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December 11, 1930

The State Loan Board,
State Capitol
Phoenix, Arizona.

Gentlemen:

I beg to present herewith a report, which relates to the present status of the Lyman Dam near St. Johns, Arizona.

It was found that the dam has settled to such an extent that the spillway capacity, as originally designed, has been greatly reduced. Following a study of pertinent data, it was concluded that the spillway capacity should be not less than 5,000 second feet, and, in view of the fact that the present capacity is only 1,200 second feet, spillway reconstruction is obviously imperative. In addition to this main defect, there are also several minor features which require early attention. The estimated cost of the spillway reconstruction and minor repairs at the main dam is $19,800.

Respectfully submitted,

W. W. Lane,
State Engineer.

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GENERAL - INTRODUCTORY

The Lyman Dam is situated on the Little Colorado River about eleven miles south of the town of St. Johns, Apache County, Arizona. The stream flows almost due west at the dam site, through a canyon 425 feet wide at river bed, flanked on the south by a red sandstone hill and on the north by a limestone hill. A combination earth and rock fill dam rises 61 feet above original stream bed to form the main dam, while a minor earth fill structure 34 feet high has been placed across a saddle, which is situated three-fourths of a mile northeast of the main dam. The smaller structure is known as the North Dike. There is a natural saddle approximately one-half mile north of the main dam, which has been deepened and widened for a spillway channel. A sketch showing the general layout of the two dams and the spillway will be found on page 2.

HISTORICAL

The Lyman Dam failed during the floods of 1915, the cause of the failure, we have been informed, being due to faulty construction. Steps were taken to reconstruct the dam immediately, and Mr. M. C. Hinderlider, Consulting Engineer of Denver, Colorado, prepared plans and specifications for a new structure which were approved by Quinton, Code and Hill of Los Angeles. The designer contemplated the construction of an hydraulic earth fill dam seventy feet high and 480 feet thick at the base. Money was raised by assessing the stockholders of the water company which formerly owned and operated the dam. Unfortunately, the money thus raised was spent and a considerable deficit incurred without completing the structure. At this juncture, the State Loan

Board was requested to assist and financial aid was thus secured. Several loans were made and several times the estimated cost of the dam was spent under force account without completing the structure. Finally, with only the foundation, outlet works, and a small amount of earth fill in place, the State Engineer of Arizona was instructed by the State Loan Board to draw up plans and specifications for the completion of the dam, which was done. Bids were invited and received and the contract awarded to Parks and Johnson. The State appointed an engineer, named Fleshman, to supervise construction and the dam was completed.

The plans which were drawn up by the State were at great variance with those originally prepared by Mr. Hinderlider. The height of the dam was reduced six feet and the type changed from an hydraulic earth fill to a combination rock and earth fill, both of which probably entered into a reduction of the base width from 480 feet to its present width of 315 feet.

Foundations

The foundation conditions at the Lyman Dam are described in two articles found among the files of the State Loan Board in the State Treasurer's office. Mr. R. S. Cookinham, who made a report to the State authorities under date of February 4, 1929, quoted from Mr. Louis C. Hill's report as follows:

> "Passing from the left, or south abutment, to the right, or north abutment, the formation of the valley floor is stiff red clay for the first 50 feet, then light blue clay for 95 feet, then fine silt and quicksand for 130 feet. Up to this point the material described reaches entirely to

bedrock. From this latter point to the northern abutment, the material consists of a very soft gray clay, overlying a hard clay cap of about the same composition which covers a sand and gravel layer extending to bedrock.

"The cut-off trench starts at the south abutment and is composed of two rows of tongue and grooved, double thickness wooden sheet piling driven for a distance across the canyon of 200 feet and joined to an additional length of 76 feet of Wakefield wooden sheet piling, making a total continuous length of core wall of 276 feet which extends to bedrock and reaches across the entire stretch of foundation upon which the original section of the dam now destroyed rested.

"At the terminus of this core wall, sand and gravel overlying bedrock was encountered, which prevented the further use of wooden piling."

