SRPDOC034

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
WASHINGTON

OFFICE OF THE DIRECTOR

OFFICE OF INDIAN AFFAIRS RECEIVED JUN 9 - 1910 47345

June 9, 1910.

17 m

Commissioner,
Office of Indian Affairs,
Washington, D. C.

Sir:

There is transmitted herewith a report prepared by Prof. H. E. Gregory at the request of your office on the "Water resources of the Navajo-Moki Reservations." The text of this report is transmitted in duplicate on the assumption that you will desire to forward one copy immediately to your Chief Engineer, Mr. Code. Only single copies of the maps and other illustrations have been prepared. Your attention is especially directed to the fact that parts II and V of this report have been written with the needs of farmers and superintendents in the field particularly in mind. It has been thought that you might desire to place copies of these portions in the hands of officials of this rank on the reservations in question. In some respects the report is incomplete, because at your request Professor Gregory has been reassigned to the field for a portion of the coming summer to carry out further

Jr

NAIRG 75
Cent. Class. Files 1907-56
47345- 1910-341 Navajo

SRP000148

INDEXED

researches in the northern and western portions, and especially in the vicinity of the lower San Juan River and Navajo Mountain. At the close of this season's field work, a supplementary report will be prepared which, together with that transmitted to you, is intended to be a complete guide in so far as it has been possible to prepare one within the limited time allotted, for preliminary water developments on the reservations.

Very respectfully,

Director.

Enclosures.

c. June 1910

OFFICE OF INDIAN AFFAIRS
RECEIVED
JUN 9 - 1910

47345

WATER RESOURCES OF THE NAVAJO-HOPI RESERVATION.

by

Herbert E. Gregory

United States Geological Survey.

SRP000150

WATER RESOURCES OF THE NAVAJO-MOKI RESERVATION.

Part I - General Report and Recommendations.

by Herbert E. Gregory.

Introduction

Scope of the reports

An arid region
A sheep country
Agriculture

Water supply

Introduction

Irrigation

Springs

Wells

Government farmers

General observations

Navajo and Hopi

Superintendents

Traders

Missionaries

Tuberculosis camps

Marsh Pass region

Navajo Mountain region

Recommendations

Part II -- Suggestions to Superintedents and Government Farmers.

Introduction

Small reservoirs

- The site
- The dam

Springs

- Introduction
- Springs in unconsolidated material
- Springs between ledge and cover of loose material
- Springs between rock strata

Wells

- Shallow dug wells
- Wells in rocks
- Flowing wells

Rainwater

Part III - The Black Falls Project.

Introduction

Little Colorado River

- The valley
- Amount of water
- The river bed

The Black Falls Project

SRP000152

Part IV - The Lower Oraibi Wash.

General description

Structure

Underground water

Recommendations

Part V - Details for consideration of farmers and superintendents on each reservation.

Recovery of water

Quality of water

The maps

Papers for reference

Part V-A and Map I: Navajo Reservation; headquarters, Fort Defiance

The Chaco Valley

Highlands along the Arizona-New Mexico Line

Black Creek Valley

Highlands between Black Creek and Chinlee-Colorado Wash

Chinlee-Colorado Wash Valley

Highlands west of Ganado

Part V-B and Map II: The Hopi Reservation; headquarters, Keams Canyon

Moki Buttes

The washes south and west of the Hopi villages

Keams Canyon region

Hopi villages

Zilh-le-jini mesa

SRP000153

Part C and Map III: Navajo Extension; headquarters, Leupp

Part D and Map IV: Western Navajo Reservation; headquarters, Tuba

Gypsum Creek Lower Chinlee

Laguna Creek

Tuba region

Little Colorado

Part E and Map V: San Juan Reservation; headquarters, Ship Rock

SRP000154

WATER RESOURCES OF THE NAVAJO-MOKI RESERVATION.

List of figures and maps.

Part II. Suggestions to superintendents and government farmers

Fig. 1. Subsurface dam

" 2. Development of springs in talus and landslides

" 3. Development of water between rock strata and upper saturated sandstone

Part III. The Black Falls Project

Fig. 4. Table of measurements of water in upper tributaries of Little Colorado.

" 5. Section showing strata in Little Colorado Valley

" 6. Lava acting as subsurface dam retaining water

Part IV. The Lower Oraibi Wash

Fig. 7. Diagram of Lower Oraibi Wash

Part V. Details for consideration of farmers, etc.

Fig. 8. Well sunk in alluvial flat -- Black Creek Valley

" 9. Geological Structure, Beautiful Valley

" 10. Springs at Indian Wells

" 11. Big Spring, Stiles ranche

" 12. Home Spring, Chandlers ranch; spring house in rock

" 13. Coyote Spring near Pyramid Butte

" 14. Mason Spring

" 15. Section of eastern tributary of Corn Creek

" 17. Water in sandstone, Big Burro Springs

Fig. 18. Section showing spring horizon, Keams Canyon region

Map I. Navajo Reservation

" II. Hopi Reservation

" III. Navajo Extension Reservation

" IV. Western Navajo Reservation

" V. San Juan Reservation.

Prof Gregory's Report on Navajo & Moki

47345

OFFICE OF INDIAN AFFAIRS
RECEIVED
JUN 9 - 1910

1

Water Resources of the Navajo-Moki Reservation.

Part I - General Report and Recommendations.

by Herbert E. Gregory.

Introduction

- Scope of the reports
- An arid region
- A sheep country
- Agriculture

Water Supply

- Introduction
- Irrigation
- Springs
- Wells

Government farmers

General observations

- Navajo and Hopi
- Superintendents
- Traders
- Missionaries
- Tuberculosis camps
- Marsh Pass region
- Navajo Mountain region

Recommendations

Water Resources of the Navajo-Moki Reservations.

Part I - General report and recommendations.

Introduction.

Scope of the reports.- The results of my studies of the water supply for the Navajo and Moki reservations during the summer of 1909 are embodied in the following reports:

1. General report and recommendations.
2. Suggestions to superintendents and farmers on reservations in the New Mexico-Arizona region.
3. Report on the Black Falls project.
4. Report on the lower Oraibi wash.
5. Four special reports with detailed suggestions dealing with local problems on the reservations visited, viz.,

   Navajo

   Hopi

   Navajo Extension

   Western Navajo.

6. A scientific paper dealing with climate, topography, surface water, ground water, and geological structure, purposely omitted from the above reports and which may appear as a Water-Supply Paper to be published by the Geological Survey.

An arid region.- The Navajo and Hopi reservations are arid. The rainfall records, the character and distribution of the plant and animal life, show aridity at the present time; the geologic and archaelogic evidence alike indicate that it has been arid for thousands of years, and the geographical position, topographical surroundings, and climatic history indicate that the aridity will continue. The deficient rainfall and its unfavorable distribution throughout the year; extensive drifting sands; a topography of canyon, mesa, and wash; drying winds; and the elevation above the sea determine for this region an unsatisfactory water supply.

Tree growth is limited to the high mesas and mountain areas, and even here it is for the most part sparse. With the exception of the forests on the mountains west of Fort Defiance and on parts of the Lukachukai-Choiska range, the timber is useful chiefly for firewood and even on these highlands the growth is hardly dense enough to exert a noticeable influence in controlling the surface run-off. Grass and certain other plants of more or less value as stock feed, while nowhere abundant and prolific, as measured by humid standards, form a soil cover over wide areas. The larger animal life consists of coyotes, rabbits and ravens.

A sheep country.- Sheep raising is one of the chief industries of New Mexico and Arizona and it is estimated by the Department of Agriculture that the Navajos alone have

SRP000159

4,000,000. Cattle will prosper here and horses also, but they use up so much feed without yielding a proportionate return that it is hardly advisable to encourage increase in stock of this character. It is possible that too many horses are already in this country. The Navajo's means of livelihood is his sheep. He receives fair prices for wool in the rough and better prices for blankets. Mutton is his chief article of diet and this in connection with the food purchased by the sale of wool and blankets enables him to secure an independent living. In fact so important is the sheep in this region that the physical improvement of the Navajo is largely dependent upon improvement in sheep-raising, which in turn depends upon an increased water supply so distributed as to make it possible to use all the natural grass lands, as well as to increase supply of fodder by artificial means. Under present conditions highly bred sheep will not prosper in this region for they can not stand the travel necessary to secure water. The coyote, the natural enemy of the sheep, must also be disposed of.

Agriculture.- In the San Juan Valley, near Tuba, and in some of the south-facing valleys of the Hopi country considerable fruit is grown, chiefly peaches, apricots and apples. Patches of melons and squashes are seen here and there over the reservation, and seem to flourish.

SRP000160

Corn, however, is the most successful and most valuable crop, the cultivation of which the Indian understands and upon which he has learned to rely. A successful government farmer would show the Indian how to increase the yield and the acreage of this crop and would consider his work accomplished when several thousand small patches of corn were successfully cultivated by Navajo and Hopi. Under such conditions permanency of abode would be facilitated, greater independence secured and the Indian's bill for flour be greatly reduced.

Water Supplies.

Introduction.- Water is desired in this region both for stock raising and for agriculture. Water supply for a grazing country involves not a few large supplies but many small ones; not an increase by storage of water where water is, but moderately permanent supply where at present it is not found. Water is needed where advantage may be taken of natural feed on the reservation.

For agriculture, a relatively small, but highly important factor of the Navajo-Hoki problem, irrigation is necessary, but even here many small supplies of water are desired.

An ideal development of water would be to secure moderate supplies 8 to 10 miles apart over the entire reservation;

SRP000161

enough water at each place to irrigate one-fourth acre or less -- to be used for corn, vegetables, alfalfa, fruit, etc. -- and at the same time enough to supply 200 to 500 head of sheep. To fulfil these conditions there is demanded not only the use of surface water in irrigation, but also the direct utilizing of rain water, the development of springs and the sinking of wells.

Irrigation.- The region is not adapted to large irrigation projects. There is no permanent stream except the San Juan, fed by the tributaries from the mountains of Colorado, and even this has stages of very low water. A few small, short, streams from the range of mountains on the Arizona-New Mexico line and a few from the Black Mesa and Navajo Mountains are permanent. The streams, however, are too small and at too great elevations to serve large areas on the plains below and some of them are in deeply cut, narrow valleys from which it is impracticable to lead them out upon the mesas. At great expense it is possible to construct reservoirs at Leupp and at Chinlee; the Black Falls project may be feasible, (see Part III); and Laguna Creek near Marsh Pass is well worthy of study. The control of the main washes such as Oraibi, Denebeto, Chinlee, First Mesa, Moencopie, etc., as well as of the Little Colorado River, down all of which come volumes of water in the rainy season, involves elaborate

SRP000162

and costly engineering work. Furthermore, these are special problems which involve much more study than has been given to them and the failures on record fully justify the irrigation engineers of the Indian Service in their refusal to recommend large projects, and their attention to schemes of moderate cost which yield definite and immediate results.

Two projects, however, of relatively small cost and which would yield adequate returns seem to be justified, namely, first, at Tuba where it is possible to make much more use of the water from Big Springs and Reservoir Canyon; and second, at Ganado, where the water from the upper part of the Colorado Wash may be taken out economically. Both of these schemes are such as would be undertaken from a commercial standpoint alone, since they would greatly increase the arable land suited for corn and alfalfa. As a means for supplying water for small Indian farms they are amply justified, and if it seems advisable to establish town sites for Indians in thickly populated areas, or to establish schools for the training of Indian farmers, these two places are admirably suited. Both these schemes, I believe, have been recommended by irrigation engineers.

A reservoir in "Blue Canyon" near Fort Defiance would increase agricultural possibilities in that region; one at Lakasakad would probably justify its expense, and more could doubtless be made of the streams tributary to Canyon de Chelly and probably of that stream itself.

SRP000163

Springs.- In a region of rough topography, dissected by canyons and washes, even if the rainfall is deficient, springs abound, and the Navajo Reservation is no exception. In fact I have been surprised at the number of small, permanent springs on the reservation. None of them, with the exception of the school spring at Tuba yields large amounts, but in the case of more than 100 springs the geologic conditions controlling the supply are readily understood, the method of development is obvious, and increased yield can be secured at small cost. As the matter now stands, some of the springs, notably Cedar Spring, Stiles' Ranch, Tuba, Burro Springs, and Keams Canyon secure a large per cent of the flow, but of the hundreds of other springs practically none of them have secured more than one-half the available supply; and in several places springs of considerable capacity are lost in land slides, buried in talus slopes or smothered by drifting sands. Furthermore, small bogs and swamps exist in several places, the water in which may be made available for use.

