WORK REPORT

CONSERVATION SURVEY

Wepo Valley Water-Spreading Area
and
Cisco-Aloe Farms, Pinon,

Land Management Unit No. 4.

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U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Southwest Region

* * *

Navajo District

Approved:

/s/ R. H. Lovald
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WEPO VALLEY WATER-SPREADING AREA
AND

Cisco-Alec Farms - Pinon, Arizona

This survey, covering an area of approximately 3,280 acres, was made to evaluate the soil characteristics and extent and severity of erosion, as a basis for determining the suitability of the area for water-spreading and general erosion control treatment. It includes a portion of the Wepo Wash of approximately 2,450 acres located one mile east of Pinon, Arizona, in Land Management Unit 4, and the Cisco and Alec Farms, comprising 780 acres, approximately 4 miles east of Pinon. The present land use of the area is grazing and farming by flood irrigation and dry farming methods.

Both areas occupy gently sloping valleys surrounded by rolling hills, in which the flood-irrigated farms are located on alluvial fans of the secondary side drainages, which spread naturally. The valleys are smooth except for small wind-deposited hummocks and shallow intermittent gullies.

In the Wepo Valley the wash enters from the northeast, fans near the lower boundary of the survey area and re-entrenches farther downstream, creating a series of active headcuts. It is proposed to completely divert the flow near the upper limit of the survey area and spread it over the adjacent range land and over such land as may be suitable for farming, thereby utilizing the water to best advantage in vegetative production and alleviating the danger of destruction of the area by headcuts.

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The approximate annual precipitation is 12 inches, the elevation 6,700 feet, and the average growing season 130 days. Most of the precipitation falls as snow during the winter months or torrential rains during the summer. Strong southwesterly winds prevail during a large portion of the year.

No information is available regarding the quality of water carried by Wepo Wash.

The soils are of alluvial origin with the exception of several small areas of residual soils. They are classified on the basis of surface texture and profile characteristics into 7 types. These are grouped into 3 range-land classes and 3 agricultural-land classes on the basis of their adaptations.

A record of the laboratory analyses follows the summary.

Floy sandy loam is a residual soil occurring on all the uplands and hills surrounding the areas. Sagebrush and grama grass, with scattered pinon and juniper, are the dominant native vegetation. Sheet erosion is very active on all areas having a slope of 5 per cent or more. Wind cutting is evident on many of the exposed slopes and occasional shallow gullies are present. The surface soil is a reddish brown, noncalcareous, permeable, mellow sandy loam. The subsoil is a calcareous clay loam or light clay, more compact than the surface, overlying a light gray sandstone. This is an excellent range forage-producing soil. Some areas are deep enough to be adapted to dry farming, but are generally not sufficiently drained to be suited to irrigation.

Soils of the Crown series are derived from light gray to grayish brown calcareous alluvial sediments. The subsoil is predominantly sandy

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in nature. Erosion is generally not serious; however, both sheet and wind removal are active and occasional gullies are present. Headcutting generally progresses very rapidly because the sandy subsoil is not resistant to the scouring action of water. Yellowbrush, chamise, and scattered grasses compose the predominant vegetation.

Crown sandy loam has a mellow, porous, sandy topsoil, varying from 6 to 18 inches in depth, underlain by a friable layer having definite clay properties. The lower subsoil is stratified and predominantly sandy. This soil is generally well adapted to irrigation and range water spreading. It is not a particularly productive grass soil because the water-holding capacity of the surface 6 to 12 inches is often low.

Crown clay loam is quite similar to the sandy loam in profile characteristics except that the water-holding capacity of the surface is slightly higher and less permeable. Its adaptations are similar.

Crown clay is composed of heavy-textured materials to a depth of from 20 to 36 inches overlying a predominantly sandy subsoil. The rate of water penetration is somewhat slow, but the soil is not impervious. The surface is friable but probably too resistant to plowing to be handled economically by Navajo tillage methods. It should respond satisfactorily to water-spreading.

