bedrock and especially the loose rock talus materials commonly have relatively large voids to be plugged and sealed;

b. High water table -- During the spring and early summer snow-melt period, inflows of groundwater into the canals tend to dislodge void-plugging materials -- including the sediment sealing agents.

2. Tentative procedures -- The sediments and sediment sealing methods that apparently give the best canal sealing results are listed below:

a. Initial priming -- In the west portal canals and especially in the newly enlarged sections, the initial priming seems to be best accomplished with a sedimenting mixture containing, in equal parts, (1) wet

sawdust, (2) Colorado bentonite, and (3) Wyoming bentonite. The hand shoveling method of applying the priming sediments into the head end of the priming flow of canal water seems crude, but it has produced good results. Therefore, no pressing need for additional development work in this regard is visualized at the present time.

b. Follow-up procedures -- The follow-up procedures required to plug the leaky zones remaining after the initial priming operation have, to date, involved hand shoveling of Colorado bentonite as a blanketing material onto the suspected leakage zones. Several mechanized equipment methods of accomplishing this work have been considered. Additional development work, however, is needed to determine the best and most practical method. One method under consideration involves the use of compressed air to shoot dry granules of Wyoming bentonite into the ponded water above the suspected trouble zone.

c. Best time -- The best time for the sediment sealing activities is late in the summer after (1) the canal flows are small enough so that a ponding procedure of sediment sealing can conveniently be used, and (2) the groundwater level and the related inflows of water into the canals have receded to a minimum level and flow.

3. Evaluations -- The current meter measurements during the snow-melt and peak run-off period are useful in determining the peak flows of the west portal canals, but they are of little value for accurately determining the seepage loss in any given section of canal. Numerous inflows of surface and underground water upset the seepage loss determinations at this time. Thus, it is concluded that the weir measurements

late in the summer season provide the best method of accurately determining the canal seepage losses. A continuation of the weir measurements on the Connection Canal is needed to determine the (a) progress of the development work within any one season, and (b) rate of deterioration of the sealing effects from one season to the next.

4. Life of sealing effect -- Because of the pushing out or dislodging effect of the spring and early summer inflows of groundwater into the west portal canals, it seemed that the sediment sealing produced during the summer of 1956 could be damaged during the early part of the 1957 summer season. Some decrease in the sealing effects in the Connection Canal has been noted, but it does not seem to be a critical decrease. It may develop, however, that a periodic renewal of the sediment sealing is needed in some areas of the canals. It is believed that the air jet method offers a potential low-cost and fast method of accomplishing this maintenance work, as needed.

5. Applications in other similar canals -- In applying the results of this development work in other canals of similar nature, similar adaptation or fitting work will undoubtedly be required, if optimum sealing results are to be obtained. The persistence and ingenuity of the west portal construction crew has been an important contributing factor in the success, to date, of the Company's sedimenting work. It is anticipated that a similar type of persistence and enthusiasm will be required at other sites, if similar successful results are to be obtained.

TENTATIVE PLANS -- SUMMER 1958

The evaluation and development work in the coming summer season will be mainly restricted to activities in the Connection Canal. The details of the work involving Company construction or people remain to be worked out with Mr. Doe, and in addition, any major construction items will have to be cleared and approved by the Company's Board of Directors. The recommended work is briefly outlined below:

1. Check structures -- Two check structures are needed: one at the drop inlet structure into Lincoln Gulch Reservoir, and the other at about the mid-point in the Connection Canal. The mid-point structure should be located at the upper end of the pond formed by checking up at the lower structure. It would be very helpful if a semi-permanent type of structure (with center support sections removable during the spring high flow period) could be installed at both locations.

2. Recorder wells -- Three recorder wells are needed: one at each of the two structues mentioned above, and one at the check structure at the outlet of Tunnel 1. The wells should be located 20 to 30 feet upstream from the structures in which the weirs are to be located. Permanent type of well set-up, with galvanized pipe and concrete bottom, would be desirable.

3. Recorders -- Three recorders, one for each of the above weir locations, are needed. An effort is being made to obtain the recorders on a loan basis for the summer.

4. Water measuring -- Assuming that the above construction (or the approved portion thereof) is completed by August 1, 1958, a schedule of continuous weir measurements is planned -- under checking conditions as outlined below:

Period	Upper Weir	Middle Weir	Lower Weir
Aug. 1 to 7	2 check boards	1 check boards	1 check board in
Aug. 7 to 14	no change	2 " "	2 " " "
Aug. 14 to 21	" "	3 " "	3 " " "
Aug. 21 to 28	" "	4 " "	4 " " "

5. Leakage areas -- As the pond levels are progressively increased as outlined above, major canal seepage areas will be located in the adjacent area below the Connection Canal. This will provide a check on the efficiency of the previous sediment sealing at the successively greater ponding depths.

6. Equipment testing and development -- Several types of mixing equipment have been constructed by the University project this winter. In addition, it is our understanding that a company in Salida, Colorado has developed a mixer that they would like to test on the Connection Canal next summer. It is planned that the equipment testing will be started about August 28th. A self-contained and portable unit that could be hooked on behind a dump truck would be desirable. The testing will probably include the air jetting method of shooting the granulated Wyoming bentonite into the pond water above the suspect zones.

7. Miscellaneous data -- Information and data of the following types will be collected:

a. Wetted area data under each ponding condition.

b. Plan, profile and cross-sections of the canal.

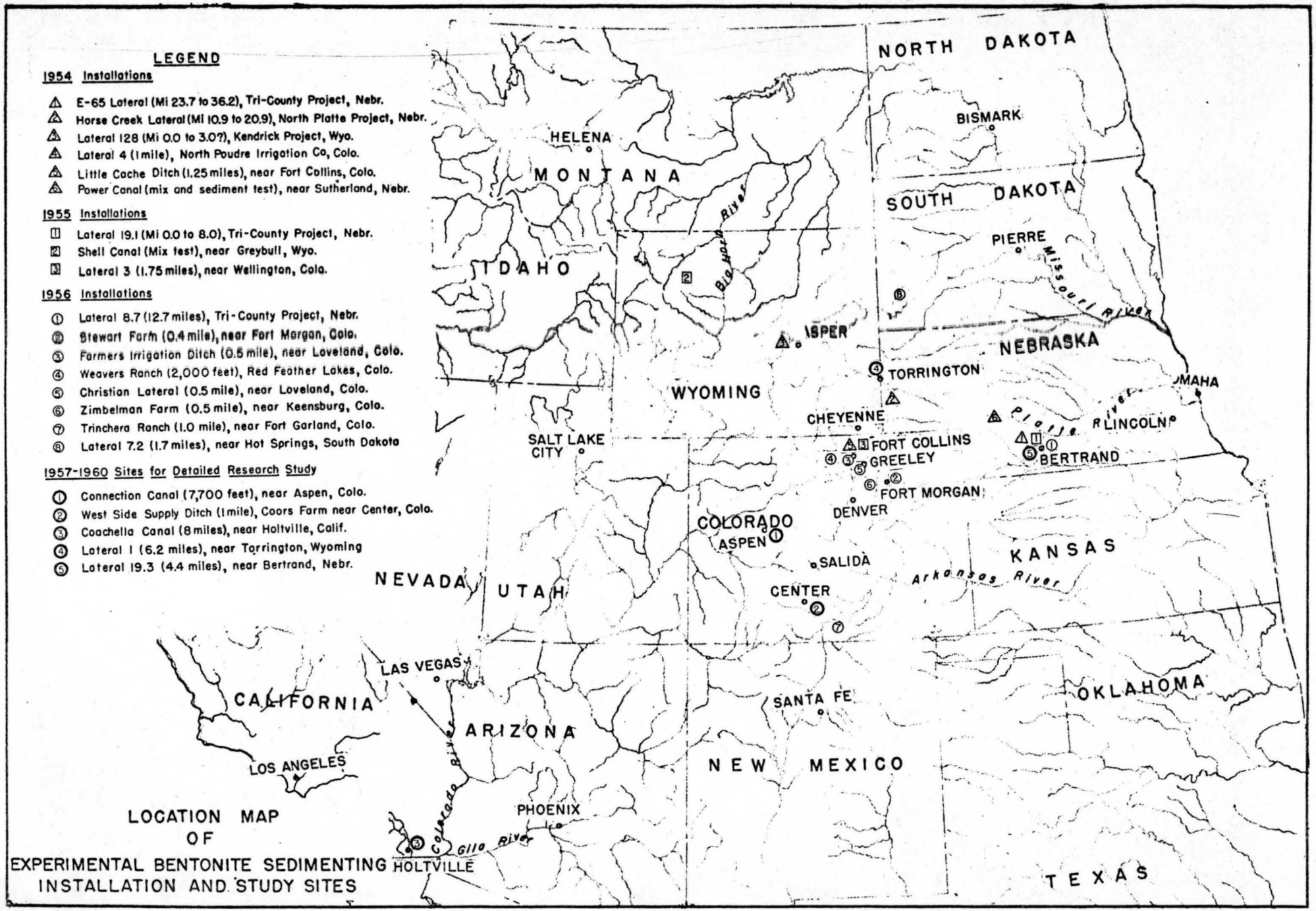
c. Detailed classification and map of canal bed materials in the Connection Canal.