Wells.- Investigations of existing wells in regions immediately adjoining the reservations, a study of the character of the rock and alluvial deposits, and special tests with a hand-drilling outfit, show that the region is well supplied with groundwater. This is especially true of the great washes, for example, the Colorado, Oraibi, Denebato, Jettyto, Laguna, Steamboat, Chinlee and Moencopie, First Mesa, and the great open valley east of Tohatchie. The alluvial "fans" and dry

SRP000164

stream beds of tributaries leading from the mountains are also saturated with water. In all of these locations, permanent wells of moderate supply may be secured at selected spots at intervals of from three to four miles and at depths rarely exceeding 30 feet. At many places, in fact, water for 100 head of sheep can be secured at depths of less than 15 feet, and in two places considerable water was found at depths of less than 6 feet.

The narrow washes of the mesas, Zilh Le Jina, Cedar Ridge, etc., furnish a number of satisfactory well sites and even the high regions dissected by narrow canyons may be watered by means of wells. In the case of the high mesas there is little space for farms or grass lands along the immediate streams, but the inter-stream spaces covered with pinion and cedar and diversified by sand dunes and ridges are good catch basins, where surface run-off is retarded and a large per cent of the rainfall is fed into the rocks below. This water is concentrated in a zone between rock and overlying loosematerial and in sandstones overlying more impervious strata. Its recovery can be accomplished in a number of places by rock wells 100 to 200 feet deep. Deeper wells in selected localities would tap known supplies and in a few places examined, the probabilities for flowing wells are good.

SRP000165

It is advised that many wells be dug on these reservations. The digging of shallow wells along the main washes might be taken up first, and the first season's work be devoted to sinking wells and developing springs in localities where the population is densest and the herds largest -- the well sites to be selected partly with reference to the education of the Indians and partly to meet the most pressing demands. At the same time or later, the more expensive wells on the high lands could be drilled and last of all the deep borings for artesian water could be undertaken.

The need for wells is so evident and the probabilities so favorable that it seems wise to put into the field at the earliest possible date two parties equipped for well digging -- each supplied with movable camp, tools, rough lumber, tile or iron casing, iron pipe, cement, etc. One of these parties should be in charge of a competent practical farmer -- one who is capable of securing results with unskilled Indian labor, and its energies should be devoted to sinking shallow wells, digging out and cementing springs, and building catch basins for rain water. This party would move from place to place under some general direction finishing each piece of work before leaving.

SRP000166

The other party should have movable camp outfit, tools, etc., and in addition should be supplied with a combined rotary and churn drill of modern pattern capable of sinking holes in rock or alluvium to depths of say 200 feet. This outfit should be in charge of an experienced well driller and the sites for boring should be selected so as to secure water at a distance from the present supplies; the exact location to be determined only after consultation with men familiar with the geological structure of the particular area involved.

These two outfits combined might reasonably be expected during the year to sink 20 to 30 wells, develop 15 to 20 springs and to drill 8 or 10 deep wells. Furthermore, one season's work should serve to teach the Indian the best methods of shallow well construction and of spring development, and should furnish data sufficient to plan intelligently for the future. Expense might be saved by repairing the old well-drilling outfit now at Oraibi, and it may be found economical to purchase a machine for the mixing of concrete and the manufacture of concrete tiling.

It is estimated that at least $10,000 per year for each of the parties is necessary. The principles involved in developing springs, and in the location and construction of wells both shallow and deep are discussed in the accompanying reports: Part II and Part V.

SRP000167

Government Farmers.

The Government farmer is an essential factor in the Moki-Navajo problem. In fact it might be said that the rapidity and permanence of the Indians' advancement depends upon the ability and character of those officials. The Navajo and Hopi alike are chiefly interested in stock-raising, agriculture, and water supply; and the man who inspires confidence, who comes closest to them and who can exert the most influence for their material and moral uplift is the man who understands sheep and corn and the securing of water.

The number of farmers is inadequate for the territory which is to be covered; and the tasks to which they are assigned are not such as to aid the Indian in the most direct way. The Navajo sees little of the farmer, for these employees are kept too much in the immediate vicinity of the schools, busy with the school garden, with repairs, and with miscellaneous duties. Men are needed who will devote their whole time to work with the Indian where the Indian lives, advising and helping through the year, paying chief attention to those things which most vitally concern the Indian.

The training of the Government farmer for the arid southwest is deficient. There is little use here for manure, ensilage, and the latest pattern of agricultural implements, and accordingly the training received in humid regions may

SRP000168

be of little use. A knowledge of simple well-digging, of the use of rough lumber, the construction of ditches, the building of roads and the use of rough stone and cement are essential. He should also know something of sheep and horses. Farmers equipped with this practical information are imperatively needed in this region; those who can adapt themselves to local conditions, make the most of incompetent help, and work intelligently and industriously at the many unsolved problems. To secure men of this type involves making the position of Government farmer more attractive by paying higher salaries, giving greater independence, and enlarging the opportunities for promotion.

As a means of securing men of greater ability it is recommended that the Civil Service examination for farmers be changed so as to have special examinations designed to test the competency of men to deal with the special problems presented in the arid Southwest. Arrangements might be made with some of the Agricultural Colleges whereby not only questions should be answered, but actual field tests could be applied much after the manner of testing of candidates for the position of forest ranger. Another scheme would be to establish a school for Indian farmers at Ganada or Keams Canyon, Tuba or Chinlee, where under competent guidance, young men, both whites and Indians, might be given direct practical instruction;

SRP000169

or again arrangements might be made for suitable instructions at the Arizona or New Mexico expetiment station. Under the present system too many incompetemt and impractical men are sent on to these reservations, and occasionally a man comes who has never harnessed a horse or guided a wagon over a rough road.

General Observations.

Navajo and Hopi.- The Hopi impresses me as a remnant of a disappearing race -- one which has reached its highest point of advancement and is destined to repeat the history of its ancestors, the cliff-dwellers; one for whom the Government can do little beyond making its dying days comfortable, by aiding its agriculture and the schooling of the children. The Hopi is a skilled agriculturist, much more skilled, it must be confessed than some of the government farmers who are assigned as agricultural teachers. But any large degree of advancement on his part involves a radical change in his habits, his customs, occupation, place of dwelling, etc. - a change which can hardly be expected.

The Navajo, on the other hand, has latent possibilities beyond any tribe of my acquaintance -- his knowledge of stock, of arid conditions; his physique, his industry and independence are remarkable. The increase in population in recent years shows that this tribe is well adjusted

SRP000170

to its environment, and it is fair to assume that the Navajo will advance to a high state of civilization in his present location. With proper assistance he is capable of developing this country, and may be expected later to mingle with the whites on terms of equality, and to be assimilated into the population in the same manner as certain less advanced Europeans. If distinction must be made between Hopi and Navajo, as regards appropriation or the character of assistance rendered, the Navajo should receive greater consideration.

Superintendents.- The Indian Bureau should be congratulated on the type of superintendents now in this region. From 1890 to 1900 the writer had occasion to see at close range a number of Indian agents, and the improvement since that time in the character of reservation officials as regards ability, honesty, and devotion to work is little short of revolutionary. I was impressed by the tact and power of organization of the Moki Superintendent; with the mental calibre, the plans, and breadth of view of Western Navajo Superintendent; with the practical ideas and the industry of the Navajo Extension Superintendent; with the genuine love for the Indians and devotion to their cause exhibited by the Superintendent at Fort Defiance.

Traders.- With two exceptions, mentioned to the commissioners, the influence of the traders seems to be helpful.

SRP000171

They apparently feel the responsibility of their position, which brings them into intimate contact with the Indians and furnishes opportunity to impress lessons of honesty and promptness and generosity in the every day dealings of man with man. There is no doubt in my mind that the greatest single influence for material, social and moral advance on the whole Navajo-Moki Reservation is the trading post at Ganada.

Missionaries.- The mission establishments on the Reservation have not in all cases fulfilled the hopes of their supporters. With some marked exceptions, the men are not of large calibre, and are not possessed of qualities which inspire confidence in their leadership. They are too impatient of results -- too anxious to secure mental assent to theoretical ideas. Rigid standards of civilized conduct are demanded, standards impractical for races of their infancy, especially in arid lands where a more or less nomadic life is essential, - standards which could scarcely be demanded of highminded whites under similar conditions. It seems to me that the government should not back missionary organizations, but individual missionaries; should inquire into the fitness of each man and woman for work in this particular field exactly as is now done with traders, and other outsiders to whom privileges are given. The effectiveness of missionary work would, I think, be increased if the money of churches and philanthropic organizations were put into hospitals and individuals

SRP000172

with missionary spirit be induced to serve as teachers, farmers, field matrons, etc., in the government service. There ought, furthermore, to be more effective machinery for summarily removing a missionary who poses as a protector of the Indians against the supposed oppression of the government.

Tuberculosis camps.- A striking paradox in this region is the fact that where white men are sent to recover from tuberculosis, the Indians are dying at an alarming rate from this disease. Apparently the chief trouble is that the present mode of Navajo and Moki life furnishes ideal opportunities for spreading the disease. For this reason tuberculosis camps are highly to be desired; not elaborate hospitals, but camps of floored tents or of open houses. A suitable location involves sufficient water of good quality, timber or coal for fuel, and access to sources of supplies. The following locations are suggested:

Lokasakad.- about three miles west of Indian Wells. Abundant good water can be secured from a spring and a reservoir could easily be constructed -- one of sufficient capacity to irrigate a small farm; firewood is ample in amount and supplies could be secured from the railroad at Holbrook or Winslow, or from the stores at Indian Wells and Cedar Springs. Another good place on the Moki Reservation is Tallyhogan Springs about six miles southwest of Keams Canyon where conditions for water and fuel are favorable

SRP000173

and to which supplies could be forwarded from Keams Canyon or from Marti's.

For the Navajo Reservation the following sites are worthy of consideration: Steamboat Canyon, some one of the springs near Hlohala, the spring about three miles south of Tohatchie. At all of these places sufficient water and fuel is within reach and access to headquarters is easy. If not considered too near the school, "Blue Canyon" near Fort Defiance is an ideal location.

Sites on the Western Navajo are limited to two regions, viz., one of the numerous springs rising in the cliffs near Moa Ave and Lyon's Ranch and some place along the upper waters of the Moencopie (Blue Canyon).

Marsh Pass Region.- Attention is called to the possibilities of extensive development in the Laguna Wash valley between Marsh Pass and Agathla Needle, as shown on the Marsh Pass Topographic sheet. There is opportunity here for the development of agriculture by irrigation from reservoirs and wells, and a good center for school, government farm, and hospital. It is moreover, a good point from which to reach the Indians living near the Utah line west of the Chinlee Wash, and along the northern edge of the Black Mountains.

SRP000174

Navajo Mountain District.- This is the least known part of the United States. It is worth careful exploration for timber, water, cliff dwellings, possibilities of irrigation, and with reference to establishing a school to serve as a center for reaching the Indians of Navajo and Piute canyons about whom little is known.

SRP000175

Recommendations.

It is recommended:

1. That the region be developed for stock, especially sheep; that no large irrigation enterprises designed for agriculture be undertaken except the projects at Tuba and at Ganada, and possibly at Black Falls.

2. That two well construction outfits with an appropriation for supervision and labor of $10,000 each be organized, and placed in the field as soon as possible.

3. That farmers for the Navajo-Hopi Reservation be selected with reference to their fitness for work in this particular part of the country, an arrangement which will involve

(a) A modified civil service examination

(b) Higher salaries

(c) More authority

(d) Freedom from duties on school grounds.

4. That a general study of water conditions be continued for another year with special attention to the San Juan and Navajo reservations including the area drained by the Chaco and the Navajo Mountain district.

SRP000176

OFFICE OF INDIAN AFFAIRS
RECEIVED
JUN 9 - 1910
47345

WATER RESOURCES OF NAVAJO-MOKI RESERVATIONS.

Part II. Suggestions to Superintendents and Government Farmers.

by Herbert E. Gregory.

