WORK REPORT

DETAILED EROSION SURVEY

TOLANI LAKES AREA, ARIZONA

NAVAJO PROJECT

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DESCRIPTION OF AREA

Tolani Lakes area is located about forty miles north of Winslow, Arizona, in the vicinity of the junction of the Oraibi and Polacca Washes. The area is triangular in shape and occupies $31\frac{1}{2}$ square miles or 20,160 acres, lying mostly in the Oraibi and Polacca drainage basin. The survey was started September 1935 and the field work was completed in December 1935. Due to the graded, partly graveled Oraibi-Leupp Highway the area is easily accessible during all seasons of the year. The population of this area is variable. During the winter, very few families remain on the area but in the spring they move in from the surrounding country to plant their crops and herd their sheep and cattle. At the peak, it is estimated that some 300 people live on the area. The entire area is under Federal Government control, the northern portion is in the Hopi Indian Reservation while the remainder is in the Navajo Indian Reservation.

About 86 percent of the area is an extensive alluvial flat, which slopes gently toward the south and southeast, except in the western part where the slope is toward the west. The residual soils occurring mostly in the west central and southern portions are characterized by a rolling topography. The elevation of the area ranges from 4903.5 feet above sea level near the south boundary to 5000 feet in the northern portion. The hilly residual soils are from 25 to 35 feet above the alluvial soils. Two main drainage ways enter the area from the north, the Oraibi in the north central, and the Polacca in the eastern part. At present the streambeds of the Polacca and Oraibi Washes are stabilized, though the steep banks, ranging in height from a few feet to 60, are subject to caving. The materials contributed in this manner in addition to the sediment carried in from the semi-barren watersheds during flood periods constitute a menace to the agricultural lands which are subject to overflow. Often large mud balls several feet in diameter, as well as silt, clay and sand, have been deposited to a depth of about three feet in the vicinity of the Oraibi Wash during one flood period. The water of the Oraibi and Polacca Washes have a moderate to high alkali content derived largely from the alkaline soils on Black Mesa. A large number of shallow drains provide good surface drainage over most of the area and a permeable subsoil provides good internal drainage except in the old lake bed areas along the southern border. Very little runoff occurs from the seasonal rains due to the fact that most of the soils have a loose level surface. It is only in a few places on the

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highly eroded residual soils that some local runoff occurs. Over most of the area there is a spotted slight to moderate vegetative cover. A good cover of Sacaton grass is present in the western portion while in the eastern part it is Chamiso. Throughout the northern, central, and southern part the vegetation is spotted, consisting mostly of Chamiso, Russian thistle, Shadscale, Saltcedar, and many annual weeds. Very little damage occurs from frost.

CLIMATE

The climate of Tolani Lakes area is arid to semi-arid with an average annual precipitation of about seven inches, the major portion of which occurs during July and August. Most of the rainfall is of the thunder shower type, although occasional all day rains may be expected. Very little snow falls on this area. The growing season averages about 150 days, from about May 20 to October 20. The temperature during the summer months is mild, averaging about 70 degrees. The winters are generally mild, although during 1933 a severe season was recorded. Strong cold winds during March are responsible for the major portion of the wind erosion, while the late fall windy season is of secondary importance. During the windy seasons dust clouds are often so dense that visibility is not more than 500 feet. The seasonal character of the winds and rainfall governs practically all cultural and planting operations. The Indian farmers usually wait until the spring winds have stopped and the early rainy season has started before he plants his crop.

AGRICULTURE

Little is known about the early agricultural practices in this area, but it is probable that the crude methods now employed have been practiced for many years. A few plows of a poor grade were observed on the area, but most of the cultivation is done with hoes. According to past records from 250 to 700 acres have been farmed depending mainly on the available water supply. Most of the soils are in excellent condition, that is they are loose textured, well drained, moderately high in plant food, relatively free from alkali in the zone of root penetration. Some waterlogging and alkali concentration occurs in

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the lower profile, especially in the southern portion in the vicinity of the old lake beds. All of the soils are subject to wind erosion, with the most severe results occurring in the eastern portion of the area in the vicinity of the Polacca Wash.

