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PRELIMINARY EXAMINATION REPORT

SANTA CRUZ RIVER WATERSHED

ARIZONA

1938

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U.S. DEPARTMENT OF AGRICULTURE

PRELIMINARY EXAMINATION REPORT

Run-off and Water-Flow Retardation and Soil-Erosion Prevention

SANTA CRUZ WATERSHED

In compliance with

Section 6 of the Flood Control Act, June 22, 1936

Public No. 738-74th Congress

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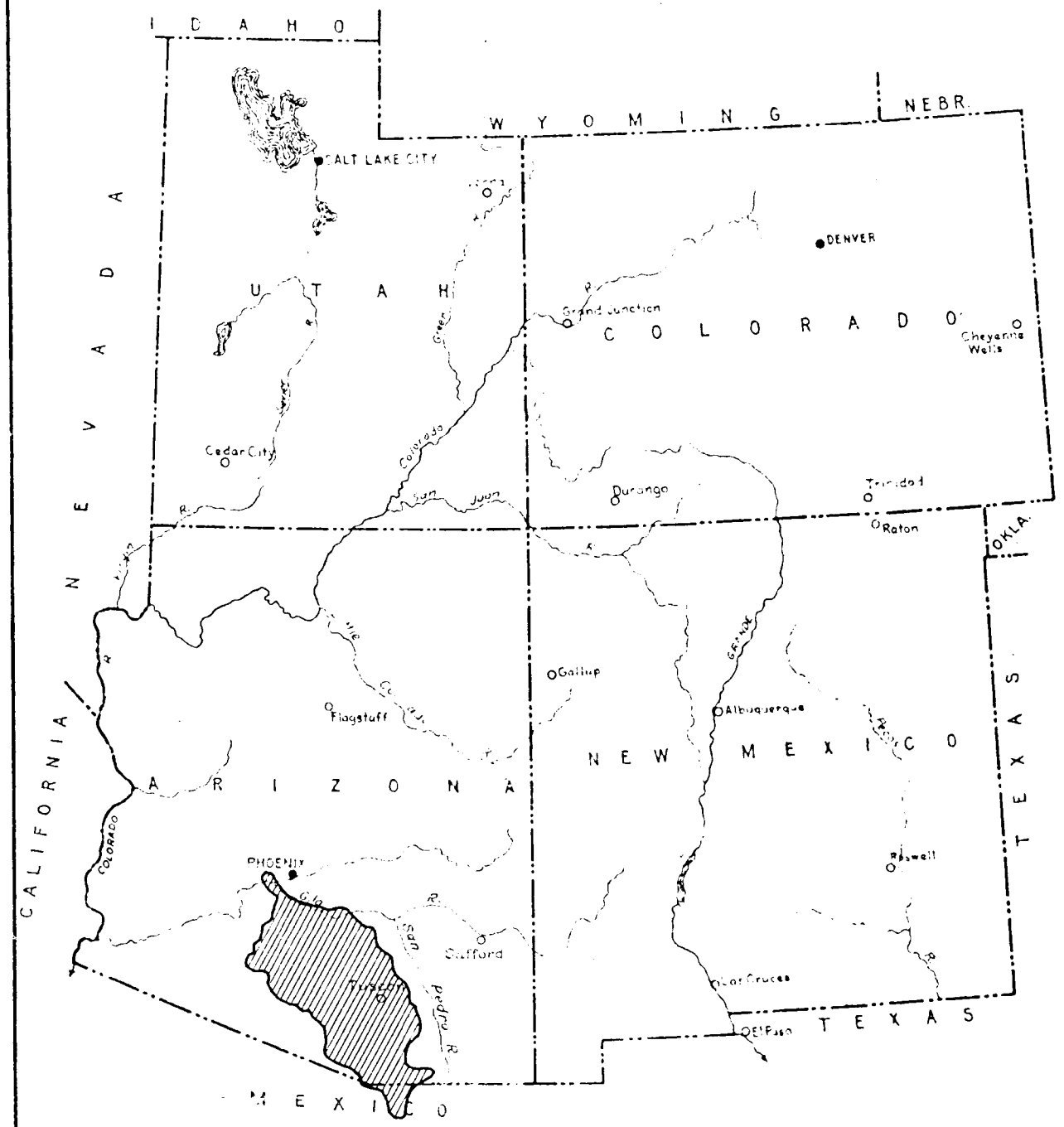
FIELD FLOOD CONTROL CO-ORDINATING COMMITTEE

UNITED STATES DEPARTMENT OF AGRICULTURE

	Soil Conservation Service
	Forest Service Southwestern Forest and Range Experiment Station
	Bureau of Agricultural Economics

JUL 25 1938
(Date)

LOCATION MAP



Santa Cruz Watershed

54 27 0 54 108 162
Scale in Miles

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

BUREAU S.C.S. F.S. & B.A.E.
APPROVED A. Fife BUREAU S.C.S.

PRELIMINARY EXAMINATION REPORT
RUN-OFF AND WATERFLOW RETARDATION AND SOIL EROSION PREVENTION
FOR FLOOD CONTROL PURPOSES

SANTA CRUZ WATERSHED

1. Authority. This report of preliminary examinations is made in compliance with the Flood Control Act of June 22, 1936, (Public No. 738, 74th Congress), as follows: "Section 6 ... The Secretary of Agriculture is authorized and directed to cause preliminary examinations and surveys for run-off and waterflow retardation and soil erosion prevention on the watersheds of . . . Santa Cruz and Sonoita Rivers, Santa Cruz County, Arizona; Sabino Canyon, Pima County, Arizona; [and] Lower Santa Cruz River, Pinal County, Arizona." (Maps 1, 2, and 3, Appendix).

2. Among other watersheds, the Flood Control Act specifically calls for preliminary examinations and surveys of the three tributary watersheds mentioned above, which together comprise the Santa Cruz watershed. But since the run-off and soil erosion problems of the upper Santa Cruz-Sonoita area are closely interrelated with similar problems of the lower Santa Cruz (Pinal Co.) and the middle Santa Cruz basin (Pima Co.), the field committee has deemed it advisable to consider the whole Santa Cruz River watershed as a unit. Further, the matters of water conservation and available water supply concern the inhabitants of the entire

Santa Cruz basin. Testimony given at the public hearings before the U. S. District Engineer, War Department, on the upper Santa Cruz-Sonoita Creek area and on the lower Santa Cruz clearly indicated the desire of the local population for flood control, run-off retardation, and soil erosion control. It further indicated that the Tucson water users will oppose any program for flood control and run-off retardation that will adversely affect their water rights and supplies. It does not seem possible to control floods, run-off, and erosion in one part of the Santa Cruz basin without affecting the available water supply in other parts. Hence in this report, the upper, middle, and lower Santa Cruz areas are considered together as a unit.

3. Sabino Canyon. Sabino Canyon, in Santa Catalina Mountains, northeast of Tucson, drains a mountainous area of about 75 square miles, emptying into the Rillito Creek at a point about 8 miles northeast of Tucson (map 2). The average annual rainfall for this area is about 23 inches.1/ There are neither flood nor erosion problems in this drainage, which consists largely of National Forest lands used for recreational purposes, including, from high to low elevation, a comparatively small area of pine-fir timber, then woodlands, chaparral, semidesert shrub, and a small desert-shrub area. In the lower part, within the National Forest, there are 13 small dams, all of which serve to retard run-off

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1/ Weighted average, based on size of areas of pine-fir (including woodland), chaparral, and semidesert shrub.

and 10 of which serve also as bridges.

I. DESCRIPTION OF AREA

A. Location and Size

4. The Santa Cruz drainage basin comprises about 8,877 square miles, or 5,681,200 acres, in southern Arizona and an additional area of 394 square miles at the upper end of the watershed in the State of Sonora, Mexico (see frontispiece). This is the dominant drainage system of south-central Arizona.

B. Surface Relief

5. For the most part, this watershed is bounded by low mountain ranges and distinct linear mountains. Some of the mountains have elevations of more than 8,000 feet. Scattered throughout the basin are several mountain ridges, short mountain ranges, and small and large groups of mountains whose elevations range from somewhat less than 2,000 feet to more than 9,000 (Santa Rita and Santa Catalina). Between the ridges, ranges, and mountain groups, the relief varies from that of broad shallow valleys to outwash slopes and foothills. (Map 4).

C. Geology and Soils

6. Geology. The Santa Cruz drainage basin is a part of the Basin and Range province. The formations include geologically recent valley-fill deposits and volcanic rocks as well as the oldest known schists and granite gneiss of some of the mountains (1). 1/ (Map 4).

1/ Figures in parentheses refer to Bibliography of Source Material, par. 84.

7. The valley-fill deposits contain the groundwater supplies. The normal flow of streams sinks and thus adds to these supplies; and flood waters that sink into these valley fills also replenish these underground waters. Gritty soils that originate from readily disintegrating crystalline rocks erode easily, whereas the heavier-textured soils that have developed from those soil-forming materials derived from dense rocks, such as dense granitic and schistose rocks, are rather resistant to erosion.

8. Soils. The soils of the Santa Cruz watershed may be classed into two broad groups: Sierozem, or Desert, and Southern Brown (map 5). The group of southern Brown soils includes three subclasses - Dark Brown, Brown, and Light Brown, named in the order of their location with reference to decreasing elevation and rainfall. At the highest elevations, where rainfall is sufficient for growth of pine and fir trees, there are areas of podzolic soils too small to be shown on the map. In the Rillito and Santa Cruz Valleys, especially in the vicinity of Casa Grande and Eloy, are areas of deep alluvial soils. Many small areas of alluvial soils are scattered throughout the watershed as likewise are areas of stony and rocky mountain land where geologic erosion is active.

9. Results of investigations of the erodibility of Desert and Southern Brown soils, in relation to origin, characteristics, vegetation, and slope location, are briefly summarized in table 1 (Appendix).

10. Drainage of swamps and lowlands. There are no important swamps nor low wet lands in the Santa Cruz basin in need of artificial drainage.

D. Natural Drainage

11. The Santa Cruz basin, largely desert and semidesert, is typical of dry regions. This drainage system is bilateral - that is, the shorter mountain streams flow on comparatively steep gradients to the east bank of the Santa Cruz River, while the larger streamways draining the gently sloping valleys constituting the western portion of the basin deposit at the west bank. The Santa Cruz River rises in Canelo Hills, in southeastern Santa Cruz County, and flows south about 15 miles into Mexico, returning to United States about 5 miles east of Nogales. It rises at an elevation of about 5,200 feet and descends to about 950 feet where it joins the Gila River. Almost the entire course of the Santa Cruz River (about 240 miles) is through open plains of broad shallow valleys whose surface and subsurface strata are valley-fill deposits. The alluvial valley through which the river flows varies widely in width, is restricted in places (as near Tucson), and widens out greatly as it meets the broad flood plain of the Gila (3).

E. History of Watershed

12. For many centuries prehistoric peoples irrigated along the Santa Cruz River. Father Kino entered this valley in 1692, and

the establishment of missions followed. Irrigation by white people developed around these missions. During the Spanish period, until 1823, the Santa Cruz basin acquired a prosperous agricultural and mining population (4-8).

13. Raids by the Apaches continued up to 1872. During the Mexican period (1823-48), irrigation canals were maintained, and fruits, cereals, vegetables, and tobacco were raised. Some years after the Gadsden Purchase (1853), especially after completion of the S. P. Railroad in 1881, settlement by white people made rapid progress (9, 10). In the lower Santa Cruz basin as around Eloy, modern agricultural developments did not begin until 1919, with a small acreage in lettuce and vegetables (11). In the lower Santa Cruz area irrigation by Indians has probably been continuous from pre-Columbian times.

14. Following the 1880's the rise of the livestock industry was rapid and the ranges soon became stocked to their limit even in favorable years. Dry years came, overgrazing resulted, and the protective grasses on extensive semidesert areas deteriorated or disappeared (12, 13). Now areas of the lower country which formerly were grasslands offer mainly shrub browse. The present status of the vegetation cover is shown on map 6 (14).

F. Population

15. The total population, 10 percent of which is Indian, was, in the Santa Cruz watershed on April 1, 1930, 68,780 (15-18). Of this total population 11.8 percent was rural farm, 32.2 percent rural non-farm, and 56 percent urban (map 7). "Average" floods have inundated land now occupied by about 1,500 people, and "extreme" floods, about 10,000 people.

II. LAND ECONOMY

16. The agriculture of the Santa Cruz watershed may be divided into two principal divisions, range-livestock and irrigation (13, 19-25, 28, 33). In 1935 approximately 1.9 percent of the area was in cultivated land and 98.1 per cent in range land.

A. Present Use of Land

17. The major trends in the use of farm land and the approximate acreage of cropland harvested in the Santa Cruz watershed are shown in table 2. Of the 136,420 acres of cropland harvested in 1936, probably 70,000 acres, or about 52 percent, were irrigated from water of the Santa Cruz River and tributaries. The remaining acreage, about 66,000 acres, was irrigated from water of the Gila River and tributaries. For the watershed as a whole, about 31,000 acres were planted either for the first time in 1937 or on land that had been idle for some years prior to 1937 (26). Of this acreage, about 25,000 acres were in cotton and over half of this cotton land was irrigated by water from the Santa Cruz River.

B. Land Ownership

18. Nearly 47 percent of the lands are Federal, 30 percent State, and 23 percent private (19). According to the U. S. Census of Agriculture, from 1930 to 1935 the number of farms increased about 35 percent. Despite the fact the acreage in farms increased 49 percent, the cropland harvested increased only about 12 percent, but the land classed as "other pasture" increased about 82 percent (map 8 and tables 3 and 4).

C. Farm Economy

19. The principal types of farming in this watershed are, according to numerical importance, as follows: Unclassified, stock ranch, cotton, part-time, general, self-sufficing, animal specialty, and poultry (15, 22-25). Other pertinent data on farm economy are given in table 3.

