PRELIMINARY
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HASSAYAMPA PROJECT
ARIZONA

Project Planning Report No. 3-8b.1-2

Febr. 1948

BUREAU OF RECLAMATION

US INTERIOR DEPARTMENT

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary

BUREAU OF RECLAMATION
Michael W. Straus, Commissioner
E. A. Moritz, Regional Director, Region 3

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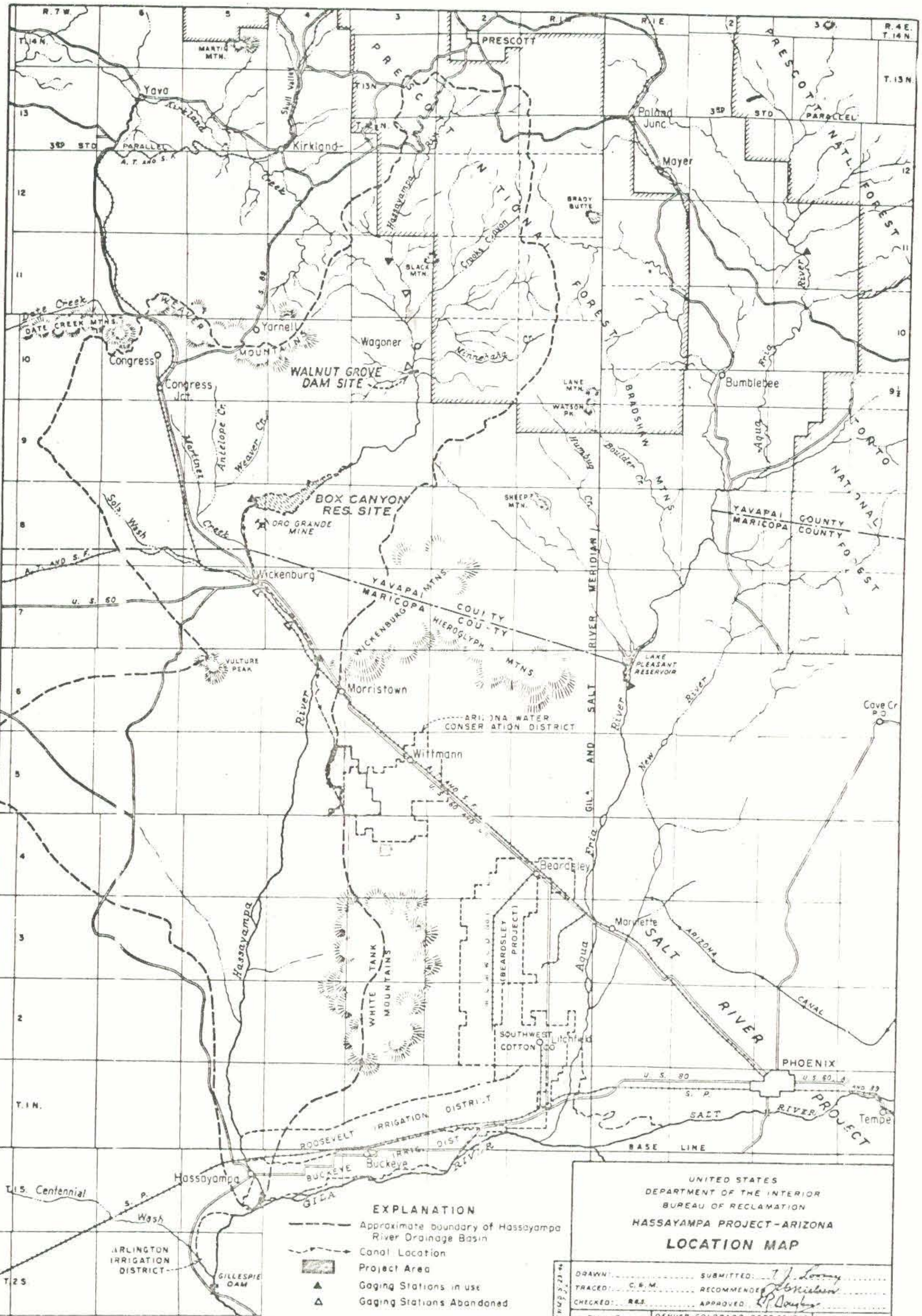

PRESCOTT
PRESCOTT NATL FOREST
NATIONAL FOREST
TONTO NATIONAL FOREST
Yava
Kirkland
Kirkland Creek
Skull Valley
Hassayampa River
Poland Junc
Mayer
Brady Butte
Black Mtn.
Crooks Canyon
Yarnell
WEAVER MOUNTAINS
DATE CREEK MTNS.
Date Creek
Congress
Congress Jct.
Wagoner
WALNUT GROVE DAM SITE
Minnehaha Cr.
Lane Mtn.
Watson Pk.
Bumblebee
BRADSHAW MTNS
Humbug Cr.
Boulder Cr.
Agua Fria River
Martinez Creek
Antelope Cr.
Weaver Cr.
BOX CANYON RES. SITE
ORO GRANDE MINE
Sols Wash
Sheep Mtn.
YAVAPAI COUNTY
MARICOPA COUNTY
Wickenburg
U.S. 60
U.S. 89
A.T. AND S.F.
WICKENBURG MTNS
HIEROGLYPH MTNS
GILA AND SALT RIVER MERIDIAN
Vulture Peak
Lake Pleasant Reservoir
New River
Cave Cr P.O.
Morristown
ARIZONA WATER CONSERVATION DISTRICT
Wittmann
Beardsley
BEARDSLEY PROJECT
Marinette
SALT RIVER
ARIZONA CANAL
WHITE TANK MOUNTAINS
SOUTHWEST COTTON CO
Litchfield
PHOENIX
Tempe
SALT RIVER PROJECT
BASE LINE
ROOSEVELT IRRIGATION DISTRICT
BUCKEYE IRRIG. DIST
Buckeye
GILA RIVER
Hassayampa
Centennial Wash
S. P.
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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
LOCATION MAP
DRAWN:
SUBMITTED:
TRACED: C.E.M.
RECOMMENDED:
CHECKED:
APPROVED:
3H-1-2
DENVER, COLORADO, SEPT. 25, 1942
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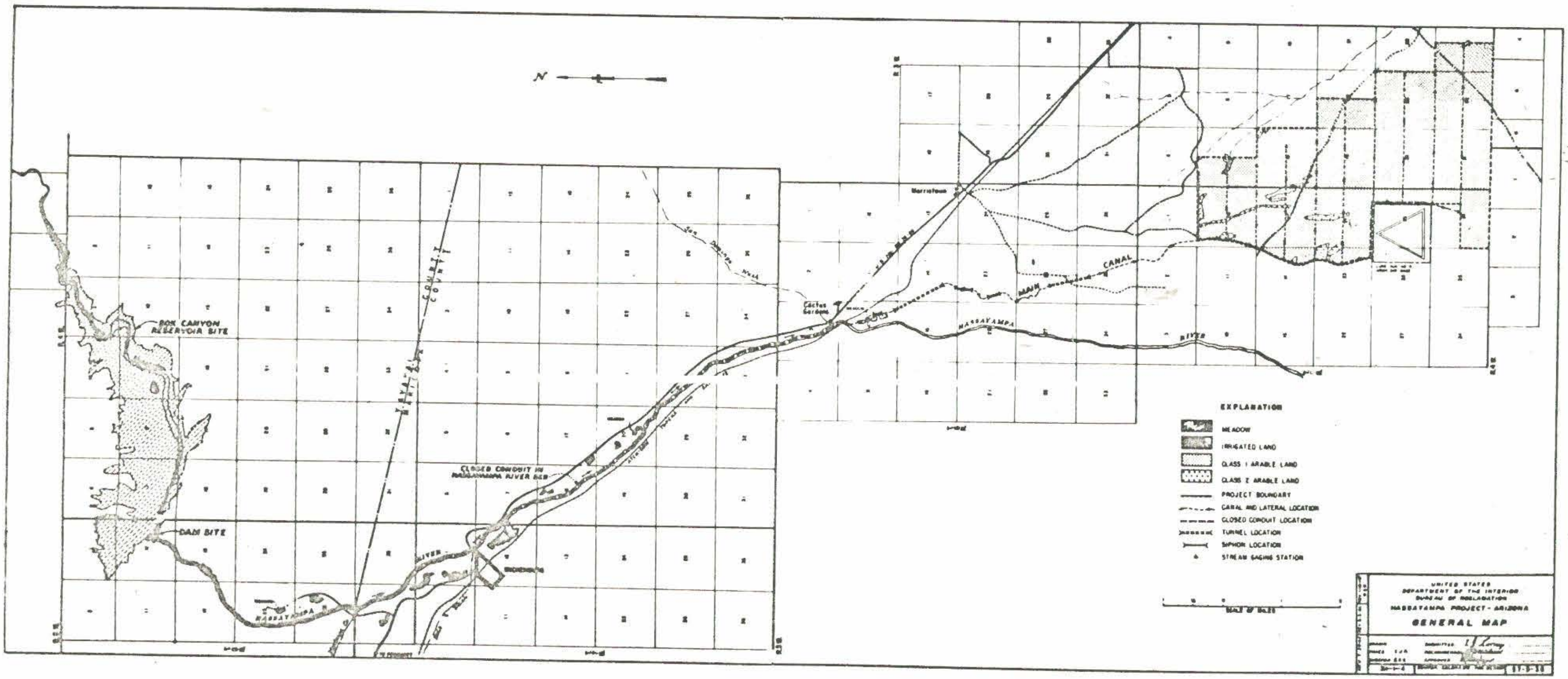
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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT - ARIZONA
GENERAL MAP

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
Region 3
Boulder City, Nevada.

To: Commissioner, Bureau of Reclamation

From: Regional Director

Subject: Plan for the Hassayampa Project, Arizona.

Transmittal

1. A plan for the development of the water resources of the Hassayampa River in Maricopa and Yavapai Counties, Arizona, is presented herein. The plan for the Hassayampa Project comprises development of Box Canyon Reservoir on the Hassayampa River, a main canal and distribution system to serve 7,000 acres of virgin land near Wittman, Arizona, and a domestic water supply system to serve the farmsteads and the project town. Benefits also will accrue from flood control, fish and wildlife conservation, and recreation.

Authority for the Report

2. This report is authorized to be made by virtue of the Federal Reclamation Laws (Act of June 17, 1902, 32 Stat. 388, and acts amendatory thereof or supplementary thereto).

Cooperation and Acknowledgments

3. Several agencies and private individuals have cooperated in the investigations leading to this report. The Los Angeles District Office of the Corps of Engineers, War Department, supplied

basic data on flood damages. The Fish and Wildlife Service, the National Park Service and the Geological Survey, of the Department of the Interior, cooperated by making surveys of fish and wildlife benefits, recreation benefits and underground water resources, respectively. Officials of the Office of the State Land Commissioner of Arizona, the Maricopa County Water Conservation District No. 1, the Buckeye Irrigation District, the Roosevelt Irrigation District, the Gillespie Land and Cattle Company, the Southwest Cotton Company, and the Salt River Valley Water Users' Association, supplied basic information from their records. Mr. Joseph W. Wittman placed his entire files on engineering investigations in the area at the disposal of the Bureau of Reclamation. Mr. W. H. Griffin of Wittmann, Arizona, gave generously of his time and supplied records of agencies preceding the Arizona Water Conservation District.

Description of the Area

4. The Hassayampa River heads in the Prescott National Forest a few miles south of Prescott, Arizona, in mountains which rise to elevations of about 8,000 feet. It flows south to join the Gila River about 37 miles west of Phoenix at an elevation of less than 900 feet above sea level. There has been little development in the Hassayampa River basin; only 470 acres are under irrigation and there are no storage developments for water conservation, flood control, hydroelectric power or other uses.

5. Lands proposed for irrigation on the Hassayampa Project are part of a desert plain lying east of the Hassayampa River near

Wittmann, Arizona, at an average elevation of 1,700 feet above sea level. These lands at present are used for range and as their carrying capacity is very low, they have a value of only about five dollars per acre. The project area is uninhabited.

6. The climate is similar to that of Phoenix, Arizona, except for slightly lower temperatures and a somewhat shorter growing season. The average temperature is 69 degrees and the average frost-free growing period is 285 days. Average annual precipitation is 9.85 inches.

Need for Development

7. Over 40,000 acres of inherently productive land near Wittmann are undeveloped for lack of irrigation water. Some of the land could be irrigated from the Hassayampa river, which has an average annual discharge of almost 46,000 acre-feet at Box Canyon. At present the flow of the river is largely dissipated into the river sands below the Box Canyon reservoir site. Application of this water to the optimum amount of land affords the best method of utilizing these undeveloped water and land resources.

Proposed Plan of Development

8. Development plans provide for the construction of an earth and rockfill dam on the Hassayampa River at the Box Canyon site about 6 miles north of Wickenburg, Arizona, 27 miles of main canal, a lateral system to serve a total net irrigable area of 7,000 acres near Wittmann, and a domestic water supply system to supply the project farms and a project town (possibly Wittmann). The total storage capacity of the reservoir would be 210,000 acre-feet, of which 190,000 acre-feet would be active storage for irrigation

purposes, 10,000 acre-feet would be reserved for flood control, and 10,000 acre-feet for silt deposition. Reservoir releases would be conveyed for the first 15 miles through a concrete pipeline to avoid excessive loss of water in the river channel. The remaining 12 miles would consist of clay-lined canal.

Multiple-purpose Aspects of Plan

9. Irrigation will be the primary purpose of the project, but it will also serve other purposes. Under the contemplated plan of operation for Box Canyon Reservoir, flood damages will be reduced, and fish and wildlife will be conserved. Municipal and farmstead water will be made available, and the area's recreational opportunities will be enhanced, through other project facilities.

Anticipated Agricultural Economy

10. Project lands are ideally suited for development under irrigation. Nearly 98 percent of the project area is Class 1 land, according to Bureau of Reclamation standards. The mild climate with a long growing season permits double cropping, and the distance to primary markets is not excessive. Crop yields are expected to equal, or even exceed those obtained in the Salt River Project and gross crop values should average about $116 an acre, based upon 1939-1944 prices.

Cost of Development

11. The cost of constructing the project, based on prices prevailing in April 1947, is estimated to be $13,079,000 of which the Bureau of Reclamation features will cost $12,900,000, and recreational facilities, as estimated by the National Park Service, will cost $179,000. Estimated construction costs are itemized

as follows:

Box Canyon Dam and Reservoir	$ 7,500,000
Main Canal	4,700,000
Lateral System	180,000
Investigations and Surveys	80,000
Operation and Maintenance during construction	70,000
Municipal and Farmstead Water System	370,000
Subtotal - Bureau of Reclamation Features	$12,900,000
Recreation Facilities	179,000
Total Construction Cost	$13,079,000

Operation and Maintenance Costs

12. Annual operation and maintenance costs are expected to average $35,400 for irrigation and farmstead water, $7,400 for municipal water, and $13,800 for recreation or a total of $56,600.

Allocation of Construction Costs

13. Allocations of nonreimbursable costs are based on the value of benefits that will accrue over the 50-year repayment period; however, benefits will accrue throughout the life of the project. The flood control benefits of $11,900 annually for 50 years, with interest at 3 percent, have a present value of $306,000. This amount would be required to purchase an annual income equal to the annual flood control benefits, and therefore is the amount of investment warranted by the anticipated annual flood control benefits. The present value of $28,200 of annual recreation benefits is $725,000, and of $18,000 annual fish and wildlife benefits is $463,000, making a total of $1,494,000 allocated to nonreimbursable features.

14. Reimbursable costs are allocated on the premise that the cost incurred in constructing works for a reimbursable feature should be chargeable to that feature. The cost of constructing works for municipal water has been estimated at $185,000, and this amount is allocated thereto. Since irrigation, including farmstead water supply, is the only remaining function served by the project, the balance of the total of $13,079,000, which amounts to $11,400,000, is allocated to irrigation and farmstead water. The total amount of reimbursable construction cost, then, is $11,585,000.

Repayment Ability

15. Reimbursable construction costs are charged to municipal water and to irrigation, including farmstead water. It is anticipated that the cost of $185,000 for providing the municipal supply will be secured by a repayment contract before construction, and that it will be repaid in full. The repayment ability of the irrigators was determined by preparing 12 farm budgets, using as a guide the reported cropping systems, yields and prices on the Salt River Project during the period 1939-44. These studies indicated that the irrigators could reasonably be expected to repay $10.50 per acre a year on construction, which amounts to $73,500 annually for a 7,000 acre project, and to $2,940,000 during the usual 40-year interest-free repayment period. The total expected repayment is thus placed at $3,125,000.

Comparison of Costs and Repayment

16. A total repayment of $3,125,000 on the reimbursable construction costs of $11,585,000 indicates a repayment of 27 percent.

Comparison of Benefits and Costs

17. Overall annual benefits are determined as follows: Irrigation and farmstead-water benefits are measured by the increase in gross crop value and the sale value of domestic water, the total is $826,600; the benefit of $14,600 for municipal water represents the sale value of the water; the benefit to flood control is the reduction of flood damages due to project construction, which is $11,900; the benefit to recreation, $28,200, and to fish and wildlife conservation, $18,000, represents the monetary value assignable to project development. Annual monetary benefits total $899,300.

18. Annual costs include the cost of operating and maintaining the project works, estimated at $56,600; and the cost of amortizing the entire investment in 50 years at 3 percent interest, which is $501,400 for the Bureau of Reclamation features and $7,000 for the National Park Service features. Total annual costs, therefore, are $565,000.

19. A comparison of overall benefits and costs shows that for each dollar expended for the project the nation will receive $1.59 of monetary benefits. In addition, numerous intangible benefits would be realized.

Relationship of Area to Colorado River Basin

20. The Hassayampa Project is in the "Lower Basin" of the Colorado River and is one of 134 potential projects presented for consideration by the affected States in the report, "The Colorado River", issued by the Secretary of the Interior in March 1946.

Pertinent excerpts from the recommendations contained in that report follow:

> "The following recommendations are made in view of the fact that there is not enough water available in the Colorado River system to permit construction of all the potential projects outlined in the report and for full expansion of existing and authorized projects, and that there has not been a final determination of the respective rights of the Colorado River Basin States to deplete the flow of the Colorado River;
>
> (1) That the States of the Colorado River Basin acting separately or jointly, recommend for construction, as the next stage of development, a group of projects the stream flow depletions of which will assuredly fall within ultimate allocations of Colorado River water which may be made to the individual States.
>
> (2) That the States of the Colorado River Basin determine their respective rights to deplete the flow of the Colorado River consistent with the Colorado River Compact."

21. Possible depletion of inflow to the Colorado River through construction of the Hassayampa Project has not been determined. It has been determined, however, that the annual consumptive use of lands irrigated by the project would be about 22,700 acre-feet and that the annual evaporation loss from Box Canyon Reservoir would average about 8,200 acre-feet.

Conclusions

22. Construction of Box Canyon Reservoir and related features would make it possible to irrigate 7,000 acres of virgin land near Wittmann, Arizona. The land is well adapted to irrigation development; almost 98 percent of the project area is Class 1 land and the favorable climate allows a long growing season. Excellent crop yields are anticipated and the farmers' repayment ability would be

relatively high. Unfortunately, because of the necessity of providing carry-over storage for extended drouth periods and of conveying water over the difficult terrain between the dam and the project area, the cost of development per acre is exceedingly high. Repayment studies indicate that the irrigators will not be able to repay all of the costs allocated to irrigation and farmstead water.

23. The plan proposed herein has engineering feasibility, in the sense that there are no insuperable physical obstacles to its construction. From the national viewpoint, the plan has economic feasibility as $1.59 in benefits would accrue for each dollar of cost. From a financial repayment viewpoint, however, the project is not attractive because only 27 percent of the reimbursable construction costs can be repaid.

Recommendations

24. It is recommended that:

(1) Construction of the Hassayampa Project for irrigation, flood control, domestic and municipal water supply, recreation, and fish and wildlife propagation be not authorized at this time;

(2) Further consideration of authorization be deferred until such time as the economic need of the Nation, lower construction costs, further information on the project, or other developments may justify such reconsideration; and,

(3) The operation of the gaging stations at Box Canyon and Morristown be continued by the Geological Survey.

--- E. A. Moritz

E. A. Moritz,
Regional Director, Region 3,
Bureau of Reclamation.

PRESENT CONDITIONS

Physical Geography

From its headwaters in the Prescott National Forest, a few miles south of Prescott, Arizona, the Hassayampa River flows south to join the Gila River about 37 miles west of Phoenix. Elevations in the river basin range from about 8,000 feet at the head to less than 900 feet at the mouth. Storms of high intensity are intercepted by the high mountains, causing numerous flash floods during the summer months, but the greater part of the annual runoff occurs during the spring floods which are caused by rain or melting snow in the higher reaches of the watershed.

Forty thousand acres of virgin lands around Wittmann invite development through irrigation. The small area for which adequate water is available is about four miles west of Wittmann and 36 miles northwest of Phoenix. It lies in the semitropical area of Arizona at an elevation of about 1,700 feet, bounded by the Hieroglyphic Mountains on the north and the White Tank Mountains on the south.

In general, the climate of the project area is similar to that of the Salt River Project near Phoenix. Compared with the latter, temperatures are slightly lower, rainfall is a few inches more, and the growing season somewhat shorter; summer living conditions are slightly more comfortable.

Continuous precipitation records from 1923 to date and continuous temperature records from 1930 to date are available for the United States Weather Bureau station at Wittmann. From the beginning of the records through 1945, the annual precipitation averaged 9.85 inches of which 7.72 inches fell during the months of February through November; temperatures varied from a maximum of 117 degrees (Fahrenheit) to a minimum of 16 degrees; the annual temperature averaged 69 degrees; and the average frost-free period was 285 days (February 26 - December 8). The average frost-free period ranged from a low of 227 days in 1938 to a high of 341 days in 1941.

Settlement

In the Hassayampa River Basin there has been little settlement, and the project area itself is uninhabited. Wittmann and Morristown, the nearest towns, have populations estimated at 25 and 100 respectively. Their static populations contrast sharply with the trend in the city of Phoenix and in Maricopa County as a whole, where the development of irrigation projects, allied industries, and winter vacation facilities, in the Salt River Valley have caused a tremendous growth as shown below:

Year		Maricopa County		Phoenix
1920		89,576		29,053
1930		150,970		48,118
1940		186,193		64,414
1946	1/	275,000	1/	90,000

Local Industry

There is practically no industrial development in the area surrounding the project. Residents of Wittmann and Morristown derive

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1/ Estimated by Valley National Bank, Phoenix, Arizona.

some income from tourist travel and the maintenance departments of the highway and railroad.

Ample transportation facilities are available to the project via Wittmann, the nearest shipping point. A branch line of the Atchison, Topeka and Santa Fe Railway, and the combined, paved highway, U. S. 60, 70, and 89, afford direct connections to Phoenix, 36 miles to the southeast, and Los Angeles, 350 miles to the west. Transcontinental truck, bus, and air lines, and the main line of the Southern Pacific Railroad, pass through Phoenix. Telephone, telegraph, and electric power services are available in the towns near the project area.

Established cooperative organizations at Phoenix serve markets such as Los Angeles, Chicago and New York. A market for eggs and dairy products exists in Phoenix and nearby towns.

Water Uses

First attempts at utilizing Hassayampa River waters were initiated in 1883 to furnish water and power for placer mining operations. The Walnut Grove Water Storage Company, organized in 1886, built the Walnut Grove Dam on the Hassayampa near Wagoner. This dam, a rockfill structure 110 feet high, formed a reservoir of 10,000 acre-feet capacity. In February 1890, before the spillway was completed, an extremely high runoff resulting from melting snow caused failure of the dam, and 129 people lost their lives in the flood.

The company went into the hands of receivers, and in June 1908 all of its assets were transferred to Mrs. Eleanor C. Wittmann of

New York by a Master Commissioner's Deed. In 1910 Mrs. Wittmann employed engineers to report on the feasibility of using the waters of the Hassayampa River for power and irrigation, and on January 1, 1914, she filed an application to withdraw 17,600 acres of land near Morristown to be irrigated from this stream. Withdrawal was effected on April 14, 1916.

During the ensuing years various attempts at forming an irrigation project were made by the Wittmann interests and the Nadaburg Irrigation District (now called the Arizona Water Conservation District). Proposed plans were submitted to the Reconstruction Finance Corporation and the Public Works Administration for financing, but negotiations were not successful. All applications for rights-of-way over Government land have been extended at different times and are now subject to closure.

Outside the project boundaries 470 acres in small scattered tracts are now irrigated from the Hassayampa River. Waters of the river are used by the town of Wickenburg (population 1043), which has pumped its domestic supply from a well near the river for many years.

The nearest developed irrigation project of any size is that of the Maricopa County Municipal Water Conservation District No. 1 (Beardsley Project) comprising about 28,000 acres irrigated by direct flow from the Agua Fria River, supplemented by storage in Lake Pleasant, and by pumping from ground water. The Agua Fria is a tributary of the Gila River and enters that stream above the Hassayampa River.

There are no storage developments for flood control, hydro-electric power, recreation or fish and wildlife conservation in the Hassayampa River basin. Heavy rains on melting snow often cause flood peaks which cause damage, particularly at Wickenburg and at the mouth of the river.

Agriculture

The project area is a typical Arizona desert region utilized only to a limited extent for grazing of livestock. A small experimental test plot at Wittmann, irrigated from a deep well, has demonstrated that all crops grown in the Salt River Valley may be successfully produced.

The most important irrigation development in the region is the Salt River Project surrounding the city of Phoenix. According to the Bureau of Reclamation 1945 Crop Report for this project, 214,346 acres in 13,087 farms are irrigated. Water for irrigation is obtained from the controlled flows of the Salt and Verde Rivers and supplemented by ground water pumped from about 200 wells. Climatic conditions are conducive to growing of cereals, hay and forage crops, vegetables and truck, fruit and nuts, and cotton. In 1945 the farm population of the project totalled 41,800 and that of towns on or near the project totaled 191,300. Crops worth $32,877,161 were produced in 1945, an average of $143.86 for each acre cultivated. The project is indicative of the agricultural development made possible through the irrigation of desert lands such as those of the potential Hassayampa Project area.

The livestock industry is of minor importance in the Hassayampa project area at present. In the surrounding area, however, livestock operations are important, particularly on the Salt River Project where the inventory value of livestock during the period 1939-1944 averaged over $5,500,000. Nearly 80 percent of this value was accounted for by dairy and beef cattle.

Ownership of Hassayampa Project lands is vested in seventeen owners including the United States and the State of Arizona; classification of ownership is as follows:

United States	3,743 acres	50 percent
State of Arizona	1,040 acres	14 percent
Private	2,717 acres	36 percent
Total 1/	7,500 acres	100 percent

Correlation of the ownership with the land classification results (See Appendix G) reveals that seven owners, excluding the United States and the State of Arizona, have 1,098 acres in excess of 160 acres of irrigable land each, or 14.6 percent of the project area.

Project lands in their present undeveloped state are utilized to a minor extent for grazing in the early part of the year and have a very small earning capacity. Their value averages only about $5.00 per acre. Irrigated lands on nearby projects are valued at from $50 to $250 or more per acre, varying with conditions

1/ Includes all land within the project boundary; it includes a small acreage of non-arable land.

within the projects. Assessed valuations in Maricopa County, about 30 percent of full and true value, average about $55 an acre and improvements about $15 an acre.

Economic Conditions

The project area is uninhabited. During the depression the relief load in Maricopa County was heavy, and there were several Works Progress Administration cases in Wittmann.

Undeveloped Resources

River flows, averaging almost 46,000 acre-feet annually, are now practically all lost in the sandy bed of the Hassayampa, and make no contribution to the area productivity. A few miles east of the river a compact body of more than 40,000 acres of inherently productive land awaits development by irrigation. At Box Canyon there is a dam site where a dam could be constructed to impound sufficient water to irrigate 7,000 acres of this land.

Geological conditions indicate the possibility of oil bearing strata beneath part of the project area. During the period February through July 1946, a total of 34 applications for lease of oil rights on Government property were approved by the Bureau of Reclamation. Several wells have been drilled in the vicinity of the main canal location but no strikes have been reported.

No undeveloped timber, mineral or power site resources have been discovered.

NEEDS OF THE AREA

The area can be developed by conserving and utilizing the erratic flow of the Hassayampa River. Such development will necessarily be expensive because of the unusually large amount of holdover storage required for even a comparatively small acreage of land. Pumping ground-water for irrigation is impractical because of the high lifts (about 400 feet) required.

PLAN OF DEVELOPMENT

The Project Plan

The plan of development is to construct Box Canyon Reservoir, a main canal and lateral system, and a domestic water supply system.

Project Lands

Lands proposed for irrigation total 7,500 acres, or 7,000 acres net after deductions to cover rights-of-way and farmsteads. They are well suited for irrigation; approximately 98 percent of the area is Class 1 land according to Bureau of Reclamation standards.

Surface soils are a light brown or reddish-brown sandy loam to heavy silt loam, either noncalcareous or only slightly calcareous or only slightly calcareous. Subsoils are calcareous, dull-red or reddish-brown sandy loam in the upper layers, becoming heavier and more calcareous in the deeper layers. The soils are relatively free of soluble salts and are not highly alkaline.

The area consists primarily of a large, gently sloping alluvial fan which is exceptionally smooth-surfaced and uniform, the surface being broken only by a few drainage channels of small intermittent streams and occasional low ridges. The slope ranges from 15 to 30 feet per mile in a southeasterly direction. Small rock fragments are scattered on the surface in places. Only a moderate amount of leveling will be required to prepare the land for irrigation.

Soil and topographic conditions are indicative of favorable drainage, both surface and internal, under irrigation. The general slope and natural drainage channels provide satisfactory surface runoff; subsurface drainage is good, owing to the open permeable nature of the subsoils. There are no poorly drained areas in the project at present, and it is not considered necessary to provide a drainage system.

Water Supply

Surplus flows of the Hassayampa River would be conserved and developed to provide a water supply for the project. Ground water beneath the project lands is at such great depths that pumping for irrigation is impracticable.

The mountains surrounding the upper part of the Hassayampa River Basin, and particularly those along the eastern rim, are the most easterly of the high mountains in south-central Arizona. This high range intercepts storms from the California area, causing higher precipitation within the Hassayampa basin than upon adjacent drainage basins. Storms of high intensity on the drainage area often result in flash floods during the summer months. During the winter, heavy falls of snow and rain produce considerable run-off, but seldom of long duration. The greater part of the year's runoff comes in the form of spring floods, which usually occur after a rain has fallen on the snow in the higher reaches of the watershed.

Water Rights. Three classes of water rights are recognized in Arizona:

1. Rights vested prior to the adoption of the Water Code in 1919;

2. Appropriations initiated under and in compliance with laws existing at the time of the initiation of appropriation where the appropriators have, in good faith and in compliance with laws then existing, commenced the construction of works for the application of the water so appropriated to a beneficial use and prosecuted such work diligently and continuously; and

3. Appropriations pursuant to the Water Code.

The Arizona state courts have held that, under existing laws, percolating subterranean waters are not subject to appropriation, unless it can be definitely and conclusively shown that the subterranean stream is subject to appropriation under the same rule as surface streams; and that groundwaters not in well defined channels are the property of the owner of the land under which they are found. Recent decisions have, however, given support to the doctrine of correlative rights of owners of land overlying the same groundwater basin.

At the present time, there are 470 acres of lands irrigated from the Hassayampa River and these lands have water rights through usage prior to the adoption of the State Water Code in 1919. About 280 acres lie above Box Canyon damsite, and will not affect or be affected by project development. The remaining 190 acres below the damsite will have to be considered in the project plan, as will the town of Wickenburg which has pumped its water supply from a well near the river for many years.

Five applications have been made to the State Water Commissioner for water right permits on the Hassayampa River since the 1919 Water Code was passed. Permits issued on three of the applications have now lapsed.

Downstream Rights: The Hassayampa River joins the Gila River some 60 miles below the Box Canyon Dam site. All flows of the Hassayampa, except those of the highest floods, are lost in the sandy river bed before reaching the Gila. The only major diversion from the Gila below the junction is at Gillespie Dam, about 10 miles downstream. Available records show that flood flows of the two rivers are almost always concurrent, indicating that storage of Hassayampa River flood flows will not interfere with surface rights of the Gillespie development, inasmuch as the Gila River will usually be flowing past Gillespie Dam when flood waters of the Hassayampa are being impounded.

In the absence of any definite decrees or permits covering appropriation of subterranean flow of the Hassayampa itself, or of channels deriving their water supply therefrom, some investigations were made of groundwater conditions in the region to determine whether development of the Hassayampa Project would adversely affect the groundwater supply of adjacent areas. Studies of groundwater contours and geophysical surveys, shown in detail in the appendix, led to the conclusion that development of the Hassayampa Project would have no adverse effect on groundwater supplies in the Gila or Agua Fria basins.

Quality of Water: Small areas in the vicinity of Wickenburg have been irrigated for years from flows of the Hassayampa River without injurious effects. Analyses of water samples taken from the river at the damsite and downstream revealed that the concentration of soluble salts was not high enough to be deleterious to most crops adapted to the area.

Water Requirements. The period 1931 to 1940 was used for determining water requirements, as it represents a decade of near-maximum requirements in the Southwest from the standpoints of both temperature and precipitation. Based on the Lowry-Johnson method, the annual consumptive use of water for agriculture on the project is estimated at 3.68 feet. The average annual precipitation in the five driest years is 0.49 feet, of which about 90 percent or 0.44 feet is effective in meeting consumptive use. Allowing for canal and lateral losses of 15 percent, and deep percolation and farm wastes of 20 percent, the average diversion requirement was placed at 4.75 acre-feet an acre. (See Appendix C for details).

Monthly distribution of irrigation water is expected to be similar to the irrigation schedule on the Beardsley Project some 13 miles southeast, with minor adjustments to suit the crops expected on the Hassayampa Project. With such a distribution, there would be a year-round delivery of water ranging from 3 percent (1,000 acre-feet) in December and January to 13 percent (4,300 acre-feet) in June.

Requirements for Prior Rights. The recorded flows at Box Canyon Dam site reflect the effect of past consumptive use of water by the 280 acres irrigated upstream. No important further upstream development is anticipated, inasmuch as the flow of the Hassayampa River during low run-off periods is inadequate to supply the present developed area.

The present irrigated area of 190 acres below the damsite presents a demand upon the flow of the river ahead of the Hassayampa Project. The annual irrigation requirement for these 190 acres, at 4.75 acre-feet per acre, is 900 acre-feet for a full supply. Part of this water will be secured from inflow below Box Canyon Dam site. At times when the natural flow belonging to these lands is inadequate for a full supply, a supplemental supply will, to avoid heavy river losses, be conveyed through the project canal. It is estimated that 500 acre-feet per year will need to be supplied to these lands through the project canal during years of low run off.

Present water use by Wickenburg amounts to about one second-foot, which is pumped from a well near the Hassayampa River. Allowing for 100 percent increase in this demand, two second-feet will be required in the future. Consumptive use of the domestic water will average less than 1 second-foot, and the remainder of the amount pumped will return to the underground water basin. Seepage around the dam at Box Canyon Reservoir, supplemented by inflow from Sols Wash and Martinez Creek, should be adequate for supplying Wickenburg. If not, it will be necessary to furnish additional water from the project canal.

Requirements for Dead Storage. Silt loads are not heavy, even during high flows of the Hassayampa River; however, as in all other streams in the region, the bed load of sand and gravel is significant. Fairly steep slopes above the reservoir indicate opportunity for transport of such bed load, and deposition in the reservoir back water.

Records from 1905 to 1935, inclusive, of the loss of capacity of Roosevelt Reservoir on Salt River show silting to the extent of 0.35 percent of the reservoir inflow. In the absence of definite data, the silting rate on the Hassayampa is estimated at 0.45 percent of the runoff. Silting of the reservoir would then be at the rate of about 200 acre-feet annually, or 10,000 acre-feet during a 50-year period. Therefore, a capacity of 10,000 acre-feet for dead storage is allowed in Box Canyon Reservoir.

Requirements for Flood Control Storage. Storage capacity is desired purely for flood control purposes to impound flash floods resulting from mountain cloudbursts, which occur rather frequently on the Hassayampa drainage area. Ten thousand acre-feet of storage capacity below the spillway crest, in addition to about 60,000 acre-feet of uncontrolled superstorage above the spillway crest, will be reserved at all times for flood control purposes.

Operation Studies. The widely fluctuating intermittent flow of the Hassayampa River precludes any consideration of direct diversion for irrigation use. Therefore, all waters for the project are to be stored in Box Canyon Reservoir for release as required.

Studies of the possible operation of the proposed reservoir were made for the period 1916 through 1945. This is the only period for which stream flow data are sufficient to enable satisfactory estimates of monthly flows of Hassayampa River at the dam site. During this period the average annual flow was 45,700 acre-feet, but during the period 1942-45 it was only 9,600 acre-feet.

Owing to the erratic nature of inflow to the reservoir, storage carryover from the periods of high run-off is necessary to permit maximum use of available stream flow. Studies of the increased cost of this carryover-storage capacity, evaporation losses and other factors established the total reservoir capacity at 210,000 acre-feet. Reservations for dead storage and flood control leave a balance for irrigation use of 190,000 acre-feet.

Since prior rights are to be satisfied from the reservoir, the flow at Box Canyon dam site, as recorded and estimated (see Appendix C), is considered as storable for project use. Deductions for evaporation losses were based on a net annual evaporation loss of 4.0 feet from the reservoir surface. Annual irrigation releases include 33,300 acre-feet for project lands and 1000 acre-feet for prior rights or possible domestic requirements.

Assuming that the reservoir had been operating during the period 1916 through 1945, with stream flow as previously recorded and estimated, the 7,000 acre project would have been furnished a full water supply during 29 of the 30 years. The only water shortage would have occurred in 1945 - a shortage of 9,700 acre-feet or 28 percent of the total demand. Erratic flows of the Hassayampa River would have been almost completely regulated. Spills would have occurred in only three years; a total of 106,000 acre-feet would have passed over the spillway, which is equivalent to an average annual spill of 3,500 acre-feet.

Project Works

Box Canyon dam and reservoir. Box Canyon reservoir will have a maximum length of about six miles, a maximum width of almost two miles, a surface area at flow line level of 2,900 acres, and an active capacity of 190,000 acre-feet. Several parcels of patented lands and mining claims will have to be acquired and power and telephone lines will require some relocation.

A narrow gorge (175 feet wide) with nearly vertical sides reaching a height of 350 feet forms the dam site. Bedrock is composed of well-cemented fanglomerates with alternating layers of basalt and basalt breccia and is covered by approximately 100 feet of sands and gravels. Foundation conditions are suitable for earth-fill dam construction.

The embankment, shown on drawing 57-D-25 in Appendix E, will have a maximum height of 246 feet above the stream bed and a crest length of 1,120 feet along a curved axis with a 750-foot radius. It will have an impervious central core of compacted clay-sand-gravel, protected by stable, semi-pervious sections both upstream and downstream. The total volume is estimated at slightly over three million cubic yards. A 3-foot layer of rock riprap will cover most of the upstream slope, and a heavy rockfill section will form the downstream slope.

An uncontrolled, open-channel spillway is to be provided in a saddle about 4,000 feet to the right of the dam, as shown on drawing 57-D-26. The overflow crest is at elevation 2,438 and the capacity, with maximum water surface at elevation 2462.6 is 69,700 second-feet.

A 20-foot diameter outlet and diversion tunnel is to be provided through the left abutment. During construction it will take care of river diversion, with a capacity of 15,000 second-feet when the reservoir water surface is at elevation 2,285 (10 feet below the crest of the coffer dam).

Impervious, semi-pervious, and rockfill materials could be obtained by screening the pit run of a borrow area near the right bank of the river about one mile upstream from the damsite. Angular rock for riprap can be quarried at any number of points in the vicinity of the damsite. Aggregate for concrete can be secured from gravel bars along the river channel about three miles downstream from the damsite, or can be produced by crushing rock from required rock excavation.

No facilities for aonstruction force are available except at the town of Wickenburg. About nine miles of new road will have to be constructed.

Electric power for construction purposes can probably be secured from the 44-kilovolt line of the Arizona Power Company, which crosses the Hassayampa River at the upper end of the reservoir, or from a smaller line crossing a short distance below the damsite..

The estimated cost of the dam and reservoir, based on current prices, is $7,500,000. This includes the cost of rights-of-way, access road, reservoir clearing, necessary relocation and construction camp.

Main Canal. The main canal is divided into three sections:

Section 1, capacity 110 second-feet, will be a 51-inch diameter, concrete conduit, with walls 6 inches thick, burried 4 feet underground in the bed of the Hassayampa River. This conduit will convey water from Box Canyon Reservoir to a point near the Atchison, Topeka and Santa Fe Railway bridge, 15 miles downstream, where the canal will leave the river.

Section 2 will be clay-lined canal in earth and rock, extending for seven miles through the rough terrain between the river and project area. Four tunnels, aggregating 9,130 feet in length, and several shallow cuts will be required to avoid long and difficult canal construction that would be required on a contour route.

Section 3 will distribute water to the lateral system throughout the irrigable area. The terrain is so steep that a total of 24 drops will be required to avoid excessive velocities in the five miles of canal in this section. The capacity reduces from 110 to 30 second-feet.

Construction costs of the main canal are estimated at $4,700,000.

Lateral system. The lateral system will consist of 10 laterals, open canals lined with a 3-inch blanket of clay, running east at one-half mile intervals. Outlets of five second-feet capacity will be provided for each 80-acre tract. The cost of the lateral system is estimated at $180,000.

Miscellaneous. The cost of investigations and surveys, past and future, is estimated at $80,000.

The cost of operating and maintaining the project during the construction period, including the priming and puddling of canals and the purchase of operating equipment, is estimated at $10.00 an acre.

A drainage system is not required for the project.

Domestic water supply. Settlement of the project will be dependent on provision of a dependable domestic water supply for the farmsteads and for the project town (possibly Wittmann). Because of excessive pumping lifts, indicated to be about 400 feet by wells adjacent to the project area, the cost of pumping from individual wells for a domestic supply would be beyond the financial ability of most settlers. To facilitate development and settlement, provision should be made for supplying a total population estimated at 800 persons, of which 400 would be on project farms and 400 in the project town. The average demand is assumed to be 500 gallons per capita per day, which amounts to about 450 acre-feet a year.

Consideration was given to a number of different plans for providing this supply. The best plan contemplates construction of a deep well at the site of a small equalizing reservoir in Section 1, T. 5 N., R. 4 W. This reservoir is at an elevation high enough to serve the entire pipe line distribution system by gravity.

The total cost of the well, reservoir, chlorination equipment, tank and distribution system is estimated at $370,000. Based on the assumption that the irrigators and the project town will use water on a 50-50 basis, the construction cost would be divided equally between the two users. The $185,000 cost for farmstead water would be considered as part of the irrigation cost, repayable under Reclamation Law in 40 years, without interest. The project town's share of the construction cost, $185,000, would probably be repaid in 50 years at three percent interest.

Summary of construction costs. Estimated costs of construction of the Bureau of Reclamation features, based on April 1947 prices, are summarized as follows:

Box Canyon Dam and Reservoir	$ 7,500,000
Main Canal	4,700,000
Lateral System	180,000
Investigations and Surveys	80,000
O and M during Construction	70,000
Municipal and Farmstead Water Supply	370,000
Total	$12,900,000

Operation and Maintenance. Trial budgets and analyses of projects operating under similar conditions indicated that operation and maintenance costs for the irrigation and farmstead water system would average about $35,400 annually, or about $5.00 an acre. Annual operation and maintenance charges for municipal water were estimated at $7,500.

Alternative Plans of Development

Plans previously considered by other interests for the development of the project contemplated using the stream bed to convey water from the reservoir at Box Canyon to the point of diversion 15 miles downstream. Construction of storage facilities on streams in southern Arizona has invariably resulted in a marked deterioration in channel capacities, resulting through the growth of water-loving vegetation. Using the stream channel to convey water from the Box Canyon Reservoir to the diversion point, would, without doubt, result in the present stream bed becoming covered, except for a narrow channel, with a growth of cottonwoods and other water-consuming vegetation, as has been the experience, under similar conditions, on the Salt and Gila River. Detailed studies and tests by the Bureau of Reclamation indicated that the annual channel loss would be about 7,800 acre-feet, that less than 5,000 acres could be irrigated with the 210,000 acre-feet reservoir, and that unit costs would be higher than for the selected plan.

A plan for transporting water to the project via a high-line canal leaving the river at Box Canyon Dam was also considered, but the steep slopes and rough rocky terrain which would be traversed by this canal indicated that it would be more costly than the selected route.

At the request of local interests, consideration was given to the development of a storage reservoir on the Hassayampa River at the Atchison, Topeka and Santa Fe Railway crossing near Morristown to eliminate the closed conduit necessary with storage at the Box Canyon site. A storage reservoir at this lower site would be costly, as it would require relocation of about 10 miles of railroad and highway. Moreover, this plan of development would not eliminate the channel losses between Box Canyon and this site.

The Wittmann interests made some studies for determining the feasibility of diverting water from Kirkland Creek, tributary of Williams River, over the divide into the Hassayampa River via Martinez Creek, to increase the project water supply. Consideration of their data together with some additional studies by the Bureau led to the conclusion that the high cost of the small amount of water thus obtainable renders the scheme impractical. Moreover, this water could be utilized for the irrigation of arable lands in the Williams River Basin at less cost.

Investigations are now in progress by the Bureau to determine the desirability of diverting water from the Colorado River to the Granite Reef Reservoir to augment supplies in the Salt and Gila River Valleys. Canals and tunnels from Lake Havasu, Marble Canyon and Bridge Canyon have been surveyed and studied. It has been determined that all water which might be made available by these plans will be needed for the relief of presently irrigated lands in the Salt and Gila River Valleys.

Agricultural Development

Although crops cannot be produced without irrigation, the project area is well-adapted to agriculture under irrigation. The project lands lie on a gently-sloping alluvial fan which is exceptionally smooth-surfaced and uniform. Nearly 98 percent of the area has been classified as Class 1 lands, which are lands suitable in every respect for irrigation and capable of producing high yields of all crops not precluded by climate. It is anticipated that the distribution of crops, yields, and values in the project area will be similar to those of the Salt River Project, as the soil and climatic conditions in the two areas are comparable. As shown in Table 25 in Appendix G, it appears that a general farming program will be practiced and that gross crop values will average about $116 an acre.

Production of livestock and livestock products is likely to be of less importance than the production of crops. On some farms, however, the dairying and feeding of beef cattle may become a major enterprise. Based on past results on the Salt River Project, an average annual livestock inventory of about $170,000 can be expected on the Hassayampa Project.

Land values and taxes. As the Hassayampa Project is developed land values will rise. On the basis of Salt River Project experience a normal or long time average value of about $175 an acre can be expected. In recent years, of course, irrigated land has sold for considerably higher prices because the prices of crops grown have been high but as crop prices decline land values will likewise decline.

On the basis of assessed values and tax rates in Maricopa and Pinal Counties during the period 1939 to 1944 it is estimated that taxes will average about $2.50 per acre for land and buildings.

Repayment ability. Repayment ability of water users was determined by the farm budget method of analysis, based on yields and prices of the Salt River Project during the period from 1939 to 1944, inclusive. Analysis of farms ranging in size from 40 to 320 acres indicates that extensive crop farms as small as 40 acres cannot pay for water or provide a reasonable level of living. Small specialty crop farms, however, may prove successful. Extensive crop farms of 80 and 100 acres appear to be typical family-sized farms as the farmer can do most of the work himself, and farms of these sizes can make a substantial payment toward construction costs in addition to providing a reasonable level of living. It is recommended, therefore, that the majority of the farms be of this size.

The analysis indicates the amount available for payment of all water costs to be $15.50 per acre. Deduction of the estimated operation and maintenance cost of $5.00 an acre leaves $10.50 per acre for repayment of irrigation construction costs. For 7,000 acres, this amounts to $73,500 annually and $2,940,000 over the 40-year repayment period.

Settlement opportunities. It is estimated that about 80 farms could be established in the project area. This estimate is based on 80 to 100 acre farms predominating, with a few smaller and some larger farms.

Excess lands total 1,098 acres. Disposal of these lands should not present a serious problem as the area is uninhabited and there are only seven landholders, excluding the United States and the State of Arizona, who own more than 160 acres of irrigable land.

Power

Power development would be uneconomical because of a fluctuating power head, erratic streamflows, and the paramount need of water for irrigation. The region is now supplied with comparatively low cost power generated on the Colorado River and in plants of the Salt River Valley Water Users Association on Salt River. Additional power developments on the Colorado River, now under construction or under study by the Bureau of Reclamation, could more economically supply the anticipated future power needs of the area.

Flood Control

Information from local residents and study of incomplete runoff records indicates that the most damaging floods originate in the mountainous area of the Hassayampa River watershed above Box Canyon Dam (drainage area 422 square miles). Damages are the heaviest along the river in the vicinity of Wickenburg and Morristown, and at the mouth of the river. During the period 1916-36 the total of evaluated flood damages was $206,000, and numerous other damages occurred for which monetary values are not available, according to information furnished by the U. S. Engineer Office at Los Angeles.

Construction of Box Canyon Dam would make it possible to substantially reduce the flow of floods originating above the reservoir. Assuming the reservoir to be at spillway level at the beginning of the flood, the maximum probable inflow of 183,000 second-feet would be reduced to a maximum outflow of 69,700 second-feet. Based on studies of potential flood damages supplied by the U. S. Engineer Office, and on studies of probable discharges prepared by the Bureau, it is estimated that uncontrolled flows of the Hassayampa River would probably cause flood damages totalling $1,440,000 in a 100-year period, which is equivalent to an average annual flood damage of $14,400. Similarly, the residual flood damages which would probably occur with flows controlled at Box Canyon Dam would average $2,470 a year, indicating an average annual reduction in flood damages of $11,900 (in round numbers).

Other Project Uses

Benefits from the operation of Box Canyon Reservoir would accrue from fish and wildlife conservation and from opportunities for recreation. Navigation uses or requirements are not present.

Fish and wildlife conservation. On the basis of a preliminary biological reconnaissance of the area the Fish and Wildlife Service considers that development of the project would be beneficial to fish and wildlife; the net annual benefit is tentatively estimated at $18,000. Realization of such annual benefits would be dependent on stipulated management conditions, but no construction work would be necessary.

Recreation. A reconnaissance survey of recreational advantages which might result from project development has been made by the National Park Service. Based on this preliminary examination, the National Park Service estimated that annual recreational benefits totalling $28,200 would be realized from project construction and operation. The cost of constructing necessary recreational facilities was estimated at $179,000, and the annual operation and maintenance cost was estimated at $13,800.

Organization

A project water users' organization would need to be formed to contract with the Government for repayment of reimbursable costs and to assume the obligation of operating and maintaining the project works. As almost one-half of the lands selected for project development lie within the boundaries of the Arizona Water Conservation District, it has been suggested that the District amend its boundaries to include the project lands and act as the contracting agency with the United States. Before proceeding with this plan, however, a thorough review should be made of the many and various legal problems involved.

Construction of the project would be accomplished in about three years. After water is delivered to project lands a development period of about seven years should be allowed before commencing repayment of reimbursable costs. During this development period only operation and maintenance costs would be collected from the settlers, allowing them to use the remainder of their income for building homes, acquiring machinery and livestock, and developing the land.

Relationship to the Colorado River Basin

The Hassayampa Project is one of the 134 potential projects presented for consideration by the affected states in the report, "The Colorado River", issued by the Secretary of the Interior in March 1946. The report showed that there is not enough water in the Colorado River system for all the potential projects outlined therein, and recommended that the States of the Colorado River Basin (1) determine their respective rights to deplete the flow of the Colorado River, consistent with the Colorado River Compact and (2) acting separately or jointly, recommend for construction a group of projects, the streamflow depletions of which will assuredly fall within ultimate allocations of Colorado River water which may be made to individual states.

The annual consumptive use of irrigation water by lands irrigated in the Hassayampa Project would be about 22,700 acre-feet a year, and the annual loss from evaporation at Box Canyon Reservoir would average about 8,200 acre-feet.

ECONOMIC ANALYSIS OF PROPOSED DEVELOPMENT

Two methods of determining the economic justification of the proposed development have been considered: (1) the ratio of benefits to costs; and (2) the relation of repayment ability to costs.