d. Water quality data -- 1956 testing indicated almost no dissolved solids content but will test again, especially late in the summer.

e. Aerial photo coverage of area, if available from the U. S. Forest Service or other similar agency.

f. Photographic coverage of summer activities, including color movie story.

g. Location of major areas of groundwater inflow from above Connection Canal.



LOCATION MAP OF EXPERIMENTAL BENTONITE SEDIMENTING INSTALLATION AND STUDY SITES

Figure 1

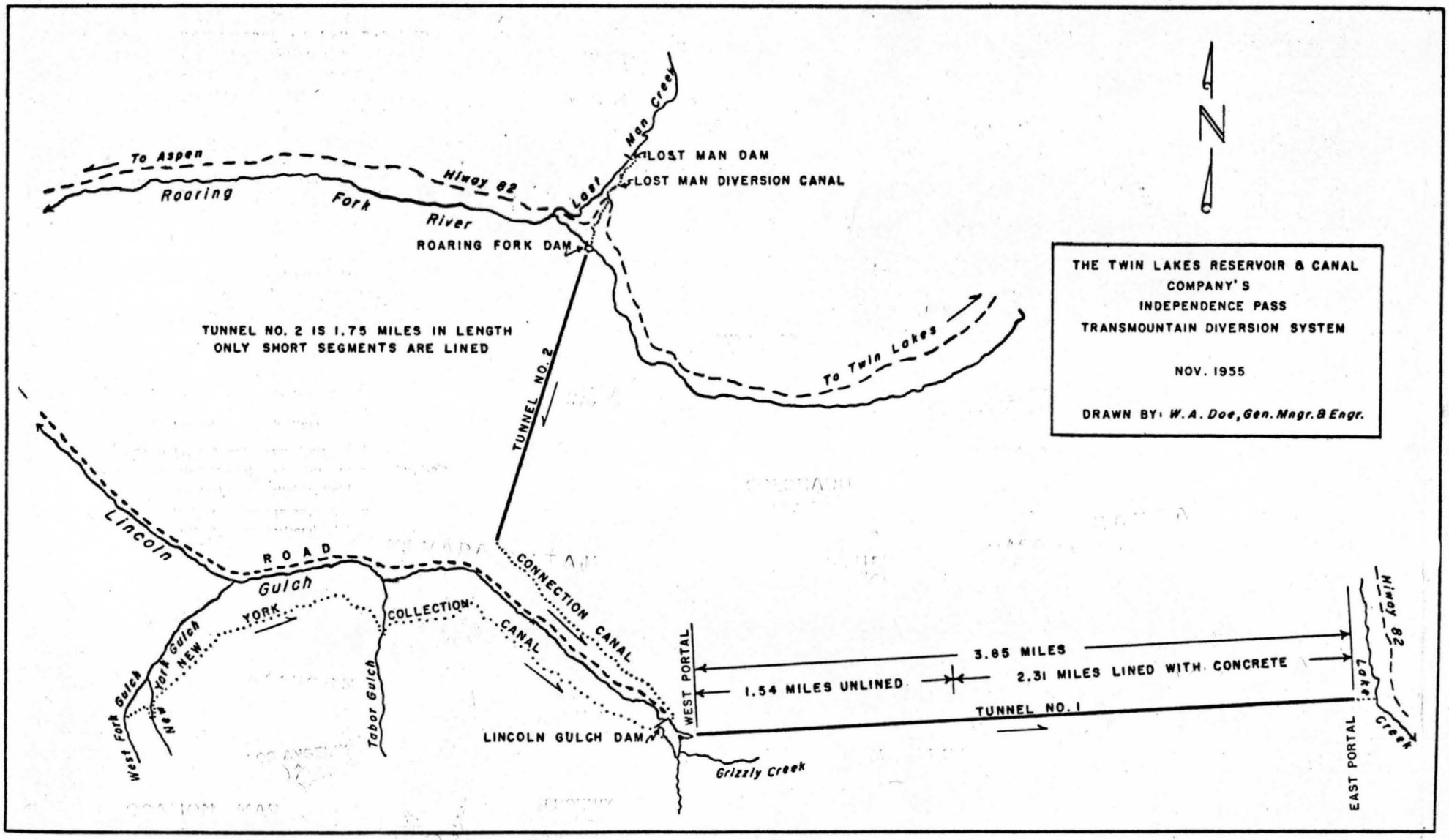

To Aspen
Roaring Fork River
Hiway 82
Lost Man Creek
LOST MAN DAM
LOST MAN DIVERSION CANAL
ROARING FORK DAM
TUNNEL NO. 2 IS 1.75 MILES IN LENGTH
ONLY SHORT SEGMENTS ARE LINED
TUNNEL NO. 2
To Twin Lakes
N
THE TWIN LAKES RESERVOIR & CANAL COMPANY'S
INDEPENDENCE PASS
TRANSMOUNTAIN DIVERSION SYSTEM
NOV. 1955
DRAWN BY: W. A. Doe, Gen. Mngr. & Engr.
Lincoln
ROAD
Gulch
YORK
COLLECTION
CANAL
CONNECTION CANAL
West Fork Gulch
York Gulch
NEW
Tabor Gulch
LINCOLN GULCH DAM
Grizzly Creek
WEST PORTAL
3.85 MILES
1.54 MILES UNLINED
2.31 MILES LINED WITH CONCRETE
TUNNEL NO. 1
EAST PORTAL
Lake
Hiway 82
Creek

Figure 2

APPENDIX

for

INTERIM REPORT

ON

BENTONITE SEDIMENT SEALING ACTIVITIES

OF

THE TWIN LAKES RESERVOIR AND CANAL COMPANY

NEAR

ASPEN, COLORADO

Colorado State University Experiment Station
Civil Engineering Section

April 1958

CONTENTS

APPENDIX

Enclosure 1

Proposal for Development of Sedimenting Procedures to fit Conditions in the Trans-Mountain System of The Twin Lakes Reservoir and Canal Company

Introduction

At the request of Mr. Wallace A. Doe, General Manager-Engineer, we made a trip to the company office at Ordway, Colorado on January 17th. We returned to Fort Collins on January 18th. The purposes of this trip were:

1. To obtain a general picture of the operating and seepage loss conditions in the Transmountain Diversion System of the Twin Lakes Reservoir and Canal Company;

2. To make recommendations concerning the development of sedimenting procedures to fit the diversion system conditions.

Because of snow conditions in the transmountain area, it was not possible to visit the diversion system. However, excellent background information was obtained in discussions with Messrs. Schroeder, Clinger, McConnel, Doak, and Pantle of the Board of Directors and with Mr. Doe. Mr. Hosig's consulting report and Mr. Doe's construction recommendations were carefully studied. The results of our past sediment lining work were outlined for Mr. Doe and the Board of Directors.

Conclusions and Recommendations

1. Since it was not possible to make detailed field examinations, the conclusions and recommendations that follow, of necessity, are quite general. Even after the initial field examinations are made, in many instances, exact procedures cannot be detailed -- for the following reasons:

a. The sedimenting method is still in a research stage of development;

b. At present, "trial and error" methods predominate during the adaptation required to fit the sedimenting procedures to the canal conditions.

2. While a fairly large background of experience on sedimenting is available, any sedimenting work in a new area is faced by some possibilities of "error". Therefore, it is recommended that development work in the collection system area be set up on a broad enough basis so that one failure won't stop appreciably or slow down the development work.