Introduction

Small reservoirs

- The site
- The dam

Springs

- Introduction
- Springs in unconsolidated material
- Springs between ledge and cover of loose material
- Springs between rock strata

Wells

- Shallow dug wells
- Wells in rocks
- Flowing wells

Rainwater.

SRP000177

WATER RESOURCES OF NAVAJO-MOKI RESERVATIONS.

Part II, Suggestions to Superintendents and Government Farmers.

Introduction.- The small annual rainfall of the Navajo-Moki Reservation and the ~~entire~~ practical absence of rain during April, May and June, and often parts also of July, make it impossible to depend directly upon rainfall and permanent stream flow for water supplies for stock-raising or agriculture.

Something is done by the Hopis and a few Navajos by planting small crops in selected water-holding soil where the seeds germinate and make small growth. For the development of crops, however, summer rains are relied upon, rains which either soak into the sand or are made available by flooding from the washes during July and August. Small irrigated tracts scattered over the entire reservation yield good results. The country is, however, preeminently designed for sheep raising. Plans for the development of water should be directed to securing numerous small supplies by means of small reservoirs, springs, wells and rainwater cisterns. These supplies, while designed primarily for stock, could also be used to irrigate small patches of corn, garden truck, alfalfa, and possibly fruit trees.

In developing water the superintendent is confronted by three problems: (1) Securing reasonably large and constant supplies at school sites for laundries, school farm, school gardens and ordinary domestic use. Different conditions must be met at Tuba, Leupp, Keams Canyon, Fort Defiance, Walpi, Shimapabi, Oraibi, St. Michaels, and the newly selected sites at Chinlee and The Cornfields, as well as Laguna Creek, Lokasaked and other points where schools could be located ~~to advantage~~ in the future; (2) maintaining watering places along the freight roads, at coal mines, etc.; (3) the development of supplies suitably located for watering stock and small cornfields.

The first problem has been studied by the irrigation engineers and inspectors, and will be but briefly considered here. The solution of the second is involved in the third -- which, because of its immediate importance to the welfare of the Indians, has been the chief object of the present study, and will be here discussed under the heads of small reservoirs, springs, wells, and rainwater cisterns.

Small reservoirs.

The larger washes and particularly those through which great volumes of water rush in times of floods, especially where the valley walls contain sand or adobe, are to be avoided in the construction of ponds or catches. The great and fluctuating volume of water, the character of the stream bed, and the presence of silt present problems which have

SRP000179

not yet been satisfactorily solved by irrigation engineers. Inexpensive storm-water reservoirs may, however, be constructed by paying careful attention to the location, construction of the dam, and position of the wasteways.

The site.- The site for a small reservoir should be selected near the heads of washes or on tributaries and particularly those branches which do not have steep gradients. In fact, the flatter the valley the better. A valley covered with grass, sunflowers, sage bushes, or greasewood, backed by slopes forested with pinion and cedar should be selected where possible.

A number of places were noted where natural depressions in bare rock could be utilized by constructing small dams across the poorly defined outlets. Where possible, also, the reservoir should be so located that the prevailing southwest winds will not have opportunity to drive waves against the embankment, a matter which is often overlooked, but is of considerable importance, even on a small reservoir ~~where the winds are strong and~~ if the dam is constructed of earth. Care should be taken where feasible to locate the reservoir not directly in the stream valley, but slightly to one side so that the rush of storm water does not spend its full force against the embankment. By keeping this fact in mind, it is possible to locate reservoirs along the sides of the larger washes where they may be filled by a portion of the storm water

SRP000180

without danger of destruction. In some cases, also, a ditch may be dug to conduct the water from the main wash to the reservoir and the temporary headgates renewed after each storm.

Natural wasteways should be selected where possible and care should be taken not to allow too much fall between the point where the water leaves the reservoir and where it enters its old channel. This fact should also be kept clearly in mind when an artificial wasteway is to be constructed, for the fall which forms at the lower end of the waste channel may eat backward with great rapidity. Where possible, wasteways should be located in the direct line of the natural stream flow, and should not be located on or near the dam, rather as far away as the topography will allow, and at least five feet below the top of the dam. Brush checks made of mattresses of greasewood, sage brush, pinion, and cedar fastened by wire may be constructed along the spillway, and in favorable localities drifting sand may be directed to build dunes which may accomplish the same results.

The dam.- Good dam sites are not abundant in this region and material for their construction is unsatisfactory; for this reason greater care should be exercised in building these earth embankments. After the site has been chosen ground should be cleared by removing the porous top soil, together with weeds, plant roots, etc., and the material thus removed should be taken outside the reservoir basin.

SRP000181

A trench ten feet wide and two feet deep should then be dug along the axis of the dam. This is a very important matter, as it enables a tight bond to be constructed between the earth and the dam and tends to break the natural water channel. It is advisable, also, to roughen the entire surface over which the dam is to be built. The dirt for the dam should be put on carefully and spread evenly in layers one foot to eighteen inches in thickness, and each layer should be tamped ~~artificially~~ by hand or by driving horses back and forth over it. This method of treatment tends to prevent the formation of horizontal and vertical seams alike. No dirt should be taken for the embankment below the dam for the holes ~~then~~ thus made may fill with water and soften the dam materials, and where borrow pits are made inside the reservoir care should be taken to leave a berme at least eight feet from the foot of the slope in order to prevent sliding. If built of loose earth the dam should not be less than 10 feet on top and the slopes must be less than those of ordinary dirt banks. The engineers of the Chicago and Northwestern Railway from whom part of the above data are obtained have found that a slope of three to one on the side next the reservoir and of two to one on the outside will secure the most satisfactory results. And the writer's experience in planning reservoirs for stock on the Great Plains is that an earth dam in an exposed situation should be as wide and as flat as the local conditions will allow.

SRP000182

The material used in the construction of the embankment must necessarily be that which can be obtained near at hand. Many places on the Hopi Reservation, in the Chinlee region, and elsewhere furnish excellent clay from decomposed shale. In other places nothing but sand is at hand. Where material may be selected it is of course more important to place the impervious material on the inside of the dam. Care should be taken to avoid soils which contain alkali and other materials which may be readily dissolved by the water. Where the material is not satisfactory, it can be much improved by puddling. Horses and cattle or sheep driven through the reservoir and over the dam when the material is soft will help in securing water-tight material. A dam may be further strengthened by facing with rock and in a number of localities abundant thin slabs of sandstone and shale are at hand for this purpose.

The most satisfactory small dam seen on the reservation is located on the trail between Ganado and Keams Canyon and was constructed by an Indian as follows: Two rows of posts ten feet apart were made into fences by weaving brush from post to post. The space between the fences was filled with sand and clay taken from the slopes nearby. Sheep and horses had apparently been driven day after day between the fences tamping down the material as it was being placed in position and also afterward. Practically no water escaped through this dam and the "lake" is known as a constant supply.

SRP000183

All the reservoirs are liable to fill with silt, a disaster which can not be avoided. A small amount of silt is of course good, as it tends to fills in the space between the sand grains and increase the water-holding capacity. By carefully selecting the site as indicated above, the filling will be very slow. But in any case filling is almost sure to occur, in which event the reservoir must be dug out or a new one built, a procedure which is feasible because of the small cost of the embankment.

Springs.

Introduction.- Of the many types of springs the one commonly represented on the Hopi-Navajo Reservation is that whose position is determined by the outcropping of a rock series including pervious and impervious strata. The water which falls as rain soaks into the ground until it encounters some relatively impervious bed and emerges at a point where these beds are cut by canyons and exposed in cliffs, or along the washes. The water is thus concentrated in definite zones and its development implies a knowledge of the geological conditions at each point. Two classes are recognized: on in which the water is confined between unconsolidated materials -- sand, gravel, clay, adobe; the other where solid rock forms the underlying and overlying beds.

SRP000184

Springs in unconsolidated material.- Springs of the first class in this region occur in the bottom of the wider washes or tributary washes, or on alluvial fans where clay and adobe are interstratified with sands and gravels. In these cases the character of material changes so rapidly that it is not always possible to determine the extent of the underground basin or the amount of water available. Such springs may emerge on a flat or gently-sloping surface. Sometimes they appear in arroyos with banks two to three feet high, and in both cases their presence is indicated by areas of sand through which water bubbles or by boggy spots. In places the water-bearing bed is at some distance below the surface and the outlet slopes obliquely upwards along some porous stratum. In other places the entire water supply is near the surface. The best method of development in these cases is to sink open boxes of wood, tile, or cement of fairly large cross section, say ten to fifteen by five feet. The boxes should be set with their longer diameter at right angles to the immediate surface slope, and in all cases should be covered and the water piped to troughs or basins at some lower level. Where flood water is liable to fill an arroyo containing the seep it is better to sink a well in the bank down to a depth below the point of emergence of the spring. Typical springs susceptible of this treatment are found in Black Creek Valley below Hunter's Point, ~~and at~~ in Coyote Wash west of Elephant Butte, at San Cone Springs, and

SRP000185

elsewhere in the Chinle region. The spring which supplies Fort Defiance is of this same general character and could be much improved.

Most springs, however, are fed by water at definite horizons, at the contact of pervious and impervious beds, i.e., by solid rock covered by loose material, by sandstone or lava underlain by shale, or by two layers of sandstone of different degrees of fineness. In all of these cases the water is in a thin sheet of great horizontal dimensions and all the plans for development should aim to collect as large an amount as possible from this shallow layer of water.

Springs between ledge and cover of loose material.- Where the water horizon is the plane between alluvial material or wash or soil and the solid ledge, the simplest method of development is to build a simple sub-surface dam of board, clay, cement or other impervious material at approximately right angles to the main underflow. This dam can be made continuous or with two wings, the only requisite being a tight contact of dam and rock and an outlet for fresh water through the dam or at ~~the~~ its end of the dam for the water. (Fig.).

It ~~is often~~ may be found advisable to dig a shallow well through the surface material into the rock itself and conduct the water to it by means o these sub-surface dams, as has been done in a crude way at Monument Pass and Onion Springs. (Fig.).

SRP000186

In places the material over the solid rock consists of talus from the cliffs above or of extensive landslide material as is illustrated on a large scale at Oraibi and First Mesa and Second Mesa. Here the surface cover is so thick that the water overlying the solid rock escapes with difficulty and usually in several places. In such cases the best method of development is to drive a tunnel directly into the hill at the point where the largest amount of water emerges, and to construct lateral tunnels leading from it. In this way the outlet is brought nearer to the chief supply and a number of small seeps may be concentrated into one strong flow (see Fig.). The water supply at Sunrise Springs and to a lesser extent at Indian Wells and Stiles Ranch is an illustration of the successful application of this principle. In certain dry stream courses where for a limited distance the rock floor is brought to or near the surface, the principle of the winged sub-surface dams might be used; for instance, at the spring on the Fort Defiance-Chinlee road north of the sawmill where Mr. Leaden has developed a much-needed supply. In some places, as for instance, Tsabeto, four miles east of The Cornfields, the presence of talus is an important factor, for the water emerging from the rock is passed so slowly through the loosened material that some water is present even in the driest season.

SRP000187

Springs between rock strata.- The spring areas -- the districts where springs constitute the chief water supply -- are the Moki Buttes including the southern parts of Moki Reservation and the non-reservation land immediately adjoining; the mesas on which are situated Oraibi, Shimopavi, Walpi, etc.; and the Tuba region. Springs also constitute the chief supply at Keams Canyon and along the cliffs forming the border of the Black Mountains. In the Moki Buttes region the water horizon is at the bottom of the broken lavas and tuffs, where these igneous rocks overlie dense sandstones, or the purple and red shales of the La Roux formation. At the Moki villages the water horizon is at the top of an extensive series of shales; similar conditions prevail in the Keams Canyon district, while at Tuba the water imbibed by the porous cross-bedded sandstone is brought to the surface by shale layers, by sandstone beds of varying density and by cracks and joints in the rock itself. There are in the Hopi Reservation ~~more than 100~~ probably 50 springs, large and small, and in addition there are many small seeps which could be converted into valuable supplies, ~~for~~ it should be remembered in the case of small springs and seeps, the amount of water emerging does not represent the amount immediately in the rocks. The evaporation in this region is so great (about 6 feet of standing water per year) that a considerable amount of water may be exhausted as it seeps through the rock face.