Benefits and Costs

Monetary benefits have been determined for irrigation and farmstead water, municipal water, flood control, fish and wildlife conservation, and recreation. Costs, in this analysis, include the amortization cost of the project, with interest, and the operation and maintenance costs. Estimates of these benefits and costs, developed on the following pages, are summarized below:

Annual Benefits

Irrigation and farmstead water	$826,600	
Municipal water	14,600	
Flood control	11,900	
Recreation	28,200	
Fish and wildlife conservation	18,000	
Total monetary benefits		$899,300

Annual Costs

Operation and Maintenance			
Irrigation and farmstead water	$35,400		
Municipal water	7,400		
Recreation	13,800		
		$56,600	
Amortization of construction costs			
Bureau of Reclamation	$501,400		
National Park Service	7,000		
		$508,400	
Total annual costs			$565,000

Ratio of Annual Benefits to Annual costs 1.59 : 1

Irrigation. Irrigation benefits are estimated to have an annual value of $812,000, which is the gross crop income from the 7,000 acres of irrigable land in the project. Since present income from those lands is insignificant the entire amount is used as the measure of benefits from irrigation. The $812,000 measures the monetary or tangible irrigation benefits accruing to both direct and indirect beneficiaries. It is assumed to be equivalent to the net economic effects of producing, processing, and handling through commercial channels the new agricultural products from the area, together with the indirect effect on others not engaged in handling these products. Beneficiaries, therefore, include the trucker, the railway, wholesalers, retailers, and many others who may or may not have a part in bringing to the ultimate consumer the raw products grown on the farms of the project.

Intangible benefits will also accrue from the project which are not readily susceptible of monetary evaluation. Among these are increased opportunities for employment both during construction, and on farms when the project is in operation. The development of this area will increase tax returns to local governments and thereby permit the improvement and extension of public services to a wider area. Federal income tax payments will be increased because of increased earning capacity of the project lands. National security will also be served by increasing the productive capacity and by spreading the population more widely.

The benefit realized from the farmstead water supply has been measured in terms of the sale value of this water. Based on a rate of $0.20 per 1,000 gallons, the benefit of providing 73 million gallons of farmstead water annually is $14,600.

Summarizing, the total value of the irrigation and farmstead water benefit is $826,600.

Municipal water. The benefit of providing a municipal water supply for the project town is also based on the sale value of this water. At a rate of $0.20 per 1,000 gallons the value of 73 million gallons is $14,600.

Flood control. Under present conditions, with flows of the Hassayampa River uncontrolled, it is estimated that flood damages will average $14,400 annually. By construction of Box Canyon Dam and control of the river, flood damages will be reduced by $11,900 annually. This decrease in damages comprises the flood control benefits.

Recreation. Based on a preliminary examination by the National Park Service, the annual value of recreational benefits is placed at $23,200.

Fish and wildlife conservation. Operation of the potential project would provide an annual fish and wildlife benefit of $18,000, according to the preliminary estimate prepared by the Fish and Wildlife Service.

Costs. Bureau of Reclamation features are estimated to cost $12,900,000; amortization in 50 years at three percent interest would require an annual outlay of $501,400. National Park Service features are estimated to cost $179,000, the annual cost of amortizing $179,000 in 50 years at three percent interest is $7,000.

Annual operation and maintenance costs of the various features have been estimated at $35,400 for irrigation and farmstead water,

$7,400 for municipal water and $13,800 for recreational facilities.

Relation of benefits to costs. A benefit-cost ratio of 1.59 to 1 was developed at the beginning of this chapter. This ratio indicates that annual benefits to the nation will average 59 percent above annual costs. In other words, for each dollar of cost, the nation will receive 1.59 of monetary benefits in addition to intangible benefits.

Costs and Repayment

Construction of the proposed project would require expenditures by the Bureau of Reclamation and the National Park Service. Allocations of construction costs can be made to irrigation and farmstead water, municipal water, flood control, fish and wildlife conservation, and recreation. Costs allocated to irrigation and farmstead water and to municipal water are reimbursable. The following summary of costs, allocations and repayment shows that 27 percent of the reimbursable costs of the project can be repaid:

Estimated Construction Cost of Project

Bureau of Reclamation features	$12,900,000	
National Park Service features	179,000	
Total construction cost		$13,079,000

Allocations of Cost

Non-reimbursable		
Flood control	$ 306,000	
Recreation	725,000	
Fish and wildlife conservation	463,000	
		$ 1,494,000
Reimbursable		
Irrigation and farmstead water	$11,400,000	
Municipal water	185,000	
		$11,585,000

Estimated Repayment

Irrigation and farmstead water	$2,940,000
Municipal water	185,000
	$3,125,000

Percentage of Repayment 27 percent.

Allocations. Non-reimbursable costs were allocated on the basis of the present value of the annual benefit occurring over a period of 50 years at 3 percent interest. The present value of annual flood control benefits of $11,900 is $306,000, of $28,200 annual recreation benefits is $725,000, and of $18,000 annual fish and wildlife benefits is $463,000.

It has been assumed that the cost of providing municipal water will be covered by a repayment contract with the project town. Therefore, the construction cost is taken as the value of municipal water and the entire cost, $185,000, is allocated thereto. Only one other function, irrigation (including farmstead water), is served by the project. Hence, the residual cost of $11,400,000 is allocated to irrigation and farmstead water.

Repayment. Repayment ability of the irrigators was calculated by the farm budget method of analysis, which indicated that the farmers could reasonably be expected to pay $10.50 per acre annually for irrigation and farmstead water. Over a 40-year interest-free repayment period, this payment would amount to $2,940,000.

Before a water supply could be provided for the project town, it would be necessary to secure a repayment contract for the entire construction cost. It has therefore been assumed that the $185,000 cost of providing municipal water would be repaid in full.

Percentage of Repayment. With anticipated repayment of $3,125,000 on reimbursable costs of $11,585,000, the repayment would amount to 27 percent. Assuming that the repayment ability would remain constant, it would require about 150 years to effect full repayment of construction costs.

APPENDIX A
GENERAL DATA

PREVIOUS INVESTIGATIONS

Engineers for the Wittmann interests, largest property owners in the project vicinity, have made several investigations of the use of Hassayampa River water for irrigation and have made private reports.

In 1927, the J. G. White Engineering Corporation of New York, New York, made a "Report on the Maricopa County Irrigation District Number One" (now Arizona Water Conservation District).

On March 27, 1937, W. C. Lefebre, Chief Engineer, Engineering Division, State of Arizona, Federal Emergency Administration of Public Works, made a "Field Report on Application of Arizona Water Conservation District, Docket No. 551." This is the most comprehensive report previously made on the Hassayampa Project. Its conclusions are briefly summarized:

(a) Water supply of Hassayampa River is adequate to supply needs for irrigation of 14,450 acres net, 18,062 acres gross.

(b) Irrigation works will consist of Box Reservoir, 160,000 acre-feet capacity; diversion dam on Hassayampa River, 14 miles downstream; ground or subsurface storage, capacity of 20,500 acre-feet between Box Reservoir and diversion dam; main canal, 1[illegible]0 c.f.s. capacity; laterals and waste ditch recovery system.

(c) Estimated cost entire system, $2,000,000.

(d) General design of proposed irrigation works is technically sound, subject to determination of type of dam to be constructed at Box Canyon site.

(e) Total cost per acre, $110.73; with grant of 45 percent from Public Works Administration bond debt per acre, $60.90.

(f) If agreement governing lands donated by J. W. Wittmann is effective, proceeds from sale and rental of lands donated by Wittmann will service bonds.

(g) Additional security afforded by returns from lands donated by J. W. Wittmann secures safety of loan.

A report by J. A. Fraps to W. W. Lane, State Engineer, State of Arizona, considers hydroelectric power development on the Hassayampa River as not feasible at that time (July 10, 1929). This report dealt with power as a separate development and not connected with irrigation.

PRESENT INVESTIGATIONS

This investigation was made by the Bureau of Reclamation under authority of Section Fifteen of the Boulder Canyon Project Act, by which the Secretary of the Interior is authorized and directed to make investigations and public reports of the feasibility of projects for irrigation, generation of electric power, and other purposes in the States of Arizona, Nevada, Colorado, New Mexico, Utah, and Wyoming, for the purpose of making such information available to said States and to Congress, and of formulating a comprehensive scheme of control and the improvement and utilization of the water of the Colorado River and its tributaries.

About 60 settlers homesteaded land in this area after World War I and tried, unsuccessfully, to establish an irrigation project. At present, however, the project area is uninhabited. This investigation was undertaken at the request of Joseph W. Wittmann and settlers in the Arizona Water Conservation District, who have long labored to secure construction of the project and hoped to take advantage of the availability of funds under various work relief programs prior to the war. The report presents the most attractive plan for utilizing the flows of the Hassayampa River. Consideration was given to importation of waters from tributaries of the Williams River, to enable increase in the project area, but the cost of such water was found to be excessive.

Detailed investigations were made of all physical features appurtenant to an irrigation project and carried to the point where the data obtained were sufficient for designs and estimates of project works, and for agricultural and economic analyses.

The investigations included the following:

Classification of lands in and adjacent to the project, to determine the amount of salts, topography, depth of soil, and general adaptability for irrigation farming.

Complete water supply studies, including measurements and estimates of flows of the Hassayampa River, study of channel losses, testing of the underground flow at a previously considered diversion damsite about 15 miles below the storage reservoir, water requirements for irrigation, project diversions, and reservoir operation studies.

Survey of the Box Reservoir site. Detail surveys of three damsites in Box Canyon and a diversion damsite at the Santa Fe Railway crossing below Wickenburg. Survey of a canal line from the storage site to the Project.

Geological examination and foundation exploration, including diamond drill borings at Box Canyon Damsites.

Digging of test pits and sampling of material in and adjacent to Box Canyon Reservoir to determine quality and amount of construction materials available for earth dams.

Detailed study of plan of development and consideration of alternative plans.

Designs of dams, canals, and other structures, and estimates of costs of the project.

Study of crops and crop yields in adjacent areas, and the adaptation of irrigation agriculture to the project.

Economic analysis of plan of development.

ACKNOWLEDGEMENTS

Acknowledgement is made to the assistance rendered by Joseph W. Wittmann who placed his entire files covering engineering investigations at the disposal of the Bureau. W. H. Griffin, a resident of Wittmann, Arizona, gave generously of his time and placed records of agencies preceding the present Arizona Water Conservation District at the service of the Bureau. S. F. Turner, Hydraulic Engineer of the Tucson District of the Geological Survey Ground Water Resources Branch cooperated in the study of underground flow. Officials of the Maricopa County Water Conservation District No. 1, the Buckeye Irrigation District, the Roosevelt Irrigation District, the Gillespie Land and Cattle Company, the Southwest Cotton Company, and the Salt River Valley Water Users' Association also gave material assistance in the preparation of this report.

Special acknowledgement is given to the Los Angeles District office of the Corps of Engineers, War Department, for their cooperation in supplying basic flood data and estimates.

PERSONNEL

These investigations were made by the Project Planning Section of the Bureau of Reclamation under the direction of E. B. Debler, Hydraulic Engineer, and supervised in the field by Engineer M. E. Bunger, prior to January 1, 1942, and after by Engineer H. G. Raschbacher.

Engineering surveys including topographic mapping, canal location, stream gaging, etc., were made by Associate Engineers A. L. B. Moser and M. O. Simons, and Assistant Engineer W. S. Gookin. Field estimates were prepared by Mr. Moser.

Project lands were classified under the supervision of Reclamation Economist E. R. Fogarty.

Geologic investigations were made by Geologist R. L. Heaton and Assistant Geologist J. M. Murdock under the supervision of Head Geologist F. A. Nickell.

Designs and estimates for Box Canyon Dam were made in the Denver office under the supervision of J. L. Savage, Chief Designing Engineer, and K. B. Keener, Senior Engineer, Dams. Field estimates for canal and lateral systems were reviewed and revised in the Denver office under the supervision of H. R. McBirney, Senior Engineer, Canals.

Two previous drafts of the report have been circulated for comments. The first was prepared by the Hydraulic Engineer in Denver in August 1943, the second by the Regional Director in November 1945. This report, which comprehends all comments on the previous drafts, was prepared in the Regional office of the Bureau of Reclamation at Boulder City, Nevada, under the general direction of Regional Director E. A. Moritz. Regional Planning Engineer E. G. Nielsen supervised the work, which was performed by Engineer T. J. Looney, Economist R. A. Greffenius, Soils Technologist W. S. Wood, Engineer D. K. Johnson and Geologist G. D. Lasson.

ENGINEERING MAPS AND DRAWINGS

Filed in the Regional office of the Bureau of Reclamation at Boulder City, Nevada, are the following maps and drawings for the Hassayampa Project:

File Number	Title	Date
3H-11-1	Precipitation Trends	May 16, 1946
3H-1-2	Location Map	Sept. 25, 1942
3H-10-3	Land Classification	July 1, 1939
3H-1-4	General Map	Feb. 25, 1941
3H-2-5	Box Canyon Saddle Spillway Site - Topography	May 27, 1941
3H-2-6	Box Canyon Reservoir Site	May 29, 1941
3H-11-7	Groundwater Studies (1 of 2)	Feb. 20, 1943
3H-11-8	Groundwater Studies (2 of 2)	Feb. 20, 1943
3H-2-9	Lower Box Canyon Site - Topography	May 23, 1941
3H-2-10	Upper Box Canyon Dam Site - Topography	May 19, 1941
3H-9-11	Box Canyon Dam - Borrow Pit Area	May 14, 1942
3H-11-12	Available Runoff Records	June 14, 1940
3H-7-13	Land Ownership	Feb. 4, 1943
3H-11-14	Box Canyon Reservoir - Area Capacity Curves	Nov. 3, 1942
3H-10-19	General Investigations - Land Classification Map	May 14, 1941
3H-11-20	General Investigation - Drainage Area Map - Hassayampa River	June 2, 1941
3H-1-21	General Investigations - Locality Map	June 26, 1941
3H-1-22	General Investigation - Hassayampa Project	April 1942
3H-5-23	Cross Sections Below Box Canyon Dam Site	July 18, 1941

File Number	Title	Date
3H-11-24	Location of Drawdown Wells in Hassayampa River June to Aug. 1940	June-Aug.1940
3H-11-25	Ground Water Studies - Hassayampa River	
3H-6-26	General Investigations District Map	May 18, 1922
3H-6-27	General Investigations District Map	June 12, 1933
3H-6-28	General Investigations District Map	June 1923
3H-6-29	General Investigations District Map	Sept.10, 1923
3H-6-30	General Investigations District Map	Aug. 6, 1928
3H-6-31	General Investigations District Map	Aug. 1924
3H-1-32	General Investigations General Map	Jan. 25, 1941
3H-11-33	Topography-Precipitation Stations & Stream-gaging Stations	June 24, 1946
3H-4-34	Main Canal - Profile and Sections	Feb. 18, 1943
3H-15-35	Upper Hassayampa River Basin - Geology Map	July 13, 1946
3H-11-36	Isohyets - Total Storm Precipitation Feb. 10-17, 1927	June 24, 1946
3H-11-37	Isohyets - 71 Year Mean Annual Precipitation 1868-1939	June 24, 1946
3H-11-38	Total Storm Precipitation Feb. 6-9, 1937	June 24, 1946
3H-15-39	Box Canyon Dam Site - Geologic Profiles	Aug. 13, 1946
3H-15-40	Box Canyon Dam Site - Topography & Geology	July 29, 1940
3H-11-41	Distribution Graph Determination Flood of Feb. 7, 1937, Bill Williams River (At Planet)	July 9, 1946
3H-11-42	Box Canyon Dam - Lag Relationships	July 9, 1946
3H-11-43	Box Canyon Dam -S-Graph-Drainage Area Above Planet Ariz.-Bill Williams River	June 11, 1946
3H-11-44	Box Canyon - S-Graph-Drainage Area Above Planet Ariz.-Bill Williams River	June 11, 1946
3H-11-45	Branch of Proj. Planning - Hydrology Div.-Hassayampa Proj. - Box Canyon Dam	
3H-11-46	Box Canyon Dam - Area Depth Curve - Maximum Probable Rain Storm	July 18, 1946

File Number	Title	Date
3H-11-47	Box Canyon Dam - Depth Duration Curve Max.Prob. Rain Storm for Drainage (Area above Box Canyon Dam)	June 25, 1946
3H-11-48	Spillway Design Flood at Box Canyon Dam	June 26, 1946
3H-11-49	Probability Curve of Peak Discharges - Hassayampa River at Box Canyon Dam	Aug. 12, 1946
3H-11-50	Box Canyon Dam - Envelope Curve - Peak Discharges - Gila & Bill Williams River Basin	June 26, 1946
3H-11-51	5-10-25-50-100 Year Probable Floods at Box Canyon Dam	Aug. 12, 1946
3H-11-52	Operations Schedule - Box Canyon Reservoir	Jan. 9, 1947
3H-11-53	Monthly Evaporation Curves - Box Canyon Reservoir	Jan. 20, 1947
3H-11-54	Correlation Curves - Hassayampa River at Box Canyon & Wagoner	Jan. 15, 1947
3H-11-55	Evaporation Curves - Arizona Stations	Jan. 13, 1947

Maps and drawings of the Hassayampa Project filed in the Denver office of the Bureau are as follows:

File Number	Title	Date
57-D-24	Box Canyon Dam - Preliminary Estimate	
57-D-25	Box Canyon Dam - General Plan and Sections - Sheet 1 of 2	Aug. 24, 1942
57-D-26	Box Canyon Dam - General Plan and Sections - Sheet 2 of 2	Aug. 24, 1942
57-D-27	Box Canyon Dam - Log of Drill Holes	Apr. 22, 1942
57-Pt-1	Box Canyon Dam site - topography (in 12 sheets)	Feb. 1939
-2	Box Canyon Reservoir site - topography (in 2 sheets)	Feb. 1939
-3	Box Canyon Saddle spillway site - topography	Mar. 26, 1939
-4	Santa Fe Diversion Dam site - reservoir topography	Mar. 20, 1939
-5	Lower Box Canyon Dam site - topography (in 2 sheets)	Aug. 1941
-6	Diversion Dam site - topography	Sept 1942
-7	Main Canal topography (in 7 sheets)	Sept. 1942

Supporting Data

The following supporting data are on file in the Regional office of the Bureau of Reclamation, Boulder City, Nevada:

Volume IV - Flood Control.

CLIMATE

The Weather Bureau established a precipitation station at Wittmann, about four miles east of the project, in December 1923, and temperature recording equipment was added in January 1930. Continuous precipitation records are available from 1923 to date, and continuous temperature records are available from 1930 to date.

In general, the climate of this project is similar to that of the Salt River Project at Phoenix, except for slightly lower temperatures and greater rainfall. The temperatures below 32 degrees occurring during December and January possibly will prove damaging to some of the less hardy crops. The climate, however, is adapted to double cropping as practiced on the Salt River Project. The elevation of the project area is about 600 feet higher than the Salt River Project, and its location in the saddle between White Tank Mountains on the south and Wickenburg Mountains to the north affords the project more complete air drainage; living conditions are slightly more desirable.

Temperature

Summaries of temperature records for 16 years at Wittmann and 45 years at Phoenix are compared below:

	Wittmann	Phoenix
Maximum temperature	117° F.	118° F.
Minimum "	16° F.	16° F.
Average "	69° F.	70° F.

Mean monthly temperatures at Wittmann are given in Table 11.

Table 1. -- Mean monthly Temperatures at Wittmann, Arizona - Elevation 1,657 feet.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Ann. Mean
(Unit-Degrees Fahrenheit)													
1930	48.8	57.8	57.6	68.6	69.2	84.4	89.7	87.6	79.6	67.8	57.6	49.4	68.2
31	49.6	54.2	59.0	67.8	76.4	84.2	93.1	87.2	81.6	69.2	54.8	47.0	68.7
32	55.6	53.0	57.2	64.0	72.5	85.6	89.8	90.0	85.4	69.6	62.0	47.4	69.3
33	46.4	47.2	58.6	61.6	69.0	85.0	94.0	90.4	85.5	75.8	61.5	52.8	69.0
34	52.0	58.4	67.8	72.6	80.9	80.8	93.2	89.8	82.5	72.6	68.8	54.1	72.1
35	51.5	55.0	53.8	64.7	69.3	85.6	89.0	87.4	82.0	69.6	55.5	52.2	68.0
36	50.6	52.1	61.4	69.3	79.0	87.7	91.4	89.4	81.4	71.0	59.9	51.0	70.4
37	39.6	51.0	56.4	64.4	76.0	83.4	91.6	92.0	86.2	73.8	60.9	55.5	69.2
38	52.8	53.6	56.3	66.6	74.2	84.2	89.2	88.8	85.4	70.8	54.0	54.7	69.2
39	49.8	45.6	59.4	69.2	76.7	84.4	92.2	89.1	80.8	69.0	62.1	55.6	69.5
1940	52.3	53.8	62.6	66.0	80.2	88.4	90.4	90.0	82.7	70.8	55.0	53.7	70.7
41	51.2	55.5	56.2	58.8	73.4	80.2	88.7	85.9	78.8	66.5	60.2	51.8	67.3
42	51.6	49.5	54.4	64.3	72.0	82.4	92.2	87.6	83.0	71.0	61.8	54.8	68.7
43	51.2	56.5	60.8	68.8	77.4	82.2	90.6	86.4	84.6	70.9	60.0	51.9	70.1
44	49.7	50.4	54.6	61.6	73.8	80.0	88.4	90.4	82.8	73.8	57.1	52.4	67.9
45	49.7	53.4	54.6	62.8	67.8	78.6	90.4	88.8	83.5	73.0	56.5	48.7	67.3
Mean	50.1	52.9	58.2	65.8	74.2	83.6	90.9	88.8	82.8	71.0	59.2	52.1	69.1

Growing seasons at Wittmann (see Table 2) are almost as long as those at Phoenix, which average 306 days (February 4 - December 7).

Table 2 .— Growing season at Wittmann, Arizona

Year	Date of Killing Frost: Last in Spring	Date of Killing Frost: First in Fall	Length of Frost-free Period in Days
1923	—	Dec. 12	—
24	March 16	Dec. 19	278
25	March 12	Nov. 15	248
26	March 11	Dec. 16	280
27	Jan. 26	Dec. 7	315
28	Feb. 16	Dec. 20	308
29	March 25	Nov. 14	234
1930	Feb. 25	Dec. 18	296
31	Feb. 22	Nov. 23	274
32	Feb. 4	Dec. 11	311
33	Feb. 21	Dec. 17	299
34	Jan. 22	Nov. 29	311
1935	Feb. 27	Dec. 14	290
36	Feb. 8	Nov. 4	270
37	March 19	Dec. 22	278
38	March 31	Nov. 13	227
39	March 11	Dec. 27	291
1940	Feb. 17	Dec. 15	302
41	Jan. 18	Dec. 25	341
42	March 26	Dec. 25	274
43	Feb. 12	Dec. 30	321
44	March 29	Nov. 26	242
1945	Feb. 22	Nov. 20	271
Average	Feb. 26	Dec. 8	285

Precipitation

Recorded precipitation at Wittmann (Table 3) has averaged 9.85 inches annually, of which 7.72 inches falls during the months of February through November. Tabulated below is a comparison with the average monthly precipitation at Phoenix (45 years record).

Average Precipitation in Inches:

Month	Wittmann	Phoenix
January	0.81	0.76
February	1.30	0.89
March	0.88	0.76
April	0.69	0.46
May	0.91	0.14
June	0.04	0.07
July	0.93	0.99
August	1.50	0.97
September	1.16	0.70
October	0.50	0.44
November	0.53	0.68
December	1.32	0.88
Total for Year	9.85	7.74

Table 3 . -- Precipitation at Wittmann, Arizona.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Total
					(Unit - Inches)								
1924	0.00	0.00	1.04	0.39	0.10	0.00	0.59	0.00	0.50	0.65	0.00	1.31	4.58
25	.05	.02	.08	.51	.00	.21	.26	1.58	1.23	2.02	.18	.14	6.28
26	.06	1.36	.92	4.45	.00	.00	2.78	.00	2.63	.15	.65	3.75	16.15
27	.15	2.80	.98	.78	.15	.12	.51	2.16	.45	.49	1.35	1.48	11.42
28	.02	1.11	.05	.00	.07	.00	1.69	.63	.52	.30	.09	.73	5.21
29	1.19	.50	.12	.30	.00	.00	.85	1.12	3.98	.00	.01	.00	8.07
1930	1.60	.20	1.95	.57	.93	.15	1.26	2.05	1.24	.29	.85	.02	11.11
31	.16	5.06	.08	.54	.25	.00	.51	6.62	.23	1.12	1.38	2.14	18.39
32	.39	3.08	.00	.00	.00	.09	.96	.32	.15	.78	.00	2.32	8.09
33	2.41	.10	.00	.97	.13	.16	.66	2.65	.68	.54	.70	.03	9.23
34	.28	.53	.03	.41	1.06	.05	.22	1.77	.18	.00	.47	1.47	6.47
35	2.24	2.15	1.32	.18	.30	.00	1.30	2.66	1.54	.00	.47	.24	12.40
36	.59	1.14	.22	.00	.00	.00	1.31	1.37	.53	.41	.66	1.46	7.69
37	1.90	1.39	1.81	.00	.05	.16	.71	.21	2.20	.00	.00	.54	8.97
38	.46	1.07	1.35	.00	.03	.00	.15	1.13	.22	.00	.00	2.30	7.01
39	.65	.44	.50	.12	.00	.00	.10	3.14	4.13	.00	1.24	.04	10.36
1940	.07	1.01	.08	.47	.05	.00	[illegible]	1.36	.84	2.02	.43	4.04	10.96
41	2.29	2.23	4.08	2.82	0.82	0.00	0.62	0.92	0.56	0.47	2.04	2.50	19.35
42	[illegible]	1.52	0.65	1.59	0.00	0.00	[illegible]	0.30	0.15	0.17	0.20	0.34	7.34
43	1.15	0.23	0.73	0.55	0.00	0.00	0.02	2.25	1.69	0.10	0.00	2.00	8.72
44	0.23	2.44	1.05	0.59	0.22	0.00	1.00	0.14	1.78	0.27	1.53	0.86	10.11
45	[illegible]	0.13	2.27	0.00	0.00	0.00	[illegible]	0.62	0.00	1.31	0.00	1.28	8.73
Aver	[illegible]	1.30	[illegible]	0.69	0.19	0.04	[illegible]	1.50	1.16	0.50	0.53	1.32	9.85
InFt	0.07	0.11	0.07	0.06	0.02	0.00	0.08	0.12	0.10	0.04	0.04	0.11	0.82

HISTORY OF ARIZONA WATER CONSERVATION DISTRICT

First efforts to harness the erratic and flashy Hassayampa River were made in 1883 by placer miners. In order to furnish water and power for the operations, the Walnut Grove Water Storage Company was organized in 1886, and Walnut Grove Dam near Wagoner was completed in 1888. This was a rockfill dam 110 feet high (the highest dam in the United States at that time) and provided for the storage of 10,000 acre-feet of water.

An extremely high runoff from melting snow occurred in February 1890. The incompleted spillway was unable to carry the flow and the dam failed after being overtopped for 48 hours; 129 people lost their lives in the flood.

After the destruction of the dam the company went into the hands of receivers, and in June 1908, all its assets were transferred to Eleanor C. Wittmann of New York by a Master Commissioner's Deed. In 1910, Mrs. Wittmann employed engineers to report on the feasibility of using the waters of the Hassayampa for power and irrigation. On January 1, 1914, the day the Carey Act became effective in Arizona, she filed an application to withdraw 17,600 acres of land near Morristown to be irrigated from the Hassayampa River. This application was granted on April 14, 1916.

Applications for rights-of-way for reservoir and dam sites in the Box Canyon, and for a canal along the river over Government land, had been made in 1910. These rights-of-way applications have never been denied and are presumed to be in force at the present time.

Engineers for Mrs. Wittmann made surveys, established gaging stations on the Hassayampa to determine whether the construction of a project was practical.

An application for a permit to use water from the Hassayampa River was filed with the State Water Commissioner January 1922, by Mrs. Eleanor Van Beuren Wittmann. A group of homesteaders in the vicinity of Nadaburg (now Wittmann) organized the Nadaburg Irrigation District in June 1923, and also applied for a permit to use water from the Hassayampa River to irrigate about 25,000 acres within their district. The State Water Commissioner decided in favor of the Wittmann interests because of their financial ability to construct the project, and issued the permit on March 5, 1924, to Joseph Wittmann, as Eleanor Van Beuren Wittmann, his wife, had previously passed away.

An agreement was made between Joseph Wittmann and the Nadaburg Irrigation District in 1928, whereby the owners of the land in the irrigation district deeded three-quarters of their land, about 12,000 acres, to Wittmann for the transfer of the water rights from Carey Act lands to district lands on the supposition that he would proceed with the construction of the irrigation system for the entire project. The transfer of the water rights from Carey Acts lands to district lands was approved by the United States General Land Office on May 19, 1928.

The name of Nadaburg Irrigation District was changed in 1929 to the Arizona Water Conservation District.

On April 24, 1933, the Arizona Water Conservation District filed an application with the Reconstruction Finance Corporation for a loan in the sum of $1,925,000. This application was later transferred to the Public Works Administration. A supplemental application was filed with the Public Works Administration in November 1933, to conform with the requirements of the National Recovery Act, and changed the amount of the requested loan and grant to $2,350,000. The state engineers for the Public Works Administration would not approve the grant, one of the reasons being that the project appeared to be largely a land promotion scheme for one interest.

The district filed an amendment to their application to the public Works Administration in September 1936, changing their plans somewhat and advising the Public Works Administration that Wittmann would deed the district 7,500 acres of land to be sold to help retire the bonds to be issued. The total cost of the project under the amended application was estimated at $1,651,000. The Public Works Administration approved the amended application but no allottment was made out of the 1938 appropriation. The district made application to the Reconstruction Finance Corporation in October 1938, for a loan of $2,000,000 to construct the irrigation works as set forth in their application to the Public Works Administration, but the executive committee of the Reconstruction Finance Corporation refused the application for the loan.

APPENDIX B
PROJECT LANDS

PROJECT LANDS

General Description

The Hassayampa Project consists of a portion of the lands occupying a large, gently sloping valley plain bounded by the Wickenburg and Hieroglyphic Mountains on the north, the White Tank Mountains on the south, the Hassayampa River on the west, and the Agua Fria River on the east. Project lands lie in a compact body a few miles west of Wittmann.

The most dominant physiographic feature of the area is a large alluvial fan, built up at the base of the enclosing mountains. The fan is exceptionally smooth-surfaced and uniform over most of the project area, the surface being broken only by the drainage channels of small intermittent streams and occasional small low ridges. The direction of slope is southeast.

Geologic materials from which the soils have developed consist primarily of quaternary alluvium, principally the outwash debris derived from igneous mountain rocks. These alluvial-fan deposits consist of angular and rounded sands, gravels and rock fragments, which are predominately granitic and quartzitic in origin. The deposits are several hundred feet or more in thickness over the basement igneous rock.

Soils

Soils of the project are alluvial in origin, and have developed under a hot, arid climate, resulting in such characteristics as a comparatively high degree of oxidation, little or no leaching of the soluble constituents, and a very low content of organic matter. The mature soils generally have a distinct reddish or pinkish tinge, and for that reason are identified as belonging to the Red Desert group of soils. Variations which occur are chiefly in soil texture, although nearly all of the soils are light textured. In places variable amounts and sizes of rock fragments and gravel occur on the surface or throughout the profile. On the basis of age, there are two main groups of soils in the project: (1) old alluvial-fan soils and (2) recent alluvial soils.

Old alluvial-fan soils cover the major part of the project area; these soils have a surface layer consisting of about seven inches of light brown or dull reddish-brown sandy loam to heavy silt loam, either not calcareous or only slightly calcareous. Below this layer, and continuing to a depth of about 12 or 15 inches, is a friable dull-red or reddish-brown sandy loam, slightly or distinctly calcareous. The upper subsoil layer is a dull-red or reddish-brown, compact, cloddy material, somewhat heavier in texture than the soil above it, highly calcareous and mottled with gray lime flecks. This layer, between 20 and 30 inches below the ground surface, merges into a deeper subsoil layer of compact, grayish, gritty loam, highly calcareous and weakly cemented with lime. In many places this layer continues with little change to six feet or more in depth where it grades into the parent material of rich brown, friable or loose, fine, gravelly loam and coarse sand particles, both angular and rounded. The parent materials, however, are often found throughout the profile. In some places small rock fragments are so numerous on the surface that they will interfere with cultivation and will require clearing.

The surface of these old alluvial soils absorbs moisture readily and internal drainage is good. Though generally free of harmful accumulations of alkali salts, a few small areas are slightly affected. The organic matter, nitrogen and available phosphorous content is low, but this condition may be readily corrected by the addition of green manure crops and superphosphate. The soils of this group, with the exception of minor areas covered with excess surface rock or comprised of coarse sandy materials, are desirable for irrigation and well suited to the production of the crops common to the region.

Recent alluvial soils border the drainage courses of the intermittent streams, or mark the old courses of depositing streams, and are of small extent in area. The surface soil, to an average depth of about 8 or 10 inches, is light brown, dull-brown or pinkish-brown friable loam or sandy loam underlaid by similar materials which are somewhat more calcareous. Some unweathered fine gravel and sand are present throughout the entire profile. Coarser, more porous strata occur in the subsoil, although compact layers, which probably represent an older soil covered by more recent overwash, are sometimes found in the lower part of the subsoil. Drainage is good and accumulations of salts are generally absent. The water-holding capacity is fair and, where not affected by excess surface rock or gravel, the soil is desirable for irrigation development. As in the mature alluvial-fan soils, the organic matter, nitrogen and available phosphorous content is low.

Topography

The topography of the project lands is highly suitable for irrigation. The alluvial fans slope steeply for a short distance from the base of the hills, but on the project area they merge into gently sloping, smooth-surfaced, uniform tracts. The slope ranges from 15 to 30 feet to the mile. Only a moderate amount of leveling will be necessary to prepare the land for irrigation.

Drainage

Soil and topographic conditions on the project are indicative of favorable drainage, both surface and internal. The general slope and natural drainage channels provide satisfactory surface runoff, and the sub-surface drainage is good due to the open permeable nature of the subsoils. There are no poorly drained areas on the project lands at the present time, and such conditions are not expected to develop extensively following irrigation. Any drainage needed will be of small extent and confined to localized areas.

Salinity and Alkalinity

The soils of the project are relatively free of soluble salts, though often highly calcareous in their subsoils, and are not highly alkaline. Soil reaction, expressed as "pH", varies from 7.8 to 8.0 and soluble salts are present in percentages averaging from a trace to 0.1 percent. A few very small tracts of land are affected by soluble salts present in amounts ranging from 0.2 percent to 0.5 percent, but alkalinity is not high and most of the salts can be successfully leached out of the soil or from the root zone to greater depths in the profile.

Land Classification

A semi-detailed land classification was made of the area in 1939 to determine the extent and character of the lands, and their suitability for development under irrigation. The classification was established by a correlation of the factors of soils, topography, and drainage; it involved the determination and delineation of the arable lands, and the segregation of these lands into two classes on the basis of their productive capacity.

Standards. Land classification standards were established by the Bureau of Reclamation, and are based on the correlation of the three physical features - soils, topography, and drainage - with crop production on similar lands under irrigation. The standards are summarized on the following page.

Semi-detailed Land Classification Standards,
Hassayampa Project - Arizona

Land Characteristics	Class 1 Land	Class 2 Land
Soils		
Texture	Sandy loam to friable clay loam	Loamy sand to friable clay
Depth*		
To sand, gravel or cobble	18 to 24 inches plus - good free-working soil	12 to 18 inches plus - good free-working soil
To relatively impervious subsoil material	48 inches plus	36 inches plus
To penetrable lime zone	18 inches with 48 inches penetrable	14 inches with 36 inches penetrable
Alkalinity	"pH" 8.6 or less, unless soil is calcareous, total salts are low and evidence of black alkali is absent	pH 9.0 or less, unless soil is calcareous, total salts are low and evidence of black alkali is absent
Salinity	Total salts not to exceed 0.2%. May be slightly higher in open permeable soils exhibiting good drainage qualities	Total salts not to exceed 0.5%. May be slightly higher in open permeable soils exhibiting good drainage qualifies.
Rock and rocky soil	No solid or loose rock that will interfere with ordinary cultivation	No rock in place. Easily removable loose rock limited to that generally cleared in similar communities where irrigation is practiced
Topography		
Slope	Smooth slopes up to 5% in general gradient; reasonably large-sized bodies sloping in the same plane	Smooth general slopes of 5% to 10% or rougher slopes less than 5% in general gradient
Surface	Even enough to require only small amount of leveling and no heavy grading	May require considerable leveling and moderate grading, but in amounts generally found feasible in like areas where irrigation is practiced.
Drainage	Soil and topographic conditions such that no specific drainage requirement is anticipated	Soil and topographic conditions such that some drainage will probably be required, but artificial drainage practicable at reasonable cost

* At the minimum depths the texture must be fine sandy loam or heavier, with some soil mixed with the gravel or cobble, and at the greater depths it must be as heavy as sandy loam. Loamy sands underlaid by coarse sand or gravel should be 24-30 inches deep (depending on the percent of silt and clay) to qualify for class 2.

Nonarable includes lands which do not meet the minimum requirements for class 2; also, small areas of arable land lying within larger nonarable areas when these would obviously not make usuable fields.

Methods. The classification standards were applied in the field to carefully observed soil characteristics, topographic features, and drainage conditions in order to appraise the suitability of the lands for irrigation agriculture. After the proper classification for each tract was determined, the area was delineated on base maps (plane-table sheets) on a scale of 1,000 feet to the inch. Classification boundaries were established along the traversed lines, the distances being determined by graphic triangulation, speedometer, or pacing and the boundaries then completed by sketching between known points. In keeping with the accuracy and detail of coverage required in a semi-detailed survey, the area was traversed at maximum intervals of one-half mile to examine surface features, and soil borings were made at the same interval, or oftener, to establish the character of the soils. The samples collected were subjected to field laboratory tests consisting of colorimetric determination of alkalinity, determination of the percentage of total soluble salts by use of the electrolytic bridge, and estimation of lime content by degree of effervescence with dilute acid.

Results of Land Classification in the Project Area

Results of the semi-detailed classification of the proposed project area based on the foregoing standards and methods are summarized as follows:

	Class 1	Class 2	Total
	Acres	Acres	Acres
Twp. 5 N., R. 3 W.	4740	36	4776
Twp. 5 N., R. 4 W.	2512	156	2668
Total project area	7252	192	7444
*Net project area	6817	181	6998

* Gross area less 6 percent to allow for rights-of-way for roads and ditches, buildings, and other nonproducing areas.

The irrigable lands of the proposed project comprise a net acreage of approximately 7,000 acres. Of this total about 98 percent of the land is Class 1, lying in one large compact body about four miles west of Wittmann. These soils have a texture, structure, depth, permeability and fertility suitable for permanent, profitable agriculture when irrigated. The water-holding capacity of the soils is good, as is drainage. The topography is smooth and gently sloping, and the lands will require only a relatively small amount of preparation for irrigation. They are well adapted to the production of all crops capable of being grown under irrigation within the climatic limitations of the region.

The extent of second-class lands is small, the tracts being scattered throughout the large body of Class 1 land or along its outer edges. They are limited in productivity, chiefly because of coarse-textured soils containing small rock fragments and gravel, or surface rock that will have to be cleared. In a few cases some leveling will also be required in addition to the removal of surface rock to prepare the land for irrigation. The Class 2 lands are, however, suitable for development and crop production with irrigation.

Nonarable lands are limited in extent on the project to a few small areas comprised chiefly of stony, coarse-textured soils of low water-holding capacity and productivity.

Selection of Project Area

The amount of land which can be put under irrigation in the Hassayampa Project is dependent entirely upon the amount of water available. There are more suitable lands available for irrigation than can be supplied water by full development of the existing water supply. The 7,000 acres selected for development, as covered by the foregoing discussion in this appendix, are among the best of these lands; they are close to an existing railroad and highway, and close to the Hassayampa River, which will minimize distribution and construction costs, and losses of water in transit to the lands.

Only a small portion of the selected project area lies within the boundaries of the existing Arizona Water Conservation District. A project could be developed to include only district lands; however, the majority of the lands within the district boundaries are less desirable agriculturally than those selected and, moreover, the main canal to serve such an area would need to be longer, and the project would be more expensive.

The total area susceptible to irrigation, if water were available, is shown on land classification drawing 3H-10-3, as well as the proposed project area, and a summary of all areas classified is presented in Table 4.

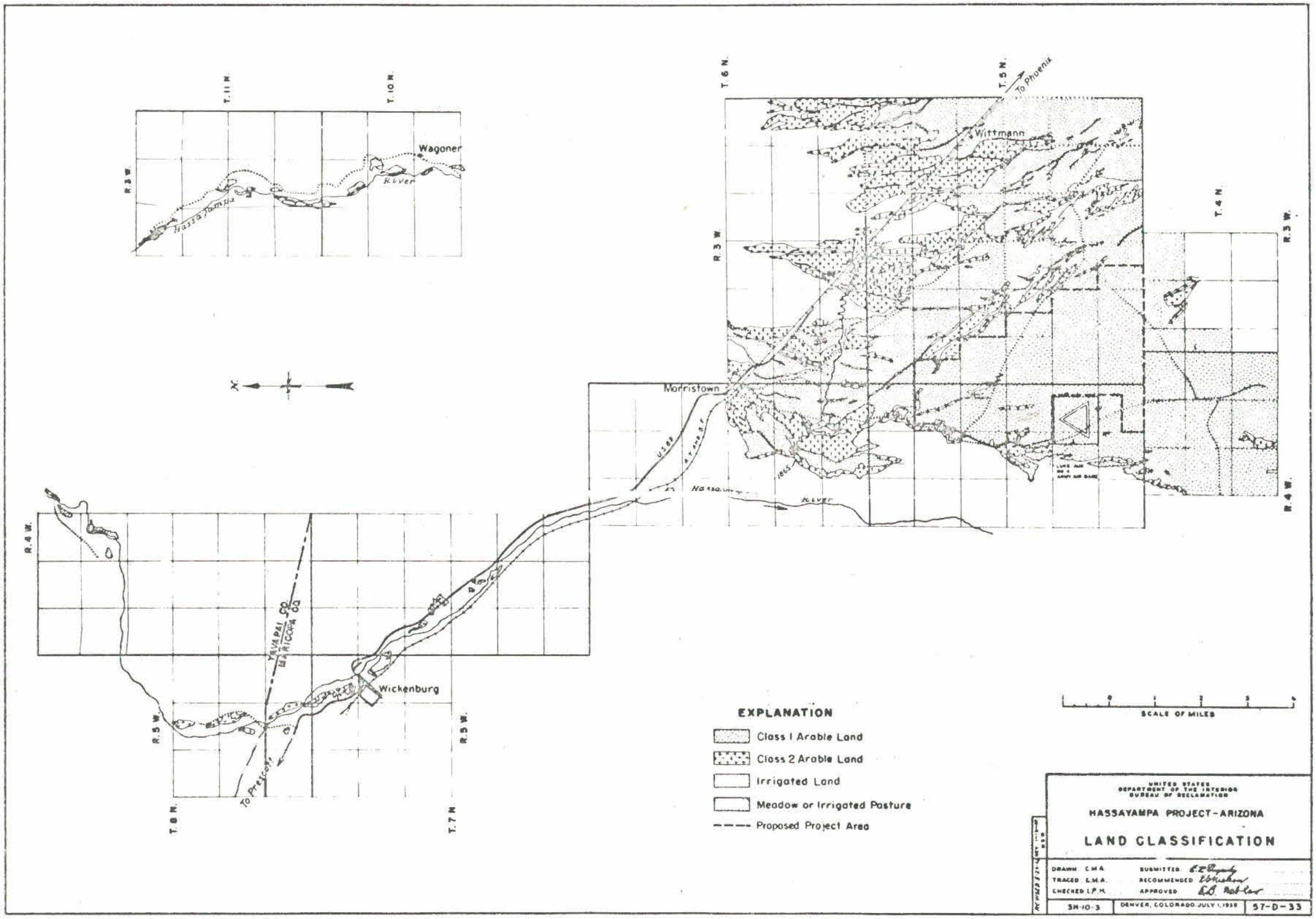

T. 11 N.
T. 10 N.
Wagoner
R. 3 W.
Hassayampa
River
T. 6 N.
T. 5 N.
To Phoenix
Wittmann
T. 4 N.
R. 3 W.
R. 3 W.
Morristown
Hassayampa
River
R. 4 W.
R. 4 W.
YAVAPAI CO.
MARICOPA CO.
Wickenburg
R. 5 W.
R. 5 W.
To Prescott
T. 8 N.
T. 7 N.
SCALE OF MILES
EXPLANATION
Class 1 Arable Land
Class 2 Arable Land
Irrigated Land
Meadow or Irrigated Pasture
Proposed Project Area
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
LAND CLASSIFICATION
DRAWN C.M.A.
TRACED C.M.A.
CHECKED L.P.H.
SUBMITTED
RECOMMENDED
APPROVED
3H-10-3
57-D-33

Table 4.- Land classification summary for area classified,
Hassayampa Project, Arizona

	Irrigated			Not Irrigated			Total Irribable
	Cultivated	Meadow	Total	Class 1	Class 2	Total	
	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)
Hassayampa River Valley above Box Canyon Dam Site	260	20	280		80	80	360
Hassayampa River Valley below Box Canyon Valley Site	180	10	190		280	280	470
Wittmann Area				30,595	9,185	39,780	39,780
Total Classified	440	30	470	30,595	9,545	40,140	40,610

APPENDIX C
WATER SUPPLY

INTRODUCTION

The Hassayampa River drains a rough mountainous area to the north of Wickenburg in southwestern Arizona. The drainage area ranges in elevation from about 900 feet at the mouth of the river to over 8,000 feet on the summits of the divide. The mountains surrounding the upper part of the basin, and particularly those along the eastern rim, are the westernmost high mountains in south central Arizona. As a result, the precipitation from the storms moving northeastward from the Gulf of California and from off the southern California coast is higher than upon the drainage of adjacent streams. Storms of high intensity on the drainage area result in flash floods during the summer months. During the winter heavy falls of snow and rain produce considerable runoff, but it is seldom of long duration.

The widely fluctuating intermittent flow of the Hassayampa River precludes any consideration of using direct diversion for irrigation use. Therefore, all waters for the project are to be stored in Box Canyon Reservoir and released, as required, into a closed conduit following the river channel to a point about 15 miles below. There the main canal will leave the river to serve the project lands located about 17 miles southeast of Wickenburg near the community of Wittmann. Because of the small supply, and the necessity of conserving water, a completely clay-lined distribution system is contemplated.

Drawing No. 3H-11-33 shows the general topography and the precipitation and gaging stations for the area above Box Canyon Damsite.

WATER RESOURCES

Available Supply

Annual runoff of the Hassayampa River has averaged 45,700 acre-feet during the period 1916-45. Preparation of runoff records and estimates has been complicated by the erratic behavior of the river, whose flows range from flash floods having high peak discharges and large volumes to mere trickles which disappear into the sandy bed for long distances. A large number of the flash floods occur during the night, probably due to summer storms occurring in the late afternoon. Spring floods constitute the greatest part of the year's flow; however, these do not occur each year. Heavy sustained flows occur after a warm rain has fallen on the snow in the higher reaches of the watershed; if the warm rains do not fall at the proper time, or the snowfall has been light; the water is lost through evaporation and ground seepage.

The channel of the Hassayampa River, from Box Canyon to its confluence with the Gila River, has a broad and sandy bottom, and gaging presents the problems of continually shifting channels. During the drier periods, there is no surface flow in most of the river channel; however, at White Point, about five miles south of Wickenburg, those

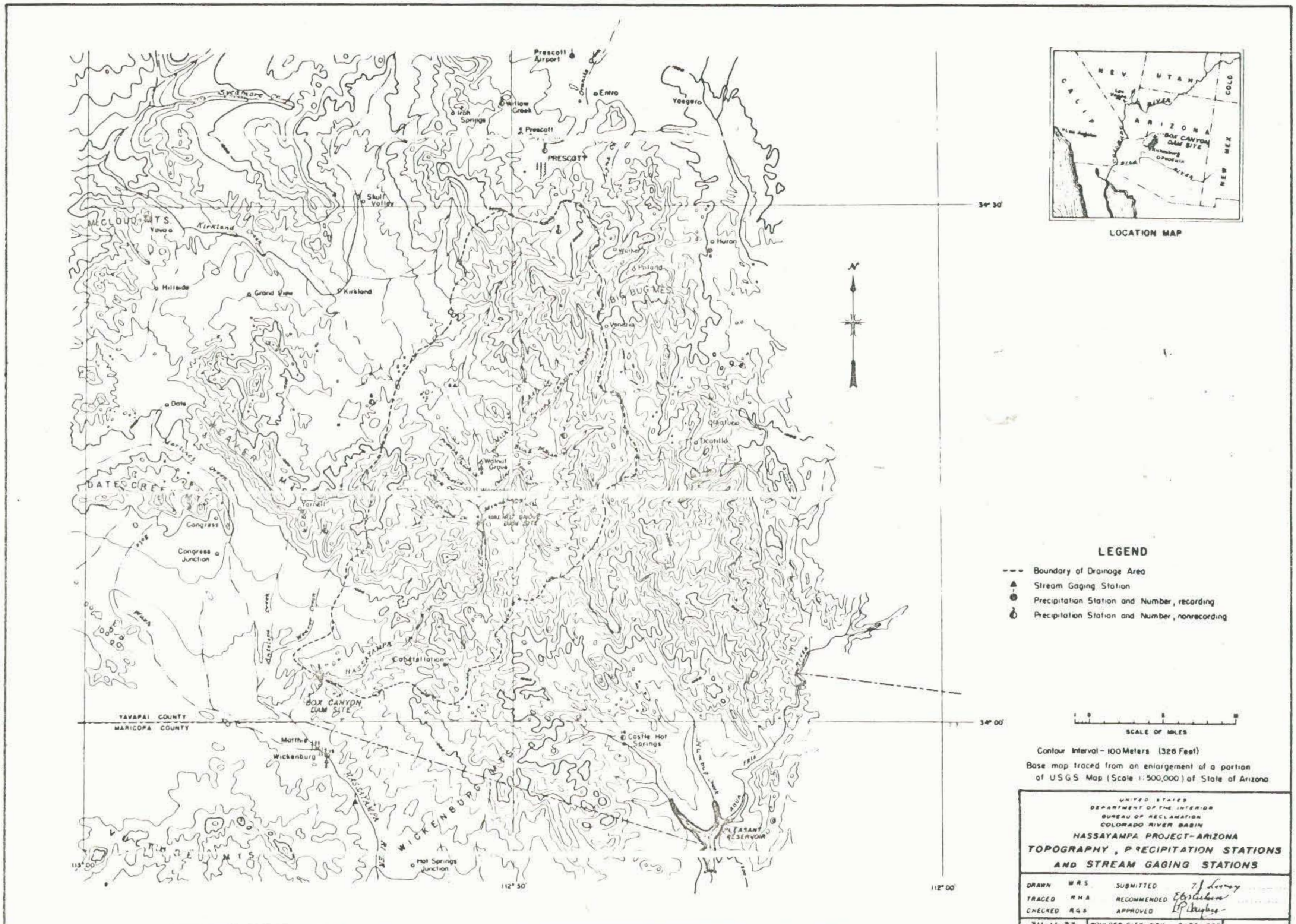

LOCATION MAP
NEV
UTAH
COLO
CALIF
ARIZONA
NEW MEX
BOX CANYON DAM SITE
LEGEND
Boundary of Drainage Area
Stream Gaging Station
Precipitation Station and Number, recording
Precipitation Station and Number, nonrecording
SCALE OF MILES
Contour Interval - 100 Meters (328 Feet)
Base map traced from an enlargement of a portion of U.S.G.S. Map (Scale 1:500,000) of State of Arizona
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER BASIN
HASSAYAMPA PROJECT-ARIZONA
TOPOGRAPHY, PRECIPITATION STATIONS
AND STREAM GAGING STATIONS
DRAWN W.R.S.
TRACED R.H.A.
CHECKED R.G.S.
SUBMITTED
RECOMMENDED
APPROVED
3H-11-33
BOULDER CITY, NEV.
Prescott Airport
Iron Springs
Willow Creek
Prescott
PRESCOTT
Skull Valley
Kirkland
Hillside
Grand View
Date
Congress
Congress Junction
Walnut Grove
Castle Hot Springs
Wickenburg
Hot Springs Junction
BOX CANYON DAM SITE
YAVAPAI COUNTY
MARICOPA COUNTY
BIG BUG MES
Huron
Yaeger
Entro
WICKENBURG MTS
34° 30'
34° 00'
113° 00'
112° 30'
112° 00'

PLATE I

-60-

persons familiar with the river state there has always been a small surface flow, even during the driest of years. The flow apparently is forced to the surface through shallow sand overlying bedrock, and is estimated to average three to four second-feet, with minimum flows of 0.50 second-feet.

Gaging stations. The first gaging station of record on the stream was established by the Geological Survey November 23, 1910, in section 20, T. 7 N., R. 4 W., about four miles below Wickenburg. This station was maintained during 1910 and 1911. From January 1 to October 31, 1912, the station was maintained in section 12, T. 7 N., R. 5 W., about one-fourth mile below Wickenburg. Only infrequent low-water measurements were made at these stations, and, because of the shifting sandy channel, rating curves were not obtained; hence, discharges were not computed.