3. Past experience indicates that a low-cost sedimenting procedure can be developed to fit the collection canal conditions. A modified sedimenting procedure -- involving the use of local clays, silts, or sawdust in combination with bentonite -- probably will be required.

4. The following steps in the development program are recommended:

a. Purchase of bentonite -- 10 cars (50 tons each) of high-swell bentonite to be delivered at rate of one car per week starting June 1, 1956. Estimated cost -- $25.00 per ton (at Aspen) x 500 tons.
Total $ 12,500.00

b. Water measuring -- reasonably accurate system of water measuring is needed to guide the sedimenting development work. To set up the system -- one 2-week period in June by D. L. Bender. Supplement checks involving two 3-day periods -- one each in July and August. Estimated cost -- 128.00 per day plus expenses. Total $ 800.00

c. Development of procedures -- consultation help on setting up procedures and in finding supplemental sediments, if needed. One 7-day period at start of work -- other time as needed. Estimated cost -- $40.00 per day plus expenses. Total $ 700.00

d. Placement and mixing -- cost of labor, air compressor, bull dozer, trucking, etc., used to transport, place and mix the sedimenting materials. Estimated cost -- 500 tons at $10.00 per ton plus 300 tons of supplemental sediments (sawdust, local clay, etc.) at $15.00 per ton.
Total $ 9,500.00

e. Overhead and contingencies -- 1,500.00

Estimated Total $ 25,000.00

Respectfully submitted,

R. D. Dirmeyer, Jr.
Project Leader

Colorado [illegible] College
Fort Col[illegible] Colorado
January 26, 1956

Enclosure 2

Evaluation of Bentonite Samples Proposed for Sedimenting Use by The Twin Lakes Reservoir and Canal Co.

Introduction

At the request of Mr. W. A. Doe, General Manager and Engineer, Twin Lakes Reservoir and Canal Company, evaulation tests were performed on two Colorado bentonite samples; one from near Las Animas and the other one from near Salida.

For a comparison, the evaluation tests were also performed on five commercial Wyoming high-swell bentonites. The tests used are given in the University of Wyoming Natural Resource Research Institute Bulletin No. 2, August 1946, by H. G. Fisk, entitled, "Bentonite - With Test Methods and Results of Tests of Wyoming Bentonites".

The grit content is the per cent by weight of the bentonite which was retained on a 325-mesh screen (44 micron openings). Where the grit content was high, the per cent retained on the 200-mesh (74 micron openings) screen was also obtained.

The colloidal yield is the per cent by weight of the bentonite which is still in suspension after 18 hours.

Procedure

Sample Preparation

The bentonite samples are crushed to a maximum size of 1/8 inch and dried in a 105°C to 110°C oven for 12 hours. The dried bentonite is stored in closed containers so that it will not gain moisture.

Grit Determination

Twenty-five grams of bentonite are thoroughly dispersed in approximately 500 ml. of water. The suspension is washed through a 325-mesh screen. The grit remaining on the screen is dried in the oven and then weighed. The percentage of grit is computed on the basis of the weight of the original sample.

The procedure for finding the amount retained on the 200-mesh screen is similar to the precedure involving the 325-mesh screen.

Colloidal Yield

Ten grams of bentonite are thoroughly dispersed in 500 ml. of distilled water. The dispersed suspension is put into a tall graduate and allowed to stand for 18 hours. At the end of this period, the material in suspension is slowly siphoned or poured off the sediment. The sediment remaining in the graduate is washed into an evaporating dish and the water removed by drying. The dried weight of the sediment enables calculation of the colloidal material still in suspension.

Results

Name	% Retained 200-mesh	% Retained 325-mesh	Colloidal Yield	Moisture Content	Remarks
Royal Earth		2.38	87.8		
Benton Clay I		4.5	66.6		Drilling mud quality
Benton Clay II		5.5	60.4		Second quality
Benton Clay III		5.4	62.4		Unknown type (probably 2nd quality)
Volclay SPV		2.26	87.2		
Salida Clay	10.9	16.9	54.2	10.5	
Las Animas Clay I	3.75	5.5	72.4	4.6	Best of Las Animas samples-picked visually
Las Animas Clay II	6.65	10.9	55.5	4.6	Representative of all the Las Animas samples

Discussion

Both of the Colorado bentonite samples have considerably more grit and a somewhat lower colloidal yield than the Wyoming bentonites. However, the Las Animas I sample, which was from one part of the deposit, compares favorably with the Wyoming bentonites.

Usually the desirable properties for a sedimenting bentonite are a low grit content (which is waste) and a high colloidal yield.

If the bentonite is not a drilling mud quality bentonite, the moisture content must also be taken into consideration. In past sedimenting work the moisture content of bentonite has been limited to less than 10

per cent. Some pit-run bentonites run as high as 40 per cent moisture. Paying freight on excess moisture is, of course, something to be avoided.

Respectfully submitted,

Don Bender
Hydraulic Engineer
Sediment Lining Project

Colorado A and M College
Fort Collins, Colorado
January 27, 1956

Enclosure 3

GENERAL NOTICE

Quotations requested for 500 tons of high-grade (drilling mud quality or better) bentonite. Submit quotations (FOB Aspen, Colo.) on one or both of the following types:

a. Granular bentonite (max. size 1/2") in bulk (preferred)

b. Powdered bentonite in 100 pound sacks

Delivery point will be at Aspen, Colorado. Delivery to be made at the rate of two cars (50 tons) each week starting June 1, 1956. Train to Aspen twice weekly -- want one carload each trip. If trucks are used -- same delivery rate of 100 tons per week, starting June 1, 1956.

Suggested standards of quality are outlined below:

a.	Moisture	10% maximum
b.	Grit*	6% "
c.	Colloidal Yield*	60% minimum

* Tests outlined in "Bentonite, with test methods and results of tests of Wyoming bentonite" by H. G. Fisk, Bulletin No. 2, August 1946, Natural Resource Research Institute, Laramie, Wyoming.

Submit quotations to Mr. W. A. Doe, General Manager-Engineer, Twin Lakes Reservoir and Canal Company, Ordway, Colorado. Deadline date -- March 1, 1956. Include certification relating to quality of bentonite referred to in quotation.

Bentonite, high-grade (FOB Aspen, Colorado)	Quantity	Unit	Total
a. Granular	500 tons	_____	_____
b. Powdered	500 tons	_____	_____

Can meet delivery schedule Yes _____ No _____

Certification _____

_____

Enclosure 4

Colorado A and M College

7 April 1956

Mr. Wallace A. Doe
General Manager-Engineer
Twin Lakes Reservoir and Canal Co.
Ordway, Colorado

Dear Mr. Doe:

As requested by you, we examined the Lamberg clay deposit near Howard, Colorado on March 20, 1956. The deposit was sampled and the results of our laboratory testing are summarized in the inclosed table. The table includes analyses of a number of other materials -- for comparison purposes.

After an examination of canal site conditions, some of the following conclusions and recommendations may be changed -- but probably not to any great extent:

1) The Lambert clay -- as represented by our sampling -- has a much lower colloidal yield than the normal Wyoming bentonite.

2) Thus, it is recommended that the low quotation by the American Colloid Company of $22.31/ton be accepted. (After including the hauling cost from the railhead to the job, our original estimate of $25.00/ton will be very nearly correct.)

3) It would be well to require that they submit a sample of the bentonite to be furnished. This would give you a chance to check the material for conformance to specifications. We would be glad to do the testing for you at our normal rate of $10.00/sample.

4) In our January 25th report, it was recommended that about 300 tons of local materials be obtained. This would be used to seal the more open leaky zones in the canal bottom -- particularly those producing the larger leakage flows into gullies below the canal.

5) For this initial work involving a local clay, it is recommended that 300 tons of the Lamberg clay be ordered. To save money I suggest that you contact Mr. Lamberg regarding:

a. the cost of pit run material from a stock pile on the main highway below the deposit -- you would have to do the hauling from the stock pile;

b. the cost of pit run material delivered to the job.

6) The Lamberg price of $21.75/ton delivered includes hauling to their mill and grinding. By the time the material is mined and hauled it is likely that most of the material would pass a 1/2-inch screen. Actually, it wouldn't hurt if it did have some lumps. For the initial blanketing of trouble-spot areas, the lumps might be a help more than a hindrance. Thus, the grinding could be eliminated. I believe that you will find Mr. Lamberg very cooperative in any efforts to reduce the overall cost of their materials.