Oraibi soil series occur on alluvial fans and along drainages where deposition has been very recent. These soils are light gray in color, calcareous, permeable, loose or mellow, highly stratified and predominantly sandy. Erosion is generally mapped as recent deposition;

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however, wind modification is universal. Like the Crown series, this soil is subject to headcutting. The vegetative cover is composed primarily of annuals, although chamise is present on some areas. Reseeding should supplement water-spreading.

Oraibi sandy loam as mapped is composed of a surface textural complex ranging from sand to clay, but a thorough mixing as a result of cultivation will eventually produce a sandy loam texture. This soil is well adapted to cultivation. It will absorb large quantities of water very rapidly.

Oraibi clay loam is similar to the sandy loam except in surface texture.

Wepo sandy loam generally occupies secondary drainageways and depressional areas. The topography is smooth and gently sloping. Sagebrush, blue grama, and bluestem are the dominant vegetative species on this type. Erosion is generally insignificant. The surface soil is a reddish brown, noncalareous, mellow, sandy loam. The subsoil is more compact, calcareous, and brown in color. This soil is adapted to grass production and should respond well to water-spreading or flood irrigation of cultivated crops.

Alkali is not significant in this area.

The attached supplement describes the soil and erosion conditions on each of the farms surveyed.

SUMMARY

All soils covered by this survey should respond satisfactorily to water-spreading.

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Reseeding should supplement the water-spreading treatment on the uncultivated portions of the Oraibi series.

SUPPLEMENT

Farm Descriptions

Farm 45.

Oraibi sandy loam composes the major portion of the farm. The surface foot is a non-calcareous heavy sandy loam, underlain by 3 feet of non-calcareous sandy material. A two-foot layer of very calcareous, heavy clay occurs at a depth of 4 feet. There is evidence of wind erosion in the form of accumulations along the north fence. The soils of this farm are suited to agricultural use, with the exception of insignificant small areas which tend to be heavy textured.

Farm 46.

The soils of this farm represent Oraibi sandy loam, Wepo clay loam and Wepo clay. A small area of Wepo clay occurs in the southwest corner of the farm, but because of the heavy surface texture it is not recommended for agricultural purposes. An alluvial fan in the east-central portion of the field is composed largely of Oraibi sandy loam, but contains spots of lighter sandy soil which are more susceptible to erosion and which limit its value for agricultural purposes. The Wepo clay loam, which constitutes the major portion of the farm, is well suited to agriculture.

Farm 46a.

This is a very small farm of Wepo sandy loam, well adapted to farming if water is available.

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Farm 46b.

This is a small farm of Wepo sandy loam. The soil is well adapted to agriculture, but is subject to wind erosion.

Farm 47.

The soil of this farm is predominantly Wepo clay loam type. It is subject to slight sheet and wind removal and local wind accumulation in the form of small hummocks. A large gully enters the farm and fans near the lower end of the field. Excess water spills into a large headout 150 feet outside the southwest corner of the field and working toward it. This farm has a slope of 2 per cent; otherwise it is very well suited to agricultural purposes.

Farm 47a.

This farm is much the same as 47 except that it is not so steep and water is not available for flood irrigation.

Farm 47b.

The soils of this farm are Wepo sandy loam and Wepo clay loam. Some wind and water erosion are evident. Very slight accumulations are present. The sandy loam area is well adapted to agriculture, but water for flood irrigation is not available. The value of the clay loam for flood irrigation is doubtful because of topography and slow permeability.

Farm 48.

The soil of this farm is predominantly Oraibi sandy loam. These soils are suited to agriculture, but flood irrigation will prove difficult because of steep slopes.

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Farm 48a.

This farm is on the lower portion of the fan occupied by farm 48. The soil is predominantly Oraibi sandy loam; however, local areas of more sandy soil occur. It is well suited to agriculture.

Farm 49.

The soil of this farm is predominantly Oraibi sandy loam type. Steep slopes render agriculture hazardous.

Farm 50.