On November 21, 1912, the Geological Survey established a gage near the line between sections 23 and 26, T. 11 N., R. 3 W., near Moore's ranch, one-fourth mile below the old Walnut Grove post office, and 4½ miles above Wagoner. The drainage area above this gage was about 96 square miles. The station was maintained until July 13, 1918, when it was discontinued. Due to infrequent measurements and shifting control, the records are classed as poor to fair. Gage heights were taken twice a day and averaged for daily mean, so flash floods were not necessarily recorded. Most of the low-water flow is diverted for irrigation above the location of the gage

On February 22, 1916, a gage was established at the head of the canyon below Wagoner at the site of the Walnut Grove Dam, by W. A. Farish, engineer for Joseph Wittmann. This station, controlling 263 square miles, was operated continuously under Mr. Farish's supervision until September 30, 1928. The station was equipped with a water-stage recorder and resident observers were employed to care for the recorder and make current meter measurements.

On June 1, 1921, Mr. Farish established another gaging station about one mile upstream from the Box Canyon Dam site, about 27 miles below the Walnut Grove Dam site. This station, also installed for the Wittmann interests, was equipped with a water-stage recorder and cable car for high-water measurements. Resident observers were employed to care for the recorder and make current meter measurements. Sometime between 1921 and 1926, the gage was moved downstream to the Box Canyon Dam site, where a cable could be installed high enough above stream bed to permit use during flood flows.

The gaging station at the Box Canyon site was taken over by the Geological Survey January 1, 1938, and operated until July 1, 1938, then abandoned. It was reestablished on April 18, 1946 in order to provide, by concurrent operation with the Morristown station, an accurate record of channel losses between the two stations.

On October 1, 1938, the Geological Survey established a gaging station on the Hassayampa River, about 15 river miles below Box Canyon near Morristown. On January 1, 1940, a gaging station was established by the Geological Survey near Wagoner, supposedly at the Walnut Grove Dam site. These stations are still in operation.

Drawing No. 3H-11-12 shows the periods for which runoff records are available on the Hassayampa and other nearby streams.

Accuracy of records. None of the runoff records secured on the Hassayampa River are of sufficient accuracy to be classed as good. The erratic occurrence of storm runoff, its short duration and nocturnal character, make it difficult to secure sufficient current meter measurements to establish good rating curves. Lack of permanent control sections and the sandy-bottomed, shiftying channels add to this difficulty. The relative inaccessibility of the gaging stations leaves the records obtained at unattended stations open to question.

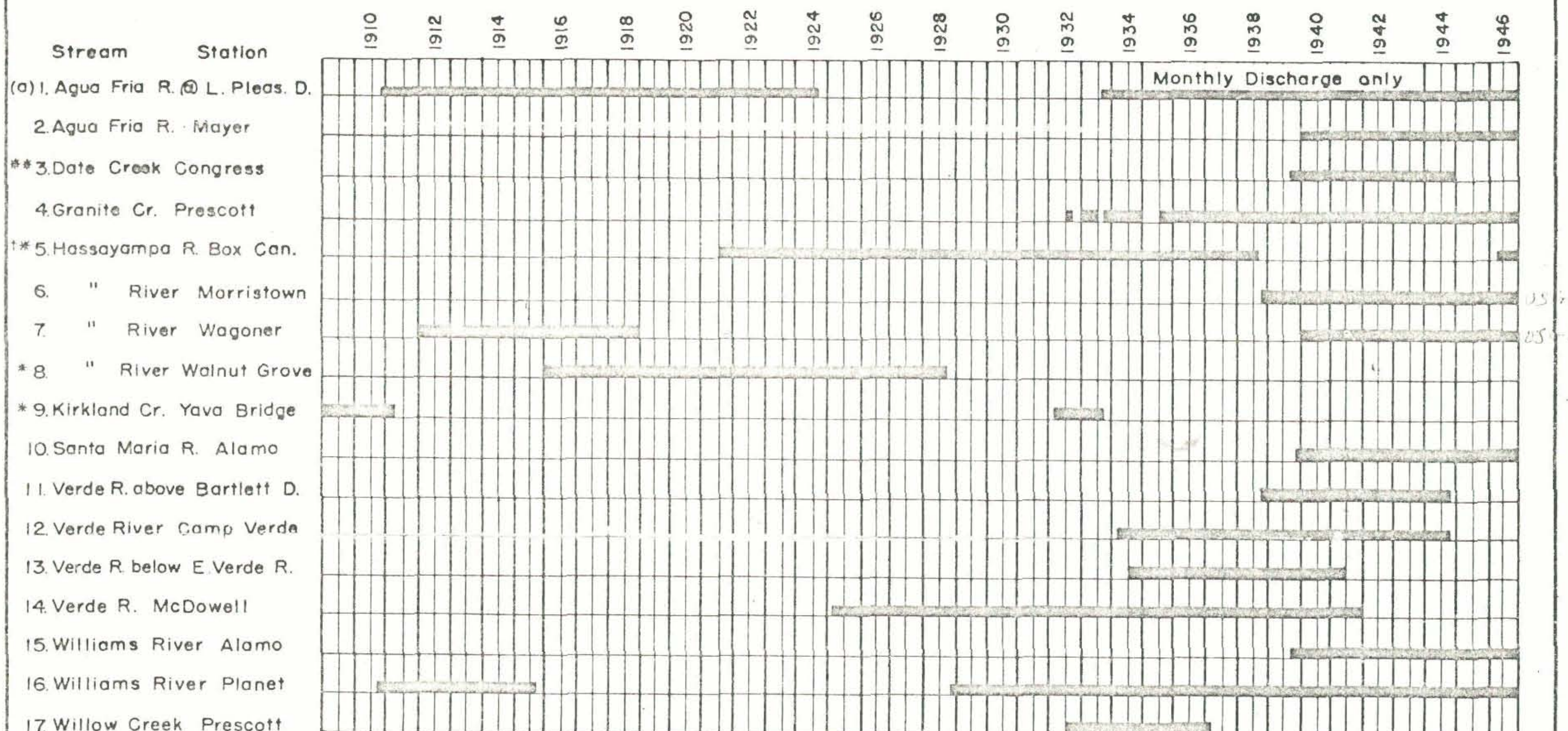
For the Geological Survey stations in the early days, discharge measurements were so infrequent that as a rule rating curves were not obtained. The shifting channel and flashy nature of the flood flows render the gage height tables of little value.

The data for the Walnut Grove and Box stations were computed and worked up by Mr. Farish. Flood discharges were determined from surface float velocity measurements and gage heights, or calculated by slope-area methods.

Review of Farish Records. Review of water records was confined to those for the Box Canyon Dam site. The river at this point includes water which has passed the Walnut Grove gaging station, and records at this site would be more desirable than those of the Walnut Grove site, or a combination of records at various sites. These records were furnished to the Bureau by Mr. Joseph Wittmann. Mr. Willmoth, an employee of the Arizona State Highway Department, formerly connected with the Arizona Water Conservation District as engineer, explained methods used in determining stream flows.

Stream gaging at the Box Canyon Dam site was begun June 1, 1921, under the direction of W. A. Farish, who computed and compiled the water records and employed several resident observers who took current meter measurements and observed the stage recorders. The station, according to Mr. Willmoth, was located upstream from the present dam site in a narrow reach of canyon 34 feet wide. The canyon extends up and downstream for some distance at about this same width. A cable and cable car were used. The automatic stage recorder was located on the south side of the canyon, the float enclosed by a square box formed by four 1-inch by 12-inch boards nailed together, and holes were drilled into the box to let in the water. A staff gage was nailed or painted on the side of the box or well.

During the low flows current meter readings were taken about one mile above the gaging station. Often during these low flows the water sank into the sand 200 to 400 feet above the gaging station. It is interesting to note that during dry periods, streams in this section



(a) November, 1910 to September 1924 (Published as Agua Fria River near Glendale)

* From records of W. A. Farish

* * Discontinued December 31, 1944

† Re-established May 4, 1946

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT–ARIZONA

AVAILABLE RUN-OFF RECORDS

DRAWN D.K.J. SUBMITTED T.J. Looney
TRACED K.L.H.–R.H.A. RECOMMENDED E.B. Nielsen
CHECKED R.G.S. APPROVED L.P. Douglas

3H-11-12 BOULDER CITY NEV. 6-14-1946

will flow at night and not in the daytime, due to the high evaporation and transpiration losses. This is true of the Hassayampa at Box Canyon, as evidenced by the recorder sheets.

In the review of the first years of measured flow, it was noted that no large flows were actually measured by current meter. Mr. Willmoth explains that the channel was so narrow and volume of water so great, that use of the cable car was not safe. From Farish's notes, flood estimates were based upon channel cross section and Kutter's formulae. The value of "n" used was .020. When floods occurred during the daytime, surface floats were used and the mean velocity computed as 0.8 of the surface velocity.

Original stage recorder sheets are available from June 1921 to November 6, 1922, but current meter notes are not. For the period, November 6, 1922 to January 1, 1923, neither were available, and a study of this period was not possible. Recorder sheets are not available until after July 31, 1930, although current meter notes are available from January 1, 1923 to January 1, 1938, except the period July 20, 1927, to August 20, 1930, which is missing. The missing records are said to have been destroyed by a fire which destroyed Mr. Farish's home.

In the early period of stream measurement trouble was experienced with the stage recorder. The sand and drift would cause the float to jam; the clock works failed on a number of occasions, and when such conditions arose the rise and fall of a flood was largely determined by resident observers. A small rise in the river could be detected the next morning by the turbidity of the water, which otherwise would have been clear.

As to the other equipment, letters were found stating that the current meters were calibrated by the Bureau of Standards and the University of California, for rod and cable suspension.

Until the water year 1926-27, no large flows were actually measured. Sometime between this period and start of the stream measurements, the gaging station was moved from its original location to a point approximately one mile downstream. There the channel was wider and flood measurements were obtainable from the cable car. The exact time when this change was made is not known.

The largest annual discharge, 155,875 acre-feet, occurred during the water year 1926-27; the maximum monthly flow, 109,840 acre-feet, occurred during February of that year. These flows were computed by Mr. Farish from gage heights and discharge tables. Surface floats were used to determine velocity, but it does not appear that the velocities so determined were used when computing the discharges. The discharge table prepared by Mr. Farish compares closely to a discharge curve developed by the Bureau for later floods.

Original records for the water system years 1927-28, and 1928-29 were not located. However, these two years experienced low flow and are believed not to be much in error. The water year 1930 has the lowest annual discharge recorded, 3,615 acre-feet. Flow was well distributed throughout the year and the total does not appear to be very much in error.

Recorder sheets are available from July 31, 1931, until January 1, 1938. The recorder did not function well, however, and missed all of the flows during August. The wooden box was still used.

Careful study of the original records - gage heights and measurements - obtained under the direction of Mr. Farish, indicates such records are and would be more reliable than any estimates which now might be made from the meager information available for the Hassayampa River drainage basin. The runoff records at the Walnut Grove and Box Canyon Dam sites furnished by the Wittmann interests have, therefore, been used as the basis for the water supply studies.

Runoff at Walnut Grove. Actual records of the runoff of the Hassayampa River at Walnut Grove (drainage area 268 sq. mi.) are available for the period 1921 through 1928. (See Table 5).

Table. 5. - Runoff of Hassayampa River at Walnut Grove

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Total
						(Unit -:1,000 Acre-feet)							
1916	35.0	25.0	15.5	7.6	1.1	0.5	0.7	0.7	3.0	6.1	0.5	0.5	96.2
17	2.6	1.2	1.6	10.8	3.2	0.8	1.5	1.7	0.4	0.4	0.4	0.4	25.0
18	0.5	0.4	0.7	0.4	0.3	0.3	0.2	2.7	0.4	0.3	0.3	1.2	7.7
19	0.8	1.9	0.7	0.4	0.3	0.2	4.7	5.2	0.5	1.2	13.6	4.5	34.0
1920	19.9	18.6	7.7	4.7	2.3	0.5	0.5	8.4	1.0	0.6	0.6	0.7	65.5
21	0.9	0.9	1.0	0.6	0.4	0.3	7.5	2.3	0.5	2.2	0.3	2.7	19.6
22	3.0	8.6	10.9	4.7	2.0	0.7	1.3	0.9	0.5	0.3	0.4	0.6	33.9
23	0.5	1.1	4.0	1.4	0.5	0.4	0.2	2.9	0.4	0.2	0.2	7.3	19.1
24	1.6	1.3	1.5	2.7	0.5	0.5	0.4	0.4	0.5	0.2	0.1	0.3	10.0
1925	0.4	0.4	0.4	0.3	0.2	0.5	3.0	1.1	9.0	2.9	0.2	0.2	18.6
26	0.2	0.2	0.3	5.8	0.5	0.2	0.8	0.5	1.7	0.2	0.1	1.8	12.3
27	0.4	19.1	6.2	2.5	0.7	0.5	0.5	2.8	1.5	0.5	0.4	1.1	36.2
28	0.6	1.7	0.9	0.4	0.3	0.2	1.2	1.0	0.1				6.4

Note: January and February 1916 are estimated

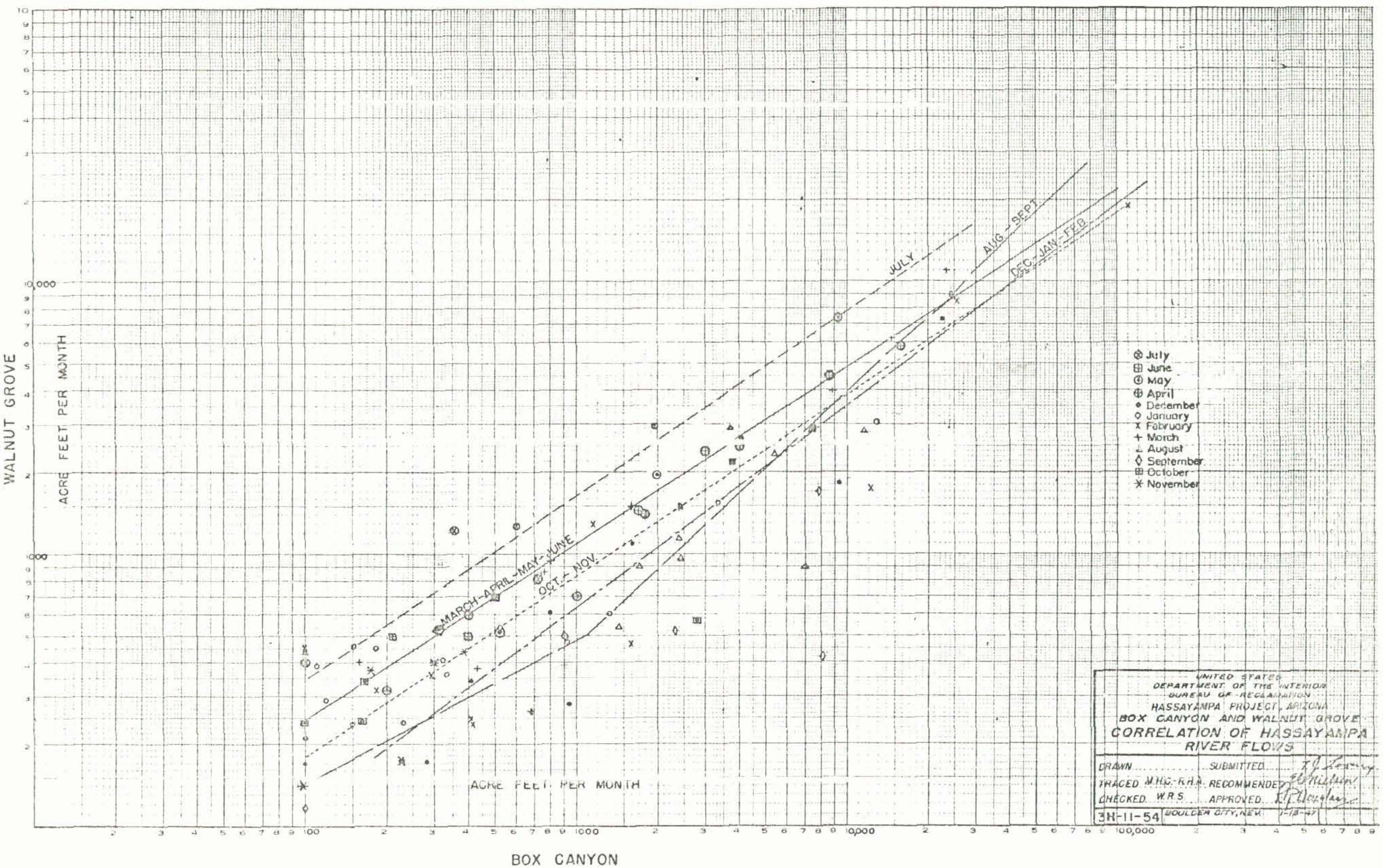
Runoff at Box Canyon. Actual records of the runoff at Box Canyon are available from June 1921 through June 1938. Records obtained at the new station established in April 1946 are not yet available.

Records at Box Canyon are concurrent with records at Walnut Grove for almost eight years. Correlation curves were plotted with fair results (see Dwg. No. 3H-11-54) making it possible to extend the Box Canyon records back to January 1916.

Runoff at Box Canyon for the period October 1938 through December 1945 was estimated on the basis of recorded flows at Morristown. Daily discharge records were inspected and a flow of 11 second-feet added whenever any flow was recorded at Morristown. 1/

As there are many days when there is some flow at Box Canyon but none at Morristown, this estimate of the increased runoff at Box Canyon should be conservative. Results of this method of estimating may be confirmed when records at the new station at Box Canyon become available.

1/ The loss between the gaging stations at Box Canyon and Morristown was determined to average 11 second-feet in the chapter on "River Channel Losses", page 77.


WALNUT GROVE
ACRE FEET PER MONTH
10,000
1000
JULY
AUG.-SEPT.
DEC.-JAN.-FEB.
MARCH-APRIL-MAY-JUNE
OCT.-NOV.
July
June
May
April
December
January
February
March
August
September
October
November
ACRE FEET PER MONTH
100
1000
10,000
100,000
BOX CANYON
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT, ARIZONA
BOX CANYON AND WALNUT GROVE
CORRELATION OF HASSAYAMPA
RIVER FLOWS
DRAWN
SUBMITTED
TRACED M.H.G.-R.H.A.
RECOMMENDED
CHECKED W.R.S.
APPROVED
3H-11-54
BOULDER CITY, NEV.
1-13-47

Runoff of the Hassayampa River at Box Canyon (Drainage area 422 square miles) is given in Table 6, based on the following records and estimates:

1. January 1916 through May 1921 - Estimated by correlation with Walnut Grove.
2. June 1921 through June 1938 - Actual records.
3. July 1938 through September 1938 - Estimated by plotting weighted precipitation against runoff.
4. October 1938 through December 1945 - Estimated by comparison with recorded flow at Morristown.

Runoff of the Hassayampa River at Box Canyon (Drainage area 422 square miles) is given in Table 6, based on the following records and estimates:

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3. July 1938 through September 1938 - Estimated by plotting weighted precipitation against runoff.
4. October 1938 through December 1945 - Estimated by comparison with recorded flow at Morristown.

Duplicate

Table 6-- Runoff of the Hassayampa River at Box Canyon

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
					(UNIT - 1,000 Acre-feet)								
1916	56.0	40.0	25.0	19.0	1.0	0.3	0.3	1.6	7.2	19.5	0.4	0.8	171.1
17	6.7	2.4	1.8	29.0	5.1	0.6	0.9	4.0	0.5	0.3	0.3	0.5	52.1
18	0.7	0.5	0.4	0.1	0.1	0.1	0.1	6.5	0.8	0.2	0.2	2.2	11.9
19	1.3	4.3	0.5	0.2	0.1	0.1	4.6	13.2	1.1	1.6	21.8	14.2	63.0
1920	31.9	29.9	19.0	9.1	2.9	0.3	0.2	21.8	2.2	0.5	0.6	1.2	119.6
21	1.5	1.5	0.9	0.4	0.2	0.1	9.2	5.3	0.9	3.7	0.2	4.0	27.9
22	12.9	25.4	23.9	8.4	2.0	0.5	0.6	1.7	2.3	0.2	0.3	0.8	79.0
23	0.5	2.0	8.7	1.7	0.3	0.1	0.4	3.7	7.9	0.2	1.6	22.6	49.7
24	3.3	1.1	1.6	3.0	0.3	0.1	0.1	0.1	0.3	0.1	0.0	0.9	10.9
1925	0.3	0.3	0.2	0.2	0.1	0.4	1.9	2.4	24.0	8.4	0.2	0.3	38.7
26	0.2	0.4	0.7	15.5	0.5	0.1	0.7	1.4	7.8	1.6	0.1	9.2	38.2
27	0.3	110.0	14.3	4.0	1.0	0.2	1.6	11.4	2.4	2.8	0.4	1.6	150.0
28	1.3	12.1	0.8	0.4	0.4	0.1	0.4	2.4	0.1	0.1	0.0	0.1	18.2
29	0.1	0.3	0.1	0.1	0.1	0.1	0.3	1.6	1.0	0.1	0.0	0.0	3.8
1930	0.2	0.1	1.8	0.2	0.1	0.0	0.1	0.8	0.1	0.0	0.2	0.1	3.7
31	0.1	10.1	0.5	0.2	0.1	0.0	0.6	18.9	0.3	0.1	0.4	1.4	32.7
32	0.5	31.5	10.7	1.9	0.4	0.1	0.5	0.1	0.1	0.3	0.1	0.7	46.9
33	2.7	0.6	0.6	0.4	0.3	0.1	0.2	0.7	3.3	0.3	0.2	0.1	9.5
34	0.1	0.1	0.1	0.1	0.2	0.1	0.1	2.5	0.1	0.1	0.2	0.1	3.8
1935	1.9	23.8	8.0	1.7	0.3	0.1	0.3	47.1	15.7	0.2	0.2	0.2	99.5
36	0.3	1.5	0.7	0.4	0.2	0.2	7.1	15.6	13.4	1.0	0.2	0.3	45.9
37	2.6	77.7	43.5	4.8	0.3	3.8	0.5	3.8	2.0	0.2	0.2	0.2	138.6
38	0.1	0.1	~~43.0~~ 13.7	0.3	0.1	0.05	0.3	1.6	0.1	0.7	0.7	2.1	~~31.1~~
39	0.7	0.7	0.8	0.6	0.0	0.0	0.0	0.5	4.5	0.7	0.8	0.8	10.0
1940	0.7	0.8	0.7	0.1	0.0	0.0	0.0	0.0	0.4	1.0	0.5	2.4	6.6
41	1.2	8.3	28.0	25.9	3.4	0.5	0.9	1.3	0.7	0.0	0.1	0.1	70.4
42	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.8
43	0.8	0.7	0.8	0.2	0.0	0.0	0.0	2.5	0.3	1.2	0.7	0.8	8.0
44	0.8	3.0	3.9	1.9	0.8	0.1	0.1	0.6	0.1	0.6	0.7	0.8	13.4
1945	0.8	0.7	6.8	3.6	0.9	0.0	0.1	1.0	0.4	0.6	0.7	0.8	16.4
Total	130.7	390.0	228.9	133.5	21.2	8.1	32.1	174.2	105.0	46.3	32.0	69.5	1371.5
Mean	4.4	13.0	7.6	4.4	0.7	0.3	1.1	5.8	3.5	1.5	1.1	2.3	45.7

Quality of Water

The quality of the water of the Hassayampa River is suitable for irrigation use. Chemical analysis of a sample taken at Box Canyon by George E. Draper, assistant agricultural chemist for J. H. O'Dell, county agricultural agent, Phoenix, Arizona, follows:

	Parts per Million
Calcium	68
Magnesium	19
Sodium	44
Chlorides	24
Sulfates	80
Carbonates	0
Bicarbonates	273
Total dissolved solids	508

This analysis shows a percent sodium of 28. The dissolved constituents are largely bicarbonates of calcium which do not detract from the suitableness of the water for irrigation.

Records of analyses of additional samples are on file in the county agent's office, but the data are incomplete, as there are no records of the dates when samples were taken or of the discharges of the stream when taken. Available data are given in Table 7.

Table 7 - Summary of Several Analyses of Hassayampa River Water.

Point of Sampling	Box Canyon	Walnut Grove	Below Wickenburg	at Wickenburg Hghwy Bridge	At S.F.R. Bridge	Hghwy 80 Bridge	Hghwy 80 Bridge
Stage of River	?	?	?	Floodwater	Floodflow	?	?
Sample No.	(Analyzed) (3/18/37)	A2233	A2345	A2625	A2622	A2383	A2627
			(Parts per Million)				
Ca	38	75	60	60	105	38	105
Mg	4	8	11	8	8	4	15
Na	26	46	62	25	46	169	253
Cl	8	24	34	12	16	172	302
SO4	35	30	40	20	80	100	200
CO3	0	-	10	-	-	-	-
HCO3	144	307	273	24[illegible]	351	156	288
T.D.S.	255	490	490	36[illegible]	606	639	1163

Although the available data are not complete, it is expected that storage will result in a blending of the flows, with the result that the diluting action of flood flows of good quality will offset the effect of low flows of somewhat questionable quality.

Small areas have been irrigated with the direct flows of the Hassayampa River for some years without injurious effects from the quality of the water.

WATER REQUIREMENTS

Consumptive Use

Extensive studies by A. F. Johnson and R. L. Lowry Jr., of the Bureau of Reclamation, have developed a relationship between consumptive use and total heat units as measured by the day-degrees above freezing temperature during the growing season. The growing season is defined as the period between the dates when the twice smoothed five-day moving average minimum temperature curve rises above freezing. The studies and resulting curves are outlined in the Transactions of the American Society of Civil Engineers, 1942.

The period of record selected for determining water requirements for the Hassayampa Project is 1930 to 1940 inclusive. From the standpoint of both temperatures and precipitation, this period represents a decade of near maximum requirement for irrigation water in the Southwest. The total average heat units in day-degrees above 32° F. during the growing season at Wittmann for this period is 18,274, corresponding to an annual consumptive use of 3.68 acre-feet per acre. The average annual precipitation in the five driest years is 0.49 feet. It is estimated that 90 percent, or 0.44 feet, is effective in meeting consumptive use, the remainder lost as runoff resulting from rainstorms of high intensity. The consumptive use to be met by irrigation water is, therefore, 3.24 acre-feet annually.

Diversion Requirements

Water must be delivered at the farmers headgate in sufficient quantity to provide for anticipated farm wastes and excess application, as well as the estimated consumptive use. Careful study of operation conditions and practices in the Gila and Salt River Valleys, led to the conclusion that an allowance of 20 percent should be made to cover expected wastes.

Losses between the farmers headgate and the reservoir will be small. Most of the main canal will be a closed conduit where losses will be negligible: the high value of irrigation water and permeable nature of the canal and lateral locations make it necessary to line the remainder of the main canal and the laterals. Sufficient data are available from operating Bureau projects to indicate that an allowance of 15 percent is ample to cover the seepage and evaporations losses which will occur in the main canal and lateral system.

Based on the above conclusions, the diversion requirement at the reservoir is set at 4.75 acre-feet per acre, as summarized below:

	Acre-feet per acre
Annual Consumptive Use	3.68
Less Effective Precipitation	0.44
Irrigation Water Consumptive Use	3.24
Farm Waste and excess application (20%)	0.81
Required farm delivery of irrigation water	4.05
Canal and lateral losses (15%)	.70
Diversion requirement at reservoir	4.75

Distribution of Demand. The lands of the Hassayampa Project are, in general, similarly situated as to climate and rainfall to those of the Maricopa County Municipal Water Conservation District No. 1 (Beardsley Project) on the Agua Fria River, some 13 miles to the southeast. Prior to 1940, when pumps were installed to supplement the gravity supply, the district was subject to acute shortages. The acreage cultivated on the project has since been reduced to conform to the available water supply, and the shortages have not been serious. Operating officials of the Beardsley Project estimate their optimum requirement at the diversion as 4.11 acre-feet per acre cultivated, distributed as shown in Table 8. The monthly distribution of demand is considered similar to that expected for the Hassayampa area. The winter demand (December and January) on the Hassayampa lands may be somewhat greater as a result of a larger proportion of alfalfa, and other forage crop, whose growth will continue during these months. Cotton, extensively grown on the Beardsley lands, requires more water during the hot summer months of July and August, when the alfalfa is more or less dormant.

Table 8 - Monthly water requirements for the Hassayampa Project, Arizona.

Month	Percent of Annual Demand: Beardsley (percent)	Percent of Annual Demand: Hassayampa (percent)	Adopted Demand Hassayampa Project (acre-feet per acre)
Jan.	2	3	0.14
Feb.	4	4	.19
Mar.	8	8	.29
Apr.	11	11	.52
May	12	12	.57
June	13	13	.62
July	13	12	.57
Aug.	13	12	.57
Sept.	12	12	.57
Oct.	6	6	.29
Nov.	4	4	.19
Dec.	2	3	.14
Totals	100	100	4.75

Return Flow

There will be no return flow available for re-use by the project. Topography of the area is such that all excess applications and farm wastes, will disappear into the underground water basin.

Evaporation Losses

Numerous evaporation stations are operated in Arizona by the Weather Bureau. In addition, several stations are operated at Lake Mead by the Bureau of Reclamation. Averages of the annual temperature and evaporation during the period of record were prepared for representative stations. These data are summarized in Table 9.

Table 9.- Evaporation and temperature data for Arizona stations.

	Period	Mean Annual Temp.	Average Annual Evaporation: Observed From Pan	Average Annual Evaporation: Free Water Surface
		F°	Inches	Feet
Lees Ferry	1922-45	61.4	89.89	5.17
Mesa Experiment Farm	1916-45	67.9	79.80	4.59
Roosevelt	1915-45	67.3	79.38	4.56
University of Arizona	1929-45	67.3	85.43	4.91
Willcox	1917-35	59.6	85.55	4.92
Yuma - Citrus	1921-45	72.1	117.42	6.75
Yuma - Valley	1932-39	69.4	104.15	5.99
Sierra Ancha	1937-45	60.0	72.30	4.16
Yuma - Evaporation	1917-27	67.9	77.74	4.40
Boulder City	1936-45	66.8	119.89	6.90
Bartlett Dam	1941-45	69.6	116.86	6.72
Safford	1941-45	63.6	70.55	4.06
Lake Mead Floating Pans Ave 1/	1936-45	72.6	98.48	6.40
Lake Mead Land Pans Ave 1/	1936-45	72.6	121.53	6.99

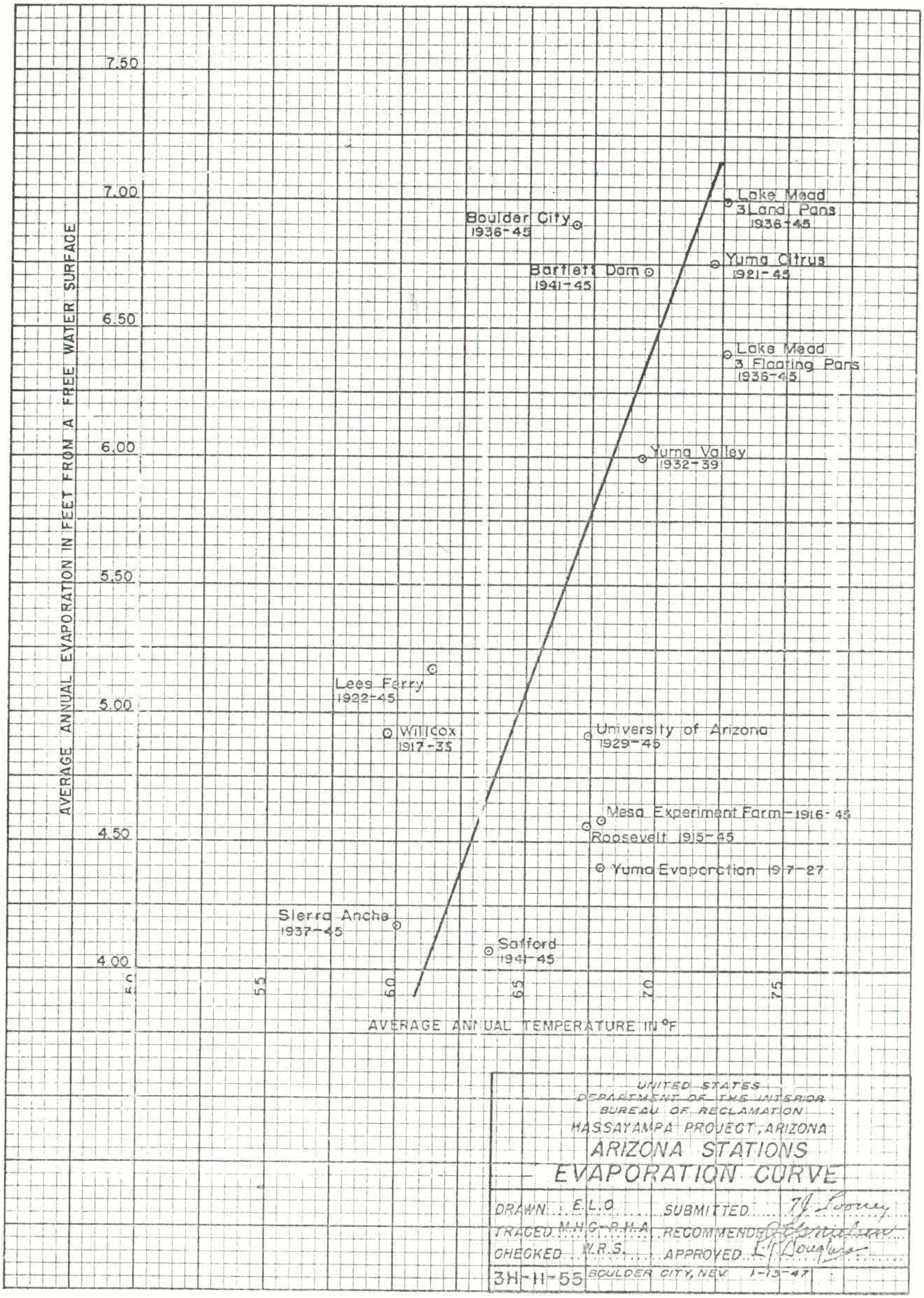
1/ Temperature at Hoover Dam.

The foregoing data, as plotted on Drawing 3H-11-55, indicate a rather erratic relationship between annual temperature and annual evaporation. As no one station is believed to represent evaporative conditions at Box Canyon Reservoir site, the expected evaporation was determined from the curve drawn on the above drawing.

Box Canyon Reservoir Evaporation. Temperature records are not available for Box Canyon, and Records for the Weather Bureau cooperative station at Wickenburg, Arizona, were used instead. This station is located about seven miles downstream from the reservoir, and climatic conditions are not materially different from those at the reservoir site. The mean annual temperature at Wickenburg is 64.7. The estimated evaporation at Box Canyon Reservoir, then, is 5.0 annually.

The monthly distribution of evaporation is based on the relation of monthly to annual evaporation at three stations: Tucson (Univ. of Ariz.), Mesa Experiment Farm, and Yuma Valley.

Some loss will occur by evaporation and transpiration from the annual precipitation on the lands which will be inundated. The average annual precipitation at the reservoir site, estimated from records at Wickenburg and Walnut Grove, is 1.17 feet, of which 1.0 foot is lost at present, indicating a net evaporation loss of 4.0 feet annually. Table 10 shows the derivation of the mean monthly evaporation in feet at Box Canyon Reservoir and Drawing No. 3H-11-53 gives monthly evaporation curves for the various reservoir capacities.


AVERAGE ANNUAL EVAPORATION IN FEET FROM A FREE WATER SURFACE
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
50
55
60
65
70
75
AVERAGE ANNUAL TEMPERATURE IN °F
Lake Mead 3 Land Pans 1936-45
Boulder City 1936-45
Bartlett Dam 1941-45
Yuma Citrus 1921-45
Lake Mead 3 Floating Pans 1936-45
Yuma Valley 1932-39
Lees Ferry 1922-45
Willcox 1917-35
University of Arizona 1929-45
Mesa Experiment Farm-1916-45
Roosevelt 1915-45
Yuma Evaporation 1917-27
Sierra Ancha 1937-45
Safford 1941-45
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT, ARIZONA
ARIZONA STATIONS
EVAPORATION CURVE
DRAWN E.L.O.
SUBMITTED
TRACED M.H.G.-R.H.A.
RECOMMENDED
CHECKED W.R.S.
APPROVED
3H-11-55
BOULDER CITY, NEV. 1-13-47

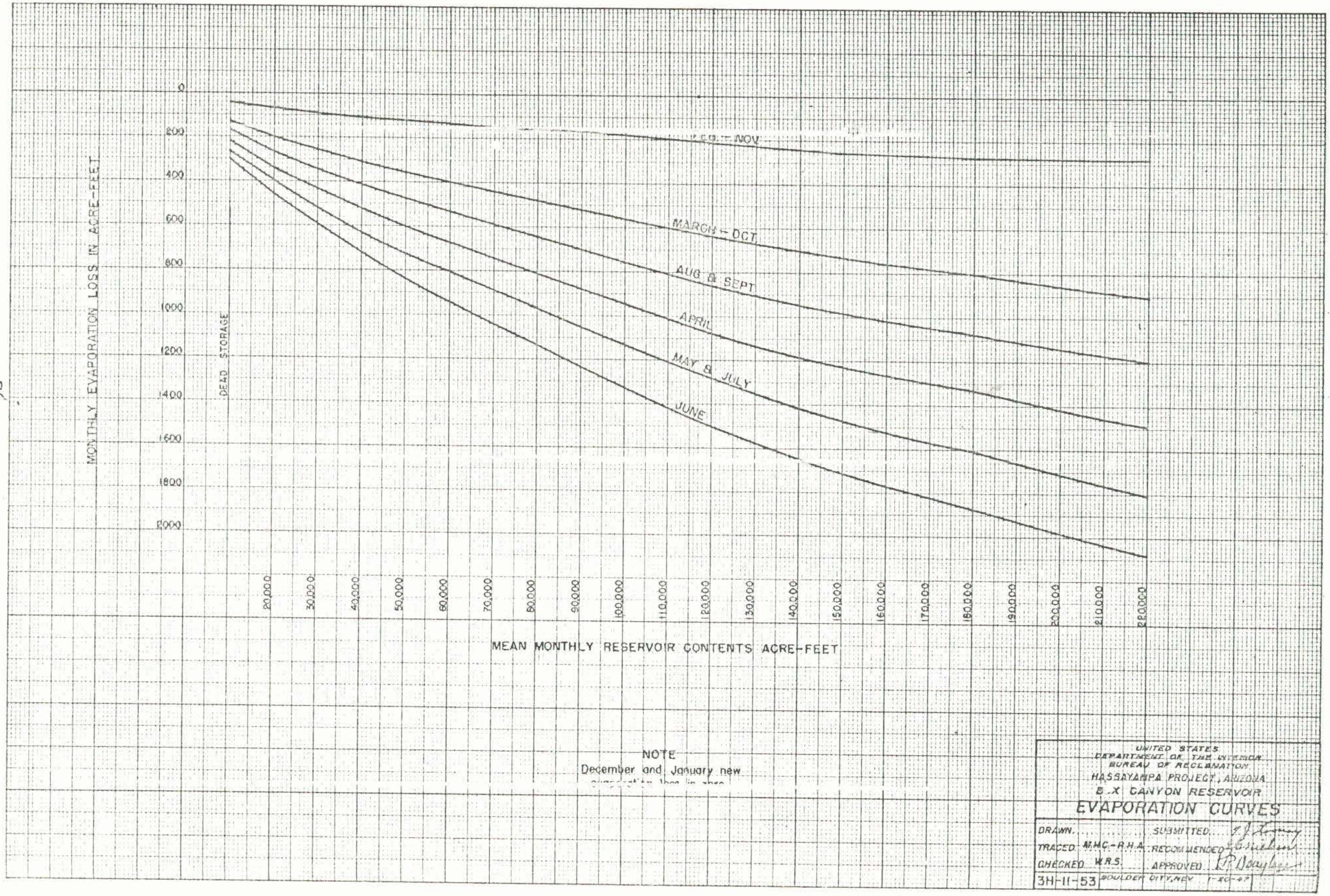

MONTHLY EVAPORATION LOSS IN ACRE-FEET
0
200
400
600
800
1000
1200
1400
1600
1800
2000
DEAD STORAGE
FEB - NOV
MARCH - OCT
AUG & SEPT
APRIL
MAY & JULY
JUNE
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000
140,000
150,000
160,000
170,000
180,000
190,000
200,000
210,000
220,000
MEAN MONTHLY RESERVOIR CONTENTS ACRE-FEET
NOTE
December and January new
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT, ARIZONA
B.X CANYON RESERVOIR
EVAPORATION CURVES
DRAWN.
TRACED M.H.C.-R.H.A.
CHECKED W.R.S.
SUBMITTED
RECOMMENDED
APPROVED
3H-11-53
BOULDER CITY, NEV

Table 10. - Estimated monthly evaporation at Box Canyon Reservoir Site.

Month	Percent Annual	Reservoir Evap.	Precipitation: Wickenburg	Precipitation: Walnut Grove	Precipitation: Estimate at Box	Est. Net Water Surface Evaporation
	(Percent)	(Feet)	(Feet)	(Feet)	(Feet)	(Feet)
January	3	0.15	0.11	0.14	0.13	0.0
February	4	0.20	0.09	0.16	0.13	0.1
March	7	0.35	0.06	0.12	0.09	0.3
April	10	0.50	0.05	0.07	0.06	0.5
May	13	0.65	0.01	0.02	0.02	0.6
June	14	0.70	0.01	0.02	0.02	0.7
July	14	0.70	0.11	0.18	0.15	0.6
August	12	0.60	0.14	0.20	0.17	0.4
September	9	0.45	0.08	0.12	0.10	0.4
October	7	0.35	0.05	0.09	0.07	0.3
November	4	0.20	0.05	0.11	0.08	0.1
December	3	0.15	0.13	0.16	0.15	0.0
Annual	100	5.00	0.89	1.39	1.17	4.0

River Channel Losses

Transpiration and Evaporation. Earlier plans considered by other interests for the Hassayampa Project contemplated using the Hassayampa River to convey the water from the reservoir to a diversion site where the main canal leaves the river. In his letter to the Secretary of the Interior, dated December 7, 1931, the late W. A. Farish, engineer for the Arizona Water Conservation District, states that he has measured Hassayampa River valley for 18 miles below the Box Canyon, and has tested the same for underground water supply. While exception may be taken to his conclusions as regards amount and availability of underground water, conferences by representatives of the Bureau with those who assisted in the measurements indicate definitely that the work of measuring was carefully and thoroughly done. He states that in the 18-mile length the river bottoms cover an area of 2,079 acres as the diversion site proposed by Mr. Farish is 15 miles below the Box Canyon, it is assumed that the area of the river bottoms between these two points is 1,733 acres.

Construction of storage reservoirs on streams in southern Arizona has always resulted in a marked deterioration in channel capacities of the streams below the reservoir, due to growth of water-loving vegetation. Unregulated floods have tended to keep channels scoured clean, and when such floods are reduced in amount and number by regulating works, channel capacities are so reduced that in many cases more damage is done by small floods than was the case for larger floods in the unrestricted channel. At some places in the Salt River it is now impossible to cross the river without chopping a trail through the underbrush and tree growth.

After completion of the storage works at Box Canyon, it is believed that if the channel of the Hassayampa River were used as a carrier of water to the diversion point it would follow the same processes as have prevailed on the Salt and Gila Rivers, and become covered with a growth of cottonwoods and general phreatophytes; 1/ however, intermittent spilling of Box Canyon Reservoir, flash floods from side drainage, and releases from the reservoir for diversion, would maintain a clear channel estimated to be approximately 100 feet wide. The total area of this channel in a length of 15 miles would be 183 acres. Thus, for computation purposes, the transmission losses between Box Canyon and the suggested diversion site, neglecting losses due to ground water and gains from side drainage, may be considered as the evaporation losses from 183 acres of water surface and wetted sand, and 1,550 acres of cottonwood trees and general phreatophytes.

In the report by the Geological Survey of the United States Department of the Interior on Water Resources of the Safford and Duncan Virden Valleys, accompanying a flood control report on the upper Gila River by the Army Engineers, the consumptive use of phreatophytes in the Duncan Virden Valley, which is similar to the portion of the Hassayampa River Valley under consideration, was found to be 5.06 acre-feet per acre for the water year 1940.

On the basis of studies made by the Bureau (see chapter on "Evaporation") it was determined that the annual free water surface evaporation from the Box Reservoir will be 5.00 feet per year. In the above-mentioned Geological Survey report, the rate of evaporation from wetted sand relative to the rate of evaporation from a free water surface is found to be expressed by the fraction 70/75. Hence, in this case, the annual evaporation from wetted sands will be approximately 4.70 acre-feet per acre. These evaporation and transpiration rates include precipitation which must be deducted in order to obtain net losses. Table 11 shows the transpiration and evaporation, by months, which would occur in the Hassayampa stream bed for the water year 1940, based on the Duncan Virden Valley studies, as given in Table 10 of the Geological Survey report. The monthly precipitation is from the Weather Bureau records at Wickenburg, since this town is located approximately halfway between Box Canyon and the diversion point.

1/ Phreatophyte - A deep-rooted plant which obtains its water from the water table or the layer of soil just above it. Webster's unabridged.

Table 11. - Channel losses to evaporation and transpiration

Month	Wetted Sand: Precipitation at Wickenburg	Wetted Sand: Evaporation from Wetted Sand Surface	Wetted Sand: Net Evaporation from Wetted Sand Area 1/	Phreatophytes: Transpiration and Evaporation From area of Phreatophytes	Phreatophytes: Net Transpiration and Evaporation from Area of Phreatophytes
		(Unit-feet)			
Jan.	0.11	0.14	0.05	0.00	0.00
Febr.	0.09	0.19	0.12	0.00	0.00
Mar.	0.06	0.33	0.28	0.16	0.10
Apr.	0.05	0.47	0.44	0.62	0.57
May	0.01	0.61	0.60	0.78	0.77
June	0.01	0.66	0.65	0.85	0.84
July	0.11	0.66	0.57	0.88	0.77
Aug.	0.14	0.56	0.45	0.79	0.63
Sept.	0.08	0.42	0.36	0.50	0.42
Oct.	0.05	0.33	0.29	0.48	0.43
Nov.	0.05	0.19	0.14	0.00	0.00
Dec.	0.13	0.14	0.04	0.00	0.00
Total:	0.89	4.70	3.99	5.06	4.53

1/ Precipitation was considered as 80 percent effective in offsetting evaporation from a wetted sand area and 100 percent effective in offsetting evaporation and transpiration from a phreatophyte area.

The net evaporation from a wetted sand area is 3.99 acre-feet per acre; on an area of 183 acres this represents a total annual loss of 750 acre-feet. The net loss of 4.53 acre-feet per acre, as shown for transpiration and evaporation from the phreatophytes area of 1,500 acres, will give a total annual loss of 7,050 acre-feet; thus, the total channel losses between Box Canyon Reservoir and the diversion dam proposed would be 7,800 acre-feet per year, equivalent to a uniform flow of 11 second-feet.

The town of Wickenburg now uses one second-foot for its domestic water supply. If an allowance be made for 100 percent increase, the demand would be two second-feet, of which at least 50 percent would return to the stream as return flow. The total deduction from irrigation water between Box Canyon and the diversion point is thus estimated at 12 second-feet.

Tending to offset this loss are the surface and underground flows of the river, contributed by side drainage below Box Canyon and the portion of the underground flow which passes Box Canyon and is, therefore, unaccounted for in the water assumed as available for storage.

An accurate estimate of the contribution from side drainage will require records covering an extended period, involving considerable expense, as the installation and maintenance of gaging stations would be necessary. However, from inspection of the streams and a general knowledge of their characteristics, it is well established that they contribute only to the surface flow of the Hassayampa River at infrequent intervals. Since storage of side drainage below Box Canyon is not contemplated, the effect of these flood flows on channel losses will necessarily be small, therefore, the main contribution of the side drainage must be in the form of underflow.

Underflow. A pumping test was made in the summer of 1940 by the Bureau, in cooperation with the Wittmann interests, to ascertain the underflow at the Farish diversion site in order to determine whether the underflow would be sufficient to supply a part of the irrigation requirements. A test well was driven in the middle of the river channel to what was presumed to be bedrock. Observation wells were placed at points upstream and downstream from this test well, and, from these, measurements were made of the variations in underground water levels while pumping from the test well. The field data collected were intended for substitution in Thiem's formula to ascertain the porosity of the underground channel. The location of the testing field was not very suitable for the purpose, as the axis of the cone at right angles to the river channel was so small that instead of a circular base with the same level, the cone took the shape of an irregular ellipse with the water levels on the sides generally lower than at the circular ends. Trouble also was experienced in carrying the water pumped from the test well downstream a sufficient distance beyond the influence of the pumping test to prevent its return upstream, and numerous breakdowns in the pumping equipment prevented continuous steady pumping over a sufficient period to furnish data for use in the Thiem formula.

All data accumulated were studied by the Tucson office, Ground Water Division of the Geological Survey, which cooperated with the Bureau in its studies. The erratic nature of the data resulted in two values of underflow by the Geological Survey, a minimum of 0.15 second-feet and a maximum of 0.41 second-feet. Based on their experience on the study of ground water, the Tucson office of the Geological Survey is of the opinion that the underflow at the point of testing is not more than 1.0 second-foot, and any constant flows as great as 7.0 or 8.0 second-foot, which were pumped at different times during the test, are very definitely questionable and probably originated from ground storage.

Estimates made by the Bureau are as follows: The cross-sectional area of the underground channel at the diversion point was found to be 32,000 square feet, and is based on the depth of the test well (108 feet), the width of the river channel (325 feet), and the general slope of the canyon walls (½:1):

Underground cross-sectional area . . . . 32,000 sq.ft.
Porosity of underground area . . . . 35 percent
Specific yield of underground area . . . . . . 15 percent
Velocity of underflow (min.) . . . . 0.00012 ft./sec
Velocity of underflow (max.) . . . . 0.0007 ft./sec

Using these values:
(32,000) (0.35) (0.15) (0.00012) = 0.20 s.f. minimum
(32,000) (0.35) (0.15) (.0007) = 1.18 s.f. maximum

Therefore, it seems safe to estimate the underflow of the Hassayampa River at the Farish diversion point as not more than 1.0 second-foot.

Investigations made by W. A. Farish, on the Hassayampa River from the diversion point to the Box Canyon Dam site, covered a year and a half in time, and included numerous analyses by a Los Angeles commercial laboratory, of samples of the river channel to obtain the percent of porosity. The average of the highest values obtained ran about 35 percent. The Tucson office of the Ground Water Division of the Geological Survey states that in the Gila Valley the specific yield of underground basins is not over 15 percent. The Salt River Valley Water Users' Association states that it estimates that ground water in this section moves at the rate of about 10 feet per day. This is equivalent to a flow of 0.00012 feet per second. Underground water in the San Fernando Valley in California moves at the rate of one-third of a mile per month, which is equivalent to a flow of 0.0007 feet per second. Bulletin 45, Division of Water Resources, Department of Public Works, State of California, states that the maximum specific yield obtainable under the most favorable conditions is not over 25 percent.

The above studies led to the conclusion that underflow is negligible when considered as a source of water supply for irrigation.

Stream measurements made by the Bureau in August 1942, failed to disprove these conclusions. These measurements were made at a time when stream flow is considered a base flow, the river being a succession of small surface flows with intervening stretches of dry channel. Measurements were made at White Point about 2.5 miles above the diversion point, and at the diversion point as follows:

No.	Date	Time	Location	Surface Flow
1	8/18/42	11:00 a.m.	White Point	3.21 s. f.
*2	8/18/42	2:00 p.m.	Diversion Point	0.14 s. f.
3	8/20/42	6:30 a.m.	Diversion Point	0.59 s. f.
4	8/20/42	7:30 a.m.	White Point	3:11 s. f.
5	8/20/42	10:15 a.m.	Diversion Point	0.64 s. f.

* At 3:30 p.m. the river channel was entirely dry for a distance of about 1.5 miles above the diversion point.

The loss in surface flow between White Point and the diversion point cannot be accounted for by assuming it is a river transmission loss to the underflow. If it were, the surface flow would not retreat upstream over a mile and a half during the heated part of the day, as it does daily. Such losses must be largely accounted for by evaporation, and transpiration by phreatophytes along the stream course.