7) You mentioned the possibility of buying 300 tons of Wyoming bentonite and 200 tons of the Lamberg clay. This might be all right if you can get the lesser amounts at the same unit costs, but my own experience has shown that the bentonite requirements are usually under-estimated rather than over-estimated. Thus, the reason for recommending the purchase of:

a. 500 tons Wyoming bentonite

b. 300 tons Lamberg clay.

Thanks again for your help and cooperation. If there are additional questions or if I can be of additional help, please let me know.

Sincerely,

R. D. Dirmeyer, Jr.
Project Leader
Sediment Lining Project

RDD/bn/351

Enclosures: 2

Table of
Laboratory Test Results (1)

Source of Sample	Grit Content (2) %	Colloidal Yield (2) %	Remarks
Commercial Bentonites			
Royal Earth Co.	2.7	86.4	
Eastern Clay Products	3.3	83.1	
American Colloid Co.	3.4	86.7	
Black Hills Bentonite Co.	4.5	81.3	
Benton Clay Co.	4.8	65.6	
		66.1	with 5% dispersant
Wyo Ben Products Co.	6.3	79.1	at normal test concentration grit did not settle--had to dilute.
Local Clays			
Lamberg #1	10.9	54.2	moisture 10.5%
Lamberg #2	10.4	12.4	obtained 3-20-56
		25.6	with 5% dispersant
Lamberg #3	9.4	9.1	obtained 3-20-56
Peach Valley	18.8	8.6	8 mi. S. of Austin, Colo.
Crawford	4.7	1.5	near Crawford, Colo.
		73.9	with 5% dispersant
Fire Mtn. #1	28.7	0.8	red clay
Fire Mtn. #2	44.5	0	red clay
Fire Mtn. #3	37.8	1.0	red clay
Ft. Lyon #1	23.5	68.5	sediment sample 3-19 with 5% dispersant
Ft. Lyon #2	33.3	.8	with 5% dispersant - flood deposit
Ft. Lyon #3	35.0	.6	with 5% dispersant - flood deposit

(1) Testing by D. L. Bender
(2) Test procedures outlined in Wyoming Natural Resource Institute Bulletin No. 2, by H. G. Fisk

Enclosure 5

Evaluation Report of Sedimenting Possibilities for The Twin Lakes Reservoir and Canal Company

by R. D. Dirmeyer, Jr., May 28, 1956

Introduction

At the request of Mr. Wallace A. Doe, General Manager-Engineer of the Twin Lakes Reservoir and Canal Company, I visited the west portal area of the Company's Transmountain Diversion System during the period of May 24 through May 27, 1956.

Persons contacted on the visit include: Messrs. Clinger, Schroeder, Pantle and McConnell of the Board of Directors, and Messrs. Doe, Peters and Kaufman of the Company's operating force.

The purposes of the trip were:

1) To obtain a general picture of the operational and seepage loss conditions of (a) the Connection Canal (Tunnel #2 to Lincoln Gulch Dam), (b) the Collection Canal (West Fork Gulch to Lincoln Gulch Dam), and (c) the Lost Man Diversion Canal (Lost Man Dam to Tunnel #2).

2) To make recommendations concerning the development of sedimenting procedures to fit the conditions found.

General Considerations

A major program of improvements in the Company's west slope collection system was started in the summer of 1955. The improvements have included: (1) cleaning, enlargement, and partial realignment of canals, (2) construction of canal bank roads, and (3) installation of corrugated metal pipe in unstable areas.

Because of the coarse rocky nature of most of the canal bed materials, significant seepage losses occur. Under peak flow conditions, extensive seepage areas appear below the canals. On the other extreme, small flows will not carry all the way through the canals. Thus, in addition to the water saving benefits, canal linings would also lengthen the water running period each year. If it was possible to maintain small winter flows in the canals, it also could eliminate a large part of the work now needed to open the canals each spring.

If cost was of no concern, metal or concrete pipe would be an entirely adequate answer to the canal lining problem. Because of the cost, however, a compromise is necessary. Metal pipe is being placed in the unstable areas of the canals; sediment linings are being developed for the pervious but more stable reaches of canal.

Since the improvement program is progressing so well, the need for fitting the sediment lining development procedures to the existing conditions becomes all the more important. Because of the very open nature of the canal bed materials, special sediment lining methods are needed, but it seems that a large part of this preliminary development work can be accomplished between now and the middle of July or before the major construction activities begin.

Conclusions and Recommendations

1) Selection of site -- After talking with Mr. Doe, it was decided that the main sedimenting effort will be concentrated on the Connection Canal. This work will be done after the peak flow period or probably during August. However, before that time, small trial runs will be needed to develop procedures to fit the unusual conditions found in the canals of the west slope collection canal system.

2) Seepage losses -- Mr. Hosig's consulting report provides excellent basic data on the seepage loss conditions in the Collection System canals, but since his flow measurements were made during a period of medium to low flows, additional flow measuring work is being accomplished this year under peak to medium flow conditions. The results of Mr. Bender's present seepage loss measurement work will be covered in a separate report. It seems likely that water measurements will be made at the following locations:

a) Outlet of Tunnel #2
b) Bridge over Connection Canal at Lincoln Gulch Dam
c) Inlet of Collection Canal into Lincoln Gulch Dam
d) Inflow from Tabor Gulch
e) Inflow from New York Gulch
f) Inflow from West Fork Gulch
g) Flow in Lincoln Gulch below outlet of Tunnel #2

3) Trial runs -- The following sequence of sedimenting materials may be necessary to produce a satisfactory sealing effect through the worst leakage zones of the canal bed materials:

a) First -- sawdust
b) Second -- Salida bentonite
c) Third -- Wyoming bentonite

Development work with sawdust has been started. It is believed that most of the worst zones can be controlled with a sawdust sediment -- at least to a point where clay sediments could finish the job. As soon as the clay is available on the job, it is recommended that trial run work be started with both the Salida and Wyoming bentonites -- similar to present work with sawdust. If possible this preliminary work should be completed by August 1, 1956.

4) Procedures for major sedimenting run -- Because of the severe leakage problems found in the Company's west slope collection system, it is not possible at this time to outline in detail the best sedimenting procedures. The results of the trial run work should be incorporated in the procedures.

Enclosure 6

Excerpt from October 12, 1956 Report by P. R. McOllough

WATER MEASUREMENT PHASE

As an initial step toward water measurement, gaging stations were installed on all canals. During the week of June 11, 1956, Mr. Donald Bender, Hydraulic Engineer, Colorado A and M College assisted me in locating and installing gaging stations in all of the canals.

Purpose

The gaging stations were installed for the purpose of:

1. Determining peak production of all canals and creeks flowing into Lincoln Gulch Reservoir.
2. Determining water losses prior to future sedimenting.
3. Evaluating bentonite sedimenting procedure.
4. Aiding water measurement in the future.

Gaging Stations

The following is a list of the gaging stations and their locations:

Station No. 1 -- Located at the headend of the connection canal and about 100 ft below the check structure at Tunnel No. 2 outlet. The staff gage for this station is located approximately 10 ft upstream from the check. Mr. Bender used the northernmost staff gage for his current-meter measurements (May, 1956). This same gage was used for the low-flow weir measurements. The weir crest elevation corresponds with a reading of 0.50 on this staff gage.

Station No. 2 -- Located near the outlet of the connection canal on the upstream end of the concrete chute. The staff gage was located in the chute under the bridge. Later this summer after consulting with Mr. Dirmeyer, it was decided that this gage position was unfavorable and the gage was reinstalled approximately 20 ft upstream from the concrete

chute. It is attached to two logs spanning the canal at a new station which may be used for future water measuring. Mr. Bender's current-meter measurements (May, 1956) were made using the staff gage under the bridge at the Connection Canal Outlet. The low-flow weir measurements were made using the relocated staff gage (20 ft upstream from bridge). The weir crest elevation corresponds with a reading of 0.62 on this staff gage.

Station No. 3 -- Located on the collection canal below the Tabor Gulch and immediately above the concrete wasteway. The gage for this station is located on the downstream end of the concrete wasteway.

