KOHALA WATER RESOURCES MANAGEMENT AND DEVELOPMENT PLAN

PHASE II
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PHASE II

Report Prepared By:
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May 1974
“...new economic alternatives for North Kohala. This is a time for great pride...”

Fred Erskine at Hawaii Biogenics ground-breaking
March 28, 1974
March 29, 1974

Mr. Frederick C. Erskine
Chairman
Department of Agriculture
State of Hawaii
Honolulu, Hawaii

Dear Mr. Erskine:

We are pleased to transmit our Phase II report of the Kohala Water Resource Management and Development Plan. In preparing this report, we have done our best to provide accurate and thorough evaluation of the water resources of North Kohala as related to the socio-economic base of the district with a special emphasis on agriculture. Our summary recommendations deal with the particular progression and growth of the water plan. Specific recommendations on technical problems are incorporated within the text.

The proposed system and water Cooperative presented in the report should provide a basis for evolving sound decisions and policies for North Kohala. It is our opinion that the water resources of the district should be used primarily to support the socio-economic activities of the residents and businesses within the district. To this end, we have done our best to integrate decision making flexibility into the plan and to explain the numerous constraints and problems related to water resource management and development.

The report is unique in that the water resources have been evaluated with careful consideration of the financial, institutional and land resource constraints of the district. We feel that this report will be of great assistance to the Kohala Task Force in seeking solutions to the many problems facing the residents of the district.

Sincerely,

Stephen P. Bowles
John F. Mink

Charles S. May
Arthur Y. Akinaka
NOTES ON AUTHORS

Stephen P. Bowles, Consulting Hydrologist-Geologist. Contracted by Kohala Task Force to create the Kohala Water Resources Management & Development Plan and prepare Phase I report. Phase II responsibility has been to select team members, conduct and coordinate various field and project assignments, and to write & edit portions of this report as needed.

John F. Mink, Consulting Hydrologist-Geologist. Contracted to conduct investigations and report on the water resources of the Kohala Mountains tributary to the district of North Kohala.

Akinaka and Associates, Ltd. Engineering Consultants. Contracted to assemble planning and engineering data, evaluate and design proposed irrigation system, prepare and report on engineering and planning aspects. Principle contributors were Arthur Akinaka, Robert Akinaka and Ronald Yama.

Charles S. May, Financial and Business Consultant. Contracted to analyze and report on financial and organizational aspects of the proposed system and plan.
ACKNOWLEDGEMENTS

As members of the consulting team, we want to take this opportunity to extend our gratitude to the many government, corporate, and private individuals who have contributed to the successful completion of our investigations. The Kohala Corporation has been particularly helpful in supplying maps, data, conducting field trips, and providing critical review of our report. Special thanks are extended to Al Stearns, Dale Sproat, and Ray Gianini for their assistance in accomplishing our Phase II investigations.

Akira Fujimoto and Bill Sewake of the Hawaii Department of Water Supply offered valuable assistance in County water policy. Ranchers Monte Richards and Gordon Lent provided welcome advice on livestock and pasture potential. Task Force guidance provided by Fred Erskine has been especially helpful and our gratitude is extended to Bill Thompson for his administrative assistance.

It is virtually impossible to prepare a report of this nature without the assistance and cooperation of the many individuals involved in the myriad of activities related to planning, water and agriculture. We thank all who have contributed, directly or indirectly, for their assistance.
Participants in the ground-breaking for Hawaii Biogenics, a new enterprise for North Kohala: L to R: Fred Erskine, Board of Agriculture Chairman; James Evans, Bank of Hawaii Vice-President; Jack Caple, Hawaii Biogenics principal; and Jesse Boyers, Kohala community representative.

A view of the large crowd who witnessed the Hawaii Biogenics ground-breaking ceremony under sunny Kohala skies.
The Kohala Sugar Company mill at Hauula. This sugar mill, the last in Kohala, is scheduled to shut down in 1975.
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INTRODUCTION

On March 1, 1971, Castle & Cooke, Inc., announced the closing of the Kohala Sugar Company. By mid-June, 1971, the Governor had appointed a Task Force whose purpose was to study possible agricultural alternatives and to expedite an economic change from sugar to other agricultural products and to seek out diversification of the local economy. A primary objective of the Task Force has been to secure jobs for those persons displaced by the loss of the sugar operation.

During the latter part of 1971, the Task Force created an executive committee composed of Lieutenant Governor George R. Ariyoshi, Hawaii County Mayor Shunichi Kimura, and State Board of Agriculture Chairman Frederick C. Erskine. The purpose of the executive committee was to follow through on the details of projects initiated by the Task Force. The legislative session of 1972 produced Act 197 which pertains to the planning and development of North Kohala. In this Act, funds were provided for the planning and development of the area and for feasibility studies of potential industries. Funds for the development of an irrigation water system were also allocated. The executive committee decided that, before monies were invested in an irrigation water system, it was important to determine what water problems existed within the district and also how the existing water facilities should be administered. At this juncture, it was decided that an appropriate step was to create what is called the Kohala Water Resources Management and Development Plan. The objectives of this plan are:

1. To consolidate all water resources and facilities into a regional solution to develop, manage and distribute the water resources of North Kohala for the common good of agricultural, industrial and domestic water needs, both public and private.
2. Except for the initial Phases I, II and III of the Plan, to direct such management and development activities toward self-support by revenue generated through water sales.
3. To enhance the economic strength of the North Kohala district and its people by the judicious use of its water resources.
4. To assist in the land use planning activities as related to the protection and the efficient use of the water resources.
5. To provide for local (North Kohala district) administration of the Kohala Water Resources Management and Development Plan by Phase IV.

The Kohala Water Plan is not a physical plan as such, but is an action plan. Because of the uncertainties in the outcome of the various proposed agricultural and other activities in the district, it is not appropriate at this time to have a detailed physical plan, but to have a plan which allows flexibility in the decision-making process. The phases of the plan are briefly described as follows:

Phase I — Preliminary findings and conclusions. A completed report submitted in May 1973 outlining the major problems facing the district of North Kohala as related to water. Recommendations for establishing investigations and activities in Phase II.
Phase II — A detailed evaluation of the district's water resources, a proposed irrigation system, a proposed operating organization and recommendations for Phase III as well as corollary recommendations related to the general socio-economic facets of the community pertaining to water.

Phase III — Intended to span the implementation of specific projects and activities related to the establishment of an expanding irrigation water program. Projects recommended in Phase II will be pursued as directed by the Task Force. Supplemental activities will be initiated as needed towards the objectives of the Kohala Water Plan and achievement of Phase IV.

Phase IV — The operation of a water system to meet the needs of agricultural users in North Kohala and maintained by revenues from water sales.

As the Phase II investigations progressed, the tropical foliage nursery broke ground, the sugar operation was extended through the 1975 crop and agreement was reached on the lands to be occupied by Hawaii Biogenics, Ltd., a large livestock growing and feeding complex. A major difficulty in planning the strategy of economic change-over has been directly related to the uncertainties of water. It is anticipated that this Phase II report can result in firming up planning and crop targets.

Phase II investigations have been devoted to the efficient development and management of the water resources. In this respect, the preparation of this report intentionally avoids water and land ownership, constraints which frequently compromise efficient resource planning. The intent of the report is to define and explain for the decision maker, those critical constraints affecting the relationship of water and land to the economy. Special attention has been paid to private involvement in water development and management. The traditional role of government in agriculture has been to assist in providing the farmer with the necessary tools, technical and economic, to grow his crops. In developing the Kohala Water Plan, this traditional role of government has been retained. It is the authors' opinion that the farmer should be involved in the planning, development, and purveying of all water used in agriculture.
SUMMARY OF CONCLUSIONS & RECOMMENDATIONS

WATER RESOURCES

Analysis of the available data on the water resources within the North Kohala district or resources which, because of physical or economic reasons, might supply the district are summarized in Figure I-1. The water units of sustained flow are expressed in MGD (Million Gallons Daily) and represent the rate at which water can be used indefinitely with no adverse effects on the water resources. In addition to the resources evaluated in this report, there is more ground water available, between Honokane Nui and Waimanu valleys, which is not presently within the range of reasonable economic development.

The total water presently available for use is about 46 MGD, of which about 40 MGD is now used in sugar production. About 81 MGD can be made available to the district with reasonable improvements to the transmission system and sources. The irrigation system proposed in this report would use an average of about 19.5 MGD in a normal year from the following sources:

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<th>Source</th>
<th>Maximum</th>
<th>Low</th>
<th>Average</th>
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<td>Kohala Ditch</td>
<td>16</td>
<td></td>
<td></td>
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<td>Basal lens</td>
<td>3.5</td>
<td></td>
<td></td>
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<td>Total</td>
<td>19.5 MGD</td>
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More water can be developed in the future. The major constraint to development is the unit cost of water and the correct combination of transmission and sources to match the demand.

PRESENT WATER SYSTEMS (MAP I-1)

Water is supplied by small, diverse domestic systems, which are fed by shallow tunnels tapping perched ground water, and a larger agricultural system supplying irrigation water. The latter is composed of the following elements listed with their presently used capacities in MGD:

1. Kohala ditch 55—60 10 26
2. Kehena ditch 10—20 0 1
3. Shafts 25 — 8
4. Wells 5 — 1

Use of the irrigation system ranges from 0 MGD, during the wettest periods, to 40 MGD during droughts. The Kohala Sugar Company and its predecessors irrigated a total of about 5,500 acres. During droughts and commencing in 1969, it was necessary to pump water from the basal ground water (elevation 4'±) to the Kohala ditch (elevation 1000'±). The cost of pumping water to the ditch was about $100/MG. The cost of water imported via the Kohala ditch was about $15/MG. In spite of attempts in the 1960's to reduce the total cost of water by overhead irrigation and source improvements, the cost and reliability of water during frequent droughts was instrumental in causing the shutdown of the Kohala Sugar Company. Two subtle yet dominant causes underly the present situation; the ownership and location of low cost water sources and
SUMMARY FLOW CHART

SURFACE AND GROUND WATERS WHICH FLOW TO OR OCCUR IN THE KOHALA AGRICULTURAL REGION IN M.G.D.

I. AVERAGE NATURAL FLOWS

LAUPAPOHOE STREAMS 13.9

AWINI
45.0

TOTAL
45.0

KEHENA DITCH 14.5

E. HONOKANE IKI
4.2

E. HONOKANE NUI SURFACE WATER 13.9

TOTAL KOHALA DITCH INTAKE 72.7

TOTAL KOHALA DITCH 77.2

E. HONOKANE NUI GROUND WATER 9.7

TOTAL 141.7

KOHALA SECTOR BASAL GROUND WATER 45.0

II. AVERAGE ACTUAL FLOWS

KOHALA SECTOR BASAL GROUND WATER 9.0

UPPER KOHALA 5.0

KEHENA DITCH

E. HONOKANE NUI SURFACE WATER 3.2

W. HONOKANE NUI 4.0

E. POLOLU 0.5

TOTAL 45.7

LAUPAPOHOE STREAMS 7.0

18 AWINI INTAKES

GAGE 7450 11.6

GAGE 7440 1.3

KEHENA DITCH

TOTAL 10.0

W. HONOKANE NUI 8.0

E. POLOLU 1.0

UPPER KOHALA 5.0

TOTAL 81.2

KOHALA SECTOR BASAL GROUND WATER 30.0

III. AVERAGE DEVELOPABLE FLOWS UNDER REASONABLE ECONOMIC AND TECHNICAL CONSTRAINTS

LAUPAPOHOE STREAMS 7.0

AWINI
17.5

TOTAL 17.5

KEHENA DITCH

TOTAL 10.0

E. HONOKANE IKI 2.5

E. HONOKANE NUI SURFACE WATER 8.0

TOTAL KOHALA DITCH INTAKE 37.7

TOTAL KOHALA DITCH 39.7

E. HONOKANE NUI GROUND WATER 9.7

TOTAL 81.2

KOHALA SECTOR BASAL GROUND WATER 30.0

VI. SUMMARY OF PROJECTIONS

LAUPAPoHoE STREAMS 13.9

AWINI
45.0

TOTAL 45.0

KEHENA DITCH 14.5

E. HONOKANE IKI
4.2

E. HONOKANE NUI SURFACE WATER 13.9

TOTAL KOHALA DITCH INTAKE 72.7

TOTAL KOHALA DITCH 77.2

E. HONOKANE NUI GROUND WATER 9.7

TOTAL 141.7

KOHALA SECTOR BASAL GROUND WATER 45.0

LAUPAPoHoE STREAMS 7.0

18 AWINI INTAKES

GAGE 7450 11.6

GAGE 7440 1.3

KEHENA DITCH

TOTAL 10.0

W. HONOKANE NUI 8.0

E. POLOLU 1.0

UPPER KOHALA 5.0

TOTAL 81.2

KOHALA SECTOR BASAL GROUND WATER 30.0

LAUPAPoHoE STREAMS 7.0

AWINI
17.5

TOTAL 17.5

KEHENA DITCH

TOTAL 10.0

W. HONOKANE NUI 8.0

E. POLOLU 1.0

UPPER KOHALA 5.0

TOTAL 81.2

KOHALA SECTOR BASAL GROUND WATER 30.0
the ownership of land. These factors lay behind many of the decisions on source and system investments and land use.

**FUTURE WATER SYSTEMS**

Water is available in North Kohala in sufficient quantity to meet any and all needs of the district in the foreseeable future. Making the water available to agriculture at a cost affordable to particular crop types is no simple task. In order to overcome some of the past experiences in agricultural water costs, it is necessary to develop a use logic or concept which matches water to land without the constraints of ownership. This procedure permits an in depth evaluation of the long range possibilities in agriculture for North Kohala.

Based on this approach, an irrigation water system is proposed (Map I-2) which can accomplish the following:

1. Take full advantage of low cost water from the Kohala ditch.
2. Use basal ground water as efficiently as possible and minimize pumping costs.
3. Establish water reliability in normal and drought years at the lowest capital and operating costs.
4. Utilize lands which can achieve the greatest productivity from irrigation.
5. Create a means of retaining agribusiness as the dominant force in the economy of North Kohala.

The system is based on a normal year demand maximum of 5.6 MGD per 1000 acre unit, which are assembled incrementally, to a maximum of 6000 acres or a demand of 33.6 MGD. When the demand is compared to the resources as shown in Figure I-1, there appears to be a large quantity of water yet to be developed. The major constraint lies in the ability to match the resource to the demand in such a manner as to produce a minimum unit cost of water delivered to the user.

The proposed system is not presented as The Plan, but rather, it expresses the logic or concept developed in this report. Restructuring the agricultural economy necessitates a building block approach. The proposed water system can result if this method is followed. Departures from the building block approach will result in high water costs and, potentially, a total collapse of the agricultural economy.

Domestic water is needed at various localities in the district. There are adequate resources to meet the present and future needs. Low cost surface water should not be assigned to domestic uses. Water should be allocated on the ability to pay and not convenience to the user location.

**WATER COSTS AND FINANCING**

Based on the proposed system capital and operating costs, an analysis was made to determine whether or not the system could (based on assumed time schedules, costs and
URBAN ZONE
POTENTIAL IRRIGATED LANDS
INCREMENT DEVELOPMENT
WELL & PUMP
(NO. INDICATES INCREMENT)
PROPOSED WATER LINE

POTENTIAL IRRIGATED LANDS
A unit charge of $50/MG was assumed, based on experience in North Kohala and elsewhere, as being a reasonable cost to an efficient bulk irrigation user. The results (Figure 1-2) indicates that depreciation and interest expenses cause the unit cost of production to climb as acreage increases.

The proposed system cannot pay for itself with those assumptions, thus, a second analysis was made assuming that only the operating costs were carried in the charge to the customer. Results, shown in Figure 1-3, indicate that a normal year demand on 6000 acres can result in a slight operating surplus.

Regardless, a severe dry spell will produce a negative cash flow as a direct result of energy required for additional pumping. Large storage at or above the user area can resolve this problem. The storage requirement for 6000 acres is about 4,000 MG. A reservoir to store excess ditch flow was rejected because of high initial capital costs and the lack of suitable sites. The most promising solution is high level ground water stored in dike compartments located above the Kohala ditch in Honokane Nui valley. Successful development of such storage would:

1) Reduce and/or delay capital investments in wells, pumps and generator sets.
2) Reduce the unit cost of water delivered in direct proportion to cost of fuel.

WATER ORGANIZATION

In order to develop and operate the proposed system, an organization will be required. The Kohala Ditch Company, a subsidiary of the Kohala Corp., presently distributes ditch water to sugar for irrigation. Both supply a single owner-user. Several advantages which result from this relationship are as follows:

1. A minimum of full time personnel to operate and maintain water facilities.
2. An extensive and skilled labor and administrative pool to assign as needed.
3. Access to low cost electrical power generated from bagasse.
4. Heavy equipment on call for any and all jobs related to water.
5. An ability to distribute water and irrigate as needed and according to management control. This allows the plantation to gamble on the acreage, scheduling and costs as deemed appropriate.

The negative aspects are the constraints offered by the land and water ownership.

Agriculture in North Kohala will be diversifying towards multiple owners and users. In order to provide water to these diverse users, it will be necessary to institute a new organization. A Cooperative appears to be the best type of organization, as it would maintain the traditional role of government to agriculture as mentioned earlier. It would be unfeasible, both from a financial and political point of view, to attempt to retain the present methods of purveying water.

The Cooperative proposal consists of a Council and an Operating Company. Such a Council would be constituted as follows and have 7 voting members:

1. Appointee, Department of Agriculture, State of Hawaii
2. Appointee, Department of Land and Natural Resources, State of Hawaii
3. Appointee, Representing the Mayor, Hawaii County
4. Elected by water users
5. Elected by land users
6. Elected by North Kohala district voters for 2 years
7. General Manager of Operating Company also Chairman of Council

It is anticipated that such a Cooperative can achieve the objectives of the Kohala Task Force and, specifically, those of the Kohala Water Resource Management and Development Plan.

RECOMMENDATIONS

The following list contains recommendations to the Task Force for commencing Phase III of the Kohala Water Plan:

1. Establish a coordinating team to solicit, organize and review community reaction to the proposals and specific recommendations in this Phase II report. Further, to assign, and expedite such assignments (to various government agencies, private institutions and individuals), the necessary tasks to accomplish the evolution to the Kohala Water Plan.

2. Commence immediately to
   a) have Bishop Estate assign to the State, County or Cooperative, the right to explore and develop high level ground water storage in Honokane Nui valley above the Kohala Ditch.
   b) have the Kohala Ditch Company maintain, at the present level, water service at least through the 1975 sugar crop and until reorganization targets can be accomplished.
   c) upon assignment of rights, drill the horizontal bore hole as recommended in the report and evaluate potential storage alternatives in Honokane Nui.
   d) perform a detailed engineering evaluation of the intake structures and flumes of the Awini Section of the Kohala Ditch in order to determine the flow characteristics of such structures and make recommendations on appropriate changes and costs of replacement.
   e) have both the State of Hawaii and Bishop Estate withhold any water charges on water licenses related to waters supplying the Kohala Ditch as a means of keeping water cost to a minimum during the transition period.
   f) request various livestock growers to actively explore ways and means of creating irrigated pastures or other possible uses for irrigation water.
   g) explore the methods of establishing a water Cooperative to replace the Kohala Ditch Company following the harvest of the 1975 sugar crop.
   h) resolve, perhaps by lease rental, a means of transferring the Kohala ditch and appurtenances to the State, County or Cooperative.
An old sugar mill smoke stack stands lonely against the sky in Hawi, a remnant of years past when North Kohala boasted six sugar mills. Soon the last remaining mill is scheduled to close down.