On most of the present farms flood irrigation is practiced, but the water thus derived is augmented by seepage from the Oraibi and a hand method, which is resorted to during protracted dry spells. The hand method is merely the direct application of water to individual plants hauled there by means of a wagon. Water is obtained from the Oraibi Wash, or Upper Lake, or wells in the vicinity of the trading post. Corn, watermelon, cantaloupe and pumpkin constitute the main crops. Alkali tests of the water of the Oraibi and Polacca indicate that it is fair to poor for irrigated agricultural purposes. A continued use of this water under improper handling methods may have a detrimental effect upon the plants grown, due to the high concentration of alkali salts present in the water. It is, therefore, recommended that friable permeable soils be used as much as possible under this irrigation system, and also that proper handling methods are practiced.

SOILS

GROUP A

The Oraibi sandy loam is the only type classed in this group. It occupies some 5365 acres of which about 500 acres are at present under agriculture. The soil is characterized by a moderately compact highly colloidal surface with a friable subsoil. Good water and air drainage is present throughout the profile. The surface in the vicinity of the present Oraibi is level, smooth, and in many places bare of vegetation, while over the remainder of the area, there is a large number of hummocks varying in size from several inches to about seven feet in height which gives the surface a choppy appearance. The general slope of about two percent is toward the southeast.

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SUGGESTED IMPROVEMENT PROGRAM AND PRECAUTIONS

In this group it will be necessary to practice flood control methods and check the amount of sand, silt, and clay deposited on the agricultural soil in the vicinity south of Oraibi Wash. If the waters of the Oraibi and Polacca Washes are used for irrigation, the drainage facilities of the soils will have to be kept open so the soil will not become waterlogged or become highly concentrated in alkali salts. Due to the overgrazed condition of this group it is suggested that proper range management practices be exercised in order that a better vegetative cover be developed. In many places it will be necessary to seed the area in order to develop a better cover. Strip planting of browse and trees in such a manner as to check wind erosion is recommended. This is especially true for the eastern portion where wind erosion is severe.

MOISTURE PENETRATION AND WATERHOLDING CAPACITY

It has been observed from laboratory studies that it requires from $2\frac{1}{4}$ to 25 minutes for water to penetrate an inch of air dry surface soil, depending mostly upon the compaction and colloidal content of the soil. This group has medium waterholding capacity.

ADAPTATION TO EROSION CONTROL PRACTICES

This group is well adapted to erosion control practices. With some slight leveling of the hummocks, water may easily be spread over the surface, due to the good surface structure, slope, waterholding capacity and rate of water absorption of this group. Because of the severe effects from wind erosion it is recommended that strip cropping be practiced wherever it is possible.

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ADAPTATION TO IRRIGATION

This group is recommended for irrigation agriculture and grass land. As previously mentioned the slope, drainage, and permeability of the soils of this group is good. The fertility of the soils are such that crops are readily grown. The alkali concentration of the soils is not serious in the zone of root penetration, but in the lower profile below seven feet the concentration is greater. The probable use of this land under proper irrigation methods will be cultivated crops or grass.

VEGETATIVE ADAPTATION

At present the vegetative cover consists mostly of Chamiso, Russian thistle, Sacaton grass, Gallota grass, Greasewood, Saltcedar, Rabbit brush, and other plants of minor extent. The present cultivated crops consist of corn, watermilon, cantaloupe, and Indian pumpkin. Under proper treatment the native vegetation will produce a good cover. Several different types of cultivated grasses, such as alfalfa, clover or other legumes, may be developed under irrigation, and also cultivated crops such as wheat, oats, potatoes, beans, and many varieties of vegetables.

VALUE OF SOIL FOR CONSTRUCTION PURPOSES

The sandy loam soils of this group are fair for construction of earth works. In the direct vicinity of this group, large areas of clay surface soils may be found and with very little extra work the two different types may easily be mixed for the construction of any earthwork that may be necessary. This combination under proper handling will make good material for construction purposes.

LIMITING FACTORS IN THE USE OF SOIL

The high concentration of white alkali in the lower profile and the tendency of the surface to blow are the main limiting factors in the use of this group.

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EROSION

The entire group is subject to wind erosion with the main areas located in the eastern part. In many places large blow outs are present leaving the surface relatively bare of vegetative cover, while in others, where the hummocks are most prevalent a large number of Chamise are growing, and the soil is blowing in and about the base of these plants.

GROUP B

Ten different soil separations consisting of both alluvial and residual soil are present in this group. The separations consist of soils varying in texture from a sandy loam to clay. The surface soil in the eastern, extreme southern and western portion is characterized by a loose friable sandy loam, while throughout the northern and central part, the group consists of a heavier textured, more compact, usually clay surface. The surface features are similar to that of Group A, which varies from a few hummocks in the western portion to a large number of high hummocks in the eastern portion. The entire surface has a choppy appearance. Except for the residual sandy loam type the alluvial soils for the most part have about a two percent slope. This group is divided into two main types, the clay and the sandy soils. It is because of the rolling topography of the sandy soils and the compact profile of the clay soils that they have been placed in this group rather than in Group A.