The directors of the Lyman Water Company in a communication to the State Loan Board, stated as follows:

"Owing to the washing away of the foundation of the dam, and the depositing of a great amount of silt, it became necessary for the engineer to drive two rows of Wakefield piling to bedrock, at an average depth of 22 feet, approximately 50,000 feet of lumber being used. The earth was removed between the two rows of piling to bedrock and in its place concrete to a height of 3½ feet was placed; from there to the top of the trench it was filled with selected clay and "puddled in". This trench extended for a distance of about 275 feet; from the end of the trench to the north abutment a distance of about 150 feet, there were three rows of two-inch pipe jetted down to bedrock and a mixture of cement and water injected under pressure of 50# to the square inch; this same method was pursued on each hillside to overcome any percolation; several carloads of cement being used."

Data secured from the above extracts were incorporated into the drawing on page 6 of this report, which shows sections of the main dam and the North Dike.

It is questionable in the mind of the writer whether or not the method of grouting the foundation on the 150 feet adjacent to the north abutment was effective. Certainly it would have been better to have continued the sheet piling entirely across stream bed, even though the cost would have been much greater.

DAM PROPER

The main dam was to have been built to elevation 150, or 70 feet above stream bed, but the plans prepared by the State Engineer fixed the crest at elevation 144, or 6 feet lower. The upstream face from river bed, or elevation 80, to elevation 114, is on a 4 to 1 slope and is covered with a 12-inch gravel blanket. From elevation 114 to the top of the dam, there is a 2½ to 1 slope, covered with a 12-inch thickness of hand placed rock. The crest width is 8 feet, and the downstream face is on a 1½ to 1 slope. The downstream toe of the dam is composed of a rock fill to elevation 113, or 33 feet above stream bed, and was built on $1\frac{1}{2}$ to 1 slope, both upstream and downstream.

The section of the dam on page 6 will give the reader an idea of the composition of the dam. The clay puddle referred to on the upstream portion of the dam was marked in this manner on available drawings and is understood to mean selected earth placed in thin layers, sprinkled and rolled. The lime rock at the toe is rock taken from the limestone hill north of the dam, and is considered a very good feature of the structure.

During the construction of the dam, a slip occurred near the south abutment, during which the rock fill at the toe sank into the soft material in the river bed some ten or twelve feet. This movement caused a mass of the soft river material to bulge up three or four feet, to form a berm. According to the records, there was a spring at the south end of the dam at the time of this accident, and it had probably completely saturated the material lying between bedrock and river bed. It therefore follows that the rock pile had to settle until a state of equilibrium was finally reached between the resistance of the soft saturated material in stream bed and the weight of the rock pile above. At the present time the material in the stream bed is relatively dry and therefore a large factor of safety against any further movement exists. If, upon filling the reservoir, this material in river bed is again saturated, there would then be grave danger of further settlement, due to the added pressure of the water load on the pressure due to the weight of the rock itself.

According to profiles taken by Mr. H. Pinney of the Arizona Highway Department, the dam has settled 3.3 feet since completion. See plotted profiles at the end of this report. This is a rather high rate of settlement, but there are no evidences of unequal settlement, or cracking, and is therefore not considered dangerous. It clearly shows the necessity for constant vigilance on the part of the owners and of the State, in order that a safe freeboard be maintained at all times.

SEEPAGE

The necessity for keeping the toe of the dam dry has been discussed earlier in this report. It is considered necessary to install tile or concrete drains below the toe in order to prevent the complete saturation at any future date. One method for securing the desired result would be to place a four-inch concrete drain, eight feet below the surface, immediately downstream from and parallel to the toe, which will discharge into a line placed at right angles to the toe and carried downstream until it reaches the surface of the old stream bed. A second plan would be to install a well at some point several hundred yards downstream from the toe of the dam, and empty the drain into the well. Pumping equipment would be installed in the well and would be used to provide drainage as well as for pumping into the canal to provide an additional water supply for the project. Drainage of the toe is considered a precautionary measure, but is essential nevertheless, as any appreciable settlement of the dam during maximum high water in the reservoir would spell disaster.

There is some seepage near the north abutment, which is occurring with approximately twenty-four feet of water in the reservoir. This seepage comes from an area about ten feet by thirty feet, is not discolored, and is estimated to be only a few gallons per minute. At the present time it does not appear to be of any danger to the structure, but should be watched carefully during periods of greater storage height in the reservoir. This water is collected in an open drain, and carried to the old river channel several hundred feet below the toe of the dam. The drain is filled with a dense growth of water cress and other similar vegetation, which makes any movement of water through the drain extremely difficult. There has been no effort to keep the ditch clean or properly maintained.