Studies of tributary washes indicate they have little effect towards reducing river transmission losses. Their surface flow is known to be extremely erratic and usually scanty. Wherever their channels have been inspected, there is no vegetation near the channel, which is usually an indication that ground water is more than 50 feet below the surface. This is confirmed by studies of the Bureau made on the Hassayampa River on June 4, 1941. At that date there was a flow of 11.5 second-feet at the Box Canyon Dam site, and 1.18 second-feet at the diversion point. The stream was at a fairly constant stage, though slightly falling. The stream was continuous between the two points and varied in width from 6 to 100 feet. The average temperature for the day at Wickenburg was 7 degrees below normal for the month. The precipitation had been above normal for the month, and also for the prior 6 months; it totaled 10.90 inches above normal subsequent to December 1, 1940. Evaporation records at Roosevelt Dam show the evaporation for June 4 to be 0.36 inches. Reduced to evaporation from wetted sand, the evaporation for the day was 0.252 inches. At the time of study, the water was spreading over the greater part of the channel in places, and the area equivalent to wetted sand is estimated at about one-half the total channel area, or 866 acres. Based on these conditions and considering relative evaporation in this area it was computed that the total evaporation was equivalent to a flow of 11.45 second-feet. The difference in surface flow between Box Canyon and the suggested diversion point was 10.32 second-feet; the evaporation loss was 11.45 second-feet, only 1.13 second-feet was received as inflow from side drainage underflow. The 1.13 second-feet inflow is probably a maximum, since the measurements were made during an exceptionally wet period and maximum evaporation losses, particularly with regard to the area exposed to evaporation, were used. High sustained floods during the previous months may have resulted in some small contribution from bank storage.

Considering the small amount of underflow involved, it may be wise to disregard it as a means of reducing river transmission losses.

Conclusions. Based on the studies of channel losses between the Box Canyon and the suggested diversion point, it is to be concluded that the greater part of the annual channel loss of 7,800 acre-feet must be supplied from stored water released from Box Canyon Reservoir before irrigation demands can be supplied, if water is to be delivered through the river channel. The intervening drainage area of Martinez Creek, Sols Wash, and Santo Domingo Wash, totaling about 390 square miles, will contribute some runoff, both on the surface in the early spring and as underflow during later months. Definite information is not available, nor easily secured without extended and costly studies, as to the probable amount and distribution of this inflow.

The amount, and its availability, is such that in dry years it cannot be depended upon to offset the losses in transit of waters from the reservoir destined for use on the project. With the limited water supply available, a closed conduit from the reservoir to the diversion point will save water in an amount sufficient to justify the cost, as compared with the plan suggested by Mr. Farish and others, for open channel flow in the streambed and the utilization of a diversion dam and headworks.

WATER RIGHTS

Introduction

Surface waters. Three classes of surface water rights are recognized in Arizona: Those vested according to local custom, or under Federal laws enacted in 1866, and 1870, codified in sections 2339 and 2340, respectively, of the United States Revised Statutes; those decreed by the district courts, under territorial laws of 1887, prescribing the manner of acquiring water rights by appropriation; and those perfected under the State Water Code of 1919. The Arizona Supreme Court has held the 1919 code to be constitutional and, further, that after the adoption of the code, water rights cannot be secured in any manner, except as prescribed by the code or by it as amended.

Ground Water. The state courts have ruled that under existing laws:

(a) Subterranean waters are not subject to appropriation, unless it can be definitely and conclusively shown that the subterranean flow is in a natural channel between well-defined banks. In the latter case, the subterranean stream is subject to appropriation under the same rules as surface streams.

(b) Ground waters not confined in well-defined or definite channels have repeatedly been held by the state courts to be the property of the owner of the land under which they are found.

(c) The rights to surface flow of the Hassayampa River constitute a valid claim to the subsurface flow in the stream bed.

Relative priority of rights: The Arizona Water Code recognizes the doctrine of "first in time is first in right," and priorities of the relative rights are determined by the courts, or by hearings held for such purpose by the State Land Commissioner. The rights to the Hassayampa River flows have not been adjudicated. In fact, few, if any, such determinations or adjudications have yet been made in the State. The relationship between the vested water rights on the Hassayampa River is, therefore, not known. Neither has a relative priority been established between rights on the Hassayampa and those on the Gila River below the mouth of the Hassayampa.

Existing Rights

Present Uses. The land classification survey made by the Bureau showed a total of 470 acres now irrigated from the Hassayampa River. Of these lands, 280 acres are located above Box Canyon Dam site, and 170 acres are located between the dam site and the mouth of the Canyon. The remaining 20 acres are located about one-half mile below the mouth of the canyon. These lands have water rights through usage which were in effect prior to the passage of the present State Water Code in 1919.

In addition to these rights for irrigation use, the City of Wickenburg pumps its domestic water supply from a well in the Hassayampa River on the outskirts of the town. This well has been in use for many years.

The Walnut Grove Dam, impounding about 10,000 acre-feet of water, was constructed in 1886-87, the water to be used for power production and placer mining. This dam was destroyed by a flood on February 22, 1890, and has never been rebuilt. Under existing law, any right attached to the dam would probably be void, due to five consecutive years of non-use.

Farther upstream, depletion will be very limited; the land classification shows only 80 acres of arable land, of which 30 acres are within the flow line of Box Reservoir. The water supply is insufficient during dry periods for the present irrigated area, and storage sites are lacking, or too expensive to develop for the limited area which can be irrigated.

Rights under Water Code. Five applications have been made to the State Land Commissioner for water right permits on the Hassayampa River since the 1919 law was passed. Permits were issued for three of the applications. Data on the applications and permits are given in Table 12.

Table 12 - Data on Water Right Applications and Permits for the Hassayampa River--Yavapai and Maricopa Counties.

Application Number	Date Filed	By Whom Filed	Permit Number	Amount and Use Claimed	Acreage to be served
R.-67	11-29-21	Joseph Wittmann	R-79	Two reservoirs Walnut Grove & Box, 120,000 A.F.	
A-260	1-22-22	" "	A-342	100 s.f. from Walnut Grove & Box Reservoirs for irrigation	17,320
A-1034	10-24-29	" "	A-701	17 s.f. from Walnut Grove & Box Reservoirs for irrigation	2,579.86
A-155	2-9-21	W. D. McClerry	None issued	2 s.f. for irrigation in Sec. 17, T.12N., R.4 W.	Not given
A-204	1-8-22	W. B. Young	None issued	25 s.f. for irrigation in Sec. 4, T.11 N., R. 4 W.	Not given

Permits R-69, A-346 and A-701, were transferred to the Arizona Water Conservation District. On December 21, 1943, the State Land Commissioner granted an extension of time for the permits of the Arizona Water Conservation District, to December 31, 1947.

The State Land Commissioner's office states that in its opinion the Arizona Water Conservation District's water claim is in good standing and that the district should not have an difficulty in establishing their right at least to 1921, if not earlier. The 1921 date is that of the filing of Joseph Wittmann on the Walnut Grove and Box Reservoirs. Presumably, such a priority could be claimed on the ground that the studies and investigations by the Wittmann interests since that date satisfy the requirements of article 1, paragraph 3288, of the State Water Code, as follows:

> "Time of construction. Actual construction, except under applications by a city or town for its municipal uses, shall begin within one year from the approval of the application, be prosecuted with reasonable diligence and completed within a reasonable time, to be fixed in the permit not to exceed five years from the date of such approval. The commissioner shall, for good cause shown, extend the time beyond the five years if the magnitude, physical difficulties and cost of the work merit such extension."

Downstream rights. The Hassayampa River joins the Gila River some 60 miles below Box Canyon Dam site. All ordinary flows and all except the highest flood flows sink into the sandy bed of the Hassayampa before they reach the Gila River.

Irrigated lands of the Roosevelt Irrigation District and the Buckeye Water Conservation and Drainage District lie along the Hassayampa River near its mouth. The irrigation supply for these lands is from wells and by diversions form the Gila River above the mouth of the Hassayampa; no attempts have been made to divert the surface flows from the latter stream. Lack of adequate water precludes irrigating these lands by pumping from Hassayampa underflows.

The Gillespie Dam on the Gila River, about 10 miles below the mouth of the Hassayampa, owned by the Gillespie Land and Cattle Company was built with the expectation of diverting a large amount of subsurface flow for irrigation. The present concrete structure, built about 1921, replaced one constructed in the 1890's which subsequently failed and was abandoned for a number of years.

The present structure was supposedly founded on bed rock; however, wells drilled in this area disclosed several distinct lava flows, each overlaid with porous material, and it is believed that the larger part of the underflow may be lost through porous strata lying below the lava flow upon which the dam was constructed. The dam did not provide the expected supply and, consequently, the irrigators of some 14,000 acres under the canal from the dam were forced to depend largely on the inadequate surface flow of the Gila River, consisting of flood waters and return flow from irrigation districts above. A series of wells have been drilled along the canal and groundwater is pumped to supplement the surface flow of the Gila. A part of this groundwater may come from the Hassayampa underflow, but undoubtedly the greater portion is from the Salt and Gila Rivers.

There are no important diversions from the Gila River below the Gillespie heading.

Effect of Prior Rights Upon Project Water Supply. Use of water by the 280 acres of irrigated land located above Box Canyon Dam site is already reflected in the discharge records of the Hassayampa River at Box Canyon. Further depletion by additional irrigation development in this region is unlikely because of the erratic stream flows which require storage, and the relatively small area (80 acres) of unirrigated land that is suitable for irrigation.

A full irrigation supply for the 190 acres of irrigated area below Box Canyon Reservoir would require diversion of about 900 acre-feet per year. All of these lands are located close to the river. To avoid heavy river losses, it is planned to deliver Hassayampa water to which these lands are entitled from the project main canal. These deliveries are estimated to average 500 acre-feet annually in low years and 900 acre-feet in years of high runoff.

Use by the town of Wickenburg, pumped from the Hassayampa underflow, has been in the neighborhood of 670,000 gallons per day, or approximately 745 acre-feet annually. With allowance for a growth in population to double the 1940 population of about 1,000, the pumpage by Wickenburg will probably not exceed 1,500 acre-feet annually from the underground flow. Of this amount, over 50 percent is expected to return to the Hassayampa River Channel, indicating a net increased depletion of about 300 to 400 acre-feet annually. Such increased use is expected to be supplied from water originating below the Box Canyon Dam.

The Gillespie rights from the Gila River, which include the contribution of the Hassayampa, would have priority to any which may attach to the proposed Hassayampa Project development. Runoff records at Gillespie Dam show that during the period from August 1921, to June 1938, inclusive, when records on the Hassayampa at Box Canyon are concurrently available, there were only two occasions (July-August 1927, and August-September 1936) when flood flows were not passing Gillespie Dam at the time of appreciable flood runoff in the Hassayampa River. It is concluded that storage of Hassayampa flood flows will not interfere with the surface rights of the Gillespie development.

Ground Water

The annual flow of the Hassayampa River at the Box Canyon Dam site averages 45,700 acre-feet annually. The discharge at the mouth of the river is estimated to average about 5,000 acre-feet annually. The difference, plus the discharge from the tributaries below Box Canyon is lost by evaporation and transpiration or by percolation to the water table by spreading over the broad sandy bed of the stream in the 60 miles between the dam site and the mouth. Data are inadequate to permit an accurate estimate of the average annual contribution is believed to be of considerable quantity.

In the absence of definite decrees or permits covering appropriation of the subterranean flow of the Hassayampa itself, or of channels deriving their water supply from the Hassayampa, some investigations were made of ground-water conditions in the region of the project to ascertain if development of the project would adversely affect the water supply for other areas which may derive their underground water supply from the Hassayampa River.

Two developed irrigated regions which might be adversely affected by project construction are as follows:

(1) About 13 miles southeast of the project area is located the Maricopa County Municipal Water Conservation District No. 1. The lands of the district are supplied in part by diversions from the Agua Fria River and Lake Pleasant Reservoir, and in part by ground-water pumping plants located along the canal line. Farther east toward the Agua Fria is located the large tract of the Southwest Cotton Company irrigated entirely by pumping from ground water.

(2) Several individual pumping plants and the pumps of the Gillespie Land and Cattle Company draw their supply from the ground waters of the Gila River bottoms below the mouth of the Hassayampa River.

Effect of Project on Agua Fria Area. The Hassayampa and Agua Fria Rivers flow along approximately parallel courses about 20 miles apart after they emerge from the mountains at the north until they join the Gila River southwest of Phoenix, a distance of about 30 miles. After leaving the mountains their courses are through structural valleys filled with alluvial material which, in many cases, is very deep. Along a considerable portion of the distance between the mountains and the Gila River the valleys of the two streams are separated by the White Tank Mountains. North of these mountains they are separated only by a low saddle of alluvial material.

For the purpose of ground-water studies, it is important to know whether any crystalline rock ridge or other barrier exists which is sufficiently high to act as an underground water divide separating the water tables of the Hassayampa and Agua Fria Rivers north of the White Tank Mountains.

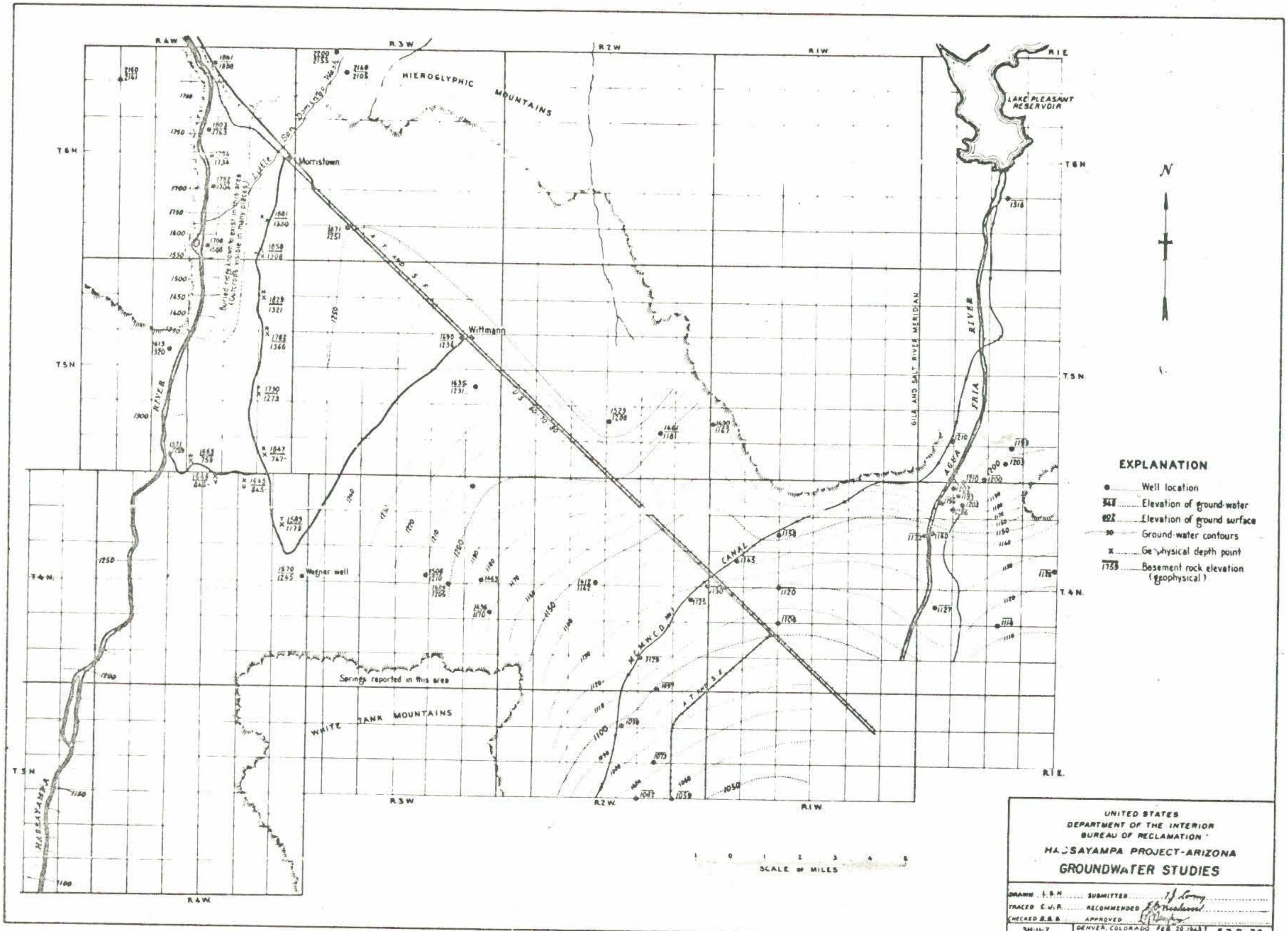
The water table of the Hassayampa River is confined to a relatively narrow valley by rock barriers on both sides down to a point approximately six and one-half miles below the point where the Santa Fe Railroad crosses the river. Below this point it is unconfined on the east and, as far as surface conditions indicate, free to spread out until it is again limited on this side by the White Tank Mountains. This distance, along which there is no apparent confinement on the east side, is approximately eight miles.

For this distance, then, from all surface indications, it is possible for the water table of the Hassayampa River to be tributary to that of the Agua Fria River. The area under which any water from the Hassayampa River valley table would have to pass on its way to the Agua Fria is, therefore, limited on the east and west by the Hassayampa and Agua Fria Rivers respectively, and on the north by the Hieroglyphic Mountains, and on the south by the White Tank Mountains.

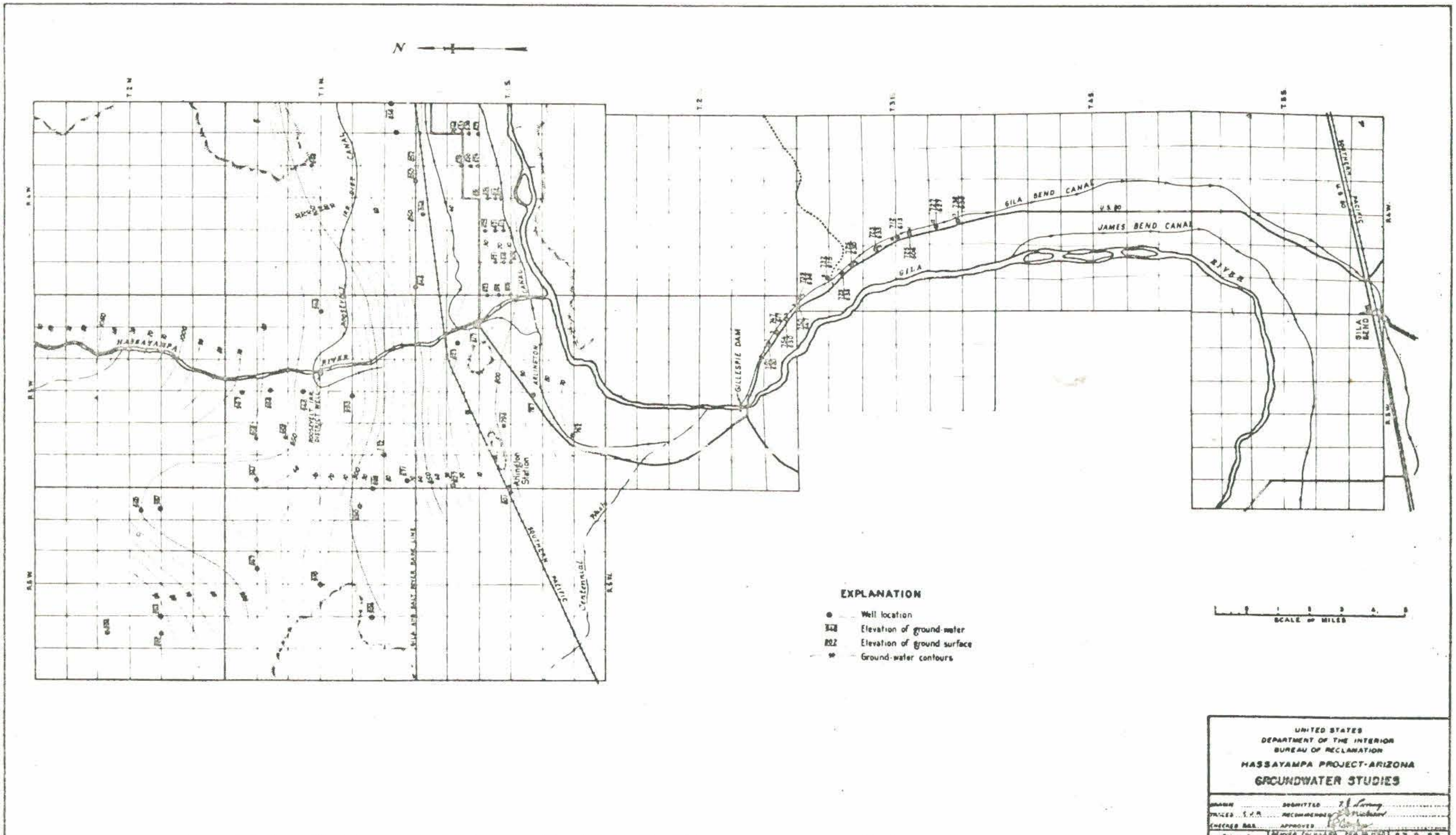
The ground-water map (Drawing No. 3H-11-7 and 3H-11-8) show the water table contours in this area, as determined from the well data given. The water table slopes toward the Agua Fria River from a northwesterly direction.

The well nearest to the Hassayampa River which could be definitely related to the water table in the Agua Fria Valley is the Wagner Well (Sec. 13, T. 4 N, R. 4 W.). The water table of this well is at a sufficiently low elevation to allow the possibility of its being supplied from the Hassayampa River, providing an impervious zone does not exist between it and the river at an elevation greater than that of the water table at the well.

Between this well and the Hassayampa River there is no information available regarding water table elevations. If a barrier



HIEROGLYPHIC MOUNTAINS
LAKE PLEASANT RESERVOIR
Morristown
Wittmann
Wagner well
Springs reported in this area
WHITE TANK MOUNTAINS
HASSAYAMPA RIVER
AGUA FRIA RIVER
GILA AND SALT RIVER MERIDIAN
CANAL
A.T. AND S.F.
R.4W. R.3W. R.2W. R.1W. R.1E.
T.6N. T.5N. T.4N. T.3N.
N
EXPLANATION
Well location
Elevation of ground-water
Elevation of ground surface
Ground-water contours
Geophysical depth point
Basement rock elevation (geophysical)
SCALE OF MILES
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
GROUNDWATER STUDIES
DRAWN
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
DENVER, COLORADO
57-D-36


N
HASSAYAMPA
RIVER
ROOSEVELT IRR. DISTRICT WELL
GILA AND SALT RIVER BASE LINE
CANAL
ARLINGTON
Arlington Station
Centennial
GILLESPIE DAM
GILA BEND CANAL
U.S. 80
JAMES BEND CANAL
GILA
RIVER
GILA BEND
EXPLANATION
Well location
Elevation of ground-water
Elevation of ground surface
Ground-water contours
SCALE OF MILES
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
GROUNDWATER STUDIES
APPROVED
57-D-37

exists to the flow of underground water, it must necessarily lie in this area. Any such barrier would probably be of the nature of a rock ridge, or an impervious zone occurring in the material above the basement rock, either of which would act as a barrier.

Geophysical Survey. A geophysical survey was undertaken in 1941 to determine the basement rock elevation along a line running approximately from Morristown to the Wagner Well and along a line from about one mile north of the Wagner Well to the Hassayampa River. The location of the points at which geophysical determinations of basement rock depth were made, with the corresponding surface and basement rock elevations, are shown on the ground-water map. Some of the basement rock elevations are followed by a "minus" sign indicating that the basement rock is at a greater depth than penetrated to in the geophysical explorations. The geophysical survey does not indicate a basement rock with an elevation higher than the water table of the Hassayampa River, as determined from wells on the river bank in this area, and no geophysical evidence was found of a crystalline rock ridge which might act as a barrier to the flow of underground water from the Hassayampa to Agua Fria water tables.

Underflow from Hassayampa River. Correlation of the geophysical survey with ground-water elevations in the region indicates a gap about five miles long and averaging about 250 feet deep, through which ground-water can flow from the Hassayampa River to Agua Fria. The easterly slope of the ground-water surface averages about 10 feet per mile. While no wells have been drilled in the zone where flow is likely to occur, a well located due east thereof (NW$\frac{1}{4}$, Sec. 1, T. 4 N., R. 3 W.) shows material encountered below the ground-water level, as follows:

Elevation - feet	Material
1230 - 1175	Fine silty sand with clay streaks.
1175 - 1173	Coarse sand and one-inch gravel layer.
1173 - 1055	Fine silty sand with clay streaks.
1055 - 980	Alternate layers of clean fine sand hard - packed sand (almost sandstone) and clay streaks.

Laboratory or field tests have not been made of this material to determine the velocity of ground flow, or its porosity; it is estimated by comparison with tests made for various soils in the Gila Valley (Geological Survey Water Supply Paper 104) that the velocity of flow will average less than 300 feet per year. The "drainage factor" probably will not exceed 10 percent, and on this basis the average annual underflow is estimated to be less than 5,000 acre-feet. The Box Canyon Reservoir will furnish practically complete control of the Hassayampa River at Box Canyon, and the future runoff (surface and underflow) at the gap north of the White Tank Mountains will be limited to the discharge from Sols Wash, Martinez Creek, and other intermittent tributaries below the Box Canyon Dam site. The operation of the Box Canyon

Reservoir will apparently not reduce the underflow to the Agua Fria area by more than 4,000 acre-feet annually.

Recharge from Project Irrigation. As discussed in this Appendix, the annual diversions for a full irrigation supply are 4.75 acre-feet per acre, and the annual consumptive use of irrigation water averages 3.24 acre-feet per acre irrigated. Of the remaining 1.51 acre-feet per acre, it is estimated 25 percent will be lost through non-beneficial consumptive use on non-irrigated lands, and 1.13 acre-feet per acre irrigated will percolate to the underground supply. With an average irrigated area of 7,000 acres, the annual recharge of ground water will be about 8,000 acre-feet.

The general surface slope of the project lands is to the southeast, except for the extreme southwest portion which slopes toward the Hassayampa River. Where the ground-water contours are defined, they also slope toward the Agua Fria River. It is believed safe to assume that at least 6,000 acre-feet of the annual ground-water recharge from irrigation on the project will move toward the Agua Fria River.

Conclusion as to Effect on Ground Water in Agua Fria Area. Since the estimated ground-water recharge from project irrigation exceeds the estimated present underflow from the Hassayampa River, it is concluded that construction of the Hassayampa Project will not interfere with existing irrigation developments from ground water pumping in the Agua Fria watershed.

Effect of Project on Ground Water for Gillespie Project. The Gillespie Project secures part of its water supply by pumping from ground water of the Gila River Valley, below the mouth of the Hassayampa River. The location of the Gillespie wells and their water surface elevation in February 1943 are shown on Drawing 3H-11-3.

The general slope of the Hassayampa ground water is southerly with an average gradient of approximately 15 feet per mile. The water table elevations secured from well records indicate that ground waters of the Hassayampa mingle with those of the Gila and other tributaries, and may constitute part of the supply for the Gillespie wells; however, the ground-water contribution from the Hassayampa River is believed to be relatively insignificant by reason of the relatively small drainage area in comparison to the total drainage area of the Gila and tributaries above the Gillespie wells. The drainage area of the Hassayampa River is 1,500 square miles, while the total drainage area between the upstream reservoirs (Coolidge on Gila, Roosevelt on Salt, and Bartlett on Verde) and the Gillespie wells is about 25,000 square miles.

Except for the Roosevelt District well, elsewhere described, no measurements have been made to determine the ground-water contribution to the Gila from the Hassayampa River, and this contribution is believed to be small. The low flows of the Hassayampa do not come within 50 miles of the Gila River, and are largely lost by evaporation from the river sands and transpiration from vegetation along the channel. Floods of the Hassayampa are greatly reduced by the time they reach the mouth of the river, and as the flood passes over the sandy channel it is absorbed and retained by this material. After the flood has passed, a large part of the water absorbed by the river sands is lost by evaporation.

The only known irrigation well along the Hassayampa River is one drilled by the Roosevelt Irrigation District near the point where their canal crosses the river channel. A description of this well is given in a letter of March 20, 1942, from John P. Van Denburgh, Superintendent of the district, to Engineer H. G. Raschbacher, as follows:

> "Answering your letter of March 19th, we drilled one well only in the Hassayampa River bed. This well is located 26½ West, 3 North, which would be in the North quarter corner of Section 22. Twp. 1 N., Range 5 W. The log of this well is as follows:
>
> 0 - 8 Soil
> 8 - 20 Sand
> 20 - 30 Gravel coarse
> 30 - 90 Sandy clay
> 90 - 95 Sandstone and caliche
> 95 - 98 Sand
> 98 - 200 Sandstone
> Not perforated
> 20" Casing
> Drilled - August 1929
> Contractors - Bert and Miller
>
> "You will note that we did not perforate the well as we never secured enough water for irrigation purposes. It is my belief that there is no underground strata in the Hassayampa River sufficient to carry a large volume of water. I believe if there were sufficient strata there would be more wells located up and down the river, and I know of no wells for irrigation purposes."

In view of the poor yield of the Roosevelt well, located in the river bed, and for other reasons discussed herein, it is not believed that construction of the Hassayampa Project would measurably reduce the ground water supply for the Gillespie Land and Cattle Company. The water supply studies for the project are based on this assumption.

WATER UTILIZATION

Storable Flow

With provisions for prior rights, as outlined on page 80 the surplus flow of the Hassayampa River is the recorded flow at the Box Canyon Dam site. The assumption has been made that no further provision need be made for downstream rights, either surface or underground, and, therefore, all waters passing the Box Canyon site, except as previously noted, may be stored or diverted.

Reservoir Losses

Due to the hot arid climate, evaporation from the reservoir surface will result in considerable loss. This loss is discussed in the chapter on "Evaporation".

Some seepage will undoubtedly take place from the reservoir. Present information indicates, however, that such loss will be small and confined to the canyon area at the site. Such seepage will largely reappear in the surface or subsurface flow of the stream, immediately below the dam, and will be used to meet, in part, the requirements for domestic use by the town of Wickenburg.

Storage Requirements

The storage requirement of the reservoir was determined to be 210,000 acre-feet, comprised of the following demands:

1. Dead storage for silt control

2. Irrigation storage to provide a dependable water supply for irrigation of project lands, including carry-over storage for years of low runoff.

3. Flood control storage to regulate "flash-flood" flows to the safe channel capacity below the dam. This control will reduce flood damage to Wickenburg, highways, the railroad, and improved property along the Hassayampa River above and below Wickenburg.

Dead Storage. The character of the drainage area above Box Canyon Dam site is such that no excessive silt load is carried by even the high flows of the Hassayampa River; however, like all other streams in the region, a considerable bed load of sand and gravel is characteristic. Fairly steep slopes above the reservoir indicate opportunity for transport of such bed load with subsequent deposit in the reservoir backwater.

Records of the loss of capacity of Roosevelt Reservoir on the Salt River for 1905 to 1935, inclusive, indicate silting at the rate of 0.35 percent of the reservoir inflow. In the absence of definite date, the silting rate on the Hassayampa is estimated as 0.45 percent of the runoff, an annual reduction in reservoir capacity of 200 acre-feet, or approximately 10,000 acre-feet during a 50-year period. A dead storage capacity of 10,000 acre-feet is proposed.

Irrigation Storage. With the erratic nature of the inflow to the reservoir, storage carry-over from periods of high runoff is needed to permit maximum use of the available stream flow. The acreage of arable lands susceptible to irrigation from Hassayampa River is over 40,000 acres. Therefore, studies of relative reservoir capacities, costs and use for different acreages of land were made in order to determine the maximum acreage that could be irrigated economically. Studies were made for the period for which runoff records are available (1916 through 1945). There were several extended drouths through the study period, the most critical one occurring during the 4-year period 1942-1945 when flows averaged only 9,600 acre-feet annually--enough to irrigate only about 2,000 acres. The results of these studies, with costs based on 1940 prices, are given in Table 13.

Table 13.- Costs and Yields for several reservoir capacities and project areas.

Project Area	Reservoir Capacity	Reservoir Cost	Average Annual Yield	Annual Cost Per acre-foot yield	Water Shortage No. of Years	Water Shortage Maximum Percent
Acres	Acre-foot	Dollars	Acre-ft	Dollars		
3,000	70,000	2,998,000	13,800	5.43	2	43
5,000	140,000	3,393,000	22,400	3.78	1	36
7,000	210,000	3,748,000	34,000	2.75	1	28
8,000	210,000	3,748,000	33,900	2.76	4	83
8,000	250,000	4,160,000	34,100	3.05	2	77

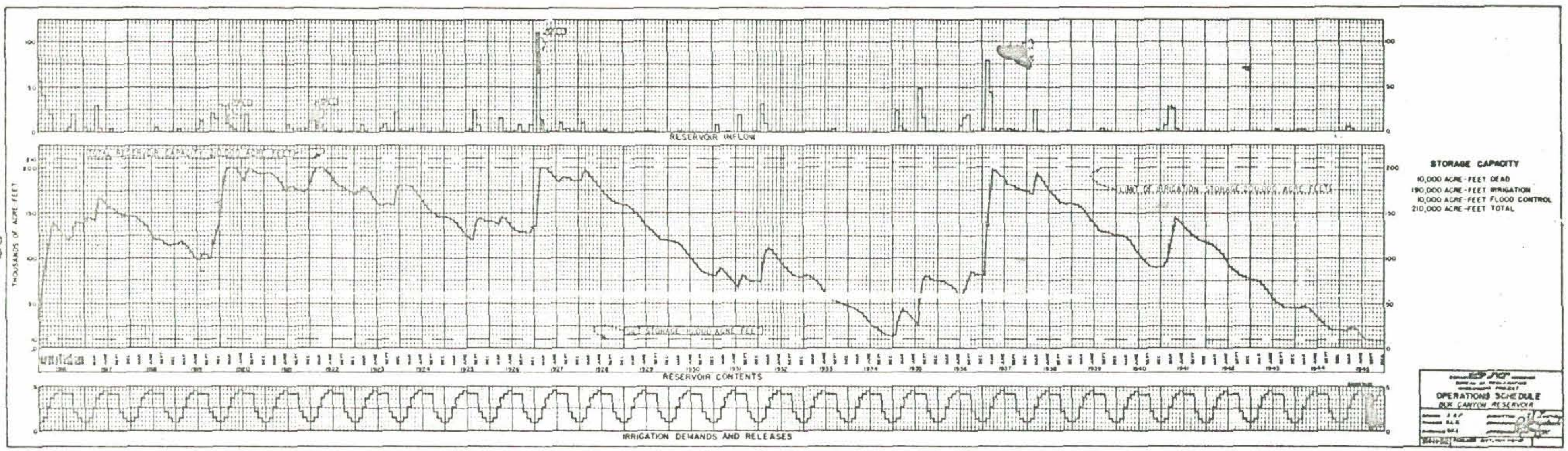
Flood control storage. Flash floods resulting from mountain cloudbursts occur rather frequently on the Hassayampa drainage area. These flood peaks will be partially controlled by providing for 10,000 acre-feet of storage capacity below the spillway crest, in addition to the super-storage above the permanent spillway. Preliminary calculations of flood control benefits by the U. S. Engineer office (See Appendix F) have been based on this capacity.

Operation Studies

Operation of Box Canyon Reservoir in accordance with the assumption outlined herein would have provided a full water supply for the project during 29 of the 30 years studied. The one indicated shortage (28%) would have occurred in 1945. Spills would have occurred in three years - an average of 3,500 acre-feet annually for the 30 year period. Table 14 and Drawing No. 3M-11-52 summarize the studies.

Table 14.- Annual summary of reservoir operation schedule, Box Canyon Reservoir

Calendar	Inflow	Evaporation Loss	Irrigation Release	Reservoir Content End of Year	Spill	Shortage
		(Unit - 1,000 Acre-Feet)				
1916	171.1	8.4	34.3	138.4		
1917	52.1	9.8	34.3	146.4		
1918	11.9	8.7	34.3	115.3		
1919	63.0	7.8	34.3	136.2		
1920	119.6	11.2	34.3	193.7	16.6	
1921	27.9	10.8	34.3	176.5		
1922	79.0	11.9	34.3	174.4	34.9	
1923	49.7	10.4	34.3	179.4		
1924	10.9	10.2	34.3	145.8		
1925	38.7	9.1	34.3	141.1		
1926	38.2	9.1	34.3	135.9		
1927	150.0	11.0	34.3	186.3	54.3	
1928	18.2	10.7	34.3	159.5		
1929	3.8	9.3	34.3	119.7		
1930	3.7	7.6	34.3	81.5		
1931	32.7	6.4	34.3	73.5		
1932	46.9	7.5	34.3	78.6		
1933	9.5	5.7	34.3	48.1		
1934	3.8	3.4	34.3	14.2		
1935	99.5	4.3	34.3	75.1		
1936	45.9	5.9	34.3	80.8		
1937	138.6	10.9	34.3	174.2		
1938	31.1	10.7	34.3	160.1		
1939	10.1	9.5	34.3	126.4		
1940	6.6	7.9	34.3	90.8		
1941	70.4	8.9	34.3	118.0		
1942	0.8	7.3	34.3	77.0		
1943	8.0	5.5	34.3	45.2		
1944	13.4	3.9	34.3	20.4		
1945	16.4	2.2	24.6	10.0		9.7
Total	1371.5	246.0	1,019.3		105.8	
Average	45.7	8.2	34.0		3.5	


RESERVOIR INFLOW
THOUSANDS OF ACRE-FEET
RESERVOIR CONTENTS
IRRIGATION DEMANDS AND RELEASES
STORAGE CAPACITY
10,000 ACRE-FEET DEAD
190,000 ACRE-FEET IRRIGATION
10,000 ACRE-FEET FLOOD CONTROL
210,000 ACRE-FEET TOTAL
OPERATIONS SCHEDULE
BOX CANYON RESERVOIR

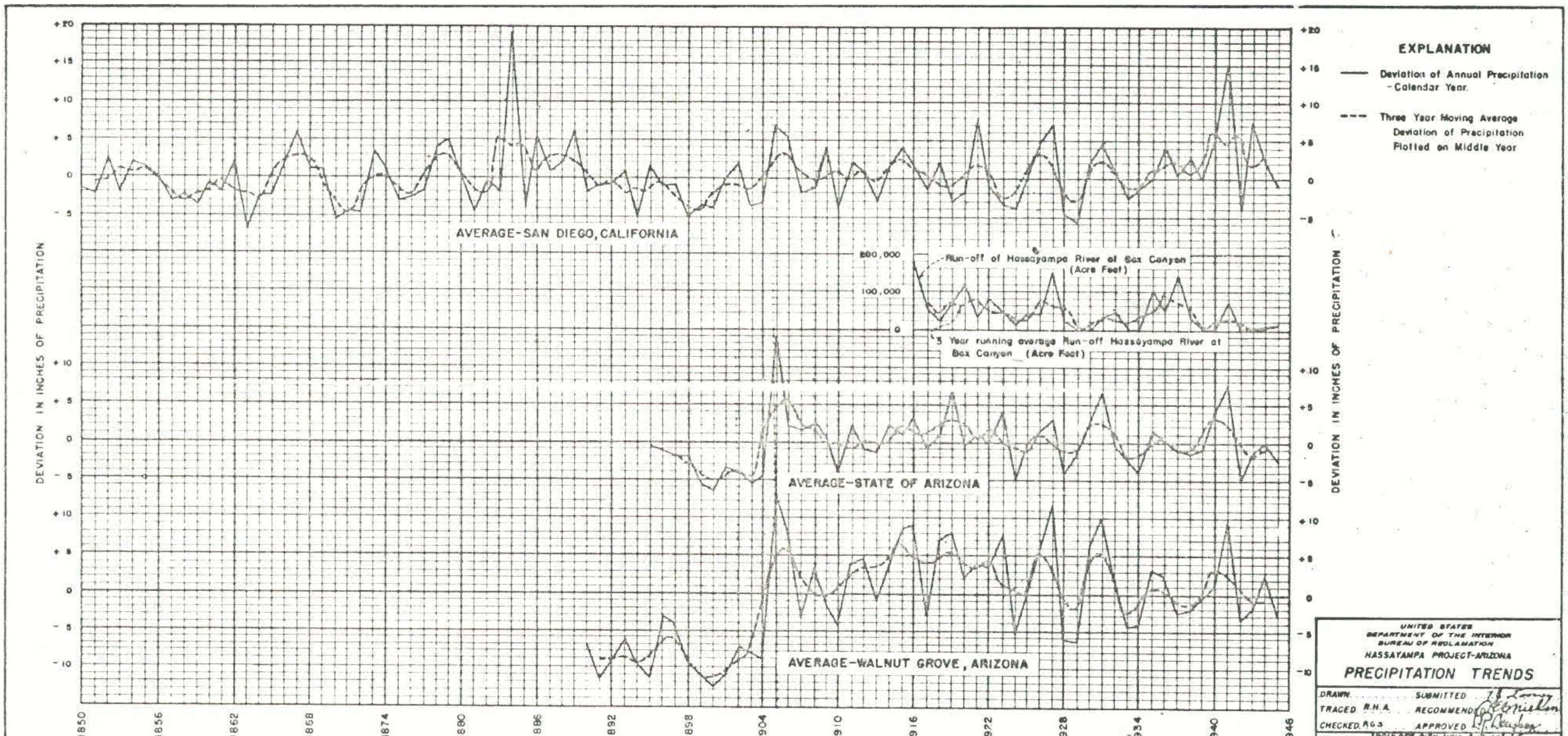
Possible Water Shortages

In the computation of the project water supply the flow at Box Canyon was used for the period 1916-45, inclusive, as recorded and computed and summarized in Table 6 of this report. The average annual flow during this period was 45,700 acre-feet. Stream flows averaged only 9,600 acre-feet annually during the period 1942 through 1945, and this was considered to be the critical period because it is the only period for which sufficient stream flow data are available by which satisfactory estimates of monthly flows could be made at the Box Canyon site. However, judging from stream flow records for other streams in the Gila River basin, and from climatological data, it is probable that droughts of greater severity than that of the 1942-45 period may have occurred in the past. If the climatic conditions indicated by the 1891-1904 drought should be repeated, it is possible that the runoff may be less than shown in Table 6.

Extensive studies have been made in an attempt to extend records of precipitation and runoff to cover a longer period of time. Although no reliable estimates of monthly flows of the Hassayampa could be made, definite correlations between precipitation trends in Arizona and Southern California were noted. Three of the curves on Drawing 3H-11-1 are a graphical representation of the annual departure from average precipitation at San Diego, the State of Arizona, and Walnut Grove. It will be noted that for the period for which these curves are concurrent there is a marked similarity. In order to indicate trends, the annual deviation from average precipitation was then averaged by a three-year moving average at each of the three locations; this average was plotted on the middle year of the three-year period on the lower curves in the chart. In this trend curve the similarity between the three is remarkable.

It is logical to assume, therefore, that precipitation trends in the State of Arizona and at Walnut Grove may follow the trends at San Diego. Inspection of the San Diego trend curve clearly indicates the periodic occurrence of droughts of varying intensity and duration.

Although streamflow is not directly proportional to precipitation, a general relation undoubtedly exists between the cyclic trends of each. The trend of runoff of the Hassayampa River at Box Canyon, shown on Drawing 3H-11-1, is quite similar to the illustrated trends of precipitation of the State of Arizona and the city of San Diego. It must be recongized, therefore, that although insufficient records are available on which to base numerical estimates, the period of study for water supply on this project does not include a drought of an intensity and duration equal to those which may have occurred in the past, or may occur in the future. The possibility of future severe droughts is present and every effort should be made to avoid overexpansion of the irrigated area in years of high runoff.


EXPLANATION
Deviation of Annual Precipitation - Calendar Year.
Three Year Moving Average Deviation of Precipitation Plotted on Middle Year
AVERAGE-SAN DIEGO, CALIFORNIA
Run-off of Hassayampa River at Box Canyon (Acre Feet)
3 Year running average Run-off Hassayampa River at Box Canyon (Acre Feet)
200,000
100,000
0
AVERAGE-STATE OF ARIZONA
AVERAGE-WALNUT GROVE, ARIZONA
DEVIATION IN INCHES OF PRECIPITATION
1850
1856
1862
1868
1874
1880
1886
1892
1898
1904
1910
1916
1922
1928
1934
1940
1946
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
PRECIPITATION TRENDS
DRAWN
TRACED R.H.A.
CHECKED R.G.S.
SUBMITTED
RECOMMENDED
APPROVED
3H-11-1

APPENDIX D
GEOLOGY

INTRODUCTION

The dam site for impounding the water of the Hassayampa River is in Box Canyon, commonly called "The Box," located about seven miles north of Wickenburg in section 12, T. 8 N., R. 5 W., Gila and Salt River Meridian, in southern Yavapai County, Arizona.

Three dam sites at Box Canyon have been considered; originally two sites were investigated, the upper site and the lower site. After foundation explorations were completed a site midway between the original sites was considered and found to be the most favorable. During the investigation, the following Geological Reports were prepared:

Report (Summarization) on Box Canyon Dam Site
by Dr. G. M. Butler - December 1929

Report on Box Canyon Dam Site
by Ross L. Heaton - July 1940

Report on Box Canyon Dam Site
by F. A. Nickell - February 1941

Report on the Geophysical Survey
by John Baird - July 1941

Report on the Spillway site
by J. N. Murdock - November 1941

It is the purpose of this appendix to summarize the contents of the previous reports, to eliminate those parts which relate to sites or features now unessential, and to correlate the exploration work, most of which was accomplished after the above Geologic Reports were prepared.

GENERAL GEOLOGY

Older rocks of the crust occupy large areas south and west of the plateau of northern Arizona. The region contains many individual block mountains having a general north or northwest trend. Between them are broad lowland basins receiving the rock waste in fans formed by erosion of the elevated elements. The ranges are composed chiefly of granites, gneisses, and schists, but many of them have tilted cappings of lava belonging to once unbroken fields. These crystalline rocks pass beneath the alluvium of the intervening depressions and no doubt form the ultimate bedrock of virtually all the country.

The Hassayampa River crosses an area containing similar structural features. The reservoir lies between a range of hills on the south and east, and an incised fan limiting the valley towards the north and west. A spur of granite gneiss runs along the west side of the stream in the lower half of the gorge, but is overlain by volcanic rocks and incumbent sedimentary deposits dipping northeast in the transverse ridge containing Box Canyon.

Volcanic Rocks

The contact between the basal crystalline rocks and the overlying volcanic rocks is exposed at river level about one-half mile below the dam site. Immediately overlying the crystalline rocks is a thick horizon of buff-colored rhyolitic tuff, which is in turn succeeded by a sequence of basalt lava and intervening breccia members. This formation extends upstream to the mid-section of Box Canyon or slightly downstream from the proposed axis.

The basalt occurs in flows without conspicuous jointing or flow structure. The member at the dam site is estimated to be nearly 1.0 feet thick. The breccia layers are less substantial, and are usually indicated by side ravines between lava ribs. They are an integral part of the abutments below the present site and will be involved in diversion tunnel construction under present proposals for which they are judged to be reasonably sound.

Sedimentary Series

The youngest basalt member along the canyon is found just below the axis. Upstream, the rock is of sedimentary origin with a somewhat smaller northeast dip manifested by crude bedding. The group includes two lithologic divisions shown by character of exposures. The principal stratigraphic type (called sandstones and conglomerates in previous reports) is a stony deposit of cobbles in a volcanic sandstone matrix. A considerable percentage, up to 10 percent, of the large fragments are granite, and the remainder are either basalt or rhyolite. For convenience of description the formation is termed fanglomerate.

Upstream from the axis about 400 feet, and on the south bank towards the head of Box Canyon, a second kind of deposit is found. Apparently, this is a mass within the body of fanglomerate which originated as a torrential or unsorted deposit. The blocks in the sandstone matrix, in cases, are two to three feet in diameter and are largely granite. Bedding is conspicuously absent and the origin is believed to have been either a talus or fan rubble. In consequence, the second type is called breccia, implying lack of stratification, larger fragments, and probably talus origin without signifying any appreciable difference in physical quality of the two kinds of sedimentary formations.

The dip is towards the right side of the canyon so that the south, or left wall, is essentially a dip slope. Slabbing effect along the bedding on this side would guide the excavation. On the north wall, which is practically vertical to a level 75 feet above the stream, the truncated edges of beds are exposed.

Upstream on the south side of the river the formation immediately adjacent to the channel has a lighter cast than the fanglomerate of Box Canyon. It is probable that a similar type of deposit will be found which owes its color change to remoteness from the darker volcanic rocks at the dam site.

Basalt-fanglomerate Contact

The fanglomerate dips 25 - 30 degrees northeast compared to the eroded surface dip of 38 degrees for the underlying basalt flow at the axis. The sedimentary beds consequently progressively overlap the lava. The contact is not sharply defined but is an irregular zone 2 to 3 feet thick consisting, where exposed, of sandy shale. This material is somewhat softer than the neighboring rocks so that undercutting tends to occur. The layer is firm and probably watertight, signifying only a weaker structural feature if a concrete dam were built.

Alluvial Deposits

Flat-topped ridges and alluvial terraces are found in the reservoir area. These are composed of silt, sand, and gravel which overlie the sandstone or fanglomerat, and were deposited by the Hassayampa River at an earlier time, possible when the high lava ridge of the Box Canyon was being eroded. These deposits were prosepected for embankment material, and two areas were explored which are deedmed suitable.

The most recent alluvial material is the river fill of sand, gravel, and boulders. This material is permeable, as shown by the flow of water which disappears and reappears at the dam site and also farther down the river in the vicinity of Wickenburg. Diamond drilling at the dam site shows this material to be up to 115 feet thick. Some cementing of the gravel was noted in the drill logs.

Structure

The fanglomerate lies under the high level sands and gravels and the extrusive basalt, and overlies the older basaltic and andesitic flows. The latter are the result of successive lava flows and were at one time in a horizontal position, or nearly so. After solidification by cooling, they were tilted to the north-east at an angle of approximately 25 degrees, and the fanglomerate was laid upon them in a horizontal position. Later another tilting took place in the same direction, so that now the fanglomerate dips from 25 to 30 degrees northeast, while the volcanic rocks dip from 45 to 50 degrees in nearly the same direction, as shown by the dip symbols on the map.

In the course of strong tilting of all older formations along Box Canyon local stresses found relief along small faults allowing minor adjustments. Numerous narrow zones exhibit generally 2 - 3 feet displacement but none with more than 20 feet offset are seen. These trend nearly northwest oblique to the canyon and without exception dip downstream 60 - 70 degrees in the direction of throw.

There is no evidence of recent movement on any of the faults in the dam site area. The disturbances originated, most likely, in a period of broad crustal adjustment reflected in the tilting of formations along Box Canyon, and once completed are not likely to recur.

The faults have had little influence on the adjoining rock. The actual zones are not over one foot wide with respect to crushed material which is now fairly well healed. It is likely that water can move more freely along these structures than it can through the undisturbed formation. On the right (north side), where the trend carries the fracture at a slight angle to the cliff, wedges of rock will require trimming in general excavation.

DAM SITE GEOLOGY

Dam

The site is located in a narrow gorge with nearly vertical sides reaching to a height of 350 feet; the bottom width of the canyon is roughly 175 feet. This narrow canyon is about one-half mile long. Below the gorge the river enters a flat alluvial plain along the toe of low volcanic hills. The reservoir area is bounded on the south by a steep volcanic ridge and on the north by a series of low alluvial terraces.

The dam will rest on tilted beds of fanglomerate, basalt and basalt breccia. Fanglomerate consisting of alternate layers of sandstone and poorly bedded gravel and cobbles, forms the right abutment above river level. The left abutment is a basalt flow, dipping about 45 degrees towards the river and overlying a relatively thick layer of basalt breccia. The basalt breccia extends under the river fill and enters the right abutment below river level.

Overburden in the stream channel composed of silt, sand, gravel, and boulders extends over 100 feet below river level. A cut-off through the river fill will be needed to prevent seepage under the dam.