SUGGESTED IMPROVEMENT PROGRAM AND PRECAUTIONS

As in the case of the A group care must be exercised in the use of the highly concentrated alkali water from the Oraibi and Polacca Washes for irrigation purposes. Since the majority of the soils in this group have a moderately compact surface and subsoil more care will be necessary to keep the soil well drained so that puddling, waterlogging, or the accumulation of alkali salts will not develop under irrigation practices. As this soil is overgrazed, range management and reseeding practices

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will have to be followed in order to improve the vegetative cover. Since most of the soils of this group have a relatively heavy textured surface or a fair vegetative cover on the lighter textured surfaces, wind erosion is not as serious on the whole as on Group A, but this does not mean that care will not have to be exercised to check it.

MOISTURE PENETRATION AND WATERHOLDING CAPACITY

On the whole, moisture penetration in this group is slower than in Group A. From laboratory studies it has been observed that on the heavier textured soils it requires from 14 minutes to 24 hours for water to penetrate one inch of air dry soil, depending mostly upon the structure and colloidal content of the soil. On the lighter textured portions of this group it requires from ½ to 19 minutes for water to penetrate one inch of air dry soil. Usually the slower water penetrates a soil, the greater is its waterholding capacity, therefore the waterholding capacity of most of the soils in this group is higher than in Group A. The sandy loam soils of this group have about the same waterholding capacity as those of group A.

ADAPTATION TO EROSION CONTROL PRACTICES

The clay soils of this group are better adapted to water spreading practices than are the loose textured soils, because the slope is more uniform, the effect of wind erosion is not as serious, the waterholding capacity is higher, though the rate of absorption is slower. Strip cropping should be practiced wherever crops are grown because of the tendency of the soils to blow. Contour irrigation would be necessary on the steeper slopes of the sandy loam type if this type were placed under irrigation, otherwise serious gullying or sheet erosion would develop.

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ADAPTATION TO IRRIGATION

This group is not recommended as highly for irrigation purposes as Group A. With proper handling of the heavier textured gently sloping soils good results may be obtained under irrigation methods of farming. This is also true for the loose textured soils, but more care will have to be exercised in the handling of the water. The steeper portions and the high residual soils are not recommended for irrigation use because it would be rather difficult to get water on them, also it would require more water because of the loose texture than could be spared to bring about fair crop results. The fertility of the soils of this group is such that a good native cover may easily be developed. The white alkali content of the entire profile of these soils is moderate and if placed under irrigation with improper handling may develop into a serious menace to plant growth. The sandy soils of the group are subject to slight amounts of black alkali in the lower portion of the profile, while the clay soils on the whole are relatively free of black alkali in the upper seven feet of the profile. It is recommended that the soils of the Polacca and the Loupp Series be the only ones used under irrigation agriculture and the remainder be left in native cover.

VEGETATIVE ADAPTATION

The present vegetative cover is similar to that of Group A and in most places the adaptations are similar to that group. The sandy soils of this group have a better cover of Sacaton grass.

VALUE OF SOIL FOR CONSTRUCTION PURPOSES

This group has a good combination of soils for construction purposes for the sandy soils on the whole have a relatively high colloidal clay content and the heavier textured soils are easily accessible.

LIMITING FACTORS IN THE USE OF THE SOIL

The outstanding limiting factors of this group are: (1) The compactness and extent of the clay layers in the heavy textured soils, (2) The moderate amount of white alkali that is present in the zone of root penetration of the heavy textured soils and the much higher

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concentration in the lower profile, (3) Presence of a slight amount of black alkali in the profile of the loose textured soils as well as white alkali, (4) The excess slope of portions of the loose textured soils and its susceptibility to the effects of wind erosion in the eastern portion of the area surveyed, (5) Some places the clay soils are severely affected by wind erosion.

EROSION

The erosion conditions of this group are similar to those of Group A. This condition is also indicated in the above paragraph.