Seepage has also been observed near the south abutment, which seems to exist only during periods when water level in the reservoir is high. Seepage from this source is quite small, is not discolored, and is not believed to be of any serious danger to the structure. Water apparently finds its way through seans in the rock and comes to the surface near stream bed elevation. It is not improbable that some of this water comes from the spring, which formerly existed in the outlet tunnel, and which will be discussed more in detail later.

OUTLET WORKS

The general features of the outlet works are shown on the drawing on page 10. Briefly stated, the works consist of an inlet structure, a reinforced concrete gate tower, a concrete pressure tunnel through the south abutment, and an outlet structure. It is mentioned that detailed drawings are lacking, and therefore much of the information about the outlet works comes second-hand.

The inlet structure is understood to be merely a flared opening covered with steel trash racks placed at an angle of sixty degrees with the horizontal. The pressure tunnel is about three hundred feet long and lined with concrete throughout its length. The portion of the tunnel upstream from the gate tower is seven feet high by ten feet wide, and downstream from the gate tower it is of the same dimensions except that it is divided into two equal parts by a vertical partition wall. The south half of the outlet tunnel is covered at the discharge end by means of one two-foot by seven-foot cast iron, hand operated slide gate, in order to raise water into the irrigation canal, which is located eighteen feet above tunnel level on the south abutment hillside. The north half of the tunnel is open at the discharge end. There are eight two-foot by seven-foot cast iron slide gates in the outlet tunnel directly beneath the gate tower. Four of these gates are for regulating the flow, and four for emergency use only. They are operated by hand from a platform at the top of the gate tower.

The gate stems, operating mechanism, and gate tower appear to be in a poor state of repair, to be a part of a district which is operating at present. The gates, stems, and operating mechanism should be immediately placed in good working order. The gate tower contains a quantity of form lumber and old timbers and does not have a ladder on the inside, which makes the gates practically inaccessible. All excess lumber should be removed, all rotten timbers replaced, a ladder installed on the inside of the tower, and the gates placed in good working order.

According to the records, a spring was encountered during the excavation for the outlet tunnel, and was carried along the north side of the tunnel by means of a crushed rock drain between the concrete and rock excavation. The drain was abandoned through oversight, after having been carried to a point near the middle of the tunnel.

A considerable volume of water finds its way out from the north wall of the outlet tunnel through an old drill hole located about sixty feet from the discharge end of the tunnel. Water passing through this opening has been observed to be discolored when muddy water exists in the reservoir, showing that it has a definite contact with the reservoir.

It is impossible to say definitely whether or not all the water coming through the drill hole is from the reservoir, as a part of it may have its source in the spring encountered during construction. Regardless of the source of water, it should not be permitted to discharge indefinitely, as it comes out under pressure and may wash away material adjacent to the outlet tunnel, thereby causing a rupture of the tunnel, and possibly complete failure.

Several methods have been considered for shutting off the water that comes through the old drill hole, but it is believed best results may be obtained by grouting. Grout would be forced into the hole at a pressure of from 60 to 100 pounds per square inch, depending upon the amount of grout taken and the readiness with which it entered the hole. In this way, both the leakage from the reservoir and any channels leading from the spring will be filled with grout and leakage positively stopped. If the spring breaks out at some other point on the hillside, it is of no particular consequence, since it is unlikely that the spring is connected with the reservoir, due to the fact that it existed before the reservoir was constructed.

When water is carried through the south half of the tunnel, leakage appears above the roof of the tunnel near the discharge end, and considerable water passes between the vertical partitition wall and the top of the tunnel. These defects may be easily remedied by shooting a one-inch thickness of gunite on the top, bottom and sides of the interior of the south half of the tunnel.

RESERVOIR

The Lyman Dam forms a reservoir which extends chiefly to the south, and covers a broad valley of the Little Colorado. With water in the reservoir to spillway crest, that is, to bottom of the twenty-five-foot channel, the capacity is 21,900 acre feet. When water is four feet higher, the area of the reservoir is 1,500 acres. An area curve could not be obtained, nor was one prepared from contour maps available, as it was not considered an essential part of this report. A capacity curve will be found on the following page.

SPILLWAY

General

The present spillway channel is situated about one-half mile north of the dam between two hills which form a natural saddle. The channel consists of a cut 5 feet deep and 115 feet wide, in the bottom of which a channel 5 feet deep and 25 feet wide was subsequently excavated. A profile along the center line of the channel and sections taken at right angles to the center line will be found at the end of this report. It was originally contemplated that this full channel be utilized, with a five-foot freeboard on the dam. The spillway channel is 1,400 feet long, has a slope of 0.001, and rock is exposed through the greater part of its length.