SRP000188

Perhaps the best method of development for springs emerging between two rock layers is first to make a basin at the point of greatest flow, second to construct tunnels and trenches so planned as to enlarge the water-bearing plane between the pervious and impervious rock. The tunnels may be driven directly into the cliff or laterally along its face, with the object of concentrating as much as possible the water lying immediately above the impervious bed (usually shale). The axis of the tunnel should in general be constructed parallel with the water plane and dug partly in the underlying shale, but largely in the saturated upper sandstone. (See Fig. 3).

In this region where evaporation and soil absorption are great it is not advisable to attempt to retain the spring water within natural materials. A basin, preferably of cement, should be made immediately at the spring, and other basins at lower points to hold all of the water which the spring can furnish. Covered troughs or iron pipes should lead from one basin to another and all the basins should be covered and made deep rather than wide.

A spring should not be considered properly developed until a constant flow is secured and all the water is saved. If there is more water than is needed for stock it should be carried in pipes to some point where irrigation is possible. No water should be allowed to go to waste. That a great deal can be done with these springs is indicated by the fact that of the numerous springs, large and small, observed on these reservations none of them are securing the maximum water supply. Most of them lose from one-fourth to

to one-half of the water; some of them two-third and in a few cases, as at Lyons' Ranch, springs of considerable size lose all their water in sand. It should also be remembered that boggy places are springs that could be dug out, the source of water found, and treated as in normal springs. As an illustration of the proper method of developing springs, attention is called to the Wepo Sheep Dip, and even here, although the principle is right, probably less than one-half the water is recovered.

In some localities it may be found cheaper to construct walls, designed to tap the water horizon indicated by springs, than to furnish material for basins and pipes.

SRP000190

Wells.

The amount of ground water on the reservation is sufficient to supply wells in most localities, and if the Indian country were to be treated as a commercial enterprise the development of springs, building of reservoirs, and digging of wells both shallow and deep, would doubtless be carried on systematically with results which would justify the expense. If the white man alone were concerned, driven wells would in general be recommended -- wells driven directly from the surface or at the bottom of shallow dug wells, and the pumping would be done by windmills. The cover of unconsolidated material in the wide washes and narrow upland valleys is eminently suited for obtaining water by the driven point method, and it is advisable to sink such wells wherever they can be taken care of. It must be borne in mind, however, that wells are for the use of Navajo and Hopi, and these Indians are at present incapable of repairing windmills or even hand pumps, and accordingly no pumping machinery should be introduced unless placed in the immediate charge of a government farmer or other official. If a windmill is used, it should be of the simplest construction, easy to erect and easy to move and one in which the gears are either protected or so arranged as to be readily replaced at slight expense; since the sand storms on the reservation especially in the southern and western parts are very severe and cut out the gears in a short time. Geological conditions on these reservations are favorable for shallow dug wells and also for wells drilled in rock and in a few places reasonable flowing wells may be obtained.

SRP000191

Shallow dug wells.- Considering the use to which wells on these reservations are to be put, the number required, and the fact that they must be constructed largely by Indian help and kept in repair by them -- it is advised that a large number of shallow wells be dug. These wells will of course provide the largest supply of water at the least depth when located in or near a wash with a large drainage area -- e.g., Colorado, Oraibi, Denebeto, First Mesa, Black Creek and Chaco.

In places it may be advisable to sink wells in the wash itself, thus securing water at a depth of four to ten feet. In such cases protections from floods may be secured by the construction of an island of brush and stone about the well. In general, however, it is better to locate the well as near as convenient to the wash, but above the reach of all but the highest floods, and the chances of success are improved when the site is selected near the junction of a tributary wash with the main channel. A little study and observation on the part of the farmer may disclose the course of underground water even when it is not apparent on the surface. Care should be taken not to locate a well where rock is near the surface and at the same time it should be borne in mind that water frequently accumulates between solid ledges and loose cover and occurs in the fractured surface of ledge. When, therefore, rock is exposed in the bottom of a well it is wise to continue sinking for a few feet in order to take advantage of this important water horizon.

SRP000192

A well of large diameter is advised, especially in places where the character of material exposed in gullies indicates the absence of coarse sand and gravel; 6 x 6 feet or 6 x 8 feet is a better size than 3 x 4 feet; and when a large amount of water ss desired, wells as large as 20 x 30 feet may be dug with profit. In such cases, however, a small test well should be dug or drilled to determine the amount and quality of water before undertaking the expense involved in removing such large quantities of earth. The object sought in constructing such large wells is to intercept a larger amount of the water which is moving slowly throuhh the materials forming the valley floor. Where material will permit, the same object may be attained by sinking a well of relatively small diameter and driving tunnels laterally from the bottom. The depth to which wells should be sunk varies with the locality and the character of the material. The unconsolidated material of the valley washes consists of a series of adobe, quicksand, sand, gravel, arranged in layers, in pockets, and in irregular beds; and it is usually impossible to tell the exact bed which will contain the largest amount and the best quality of water.

Drilling tests indicate that in most of the larger valleys a depth if 15 to 30 feet is sufficient to secure a reasonable supply of water. If greater depth is required, it is still practicable to sink wells in adobe, sand and silt to depths of 60 or 70 feet, with no other tools than pick and shovel, windlass, and bucket, as has been clearly shown by the successful well at The Cornfields dug under the supervision of Mr. Leaden. The chief obstacle to rapid and economical

SRP000193

construction of shallow open wells in the presence of quicksand which is liable to be encountered at any depth from the surface down. It is not to be expected that an Indian can overcome this difficulty; the supervision of a practical farmer or a superintendent with some knowledge of well-drilling or mining is essential. There must be at hand water-tight wooden boxes, or better yet sections of iron tile or cement casing so flanged as to make water-tight joints. This protective box is sunk as digging proceeds, and may be used not only to prevent caving, but also to shut off less desirable water where more than one water-bearing bed is encountered. It should be borne in mind that the pressure exerted by quicksand on well casing is very great; that when saturated with water the lateral pressure of sand is equal to 1/2 the vertical pressure and that beyond the point of saturation the vertical and lateral pressure ~~are~~ is equal. The casing must therefore be strong; it must also be water-tight, for saturated quicksand flows wherever water will flow, passing even through 100-mesh screens. The nature of quicksand and its method of treatment seem to be pretty well understood in this region, but suitable material for casing is not at hand. If wells are to be sunk economically and without loss of time a supply of suitable casing should be provided. If many wells are to be dug it may be found less expensive to purchase machinery for molding cement tiles. Until the Indians

SRP000194

the upper sandstones down to the impervious shales below. The springs at Oraibi, Keams Canyon, and east along the base of Salaki Mesa indicate a definite water horizon underlying the Black Mountain region water-bearing strata, which may be reached by boring 800 to 1600 feet, depending upon the location. It should be clearly understood that such wells are expensive and that they may yield too little water to justify the expense. Careful thought, therefore, should be given to their location and boring should not be undertaken before obtaining expert advice. However, in order to obtain data for future investigations it seems advisable to drill 1000-foot wells on the western part of Zilh-le-jini mesa between the Boo Koo dot-Keish and Red Lake and on the high mesa between the Denebeto Wash and the Little Colorado. Insufficient knowledge of local geologic structure is responsible for two costly failures, viz., at Oraibi and at Cross Canyon, the former being sunk entirely in practically impervious shales and the other where the supply area is but a fraction of a square mile.

Flowing wells.- A few places on the reservation, e.g., upper Chinlee Valley, Keams Canyon, Monument Pass, the base of the Carrizos and branches of the Chaco have a geological structure favorable for flowing wells. There are a number of flowing wells at Bluff and at Goodridge on the San Juan and a shallow artesian well of rather unusual type is found at St. Michaels. However, more study should be given to this problem before deep rock drilling designed to secure a natural flow shall be undertaken.

SRP000195

Rainwater.

In arid and semi-arid regions, water from all sources, surface, underground and rain, should be stored for use -- and it is surprising that New Mexico and Arizona have paid so little attention to one of these sources, namely, rainwater. By storing rainwater, supplies for domestic purposes and for small flocks may be secured in parts of the reservation where surface water and springs are absent and where wells are too expensive to justify construction. Rainwater cisterns for travelers and for teams might be constructed on the long roads which must be traversed on entering the reservation and in going from place to place across it, and the amount of water available at stores, missionary settlements and government headquarters might be increased by similar means.

Collected rain is particularly desirable, where the present water supply though sufficient in amount and available for stock is unsuited for man because of alkali, salt, etc. For instance, at Red Lake, northeast of Tuba, the surface, spring and well waters are unfit for drinking, but an ample supply for household purposes is obtained by storing the water which falls on half the store roof. The water is conducted into a cement-lined cistern six feet in diameter and eleven feet deep. Every building on the reservation should be supplied with rain troughs and cisterns, for there are few places where rainwater is not more desirable for domestic use than the supplies now at hand.

SRP000196

Clean rock surfaces may be used also to collect rainwater by the construction of small cement dams at the foot of slopes; and it is entirely feasible, as is done in Bermuda and elsewhere, to clear off certain hillsides, cover them with cement, thus making shallow collecting basins from which water may be directed to a suitably constructed cistern or closed basin below.

Rainwater, if kept clean, is palatable and entirely wholesome and its storage offers one of the best opportunities to meet the demand for good drinking water in this section.

SRP000197

WATER RESOURCES OF THE NAVAJO-MOKI RESERVATION.

Part III - The Black Falls Project

47345

OFFICE OF INDIAN AFFAIRS
RECEIVED
JUN 9 - 1910

Introduction

Little Colorado River

The valley
Amount of water
The river bed

The Black Falls Project

O.K.

Water Resources of the Navajo-Moki Reservation.

Part III - The Black Falls Project.

Herbert E. Gregory.

- - - - -

Introduction: The proposition of Mrs. P. G. Gates to establish a colony at Black Falls has been presented to the Indian Commissioner and has been studied in a preliminary way by the engineers of this Bureau. The proposed plan, in brief, is to take water from the Little Colorado River at a point three miles above Black Falls, to lead out onto an area east of the river where 1200 to 2000 acres of good land may be served by the construction of eleven miles of ditch. By this arrangement a number of small irrigated tracts would be made available as homes for students who return to the reservation after graduation from Indian schools. The success of the project depends partly upon the possibility of augmenting the naturalflow during the dry months.

This region was visited in May in company with Mr. Mendenhall and Mr. Campbell of the United States Geological Survey under the guidance of Mr. H. F. Robinson of the Indian Irrigation Office. A detailed examination was made on June 19 to 21, a date purposely chosen so as to study the conditions during the most unfavorable part of the year.

The Little Colorado River.

The Valley: The drainage area of Little Colorado

extends from the Continental Divide to the San Francisco Mountains and from Mogollon Mesa to the Grand Canyon. From 15 miles below Winslow to the Colorado River, a distance of over 100 miles, the river either crosses or forms the boundary of the Navajo Reservation. From Winslow to Tolchato the stream flows in a wide flood plain, meandering freely between poorly defined banks of unconsolidated material. A short canyon occurs below Wolf's Crossing, and at Grand Falls the river has been diverted from its channel by a lava flow and regains its former course by dropping over falls seventy-five feet high. Black Falls, likewise, is caused by a lava flow and below this point the river flows through alternating stretches of canyon and open valley until it drops into a deep box canyon below Tanner's Crossing, and finally emerges to join its master stream, the Colorado.

Amount of Water: The fluctuation in volume of the Little Colorado is great. The stream gaging measurements above Winslow show that the flow is large, but extremely irregular and even at Holbrook where the run-off from 6,000 square miles is augmented by the flow from the Rio Puerco, the bed is occasionally dry. Throughout the distance from Winslow to its mouth the stream receives but two important tributaries, viz., Canyon Diablo with a drainage of 1220 square miles and the Moencopie, which collects water from approximately square miles. Both of these tributaries are dry for seven or eight months of a year.

The amount of water in the upper tributaries of the Little Colorado has been recorded; some measurements have been

SRP000200

made at Holbrook, on the Chevelon Fork, and also at Clear Creek (see table p. 2a)but no figures are at hand to show the amount of water in the river at any point where it may be made available for irrigation projects on the Navajo Extension or the Western Navajo reservation. Detailed records are not however essential for there is no doubt of the fact that there is abundant water for large enterprises, if some system of storage of surface water or means of utilizing the underflow can be devised, which will yield returns proportionate to the expense involved. The river is so variable in its behavior that a single year's record as to height of water and its distribution by months cannot be considered typical; yet enough is known to establish the fact that projects for using the water of the Little Colorado from Winslow to Tanner's Crossing must be based on the assumption that there is no surface flow during the months of May, June and parts of July.