Station No. 4 -- Located at the lower end of the collection canal approximately opposite the point where the road crossing Lincoln Gulch Dam joins the canal road. The gage for this station is attached to a two-by-four directly downstream from the three-by-twelve spanning the canal.

Station No. 5 -- Located approximately opposite the outlet of Tunnel No. 2 on Lincoln Creek. This station was used by Mr. Bender once and no gage was installed. No other measurements were made at this station.

Station No. 6 -- Located approximately 100 ft upstream from 72-in. pipe near Tabor Gulch. The staff gage for this station is located on a two-by four attached to the three-by twelve spanning the canal.

Station No. 7 -- Located approximately 800 ft below New York Gulch on the collection canal. The gage is attached to a two-by-four directly downstream from the station.

Station No. 8 -- Is a rectangular contracted weir located on Grizzley Creek immediately below the Superintendent's home. The length of this weir is 10.78 ft. A rating curve for this weir is included in the latter part of this report.

Station No. 9 -- Located approximately 50 ft upstream from West Fork wasteway. A staff gage is located in the pond directly upstream from the station. This station was rated before any water was diverted to the West Fork Canal.

Summary of Water Measurements

Station	Date	Time	Flow	Gage Height	Method	Typical Depths			Remarks
						78.8	80	89	
No. 1	5/27	2:30am	154	2.65	.2-.8	1.85	2.3	4.4	
Outlet	5/28	10:30am	119	2.40	.2-.8	1.6	2.15	4.1	
of	5/28	3:30pm	170	2.85	.6	1.95	2.50	4.5	
Tunnel	5/29	4:00pm	245	3.65	.6		3.3	5.3	
#2	5/30	9:15am	214	3.35	.6	2.75	3.05	4.95	
	5/30	7:50pm	291	4.25	.6	3.55	4.0	5.8	Steady
	5/31	8:45am	263	3.80	.2-.8	3.2	3.6	5.4	Fairly Steady
	5/31	5:25pm	290	4.25	.2-.8	3.6	4.0	5.8	
									By D.B.
No. 2	5/27	4:00pm	144	2.7	.2-.8	2.80			
Outlet	5/28	1:30pm	131	2.45	.2-.8	2.60			Depth somewhat high
Connection									
Canal	5/28	3:45pm	156	2.80	.6	2.80			
	5/29	4:50pm	234	3.5	.6	3.8			
	5/30	10:00am	195	3.1	.6	3.35			
	5/30	11:30am	169	3.0	.2-.8	3.0			
	5/30	8:50pm	267	3.75	.6	4.1			Steady
	5/31	10:15am	223	3.4	.2-.8	3.75			Steady
	5/31	6:35pm	293	3.85	.6	4.2			
									By D.B.
Lincoln Creek	5/31	2:30pm	21						
									By D.B.
No. 9	6/15	9:25am	25.31	3.95	.2-.8				
	6/18	1:10pm	26.25	4.20	.2-.8				
	6/18	4:20pm	28.72	4.39	.2-.8				
									By P.R.M.
No. 7	6/16	9:50am	13.84	1.60	.2-.8				
	6/18	10:10am	23.89	2.02	.2-.8				
	6/18	3:15pm	34.28	2.20	.2-.8				
									By P.R.M.

Station	Date	Time	Flow	Height	Method	Typical Depths			Remarks
						78.8	80	89	
No. 6	6/14	2:10pm	15.03	2.37	.2-.8				
	6/19	3:15pm	19.38	2.59	.2-.8				
	6/19	4:50pm	20.39	2.60	.2-.8				
	6/20	9:30am	15.22	2.45	.2-.8				
									By P.R.M.
No. 8	6/26	8:30am	11.1	0.47	Weir				
	6/26	9:00am	11.1	0.47	"				
	6/26	9:30am	11.1	0.47	"				
	6/26	10:25am	10.7	0.46	"				
	6/26	11:45am	11.1	0.47	"				
	6/26	1:10pm	11.6	0.48	"				
	6/26	2:20pm	12.5	0.50	"				
	6/26	3:00pm	12.8	0.51	"				
	6/26	4:00pm	13.7	0.53	"				
	6/26	5:00pm	15.0	0.56	"				
									By P.R.M.
No. 4			40.78	1.75	.2-.8				
			33.23	1.51	.2-.8				
			26.91	1.18	.2-.8				
			32.96	1.50	.2-.8				
			54.16	2.0	.2-.8				
									By D.B.

CONCLUSIONS

Water Measurement

The 1956 probable peak flows are tabulated below:

	Peak Flow	Date
Connection	293*	5/31/56
New York Collection	54	
Lincoln Gulch	21	5/31/56

*For peak loss determinations on the Connection Canal see D. L. Bender's Report (June 9, 1956).

1. The peak capacity of the New York Collection Canal between New York Gulch and Tabor Gulch was 36 cfs.

2. The peak water loss on the New York Collection Canal between New York and Tabor Gulches was determined to be approximately 44 per cent.

3. West Fork Gulch water was not diverted until June 9, 1956 due to the inadequate capacity of the New York Collection Canal between New York and Tabor Gulch.

4. The peak water losses on the New York Collection Canal between Tabor and Lincoln Gulches are high. At this time no definite loss value can be assigned, however, it is estimated that the loss ranges from 30 to 40 per cent.

RECOMMENDATIONS

Water Measurement

It is recommended that:

1. Concrete rating sections and water stage recorders be installed in:

   a. The Connection Canal below the concrete check at Tunnel No. 3 outlet and at the outlet of the canal.

b. The Collection Canal near Lincoln Gulch Dam and immediately below Tabor Gulch.

2. A Parshall flume and water recorder be installed in Grizzley Creek.

3. A timber, check-type rating station be installed in Lincoln Gulch above the reservoir. This installation also should include a water-stage recorder.

4. Water measuring be continued to secure more accurate and complete ratings.

Enclosure 7

COLORADO A and M COLLEGE
Civil Engineering Department

REPORT
OF
SEDIMENT LINING ACTIVITIES
DURING
SUMMER OF 1956

in

Connection Canal
Trans-Mountain Canal System
The Twin Lakes Reservoir and Canal Company

by
R. D. Dirmeyer, Jr.
Project Leader
Sediment Lining Project

Fort Collins, Colorado

October 16, 1956

REPORT OF SEDIMENT LINING ACTIVITIES DURING SUMMER OF 1956

Introduction

At the request of Mr. Wallace A. Doe, General Manager-Engineer of The Twin Lakes Reservoir and Canal Company, I visited the west portal area of the Company's trans-mountain diversion system during the period of July 23rd through August 1, 1956.

The major purpose of the trip was to assist Messrs. Peters and McOllough in starting the work required to develop practical sedimenting methods of sealing the very pervious bed materials of the Connection Canal. Since this initial work, additional information in regard to the subsequent development work has been obtained from Messrs. Doe, Peters and McOllough. The primary purpose of this report is to summarize the results of the development work completed during the summer of 1956 and to offer recommendations and suggestions relative to future sedimenting work in the trans-mountain diversion system.

General Considerations

During the past two summers the Company has been enlarging and sealing the west portal canals. Except in unstable ground where metal pipe probably will be installed, a low-cost method of sedimenting is being developed to accomplish the sealing. For best results from sedimenting, some development work will be needed in any canal system. In the west portal canals the development work has been complicated by the following factors:

1. Coarse rocky nature of canal bed materials. -- plugging of relatively large holes is necessary.

2. In-flow of ground water from above canal.-- during the spring run-off the seepage conditions, and of consequence the canal sealing problems, are quite different than those later in the summer.

The initial sedimenting trials were made on the Connection Canal between the outlet of Tunnel No. 2 and Lincoln Gulch Dam. The canal is about 7,700 feet long (from outlet of Tunnel 2 to Lincoln Gulch Dam) and has a design capacity of 350 cfs.

Water Measuring

In the development of sedimenting procedures, inflow-outflow water measurements are the "yard stick" used to guide the work in the canal reach being sealed. Since the initial sedimenting work on the Connection Canal was started after the peak run-off period, the flows were relatively small and were measured with temporary weirs. The weir structures at each end of the Connection Canal were also utilized as check structuresso that the water could be controlled and ponded during the trial sedimenting runs.