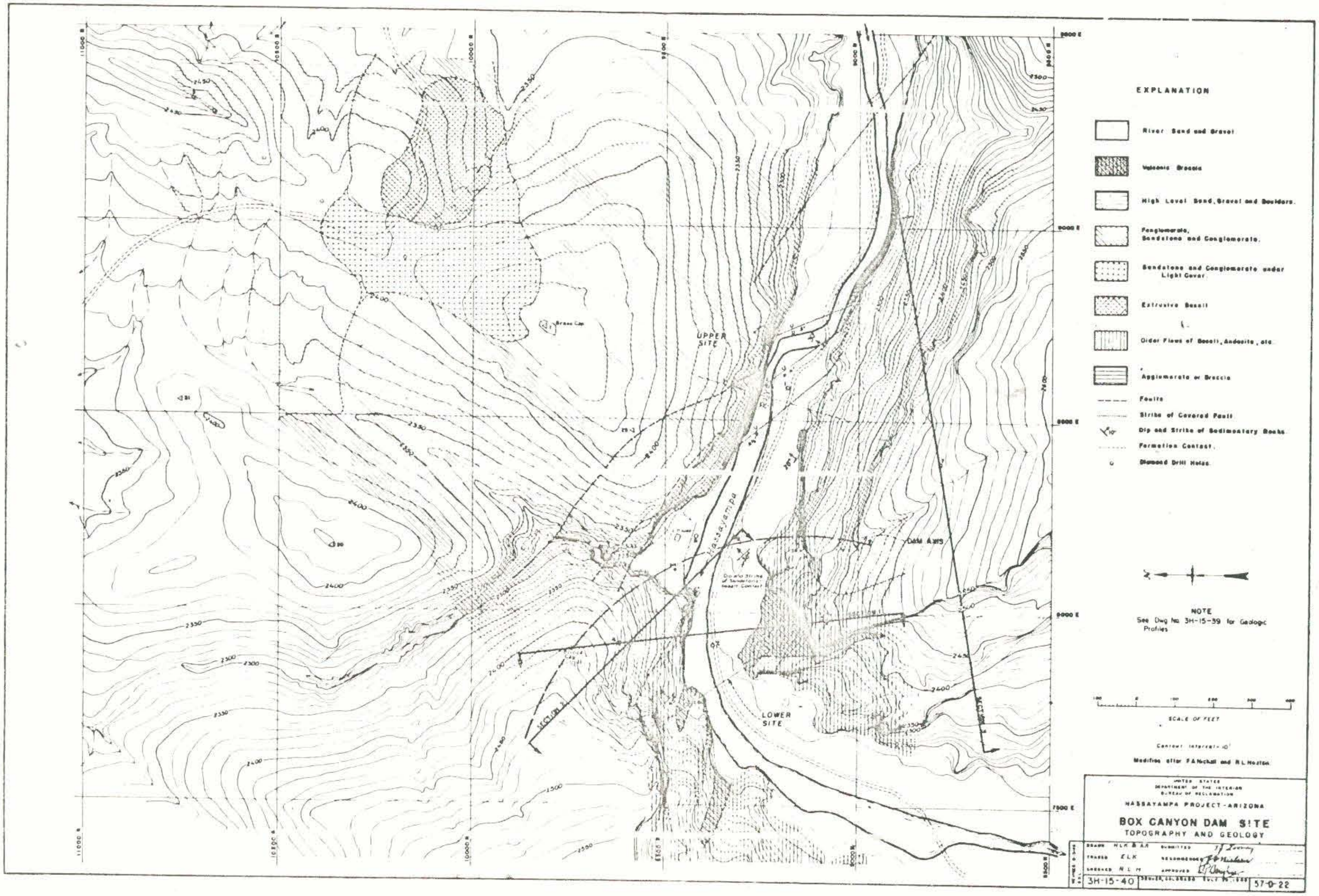
Diversion Tunnel

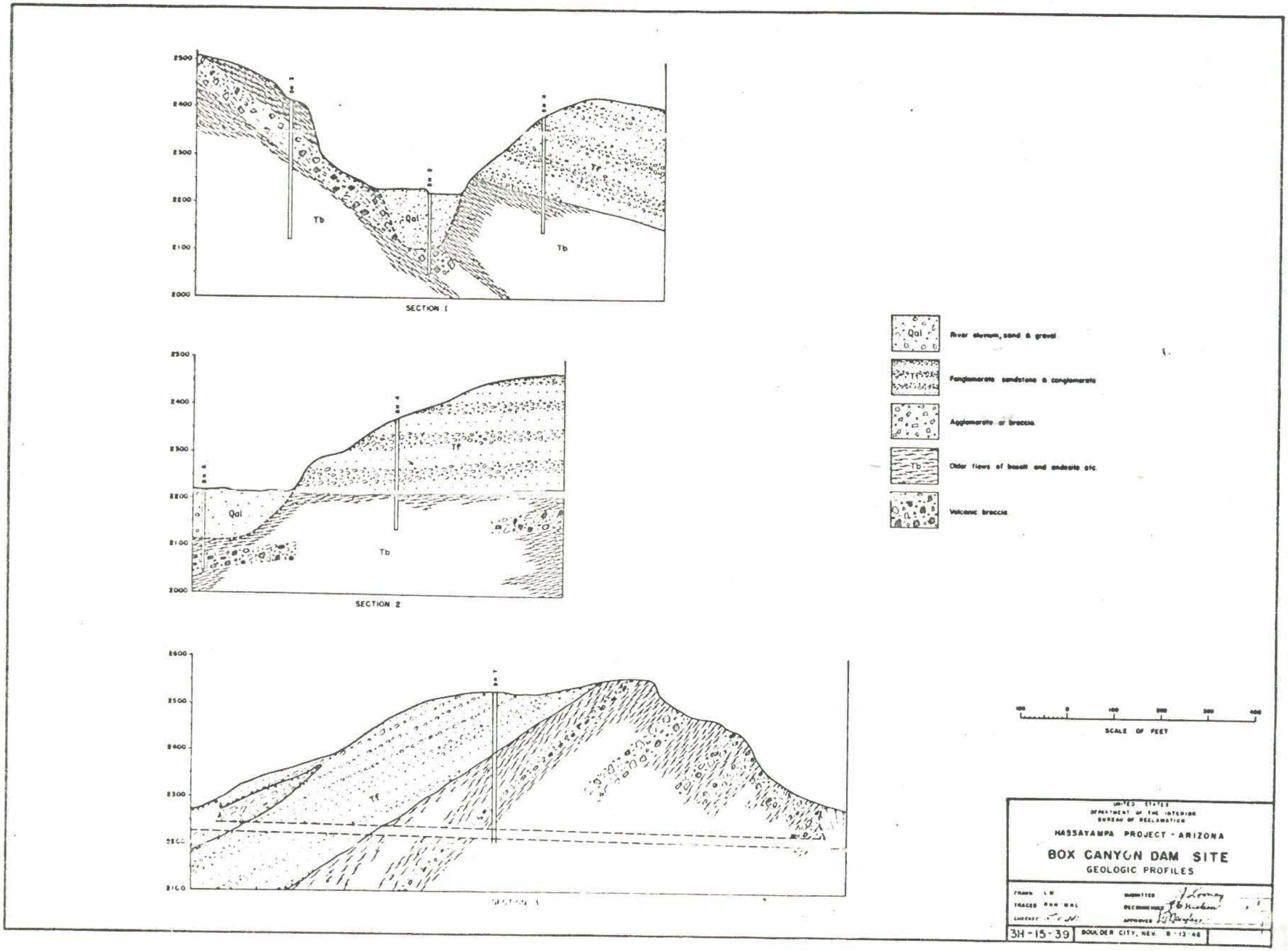
The diversion tunnel, in the left abutment, will go successively through fanglomerate, basalt, and basalt breccia. The shaly contact between the formations and the intra-flow breccia member in the lava series may need light supports. Unless jointing and bedding, particularly in the fanglomerate, are encountered, no trouble is anticipated. Lining will be required in any case.

Spillway

An off-dam spillway site in a natural saddle, about 4,000 feet to the north of the dam site, has been explored and determined feasible.

It is planned to construct a spillway structure with concrete lining for a distance of 700 feet, and then use the natural draw which empties into the Hassayampa River 4,300 feet below the dam site.


EXPLANATION
River Sand and Gravel
Volcanic Breccia
High Level Sand, Gravel and Boulders.
Fanglomerate, Sandstone and Conglomerate.
Sandstone and Conglomerate under Light Cover.
Extrusive Basalt
Older Flows of Basalt, Andesite, etc.
Agglomerate or Breccia
Faults
Strike of Covered Fault
Dip and Strike of Sedimentary Rocks
Formation Contact.
Diamond Drill Holes.
UPPER SITE
LOWER SITE
Hassayampa River
DAM AXIS
NOTE
See Dwg No. 3H-15-39 for Geologic Profiles
SCALE OF FEET
Contour interval = 10'
Modified after F.A. Nickell and R.L. Hoston
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
BOX CANYON DAM SITE
TOPOGRAPHY AND GEOLOGY
DRAWN H.L.K. & A.R.
TRACED E.L.K.
CHECKED R.L.H.
SUBMITTED
RECOMMENDED
APPROVED
3H-15-40
57-D-22



2500
2400
2300
2200
2100
2000
Tb
Qal
Tf
Tb
SECTION 1
2500
2400
2300
2200
2100
2000
Qal
Tf
Tb
SECTION 2
2600
2500
2400
2300
2200
2100
Tf
Qal
River aluvium, sand & gravel
Tf
Fanglomerate sandstone & conglomerate
Agglomerate or breccia
Tb
Older flows of basalt and andesite etc.
Volcanic breccia
100
0
100
200
300
400
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT - ARIZONA
BOX CANYON DAM SITE
GEOLOGIC PROFILES
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
3H-15-39
BOULDER CITY, NEV.

The rock at the spillway saddle is sandstone or fanglomerate overlying basalt, which in turn overlies basalt breccia. The basalt breccia extends about halfway down the draw, where it is cut off by older rock outcrops that extend to the river. This older rock is a series of intrusive igneous rock, including granites, andesite, and dacite. Numerous granite dikes and stringers of schist and gneiss cut the older rock at various angles.

A total of ten test pits were dug at the site of the spillway structure and these show the overburden to be from 0.5 feet to 5.3 feet in depth. Basalt and basalt breccia outcrop on the surface and on each side of the saddle, but the spillway gate structure will be in sandstone. This rock, as exposed in the test pits, is poorly cemented at the surface, but improves with depth.

The geophysical survey made at this site without test pits for correlation evidently mapped the underlying sandstone-lava contact and missed the overlying thin sandstone which is not apparent from surface outcrops.

A small amount of alluvial material is seen scattered along the floor of the draw, which will undoubtedly be removed by water flowing down the draw, but no damage of importance will occur.

The basalt breccia and the hard resistant intrusive rocks at the lower half of the spillway draw are believed to be sufficiently resistant to withstand the erosive action of the water. Any debris picked up in the spillway draw will be deposited along the wide channel of the Hassayampa River without noticeable damage.

EXPLORATION

Diamond Drilling

A total of seven diamond drill holes, with percolation tests, were drilled in the vicinity of the dam site. The logs of these holes are included in the supporting data.

The river-fill material was found to be permeable. Many of the drill holes showed water losses in excess of 26 gallons per minute with zero collar pressure. The sandstone or fanglomerate showed moderate water losses with some variation due possible to porous, coarse, or poorly cemented layers. This is not considered serious as they can be grouted where necessary.

The basalt and basalt breccia showed no loss in some holes when tested with 90 pounds collar pressure, and the loss was low in all holes in the undisturbed lava.

Seepage through the abutments is expected to be small as the water which might enter the fanglomerate would have no ready passage through the underlying basalt series.

Embankment Materials

Two borrow areas, each of which is an alluvial river terrace, were explored for the purpose of locating embankment material.

Borrow area No. 1 (Dwg. No. 3H-2-6, Appendix E), located one mile upstream from the dam site, consists of an impervious layer of silt, fine sand and some clay underlain by a deposit of well-rounded sand, gravel and boulders. The impervious material averaged 7.1 feet thick and the pervious material averaged 12.6 feet thick.

A total of 42 test pits were excavated in the No. 1 borrow area. Samples, containing approximately 100 pounds each, were taken from each stratum in the 42 pits. These samples were screened to determine the percent of the gravel and oversize rocks. Small samples of the material were submitted to the Denver laboratory for mechanical analysis, but the 100 pound samples were stored in the Bureau of Reclamation warehouse at Phoenix, Arizona.

Similar work was completed in borrow area No. 2, located about two miles above the dam site. The material is very much the same as in area No. 1, with an average depth of impervious material of 6.2 feet and average depth of gravels and boulders of 23.2 feet. Ten test pits were completed in this area. This area can be used if necessary, but because of the greater haul distance, area No. 1 is preferable. By regulating the shovel cut and utilizing the desired portion of fines and gravel, a suitable grading can be obtained.

Screening tests made on the material taken from test pits in the prospective borrow areas showed a high percentage of oversize boulders in both deposits. The results of these tests are recorded on the test pit logs.

Riprap

Riprap for the upstream slope of the dam can be quarried from the dense hard basalt which forms the crest of the high ridge adjacent to the dam site. This rock should quarry well, and produce a hard durable riprap.

Concrete Aggregate

Suitable concrete aggregate can very likely be obtained from sand and gravel deposits in the Hassayampa River bed below the dam site. No samples were taken from these deposits, but this gravel has been used successfully in small structures on nearby highways.

SUMMARY

(a) The Box Canyon Dam site is considered suitable from a geological standpoint for an earth dam to the height contemplated.

(b) The dam will rest on tilted fanglomerate, basalt and basalt breccia. The rock is dipping upstream, and into the right abutment.

(c) The diversion tunnel will be in fanglomerate, basalt, and basalt breccia. No trouble is anticipated, but lining is considered a necessity.

(d) The use of a natural draw for part of the spillway is considered a practical plan which will not result in excess maintenance.

(e) Construction materials are available in sufficient quantities within reasonable distance of the dam site.

(f) Nothing was encountered in the drilling which would indicate structural defects in the foundation or abutments. Slabbing effect in the sandstone and conglomerate on the south or left wall would guide the excavation of the left abutment.

APPENDIX E
PLANS AND ESTIMATES

PROJECT WORKS

The Project Plan

Irrigation works for the Hassayampa Project would consist of a multiple-purpose earth dam located about 6 miles due north of the town of Wickenburg, Arizona, creating the Box Canyon Reservoir for the storage of the flood waters of the Hassayampa River. The reservoir would have a total storage capacity of 210,000 acre-feet, of which 10,000 acre-feet would be dead storage reserved for silt, 190,000 acre-feet for irrigation, and 10,000 acre-feet for flood control. An unregulated remote spillway with a maximum capacity of 69,700 c.f.s. would protect the dam against overtopping.

Stored water from the Box Canyon Reservoir would be released through outlet works with a maximum capacity of 500 c.f.s. and, in order to avoid excessive channel losses, would be carried in a closed conduit, approximately 15 miles in length, buried in the Hassayampa River channel, to the Santa Fe Railway bridge, about 8 miles below the town of Wickenburg. The conduit would be circular concrete pipe with a maximum capacity of 110 c.f.s. From the lower end of the closed conduit an open clay-lined canal would carry the water to the project lands about 6 miles to the south. The main canal reduces in size as laterals tap its supply, and a complete distribution system brings the water to the high point of each farm unit.

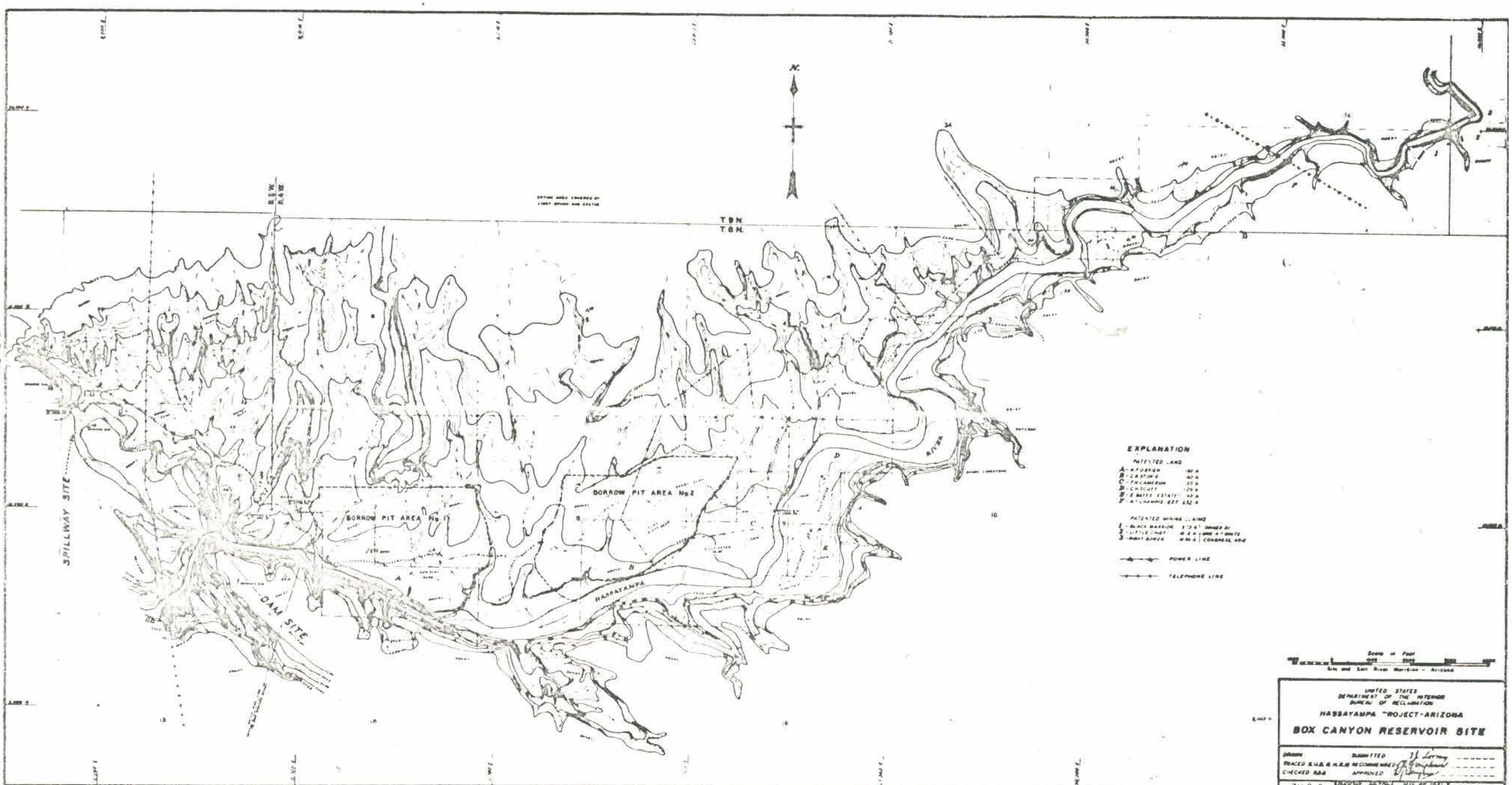
Box Canyon Reservoir

Location and description. Box Canyon Reservoir would be formed by impounding the flows of the Hassayampa River by constructing an earthfill dam in the SE$\frac{1}{4}$, Section 12, T. 8 N., R. 5 W., Gila and Salt River Meridian, Arizona. The river runs close to high bluffs along the south side of the reservoir and practically all storage is in the valley north of the river, which is flooded for a maximum length of about 6 miles and a maximum width of about 1-3/4 miles. At flow line level, the average depth of the reservoir is 72.4 feet. (See drawing 3H-2-6). The drainage area above the reservoir is 422 square miles.

Area and capacity. At the normal water surface, elevation 2,438, the capacity is 200,000 acre-feet and the area is about 2,800 acres. At maximum water surface, elevation 2,461, the total capacity is 270,000 acre-feet and 3,300 acres are inundated.

Box Canyon Dam

Preliminary designs and estimates were prepared in the Denver office of the Bureau of Reclamation in September 1942 under the direction of J. L. Savage, Chief Designing Engineer. Three different sites in Box Canyon were considered: the upper, the middle, and the lower,


N.
T9N.
T8N.
BORROW PIT AREA No 1
BORROW PIT AREA No 2
SPILLWAY SITE
DAM SITE
HASSAYAMPA
RIVER
EXPLANATION
PATENTED LAND
POWER LINE
TELEPHONE LINE
PATENTED MINING CLAIMS
Scale in Feet
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
BOX CANYON RESERVOIR SITE
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
3H-2-6
37-3-23

Preliminary studies of embankment and spillway costs proved the superiority of the middle (or curved axis), and studies for a dam at this axis only were carried to the report stage.

Dam site. Bedrock at the dam site is composed of massive beds of well-cemented fanglomerates with alternating layers of basalt and basalt breccia. Except for several faults with displacements of two to four feet and minor fractures, the rock may be considered ideal for abutments and foundations for any type of dam, and are sufficiently watertight for an earth dam with a reasonable amount of grouting. The faults lie upstream from the axis and, except for a portion of one, are blanketed by the embankment. In general, the faults are fairly well healed and are not believed to present a special construction problem. The river fill material is composed of fine sand and gravel extending to a depth of approximately 100 feet.

Dam. The proposed embankment, shown on drawing 57-D-25, has a maximum height of 246 feet above stream bed and a total volume of 3,088,000 cubic yards. Materials in the embankment will be zoned so as to utilize, with a minimum of waste, the complete run of the proposed borrow pit and all materials from the cut-off excavation and from the diversion tunnel. The embankment is to be composed of a central core of impervious clay, sand, and gravel rolled in 6-inch layers, protected by stable semipervious sections upstream and downstream. A 3-foot layer of rock riprap will cover most of the upstream slope, and a heavy rockfill section will form the downstream slope.

The axis is curved on a 750-foot radius, arranged to produce the required structure with the least embankment volume. Although a large portion of the embankment on the right abutment spreads to form a blanketing of the canyon slope, this location requires less yardage than the one with the axis downstream at the narrowest point in the canyon. Also, under this arrangement, badly broken sections of the canyon walls immediately downstream are avoided, and the required length of diversion tunnel is materially reduced.

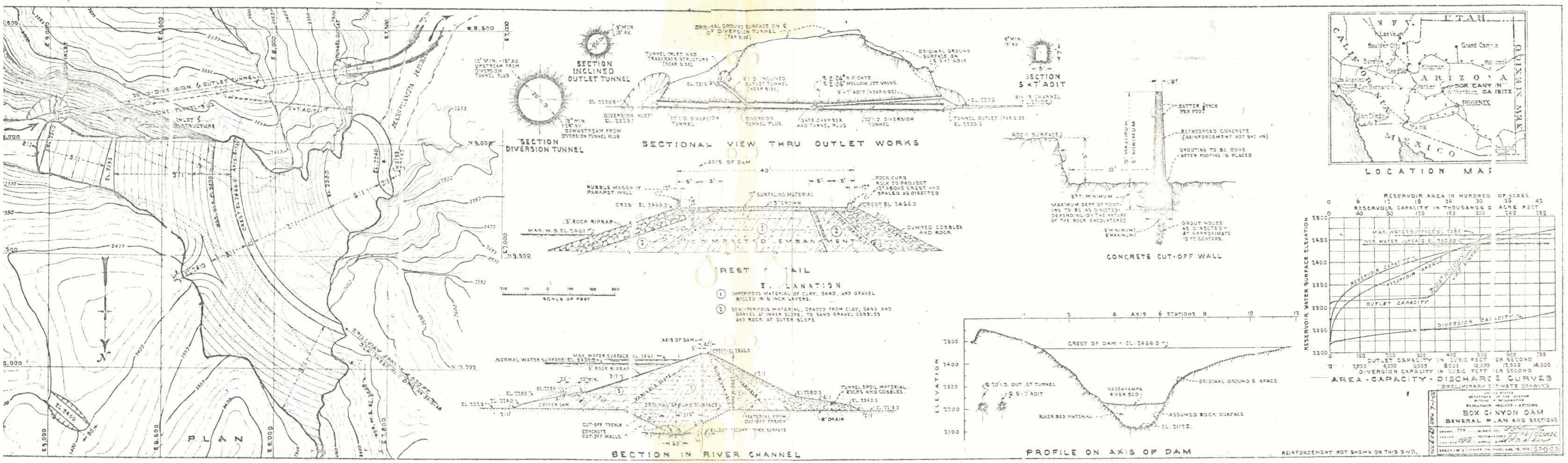
A cut-off trench extends approximately 120 feet to bedrock. The trench has a maximum width of 60 feet and side slopes of 2:1. Two concrete cut-off walls are to be placed along the floor of the cut-off trench. A rubble masonry parapet wall and curb are to be constructed along the crest of the dam.

Spillway. An uncontrolled open channel spillway is to be located in a saddle about 4,000 feet to the right of the dam, as shown in drawing 57-D-26. With the overflow crest at elevation 2,438, the capacity under maximum water surface at elevation 2462.6 is 69,700 second-feet. Concrete lining is proposed for 650 feet of the total excavated lineal distance of 1,650 feet. The structure will be founded on basalt, is curved in plan, and super-elevated along the portion of greatest curvature and incline. Water through the spillway will discharge into a draw and re-enter the river at a point about 4,300 feet downstream from the dam. Rock is exposed in the bottom of the draw for most of its length, and it is apparent that the draw would withstand the flood flows without excessive erosion.

Outlet Works. A 20-foot diameter outlet and diversion tunnel is located through the left abutment. Control of the flow is provided by two 24-inch ring-follower gates and two 24-inch hollow-jet valves located in a chamber about 550 feet above the downstream portal of the tunnel. Since the valve discharges into the open tunnel downstream, a separate 5- by 7-foot access adit is provided from near the downstream toe of the dam. When final construction drawings are prepared, provision will be made for the discharge of 110 second-feet into a closed conduit in the river bed.

In providing dead storage for silt, amounting to 10,000 acre-feet, the permanent intake for the outlet works is placed at an elevation of 2,314 feet, or about 91 feet above the invert of the tunnel. A 9-foot diameter inclined tunnel leads from the outlet trashrack structure to the 20-foot diameter diversion tunnel. A tunnel plug will be placed just upstream from the junction of the two tunnels.

Estimated Cost. The estimated cost of the dam, based on 1940 unit prices is $3,748,000, as shown on drawing 57-D-24. This includes rights-of-way, access road, reservoir clearing, reconstructing the Oro Grande pipeline, transmission line relocation, and construction camp. Using the April 1947 price index of 2.0, the cost of construction would be $7,500,000.


PLAN
SECTION INCLINED OUTLET TUNNEL
SECTION DIVERSION TUNNEL
SECTIONAL VIEW THRU OUTLET WORKS
SECTION 5'x7' ADIT
CONCRETE CUT-OFF WALL
CREST DETAIL
EXPLANATION
COMPACTED EMBANKMENT
SCALE OF FEET
SECTION IN RIVER CHANNEL
PROFILE ON AXIS OF DAM
LOCATION MAP
UTAH
ARIZONA
MEXICO
PHOENIX
AREA-CAPACITY-DISCHARGE CURVES
RESERVOIR WATER SURFACE ELEVATION
PRELIMINARY ESTIMATE DRAWING
BOX CANYON DAM
GENERAL PLAN AND SECTIONS
REINFORCEMENT NOT SHOWN ON THIS DWG.

Main Canal

The main canal is divided into three sections: 15 miles of closed conduit along the bed of the Hassayampa River; seven miles of contour canal through uneven topography from the river to the project area; and five miles along a smooth ridge in the project area. Each of these sections is discussed separately.

Section 1. The first section of the canal is 51-inch concrete pipe having walls six inches thick and a capacity of 110 second feet; it will be buried a depth of at least four feet in the bed of the Hassayampa River. The conduit will extend from the reservoir a distance of 15 miles, to a point near the Santa Fe railroad bridge (the Farish Diversion Dam site), where an open canal will continue from the river, through the "breaks" to the project area.

Provisions are made in the estimate for unwatering the conduit excavation during construction, and for protection against scour and other flood damage.

The costs of construction of this section are summarized as follows:

Estimate - Main Canal - Section 1

Canal excavation	475,000	c.y.	at	.20	$ 95,000
Structure excavation	13,000	c.y.	at	1.00	13,000
Backfill	410,000	c.y.	at	.25	102,500
Concrete	23,250	c.y.	at	25.00	581,250
Reinforcement	3,000,000	lbs.	at	.055	165,000
Unwatering	74,800	l.f.	at	2.00	149,600
Manhole covers	30	ea.	at	10.00	300
Protection, riprap, etc.	74,800	l.f.	at	1.00	74,800
Subtotal					$1,181,450
Plus 15 percent for contingencies					177,217
Subtotal					$1,358,667
Plus 10 percent for engineering & overhead					135,867
Total estimated cost (1940 prices)					$1,494,534
Present cost (using April 1947 cost index of 1.97)					$2,950,000

Section 2. The second part of the canal is located in earth and rock, with a bottom width of 8 feet, a water depth of 3.9 feet, side slopes of $1\frac{1}{2}$:1, and a 12-inch clay lining. The capacity is 110 second-feet.

Four tunnels, aggregating 9,130 feet in length, and several shallow cuts, must pass through ridges in order to avoid long and difficult canal construction.

Two inverted siphons and eight 30-inch culverts are required to handle cross drainage.

Costs of construction are summarized as follows:

Main Canal Section 2, Station 10 to 387/50

Canal excavation, common	164,500	cu. yds.	at	$ 0.18	$ 29,610
Canal excavation rock	202,800	" "	at	0.75	152,100
Structure excavation	340	" "	at	1.50	510
Tunnel excavation	17,000	" "	at	13.50	229,500
Backfill	6,940	" "	at	.25	1,735
Compacted backfill	1,600	" "	at	.50	800
Clay blanket	26,000	" "	at	1.50	39,000
Concrete in structures	520	" "	at	27.50	14,300
Concrete in tunnel lining	5,300	" "	at	18.00	95,400
Reinforcement steel	52,000	lbs.	at	.055	2,860
Steel tunnel supports	260,000	lbs.	at	.08	20,800
Timber " "	271	Mft.b.m.	at	100.00	27,100
30" precast concrete pipe	480	l.f.	at	3.50	1,680

Subtotal	$615,395
Plus 15 percent for contingencies	92,309
Subtotal	$707,704
Plus 10 percent for overhead and engineering	70,770
Total estimated cost (based on 1940 prices)	$778,474
Present cost (using April 1947 cost index of 2.0)	$1,555,000

Section 3. The last section is through the irrigable area and will also be clay-lined. It is located on top of a smooth ridge where the ground slope is so great that a total of 24 drops are required to avoid excessive velocities. The capacity is gradually reduced from 110 to 30 second-feet. Construction costs are itemized here:

Estimate - Main Canal - Section 3

Canal excavation	65,000	cu. yds.	at	$ 0.18	$11,700
Structure excavation	500	" "	at	1.50	750
Backfill	2,200	" "	at	0.25	550
Compacted backfill	1,100	" "	at	0.50	550
Clay blanket	21,590	" "	at	1.50	32,385
Concrete	817	" "	at	27.50	22,467
Reinf. steel	60,860	lbs.	at	0.055	3,347
Structural steel	40,800	lbs.	at	0.12	4,896
Welded steel mesh	5,400	lbs.	at	0.08	432
Gate steel	1,900	lbs.	at	0.15	285
18" p.c. pipe	30	l. f.	at	2.20	66
24" " "	50	l. f.	at	3.00	150
30" " "	100	l. f.	at	3.50	350

Subtotal	$77,928
Plus 15 percent for contingencies	11,689
Subtotal	$89,617
Plus 10 percent for overhead and engineering	8,962
Total estimated cost	$98,579
Present cost (using April 1947 cost index of 2.0)	$195,000

Summary of Main Canal estimates: Estimated costs of the three sections of the main canal are summarized below:

Section 1	$2,950,000
Section 2	1,555,000
Section 3	195,000
Total cost	$4,700,000

Lateral System

Open earth canals with 3-inch clay lining will run east at half-mile intervals, providing a standard delivery of five second-feet for each 80-acre tract or a proportionate amount for larger or smaller farm units. Project lands have excellent topography with a fairly uniform slope of about eight feet per mile east and west from the main canal.

Estimates of lateral system costs are here summarized:

Canal excavation	53,500 cu. yds.	at $0.20	$10,700
Structure excavation	840 " "	at 1.50	1,260
Backfill	10,100 " "	at 0.25	2,525
Compacted backfill	3,200 " "	at 0.50	1,600
Clay blanket	8,400 " "	at 1.50	12,600
Concrete	1,080 " "	at 27.50	29,700
Reinf. steel	86,200 lbs.	at 0.055	4,741
Gate steel	13,300 lbs.	at 0.15	1,995
18" p.c. pipe	1,430 l. f.	at 2.20	3,146
24" " "	600 l. f.	at 3.00	1,800
30" " "	310 l. f.	at 3.50	1,085
Subtotal			$71,152
Plus 15 percent for contingencies			10,674
Subtotal			81,826
Plus 10 percent for overhead & engineering			8,183
Total estimated cost			90,009
Present cost (using April 1947 cost index of 2.0)			$180,000

Investigations and Surveys

As of April 30, 1947, approximately $70,000 had been spent on the investigations of the Hassayampa Project. In the event that the project is authorized for construction, it is estimated that an additional $10,000 will be needed to complete the investigations; this would include a topographic survey of the project area.

Operation and Maintenance During Construction

The cost of operating and maintaining the project during the construction period, including the priming and puddling of canals and the purchase of operating equipment, is estimated at $10 per acre, or a total of $70,000.

Drainage

As stated in Appendix B, Project Lands, a drainage system is not considered necessary, and an allowance for drainage has not been included in the cost estimates.

Domestic Water Supply System

Provision of an adequate water supply system for the project homes and for the project town or headquarters (possible Wittmann) is essential to successful development of the area. Preliminary field estimates indicate that the cost of the system will be about $370,000 (see appendix F for details).

Summary of Estimated Costs

Construction costs. Present costs of construction for the Bureau of Reclamation features are summarized as follows:

Box Canyon Dam and Reservoir	$7,500,000
Main Canal	4,700,000
Lateral System	180,000
Investigations and Surveys	80,000
O. & M. during construction	70,000
Domestic water supply system	370,000
Total	$12,900,000

Operation and Maintenance

Consideration of recorded operation and maintenance costs on irrigation projects in this region, when studied in connection with a budget analysis of probable conditions during the repayment period, led to the conclusion that operation and maintenance costs for irrigation and farmstead water will probably average about $35,400 a year, divided as follows:

Salaries and Directors' expenses	$8,000
Office and travel expenses	2,000
Legal and auditing expense	1,000
Labor and materials	14,500
Farmstead Water (See App. F)	6,700
Contingencies (10 percent)	3,220
Total	$35,420
Cost an acre (7,000 acres)	$5.06
(in round numbers)	$5.00

Design and Construction Problems

Construction facilities. Facilities are not available at the dam site for construction operations. Housing and other facilities for a construction force could probably be secured at the town of Wickenburg, 12 miles distant.

Water supply for construction operations can be secured by the installation of a filter crib in Hassayampa River upstream from the construction area.

Electric power for construction purposes can be secured at a reasonable cost either from the 44-kilovolt line of the Arizona Power Company, crossing the river at the upper end of the reservoir, or from a smaller line crossing a short distance below the site of the dam.

About 9 miles of road, suitable for construction use, will need to be constructed from a point on U. S. Highway 60, about three miles northwest of Wickenburg, to the site.

Construction materials. Impervious, semipervious, and rockfill materials will be produced by screening the pit run of a borrow area located near the right bank of the river about one mile upstream from the dam site. Angular rock for riprap can be quarried from any number of points in the immediate vicinity. Aggregate for concrete may be secured from gravel bars along the river channel about three miles downstream, by crushing rock from required rock excavation, or by quarrying expressly for this purpose.

Design flood. The spillway design flood derived by the unit graph analysis method is estimated to have a peak discharge of 183,000 second-feet and a volume of 132,340 acre-feet. Details are given in Appendix F.

Diversion during construction. Estimates of peak flood discharges have been made during the period 1921 to 1937, inclusive, when a gaging station was operated at the reservoir site. The maximum estimated flow during this period was 27,122 second-feet on February 16, 1927; a mean-daily discharge of 21,700 second-feet was recorded for that date. Therefore, provision for diversion of 15,000 second-feet, without appreciable cofferdam storage, is recommended during construction.

There appears to be little likelihood of floods during the period from mid-May to July first. Floods have been experienced at all other seasons of the year.

During construction of the embankment, the river will be diverted through the 20-foot diameter diversion and outlet tunnel. A portion of the upstream toe of the dam will form the upstream cofferdam. The tunnel has a capacity of 15,000 second-feet with the water surface at elevation 2,265. In addition to diverting the flow of the river during construction, the works will have to be protected against run-off in the draw at the right abutment for about six months of the year. The cost of this protection is incorporated in the estimate.

Construction Period. Based on construction periods required for Bureau of Reclamation dams, it is estimated that it will take three years to construct Box Canyon Dam. The remaining project works would be constructed during this same period.

Rights-of-Way. Construction of the reservoir will involve the purchase of 6 parcels of patented lands totalling 1,232.51 acres. Also 3 patented mining claims are involved, as shown on drawing 3H-2-6. A tabulation of the privately-owned lands follows:

Patented Lands

Identification on Drawing 3H-2-6	Owner	Area	Cultivated Area
A	A. F. O'Brien	160 Acres	0
B	C. G. Storie	160 Acres	0
C	F. H. Cameron	120 Acres	14 Acres
D	C. H. Scott	120 Acres	37 Acres *
E	E. Bates Est.	40 Acres	
F	A. F. Champie	632.51 "	

* D and E combined.

The patented mining claims, all owned by Mrs. A. F. White of Congress, Arizona, are:

Name of Claim	Area
Black Warrior	15.73 Acres
Little Chief	18.15 "
Right Bower	14.66 "

These claims are filings for placer gold mining and are not being worked.

The cost of purchasing lands in the reservoir area and clearing 2,100 acres of brush and scattered timber are estimated as follows:

Item	Area-Acres	Unit Cost	Amount
Cultivated land, partly irrigated	62	$100	$6,200
Grazing land	1,170	10	11,700
Clearing reservoir	2,100	5	10,500
Total Costs			$28,400

The Oro Grande Mine, about three miles east of Box Canyon, secures a water supply from the Hassayampa River through a surface line and a pumping plant near the proposed dam site. The status of this water right is not known; the mine has been operated only intermittently in the past years and has been completely shut down since 1939. Should it become necessary to provide for the continuance of this supply after construction of the project, this could be done by moving the present plant downstream, below the dam. This would require about 5,000 feet of 4-inch pipe (to connect the new pump site with the present line by the shortest feasible route up the canyon wall), a new pumphouse, and improvement of the existing road for access to the pump. The estimated costs for these features are:

Pipe line - 5,000 lin. ft. 4-inch at $1.00	$5,000
Pumphouse - Moving and installation of pumps	600
Access road - Improving 2-½ miles, including culverts	1,500
Total	$7,100

Since the mine is at present inactive, it is possible that a cash settlement for a lesser amount than $7,100 would be accepted in preference to the relocation.

A 44-kilovolt electric transmission line of the Arizona Power Company, running from Prescott to Wickenburg, crosses the reservoir site in Section 36, T. 9 N., R 4 W., and a telephone line crosses the edge of the reservoir area in Sections 1 and 12, T. 9 N., R. 5 W. The cost of relocating these is estimated at $2,000. The total costs of reservoir right-of-way, including relocations of improvements, are estimated at $37,500.

ALTERNATIVE PLANS

Four alternative plans were considered:

1. Hassayampa River diversion near Morristown
2. Highline canal for Box Canyon Reservoir
3. Williams River diversion
4. Colorado River diversion

Hassayampa River Diversion near Morristown

Waters of the Hassayampa River would be stored at Box Canyon Reservoir, released into the natural river channel, and diverted at the diversion dam site at the Santa Fe Railroad crossing near Morristown. The storage reservoir, canal system, and lateral system would be similar to the adopted plan but the closed conduit in the river channel would be eliminated.

The main disadvantage of this plan is that large channel losses occur beywoen the reservoir and the point of diversion. These losses, as discussed in Appendix C under the heading "River Channel Losses", are estimated to average 7,800 acre-feet per year. Offsetting contributions from side streams and for underflow are shown to be negligible. As a result, less than 5,000 acres could be assured a dependable irrigation supply by the 210,000 acre-foot reservoir at Box Canyon.

Preliminary cost studies based on field estimates showed that the cost per acre irrigated would be higher than for the selected plan.

Highline Canal from Box Canyon Reservoir.

As in the selected plan, water would be stored at the Box Canyon Reservoir site for delivery to the project area near Wittmann. A highline canal would be diverted through Box Canyon Dam at dead storage level (about 100 feet above the river bed) and follow the most feasible location down to the project area.

Stadia surveys of the canal route showed that the first 2,100 feet would be located along steep, rocky slopes, the next 10,000 feet in tunnel, and the next eight miles would consist of alternating tunnels and heavy rock cuts. The remainder of the route was not surveyed. Preliminary cost estimates showed that construction costs of this highline route would exceed the costs of the riverbed conduit.

Should the Hassayampa Project be authorized for construction it would be advisable to consider in greater detail, with the aid of aerial photographs and strip topography, several routes at different elevations between the river bed and dead storage level. Such surveys would be expensive and are not believed warranted at this time; any changes in cost estimates based on more detailed information would not be of sufficient magnitude to materally affect the feasibility of the project.

Williams River Diversion

The Wittmann interests made investigations, prior to the study of the project by the Bureau, for determining the feasibility of diverting water from Kirkland Creek, a tributary of the Williams River, over the divide into the headwaters of Martinez Wash for use on the Hassayampa Project. A study of the data obtained together with some research by the Bureau indicates that the high cost of the small amount of water obtained renders the scheme infeasible.

This plan of development contemplated a canal diverting from Kirkland Creek at a point near Yava and emptying into Box Reservoir to augment the water supply of the Hassayampa Project. Such a canal would also intercept Date Creek and Martinez Creek. Regulatory storage on Kirkland Creek above the canal healing would be necessary.

Records of the flow of Kirkland Creek are available from February 1908, to February 1911, inclusive, and from March 1932, to September 1933, inclusive. Because sufficient stream flow records were not available for an adequate correlation, an attempt was made to correlate the flow of Kirkland Creek with the average precipitation on the drainage basin as determined by the Theissen method. For the period 1908-1911 precipitation at Yarnell was weighted 47 per cent, Prescott 34 per cent, Congress 12 per cent, and Walnut Grove 7 per cent. For the 1932-1933 period precipitation at Tonto Ranger Station was weighted 54 per cent, Walnut Grove 41 per cent, and Prescott 5 per cent. Plotting the data obtained, both by years and by four-month periods, resulted only in a scattered group of points through which a smooth curve could not be drawn.

An endeavor was made to convert the data into usable form by plotting cumulative precipitation and run-off, but the runoff was so small in comparison with the precipitation that a conclusion could not be reached. Precipitation was plotted against absorption, but without satisfactory results, and this method was also abandoned.

A further attempt was made to determine the average precipitation in the Kirkland Creek drainage area by establishing a relation between rainfall and elevation. The proportion of the area in different elevation bands was computed by planimeter. The average rainfall at numerous available stations in Yavapai and nearby counties was determined for the 1908-1911 period, also for the period 1930-1939. These averages were plotted against the elevation of each particular station and satisfactory curves were drawn; and the precipitation in each band weighted in production to the area of the band. By these methods of determination, the average annual precipitation on the total drainage area was found to be 21.2 inches for the 1908-1911 period and 21.0 inches for the 1930-1939 period.

The foregoing method was used for the Hassayampa River drainage area above Walnut Grove, and a separate rainfall elevation curve made for the period of Walnut Grove stream flow record, 1916-1928. The average annual precipitation was found to be 23.5 inches for this period, and the average annual runoff 3.1 inches, indicating 20.4 inches absorption. This absorption, applied to Kirkland Creek drainage area, indicates a runoff during the 1930-1939 period of 0.6 inch, equivalent to an average annual runoff of 10,600 acre-feet.

The same method was also applied to the area above the proposed canal between the Kirkland Creek drainage area and Box Canyon Reservoir. Annual rainfall was found to be 19.05 inches. This is less than the normal absorption assumed for the vicinity, and it is assumed an appreciable runoff would not be intercepted by the canal. Flash flows resulting from intense storms might possibly yield sufficient runoff to offset the losses from the diversion canal.

Because of the long diversion canal required, the rough terrain through which much of the canal would be constructed, and the necessity for development of additional storage on Kirkland Creek, the runoff which could be diverted from the Kirkland Creek drainage area is not sufficient to justify the construction costs. Moreover, preliminary studies of runoff at the headwaters of the Williams River indicate these waters would be utilized for irrigation within the basin at a lesser unit cost. These waters should not be considered for export to the Hassayampa River basin.

Colorado River Diversion

Investigations are now in progress by the Bureau to determine the feasibility of diverting Colorado River water into the Salt and Gila River Valleys. Studies have been made of three alternative routes: (a) Canal from Lake Havasu on the Colorado River to McDowell Reservoir on Salt River; (b) Tunnel from Marble Canyon on the Colorado River to the Verde River and thence by that river to McDowell Reservoir; (c) Tunnel from Bridge Canyon on the Colorado River to Big Sandy Creek and thence by aqueduct to McDowell Reservoir. These investigations have progressed sufficiently to show that the water which might be made available under any of these plans will be needed for the relief of presently irrigated lands in the Salt and Gila River Valleys.

Preliminary surveys for the canal lines from Havasu and Bridge Canyon have been completed, and it has been found that all of the Hassayampa Project lands lie well above the canal. Also, Project lands are too remote from the Marble Canyon-Verde River route to permit this being a feasible source of water. Hence, these plans will not in any way effect present consideration of the Hassayampa Project.

APPENDIX F
MULTIPLE USES

POWER

The project lands are located in an area served by the comparatively cheap power generated on the Colorado River and by the plants of the Salt River Valley Water Users Association on Salt River. Therefore, any power development of the Box Canyon Reservoir must be of low cost in order to compete with present and contemplated low cost power. Irrigation needs are paramount for the Hassayampa Project, and any possible power development must be considered as only incidental. The widely fluctuating power head at Box Canyon Dam, varying from a maximum of about 217 feet to a minimum of 90 feet in comparatively short periods of time, and the variations in water available for power generation which varies month to month from a maximum average of 13 per cent to an average minimum of 3 per cent, precludes any consideration of power development which could compete with power already delivered in the area. In addition, the almost complete utilization of available water supply for irrigation purposes prevents any consideration of power development with waters which would usually be wasted.

FLOOD CONTROL

Acknowledgement

This appendix was prepared with the cooperation of the Los Angeles District Office of the Corps of Engineers, War Department, who made available basic data resulting from a flood damage survey conducted by that office, and preliminary calculations to determine the average annual flood damages and flood control benefits.

Floods of Record

There are no reliable data available indicating the dates or magnitudes of floods that have occurred in the Hassayampa River Basin prior to 1890. During the period (1890-1945) for which hydrologic data are available, medium to large floods occurred in the years of 1890, 1905, 1916, 1919, 1921, 1923, 1925, 1927, 1931, 1932, 1935, 1937, and 1941. The largest floods occurred in 1916, 1925, 1927, 1935, and 1937.

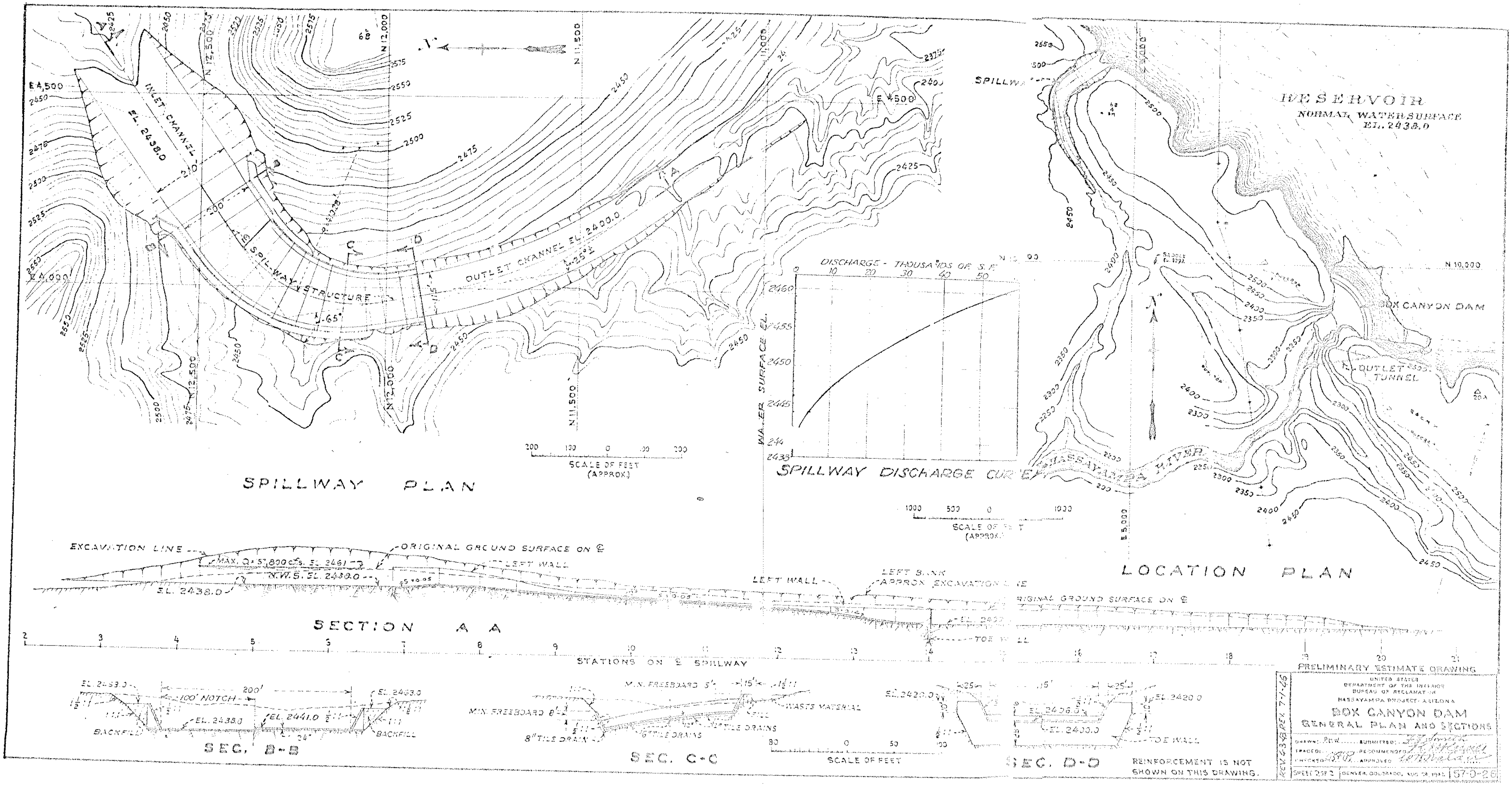
Runoff records are available for six stream gaging stations in the Hassayampa River Basin. None of the runoff records secured at these stations prior to 1938 are of sufficient accuracy to be classed as good records. The erratic occurrence and short duration of flood runoff make it difficult to secure accurate measurements. The relative magnitude of past major floods of record in the basin are compared by means of their peak discharge and total runoff volumes as shown in Table 15.

Crest El. 2466
Normal W. S. El. 2438
Max. W. S. El. 2461
Max. height 246 ft.
Spillway capacity 57,800 c. f. s.
Outlet capacity 500 c. f. s.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT - ARIZONA
BOX CANYON DAM
PRELIMINARY ESTIMATE

Compiled: B.F.P. and J.D.O. - 1942.
Checked: R.B.S. Revised 7-1-46
Storage capacity 200,000 ac. ft.
Active storage capacity 190,000 ac. ft.
Diversion capacity 15,000 c.f.s.