A possible replacement for sugar in North Kohala, sorghum. Extensive experiments by the University of Hawaii are testing the best conditions for growing sorghum.
WATER RESOURCES AVAILABLE TO THE AGRICULTURAL LANDS OF THE NORTH KOHALA DISTRICT

INTRODUCTION

The water resources of the Kohala Mountains, especially the portion draining to the north, have been the subject of formal investigation and the object of development for more than 80 years. At the turn of the century, the desire to increase sugar cane production by extending the cultivated fields to dry areas which would require substantial irrigation was the incentive to seek water supplies from the obviously high rainfall regions of Honokane Nui Valley and the wet forests to the east and south of it. Collection and transmission systems were constructed to exploit the surface run-off of the wet northern slopes of the Kohala dome, and these systems continue to provide the largest and most relied upon water supply to the irrigated area between Pololu Valley and Upolu Point.

The first water resources investigation within this region was made by W. W. Brunner in 1889-1890 (Davis and Yamanaga, 1963), during which time he measured stream flows in the east and west branches of Honokane Nui. Somewhat over a decade later, in 1901-1902, A. S. Tuttle (Tuttle, 1902) more thoroughly evaluated the surface water resources of Honokane Nui and proposed a system for diverting the waters of the east and west branches to the sugar cane lands of Kohala. Although his plan was not implemented exactly as he had proposed, his survey was the impetus which led in 1905-1906 to the construction of the Kohala-Awini collection and transmission system, consisting of intakes, tunnels, flumes and open ditches and reaching to Waikoloa Stream in the Hamakua District about three miles to the east of Honokane Nui.

In 1912-1914 the Kehena Ditch system was constructed in the high forested slopes between the head of Honokane Nui canyon and the crest of the Kohala dome. Starting at an elevation of just over 4,200 feet, the Kehena Ditch over most of its course lies several miles to the south and several thousand feet higher than the Kohala Ditch (see Map II-1). Engineering descriptions of both the Kehena and Kohala-Awini Ditch systems are given in Randolph (1965), and in Bowles (1973).

Contemporaneously with the evolution of the major ditch systems, small quantities of high level water, ordinarily occurring at elevations above 1,000 feet, were being developed in the main Kohala region between Pololu Valley and Hawi. Although the springs and tunnels that drain this high level water are important in local domestic, irrigation and stock uses, the total available volume is minor in relation to the ditch flows.

It is interesting to note that even before the surface water collection and transmission systems were planned, successful initiatives had been made to develop and utilize the basal ground water underlying practically the entire plantation area. In 1899 Hawi Plantation drove a
GROUND WATER LEVEL
in Feet above sea level
EQUAL ANNUAL RAINFALL
LINE in Inches
URBAN ZONE

WATER RESOURCES
shaft to basal water just 700 feet from the coast and pumped useable water. Kohala Sugar Mill
did the same in 1901. However, even though the basal ground water resource between Pololu
Valley and Upolu Point is substantial, it has always played a secondary role to the ditch systems
water because of pumping costs.

In the years since the turn of the century a great deal of hydrologic data has been collected
on the water resources ancillary to the ditch systems. The chief purpose of the data collection
has been, however, to differentiate flows on the basis of land ownership rather than to elucidate
the hydrologic characteristics of the drainage basins. The data is voluminous and very useful
but is not sufficiently diverse to define flow patterns except by averaging. Nevertheless reason­
able estimates of natural flows in the basins draining to the ditch systems can be made by
employing the ditch flow data and flow measurements on nearby streams.

In describing and discussing the hydrology and water resources of the North Kohala­
Hamakua Districts, the primary objective is to relate the occurrence and developability of the
resources to the economic realities of the user programs. To accomplish this objective, the fresh
water resources available to North Kohala will first have to be discussed with minimum regard
for economic and technical constraints, to be followed by evaluation of the resources now being
developed and whether additional resources could be added to the already constructed
systems at reasonable cost. Water resources which could be developed with significant capital
investment will also have to be discussed so that new developments could be considered as
economic constraints allow.

The region of study is highly diverse environmentally and must be divided into sectors for
hydrologic analysis. The approximate boundaries extend from Mahukona to Waikoloa Stream in
the Kohala Forest Reserve over an area of about 100 square miles. Mahukona with an average
annual rainfall of 10 inches or less is one of the driest spots in the State of Hawaii, while the
slopes of the Kohala Forest Reserve have average annual rainfalls in excess of 200 inches.

The hydrologic sectors of the region can be conveniently drawn as compromises between
environmental features and the existing development systems. The major sectors are the
Kohala-Awini Ditch System, subdivided into the Awini section, the Honokane Nui section, and
miscellaneous drainages; the Kehena System; the upper Kohala sector, lying between the
Kohala and Kehena Ditches to the west of Pololu Valley; and the basal ground water sector,
extending from Pololu Valley around to Mahukona.

GENERAL ENVIRONMENTAL SETTING OF KOHALA

The Kohala volcanic dome encompasses an area of about 234 square miles within an
ellipsoidal configuration striking in a northwest-southeast direction with maximum dimensions
of 22 and 15 miles and a maximum elevation of 5,505 feet. Stearns and Macdonald (1946)
provided the most detailed description of the Kohala region, and subsequent geologic and
hydrologic investigations have been profoundly influenced by this basic work. The general
geologic framework of the region as described by Stearns and Macdonald has not been significantly modified by later investigations, but much additional and more extensive hydrologic information has accumulated in the last 30 years.

The Kohala volcano, though the oldest on the island of Hawaii, is geologically very young, having first erupted above sea level about 450,000 years ago (McDougall and Swanson, 1972). The first and major phase of activity followed the normal Hawaiian volcanic sequence by effusing immense volumes of basalt and olivine basalt, now called the Pololu volcanic series. This eruptive phase ended about 300,000 years ago and was followed by volumetrically small but areally significant flows of the Hawi volcanic series, consisting chiefly of andesites, which erupted over an interval from as recently as 60,000 years ago to 250,000 years ago (McDougall and Swanson, 1972). These two volcanic series cover the entire region of study and in large measure determine its hydrologic characteristics.

The basalts of the Pololu volcanic series are highly permeable and form the major aquifers in the region. The Awini and Honokane Nui subdivisions of the Kohala-Awini Ditch System are underlain entirely by Pololu basalts, and the basal ground water aquifer between Pololu Valley and Mahukona consists of the same permeable formation. The andesites of the Hawi volcanic series are much less permeable than the Pololu basalts and by comparison make poor aquifers. Hawi andesites cap the region between the amphitheater palis of Honokane Nui and the crest of the Kohala dome, where the Kehena Ditch System originates, and extend westward to Hawi. The hydrology of the Kehena System and the Upper Kohala sector is dominated by the andesites.

The original caldera of the Kohala volcano was centered near the head of Waipio Valley (Kinoshita, 1965), from where the primary rift zone strikes northwest through Honokane Nui toward the coast between Mahukona and Upolu Point. Dikes in the deeply eroded East Honokane Nui canyon suggest that the northern margin of the rift zone passes near the Honokane intake of the Kohala Ditch and the head of the west branch of Pololu, then becomes less defined toward the coast. It is probable that the basal ground water of the Kohala sector is bounded inland by the rift zone.

Rainfall distribution in the Kohala region shows the typical Hawaiian pattern where mountainous lands are exposed to tradewinds coming from the sea. Maximum rainfalls of greater than 200 inches annually are experienced on the windward slopes of the Kohala Mountains between Honokane and Kawainui Valleys (see Map II-1). Rainfall diminishes markedly to the westward as elevations decrease, and on the lee of the dome the annual average of Mahukona is about 10 inches. Between Honokane and Hawi the annual averages gradually decline from about 150 inches to 50 inches. Expectably, erosion is more pronounced where rainfall is greatest, but the covering of the Hawi andesite has muted erosional effects above and to the west of Honokane canyon. The enormous depth of Honokane canyon, about 2,500 feet at its head, results from the combined effects of high rainfall and high water tables within dike compartments.
An irrigation ditch fed by the Kohala Ditch slated to nourish grain crops instead of sugar cane.

The concrete-lined walls of the Kohala Ditch cuts across the Kohala countryside for miles on end. The system is approximately 75 years old.
Awini Falls, with millions of gallons of water cascading down the steep walls of cloud-shrouded Honokane Valley.
HYDROLOGY BY SECTORS

KOHALA-AWINI DITCH SYSTEM

The Kohala-Awini Ditch System starts at an elevation of 1,860 feet on Waikoloa Stream in the Kohala Forest Reserve and extends by way of Honokane Nui as 22 miles of tunnels, ditches and flumes to a delivery elevation of about 1,000 feet near Hawi. It was one of many heroic engineering feats undertaken in the early part of this century in Hawaii for the collection and transmission of surface water for sugar cane irrigation.

The source region of the ditch system may be conveniently divided into two principal parts which are environmentally distinct and which have different engineering characteristics. The Awini section collects flows from many shallow streams, which are supplied solely by rainfall runoff and bank storage, while from the Honokane Nui section both direct runoff and high level ground water, mostly from dike compartments but a significant quantity also from small aquifers perched on ash beds, are collected. The Awini transmission route lies at an elevation of about 1,800 feet; at its terminus high on the steep east wall of the East Branch of Honokane Nui its water plunges as an impressive cascade to the floor of the canyon more than 800 feet below.

The Honokane intake to the Kohala Ditch lies at an elevation of about 1,000 feet just downstream from the Awini waterfall. Practically all of the water transmitted to the agricultural areas of Kohala is collected in the Awini section and from the East Branch of Honokane Nui. Two U.S. Geological Survey stream gaging stations, with records exceeding 30 years in length, differentiate flows from Awini and Honokane. U.S.G.S. gage 16-7430 (hereafter called gage 7430) is located on Awini Ditch immediately to the east of the intake on East Honokane Iki Stream; U.S.G.S. gage 16-7510 (hereafter called gage 7510) is located in Pololu Valley and includes, in addition to Awini and East Honokane Nui flows, the much smaller flows from East Honokane Iki, West Honokane Nui, and East Pololu. These two gages provide the basic data for hydrologic analyses because of their long records and volumes of flow. The quantity of water measured at the Pololu gage is considered the input to the agricultural region.

AWINI

The Awini Ditch tranverses about nine miles of a high rainfall forested region which today is rarely visited but which at one time, before the construction of the ditch, was sparsely inhabited and was known for its orange and coffee orchards (Tuttle, 1902). The drainage area above the ditch system lies between the 1,900 and 4,500 feet elevations and includes 8.22 square miles. The entire drainage area is not tributary to the ditch system, however, because tunnels through ridges between streams by-pass surface drainage. By conservative estimate, the drainage area available to the ditch system is 7.5 square miles.

Eighteen streams to the east of Honokane Iki are collected by the ditch system. The largest, from east to west, are the East Branch of Waikoloa (area 1.28 square miles), Ohianuea (area 1.55
square miles), West Branch of Honopue (1.39 square miles), and the West Branch of Honokea
(0.92 square miles). All other streams have areas of less than 0.6 square miles, ranging from
0.02 square miles for the West Branch of Nakooko to 0.55 square miles for the East Branch of
Nakooko.

The entire drainage area is underlain by basalts of the Pololu volcanic series. Above the
ditch level the stream valleys are very shallow and narrow. Exposed dikes have not been
reported anywhere above elevation 2,000 feet between East Honokane Nui and Kawainui, which
lies to the east of Awini. Nor have water-perching ash beds been noted, though locally they may
occur. Consequently, drainage to the ditch must consist predominantly of direct surface runoff
following rain showers, supplemented by minor bank storage leakage.

Along the ditch rain gage records at Awini, Honopue and Kukui show the average annual
rainfall averages 140-150 inches. There are no records for the 3 to 4 mile reach above the ditch
to the top of the drainage area at 4,500 feet elevation, but by analogy with rainfall distribution in
regions with similar exposure to the prevailing trades elsewhere in Hawaii it is likely that a
maximum annual average of more than 250 inches occurs at about 3,000 feet elevation. The
weighted rainfall average over the drainage area probably exceeds 200 inches per year. The
rain gage at the head of the Kehena Ditch at elevation 4,250 feet near the headwaters of
Honokane Nui shows a long term average of 165 inches per year, but this gage lies down the
rainfall gradient from the maximum isohyet.

The maximum monthly average rainfall occur in December, March, April, July and August,
the latter two months being considered among the driest in the agricultural region. The persist­
tent, strong tradewinds in July and August result in frequent orographic showers. In the winter
months cyclonic disturbances bring widespread rains. The driest sequence of months runs from
September through November.

**NATURAL FLOWS IN THE AWINI SECTION**

The total natural flow characteristics of the Awini drainage area are not reflected by the
measurements at gage 7430. The intakes, flumes, open ditches and tunnels of the Awini system
form a set of constraints which determine the quantity of surface water the system could handle
on an instantaneous basis. Gage 7430 provides data which only defines flow expectations of the
system as presently constructed. To evaluate natural flows in the drainage basins above the
ditch system, unconstrained flow records would be necessary.

Fortunately, the U. S. Geological Survey maintained gaging stations on six streams between
the terminus of Awini Ditch at Waikoloa and Kawainui at the approximate elevation of the ditch
for a minimum period of 10 years, though all stations have now been discontinued. Five of these
streams lie within 2.3 miles of Waikoloa Stream and drain a geologic-geomorphic-rainfall
region similar to the Awini drainage. Analysis of these flow characteristics can provide an
estimate of the characteristics of the natural drainage to Awini Ditch. A data summary for the five
streams is given in Table 1. Areas were determined by planimetry from the U.S.G.S. 1:24000 topographic sheets. The areas listed in the U.S.G.S. compilation of flow records (Water Supply Paper 1319, 1961; Water Supply Paper 1739, 1964) are in error except for Kukui and Kaimu Streams, presumably because areas for the other streams were planimetered from older, less accurate maps. The erroneous areas have been carried over into State of Hawaii Reports (R27, 1965; R34, 1970; R47 1973). For convenience, the five streams used for analysis will be collectively referred to as the Laupahoehoe streams to conform with the land subdivision within which they fall.

Table 1
Gaged streams of Laupahoehoe, from Waikoloa to Kaimu

<table>
<thead>
<tr>
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<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Kukui</td>
<td>7420</td>
<td>1940</td>
<td>0.21</td>
<td>1.29</td>
<td>6.14</td>
</tr>
<tr>
<td>Paopao</td>
<td>7410</td>
<td>1910</td>
<td>0.26</td>
<td>2.17</td>
<td>8.35</td>
</tr>
<tr>
<td>Waiaalala</td>
<td>7400</td>
<td>1880</td>
<td>0.10</td>
<td>0.71</td>
<td>5.18</td>
</tr>
<tr>
<td>Punalulu</td>
<td>7390</td>
<td>1870</td>
<td>0.80</td>
<td>4.14</td>
<td>7.10</td>
</tr>
<tr>
<td>Kaimu</td>
<td>7380</td>
<td>1980</td>
<td>0.90</td>
<td>5.54</td>
<td>6.16</td>
</tr>
</tbody>
</table>

2.27     13.85     6.10
(Total)  (Total)  (Weighted Av.)

Table 1 provides striking evidence that the natural flows of the Awini drainage must be far greater than those captured by the ditch system. If an average flow of 6 mgd per sq. mi., based on the Laupahoehoe weighted average from Table 1, is used for Awini, the total daily average flow of the sector would be 45 mgd (6 mgd x 7.5 sq. mi.) Gage 7430 at the western end of Awini records an average daily flow of only 11.7 mgd. Although it is not possible to capture the entire spectrum of instantaneous flows because of its broad range, it is likely that the ditch systems, or components of it, such as intakes and flumes, are under-designed with respect to the surface water available.

The natural flow duration curves for all of the streams in the Awini section may be constructed by extrapolating from the curves computed from the Laupahoehoe records. Figure 1 shows the flow duration curves for the five Laupahoehoe streams, and the weighted average curve on a flow per square mile basis. The synthetic flow duration curve for Awini as a single drainage unit is given in Figure 2, which also shows the real flow duration curve for gage 7430, representing only those flows caught by the ditch system. Data for the gage 7430 curve were obtained from the 1939 report of the Territorial Planning Board.
LAUPAHOEHOE STREAMS: FLOW-DURATION CURVES (U.S.G.S. GAGE NO.)
AWINI SECTION: FLOW - DURATION CURVES
NATURAL FLOW AND ACTUAL FLOW AT U.S.G.S. GAGE 7430
The 50 percentile natural flow of the Awini section is slightly less than 20 mgd; the 90 percentile, normally considered reliable base flow, is about 5 mgd. Records for gage 7430 show zero flow at times, but undoubtedly this happens only when flow is deliberately turned out from the ditch before reaching the gage. The minimum natural flow of the section should be 1.5 to 2.0 mgd.

Flow duration curves are actually probability statements about flow occurrences. A look at the curves shows that on an average daily basis the flows are approximately log normally distributed, that is, the frequency of the log of the flow follows the normal probability distribution. If the distribution were perfectly log normal, the curves would be continuous straight lines in Figures 1 and 2. Because the distribution is more near log normal than normal, the average daily flow and the 50 percentile flow are not equal. The computed average flow of the entire Awini section is 45 mgd, more than twice the median flow. This means that much of the flow volume results from high instantaneous flow rates.

Flow duration curves are useful in determining expected availability of water over long periods, such as the life of a large scale agricultural investment, but are not practical for short term evaluations. If a project life is about 10 years or more, flow duration curves are useful in calculating gross quantities of water available over the 10 year interval, thus permitting economic evaluations to be made of possible supplemental water sources. For instance, if a project were to have a 10 year life and only the natural flow from Awini were available, 90% of the time the expected flow would be 5 mgd or greater, so that if the project required a minimum daily flow of 5 mgd, arrangements would have to be made to provide an alternative water source for the 10% of the time the flows fell below 5 mgd. The practical usefulness of flow duration curves will become clearer when gage 7510 (Kohala Ditch at Pololu) is discussed, because this gage measures the output from the Kohala-Awini Ditch System to the Kohala agricultural sector.

Another way of looking at flow probabilities as related to irrigation requirements is to consider the recurrence intervals of low flows. Report R27 (1965) of the Division of Water and Land Development, State of Hawaii, discusses in detail the method of computing recurrence intervals and summarizes the relevant data from which these intervals could be computed for the low flows of the Laupahoehoe streams. Figure 3 gives the recurrence intervals for consecutive 7 day, 14 day, and 30 day natural low flows for the whole Awini drainage area as derived by linear extrapolation from data for the Laupahoehoe streams. The natural low flows probably coincide with the low flows measured at gage 7430 except during turn-out periods.

