NAVAJO

U.S. Indian Service

THE GANADO RESERVOIR IRRIGATION PROJECT

NAVAJO RESERVATION, ARIZONA

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Superintendent of Irrigation

Report and Estimate of Cost of The G A N A D O Storage and Irrigation Project.

H. F. Robinson,
Superintendent of Irrigation.

Albuquerque, N. M.
October 15
1910.

C O N T E N T S.

List of Maps and Drawings.

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Photographs.

Photographs showing details of the situation at all points under discussion.

Report on
Ganado Project.

DEPARTMENT OF THE INTERIOR

UNITED STATES INDIAN IRRIGATION SERVICE

SUPERINTENDENT OF IRRIGATION

Albuquerque, N. M.

October 15 1910.

Mr. W. H. Code,

Chief Engineer,

526 Federal Bldg.,

Los Angeles, Cal.

Dear Sir:

In accordance with instructions, I have had a survey made of the proposed reservoir site near Ganado, a portion of the land lying under it, and the distributing system, together with an estimate of costs. The following is a report of the same.

The project, as you already know from former reports, is to construct a reservoir about three miles from Ganado, Arizona, by impounding the waters of the Rio Pueblo Colorado in a reservoir in a flat on the north side of the stream, where a small lake now exists, and to irrigate land lying along the stream below from it.

The land. The valley of this stream is, like most of the valleys in this region, long and narrow. The irrigible land commences almost at the reservoir, and extends down the stream for at least 40 miles, so the area available is only limited to the supply of water and the cost of the distributing system.

The elevation is about 6100 feet, and the land and climate adapts it to the cultivation of corn, alfalfa, wheat and

other crops of the temperate zone.

The land is all in the Navajo Reservation, in a part set aside by Executive Order, and is not a part of the treaty lands. It is all occupied by the Indians with the exception of 160 acres of land belonging to Mr. J. L. Hubbell, and a small tract set aside for mission under the charge of the Rev. C. H. Bierkemper.

Water available. No definite statement can be made of the amount of water available. Investigations would indicate, however, that the supply is ample for the proposed project.

In a report by Superintendent Martin, dated February 18 of this year, he covers interviews with a number of persons fully familiar with the stream, and the consensus of opinion is that the supply will prove ample.

Late investigations with the latest maps would indicate that the drainage area of this stream above the reservoir is about 205 square miles.

The nearest rainfall records have been kept at Fort Defiance about 30 miles distant, where the average for seven years - 1897 to 1903 was 12.61 inches. The maximum 18.51 and the minimum 6.52.

Prior rights. Mr. Hubbell, who owns 160 acres of land under this system, and who originally planned this reservoir system, has acquired water rights from the stream by building a ditch and actually using the water on his land.

Mr. Hubbell has proposed to the Indian Office to merge

his rights with that of the Indians, and if the Department will construct this reservoir and ditch system, he will turn over to the Department his ditch, with a length of about 2½ miles, and, to quote a letter from him:

"will guarantee that the ditch will be cleaned to four miles from the reservoir, and kept in condition to run the water except where flumes or headgates are destroyed by floods.

In making this agreement with you, I consider that at the present time I have to do it to get water to my place, and the keeping it in repair for two miles more will be only a very small expense to me in case the Indians fail to do it. The benefits accruing to this community, would more than offset the little expense I would have. In other words I have perfect faith that the Indians in this community will use the water, and would not want Government help except in extraordinary cases of destruction by floods of flumes and headgates."

In other words, Mr. Hubbell proposes to turn over his ditch and guarantee to maintain the ditch system for a distance of four miles in return for the privilege of securing his water from the reservoir. He does not ask for any additional water, but the benefit he will receive from getting his water from the reservoir at such times as he needs it instead of from the stream at such times as the water is flowing will more than compensate him for surrendering his ditch and agreeing to the maintenance.

Duty of water. In the following, the duty of water at Ganado is assumed as being 2.5 feet, and the capacity of ditches on the delivery of one second foot for each eighty acres.

Area of land and quantity of water.

Plans have been made for a reservoir dam 20 feet high, with high water at 16 feet. This reservoir will contain 4438 acre feet of water, and assuming that it will be filled but once during the year, and that the low summer flow will be sufficient

to compensate for seepage and evaporation, there will be sufficient water to care for 1775 acres of land.