The condition of this river in 1908-1909 is probably near the average. In December 1908 the school grounds at Leupp were flooded and the buildings at Tolchato had to be protected by temporary embankments. During the fore part of May there was a considerable flow at Leupp, Grand Falls and Black Falls. During the latter part of May, all of June and most of July the stream was dry. During August the extreme high water made crossing dangerous, and on several occasions it was impossible. On one occasion the writer recalls crossing a practically dry bed on this stream, and then waiting four days before it was possible to re-cross. "Always camp on the other side of a stream" indicates the uncertainty existing at all times of the year.

SRP000201

The river bed.- Since the success of the Black Falls project depends upon the feasibility of recovering the under-flow, an examination was made of the materials which form the bed of the Little Colorado. Above Leupp the valley floor is cut in soft, easily decomposed shales of the "Bad Land" (La Roux) formation, and vast quantities of the finest sediment are carried into the stream with each shower. The sand storms which prevail through several months of the year also increase the amount of the finely divided material. In places it is possible to walk for a mile in the dry stream bed without finding material coarse enough to be called gravel or even sand. In places the stream bed is formed of quicksand which makes crossing dangerous, a condition which partly accounts for the fact that Holbrook and even Gallup rather than Winslow are the railroad outlets for the Moki villages. Below Tolchato the stream valley is cut in firmer materials. The river bed contains sand, gravel and even large boulders in several places and the lower mesas bordering the stream are covered with a pavement of pebbles one to three inches in diameter, showing how completely the finer material has been removed by the wind and water. Immediately above Black Falls an unusually large amount of coarse material is present.

SRP000202

The top layers of the alluvial filling do not, of course, indicate the character of the material below, but the numerous well sections, and the sections revealed by channeling in the main stream and its tributaries, bear out the evidence obtained from drilling, viz., that the valley is filled by a series of overlapping lense-shaped deposits varying in texture from coarse gravel to the finest silts. (See figure 4 below).

The strata are usually three to ten inches thick and so distributed that it is impossible to determine beforehand what texture will be encountered at a given depth, and accordingly what mesh must be used as screen to keep out the sand. The chances are very good, however, that sand of satisfactory coarseness will be found at moderate depths.

SRP000203

The degree of saturation of the materials forming the river bed and the rate of movement of the underflow have not been measured, but the wells at Holbrook, Winslow, Leupp and Tolchaco, and the position of underground water in the short canyon stretches below Grand Falls, near Box Springs and above and below Black Falls prove the presence of large amounts of water at short distances below the surface during the driest month of the year.

At Holbrook are more than 100 wells, many of them using wind power. Water is encountered at 10 to 20 feet, but points are driven 20 to 35 feet -- some of them 60 to 100 feet -- in the hope of striking the "second" or "third water," evidently the underflow from the Puerco. The Santa Fe Railroad has an open dug well 30 feet in diameter and 65 feet deep in which water stands within 14 feet of the surface. The well is pumped from two to four hours per day and for the week ending June 27th, the time of my visit, was yielding an average of 52,800 gallons per day; while fairly palatable, this water is treated with lime and soda ash before being used in boilers.

At Winslow, the conditions are similar to those at Holbrook.

At Leupp, the valley deposits are of finer texture than those at Holbrook and much finer than at Black Falls.

SRP000204

The school obtains water from two points driven 30 feet, and four points driven 20 feet, using respectively 90 and 100 mesh gauze.

At Tolchato, an abundance of water of fairly good quality is obtained by sinking points 14 to 18 feet.

During the month of June the fine silts in the canyon below Wolf's crossing were found tombe saturated in four test holes dug. Six holes dug between Grand Falls and the mouth of the Denebeto showed similar results; and the water holes in the canyon above Black Falls and the "springs" in sand below the Falls indicate that the same conditions exist here.

The Black Falls Project.- An admirable spot has been selected for the intake of the proposed ditch at Black Falls. The point chosen by Mr. Robinson is 3± miles above the Falls and just below the mouth of a rock canyon 800 feet wide and bordered by walls 40 to 50 feet high. Water could be diverted while the river is running and the problem is: Can sufficient water be obtained by pumping at or near the intake to insure a supply during the dry months?

The conditions are as follows: A small lava flow, apparently from a vent west of and near the brink of the present falls has extended up the river and into the canyon. During the time elapsing since the eruption the river has almost or entirely removed the thin sheet of

SRP000205

The school obtains water from two points driven 30 feet, and four points driven 20 feet, using respectively 90 and 100 mesh gauze.

At Tolchato, an abundance of water of fairly good quality is obtained by sinking points 14 to 18 feet.

During the month of June the fine silts in the canyon below Wolf's crossing were found to be saturated in four test holes dug. Six holes dug between Grand Falls and the mouth of the Denebeto showed similar results; and the water holes in the canyon above Black Falls and the "springs" in sand below the Falls indicate that the same conditions exist here.

The Black Falls Project.- An admirable spot has been selected for the intake of the proposed ditch at Black Falls. The point chosen by Mr. Robinson is 3± miles above the Falls and just below the mouth of a rock canyon 800 feet wide and bordered by walls 40 to 50 feet high. Water could be diverted while the river is running and the problem is: Can sufficient water be obtained by pumping at or near the intake to insure a supply during the dry months?

The conditions are as follows: A small lava flow, apparently from a vent west of and near the brink of the present falls has extended up the river and into the canyon. During the time elapsing since the eruption the river has almost or entirely removed the thin sheet of

SRP000206

basalt in the region near the canyon leaving a fringe along the valley side above and at the proposed intake; accordingly the valley is here filled with alluvium resting on arenaceous shales and calcareous sandstones. An examination of the valley and the bordering mesas for two miles above the proposed headgates shows that very little fine material is being carried into the river at this point. The mesas for the most part are covered with pebbles one to four inches in diameter, resting on solid rock, and the tributary valleys are floored with sand, gravel and volcanic ash. The bed of the Little Colorado indicates the same conditions. For 2,000 feet below the canyon mouth the dry bed is about half covered with rounded boulders of lava, sandstone, etc., ranging in size from four inches to three feet.

So far as surface indications go, therefore, the deposits in the river bed are ideal for holding a large quantity of water readily accessible. In order to determine the character of the underlying strata, five drill holes were sunk in the river bed at depths of 5, 7, 8, and 10 feet respectively. In each hole irregularly stratified sand of fairly coarse texture was found, in which were embedded boulders which made it impossible to drive the hand drill to greater depths. All of the holes filled with water almost immediately. An attempt to sinl a test well three feet by five feet was begun, but here again it was not possible to go to any depth

SRP000207

because of the inability to keep out the water with rough lumber boxes, and simple baling apparatus at hand. Down to a depth of six feet the material was found to be sand and gravel with almost a complete absence of silt, but containing numerous pebbles two to six inches in diameter so closely packed as to resemble solid conglomerate.

Baling tests showed that water accumulated to a depth of 8 inches in the bottom of this three by five foot well in 16 minutes. The water was of good quality with a very slight taste of alkali. Arrangements were made with a local man to have this test pit sunk to a depth of 15 feet, but before proper appliances and help could be secured, the river was again full of water.

Two other points are worthy of notice; first, the gradient of the river here is such as to carry the finer material farther down stream; and second, the lave filled the bed of an ancient stream from which it has in part been removed, and tha basalt occupying the valley near the falls acts as a subsurface dam to retain the water in the ancient and modern alluvial deposits in the vicinity of the proposed intake, a condition roughly indicated by the adjoining section.

SRP000208

The above considerations indicate that sufficient water may be obtained from the underflow to irrigate a tract of the size proposed. The water can be recovered by sinking a large well, perhaps 20 by 30 feet at right angles to axis of stream and as near as practicable to the river. The well should be 30 to 40 feet deep, extending through the lava into the old river bed below. The same results would be accomplished by sinking a well of smaller diameter and driving tunnels under the bed of the stream.

Before actual work is begun test holes should be made with a drill both on the bank and in the stream bed itself.

SRP000209

47345

WATER RESOURCES OF THE NAVAJO-MOKI RESERVATIONS.

OFFICE OF INDIAN AFFAIRS
RECEIVED
JUN 9 - 1910

Part IV - The Lower Oraibi Wash.

General description

Structure

Underground water

Recommendations

O.K.

WATER RESOURCES OF THE NAVAJO-HOKI RESERVATION.

Part IV. The Lower Oraibi Wash.

By Herbert E. Gregory.

The Lower Oraibi Wash between Leupp and the Hopi villages was visited in May 1909 under the guidance of Mr. H. F. Robinson, Engineer of the Indian Service, and in company with Messrs. Mendenhall and Campbell of the United States Geological Survey. The topography of the region, the presence of grass and the success already attained by a few Indians here, seemed to justify further examination, and accordingly the area was revisited in June at the time of its greatest aridity.

General description.- The Oraibi and First Mesa washes draining with their northern and eastern tributaries a large part of the Black Mountain region, unite in the vicinity of The Lakes, finally reaching the Little Colorado above Leupp. These two washes combined drain approximately 3,000 square miles, and during the rainy season are impassible on account of floods. Both the surface and ground water flow from these washes is concentrated in the northeastern part of the Navajo Reservation.

In form the region is a plain sloping gently to the south, bordered on the west by a wall of red rock extending northeastward from Monument Point, and on the east by broken mesas extending southward to Flat Rock. The bed rock is concealed over most of the area, occurring near the lakes however, in small buttes of thin bedded calcareous, argillaceous sandstone. At Big Burro (~~Moencovi~~) Springs the wash is about 1-1/2 miles wide between rock walls and near this place the ledge is exposed on the bottom of the arroyo. From Burro (Moencovi) Springs, southward, the wash has cut a definite channel in alluvial sands forming a canyon 50 to 150 feet wide, 20 to 50 feet deep, and extending for about ten miles. Beyond this point the arroyo disappears and the water spreads out widely and deposits its load of silt. The volume of water as well as the speed with which the stream emerges from the arroyo may be judged by the presence of numerous mud balls one to five feet in diameter, which are strewn over the alluvial flats. At the southern end of this gently sloping plain is a group of lakes located on a flat divide. The series consists of four partly detached bodies of water, each 15 to 20 acres in extent and with a probable depth of 10 to 30 feet, and three others apparently filled in the rainy season. The shore line shows that the lakes

SRP000212

are subject to great fluctuation and that in June they contained less than one-half their maximum supply. That the lakes are perennial is indicated by the small growths of cottonwood, the presence of numerous water birds, frogs, reeds and green algae; the statements of the Navajos also bear out this supposition.

The region between the Lakes and Burro (~~Moencovi~~) Springs is open to the strong southwest winds which carry the sands from the Little Colorado Valley, and the work of the wind is evident everywhere in the Lower Oraibi Wash. Wind-blown sand covers the surface and severe sand storms are common. A little farther to the west on the border of the Denebito Wash rock basins have been hollowed out by the wind and it is quite possible that this agent has been a factor in forming the lake basins. The surface of this valley plain is extremely irregular, diversified by mounds and ridges of sand, by dry lake beds of variable size, by patches of grass alternating with areas of sage brush and greasewood, with here and there a lone tree. The water courses are shallow gullies from the main wash and are distributed in the region without order, wandering here and there as the slight surface irregularities direct.

Structure.- The Lower Oraibi Wash may be described as an alluvial fan of low grade, built of material furnished by wind and water and atmosphere in the region of the Hopi villages. This material is carried through the

SRP000213

narrow channel at Burro (~~Moenecovi~~) Springs and spread out to the south toward the Little Colorado. (See accompanying diagram Fig. 6). The alluvial deposits conceal the bed rock except near Burro Springs and at The Lakes. At the former place the rock is thin bedded sandstone; at the latter calcareous sandstone and shales belonging to a lower geologic horizon.