A thorough study will be made of the various factors, which will have an effect upon the determination of the required spillway capacity at the Lyman Dam. This requires a study of all characteristics of the drainage basin, and in the following pages, topography, plant growth, rainfall, and run-off will be discussed. All available data on factors that might affect the maximum flow of the Little Colorado at Lyman Dam have been secured and are presented herewith.

Drainage Area - Topography and Plant Growth

The drainage area above the Lyman Dam comprises approximately

785 square miles, as measured with a planimeter on N. H. Darton's map of the State of Arizona, and a map published by the State of New Mexico. These maps are not particularly suited for obtaining the area of a small drainage basin, as the scale is one inch to eight miles, but the determination is believed sufficiently accurate for the purpose intended.

A considerable portion of the drainage basin is in a region once covered with active volcanoes, as evidenced by numerous extinct craters and the presence of volcanic ash and cinders. This region lies west of the Little Colorado and north and west of Springerville. It is a rolling country, covered with a sparse growth of grass, and no trees. While much of the region is covered with volcanic ash and cinders, yet the evidences of erosion are but slight. This is no doubt due to the porosity of this material, and the water must seep into the ground instead of running off as surface flow.

The lower part of the drainage area, east of the river, and north and east of Springerville appears to lend itself more readily to rapid run-off after heavy storms. The topography and vegetation is quite similar to that of the volcanic region just described, except that there are a few trees, and the surface covering appears to contain quite a bit of clay. During the heavy summer storms, it is believed this material would offer but little resistance to rapid run-off, as it does not appear to be capable of absorbing water rapidly.

The upper reaches of the watershed, or above elevation 8,000, are heavily wooded. The country is mountainous, but only moderately steep. It comprises the north slopes of the White Mountains, which are not to be compared to the south slopes for steepness and ruggedness. The heavy growth of trees and shrubs prevents the occurrence of flash floods from this region, but is conducive to floods of low peak and long duration.

Reference is made to the map of the drainage basin on the following page, which portrays general topographic features.

Rainfall Records

There are but two rain gaging stations within the drainage area of the Little Colorado above the Lyman Dam, one at Springerville and the other at Greer. There are also stations at St. Johns and Alpine, which are just outside the area, and another at Luna, New Mexico, which is a little farther beyond the boundary of the basin. Data pertaining to mean annual rainfall are tabulated below.

STATION	ELEVATION	LENGTH OF RECORD, YEARS	MEAN ANNUAL PRECIPITATION INCHES
Springerville	6,862	13	12.42
Greer	8,500	4	22.75
St. Johns	5,650	13	11.42
Alpine	8,500	4	23.67
Luna, New Mex.	7,300	11	15.43

The above tabulation shows that the rainfall is slight over the rolling, bare country in the vicinity of Springerville and St. Johns, and that it is quite heavy in the mountainous and forested area common to Greer and Alpine. The monthly distribution for the entire area is practically the same as prevails in Southern Arizona, with peaks during the summer months of July and August and during the winter months of December, January, February and March, the latter peak being much less pronounced than the former. The winter precipitation is general and largely in the form of snow, as would naturally be expected for such altitudes. Usually, summer storms are not general over an extended area, but are severe in character and produce a large run-off from a comparatively small area. The monthly totals for different stations usually show rather close agreement during these months, but the daily records for adjacent stations differ widely.

It follows that the winter storms usually produce large floods with peaks extending over several days, while the summer storms, being torrential in character and extending over only a portion of the drainage area, would result in higher flood peaks, lasting for only a few hours. Further, summer floods come at a time when the natural flow of the stream will likely be small, but winter floods are apt to occur on top of an already bank-full stream. The conclusion is reached that provisions should be made for the winter floods, and the spillway will then safely accomodate the summer floods. A double peak winter flood of long duration is much more severe than a sharp, single peak summer flood, due to the ability of the reservoir to absorb a sharp peak of short duration.

Stream Flow Records

The stream flow records are very meager in extent, covering only twenty-six months of 1906, 1907 and 1909. The measurements were made at St. Johns, hence record the run-off from a largerdrainage area than exists above the Lyman Dam. Records are not available for periods of known high run-off, such as occurred in 1905, and again during the winter of 1915-1916, hence the records are not well adapted to the study at hand, but are presented in the table on the following page for the reader's reference.