A ditch has been surveyed on the south side of the stream for a distance of 27,400 feet, (5 and 1/5 miles), which will cover 707 acres of good land. A short extension will cover an additional 75 or 80 acres. A line carried down on the north side of the river from Sta. 91 for a distance of about four miles will cover not less than 800 acres, or a total of about 1600 acres of land. Further extensions can be made as found advantageous, to the limit of the water supply, which will be according to the number of times the reservoir can be filled during the year, after the irrigation season opens. There is a chance for a supplemental reservoir, for future consideration if thought desirable, which is shown on the map.

Diversion works.

Since the plan was first considered, the conditions at the diversion point has materially changed, and the plan and cost will be somewhat increased. At that time the water was flowing over a rock bed at the elevation desired to divert it. Since then, the river current cut into the south (or east) bank and it was found that the rock bottom was a ledge, and the water cut a channel down the face of this ledge to about 13 feet below the top. To divert the water it is necessary to throw it back to the top of the rock. A rock-fill crib dam is proposed, which will be carried to an elevation 7 feet above the top of the rock. This dam to rest on piling driven in the bottom, to bed rock or to a firm bearing. On the upstream side an earth fill.

The north-east abutment to be a concrete wall. On the other end an earth dyke will be an extension of the dam.

For the diversion of the water, a lip of concrete will be built across the rock as a continuation of the dam. This will be only high enough to level up the rock, being from nothing to a little over a foot, in a depression. (See plans and map)

The Diversion canal will head opposite the end of this lip. The canal will be built on a grade of 5.28' to the mile, 16 feet on the bottom, side slopes 1½ to 1. The bottom of the gate will be 1 ft. below top of diversion lip. With water one foot deep the discharge will be 27.8 second feet, v. 1.59. Two feet deep, discharge 95.7 second feet, v. 2.52. Three feet deep, discharge 198.0 second feet, v. 3.22. Should there be a still larger discharge of the stream, the canal could carry it as it is in a through cut. Where the canal discharges into the reservoir it will be necessary to pave the slope to prevent wash and retrogression of grade. Supt. Martin suggests a canal with a capacity of 200 second feet, but fails to indicate the depth of water. It might be advisable to increase the width of the ditch to secure a greater capacity at less depths.

The headgate to be entirely of concrete, reinforced where necessary, with four openings, four feet in the clear with wooden gates, raised by means of the Vulcan Iron Works ball bearing lifts, and also provided with grooves for flash boards outside of the gates to control the entrance of sand and silt during floods, only drawing from the surface water if thought best, see plan.

Storage Works. Dam.

The dam to form the storage reservoir is to be an earth embankment, with a maximum height of 20 feet, a width on top of six feet, inside slopes 2½ to 1, outer slopes 2 to 1. It is to be covered with one foot of broken stone on both the inner and outer slopes as a protection against the workings of gophers and other burrowing animals, and covered with larger rock on the water side in the shape of rough slope paving, to care for the water action. The hills on both sides of the reservoir are covered with rock - (see photos).

The earth is to be placed with scrapers, after the diversion dam and canal is completed, and will be constructed in the following manner. First carefully clear and plow the ground, excavating a trench two or three feet deep, replacing the earth with water to thoroughly puddle it. The earth to be taken from the inside of the reservoir, leaving not less than 20 feet as a berm. A small ridge is to be thrown up at the toe of each slope and the water from the canal is led between them, filling the depression. The earth fill is then made, dumping the material into the water so it will thoroughly puddle. The outside ridge is then carried up to a higher elevation and the process repeated until the top of the fill is reached.

The waste way. No water is supposed to enter the reservoir excepting through the canal, but to avoid accidents, and to care for any rainfall on the few acres which forms the drainage into the reservoir, it will be necessary to construct some kind of a

wasteway. There is a low saddle between this flat and the next one down the stream. This second flat is the second proposed reservoir site. By cutting a canal 10 feet wide through the saddle, a distance of about 1840 feet, with a maximum cut of 3.5 feet a good wasteway will be secured which will carry from 17 second feet at 1 foot depth to 136 second feet at three feet in depth, the grade to be 2 feet in 1800.

Should the second reservoir ever be constructed this would be used as the feeder for it. A masonry lip at the head of the ditch should be provided to prevent washing.

Reservoir Outlet.

For the discharge from the reservoir it is proposed to use twin discharge pipes, 12" in diameter. With the reservoir full each pipe will have a discharge of about 17 second feet.