The character of the material composing the Oraibi fan was determined by a study of the sections exposed in the arroyos and by an examination of the drill washings. The bank of the arroyo west of Flat Rock was found to consist of ten feet of adobe, and hard-packed wind-blown sand in lenses, below which was 30 feet of thin (1"-3" thick) beds of sand, clayey sand and adobe arranged in lenses or regular beds down to rock. The beds vary in thickness and in structure within short distances, and the composition of material in this 40-foot section varies from coarse angular gravel to the finest silts. Drilling in the bed of the wash three miles farther south, gave the following section:

2 feet,	wind-blown sand
6 "	hard-packed adobe
1 foot	fine red clay, soft
3 feet	very fine sand, hard-packed
1 foot	gravel
5 feet	white, tenacious, dry clay
4 "	fine sand, moist
6 "	clay and sand, moist
6 "	fine sand (would require 80-mesh screen) saturated with water.
34 feet	

This section, together with the sides of the arroyo in this vicinity, give the character and dittribution of the material for a depth of 58 feet; and it is fair to assume that the entire alluvial fan is made of wind and water deposits distributed practically as indicated here.

SRP000214

Underground water.- Of the water which falls as rain in this vicinity, a large part is evaporated, while owing to lack of permanent and well defined channels little is represented in the run-off. A reasonable amount is absorbed by the soil in spite of the relatively impervious character of some of the surface material, a process facilitated by the presence of numerous surface cracks from one to six inches wide, extending downwards ten to twenty feet. In certain places sufficient rain water is held in sand dunes to enable Indians to raise a crop of corn. It is reported that During rains the fan becomes practically a sheet of water ~~six~~ one or ~~eight~~ two miles in width, above which rise the higher dunes and ridges. At such times large amounts of water must be fed into the soil even though its absorbing capacity is small. There is, moreover, a continuous underground flow from the Upper Oraibu Wash more or less concentrated at Burro (~~Meenecovi~~) Springs, but continuing southward to and beyond The Lakes. At the time of my visit the sand forming the bed of the arroyo was moist just above the rock floor and in a number of cases little caves or tunnels extending into the banks indicate the course of ground water during less arid parts of the year. During June the water table was below the top of the porous sandstone ledge exposed in the wash near Burro (~~Meenecovi~~) Springs; ten miles further south the water table was probably 50 feet or more above the rock surface. And even at Borro Springs,

SRP000215

the water table could not be far below the surface, owing to the underlying shales. At The Lakes, the water table reaches the surface for two reasons: (1) The rock which forms the bed of the alluvial fan is here at or near the surface; (2) continued flow of underground water is checked by uneroded rock which rises at higher levels to the south.

Recommendations.- I believe that sufficient water can be secured not only for grazing purposes, but for agriculture, by sinking wells in the Lower Oraibi Wash, and that good results could be secured at any one of the following localities:

1. A few miles below Big Burro (Moencovi) Springs where water could doubtless be secured at depths of 40 to 60 feet.

2. In the lowland near the "Lone Cottonwood" east of Monument Point, where conditions are favorable for wells at the contact of rock and alluvial cover at depths of 50 feet or more.

3. On the flat at The Cornfields near the main axis of the present Wash, where saturated gravel lenses may be encountered at 60 to 150 feet below the surface.

4. Near the lakes where shallow holes will secure wells not subject to extinction by drought, and so placed as to be made available for irrigation of exposed lake beds. The wells should be sunk, where possible, into the rock below, but is is quite likely that gravel lenses of sufficient water capacity for a small farm or herd of sheep will be reached at shallower depths.

SRP000216

Before well sinking is undertaken on any large scale, it is advised that a number of test wells be drilled along the line indicated in the adjoining sketch. In materials of this sort wells could be drilled at a rapid rate and sufficient data obtained to enable an engineer to make plans for future development.

SRP000217

47345
OFFICE OF INDIAN AFFAIRS
RECEIVED
JUN 9 - 1910
47345

1

WATER RESOURCES OF THE NAVAJO-MOKI RESERVATION.

Part V - Details for consideration of farmers and superintendents on each reservation.

Recovery of water

Quality of water

The maps

Papers for reference

Part V-A and Map I: Navajo Reservation; headquarters, Fort Defiance

The Chaco Valley

Highlands along the Arizona-New Mexico Line

Black Creek Valley

Highlands between Black Creek and Chinlee-Colorado Wash

Chinlee-Colorado Wash Valley

Highlands west of Ganado

Part V-B and Map II: The Hopi Reservation; headquarters, Keams Canyon

Moki Buttes

The washes south and west of the Hopi villages

Keams Canyon region

Hopi villages

Zilh-le-jini mesa

Part V-C and Map III: Navajo Extension; headquarters, Leupp

Part V-D and Map IV: Western Navajo Reservation; headquarters, Tuba

Gypsum Creek, Lower Chinlee

Laguna Creek
Tuba region
Little Colorado

Part V-E and Map V: San Juan Reservation; headquarters, Ship Rock

SKP000218

WATER RESOURCES OF NAVAJO-MOKI RESERVATION.

Part V. - Details for Consideration of Farmers and Superintendents on each Reservation.

by Herbert E. Gregory.

The object of this part of the Report on the Navajo-Moki Reservation is to supplement by means of maps and local descriptions the more general discussion of Part II, Suggestions to Superintendents and Farmers.

Recovery of water.- The digging of shallow wells with windlass, bucket, shovel, the use of casing for quicksand, and the installation of hand pumps, well sweep or rope and pulley has been discussed in Part II, and is doubtless well understood by the Government farmer. If driven wells are desired and wind power is to be used, it is advised that the farmer examine the well at Oraibi and particularly the methods of securing water at the cattle ranches north of Holbrook and Adamana. A design for an inexpensive horse-power pump may be obtained from H. F. Robinson, Superintendent of Irrigation, Albuquerque. Drilling of rock wells should be done under the direction of the Chief Engineer of the Indian Service. For a satisfactory method of developing springs attention is called to the spring at Wepo north of Walpi.

Quality of water.- With few exceptions the water from springs and wells of the entire region contains alkalies or salts, but the mineral content is not such as to prevent the use of water by man or beast, except in Gypsum Wash. Even in shallow pits dug along the main washes good water may be secured by proper casing, because where unpalatable water may occur in one stratum, palatable water may be found in the next. On the reservation as a whole, both springs and wells are in general filthy, and little trouble is taken to prevent pollution; even the big supply spring for Fort Defiance is exposed to contamination and would be condemned by a careful health officer in a more thickly settled community. A spring used in common by sheep and men should not exist.

Springs are easily protected by building a covered cement or wood, or even earth, basin at the point of emergence of water and leading the water from this basin to troughs. Parts of the danger from pollution of wells may be avoided by bringing the casing above the surface and building up the earth about the well so that storm water is carried away from, not toward the well. The spring at Keams Canyon store and the admirably protected supply at Indian Wells secure freedom from contamination by inexpensive methods. The open pit at Walpi and the spring at Chilchinvite are illustrations of supplies that may readily be polluted.

SRP000220

The maps.- The maps accompanying this part of the report are designed to indicate the locations where water may be obtained by one of the several methods discussed. These positions are necessarily only approximate, because the base maps are not sufficiently detailed to allow of exact location. It should be remembered that actual drilling tests have been made at but few points and that the data embodied in this report and shown on the maps are such as were secured during a reconnaissance of a large area during a single season. This report is therefore intended to be suggestive rather than to state the results of detailed scientific investigation. It is hoped, however, that the descriptions and discussion will be found helpful to those whose task it is to improve the water supply of the Navajo and Moki Reservations.

SRP000221

Papers for reference.- The following publications will be found useful to superintendents and farmers, who are studying the problems of water supply:

Veatch, A. C. - Methods and cost of well making, Chap.III, Professional Paper No. 46, U.S.Geol.Survey. Geology and underground water of Louisiana and Arkansas.

Fortier, S. -- Use of small water supplies for irrigation, Year Book, Dept. of Agriculture, 1905.

Mead, E. ----- Relation of irrigation to dry farming, Year Book, Dept. of Agriculture, 1905.

Bowie, ------ Distribution of water, Annual Rept., Irrigation and Drainage Investigation, 1904, pp. 347-507, Dept. of Agriculture. Irrigation in southern Texas, pp. 357-363, and 484-488.

Hermann, T. C.- Small reservations in Wyoming, Montana and South Dakota, Bull. 179, Office of Experiment Stations, Dept. of Agriculture.

U.S.Indian Service ------ Unpublished reports of investigations made by Irrigations Engineers on methods of developing water at Fort Defiance, Chinlee, Tuba, Leupp, Ganado, Wheatfields, etc.

SRP000222

Part V-A, and Map I. Navajo Reservation; Headquarters, Fort Defiance.- For the purpose of discussing the water supply, this reservation will be divided as follows: The Chaco Valley, Highlands along the Arizona-New Mexico line, Black Creek Valley, Highlands between Black Creek and Chinlee Valley, the Chinlee-Colorado Wash Valley, the highlands west of Chinlee-Colorado Wash.

The Chaco Valley.- That part of the Chaco Valley extending from Gallup north to the San Juan is a syncline made up of sandstone, shales and coals of Cretaceous age. The dip of the strata eastward from the well watered Choiska Mountain supplies water to the bed rock and carries it underneath the valley floor. Deep wells in selected localities along the Gallup-Ship Rock Road may be expected to yield flowing water of sufficient quantity to be useful for irrigation. The depth required for these wells has not yet been determined. Along the west side of the valley water may be obtained by developing the present springs and still larger amounts may be secured by sinking wells of suitable character near the washes leading from the Choiska range. At the Tohatchie school a well sunk in rock near the wash and connected with tunnels running underneath the bed of the ephemeral stream furnishes a fairly satisfactory supply; and then it is remembered that before this well was sunk by Mr. Leaden, the school had no supply on which it could depend, the possibility of securing water even in unfavorable localities is demonstrated. The mission near Tohatchie is supplied by a 45-foot well sunk in

SRP000223

rock near the emergence of a dry wash from the mountain, and may serve as an illustration of what may be done at a number of localities along the western border of the Chaco. It would seem as if windmills could be profitably used in this valley, and that cisterns constructed to catch the run-off from the roofs of store and mission and Government farm buildings would repay the expense.

Highlands along the Arizona-New Mexico line.- Surface water in sufficient amount and satisfactory in quality is found in the Choiska and Tunitcha Mountains including the western slopes where Tsalee, Wheatfields, Whiskey and other smaller creeks may be relied upon. These streams are fed by numerous springs which might well be developed so as to irrigate small patches; and the Government irrigation plant at Wheatfields shows what may be done in a larger way. The well at Crystal illustrates what may be done in a number of places throughout these highlands. Here a wide, open, flat bottomed grass covered valley receives water from the surrounding highlands and from rain. The alluvial materials filling the valley are apparently saturated with water near their contact with the underlying rock. At Moore's a well 11 feet deep, operated by hand-pump furnishes a satisfactory supply. It is suggested that a careful study be made of the conditions at Crystal, with a view to using this knowledge in developing the ten or twelve valleys

SRP000224

similarly located about Sonsala Butte and along the east side of Black Creek Valley. It is believed that wells in these upper valleys will secure water at depths less than 20 feet.

That portion of the highlands south of the latitude of Fort Defiance offers less opportunity for securing water by shallow wells. Even here small supplies may be obtained from near the heads of washes and storm water reservoirs may be constructed at a number of places. The dip of the rock is favorable for artesian flows, but the thickness of rock to be penetrated before an impervious bed is encountered, probably renders the drilling of deep wells impracticable. If it is desired to develop any springs or seeps through the deeply dissected mountains it is advisable to examine the spring at Rock Springs (Sampson's store), where an insufficient flow was greatly increased by tunneling in on top of the shale for a distance of approximately 150 feet.

Black Creek Valley.- Black Creek Valley from Red Lake to Houck's Tank is on the average about a mile wide, but receives an unusual amount of water owing to the attitude of its bordering lands. In general, the alluvial filling of this valley is less than 50 feet and through probably half the river's course the rock is within 15 feet of the surface. The number of successful shallow wells in this valley located near the junction of tributaries with the main

SRP000225

stream illustrates a method by which water can be obtained. The Government irrigation scheme at Red Lake is successful and small projects of this sort supplying water for an acre or less are feasible at a number of localities. Buells Park is particularly worthy of investigation. Inside this area shallow wells sunk 15 or 30 feet to rock would yield permanent supplies; and the narrow canyon outlet of the park furnishes an excellent dam site for a reservoir which would serve to irrigate lands further east.