GROUP C

This group is characterized by four different soil separations consisting of both residual and alluvial soils such as Tolani sandy clay, Corn Creek clay shallow phase, Ives clay, and Tovar sandy clay. The surface soil usually has a moderately compact structure, while the subsoil is variable consisting of either a compact or moderately friable subsoil. Areas of the Tolani sandy clay, located in the western portion of the area, are characterized by a friable subsoil, while the remainder of the soils are compact. The general topography of this group is level to gently sloping with an average slope of 2 to 3 percent. Due to the general heavy texture of the surface soil very little wind erosion has occurred in this group. The drainage facilities of the Ives clay are not good, and many places this soil has indications of poor subsoil drainage. The other types in this group indicate that they have fair drainage throughout the profile. In many places the profile of the Tovar sandy clay is shallow and vegetation is sparse.

SUGGESTED IMPROVEMENT PROGRAM AND PRECAUTIONS

Since the majority of the soils of this group are characterized by a heavy surface and subsoil texture it is recommended that deep rooted cultivated plants such as alfalfa be used if this section is to be placed under irrigation so they may aid in keeping the drainage open. If very little or no irrigation water is used then the native cover of Sacaton grass may be increased under better range

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management practices. At present the Ives clay is the only type that does not have a Sacaton grass cover, the other with a little care will develop an excellent stand. In a few places Cockleburs are present, especially one mile north of the trading post. It will be necessary to remove them before this section can be improved to such an extent that cultivated grasses will grow. The accumulation of black and white alkali will have to be considered in this group.

MOISTURE PENETRATION AND WATERHOLDING CAPACITY

On the whole, moisture penetrates the soils of this group slower than in the two previous groups due to the greater compaction of the majority of the soils. The [illegible] sandy clay occurs in what is known locally as the Seven Small Lakes, and the Ives clay was a lake bottom at the time the Oraibi flowed southeast past the trading post. It is due to the compact surface and subsoil that water remains on the surface of these types for a long period. After several weeks of dry weather the lower profile of the heavy textured soils was moist, indicating that the waterholding capcity of the soil was high.

ADAPTATION TO EROSION CONTROL PRACTICES

Only in a few local places has sheet erosion developed to such an extent that it is serious and these places are along the breaks of the main drainage way in the western portion of the area and along the base of the foothills in the western and southern portion of the area where the Tovar sandy clay has been mapped. Aside from these places this soil group is not subject to very much damage from sheet, wind, or gully erosion, due to the heavy texture of the soil and the level topography.

ADAPTATION TO IRRIGATION

This group is not recommended for regular irrigation practices, but can be used if necessity should arise. The other two groups are much more desirable. They are extensive enough to use all water supply from the Oraibi and Polacca Washes. White alkali concentration is slightly higher in this group than is present in the other two groups. The concentration of black alkali is about the same but comes a little closer to the surface in this group. The soils of this group can best be utilized for grazing.

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VEGETATIVE ADAPTATIONS

The present vegetative cover consists mostly of Sacaton grass in the western portion, Shadscale in the southern and south-western portion, and several groups of annual plants in the west central and southeastern portions.

VALUE OF THE SOIL FOR CONSTRUCTION PURPOSES

This group can be used for construction purposes, but it is advisable that the compact adobe clay of some of the soils of this group be mixed with some lighter textured soils for the best results. This is easily accomplished due to the nearness of the light textured soils to this group.

LIMITING FACTORS IN USE OF THE SOIL

The main limiting factors of this group are: (1) Compactness of the soil profile of the majority of the soils; (2) The shallow profile of Tovar sandy clay; (3) The presence of white and black alkali in the profile.

EROSION

As previously mentioned erosion is not a serious factor on this group except in a few local places.

GROUP D

The Tovar sandy clay shallow phase is the only type in this group. The slight soil development consists mostly of the geologic formation of Chinlee shale and sandstone. The topography is rolling to rugged, giving the impression of rough broken land. Due to the nature of this group it is not recommended for irrigated cultivated

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crops or grass. It is suggested that it be left in its native cover which consists mostly of Shadscale and clumps of Sacaton grass. With better range treatment a better cover may be developed. Sheet erosion and gullies are serious over most of this group, but since most of the soil has been removed checking of this condition will seldom be economically feasible.