This farm is located on an alluvial fan. The eastern three-fourths is Oraibi sandy loam. Toward the southern portion a lens of clay occurs near the surface but is too small to delineate. The western part is Crown sandy loam to light clay with the light clay predominating. The sandy loam area is excellent for flood irrigation; the light clay is probably too heavy for best results under Navajo management without permanent water for irrigation. Some provision should be made to stop waste water from dropping over the arroyo bank to the south of this farm.

Farm 51.

The soil of this farm is Oraibi sandy loam. No treatment is recommended because the water is being spread satisfactorily. The soil is excellent for agricultural purposes.

Farm 52.

The soil of this farm is Crown clay loam. A small area on the west portion is lighter in texture and another toward the north end is slightly heavier. This area is fairly well adapted to agriculture.

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Farm 55.

The soil of this farm is predominantly Nepo clay loam with a light-textured subsoil. Flood water spreads satisfactorily on the agricultural area but concentrates in an old road below the farm. Spreader fences or dykes are recommended to keep water out of this road. This soil is well adapted to agricultural purposes.

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Warren V. Turner

Steamboat Demonstration Area

Geology.

The Steamboat area lies near the edge of the Black Mesa physiographic subprovince. It is bounded to the northeast by the scarp of Salaiki Mesa, a disconnected southwesterly portion of Black Mesa proper, which, along the northern margin of the Area breaks down without cliffs, by reason of the northeasterly dip of the strata in a long and gradual transition district towards the Hopi Buttes subprovince.

The rocks exposed on the Area (see map) may be distinguished as representatives of the following formations:

Alluvium, landslide debris and terrace gravels - - - - - - - - - - - - - - - - - Quaternary

"Tertiary" sands - - - - - - - - - - - - - - - - - - (see discussion below)

Mesaverde Formation - - - - - - - - - - - - - - - - Upper Cretaceous

Mancos Shale - do.

Dakota Formation - - - - - - - - - - - - - - - - - - do.

McElmo Formation - - - - - - - - - - - - - - - - - - Lower Cretaceous (?)

Of these the Quaternary materials and the Dakota probably account for over 60% of the total area. In the following paragraphs the above units will be briefly characterized.

Quaternary materials embrace, as noted, alluvium, landslide debris and (minor) terrace gravels. These have not been accurately delimited, inasmuch as the detailed soil survey of the Area recently completed by Mr. Thomas, adequately covers this ground. Alluvium floors the broad valleys to shallow depths. An Indian Service well (#771) near the center of the Area in Toch-la-kah-da-lus-kan Valley records black adobe extending to 42 feet, and underlain by soft yellow sandstone (McElmo). While it is probable that this well did

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not penetrate a maximum thickness of alluvium, being situated east of the center of the valley. It seems unlikely that the alluvium exceeds double the thickness quoted. The nearest other logged well occurs some 1½ miles to the south in the same valley. Here the alluvium is underlain by Mancos Shale, which makes the bedrock contact difficult to recognize in the crude log descriptions. The most likely depth would seem to be about 60 feet, above which the material is noted as "black clay and yellow clay," and below which as "black clay and mud." Judging by their size and general cross section the other valleys of the Area must have comparable or lesser thickness of alluvium. The character of the alluvium depends of the parent materials: east of a north-south line through Eagle Crag the largest contributions have been made by the Dakota Formation, of which between a third and a half is sandstone, the remainder of carbonaceous clays and coal; west of such a line the most important contributing formation has been the Mancos Shale. It follows that the alluvium of the eastern Valleys within the Area is dominantly a sandy clay, that of the western valleys a heavy clay with very minor sand. Exceptions to this general rule are of course recognizable. In common with alluvium throughout the Navajo Reservation that of the Steamboat Area is peculiarly [illegible] of rock fragments. As the material has been transported for only short distances this observation must be explained by the ease of disintegration of the normally weakly cemented country rock under the type of weathering prevailing in a subarid climate.