The supply of ground water in this valley is well shown by the wells immediately east of Fort Defiance. One well 10 feet in depth contains 4 feet of water; the well at the hospital is likewise only 10 feet in depth; and the Government well 35 feet deep contains 15 feet of water. It is entirely feasible in the wider parts of the valley for each hogan to have its water supply; and if a simple windmill could be used, each well might be counted on to furnish sufficient water for the irrigation of half an acre or more of land. The spring in the Bonito Canyon at Fort Defiance is supplied by water collected on top of the eastward sandy shales. If this spring were enlarged and deepened, more water could be secured and a different type of spring-house would remove the danger of contamination.

Another way of increasing the supply for Fort Defiance is to construct a reservoir in the Blue Canyon where a large amount of water could be impounded at a small expense. It

SRP000226

is believed that flowing wells could be constructed between Fort Defiance and the Haystacks, directly east, but the yield would probably be small. At St. Michael's the water is accumulated in the sands and clays of an old lake bed. Water is supplied to the sands by a few small tributaries leading from the mountains into Black Creek, and certain clay layers bring the water table to within 5 to 8 feet of the surface. Wells sunk to rock at this place may be counted on for permanent supplies. In the wider parts of the Black Creek Valley from St. Michael's to Hunters Point conditions similar to those at St. Michael's exist, and shallow wells may be located near the junction of the eastward flowing tributaries with the main wash. At The Narrows, 8 miles below Hunters Point, the water stands in the bottom of the arroyos, but it is unpalatable. The three springs issuing at the edge of this part of the valley should be developed as indicated in Part II of this report, but the springs emerging in quicksand in the arroyo itself might better be replaced by wells sunk in the wide alluvial flat as shown in fig. 8.

Highlands between Black Creek and Chinlee-Colorado Wash.- This area attains an elevation of over 7,000 feet on the forest-covered "mountain" west of Fort Defiance, from which point there is a gradual surface slope toward the Chinlee and Colorado washes. The sedimentary beds, mostly sandstone,

SRP000227

composing this highland also dip west in conformity with the surface slope. Accordingly both surface water and underground water tend in general to move westward. The dip of the rock and the large area over which water may be absorbed are conditions favorable for securing rock wells which may possibly yield artesian flows. The relation of pervious to impervious strata has not been determined for this section, but judging from the facts observed in other localities wells less than 1,000 feet in depth are not to be advised. The 800-foot drilled well at Cross Canyon in which 80 feet of water is standing, is practically a dry hole with the exception of the water which comes into the well from the contact of loosened surface material and bed rock. The well is not deep enough, but in any case its position at the edge of a canyon is unfavorable. In fact, if not sunk deeper the well could be improved by plugging it about 80 feet below the surface.

Because of its cover of timber and grass and the large areas of bare rock, this region furnishes a large number of admirable sites for storm water reservoirs. Judging from the number observed, there are probably over 50 locations where water may be inexpensively stored by methods explained in Part II, or by adapting the plans outlined for the proposed reservoir at Ganada (See report of Irrigation Engineer). Springs are rare in this area and so far as observed they emerge from bare or thinly covered rock; in most cases

SRP000228

ping beds have been truncated by small canyons. It is not practicable to develop springs issuing from rock at the bottom of shallow canyons subject to storm floods; and in the cases observed, a well sunk on the bank above the reach of storm water would be more satisfactory than developing the spring by tunneling. Near Zilh Tusayan Butte there are a number of seeps and three well developed springs; in fact, the butte is practically surrounded by a wide trench in which the water table is near the surface. The water seems to be brought to the surface by coming into contact with the igneous mass. It is believed that water sufficient for irrigation of small tracts may be developed here by sinking shallow large wells at convenient places on the west, north, and southeast sides of the butte.

Shallow wells of three types are feasible in this area: 1, those sunk in the decomposed and fractured upper surface of ledges near the junction of tributary streams with main

SRP000229

washes, as may be seen at the well on the St. Michael's Cross Canyon road. 2, wells sunk in the upper ends of washes where a small rock-walled amphitheater filled with loosened material exists. The well at the sawmill will serve as an illustration. Here, the head of the draw is filled by 14 feet of overlying loose material and the well sunk through this cover to the rock below taps the water horizon lying on the ledge and produces a satisfactory supply. At about 500 feet distance is a dry well sunk directly into the rock. About six miles northwest of Fort Defiance on the Sawmill road at a place where there is now an unsatisfactory well there is opportunity for securing water by sinking a well of large diameter 15 to 20 feet into the alluvium of the wash. 3, shallow wells in wash material where the streams leading from the highlands to the west and southwest have opened up wide valleys as in the Cottonwood Wash between Hunters Point and Tanners Spring and the wash leading southwest from Cross Canyon.

SRP000230

Special reports have been prepared on the water conditions in the Canyon de Chelly region and there is no doubt that large supplies for irrigation may be developed by taking the underflow from this stream; and shallow wells will yield water at almost any point within 10 to 15 miles from the canyon's mouth. Special attention is called to Beautiful Valley 15 miles north of Ganado where a rock-walled depression covering nearly 100 square miles exists. Here the water is near the surface and can be tapped by wells 10 to 20 feet deep which, with the addition of small storm water reservoirs in the tributaries entering the valley, will furnish supplies for an agricultural community of considerable size.

Chinlee-Colorado Wash Valley.- This wide open valley is practically continuous from Chinlee to the Santa Fe railway. A divide however exists near Ganado from which the Chinlee flows north, and the Colorado wash southwest. This well populated valley is preeminently a region for the construction of shallow dug wells and of driven wells to be operated by windmills or other power. The two wells at Hubbell's store, each about 15 feet in depth, the one at Mission 20 feet in depth, the well at Sunrise 18 feet in depth, and the well at The Cornfields 60 feet in depth, in addition to 8 other wells less than 25 feet deep indicate to the Government farmer the conditions prevailing in the central part of this great valley. Farther south beyond

SRP000231

the borders of the reservation are many satisfactory driven wells 40 to 50 feet in depth operated by windmills. At Sharp's Ranch, abundant supplies for stock came from three wells. The two examined had driven points 20 and 15 feet respectively, and are said to supply 300 head of cattle. The wells on the Wallace, Donahue, and Hennesey ranches north of Adamana are interesting in that they encountered alkaline and salt water at 17 feet, water with less salt at 30 feet, and water of excellent quality at 40 feet. The Government farmer may receive a suggestion for the location of shallow wells by examining the Tsebeto wash east of the Cornfields, where I have advised the sinking of a well 20 feet in depth near the old Stewart place; and another one a mile and a half above the Stewart place at the junction of the wash from the northeast.

In most of the places shown on the map, if sites are selected as suggested in Part II of this report, it is believed that wells permanently beyond the reach of floods will secure water at depths of less than 40 feet, and in many cases less than 20 feet.

The upper Chinlee Valley is not nearly so well supplied with surface and ground water as is the Colorado Wash. A number of tests were made with the hand drill in the bed of the dry lakes 12 miles north of Ganado. Sticky clays saturated with water were encountered but no water seeped into the holes at depths of 6 to 10 feet. The chance for securing water at 30 feet or so is good at about a mile east of the

SRP000232

dry lakes. The floor of the valley is so flat, however, at this place, that the water would be expected to move slowly and wells of large diameter are therefore advised. Seven miles north of the dry lakes a drill passed through 4 feet of fine clay and sand, 10 feet of fine sand, 2 feet of wet sand, 8 feet of white-yellow sand, 1 foot of black sand, 6 feet of red-yellow sand saturated with water. Decomposed rock was struck at 38 feet and water entered the drill hole, but not in sufficient quantity to justify sinking a well. Wells in this wash will need to be sunk to the ledge or a little beyond. In the wide flat between Hlohala and Salakai mesa there is an opportunity for developing water by wells to an extent required for irrigation on a moderate scale. Surface water from a large drainage area now flows to depressions where it remains for a longer or shorter time. Much water is also absorbed in the sands. The upper surface of the sandstone which forms the bed rock is very porous and in places as at Totoeung, springs emerge where the decomposed sandstone rests upon the firmer rock below. It is believed that wells passing through the surface cover and 15 to 20 feet into the rock ledge could be relied upon for a permanent supply. Directly west of Beautiful Valley it is possible that flowing wells may be secured, as is indicated by the geological structure (see fig.9.).

Highlands west of Ganado.- The rocks forming the mesas from Hlohala to Steamboat Canyon and beyond, are sandstones including strata of shale and coal. This region contains numerous springs, two permanent and several ephemeral lakes,

SRP000233

and a few artificial reservoirs. Springs occur at definite horizons, usually between two layers of sandstone, as is typically illustrated at Togay and Rock Water east of Eagle Crag. At a few places the conditions at the springs are identical with those described on the Hopi Reservation (see Part V-B). All the springs visited could be made to yield more water by developing as indicated in Part II.

Additional permanent water supplies may be developed in the larger washes, Steamboat Canyon, etc., by sinking wells in alluvium. In many little rock floored canyons in the forwsted part of this district are excellent sites for storm reservoirs, some of which have been taken advantage of here and there by the Indians. More could be done along this line. In the neighborhood of the three ephemeral lakes mapped in this area, shallow wells may be dug to furnish water during the dry season.

Part V-B, and Map II. The Hopi Reservation. Headquarters, Keams Canyon.-- For convenience in discussing its water supply the Hopi Reservation will be divided into five parts: (1) Moki Buttes, (2) the great washes south and west of the Hopi villages, (3) the Keams Canyon district, (4) the Hopi villages, and (5) the Zilh-le-jini Mesa.

Moki Buttes.- The problem here is chiefly one of improving the numerous springs. On the maps prepared

SRP000234

by Mr. Keepers, alloting agent, twenty-one springs are shown in three townships bordering the Hopi Reservation on the south, and in this region as a whole there are probably sixty springs and seeps, from all of which increased supplies may be secured. The springs occur at two horizons, namely, at the base of the lava or tuff and at the base of the heavy sandstones overlying the shales. In most places the exact point of emergence is concealed by accumulations of boulders and pebbles, but the source of the water is at the contact of the rock types mentioned above and efforts should always be made to locate the exact water horizon.

The method of development of springs emerging from rock is discussed in Part II, and may be further illustrated by two cases: namely, Indian Wells and Stiles Ranch, where most of the available water has been secured; The supply at Indian Wells (Fig. 10) might be somewhat increased by driving tunnels obliquely downward with the idea of tapping the water horizon and by developing the small seeps near the store. At Stiles Ranch the Government spring secures its water on top of the shale and marl and could be further improved by driving tunnels or digging trenches along the base of the overlying lavas and tuffs. Big Spring (see fig. 11) could be improved by enlarging and increasing the number of feeders leading to the main supply box. A good method of securing uncontaminated water for

SRP000235

domestic use is illustrated by the Home Spring at Chandlers Ranch where the spring house is made by blasting directly into the rock (see fig. 12). In parts of this area a cover of broken lava and decomposed sandstones and shales overlies the shale bed and water emerges above the shales along the sides of the wash as illustrated by Coyote Spring, near Pyramid Butte, where seeps are seen for a distance of three or four hundred feet along the valley side (see fig. 13.)

At Mason Spring, an accumulation of sand dunes and irregularly deposited stream materials forms the water-bearing beds (see fig. 14). Comar Spring is apparently of this same general type, and as stated by D. B. Johnson of the Forest Service, could easily be developed to secure a larger supply. Cottonwood Spring is a good illustration of these supplies coming from the base of the lava, which could be increased by tunneling. As indicated on the map, wells 30 feet or less in depth may be sunk with profit in the Twin Buttes region and in the flat valley south of Cedar Springs. Deep rock wells cannot be recommended because the region is underlaid by several hundred feet of almost impervious clays and marls.