STREAM FLOW RECORDS

LITTLE COLORADO AT ST. JOHNS

MONTH AND YEAR	DISCHARGE IN SECOND FEET		TOTAL DISCHARGE
	MAXIMUM	MINIMUM	ACRE FEET
Apr. 19-30, 1906	460	190	7,620
May	185	18	3,950
June	180	7	708
July	39	9	972
Aug.	260	16	3,310
Sept.	46	8	845
Oct.	15	10	695
Nov.	23	11	952
Dec.	533	23	5,300
Jan. 1907	82	36	3,570
Feb.	95	53	4,190
Mar.	428	75	10,600
Apr.	554	65	12,500
May	70	27	2,450
Jan. 1909	43	25	2,010
Feb.	40	23	1,550
Mar.	45	20	2,340
Apr.	240	43	5,930
May	170	27	5,020
June	26	8	750
July	480	10	3,020
Aug.	798	52	9,780
Sept.	574	40	9,580
Oct.	43	27	1,970
Nov.	30	25	1,650
Dec.	38	26	2,000

The maximum recorded flow was 1,640 second feet and occurred on August 16, 1909. This measurement was made by Mr. W. D. Rencher of St. Johns, who stated that the flow was largely augmented by two washes which enter the river between Lyman Dam and St. Johns. Mr. Rencher also made the statement that from personal observation the flow of August 16, 1909 was the largest of record, except after the breaking of the Lyman Dam in 1915.

There are two large floods recorded at Woodruff, one of 25,000 second feet on December 5, 1919 with a gage height of 12.0 feet, and another, January 19, 1916, which registered a gage height of 12.7 feet, but whose discharge was not determined. The drainage area above Woodruff has been computed to be 8,910 square miles, and from this it was found that the flood of 1919 came as a result of an average run-off of 2.8 second feet per square mile of drainage area. It is the writer's estimate that a run-off of approximately 3.3 second feet per square mile occurred in 1916.

Required Spillway Capacity

All available data are believed to have been presented in the preceding pages, and it is at once apparent that they are not sufficient for any rational mathematical determination of the probable maximum flood at the Lyman Dam. It is therefore a matter for personal judgment, and after giving due consideration to the factors affecting maximum run-off, it has been decided that the spillway channel should accomodate 5,000 second feet with a five-foot freeboard at the dam. There is an added available capacity of 1,500 second feet in the outlet tunnel with full reservoir head, which provides an added factor of safety, but which in nowise would be construed to reduce the required spillway capacity below

5,000 second feet. In reaching this conclusion cognizance was taken of the fact that the surface area of full reservoir is 1,500 acres, and in the event that the peak of 5,000 second feet is exceeded for short periods, it can be done without encroaching materially upon the freeboard. For example, the peak of 5,000 second feet could be exceeded 50% for three hours with an increase of only 0.5 feet in the water surface elevation in the reservoir.

Present Spillway Capacity

The present spillway capacity, with a five-foot freeboard at the dam, is not more than 1,200 second feet. This is much less than the original capacity, for the dam has settled 3.3 feet since completion. Computations were made which show that the lowest point on the crest of the main dam would be overtopped 0.4 feet if the present spillway channel was forced to carry 5,000 second feet. It is at once apparent that the present spillway capacity is grossly deficient, and should be immediately increased to discharge safely 5,000 second feet.

Spillway Reconstruction

Two feasible methods appear to be available for increasing the present spillway capacity to 5,000 second feet, and at the same time to retain a freeboard of five feet above maximum high water level in the reservoir.

The first solution is to raise the crest of the dam to an elevation 5.4 feet above the lowest existing point, or to approximately elevation 146.1. The head required to discharge 5,000 second feet through the present spillway channel was computed from Russell's equation for non-uniform flow, as developed in his "Text-Book on Hydraulics", and the entrance velocity head added. In order to raise the dam to elevation 146.1, it will be necessary to add rock and earth on the downstream slope, in order to maintain the present slope of 1½ to 1. It was assumed that the upstream slope, which would be paved with hand placed rock riprap, could be placed on a ½ to 1 slope, since the portion to be added will serve only as a freeboard. This work will entail the placing of 6,600 cubic yards of rock and 8,000 cubic yards of earth.