POROSITY STUDIES IN RELATION TO WATER PENETRATION

Soil Type	Soil Depth	Vol. Wt.	Porosity	Water Penetration	Swelling
Oraibi Cl.	12 - 24"	1.59	38.4%	8 Min. per inch	Negligible
Polacca Cl.	12 - 24"	1.60	34.7%	14 " " "	"
Oraibi Cl.	0 - 8"	1.58	36.3%	----------	----------
Oraibi S.L.	0 - 12"	1.48	42.6%	25 " " "	"
Polacca Cl.	0 - 12"	1.82	23.5%	24 Hours " "	20%
Corn Creek Cl.	0 - 15"	1.81	26.7%	6½ " " "	32%

In making the tests of the above results, a paraffin wax was placed about a cindrical inch piece of undisturbed air dry soil, in order to help hold the soil in its natural state, also to help in obtaining accurate results. The rate of penetration in paraffin sealed columns is slower because of thenecessity of forcing air ahead of the water, also swelling tightens the column. The following results were observed on paraffin free one-inch cubes of air dry soil.

Soil Type	Soil Depth	Time of Water Penetration
Corn Creek Clay Shallow Phase	0 - 15"	11-3/4 Min. for 1 inch of soil
Oraibi Sandy Loam	0 - 6"	5½ Min. for 1 inch of soil
Oraibi Sandy Loam	6 - 12"	2-1/3 " " " " " "
Oraibi Sandy Loam	0 - 8"	2-2/3 Min. for 1 inch of soil
Oraibi Sandy Loam	8 - 18"	8-3/4 " " " " " "
Oraibi Sandy Loam	18 - 24"	4-1/3 " " " " " "
Polacca Clay	0 - 12"	5 Hours for 1 inch of soil
Polacca Clay	12 - 24"	3 Min. " " " " "
Polacca Clay	0 - 12"	1 Min. for 1 inch of soil
Polacca Clay	12 - 24"	19 " " " " " "
Oraibi Clay	0 - 12"	63 Min. for 1 inch of soil
Oraibi Clay	12 - 24"	5 " " " " " "
Tolani Clay	0 - 12"	1 Min. for 1 inch of soil
Tolani Clay	12 - 24"	4-1/3 " " " " " "
Tolani Sandy Clay Loam	0 - 15"	1 Min. for 1 inch of soil
Tolani Sandy Clay Loam	15 - 24"	3/4 " " " " " "
Tolani Sandy Loam	0 - 12"	1/3 Min. for 1 inch of soil
Tolani Sandy Loam	12 - 24"	1/3 " " " " " "
Corn Creek Clay	0 - 24"	10 Min. for 1 inch of soil
Oraibi Clay	0 - 8"	33 Min. for 1 inch of soil
Oraibi Clay	8 - 16"	3-1/2 " " " " " "
Oraibi Clay	16 - 24"	5 " " " " " "
Oraibi Sandy Loam	0 - 12"	3 Min. for 1 inch of soil
Oraibi Sandy Loam	12 - 24"	25 " " " " " "

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RESULTS OF ALKALI DETERMINATIONS - TOLANI LAKES DEMONSTRATION AREA

Soil Type No.	Location	Average Concentration Alkali in profile expressed in P.P.M.* White Alkali	Black Alkali CO_3
10	1-1/2 Mi. W. Lake	1953	Strong
10	3/4 Mi. W. Bridge	1570	Moderate
12	2 Mi. N. Red Lake Store	1363	None
12	1-1/4 Mi. E. Lake	1142	None
12	3 Mi. N. Store	12[illegible]9	None
12	3 Mi. NW Store	10[illegible]	None
12	1/2 Mi. S. Oraibi	11[illegible]	None
12	1 Mi. N. Store	108[illegible]	None
12	1/4 Mi. S. Oraibi	1[illegible]	None
12	1 Mi. E. Bridge	[illegible]7	None
12	1/4 Mi. S. Oraibi	1[illegible]7	None
14	1 Mi. NE Bridge	2065	None
14	1-3/4 Mi. N. Store	1630	None
14	1-1/4 Mi. NE Bridge	16[illegible]0	None
14	1-1/2 Mi. NW Store	18[illegible]4	None
14	South edge of Lake	2013	None
14	1 Mi. W. Store	2017	None
15	2-1/4 Mi. NE Store	1503	None
15	1-1/2 Mi. E. Lake	1462	None
15	2-1/4 Mi. N. Store	1512	None
15	1 Mi. NE Store	1440	None
15	1/2 Mi. NE Store	1553	None
15	1 Mi. NE Store	1200	None
15	2 Mi. NE Store	1963	None
15	1/2 Mi. E. Store	1700	None
15	3/4 Mi. NW Store	2[illegible]90	Slight
15	1/2 Mi. S. Oraibi	1[illegible]0	None
15	2 Mi. NW Store	1470	None
15	1/2 Mi. E. Bridge	1543	None
19	200 Ft. N. Lake	7965	None
19	1000 Ft. N. Lake	4050	None
19	1 Mi. N. Lake	1390	None
19	1 Mi. E. Oraibi	1005	Slight
19	1-1/2 Mi. NW Lake	850	None
19	1/2 Mi. E. Oraibi	1337	Slight
20	1/4 Mi. E. White Bridge	2497	Slight
20	1 Mi. SE White Bridge	1480	None
20	1/4 Mi. E. Bridge	1840	Moderate