The gates of these discharge pipes will be operated from a light steel tower. The plans suggest one of the Aermotor Trussed Tripod Tower. These are the three legged towers built for 14' wind mills. Secure one of the 30 foot towers, and use only the lower 20 feet. This will give a triangular top a little over three feet on a side upon which to rest the end of the wooden foot bridge connecting with the top of the bank. To the top of this tower will lead the valve stems, operated by a rising screw. The discharge pipes will not be placed in the bank, but at the end, and in excavation in the hill side.

Distributing System.

The ditch system is planned to carry 22 second feet from

the reservoir to the division gates at Sta. 92 where one ditch will continue down on the north side of the stream and the other will cross the stres. to cover the south side, and will be 5 feet on the bottom, carrying the water 1½ feet deep. From there it will be narrowed to 4 feet on the bottom, when the capacity will be 16.5 second feet. At Station 209 the capacity is again reduced to 12.5 second feet and beyond Sta. 275 the width will be 3 feet and the capacity 7.5 to 8 second feet.

There will be several drops of ten feet each on the ditch to take up the excessive fall of the country, and the streams and arroyos will be crossed with flumes, the substructures being of timber and the waterway of steel. (See plans and List of Structures).

At Station 99, connection is made with the Hubbell Ditch, a short distance from its head, and continue down it to about Station 200. This ditch will need some repairs, and the rebuilding in part of one flume and entirely of another. (See Estimates).

Labor. Practically all of the labor will be done by Navajo Indians. The Indians are very anxious for the work to be done and I do not anticipate much difficulty in getting allof the men needed. Mr. Hubbell is perhaps the most influential man on the entire Navajo reservation, and he promises that he will personally see that we have plenty of laborers.

Estimates of Cost.

The following estimates of cost are made on diversion works, storage reservoir with dam at a maximum of 20 feet high, water 16 feet deep, and distributing system to care for 1600 to 2000 acres.

The following unit prices for labor and material are used as the basis for the estimates.

Data upon which cost estimates are based.

Indian Labor. Men 1.25 per day
Teams 2.50 per day

Cost of freighting from the railroad at Gallup to Ganado, a distance of 60 miles - - 65c. per 100 lbs.

Cost of material: at Gallup unless otherwise specified.

Cement, 3.39 per bbl.

Logs for crib and piling, from 15 to 25 ft. long. average cost $2. each. Estimated at 11c. per ft.

Lumber, delivered at Ganado, purchased from Government sawmill on Reservation, $20. per M.

Iron for reinforcing etc. 5.5cts per lb. delivered.

Sand. Hauled 3 miles, (poor roads), 2 round trips a day for $2.50, ¾ yd. per load.

Broken Stone, breaking and handling per cu. yd. $1.10
Stone for paving, laid (not hand placed) 55c. sq. yd.
Steel flume. Waterway. No. 60. Top Diam. 3.18' area 3.97 sq. ft. Wt. per ft. 10.5 lbs. Price at factory per ft. $1.00 estimated cost at Gallup $1.40 per ft.
Concrete in place from $15. to $20. per cu. yd.
Driving 12' piles, each $1.50
Gate Lifts for Diversion Gates $18. each in Chicago.
Gates for discharge pipes with stems $61. for two delivered.
Steel tower, 30' high (at Albuquerque) $33., $57. and $63.

Estimates-- Ganado Project.

Diversion Section.

Dam.

Crib.	4852 lineal feet of logs at 11c.		533.72
	44 piling 12' long at 2.00		88.
	driving piling at 1.50 each		66.
	carpenter labor on cribs est.		125.
	rock fill of cribs, 920 cu. yds. at 1.10		1,012.
	excavation for cribs, 741 cu. yds. at 25c.		185.25
	earth extension to crib, 429 cu. yds. at 25c.		107.25
	earth fill above crib, 663 cu. yds. at 25c.		165.75
	hardware, about 875 - 18"x¾" drift bolts 1960# est. delivered 5.5c. per#		107.80
	excavation and backfill in addition to above, and additional cost to care for water and wet excavation, estimated		200.00
			2,590.77
Concrete.	Wall at end of crib, diversion weir and wall along edge of rock break, at right angles to dam.		
	13.8 cu. yds. of concrete at 15.$207.		
	4.5 " " " " " 20. 90.		297.00
Slope paving.			
	Between head gates and stream.		
	7200 square feet of paving (800 sq.yds.) at 55c. per sq. yd.	440.00	
	slope dressing	140.00	580.00
Headgates.			
	Concrete in gates proper, 16.69 cu.yds. at 15.	250.35	
	Concrete in wing walls, each 10' long-7 yds. at 15.	105.00	
	Reinforcing, 150# at 5½c.	8.25	363.60
	Gates and lifts, 4 ball bearing lifts		120.00
	150 ft. lumber at 20.		3.
	hardware		2.
	Lumber for forms, to be used afterwards for floor of bridge etc. 500 ft. at 20. per M.		10.
	Carpenter work		25.
	Placing lifts, and extra labor - contingencies estimated		25.
			548.60