20. Farm and ranch income is divided as follows:

Item	1930 1/		1937 2/	
	Total	Percent	Total	Percent
Crops (including plants, flowers, etc.) sold or traded	$1,898,315	39.6	$6,402,000	68.7
Livestock sold or traded	1,654,527	34.6	904,000	9.7
Livestock products sold or traded	871,093	18.2	1,023,000	11.0
Forest products sold	63,237	1.3	84,000	0.9
Farm products used	205,458	4.3	270,000	2.9
Government payments	...	...	133,000	1.4
Receipts from boarders, etc.	95,396	2.0	500,000	5.4
	$4,788,026	100.0	$9,316,000	100.0

1/ Estimated from Federal census data.
2/ Estimated from crop reports, etc. (23-25).

21. According to the 1930 census, the typical value of farm products sold, traded, or used by operators' families was less than $250 for the self-sufficing farms and $5,000 for the dairy farms. Approximately 200 farms reported gross incomes in excess of $6,000 per farm.

22. The average assessed valuations per acre in 1936 of grazing land in Pima, Pinal, and Santa Cruz Counties were $1.00, $1.59, and $1.25, respectively; while irrigated land was $21.74, $22.79, and $27.75 (27).

23. The trend of county and state taxes (27) per $100 assessed valuation (special districts not included) for Pima, Pinal, and Santa Cruz Counties from 1915 to 1935 may be indicated as follows:

	1915	1920	1925	1930	1935
Pima	$0.86	$1.005	$1.22	$1.22	$2.081
Pinal	.695	.6198	1.035	.9162	2.17
Santa Cruz	1.373	1.2593	1.652	1.5642	3.028

D. Wildland Economy

24. The control of lands not in private ownership, amounting to about 4,115,000 acres, or about 72 percent of all land, rests principally with the Federal and State governments. The lease, rental, permit or use value of these lands approximates $187,000 annually. This estimated income is included in the total farm and ranch income. Map 9 shows, by areas, the present status of range forage conditions.

III. HYDROLOGIC DATA

A. Meteorological Facts

25. Rainfall. The average annual rainfall in the low country of the Santa Cruz basin varies from 8 to 15 inches; and at the highest elevations, from 25 to more than 34 inches (29, 30). The average[1/] for the watershed is about 13.5 inches, based on 19 Weather Bureau standard gages (except one recording at the University of Arizona), supplemented by 4 Desert Laboratory gages. The records of the latter are seasonal in nature (map 10).

26. Pertinent data on annual rainfall at the various stations in the watershed are given in table 5 (29).

27. Two rainfall seasons are recognized: summer (July to September) and a lesser fall-winter season (December to March). The other months are dry. The summer storms are usually local; some are torrential and cause local flash floods and destructive erosion. The winter storms are usually lighter and of longer duration, allowing ground absorption of rain water. Below Red Rock the total summer fall is less than the fall-winter total, whereas above or south of this point the reverse is true.

28. There is no regularity in the occurrence of local summer storms. A given locality may receive two to four such storms in a season, and downpours may occur in two successive years and not again for several years.

1/ Weighted average, based on the size of component divisions of the watershed.

29. Intensity of rainfall data are too meager to enable one to gain a complete picture of the amount of rainfall per hour in different parts of the watershed. However, the following data may give some idea of rainfall intensity:

Station		Total fall	Highest fall in minute periods					
			10	20	30	40	50	60
		In.	In.	In.	In.	In.	In.	In.
Tucson	Heaviest in period 1928-35 July 31, 1935, Lasted 1 hr.	2.04	0.85	1.44	1.83	1.94	2.02	2.04
Do.	Second heaviest in period Aug. 21, 1932. Lasted 4 hr.	1.01	0.39	0.62	0.70	0.80	0.86	0.91
Do.	Oct. 11, 1932 Lasted 2 hr. 35 min.	0.94	0.39	0.50	0.61	0.63	0.69	0.71

Precipitation records indicate that 2-and 3-inch falls per hour are common, and that the greatest intensity may be 3 inches in 1 hour. Ordinarily, an intense storm does not last more than 1 hour.

30. Snowfall. On areas at 6,000 and more feet, some snow falls during winter months; but since only about 8 percent of the Santa Cruz watershed lies above 5,000 feet, snowfall is of minor importance. Winter or winter to spring flows from the highest mountain areas may be due to melting snow, or rain combined with melting snow.

B. Stream Flow

31. General discussion. The streams of this basin are ephemeral and perennial. The headwater streams of the Santa Cruz River are perennial. The higher parts of some of its upper tributaries are likewise perennial, or nearly so. A rainy winter may

prolong the flow of some of the intermittent streams for several months, otherwise such streams flow only after sporadic heavy rains. The length of the surface flow of the Santa Cruz varies greatly. This surface flow ordinarily does not reach the Gila. Whatever water is contributed to the Gila comes from a slow underground flow.

32. Streamflow records of five U. S. G. S. stations within the Santa Cruz watershed cover periods ranging from 6 to 31 years (31). The locations of these stations are shown on map 10. Such stations are few because of the fact that most of the streams are dry most of the time.

33. Discharge. Data relative to discharge, minimum and maximum monthly flows, and highest peak flows of streams at the five streamflow stations are briefly given in table 6.

34. Frequency of floods. In general, flash floods, which originate principally from summer storms, do not occur with any regularity. On a given local area such flows may occur two to four times in a season for two successive seasons and not again for several years. For example, high flood flows occurred at Tucson on July 31, 1890, August 17, 1891, and not again until August 13, 1901 (32). Serious floods may occur from three to five times in 10 years. Flood flows of the upper Santa Cruz, even when combined with flood discharge from Rillito Creek, extend only a short distance below Tucson. Such flood flows reach the Gila

once in about 10 or 20 years (3). In the lower Santa Cruz, floods usually result from heavy local storms. Heavy flood flows are common in the lowest part of Santa Cruz basin, where the flood waters come from Santa Rosa Wash (33).

35. Probability of extreme floods in the Santa Cruz at Tucson and from combined flows of the Santa Cruz and Rillito, under present conditions obtaining in the upper Santa Cruz River, seems to be one occurrence in about 100 years (2); but it is reasonable to assume that if the present upper watershed values are not protected from floods and erosion, the probability is that floods with a frequency of considerably less than one in 100 years will be as damaging as the 100-year floods are at the present time.

36. Stream behavior. The Santa Cruz River at Tucson may be dry from 1 to 12 months at a time. A prolonged winter flow, however, may last as long as 3 months. The flood waters of Santa Cruz and Rillito are dispersed and absorbed in the area to the south and southwest of Picacho Peak. Rillito Creek is largely a winter stream, whereas summer performance is characteristic of Pantano Wash (34, 35). In general, the summer flood flows are characterized by sudden rises ordinarily in previously dry channels, fluctuating or decreasing for a few hours after peak, and then disappearing within a few days. Winter flows, some of which are severe, are usually followed by measurable flows for some time afterward. Pertinent data on component sub-drainages

and on stream behavior are given in tables 7 and 8 (3).

37. Groundwater conditions. There is an accessible supply of water beneath both the channel bed and the flood plain along virtually the entire course of the Santa Cruz River from Mexico to the northern point of the Tucson Mountains. Similar groundwater conditions obtain in the Eloy-Casa Grande area. The wells in upper Santa Cruz Valley extending to the northern point of the Tucson Mountains and in Rillito Valley are replenished during spring-winter flows. Water levels under Tucson and in the vicinity of Tucson have been permanently lowered by about 9 feet during the last 13 years (13). With the possible exception of the wells in the eastern section of Tucson, the replenishment of the water-carrying strata, for the most part, is by direct percolation from surface flows in the stream channels. In the Coolidge area, replenishment is from seepage losses from irrigation systems, principally in the San Carlos project. More detailed studies are necessary to determine the areas best fitted for water-spreading and also the relation between the groundwater supplies and the conservation of flood waters. (31,33,35).

38. Turbidity. Measurements of turbidity are very meager. A test of the Rillito Creek flow in 1909 by the University of Arizona showed 9 percent silt. From observations, headwater flows at high elevations are usually clear. Elsewhere the channel flows are muddy and the load of sand and silt carried by flood flows

varies with turbulence and with the rate and volume of surface run-off.

IV. FLOODS

A. Flood History

39. Early records show that torrential flows in headwater streams and in the upper-middle Santa Cruz area occurred before white men settled here, when the country was covered with the original or natural vegetation. However, these floods did not occur with the frequency and flashy and destructive character of the flood flows since the late 1880's (36-40). The following is a list of heavy floods:

Upper and Middle Santa Cruz Basin

Date	Notes
1890, July 31,	Channel erosion began. Damage down river to Tucson.
1891, August 17,	Much damage at Tucson. Farm lands destroyed. Channeling of river bed.
1901, August 14,	Channel cutting. Damage at Tucson.
1902, October,	Damaging floods in Santa Cruz and Rillito Valleys.
1904-5, Winter,	Damage in upper Santa Cruz basin and overflow in Rillito Creek.
1914-15, Winter,	Much damage from Nogales to Rillito. Flood reached Gila.
1929, September,	Heavy damages in Continental, Nogales, and Altar Valley areas.
1931, August,	Much stream-bank cutting.
1935, August 31,	Much damage in Rillito Valley.

Lower Santa Cruz Basin

1904-5, Winter,	Lands flooded (agriculture by white people not yet begun).
1914-15, Winter,	Eloy-Casa Grande-Maricopa area inundated. Much damage.
1924, August,	Cotton fields and lands east of Eloy flooded.
1929, September,	300 acres of land destroyed in Eloy area.
1933, Summer,	Town of Eloy flooded.
1936, Summer,	Santa Cruz flooded area from Coolidge to Maricopa.
1937, Summer,	Santa Rosa water flooded cotton fields near Maricopa.

B. Causes of Floods

40. The causes of flash floods of recent years have been heavy summer and winter local downpours in or above the flooded areas on lands with little vegetation. Hence the rapid surface run-off and destructive soil erosion.

C. Condition of Stream Channels

41. Excessive channel filling is in progress in many places; in others, recessive cutting. Filled channels are becoming broader. The large volume of erosion products in flash flows partly obstructs the channels at times, impedes the current, and modifies the gradient of channel beds. The silt temporarily deposited on low level areas in about the middle part of the Santa Cruz drainage contributes, at times, much damaging silt to lower areas such as the Eloy-Casa Grande area.

D. Land Use-Cover-Flood Relationships

42. Prior to 1880 the Santa Cruz and tributaries did not have the active erosion channels which they now have (7). From early records by U. S. topographic engineers, travelers, and pioneers, the upper and middle Santa Cruz basin and the mesas and higher lands of lower Santa Cruz had a protective cover of vegetation. The lowest and driest areas seem to have had more vegetation than now. Following 1880, heavy grazing reduced the ground cover; on many lower areas the grasses disappeared, and accelerated surface run-off and soil erosion resulted (13, 36, 39, 41-48). River-channel erosion of the Santa Cruz began about the same time

that flash summer floods and accelerated surface run-off began (1890, 1891), following the deterioration of range vegetation.

E. Effect of Stream Improvements

43. Santa Cruz County has constructed permanent masonry protection work in the wash through Nogales for the control of channel erosion. Some emergency work has also been done in the Santa Cruz channel. Flood control measures have been carried out in Nogales, Mexico, through an international project. Emergency work to protect stream banks from cutting has recently been done on the Santa Cruz near Tucson, on the Pantano, and on Rillito Creek by the Arizona State Highway Department, by Pima County, the Indian Service, and the Soil Conservation Service.

V. PROBLEMS OF DAMAGES[1/]

A. Damage by Floods, High Water, and Excessive Run-off

44. Damage to crops may occur every year, particularly along the narrow fringe of level land adjacent to Rillito Creek, Pantano Wash, and the Santa Cruz River. This loss approximates $21,700 annually (13, 24, 33).

1/ In damage statements it should be kept in mind that in most cases the estimates of damage in monetary terms are based on incomplete data.

45. Municipal and industrial properties have been damaged an amount exceeding $7,200 annually during the period from 1890 to 1937 (13, 33).

46. Local floods have damaged bridges, railways, highways, and communication lines to an undetermined extent. Partial information obtained (13, 33) indicated average annual damages to be: to bridges, $2,400; to railways, $800; to highways, $3,800; or an annual total of $7,000.

47. Dams, pumping plants, irrigation systems and other rural property have suffered flood damages amounting to $6,200 annually (13, 33, 50), including the cost of replacing and protecting irrigation works.

48. There are no available data on damages to livestock and wildlife, nor were any reported at the public hearings.

49. Disruption of railway service, flooded highways, washed out bridges, inundation of parts or all of Calabasas, Eloy, Maricopa, Casa Grande, and the city of Nogales prevented the usual marketing of farm products and the retailing of merchandise, also decreased school attendance and increased the sanitation problems (13, 33). It is impossible to express these damages in monetary terms.

50. Eight people have lost their lives in floods during the period 1901-1936.

51. A summary of estimated damages by floods, high water, and "excessive" run-off in the Santa Cruz watershed follows:

Item	Annual damage
To crops, agricultural land, etc.	$21,700
To municipal and industrial properties	7,200
To bridges, railways, highways and communication lines	7,000
To other property and improvements	6,200
To livestock and wildlife	.....
Intangibles	.....
Loss of life	.....
Total	$42,100

B. Damage by Erosion

52. Erosion conditions. In general, on the desert soil areas (map 5) active sheet and gully erosion is in progress, owing to the alkaline-calcareous nature of the soils and lack of protective ground cover. On the Brown soil areas erosion is slight to moderate, owing to the heavier texture of the soils and the occurrence of protective vegetation. In certain of these areas the protective vegetation is fully adequate. The erosion conditions are classified on map 11 according to the following five groups: (a) irrigated lands and Brown soil areas with none to slight erosion (17 percent of the watershed), (b) areas with slight to moderate erosion (4 percent of the total area), (c) moderate erosion (34 percent of the watershed), (d) moderate to severe erosion (6 percent of the total acreage), and (e) severe erosion (39 percent of the watershed). In this final class certain areas of silt deposition are included.

53. Damage to lands through soil removal may be estimated on the basis of resultant loss of grazing capacity plus the value of arable lands destroyed through channeling and stream-bank cutting. According to local information and data submitted at the public hearings, it is estimated that 3,000 acres of arable lands have been destroyed in the Santa Cruz, Rillito, and Pantano Valleys during the last 50 years, representing an estimated annual loss of $900. Deterioration of range land on account of soil erosion is estimated at 85 percent of the total deterioration of range value, or about $32,000 annually. (See map 9).

