WORK REPORT

CONSERVATION SURVEY

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Land Management Unit 3
Navajo Project

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final correlation by the Inter-Bureau
Correlation Committee

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INTRODUCTION

Land management Unit Number 3 is located in the extreme western portion of the Navajo Indian Reservation. It lies within Coconino County, Arizona, approximately between 35°45' and 36°45' parallels of latitude and 111° and 112° meridians of longitude. The south portion of the Unit is rectangular in shape, but the north portion forms a narrow wedge extending northward to Lee's Ferry, located on the Colorado River. The river forms the northwest boundary, not only of this Unit but also of the Navajo Indian Reservation. The east boundary of the Unit is very irregular, touching or following such natural landmarks as Echo Cliffs, in the north portion, Crooked Ridge, Preston Mesa, Little Mesa, Cow Springs Wash, Blue Canyon, and Dinnebito Wash. From a point on the Little Colorado River, known locally as Black Falls, the boundary follows the south and west boundary of the Navajo Indian Reservation to the confluence of the Little Colorado and Colorado rivers. The unit embraces 1,759,336 acres.

U. S. Highway 89 extends north and south through the central portion of the Unit for a distance of approximately 85 miles. Other important roads branching from this highway are: (1) the main highway leading west to the Grand Canyon National Park, leaving Highway 89 at Cameron, Arizona, located on the Little Colorado River; (2) the main road leading northeast to Tuba City and Kayenta: (3) the Tuba City-Hotevilla road leading southeast from Tuba City, which is located in the central portion of the Unit. The entire Unit is accessible by secondary roads and truck trails.

Physiographic Features

The main physiographic features of Unit 3 are: Gray Mountain and the deep gorge of the Little Colorado River in the southwest; steep, rugged canyon walls in the west; Shadow Mountain and extensive rough broken "badlands" in the central; Echo Cliffs and Kaibito Mesa in the north; and Coal Mine and Blue Canyons and Moencopi Plateau in the east portions of the Unit. Stony outcrops and steep mesa escarpments are common to all parts of the Unit, but numerous broad smooth gently sloping or rolling uplands and valleys dominate the southwest and west portions. The northeast and east portions are characterized by an upland, plateau or mesa topography, the surface of which is characteristically hummocky.

The steep character of the terrain is conducive to rapid runoff, especially during the rainy season in late summer. Torrential storms falling on relatively impervious soils have resulted in excessive erosion, both on the rugged slopes and on the alluvial soil deposits below the steep escarpments. Extensive areas, located in the central part of the Unit, are practically barren of soil cover.

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With the exception of relatively flat mesa tops in the east and northeast portions, the Unit is well or excessively drained. Practically all surface drainage leads to the Little Colorado River, which traverses the southwest portion of the Unit. The Moencopi drainage system, which empties into the Little Colorado River near Cameron, drains the central and northeast portions of the Unit. A very minor portion of the Unit is drained by small intermittent streams which empty directly into the Colorado River. Drainage from the extreme eastern border reaches the Little Colorado River through the Dinnebito Wash.

Climate

The lowest elevation, 3200 feet, is at Lee's Ferry in the extreme north portion, and the highest, 7000 feet, on Gray Mountain in the southwest portion. Climatic conditions vary considerably between the extremes in elevation, but the Unit as a whole is semi-arid or arid. Tuba City has an elevation of 4500 feet. Available climatological data over a 29-year period (1897-1930), at this place indicate that the average annual precipitation is 6.9 inches. Extreme years occurred in 1906 and 1924, with an annual precipitation of 12.57 and 1.58, respectively. The mean annual temperature is 54°; the maximum, 108°, and the minimum -15°. The average frost-free growing season is 179 days, from April 22 to September 19. The climate of the Unit is characterized by a high percentage of clear days, low rainfall and humidity, and very little snow. The rate of evaporation and transpiration is very high as a result of hot summer days, and high southwest winds in the spring and fall. These conditions, in a large measure, account for the sparse native vegetation over most of the Unit, and for the fact that very little dry farming is practiced.

Agricultural History and Present Land Use.

The land in Unit 3 is primarily adapted to grazing. Forestry and agriculture are of minor importance. Properly utilized, the area is capable of producing a considerable quantity and variety of native browse and grass, but the Unit is typical of the Reservation as a whole in that soil and native vegetation is in a depreciated state, in most cases the result of improper range use.

Agricultural development is limited not only by precipitation, but also by a lack of soil adapted to that purpose. Approximately 1100 acres are under irrigation at Moencopi Village near Tuba City from an Indian Service diversion dam located on Moencopi Wash. Another small area at Moenave is irrigated from springs, located along the base of Kaibito Mesa.

Historical data are not available, but probably some irrigation has been carried on here since the Mormon pioneers entered the country about 1870. Some wind and water erosion has resulted from improper

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agronomic and irrigation practices. More significant, from a Soils point of view, is the fact that valuable farmland at Moencopi has become impregnated with, and abandoned because of, harmful quantities of alkali. It would seem advisable, in view of the limited area of good agricultural land in this section, to initiate alkali investigations on this area for the purpose of discovering the cause, present status, and feasible methods of protection and reclamation of valuable agricultural land.