Diversion Canal,	
Earth work, 18,289 cu.yds. at 25c.	4,572.25
this earth has many large boulders, but much of the spoil, both earth and rock will go to fill the crib dam, for which allowance to the extent of $1,177.75 was made which will cover extra costs of excavation.	
Paving lower end of canal. No particular plan made for this. Estimated --	125.00
	4,697.25
Storage Section.	
Dyke for Reservoir.	
Earth in embankment.	
50,490 cu.yds. at 26c.	13,127.40
Broken stone for dressing on both slopes, 7180 cu.yds. at 1.10	7,898.00
Paving on upper slope, 11,774 sq.yds.at 55c.	6,475.70
Puddle trench, clearing etc.	200.00
	27,701.10
Outlet from Reservoir.	
Plan with skeleton tower,	
Twin outlet pipes- 12" diam. as per plans 60 ft. between portals--	300.
2 - 12" gates complete with stems	61.
1 - trussed steel windmill tower, (Aermotor type) 20 feet high -	50.
Foundations for tower,	20.
Foot bridge	35.
	466.
Reservoir waste way.	
By cut over divide	
Ditch 10' base, 1½:1, 1840 ft. long	
Contents - 1796 cu. yds. at 25c.	449.00
Masonry lip from reservoir,	25.00
	474.00
Distributing System.	
1st section - Sta. 0 to 99	
Excavation, earth 1537 cu. yds. at 25c.	384.25
loose rock, 7217 cu. yds. at 40c.	2,886.80
1 headgate, lateral.	105.
1 flume, 16' long	56.96
1 flume, 250' long	950.
2 concrete drops, 10' high at 419.35	838.70
1 combination 10' drop and division gate	516.35
	5,738.06

2d section. The Hubbell ditch.	
Excavation (repairs and enlargement) 3483 cu. yds. at 25c.	870.75
1 flume to be rebuilt	313.16
1 flume 100' long	401.
2 lateral headgates at 105.	210.
5 small water bridge flumes at 8.	40.
	1,834.91
3rd section. Sta. 204 to Sta. 274	
Excavation, earth, 1315 cu. yds. at 25c.	328.75
loose rock 567 cu. yds. at 40c.	226.80
2 flumes 60' and 24'	377.44
1 10' drop	419.35
	1,352.34
location not specified.	
3 under drainage culverts	525.00
3 lateral headgates at 105.	315.00
3 highway bridges	75.00
	915.00

Recapitulation.

Diversion.			
Crib dam complete,			2,590.77
Concrete at head,			297.00
Slope paving,			580.00
Headgate,			548.60
Diversion canal,			4,697.25
Reservoir.			
Dyke,			27,701.10
Outlet,			466.00
Wasteway,			474.00
			37,354.72
Engineering and contingencies	20%		7,470.94
		Total	$ 44,825.66
Distributing System.			
Section 1. Sta. 0 to 99.			5,738.06
Section 2. Hubbell ditch section			1,834.91
Section 3. Sta. 204 to 274			1,352.34
Miscellaneous			915.00
			9,840.31
Engineering and contingencies, 20%			1,968.06
		Total	$ 11,808.37
Total, Diversion and Distributing System			$ 56,694.03
Extensions not surveyed, estimated			3,400.00
			$ 60,094.03
Total amount stored, one filling of reservoir,			4438 acre feet.
Total area under surveyed area and proposed immediate extensions,			1587 acres.
Area estimated stored water will care for,			1775 acres
Cost per acre served, Storage,			$25.25 per acre
Cost per acre for diversion system for 1587 acres,			$9.60 per acre

List of Structures on Distributing System, with estimates of cost.