54. Damages from deposition of silt and other erosion products from the silting of irrigation ditches, canals, and rock and brush diversion dams caused by flash floods during the last 45 years are impossible to estimate. No technique has been developed which measures in monetary terms all erosion losses on range and agricultural lands.

C. Damage to Water Supplies

55. It is not known to what extent any lowering of groundwater levels is due principally to high surface run-off and decreased infiltration.

56. Conditions that result in flash floods have probably shortened the period of above-ground flows in the upper Santa Cruz basin. Data are not available for estimating the monetary damages due to any decreased flows.

57. Only occasionally have floods injured wells used for domestic purposes. The amount of such damages is not known.

D. Damage to Wildlife

58. From early Southwestern accounts by travelers, government surveyors, and others, the Santa Cruz basin abounded in wildlife - bears, foxes, antelopes, deer, wild turkeys, and quail. The Santa Cruz River had fish in abundance, and beavers were numerous down as far as the mouth of Rillito Creek. Wild ducks and geese were also abundant. (12, 40, 44, 49). The changes in the streams resulting from accelerated surface run-off and erosion may be mainly responsible for the disappearance of the fish, beavers, and wild fowl. It is impossible to estimate the damage done to wildlife.

E. Damage by Insects and Weeds

59. No appreciable damage is known to have resulted from the spread of any insects or weeds by flood waters in the Santa Cruz watershed.

F. Other Land-Use Problems

60. Data are not available to determine the effects of siltation, impairment of water supply, and damage by floods on standards of living, tenancy, or mortgage indebtedness.

G. Summary of All Damage

61. The total known damages from floods and erosion in the Santa Cruz watershed may be summarized as follows:

Item	Av. annual damage
Damage by floods, highwater, and excessive run-off:	
To agricultural lands (par. 44)	$21,700
To municipal and industrial properties (par. 45)	7,200
To bridges, railways, highways, and commercial lines (par. 46)	7,000
To other properties and improvements (par. 47)	6,200
To livestock and wildlife (par. 48)	.....
To intangibles (par. 49)	.....
To loss of life (50)	.....
Damage by erosion:	
To farm lands by soil removal (par. 53)	900
To range lands by soil removal (par. 53)	32,000
From siltation (par. 54)	.....
Intangibles (to markets, human welfare, etc.)	.....
Damage to water supplies	.....
Damage to wildlife	.....
Damage by insects and weeds	.....
Intangibles	.....
Total	$75,000

VI. REMEDIAL MEASURES

62. Problem areas. The Santa Cruz basin may be divided into the following problem areas: (A) lower irrigation area, (B) Tucson-Nogales area, (C) major surface run-off and silt-contributing area, and (D) areas that are well protected from erosion or have only local erosion and run-off problems (see map 12 for areas and major problems). The control of flood flows and silt carried by the Santa Cruz River, as they affect problem area A, lies principally in measures that may be applied on problem area C.

A. Flood and Erosion Measures in Effect

63. In addition to the stream improvements mentioned in paragraph 43, several C. C. C. camps have introduced conservation programs on the Santa Cruz watershed, directed by the Soil Conservation Service, the Forest Service, and the Division of Grazing. These involved mechanical measures, such as water spreaders, gully plugs, water developments, fencing, etc., with fair to good results on comparatively small areas. The Agricultural Adjustment Administration has conducted programs with both farm and ranch operators on other than Federal lands, including crop rotations, water developments, fencing, rodent control, deferred grazing, spreader dams, contouring, and revegetation. There has been some regulation of grazing by agreements between the Soil Conservation Service and livestock operators. On the National Forest areas grazing regulation is in effect, and certain areas have been closed to grazing.

B. Changes in Land Use

64. The entire range area, but more particularly about 1,000,000 acres in critical condition, should be given detailed study. Within the critical area, fairly extensive withdrawal from range use may be necessary.

C. Changes in Land Management Methods

65. On extensive areas a reduction in the number of stock would allow improvement of ranges through the recovery of vegetation. The

restriction and regulation of irrigated areas may be necessary to safeguard established water rights. Grazing and zoning regulations, possibly with accompanying government subsidies may be required.

D. Changes in Ownership

66. Detailed investigations will have to be made to determine what adjustments are necessary to establish the proper relationship between acreage of irrigated land and the usual supply of water. Also, consideration should be given to public acquisition of critical range areas which are unsuited to continued grazing, if flood damages and soil erosion are to be prevented.

E. Engineering Devices

67. A tentative plan of the local interests include a non-storage dam and dike near the head of Green Canal to check the flood waters of the Santa Cruz and Avra Wash and to improve the water supply of the Eloy District. Two other non-storage dams for better utilization of flood-flow waters are also contemplated (11, 33). In the control of silt on problem area C, for the protection of area A, engineering is primarily needed to supplement vegetation as a means of spreading surface run-off, stopping gully head cutting, and holding back silt. Critical areas should be retired from use, artificial revegetation conducted on areas that will justify such effort, revegetation encouraged through conservative land use, fencing and water developments constructed, and grazing regulation practiced.

68. In problem area B, plans proposed by local interests for the conservation of water for Tucson and areas above require engineering works in Sonoita Creek and upper Santa Cruz River near Nogales to serve as control outlet detention reservoirs (13). Similar works are proposed for Canada del Oro, Rillito Creek, and Pantano Wash. (Map 12). On range lands in problem area B and in critical spots on "D" areas, the control of surface run-off and soil erosion may require any or all of the measures outlined in paragraph 67.

F. Other Remedial Measures

69. Investigation will probably show the need for control measures other than those previously mentioned.

VII. BENEFITS FROM PROPOSED MEASURES

A. Water Conservation

70. Owing to the fact that most of the water used in the Santa Cruz watershed is pumped, considerable importance is to be attached to the beneficial effect that stream regulation and the control of surface run-off will have on groundwater recharge.

B. Soil Conservation

71. It is estimated that proposed control measures will reduce by about $25,000 the present soil losses of about $32,900 annually (par. 53).

C. Deposition Correction

72. It may be assumed that with measures to control surface run-off and soil erosion, the silt load of flash flood flows would be materially reduced. However, it is not possible to evaluate such benefits.

D. Wildlife Benefits

73. No means are known of estimating benefits to wildlife in the Santa Cruz watershed from the control of floods, surface run-off, and soil erosion.

E. Sanitation

74. Retardation of flash floods should decrease markedly the inconveniences suffered by persons who live in areas that have been inundated, and should make secure a sanitary water supply.

F. Extent of Damage Reduction

75. Proposed flood control measures will probably reduce annual damages as follows: To crops, $19,530; to municipal and industrial properties, $3,600; to bridges, railways, and highways, $6,300; to rural property (including irrigation works), $4,960; or a total of $34,390 annually of $42,100 damages (par. 51).

G. Economic and Social Consequences of Remedial Measures

76. Enhanced value of property might not result from proposed improvements; but without such treatment values may possibly decline about 25 percent in the next 50 years, unless flood and erosion control programs are developed.

77. The mitigation of floods and accelerated surface run-off and

erosion should tend to encourage settlement in areas heretofore considered unsafe. Concurrent with this expected increase in population, irrigation agriculture will probably become both absolutely and relatively more important than at present. Public revenues will probably increase with general watershed improvement and community development.

78. Any retardation of flood flows and control of destructive flash floods should not only increase business confidence but also the prosperity of the people and agencies concerned. Such intangible benefits cannot be estimated.

H. Total Benefits

79. A summary of the foregoing benefits follows:

Item	Estimated Annual Benefit
Water conservation (par. 70)	$ .....
Soil conservation (par. 71)	25,000.00
Deposition correction (par. 72)	.....
Wildlife (par. 73)	.....
Sanitation (par. 74)	.....
Reduction of flood, high water and excessive run-off damages to crops, municipal and industrial properties, bridges, railways and other property (par. 75)	34,390.00
Economic and social consequences (par.76)	.....
Total annual benefits	$59,390.00

Of these $59,390 estimated annual benefits, about $44,540 will accrue to the public.

VIII. COOPERATION

80. Chapter 81, Article 5 (Drainage Districts) and Article 6 (Flood Control Districts) of Arizona statutes provide for Federal co-

operation in the application of measures for the control of floods.

81. These Articles provide for the organization of a flood control district in the same manner as is provided by Article 5 relative to drainage districts, to-wit: "Whenever five or more holders of title or evidence of title to improve lands that are subject to overflow or washing or menaced or threatened by the unusual flow or flood of any natural water course ... whether partial, intermittent, or flood, and capable of being protected or relieved from such overflow or menace, desire to provide for the protection of such lands...." Article 5 covers the matters of right-of-way, maintenance, and liability.

82. Outside of stream improvement (par. 43), erosion control and surface run-off treatment in the Santa Cruz basin have been confined to work by the Forest Service on National Forest areas (map 8) and on limited areas by the Division of Grazing and the Soil Conservation Service through the use of Civilian Conservation Corps labor (par. 63).

83. Cooperative plans by Federal agencies for a survey and the application of measures for the control of floods, surface run-off, and soil erosion for the conservation of natural resources in the Santa Cruz watershed have received support in signed resolutions presented to the District Engineers (War Department) by the Pinal and Santa Cruz Counties Boards of Supervisors and the Nogales Chamber of Commerce. The Tucson representatives expressed approval and cooperation provided their water rights were respected.

APPENDIX

A. Bibliography of Source Material

84. 1. Darton, N. H. Geologic Map of the State of Arizona. 1933.

2. Knapp, Frank. Engineering Report on the Santa Cruz Watershed. S. C. S. 1937, unpublished.

3. Sykes, Godfrey. The Santa Cruz, A Study of A Desert Drainage System. Manuscript, Desert Lab. of Carnegie Institution, Tucson, 1937.

4. Lockwood, F. C. Pioneer Days of Arizona, 1932.

5. Bandalier, Adolph F. Final Report of Investigations Among the Indians of the Southwestern United States. (Papers, Archaeological Institute of America, American Series, Vol. 3. Cambridge, 1890).

6. Fewkes, J. W. Archaeological Expedition to Arizona in 1895 (Seventeenth Annual Report, Bureau of American Ethnology, Washington, 1898).

7. Lockwood, Dean Frank C., and Capt. Page, D. W. Tucson the Old Pueblo. Phoenix, 1930.

8. Farish, Thos. Edwin. History of Arizona. Phoenix, 1925.

9. Lockwood, F. C. With Padre Kino on the Trail. Univ. Ariz. Social Sci. Bull. No. 5, 1934.

10. Lockwood, F. C. The Apache Indians, 1938.

11. Fiscel, L. O. Lower Santa Cruz River, Pinal County, Ariz. Preliminary Report given at Public Hearing before U. S. District Engineer, 1937.

12. Forbes, Robert H. Arizona Material, Notebook. Tucson, Ariz.

13. Proceedings before the United States District Engineer (War Dept.) in the matter of the Public Hearing Re: Preliminary Examinations of Santa Cruz and Sonoita Rivers. Santa Cruz County, Ariz. 1937, p. 46.

14. Nichol, A. A. The Natural Vegetation of Arizona. Ariz. Agr. Expt. Sta. Tech. Bull. 68, 1937.

15. Federal Farm Census, 1930 and 1935.

16. Maps of State-wide Planning Survey sponsored by the Arizona State Highway Dept. in cooperation with the U. S. Dept. Agr., Bureau Public Roads. Unpublished.

17. Maps of the Gila and Maricopa Indian Reservations, Unpublished.

18. Maps of Pima Indian Reservation and of San Xavier Reservation. Unpublished.

19. Land ownership maps of Arizona State Planning Board, corrected to December 1936. Unpublished.

20. Reports of Arizona State Planning Board; Volume II, Land Use Planning, Water Resources, Flood Control and Power, December 1936.

21. Notes on the Upper Santa Cruz Watershed, Arizona. Section of Human Surveys, SCS, Region 8, November 1937.

22. Agricultural Planning Study-Arizona-September 1935. A Cooperative study of the Agricultural Adjustment Administration, Bureau of Agricultural Economics, and Agricultural Experiment Station, University of Arizona.

23. Henness, K. K., Annual Reports, County Agricultural Agent, Pinal County, Arizona.

24. Brown, C. B., Annual Reports of County Agricultural Agent, Pima County, Arizona.

25. Crop Reports of the San Carlos Project (1937), Coolidge, Arizona; the Maricopa Indian Reservation; the Gila Indian Reservation; the Papago Indian Reservation; and interviews with officials of the respective agencies.

26. Arizona Agricultural Conservation Service Crop Data. Unpublished.

27. Thirteenth Biennial Report of the State Tax Commission of Arizona.

28. Data from Dr. George W. Barr, Department of Agricultural Economics, and Dr. G. E. P. Smith, Department of Agricultural Engineering, University of Arizona. Unpublished.

29. United States Weather Bureau Records for Arizona.

30. Smith, H. V. The Climate of Arizona. U. of Ariz. Bulletin 130, 1930.

31. U. S. G. S. Water Supply Papers for Colorado River Basin (those that contain data on the Santa Cruz drainage basin).

32. Weir, W. W. Statements Describing the Early Conditions Regarding Ground Cover, Flood Flows, Wildlife, and Agriculture in the Southwest. S. W. F. and R. Expt. Sta. 1937.

33. Transcript of Public Hearing on the Lower Santa Cruz River, Pinal County, Arizona, 1937.

34. Youngs, F. O. and others. Soil Survey of the Tucson Area, Arizona. Series 1931, No. 19, Bureau Chem. and Soils, U. S. Dept. Agr., p. 3.