The graph really shows the probability of occurrence of given consecutive periods of low flows over a long span of time. For instance, it could be expected that once in every 10 years a natural low flow of 2.14 mgd will continue for 14 consecutive days, but such a phenomenon might occur more than once in one decade but not at all in another. Nevertheless, as with flow duration curves, low flow recurrence interval evaluations provide a basis for quantitatively considering alternative supplementary sources of water for long term projects.
AWINI SECTION: NATURAL LOW FLOW FREQUENCY CURVES
ACTUAL FLOWS FROM THE AWINI SECTION

The actual flows measured at gage 7430 at the western terminus of the Awini section are a depressed reflection of the natural flows of the drainage area. The average daily flow at gage 7430 is 11.7 mgd, while the computed natural flow is 45 mgd. The large difference is caused by the structural constraints of the collection and transmission components of the ditch system. For Hawaiian streams it is not feasible to design a system to collect all natural flows because of extreme instantaneous flow peaks, but it is probable that the actual average-to-natural average ratio of 0.26 for Awini is lower than that practicably obtainable.

In Figure 2 the marked depression of the flow distribution at gage 7430 below the natural flow duration curve is obvious. The absolute upper limit of flow in the ditch system is not accurately known but apparently is of the order of 33 mgd because records show that both the maximum instantaneous and maximum day flows are about 33 mgd. Thus the fraction of the natural flows exceeding the above overflow the system and are lost to the sea.

The median flow of 11 mgd at gage 7430 is nearly equal to the average flow of 11.7 mgd, suggesting the actual flows are more nearly normally distributed rather than log normally distributed as are the natural flows. This is an expectable phenomenon because of the truncation of high flows from the collectible range. The recorded minimum flow of the gage is zero, but this is probably the result of turn-outs during maintenance operation at the ditch; the actual minimum flow should equal the natural minimum flow of about 1.8 mgd.

Low flow recurrence intervals at the gage are likely to be identical to those of natural low flows (Figure 3) because at these levels the system could be expected to collect all flows.

The structural constraints which limit flow in the ditch system consist of intakes, tunnels, open ditches and flumes. If more water from the Awini section is required to satisfy needs in the future, a thorough study of the collection and transmission components will have to be made, but in the meantime an estimate of the present maximum transmission capacity is available from engineering descriptions of system components, of which the most absolutely limiting are the tunnels and open ditches. Table 2 summarizes estimated tunnel and ditch capacities for various flow regimes and assumed hydraulic parameters. The dimensions are from Bowles (1973), and the hydraulic parameters have been estimated by Akinaka & Associates, Ltd., Consulting Engineers.

The most probable estimate of the carrying capacity of the transmission components of the system lies between 33 and 45 mgd, a range within which the record maximum instantaneous and daily flow of 33 mgd falls. A conservative estimate of 35 mgd for transmission capacity is reasonable for purposes of analysis. This means that the average flow in the system must be considerably less than 35 mgd because many of the daily flow rates total less than the carrying capacity. It is not unreasonable to expect, however, a potential average flow rate greater than the current 11.7 mgd now recorded, particularly if the easily adjustable components of the system, the intakes and flumes, were improved. If the intakes are too small, much stream flow is
Table 2
Open channel flow calculations, rectangular section
Awini Ditch System

<table>
<thead>
<tr>
<th>Depth Water, ft</th>
<th>Velocity, ft./sec</th>
<th>Flow rate, cfs</th>
<th>Flow rate, mgd</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.10</td>
<td>21.00</td>
<td>13.57</td>
</tr>
<tr>
<td>3</td>
<td>2.40</td>
<td>36.11</td>
<td>23.34</td>
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<tr>
<td>4</td>
<td>2.60</td>
<td>52.18</td>
<td>33.73</td>
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<tr>
<td>5</td>
<td>2.75</td>
<td>68.80</td>
<td>44.47</td>
</tr>
</tbody>
</table>

(1) Computation by Akinaka & Associates, Ltd.
(2) Hydraulic parameters:
Manning coeff., n = .024 (rock-lined channel)
Slope = 0.10%
Section = 5 ft. square

wasted; if the flumes are too narrow, flow spills off to the gulches. Map II-1 shows the location of the components of the ditch system in the Awini section.

The flow duration characteristics of the Laupahoehoe streams extrapolated to the Awini section can be employed to determine the flow of the ditch system under given flow constraints, assuming that average daily flows are unit daily flows rather than means of instantaneous flows. This assumption obviously is not entirely realistic because reported daily average flows are the integration of many differing instantaneous flows, some of which exceed the average, others of which fall below the average, but nevertheless the theoretical model will provide guidance to estimating the developable portion of surface runoff in the drainage area.

On an integral day basis the carrying capacity of the system required to insure a selected average flow may be calculated by using volume duration and flow duration curves. The volume of outflow over time for all flow rates equal to or less than a given rate (e.g., system carrying capacity). Figure 4 is the volume duration curve of the natural flows of Awini as computed from extrapolation of comparable curves for the Laupahoehoe streams. Figure 4 shows, for example, that the outflow of the Awini section accruing from daily flows of less than 100 mgd amounts to 50% of the total outflow, which means that the averaged daily output for all flows less than 100 mgd is $0.50 \times 45 \text{ mgd} = 22.5 \text{ mgd}$.

To evaluate the theoretically developable flows of the Awini system under present fixed constraints, assume that the carrying capacity of the ditch-tunnel components is 35 mgd. From Figure 4, the volume outflow for flows equal to or less than 35 mgd is 22% of the total outflow, and thus the averaged outflow rate is $0.22 \times 45 = 9.9 \text{ mgd}$. However, the system also collects 35 mgd of all flows equal to or greater than 35 mgd; from the natural flow duration curve (Figure 3) it is noted that for 30% of the time (110 days each year) the daily flows exceed 35 mgd, and therefore the contribution to the system from these high flows averages: $110 \text{ days} \times 35 \text{ mgd} \div$
FIGURE 4

PERCENTAGE OF TOTAL VOLUME OUTFLOW FOR ALL FLOWS EQUAL TO OR LESS THAN INDICATED

AWINI SECTION: NATURAL FLOW VOLUME DURATION CURVE
365 days = 10.6 mgd. It follows that the total average flow collected by the Awini system should theoretically be: 9.9 mgd + 10.6 mgd = 20.5 mgd, if the capacity constraint is 35 mgd.

Figure 5 shows the theoretically expectable average flows of a collection-transmission system as a function of system constraints. The theoretical carrying capacity of the Awini system required to yield the current average flow of 11.7 mgd is only 14 mgd. The curve also shows that the rate of increase of average flow with increasing carrying capacity markedly decreases above a carrying capacity of about 40 mgd. This implies that the marginal cost of developing new water by enlarging tunnel and ditch capacities would have to be carefully scrutinized before additional investments were made.

The theoretical model is based on average daily flows and therefore the computed recoverable average value of 20.5 mgd would be valid only if instantaneous flows were distributed such that no instantaneous flow on a given day exceeded the average flow of that day, meaning that the reported daily average was constant throughout the day. This is not a realistic model for high rainfall Hawaiian conditions where streams are small and showers are numerous. To construct a more realistic model the distribution of instantaneous flows would have to be determined, but until such a laborious analysis is undertaken the theoretical model may be modified by a correction factor based on a first approximation of the distribution of instantaneous flows. The approximation assumes that half the instantaneous flows exceed the theoretical collectible average of 20.5 mgd, and half are uniformly distributed between 20.5 mgd and zero flow. This would result in average actual flow of: $0.75 \times 20.5 = 15.4 \text{ mgd}$, nearly 4 mgd greater than the present average at gage 7430. Most probably the developable average of the Awini system as presently constrained by tunnel and ditch dimensions lies between 15 mgd and 20 mgd. To achieve the developable average, the intake and flume components of the system will have to be improved.

**FLOWS FROM HONOKANE IKI**

A short distance to the west of gage 7430, the flows of East Honokane Iki are measured at gage 7440 before entering the ditch system. East Honokane Iki drains an area of 0.70 sq. miles, but the long term average flow at gage 7440 is only 1.2 mgd. The average natural flow is probably nearer 4 mgd, based on the measured natural flows of the Laupahoehoe streams.

Somewhat farther west of East Honokane Iki the ditch system crosses the West Branch of Honokane Iki but does not collect its water. The West Honokane Iki drainage area is 0.86 sq. miles, which should provide an average flow of approximately 5 mgd.

An evaluation should be made of the Honokane Iki drainage to determine whether a greater portion of the flow from the east branch could be captured and whether it is feasible to divert flow from the west branch to the collection system.
AWINI SECTION: EXPECTED AVERAGE DAILY DITCH FLOW AS FUNCTION OF TRANSMISSION CAPACITY
THEORETICAL MODEL BASED ON AVERAGE DAILY FLOWS
FLOWS FROM THE LAUPAHOEHOE STREAMS

The Laupahoehoe streams (Kukui, Paopao, Waiaalala, Punalulu and Kaimu) lie beyond Waikoloa, the Awini Ditch terminus, but represent an undeveloped surface water resource, which could be collected by extending the ditch system, should economic conditions justify. The average natural flow of these streams totals 13.9 mgd; the combined base flow is less than 1 mgd.

However, to capture the Laupahoehoe flows not only would about 2 miles of new ditches and tunnels have to be built, but the existing transmission system in the Awini sector would have to be substantially enlarged to handle both the Awini and Laupahoehoe flows. The new construction would be costly, an investment which would not likely to be economically feasible for a considerable time yet.

EAST HONOKANE NUI

The water from the Awini section flows through a tunnel parallel to and within the east wall of East Honokane Nui canyon, then plunges from an elevation of 1,840 feet to the canyon floor about 800 feet below. There it mixes with East Honokane Nui Stream and is diverted to a large intake a very short distance below the cascade. The intake is the origin of the Kohala ditch portion of the Kohala-Awini Ditch System.

The canyon of East Honokane Nui is deeply incised in Pololu basalt. It is a young erosional phenomenon with relatively unstable side-walls. The farthest accessible point in the canyon floor at the head of the canyon lies at an elevation of 1,730 feet, about 2,300 feet below the edge of the top of the canyon wall. The distance from the intake to the canyon head is about one and a half miles.

East Honokane Nui and West Honokane Nui meet at an elevation of 730 feet, a linear distance of approximately 4,000 feet downstream from the Kohala ditch intake. Below the confluence the slope of the canyon is a gentle 3 to 4 feet per 100 feet; above it the slope steepens to 10 per cent and greater. The stream loses its perennial characteristics a short distance below the confluence.

East Honokane Nui is eroded to a much deeper level than West Honokane Nui and as a consequence is the principal drain on the high level ground water in the region. The flow of West Honokane Nui is dependent on surface runoff from rainfall and is therefore less voluminous and far less reliable than the flow of East Honokane Nui.

The total area which under pre-development conditions would drain to the intake in East Honokane Nui is 5 sq. miles, but today the drainage from only 2.1 sq. miles moves freely to the intake, the drainage from the remaining 2.9 sq. miles falling within the Kehena Ditch System. The canyon area itself amounts to 1.29 sq. miles, and the slopes above the canyon total the other 0.81 sq. miles. During high surface flows, however, overflow from the Kehena ditch drains to the canyon.
Rainfall in the upper Honokane Nui drainage basin reaches an average maximum in excess of 200 inches per year. Near the confluence the annual average is 140 to 150 inches per year.

Upstream of the confluence the canyon of East Honokane Nui cuts deeply into the major rift zone of the Kohala volcano. The canyon is incised in basalts of the Pololu volcanic series, while the slopes south and west of the canyon head are covered by the more resistant andesites of the Hawi volcanic series. The rift zone has a northwest-southeast trend, extending from the original central caldera at the head of the Waipio drainage system through Honokane Nui and the most inland tip of Pololu Valley toward the northwest bulge of the island.

The dikes of the rift zone are approximately normal to the canyon, and as a result the high level ground water in the small aquifers between these nearly impermeable dikes discharges into East Honokane Nui Stream. The most downstream dike observed occurs as a weak intrusion near the confluence. The largest dike is the next one upstream, first occurring within 1,000 feet of the intake, then curving slightly from a strike of N 35° W to N 55° W and splitting into at least 2 discrete dikes near the intake. This single dike, identified by Macdonald (Stearns and Macdonald, 1946) as a trachyte dike of the Hawi series, is 15 to 20 feet thick and nearly vertical. According to Stearns, it also cuts the canyon head of Pololu Valley (See Map III-4).

This trachyte dike is so large and continuous that it may be used as the effective downstream boundary of the rift zone, even though it is much later in age than the Pololu basalts. Upstream of the intake, dikes become numerous, increasing in frequency toward the canyon head in conformance with the usual transition from the marginal dike zone, in which dike rock composes about 5 per cent or less of the total rock, to the dike complex, where dikes account for more than 5 per cent of the total rock. The head of the canyon has not yet been eroded into the core of the dike complex.

Stearns mapped 35 dikes in East Honokane Nui above the intake and 3 in West Honokane Nui. Other investigators corroborate Stearns and agree that near the head of East Honokane Nui ground water issues from the east wall of the canyon from dike compartments, evidence of the storage potential of the dike zone. Little ground water discharges from the west bank of the valley. In the early nineteen forties an attempt was made to exploit the dike water by driving a tunnel into the head of East Honokane Nui canyon at an elevation of 1,900 feet; the tunnel proved that storage capacity was available, but it did not develop new water as had been hoped.

Probabilities are excellent that the storage potential of the dike zone at the head of the canyon could be exploited. An especially noticeable opportunity may exist somewhat further downstream, at a valley floor elevation of 1,190 feet, where a spring on the east wall at an elevation of 1,772 feet apparently overflows the intersection of two dikes, one striking N 50° W and the other about E-W. The spring flows at a rate of approximately 0.1 to 0.3 mgd. Between this site and the canyon head other opportunities for exploiting storage in the east wall may occur.

Should the development of high level storage above stream level prove practical, flow would be by gravity and would require no energy input to direct it to the intake. High level storage also
occurs at and below stream level, but the ground water would have to be pumped to stream level to make it available to the ditch system. An attempt was made by Kohala Sugar Co. (1966) to determine the feasibility of developing ground water lying below stream level. Four AX core holes were drilled, three near the intake and one at a valley floor elevation of 1,196 feet. Because the holes were so small (1-7/8 inch diameter) the results of the infiltration and water level tests were ambiguous, as were core interpretations, but the indications were that the high level ground water table in the valley lay at stream level. This would be the expectable condition, the certainty increasing with distance toward the canyon head.

High level perched water also issues as springs from the east wall of East Honokane Nui. The perched water lies above ash beds occurring between the confluence and the intake. Under natural conditions the water seeped out of the valley wall to drain to the stream, but in the early nineteen thirties tunnels were driven on top of the ash beds to concentrate the flow which totalled about 2 mgd. Until several years ago the tunnel flow was directed to two pumps energized by hydraulically driven turbines to lift water from the stream below the intake to the intake. The operation of Pump 2 was discontinued about 15 years ago. While in combined operation, the pumps delivered 1 to 2 mgd to the intake.

The floor of Honokane Nui is covered with poorly sorted alluvium resulting from normal fluvial processes and from catastrophic phenomena, particularly landslides induced by earthquakes. Stearns in his investigations observed valley debris caused by earthquakes, and during a recent field trip to East Honokane Nui the landslides induced by the April 1973 earthquake were seen to cover significant portions of the valley floor toward the canyon head. The valley is in an early stage of development and the canyon walls have not attained equilibrium slopes.

The East Honokane Nui section provides opportunities for additional water development, most importantly under present constraints in terms of subsurface storage rather than increments of new water. But as in the Awini section, more surface runoff could be captured if the components of the ditch system were improved. Available water resources in Awini are restricted to surface flows; in East Honokane Nui both ground water and surface water are exploitable.

NATURAL FLOWS OF EAST HONOKANE NUI AND OTHER AREAS ANCILLARY TO GAGE 7510

The flows of East Honokane Nui consist of dike water, perched water, and direct surface runoff. These flows combine with the waters from the Awini section and East Honokane Iki practically at the Kohala ditch intake on the west bank of the stream.

Miscellaneous measurements have been made of East Honokane Nui flow above the intake but no long term station has been established. The U.S.G.S. constructed gage 7475 about 500 feet upstream from the intake in 1963, but the records are poor and the station was discontinued.
in 1969. Minimum recorded daily flow was 9.1 mgd, the maximum 97 mgd over the period March 1963 to September 1969 (U.S.G.S., 1969). The minimum flow represents the ground water component of the drainage region above the intake.

U.S.G.S. gage 7510 on Kohala ditch where it crosses into west Pololu Valley has a 46 year record, and it, along with gage 7430 at Awini, can be used to define the regional contributions to the ditch system. Correlation between gage 7430 and gage 7510 may also be used to determine natural flows at the lower end of the flow range in East Honokane Nui, and by linear extrapolation of these flows the natural flow duration curve and low flow recurrence intervals for the stream above the intake. Gage 7510 integrates the flows from Awini, East Honokane Iki, East Honokane Nui, West Honokane Nui, and East Pololu, but about 90 per cent of the average flow at the gage comes from Awini and East Honokane Nui.

Figure 6 is a correlation plot of flows at gage 7510 and gage 7430 for the low flow range (≤ 20 mgd). At these low flows the Awini ditch is assumed to collect essentially all of the drainage from its area, as gage 7510 is assumed to represent the total low flows from its various sectors. The values used in the plot are the daily flows in c.f.s. for the months of October and June, two of the driest months of the year, over the period 1959-1964 (U.S.G.S., Water Supply Paper 1937, 1971). Assuming a linear correlation over the entire range of flow, the correlation equation for the low range can be employed to determine the higher natural flows in East Honokane Nui. The spread about the correlation line in Figure 6 is due in part to contributions from East Honokane Iki, West Honokane Nui, and East Pololu as flows increase. The correlation line was drawn as a best fit rather than statistically computed.

The correlation equation in units of mgd (note that the plot values are in units of c.f.s.) is:

\[ Q_{7510} = 9.7 + 1.5 Q_{7430} \]

where \( Q_{7510} \) is flow at gage 7510 and \( Q_{7430} \) is flow at gage 7430. The intercept, 9.7 mgd, is equivalent to the ground water flow from East Honokane Nui above the Kohala ditch intake.

Actually, the intercept at the true Awini minimum flow of about 1.8 mgd should be used, but this value of 11.6 mgd must be diminished by the 1 to 2 mgd contributed to the intake from the stream below the intake by Pumps 1 and 2, and by the small flow (≤ 0.5 mgd) from O'Shaugnessy Tunnel. The net result is that the correlation equation is approximately correct; the intercept (ground water) may be closer to 9 mgd than 10 mgd, however.