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(Alkali Tolani Lakes, continued)

Soil Type No.	Location	Average Concentration Alkali in profile expressed in P.P.M.* White Alkali	Black Alkali CO_3
26	3 Mi. NE Store	1037	None
26	3-3/4 Mi. NE Store	1020	None
28	1/2 Mi. NW Store	2693	None
28	1/2 Mi. W. Store	2907	None
29	1-3/4 Mi. W. Lake	1433	Slight
29	1-1/2 Mi. W. Lake	1289	Slight
31	4 Mi. N. Store	707	None
31	2 Mi. W. Lake	1680	Moderate
31	4 Mi. N. Store	200	Slight
31	4-1/2 Mi. NE Store	333	Slight
31	1/4 Mi. W. Lake	200	Slight
32	1-1/4 Mi. NW Lake	2148	Moderate

(*P.P.M. = Parts per million to convert to percent place decimal point before fourth digit.)

WATER ANALYSIS

Sample Location	Total Salts ppm	Ca ppm	Mg ppm	Na ppm	CO_3 ppm	HCO_3 ppm	CL ppm	SO_4 ppm	AL_2O_3 ppm	AL ppm	Grade
Oraibi Wash	3430	136	44	716	6	110	105	2000	0	0	Fair
Polacca Wash	3632	228	50	868	6	112	247	2125	0	0	Poor
Tolani Lake	2408	243	108	300	0	.191	69	1400	430	228	Fair
Tap Water	2478	174	110	436	0	198	228	1300	364	197	Fair
Windmill Water	1494	141	11	350	0	224	19[illegible]	700	0	0	Fair

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TOLANI LAKES WATER TABLE STUDY

This report is intended to augment the available information on the proposed Tolani Lakes Cooperative Project. The Land Planning Committee asked that a water table study be made. The data obtained are to be used to determine the feasibility of sub-irrigation on the project.

The proposed project is located about forty two miles north of Winslow, Arizona, on the Winslow-Oraibi road. This survey covers a roughly triangular area of approximately six and one-half square miles, located between the Red Lake Trading Post and Tolani Lake. Beginning at the windmill near the Trading Post, the east boundary bears north to its intersection with the north boundary line drawn east from a point on the Oraibi road three-eighths of a mile north of the white bridge. From this point the southwest boundary follows the Indian Service road back to the point of origin.

The surface of the area under study is fairly smooth, although there are some windblown hummocks in the east-central portion. The southwest boundary follows a rocky slope, at the base of which is a flat, sloping gently to the southeast. The northeastern part of the area slopes to the south and to the west, having a drop of about seven and one-half feet to the mile. The old Oraibi Wash traverses the area paralleling the east boundary.

Coordinates were surveyed at one-half mile intervals in an east-west and north-south direction and, at the intersections of these lines, test holes were bored. The auger holes are three inches in diameter and were bored to a depth of twenty feet or to the water table if less than twenty feet. The test holes were logged to determine the flow of the ground water and, if possible, to determine reasons for differences in water levels.

Three types of ground water are recognized in this study. They are: hygroscopic moisture, capillary water and hydrostatic water. Hygroscopic water is moisture held by the soil when air dry. This type of water is inert in soil functions therefore will not be considered further. Capillary water is water held in suspension in the capillaries between the soil particles. Hydrostatic water is commonly called ground or gravitational water. It is free to move under the influence of gravity. The suspended water may be derived from the hydrostatic or ground water below or from passage of ground water following precipitation or flooding. The height to which water can be drawn by capillary action varies with the texture of the soil.

In this study the water table is defined as the upper surface of a zone of saturation.

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The water table is not level due to variations of strata in the subsoil, variations in topography and relative elevation of the sources and outlets of the ground water. It was encountered within twenty feet of the surface of the flat at the base of the rocky slopes along the southwestern boundary. (See chart). The moist area is east of this while the very dry holes occupy the east-central portion of the area.