ITEM No.	ITEM	QUANTITY		MATERIAL AND LABOR FURNISHED BY THE CONTRACTOR		MATERIAL FURNISHED BY THE GOVERNMENT		SUMMARY	
		AMOUNT	UNIT	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST	UNIT COST	TOTAL COST
	DAM								
				$	$	$	$	$	$
	Diversion and care of river	Lump Sum		LS	50,000			LS	50,000
	Excavation, common, stripping borrow pit	50,000	cy	0.20	10,000			0.20	10,000
	Excavation, common, stripping of foundation of dam	90,000	cy	0.30	27,000			0.30	27,000
	Excavation, rock, for foundation of dam	12,500	cy	2.00	25,000			2.00	25,000
	Excavation, rock, for cut-off wall footing	900	cy	10.00	9,000			10.00	9,000
	Excavation, common, for toe drain and cut-off trenches	225,400	cy	0.65	146,510			0.65	146,510
	Excavation, common, in borrow pits, separation and transportation to dam	1,396,000	cy	0.40	558,400			0.40	558,400
	Excavation, common, in borrow pits and transportation to dam	1,620,000	cy	0.35	567,000			0.35	567,000
	Excavation, rock, in borrow pits and transportation to dam	42,000	cy	1.00	42,000			1.00	42,000
	Earth fill, in embankment	2,509,000	cy	0.12	301,080			0.12	301,080
	Cobble and rock fill in embankment	520,000	cy	0.20	104,000			0.20	104,000
	Riprap	59,000	cy	0.40	23,600			0.40	23,600
	Concrete cut-off wall footing	900	cy	12.00	10,800	4.00	3,600	16.00	14,400
	Concrete cut-off wall	900	cy	20.00	18,000	4.00	3,600	24.00	21,600
	Reinforcing steel	109,000	lb	0.02	2,180	0.04	4,360	0.06	6,540
	Drain tile, 8-foot vitrified, laid in gravel	550	lf	0.75	413	0.30	165	1.05	578
	Concrete, parapet and curb	440	cy	20.00	8,800	4.00	1,760	24.00	10,560
	Pressure grouting	15,000	cf	1.00	15,000	0.75	11,250	1.75	26,250
	Placing grout pipe and fittings	4,200	lb	0.10	420	0.10	420	0.20	840
	Drilling grout holes, 0 feet to 25 feet	3,000	lf	1.00	3,000			1.00	3,000
	Drilling grout holes, 25 feet to 50 feet	3,000	lf	1.25	3,750			1.25	3,750
	Drilling grout holes, 50 feet to 100 feet	3,000	lf	1.50	4,500			1.50	4,500
	TOTAL FOR DAM				$1,930,453		$25,155		$1,955,608
	OUTLET								
	Excavation, common, in open cut	5,000	cy	0.50	2,500			0.50	2,500
	Excavation, rock, in open cut	40,000	cy	1.25	50,000			1.25	50,000
	Excavation, all classes, in tunnel and adit	23,500	cy	10.00	235,000			10.00	235,000
	Furnishing and installing tunnel supports	100,000	lb	0.12	12,000			0.12	12,000
	Drilling grout holes in tunnel	2,000	lf	1.25	2,500			1.25	2,500
	Placing grout pipe	1,000	lb	0.05	50	0.10	100	0.15	150
	Pressure grouting	5,000	cf	1.25	6,250	0.75	3,750	2.00	10,000
	Drilling weep holes	600	lf	1.25	750			1.25	750
	Concrete in 20-foot 0-inches tunnel lining	6,200	cy	15.00	93,000	5.00	31,000	20.00	124,000
	Concrete in adit and inclined tunnel lining	1,050	cy	18.00	18,900	5.00	5,250	23.00	24,150
	Concrete in trashrack structure and transition	70	cy	20.00	1,400	3.50	245	23.50	1,645
	Concrete in tunnel plug	1,000	cy	12.00	12,000	3.50	3,500	15.50	15,500
	Placing reinforcing bars	50,000	lb	0.025	1,250	0.035	1,750	0.06	3,000
	Installing trashrack metal	15,000	lb	0.02	300	0.08	1,200	0.10	1,500
	Installing ring-follower gate	25,000	lb	0.05	1,250	0.25	6,250	0.30	7,500
	Installing ring-follower gate controls	2,000	lb	0.05	100	0.20	400	0.25	500
	Installing hollow jet valve	8,000	lb	0.05	400	0.55	4,400	0.60	4,800
	Installing miscellaneous metalwork	4,000	lb	0.05	200	0.15	600	0.20	800
	Installing electrical conduit	1,200	lf	0.50	600	0.50	600	1.00	1,200
	TOTAL FOR OUTLET				$440,950		$62,545		$503,495
	SPILLWAY								
	Excavation, sandstone	140,800	cy	0.80	112,640			0.80	112,640
	Excavation, rock	90,700	cy	1.25	113,380			1.25	113,380
	Backfill	8,700	cy	0.75	6,530			0.75	6,530
	Concrete in channel floor	4,800	cy	12.00	57,600	3.50	16,800	15.50	74,400
	Concrete in counterfort and cantilever walls	1,010	cy	18.00	18,180	3.50	3,540	21.50	21,720
	Concrete in lined walls	510	cy	15.00	7,650	3.50	1,790	18.50	9,440
	Concrete in cut-offs, headwalls and bucket	1,300	cy	15.00	19,500	3.50	4,550	18.50	24,050
	Construction of 8-inch tile drains	1,050	lf	0.70	740	0.30	310	1.00	1,050
	Construction of 6-inch tile drains	1,050	lf	0.60	630	0.20	210	0.80	840
	Construction of 4-inch tile drains	7,400	lf	0.50	3,700	0.10	740	0.60	4,440
	Drilling holes for anchor bars and grouting bars in place	9,880	lf	1.00	9,880	0.25	2,470	1.25	12,350
	Reinforcement steel	661,600	lb	0.025	16,540	0.035	23,150	0.06	39,690
	Miscellaneous metalwork	10,000	lb	0.10	1,000	0.15	1,500	0.25	2,500
	TOTAL FOR SPILLWAY				$367,970		$55,060		$423,030
	SUBTOTAL - DAM, OUTLET, AND SPILLWAY				$2,739,373		$142,760		$2,882,133
	Contingencies - 15%								432,320
	SUBTOTAL								$3,314,453
	Engineering and inspection - 6%								198,867
	Superintendence and accounts - 1½%								49,717
	General expense - 2½%								82,861
	TOTAL ESTIMATED COST								$3,645,898
	Right-of-way								17,900
	Access road								15,000
	Reservoir clearing								10,500
	Oro Grande pipe line								7,100
	Transmission line change								2,000
	Camp								50,000
	TOTAL								$3,748,398
	NOTE: Based on 1940 prices								
	Cost per acre foot $18.95								57-D-24
	X-D-853								


SPILLWAY PLAN
INLET CHANNEL
EL. 2438.0
SPILLWAY STRUCTURE
OUTLET CHANNEL EL. 2400.0
SCALE OF FEET (APPROX)
DISCHARGE - THOUSANDS OF S.F.
WATER SURFACE EL.
SPILLWAY DISCHARGE CURVE
RESERVOIR
NORMAL WATER SURFACE EL. 2438.0
BOX CANYON DAM
OUTLET TUNNEL
HASSAYAMPA RIVER
LOCATION PLAN
EXCAVATION LINE
ORIGINAL GROUND SURFACE ON ℄
LEFT WALL
N.W.S. EL. 2438.0
EL. 2438.0
LEFT BANK
APPROX. EXCAVATION LINE
TOE WALL
SECTION A A
STATIONS ON ℄ SPILLWAY
100' NOTCH
EL. 2441.0
BACKFILL
SEC. B-B
MIN. FREEBOARD 5'
WASTE MATERIAL
TILE DRAINS
8" TILE DRAIN
SEC. C-C
SCALE OF FEET
EL. 2420.0
EL. 2400.0
SEC. D-D
REINFORCEMENT IS NOT SHOWN ON THIS DRAWING.
PRELIMINARY ESTIMATE DRAWING
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
HASSAYAMPA PROJECT - ARIZONA
BOX CANYON DAM
GENERAL PLAN AND SECTIONS
DENVER, COLORADO
57-D-26

The maximum flood of record on the Gila River is that of January 1916, which had a peak of 200,000 second-feet near Yuma, Arizona. There are no records of stream flow available on the Hassayampa River during this flood, but it is believed from examination of discharge records of other Gila River tributaries and rainfall records that the discharge near Morristown probably exceeded 50,000 second-feet.

Table 15.--Maximum Discharges on Hassayampa River at Walnut Grove and at Box Canyon Dam site. 1/

Year	Period	Hassayampa River at Walnut Grove: Maximum Discharge (Sec.-feet)	Hassayampa River at Walnut Grove: Total Run-off Volume (Acre-feet)	Hassayampa River at Box Canyon: Maximum Discharge (Sec.-feet)	Hassayampa River at Box Canyon: Total Run-off Volume (Acre-feet)
1916	October 7,	18,000			
1919	August 6,	4,800			
1919	November 27,	20,000			
1920	August 24,	5,300			
1921	July 31			13,000	
1923	September 17,			4,100	
1923	December 26 - 31,			13,400	22,200
1925	September 16 - 22,			25,500	23,500
1926	April 6			4,600	
1927	February 14 - 22,			27,100	106,500
1932	February 10,			5,000	
1935	February 6 - 12,			7,600	21,600
1935	August 22 - 25,			30,000 2/	26,100
1935	August 30 - September 5,				25,700
1936	August 9,			8,700	
1937	February 7 - 12			22,000	45,300
1937	February 14 - 22,				29,700
1937	March 16 - 25,				37,800
1937	June 29,			5,400	
1938	February 28 - March 9,			10,000	

1/ Authority - W. A. Farish, private engineer, and U. S. Geological Survey.

2/ Estimated from gage height.

Potential Floods

General

The frequency and magnitude of potential floods in the Hassayampa River Basin has been determined for use in spillway design, and for making estimates of potential flood damages and benefits of flood control. The spillway design flood, which is also called a maximum probable flood, is defined as the flood computed by means of the forecast worst storm, the highest runoff factors, and the worst runoff producing combinations for the drainage area in question. The characteristics and features of this flood which are pertinent to the design of the spillway have been determined by a synthesis based on the available hydrologic information. The translation of storm rainfall quantities into runoff quantities has been accomplished by a method incorporating unit-graphs 1/ and synthetic graphs. In addition, there were prepared for comparative purposes, a frequency analysis of peak discharges, and envelope curves of peak discharges and runoff volumes in the general region.

Hydrometerological characteristics.

There are three distinct types of storms that occur in the Hassayampa River Basin; general winter, local summer, and general summer storms. Storm studies indicate that a maximum probable flood at Box Canyon Dam site will be caused by a general summer storm. This type of storm, which is infrequent in occurrence, usually approaches from the southwest and is of tropical origin.

Unit Graph Analysis

Method of runoff collection. There are no runoff data suitable for the establishment of rainfall-runoff relationships or for the determination of unit-graphs for the drainage area above Box Canyon Dam site. Therefore, in deriving the spillway design flood hydrograph at Box Canyon Dam site, the synthetic unit-graph method of runoff collection was used.

Development of the synthetic distribution graph. In the determination of the synthetic distribution graph at the dam site, it is assumed that runoff characteristics for various drainages in a given region are sufficiently similar that, if the characteristics for one drainage are known, those for another can be evaluated through some medium of transpostion. The medium of transposition used is "lag time". Lag time for an area is defined as the elapsed time (in hours) from the center of unit excess rainfall to the instant that 50 percent of the unit runoff volume has passed the collection point. The lag time for drainage areas with known runoff characteristich are correlated with the physical

---

1/ The unit-graph for an area is an expression of the time distribution of runoff resulting from unit excess rainfall. Unit excess rainfall is rainfall of unit duration which is in excess of that lost by infiltration, evaporation, transpiration, absorption and detention, and which thus becomes surface runoff.

features and dimensions of the respective drainages and with the time-distribution of runoff. These two relationships are termed, respectively, "lag curve" and "S-graph". With the use of the lag curve and S-graph a synthetic distribution graph for the drainage area above the proposed Box Canyon Dam was developed.

Lag curve. Unit-graphs were determined for 14 drainage areas located in southern California and western Arizona. For each of the drainage areas a lag time was determined. Measurement of these lags demonstrates that lags for these areas could readily be expressed by the empirical formula;

$$\text{Lag (in hours)} = C_t \left(\frac{L \times L_{ca}}{S^{\frac{1}{2}}}\right)^m$$

C_t and m = constants (see below).

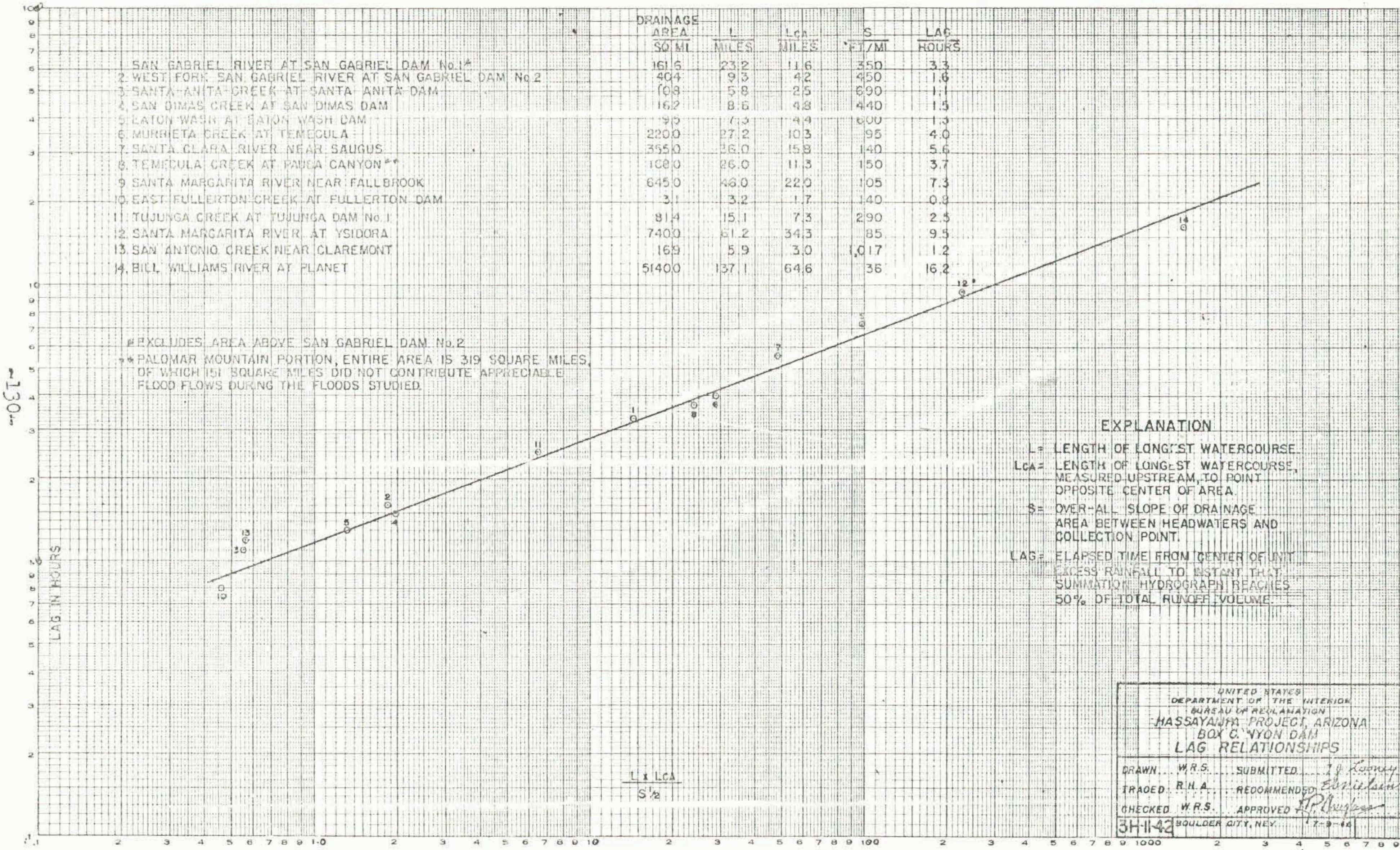
L = length of longest watercourse, in miles.

L_{ca} = length along longest watercourse, measured upstream to a point opposite center of area, in miles.

S = over-all slope of drainage between the headwater and the collection point, in feet per mile.

On drawing No. 3H-11-42 is shown the derivation of this equation accomplished by plotting to logarithmic scale, observed lag time versus $\frac{L \times L_{ca}}{S^{\frac{1}{2}}}$; the plotted points suggest a straight line whose slope, m is 0.38 and whose intercept C_t is 1.18.

S-graph. An S-graph expresses the distribution of accumulated observed runoff (in percent of total runoff volume) as a function of the lag time. The S-graph for an area is derived from its summation graphs by converting the scale of the abscissa from absolute time to time in percent of lag time. The summation graph for an area is a graph of accumulative runoff volume at the point of concentration resulting from continuous generation of excess rainfall over the drainage area. The S-graph on drawing No. 3H-11-44 is based upon a unit-graph analysis of the February 1937 flood on the Bill Williams River above Planet, Arizona, (see drawing No. 3H-11-41). This S-graph was assumed to be satisfactorily representative of the average characteristic time-distribution of runoff for this general region and to be suitable for use in the adjacent Hassayampa River Basin for any drainage area where the basic runoff data do not exist. With the use of this S-graph the percentages of total volume of runoff which represent a synthetic distribution graph were derived for the drainage area above the proposed Box Canyon Dam. These distribution percentages are tabulated on Table 16.



	DRAINAGE AREA SQ MI	L MILES	LCA MILES	S FT/MI	LAG HOURS
1. SAN GABRIEL RIVER AT SAN GABRIEL DAM No.1*	161.6	23.2	11.6	350	3.3
2. WEST FORK SAN GABRIEL RIVER AT SAN GABRIEL DAM No.2	40.4	9.3	4.2	450	1.6
3. SANTA ANITA CREEK AT SANTA ANITA DAM	10.8	5.8	2.5	690	1.1
4. SAN DIMAS CREEK AT SAN DIMAS DAM	16.2	8.6	4.8	440	1.5
5. EATON WASH AT EATON WASH DAM	9.5	7.3	4.4	600	1.3
6. MURRIETA CREEK AT TEMECULA	220.0	27.2	10.3	95	4.0
7. SANTA CLARA RIVER NEAR SAUGUS	355.0	36.0	15.8	140	5.6
8. TEMECULA CREEK AT PAUBA CANYON**	168.0	26.0	11.3	150	3.7
9. SANTA MARGARITA RIVER NEAR FALLBROOK	645.0	46.0	22.0	105	7.3
10. EAST FULLERTON CREEK AT FULLERTON DAM	3.1	3.2	1.7	140	0.8
11. TUJUNGA CREEK AT TUJUNGA DAM No.1	81.4	15.1	7.3	290	2.5
12. SANTA MARGARITA RIVER AT YSIDORA	740.0	61.2	34.3	85	9.5
13. SAN ANTONIO CREEK NEAR CLAREMONT	16.9	5.9	3.0	1,017	1.2
14. BILL WILLIAMS RIVER AT PLANET	5140.0	137.1	64.6	36	16.2

*EXCLUDES AREA ABOVE SAN GABRIEL DAM No.2

**PALOMAR MOUNTAIN PORTION, ENTIRE AREA IS 319 SQUARE MILES, OF WHICH 151 SQUARE MILES DID NOT CONTRIBUTE APPRECIABLE FLOOD FLOWS DURING THE FLOODS STUDIED.

EXPLANATION

L = LENGTH OF LONGEST WATERCOURSE.

LCA = LENGTH OF LONGEST WATERCOURSE, MEASURED UPSTREAM, TO POINT OPPOSITE CENTER OF AREA.

S = OVER-ALL SLOPE OF DRAINAGE AREA BETWEEN HEADWATERS AND COLLECTION POINT.

LAG = ELAPSED TIME FROM CENTER OF UNIT EXCESS RAINFALL TO INSTANT THAT SUMMATION HYDROGRAPH REACHES 50% OF TOTAL RUNOFF VOLUME.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT, ARIZONA
BOX CANYON DAM
LAG RELATIONSHIPS

DRAWN	W.R.S.	SUBMITTED	[illegible]
TRACED	R.H.A.	RECOMMENDED	[illegible]
CHECKED	W.R.S.	APPROVED	[illegible]
3H-II-42	BOULDER CITY, NEV.		7-9-46

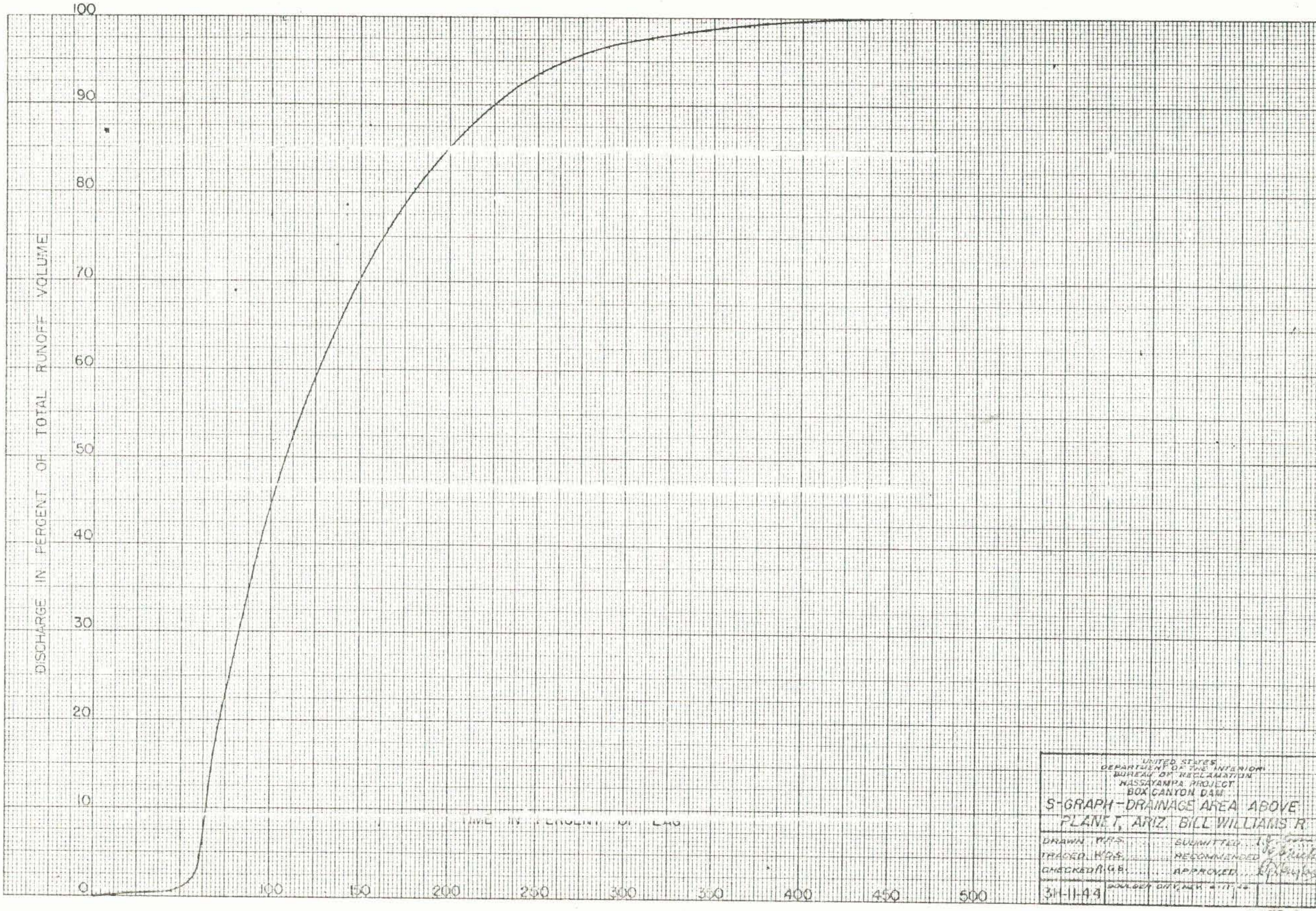
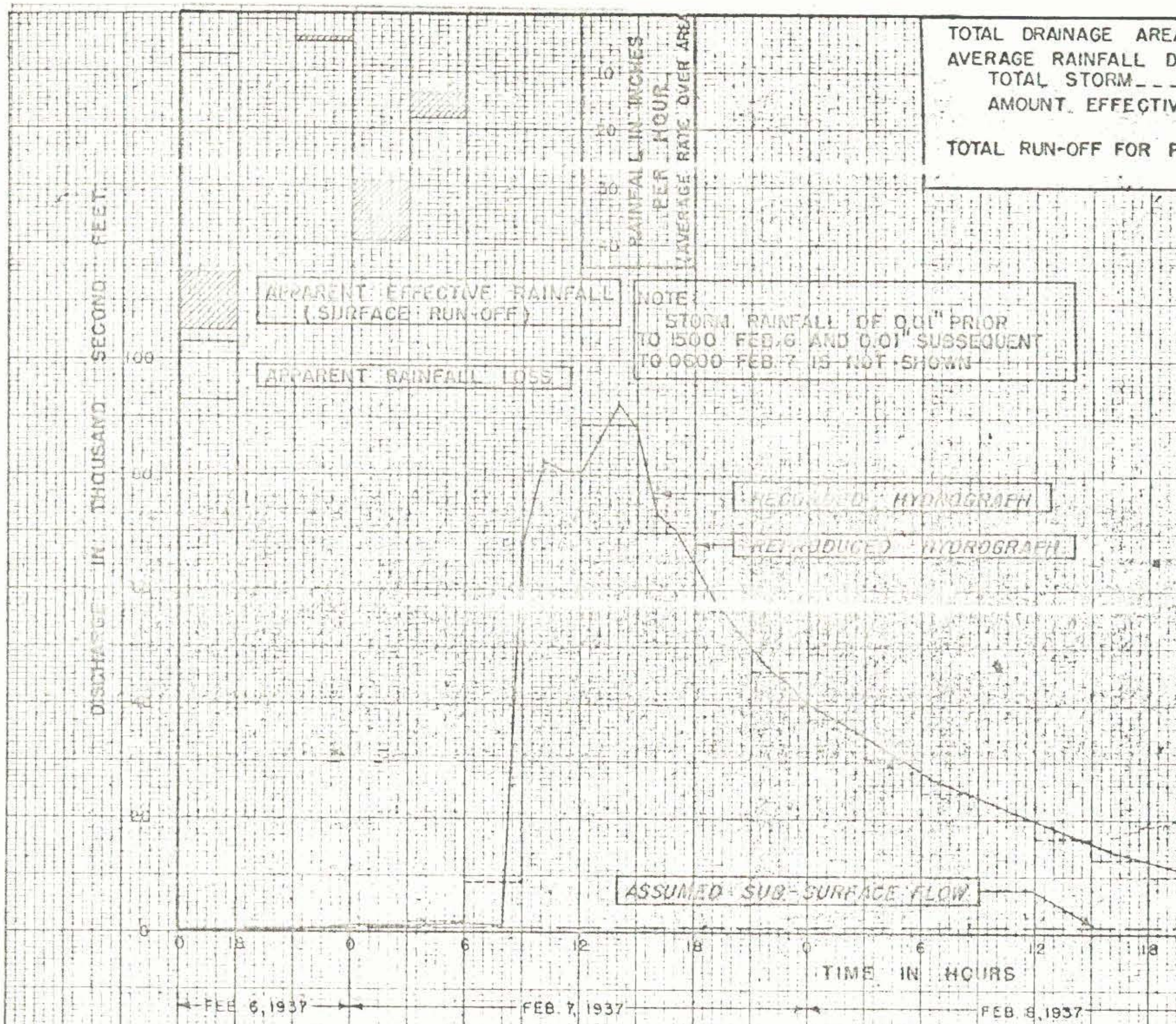

DISCHARGE IN PERCENT OF TOTAL RUNOFF VOLUME
100
90
80
70
60
50
40
30
20
10
0
100
150
200
250
300
350
400
450
500
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT
BOX CANYON DAM
S-GRAPH - DRAINAGE AREA ABOVE
PLANET, ARIZ. BILL WILLIAMS R.
DRAWN W.R.S.
TRACED W.R.S.
CHECKED R.G.B.
SUBMITTED
RECOMMENDED
APPROVED
3H-11-44

PLATE 9



TOTAL DRAINAGE AREA _ 5,140 SQ. MI.

AVERAGE RAINFALL DEPTH OVER AREA

TOTAL STORM _ 2.15 INCHES

AMOUNT EFFECTIVE (SURFACE RUN-OFF) _ _ _ _ _ _ 0.46 INCH

TOTAL RUN-OFF FOR PERIOD OF SURFACE RUN-OFF _ _ 135,000 AC-FT
0.49 INCH

DISTRIBUTION GRAPH PERCENTAGES

3 HR. PERIOD	PERCENT	3 HR. PERIOD	PERCENT
1	0.2	13	2.8
2	0.3	14	2.1
3	1.0	15	1.5
4	21.4	16	1.1
5	15.6	17	0.8
6	12.8	18	0.6
7	10.1	19	0.5
8	8.2	20	0.4
9	6.7	21	0.3
10	5.4	22	0.2
11	4.3	23	0.1
12	3.5	24	0.1

Note: Data taken from the Corps of Engineers U.S. Army Report, "Hydrology Alamo Reservoir Bill Williams River, Arizona" Dated March 29, 1946.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT
DISTRIBUTION GRAPH DETERMINATION
FLOOD OF FEB. 7, 1937
BILL WILLIAMS RIVER AT PLANET

DRAWN .... SUBMITTED ....
TRACED ..K.L.H... RECOMMENDED ....
CHECKED ..R.G.S.. APPROVED ....

3H-11-41 | BOULDER CITY, NEVADA | Jy. 3, 1946

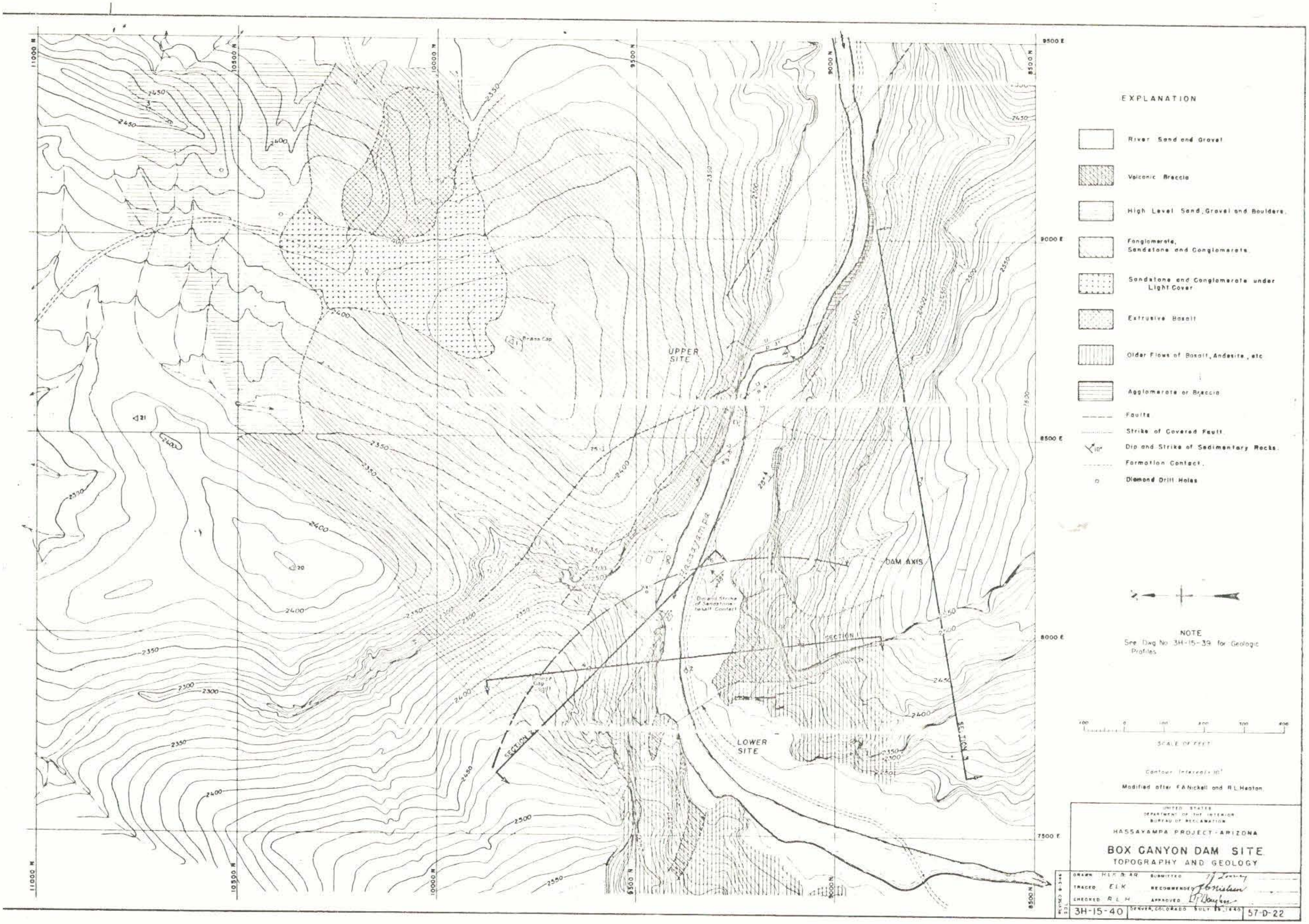

EXPLANATION
River Sand and Gravel
Volcanic Breccia
High Level Sand, Gravel and Boulders.
Fanglomerate,
Sandstone and Conglomerate.
Sandstone and Conglomerate under Light Cover
Extrusive Basalt
Older Flows of Basalt, Andesite, etc
Agglomerate or Breccia
Faults
Strike of Covered Fault
Dip and Strike of Sedimentary Rocks.
Formation Contact.
Diamond Drill Holes
UPPER SITE
LOWER SITE
DAM AXIS
HASSAYAMPA
SECTION 1
SECTION 2
SECTION 3
Brass Cap
NOTE
See Dwg No 3H-15-39 for Geologic Profiles
SCALE OF FEET
Modified after F.A.Nickell and R.L.Heaton
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
BOX CANYON DAM SITE
TOPOGRAPHY AND GEOLOGY
DRAWN H.L.K. & A.R.
TRACED E.L.K.
CHECKED R.L.H.
SUBMITTED
RECOMMENDED
APPROVED
3H-15-40
DENVER, COLORADO
57-D-22

Table 16. - Synthetic distribution - graph percentages for drainage area above Box Canyon Dam site.

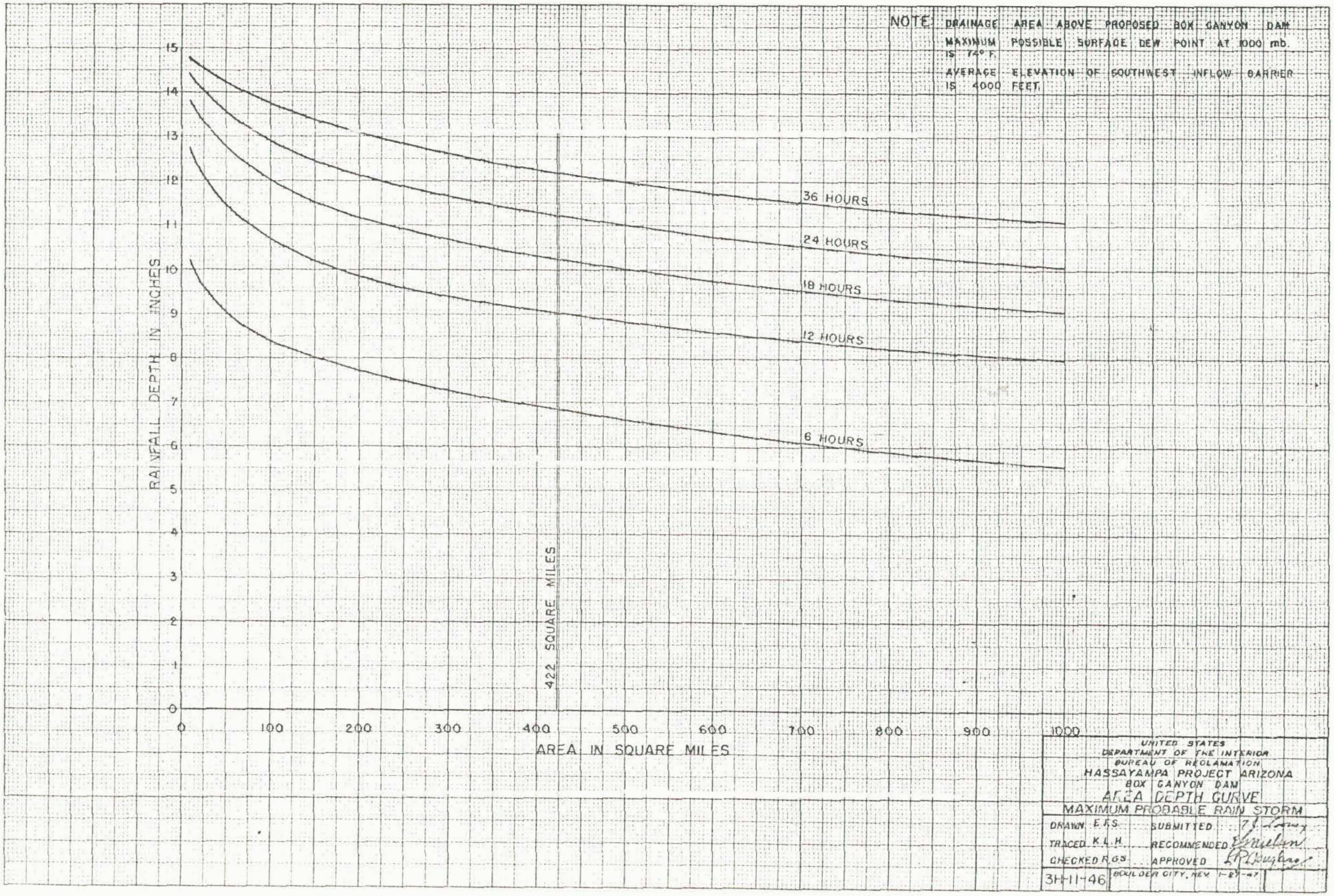
Time Interval (Hours)	Percent of Total Volume of Runoff
0-1	0.2
2	0.2
3	0.2
4	6.4
5	17.8
6	12.9
7	11.8
8	8.7
9	7.6
10	6.0
11	5.3
12	4.5
13	3.7
14	3.0
15	2.5
16	2.2
17	1.6
18	1.2
19	1.0
20	0.8
21	0.5
22	0.4
23	0.4
24	0.4
25	0.2
26	0.2
27	0.1
28	0.1
28-29	0.1

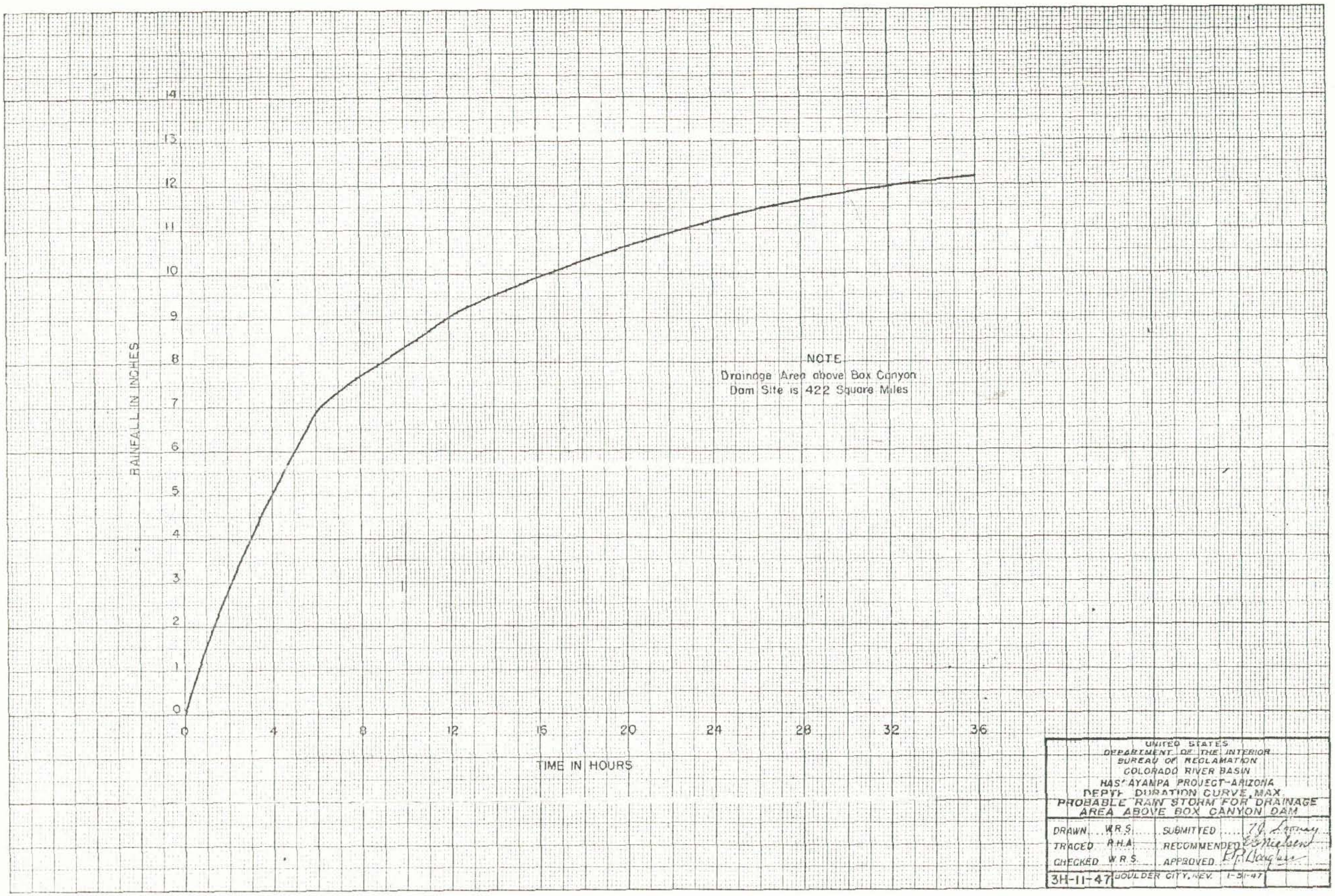
Maximum probable storm. To date, there have been no maximum possible rain storms developed by the Weather Bureau for the Hassayampa River Basin. However, the Hydrometeorological Section of the Weather Bureau made a preliminary estimate in 1945 for the Corps of Engineers, U. S. Army, of the maximum possible precipitation in the Bill Williams River Basin, Arizona. This estimate was based upon the tranposition of a maximum possible rain storm, derived by the Hydrometeorological Section, for the Pecos River Basin, New Mexico, to the Bill Williams River Basin. Since the storm potentialities of the Bill Williams River

Basin, with respect to exposure and source of moisture are similar to those of the Hassayampa River Basin, it is believed that by transposing the Pecos storm to the upper Hassayampa River Basin, using the same method of dewpoint and average inflow barrier altitude difference adjustments employed by the Hydrometeorological Section, a fair estimate of a maximum probable rain storm would be derived. The average inflow barrier for both the Pecos and the upper Hassayampa River Basins are found to be at an elevation of 4,000 feet. The maximum surface dewpoint for the Pecos River Basin was determined to be 79° F. (1000 millibars). The maximum surfacedewpoint for the upper Hassayampa Basin was estimated to be 74° F. (1000 millibars). The design storm being an exact fit in relation to the orientation over the drainage area is an extreme rarity and is believed to be improbable. An estimated adjustment factor of 85 percent was used to account for this misfit. In transposing the maximum possible rain storm from the Pecos to the upper Hassayampa River Basin with the use of dewpoint and average inflow barrier altitude difference adjustments and also the estimated adjustment factor of 85 percent, a reduction factor of 60.4 percent was derived. The resulting area-depth (6, 12, 18, 24 and 36 hour duration) and depth-duration curves of the maximum probable rain storm for the upper Hassayampa River Basin are shown on drawing Nos. 3H-11-46 and 3H-11-47.

Rainfall intensity patterns. A unit-time of one hour (approximately ¼ of the lag time) was selected as the smallest time interval for which data on rainfall intensities would be required in developing the maximum probable storm. With the use of the depth-duration curve of the maximum probable rain storm on drawing No. 3H-11-47, the increment amounts of rainfall for each succeeding unit-time period were determined. By using the synthetic distribution graph developed in the paragraph entitled "S-graph" as a guide, these unit-time rainfalls were arranged into a critical pattern which would give a maximum rate of runoff at Box Canyon Dam site. The design rainfall pattern is tabulated in column (3) of Table 17 and shown on drawing No. 3H-11-48.

Precipitation retention rates. The hydrologic records for the drainage area above Box Canyon Dam site are inadequate to permit a study of precipitation retention rates which could be used as a basis to determine ground conditions that are conducive to maximum runoff in the drainage. However, minimum retention rates (retention with the ground saturated) were estimated through a general study of the surface soils and a comparison of these soils with those in an adjacent drainage area for which retention rates have been determined. In the Bill Williams River Basin, a unit-graph analysis of the February 1937 storm indicated an average retention rate of 0.29 inches per hour during the 3-hour period when the rain was heaviest over the area. Based upon the retention rates determined by this unit-graph analysis, it was estimated that the minimum retention rate would be 0.27 inches per hour for the Hassayampa Basin above Box Canyon Dam site.


NOTE: DRAINAGE AREA ABOVE PROPOSED BOX CANYON DAM.
MAXIMUM POSSIBLE SURFACE DEW POINT AT 1000 mb. IS
AVERAGE ELEVATION OF SOUTHWEST INFLOW BARRIER IS 4000 FEET.
RAINFALL DEPTH IN INCHES
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
36 HOURS
24 HOURS
18 HOURS
12 HOURS
6 HOURS
422 SQUARE MILES
0
100
200
300
400
500
600
700
800
900
1000
AREA IN SQUARE MILES
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT ARIZONA
BOX CANYON DAM
AREA DEPTH CURVE
MAXIMUM PROBABLE RAIN STORM
DRAWN E.F.S.
SUBMITTED
TRACED K.L.H.
RECOMMENDED
CHECKED R.G.S.
APPROVED
3H-11-46
BOULDER CITY, NEV.


RAINFALL IN INCHES
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TIME IN HOURS
0
4
8
12
16
20
24
28
32
36
NOTE
Drainage Area above Box Canyon Dam Site is 422 Square Miles
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER BASIN
HAS'AYAMPA PROJECT-ARIZONA
DEPTH DURATION CURVE, MAX.
PROBABLE RAIN STORM FOR DRAINAGE
AREA ABOVE BOX CANYON DAM
DRAWN W.R.S.
TRACED R.H.A.
CHECKED W.R.S.
SUBMITTED
RECOMMENDED
APPROVED
3H-11-47
BOULDER CITY, NEV. 1-31-47

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Time Interval	Increment of Rainfall	Design Pattern Incr. of Rainfall	Retention Rate	Effective Rainfall	RUNOFF		BASE FLOW	TOTAL RUNOFF
					Inches	Sec. Ft.	Sec. Ft.	Sec. Ft.
(hours)	(inches)	(inches)	(inches)	(inches)				
0--1	1.63	.24	.27	.00	.00000	0	420	420
2	1.33	.34	.27	.07	.00014	40	"	460
3	1.09	.34	.27	.07	.00028	80	"	500
4	1.02	.35	.27	.08	.00044	120	"	540
5	.97	.35	.27	.08	.00494	1,340	"	1,760
6	.85	.35	.27	.08	.01742	4,740	"	5,160
7	.44	.44	.27	.17	.02727	7,420	"	7,840
8	.35	.97	.27	.70	.03855	10,490	"	10,910
9	.35	1.02	.27	.75	.04727	12,870	"	13,290
10	.35	1.09	.27	.32	.05919	16,110	"	16,530
11	.34	1.33	.27	1.36	.11656	31,730	"	32,150
12	.34	1.63	.27	1.36	.23140	62,980	"	63,400
13	.24	.85	.27	.58	.32704	89,020	"	89,440
14	.22	.22	.27	.00	.43268	117,770	"	118,190
15	.20	.20	.27		.56231	153,060	"	153,480
16	.19	.19	.27		.65600	178,560	"	178,980
17	.18	.18	.27		.59536	162,050	"	162,470
18	.18	.18	.27		.48961	133,270		133,690
19	.16	.16	.27		.40218	109,470	"	109,890
20	.16	.16	.27		.33221	90,420	"	90,840
21	.16	.16	.27		.27702	75,400	"	78,820
22	.16	.16	.27		.23260	63,310	"	63,730
23	.16	.16	.27		.19566	53,260	"	53,680
24	.16	.16	.27		.16006	43,780	"	44,200
25	.12	.12	.27		.13082	35,610	"	36,030
26	.12	.12	.27		.10666	29,030	"	29,450
27	.11	.11	.27		.08641	23,520	"	23,940
28	.11	.11	.27		.06663	18,140	"	18,560
29	.09	.09	.27		.05077	13,820	"	14,240
30	.08	.08	.27		.04016	10,930	"	11,350
31	.07	.07	.27		.03179	8,650	"	9,070
32	.07	.07	.27		.02394	6,520	"	6,940
33	.06	.06	.27		.01909	5,200	"	5,620
34	.05	.05	.27		.01609	4,380	"	4,800
35	.05	.05	.27		.01314	3,580	"	4,000
35	.04	.04	.27		.00943	2,570	"	2,990
36					.00651	1,770	"	2,190
38					.00440	1,200	"	1,620
39					.00301	820	"	1,240
40					.00194	530	"	950
41					.00058	160	"	580
41-42					.00000	0	"	420
TOTAL	12.20	12.20		5.82	5.81835	1,583,720	17,640	1,601,360
		(130,907Ac-Ft)						(132,344 Ac-Ft)

laximum 24 hour runoff is 1,553,330 S.F. or 128,374 Ac. Ft.

Explanation of items in regard to Table 17 not explained in test:

Col. (2). From Drawing 3H-11-47

(6). Represents the multiplication and accumulation of Table 16 with column (5)

(7). Column (6) x 422 x 645.

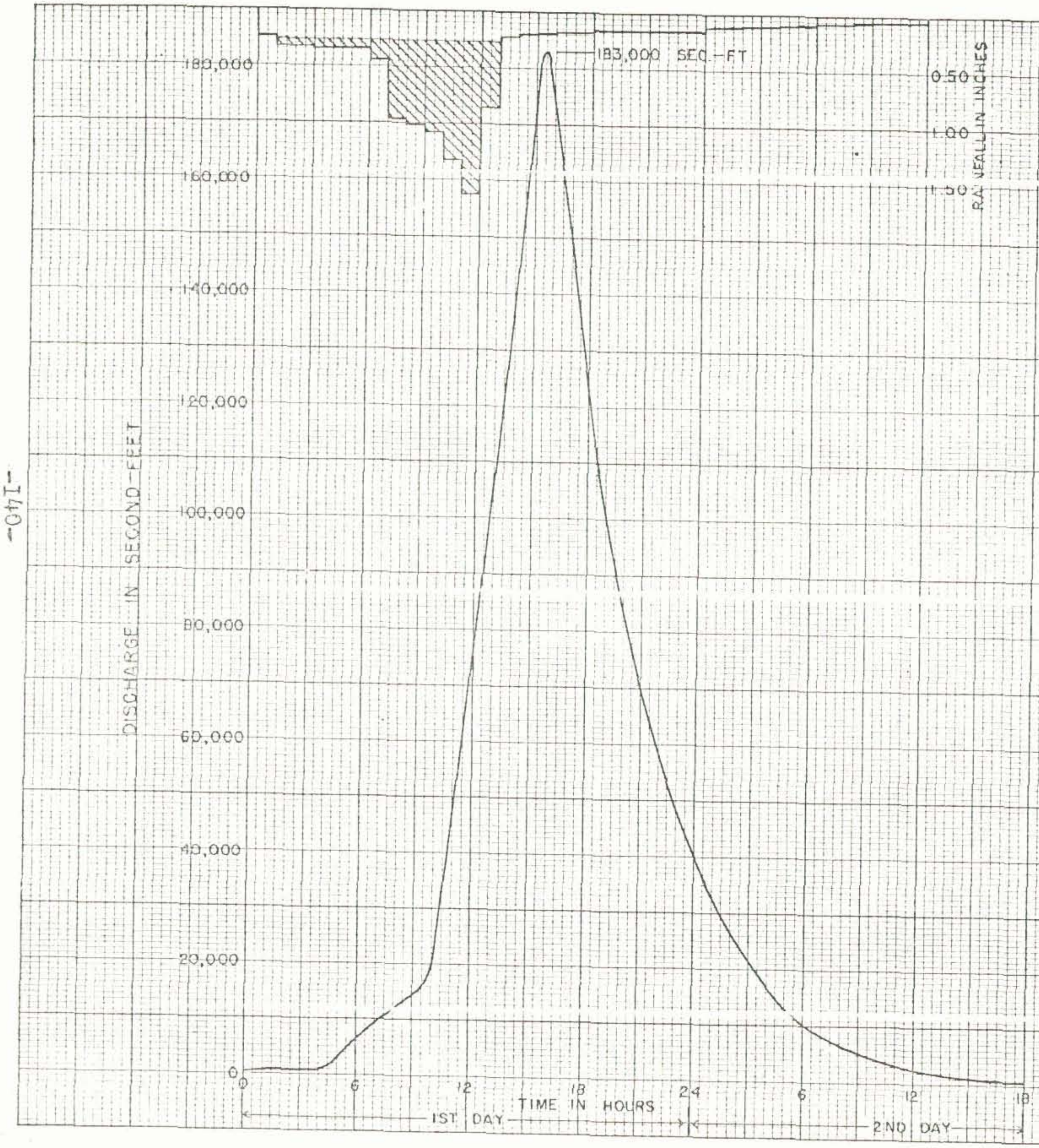
Base flow. As considered in this study, base flow in the streams during floods consisted of water which percolates into the ground during the storm and flows beneath the surface to the streams, in addition to the ground water flow due to prior rains. Unit-graph studies of the 1937, 1940, and 1941 floods indicated a maximum base flow of approximately 0.5 second-feet per square mile for the Bill Williams Basin. By comparing the geology and soils of the Bill Williams and the upper Hassayampa Basins, it was estimated that the maximum base flow to be expected for the drainage above the proposed Box Canyon Dam would be 1 second-foot per square mile. For the duration of the spillway design flood, base flow was assumed to be at a maximum at the beginning of surface runoff and to remain constant until the end of surface runoff.