This ground water component of 9 to 10 mgd is supported by the minimum flow of 9.1 mgd recorded at gage 7475 located upstream of Awini Falls. Stearns estimated the base flow above the intake to be 10.5 to 13.5 mgd, including 1.4 mgd diverted to the intake from the ash beds below it. Ned Broadbent on September 1, 1953, during an extremely dry period, made current meter measurements from the head of the canyon to the intake and concluded that the ground water flow to the intake amounted to 8.8 mgd. Tuttle (1910) estimated the dry weather flow at the confluence to be about 8.7 mgd. It is quite clear from the data and observations available that the base flow, equivalent to the high level dike water component, of the stretch of East Honokane
FIGURE 6

KOHALA DITCH GAGE 7510, cfs

AWINI GAGE 7430, cfs

CORRELATION DAILY FLOWS:
MONTHS OF OCTOBER AND JUNE,
1959-1964.
EQUATION:
cfs UNITS: \( Q_{7510} = 15 + 1.5Q_{7430} \)
MGD UNITS: \( Q_{7510} = 9.7 + 1.5Q_{7430} \)

GAGE 7510 AND GAGE 7430: CORRELATION DIAGRAM
Nui between the intake and the canyon head, is no more than 10 mgd and, more likely, is closer to 9 mgd.

The equation of input to gage 7510 can be stated as follows:

\[ Q_{7510} = GW + SW + Q_{7430} + Q_i \]

where GW is the ground water from East Honokane Nui; SW is the surface water from the same area; \( Q_i \) is the combined contributions from East Honokane Iki, West Honokane Nui, and East Pololu. By substituting the correlation equation into the above, the following results:

\[ SW + Q_i = 0.5 Q_{7430} \]

This equation applies to East Honokane Nui, as it is presently affected by Kehena ditch - capture of water from its upper drainage basin.

Taking the average flow at gage 7430 as 45 mgd, \( SW + Q_i = (0.5) (45) = 22.5 \) mgd. The approximate average natural flows, on the basis of drainage areas, for East Honokane Iki, West Honokane Nui, and East Pololu are 4.2, 4.0, and 0.5 mgd, respectively, for a total of 8.7 mgd, leaving the natural average surface water component of East Honokane Nui as 13.8 mgd. If Kehena ditch, which has an average flow of 7.4 mgd, were not intercepting drainage which would naturally go to Honokane Nui, the average total surface water component of both branches of the valley above the intakes would be 13.8 + 7.4 = 21.2 mgd. Natural drainage to West Honokane Nui now intercepted by Kehena would average approximately 1.4 mgd, giving the unconstrained average natural surface water input to East Honokane Nui of 19.8 mgd. Thus the pre-development average natural flow of East Honokane Nui above the intake totalled 29.5 mgd, of which 9.7 mgd was ground water and 19.8 mgd was surface water. With Kehena ditch as a constraint, the average natural flow above the intake is 9.7 + 13.8 = 23.5 mgd. Evidently not all of the surface water of East Honokane Nui is captured at the intake, for if it were the average flow at gage 7510 would be at least 35.2 mgd, the combined flow of gage 7430 (11.7 mgd) and 23.5 mgd, rather than the recorded long term average of 26.7 mgd.

The correlation equation may be used to construct an approximation of the flow duration curve which describes the flow characteristics of natural flows from all drainage areas ancillary to gage 7510 with the exception of the flows intercepted by the Kehena ditch. Figure 7 shows this curve and also the actual flow duration curve at the gage.

Natural low flow recurrence intervals for gage 7510 are given in Figure 8. A scan of the records covering the severe drought of 1962 shows that for the 27 days between October 26 and November 22 the flow was only 9.7 mgd, while at gage 7430 at Awini it ranged from 0.2 mgd to 1.2 mgd. This phenomenon probably has a recurrence interval of far greater than 10 years, yet during another drought in 1965 the flow at 7510 was only 11 mgd for 30 days, which would also have a recurrence interval in excess of 10 years. These examples illustrate the statistical nature of the concept of low flow recurrence intervals and the corollary that such a concept is meaningful only over long periods of time.
KOHALA DITCH GAGE 7510: FLOW-DURATION CURVES, DAILY BASIS
FIGURE 8

KOHALA DITCH GAGE 7510: NATURAL LOW FLOW FREQUENCY CURVES
ACTUAL FLOWS AT GAGE 7510

According to Randolph (1965) the transmission capacity of Kohala Ditch is 65 mgd, but Stearns gave it as 76 mgd. The maximum recorded daily flow at gage 7510 has been 66 mgd, and the maximum instantaneous flow 76 mgd (Territory Hawai'i, 1939). The probable transmission capacity lies between 65 and 75 mgd, which is a somewhat less than optimal design for the quantity of flow potentially available.

The intake to Kohala ditch lies at an elevation of 1,040 feet just upstream from a small concrete retaining dam. The dam does not appear to be able to retard high flows and, in fact, leaks even during low flows. Undoubtedly a significant portion of flush flows caused by high rainfall overspills the dam. Whether this loss is meaningful is questionable, however, since the terminal storage of the ditch system is very small.

Gage 7510 because of its long continuous record is the most reliable measure of the quantity of water delivered to the agricultural region from the ditch complex east of Pololu Valley. The flow duration curve of actual flows at 7510 on a daily basis is given in Figure 7. This curve may be used to estimate the supplementary water needed to satisfy a given daily requirement over a very long time scale. For example, if the agricultural region needed a minimum of 20 mgd every day, the curve shows that 30 per cent of the time (110 days per year) supplementary water would have to be provided. Further refinement of actual additional requirements may be made by averaging over duration intervals; thus, 25 per cent of the time (91 days per year) the expected flow would fall between 10 and 20 mgd, or an average of 15 mgd, and a supplement of 5 mgd would be necessary to satisfy the 20 mgd requirement. For the remaining 5 per cent of the time (19 days per year) a supplement of 11 mgd would be required.

Most agriculture is not so tightly constrained as to require an absolute daily input of water. The use of a longer time interval for flow averaging is more practical because agriculture practices can be manipulated to utilize lower irrigation flow rates during short periods of drought. Average monthly flows are a reasonable compromise for evaluating the temporal distribution of input to Kohala via gage 7510.

Figures 9 and 10 show the flow duration curves on a monthly basis for gage 7510 for the 33 year period 1928 through 1960, and Table 3 summarizes some of the instructive flow parameters. Flows for each month are essentially normally distributed, probably because the ditch system does not efficiently collect high flows and because the period of aggregation of flows is relatively long. The normality of the distribution is reflected by the close agreement between the means and medians as given in Table 3; in a perfectly normal distribution the mean and median would be equal.

The monthly flow duration curves exhibit numerous striking features. First, the dry summer months of July and August provide the highest average and median flows and the nearly highest low flows in contradistinction to the hot and dry weather conditions in the irrigated region. The high summer flows result from numerous persistent orographic showers in Awini and Honokane
KOHALA DITCH GAGE 7510 (1928-1960): FLOW DURATION CURVES, BY MONTHS
Nui, from which a large fraction of the direct runoff is collected by the ditch system because instantaneous flow peaks are not as high as during the sporadic winter storms. This phenomenon is a positive benefit to agricultural planning.

Another feature is the small spread between average flows among months. The highest (31.7 mgd in July) is only 7.7 mgd greater than the lowest (24.0 mgd in February). Also, the difference between the percentile flows for each month is not extraordinarily great as it is for the log normal distribution characteristic of natural daily flows; for instance, the July 90 percentile flow is 23.9 mgd and the median 31.9 mgd, a difference of 8 mgd, while the 10 percentile is 40.8 mgd, indicating that the high flow range is less than double the low flow range. Minimum average flows are substantial but are unusually low for the months of February, September and October.

Table 3

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean</th>
<th>Median</th>
<th>90th Percentile</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>24.1</td>
<td>24.5</td>
<td>18.1</td>
<td>14.9</td>
<td>35.5</td>
</tr>
<tr>
<td>February</td>
<td>24.0</td>
<td>24.3</td>
<td>15.2</td>
<td>8.6</td>
<td>37.1</td>
</tr>
<tr>
<td>March</td>
<td>27.0</td>
<td>28.4</td>
<td>18.7</td>
<td>15.1</td>
<td>38.4</td>
</tr>
<tr>
<td>April</td>
<td>30.2</td>
<td>30.0</td>
<td>24.0</td>
<td>18.1</td>
<td>39.3</td>
</tr>
<tr>
<td>May</td>
<td>30.0</td>
<td>30.0</td>
<td>23.8</td>
<td>21.3</td>
<td>39.4</td>
</tr>
<tr>
<td>June</td>
<td>29.1</td>
<td>29.0</td>
<td>21.8</td>
<td>20.6</td>
<td>43.0</td>
</tr>
<tr>
<td>July</td>
<td>31.7</td>
<td>31.9</td>
<td>23.9</td>
<td>18.3</td>
<td>40.7</td>
</tr>
<tr>
<td>August</td>
<td>31.0</td>
<td>30.7</td>
<td>23.0</td>
<td>17.0</td>
<td>47.4</td>
</tr>
<tr>
<td>September</td>
<td>24.3</td>
<td>24.0</td>
<td>19.3</td>
<td>10.6</td>
<td>31.5</td>
</tr>
<tr>
<td>October</td>
<td>21.8</td>
<td>21.9</td>
<td>16.7</td>
<td>9.0</td>
<td>30.1</td>
</tr>
<tr>
<td>November</td>
<td>25.3</td>
<td>25.7</td>
<td>16.0</td>
<td>16.3</td>
<td>36.0</td>
</tr>
<tr>
<td>December</td>
<td>26.4</td>
<td>26.6</td>
<td>18.8</td>
<td>12.1</td>
<td>43.2</td>
</tr>
</tbody>
</table>

The monthly flow duration curves may be put to practical use in agricultural planning as noted earlier, the flow duration curve is a probability statement, and for any long term investment, the quantity of supplemental water, if required, could be computed. The costs of developing the supplementary water supply would then determine the feasibility of the project.

For example, if a crop were planted which had some resilience to drought such that it could survive for several weeks without irrigation, the monthly flow duration curves indicate the summation of time during which supplemental water might be required. Growing conditions differ for each month, but for purposes of explanation assume that the required input to the agricultural region during July totals 600 mg (million gallons), equivalent to 19.4 mgd, although
no one day might actually yield exactly 19.4 mgd. Expectably, 97.5 per cent of all Julys would meet this requirement; 2.5 per cent would require supplemental water, or one July out of 40. But if the requirement totalled 1000 mg, approximately 50 per cent of all Julys would produce less than this, and over the life of the investment supplementary water would be required one out of two years.

To compute the actual quantity of supplementary water needed, average flows within duration intervals are determined and subtracted from the required flow, giving the needed supplementary flow for that period of time. For example, if the July requirement were 32.3 mgd, computations suggest that a supplemental source of about 10 mgd would have to be available. If basal ground water were the alternative source, a minimum of five 2 mgd wells would be necessary.

**ADDITIONAL WATER DEVELOPMENT IN HONOKANE NUI**

The only additional sustainable supply of water which could be exploited in Honokane Nui above the Kohala ditch is the surfac runoff that escapes the intake. All of the sustainable ground water except the leakage through the intake dam is already captured, although water stored in dike compartments can provide temporary additional increments to total flow.

An average surface runoff of about 10.6 mgd is not now captured by the ditch system. This does not include the 7.4 mgd intercepted by Kehena ditch in the upper part of the drainage area. To capture a portion of the escaping runoff the intake structures will have to be greatly improved. Not all of the 10.6 mgd is collectible in any event. Some part of it results from extremely high instantaneous flow rates which even the transmission ditch could not handle. With improvements, perhaps half (say 5 mgd) of the overflow may be saved.

Below the intake dam several million gallons per day could be pumped to the tunnel as in the past but an outside source of energy would be required unless the old hydraulic system is repaired or a new one installed.

Although no new significant sustainable yields of ground water are obtainable from Honokane Nui, in the dike zone a large volume of water is stored which could be exploited by withdrawing it in a controlled way. The inter-dike aquifers could also be used to store surplus runoff for later withdrawal.

An effort was made between 1942 and 1946 to develop additional water in Honokane Nui by driving a tunnel normal to the rift zone at the head of the canyon starting at an elevation of 1,900 feet, about 200 feet above the canyon floor. The purpose was to find new water. but subsequent experience there and elsewhere showed that tunnels penetrating dike compartments merely concentrate flow which normally overflows the compartments to drain to the streams cutting them. Before the tunnel was driven normal flow at the head of the canyon was 1.5 to 2.0 mgd; after the ground water storage had been drained by the tunnel by mid-1950, the base flow at the head of the canyon returned to its initial value.
The tunnel (U.S.G.S. No. 36) was started in January of 1942 and completed in December, 1946, five years later (See Map III-4). Construction was frequently discontinued for long intervals. The tunnel has a bearing of S 29° 30' W, approximately perpendicular to the trend of the rift zone and the principal strike of the dikes. It is 1,862 feet long; a 129 feet lateral was driven several hundred feet in from the portal. Twenty-three dikes were encountered, totalling just about 5 per cent of the rock mass. Frequency of occurrence of the dikes indicates that the tunnel lies mainly within the marginal dike zone rather than the dike complex. Dike thicknesses range from less than one foot to nine feet with most of them less than four feet.

Apparently no exceptionally large flush flows were experienced during tunnelling. As digging proceeded, flow gradually increased to a maximum of 6.6 mgd in December of 1945, then very gradually declined thereafter. From the records, no particular dike stands out as having been a key control on stored water.

An analysis was made of the flow record for the decay period, starting with the maximum flow of 6.6 mgd, in order to estimate the recession constant and the maximum storage of the entire tunnel system. Figure 11 is a plot of the available data from which the decay equation has been computed.

The recession constant is quite small \( a = .00075 \), indicating more poorly permeable conditions than is ordinarily encountered in the marginal dike zone. The decay equation is:

\[
Q = 6.6 \exp(-.00075 \cdot t)
\]

in which \( Q \) is the flow rate in mgd at any time \( t \), in days, after the start of decay. For \( Q \) to reach the base flow of approximately 2 mgd, a period of 1,592 days (4.36 years) was needed. Decay started January 1, 1946, and base flow was reached in early May, 1950.

The total volume output of the tunnel during the 1,592 days of decay was:

\[
V = Q_0/a = 6.6/0.00075 = 8800 \text{ mgd}
\]

where \( V \) is the total volume, and \( Q_0 \) is initial flow. Of the 8800 mg, base flow accounted for 2 mgd \( \times 1,592 \text{ days} = 3184 \text{ mgd} \), leaving 5616 mg as storage output. Also, graphical integration of the record between October 1, 1943, the start of flows exceeding 2 mgd, and December 31, 1945, yields a total output of 3270 mgd, of which 1640 mgd was base flow, leaving 1630 mgd as storage flow. If the small flows between August 1, 1942 and October 1, 1943, each less than 2 mgd but totalling 390 mgd, are considered storage flows, the total storage output, \( V_s \), from the tunnel system amounted to:

\[
V_s = 5616 + 1630 + 390 = 7636 \text{ mgd}
\]

From the decay equation and assuming instantaneous penetration of the dikes, the theoretical initial flush flow, \( Q_i \), of the system is calculable as:

\[
Q_i = Q_{os} + Q_R = (.00075) (7636) + 2 \text{ mgd} = 7.7 \text{ mgd}
\]

where \( Q_{os} \) is initial flow from storage and \( Q_R \) is base flow.

The key characteristics of the high level dike aquifers as indicated by the analysis of Tunnel 36 are that the rock is only moderately permeable, the storage volume is very large, and the
FIGURE II

TUNNEL 36, EAST HONOKANE-NUI: FLOW DECAY CURVE

\[ Q = 6.6e^{-0.0075t} \]
storage flow rates are moderate. As a consequence, where storage is properly exploited, flows in excess of base flow could be expected to occur over a long period of time.

In 1948, before decay from storage was completed, a bulkhead was placed across the tunnel about 495 feet from the portal at an eight inch dike in an effort to save storage water. The bulkhead was first closed and tested in 1949. Pressure rapidly built up to a maximum of 99 psi behind the bulkhead and a maximum flush flow of 9.7 mgd was measured. The decay was rapid, the computed recession constant being $a = .01$, considerably greater than the whole tunnel recession constant.

A second test on March 2-12, 1949, also before the original decay was completed, gave a maximum pressure build-up of 99 psi, a maximum flush flow of 7 mgd, and a recession constant of .0186, from which a computed storage volume of 376 mg could be derived. Flow decayed from 7 mgd to 5.8 mgd over the five day period.

Another test in January, 1953, after original storage was lost, showed a flush flow of 5 mgd, a recession constant of .02, and a computed volume of 250 mg. Although the results of the three tests differ they are in approximate agreement, given the difficult conditions under which the tests were conducted. Evidently, the bulkhead as located could only store up to about 300 mg and provide a maximum flush flow between 5 and 9 mgd.

At present Tunnel 36 is almost impossible to reach by foot and to attempt further use of the tunnel for ground water storage would require much effort and great cost. The bulkhead is not optimally located with respect to storage. Any effort to exploit the storage potential of dike compartments should probably be done elsewhere and by means other than tunnelling. A logical development site is in the valley at the head of the canyon at elevation 1,730 feet, directly below Tunnel 36. A horizontal drill hole would be preferable to tunnelling. At this site the base flow that now drains to Tunnel'36 would be captured and 170 feet of storage could be exploited.

Another possibility occurs where two dikes intersect on the east wall of the canyon where the stream elevation is 1,190 feet. From the exposed top of the intersection at elevation 1,772 feet a spring discharges about 0.1 to 0.3 mgd; if the rock is saturated from the valley floor to the spring, a difference of 582 feet, the enclosed dike compartment may store a large volume of water.

Whether the intersecting dikes indeed enclose a saturated compartment could be easily proved with a horizontal drill hole. If proven so, the storage volume could be manipulated to yield high rates of flow to meet short term demands.

It should be reiterated that the exploitation of dike water will not provide new sustainable ground water supplies. Daily infiltration to the dike compartments already finds its way to the stream; additional development would only add stored water, a one time resource. More importantly, however, it would provide opportunities to manipulate storage volumes so that appreciable flows could be withdrawn in times of need.
Dale Sproat, a legend in Kohala, rambles along the famed Kohala Ditch Trail with a couple of his "friends".
Kohala abounds with small plantation towns which have disappeared from the scene in many other places throughout the State. Hawi town is typical but deteriorating fast.

Quaint friendly wooden buildings with a western-like facade are showing the ravages of time. Kapaaau is in need of renovation to carry on as the civic center of Kohala.

A remnant of the once flourishing Chinese culture in North Kohala is reflected in this Chinese Society building at Makalapa.
SUMMARY OF ACTUAL FLOWS IN THE KOHALA-AWINI DITCH SYSTEM
AND OF NATURAL FLOWS IN ITS DRAINAGE AREA

Figure 12 gives two flow diagrams for the Kohala-Awini Ditch System, one of the average natural flows of the drainage areas above the collection and transmission structures, excluding the flow intercepted in the upper portion of East Honokane Nui by Kehena ditch, and the other of the average actual flows which eventually reach gage 7510 on the ditch in Pololu Valley. The natural flows expectably are much greater than the actual flows measured in the ditch at the output points for each drainage unit. The natural surface water components exceed the comparable collected components by a factor of about three.