Quaternary landslide debris occurs as a discontinuous mantle over the Mancos slopes of the north and west margins of the Area. It consists of aggregates of broken and jostled Mancos sandstones and shales, and is of especial importance by reason of the relatively high permeability. The landslides have included both the ordinary "rock stream" type and the interesting "rotated-block" variety which [illegible] best examples in the district of the

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Hopi villages. Those of the latter type are limited in the area to a short stretch along the western margin. The blocks of sandstone which have slipped downward without breaking up, on customarily concave fracture surfaces, have been thereby rotated so as to dip strongly towards the cliff from which they were detached. The long continuance of landsliding is evidenced by the distance from the present cliffs at which landslide accumulations are now found.

Under the term "terrace gravels" have been mapped a few cobbly to bouldery gravel deposits, the transported character of which is attested by rounding of the constituents. In the south-central part of the Area these form a dissected terrace; in the small patch in the north they occupy a low hill, and should perhaps be lumped with the surrounding finer grained alluvium. Aside from the once noted terraces are found only in the southern of the three lowland tributaries of Toh-ni-toi Wash, which will receive comment later.

"Tertiary" sands. In mapping the Navajo Reservation Gregory noted the presence of unconsolidated sands in the districts surrounding the Pueblo Colorado Wash, and hazarded a correlation of these with the Tertiary deposits occurring on the Chuska Mountains, and in the central part of the San Juan basin to the east. These latter have been shown by paleontologic evidence to be lower Tertiary. I am informed* that a field party of the American Museum has recovered vertebrate remains from the "Tertiary" sands a few miles east of Steamboat Area, which (unpublished) establish the Plio-Pleistocene age of these sediments. This dating is applicable to all the so-called Tertiary of the districts about the Pueblo Colorado, including those of the Steamboat Area. Three discrete areas of "Tertiary" outcrop are shown on the accompanying map; of these the western two are probably coalescing

* Prof. Howell Williams - oral communication.

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[illegible] villages. Some of the latter type are limited in the area to a short [illegible] along the eastern margin. The blocks of sandstone which have slipped [illegible] of short breaking up, on outwardly concave fracture surfaces, have been thereby rotated so as to dip strongly towards the cliff from which they were detached. The long continuance of landsliding is evidenced by the distance from the present cliffs at which landslide accumulations are now found.

Under the term "Quaternary" have been mapped a few cobbly to bouldery gravel deposits, the transported character of which is attested by rounding of the constituents. In the south-central part of the Area these form a dissected terrace; in the small patch in the north they occupy a low hill, and should perhaps be lumped with the surrounding finer grained alluvium. Aside from the cross-axial terraces are found only in the southern of the three northern tributaries of Moonshine Wash, which will receive comment later.

"Tertiary" sands. In mapping the Navajo Reservation Gregory noted the presence of unconsolidated sands in the districts surrounding the Pueblo Colorado Wash, and hazarded a correlation of these with the Tertiary deposits occurring on the Shinarump Mesa, and in the central part of the San Juan Basin to the east. These latter have been shown by paleontologic evidence to be lower Tertiary. I am informed* that a field party of the American Museum has recently collected vertebrate remains from the "Tertiary" sands a few miles east of Moonshine Wash, which (unpublished) establish the Plio-Pleistocene age of these sediments. This dating is applicable to all the so-called Tertiary of the districts about the Pueblo Colorado, including those of the Moonshine Area. Three discrete areas of "Tertiary" outcrop are shown on the accompanying map; of these the northern two are probably coextensive

* Prof. Howell Williams - oral communication.

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The best exposures of the material are in the steep slopes along the northwestern margin of the Area. Here there is a maximum thickness of about 130 feet, lensing to north and south, and occupying, presumably an old valley. The sands are white, loose, lithoarted, dominantly of medium grade and rounded to subrounded outline. Bedding is very obscure but seems to roughly parallel that of the older formation. The upper 5 to 10 feet, and an 18 inch lens about 6 feet above the base have been cemented by lime, and appear as fairly hard white sandstones; a continuation of the process is seen in sporadic limy nodules at several horizons. The upper sandstone is dominantly of fine to very fine grade, with moderately uniform grains. The "Tertiary" of the southwestern part of the Area resembles that described, with the exception that limy beds are rather more abundant, and occasional thin grey bentonitic (?) beds may be found. In the southeastern part of the Area the lower 10 to 25 feet of the "Tertiary" is composed of finely sandy red silt; the material above this being similar to the white sands above described. While the surface on which the "Tertiary" was deposited was for the most part one of low relief with open broad valleys occasional vertical walled channels in the Monterey sandstone were present, and filled. To a far greater extent than was true of the landslide accumulations already noted, the "Tertiary" of this region forms a permeable, porous mantle of the utmost value in absorbing rainfall.