Approximately 1000 acres of land, located on top of Moencopi Plateau, is flood-irrigated at the present time. An additional 200 acres is included in scattered dry farms in the same section. Removal of native vegetation on these sandy soils has resulted in severe wind erosion. The present condition warrants the attention of an agronomist to consider methods of effective control.

SOILS

The soils of Unit 3 are derived from reddish brown Morrison and Wingate sandstone in the east and northeast portions, reddish brown or maroon Chinle and Moenkopi shale in the central, and grayish brown Kiabab limestone in the west portion. Soils derived from igneous rock occur in the extreme south part of the Unit. These parent materials have imparted to the soils different characteristics which influence their productivity and susceptibility to erosion. For example, those derived from shale are more susceptible to water erosion; but those developed from limestone and igneous rock are little affected by any form of erosion, due to the stabilizing effect of the vegetative cover.

In addition to origin, the soils of this Unit have been classified according to mode of formation, chemical composition, stage of soil development and surface texture. Using these criteria, the soils of the Unit have been placed in 15 series embracing 23 types. Other miscellaneous land classes include rough, broken and stony geologic materials, and riverwash. In this survey, the soils are also classified according to land use, slope and erosion.

The main purpose of such a classification is to determine, as far as possible, the productive capacity of the soil under present land use, and the need for and the adaptability of these soils to an improved land-use program. In this latter classification, the soils have been grouped into five land classes, according to range adaptation or quality from a range point of view. These five land class groups are briefly described. Their location is shown on the land class map.

Factors Considered in Grouping Soils

Soil moisture is probably the chief limiting factor in forage production; therefore, in grouping soils according to range adaptation, soil conditions which influence moisture relationships are given special

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emphasis. Factors thus considered important are: slope, erosion, permeability, water-holding capacity, and alkali content.

Group A Soils (excellent range soils) consist of those having: moderate slope (generally less than 5 per cent), less than 25 per cent of the topsoil removed by erosion, occasional shallow gullies, permeable surface soil, deep, moderately heavy-textured subsoil providing good water-holding capacity, and an alkali content which does not preclude the growth of desirable native vegetation.

Group B Soils (good range soils) consist of those having: a slope generally between 5 and 15 per cent, between 25 and 75 per cent of the topsoil removed by erosion, occasional shallow gullies, moderate permeability and water-holding capacity, and an alkali content which does not affect the type of native vegetation.

Group C Soils (fair range soils) consist of those having steep slopes (generally between 15 and 30 per cent), over 75 per cent of the topsoil removed by erosion, frequent shallow or occasional deep gullies, fair permeability and water-holding capacity, and an alkali content sufficiently high to affect the type of native vegetation, resulting in a lower carrying capacity.

Group D Soils (poor range soils) consist of those having more than 30 per cent slope, soil cover essentially destroyed by erosion, low permeability and water-holding capacity, and an alkali content sufficiently high to affect not only the type but the amount of native vegetation.

Land Class E (essentially no range value) consists of geologic outcrops of sandstone and shale, supporting practically no vegetative cover.

Note: Any one of the above factors may serve to place a given soil in the next lower class.

Group A

This group consists of soils having excellent range qualities. They are deep, permeable, slightly eroded, and have a low alkali content. The native vegetation consists largely of blue grama and big sage. In most places the vegetative cover is sufficient to provide ample protection to the friable surface soil. Isolated small areas where the vegetative cover has been damaged by heavy grazing, resulting in accelerated sheet and gully erosion, can be corrected by controlled grazing. These soils will respond quickly, in terms of increased vegetative growth, to a land management program.

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The several soil series and types placed in this group, together with their soil characteristics, are presented in Table I. Of those which qualify in this group, the types in the Kiabab and Springerville series are the most important from the standpoint of area. These soils, developed from basaltic rock and Kiabab limestone, are mapped extensively in the west portion of the Unit. In some places the soil cover is broken by frequent stony outcrops, probably the result of natural geologic erosion.. Extensive areas of these soils were placed in a lower class because of the shallow intermittent soil cover.

Improvement Program Feasible from a Soils Standpoint

The slight sheet and gully erosion on Group A soils can, in most cases, be effectively controlled by regulated grazing, although a few isolated gully-heads may require mechanical treatment for immediate results. In that event, these soils may be regarded as suitable material for structural purposes. If the slope is not too steep, Dinnebito sandy loam, by reason of its geographic location along the base of foothills and escarpments, is best adapted for water-spreading purposes. With water available for irrigation, the soils of this series are also adapted to agricultural development.

Precautions

A good grass cover renders these soils more resistant to erosion than those of other groups, but there is evidence of the beginning of accelerated erosion in some locations, probably the result of present grazing methods. A good grass sod is not only important to protect the surface soil from erosion, but also to check the rate of run-off, thereby resulting in a greater degree of water absorption. To that extent, the plant cover serves to improve soil-moisture conditions. The destruction of native vegetative cover as the result of developing land for agricultural purposes should be compensated for, as far as possible, by artificial plant cover and other erosion-control devices to protect the soil from undue wind erosion. The sandy loam soils are usually best adapted to Navajo farming. These soil types are also the most susceptible to wind erosion.