The movement of water in heavy clays, heavy sandy clays, and heavy silty clays is very slow. A hole bored to the water table in soils of this nature will take a considerably longer time to fill to the ground water level than will holes in more permeable soils. Therefore, the water table was determined most accurately in those test holes containing strata of free draining material such as loams. Several holes in the moist area were checked two or three days after they were drilled but no water was found. In most cases these test holes had penetrated thick beds of plastic clay and muck.

The soils of the area under consideration are heterogeneous. They range in texture from loamy sands to heavy clays. The flat, in which the water table was encountered within twenty feet, is a shallow trough sloping gently to the southeast. To understand the underground water flow better, a contour map was made of the surface of the water table. Surface contours were also drawn so that a comparison of surface and water table contours at intersections could be made to determine the relative depth of the water table at that point. The dotted line from test hole 29 through 31 and on to the base of the rocky slopes shows the probable high point in the water table at the time of the survey. It is probable that an underground saddle of Chin Lee material joins the opposing rocky slopes causing this high point. The underground flow from these slopes splits on the saddle, the majority of it flowing south east toward the Old Oraibi Wash, while a small amount flows north. At test hole 34, the Chin Lee formation was found at a depth of seven feet, its damming action probably causing the high water table found at numbers 30, 31, 32, and 33. The high concentration of salts found at 33 indicates lack of water movement in this area.

Another underground flow of water drains the northeastern area toward the southwest probably splitting on the saddle at the south end of the lake. There is also evidence of an underground flow from the rocky slopes along the southwest boundary as indicated by the sloping water table and low salt concentration of the water from the ECW well and test holes 44, 43, and 42.

The bottom of Tolani Lake is probably sealed against any appreciable subsurface flow. The marshy area, located at the south end of the lake, is subject to overflow during flood periods. It is possible that this adds considerably to the underground flow.

F. W. 631

The very dry area shown on the chart is covered with hummocks one to six feet in height of wind origin. The soil varies in texture but is dominantly a clay loam. Considerable trouble was experienced in boring the holes within this area because of the extreme dryness of the soil. Water penetration in the compact subsoil was observed to be less than one inch per hour.

The water table at the time of the survey had probably attained its maximum height. Two primary factors account for this condition; dormancy of plant growth and excessive flood flow from the contributing watersheds. The transpiration of ground water by plants during the growing period tends to lower the water table, but during the period of dormancy the water supply becomes greater than the water use, which results in a higher water table. Because of the lack of available information, it is not possible to predict the relative rate of ground water depletion. This may be done by measuring the water level in the various wells over a period of time.

The accompanying permeability chart was made from the data on several test holes in the area. Each test hole was placed on the chart at its respective surface elevation as found on the contour map. The soil textures were graded into three classes according to their relative permeability, the permeable class having less than 20% clay, semi-permeable having 20% to 40% clay, and the slowly permeable class having 40% or more. In most cases the upper part of the profile generally contains thick layers of plastic clay which will tend to maintain a constant water table.

It would be advisable to maintain as constant a water table as possible in order to eliminate the dangers accompanying a fluctuating saturated zone. The heavy plastic layers will tend to stabilize the water table. Irrigation water will penetrate these layers so slowly that it will probably take a number of years to raise the water table an appreciable amount. Superimposed water tables might develop above extensive impervious strata.

Correct interpretation of the data obtained from the alkali analysis of an area affords a means of predicting the future of an area after being submitted to irrigation for a few years. The alkali danger on the Tolani Lakes area is not very eminent except in isolated spots. The whole area is slightly affected but the salts are not excessive and at present cause no particular damage to the vegetation.

Eight samples of the ground water were analyzed for alkali salts. The alkali coefficient was determined and the samples classified as good, fair, poor or bad. The alkali coefficient is defined as, "the depth in inches of water which on evaporation would yield sufficient alkali to render a four foot depth of soil injurious to the most sensitive plants". (1)

F. W. 632

CV-6417-201 NN001260

Analyses of the ground water showed a relatively high salt concentration in all the samples. They were generally high in sodium and calcium sulfates and chlorides. No indications of black alkali were found.

Much of the alkali in the Tolani area has been introduced by flood water, and has been concentrated in the lake and in the soil through evaporation. Samples obtained from the Oraibi and Polacca washes were exceedingly high in total salts. These were taken during the dry season and give very little information on the amount of salts that will be in the irrigation water. The total salts analysis of the two washes should be lower during the flood season but will vary according to the source of the flood. As we have very little available information on the salt content of the waters of these washes, more data must be accumulated before the utility for irrigation can be determined.