The washes south and west of the Hopi villages.-- In this region shallow wells driven partly or entirely through the valley fill overlying bed rock are advised. The well sites indicated on the map are the only ones particularly examined;

SRP000236

but other spots may be selected according to the principles explained in Part II. The depth to which these wells should be sunk depends upon the amount of valley fills and the presence or absence of gravel beds, as well as the nearness to the main channel of the wash. It is recommended that the wells be sunk as near the present line of intermittent flow as is possible without danger of floods. At several localities in the lower Denebeto, Middle Oraibi and Second Mesa Washes seeps are known to occur at the contact of bed rock and the overlying alluvium, and it is believed that, in general, wells sunk through the drift and a short distance into the rock will secure small supplies. The Bargeman well on the upper eastern tributary of Corn Creek illustrates fairly well the conditions prevailing in most of the larger washes (see fig. 15). In this place water was found on top of the bed rock at a depth of 19 feet and 5 feet of water can usually be depended upon. Well diggers working in this region are advised to examine the Bargeman well and to study the relation of stream channel, valley fill and rock floor exhibited by the 60-foot well recently sunk at The Cornfields near Ganado. Localities where water emerges from sandstone are illustrated by Little Burro and Big Burro Springs (see fig. 16). In both these cases advice regarding the improvement of the supply has been given directly to the Hopi in charge. For recommendations regarding the Lower Oraibi Wash see Part IV.

SRP000237

Keams Canyon region.- Keams Canyon is also a district of springs, Here the water horizon is at the base of the sandstone forming the canyon walls, and immediately above the shales associated with coals; the relation of rock strata to water may be seen at the spring supplying Hubbell's store, and also at the group of springs used as a water supply for the Indian School. At Marty's and also at Jettyto and Tallyhogan the water emerges at the same rock horizon as at Keams Canyon. At Tallyhogan, however, the water is concentrated by large joint cracks above the shale and care should be taken to include all cracks yielding water in the plans for improvement. At Jettyto the talus and landslide material has concealed the exact rock outcrop. At Marty's, Tallyhogan and Jettyto there is an excellent opportunity to increase the supply both by trenching at the springs themselves and by securing the water now wasted in the numerous small seeps. The spring horizon of this area is illustrated in the section, fig. 19.

Shallow wells will yield water in the Jettyto Wash and on the eastern borders of the First Mesa Wash. Deep rock wells in this district can be counted on to secure water if sunk on the mesas down to the strata through which springs emerge. Nothing will be gained by drilling deep rock wells in the canyons unless they are sunk deep enough to pass through shales to the sandstone below. This will require boring 500 to 800 feet, at which depth it is likely that a water-bearing bed will be encountered from which water will rise in the well and perhaps overflow.

SRP000238

Hopi villages.- The Hopis depend largely on springs for their domestic supply; and in fact, the location of the Hopi villages seems to have been in part determined by the presence of small permanent streams of water issuing from rock and talus. Conditions, however, are not favorable for securing an adequate supply by this means because these long narrow mesas are too small in extent to gather a large quantity of water to be fed to the spring below. Furthermore, the presence of landslides and talus has resulted in concealing the point of emergence of water from the rocks.

The Indians at Walpi and other villages on the First Mesa obtain water from a big open pit, a second pit having been abandoned, presumably for some ceremonial reason. This spring or well might be improved by sinking tunnels into the mass of loose rock back to the ledge thereby concentrating all the flow at one point as suggested in Part II (see also fig. 3). The well at the school is favorably located so far as obtaining water is concerned but is in danger of contamination from the polluted water in the "spring" near by. It is not probable that even after development the springs at First Mesa will furnish the water desired; but an adequate supply for these villages may be obtained by sinking shallow wells in the wash at a short distance from the present village site. If found desirable water might even be piped six miles from Wepo Spring.

SRP000239

Advantages to be gained by developing springs are well illustrated at this latter point (Wepo) where two cemented reservoirs have been constructed and a part of the water secured from three big springs one of which fills a 5,000-gallon tank in seven hours. Probably less than half the water is however recovered in this place and it is believed that by an expenditure of approximately a thousand dollars, water enough could be secured not only for the sheep dip, and for stock, but for the irrigation of a considerable tract.

The conditions at the Second Mesa are practically identical with those at Walpi except that the water here is somewhat better cared for. The amount of water is barely sufficient to supply the local needs, but may be increased at Mishonginivi and Shipaüiluvi by developing the springs. This is highly desirable because the spring at the Shimopavi school furnishes barely a gallon per minute. In case the springs do not yield enough water, wells may be sunk in the broad valley south ofd east of the Second Mesa villages. The large area contributing to the Second Mesa Wash taken in connection with the fact that shales are near the surface makes it reasonable to suppose that a satisfactory supply can be secured by wells 30 to 40 feet in depth.

At Oraibi the spring at the base of the cliff underneath the sandstone yields a small continuous supply while the two wells back of the store sunk 15 feet are without water during the dry season, and even the spring northwest of the store dries out. These springs and wells might be somewhat

SRP000240

improved by a series of tunnels penetrating the overlying landslide and talus material, reaching back to the bed rock (see fig. 3). The most satisfactory supply for Oraibi however, is to be obtained by sinking wells in the wash east of the Government schools, carrying or forcing the water to the buildings. The large drainage area contributory to Oraibi wash and the presence of shales near the surface indicate the presence of a large amount of ground water at a slight depth; and this supposition is abundantly proven by the fact that the Government well now used, sunk to a depth of 28 feet contains, according to Mr. Stauffer, four feet of water at all times; and by the fact that a 34-foot well at the Mission showed no change in amount after continuous pumping for twenty-four hours. Deep rock wells at Oraibi cannot be recommended unless as at Keams Canyon they can be sunk to depths of 600 feet or over, so as to pass entirely through the shale and into the sandstone below. And even a well of great depth should be considered as an experiment.

The Denebeto Wash between Oraibi and Cedar Ridge has in general a filling of between 20 and 30 feet and the presence of seeps at the contact of rock and valley fill indicates that wells sunk in this area to rock will be successful. It is recommended that all the Government buildings at the Hopi villages be equipped with eave-troughs and cisterns as an additional precaution.

SRP000241

Zilh-le-jini Mesa.- Water may be developed in these highlands by digging shallow wells in sands on the floor of the washes and by sinking shallow wells of large diameter at the heads of valleys filled with rock debris. This area is, however, peculiarly adapted to the construction of storm water reservoirs because the rock is almost everywhere at or near the surface and there is a cover of vegetation. The surface of the mesas is roughened by dunes and undrained basins, and the surface rock is porous. The rain is therefore absorbed in large amounts and sinks directly into the strata below. For this reason, wells sunk 75 to 100 feet in the rock will probably yield water and wells penetrating the sandstone 600 to 1600 feet (i.e., to the strata of shale lying below) are likely to secure larger amounts of water and possibly artesian flows;still deeper wells passing through the shale might also secure water, but the depth required, 2000 feet or overm would probably render this plan impracticable.

In the Chilchinvito region the water comes from shales and shaley sandstones and is so strongly alkaline that development of the existing springs could hardly be advised, a better method being to construct storm water reservoirs.

Part V- C. and Map III Navajo Extension Headquarters, Leupp.- This small reservation is bisected by the Little Colorado River; in fact, it may be said to be a part of the Little Colorado Valley. For some years at least water both for

SRP000242

stock and irrigation will be developed along the immediate line of this river and there is therefore no occasion to discuss other possible sources. The wells of Tolchaco, the old wells at Leupp, and those sunk during the present spring have demonstrated that the wider parts of the rock valley are filled with saturated silts. Wells are therefore feasible. The following reports in the hands of the Indian Office give sufficient detail regarding conditions in the Navajo Extension reservation:.(1) Report on the Canyon Diablo project, in which is discussed the conditions in the vicinity of Leupp; (2) the Black Falls project, Part III of the present report, in which the character of the deposits covering the valley floor of the Little Colorado are discussed; (3) the Lower Oraibi Wash, Part IV of this report, which discusses the water conditions in the vicinity of Many Waters Lakes; (4) Part V-B of this report, which deals with the conditions in the region north of Winslow, an area which may be at some later time attached to this Reservation.

Part V-D, and Map IV. Western Navajo Reservation, Headquarters, Tuba.- Four areas within the Western Navajo reservation were visited during the past year. First, that part of the reservation which lies in Utah, the region including Gypsum Creek and the lower part of the Lower Chinlee Valley; second, the Laguna Creek Valley; third, the region about Tuba; and fourth, a portion of the Little Colorado Valley. It is planned during the present season to revisit the northern portion of this reservation and therefore the discussion is at present limited to the following details.

SRP000243

Gypsum Creek-Lower Chinlee.- Much of the surface water in this district is useless because of its large alkaline content. This is particularly true of Gypsum Creek. Ground water may however be obtained in three ways: by shallow wells, from sand seeps, and from deep rock wells. The Lower Chinlee Wash is admirably adapted to shallow wells sunk in the valley fill to bed rock or to some coarse stratum. In several places observed 30-foot wells would yield permanent supplies. In the Monument Pass region the sand dune cover is heavy and many small arroyos have been completely filled. Wells may be dug in these sand-filled valleys or the seeps may be developed by enlarging the size of the openings and connecting several small supplies. The strata underlying the Chinlee Valley, Gypsum Valley, and the valley lying west of Monument Pass are folded into a series of anticlines and synclines whose structure is admirably adapted for flowing wells. The depth to which these wells may be sunk in the rock has not been determined, but judging from the wells at Bluff and from those in the Oil Fields at Goodridge, it is necessary to penetrate 600 to 1,000 feet of sandstone before reaching the impervious beds of limestone and shalembeneath which sandstone again occurs. Between Gypsum Creek and Oljato, there are several spots admirably adapted to the collection of storm water by inexpensive dams.

Laguna Creek.- Laguna Creek is a permenent stream and the flats along its side in a number of places offer good

SRP000244

opportunities for small irrigation projects. In the wide basins northeast of Marsh Pass (e.g., Karenta) water may be obtained by shallow wells. On the east side of Upper Gypsum Wash southeast of Chaeskla flowing water can probably be obtained from the rock.

Tuba region.- This district contains one of the most remarkable groups of springs in the United States. In addition to the school spring at Tuba, furnishing 120,000 gallons a day, there are the springs supplying Reservoir Canyon, and the fringe of springs along the base of the cliff overlooking the Little Colorado, and the Moencopie. These springs in connection with the water from the Moencopie furnish an abundant supply not only for stock, but for extensive irrigation; in fact, the water problem in the immediate vicinity of Tuba is one of conserving the supply rather than of increasing it. Studies made by Mr. Ritter and recorded in the reports to Mr. Robinson dated April 5th and May 4th, 1908, show clearly that the importance of the springs is realized. That the best method of development is clearly understood is proven by the fact that although much of the water at Moa Ave, Lyons Ranch, and other springs is wasted, yet the small springs at The Farm have been so developed as to yield a maximum amount of water of fine quality.

In the region between Tuba and Navajo Canyon rock wells 100 to 200 feet in depth might recover the water stored in the sandstone. Shallow wells, however, are not advised, because

SRP000245

for which feed is available. Upon the slopes of the Carriso, narrow canyons are occupied by permanent streams and there is an opportunity here for the building of relatively inexpensive reservoirs from which water may be led down for irrigation purposes. Moreover, the rocks dip outwardly in all directions from the center of the igneous mass furnishing conditions favorable for flowing wells. The rocks upturned in the Carrisos flatten out eastward and become a part of the coal series in which shale and sandstones occur at different horizons, furnishing the pervious and impervious layers essential for flowing wells. The great amphitheater included between the Lukachukai and Carriso Mountains is an area well worthy of careful investigation. The present springs could be developed, and the water between alluvium and bed rock could be reclaimed in the washes southwest, west and northwest of Red Rock store, and also in the region of cliff dwellings at the southeast base of the Carrisos. There is here also a chance for deep rock wells. The dip of the strata to the east at an angle of two to ten degress is favorable, the coarse sandstone allows the ready percolation of water and the shales and marls below the red sandstone prevent its escape.

The lower Chinlee between Canyon de Chelly and the Utah line is partly in a rock floored valley and partly

SRP000246

consists of alluvium flats in which the valley attains a depth of 30 to 100 feet. Inexpensive dams in the little canyons tributary to the main wash may be constructed for storage. Wells may be sunk to rock or to some water-bearing bed nearer the surface. Such wells within a mile of the main channel could generally be relied upon to furnish small permanent supplies. Deep rock wells attaining a depth of 600 to 800 feet and reaching through the sandstones to the shales dipping eastward from Gypsum valley, would yield water and might produce flowing wells.

SRP000247