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TABLE I CHARACTERISTICS OF SOILS INCLUDED IN CLASS A - RANGE SOILS

Soil Type	Nos. on maps	General Location	Erosion: Water: Sheet	Erosion: Water: Gully	Erosion: Wind: Removals	Erosion: Wind: Accum.	% Slope	Permeability	Water Holding Capacity	Alkali
Todilto Sandy Loam	21.7	Scattered Areas in Eastern portion of Unit	0	0	Slight	0"-6"	0-3	Permeable	High	Low
Springer-ville clay loam	25.13	Southwest portion of Unit - Near Grey Mountain	Slight	Occa-sion-al	0	0	3-10	"	"	"
Kiabab sandy loam	43.7	Northwest part of Unit. Near Little Colorado	"	"	Slight	0	3-10	"	"	"
Bonito clay loam	75.13	West of Cedar Ridge Trading Post.	"	"	0	0	0-3	"	"	"
Dinnebito sandy loam	76.7	Southeast portion of Unit.	"	0	0	12-36"	0-3	"	"	"
Dinnebito clay loam	76.13	"	"	0	Slight	6"-12"	0-3	"	"	"
Hunt sandy loam	60.7	North central portion of Unit.	"	Occa-sion-al	0	0-6"	0-3	"	"	"
Shavano sandy loam	42.7	North central portion of Unit.	"	"	0	0	3/20	"	"	"

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TABLE I CHARACTERISTICS OF SOILS INCLUDED IN CLASS A - RANGE SOILS

Soil Type	Nos. on maps	General Location	Erosion: Water: Sheet	Erosion: Water: Gully	Erosion: Wind: Removals	Erosion: Wind: Accum.	% Slope	Permeability	Water Holding Capacity	Alkali
Todilto Sandy Loam	21.7	Scattered Areas in Eastern portion of Unit	0	0	Slight	0"-6"	0-3	Permeable	High	Low
Springer-ville clay loam	25.13	Southwest portion of Unit - Near Grey Mountain	Slight	Occa-sion-al	0	0	3-10	"	"	"
Kiabab sandy loam	43.7	Northwest part of Unit. Near Little Colorado	"	"	Slight	0	3-10	"	"	"
Bonito clay loam	75.13	West of Cedar Ridge Trading Post.	"	"	0	0	0-3	"	"	"
Dinnebito sandy loam	76.7	Southeast portion of Unit.	"	0	0	12-36"	0-3	"	"	"
Dinnebito clay loam	76.13	"	"	0	Slight	6"-12"	0-3	"	"	"
Hunt sandy loam	60.7	North central portion of Unit.	"	Occa-sion-al	0	0-6"	0-3	"	"	"
Shavano sandy loam	42.7	North central portion of Unit.	"	"	0	0	3-10	"	"	"

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Group B

This group consists of soils having good range qualities, but for reasons specified do not meet the requirements of Group A. Erosion is usually more advanced on these soils, and for that reason control measures are more timely; but more significant is the fact that the soil cover is not as yet seriously damaged. The soils of this group are of such quality as to make erosion-control work feasible and effective, and they will respond to a land-management program.

The soil series and types in this group are presented in Table II. The Todilto series is the most important from the standpoint of area. This series, developed from Morrison and Wingate sandstone, occurs extensively in the east and northeast portions of the Unit. The soil is usually characterized by a light, loamy sand surface texture, and, unless protected by a good vegetative cover, is very susceptible to wind erosion. Wind hummocks and drift sand are common. The native vegetation consists of blue grama, Mormon tea, yellow brush and Spanish dagger.

Improvement Program Feasible from a Soils Standpoint

In general, a range-management program will serve to correct the damage from erosion on this group. These soils, however, probably will not respond so quickly to such a program as will those of Group A. To obtain the most effective results, a larger portion of these soils will require mechanical treatment or intensive erosion control. This applies especially to sheet and gully erosion on some of the alluvial soils, such as the Hunt and Dinnebito series. In some places, the total exclusion of livestock by fencing might be justifiable.

Precautions

As mentioned before, Todilto loamy sand is subject to wind erosion. A maximum vegetative cover should be developed and maintained. Gully erosion, if allowed to continue at its present rate on certain alluvial soils, will eventually render otherwise potentially good agricultural or range land worthless.

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TABLE II CHARACTERISTICS OF SOILS INCLUDED IN CLASS B - RANGE LANDS

Soil Type	Hes. on Map	General Location	Erosion: Water: Sheet	Erosion: Water: Gully	Erosion: Wind: Removals	Erosion: Wind: Accum.	% Slope	Permeability	Water Holding Capacity	Alka
Todilto loamy sand	21.7	Eastern part of Unit.	Slight	Occasional	Moderate	12-36"	0-3	Permeable	Moderately High	Low
Dinnebito sandy loam	76.7	South of Blue Canyon	Slight	0	"	6-12"	0-3	"	High	"
Hunt Clay loam	60.13	In valley along Moenscopi Wash.	"	Occasional	Slight	0-6"	0-3	"	"	"
Kiabab sandy loam	43.7	Southwest part of Unit.	Mod.	"	"	0-6"	10-25	"	Moderately High	"
Cameron clay loam	79.13	In valleys in southwest part of Unit.	"	"	"	0 -	0-3	"	"	"

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Group C

Group C soils have a fair or relatively low productive capacity, which may be a natural condition, or the result of accelerated erosion due to misuse of the land, such as overgrazing. Any one or more of the following factors may be the reason for placing a given soil in this group: low permeability, low water-holding capacity, rough, broken or stony land, accelerated erosion, or high alkali content.