Sedimenting Operation

The sedimenting trial work is outlined in detail in Mr. P. R. McOllough's report for the summer. The work is summarized in this report.

Five hundred tons of high-swell bentonite and three hundred tons of low-swell Colorado bentonite were purchased for the sedimenting work by the Company. Two trial runs were made: the first from July 28th to August 5th, and second from August 23rd to September 1st. In the first run, about fifty tons of bentonite were placed in the canal just below Tunnel No. 2. In the second run, about one hundred and fifty tons wereplaced at eight different locations in the canal and near the major seepage areas.

Various mixing methods were used. Since many of the leaks in the canal bed materials are apparently quite large, the main purpose of the initial runs was to produce lumpy mixes -- with the hope that the larger voids would be plugged by the bentonite lumps. This was accomplished by placing the bentonite in dams, allowing the water to pond until the dam was overtopped, and then helping to wash-out the bentonite dams by working a backhoe bucket in the break. Compressed air jetting was also tried.

The resulting bentonite mixes were ponded -- both by bentonite dams and at the lower end by a temporary check structure. The bentonite sedimenting was accomplished during the ponding intervals.

In addition to the sedimenting work, about fifty tons of the Colorado bentonite was used for blanketing of the downhill side slope area in the canal from about Station 34+00 to 77+00.

Results

From July 27th until July 31st, the inflow in the Connection Canal varied from a minimum of 10.1 cfs to a maximum of 12.9 cfs. The losses

in the canal during this same period varied from 4.0 cfs to 6.2 cfs. After the first trial the losses varied from 2.1 cfs to 2.8 cfs with an inflow of 8.9 cfs to 10.1 cfs. Thus, as a result of the first trial run, the losses were roughly cut in half.

Just before the second trial (about three weeks after first trial) the losses varied from 1.1 cfs to 1.4 cfs with an inflow of 7.4 cfs to 7.7 cfs. After the second trial, the losses varied from 0.7 cfs to 1.2 cfs with an inflow of 3.8 cfs to 4.2 cfs.

According to Mr. Peters, in previous years a flow of 6 cfs or less would not run all the way through -- in most cases not more than 1,000 feet downstream from the tunnel.

Conclusions and Recommendations

1. Water measuring -- Sufficient current meter and weir measurements were made during the past summer to indicate the general magnitude of losses. Systematic and close-spaced readings -- with some water-stage recorder stations -- are needed. However, if accurate seasonal delivery and loss figures are to be obtained for the west portal canals, it is recommended that a full-time hydrographer be hired or arranged for -- see cover letter in regard to later possibility.

2. Mixing -- The backhoe and compressed air jetting methods of mixing satisfactorily served their purpose during the initial trial work, but in the future work the use of multiple jet mixer is recommended. This type of mixer could be used to produce both lumpy and lump-free mixtures. It is recommended that an experienced mixing contractor be employed for this work -- at least for the work next summer.

3. Future sedimenting work -- Good results were obtained from the initial sedimenting trials with bentonite alone. The major problem now narrows down to one of finding a local silt or clay material (or sawdust) that can be used to plug the larger holes or voids in the canal bed materials. The mud deposit formed in the lake by Grizzly Creek probably will be satisfactory, but it probably cannot be worked when the lake is up. It is recommended that the work next summer be accomplished:

   a. Connection Canal -- A silting with lake silt (or substitute material) is needed -- preferably as the canal is opened-up next spring. The stationing and loads used in the second (1956) sedimenting -- this time with lake silt -- is recommended. This is needed to plug the larger holes and at the same time provide some protection for the bentonite placed by the sedimenting work during the past summer. Depending

on the indications from loss measurements, a follow-up bentonite sedimenting may be needed.

b. Collection Canal -- If possible, it would be helpful to determine the losses in the section of this canal from Tabor Gulch to the dam before doing any silting or sedimenting. After the initial water measuring, it is recommended that the Collection Canal be silted with a local silty to clayey material. The material at New York Gulch could be tried first. While this material is saturated with water in the spring, it could be easily jetted and washed into the canal. Stability of the slopes will be a problem, but this probably could be controlled by watching the slopes very carefully and by spreading out the jetting. Jetting a big excavation at one spot should be avoided. A follow-up sedimenting with bentonite will probably be needed to obtain a maximum sealing effect.

Enclosure 8

Excerpt from October 12, 1956 Report by P. R. McOllough

BENTONITE SEDIMENTING PHASE

During the summer of 1956 the Twin Lakes Reservoir and Canal Company purchased 800 tons of bentonite clay for the purpose of lining their canals in order to reduce the seepage losses and thus make more water available for storage and irrigation. Five hundred tons of a high-swell Wyoming bentonite (American Colloid Company) were hauled from the rail center at Aspen, Colorado, while an additional three hundred tons of low-swell Colorado bentonite (Lamberg and Sons) were delivered to the West Portal.

The Connection Canal was selected for the initial trial sedimenting run. Working in cooperation with Mr. R. D. Dirmeyer, consultant from Colorado A and M College, plans were formulated for the preliminary sedimenting run. The purpose of the preliminary sedimenting run was to work out an acceptable routine procedure which would produce good results in future sedimenting runs. Approximately 90 tons of bentonite were used for the preliminary sedimenting run and an additional 150 tons were used in the second sedimenting run.

Measuring Stations

In order to determine the water losses in the Connection Canal prior to the application of bentonite clay, two low-flow measuring stations were established. The two stations are described below: Station No. 1 -- Measuring Station No. 1 was relocated in the center opening of the concrete check just below the Tunnel No. 2 outlet. The two side openings of the check were closed with check boards and water proofed by a tar paper and bentonite. The measuring device used at this station was a 5'-0" sharp crested, rectangular contracted weir. The weir was placed with considerable care and the crest elevation was located on the northern-most staff gage. This particular weir was designed to measure a maximum flow of 12 cfs. Station No. 2 -- This station is located at the bridge crossing the Connection Canal outlet into the reservoir. Again, a 5'-0" rectangular contracted weir was installed to measure the amount of water flowing out of the Connection Canal into the reservoir. The weir was placed in a check-type structure which had been waterproofed by means of tar paper and bentonite. The staff gage for this weir is located approximately 20 ft upstream from the bridge.

Water Loss Measurements on the Connection Canal Prior to Preliminary Sedimenting Run

Prior to the application of the bentonite clay to the Connection Canal, the losses were determined for a five-day period. The losses are outlined on the following pages:

July 27, 1956

Station	Gage Height	Flow	Time	Loss	Per Cent Loss
No. 2	0.51 ft	6.0 cfs	1:20pm	4.58 cfs	43.4
No. 1	0.76	10.58	1:30pm		
No. 1	0.76	10.60	2:00pm	4.60	43.5
No. 2	0.51	6.0	2:10pm		
No. 2	0.52	6.1	3:00pm	4.80	44.0
No. 1	0.77	10.9	3:10pm		
No. 1	0.77	10.9	3.55pm	4.80	44.0
No. 2	0.52	6.1	4:10pm		
No. 2	0.52	6.1	4:55pm	4.80	44.0
No. 1	0.77	10.9	5:05pm		
No. 2	0.52	6.1	6:00pm	4.50	42.5
No. 1	0.76	10.6	6:05pm		
No. 2	0.50	5.8	8:10pm	4.70	44.8
No. 1	0.75	10.5	8:20pm		
No. 2	0.49	5.6	9:30pm	4.90	45.6
No. 1	0.75	10.5	9:40pm		
		10.63 cfs	average inflow	4.71 cfs	average loss

Weather

Max. Temp. . . . .77°F.
Min. Temp. . . . .36°F.
Total Precipitation . . . .Trace

July 28, 1956

Station	Gage Height	Flow	Time	Loss	Per Cent Loss
No. 2	0.49 ft	5.6 cfs	9:15am	5.0 cfs	47.2
No. 1	0.76	10.6	9:25am		
No. 2	0.50	5.8	1:10pm	4.7	44.8
No. 1	0.75	10.5	1:15pm		
No. 2	0.49	5.6	4:00pm	4.5	44.5
No. 1	0.73	10.1	4:05pm		
No. 2	0.48	5.4	5:45pm	4.9	47.5
No. 1	0.74	10.3	6:00pm		
No. 2	0.49	5.6	9:00pm	5.3	48.7
No. 1	0.77	10.9	9:10pm		
No. 1	0.85	12.9	11:00pm	6.2	52.0
No. 2	0.55	6.7	11:07pm		
		10.88 cfs	average inflow	5.1 cfs	average loss

Weather

Max. Temp. . . . .74°F.
Min. Temp. . . . .37°F.
Total Precipitation . . . .0.08 in.
Hours and times of precipitation . . . .3 hr, from 2:00 pm to 5:00 pm.