35. Smith, G. E. P. Groundwater Supply and Irrigation in the Rillito Valley. U. of Ariz. Bulletin 62, 1910.

36. Browne, J. Ross. The Apache Country, A Tour Through Arizona Sonora. New York, 1869.

37. Rusling, James F. Across America or the Great West. New York, 1874.

38. Huntington, Ellsworth. The Climatic Factor. Carnegie Inst. of Washington Pub. 192, 1914.

39. Forbes, Robert H. The Penningtons, Pioneers of Early Arizona. Tucson, 1919.

40. Kitt, Edith Stratton. Reminiscences of Emerson Oliver Stratton as Told to His Daughter. Tucson, 1925.

41. Hayns, Judge Benjamin. Diary, Journey Overland from Socorro [N. Mex.] to Warner's Ranch [Calif.], from 1849 to 1850.

42. Parke, Lt. John G. Ex. Senate Doc. 91 H. 33rd Congress 2nd Session, Vol. 7, 1851.

43. Graham, Lt. Col. Report. Ex. Senate Doc. 121, 32nd Congress, 1st Session. Rept. Sec. War. 1852.

44. Bartlett, John Russell. Personal Narrative of Explorations and Incidents. Vol. 2. New York, 1854.

45. Noon, A. H. Before the Railroad. Chicago Tribune, 1879.

46. Hannum, A. P. A Quaker Forty-Niner. Philadelphia, 1930.

47. Bell, James G. A Log of the Texas-California Cattle Trail. Southwestern Historical Quarterly, Vol. 35, No. 4, 1932.

48. The Western Range. Senate Doc. 199, 74th Congress, 2nd Session.

49. Standage, Henry. Diary 1841-1846.

50. Data from Works Progress Administration, Tucson, Ariz. Unpublished.

51. Cooperrider, C. K. and Hendricks, B. A. Soil Erosion and Stream Flow on Range and Forest Lands of the Upper Rio Grande Watershed in Relation to Land Resources and Human Welfare. Tech. Bull. 567, U. S. Dept. Agr.

B. Maps of Watershed Available

85. Following is a list of maps that are available and will be found useful in making the survey and in preparation of the survey report. Their suitability for specific purposes is indicated by their titles:

Irrigated areas in Arizona by Counties. Prepared by Dept. of Agr. Econ. Univ. of Ariz. and Land Utilization Division, R. A., 1936.

Darton's Geological Map of Arizona, with report. 1923.

Darton's Topographic Map of Arizona. 1933.

Santa Cruz County, by Santa Cruz County Engineer.

Land Ownership Maps (detailed). Tucson.

San Carlos Irrigation Project Maps. Tucson.

Flowing Wells Irrigation District Maps. Tucson.

San Xavier Irrigation District Maps. Tucson.

Land Use Field Sheets of the Agr. Con. Program of A. A. A., U. S. Dept. Agr., 1937. Tucson and Phoenix.

State-wide Highway Planning Survey Maps of Santa Cruz, Pima, Pinal, and Maricopa Counties. Tucson and Phoenix.

U. S. G. S. Quadrangle Sheets.

Soil Survey of Nogales Area, U. S. Dept. Agr., Bureau of Chemistry and Soils, Ser. 1930, Rept. 6.

Soil Survey of Tucson Area, U. S. Dept. Agr., Bureau of Chemistry and Soils, Ser. 1931, No. 19.

Soil Survey of Casa Grande Area, U. S. Dept. Agr., Bureau of Chemistry and Soils. Unpublished.

Soil Survey of Middle Gila. Field Operations, Bur. Soils, 1917. Published 1920.

Soil Surveys of White Lands of San Carlos Project. Dept. Int., Indian Service.

Soil Surveys of Indian Lands. Dept. Int., Indian Service.

Conservation Surveys of Indian Lands in Progress by S.C.S.

Coronado National Forest Maps, Office, Tucson.
Base Maps showing forest areas
Type Maps (vegetation)
Management Maps

Aerial mosaics, S. C. S., Albuquerque, N. Mex.

Conservation Surveys, S. C. S., Albuquerque, N. Mex.

C. Federal and State Agencies Consulted

86. Agricultural Conservation Program of A. A. A. Office, Tucson.

U. S. District Engineers. Office, Los Angeles, Calif.

U. S. Geological Survey Office, Tucson, Arizona.

U. S. Indian Service Offices, Soils, Sacaton, Coolidge, Tucson, Arizona.

U. S. Weather Bureau Office, Phoenix, Arizona.

University of Arizona, Tucson, Arizona.

D. Organizations and Individuals Consulted

87. Mr. K. K. Henness, Pinal County Agricultural Agent, Casa Grande, Arizona.
Mr. C. B. Brown, Pima County Agricultural Agent, Tucson, Arizona.
Mr. H. A. Ireland, Agricultural Extension Agent, Gila and Maricopa Indian Reservations, Sacaton, Arizona.

Mr. A. H. Condron, Secretary, Chamber of Commerce, Nogales, Ariz.
Miss Doris Weston, Community Service Worker, U.S.D.A., Tucson.
Mr. F. Ellis Nielson, Farm Agent, San Xavier Reservation, Tucson.
Mr. Roy H. Wollam, Secretary, Chamber of Commerce, Tucson, Ariz.
Prof. G. E. P. Smith, Irrigation Engineer, University of Arizona.
Mr. H. W. Schwalen, Irrigation Engineer, University of Arizona.
Mr. Phil J. Martin, Jr., Supt., City Water Dept., Tucson, Ariz.
Leading residents of Santa Cruz watershed.

Public Hearings

88. A public hearing was held at Nogales, Arizona, September 21, 1937, before the U. S. District Engineer, War Department, in the matter of preliminary examination of Santa Cruz River and Sonoita Creek, Santa Cruz County, Arizona. A similar hearing was held at Casa Grande, Arizona, September 22, 1937, in the matter of preliminary examination of lower Santa Cruz River, Pinal County. Representatives of the Department of Agriculture attended both meetings, and local interests were well represented. The Tucson representative at the Nogales hearing, although in favor of "flood control whereby erosion may be stopped, destruction of highway bridges and much other property damage avoided", expressed disapproval of storage reservoirs in upper Santa Cruz, but favored detention dams.

Table 1.-Soils of Santa Cruz Watershed

Soils and percent of watershed	Origin of soil-forming materials	Color and texture: Topsoils	Color and texture: Subsoils	Vegetation cover (natural)	Slope location	Infiltration rate[1]	Dispersion ratio[1]	Erodibility[1]
Sierozem or Desert 56 percent	Granites Basalt Rhyolite Schist Limestone	Gray to light reddish brown Sandy loam Loam	Grayish to light reddish brown Sandy loam Heavy sandy loam Calcareous hardpan	Desert shrub Desert grass-shrub	Plainlike areas and gentle to rather steep slopes	Low to medium	Very high	High
Southern Brown 44 percent exclusive of Mexico part	Basalt Rhyolite Granites Limestone Shales Schist	Light grayish brown to dull reddish brown Sandy loam Loam Clay loam	Grayish brown to dull reddish brown Heavy loam Clay loam Clay	Woodland Grassland Semidesert grass-shrub	Gently rolling lands to steep slopes	Higher than desert soils	Medium to high	Medium to high

1/Conclusions by Joel E. Fletcher, Soil Conservation Service, based on erodibility investigations of some soils of the upper Gila watershed. 1937 - Unpublished ms.

Table 2.-Major Uses of Farm Lands, Distribution of Cropland Into Principal Crops, and Numbers of Livestock (1935) for Santa Cruz Watershed*

	1930	1935	1937
Approximate acreage in watershed	5,681,200	5,681,200	5,681,200
Approximate acreage in farm land	1,350,096	2,014,177	
Proportion of land in farms	(23.76%)	(35.45%)	
Acreage of farm land area in -**			
Cultivated -	98,081	102,266	
Cropland harvested	49,163	57,589	136,420
Irrigated cropland harvested***		52,437	
Crop failure	7,771	9,306	
Cropland idle or fallow	41,147	35,371	
Natural -	1,252,278	1,911,925	
Plowable pasture	9,256	16,449	
Woodland pasture	210,335	38,234	
Other pasture	995,582	1,817,208	
All other land in farms	37,105	40,034	
Acreage of cropland harvested in (selected crops)			
Soil-protecting crops		18,095	29,060
Alfalfa		10,257	16,560
Barley		3,394	7,180
Winter wheat		4,444	5,320
Non-Soil-Protecting Crops -		27,321	95,420
Corn for grain		1,049	1,820
Cotton		24,957	88,600
Sorghums for grain		1,315	5,000
Horses and mules--all ages		11,482	
Cattle and calves--all ages		110,599	
Cows and heifers milked during all or part of 1929, 1934		4,060	
Sheep and lambs on farms		3,783	
Chickens on hand over 3 months old		80,428	
Turkeys on hand over 3 months old		4,268	
Swine on farms, all ages		3,495	
Goats and kids of all ages		5,298	

*Approximations from Federal Farm Census, years 1930 and 1935. Estimates for year 1937 were compiled from reports and data from County Agricultural Agents of Pima and Pinal Counties, Dept. of Agricultural Engineering, Dept. of Agricultural Economics, and Arizona Agricultural Experiment Station of the University of Arizona. In 1937 the cropland of the Santa Cruz watershed was irrigated from waters of Gila River and tributaries (about 48%) and also of Santa Cruz River and tributaries (about 52%). Between 1930 and 1936, the number of farmers increased from about 1,600 to about 2,100, thus accounting possibly for the large increase in "other pasture" land.

**Acreage data are used instead of percentage of land in farms because the proportion of cultivated and natural lands to total acreage in the watershed is very small.

***Irrigated cropland harvested is included in "cropland harvested."

Table 3.-Trend in Number of Farms, All Land in Farms, Cropland Harvested, Specified Farm Values, Owner-Operated and Rented Farm Land, and Farm Tenancy in the Santa Cruz Watershed, Arizona
(Approximated from Federal Farm Census)

		1930	1935
Number of farms April 1, 1930, & Jan. 1, 1935		1,582	2,099
All land in farms	acres	1,350,096	2,014,177
Average per farm	"	8,534	9,596
Total cropland harvested, 1929 & 1934:			
Farms reporting	number		1,171
Acreage	acres	49,163	57,589
Average per farm	acres		49
Percentage of all farms	percent		55.7
Total irrigated cropland harvested in 1929 & 1934:			
Farms reporting	number		982
Acreage	acres		52,437
Average per farm	acres		53
Percentage of all farms	percent		46.8
Dry farm cropland harvested in 1929 & 1934:			
Acres	acres		
Percentage harvested	percent		
Specified farm values, 4/1/30 and 1/1/35:			
Farm land and buildings	$	20,143,431	18,086,893
Average per farm	$	12,732	8,617
Average per acre	$	15	9
All farm buildings	$	2,633,534	
Average per farm	$	1,665	
Farm machinery and implements	$	1,492,522	
Average per farm	$	943	
Owner-operated and rented farm land:			
Owner-operated farm land			
Acreage	acres		941,885
Percentage of all land in farms	percent		46.3
Rented farm land -			
Acreage	acres		1,094,355
Percentage of all land in farms	percent		53.7
Number and percentage of operators by tenure:			
Owners -			
White	number		861
Colored	number		569
Percentage of total	percent		68.2
Part Owners -			
White	number		157
Colored	number		5
Percentage of total	percent		7.7
Managers -			
White	number		63
Colored	number		10
Percentage of total	percent		3.5
Tenants and croppers -			
White	number		411
Colored	number		22
Percentage of total	percent		20.6

Table 4.-Land Ownership in the Santa Cruz Watershed

(Approximated from Land Ownership Maps of Arizona State Planning Board)

	Sq. Miles	Acres	Percent
Federal lands:			
National Forests	854.66	546,980	9.6
National Monuments	63.82	40,843	0.7
Indian Reservations	2,227.96	1,425,893	25.1
Public domain and other	1,019.62	652,558	11.5
Subtotal	4,166.06	2,666,274	46.9
State lands:	2,634.07	1,685,802	29.7
Private lands:	2,076.76	1,329,124	23.4
TOTAL	8,876.89	5,681,200	100.0

Table 5.-Annual Rainfall and Minimum and Maximum Fall on Santa Cruz Watershed[1]

Station	Elevation	Length of record	Average annual	Minimum[2] annual	Maximum annual
	Feet	Years	In.	In.	In.
1. Maricopa	1,186	61	8.12	0.38	14.04
2. Sacaton	1,280	29	9.60	5.43	16.75
3. Casa Grande	1,400	53	8.30	2.02	19.52
4. Florence	1,500	42	9.88	5.25	17.51
5. Red Rock	1,856	35	9.61	3.29	15.16
6. Indian Oasis	2,400	12	12.56	10.12	20.28
7. Tucson	2,423	70	11.28	5.26	24.17
8. Silver Bell	2,664	16	13.19	11.42	15.01
9. Vail	3,241	35	10.98	2.93	20.12
10. Pantano	3,538	22	12.37	3.35	18.84
11. Nogales	3,839	41	16.43	9.37	25.88
12. Santa Margarita	4,000	20	19.28	8.99	30.34
13. Fresnal School	4,000	15	18.50	10.93	26.86
14. Patagonia	4,044	16	18.05	13.37	26.45
15. Helvetia	4,300	22	19.70	12.79	38.21
16. Oracle	4,522	44	18.73	10.72	34.12
17. Rosemont	4,800	17	17.73	10.68	27.41
18. Elgin	4,900	25	15.85	9.87	25.77
19. Canille	5,225	26	19.82	10.89	30.92

1/Data for the four Desert Laboratory Stations are as follows: Baboquivari, El. 3,675, 5 yr., summer 12.5 in. winter 6.0 in., av. annual 18.3. Sierrita Mts., El. 4,100, 9 yr., summer 10.5 in., winter 5 in., av. annual 16.9. Avra Valley, El. 2,400, 10 yr., winter 6.05 in., summer 3.55 in., av. annual 9.6 in. Soldiers' Camp, El. 7,875, 11 yr., summer 18.37 in., winter 15.8 in., av. annual 34.2 in.

2/Minimum and maximum are for lowest and highest year.