All or part of the types in the following soil series have been placed in this group: Moencopi, Dinnehotso, Tolani, Concho, Todilto, Tees-Nos-Pos, and Gila (See Table III). Types in the first three series are derived from Chinle and Moenkopi shales, located in the central portion of the area. These soils, especially the heavier-textured types, have a high rate of run-off which makes them unusually susceptible to water erosion. The rate of run-off is governed largely by topography, but also by a relatively impervious surface soil and a lack of vegetative cover. Heavy grazing is, as usual, an important contributing factor, but low permeability affecting soil moisture is also important.

The alkali content and dispersion of the surface soil are frequently high in soils derived from shales. Water penetration is low in a dispersed soil, and a high alkali content gives certain relatively non-palatable, ineffective erosion-control vegetation a natural advantage over other vegetation having a higher carrying capacity. Greasewood and salt bush are the main vegetative types on most of the soil types of this group. An exception is Todilto loamy sand, mapped northeast of Tuba City. This soil has been placed in Group C because of severe wind erosion. The typical erosion condition here is represented by small sand dunes which range from 36 to 72 inches in height. Some large active sand dunes also occur.

Improvement Program Possible from a Soils Standpoint

In considering the soils of this group from the standpoint of a land-management program, two factors should not be overlooked: the serious need for soil conservation where accelerated erosion has reached a severe state, and the limitations of such a soil-conservation program. The latter has reference to soil areas which are so badly depleted that mechanical work is impracticable, and also to extensive areas on which erosion is largely the result of a natural geologic process. In this case, a very shallow, intermittent soil cover would offer very definite limitations to an improvement program. (See map, Class C land with rough, broken and stony symbol, 198 and 198.) Range improvement will also be limited by soils having a sufficiently high total salt content to favor vegetation with a low carrying capacity.

Soils placed in this group as a result of accelerated erosion represent what might be referred to as a critical stage of erosion because of the need for immediate action to save the soil areas from passing into a veritable wasteland. In some places, conservation should consist

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not only of restricted grazing, but also of mechanical treatment. This soil group is important from a land-management standpoint because of the possibility of doing a great deal of good, on the one hand, and the probability of not doing sufficient good to warrant the required expenditure of labor and materials because of natural soil limitations, on the other.

Precautions

Soils of the Leencopi, Dinnehotso, Hunt and Concho series frequently have a high clay content and an alkali content which result in a dispersed condition. The use of these soil materials for structural purposes is dependent upon approval after laboratory analyses to determine the degree of dispersion. An intensive alkali investigation should usually be made before attempting to reseed or develop these soils for agricultural purposes. The soils of this group, because of erosion, will not respond readily to a land-management program. In some isolated places, it might be impossible to establish a soil cover sufficient to support a vegetative cover. It is advised that grazing be restricted accordingly.

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TABLE III CHARACTERISTICS OF SOILS INCLUDED IN CLASS C - RANGE LANDS

Soil Type	Nos. on Map	General Location	Erosion: Water: Sheet	Erosion: Water: Gully	Erosion: Wind: Removal	Erosion: Wind: Accum.	% Slope	Permeability	Water Holding Capacity	Alkali
Concho Clay	55.16	In valley of Cow Springs Wash.	Mod.	Occasional	Mod.	12-24"	0-3"	Impermeable	High	Mod. Low
Dinnehotso clay	57.16	Area northeast of Red Lake	Slight	B class	0	0	0-3"	"	"	"
Dinnehotso sandy loam	57.7	Area northeast of Moenave Dem. Area.	"	EROSION			0-3"	Permeable	Low	"
Moencopi sandy loam	46.7	South end of Unit	Slight	Occasional	Mod.	12-24"	0-3"	"	"	Low
Moencopi sandy loam	46.7	Central portion	Mod.	"	Slight	0-6		Non-permeable	High	Mod.
Telani sandy loam	68.7	Along Little Colorado. S. end of Unit	Slight	"	Mod.	24-36"	0-3"	Permeable	Low	Low
Gila clay loam	70.13	Along Colorado in extension from Unit 5.	"	"	Mod.	0-6"	3-10	"	Mod.High	Mod. Low
Tees-Nos-Pos sandy loam	72.7	South of River in Western portion	Severe	"	Slight	0-6"	3-10	"	" "	"
Kiabab sandy loam	43.7	Western portion	Rough		Stony			"	Low	Low
Todilto loamy sand	21.1	Eastern part of Unit.	0)	Occasional	Mod.	36-72"	3-10	"	Mod.High	Low

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Group D

The soils of this group have many characteristics in common with those of Group C. However, they are less permeable, may have a higher alkali content, affecting not only the type but the amount of vegetation, or might be more severely eroded. This group is composed largely of rough stony and broken land with an intermittent, shallow soil cover (See Table IV). The vegetative cover is sparse, and consists mostly of salt bush.