It may be said that injurious results due to alkali salts in irrigation water depend on the texture of the soil and the general drainage conditions. Any appreciable underground flow toward a permanent outlet will tend to lessen the danger from the concentration of alkali salts. The contour map of the water table shows an appreciable underground flow from the vicinity of hole 55 toward the Old Oraibi Wash. This flow should be sufficient to drain this portion of the area and prevent dangerous alkali accumulation if the irrigation waters are relatively free. The first alkali trouble will occur in the basin formed by the underground saddle and the bench near test hole 34. Here, the salt concentration in the ground water is very high indicating poor drainage.

Moisture will move upward through heavy clay at the rate of about a foot in twenty four hours. In sandy soils, moisture will rise about a foot in six hours. Moisture rises most rapidly in light textured soils but higher in heavy textured soils. Thick beds of plastic clay are quite common in the area. Moisture movement through these beds is usually too slow to support active plant growth.

Subsurface irrigation to be successful must keep the water table at a high level because the majority of plant roots feed efficiently only in the first four feet of soil. Moisture below seven feet will carry deep rooted plants over a period of drouth but will not produce a good crop.

F. W. 633

CV-6417-201 NN001261

SUMMARY

The area includes approximately six and one-half square miles It is located about forty-two miles north of Winslow, Arizona, on the Winslow-Oraibi road.

A water table study was made to determine the feasibility of sub-irrigation. The water table, within twenty feet, was found in the flat at the base of the rocky slopes along the southwest boundary.

A contour map was made of the surface of the water table. The main underground flow is from the dotted line on the chart south east toward the Old Oraibi Wash. Another underground flow from the rocky slopes along the southwest boundary is indicated by the lower salt concentration in test holes 42, 43, and 44.

Alkali analysis of the ground water showed a relatively high salt concentration but there were no indications of black alkali. More data must be accumulated before the utility of the irrigation water is known. The first alkali trouble will occur in the basin formed by the underground saddle and the bench near test hole 34.

The water table should be maintained at a relatively constant level and should be fairly high.

Bibliography

(1) The Quality of the Waters of Southeastern Nevada, Drainage basins and water resources. 1934. By George Hardman and Meridith R. Miller. The University of Nevada Agricultural Experiment Station, Bulletin No. 136, P. 20.

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F. W. 634

ALKALI ANALYSIS OF THE GROUND WATER AT TOLANI LAKES

	Well No.	Total ppm	Ca ppm	Mg ppm	Na ppm	CO_3 ppm	HCO_3 ppm	CL ppm	SO_4 ppm	Alkali k	Grade
	2	10896	494	239	2660	0	690	513	6500	1.6	Poor
	33	13676	580	192	3327	0	181	4190	3750	.47	Bad
	32	4888	387	65	1152	0	284	266	3000	3.6	Poor
	53	3830	322	94	796	0	307	266	2200	4.4	Poor
ECW Well		2578	86	21	756	0	221	366	1200	3.8	Poor
	43	3782	339	62	633	0	3[illegible]	318	2050	4.5	Poor
(44) W.M.Well		1494	141	11	350	0	2[illegible]	190	700	7.8	Fair
	42	2830	455	50	320	0	53[illegible]	10[illegible]	1400	11.0	Fair
Oraibi Wash		3430	136	44	716	0	11[illegible]	105	2000	6.7	Fair
Polacca Wash		3632	228	50	868	6	1[illegible]	2[illegible]	2125	4.3	Poor
(From Tap)		2473	174	110	436	0	1[illegible]	228	1300	6.4	Fair
Tolani Lake		2408	243	108	300	0	1[illegible]	69	1400	13.9	Fair

Classification of Waters for Irrigation by Content of Alkali.
Alkali Coefficient = k

Greater than 18 - Good. Have been used successfully for many years without special care to prevent alkali accumulation.

From 18 to 6 - Fair. Special care to prevent alkali accumulation has generally been necessary except on loose soils with free drainage.

From 6 to 1.2 - Poor. Care in selection of soils has been found to be imperative and artificial drainage has frequently been found necessary.

Less than 1.2 - Bad. Practically valueless for irrigation.

Alkali Coefficient and Irrigation Classification from the Quality of the Waters of Southeastern Nevada, Drainage Basins and Water Resources, by George Hardman and Meridith R. Miller. The University of Nevada Agricultural Experiment Station, Bulletin No. 136, P. 20.

F.W. [illegible] 635

NN001263