The relatively moderate actual flows result from structural constraints of the ditch system. However, the natural flows could not under any reasonable design be captured in their entirety by a collection and transmission complex. For example, instantaneous flows of greater than 1000 mgd are not uncommon in the Awini section, and their full capture would require enormous intake and carrying facilities. A detailed study of the distribution of instantaneous flows would be necessary before an optimal design of the collection and transmission system were possible.

On the other hand, the existing ditch complex could probably be improved at an acceptable cost to yield a greater average flow to gage 7510. The intakes and flumes of the Awini section should be examined and reconstructed if necessary to enhance efficiency. The Kohala ditch intake and its small retaining dam in East Honokane Nui should also be examined. The moderate effort required for these improvements would probably result in an average flow at gage 7510 of between 30 and 35 mgd rather than the current 26.7 mgd.

The fraction of the natural flows which could be handled by the ditch complex is ultimately limited by the transmission capacities of the tunnels. These limits will also determine whether any of the flow from the Laupahoehoe streams could be diverted to the Awini ditch. Although the average flow from the Laupahoehoe streams is nearly 14 mgd, the present flumes and tunnels of Awini may not be able to accept any of it because of their suboptimal size. A detailed engineering analysis will have to be made of the Awini ditch system before any decisions are made to seek additional water from the Laupahoehoe streams.

KEHENA DITCH SYSTEM

Kehena Ditch was constructed between 1912 and 1914 in an apparent effort to supplement the water supply of the already completed Kohala-Awini Ditch system. The ditch originates as an intake at elevation 4,250 feet on Honokane Nui Stream approximately 4,000 feet upstream of the point where the stream cascades over the lip of the pali of the East Branch of Honokane Nui. It follows a generally northwesterly direction for about 15 miles to empty in the terminal reservoir at Puuokumau at elevation 1,800 feet. Most of the transmission system consists of unlined open...
I. AVERAGE NATURAL FLOWS (M.G.D.) IN THE KOHALA-AWINI DITCH SYSTEM DRAINAGE AREA EXCLUDING THE FLOW CAPTURED BY KEHENA DITCH

KEHENA DITCH 7.4

AWINI 45.0

E. HONOKANE IKI 4.2

E. HONOKANE NUI SURFACE WATER 13.8

W. HONOKANE NUI 4.0

E. POLOLU 0.5

LAUPAHOEHOE STREAMS 13.9

TOTAL 45.0

TOTAL 49.2

TOTAL 72.7

TOTAL 77.2

E. HONOKANE NUI GROUND WATER 9.7

II. AVERAGE ACTUAL FLOWS (M.G.D.) IN THE KOHALA-AWINI DITCH SYSTEM

KEHENA DITCH 7.4

18 AWINI INTAKES

E. HONOKANE IKI

E. HONOKANE NUI SURFACE WATER 3.2

W. HONOKANE NUI

E. POLOLU 1.0

GAGE 7430 11.6

GAGE 7440 1.2

KOHALA DITCH INTAKE 25.7

E. HONOKANE NUI GROUND WATER 9.7

KOHALA DITCH GAGE 7510 AT POLOLU 26.7
ditch (approximately 12 miles); only about 2.5 miles consists of tunnels. The ditch system is described in detail by Randolph (1965) and the State of Hawaii Department of Land and Natural Resources Circular C53 (1969).

According to Randolph the ditch system includes 84 intakes over its full length, but most of the water is captured in a source area of high rainfall in the headwaters of the drainage basins of the East and West Branches of Honokane Nui. Gage 7550, whose record extends from 1929 through 1965, was located at elevation 3,850 feet near the canyon head of the West Branch of Honokane Nui and consequently measured most of the flow tributary to the ditch.

The elevation of the source area above gage 7550 varies from 4,000 to 5,500 feet. In this area the ditch system captures flow from 11 drainage basins ranging in size from 0.09 to 1.08 square miles over a reach of about 4 miles (Circular C53). The largest drainage unit is unnamed on the standard topographic map but was referred to as "Big Gulch" by Randolph. In the drainage basin of the East Branch of Honokane Nui 2.90 square miles lies above the ditch, and from the headwaters of the West Branch .73 square miles drains to the ditch, giving a total source area drainage of 3.63 square miles (note: in C53 drainage area is established as 3.75 square miles; in Randolph as 3.4 square miles; the value of 3.63 square miles is derived from planimetric measurements by Akinaka & Associates, Ltd.).

The average annual rainfall in the source area ranges from 125 inches at gage 7550 to 165 inches at the intake on Honokane Nui. The highest rainfall is on the decay gradient from the maximum regional isohyet, which lies somewhat to the north in the Awini section drainage region. For the 3.63 square miles above gage 7550 the weighted average annual rainfall approximates 140 inches.

All of the source area and the remainder of the ditch traverse except for one to two miles near its terminus at Puuokumau is covered by andesite, trachyte, and related pyroclastics of the Hawi volcanic series. According to Stearns and Macdonald (1946) the andesite forms a carapace 10-150 feet thick, averaging about 40 feet, over the far more permeable Pololu basalt. Trachyte has a very limited distribution, as do the pyroclastics, relative to the andesite. Because the permeability of the andesite is considerably less than that of the basalt, its runoff-rainfall coefficient is greater. Another feature resulting from the low andesite permeability is the occurrence of swamps in the high rainfall area. Water draining from the swamps is amber-colored from high concentrations of organic decay products such as tannic and humic acids.

Drainage to Kehena Ditch consists almost entirely of direct surface runoff from rainfall; the small quantity of swamp seepage and bank storage which also drains to the ditch ceases entirely during extended dry weather. As a result, flow characteristics of Kehena more nearly resemble the Awini section, which also collects only surface water, than the East Branch of Honokane Nui, which captures a large volume of ground water.

Randolph states that the capacity of the ditch is 50 mgd, while Stearns and Macdonald report it as 86 mgd. These estimates were probably made from gage 7550 records, which show
a maximum integrated daily flow of 54 mgd and a maximum instantaneous flow of 86 mgd (Terr. Hawaii, 1939). The average flow at 7550 for the period of record (1920-1965) was 7.4 mgd (U.S.G.S., 1971). Figure 13, redrawn from a graph given in Circular C53, is the duration curve of daily flows at gage 7550. The shape of the curve resembles gage 7430 (Awini) and gage 7550 (Kohala) in illustrating the effects of an upper limit on capacity in the high flow range.

Kehena is neither an efficient collector nor transmitter of runoff from its source area. It collects a greater proportion of available runoff than does the Awini system but its efficiency of transmission is grossly poorer. Kehena is an unlined ditch and seepage losses are enormous. Randolph analyzed measurements of flows at gage 7550 and at the entrance to Puuokumau Reservoir over a six-month period through June, 1964, and concluded that over the 8 mile stretch of unlined ditch 80% of the flow leaving gage 7550 was lost by seepage. He also noted that flow at 7550 must be at least 2 mgd before any of it could reach the reservoir. A flow of 2 mgd is the 65 percentile on the flow duration curve, indicating that on the average flow from the source area reaches the reservoir only 128 days of the year. Ditch losses in the source area are also analyzed in Circular C53.

At best the Kehena System is an erratic source of water supply. The median flow at gage 7550 is 3.8 mgd, just about half the average flow. The 90 percentile flow is only 0.3 mgd, and consecutive no flow days are common. During the drought of 1962, for 41 consecutive days in October-November no flow could be measured. For the entire period of record the maximum run of no flow days totalled 71, occurring in September-November, 1929 (Circular C53). On the average 18.9% of the days from September through February and 5.8% from March through August recorded no flow (Randolph). Typically 56 days of each year show no flow.

Figure 14 is a plot of low flow frequency curves for 7, 14 and 30 day intervals (data from Circular C53). The recurrence intervals for these selected low flows compare very unfavorably with the Awini section when recomputed to a standard datum, such as mgd/sq. mile. For instance, a recurrence interval of five years gives a 30 day low flow of .25 mgd (.07 mgd/sq. mile) at Kehena while at Awini it gives 4.8 mgd (.64 mgd/sq. mile), greater by a factor of nearly ten. Part of the difference is due to higher rainfall in Awini and its more equable distribution throughout the year, and part is due to the large leakage losses in Kehena Ditch. On the other hand Kehena captures an average of 2.03 mgd/sq. mile compared to average Awini capture of 1.56 mgd/sq. mile, even though the rainfall in Awini is appreciably greater than in the Kehena drainage, illustrating the higher efficiency of the collection components of the Kehena system.

Figure 15, also taken from Circular C53, shows average flows at gage 7550 on a monthly basis. The relative distribution of flows resembles that at gage 7510 on Kohala Ditch in that the high averages occur from March through August and the lowest during September and October.

Like the collection-transmission system of the Awini sector, and to a lesser extent that of the East Branch of Honokane Nui, the Kehena system accounts for only a fraction of available direct surface runoff in its source area. An average rainfall of 140 inches per year, equivalent to 6.7
FIGURE 13

KEHENA DITCH GAGE 7550 - FLOW DURATION CURVE
(DATA FROM DLNR CIRCULAR C 53)
KEHENA DITCH GAGE 7550 - NATURAL LOW FREQUENCY CURVES
(DATA FROM DLNR CIRCULAR C53)
STREAM DATA

Period of Record —— 1929-1966
Max. Daily Flow —— 54 mgd
Mean Daily Flow —— 7.35 mgd
Min. Daily Flow —— 0 mgd

KEHENA DITCH GAGE 7550 - MEAN MONTHLY FLOW
(DATA FROM DLNR CIRCULAR C 53)
mgd/sq. mile, falls on the drainage tributary to gage 7550. From analyses made earlier for the East Branch of Honokane Nui the average surface runoff rate under natural conditions (i.e. no intercepting ditches) for the area above the Kohala Ditch intake would be 19.8 mgd from 5.0 square miles, or just about 4 mgd/sq. mile. This value is substantiated by data derived for the Kohakohau Dam study (Parsons, et al., 1970) which lists runoff rates for similar predominantly Hawi andesite terrains and similar rainfall regimes. In that study flows per square mile for streams without significant diversions ranged between 5.62 (Waikoloa) and 3.98 (Kawaiki).

Applying an average natural surface runoff rate of 4 mgd/sq. mile to Kehena above gage 7550 the runoff-rainfall ratio would be 4/6.7 = 59.7%, and the average runoff potentially available to the ditch would be 3.63 sq. miles × 4 mgd/sq. mile = 14.5 mgd. The measured average flow at gage 7550 is 7.4 mgd, or 51% of the total runoff. This fraction is considerably greater than for the Awini section, but it probably could be further increased by improving the intake structures and lining the ditch.

The most constraining factor on the ditch system as a dependable supplier of water to Puuokumau Reservoir is its high leakage rate. No matter how efficient the collection components in the source area may be, very little water will reach the reservoir unless the ditch is lined throughout its length with gunite or some other sealant. If this is not done, the agricultural area will not be able to look to the ditch for a reliable supply of supplemental water. If repairs are made, it is not unreasonable to expect the ditch to yield an average flow in the neighborhood of 10 mgd. Such a flow regime would take the Kehena system an important contributor to the irrigation of presently under-utilized lands near Mahukona.

POLOLU VALLEY

The Kohala Ditch enters the Pololu watershed at an elevation of about 960 feet, collects water from an intake on the East Branch of the valley, is measured at gage 7510, then continues through a ridge to the West Branch and on down the west wall of the canyon to the agricultural area which starts near Waiakalae Stream.

The Pololu drainage basin above Kohala Ditch totals about 3.1 sq. miles and reaches to Puu Pili at elevation 4,708 feet. The upper 1.3 sq. miles of the basin lies above the Kehena Ditch. Drainage to West Pololu from below Kehena Ditch but above Kohala Ditch totals about 1.4 sq. miles, and in East Pololu drainage to the intake is about 0.4 sq. miles. Rainfall averages between 100 and 120 inches per year.

The entire drainage area above Pololu canyon is covered by the Hawi volcanic series, of which a tongue of andesite also extends about 1.5 miles into the East Branch. Otherwise the canyons expose Pololu basalt. Only one dike has been observed in Pololu Valley, which strikes across the head of West Pololu canyon as a continuation of the massive trachyte diked mapped near the intake in the East Branch of Honokane Nui (Stearns and Macdonald, 1946).
Neither the West nor the East Branch of Pololu has eroded far enough into the rift zone to encounter high level dike water. Thus no base flow of ground water occurs; all stream water consists of direct runoff plus a small quantity of bank storage. It is likely that this phenomenon discouraged the ditch engineers from attempting to construct intakes on the West Branch and its tributaries.

Randolph (1965) stated that the average contribution of East Pololu to the Kohala Ditch is 0.44 mgd. The average natural flow, however, is greater, probably near 1 to 1.5 mgd, but its total capture is subject to the same constraints which control input to the Awini Ditch. The considerably larger drainage area of West Pololu below Kehena Ditch should have an average natural flow of 4 to 5 mgd, but none is now captured. Above Kehena Ditch the average natural flow should approximate 4 mgd, but whatever fraction is captured by the ditch is greatly reduced by seepage losses in the unlined ditch leading to Puuokumau.

The total natural runoff tributary to Kohala Ditch from the Pololu watershed below Kehena Ditch totals about 5 mgd, of which perhaps 2-3 mgd is within the collectible instantaneous flow range. Whether construction of the components required to capture this quantity is economically feasible, however, is questionable.

UPPER KOHALA

In the highland zone lying between Kohala Ditch (elevation 1,000 feet) and Kehena Ditch (elevation 4,000 to 1,800 feet), from Pololu Valley to about Puuokumau Reservoir, numerous small perched aquifers occur which provide a significant total volume of water of great importance in local situations. It is convenient to call this sector “Upper Kohala” to distinguish it from the irrigated region lying below Kohala Ditch.

Upper Kohala is covered by Hawi andesite which was extruded from the rift zone long after emplacement of the Pololu basalts. In the interval between the two main periods of volcanic activity erosion of the basalts took place, leaving a surface of residuum cut by numerous gulches in which alluvium accumulated. Onto this surface the andesite flowed, forming a thin blanket on the ridges and filling the gulches. The alluvium and residuum underlying andesite in the gulches became aquitards because of their relatively low permeability, and the clinkery base of the andesites lying immediately above the old surface became aquifers.

The aquifers are small and are restricted to gulches. Water accumulates at the contact of the andesites and the Pololu sediments and under natural conditions discharges as high level springs, generally in the elevation belt from 1,000 to 2,000 feet. These springs attracted attention very early in the history of agriculture in Kohala and their exploitation was among the first of the water development schemes.

The principal source of water for the aquifers is the moderate rainfall of the highlands. The annual average rainfall varies from 100 inches at Pololu to about 65 inches near Puuokumau. A
secondary source is leakage from Kehena Ditch over its traverse from gage 7550 to the terminal reservoir. Except for the small flow of each spring none of the streams west of Pololu are perennial, but during rainy periods the gulches carry large flows, portions of which are captured by 14 intakes between Pololu and Upolu. Unfortunately no stream gages were placed on any of the gulches and therefore there are no accurate records of input to the ditch.

To enhance and better control flows of the perched springs of Upper Kohala, 32 development tunnels have been built and 11 springs modified (Report R34). The largest average flow for a tunnel is about 1.25 mgd (Bond No. 1 Relief; Watt No. 1), but numerous tunnels are nearly dry most of the time. The largest average flow for a modified spring is .15 mgd (West Branch Halawa Gulch). The total average flow for all tunnels is 4 to 5 mgd, the maximum is 17 to 18 mgd, and the minimum 1 mgd (Davis and Yamanaga, 1963).

The springs and tunnels for many years have effectively served domestic needs and supplemented agricultural supply in limited areas. However, the total average flow of about 5 mgd is not capable of being appreciably increased. Because of the relatively small quantity of water available from each perched aquifer and the distances between them, the Upper Kohala resource cannot be looked to as a reliable supplement for agriculture beyond its present duty.

**BASAL GROUND WATER RESOURCES**

Throughout the entire North Kohala District a nearly continuous lens of basal ground water occurs over a band several miles wide from the coast inland to the rift zone of the Kohala volcano. The highest water levels are found seaward of the high rainfall area of the Awini section and the lowest near Mahukona on the semi-arid leeward coast line of the District. The basal ground water resources east of Pololu Valley, though very large, will not be discussed in detail in this report because they are too remote from the areas of potential use to be practicably developable under current and reasonably distant economic constraints.

Fresh water which accumulates and floats on salt water is called basal ground water if it freely flows through an aquifer to discharge at the coast line. The water level elevation (head) of a fresh water basal lens in a basalt aquifer is usually 10 feet or less and its thickness below sea level is roughly 40 times the head. This simple hydrostatic model is significantly modified by dynamics of flow, but it is commonly a surprisingly good approximation of actual conditions.

Heads increase inland and are highest where rainfall, or other recharge, is greatest. In the Kohala region the highest heads occur toward Pololu Valley where they probably reach about 10 feet; toward Mahukona comparable inland heads decreases to 2 feet or less.

The extension of the northwest rift zone toward Honoipu Landing from Honokane Nui may act as an impermeable inland boundary to basal ground water for some distance beyond Pololu, but the impermeable structures (dikes, chiefly) of the rift zone probably lie too far below the surface in the northwest part of the dome to effectively disrupt hydraulic continuity between the
Mahukona area and the basal water on the north side of the rift. Nevertheless it is convenient to
divide the basal lens into two sectors, one lying on the north side of the rift zone extending from
approximately Honoipu to Pololu, a coast line distance of 12 miles, and the other on the south
side from Honoipu to Mahukona, a coast line distance of 5 miles. In the northern (Kohala) sector
a large quantity of fresh ground water can be developed; toward Mahukona brackish water
occurs except very far inland where a small quantity of fresh water may be developed.
Even though the basal ground water resources are very large in the Kohala section, they
have been exploited only in part because of the high cost of pumping water to the surface. Ditch
water, which flows by gravity to the sugar cane fields, is preferentially used because its unit cost
is very much smaller than that for basal ground water. However, an enormous volume of fresh
water is stored in the basal lens, more than enough to support agriculture during the longest and
severest droughts when ditch flow is minimal. The combined use of ditch and basal water, each
allocated so as to minimize total costs, could sustain large scale agriculture in the Kohala
region indefinitely.

CLIMATE AND HYDROGEOLOGY

The highest rainfall in the Kohala section occurs toward the head of Pololu Valley where the
average annual isohyet is 100 to 120 inches, which decays to 60 to 80 inches near the coast.
Rainfall decreases toward Hawi, where the average annual is about 50 inches, then is sharply
reduced farther west and south toward Mahukona, one of the driest spots in all of Hawaii, where
on the average only 14 inches are measured annually. The relatively high rainfall east of Hawi
provides opportunity for significant infiltration to the ground water lens; between Hawi and
Mahukona recharge is slight, and therefore the ground water flow is small.