Improvement Program Feasible from a Soils Standpoint

Group D soils are very limited in their adaptability to a land-management program, much of the area consisting of raw shales and very thin soil on which erosion is largely geologic. A program of restricted grazing is recommended for the purpose of permitting maximum vegetative recovery, although bare shales and shallow soils are very slow to develop a vegetative cover.

Costly mechanical treatment is not practical unless for the purpose of protecting better soils.

Precautions

The same precaution with reference to the quality of the soil for structural and roadbed purposes applies here as in Group C.

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TABLE IV CHARACTERISTICS OF SOILS INCLUDED IN CLASS D - RANGE SOILS

Soil Type	Nos. on map	General Location	Erosion: Water: Sheet	Erosion: Water: Gully	Erosion: Wind: Removals	Erosion: Wind: Accum.	% Slope	Permeability	Water Holding Capacity	Alkali
Moencopi clay loam	46.13	Central and south part of Unit.	Severe	Frequent	0	0	10-20	Permeable	Mod. High	Low
Moencopi clay	46.16	Central and south parts	"	"	0	0	20-40	Impermeable	High	Mod. Low
Todilto loamy sand	21.1	Eastern portion	Slight	Occasional	Very severe	36-72	10-20	Permeable	Low	Low
Rough broken	19B	Scattered generally over Unit	Severe	Frequent	0	0	20-40	Impermeable	High	Mod. High

TABLE IV - a. CHARACTERISTICS OF SOILS INCLUDED IN CLASS D - RANGE SOILS

Rough stony	19C	Scattered generally over Unit	[illegible]	[illegible]	[illegible]	[illegible]	40%	Impermeable	Low	Low
Rough broken	19D	"	[illegible]	[illegible]	[illegible]	[illegible]	"	Impermeable	Low	Low

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Agricultural Soils

No attempt was made in this survey to group soils on the basis of their agricultural adaptability, consequently, in a discussion of agricultural soils, reference will be made to soil series and types. In so doing, an appraisal will be made of their characteristics from an agricultural point of view.

Agricultural soils on this Unit are limited to alluvial deposits along Moencopi Wash and the Little Colorado River. The most important farming area is located at Moencopi Village, near Tuba City. Local soil accumulations from the Todilto series, located on Moencopi Plateau, may be appropriated for agricultural use with some hazards from uncertain rainfall and wind erosion.

The alluvial soil types which are more or less adapted to agricultural development are grouped in the following series: Dinnehotso, Hunt, Concho, Dinnebito, Gila and Cameron. Each of these soils will be briefly considered from the standpoint of agricultural use.

Types in the Dinnehotso, Hunt and Tolani series have many things in common, all being derived from Chinle and Moenkopi shales. Soils with that origin frequently have a high clay and alkali content, resulting in a dispersed soil. The topography is level or gently sloping, with the surface invariably broken by wind hummocks and sand drifts, varying in height from 12 to 36 inches. This materially increases the subjugation costs of these soils for agricultural development. The native vegetaion consists of greasewood, salt bush and sacaton. These soils occur along the Moencopi Wash and secondary drainages from Moencopi village, near Tuba City, southwest of Cameron.

Types in the Dinnehotso series have a deep friable subsoil which gives them an advantage over the soils in the other two series. The sandy loam and clay loam types are usually classed as Class A agricultural land, provided the alkali content does not exceed .2 of one percent. They comprise about _____ acres of Unit 3.

Types in the Hunt Series differ from those in the Dinnehotso in agricultural adaptation by the frequent occurrence of heavy, impervious substrata, which results in poor subdrainage. This is very significant because these soils derived from Chinle shale contain appreciable quantities of alkali salts. Unless subdrainage is adequate to facilitate a free movement of water and some leaching of salts, the soils are not adapted to agricultural use. Hunt sandy loam is rated B or C agricultural land, but the heavier types are not normally adapted to irrigation. There are approximately _____ acres of Hunt sandy loam in the Unit.

Types in the Tolani series consist of recent alluvial overwash, usually deposited upon one of the types in the other series. The soil is shallow and light in texture and very susceptible to wind erosion. The

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salt content is probably lower than in the other two series, the subsoil is usually open and friable, but severe wind and water erosion reduce its agricultural value to C class. _____ acres are mapped in the Unit.

Types in the Gila series occur along the Little Colorado River bottom, southeast of Cameron. They are favorably located from the standpoint of water for irrigation purposes. The texture, both on the surface and in the subsoil, is predominantly light. This soil is approved for agricultural development provided the alkali content or a high groundwater table does not prohibit its use. In view of the limited amount of soils which are adapted to agricultural purposes in this Unit, it is advised that consideration be given the possibility of some development on types of this series. The Gila series comprise _____ acres.

Concho Series: Types in the Concho series are distributed along the Moencopi drainage from Tonalea Trading Post south to the mouth of Blue Canyon. The topography is level to hummocky. The subsoil is heavy and often impervious. The surface soil is often highly dispersed by the physical action of certain salts on the usual high colloidal content. The vegetation consists of greasewood.