Monterey Formation. The northern and part of the western boundary of the Area is a cliffed slope of Monterey sandstones, with minor intercalating mudstones and shales. Of the earlier formation erosion has left locally only the lower, dominantly sandy beds (the Gillig sandstone of the Gallup-Dent Basin; the ~~[illegible]~~ Point Lookout sandstone of the Elderock district). This material, constituting as it does merely a part of the "fence" of the Area, has not been studied in detail during this survey. Its dominantly buff, fairly well indurated and sorted, calcareous cross-bedded fine to medium grained

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sandstones, and dark grey more or less carbonaceous shales appear similar to those of this part of the formation where ever examined in the Black Mesa environs. It is probable that coal may be found by detailed study of this formation.

Mancos Shale. Conformably underlying the Mesaverde are the dark grey soft fissile shales of the Mancos. At or within 20 feet of the base of this formation is the highly fossiliferous horizon which is nearly coextensive with this unit wherever studied. Small gastropods and Inoceramus predominate, but an occasional large (10 inch) specimen may be found. The upper and lower contacts of the Mancos are not sharply marked, but gradational. Along the west border of the Area the upper transition zone is about 60 feet thick, and includes, locally, considerable chert. The base of the formation is drawn at the top of the three relatively continuous sandstone members as one descends the section, although shales of Mancos type are generally present below that horizon. Of the formations of the Navajo country the Mancos is second to none in its impermeability. It is generally markedly gypsiferous.

Dakota Formation. The character of the Dakota formation is extremely variable within short distances, although the rock types involved are similar. Sandstones, mudstones, shales and coal in varying proportions make up the whole. A specimen section of the formation, measured about midway of the north wall of Tsoh-ni-toi valley may be taken as an example.

bed top	Thickness	character
1	15.7 ft.	light buff (weathering reddish brown) weakly cemented, clean, sorted, angular, very fine grained sandstone in 10 to 15 inch cross bedded units. Ferromagnesian grains, including chlorite, rare. Some coarse ripply marking.
2	5.3	1.3 ft. olive grey, soft, weakly fissile sandstone. 4.0 ft. grey finely silty soft shale with abundant light yellow limonitic lenses throughout.
3	8.2	1.0 light yellowish grey, soft, lensingly thin bedded silty very fine angular sandstone.

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bed (key)	thickness	character
3	8.2	2.9 dull olive grey thin-bedded, fissile, fairly clean, uncemented coarse silts, slightly clayey near base. 2.5 dark grey, soft, finely silty shale. Cypraiforous. 1.8 soft coal of good grade, grading below into highly carbonaceous soft fissile silt.
4	3.2	light yellowish grey, massive, flaky, almost loose, fairly clean, sorted, subangular fine sand, with minor carbonaceous silt laminae. (muscovite?)
5	5.5	brown, somewhat carbonaceous fissile silt (above) grading below into black soft shale below.
6	2.4	light buff thinly and lenzingly interbedded very weakly cemented coarse silts and silty angular very fine sands.
7	0.0	brownish grey, variably carbonaceous soft fissile mudstones, indefinitely bounded below. One 8" bed of well cemented very fine sandstone.
8	13.1	dark grey highly fissile shales, variably carbonaceous. Near middle several feet of shaley coal to coaly shale.
9	5.3	0.2 ft. massive, limonitic and calcareous fairly well cemented very silty, angular very fine grained sandstone. 0.5 ft. light grey, hard, thin bedded very finely sandy siltstone. 3.0 ft. like bed 6.
10	8.3	grey and light greyish brown, massive to weakly fissile slightly carbonaceous compact clayey soft siltstones.
11	17.2	light bluish grey, vaguely bedded, slightly carbonaceous, flaky, nearly loose, angular very fine grained sand. Tastes strongly alkaline.
12	5.9	buff, readily friable, coarsely cross-bedded in stout lenses with up to 2 feet thick, clean, ill-sorted, dominantly medium grained angular to subrounded sandstone. Many of the larger grains rounded and frosted.
13	1.0	confused lens of fissile coaly silt and grey loose fine sand with charcoal fragments.
14	5.0	white, calcareous, weakly cemented, clean, perfectly sorted, angular sand on the very fine-fine grade size boundary. Cross bedded at low angles. Has peculiar milky surface appearance.
15	3.2	lens of loose, highly carbonaceous streaky fine to very fine sand.
16	13.3	like bed 11, but light yellow, and with a thin clayey grain coating. Irregularly cross-bedded throughout. Occasional