Snowfall. At Walnut Grove (elevation 3,469 feet), near the center of the tributary area, the annual snowfall averages only 1.23 inches; and at Prescott (elevation 5,354), some four miles north of basin boundary, the annual average is 31.8 inches. Except on the higher peaks, the snowfalls are not severe or lasting, seldom remaining on the ground over a few days at a time, and seldom accumulating to depths of more than 12 to 15 inches. Snow-melt was not considered an appreciable factor in the spillway design flood. A large flood could be caused by runoff originating from both rainfall and snow-melt during the months of February through April, but a flood of the magnitude of the spillway design flood would result from rainfall in the summer rainy season (July to October) on bare, saturated ground long after the snow in the drainage area has all melted and drained off.

Spillway design flood. With the use of the previously derived design rainfall pattern, minimum retention rates, synthetic distribution graph and maximum base flow, a spillway design flood hydrograph which has a peak discharge of 183,000 second-feet was derived for the Box Canyon Dam site as shown on drawing No. 3H-11-48. The computations are shown on Table 17. A summary of hydrology of this design flood is given on drawing No. 3H-11-48.

Frequency Analysis (Hazen Method)

Probability studies of peak discharge. Due to the paucity of runoff records in the upper Hassayampa River Basin, a direct probability study of peak discharges at the Box Canyon Dam site could not be made. However, with the use of the Hazen Probability Method, an indirect analysis was made. Coefficients of skew and variation were determined for 11 drainages, which have flood histories of 12 consecutive years or more and are located in the Bill Williams and Gila River Basins. The Bill Williams and the Gila River Basins are considered to form a general region that has similar storm characteristics. The coefficients of skew and variation were correlated and weighed in order that an average skew and variation coefficient could be determined for this general region. The average coefficient of skew and variation derived were 1.70 and 0.90 respectively. By means of the Hazen Method and the use of the above-mentioned coefficients, a probability curve of



DISTRIBUTION GRAPH PERCENTAGES

1 HR PERIOD	PERCENT	1 HR PERIOD	PERCENT
	0.2	16	2.2
2	0.2	17	1.6
3	0.2	18	1.2
4	6.4	19	1.0
5	17.8	20	0.8
6	12.9	21	0.5
7	11.8	22	0.4
8	9.7	23	0.4
9	7.6	24	0.4
10	6.0	25	0.2
11	5.3	26	0.2
12	4.5	27	0.1
13	3.7	28	0.1
14	3.0	29	0.1
15	2.5		

TOTAL DRAINAGE AREA	422 SQ MI.
AVERAGE RAINFALL DEPTH OVER AREA	
MAXIMUM 24-HOUR	11.23 INCHES
TOTAL STORM	12.20 "
SURFACE RUNOFF	5.82 "
RUNOFF (INCLUDING BASE FLOW)	128,370 AC-FT
MAXIMUM 24-HOUR	5.71 INCHES
TOTAL FOR PERIOD OF SURFACE RUNOFF	132,340 AC-FT. 5.88 INCHES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT

SPILLWAY DESIGN FLOOD
AT BOX CANYON DAM

DRAWN E.F.S. SUBMITTED
TRACED K.L.H. RECOMMENDED
CHECKED R.G.S. APPROVED
3H-11-48 BOULDER CITY, NEV. 1-28-47

of peak discharges at Box Canyon Dam site was determined as shown on drawing No. 3H-11-49. Probable peak discharges at Box Canyon Dam versus various frequencies, as indicated by this curve are tabulated as follows:

Frequency in Years	Probable Peak Discharge (Second-feet)
5	15,900
10	22,000
25	30,300
50	37,300
100	44,000
1,000	70,900
10,000 (assumed to represent a maximum probable flood)	103,600

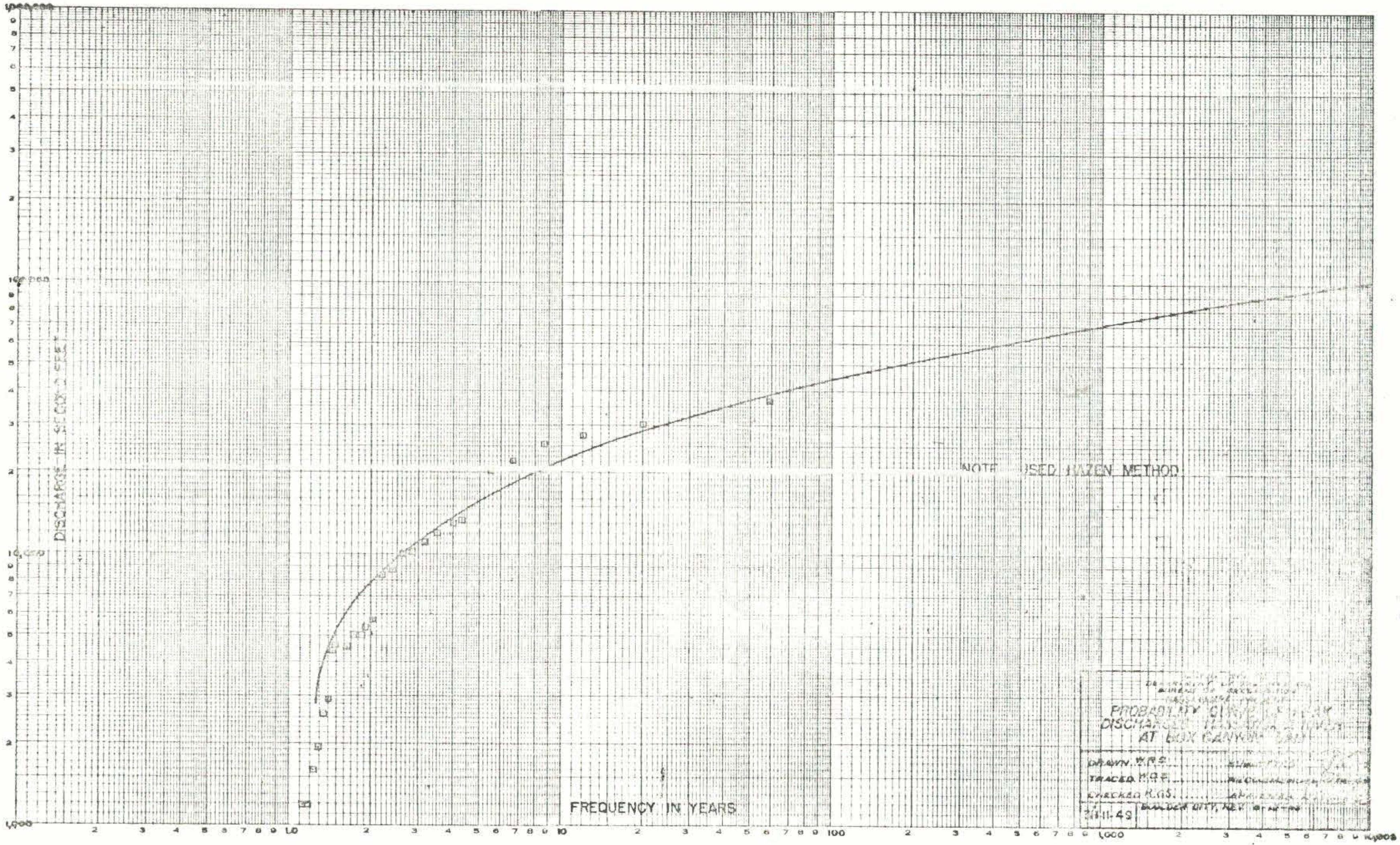
Envelope Curve Analysis

Envelope curve of peak discharges. All available maximum recorded flood discharges in second-feet for streams located in the Bill Williams and Gila River Basins were plotted against their respective drainage areas above the gaging stations. Drawing No. 3H-11-50 shows these points in their relative positions and an envelope curve through the maximum discharges. Description of the recorded discharges controlling or supporting this envelope curve are given as follows:

Salt River at Granite Reef, Arizona (point 39): The Salt River is a westward flowing tributary on the Gila River with its mouth located about 12 miles southwest of Phoenix, Arizona. The determination of peak runoff was made by slope measurements. This maximum discharge which resulted from melting snow and extensive rainfall occurred on February 24, 1891, and is believed to have closely approached the maximum probable.

Salt River below Phoenix, Arizona (point 43): The description given above also applies here. It is not known whether this peak discharge is the result of exact measurements or based on slope measurements. This maximum discharge which resulted from melting snow and extensive rainfall occurred in February 1891, and is believed to have closely approached the maximum probable.

Alder Creek at mouth, Arizona (point 73): 1/ Alder Creek is a southeastward flowing tributary of the Blue River with its mouth located approximately 10 miles upstream from where the Blue River enters the San Francisco River. The determination of runoff was made by slope measurements. The flood marks attesting this enormous



FREQUENCY IN YEARS
NOTE: USED HAZEN METHOD
1,000
10,000
100,000
1,000,000
1.0
10
100
1,000
10,000
DRAWN
TRACED
CHECKED

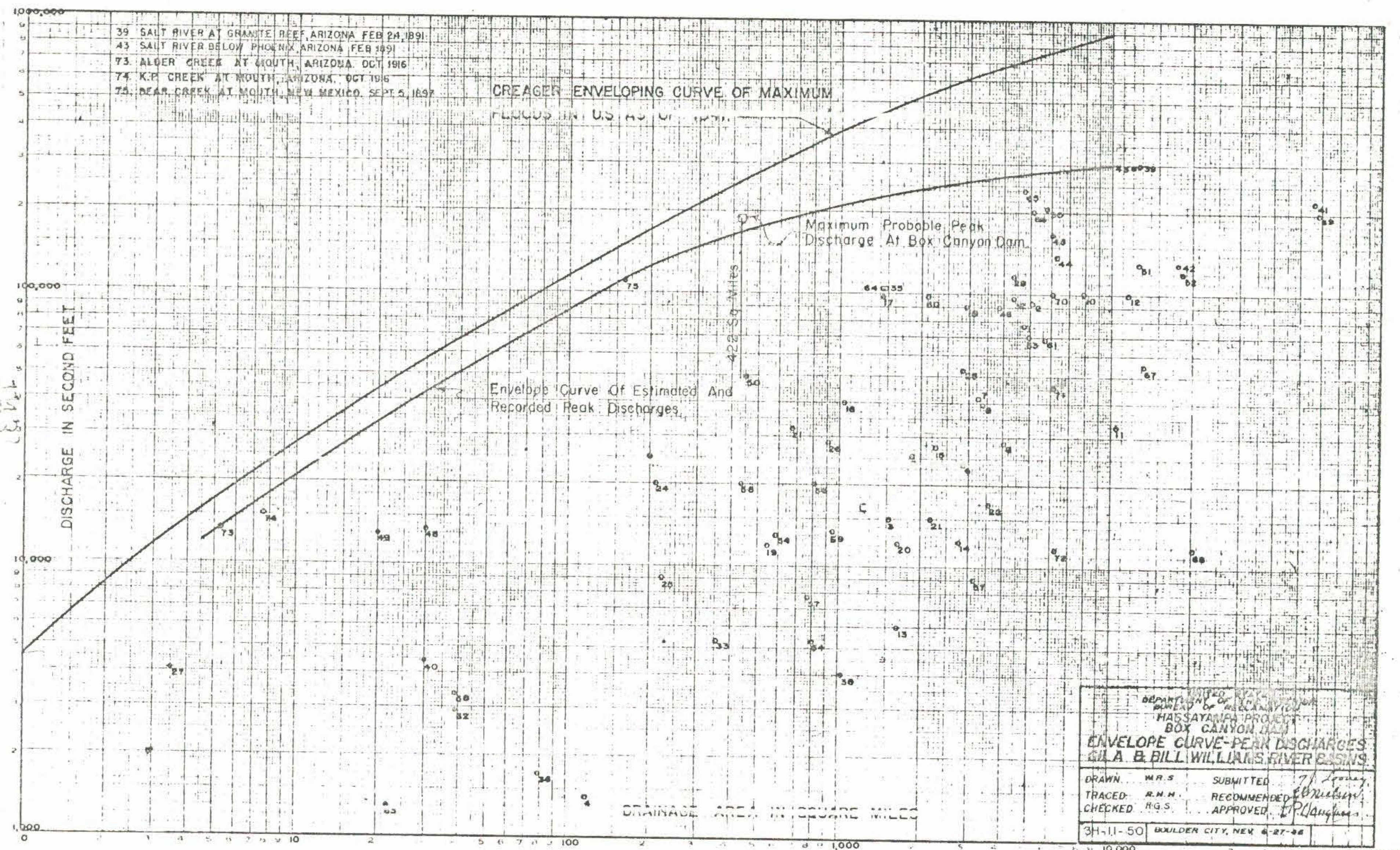

39 SALT RIVER AT GRANITE REEF, ARIZONA FEB 24, 1891
43 SALT RIVER BELOW PHOENIX, ARIZONA FEB 1891
73. ALDER CREEK AT MOUTH, ARIZONA. OCT 1916
74. K.P. CREEK AT MOUTH, ARIZONA. OCT 1916
75. BEAR CREEK AT MOUTH, NEW MEXICO. SEPT 5, 1897
CREAGER ENVELOPING CURVE OF MAXIMUM
Maximum Probable Peak Discharge At Box Canyon Dam
422 Sq. Miles
Envelope Curve Of Estimated And Recorded Peak Discharges
DISCHARGE IN SECOND FEET
1,000,000
100,000
10,000
1,000
DRAINAGE AREA IN SQUARE MILES
10
100
1,000
10,000
100,000
HASSAYAMPA PROJECT
BOX CANYON DAM
ENVELOPE CURVE-PEAK DISCHARGES
GILA & BILL WILLIAMS RIVER BASINS
DRAWN W.R.S
TRACED R.N.H.
CHECKED R.G.S.
SUBMITTED
RECOMMENDED
APPROVED
3H-11-50
BOULDER CITY, NEV. 6-27-46

PLATE I

runoff are unmistakable and were verified by eye-witnesses of the flood who were present when they were made. This maximum peak discharge occurred in the October 1916 flood, and is believed to have closely approached the maximum probable.

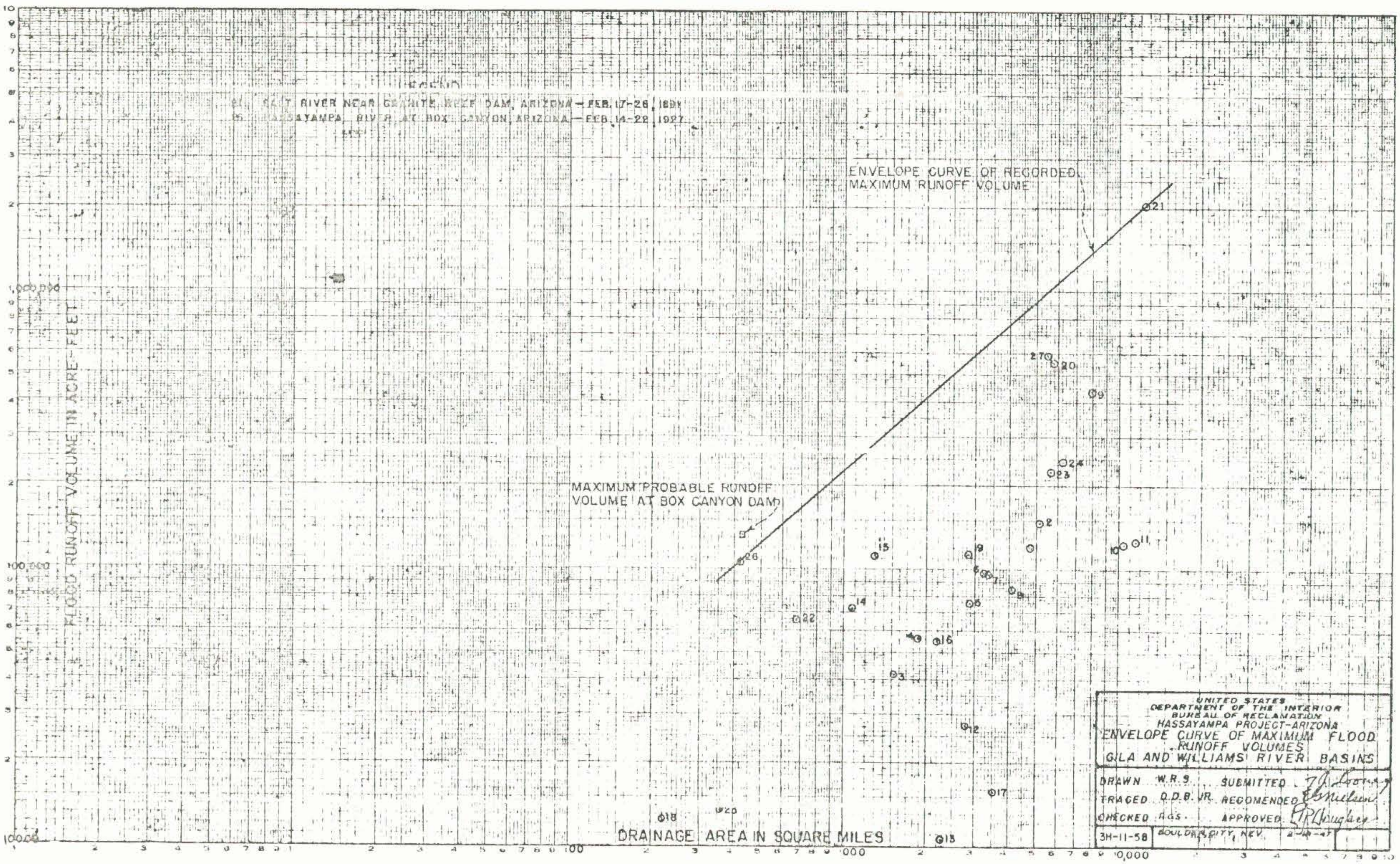
K. P. Creek at mouth, Arizona (point 74): 1/ K. P. Creek is also a southeastward flowing tributary of the Blue River with its mouth located approximately 37 miles upstream from where the Blue River enters the San Francisco River. It is not known whether this peak discharge is the result of exact measurements or based on slope measurements; however it is probably the latter. This maximum discharge occurred in the October 1916 flood and is believed to have closely approached the maximum probable.

Bear Creek at mouth, Arizona (point 75): 1/ Bear Creek is a westward flowing tributary of the upper Gila River with its mouth located near Cliff, New Mexico. At the time of the flood, September 5, 1897, the drainage area was about 15 percent timbered practically denuded of sod protection and badly eroded. Whether this peak is based on exact records or on slope measurements is not known; however, it is probably the latter. This peak discharge is the highest of record in any part of the Gila River Basin for any drainage area comparable in size. It is believed that this flood very closely approached the maximum probable.

The runoff characteristics of the foregoing drainages and the upper Hassayampa River Basin are believed to be comparable. As the maximum discharges which control or support the envelope curve are based upon estimates, the degree of accuracy of these points is not too high. By comparing these points with Creagers envelope curve of maximum peak discharges in the United States as of 1941 2/ and taking into consideration the accuracy of peak discharge data, relative location, and elevation of the above-mentioned drainages, it is believed that an envelope curve passed through these control points as shown on drawing No. 3H-11-50 would give a maximum peak discharge for the drainage area above the proposed Box Canyon Dam that would closely approach the maximum probable flood. This envelope curve indicates a maximum flood peak of 163,000 second-feet for the drainage area of 422 square miles above the Box Canyon Dam site.

1/ Gila River Flood Control by Frank H. Olmstead, March 3, 1919, Senate Document 436.

2/ Engineering for Dams by Creager, Justin and Hinds, 1945 Edition, Page 126.


RIVER NEAR GRANITE DAM, ARIZONA — FEB. 17-26,
AYAMPA RIVER AT BOX CANYON, ARIZONA — FEB. 14-22, 1927
ENVELOPE CURVE OF RECORDED MAXIMUM RUNOFF VOLUME
MAXIMUM PROBABLE RUNOFF VOLUME AT BOX CANYON DAM
FLOOD RUNOFF VOLUME IN ACRE-FEET
DRAINAGE AREA IN SQUARE MILES
100,000
10,000
1000
100
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
HASSAYAMPA PROJECT-ARIZONA
ENVELOPE CURVE OF MAXIMUM FLOOD RUNOFF VOLUMES
GILA AND WILLIAMS RIVER BASINS
DRAWN W.R.S. SUBMITTED
TRACED O.D.B. JR. RECOMENDED
CHECKED R.G.S. APPROVED
3H-11-58
BOULDER CITY, NEV.

Envelope curve of runoff volumes. All available maximum recorded runoff volumes in acre-feet resulting from single storms for streams located in the Bill Williams and Gila River Basins were plotted against their respective drainage areas above the gaging stations. Drawing No. 3H-11-58 shows these points in their relative positions and an envelope curve through the maximum runoff columes. Descriptions of the recorded runoff volumes controlling this envelope curve are given as follows:

> Salt River at Granite Reef, Arizona (point 21): The Salt River is a westward flowing tributary of the Gila River with its mouth located about 12 miles southwest of Phoenix, Arizona. The point of measurement, Granite Reef Dam, is located just below where the Verde River enters the Salt River. This maximum recorded runoff volume which resulted from melting snow and extensive rainfall occurred during the 10 day period February 17-26, 1891. This flood is believed to approach the maximum probable.
>
> Hassayampa River at Box Canyon, Arizona (point 26): This point of measurement is located at the proposed Box Canyon Dam site. This maximum recorded runoff volume which resulted from melting snow and extensive rainfall occurred during the 9 day period February 14-22, 1927. It is believed that the runoff volume resulting from a 2 or 3 day pure rain flood occurring in the late summer can exceed this flood of record.

The runoff characteristics of the Salt River and the Hassayampa River drainages are believed to be comparable. It is also believed that an envelope curve passed through these control points as shown on drawing No. 3H-11-58 would give a maximum runoff volume for the drainage area above the proposed Box Canyon Dam that would approach the maximum probable flood. This envelope curve indicates a maximum runoff volume of 106,000 acre-feet for the drainage area of 422 square miles above the proposed Box Canyon Dam site.

Summary of Analyses and Adopted Design Flood.

The following table is a summary of results obtained by methods previously discussed:

Method	Max. Probable Peak Discharge (second-feet)	Max. Probable Runoff Volume (Acre-feet)
Unit Graph Analysis	183,000	130,900
Envelope Curves	163,000	106,000
Frequency Analysis of Peak Discharges (Hazen Method)	103,000	

The unit-graph analysis is an exact determination of flood distribution, runoff rates, and volumes. The envelope curves and frequency analysis of peak discharges are check or approximate methods of the determination of maximum probable peak discharges and runoff volumes. The spillway design for Box Canyon Basin has been based on the maximum probable flood hydrograph derived by the unit graph analysis and shown on drawing No. 3H-11-43. In making the spillway design routing studies, the reservoir has been considered full to conservation storage level as the design flood is approaching.

FLOOD DAMAGES

Area affected by floods.

The town of Wickenburg, with a population of about 1,000, is located just below the junction of Sols Wash and the Hassayampa River. In times of extreme flood part of the town would be damaged, as would tourist courts and other developments on the outskirts, including the sewage disposal plant. A branch of the Atchison, Topeka and Santa Fe Railroad between Phoenix and Los Angeles enters the flood plain near Morristown, crosses the Hassayampa River on a steel truss bridge, and follows along the west side of the river for a distance of eight miles to Wickenburg. The toe of the railroad fill in many places between the Morristown bridge and Wickenburg is in or near the stream channel and subject to flood damage. Extreme floods would also damage the bridge approach and inundate three miles of track.

United States Highway No. 60 extends along the east side of the river above Morristown, crossing at Wickenburg. Severe floods would endanger portions of the highway and the bridge.

Between Wickenburg and Morristown there are about two hundred acres of irrigated farm lands usually served by small gasoline-powered pumping plants in the flood plain. A gravel plant is located on the bank of the river about five miles below Wickenburg. Near its mouth, the river is crossed by the main line of the Southern Pacific Railroad, United States Highway No. 80, and laterals from the Roosevelt and Arlington Canals. About 2,000 acres of irrigated lands are also located near the stream channel. All these improvements are subject to flood damage.

Recorded flood damages.

The Corps of Engineers made a field investigation to determine past damages caused by floods originating above Box Canyon Dam site. Their investigation, supplemented by data submitted by local interests, resulted in an evaluation of part of the flood damages which have occurred in the area under consideration. These damages are listed in Table 18. Following Table 18 is a list of additional recorded damages for which no monetary evaluation could be made.

Table 18.- Summary of evaluated flood damages in Hassayampa basin, below Box Canyon Dam site.

Year	Character of Damage	Amount of Damage
1916	Destroyed large pumping station, concrete irrigation ditches, more than 50 acres of agricultural land, underground pipe lines and fences	$ 20,000
1927	Destroyed pumping station and river jetties	4,000
1934	Damaged roads near Wickenburg	4,000
1935	Washed out both approaches to Sols Wash Highway Bridge North of Wickenburg, cost to increase bridge length by 2 spans	20,000
1935	Damage to Hassayampa River bridge at Wickenburg	2,000
1935	Washed out highway fill and river jetties 5 miles south of Wickenburg	5,000
1935	Damage to roads near Wickenburg	4,000
1935	Destructive damage and loss of business during shut-down of sand and rock company at Hassayampa	3,000
1936	Washed out highway fill 5 miles south of Wickenburg	8,000
1936	Damage to roads in vicinity of Wickenburg	4,000
1920-1936	Damage to railroad property 1/	112,000
1919-1936	Erosion of 80 acres of improved land 1/	5,000
1920-1936	Destruction of pumping plant and machinery 1/	15,000
	Total of evaluated flood damage	$ 206,000

1/ Additional flood damage, the year of occurrence not known.

Flood damages for which no values could be obtained are listed below:

Year	Character of Damage
1917	Washed out railroad bridge and damaged another
1917	Destroyed concrete wall, irrigation ditches and scoured deep channel near Morristown.
1919	Washed out about one mile of Santa Fe tracks near mouth of Sols Wash.
1919	Destroyed pumping plant, Hassayampa bridge and land.
1920	Damaged railroad bridge
1923	Damaged railroad bridge
1927	Washed out large engine, hoist and derrick at Morristown together with concrete irrigation ditches, roads, fences, valuable trees and about 30 acres of pasture lands.
1928	Damaged railroad bridge
1929	Damaged 2 railroad bridges
1931	Damaged 2 railroad bridges and section of embankment
1935	Destruction of 15 acres of tillable land and one mile of fence
1935	Destruction of Wickenburg water supply pipe line across Sols Wash and damage to sewage treatment plant.
1935	Washed out 1,000 feet of railroad and damaged 6 or 7 other points, washed out extensive riprap protection and damaged 4 railroad bridges in vicinity of Wickenburg.
1936	Damaged railroad track and bridge.
1915-36	Destruction of 120 acres of tillable land.

Potential Flood Damages

The Corps of Engineers also made a field examination of the Hassayampa River between Box Canyon Dam site and its junction with the Gila River to determine the area that would be flooded, the value of improvements within the flood plain, and the amount of damage that would occur with large floods. To aid in determining the flooded area, 21 transverse sections were surveyed at critical intervals along the river channel and stage-discharge curves prepared for each. It was found that the area of river channel was 4,100 acres for all floods considered and that the gross area flooded varied as tabulated below:

Peak Rate of Discharge at Box Canyon Dam Site (second-feet)	Gross Area Flooded (Acres)
78,000	16,100
60,000	15,700
40,000	15,200
20,000	13,500

The estimated damages with these floods are shown in Table 19.

Using the probability curve of peak discharges at the Box Canyon Dam site as previously derived in the paragraph entitled "Probability studies of peak discharges" as a basis, a tabulation, shown as follows, was prepared that gives selected flood discharges versus probable number of occurrences in one hundred years.

Discharge at Box Canyon Dam Site (Second-feet)	Probable Number of Occurrences in 100 years
5,000	68.49
10,000	38.31
20,000	12.50
30,000	4.17
40,000	1.51
50,000	.57
60,000	.24
70,000	.11
78,000	.06
183,000	Maximum Probable

Table 19.- Probable flood damages
Hassayampa River Basin.

Type of Damage	Value	Estimated Flood Damage							
		78,000 c.f.s.		60,000 c.f.s.		40,000 c.f.s.		20,000 c.f.s.	
		Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Residential	$ 35,000	$ 26,000	$ 9,000	$ 17,000	$ 6,000	$ 10,000	$ 3,500	$ 5,000	$ 2,000
Business	10,000	5,000	2,000	4,000	1,400	2,500	900	1,000	400
Industrial -									
Gravel Plant	5,000	3,000	1,000	2,000	700	1,000	400	0	0
Public		0	0	0	0	0	0	0	0
Flood Control		500	0	500	0	0	0	0	0
Agricultural -									
Land-erosion		4.500	0	2.600	0	1.300	0	300	0
Releveling		48,000	0	35,000	0	15,000	0	3,500	0
Buildings	5,000	4,000	1,400	3,000	1,000	2,000	700	1,000	400
Machinery	9,000	2,000	700	1,600	500	1,000	400	500	200
Crops		15,000	5,000	12,000	4,000	7,000	2,500	1,200	400
Livestock		1,000	200	500	100	0	0	0	0
Irrigation Works	16,500	16,500	500	11,000	200	500	100	0	0
Highways & Roads		15,000	55,000	11,000	27,000	7,000	11,000	1,000	2,000
Bridges	173,000	173,000		60,000		30,000		5,000	
Railroads		27,000	15,000	14,000	5,000	7,000	2,000	3,000	500
Bridges	50,000	25,000		0		0		0	
Utilities -									
Electric Power		2,000	1,000	1,000	400	500	200	0	0
Sewer		5,000	3,000	3.000	2,000	1,000	500	0	0
Totals		372,500	93,800	198,200	48,300	85,800	22,200	21,500	5,900
		$466,300		$246,500		$108,000		$27,400	

Note: Data supplied by Los Angeles District, Corps of Engineers. Discharges represent peak flows at the Box Canyon Dam site.

The floods from the various sub-drainages were determined by the Corps of Engineers by superimposing a rainstorm over the Hassayampa Basin equivalent to a 78,000 second-feet peak discharge at Box Canyon Dam site. The peak discharge of these derived floods are tabulated as follows:

Sub-drainage	Area (Square miles)	Peak Discharge (Second-feet)
Hassayampa Above Box Canyon Dam site	422	78,000
Martinez Creek	121	21,900
Sols Wash	178	13,500
San Domingo Wash 1/	124	16,900
Large Unnamed Wash 2/	476	19,400

Peak discharges of 105,000 second-feet on the Hassayampa River below Sols Wash at Wickenburg and 90,000 second-feet at mouth resulting from superimposing the above-mentioned storm was derived by the Corps of Engineers by accumulating the derived floods for the sub-drainages and making due allowance for channel storage and time of travel. The mean peak discharge in the flood damage area was also determined to be 97,500 second-feet (direct average of the peak flow below Wickenburg and mouth of river).

With the use of this Corps of Engineers study as a basis, the probable floods from the various sub-drainages associated with the previously selected flood peaks at Box Canyon Dam site and the resulting flood peaks on the Hassayampa River below Wickenburg and at mouth were estimated. In Table 20 are shown the selected peak rates of discharge for an uncontrolled flood (Box Canyon Dam not built) at the Box Canyon Dam site, the estimated peak rates of discharge below Sols Wash at Wickenburg and at the mouth of the river, and the mean discharge in the area subject to flood damage. By plotting the mean discharge in the flood damage areas equivalent to peak discharges of 20,000, 40,000, 60,000 and 78,000 second-feet at Box Canyon Dam site versus the resulting total flood damages as given in Table 19 a discharge-damage curve (see drawing No. 3H-11-56) was constructed. Application of the discharge-damage curve indicates that a 78,000 second-feet peak uncontrolled flood at Box Canyon Dam site, equivalent to a mean discharge of 97,500 second-feet in the damage area, would result in flood damages of $466,000. The amounts of damages that occur with the specified floods were determined in this manner and tabulated in Table 20.

<u>Average annual damage from uncontrolled floods.</u> Using Table 20 as a basis, the total flood damages in the mean flooded area during a 100-year period was determined graphically as shown on drawing No. 3H-11-57. The total flood damage in 100 years which is represented

1/ Includes Little San Domingo Wash.
2/ Includes 138 square miles along the main channel.

Table 20.- Probable flood damages in Hassayampa River basin
Box Canyon Dam not built.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Prob. No. of Occur. In 100 yrs.	Uncontrolled Peak At Dam Site	Uncontrolled Peak From Dam (At Wickneburg)	Outflow from Martinez Cr. (At Wickenburg)	Outflow From Sols Wash (At Wickenburg)	Peak Flow (At Wickenburg)	Peak Flow (Mouth of River)	Mean Flow In Damage Area	Damage
	(Sec.-Ft.)	(Sec.-Ft.)	(Sec.-Ft.)	(Sec.-Ft)	(Sec.-Ft.)	(Sec.-Ft.	(Sec.-Ft.)	(Dollars)
Max. Prob.	183,000	165,400	49,300	31,700	246,400	211,200	230,000	
.06	78,000	70,500	21,000	13,500	105,000	90,000	97,500	460,000
.11	70,000	63,300	18,100	21,100	93,500	80,100	86,800	352,000
.24	60,000	54,200	16,200	10,400	80,800	69,200	75,000	243,000
.57	50,000	45,200	13,500	8,700	67,400	57,800	62,600	170,000
1.49	40,000	36,200	10,800	6,900	53,900	46,200	50,000	108,000
4.17	30,000	27,100	8,100	5,200	40,400	34,600	37,500	63,000
12.50	20,000	18,100	5,400	3,500	27,000	23,100	25,000	29,000
33.31	10,000	9,000	2,700	1,700	13,400	11,500	12,400	8,000
68.49	5,000	4,500	1,300	900	6,700	5,700	6,200	3,000

Explanation:

Column (1) and (2) taken from page 13.

Column (3) is Column (2) x .904

Column (4) is $\frac{\text{Column (2)}}{183,000} \times .959 \times 51,400$.

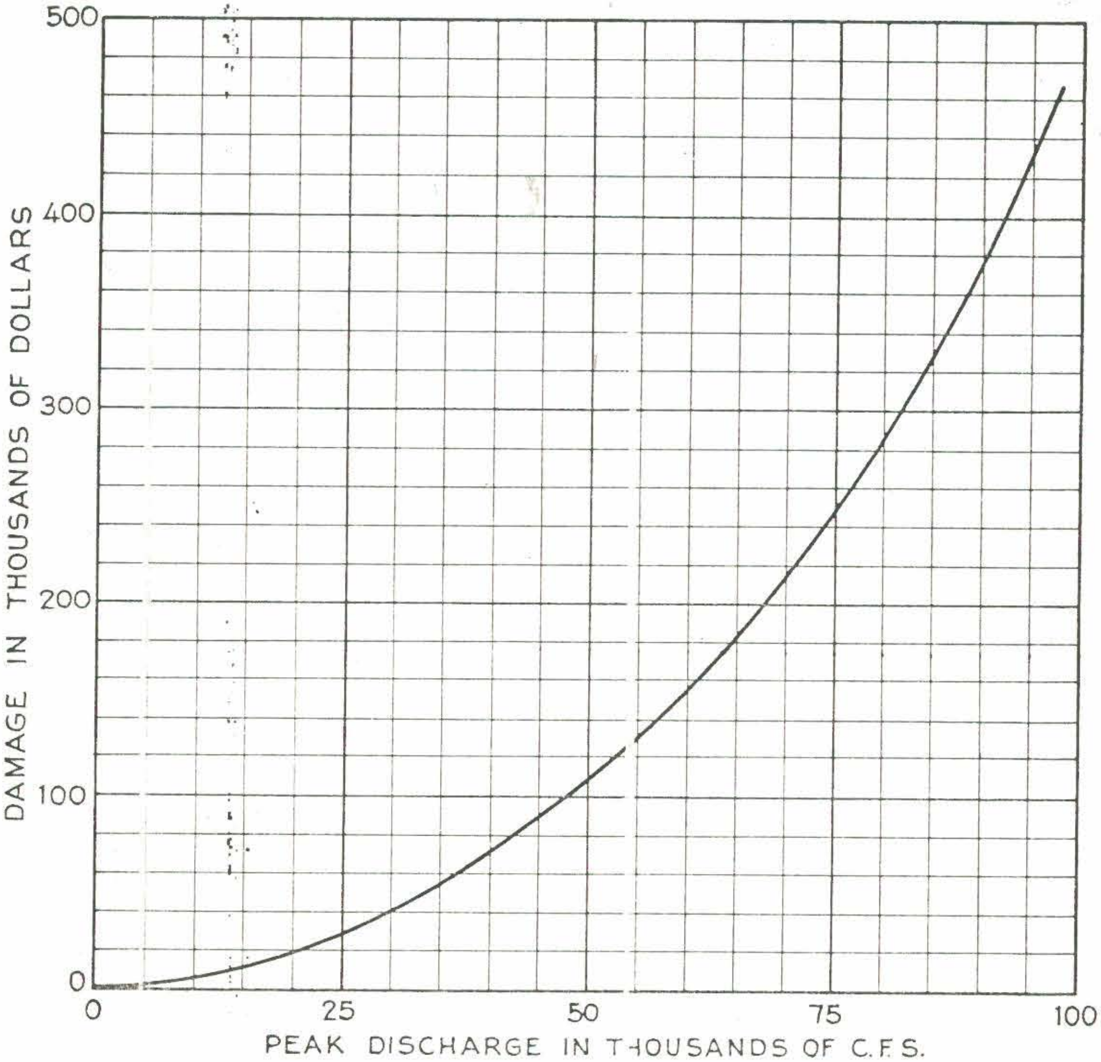
Column (5) is $\frac{\text{Column (2)}}{183,000} \times 31,700$

Column (6) is Columns (3) + (4) + (5).

Column (7) is Column (6) x .857

Column (8) is $\frac{\text{Columns (6)} + (7)}{2}$

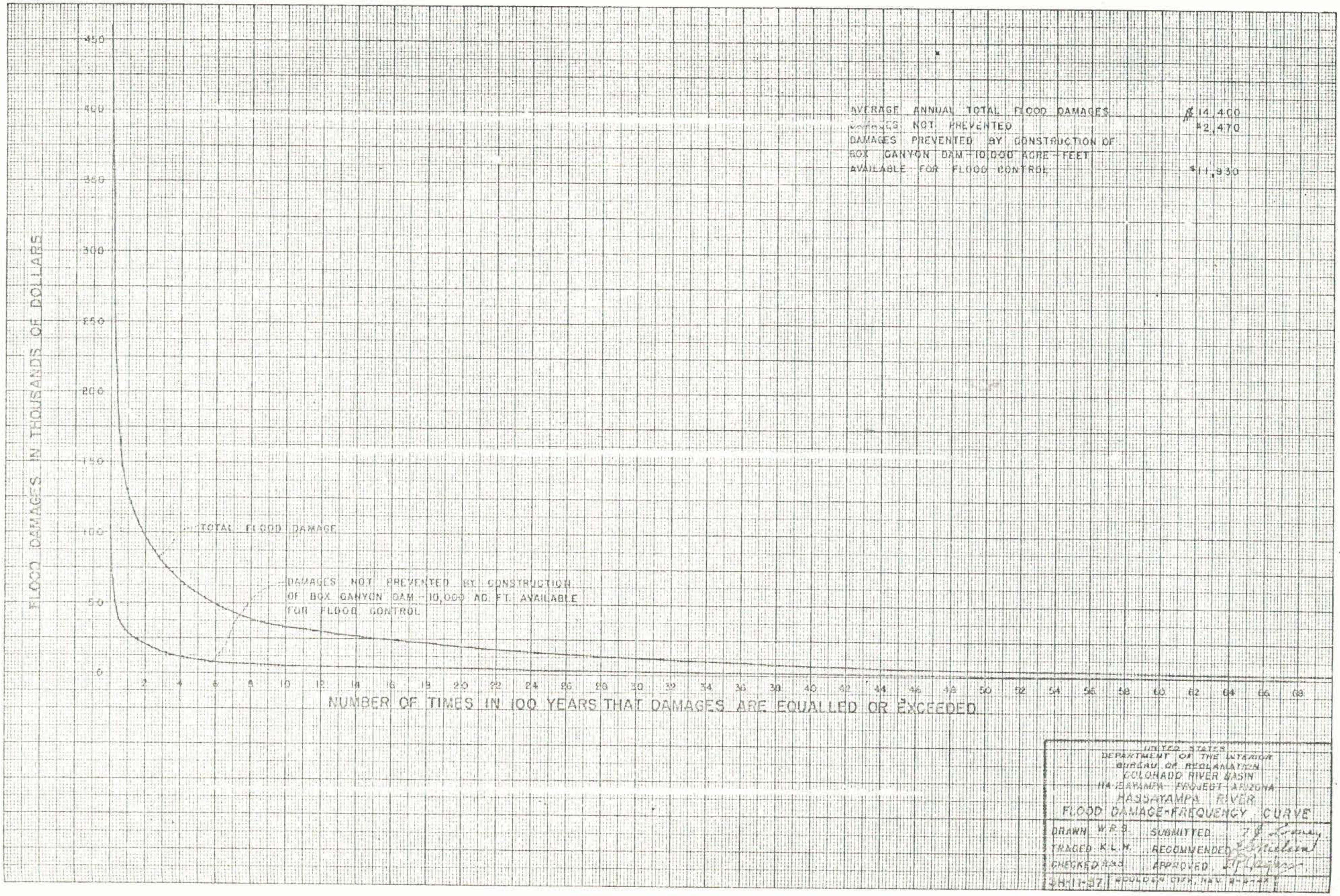
Column (9) is taken from drawing No. 3H-11-56.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER BASIN
HASSAYAMPA PROJECT-ARIZONA

HASSAYAMPA RIVER
FLOOD DAMAGE DISCHARGE CURVE

DRAWN...............	SUBMITTED ...... T. J. Looney
TRACED M.H.C.-R.H.A.	RECOMMENDED E. Nielsen
CHECKED R.G.S.	APPROVED ...... L. P. Vaughn
3H-11-56	BOULDER CITY, NEV. 1-31-47


AVERAGE ANNUAL TOTAL FLOOD DAMAGES $14,400
DAMAGES NOT PREVENTED $2,470
DAMAGES PREVENTED BY CONSTRUCTION OF BOX CANYON DAM - 10,000 ACRE - FEET AVAILABLE FOR FLOOD CONTROL $11,930
FLOOD DAMAGES IN THOUSANDS OF DOLLARS
0
50
100
150
200
250
300
350
400
450
TOTAL FLOOD DAMAGE
DAMAGES NOT PREVENTED BY CONSTRUCTION OF BOX CANYON DAM - 10,000 AC. FT. AVAILABLE FOR FLOOD CONTROL
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68
NUMBER OF TIMES IN 100 YEARS THAT DAMAGES ARE EQUALLED OR EXCEEDED
DEPARTMENT OF THE INTERIOR
COLORADO RIVER BASIN
HASSAYAMPA RIVER
FLOOD DAMAGE-FREQUENCY CURVE
DRAWN W.R.S.
SUBMITTED
TRACED K.L.H.
RECOMMENDED
CHECKED
APPROVED

by the area under the curve is $1,440,000. The average annual flood damage is $14,400.

Regulation and Benefits

Effect of Box Canyon Reservoir on floods. The operating graph, (Drawing No. 3H-11-52, page 97) is based on the assumption that 10,000 acre-feet of live storage capacity will be reserved at all times for flood control. Additional storage will be effective for flood control purposes as follows:

(a) 76,000 acre-feet of superstorage (uncontrolled) above the spillway crest, up to the high-water line (2462.6 feet) occurring with the maximum probable flood.

(b) Variable amounts of irrigation storage capacity which may be vacant.

With the reservoir operated as shown herein, the irrigation storage capacity would have controlled all floods except three of the floods recorded during the period 1916 through 1945. Spills would have occurred totaling 16,600 acre-feet in 1920, 34,900 acre-feet in 1922, and 54,300 acre-feet in 1927.

The large spill in 1927 occurred because the reservoir was approximately three-fourths full at the time of one of the largest floods of record. Even so, the available storage capacity reduced the flood inflow peak from 27,100 second-feet to a maximum outflow peak of 5,900 second-feet.

Operation studies of Box Canyon Reservoir show that, with the assumption of full irrigation storage at the start of the flood, when the spillway design flood is routed through the reservoir, the maximum outflow is 69,700 second-feet.

With the use of this maximum outflow of 69,700 second-feet from Box Canyon Reservoir resulting from a maximum probable inflow of 183,000 second-feet and the peak discharges associated with this same general flood that were estimated at the mouths of Martinez Creek and Sols Wash, the resulting peak discharges downstream from Box Canyon Reservoir were estimated and are tabulated as follows:

Below Dam site	69,700 second-feet
Below Sols Wash at Wickenburg	144,100 second-feet
At mouth of river	123,500 second-feet
Mean in flood damage area	134,500 second-feet

Residual flood damages. In Table 21 are shown the estimated peak rates of discharge for a controlled flood (Box Canyon Dam built) at the Box Canyon Dam site, below Sols Wash at Wickenburg, at the mouth of the river, and the mean discharge in the area subject to flood damage.

Table 21.- Probable flood damages in Hassayampa River basin
Box Canyon Dam built.

(1) Prob. No. Of Occur. In 100 yrs.	(2) Uncontrolled Peak at Box Canyon Dam Site (Sec.-Ft.)	(3) Controlled Peak at Box Canyon Dam Site (Sec.-Ft.)	(4) Controlled Peak From Dam (At Wickenburg (Sec.-Ft.)	(5) Outflow From Martinez Cr. (At Wickenburg) (Sec.-Ft.)	(6) Outflow From Sols Wash (At Wickenburg) (Sec.-Ft.)	(7) Peak Flow (At Wickenburg) (Sec.-Ft.)	(8) Peak Flow (Mouth of (River (Sec.-Ft.)	(9) Mean Flow In Damage Area (Sec.-Ft.)	(10) Damage Dollars
Max. Prob.	183,000	69,700	63,000	49,300	31,700	144,000	123,400	134,400	
.06	78,000	20,100	18,200	21,000	13,500	52,700	45,200	49,200	105,000
.11	70,000	17,000	15,400	18,100	12,100	45,600	39,100	42,600	82,000
.24	60,000	13,200	11,900	16,200	10,400	38,500	33,000	35,900	57,000
.57	50,000	9,700	8,800	13,500	8,700	31,000	26,600	28,900	37,000
1.49	40,000	6,500	5,900	10,800	6,900	23,600	20,200	22,000	24,000
4.17	30,000	3,700	3,300	8,100	5,200	16,600	14,200	15,500	11,000
12.50	20,000	1,300	1,200	5,400	3,500	10,100	8,700	9,400	5,000
38.31	10,000	0	0	2,700	1,700	4,400	3,800	4,100	2,000
68.49	5,000			1,300	900	2,200	1,900	2,100	None

Explanation:

Column (1) and (2) taken from page 150

Column (3) determined by reservoir routing study.

Column (4) is Column (3) x .904

Column (5) is $\frac{\text{Column (2)}}{183{,}000} \times .959 \times 51{,}400$

Column (6) is $\frac{\text{Column (2)}}{183{,}000} \times 31{,}700$

Column (7) is Columns (4) + (5) + (6).

Column (8) is Column (7) x .857

Column (9) is $\frac{\text{Columns (7)} + (8)}{2}$

Column (10) is taken from drawing No. 3H-11-56.

Application of the Discharge - Damage curve (see drawing No. 3H-11-56) shows that a 78,000 second-feet flood at the Box Canyon Dam site, controlled by Box Canyon Dam, which is equivalent to a mean discharge or 49,200 second-feet in the damage area, would result in damages of $105,000. The amounts of damages that occur with the specified floods were determined in this manner and tabulated on Table 21. Plotting the above-mentioned damage values as a Damage-Frequency curve, drawing No. 3H-11-57, shows total residual flood damages in 100 years, which is represented by the area under the curve, of $247,000. The average annual residual flood damage is $2,470.

Flood control benefits. The reduction in flood damage along the Hassayampa by operation of the Box Canyon Reservoir with a flood control storage of 10,000 acre-feet is estimated to be $11,930 annually, as follows:

Average annual damage with uncontrolled flow	$14,400
Residual average annual damage with controlled flow	2,470
Reduction	$11,930

No attempt has been made to evaluate the effect of the Box Canyon Reservoir on the Gila River floods. In view of the large volumes of the Gila floods and the relatively small amount contributed by the drainage basin above the Box Canyon Reservoir site, the effect is believed to be negligible.

Capitalizing $11,930 at 3.89 percent (50 years at 3 percent interest) indicates total flood control benefits of $307,000.

MUNICIPAL AND FARMSTEAD WATER SUPPLY

Present Development

Present development is limited to a few deep wells in Wittmann-the project area is uninhabited.

Anticipated Needs

Studies of probable farm programs indicate that there will probably be about 80 farm units on the project. Provision should be made to supply domestic water for about 400 people on project farms and an equal number in the project town, a total of 800 people. This should cover the population growth during the repayment period.

Water Requirements

The average demand is assumed to be 500 gallons per capita per day, or a total of 400,000 gallons per day, amounting to an annual demand of 146 million gallons or 450 acre-feet. The maximum demand is estimated at 400,000 gallons in 12 hours. While this rate of consumption is higher than normal, it is not considered excessive, in view of the fact that the town of Wickenburg pumped 242,612,400 gallons in 1940, or 637 gallons per capita per day for the 1,043 inhabitants, as listed in the 1940 Census. Local officials of Wickenburg attribute this excessive demand to the large number of tourist courts and the widespread use of evaporative coolers.

It is probable that some dairying will develop on the project, and the demand for watering of cattle, cleansing of barns, etc., will be high. In any event, water will have to be supplied to domestic animals, which are not an important factor in the Wickenburg supply. Water will also be used for operating evaporative coolers in the project town and on the farmsteads. Seasonal demands for domestic water vary widely because of the climate. The June, July, and August monthly demands in Wickenburg are more than four times that of January; therefore, the delivery of the estimated daily demand of 400,000 gallons in twelve hours will sometimes be necessary to cover peak loads. No detailed estimate of the distribution in water use between the town and farms was made. On the basis of available information it was assumed that each would use, on the average, about 50% of the water supplied for farmstead and municipal purposes.

Potential Development

It would be possible for each individual farmer to provide his own farmstead water supply by drilling a well about 600 feet to penetrate the artesian aquifers. In addition to the well, the owners would be required to purchase pumping equipment, provide necessary storage facilities, pay for pumping power and the necessary upkeep of the well and equipment. The initial cost of a complete installation at each farm is estimated at $5,000 based on the 1947 cost index. Few settlers would be able to make such an outlay for a farmstead supply. A domestic water supply system is, therefore, included in the original plan of construction for the project.

Six methods of providing this water supply were considered:

1. Separate wells for each farm, and for the project town.
2. Group wells to serve 4 farms each, separate well for town.
3. Single well at site of equalizing reservoir.
4. Single well on river opposite reservoir.
5. Single well on river near railroad bridge.
6. Delivery of water from project canal to equalizing reservoir.

The approximate construction cost and total annual cost for each different plan was computed under the same basic assumptions as to water requirement, pumping head, power cost and replacements cost. These studies showed that annual costs would be highest for Plans 1 and 2 and approximately equal for other four plans. Plan 3 contemplates tapping the underground storage belt, while Plans 4, 5, and 6 would draw water from the Hassayampa River channel.

A domestic water system must be assured a supply at all times, although minor shortages in the amount of water available are permissible. The Hassayampa River, due to its erratic flow, does not appear to be a dependable source of supply. Reservoir operation studies show that during the period of study Box Canyon reservoir would have been drawn down almost to dead storage level in 1934, and that it would have been at dead storage level for six months in 1945. During the latter period no water could have been released to the domestic water supply system, Furthermore, it is probable that the subsurface flow of the river would become negligible during the latter period. Therefore, the deep well of Plan 3 offers the most dependable source of water for a domestic supply.

Plan of Development

Water for both municipal and farmstead uses would be supplied from a single well located at the equalizing reservoir site in section 1, T. 5 N., R. 4 W. Water would be distributed to each farm through a pressure system. The slope of the land is such that pumping into the pipe lines would not be required, and the entire distribution system would deliver the water by gravity at not less than 30 pounds pressure per square inch. However, to supply the higher one-third of the project area with water at this pressure will necessitate an elevated storage tank 50 feet above ground surface at the reservoir. The distribution mains would be double-dipped and wrapped steel pipe ranging in size from 10 inches to 4 inches.

Preliminary plans and estimates for this system have been based on the following assumptions:

a. The equalizing reservoir will be a concrete tank, size 110 feet by 110 feet. It will be divided into two bays, each having a capacity of 400,000 gallons, to permit storage of a two-day supply. When one bay is being cleaned the other bay can be kept in operation and provide a one-day supply. Chlorination equipment will be provided at the reservoir but no other treatment is contemplated.

b. The well will have a depth of 600 feet, a pumping head of 400 feet, and a capacity of 560 gallons per minute, or 1.25 second-feet. At 65% efficiency, the pumping load would be about 65 kilowatts.

c. The distribution system will have sufficient capacity to deliver 400,000 gallons in 12 hours. Pipe sizes will range from 10 inches in diameter at the reservoir to four inches in diameter at the farm unit. The estimate does not include the cost of connecting the main with the various farm buildings, nor the cost of the town's distribution system.