The soils of this series have about the same agricultural qualities as those in the Hunt series. The sandy loam and clay loam types have similar adaptations, which depend upon the alkali content in the root zone and upon the clay content of the subsoil. Heavy concentrations of alkali are almost certain unless good-sub-drainage is facilitated by an open and friable subsoil. The soils of this series should be investigated carefully prior to costly agricultural development. They are usually alkali concentrations under irrigation. In all, the Concho series comprise _____ acres.

Types in the Dinnebito series, located in the southeast portion, and the Cameron series, located in the southwest portion of the Unit, are good or excellent range soils. Their development for agricultural use depends upon the development of an adequate supply of irrigation water.

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ALKALI DISCUSSIONS.

Alkali is an important factor limiting the value of the soils of the Unit for structural and agricultural purposes and for reseeding. It occurs in all the soils derived in part from shales; namely, the Moencopi, Concho, Hunt, Dinnehotso, and Tolani series. It is also concentrated, in the vicinity of Tuba City, in soils of the Tonilto series. Alkali concentrations occur in this series because of the presence of a relatively impervious substratum consisting of Wingate sandstone which, together with low rainfall, prevents the leaching of salts to lower depths or from the soil.

Concentrations of alkali on cultivated lands which warrant special consideration at this time are those which occur on Moencopi farms. The alkali results presented in Table No. V are of soil samples taken from this area. The results show alkali concentrations too high for the tolerance of most cultivated plants.

In another portion of this report it has been suggested that an alkali investigation be made of this area at an early date. Justification for such an investigation is found in the obvious need to find practicable ways and means of preventing alkali-affected areas from spreading to productive agricultural land. This would necessitate discovering the cause or combination of causes which have produced the present condition. Such an investigation might also determine, at least from a Soils point of view, a feasible method of reclaiming this alkali land for agricultural use.

"ALKALI"

"In agricultural literature the term "Alkali" refers to any excess of soluble salts, though only the carbonate form of the common soluble salts are a true alkali in a chemical sense. Many alkali salts are used in the growth of plants or are stimulating when present in small amounts. However, since plants feed by a process of osmosis, they cannot take up moisture or plant food when the soil solution becomes of greater density than the sap solution inside the roots of the plant.*

Plant adaptation to alkali conditions is brought about by long continued growth and natural selection of those that can maintain a highly concentrated sap solution.

" In soils of high alkali content seeds may fail to germinate, or if they do the plant does not make a normal growth unless through centuries of growth on such land, it has become adapted to alkali conditions. Even after a plant is established

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* E. J. Carpenter, Regional Chief of Soils.

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on alkali lands, a change in the water table or other factors may cause the alkali to concentrate within the feeding zone of the plant roots with resulting injury or death to the plants.

"The amount of injury that may be expected from a given concentration of alkali will depend on a number of factors, chief of which is the character of the salts present, the position of the greatest concentration of alkali in the soil profile, the soil texture and the crop grown.

" Of the commonly found salts, the carbonate salts or black alkali are a true alkali in a chemical sense and they are the most injurious to plants largely because of their corrosive action on plant tissue. They also tend to deflocculate the soil producing a physical condition unfavorable to plant growth. Magnesium sulphate and magnesium chloride are seldom found in soil but when present the latter especially appears to be more toxic than even the carbonates. Sodium bicarbonate (common baking soda) is generally considered to be the next most harmful salt, since under irrigation it changes to the true carbonate form. Sodium chloride (common salt) is one of the more abundant alkali salts and ranks next in toxic properties, with sodium sulphate (Claubers salt) another very common alkali salt ranked as the least harmful. Instances are quoted of sodium chloride being equally as harmful as sodium carbonate, though it is believed that this is not a common result.

"If alkali salts are concentrated in the surface foot of soil, they are far more injurious than if concentrated in the sub-soil or distributed throughout the profile. Instances have been observed where .2 of 1 percent (2,000 p.p.m.) of alkali concentrated in the surface 6 inches of soil has prohibited the growth of cultivated crops, while other instances have been noted where 2 per cent (20,000 p.p.m.) of the same alkali salts confined to the lower subsoil has had no marked effect on the growth of barley.

"The amount of injury that may be expected from the same concentration of alkali will depend somewhat on weather conditions and agricultural practices. If there is a high humidity and overcast sky, the transpiration rate from plants and evaporation from the soil will be low and less injury will result. In soils of loam texture or others having the property of holding large quantities of water, the injury from a given quantity of alkali is less than on soils of low water holding capacity. As a rule less injury is experienced from a given concentration of alkali on calcareous soils than on those that are non-calcareous.

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"Plants differ greatly in their tolerance of alkali, and those plants should be selected for alkali affected lands that have a tolerance which will insure profitable yields or production of forage. The following table indicates the approximate maximum concentration of alkali salts under which fairly satisfactory growth of various domesticated and native plants can be secured. The total salts indicated as maximum tolerance of various plants should be considered as only approximate since an unusual concentration of chloride or carbonate salts may materially reduce plant tolerance.