At sea level the entire region is underlain by primitive basalts of the Pololu volcanic series.
Hawi andesite caps the surface between Kohala and Kehena Ditches for 5 miles west of Pololu,
almost to Puuokumau Reservoir, and extends northward as irregular fingers between Kohala
Ditch and the coast over the same distance. Elsewhere Pololu basalt lies at the surface. Near the
crest of the dome some late pyroclastics and trachyte flows occur in conjunction with the
andesite. Sediment wedges fill gullies near the coast, but no continuous rim nor extensive
blanket of sediments, either terrestrial or marine, ring the coast line as is the case in the older
islands, such as Oahu.

The basal ground water aquifer is composed of Pololu basalt. Like other primitive basalts of
Hawaii (e.g., the Koolau basalt on Oahu), the Pololu series has a very high permeability, on the
order of 1,000 feet or more per day. Where recharge is good and heads are about 2 feet or more,
basalt aquifers are easily exploited.

The high heads in the Kohala section are sustained by recharge from the moderately high
rainfall between Kehena and Kohala Ditches and perhaps by spillover of high level ground
water from the rift zone. Toward Hawi in the irrigated agricultural region return irrigation water
contributes to recharge. In the Mahukona sector only infiltration from irregular storms sustain the thin lens.

Where basal heads are about 3 feet or more, the natural salinity of the ground water is low, on the order of 50 ppm chloride or less. This condition is most notable in the Kohala sector east of Hawi. Toward Mahukona the chloride content increases sharply as the regional head goes down, and all of the basal water within several miles of the coast between Upolu and Mahukona is brackish. At Mahukona dug wells yield water with chlorides as high as 5,000 ppm. South of Mahukona the Kahua Ranch well (elevation 60 feet, bottom at — 30 feet) gives water with about 2,000 ppm chloride. This quality is typical of the basal water where the head is less than 2 feet.

ESTIMATE OF THE QUANTITY OF BASAL WATER RESOURCES

A first order approximation of the volume of ground water flowing through the lens under natural conditions may be made by a hydrologic input-output analysis in which the input consists of infiltration from rainfall and the output of the springs that discharge along the coast line. The actual conditions in the Kohala section are complicated by pumpage from the lens and excessive irrigation in the dry plantation area. However, in the first approximation a strict evaluation of these activities was not made because they partially counteract each other's effects and because their magnitudes are much smaller than those of the natural input-output processes.

In the Kohala section the computed recharge to the basal lens from rainfall lying to the north of the extended rift zone is 40 mgd. If return irrigation water were included as input, approximately 10 mgd would percolate as recharge, 5 mgd of which would be balanced by the net draft from the lens, leaving a balance of 5 mgd as net irrigation recharge. If the crest of the Kohala dome rather than the rift zone line were treated as the inland boundary of the lens, the natural flow would be 58 mgd rather than 40 mgd.

A second way of estimating flow through the lens is by utilizing Darcy's fundamental equation of flow in porous media, which is:

\[ q = -k \frac{dh}{dx} \]

where \( q \) is specific flow, \( k \) is permeability, and \( \frac{dh}{dx} \) is the gradient, or change in head with change in distance. The total flow is obtained from:

\[ Q = ql \]

where \( Q \) is the total flow over a given length of coast line, 1.

Water table measurements provide a gradient in the Kohala section and if the permeability is assumed to be 1,000 feet per day, the total flow through the section is computed as 48 mgd, which is of the same magnitude as that obtained by input-output analysis. Neither exercise is very exact because there is not enough hydrologic data to make refined analyses, but nonetheless they provide a good approximation of the magnitude of the flow. Thus for the Kohala section
The average natural ground water flow is estimated to fall between 40 and 50 mgd, say 45 mgd.

Not all of this 45 mgd could be withdrawn from the lens, however. A reasonable estimate of the developable fraction of the flow is 30 to 35 mgd, about 75% of the total. If an average of 30 mgd were withdrawn, the equilibrium head of 7 feet now found in the eastern part of the section would be reduced to 4 feet, and the equilibrium head of 3 feet near Hawi would fall to 2 feet.

In the Mahukona section the basal ground water flow is much less than in the Kohala section. Practically no ground water data is available for the region inland of the coast, but by extrapolating the equipotential lines southward from Upolu and Hawi (see Map II-1) and by using a permeability of 1,000 per day, the flow between Honoipu and Mahukona is estimated to be less than 5 mgd. Water containing less than 1,000 ppm chloride probably does not occur within 2 miles of the coast in this section. Brackish water is safe for certain types of agriculture, but no more than about 2 to 3 mgd of brackish water (containing less than 2,000 ppm chloride) could be developed in the Mahukona section. Investigations by Lao et al. (1968), and Cox et al. (1969) concluded that significant development of fresh ground water is not possible along the northwest coast of the island of Hawaii.

DEVELOPMENT OF BASAL GROUND WATER

The basal ground water of North Kohala was first exploited before the construction of the Kohala-Awini Ditch System. A well was drilled at Union Mill in 1898, and three shafts (Waikane, Hoae, and Kohala) were constructed by 1901. All three of these shafts have been operated since the turn of the century. A fourth station, Alaalea, has been abandoned.

In recent years only the three shafts and three drilled wells have been used to produce basal water. Several other wells have been drilled but have either been abandoned or closed off. The combined average draft of the three shafts and wells has been about 10 mgd.

In 1964 an effort was made by Kohala Sugar Co. to determine the extent and characteristics of the basal aquifer. Seven test holes were drilled, of which 5 successfully penetrated to basal water. The hydrologic data from these test holes, supplemented with data from the shafts and other wells, was used to construct the ground water map (Map II-1).

The test holes showed that without a doubt an extensive basal ground water lens, which could provide a large volume of fresh water, underlies the Kohala section. However, the high cost of pumping has discouraged both further attempts at development and increased production from operating stations.

Both Waikane and Hoae Shafts are near the coast, far down the hydraulic gradient from the region of high heads, and produce relatively brackish water. Waikane, rated at 3 mgd, produces water ranging from 500 to 1,500 ppm chloride, and Hoae, rated at 7.5 to 8 mgd, pumps water with 300 to 700 ppm chloride. Kohala Shaft (presently used to supply the mill), on the other hand,
is several thousand feet inland where the head is 6 to 7 feet, a combination of circumstances which should yield low chloride water if managed properly. However, the chloride rises to 1,000 ppm, probably as a result of pumping at full capacity (7.5 mgd).

The Halaula well, which is located more than a mile from the coast where the head is 7 to 8 feet, yields water with 25 ppm chloride. The basal water of Kohala can be most optimally developed by wells which are properly located, sized, fitted, and operated.

A summary of descriptive information about the shafts, wells and test holes, and relevant hydrologic information obtained from them, is given in Table 4.

The new Union Mill No. 1 near test hole 5 was completed between October 23 and December 20, 1965 and successfully tested at rates of flow up to 2,000 gpm. The pumping test for this well is the only one for which a record of results could be found, but the record is sketchy and incomplete.

Table 4

Data Summary for Shafts, Wells and Test Holes in the Basal Lens of the Kohala Sector

<table>
<thead>
<tr>
<th>Installation Type</th>
<th>Identification</th>
<th>Elev. (ft.)</th>
<th>Bottom Elev. (ft.)</th>
<th>Characteristic head or head range (ft.)</th>
<th>Chloride (ppm)</th>
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</thead>
<tbody>
<tr>
<td>Shaft</td>
<td>Waikane</td>
<td>33</td>
<td>-15</td>
<td>0.5</td>
<td>600-1500</td>
</tr>
<tr>
<td></td>
<td>Hoea</td>
<td>52</td>
<td>-15</td>
<td>2.0</td>
<td>300-700</td>
</tr>
<tr>
<td></td>
<td>Kohala</td>
<td>120</td>
<td>-15</td>
<td>7.0</td>
<td>75-1000</td>
</tr>
<tr>
<td>Wells</td>
<td>Halaula</td>
<td>344</td>
<td>-161</td>
<td>7.8</td>
<td>60-100</td>
</tr>
<tr>
<td></td>
<td>Union No. 1</td>
<td>311</td>
<td>-101</td>
<td>7.0</td>
<td>60-100</td>
</tr>
<tr>
<td></td>
<td>Union No. 2</td>
<td>420</td>
<td>-102</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Test Holes</td>
<td>T-1 (Halawa)</td>
<td>170</td>
<td>-97</td>
<td>6.2-7.4</td>
<td>44-52</td>
</tr>
<tr>
<td></td>
<td>T-2 (Aamakoa)</td>
<td>171</td>
<td>-84</td>
<td>6.1-7.1</td>
<td>20-36</td>
</tr>
<tr>
<td></td>
<td>T-3 (Waikane)</td>
<td>161</td>
<td></td>
<td>(did not reach basal water)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-4 (Union Mill No. 2 Test)</td>
<td></td>
<td></td>
<td>(abandoned before reaching basal water)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-5 (Union Mill No. 1 Test)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T-6 (Upolu)</td>
<td>293</td>
<td>-67</td>
<td>0.7-2.8</td>
<td>300-1500</td>
</tr>
<tr>
<td></td>
<td>T-7 (Alaaloa)</td>
<td>362</td>
<td>-88</td>
<td>3.5-5.2</td>
<td>20-24</td>
</tr>
</tbody>
</table>
The results of a step drawdown test held for 17.5 hours from December 28 to December 31, 1965 were as follows:

<table>
<thead>
<tr>
<th>Q (Rate in gpm)</th>
<th>s (Drawdown in feet)</th>
<th>Q/s (Specific capacity in gpm/ft.)</th>
<th>Chloride, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>750</td>
<td>1.1</td>
<td>682</td>
<td>38</td>
</tr>
<tr>
<td>1,000</td>
<td>4.3</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>1,350</td>
<td>7.3</td>
<td>185</td>
<td></td>
</tr>
<tr>
<td>1,575</td>
<td>9.1</td>
<td>173</td>
<td></td>
</tr>
</tbody>
</table>

It is evident from the above that much of the drawdown was attributable to turbulence at the well face rather than to aquifer resistance. When drawdown reflects only aquifer losses, the specific capacity remains constant at all pumping rates.

A second test at a sustained pumping rate of 1,300 gpm for 256 hours (January 3 to January 14, 1966) gave a stable drawdown of 4.6 feet, equivalent to a specific capacity of 283 gpm per foot. The chloride content rose from 46 ppm to 55 ppm, where it leveled off.

A third test conducted for 365 hours (January 15 to January 31, 1966) at a steady pumping rate of 2,000 gpm gave a stabilized drawdown at the well of 8.7 feet (specific capacity of 230 gpm per foot) and caused a rise in chlorides from 56 ppm to 70 ppm. During this test head measurements were also taken at test hole T-5 at a distance of 73.4 feet away from the pumping well. The final, apparently stable, drawdown at T-5 was 0.8 feet, which would yield a transmissivity value for the aquifer of about 1 mgd per foot if steady state conditions were assumed.

The infrequent head readings at T-5 could also be used in a non-steady state analysis to obtain transmissivity. At T-5 drawdowns were 0.6 feet on January 15, 1966, 0.7 feet on January 16, 1966, 1.0 feet on January 17, 1966, and 0.8 feet on January 18, 1966. This sketchy data when used in the Jacob approximation results in a transmissivity of about 2 mgd per foot.

Evidently the magnitude of the transmissivity value lies between 1 and 2 mgd per foot, equivalent to a minimum permeability of 500 to 1,000 feet per day for the Pololu basalt, comparable to primitive basalts elsewhere in Hawaii.

**SUMMARY AND COMMENTS: BASAL GROUND WATER RESOURCES**

A large supply of basal ground water is developable in the Kohala sector between Honoipu and Pololu. The total flux of the lens is estimated at 40 to 50 mgd, of which 30 to 35 mgd could be safely withdrawn using present technology. In recent years an average of nearly 10 mgd of ground water has been pumped from this sector, most of it of poor quality because of location of the pumping stations near the coast. Redevelopment with wells would yield 30 to 35 mgd of water which would meet U. S. Public Health Services standards for drinking water (e.g. 250 ppm chloride or less).
The best ground water supply lies between Hawi and Pololu where heads exceed 4 feet. Between Hawi and Upolu heads are 2 feet or less over much of the area and the water quality, though suitable for most agriculture, would not meet domestic standards.

The basal ground water of the Mahukona sector is brackish within several miles of the coast line. Recharge is slight, heads are low, and the basal lens is thin. Wells located very far inland might strike reasonably fresh water (less than 500 ppm chloride), but the depth of drilling to basal water would be very great, exceeding 1,000 feet. Some of the brackish water, especially in the northern part of the sector, could be used in agriculture but the total sustainable draft would be less than 3 mgd.

The basal ground water of North Kohala is an important resource not only because of its location in an agricultural district but because of its proximity to potentially developable lands southward to Mahukona and beyond. If most of the basal water were to be used for agriculture, there would be a greater range of choices for development sites than there would be if domestic quality water were the goal; but wells designed as public drinking sources would have to be restricted to regions where heads were greater than 3 feet and distances inland were about a mile or more. For instance, if the costs were acceptable, wells placed along Kohala Ditch (elevation 900 to 1,000 feet) from Hawi to Pololu could supply domestic quality water for transmission via the ditch or a separate line to the dry area above Mahukona.

The appropriate way to develop the basal ground water of the Kohala sector is by means of drilled wells. If the resource is to be exploited to full capacity, however, care must be exercised in locating and designing production sites. Neither random location of wells nor over design of pumping capacity should be tolerated.
Typical tunnel along Kohala Ditch

Typical pre-stressed concrete flume

Typical intake

Typical redwood flume
Kohala Mill shaft pump room

Union Mill hydroelectric plant

Diesel direct driven pump

1500 6PM sprinkler
INTRODUCTION

The water resources described in the previous section represent a major asset for the economic welfare of North Kohala, both now and in the future. Resources alone are not adequate to generate a stable economic base. Management and development of the resources must be accomplished in order to establish a sound interrelationship of these resources which will facilitate an appropriate economic growth. Agriculture has always been essential to North Kohala and, at the request of the Kohala Task Force, the emphasis of this report and particularly this section is oriented toward the strengthening of agriculture within the district.

The purpose of this section of the report is to:

1. assist the Kohala Task Force in analysis of the various agricultural programs and projects as well as other developments considered for North Kohala by evaluating and coordinating the water demand and costs in such a manner as to be consistent with the efficient development of the water resources.

2. perform engineering and construction feasibility studies as might be required to implement the water development. These studies will be devoted primarily to test various alternatives for consistency with the Task Force objectives.

3. examine both State and County land use objectives for North Kohala; integrate the water plan with land use planning.

KOHALA CORPORATION IRRIGATION WATER SYSTEM

PRESENT WATER SOURCES

During the drought periods, the flow of the Kohala Ditch is inadequate to irrigate the sugar cane fields. Vertical shafts, tunnels, and drilled wells have been constructed to offset the deficiency in ditch flow. Based on pumping capacity, these ground water sources can supply approximately 25.4 mgd (million gallons per day). The Kohala, Hoea and Waikane wells with pumping capacities of 9 mgd, 8 mgd, and 3 mgd, respectively were constructed in the early 1900's and are of the vertical shaft and horizontal tunnel types (see Map III-1 for location). Union Mill No. 1 and Union Mill No. 2 are drilled wells and were placed in operation in 1969. These two wells can each supply 2.7 mgd. Each of the Union well pumps is coupled with a booster pump having equal flow capacity and together as a unit can pump to a maximum of 960 feet above sea
level. (See Table III-1 for well and pump data). The estimated useful life of the Hoea and Waikane pumps are 10 and 3 years respectively. The original pumps in both Hoea and Waikane were replaced by new pumps in 1966 and are currently in good running condition. The outlet pipes and the access to the pumps and pump houses are in fair to poor condition. The Waikane pump lifts water to a 3.4 mg earth reservoir at elevation 235'. The Hoea well pump together with the Hoea Mill and Kaaihue booster pumps lifts water to a 4 mg earth reservoir at elevation 300’ and

**TABLE III-1-a**

**KOHALA CORP. EXISTING WELLS AND PUMPS DATA**

<table>
<thead>
<tr>
<th>NO.</th>
<th>ITEM</th>
<th>KOHALA MILL</th>
<th>UNION MILL NO. 1 DEEPWELL PUMP</th>
<th>UNION MILL NO. 1 BOOSTER PUMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Depth of Well</td>
<td>135 Ft.</td>
<td>411 Ft.</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>Static Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface Elev.</td>
<td>7.0 Ft.</td>
<td>6.2 Ft.</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>Floor Elev. at Pump Setting</td>
<td>8 Ft.</td>
<td>310 Ft.</td>
<td>—</td>
</tr>
<tr>
<td>4</td>
<td>Lift (Pumping Head)</td>
<td>275 Ft.</td>
<td>465 Ft.</td>
<td>500 Ft.</td>
</tr>
<tr>
<td>5</td>
<td>Type of Pump</td>
<td>2-State Horizontal Centrifugal</td>
<td>Submersible mixed Vertical Turbine Flow</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pump Manufacturer</td>
<td>Allis Chalmers</td>
<td>Byron-Jackson</td>
<td>Byron-Jackson</td>
</tr>
<tr>
<td>7</td>
<td>Pump Horsepower</td>
<td>1 @ 300 Hp</td>
<td>250 Hp</td>
<td>250 Hp</td>
</tr>
<tr>
<td></td>
<td>1 @ 150 Hp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Pumping Rate (gpm)</td>
<td>6250 GPM</td>
<td>1850 GPM</td>
<td>1850 GPM</td>
</tr>
<tr>
<td>9</td>
<td>Number of Pumps in Station</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Type of Motor</td>
<td>Squirrel Cage</td>
<td>Vertical</td>
<td>Vertical</td>
</tr>
<tr>
<td></td>
<td>2.3 kv</td>
<td></td>
<td>Westinghouse</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>12</td>
<td>Power Source</td>
<td>2.4 kv from Kohala Mill Power Bus</td>
<td>Kohala Mill Transf. to 2.4 kv at Site</td>
<td>Kohala Mill Transf. to 2.4 kv at Site</td>
</tr>
<tr>
<td>13</td>
<td>Pump Shelter</td>
<td>Wood Frame &amp; corr. iron bldg. at top of shaft</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>14</td>
<td>Condition of Shelter</td>
<td>Fair</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>15</td>
<td>System Estimated Useful Life</td>
<td>10 Yr.</td>
<td>16 Yr.</td>
<td>16 Yr.</td>
</tr>
<tr>
<td>16</td>
<td>Pump — Date Installed</td>
<td>1933</td>
<td>1966</td>
<td>1966</td>
</tr>
</tbody>
</table>
to a ditch at elevation 360’. The area served by these two wells and booster pumps is limited to lands below elevation 360’. (See Map III-1 for locations).