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	pebbles of coarse to very coarse grain, or with abundant carbonized wood fragments. There is no noticeable systematic cross-grain bounds bases. Rests on channelled McElmo surface
119.4 ft. Total	unknown at this locality.

In discussion of the above section it may be noted that the upper bed (#1) lenses out entirely within a quarter mile in one direction, and splits into four thin seams each with intervening shales in the other in a similar distance. On the other hand, beds 13, 15 and 16 while generally present and characteristic are locally absent (as along the eastside of Tsoh-Ai-Ai-Ksan valley) by reason of local irregularities in the old McElmo surface. Recording and redeposition of sands from the underlying McElmo are in places so pronounced as to render the exact contact somewhat difficult to place. In one of the minor southern tributaries of Tsoh-ai-toi valley there is a lens of fairly good quality coal between two and three feet thick.

In post-McElmo pre-Dakota time an erosion had cut in the former formation a surface of 20 to 30 foot maximum relief which has been noted wherever the contact has been studied on the Navajo Reservation. One of the best exposures of this erosional unconformity may be seen in the west wall of lower Tsoh-ai-toi valley within the [illegible] area. A diagrammatic sketch of this outcrop is reproduced below.

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Moenkopi Formation. Outcropping over much of the Area in narrow cliffed belts or in rounded low hills covered by residual soils are the chalky white soft nearly massive sandstones of the Moenkopi Formation. These sediments are silty, but nearly lacking in the clay fractions. They vary from very fine to coarse in grade. As a rule rather poorly sorted, the dominant grain size is that of a medium sand. A greenish tinge is not uncommon. The Indian Service well bearing reference has already been made encounter ed the Moenkopi about 42 feet below the surface, and perhaps 75 feet below the top of the formation. Below 42 feet the material encountered was logged as 'yellow sandstone' and as 'chalky sandstone' to a depth of 395 feet, and from there to 'soft sand' at about 420 feet, and tested, on completion of the hole, 135 gallons per hour, a record which the well has not been able to maintain. As the lower third or so of the Moenkopi is quite earmarly red or streaked with red it is probable that the red shale logged in the Moenkopi. Quite probably it is more correctly a siltstone than a shale. It would appear that production from the Navajo sandstone might have been obtained at a depth around 600 feet. As article water derived from the Moenkopi, except very near the outcrop of that formation, is distressingly alkaline.

Structure. The Steamboat Area lies sufficiently close to the southeastern margin of the great Black Mesa basin to escape being involved in the inward directed dips which characterize that structure. On the west side of the Area there is a persistent southwesterly dip of 5 degrees or so. In the central part of the Area there is a low asymmetric anticlinal axis, indicated on the map, from which the strata dip more sharply (up to 14°) to the southwest than to the northeast. In fact the northeasterly dips from this axis are only locally observable with certainty, and the structure might more correctly be termed a monocline. North and east of this structure there appear to be a series of

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erratically disposed wave wrinkles. Throughout the area determination of true dip is rendered difficult by the ubiquity of cross-bedding at low angles. It is probable that detailed plane table mapping would resolve the data at hand into more systematic form. Such work has not been considered justified at the present time.