The second solution consists of raising the crest of the dam to an elevation 1.3 feet above the present lowest point; the widening and deepening of the present spillway channel for the first 400 feet adjacent to the entrance, and the construction of 300 feet or new spillway southwest from Station 4+0.0 of the existing spillway. This is shown on the drawings on the following page. The size of channel and depth of water at the entrance was computed from the formula for discharge over a broad crested weir -- $Q = 3.09\ LH^{1.5}$. It was found that a depth of water of 6.4 feet in the reservoir would give the desired discharge of 5,000 second feet, with a crest width of 100 feet. In order that the above equation apply, it is essential that the depth of water in the channel downstream from the crest of the weir be not more than 2/3 of 6.4, or 4.27 feet. Using Kutter's formula and a value of "n" = .025, it was found that a slope of .0065 must be maintained in the floor of the spillway downstream from the crest.

A ground inspection leads the writer to believe that all the excavation required for the spillway reconstruction will be through earth. This is advantageous from the standpoint of excavation costs, but will cause an added expenditure for a concrete cut-off wall to bedrock, which will be necessary in order to maintain spillway crest at the desired elevation. However, it is further believed that bedrock lies within six feet of the surface at the point where the cut-off wall could be constructed. The estimates prepared for this solution were based on the above assumption, but before its final adoption test pits should be sunk to ascertain definitely the depth to bedrock. It is estimated that a total of 14,000 cubic yards of earth must be moved, and 180 cubic yards of concrete placed to construct an adequate spillway by the second method.

If the assumptions upon which the estimates for the second plan were based proved to be correct, it will be the most economical method for obtaining the desired spillway capacity. In the estimates which follow, the second method is assumed to be the most feasible. It has the advantage of lowering the height to which water would ever rise in the reservoir. This is considered a distinct advantage because of the questionable conditions below stream bed at the main dam.

NORTH DIKE

The North Dike is an auxiliary structure across a saddle at the north end of the reservoir. It is of the earth fill type, rising to a maximum height of thirty-four feet above the ground at the upstream face. The upstream slope is 3 to 1, covered with a foot of gravel and six inches of random rock riprap. The crest width is eight feet, and the downstream slope 2½ to 1. A section of the structure is shown on page 6.

At the present time, the lowest point on the North Dike is 9.1 feet higher than the lowest point on the crest of the main dam. If the lowest point on the main dam is raised 5.4 feet, and a five-foot freeboard on the main dam maintained, then there will be an 8.7 foot freeboard on the North Dike. If the second plan is followed and the dam raised 1.3 feet, then there will be a freeboard of 12.8 feet on the North Dike. In either case an ample freeboard will result.

The North Dike appears to be in a good state of repair, and there are no suggestions for any immediate repairs.

ESTIMATE OF COST

The following estimate is of a preliminary nature only, as detailed surveys will be necessary for the preparation of a final estimate. The quantities are believed to be adequate and the resulting estimate of cost conservative.

Drains at toe -			
700 cu. yds. earth excavation	at	$2.00	$ 1,400
1,000 lin. ft. 4-inch pipe	at	1.00	1,000
Outlet Tunnel -			
6,000 sq. ft. gunite lining	at	20¢ . . .	1,200
Grouting			800
Outlet Tower -			
75 ft. steel ladder	at	$2.00 per ft.	200
Clean up outlet tower			300
Repair gates, stems, operating mechanism			800
Spillway (second solution)			
14,000 cu. yds. excavation	at	50¢ . . .	7,000
180 cu. yds. concrete	at	$25.00	4,500
			$ 17,200
Engineering and contingencies		15% . . .	2,600
Total			$ 19,800

OPERATION OF PROJECT

Operation of the Lyman Project has received the casual attention of this office, although it has not been possible to make detailed studies of this feature. A few remarks incident to the methods employed in the operation of the project are considered an essential part of this report. One outstanding item relative to operation is the apparent lack of adequate maintenance. Of course, it was realized that the farmers in the project were generally poor, and without funds to pay for repairs necessary to keep the irrigation system in proper shape. This excuse should no longer exist, since the State of Arizona now owns the major portion of the project. In my opinion the State should not abandon and thereby lose the investment it has in the Lyman Project, but should make every reasonable effort to realize the greatest possible amount therefrom. This will require the efficient development of a portion of the land originally included under the project.