Cost estimates are summarized as follows:

Well and pumping plant	$10,000
Reservoir	30,000
Chlorination equipment	2,000
Elevated tank	7,000
Distribution system	160,000
Total (Based on January 1940 prices)	$209,000
Total cost (Based on April 1947 prices)	$370,000

Plan of Repayment

Provision of a farmstead water supply for the irrigators is deemed essential to successful project development. In addition, domestic water will be needed for the project town and supporting population; provision of this water can be accomplished most economically by constructing the municipal and farmstead water supply system as one unit. It has been assumed that the project town and the irrigators would each use about 50 percent of the water, or 73 million gallons each; and that each would be required to repay 50 percent of the construction costs, or $185,000.

The portion of construction costs to be rapaid by the project farmers has been considered as coming within the scope of Reclamation law and repayable in 40 years without interest. On this basis, the annual construction cost to be repaid by the project would be about $4,600.

Construction costs chargeable to the project town would have to be repaid at interest, however, and a repayment period of 50 years at three percent is assumed. Therefore, the average annual payment required from the town would be $7,200.

Annual Costs

A reserve for repairs and replacements has been calculated on the basis of the expected life of the various features and assuming a rate of three percent interest during the repayment period. These calculated annuity factors indicate an annual cost for this program of $4,500.

Operation and maintenance of the system will probably require the equivalent of the services of two men from the irrigation district's organization. Salaries plus minor maintenance expenditures are estimated to total $6,000 annually.

Annual power requirements for pumping 450 acre-feet of water an average lift of 400 feet are estimated at 285,000 kilowatt hours (at 65 percent efficiency). Based on present and anticipated rates in the general area, the average cost of electric energy is estimated at $0.01 a kilowatt hour. Pumping charges would then average about $2,900 a year.

Estimated annual costs for the operation and maintenance of the municipal and farmstead water supply system are summarized as follows:

Reserve for repairs and replacement	$ 4,500
Operation and maintenance	6,000
Electric energy for pumping	2,900
Total annual cost	$13,400
Cost to project water users	$ 6,700 1/
Cost to project town	$ 6,700 1/

Annual cost to farmers. The net annual cost of the farmstead water supply would consist of the construction cost and operation and maintenance costs. In accordance with the plan of operation and repayment, however, these costs would be considered as part of irrigation costs, not as a separate item.

Annual cost to project town. The total annual cost of municipal water chargeable to the project town would be as follows:

Amortization of construction costs ($185,000 in 50 years at 3 percent interest)		$ 7,200
Operation and Maintenance	6,700	
Contingencies	700	
		7,400
		$14,600

Based on experiences and practices in this section of the country, the wholesale value of domestic water is placed at $0.20 per 1,000 gallons. On this basis, the value of the 73 million gallons supplied annually to the town would be $14,600.

1/ In addition, a reserve for contingencies is believed necessary; such a reserve is included in the final cost summaries.

APPENDIX G
AGRICULTURAL ECONOMY

PRESENT AGRICULTURAL DEVELOPMENT

Lands to be included in the potential project area are desert lands which have limited value for grazing. Owing to arid climatic conditions, dry-farming is not possible. North of the project area there are about 470 acres in small scattered tracts which are irrigated from the Hassayampa River. The several attemps which have been made to promote an irrigation project in the Hassayampa River basin have all failed; these have been discussed in Appendix A.

Under irrigation the lands are potentially some of the most productive in the Lower Colorado River basin. Their agricultural development will compare favorably with the Salt River Project, where under irrigation a wide variety of crops are grown. Economic and agricultural conditions prevailing in the Salt River Project can be accepted as being representative of what can be expected in the Hassayampa Project. Crop acreages and values in 1945 for the Salt River Project are shown in Table 22; the gross crop value per acre cropped amounted to $74.69. The value per acre cultivated, however, was $143.86, due to the fact that 92.6 percent of the area irrigated was double-cropped. During the period 1939 to 1944, the average gross crop value amounted to slightly over $112 an acre (See section on Crops).

Table 22.- Crop acreages and values, Salt River Project, 1945.

	Acreage	Crop Production	Unit Yield	Total 1/ Value	Value per Acre
				(Dollars)	(Dollars)
Cereals	64,082	2,704,366	Bu.	2,955,613	46.12
Seed	7,516	334,142	Bu.	988,533	131.52
Hay & Forage	291,159	436,280	Ton	10,364,071	35.60
Vegetables & truck	36,452	9,892,895	Bu.	12,143,713	334.14
Fruits & nuts	12,396	199,054,215	Lbs.	5,558,491	448.41
Cotton Lint	6,717	6,088	Bales	671,765	100.01
Cotton Seed	6,717	2,552	Ton	130,175	19.38
Misc.	176	-	-	64,800	368.18
Soil Improv.	14,994	-	-	-	-
Total	440,209			32,877,161	74.69
Less Dup. Area	211,676			-	-
Net Area	228,533			32,877,161	143.86
Less Fallowed	14,187			-	-
Total Irrigated	214,346				

Land Ownership and Excess Holdings.

Ownership of the Hassayampa Project area is vested in the hands of 17 owners, including the United States and the State of Arizona. Thirty-six percent of the project area is privately owned, 14 percent belongs to the State of Arizona, and the remaining 50 percent belongs to the United States. (See Table 23).

A correlation of ownership holdings with land classification data shows that seven owners, excluding the United States and the State of Arizona, own irrigable land in excess of 160 acres. The total excess holdings amount to 1098.36 acres or 14.6 percent of the project area.

1/ Does not include payments received from Federal and commerical payments.

Source: Crop report, Salt River Project, 1945.

Table 23.- Land ownership and excess holdings,
Hassayampa Project, Arizona.

Owner	Classification of Ownership (7,500.52 Acres)				Irrigable Lands	Excess Holdings 1/
	Vacant	Reclamation	State	Private		
			(In Acres)			
United States	320.00	3,423.32			3,686.78	
State of Arizona			1,040.00		1,040.00	
Ora Collier				238.20	238.20	78.20
Theodore W. Stemmler				243.00	243.00	83.00
Langmade and Langmade				79.34	79.34	
R. G. Langmade				140.00	140.00	
Stephen W. Langmade				379.04	379.04	219.04
Louise Langmade				40.00	40.00	
William Langmade				40.00	40.00	
Robt. H. Langmade				40.00	40.00	
W. S. Griffin				239.12	239.12	79.12
Guy C. Griffin				240.00	240.00	80.00
Alvin Griffin				240.00	240.00	80.00
Ada Griffin				39.50	39.50	
W. F. Ebert				40.00	40.00	
Stephen B. Rayburn				639.00	639.00	479.00
George Evans				80.00	80.00	
Total acres	320.00	3,423.32	1,040.00	2,717.20	7,443.98 2/	1,098.36

1/ Excess holdings are the holdings of irrigable land in excess of 160 acres.

2/ The difference between the project area and class 1 and 2 lands amounting to 56.54 acres is classified as nonarable land.

Source: Ownership data obtained from Maricopa County Records. Data current as of January 1947.

ANTICIPATED AGRICULTURAL DEVELOPMENT

Type of Development

The project area is well-adapted to irrigation agriculture; the lands consist of a gently-sloping alluvial fan which is exceptionally smooth-surfaced and uniform. Land development costs, therefore, should not be excessive. According to Bureau of Reclamation standards, approximately 98 percent of the arable lands have been classified as Class 1, and about two percent as Class 2.

Climatic conditions are exceptionally favorable for development of an irrigation project. The average mean temperature at Wittmann is 69°F., the frost-free period is 285 days, and the average annual precipitation is 9.85 inches. A small experimental test plot at Wittmann - irrigated from a deep well - has demonstrated that the crops now grown in the Salt River Valley can be grown in the project area. Because of the exceptionally good lands and the favorable climate, the crop yields in the project area are expected to equal or even exceed those obtained in the Salt River Valley.

Crops

The Hassayampa Project is only 36 miles from the Salt River Project, and the climatic and soil conditions in the two areas are similar; therefore, it has been assumed that the highly successful agrucu.ture of the Salt River Project would be an excellent indicator of the agricultural potentialities in the Hassayampa Project area.

The average annual crop distribution was determined for the Salt River Project based on crop reports for the base period 1939 to 1944, inclusive; yields obtained and prices received by Salt River Project farmers were also determined for the base period. (See Table 24). These values were then used in calculating the anticipated land utilization of the Hassayampa Project area and in determining the expected gross crop income per acre.

In general it was assumed that the proportion of the various crops anticipated for the project would approximate Salt River Project conditions; the principal exceptions being cotton and alfalfa. The cotton acreage has been declining steadily on the Salt River Project and fell from 50,332 acres in 1940 to 6,700 acres in 1945; during the period 1939-44 the acreage amounted to 40,275 acres annually. The future of the cotton industry in the southwest is so uncertain that any predictions with respect to cotton would be extremely hazardous. Therefore, the estimated cotton acreage on the Hassayampa Project has been placed at a conservative figure of 10 percent. Alfalfa on the other hand seems assured of a market in the Los Angeles milkshed, which accounts for an estimate of about one-third of the acreage in alfalfa as compared to about 20 percent of the irrigated acreage in the Salt River Project.

Table 24.- Average crop distribution and weighted gross crop value per acre, Salt River Project, for the period 1939 to 1944 inclusive.

Crop	Acreage Cropped (acres)	Distribution (Percent) 1/	Yield Per Acre: Amount	Yield Per Acre: Unit	Price Per Unit (Dollars)	Weighted gross value per irrigated acre (Dollars)
Barley	20,579	9.1	21.0	Cwt	1.69	3.23
Grain Sorghums	20,124	8.9	25.2	"	1.50	3.36
Oats	2,656	1.2	17.7	"	2.00	0.42
Wheat	13,496	5.9	14.5	"	1.72	1.47
Alfalfa	46,240	20.4	4.6	Ton	3/ 16.00	15.01
Alfalfa Seed	3,278	1.4	179	Lbs	0.255	0.56
Alfalfa grain	32,398	14.3	1.7	Ton	11.63	2.83
Alfalfa (after grain)	32,398	14.3	3.2	"	3/ 16.00	7.32
Pasture - Bermuda, etc	19,858	8.8	Acre		11.27	0.99
Pasture grain - alfalfa	115,368	50.8	Acre		11.88	6.04
Corn fodder	1,073	0.5	11.9	Ton	3.58	0.21
Sudan	2,336	1.0	2.6	"	6.62	0.17
Truck & Vegetables	36,280	16.0	Acre		256.47	41.04
Fruit	13,273	5.8	"		183.81	10.66
Cotton (lint)	40,275	17.7	.846	Bales	90.43	13.54
Cotton (seed)	40,275	17.7	.43	Ton	35.20	2.68
Misc. 2/	4,581	2.0	Acre		144.23	2.88
Idle & fallow	11,073	4.9				
Total acreage cropped	455,561					112.41
Total acreage irrigated	226,942					

1/ Cropped acreage in percent of 226,942 acres.
2/ Includes all seed crops except alfalfa seed and all misc. crops except cotton lint and cotton seed.
3/ Baled hay. Price reported by BAE during period 1939-44, plus a baling charge of $3.50 per ton.

Source: Bureau of Reclamation Crop Reports, Salt River Project, Arizona.

Table 25.- Anticipated crop distribution, yields and values, Hassayampa Project, Arizona.

Crop	Acreage Cropped	Distribution[1/] (Percent)	Yield Per Acre: Amount	Yield Per Acre: Unit	Price Per Unit	Weighted gross value per irrigated acre
	(Acres)				(Dollars)	(Dollars)
Barley	910	13.0	21.0	Cwt.	1.69	4.61
Grain Sorghums	840	12.0	25.2	"	1.50	4.54
Wheat	350	5.0	14.5	"	1.72	1.25
Alfalfa	2,310	33.0	4.6	Ton	2/ 16.00	24.29
Alfalfa seed	140	2.0	179	Lbs.	0.225	.81
Alfalfa grain	1,400	20.0	1.7	Ton	11.63	3.95
Alfalfa (after grain)	1,400	20.0	3.2	Ton	2/ 16.00	10.24
Pasture - Bermuda, etc.	560	8.0	Acre		11.27	.90
Pasture grain - alfalfa	3/ 2,660	38.0	"		11.88	4.51
Corn fodder	210	3.0	11.9	Ton	3.58	1.28
Truck & vegetables	1,050	15.0	Acre	Acre	256.47	38.47
Fruit	350	5.0	"	"	183.81	9.19
Cotton (lint)	700	10.0	.846	Bale	90.43	7.65
Cotton (seed)	700	10.0	.43	Ton	35.20	1.51
Miscellaneous	140	2.0	Acre		144.23	2.88
Idle & fallow	280	4.0				
Total acreage cropped	14,000	200.0				116.08
Total acreage irrigated 4/	7,000					

1/ Cropped acreage in percent of 7,000 acres.
2/ Baled hay. Price reported by BAE during period 1939-1944, plus a baling charge of \$3.50 per ton.
3/ On the basis of studies conducted for the Central Arizona Project Investigations, it was found that approximately one-half of the alfalfa and two-thirds of the grains, exclusive of grain sorghums, are pastured annually; these percentages were used in estimating the acreage for the Hassayampa project.
4/ Gross project area amounts to 7,500 acres.

Source: Salt River Project crop reports for the years 1939 to 1944 inclusive provided the basic data for projecting the anticipated use, etc., of the Hassayampa Project.

An average gross crop income of about $116 per acre can be expected, which for a net irrigated area of 7,000 acres amounts to a total of $812,000 annually. (See Table 25).

Livestock

It is expected that the production of livestock and livestock products will be relatively as important in the Hassayampa area, as it is to the Salt River Project. Cash receipts from marketings of livestock and livestock products are not available for the Salt River Project, but an inventory of numbers and values of livestock is available. This inventory gives an indication of the importance of the livestock industry.

During the period 1939-1944 the average annual inventory value of all livestock amounted to $5,534,198, (See Table 26). Dairy and beef cattle accounted for nearly 80 percent of the total value. Since the irrigated acreage averaged 226,9?2 acres, the inventory value of livestock amounted to $24.39 an acre. Assuming that a similar situation will develop in the Hassayampa area, a livestock inventory value of about $170,000 may be expected with 7,000 acres irrigated.

The intense summer heat will probably prevent the area from developing into an intensive dairy region, although some dairying will no doubt develop in order to supply the immediate needs of the area. There will be some finish-feeding of cattle for market, and some of the irrigated hay land will probably be used for a part of the year as pasture.

Although the production of livestock and livestock products will probably not play a dominant part in the project economy, it will nevertheless be important, and for some farms it may become a major enterprise.

Transportation and Markets

The area is well situated with respect to transportation facilities. A branch line of the Atchison, Topeka & Santa Fe Railroad passes through Wittmann about four miles northeast of the project area. The Santa Fe Railroad and paved highways afford direct connections to Phoenix, 36 miles southeast of the area; Los Angeles, 350 miles west; and Ashfork, 155 miles north. The branch line going into Ashfork connects with the main east-west line of the AT&SF Railroad. At Phoenix, rail connections can be made with the Southern Pacific Railroad to the west coast and eastern markets.

Agricultural products, including livestock and livestock products, will be forced into competition with products originating from the Salt River Valley. With the steadily increasing population in the southern California coastal region, the resultant increase in demand for dairy products, alfalfa and feed crops grown in the Hassayampa area should find a ready market in the southern California Coastal area. Speciality crops will probably move to both western coast and eastern markets.

Table 26.- Livestock inventory, Salt River Project, Arizona. 1939-1944, inclusive. 1/

	1939	1940	1941	1942	1943	1944	Total	6-year Average	Percent
Horses & Mules									
Number	4,996	4,277	4,071	3,938	4,278	3,964	25,524	4,254	
Value	349,720	299,390	293,112	326,854	346,518	325,048	1,940,642	323,440	5.8
Beef									
Number	18,492	15,039	15,615	18,602	33,881	20,566	122,195	20,366	
Value	1,294,440	1,097,847	1,374,120	1,971,812	3,978,668	2,318,807	12,035,694	2,005,949	36.2
Dairy Cattle									
Number	23,096	22,469	19,800	26,170	26,070	27,294	144,899	24,150	
Value	1,431,952	1,460,485	1,683,000	2,512,320	3,258,750	3,705,979	14,052,486	2,342,081	42.3
Sheep (range feeders)									
Number	25,312	14,004	12,287	22,408	25,108	31,087	130,206	21,701	
Value	116,435	63,718	66,964	141,170	175,756	258,022	822,065	137,011	2.5
Hogs									
Number	12,228	13,781	10,650	11,431	15,436	10,154	73,680	12,280	
Value	113,109	128,163	166,140	240,051	306,907	177,695	1,132,065	188,677	3.4
Turkeys									
Number	7,523	11,936	11,186	10,422	11,358	7,123	59,557	9,926	
Value	18,808	26,856	27,965	31,266	74,963	43,806	223,664	37,277	0.7
Fowl									
Number	287,087	287,282	286,475	260,461	288,217	219,998	1,629,520	271,587	
Value	200,961	172,369	214,856	255,252	345,860	263,998	1,453,296	242,216	4.4
Bees (hives)									
Number	5,150	7,419	5,382	4,582	4,647	5,174	32,354	5,392	
Value	14,163	20,402	16,146	18,328	27,882	31,044	127,965	21,328	0.4
Other Stock									
Value	144,472	192,371	198,975	286,524	324,717	270,252	1,417,311	236,219	4.3
Total Stock value	3,684,060	3,461,601	4,041,278	5,783,577	8,840,021	7,394,651	33,205,188	5,534,198	100.0
Total irrigated acreage (av. during period 1939-44)								226,942	
Livestock inventory per irrigated acre (Dollars)								24.39	

1/ Inventory as of December 31.

The Phoenix metropolitan area, Wickenburg, Buckeye, Morristown, and other small settlements within the immediate area are potential local markets, particularly for dairy and poultry products.

Land Values and Taxes

In the bulletin "Arizona Agriculture, 1945" prepared by George W. Barr of the University of Arizona, it is reported that during the last six months of 1944 cotton-alfalfa land, without buildings, in the Chandler area of the Salt River Valley sold for about $250 an acre. Alfalfa-vegetable land in the Glendale area sold at $275 to $300 an acre. Information compiled by the Bureau of Agricultural Economics of noncitrus land transfers in the Salt River Project during the third quarter of 1944, shows an average sale price of $318 an acre as compared with $305 in the third quarter of 1942; the sale prices included buildings and improvements.

From charted information in the previously cited bulletin, the sale price of cotton-alfalfa land in the Salt River Project for various years was as follows:

Year	Price per Acre
1930	$ 225
1932	125
1934	110
1936	155
1938	160
1940	165
1942	197
1944	275

Dr. Barr points out in his bulletin that the price of land in the Salt River Project in any given year is determined by the price of crops in the preceding year. Since it has been assumed that agricultural developments in the Hassayampa area will be similar to the Salt River Valley Project, the land values will likewise be similar. It is estimated that the normal or long time value of land will average $175 per acre, and that for any given year the value of land will continue to follow the trend of prices of crops grown.

Irrigated real estate, including improvements, is assessed at about 30 percent of full and true value. The assessed valuation of land in Maricopa County from 1939 through 1944 has averaged about $55 per acre and $15 per acre for improvements. Average tax rates in Maricopa and Pinal Counties per $100 of assessed valuation have been calculated as follows:

Year	Tax Rate Per $100 Maricopa County	Pinal County
1939	$ 5.34	$ 3.54
1940	4.12	2.93
1941	3.50	2.69
1942	2.63	1.90
1943	2.84	1.74
1944	2.79	1.07
1945	4.02	1.86

For the Hassayampa area the average tax rate will probably fall somewhere between the rates given for the two counties. In Maricopa County the rates are heavily influenced by non-farm improvements whereas in Pinal County they are not so heavily influenced. Therefore, a rate of $3.50 per $100 assessed valuation - or about $ 2.50 per acre for land and buildings - seems reasonable. For other property, a rate of $0.75 per $100 of inventory value (one-half of original cost) has been estimated.

Farm Improvements Required

Establishment of irrigation farming in this area will require complete development, including: clearing and leveling the land, construction of farm laterals and ditches, and the construction of houses, barns, fences and other improvements. Clearing and leveling over most of the area can be accomplished in one operation as the lands are relatively smooth and are covered primarily with creosote bush and white sage. While there is some mesquite, clearing will not be difficult.

Because the drilling of wells to provide domestic water would be beyond the financial means of most prospective settlers, a domestic water supply system has been planned as an integral part of the project plan and the cost is included in the total project construction cost.

Repayment Ability

General. The expected repayment ability of farmers on the project was estimated on the basis of farm budgets. A series of 12 budgets was prepared for farms ranging in size from 40 to 320 acres. The cropping systems included alfalfa only, cotton only, and several combinations of crops.

While it is estimated that between 5 and 10 percent of the project area will be used for the production of fruits and vegetables, budgets were not prepared for these types of farm because it was believed they would give a distorted impression of probable returns and repayment ability. Management is usually the deciding factor between profit and loss, wide fluctuations in prices received and costs of production cause decided variations in returns from year to year, and unforeseen adverse contingencies appear to be impossible of reasonably accurate measurement. Although high returns are often obtained, losses are not uncommon. For a few years these types of farm may be able to pay high water costs but the attendant hazards make it appear doubtful if this amount would be large over a long period of time.

Bases of estimates. The Hassayampa Project area is located only 36 miles from the Salt River Project and has similar growing conditions. It was assumed, therefore, that crops produced and farming practices in the project area would follow closely those of the Salt River Project. It was also assumed that prices received by farmers of the project for their agricultural products would be similar to those of the Salt River Project.

The rate of $5.00 per day for common labor was used in the preparation of the farm budgets. The farm operator was compensated at this wage rate for the number of days he worked on the farm. Since this amount was obviously not sufficient to compensate him for his efforts as both laborer and entrepreneur, the farmer was also allowed a compensation for his management effort at the rate of 10 percent of the gross receipts from the farm.

No fixed sum was deducted from farm earnings for family living. It was assumed, however, that $1,600 a year would be required for this purpose of which $1,200 in cash would be needed. The cash would be made available from two sources: (1) wages for the time he worked, plus (2) compensation for management. The remainder of the $1,600 would be available from (3) $100 for farm privileges such as a garden, and (4) rent on the farm dwelling at its actual cost to the farm. 1/ If the sum of the two items, wages and management, did not total $1,200 or if the four items did not total $1,600 the difference was allowed as "balance for family living."

The value of land in the farm was computed as the sum of the value of raw land in its present state, estimated at $5.00 per acre, and the cost of clearing, leveling, and installation of farm irrigation facilities estimated at $75.00 per acre.

The amount of interest paid was computed as 3 percent of the investment to "earmark a fund sufficient to cover interest costs of the farmers during the repayment period." This amount was handled as a cash expense.

Agricultural commodity prices used in preparing the farm budgets were based on farm product prices received by Salt River Project farmers at the price level that existed during the years from 1939 to 1944 inclusive. It is anticipated that this price level will

1/ Rent on the farm dwelling is composed of the following items: interest, depreciation, taxes, and repairs based on the rates given in Table 27.

approximate the average for the repayment period. An exception was made in the case of alfalfa hay because of doubt as to whether baling costs were included in Salt River Project prices. The price used for baled alfalfa hay was computed as the 1939-44 average price received by Arizona farmers for loose alfalfa hay, as reported by the Bureau of Agricultural Economics, plus an estimated cost of baling. Prices used in the farm budgets are shown in Table 27.

Table 27 - Prices of Agricultural Products received by farmers, 6-year average, 1939-44 inclusive. 1/

Item	Unit	Price Per Unit
		(Dollars)
Alfalfa	Ton	2/ 16.00 (baled)
Alfalfa seed	Lb.	0.225
Barley	Cwt.	1.69
Cotton Lint	Lb.	0.18
Cotton seed	Lb.	0.0176
Pasture (grain & alfalfa)	Acre	11.88

1/ Based on average prices received by Salt River Project farmers during the period 1939-1944, inclusive (except for alfalfa).

2/ Average price of loose alfalfa hay as reported by the Bureau of Agricultural Economics for the period 1939-1944, inclusive, plus an estimated baling charge of $3.50 per ton.

Yields per acre were based on average yields of various crops in the Salt River Project for the 6-year period from 1939 to 1944 inclusive. Average yields used in the farm budgets are shown in Table 25. Unit rates and miscellaneous items used in the calculations are shown in Table 28.

Table 28. - Unit rates and miscellaneous items used in farm budgets.

Item	Unit	Cost Per Unit
Hired labor	Hour	$ 0.50
Picking cotton	Cwt. of raw cotton	1.50
Baling hay, pick-up baler	Ton	3.50
Ginning cotton	Cwt. of lint	0.65
Fuel, oil and repairs on power equipment:		
Wheel tractor, 10-15 IHP	Hour operated	0.30
Auto	Annual cost, farm share	100.00
Repairs other equipment:		
General farm machinery (excl. of auto)	$100 of original cost	2.50
Farm buildings	" " "	1.00
Depreciation rates:		
Tractor and trucks	" " "	10.00
General farm equipment	" " "	7.00
Farm buildings	" " "	2.50
Farm auto	Farm share	75.00
Taxes:		
Farm land and buildings	Acre	2.50
Other property 1/	$100 of inventory value	0.75
General misc. expenses (excl. of deprec.)	$100 of other expenses	5.00
Threshing	Acre	3.50
Hauling:		
Barley	Acre	1.65
Cotton	"	1.50
Other crop expenses:		
Cotton - baling, storing and insect treatment	Acre	3.00
Barley and alfalfa seed - sacks and twine	Cwt.	0.125
Cleaning alfalfa seed	Cwt.	2.00
Insurance:		
Car	Farm share	12.50
Buildings, machinery and tractor 1/	$100 of inventory value	1.50
Labor (hired)	Per $100 of cost	2.26
Seeding rates:	Pounds per acre:	Cost per Acre
Alfalfa	20	4.50
Barley	96	1.60
Cotton	50	1.00

1/ Inventory value is one-half of the original investment.

<u>Analysis of farm budgets.</u> The budgets indicated that the size of a farm had a pronounced effect upon its earnings. Relative earnings are illustrated by alfalfa farms of various sizes in the following tabulation:

Illustrative sizes of farms in acres	Net farm income in dollars per acre cropped
40	$ 15.57
80	25.65
100	28.44
160	31.34
320	33.36

The net farm income per acre cropped varied directly with the size of farm from $15.57 for the 40-acre farm to $33.36 for the 320-acre farm. Because of this wide variation of over 100 percent, the different size groups were studied individually.

Although the farm budgets indicate that one-crop alfalfa farms produce greater returns than other extensive crops or crop combinations, it is not expected that production in the project area will be confined to a one-crop type of farming. Budgets illustrating several cropping systems, for staple crops, therefore, were included for each of the size groups except the 40-acre and 320-acre groups.

The per acre return to water, land, and invested capital for each cropping system together with the average for each size group is shown in Table 29.

Table 29.-Average return per acre to Water, Land, and Invested Capital by Size of Farm Groups.

Type of Farm	40 Acre	80 Acre	100 Acre	160 Acre	320 Acre
		(Dollars)			
Alfalfa	- 5.95	18.57	21.31	24.22	26.23
Alfalfa - cotton	-	14.92	19.04	20.55	-
Alfalfa - cotton, small grains	-	9.93	-	17.92	-
Cotton	-	11.95	14.17	-	-
Average	-	13.84	17.84	20.90	-

The 40-acre alfalfa farm failed by $5.95 per acre to produce a net return for water, land, and invested capital. See Table 30. As alfalfa is more profitable than the other types studied, it was concluded that 40-acre farms in this area are too small for successful production of extensive crops. But as the area is similar to the Salt River Project where vegetables and fruits are grown to a large extent, often on small farms, 40-acre or smaller farms of this type may be expected to be established before the project has been in operation many years.

Table 30.-Returns and labor requirements by Size and Type of Farm.

Budget No.	Size and Type of Farm	Return to water, land, & capital: Total	Return to water, land, & capital: Per Acre Cropped	Labor Requirements: Total	Labor Requirements: Operator	Labor Requirements: Hired
		(Dollars)		1/ (Man Days)		
1	40 acres - alfalfa	-220	-5.95	81	81	0
2	80 " "	1,393	18.57	165	165	0
3	100 " "	2,025	21.31	209	206	3
4	160 " "	3,681	24.22	334	281	53
5	320 " "	8,000	26.23	671	312	359
6	80 acres cotton	896	11.95	660	187	473
7	80 " cotton, alfalfa	1,119	14.92	396	196	200
8	80 acres cotton, alfalfa, barley	745	9.93	315	186	129
9	100 acres cotton	1,343	14.17	836	202	634
10	100 acres cotton, alfalfa	1,714	18.04	503	221	282
11	160 acres cotton, alfalfa	3,123	20.55	843	275	568
12	160 acres alfalfa, alfalfa seed, cotton, barley	2,724	17.92	622	257	365

1/ One-man day equivalent to 10 hours.

Budgets for the 80-acre farms show an expected average return to water, land, and invested capital of $13.84 per acre, which is a reasonably large return. (See Table 29.) A farmer can operate an 80-acre alfalfa farm without hiring outside labor but he will work only about six months out of the year and earn at prevailing wage rates only $825 for his labor. Judged on the basis of the farmer operating the farm without hired assistance, this is a true family farm with sufficient return to make a substantial payment for water. It has the disadvantage of keeping the farmer employed only about half time.

The 100-acre farms average $17.84 per acre return to water, land, and invested capital or $3.00 per acre more than the 80-acre farms. (See Table 29). The 100-acre alfalfa farm required 209 man-days of labor of which the farmer could do 206 himself. (See Table 30). A farmer with little difficulty could operate this farm without hiring any labor. For his 8 months of labor the farmer would earn over $1,000. The 100-acre alfalfa farm is a family-sized farm which permits the farmer to earn a comfortable living by working about two-thirds of the time and allows a somewhat higher payment for water than the 80-acre farm.

The 160-acre farms give an average return to water, land, and invested capital of $20.90 per acre; slightly over $3.00 more than the 100-acre farms. On the 160-acre alfalfa farm, the farmer would perform 201 days of labor but would have to hire two man-months of outside labor. For almost 11 months of work on his farm, the farmer would earn over $1,400 in wages. Unless a farmer has children of working age to assist in the farm work, this farm somewhat exceeds a family size. It permits a larger payment for water and furnishes practically full employment for the farmer.

The 320-acre alfalfa farm showed a return to water, land, and invested capital of $26.23 per acre, which is $2.00 per acre more than the 160-acre alfalfa farm. While the 320-acre farm permits the farmer to earn over $1,500 annually for his labor on the farm, it would require of him twelve 26-day months of labor which is generally more than a farmer can perform. Furthermore, it requires the hiring of over one man-year of outside labor. Because the labor requirements so greatly exceed the amount of work that could be performed by the farmer it can hardly be considered a family-sized farm, although its return is somewhat greater than the 160-acre farm.

Labor requirements for cotton and combinations of cotton and other crops are higher than those for alfalfa alone. A family-sized farm of these types, based on the amount of farm work that could be performed by the operator, at least until harvest, would be smaller than an alfalfa farm.

Repayment of construction charges. In the interest of furnishing farm homes for the greatest number of prospective farmers, while still maintaining a reasonable repayment ability per acre of farm land, it is recommended that a decided effort be made to encourage farms of 80 to 100 acres in size. While it is believed that farms of these sizes should predominate, it is recognized that a few larger farms and even some intensive smaller farms also will be established, although they should be much less numerous than the medium-sized ones recommended. In the computation of average return to water, land, and invested capital these factors were taken into consideration. Accordingly, the 80- and 100-acre farms were given predominant weight. A few 160-acre farms were included to compensate for the somewhat greater returns that might result on larger farms and on small intensive farms. The following ratio was therefore used between 80-, 100-, and 160-acre farms respectively, 2 : 2 : 1. Table 31 indicates the method of computation of the average return per acre for the project area.

Table 31.-Average return per acre to water, land, and invested capital from extensive farming.

Farm Size	Weight	Return per Acre	Product
		(Dollars)	
80 Acres	2	13.84	27.68
100 Acres	2	17.84	35.68
160 Acres	1	20.90	20.90
Total	5	-	84.26
Weighted Average	-	16.85	-

Average return per acre to water, land, and capital	$ 16.85
Less: Contingencies (safety factor), and return to land and capital	1.35
Return to water	15.50
Less Operation and Maintenance	5.00
Repayment ability - available for repayment of construction	$ 10.50

The return to water, land, and invested capital represents the amount that would remain after all cash expenses of the farm have been paid and an adequate amount has been provided for the family living. This amount of return will be available for payment for water, both operation and maintenance costs and construction charges, for the payment for land and necessary improvements, and for expenses caused by unforeseen contingencies. Provision for maintaining a healthy financial status of the farm requires that some funds be available for these purposes.

The average return to water, land, and invested capital for the project is estimated as $16.85 per acre. (See Table 31). If an amount of $1.35 per acre is earmarked for contingencies and return to land and invested capital, a residual of $15.50 per acre will remain as the amount available for payment of water. After the estimated $5.00 per acre is paid for annual operation and maintenance costs, $10.50 per acre, or approximately $2.21 per acre-foot, would be available annually for repayment of construction charges. On this basis the annual payment for the 7,000 acres of the project would be $73,500 a year or $2,940,000 over a period of 40 years.

Settlement Opportunities

The entire project area is available for establishing new farm units. The studies on repayment ability have shown that farms of 80 and 100 acres would be typical family-size farms, which would provide a reasonable level of income for the farm family and also make a substantial contribution toward repaying irrigation construction costs and these sizes have been recommended. It is realized, however, that all farms on the project will not conform to this recommendation. In estimating the number of new farm homes the project would provide, it was assumed that 80- and 100-acre farms would constitute about two-thirds of the total and that the remaining third would be composed of some larger and a few smaller farms. It is estimated that 80 new farms can be provided; the distribution being about as follows:

Average Acreage Per Farm	Farms Number	Farms Percent
20	7	9
40	9	11
80	25	31
100	26	33
160	11	14
320	2	2
	80	100

As indicated in the tabulation 78 percent of the farms would be 80-, 100-, and 160-acre farms with 64 percent of the 80- and 100-acre sizes. The small farms would comprise 20 percent of the total.

Farm Budgets

Included in the following pages are the 12 farm budgets used in the study of repayment ability. In preparing these budgets yields were based on Table 25, prices were taken from Table 27, and unit rates and miscellaneous items were based on Table 28 as previously discussed.

Budget No. 1. - A 40-acre alfalfa farm at mature development.
Hassayampa Project, Arizona.

Crops	Land Acres	Man Work Days	Production Unit	Production Yield per acre	Production Total	Products Sold Amount	Products Sold Price	Products Sold Value (Dollars)
Alfalfa	30	66	Ton	4.6	138	138	16.00	2208
(Alfalfa pasture)	(18)		Acre		18	18	11.88	214
Alfalfa (new)	7	15	Ton	2.0	14	14	16.00	224
Farmstead	3							
Total	40	81						2646

Investment		Days Work		Summary	
Land	$3200	Total	81	Net farm income	$576
Buildings	5000	Operator	81	Less:	
Tractor	1000	Hired	0	Management	265
Machinery & equipment	1000	Contract	0	Return to water, land & capital	311
Auto 1/	500			Less balance for family living	531
	$10700			Loss	-220
				Same per acre	- 5.95

Family living

Labor	$405
Management	264
Subtotal	$669
Rent	355
Farm privileges	100
	$1124
Balance required to provide $1200 cash	531
Available for family living	$1655

1/ Farm share.

Current Farm Expenses	
Seed	$ 32
Labor	
Operator	405
Contract machine	532
Tractor expenses	65
Auto " 1/	100
Electricity 1/	10
Repairs:	
Buildings	50
Machinery	25
Taxes	109
Interest	321
Insurance	65
Miscellaneous expenses	86
Depreciations:	
Buildings	125
Machinery	70
Tractor	100
Auto 1/	75
Total farm expenses	$2170
Receipts	
Crops	2646
Farm privileges	100
Gross farm income	$2746
Less farm expenses	2170
Net farm income	$ 576

Budget No. 2. - An 80-acre alfalfa farm at mature development.
Hassayampa Project, Arizona.

Crops	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price (Dollars)	Products Sold: Value (Dollars)
Alfalfa	60	132	Ton	4.6	276	276	16.00	4416
(Alfalfa pasture)	(35)		Acre		35	35	11.88	416
Alfalfa (new)	15	33	Ton	2.0	30	30	16.00	480
Farmstead	5							
Total	80	165						5312

Current Farm Expenses	
Seed	$ 67
Labor:	
Operator	825
Contract machine	1071
Tractor expense	131
Auto " 1/	100
Electricity 1/	10
Repairs:	
Buildings	50
Machinery	25
Taxes	209
Interest	417
Insurance	65
Miscellaneous expense	148
Depreciation:	
Buildings	125
Machinery	70
Tractor	100
Auto 1/	75
Total farm expenses	$3488
Receipts:	
Crops	5312
Farm privileges	100
Gross farm income	$5412
Less farm expenses	3488
Net farm income	$1924

Average Farm Investment	
Land	$6400
Buildings	5000
Tractor	1000
Machinery & equipment	1000
Auto 1/	500
Total	$13900

Days Work	
Total	165
Operator	165
Hired	0
Contract	0

Summary	
Net farm income	$1924
Less:	
Management	531
Average return to water, land & capital	$1393
Same per acre	18.57

1/ Farm share.

Budget No. 3. - A 100-acre alfalfa farm at mature development, Hassayampa Project, Arizona.

Crops	Land: Acres	Man: Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price (dollars)	Products Sold: Value (dollars)
Alfalfa	76	167	Ton	4.6	350	350	16.00	5600
(Alfalfa pasture)	(47)		Acre				11.88	558
Alfalfa (new)	19	42	Ton	2.0	38	38	16.00	608
Farmstead	5							
Total	100	209						6766

Current Farm Expenses	
Seed	$ 85
Labor:	
Hired	15
Operator	1030
Insurance	1
Contract machine	1358
Tractor expense	165
Auto 1/	100
Electricity 1/	10
Repairs:	
Buildings	50
Machinery	25
Taxes	259
Interest	450
Insurance	65
Miscellaneous expenses	181
Depreciation:	
Buildings	125
Machinery	70
Tractor	100
Auto 1/	75
Total farm expenses	$4164
Receipts:	
Crops	$6766
Farm privileges	100
Gross farm income	$6866
Less farm expenses	4164
Net farm income	$2702

Investment		Days Work		Summary	
Land	$8000	Total	209	Net farm income	$2702
Buildings	5000	Operator	206	Less:	
Tractor	1000	Hired	3	Management	677
Machinery & equipment	1000	Contract	0	Average return to water, land & capital	$2025
Auto 1/	500				
Total	$15000			Same per acre	21.31

1/ Farm share.

Budget No. 4. - A 160-acre alfalfa farm at mature development.
Hassayampa Project, Arizona.

Crops	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price (Dollars)	Products Sold: Value (Dollars)
Alfalfa	122	268	Ton	4.6	561	561	16.00	8976
(Alfalfa pasture)	(75)		Acre		75	75	11.88	891
Alfalfa (new)	30	66	Ton	2.0	60	60	16.00	960
Farmstead	8							
Total	160							10827

Investment		Days Work		Summary	
Land	$12800	Total	334	Net farm income	$4764
Buildings	5000	Operator	281	Less:	
Tractor	1000	Hired	53	Management	1083
Machinery & equipment	1000	Contract	0	Average return to water, land & capital	$3681
Auto 1/	500				
Total	$20300			Same per acre	24.22

Current Farm Expenses	
Seed	$ 135
Labor:	
Hired	265
Operator	1405
Insurance	6
Contract machine	2173
Tractor expense	265
Auto " 1/	100
Electricity 1/	10
Repairs:	
Buildings	50
Machinery	25
Taxes	409
Interest	609
Insurance	65
Miscellaneous expenses	276
Depreciation:	
Buildings	125
Machinery	70
Tractor	100
Auto 1/	75
Total farm expenses	$6163
Receipts:	
Crops	$10827
Farm privileges	100
Gross farm income	$10927
Less farm expenses	6163
Net farm income	$ 4764

1/ Farm share.

Budget No. 5. - A 320-acre alfalfa farm at mature development.
Hassayampa Project, Arizona.

Crops	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price	Products Sold: Value
							(Dollars)	
Alfalfa	245	539	Ton	4.6	1127	1127	16.00	18032
(Alfalfa pasture)	(152)		Acre		152	152	11.88	1806
Alfalfa (new)	60	132	Ton	2.0	120	120	16.00	1920
Farmstead	15							
Total	320	671						21758

Investment	
Land	$25600
Buildings	5000
Tractor	2000
Machinery & equipment	1170
Auto 1/	500
Total	$34270

Days Work	
Total	671
Operator	312
Hired	359

Summary	
Net farm income	$10176
Less:	
Management	2176
Average return to water, land & capital	$8000
Same per acre	26.23

Current Farm Expenses	
Seed	$ 270
Labor:	
Hired	1795
Operator	1560
Insurance	41
Contract machine	4365
Tractor expense	530
Auto " 1/	100
Electricity 1/	10
Repairs:	
Buildings	50
Machinery	29
Taxes	816
Interest	1028
Insurance	73
Miscellaneous expenses	533
Depreciation:	
Buildings	125
Machinery	82
Tractor	200
Auto 1/	75
Total farm expenses	$11682
Receipts:	
Crops	$21758
Farm privileges	100
Gross farm income	$21858
Less farm expenses	11682
Net farm income	$10176

1/ Farm share.

Budget No. 6. - An 80-acre cotton farm at mature development.
Hassayampa Project, Arizona.

	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price (dollars)	Products Sold: Value (dollars)
Cotton lint	75	660	Pound	423	31725	31725	0.18	5711
Cotton seed	(75)		Pound	860	64500	64500	0.0176	1135
Farmstead	5							
Total	80				96225			6846

Current Farm Expenses	
Seed	$ 75
Labor:	
Hired	490
Contract	1443
Operator	935
Insurance	11
Ginning	206
Hauling	113
Tractor expense	383
Auto " 1/	100
Electricity 1/	10
Repairs:	
Buildings	50
Machinery	25
Other crop expense	225
Taxes	209
Interest	417
Insurance	65
Miscellaneous	238
Depreciation:	
Buildings	125
Machinery	70
Tractor	100
Auto 1/	75
Total farm expenses	$5365
Receipts:	
Crops	6846
Farm privileges	100
Gross farm income	$6946
Less farm expenses	5365
Net farm income	$1581

Investment	
Land	$6400
Buildings	5000
Tractor	1000
Machinery & equipment	1000
Auto 1/	500
Total	$13900

Days Work	
Total	660
Operator	187
Hired	98
Contract	375

Summary	
Net farm income	$1581
Less:	
Management	685
Average return to water, land & capital	896
Same per acre	11.95

1/ Farm share.

Budget No. 7. - An 80-acre cotton and alfalfa farm at mature development.
Hassayampa Project, Arizona.

Crops	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price (Dollars)	Products Sold: Value (Dollars)
Cotton lint	35	308	Lbs.	423	14805	14805	0.18	2665
Cotton seed	(35)		Lbs.	860	30100	30100	0.0176	530
Alfalfa	32	70	Ton	4.6	147	147	16.00	2352
(Alfalfa pasture)	(20)		Acre				11.88	238
Alfalfa (new)	8	18	Ton	2.0	16	16	16.00	256
Farmstead	5							
Total	80	396						6041

Investment		Days work		Summary	
Land	$6400	Total	396	Net farm income	$ 1723
Buildings	5000	Operator	196	Less: Management	604
Tractor	1000	Hired	25	Average return to water, land & capital	1119
Machinery & equipment	1420	Contract	175		
Auto 1/	500				
Total	$14320			Same per acre	14.92

Current Farm Expenses	
Seed	$ 71
Labor: Hired	125
Insurance	3
Contract	674
Operator	980
Contract machine	570
Hauling	52
Ginning	96
Tractor expenses	248
Auto expense 1/	100
Electricity 1/	10
Repairs: Buildings	50
Machinery	35
Other crop expenses	105
Taxes	211
Interest	430
Insurance	68
Miscellaneous	191
Depreciation: Buildings	125
Machinery	99
Tractor	100
Auto 1/	75
Total farm expenses	$4418
Receipts:	
Crops	6041
Farm privileges	100
Gross farm income	$6141
Less farm expenses	4418
Net farm income	$1723

1/ Farm share.

Budget No. 8. - An 80-acre alfalfa, cotton and barley farm at mature development.
Hassayampa Project, Arizona.

	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price	Products Sold: Value
							(Dollars)	
Alfalfa	24	53	Ton	4.6	110	110	16.00	1760
(Alfalfa pasture)	(15)		Acre		15	15	11.88	178
Alfalfa (new)	6	13	Ton	2.0	12	12	16.00	192
Barley	20	29	Cwt.	21.0	420	420	1.69	710
(Pasture)	(14)		Acre				11.88	166
Cotton lint	25	220	Lbs.	423	10575	10575	0.18	1903
Cotton seed	(25)		Lbs.	860	21500	21500	0.0176	378
Farmstead	5							
Total	80							5287

Investment		Days Work		Summary	
Land	$ 6400	Total	315	Net farm income	$ 1274
Buildings	5000	Operator	186	Less: Management	529
Tractor	1000	Hired	4	Average return to water, land & capital	$ 745
Machinery & equipment	1730	Contract	125		
Auto 1/	500				
Total	$14630			Same per acre	9.93

Current Farm Expenses	
Seed	$ 84
Labor: Hired	20
Insurance	1
Contract	481
Operator	930
Contract machine	497
Hauling	70
Ginning	69
Tractor expense	218
Auto expense 1/	100
Electricity 1/	10
Repairs: Buildings	50
Machinery	43
Other crop expense	127
Taxes	212
Interest	439
Insurance	70
Miscellaneous expenses	171
Depreciation:	
Buildings	125
Machinery	121
Tractor	100
Auto 1/	75
Total farm expenses	$4013
Receipts:	
Crops	5121
Farm privileges	100
Gross farm income	$5287
Less farm expenses	4013
Net farm income	$1274

1/ Farm share.

Budget No. 9. - An 100-acre cotton farm at mature development.
Hassayampa Project, Arizona.

	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price (Dollars)	Products Sold: Value
Cotton lint	95	836	Lbs.	423	40185	40185	0.18	7233
Cotton seed	(95)		Lbs.	860	81700	81700	0.0176	1438
Farmstead	5							
Total	100	836						8671

Investment		Days Work		Summary	
Land	$ 8000	Total	836	Net farm income	$2213
Buildings	5000	Operator	202	Less: management	867
Tractor	1000	Hired	159	Average return to	
Machinery & equipment	1000	Contract	475	water, land & capital	$1346
Auto 1/	500				
Total	15500			Same per acre	14.17

Current Farm Expenses	
Seed	$ 95
Labor: Hired	795
Insurance	18
Contract	1828
Operator	1010
Ginning	261
Hauling	143
Tractor expense	484
Auto 1/	100
Electricity 1/	10
Repairs:	
Buildings	50
Machinery	25
Other crop expense	285
Taxes	259
Interest	465
Insurance	65
Miscellaneous	295
Depreciation:	
Buildings	125
Machinery	70
Tractor	100
Auto 1/	75
Total farm expenses	$6558
Receipts:	
Crops	8671
Farm privileges	100
Gross farm income	8771
Less farm expenses	6558
Net farm income	$2213

1/ Farm share.

Budget No. 10. - An 100-acre cotton and alfalfa farm at mature development.
Hassayampa Project, Arizona.

Crops	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price (Dollars)	Products Sold: Value (Dollars)
Cotton lint	45	396	Lbs.	423	19035	19035	0.18	3426
Cotton seed	(45)		Lbs.	860	38700	38700	0.0176	681
Alfalfa	40	86	Ton	4.6	184	184	16.00	2944
(Alfalfa pasture)	(25)		Acre				11.88	297
Alfalfa (new)	10	21	Ton	2.0	20	20	16.00	320
Farmstead	5							
Total	100							7668

Current Farm Expenses	
Seed	$ 90
Labor: Hired	285
Contract	866
Operator	1105
Insurance	6
Contract machine	714
Ginning	124
Hauling	67
Tractor expense	317
Auto 1/	100
Electricity 1/	10
Repairs:	
Buildings	50
Machinery	25
Other crop expense	135
Taxes	259
Interest	465
Insurance	65
Miscellaneous	234
Depreciation:	
Buildings	125
Machinery	70
Tractor	100
Auto 1/	75
Total farm expenses	$5287
Receipts:	
Crops	7668
Farm privileges	100
Gross farm income	$7768
Less farm expenses	5287
Net farm income	$2481

Investment		Days Work		Summary	
Land	$8000	Total	503	Net farm income	$ 2481
Buildings	5000	Operator	221	Less: Management	767
Tractor	1000	Hired	57	Average return to water,	
Machinery & equipment	1000	Contract	225	land & capital	$ 1714
Auto 1/	500				
				Same per acre	18.04
Total	$15500				

1/ Farm share.

Budget No. 11. - An 160-acre alfalfa and cotton farm at mature development.
Hassayampa Project, Arizona.

Crops	Land Acres	Man Work Days	Production Unit	Production Yield per acre	Production Total	Products Sold Amount	Products Sold Price (Dollars)	Products Sold Value (Dollars)
Cotton lint	77	678	Lbs.	423	32571	32571	0.18	5863
Cotton seed			Lbs.	860	66220	66220	0.0176	1165
Alfalfa	60	132	Ton	4.6	276	276	16.00	4416
(Alfalfa pasture)	(37)		Acre		37	37	11.88	440
Alfalfa (new)	15	33	Ton	2.0	30	30	16.00	480
Farmstead	8							
Total	160	843						12364

Investment		Days Work		Summary	
Land	$12800	Total	843	Net farm income	$ 4359
Buildings	5000	Operator	275	Less: Management	1236
Machinery & equipment	1420	Hired	183	Average return to water, land & capital	$ 3123
Tractor	1000	Contract	385		
Auto 1/	500				
Total	$20720			Same per acre	20.55

Current Farm Expenses		
Seed		$ 145
Labor:	Hired	915
	Contract	1482
	Operator	1375
	Insurance	21
Ginning		212
Hauling		116
Tractor expense		475
Auto 1/		100
Electricity 1/		10
Repairs:	Buildings	50
	Machinery	35
Taxes		411
Interest		622
Insurance		68
Other crop expense		231
Contract machine work		1071
Miscellaneous		367
Depreciation:	Buildings	125
	Machinery	99
	Tractor	100
	Auto 1/	75
Total farm expenses		$ 8105
Receipts:		
	Crops	$12364
	Farm privileges	100
Gross farm income		$12464
Less farm expenses		8105
Net farm income		$ 4359

1/ Farm share.

Budget No. 12. - An 160-acre alfalfa, alfalfa seed, cotton and barley farm at mature development.
Hassayampa Project, Arizona.

Crops	Land Acres	Man Work Days	Production: Unit	Production: Yield per acre	Production: Total	Products Sold: Amount	Products Sold: Price (Dollars)	Products Sold: Value (Dollars)
Alfalfa	48	106	Ton	2.6	125	125	16.00	2000
(seed)	(48)		Lbs.	179	8592	8592	0.225	1933
Alfalfa (new)	12	26	Ton	2.0	24	24	16.00	384
Barley	42	50	Cwt.	21	882	882	1.69	1491
Barley (pasture)	(29)		Acre				11.88	345
Cotton lint	50	440	Lbs.	423	21150	21150	0.18	3807
Cotton seed	(50)		Lbs.	860	43000	43000	0.0176	757
Farmstead	8							
Total	160	622						10717

Current Farm Expenses	
Seed	$ 171
Labor: Hired	575
Insurance	13
Contract	962
Operator	1285
Contract machine	521
Hauling	144
Ginning	137
Tractor expense	447
Auto expense 1/	100
Electricity 1/	10
Repairs: Buildings	50
Machinery	66
Other crop expense 2/	595
Taxes	415
Interest	658
Insurance	77
Miscellaneous	311
Depreciation: Buildings	125
Machinery	184
Tractor	100
Auto 1/	75
Total farm expenses	$7021
Receipts: Crops	$10717
Farm privilege	100
Gross farm income	$10817
Less farm expenses	7021
Net farm income	$ 3796

Investment		Days Work	
Land	$12800	Total	622
Buildings	5000	Operator	257
Tractor	1000	Hired	115
Machinery & equipment	2630	Contract	250
Auto 1/	500		
Total	$21930		

Summary	
Net farm income	$ 3796
Less: Management	1072
Average return to water, land & capital	$2724
Same per acre	17.92

1/ Farm share.
2/ Includes $50 for combine fuel and lubricant, and $112.50 for hired tractor work.