Terraces. One of the most striking physiographic attributes of the Navajo region is the general absence of clearly defined alluvial terraces. Rock-cut terraces, developed on bedrock are by no means uncommon. It appears that the recent history of the region has been so predominantly aggradational that trenching and sidecutting of streams has been essentially non-concurrent. The gullies of the present existing phase, which an increasing weight of evidence relates to overgrazing, have in relatively few cases side-cut sufficiently to develop terraces. In view of these facts the occurrence of well developed alluvial terraces, due to a past erosional phase, in the southern headward tributary of Naha-ni-toi valley are of considerable interest. The age of these features is indicated not only by the healed and grassed slopes, but by numerous mature pinon and juniper trees growing in the bottoms of the old washes. These trees may be taken as indication that the cutting in this case occurred a minimum of a century ago. As in most of the alluviated valleys of the region the greater part of the fill has been brought in from the side, and does not represent material in "long-valley" transport. As a result a cross profile of the surface of the valley-fill shows a relatively short central horizontal segment, bounded by much longer gentle side slopes which rise to the bedrock margins of the valley. In the case of the terraces under discussion the gradient of the old washes was much less than that of the surface of the fill into which they cut, so that while the cut depth was 5 feet or so near the center of the valley it was 20 or more feet where the minor lateral tributaries merge

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from the bounding bedrock slopes. A further interesting item is the failure of the old cutting to extend itself into the headward parts of the main valley in which it occurs. Why the particular valley noted should be so affected is not clear. There is a small ruin on the divide 0.8 miles to the south whose inhabitants may have filled the valley destructively, but in that case the cutting should be nearer a thousand than a hundred years old, an age by no means improbable, though difficult of proof.

Ground water. Omitting the bounding high mesas to north and northwest from consideration the available aquifers of the Area are the "Tertiary", Dakota, Moffat and Navajo formations, the last named occurring at depths of 600 to 900 feet, and not outcropping. The development of wells in the "Tertiary" would depend largely on the previous identification of channels and valleys cut in the impermeable underlying Mancos and filled by the "Tertiary" sands. Production would probably be small, and would certainly be limited to the southwestern part of the Area; on the other hand the wells would be relatively shallow (less than 120 feet). The difficulty of locating the old channels might render the use of this formation impractical. Water production from the Dakota as from the "Tertiary" would be limited to the southwestern part of the Area, where it occurs at shallow depths (roughly from 50 to 200 feet, according to location). As the intake area for this formation is everywhere narrow, and the main outcrop areas are not available in this connection, due to intervening topographic lows, the formation is not a good bet on the Steamboat Area. It is probable that water can be obtained from the Moffat almost anywhere in the Area. As the intake areas are comparatively near at hand the quality of the water should be fair to good. The horizon which yields water occurs 220 to 250 feet below the top of the formation throughout this district, and its approximate depth in any well may be computed from observed dips where the formation

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outcrops, being deepest in the southwest. Obviously the immediate neighborhood of the structural axis mapped should be avoided. Northeast of that line it will be possible to identify shallow synclinal troughs especially favorable for drilling. At depths 300 to 400 feet greater than those of the Nellie water it is reasonable to suppose that water might be produced from the underlying Navajo formation, above the thin fresh water limestones which generally occur in its upper portion.

Consent. At this writing the location of the northeastern boundary fence of the Area has not been decided. On geologic grounds it is urged that the fence follow the main divide as far westward as possible before being tied in to the cliffs of Tsoh-ni-toi valley. Along this divide there is a belt of "Tertiary" of varying width, which caps the Mesaos. If a vegetative cover can be maintained on the "Tertiary" the latter will act to control runoff both ways from the divide, due to its high permeability. If the present vegetation is permitted to decrease the "Tertiary," being incoherent, will be progressively removed from the Mesaos, widening the belt of that impervious (hence from the standpoint of run-off, hazardous) formation. In any forward looking program it must be realized that the "Tertiary" muds of the entire district are especially worthy of protection, even though it cannot be gainsaid that they will probably stand more abuse than the other formations.

P. R.

Albuquerque
July 10th, 1935

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