**KOHALA AND KEHENA DITCH SYSTEMS**

The development and history of the Kohala Ditch which includes the Awini Section, Awini Falls to Niulii Section, Kohala Section, and the Kehena Ditch are reported in the Phase I report and Water Resources Section of this report and are referred to for background information. Field

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**TABLE III-1-b**

**KOHALA CORP. EXISTING WELLS AND PUMPS DATA**

<table>
<thead>
<tr>
<th>NO.</th>
<th>ITEM</th>
<th>UNION MILL NO. 2 DEEPWELL PUMP</th>
<th>UNION MILL NO. 2 BOOSTER PUMP</th>
<th>HOEA WELL &amp; PUMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Depth of Well</td>
<td>470 Ft.</td>
<td>—</td>
<td>61 Ft.</td>
</tr>
<tr>
<td>2</td>
<td>Static Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface Elev.</td>
<td>7.1 Ft.</td>
<td>—</td>
<td>2.0 Ft.</td>
</tr>
<tr>
<td>3</td>
<td>Floor Elev. at Pump Setting</td>
<td>470 Ft.</td>
<td>470 Ft.</td>
<td>5.8 Ft.</td>
</tr>
<tr>
<td>4</td>
<td>Lift (Pumping Head)</td>
<td>465 Ft.</td>
<td>500 Ft.</td>
<td>145 Ft.</td>
</tr>
<tr>
<td>5</td>
<td>Type of Pump</td>
<td>Deepwell</td>
<td>Submersible</td>
<td>Horizontal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Split-casing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>centrifugal</td>
</tr>
<tr>
<td>6</td>
<td>Pump Manufacturer</td>
<td>FMC Peerless</td>
<td>FMC Peerless</td>
<td>Allis Chalmers</td>
</tr>
<tr>
<td>7</td>
<td>Pump Horsepower</td>
<td>250 Hp</td>
<td>250 Hp</td>
<td>300 Hp</td>
</tr>
<tr>
<td>8</td>
<td>Pumping Rate (gpm)</td>
<td>1850 GPM</td>
<td>1850 GPM</td>
<td>5560 GPM</td>
</tr>
<tr>
<td>9</td>
<td>Number of Pumps in Station</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Type of Motor</td>
<td>Vertical G. E.</td>
<td>Vertical G. E.</td>
<td>Squirrel Cage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hollow Shaft</td>
<td>Hollow Shaft</td>
<td>2.3 kv</td>
</tr>
<tr>
<td>12</td>
<td>Power Source</td>
<td>Step to 2.3 kv at Union Sub-Sta.</td>
<td>Step to 2.3 kv at Union Sub-Sta.</td>
<td>2.4 kv from Hoea Sub-Sta.</td>
</tr>
<tr>
<td>13</td>
<td>Pump Shelter</td>
<td>None</td>
<td>None</td>
<td>Wood Frame &amp; corr. roof House at Top</td>
</tr>
<tr>
<td>14</td>
<td>Condition of Shelter</td>
<td>—</td>
<td>—</td>
<td>Fair</td>
</tr>
<tr>
<td>15</td>
<td>System Estimated Useful Life</td>
<td>16 Yr.</td>
<td>16 Yr.</td>
<td>10 Yr.</td>
</tr>
<tr>
<td>16</td>
<td>Pump - Date Installed '69</td>
<td>1969</td>
<td>1966</td>
<td></td>
</tr>
</tbody>
</table>
trips were taken during the present investigation to evaluate the present condition of the Kohala Ditch and its supporting facilities. The flume inventory list, prepared by Kohala Corporation (Bowles 1973, appendix E, sh. 6 of 6) and the asset ledger list of the Kohala Ditch Company with minor revisions or clarifications noted in the field by Kohala Corporation personnel, were also used to evaluate the viability of the Kohala Ditch.

TABLE III-1-c
KOHALA CORP. EXISTING WELLS AND PUMPS DATA

<table>
<thead>
<tr>
<th>NO.</th>
<th>ITEM</th>
<th>HOEA MILL BOOSTER PUMP</th>
<th>KAAIHUE BOOSTER PUMP</th>
<th>WAIKANE WELL &amp; PUMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Depth of Well</td>
<td></td>
<td></td>
<td>42 Ft.</td>
</tr>
<tr>
<td>2</td>
<td>Static Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface Elev.</td>
<td></td>
<td></td>
<td>0.5 Ft.</td>
</tr>
<tr>
<td>3</td>
<td>Floor Elev. at Pump Setting</td>
<td>137 Ft.</td>
<td>232 Ft.</td>
<td>7.4 Ft.</td>
</tr>
<tr>
<td>4</td>
<td>Lift (Pumping Head)</td>
<td>100 Ft.</td>
<td>200 Ft.</td>
<td>220 Ft.</td>
</tr>
<tr>
<td>5</td>
<td>Type of Pump</td>
<td>Horizontal Split-casing, Centrifugal</td>
<td>Horizontal Split-casing, Centrifugal</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Pump Manufacturer</td>
<td>Peerless</td>
<td>DeLaval</td>
<td>Byron-Jackson</td>
</tr>
<tr>
<td>7</td>
<td>Pump Horsepower</td>
<td>200 Hp</td>
<td>2 @ 75 Hp</td>
<td>200 Hp</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 @ 40 Hp</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Pumping Rate (gpm)</td>
<td>5200 GPM</td>
<td>5200 GPM (Total)</td>
<td>2080 GPM</td>
</tr>
<tr>
<td>9</td>
<td>Number of Pumps in Station</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Type of Motor</td>
<td>Squirrel Cage</td>
<td>Squirrel Cage</td>
<td>Squirrel Cage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.3 kv</td>
<td>440 v</td>
<td>2.3 kv</td>
</tr>
<tr>
<td>12</td>
<td>Power Source</td>
<td>2.4 kv from Hoea Sub-Sta. reduced to 480 v</td>
<td>Kaaihue Sub-Sta.</td>
<td>2.4 kv from Hoea Sub-Sta.</td>
</tr>
<tr>
<td>14</td>
<td>Condition of Shelter</td>
<td>Fair</td>
<td>Fair</td>
<td>Fair to Poor</td>
</tr>
<tr>
<td>15</td>
<td>System Estimated Useful Life</td>
<td>15 Yr.</td>
<td>7 Yr.</td>
<td>3 Yr.</td>
</tr>
<tr>
<td>16</td>
<td>Pump - Date Installed '33</td>
<td>1933</td>
<td>1933</td>
<td>1966</td>
</tr>
</tbody>
</table>

Reference: Kohala Corporation and Field Reconnaissance.
KOHALA DITCH-AWINI SECTION

Due to scheduling and climatic conditions, there has not been a field trip to the Awini Section in Phase II. Weather permitting, a field trip will be scheduled to evaluate the present condition of the Awini Section improvements.

KOHALA DITCH-AWINI FALLS TO NIULII SECTION

This section of ditch is covered in the Water Resource Section as to physical description and present conditions.

KOHALA SECTION

During the field inspection by Stephen Bowles and Akinaka & Associates, Ltd. of the Kohala Section of the Ditch in January, 1974, the following observations were made:

1) The redwood flumes are subject to damage by falling rocks and boulders from intakes and slopes above flumes during peak stream flows.
2) The prestressed concrete flumes are not significantly damaged by falling boulders.
3) The maintenance of the ditch by removing debris in intakes and flumes is a problem and requires a regular maintenance program.
4) The tunnel sections appear to require very little maintenance.
5) The structural condition of the piers which support the redwood and concrete flumes are very good and new flumes can be continued to be built on the piers. There was no evidence of structural damage due to the recent 1973 Honomu earthquake.
6) The redwood flumes do require a periodic repair program due to fallen boulders and rotting of flume members. Entire replacement of flumes is only necessary when main supporting structural members need extensive work and replacement. It was concluded that the Kohala Ditch Company estimated replacement dates of the flumes were reasonable estimates.
7) The concrete lining of the open ditch section is in fair to poor condition.

KEHENA SECTION

This section of the ditch is covered in the Water Resource Section as to physical description and present conditions.

PRESENT IRRIGATION SYSTEM

The Kohala Sugar Company's present irrigation system utilizes an overhead sprinkler system with the Kohala Ditch water as the principal source. The overhead irrigation system
presently serves much of the irrigated cane lands. Five main feeder lines off the Kohala Ditch transmit water to the overhead irrigation system. One main, a 30" steel pipe, taps off Kohala Ditch at the intersection of Kohala and Kehena ditches and by gravity flow, feeds the Hawi Hydroelectric plant as well as the overhead irrigation system. A second main, (24" steel pipe) taps off Kohala Ditch near Hawi 3 reservoir and, by gravity flow, feeds into the overhead irrigation system, extending as far as lower Upolu. A third main, (14", 12-3/4" & 10-3/4" steel pipes), begins at Kohala Ditch at the upper end of Honomakau and by gravity flow, serves lands in Pahoa and Hawi. A fourth main, (24" steel pipe), connected to Kohala Ditch at Puehuehu, runs along Kynnersley Road and by gravity flow, feeds the lands surrounding Union Mill as well as the Union Mill hydroelectric plant. A fifth main (14-3/4" and 10-3/4") begins at Old Reservoir, which is fed by Kohala Ditch through a ditch, flows by gravity to lower Ainakea.

There is also a network of ditches connecting the earth reservoirs which have storage capacity totalling approximately 164 million gallons. With the overhead irrigation system operating from water piped directly from Kohala Ditch, only a few of the reservoirs are in use. (See Map 111-1).

**PROPOSED IRRIGATION WATER SYSTEM**

**INTRODUCTION**

The purpose of this section is to; (1) identify present lands in agriculture, (2) research all available information on water requirements of different crops and classify these crops according to water requirements, (3) research present methods of irrigation and adopt a possible method suitable for North Kohala’s environment and potential agricultural development, and (4) propose an irrigation water system based on the above mentioned considerations for North Kohala.

**LANDS IN AGRICULTURE**

For the purposes of this study, the area of lands used for agriculture in North Kohala have been planimetered and their acreages have been approximately determined. (See Map 111-2).

- Sugar cane lands .......................................................... 15,440 acres
- Unirrigated ................................................................. 9,500 acres
- Irrigated .......................................................................... 5,500 acres
- Planters' cane ................................................................. 440 acres
- Macadamia Nut orchards .............................................. 450 acres
- Pasture lands ................................................................. 47,000 acres


**IRRIGATED LANDS**

The presently irrigated lands derive gravity water from the Kohala and Kehena ditches partly and the remainder from pumped ground water to meet water requirements.

The irrigated lands lie almost wholly below the main highway from the vicinity of Kokoiki Homesteads to Halawa Gulch in parcels or cane fields of varying sizes and separated by intervening gulches. (See Map III-2).

| Vicinity of Kokoiki Homesteads to Kaauhuhu | 3,410 acres |
| Kaauhuhu Homesteads to Kamakua Gulch | 600 acres |
| Between Kamakua and Kapua Gulches | 90 acres |
| Between Kapua and Ohanaula Gulches | 445 acres |
| Between Ohanaula and Hanaula Gulches | 195 acres |
| Between Hanaula and Kapaau Gulches | 60 acres |
| Between Kapaau and Wainaea Gulches | 515 acres |
| Along Halawa Gulch | 95 acres |
| Vicinity of Puakea Reservoir | 100 acres |

5,510 acres

**SITES FOR NEW AGRICULTURAL VENTURES**

Recognizing that sugar production will be phased out by the end of 1975, the North Kohala district must have new agricultural ventures established. Because past experience has not developed an equally productive agricultural crop on large scale, the problem of replacing sugar cane with alternative crops has been challenging. Hawaii's economy cannot afford to fallow its limited and more productive lands. Every effort should be made towards a maximum utilization of the 15,000 acres of available farm lands in North Kohala.

The experimental efforts in growing replacement crops such as sorghum and corn by Kohala Grain Company, a Castle & Cooke subsidiary, have yet to show promise on a large scale. It may still be premature to conclude that sorghum production will not be successful with further efforts in its culture.

Presently, Hawaii Biogenics, organized by Midwest farmer investors with feedlot expertise, have leased 2,000 acres of State and Kohala Corporation lands in the vicinity of Hawi and Upolu Point for a combined grain and forage production and feedlot operation. They propose beginning with 300 to 500 acres in crop production, and eventually hope to expand this to as much as 5,000 acres.

About 200 acres of State owned land near Hawi and mauka of the Hawi-Kawaihae highway are being earmarked for diversified crop farmers. Fourteen farm lots, ranging from 10 to 20 acres...
in size, are considered sufficient to meet present land requests. Roads and water mains meeting County subdivision standards are being proposed to service these lots. It is mentioned here that the cost to the State for development of the farm lots is kept to a minimum because of site selection which is based upon the proximity to existing urban and irrigation facilities.

Besides these ventures, there have been plans for and consideration of such diverse economic pursuits as hog raising, aquaculture, dairy heifer replacement, quail farm, slaughter house—meat packing—rendering, tropical plant nursery, major orchid nursery, broiler farm and light industrial plants. To date, most of these have yet to break ground. However, an 80 acre tropical plant nursery called Kohala Nursery has begun operations.

There is also interest by the two large ranchers of the area in irrigated pastures in the lands west and southwest of Hawi. It seems that if provided with a reliable, additional quantity of irrigation water, fuller use of these lands could enhance such ranching business.

The lands receiving a greater rainfall, uncertain at times as it might be, are in the east portion of the cultivated lands of North Kohala and the lands receiving lesser rainfall in the west portion have been provided in the past with irrigation water. For future agricultural pursuits, it becomes apparent that such lands that are provided with irrigation water would be preferred to avoid risking crops during drought periods.

With the above launched and proposed ventures as reference, a rationale for furnishing water from available and developable new water sources can be submitted. The water system being proposed is based on a general overview at this stage and is subject to later refinement as specific water supply requests become known.

The first increments are assigned to the general area which Hawaii Biogenics and the 14 diversified farm lots are to occupy. This area is designated as the core development. The ensuing 1,000 acre increments flank the core development first to the east and thence east and west equally and thereafter to the west. This incremental approach permits use of a major portion of the lands presently cultivated and irrigated. These increments would be followed by opening of lands now in pasture.

Because the Kohala Nursery is located outside of the core development and based on the above incremental program, it appears that its water requirements should be served temporarily from domestic sources.

The general concept, which is being covered more in detail later, is based on an interrelated program of an incremental water development with expanding future water requirements. The concept meets requirements but avoids heavy initial capital expenditures.

With the direction of expansion of irrigated lands in a southwestward direction from Hawi, such utilization is limited by the possible extent of development of new water resources.

Early in the study, consideration was given to establishing three pressure zones. One pressure zone is derived from the Kohala Ditch water source as this water is conveyed to its lower elevations. Because the required supplemental water is proposed to be met from basal
ground water sources, well drilling and pumping at locations inland would be preferable to utilizing or installing new installations along the shoreline where these might be subject to salt water encroachment. A two pressure zone approach was finally selected as the necessary number of wells could be drilled along a transmission system and could be inter-connected with existing wells and pumps in the future. It is to be pointed here that setting a slightly lower elevation for the line of wells would correspondingly lower pumping costs and increase transmission costs. Such lower setting of the line of wells can be studied further.

IRRIGATION REQUIREMENTS

According to Hawaii Agricultural Experiment Station figures, water requirements for farm crops have been generally placed in the neighborhood of 0.20 inch per day or 6 inches per month and varies with local conditions. This amount applies to natural rainfall and/or sprinkler irrigation. Where flood irrigation is used, water is applied to offset the loss by infiltration. If sprinkler irrigation is substituted by drip or trickle irrigation, recent data indicates that a water savings of up to 30 per cent can be accomplished. A few crops have larger requirements for water than others. For example, sugar cane, cultivated by ditch and furrow irrigation may require 10 to 15 inches per month, while corn or sorghum and irrigated pastures require lesser amounts.

In order to establish a basis for estimating irrigation water requirements or demand in North Kohala, the following steps were performed:

1) Assembling field data on present water applications on sugar and experimental sorghum crops in the district.
2) Requesting use estimates from various ranches (Parker, Kahua and Hawaiian Ranch Co.) for irrigated pastures.
3) Evaluating published data pertaining to irrigation and consumptive use in Hawaii.
4) Interviewing growers of papayas, passion fruit and macadamia nuts on Hawaii, Maui and Oahu.
5) Requesting comments on demand for various crop types.
6) Creating a computer program based on results of the five items listed above which was capable of analyzing data on water deficiencies for selected locations within the district.

The above mentioned investigations resulted in the creation of an irrigation model capable of providing varying seasonal and acreage demand as well as showing deficiencies in supply. Details of the construction and use of this model are explained later in the text.

In Table III-2, estimates for water requirements have been classified very generally under “large” and “moderate” categories. Data have been derived from various and independent sources and the resulting compilation furnishes a preliminary insight in supplying water. Where flood irrigation is used, one should move the use up one category as most soils in Hawaii have relatively high infiltration rates and up to 50% or more of the applied water would be lost. If drip or trickle irrigation is used, one may classify the crop one category lower. In areas where wind is
a serious problem, such as Kohala, water use will be increased by as much as 0.05-0.10 inches of water per day unless effective windbreaks are used to reduce this effect. Micro-climate will also have an effect on water use.

Most of the soils in Hawaii hold between 0.10 and 0.14 inches of water per inch of soil or 1.2 to 1.7 inches of water per foot of soil. This means that for most vegetables one should apply water every 4 to 5 days if the consumptive use is 0.20 inch per day. More frequent application is necessary when plants are small or root system are poorly developed.

CROP YIELD AND ESTIMATED GROSS INCOME PER ACRE

Together with water requirements per acre, it is relevant to mention a little more about agricultural crops that might be grown in the district. The State Department of Agriculture keeps a running record of in-shipments, yield per acre, and farm prices for the State. These are published in their annual reports entitled, "Statistics of Hawaiian Agriculture." From this data, the estimated gross income per acre has been derived and shown, together with relative water needs. (See Table III-2)

It is cautioned that the possible crops that can be grown in North Kohala should be determined not only by suitability to the locality and yield per acre but more important, the farmer's insight into current supply-demand market situations. Opening new acreage in the district for various truck crops which create surpluses on the State market can result in economic losses to farmers elsewhere in the State. Expansion of such production within North Kohala should be based upon replacement of in-shipments and the establishment of new overseas markets. The growing demand, local and worldwide, for beef and pork products, offers an excellent opportunity for expansion in North Kohala.

WATER DEMAND MODEL

Water needs for irrigation are based on such factors as temperature, humidity, wind, soil condition, cloud cover, evaporation rate, rainfall, slope of ground and evapo-transpiration requirements of the different crops. Studies incorporating these factors are on-going projects by various government agencies and this study will not go any further than to arrive at general requirements. An empirical method for estimating water needs for irrigated pasture in North Kohala is being applied by Kahua Ranch Co. and has been used for this study. This method determines irrigation requirements based on a percentage of pari evaporation less rainfall deficit.