July 29, 1956

Station	Gage Height	Flow	Time	Loss	Per Cent Loss
No. 2	0.59 ft	7.4 cfs	8:55am	4.60 cfs	38.4
No. 1	0.82	12.0	9:05am		
No. 1	0.82	12.0	10:30am	4.60	38.4
No. 2	0.59	7.4	11:15am		
No. 1	0.79	11.3	2:50pm	4.60	40.8
No. 2	0.55	6.7	3:00pm		
No. 2	0.58	7.0	10:00pm	5.90	45.8
No. 1	0.86	12.9	10:20pm		
		12.05 cfs	average inflow	4.92 cfs	average loss

Weather

Max. Temp. . . . .73°F.
Min. Temp. . . . .36°F.
Total Precipitation . . . .0.05 in.
Hours and Times of Precipitation . . .2 hrs, 3:00pm to 5:00 pm.

July 30, 1956

Station	Gage Height	Flow	Time	Loss	Per Cent Loss
No. 2	0.62 ft	7.9 cfs	9:05am	4.20 cfs	34.8
No. 1	0.83	12.1	9:20am		
No. 2	0.62	7.9	10:30am	4.10	34.1
No. 1	0.82	12.0	10:40am		
No. 2	0.63	8.2	11:30am	3.90	32.2
No. 1	0.83	12.1	11:40am		
No. 2	0.62	7.9	1:20pm	4.20	34.8
No. 1	0.83	12.1	1:30pm		
No. 1	0.81	11.9	2:50pm	4.00	33.6
No. 2	0.62	7.9	3:00pm		
No. 2	0.62	7.9	4:30pm	4.80	37.8
No. 1	0.85	12.7	4:37pm		
No. 1	0.86	12.9	7:40pm	4.40	34.1
No. 2	0.65	8.5	7:45		
		12.25 cfs	average inflow	4.23 cfs	average loss

Weather

Max. Temp. . . . .78°F.
Min. Temp. . . . .38°F.

Total Precipitation . . . .0.81 in.
Hours and Times of Precipitation . . . 4½ hrs.
1:00pm to 5:30pm

July 31, 1956

Station	Gage Height	Flow	Time	Loss	Per Cent Loss
No. 2	0.67 ft	8.9 cfs	9:15am	4.0 cfs	31.0
No. 1	0.86	12.9	9:40am		
No. 2	0.67	8.9	10:30am	1.9	17.6
No. 1	0.76	10.8	10:40am		
Probably an error in reading -- disregard					
No. 2	0.65	8.5	12:10pm	3.9	31.4
No. 1	0.84	12.4	12:20pm		
		12:03 cfs	average inflow	3.26 cfs	average loss

Weather

Max. Temp. . . . .70°F.
Min. Temp. . . . .40°F.

Total Precipitation . . . .0.28 in.
Hours and Times of Precipitation . . . 9½ hrs.
7:00am to 4:30pm.

Preliminary Sedimenting Procedure

The following step-by-step procedure was used for the preliminary sedimenting run in the Connection Canal.

1. Approximately fifty tons of Wyoming bentonite clay were dumped in the Connection Canal below the concrete check at Tunnel No. 2 outlet.

2. Checkboards were placed in the concrete check in order to dry up the channel below the check.

3. Eight tons of the bentonite clay were used to construct a dam in the canal approximately 100 ft downstream from the check.

4. The remaining forty-two tons of bentonite clay were spread in the channel between the check and the dam.

5. The bentonite blanket between the check and the dam was then mixed for a period of one and one-half hours using the air compressor and the company backhoe.

6. The checkboards were then removed and the water which had been stored above the check during the one and one-half hour period was allowed to over-top and erode the bentonite dam.

7. The west bank of the Connection Canal was blanketed with 40 tons of Salida bentonite clay from Station 34+00 to Station 76+92.5.

By following the above procedure a milky flow of water was run down the canal. Chunks of unmixed bentonite which were carried downstream tended to fill the larger voids in the channel for a distance of approximately 200 ft. As the milky water approached the No. 2 check at the outlet of the canal, checkboards were placed to a depth of four feet and the water was allowed to store in the channel until it was evident that the majority of the bentonite mixture had been used up.

After checking the canal to a depth of 4.3 ft, no water was spilled into Lincoln Gulch Reservoir. All of the water flowing into the canal was lost mainly through seepage. During this checking period numerous leaky zones were located and marked on the west bank of the canal. It was observed that several of the leaks were flowing milky water while others were flowing clear water. The clear water leaks indicated that the bentonite particles were retained in the channel subsurface. The milky water leaks indicated that larger sediment particles were needed to bridge over and plug the leaks.

After the milky water had been allowed to stand for several days the canal was drained and normal flow conditions were restored. Weirs at measuring stations one and two were repaired and rechecked. After draining the canal it was observed that bentonite clay had been deposited in the channel and side slopes of the canal. This layered deposit was evident throughout the length of the canal. Of more importance is the bentonite that had penetrated into the canal bed materials and which could not be seen.

Water Loss Measurements After Preliminary Sedimenting of Connection Canal

On August 5, 1956, the loss studies were resumed to evaluate the preliminary sedimenting procedure. The results are outlined:

August 5, 1956

Station	Gage Height	Flow	Time	Loss	Per Cent Loss
No. 1	0.73 ft	10.1 cfs	8:50am	2.60 cfs	25.8
No. 2	0.60	7.5	9:05am		
No. 2	0.59	7.4	9:55am	2.70	26.7
No. 1	0.73	10.1	10:08am		
No. 1	0.73	10.1	10:30am	2.70	26.7
No. 2	0.59	7.4	10:40am		
No. 2	0.61	7.8	11:30am	2.30	22.8
No. 1	0.73	10.1	11:40am		
No. 2	0.60	7.6	1:45pm	2.30	23.3
No. 1	0.72	9.9	2:00pm		
No. 2	0.60	7.6	3:10pm	2.10	23.1
No. 1	0.71	9.7	3:20pm		
No. 1	0.68	9.1	5:35pm	2.10	23.1
No. 2	0.57	7.0	5:45pm		
No. 2	0.52	6.1	9:30pm	2.80	31.5
No. 1	0.67	8.9	9:40pm		
		9.87 cfs	average inflow	2.45 cfs	average loss

Weather

Max. Temp. . . . .70°F.
Min. Temp. . . . .36°F. Total Precipitation . . . .0.0 in.

On August 23, 1956 before additional bentonite was placed in the Connection Canal, new loss measurements were conducted. These measurements were necessary because the canal stage had changed since the preliminary loss measurements were taken. The losses are tabulated below:

August 23, 1956

Station	Gage Height	Flow	Time	Loss
No. 2	2.15 ft	6.3 cfs	9:37am	1.4 cfs
No. 1	1.11	7.7	9:45am	
No. 1	1.11	7.7	10:00am	1.4
No. 2	2.15	6.3	10:10am	
No. 2	2.15	6.3	10:36am	1.4
No. 1	1.11	7.7	10:45am	
No. 1	1.11	7.7	11:06am	1.4
No. 2	2.15	6.3	11:13am	
No. 2	2.15	6.3	1:50pm	1.3
No. 1	1.10	7.6	2:05pm	
No. 1	1.10	7.6	2:30pm	1.3
No. 2	2.15	6.3	2:40pm	
No. 2	2.15	6.3	3:45pm	1.1
No. 1	1.09	7.4	4:00pm	
No. 1	1.09	7.4	4:25pm	1.2
No. 2	2.14	6.2	4:40pm	
No. 2	2.14	6.2	9:12pm	1.2
No. 1	1.09	7.4	9:22pm	
		7.57 cfs average inflow		1.2 cfs average loss

Weather

Max. Temp. . . . .69°F.
Min. Temp. . . . .34°F.
Total Precipitation. . . .0.08 in.