Section 1.		
Station 30,	Headgate	105.00
52+80)	Connected by ditch, 16' flume	56.95
57+25)		
72	Drop, 10'	419.35
86	Drop 10'	419.35
91	Combination drop and gate	516.35
92+84	Flume 250'	950.00
Section 2.		
H 21+55	Water bridge (now in)	
H 35+40	Small overhead flume	8.00
H 38+40	Flume now in. Will need new waterway, and short underpinning. The present substructure will do. See photo. 76'	313.16
H 43+30	Small overhead flume	8.00
H 54	Headgate	105.00
H 48	Small overhead flume	8.00
H 57	" " "	8.00
H 61	Lateral headgate	105.00
H 101-50	Flume 100'	401.00
Section 3.		
232	Flume 60'	254.60
273+50	Flume 24'	122.84
243	Drop 10'	419.35
Miscellaneous. Location not specified.		
3	underdrainage structures	525.00
3	highway bridges	75.00
3	lateral headgates	315.00

Analysis of Cost.

The actual construction figured upon would make the cost per acre all out of reason, as the surveyed ditch covers but 707 acres of land and the estimated cost is $56,694.03.

It is now estimated, that the reservoir will care for 1775 acres of land, at a total cost of $44,825.66, or $25.25 per acre. If the supply of water is greater than sufficient to fill the reservoir once, then the per acre cost will be reduced in proportion.

The distributing system is estimated at $11,808.37, or with the land actually under the proposed ditch a cost of $16.70 per acre.

The ditch system, however, will care for water for about 2000 acres of land as far as built, and the following estimates of cost of lateral extensions has been made without detailed surveys. Lateral from end of survey, cost about $200. cover 80 acres of land. From the division gate at Sta. 91, a ditch is to be carried for a distance of about four miles on north side of stream, at an estimated cost of $800 per mile. Land covered, about 800 acres. These two extensions will cost about $3400. and cover 880 acres of land. This will make the total cost of distributing system, $15,208., and the area under ditch, 1587 acres, or a cost of $9.60 per acre. Further extensions can be made at a reasonable cost, and additional land can be brought under the system.

The estimates are all on the best of construction. Practically all of the structures are of concrete, the flumes are

steel water ways on wooden trestles resting on concrete piers or on piling, whichever is better suited to that particular point; all gates have steel screw gate lifts, the lateral headgates are concrete pipe outlets with steel gates and lifts, and all construction is planned to be the most permanent character.

By substituting wooden structures, and slighting construction, as is often done in pioneer work, the first cost could be materially reduced, but the system would need constant repairs, and the ultimate cost would be greater.

With the complete system finished, the cost will be a little less than $35.00 per acre, which is a reasonable price for a first class system.

Extension.

There is a further extension of the work which can be done. That is, to build some kind of a diversion dam in the stream at the head of the Hubbell Ditch, and place headgates there for the purpose of diverting flood waters which may come down in excess of the amount diverted into the reservoir, or when it is carrying too much silt for storage.

At the head of this ditch there is no bedrock within reasonable distance, and it is probable that a rock-fill crib, resting on piles, with a good apron, or a rock and brush dam are the only ones worth considering for the present. After a large area is put under cultivation and the value of the water is greater, it might be worth while to put in a dam of the type exploited by the Ambursen Hydraulic Co., the hollow concrete dam. No plans or estimates have been made of this.

Purchase of Machinery. It will be necessary to purchase and install a portable rock crusher, with power, to furnish the broken rock for the slopes of the dyke. In making my estimates the first cost of such a plant has not been taken into consideration, as I had no prices on the machinery. The cost used on the broken stone is about the cost of producing and hauling it. The 20% added for contingencies and engineering should be enough to care for such items however, when the salvage value is considered at the end of the work.

Conclusions. The surveys show a slightly smaller area of land within a short distance of the reservoir than was contemplated, and the estimates are somewhat higher than was reported by Mr. Hubbell as the finding of his engineer; but the work is the best that can be devised, and the difference in the quality of the work and the structures will largely account for the difference.

The resulting cost of $35 per acre for storage and diversion is reasonable, and in view of the shortage of water on the entire Navajo Reservation, and its value when developed, I consider that the project is of sufficient merit to warrant construction.

Very respectfully,

N. J. Robinson

Superintendent of Irrigation.

G A N A D O .

Table of Reservoir Capacities.

Contour.	Areas.	Capacities in acre feet. Between Contours.	Total.
Original lake			96.8
488.3	96.8		
490	140.4	201.6	298.4
492	181.3	321.7	620.1
494	218.	399.3	1019.4
496	240.8	458.8	1478.2
498	261.	501.8	1980.
500	281.9	542.9	2522.9
502	306.	587.9	3110.8
504	353.8	639.8	3750.6
506	353.6	687.4	4438.0