	$Na\ CO_3$ P.P.M.*	Total Salts P.P.M.*
Alfalfa (Young)		1,650
Alfalfa (Old)	100-500	6,500
Sweet Clover	1,500	7,000
Berseem (Egyptian Clover)		4,000-6,000
Hairy Vetch	100-250	4,300
Field Peas		2,000-4,000
Beans		2,000-3,000
Timothy	700	4,000-6,000
Orchard Grass		4,000-6,000
Brome Grass		5,000-7,000
Red Top		4,000-6,000
Bluegrass		500-1,000
Western Wheat Grass		6,000-8,000
Japanese Wheat Grass		2,330
Rye Grass (Lolium italicum)		1,300-4,000
Fescue		1,100-3,000
Tall Meadow Oat Grass		5,000-7,000
Salt Grass	8,500	20,000-50,000
Blue Stem	320	10,000-26,000
Modiola	1,190	12,100
Salt Bushes (Atriplex spp.)	1,200	8,000-10,000
Giant Rye Grass		30,000-31,000
Millets		800-1,100
Sorghums	500-750	5,000-7,000
Rape		6,000-8,000
		4,000-6,000 Hay
Wheat	400	1,000-4,000 Grain
		6,000-8,000 Hay
Barley	740	4,000-6,000 Grain
		5,000-7,000 Hay
Oats	650	3,000-4,000 Grain
Rye		4,000-6,000 Grain
Corn	100-250	1,000-3,000
		4,000-6,000 Hay
Emmer	400	1,000-4,000 Grain
Sunflowers	100-250	3,700
Sugar Beets	500-700	4,000-6,000

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	$Na\ CO_3$ P.P.M.*	Total Salts P. P. M.*
Potatoes		2000-4000
Onions		4000-6000
Asparagus		6000
Celery		4000
Radishes	100-750	4000
Flax		4000
Cotton		4000-6000
Grapes	50-10	2860
Inkweed or Saltwort (Sugoda spp.)	850	38000 - 3000 (Optimum)
Sporobolus airoides	1437	31000 Exist
Bushy Samphire	300	30000
Dwarf Samphire	757	27000
Greasewood (Sarcobatus Vermiculatus)	1170	8000-10000
Alkali-heath	1224	17000
White Sage		1200

"Other plants that do well on alkali soils but for which there seems to be little data on maximum tolerance are:

Rabbit brush or false golden rod (Chrysothamnus spp.)
Plowmans wort (Pluchea camphorata)
Little Rabbit brush (Isocoma veneta. Gray)
Spike weed (Hemizonia pungens)
Arrow weed (Pleuchea borealis)
Aster angustus
Aster pauciflorus
Aster zylorhiza
Wild Barley (Hordeum nodosum)
Wild Rye (Elymus salinus)
Alkali Meadow Grass (Puccinellia airoides)
Goose foot or pigweed (Chenopodium rubrum)
Tamarick (Tamarix Gallica)
Russian Olive)
Golden Willow) Moderate alkali
Pomegranate)

(*P.P.M. Parts per Million; for example 1650 parts salt per million soil = .165%; or 20,000 P.P.M. = 2.0%.)

"In the reclamation of alkali affected soils it is essential that the soil be provided with good subdrainage and large quantities of water for use in leaching. Better results in leaching will be secured if the irrigation water contains calcium salts in solution since even on "white alkali" land the "black alkali" salts form in the latter stages of leaching if the original salts were principally sodium salts. Calcium

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salts tend to neutralize the black alkali and prevent the soil from "freezing up" or refusing to take water. Calcium salts are relatively insoluble and are never the source of soil alkali. The reclamation of soils that have heavy-textured subsoils to a depth of five feet or more and contain a high concentration of alkali is not economically feasible as a rule, since an insufficient quantity of water can be forced through the soil to leach out to the alkali. The application of organic manures to all alkali lands will assist in their reclamation and unless the irrigation water contains calcium salts the application of gypsum or sulphur to black alkali land together with organic manures will materially assist and, in case of heavy textured soils, it is generally absolutely essential to the reclamation of such land.

WATER FOR IRRIGATION

"Water for irrigation in arid regions should not contain as a rule, more than 500 to 700 p.p.m. if the salts are principally carbonates, becarbonates, or chlorides, with the higher concentration permissible only with water containing chlorides principally. If an appreciable part of the water for plant growth is supplied by rain, higher concentrations are permissible.

"If soils take water rapidly and have good drainage 1750 p.p.m. of salts in irrigation water can be safely used in arid regions if the carbonate salts are not present. Water applied to heavy textured soils that take moisture slowly should not contain more than 1000 p.p.m. of the neutral or white alkali salts. Instances are cited of water containing 2500 p.p.m. sodium sulphate being used successfully in sandy soils of good drainage. If irrigation water contains calcium sulphate (sypsum) or calcium chloride, higher concentrations of all salts, particularly carbonate salts, are permissible. Because of the floculating action of soils of salts containing calcium, water for irrigation containing such salts in superior to that without them."

2. The Dispersion Ratio

The use of an indicator of the value of soils for construction purposes.

" .....Non-dispersed sandy clays and clays are the most resistant to washing under intermittent use. (For spillways).