Table 6.-Discharge of Streams of Santa Cruz Watershed

Areas, station, and drainage	Size of drainage area	Period of record	Average annual discharge	Monthly surface flow 2/ Minimum	Monthly surface flow 2/ Maximum	Highest peak flow 2/
	Sq.Miles	Yr.	Acre-Ft.	Acre-Ft.	Acre-Ft.	Sec.-Ft.
Area 1 Station A 1/ Upper Santa Cruz, including Mexico part	473	24	19,268	0.00 Not uncommon	17,800 Aug. 1931	14,000 Aug. 31, 1935
Area 4 Station B Sonoita Creek	Less than 242	8	7,727	0.2 Aug.1933 Aug.1935	4,710 3/	20,000 Aug. 1934
Areas 1, 2, and 4 Station C Santa Cruz above Tucson	2,080	32	16,397	0.00 Common	54,900 Dec. 1914	11,400 Sept.28, 1936
Station D Sabino Canyon	37	7	5,590	0.00 Oct-Dec. 1936	3,810 Feb. 1935	700 July 15, 1932
Areas 5 and 6 Station E Rillito-Pantano-Cienega	Less than 911	23	20,645	0.00 Common	107,000 Dec. 1924	24,000 4/ Sept.23, 1929

1/For location of stations, see map 10.
2/During the length of period indicated.
3/During period of no record (Dec. 1933 to June 1935); determined from highwater marks.
4/Estimated.

Table 7.—Discharge of Santa Cruz River at Tucson
(Drainage area, 2,080 miles)

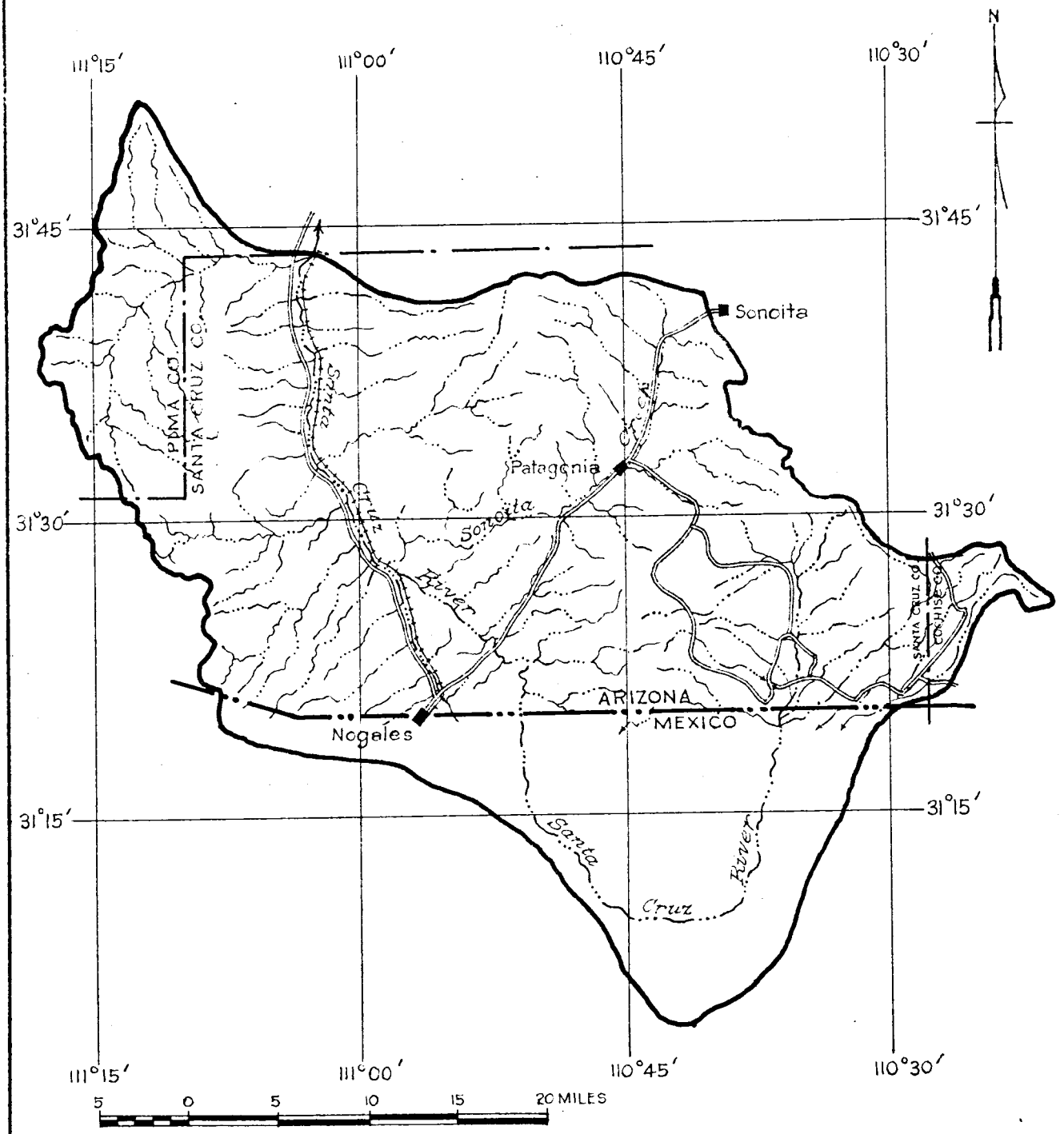
Year[1]	Annual (A.-ft.)	By months in acre-feet											
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1905-06	27,000	--	12,800	2,190	615	9,320	2,080	0	0	0	0	0	0
1906-07	2,640	0	0	2,640	0	0	0	0	0	0	0	0	0
1907-08	12,480	0	0	0	130	1,750	130	90	0	0	8,100	2,280	0
1908-09	15,340	0	0	78	120	140	130	230	50	0	5,820	7,510	1,260
1909-10	5,940	200	160	200	0	28	143	0	70	0	4,441	690	8
1910-11		*95	*0	*242	--	--	--	--	--	--	--	--	--
1911-12		--	--	--	*0	*0	*0	*0	*0	--	--	--	--
1912-13	2,810	129	300	606	775	655	85	0	0	0	0	193	67
1913-14	1,820	0	18	18	0	4	18	0	0	40	762	960	0
1914-15	80,160	170	360	54,900	10,400	11,200	3,070	4	0	0	60	0	0
1915-16	37,300	0	0	0	24,500	587	0	0	0	0	2,700	8,180	1,330
1916-17	28,430	141	0	0	0	0	0	0	0	0	8,550	10,400	9,340
1917-18	4,940	0	0	0	0	33	12	0	0	77	224	4,590	0
1918-19	27,520	25	0	80	0	0	0	0	0	0	15,400	9,840	2,170
1919-20	7,920	0	464	473	3,760	242	0	0	0	12	455	1,830	684
1920-21	32,000	0	0	0	0	0	0	0	0	0	5,200	23,600	3,200
1921-22	10,860	0	0	0	412	0	0	0	0	0	4,060	5,520	863
1922-23	15,680	0	0	0	0	0	0	0	0	0	4,360	11,300	18
1923-24	3,700	0	2,180	546	248	0	337	103	0	0	286	0	0
1924-25	6,940	0	0	0	0	0	0	0	0	30	1,730	2,700	2,480
1925-26	20,220	92	369	16	71	2	31	60	0	0	228	750	18,600
1926-27	3,140	221	107	203	16	10	0	0	0	0	274	1,190	1,120
1927-28	2,920	0	0	0	0	52	0	0	0	0	406	2,210	250
1928-29	24,300	0	0	0	0	0	0	0	0	0	4,800	8,500	11,000
1929-30	8,080	0	0	0	0	60	1,290	0	65	1,350	2,080	3,020	210
1930-31	15,670	0	2	2	2	4,600	0	0	143	60	5,440	2,400	3,020
1931-32	14,740	4	1,320	0	3,620	0	0	0	0	0	6,740	3,050	0
1932-33	7,300	294	0	0	0	6	0	0	0	0	920	1,560	4,520
1933-34	7,570	202	2	0	20	16	0	0	0	0	536	6,540	250
1934-35	20,440	0	0	83	422	331	32	0	0	0	1,210	8,250	10,110
1935-36	8,760	0	597	149	54	131	0	0	0	0	3,720	3,310	801
1936-37[2]	8,260	0	0	0	2	0	0	0	0	0	1,760	5,400	1,100
Average	15,490	51	620	2,073	1,505	970	245	16	11	52	3,009	4,525	2,413

1/Records prior to 1926 were taken by the Univ. of Ariz.
2/1937 record subject to correction by U.S.G.S.
* Not included in yearly total nor in monthly average.
--No record taken

Table 8.-Component Subdrainages of Santa Cruz Watershed and Gradient of Streams

Subdrainage area	Length	Average width	Area	Main stream course: Thalweg length	Main stream course: Total fall	Main stream course: Av. fall per mile
	Miles	Miles	Sq.miles	Miles	Ft.	Ft.
1. Santa Cruz above Intake damsite, including part in Mexico	25	20	543	66.0	1,804	27.0
2. Santa Cruz above Tucson	65	20	1,396	85.0	1,148	13.5
3. Santa Cruz below Tucson	80	18	1,575	89.0	820	9.0
4. Sonoita Creek	15	15	242	24.0	1,148	48.0
5. Cienega Creek	30	12	406	33.0	1,650	50.0
6. Rillito-Pantano	30	16	506	42.0	2,132	51.0
7. Canada del Oro	24	10	260	31.5	1,804	57.0
8. McClellan Wash	30	15	449	27.0	1,312	49.0
9. Avra-Altar	80	18	1,420	87.0	2,132	24.5
10. Greens Reservoir	15	7	116	15.0	200	13.0
11. Santa Rosa, east branch	50	16	808	54.0	980	18.0
12. Santa Rosa	72	19	1,357	87.0	1,300	15.0
13. Santa Rosa, west branch	36	9	330	42.0	1,050	25.0

SANTA CRUZ RIVER & SONOITA CREEK DRAINAGE
SANTA CRUZ COUNTY ARIZONA



U.S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149-150-151 MAP NO. 1

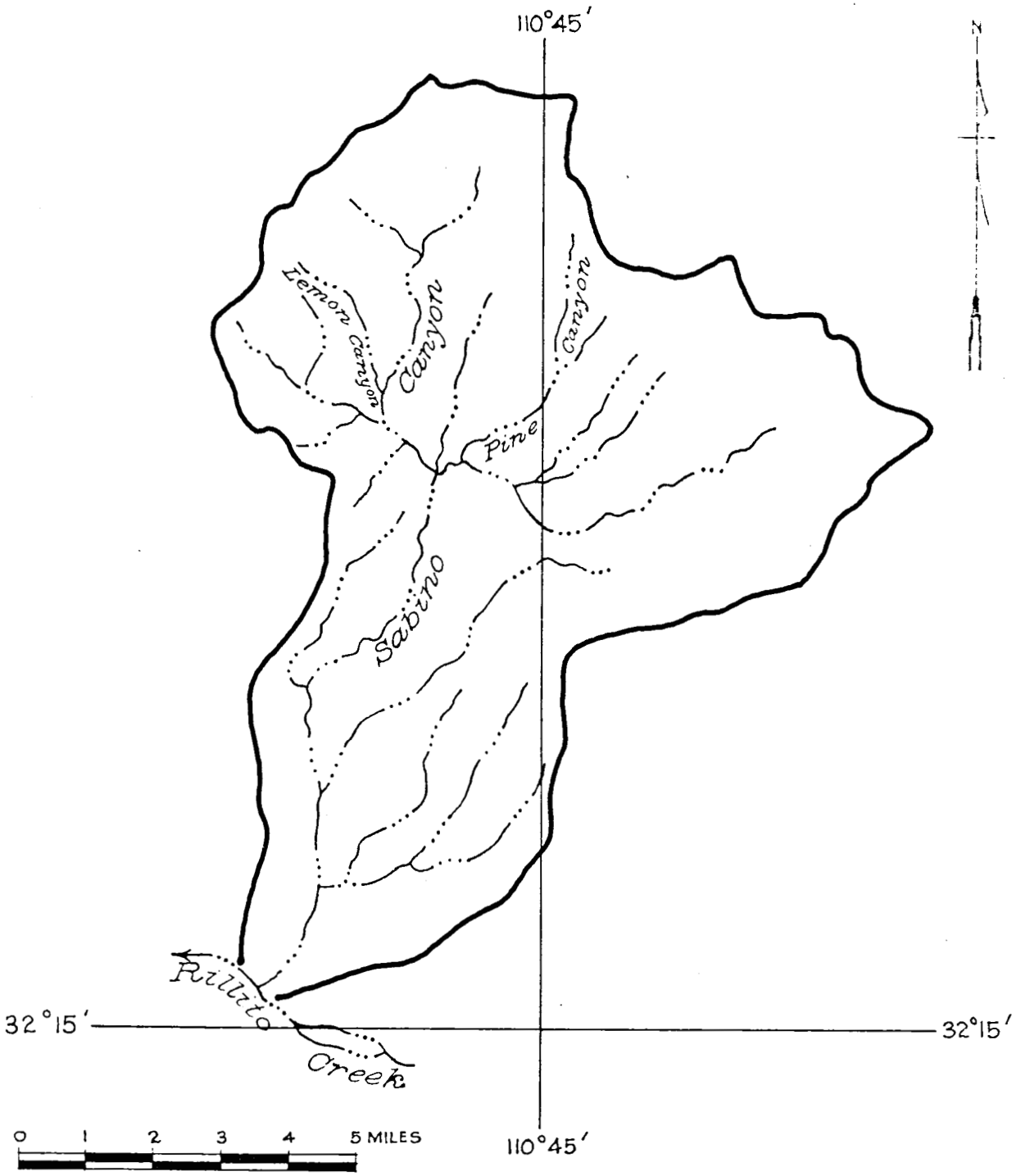
SOURCE OF DATA U.S.G.S. Maps

COMPILED BY Glenn Kiff DATE 2-10-38

BUREAU S.C.S.