August 24, 1956

Station	Gage Height	Flow	Time	Loss
No. 2	2.15 ft	6.3 cfs	9:00am	1.3 cfs
No. 1	1.10	7.6	9:10am	
No. 2	2.15	6.3	10:35am	1.1
No. 1	1.09	7.4	10:45am	
		7.5 cfs average inflow		1.2 cfs average loss

Weather

Max. Temp. . . . .68°F.
Min. Temp. . . . .30°F.

Total Precipitation . . . .0.06 in.

Second Sedimenting Run

The second sedimenting run consisted of placing bentonite dams immediately above and below the leaky zones in the Connection Canal. Bentonite dams were placed at the following stations:

Station	Approximate No. of Tons Bentonite per Dam
7+00	20
11+00	20
15+00	20
21+00	20
27+00	20
37+00	20
39+00	5
63+00	25
	Total 150 tons

The second application of bentonite was applied after the construction program on New York Collection Canal had begun. Superintendent Peters hauled and placed the bentonite dams at the predetermined stations. After a dam was constructed, above a leaky zone, the channel was allowed to store the inflowing water until the dam was ready to be overtopped. The company backhoe was then used to make a narrow cut in the dam, thus attaining a high velocity flow through the dam. As the dam eroded the bentonite sediment was carried to the lower end of the canal and the larger pieces of un-mixed bentonite were deposited through the leaky zone. If all of the bentonite in the dam was not eroded then the dam was reconstructed and the above procedure was repeated until the majority of the bentonite was transported and deposited downstream.

The water loss measurements after the second sedimenting run are tabulated below:

September 3, 1956

Station	Gage Height	Flow	Time	Loss
No. 2	1.94 ft	3.0 cfs	11:10am	1.19 cfs
No. 1	0.90	4.19	11:20am	
No. 2	1.97	3.40	12:40pm	0.79
No. 1	0.90	4.19	12:15pm	
No. 2	1.95	3.10	1:30pm	1.09
No. 1	0.90	4.19	1:40pm	
No. 1	0.90	4.19	2:00pm	1.09
No. 2	1.95	3.10	2:20pm	
No. 2	1.96	3.30	2:50pm	0.80
No. 1	0.90	4.10	3:50pm	
No. 2	1.97	3.40	4:15pm	0.79
No. 1	0.90	4.19	4:20pm	
No. 1	0.90	4.19	4:45pm	1.09
No. 2	1.95	3.10	4:55pm	
No. 2	1.95	3.10	6:00pm	0.90
No. 1	0.89	4.00	6:10pm	
		4.15 cfs average inflow		0.97 cfs average loss

Weather

Max. Temp. . . . . 65°F.
Min. Temp. . . . . 37°F.

Total Precipitation. . . . 0.0 in.

September 4, 1956

Station	Gage Height	Flow	Time	Loss
No. 2	1.93 ft	3.10 cfs	9:25am	0.90 cfs
No. 1	0.89	4.00	9:30am	
No. 1	0.88	3.80	9:45am	0.70
No. 2	1.95	3.10	9:55am	
No. 2	1.95	3.10	11:15am	0.90
No. 1	0.89	4.00	11:25am	
		3.93 cfs average inflow		0.83 cfs average loss

Weather

Max. Temp. . . . .68°F.
Min. Temp. . . . .38°F. Total Precipitation . . . .0.0 in.

CONCLUSIONS

Bentonite Sedimenting

The following table shows the sedimenting sequence, average losses, and the amounts of bentonite clay used per sedimenting run.

Canal	Date	Daily Average Loss Before Sedimenting cfs	Average Inflow cfs	Average Loss After 1st Sedimenting cfs	Average Loss After 2nd Sedimenting cfs	Tons Bentonite per Run
Connection	7/27/56	4.71	10.68			92
	7/28/56	5.10	10.88			92
	7/29/56	4.92	12.05			92
	7/30/56	4.23	12.25			92
	7/31/56	3.26	12.03			92
	8/5/56		9.87	2.45		92
	8/23/56		7.57	1.20		150
	8/24/56		7.50	1.20		150
	9/3/56		4.15		0.97	150
	9/4/56		3.93		0.83	150

1. It is evident from the above table that the sedimenting has produced favorable results

2. Approximately 242 tons of bentonite clay were used for sedimenting and blanketing the Connection Canal.

RECOMMENDATIONS

Bentonite Sedimenting

It is recommended that:

1. Sedimenting be continued in the Connection Canal pending future loss measurements.

2. New York Collection canal be sedimented from Tabor Gulch to Lincoln Gulch.

Enclosure 9

STATEMENT

On October 17, 1956, at 12:30 PM the Roaring Fork dam gates were closed which diverted the very small Lost Man Creek and Roaring Fork River flows into Tunnel No. 2 and thence through Tunnel No. 2 into the 7700 foot long Connection Canal.

This diversion was made possible only by the release of compensatory water from Lincoln Gulch Reservoir, since the West Slope prior rights had called for all water on August 11, 1956, at 10:00 AM and still retained the water on this date.

At about 5:30 PM, on October 18th (about 29 hours after being diverted) this very small flow had reached, and was flowing into, Lincoln Gulch Reservoir for the first time in the history of the project, under correspondingly dry condition of the watersheds.

Due to the press of other detail work required to prepare the project for winter, plus a heavy, early snowfall, there was no opportunity to measure the inflow at the upper end of the Connection Canal, and the outflow at the reservoir end of the canal to determine actual losses.

Although temperature at the West Portal has been below zero several times, the small head of water continues to flow through the Connection Canal into Lincoln Gulch Reservoir on this date (November 8, 1956).

West Slope rights released the water to The Twin Lakes Reservoir and Canal Company on October 24, 1956, at which time compensatory flow from Lincoln Gulch Reservoir was discontinued.

Wallace A. Doe,
General Manager-Engineer
The Twin Lakes Reservoir
and Canal Company

November 8, 1956

Enclosure 10

WATER LOSS MEASUREMENTS ON THE CONNECTION CANAL OF THE WEST PORTAL SYSTEM THE TWIN LAKES RESERVOIR AND CANAL COMPANY DURING PERIOD OF AUGUST 19-31, 1957

Date	Upper Weir Station*			Lower Weir Station*			Approximate Loss
	Time	Gauge	cfs	Time	Gauge	cfs	
8/21/57	14:05	.47	4.19	13:48	.24	1.55	
	15:00	.47	4.19	14:28	.30	2.16	
	15:20	.47	4.19	15:20	.35	2.71	
	15:40	.47	4.19	15:40	.36	2.82	
				16:00	.37	2.94	
				16:20	.37	2.94	1.25
	17:00	.50	4.59	17:00	.38	3.06	
	17:20	.50	4.59	17:20	.38	3.06	1.53
	17:40	.52	4.86	17:20	.39	3.18	
	21:02	.59	5.86	20:52	.47	4.19	
8/22/57	8:32	.55	5.28	8:21	.45	3.93	
	11:45	1.47	22.0	11:58	.87	10.3	
	13:15	1.43	21.1	13:15	1.19	16.3	
	13:45	1.41	20.7	13:45	1.24	17.3	
	14:15	1.39	20.3	14:15	1.28	18.1	
	14:45	1.38	20.1	14:45	1.30	18.5	
	15:15	1.36	19.7	15:15	1.29	18.3	
	15:45	1.34	19.3	15:45	1.29	18.3	1.0
	19:31	1.32	18.9	19:52	1.22	16.9	2.0
	21:15	1.35	20.1	21:00	1.22	16.9	3.2
8/23/57	8:10	1.33	19.1	8:02	1.25	17.5	1.6
	10:11	1.30	18.5	10:00	1.22	16.9	1.6
8/24/57**	8:10	1.67	26.3	8:00	1.57	24.1	2.2
8/26/57	8:55	1.73	27.7	8:45	1.62	25.2	2.5
8/27/57	8:00	1.57	24.1	7:40	1.47	22.0	2.1
8/28/57	8:25	1.49	22.4	8:10	1.34	19.3	3.1
8/29/57	8:15	1.43	21.1	8:00	1.31	18.7	2.4
8/30/57	8:25	1.83	30.0	8:15	1.68	26.6	3.4
8/31/57	8:15	1.83	30.0	8:00	1.72	27.5	2.5

* 4 foot rectangular weir, contracted and sharp edge

** Measurements from here on made by Mr. Peters, Superintendent