"The use of soils of over thirty percent dispersion for small dikes will result in almost total failure. In dikes with a four to ten foot base, soils of 30 - 50 percent dispersion are still quite unsafe, with soils of over 50% dispersion, almost complete failure results on all dikes or dams with less than an eighteen foot base, unless adequate core walls are built or similar precautions taken.

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"Soils of less than 10 percent dispersion are safe for structures built according to accepted engineering practices for normal soils. Soils of 10 - 30 percent dispersion vary in their suitability inversely proportional to the percent dispersion."

(THE DEGREE OF DISPERSION OF SOILS AS A FACTOR IN DETERMINING THEIR SUITABILITY FOR EARTH WATER-RETENTION STRUCTURES.
C. M. Volk, Associate Conservation Specialist, 1936.)

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SUMMARY OF EROSION CONDITIONS

Extremes in erosion conditions on Unit 3 vary from the slightly affected types in the Kiabab and Springerville series to the severely eroded Todilto, Hunt and Tolani types, some areas of which are essentially destroyed. Soil and climate both contribute to an environment which is fundamentally conducive to erosion. Low rainfall makes for a sparse vegetation. Heavy impervious soils, especially those with a steep topography, intensify the effects of this climatic factor. Torrential rains, common to this section in late summer, further increase the destructiveness of water erosion through rapid run-off.

High southwest winds are probably the most destructive erosion agent in this Unit. With the exception of some of the grasslands, the entire Unit is affected to some degree by this agent. Wind erosion is most severe on the light-textured alluvial soils and the residual Todilto types. Wind hummocks range generally from 12 to 36 inches in height, but are much higher in some localities. Active sand dunes are common northeast of Tuba City.

Corrective measures from a Soils standpoint justify the maximum in land-management policy and practice. This covers the Unit as a whole. Focal points or critical areas will require absolute exclusion of livestock during the growing season. Mechanical treatment is necessary to supplement and make these measures most effective. Mechanical treatment would probably be most effective on restricted watersheds and alluvial valleys adjacent to and within areas indicated on the map as types in the Tolani and Hunt series. In this manner, especially if water spreading is feasible, certain chamise and sacaton grass soils, seriously depleted of grass cover at present, could be made very productive of native vegetation.

There is some need for flood-control work on valuable farmland adjacent to Moencopi Wash. It is suggested that flood control consist of: (1) a comprehensive land-management program on the upper watershed of Black Mesa, involving both water retention and spreading as well as controlled grazing; and, (2), mechanical control at strategic points along the main channel in the vicinity of Moencopi farms. A more intensive soil and erosion-control investigation will be necessary on areas proposed for agricultural development or intensive erosion-control work, to determine more specifically the problems involved.

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RESULTS OF ALKALI ANALYSIS OF SOIL SAMPLES COLLECTED
FROM
MOENCOPI FARMING AREA, TUBA CITY, ARIZONA

By Ray H. Kerr
Collected 12/28/36

Lab. No.	Field No.	Total Salts	P. P. M.* Na_2CO_3	Mechanical Analysis % Sand	% Silt	% clay	pct. Dispersion
3676	1-A-1	.06	Trace				
3677	2-A-1	1.09	2300				
3678	2-A-2	.16	375				
3679	1-A-3	.02	Trace				
3680	3-A-1	.17	0				
3681	3-A-2	.28	0				
3682	3-A-3	.53	488				
3683	4-A-1	3.00	Trace				
3684	4-A-2	3.00	Trace				
3685	5-A-1	1.11	329				
3686	5-A-2	.145	116				
3687	6-A-1	.80	2374				
3688	7-A-1	1.23	774				
3689	7-A-2	2.00	1272				
3690				32.6	49.2	18.2	
3691				78.1	12.9	9.0	45.7
3692				82.1	8.4	9.5	18.8
3693				84.3	9.4	6.3	
3694				83.1	7.1	9.0	
3695				76.9	9.7	13.4	
3696				75.9	6.2	17.9	

* P. P. M. Parts per million. 100 p.p.m. = 0.01%

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Tuba City - Soil Samples
Collected 3/1/37

Collected by:
Ray M. Kerr and
L. A. Hill

Lab. No.	Field No.	Pct. Total Salts	P. P. M.* Na_2CO_3
3854	1A-1	3.0	31
3855	1A-2	1.28	Trace
3856	1A-3	1.35	83
3857	2A-1	.42	0
3858	2A-2	.17	0
3859	2A-3	.17	0
3860	3A-1	.68	Trace
3861	3A-2	.21	0
3862	3A-3	.16	0
3863	4A-1	.56	0
3864	4A-2	.14	52
3865	4A-3	.14	229
3866	S1-11-03	.09	0
3867	S1-11-03	.07	0
3868	S1-11-03	.11	0
3869	S2-11-03	3.0	0
3870	S2-11-03	1.06	208
3871	S2-11-03	1.11	0
3872	S3-11-03	.15	0
3873	S3-11-03	.105	0
3874	S3-11-03	.10	Trace
3875	S4-11-03	3.0	0
3876	S4-11-03	1.9	Trace
3877	S4-11-03	1.7	166
3878	S5-11-03	.33	0
3879	S5-11-03	.19	0
3880	S5-11-03	.23	0

* P.P.M. = parts per million

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