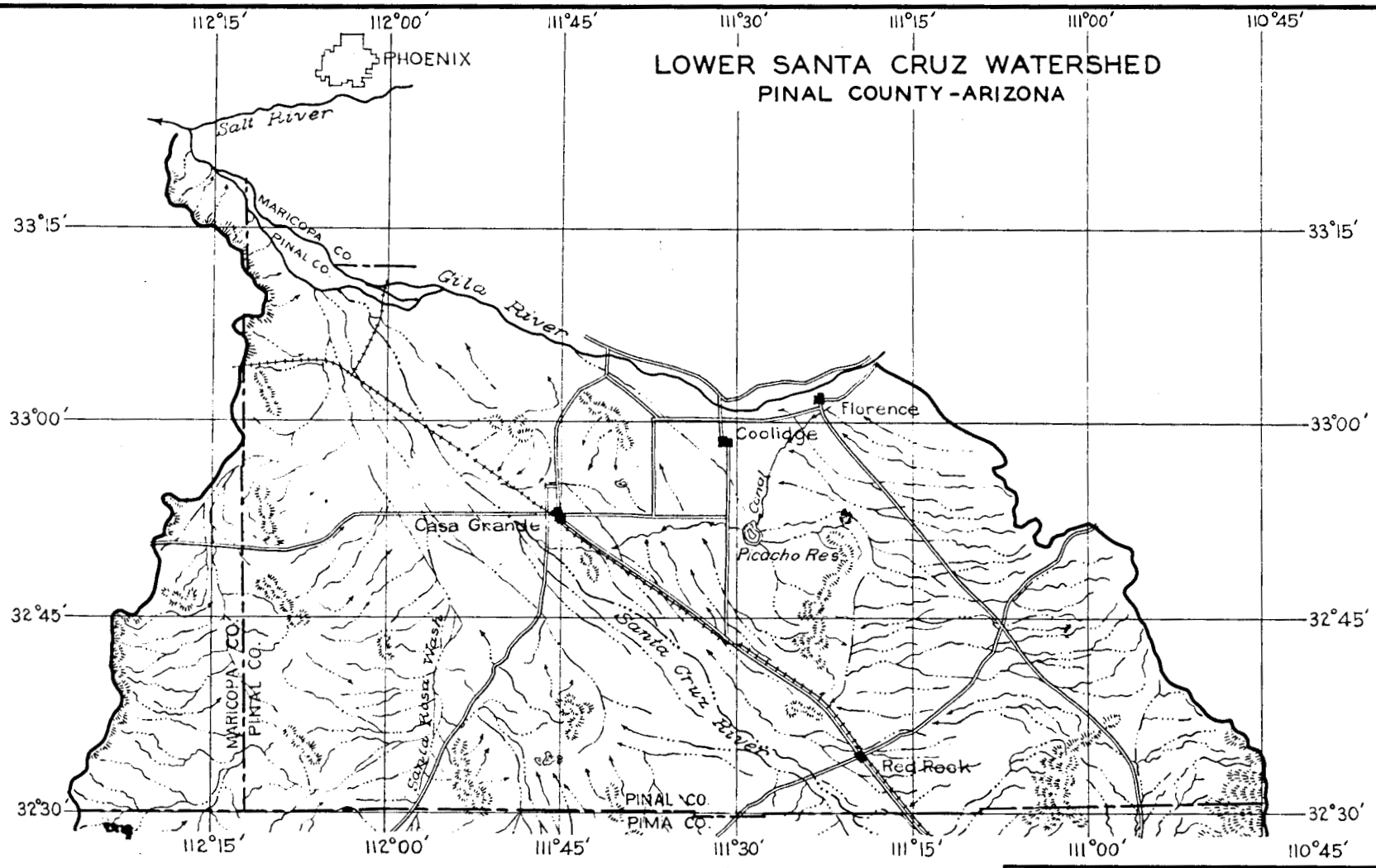
APPROVED H.G.Calkins BUREAU S.C.S.

SABINO CANYON
PINAL COUNTY - ARIZONA



U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149-150-151 MAP NO. 2
SOURCE OF DATA U.S.G.S. Maps
COMPILED BY Glenn Kiff DATE 2-10-38
BUREAU S.C.S.
APPROVED H.G.Calkins BUREAU S.C.S.



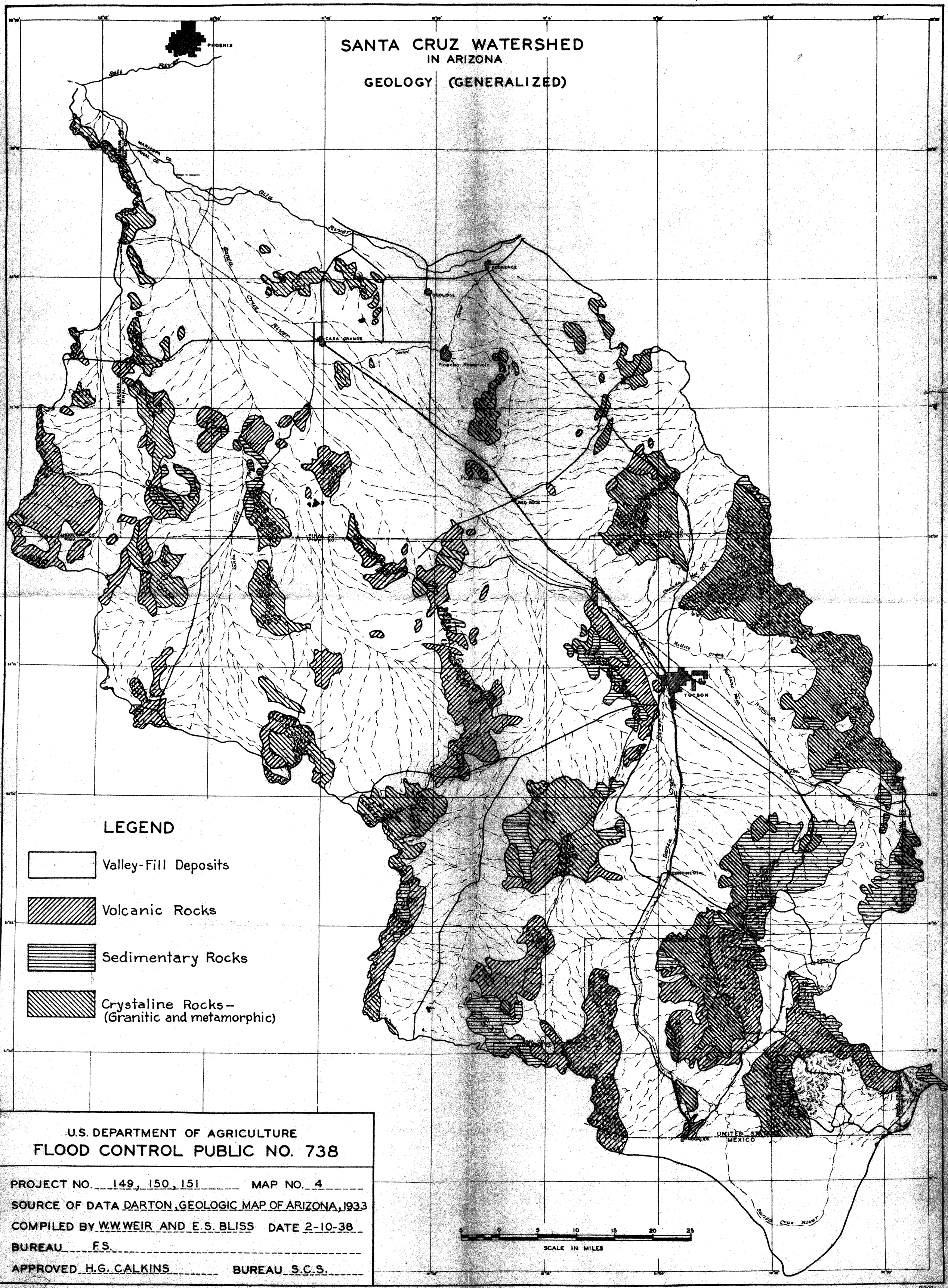
Scale
10 5 0 5 10 15 20 MILES

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149-150-151 MAP NO. 3
SOURCE OF DATA U.S.G.S. Maps
COMPILED BY Glenn Kiff DATE 2-10-38
BUREAU S.C.S.
APPROVED H.G. Calkins BUREAU S.C.S.

L-1047

SANTA CRUZ WATERSHED
IN ARIZONA
GEOLOGY (GENERALIZED)



U.S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 4

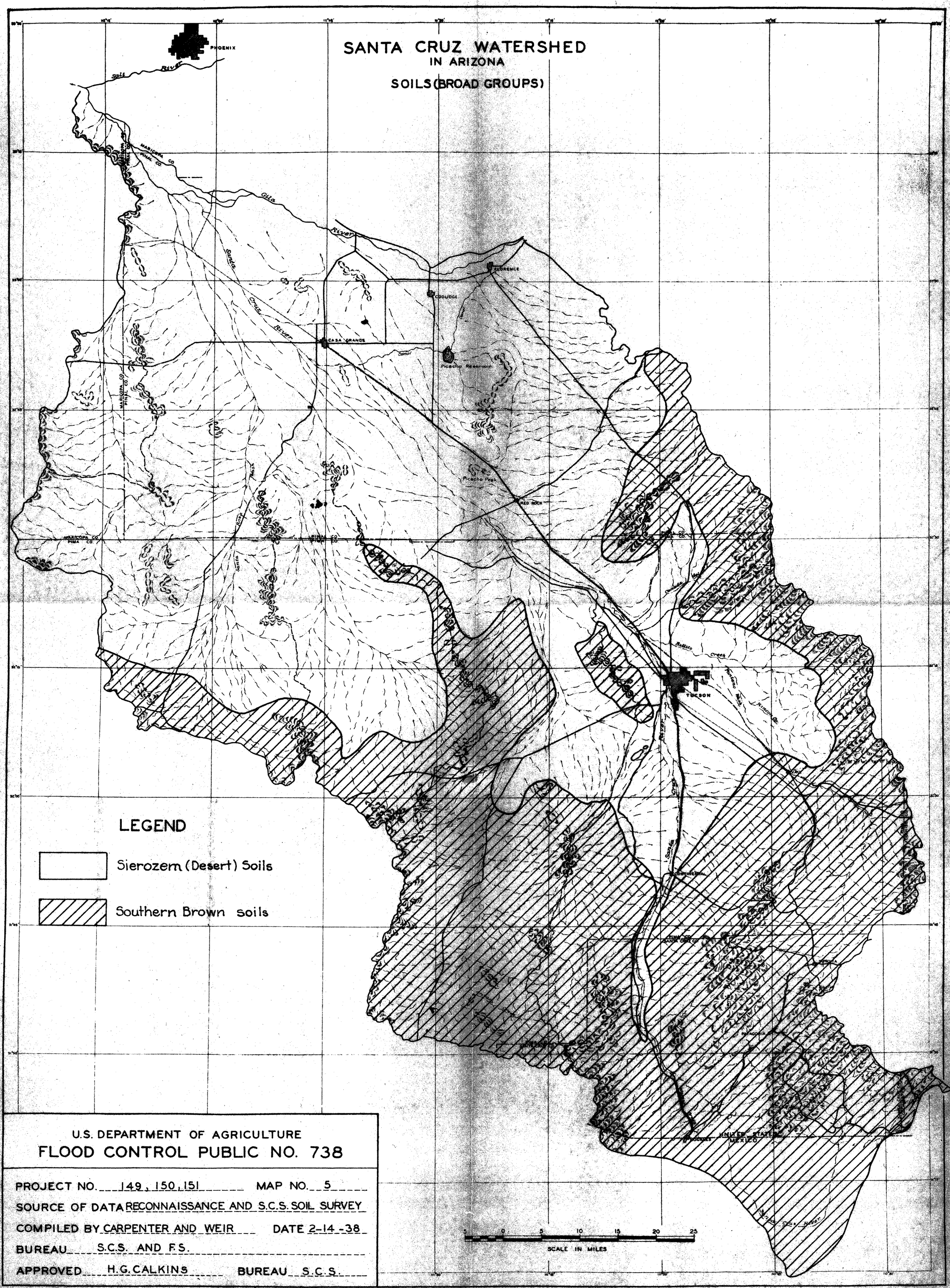
SOURCE OF DATA DARTON, GEOLOGIC MAP OF ARIZONA, 1933

COMPILED BY W.W. WEIR AND E.S. BLISS DATE 2-10-38

BUREAU F.S.

APPROVED H.G. CALKINS BUREAU S.C.S.

R998



U.S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 5

SOURCE OF DATA RECONNAISSANCE AND S.C.S. SOIL SURVEY

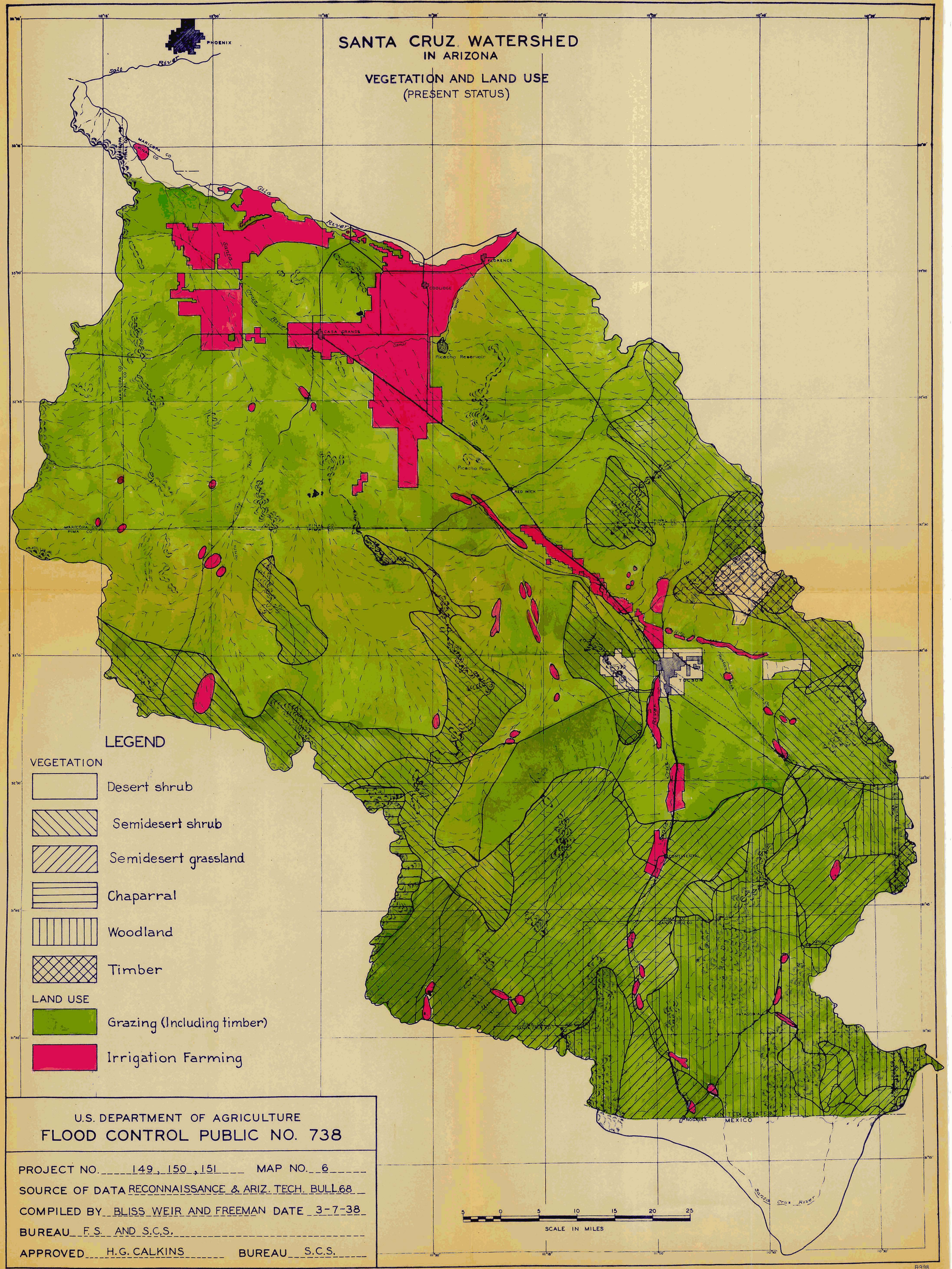
COMPILED BY CARPENTER AND WEIR DATE 2-14-38

BUREAU S.C.S. AND F.S.