It will be necessary to maintain the Lyman Dam, its appurtenances, the main canal, and necessary portions of the lateral system in a thorough, efficient manner. Since the entire project is dependent upon the Lyman Dam, no effort should be spared to place this structure in good condition. Losses in the main canal are undoubtedly tremendous, and will continue to be so until the canal is cleaned and deepened where necessary, and structures placed in good repair. At present, the lateral system is extensive, and ill kept. Efforts should be concentrated on the portion of the system essential for present needs, and the remainder abandoned until development of the project demands expansion.

A large question immediately presents itself when an attempt is made to limit the area of the project. There is no doubt, however, that an area of 15,000 acres, as originally included in the project, can not be provided an adequate supply of water from a reservoir of 21,900 acre feet capacity, when the stream entering the reservoir is unable to fill it each year, and the land within the project receives only twelve inches of rainfall annually. After a review of available stream flow records, which extend over very few years, there appears to be no way of reaching a definite conclusion regarding the ultimate gross area that can be supplied with water. The solution is therefore relegated to the future, and in the meantime, the acreage must be fixed at the beginning of each irrigation season by the amount of water stored in the reservoir, and the normal expectancy from the river.

Distribution of water to project lands has not been accomplished in an efficient manner in the past. This has been caused, in part, by a poorly constructed system, and, also by inefficient irrigation and management. In Salt River Valley night irrigation is a necessity, and farmers tend the water at night as well as during the day. While night irrigation is also a necessity in the Lyman Project, yet farmers seem inclined to let the water take care of itself during the night. This may be overcome by limiting the amount of water allowed to each farmer to a fixed number of acre feet per acre under cultivation.

Mention has been made of the possibility of placing a well several hundred yards below the toe of Lyman Dam, and pumping water from the well to provide drainage for the toe, and to increase the water supply for the project. This has been mentioned as a possibility, but should receive more careful study and investigation in the future. There appears to be no need for additional water at this time, but future expansion may warrant the development of wells. Experience has shown that a project depending upon surface run-off and reservoir storage for its supply suffers more during an extreme drouth than the project that has a pumped water supply in reserve.

This report offers recommendations for necessary repairs to Lyman Dam, but lack of detailed information prevents anything more than a general recommendation relative to operation of the project. It is suggested that detailed surveys and studies be made to determine the essential repairs required for the main canal and the lateral distribution system, and to fix the acreage to be irrigated each year.

CONCLUSIONS

1. The toe of the dam should be drained, as an appreciable settlement is likely to occur under full reservoir if the material at the toe becomes saturated.

2. It is apparent that the gate stems and operating mechanism for the slide gates are in need of repair.

3. Old timbers and form lumber clutter up the gate tower and there is no ladder inside, which combine to make the gates practically inaccessible. This condition should not be permitted to continue.

4. A serious leak exists in the north side of the outlet tunnel, which should be remedied effectively at an early date.

5. There is considerable leakage through the roof of the south half of the tunnel, and between the roof and the vertical partition wall, both of which should be remedied.

6. Calculations show the present spillway has a capacity of 1,200 second feet with a five-foot freeboard at the dam, but the conclusion is reached that the spillway capacity should be not less than 5,000 second feet with the same freeboard.

7. The North Dike has ample freeboard, and appears to be in good condition.

8. A preliminary estimate indicates that the cost of repair work and reconstruction will total $19,800.

RECOMMENDATIONS

1. Tile or concrete drains should be installed at the downstream toe of the dam.

2. The slide gate stems and operating mechanism should be reconditioned, and the gates repaired, if necessary.

3. A thorough clean-up inside the gate tower and the installation of a steel ladder from top to bottom are needed.

4. Grouting under suitable pressure is recommended to remedy the leak that exists on the north side of the outlet tunnel.

5. A one-inch thickness of gunite should be placed in the south half of the outlet tunnel between the gate tower and the outlet.

6. In order to obtain the required spillway capacity, the crest of the dam should be raised 1.3 feet; the first 400 feet of the spillway channel deepened and widened; and a new spillway channel constructed from station 4+0.0 of the existing channel to the head of the wash 300 feet southwest, as shown on the drawing, page 23.

7. It is urgently recommended that the repairs and reconstruction listed above be completed at the earliest possible date, in order that the lives and property of people living below the dam be safeguarded.

Respectfully submitted,

W. W. Lane,
State Engineer.

File 41-8
Lyman Dam Irrig Proj.
Schwalen Coll.
UA Spl. Coll.