APPROVED H.G. CALKINS BUREAU S.C.S.

SANTA CRUZ WATERSHED
IN ARIZONA

VEGETATION AND LAND USE
(PRESENT STATUS)

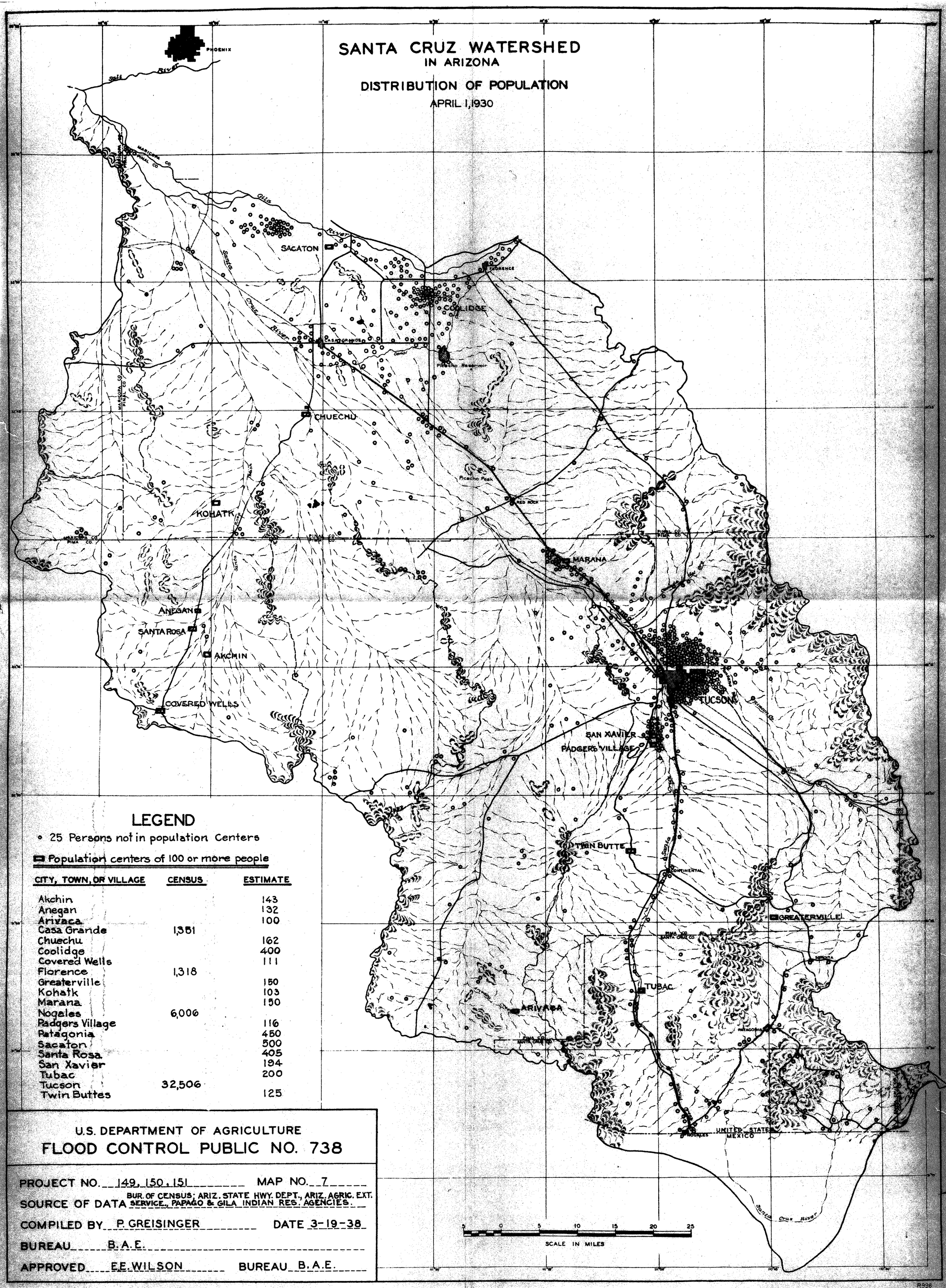


U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 6
SOURCE OF DATA RECONNAISSANCE & ARIZ. TECH. BULL. 68
COMPILED BY BLISS WEIR AND FREEMAN DATE 3-7-38
BUREAU F.S. AND S.C.S.
APPROVED H.G. CALKINS BUREAU S.C.S.

R998

SANTA CRUZ WATERSHED
IN ARIZONA
DISTRIBUTION OF POPULATION
APRIL 1, 1930



LEGEND

• 25 Persons not in population Centers

▭ Population centers of 100 or more people

CITY, TOWN, OR VILLAGE	CENSUS	ESTIMATE
Akchin		143
Anegan		132
Arivaca		100
Casa Grande	1,351	
Chuechu		162
Coolidge		400
Covered Wells		111
Florence	1,318	
Greaterville		150
Kohatk		103
Marana		150
Nogales	6,006	
Padgers Village		116
Patagonia		450
Sacaton		500
Santa Rosa		405
San Xavier		194
Tubac		200
Tucson	32,506	
Twin Buttes		125

U.S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 7

SOURCE OF DATA BUR. OF CENSUS; ARIZ. STATE HWY. DEPT., ARIZ. AGRIC. EXT. SERVICE, PAPAGO & GILA INDIAN RES. AGENCIES.

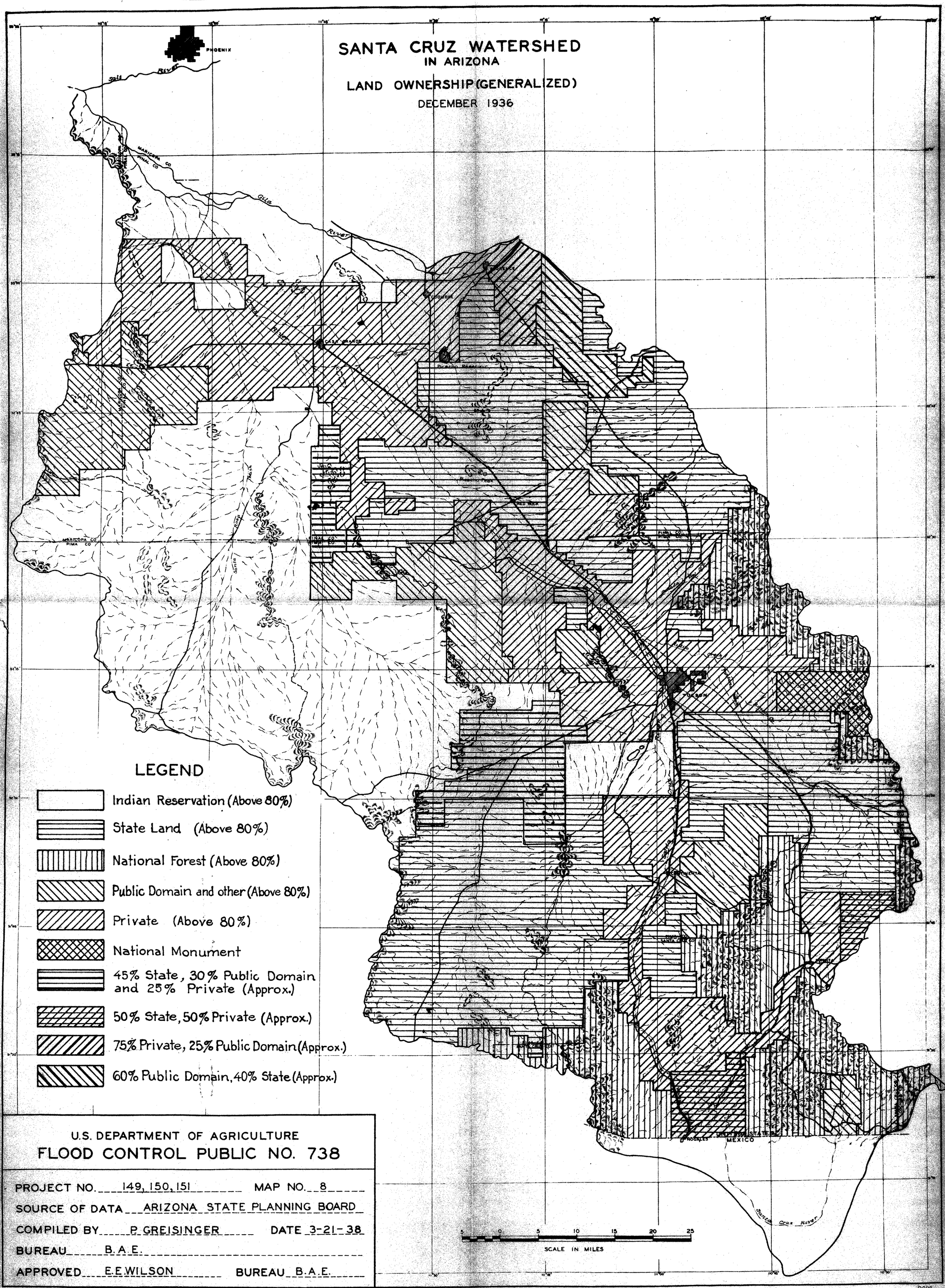
COMPILED BY P. GREISINGER DATE 3-19-38

BUREAU B.A.E.

APPROVED E.E. WILSON BUREAU B.A.E.

R998

SANTA CRUZ WATERSHED
IN ARIZONA
LAND OWNERSHIP (GENERALIZED)
DECEMBER 1936



U.S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 8

SOURCE OF DATA ARIZONA STATE PLANNING BOARD

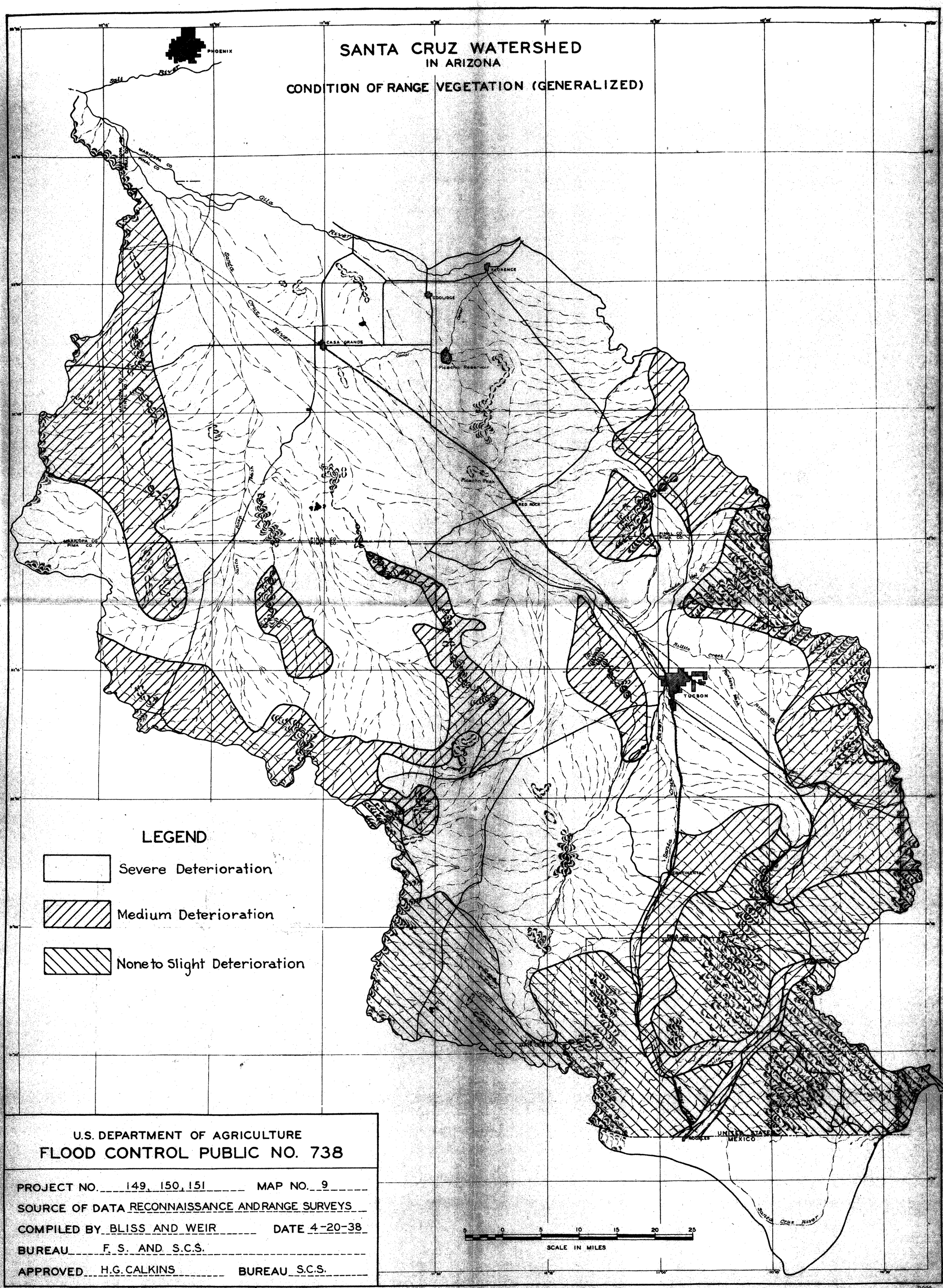
COMPILED BY P. GREISINGER DATE 3-21-38

BUREAU B.A.E.

APPROVED E.E. WILSON BUREAU B.A.E.

R998

SANTA CRUZ WATERSHED
IN ARIZONA
CONDITION OF RANGE VEGETATION (GENERALIZED)



U.S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 9

SOURCE OF DATA RECONNAISSANCE AND RANGE SURVEYS

COMPILED BY BLISS AND WEIR DATE 4-20-38

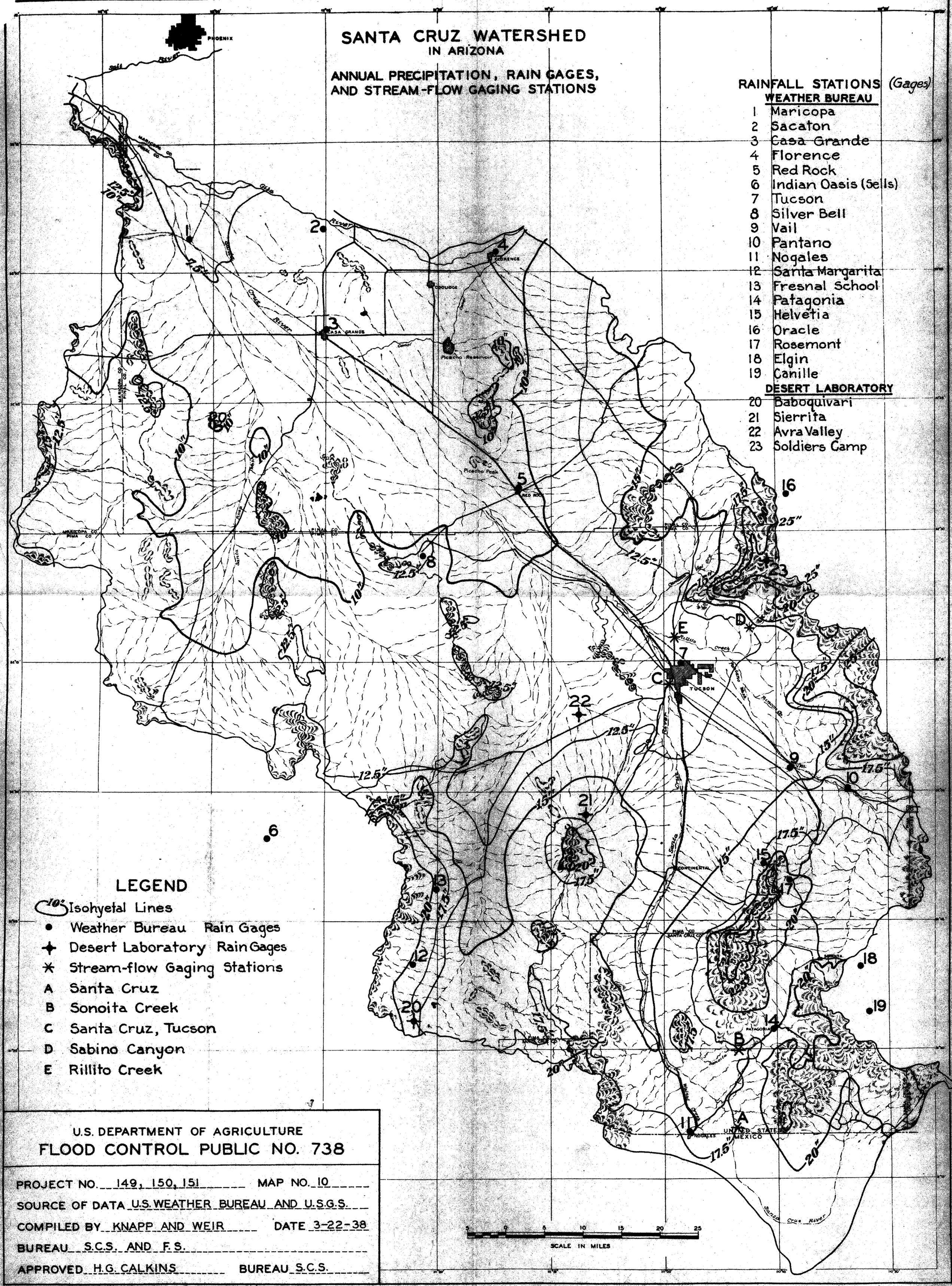
BUREAU F. S. AND S.C.S.

APPROVED H.G. CALKINS BUREAU S.C.S.

R998

SANTA CRUZ WATERSHED
IN ARIZONA

ANNUAL PRECIPITATION, RAIN GAGES, AND STREAM-FLOW GAGING STATIONS



U.S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 10

SOURCE OF DATA U.S. WEATHER BUREAU AND U.S.G.S.

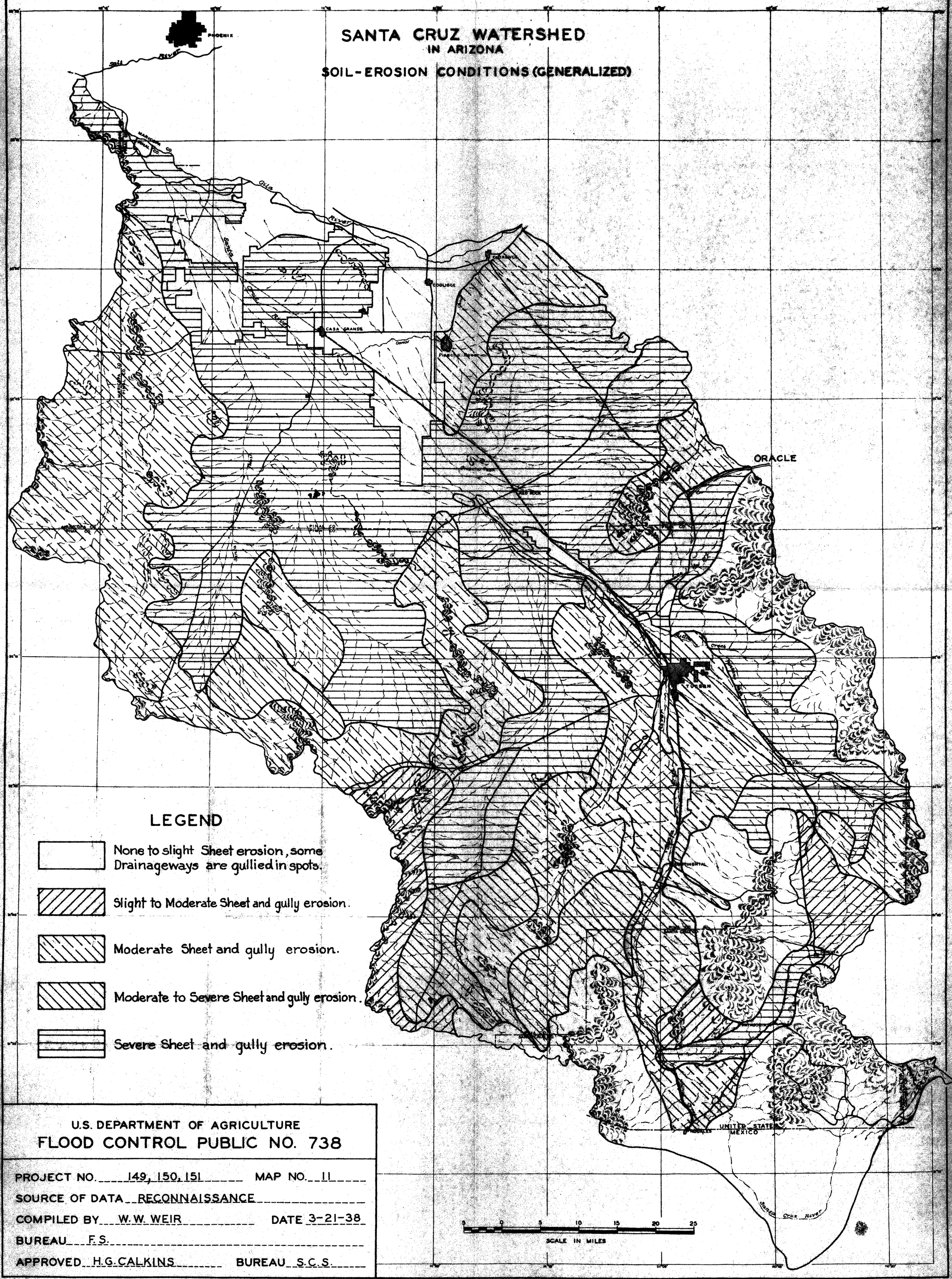
COMPILED BY KNAPP AND WEIR DATE 3-22-38

BUREAU S.C.S. AND F.S.

APPROVED H.G. CALKINS BUREAU S.C.S.

R998

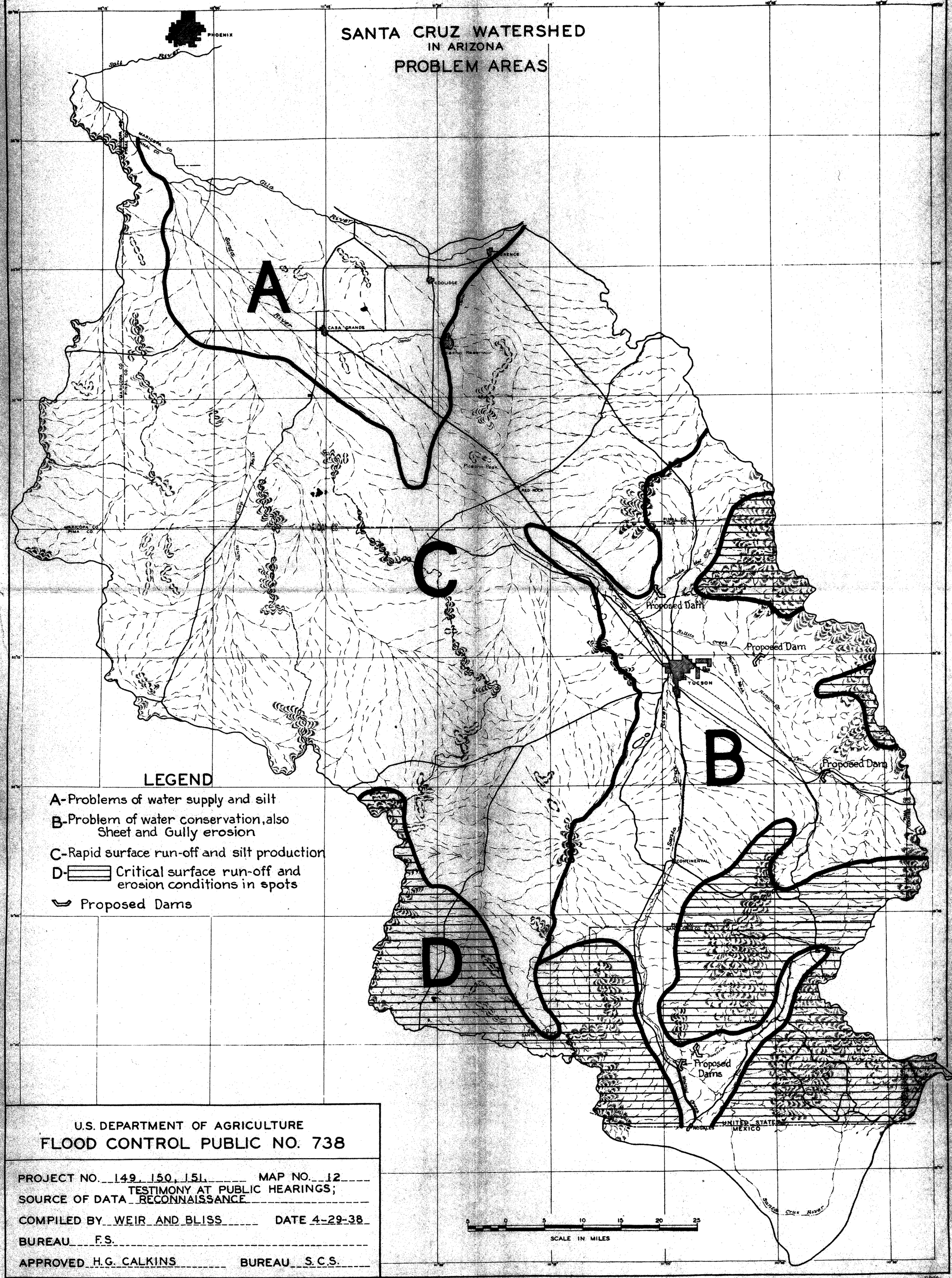
SANTA CRUZ WATERSHED
IN ARIZONA
SOIL-EROSION CONDITIONS (GENERALIZED)



U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 11
SOURCE OF DATA RECONNAISSANCE
COMPILED BY W.W. WEIR DATE 3-21-38
BUREAU F.S.
APPROVED H.G. CALKINS BUREAU S.C.S.

SANTA CRUZ WATERSHED
IN ARIZONA
PROBLEM AREAS



U.S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

PROJECT NO. 149, 150, 151 MAP NO. 12

SOURCE OF DATA TESTIMONY AT PUBLIC HEARINGS; RECONNAISSANCE

COMPILED BY WEIR AND BLISS DATE 4-29-38

BUREAU F.S.

APPROVED H.G. CALKINS BUREAU S.C.S.