Recognizing that crop demand varies according to type and season, it was necessary to develop irrigation demand into a flexible model. The following steps were performed in order to establish demand:
<table>
<thead>
<tr>
<th>Crop</th>
<th>Amt. of Water</th>
<th>1972 Inshipments 1000 lbs.</th>
<th>Yield per Acre 1,000 pounds</th>
<th>1972 Farm price cents/lb.</th>
<th>Estimated Gross/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>•</td>
<td>24.0</td>
<td>24.2</td>
<td>$ 5,800.</td>
<td></td>
</tr>
<tr>
<td>Artichoke</td>
<td>•</td>
<td>248</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Asparagus</td>
<td>•</td>
<td>212</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Avocados</td>
<td>•</td>
<td>36</td>
<td>11.3</td>
<td>11.8</td>
<td>1,330.</td>
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<td>Bananas</td>
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<td>3,111</td>
<td>8.3</td>
<td>12.0</td>
<td>1,000.</td>
</tr>
<tr>
<td>Beans</td>
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<td>277</td>
<td>12.2</td>
<td>38.7</td>
<td>4,700.</td>
</tr>
<tr>
<td>Beets</td>
<td>•</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Bitter Melon</td>
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<td>—</td>
<td>12.4</td>
<td>34.0</td>
<td>4,200.</td>
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<td>Broccoli</td>
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<td>1,108</td>
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<td>Brussel Sprouts</td>
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<td>9</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Burdock</td>
<td>•</td>
<td>20</td>
<td>19.5</td>
<td>28.6</td>
<td>5,600.</td>
</tr>
<tr>
<td>Cabbage, Chinese</td>
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<td>85</td>
<td>21.4</td>
<td>8.2</td>
<td>1,750.</td>
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<td>Cabbage, Head</td>
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<td>321</td>
<td>26.0</td>
<td>8.2</td>
<td>2,130.</td>
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<td>Cabbage, Mustard</td>
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<td>28</td>
<td>13.4</td>
<td>14.2</td>
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</tr>
<tr>
<td>Cantaloups</td>
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<td>2,171</td>
<td>5.0</td>
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<td>860.</td>
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<td>Carrots</td>
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<td>4,008</td>
<td>16.0</td>
<td>12.8</td>
<td>2,050.</td>
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<td>Cauliflower</td>
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<td>270</td>
<td>8.3</td>
<td>18.1</td>
<td>1,500.</td>
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<td>Celery</td>
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<td>3,112</td>
<td>40.6</td>
<td>11.7</td>
<td>4,750.</td>
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<td>Chayote</td>
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<tr>
<td>Coffee</td>
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<td>—</td>
<td>1.4</td>
<td>34.5</td>
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<td>13.9</td>
<td>500.</td>
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<td>17.1</td>
<td>3,930.</td>
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<td>29</td>
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<td>570.</td>
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<td>Dasheens</td>
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<td>75</td>
<td>25.7</td>
<td>41.0</td>
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<td>Endive</td>
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<td>Egg Plant</td>
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<td>101</td>
<td>22.2</td>
<td>22.8</td>
<td>5,060.</td>
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<td>252</td>
<td>—</td>
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<tr>
<td>Ginger Root</td>
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<td>313</td>
<td>29.4</td>
<td>41.8</td>
<td>12,290.</td>
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<td>Guavas</td>
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<td>—</td>
<td>—</td>
<td>5.8</td>
<td>—</td>
</tr>
<tr>
<td>Grapes</td>
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<td>1,919</td>
<td>—</td>
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<td>Honeydew Melons</td>
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<td>Kale</td>
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</tr>
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<td>Kohl Rabi</td>
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<tr>
<td>Lettuce</td>
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<td>9,292</td>
<td>12.6</td>
<td>16.5</td>
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<tr>
<td>Crop</td>
<td>Amt. of Water</td>
<td>1972 Inshipments</td>
<td>Yield per Acre</td>
<td>1972 Farm price</td>
<td>Estimated Gross/acre</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------</td>
<td>------------------</td>
<td>----------------</td>
<td>-----------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>Moderate</td>
<td>1000 lbs.</td>
<td>1,000 pounds</td>
<td>cents/lb.</td>
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<td>53.7</td>
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<td>Macadamia Nuts</td>
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<td>2.8</td>
<td>22.3</td>
<td>620.</td>
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<td>Muskmelon</td>
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<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Okra</td>
<td>●</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Onion, Dry</td>
<td>●</td>
<td>8,866</td>
<td>17.2</td>
<td>14.1</td>
<td>2,430.</td>
</tr>
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<td>14.7</td>
<td>28.7</td>
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<td>15.1</td>
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<td>—</td>
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<tr>
<td>Passion Fruit</td>
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<td>—</td>
<td>—</td>
<td>5.4</td>
<td>—</td>
</tr>
<tr>
<td>Peanuts</td>
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<td>460</td>
<td>—</td>
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<td>—</td>
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<tr>
<td>Peas</td>
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<td>35</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Peppers, Bell</td>
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<td>853</td>
<td>14.8</td>
<td>30.1</td>
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<tr>
<td>Potatoes, Irish</td>
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<td>27,163</td>
<td>10.7</td>
<td>6.9</td>
<td>740.</td>
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<tr>
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<td>123</td>
<td>11.2</td>
<td>13.9</td>
<td>1,560.</td>
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<td>10.5</td>
<td>20.0</td>
<td>2,100.</td>
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<td>Rhubarb</td>
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<td>—</td>
<td>—</td>
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<td>—</td>
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<tr>
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<td>639</td>
<td>14.0</td>
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<td>1,710.</td>
</tr>
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<td>Ruta Baga</td>
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<td>24</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Salsify</td>
<td>●</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Seed corn</td>
<td>●</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Soy beans</td>
<td>●</td>
<td>1,354</td>
<td>—</td>
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<td>Spinach</td>
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<td>—</td>
<td>—</td>
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<tr>
<td>Squash, Italian</td>
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<td>325</td>
<td>12.2</td>
<td>18.6</td>
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<td>Strawberry</td>
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<td>385</td>
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<td>—</td>
<td>—</td>
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<tr>
<td>Sweet Potatoes</td>
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<td>394</td>
<td>17.8</td>
<td>13.4</td>
<td>2,390.</td>
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<td>—</td>
<td>—</td>
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<td>—</td>
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<td>Sorghum</td>
<td>●</td>
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<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Tangerines</td>
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<td>294</td>
<td>9.6</td>
<td>15.8</td>
<td>1,520.</td>
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<tr>
<td>Taro, Dry land</td>
<td>●</td>
<td>—</td>
<td>—</td>
<td>19.8</td>
<td>8.4</td>
</tr>
<tr>
<td>Taro</td>
<td>●</td>
<td>—</td>
<td>8.4</td>
<td>1,660.</td>
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<td>Tomatoes</td>
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<td>23.8</td>
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<td>2</td>
<td>72.3</td>
<td>18.3</td>
<td>13,230.</td>
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<td>Watermelon</td>
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<td>4,333</td>
<td>12.6</td>
<td>11.7</td>
<td>1,470.</td>
</tr>
</tbody>
</table>
1) Assume that truck crops represent only a minor portion of demand and had little influence on the outcome of demand.

2) Assume that sugar was the highest water user (100% of pan deficit).

3) Corn, sorghum and irrigated pastures have comparable usage at about 85% of pan deficit.

4) Irrigated pasture has the lowest critical demand, i.e., in a drought period, grass or standing hay is adequate to support the animals and 10 to 15 days of inadequate water does not result in crop failure.

5) Monthly runoff probability from the Kohala Ditch was matched with demand to establish the adequacy of supply.

6) A sprinkler model capable of irrigating a 1,000 acre unit was created and is explained later.

7) Service and pressure zones were established between 1,000 feet and sea level. These zones were selected to achieve the maximum service coverage at the lowest capital and operating costs and within the resource constraints (see Water Resources Section).

8) For purposes of this Section, the logic was constrained to meet normal seasonal demand and not droughts. Droughts are covered by using pumped water or stored ground water for supply and by placing emphasis on non-critical crops such as irrigated pasture.

9) For design purposes, a core development area was selected based upon the 2,200 acres under lease to Hawaii Biogenics, Ltd. and the Kahei farm lots and existing overhead irrigation system components.

10) All increments indicated beyond the core area are programmed to fit demand; system improvements and supply are based on increment additions of 1,000 acre units after the third year.

In order to lend credence to such an approach as outlined above, it should be noted that a model of this nature is necessary to obtain a bottom line figure of $/million gallons delivered. Deviations from this model would result in changes to that figure. Results from the computer analysis indicate a maximum monthly demand of 5.6 MGD per thousand acres.

**SPRINKLER SYSTEM MODEL**

Given the irrigation rate based on crop requirement, the next consideration was the method of application itself. Overhead irrigation was chosen since it is the most practical at this time. Ditch and furrow flood irrigation is wasteful of water but requires a minimum of capital investment. Drip irrigation still requires solution of its filter requirement to prevent clogging of emitters when ditch water is used. However, when these problems are resolved, it should have wide application and will result in very efficient use of water.

A thousand acre sprinkler model using "water winches," a brand name of giant sprinklers (500 gpm/sprinkler), was studied using a 24-hour irrigation schedule. It was determined that a
thousand acre parcel would require a 6,000 gallons per minute continuous source to meet the maximum demand of 5.6 mgd.

CONSTRAINTS ON SPRINKLER SYSTEM MODEL

This sprinkler model is merely a base upon which the proposed irrigation transmission system could be evaluated. Some constraints on the water consumer are necessary based on the proposed system and they are: (1) a maximum continuous draft of 6,000 gallons per minute or equivalent to a 8.6 mgd per thousand acres irrigated; (2) the consumer would be required to boost the water pressure if high pressures are needed for irrigation equipment; (3) the consumer would be required to provide the necessary piping and irrigation equipment to hook up to the proposed transmission system; and (4) the consumer would have to provide his own supplemental storage facilities, if necessary, for his efficient use of the water.

SERVICE PRESSURE ZONES

For this study, it was concluded that economically priced water to the farmer necessitates that ground water not be pumped in excess of a vertical lift of 500 feet. Any higher lifts above this 500 feet should be considered by each individual farmer and based on his farm operation. This constraint, in effect, establishes a basis for locating a crop based on its ability to pay. In order to achieve the lowest unit cost of water and utilize the Ditch flow (the least costly water) to its fullest advantage, pumping must be limited to the lowest lift within reason and only during periods of ditch water shortage. Lands not receiving water directly from the proposed irrigation system could acquire water at the established unit price and assume the cost and responsibility for moving it to the user's area. The purpose of this step is to insure water at the lowest unit cost to the bulk water user with a low gross income per acre. For example, stock water could be made available at the Kohala Ditch for the same unit cost as the bulk user near Hawi and the rancher absorbs the cost of moving the water to his troughs. Because the quantity of water required is small, the ultimate unit cost at the trough is high. On the other hand, the negative effect on his income per acre would be relatively small. In this way, the potential agricultural development would not be limited to high income crops.

Providing for head loss and residual pressure of 40 pounds per square inch, a lower service pressure zone was set between elevation 0 and 350 feet based on pumping a maximum of 500 feet vertical lift.

Logically then, the upper area below Kohala Ditch down to elevation 350 would be irrigated during the dry months by Ditch water. It may be desirable to split this latter area into two pressure service zones to reduce the internal static and residual main pressures. Two pressure zones will permit maximum static internal main pressure of 130 pounds per square inch and reduce maintenance costs of the system due to high pipe pressures. However, the splitting of this upper area into two pressure zones will be an option of the farmer and at his expense.
Therefore, for this study report, two general service zones would be provided to the farmer; the lower service zone from elevation 0 to 350 feet and the higher service zone from elevation 350 to the elevation of the Kohala Ditch. Consideration was given to a three zone separation. This zoning was rejected on the basis of construction costs.

**PROPOSED IRRIGATION SYSTEM BASED ON POTENTIAL DEVELOPMENT** (See Map III-3)

Based on the presently irrigated sugar lands, the potential agricultural lands beyond the terminus of Kohala Ditch (Class A and Class C soils, SCS), 6,000 acres were identified as potential agricultural lands for this study.

The ultimate irrigation system to serve the 6,000 acres will require that there be: (1) improvements to Kohala Ditch, (2) construction of wells with necessary pumps and power system, (3) construction of a transmission pipe system for the lower pumped water system, and (4) possible construction of earth reservoirs along the transmission pipe system.

The portion of the study area currently under cultivation by the Kohala Sugar Company contains some 13 reservoirs with a total possible capacity of 140 million gallons. In addition, there is a system of existing ditches which feed and interconnect these reservoirs. There are also five piping systems with intakes at Kohala Ditch which run perpendicular to the contour and Kohala Ditch and furnish overhead sprinkler irrigation water. (See Section on Existing Irrigation System). Finally, there are the Union Mill, Hoea and Waikane well systems which can furnish water at a maximum rate of 16.4 mgd. The proposed ultimate system would incorporate Kohala Plantation's Hawi 3 and No. 5 reservoirs, Union Mill wells and pump and three large pipelines between Kohala Ditch and the Hawi-Mahukona Road. The Hoea and Waikane wells and force mains were not incorporated in the ultimate irrigation system since their estimated useful lives are 10 and 3 years, respectively and their maximum vertical lift is to the 360 feet ground elevation. These two sources might be considered for integration into the system should it be necessary.

The probable location of the lower pumped water transmission system was laid out considering the existing contour of the land, road system and field layout. This system would begin at Kohala Sugar Company's Reservoir No. 5, elevation 490 feet, located some 5,000 feet west of the intersection of Hawi Road and Hawi-Mahukona Highway and 2,500 feet north of the Highway. This Reservoir would contain the system intake structures and serve as a terminus for receiving pumped ground water and excess from the Kohala Ditch. Reservoir No. 5 has a capacity of 18.2 million gallons and would be used for storing water to meet high demand flow rates and to offset low flow of the Kohala Ditch. The transmission system as planned would consist initially of 5,000 feet of pipeline within the 2,000 acre core development. Then in 1,000 acre increments, the system would proceed first, in an easterly direction for 8,300 feet connecting with existing Union Mill #1 and Union Mill #2 wells, pumps and piping system and
secondly, in a westerly direction from the core development toward Mahukona for a distance of 20,000 feet. The pipeline would range in size from 30 inches to 12 inches in diameter and have low internal pressures limited to approximately 22 psi resulting from the placement of the main at a higher elevation than the service pressure zone upper limits to allow greater potential area coverage by this lower system should a low pressure water source become desirable. An alternate to the pipeline is to continue an open ditch section throughout resulting in a lower initial capital cost but in higher maintenance costs relative to pipe main transmission system.

Ground water can be made available to serve the pumped water system by drilling wells and installing deepwell pumps. Along the transmission system between the existing 18.5 mg Reservoir No. 5 and the Union Mill Wells, deepwells and pumps can be drilled and installed at 1,000 feet on centers, with each well and pump having a capacity of 2 mgd or 1,400 gpm. From the existing Reservoir No. 5 to the end of the ultimate development area, wells and pumps with a capacity of 1 mgd or 700 gpm, each, and spaced 2,000 feet on centers can be drilled and installed along the transmission system to provide additional water.

It is most economical to construct open, dirt, rubber-lined reservoirs, with a maximum capacity of 5 mg each, along the transmission system to provide a means of suppressing surges in the transmission pipes during pump operation, as additional overnight storage, as mixing points for brackish water and for receiving excess water from the Kohala Ditch.

The construction of the ultimate system as outlined above can be on an as required basis with the pumped water system with source wells coming prior to land utilization when maximum demand exceeds the 10 mgd provided by Kohala Ditch during low flow periods. The combined 110 mg storage capacity of the existing reservoirs would be able to cover the low flow periods of Kohala Ditch for short durations only but is not considered essential in the ultimate irrigation system. However, it is desirable to include Hawi 3 Reservoir and Reservoir No. 5. The 38.6 mg capacity Hawi 3 Reservoir, located near the end of Kohala Ditch, can be incorporated into the ultimate system as a means of storing excess water from the Kohala Ditch. The 18.5 mg Reservoir No. 5 can be made a part of the pumped water system since it is located within the core development area and at the 500 feet elevation. Reservoir No. 5 can also be used to interconnect the Kohala Ditch with the lower pumped transmission system.

The study indicates that, the 10 mg furnished by the Kohala Ditch during low flow periods can be effectively used to irrigate approximately 1,000 acres. All other lands must be furnished water from ground water sources utilizing deepwells, pumps and a transmission pipe system.

ALTERNATE GROUND WATER SOURCES AND STORAGE

The preceding development program has been based on surface runoff from Awini, high level ground water leakage from Honokane Nui and pumped ground water from the basal lens. These three water sources have been combined into a working relationship to produce the lowest operating costs at a minimum capital investment. While certain system refinements
might reduce these costs, it should be recognized that a heavy capital investment is required to pump water into the system. In addition, operating costs increase above maintenance as a function of the energy consumed during pumping.

As discussed in Water Resource Section, the surface runoff to the Kohala Ditch is directly related to the rainfall. During dry months and as the demand exceeds 10 mgd (the low flow from Honokone Nui), ditch water must be supplemented. Drilling wells in the user area to meet this deficit is the simplest and surest approach.

Large surface reservoirs have been considered by various investigators in the past. Such reservoir solutions have been rejected because of the lack of suitable sites and the huge capital investment for a facility which would be used intermittently. Basal ground water storage can be tapped by wells as projected in the preceding program as a solution. Of more importance, would be high level dike storage compartments located above the Kohala Ditch (see Map III-4). Such compartments are known to exist in Honokone Nui. Water stored in these compartments could be released during droughts or low flow periods to offset the amount of water which must be pumped. The significance of such storage release will be explained later in this report. As demand grows beyond the limits outlined in the preceding program, it may be necessary to consider a major high level tunnel from Honokone Nui in the direction of Waipio to recover high level water now escaping to Waimanu and to tap storage compartments enroute.

DEVELOPMENT AND MAINTENANCE OF THE KOHALA DITCH

A description of the Kohala ditch is contained in the Phase I report (Bowles 1973) and the reader is referred to that report for details. Under the proposed development program, the Kohala ditch provides the basis for obtaining low cost agricultural water. Data on the ditch flow provided in the Water Resource Section readily defines the present and future role of the ditch as a source of supply. Improvements to the ditch intakes and flumes are justified in the Water Resource Section and will not be reiterated here. Such improvements have been incorporated for cost analysis and are needed to improve delivery volume. The extent and timing of such improvements are dependent upon acceptance of the development program.

The Kehena ditch, while providing small amounts of water to the supply, is needed to provide water when the Kohala ditch flow is interrupted for flume changes and other maintenance activities. Such maintenance is normally scheduled when the Kehena ditch has adequate flow. The following paragraphs are devoted to those activities related to the proposed development program and are necessary to maintain the Kohala ditch as a major asset to agricultural water supply.

OPERATION AND MAINTENANCE PROGRAM FOR CONTINUED DITCH OPERATION

1) Mr. Dale Sproat of the Kohala Ditch Company has confirmed that it required a minimum of 6 men skilled in the operation and maintenance of the ditch to provide minimum mainte-
PROPOSED WATER DEVELOPMENT

UPPER SECTION

WATER SYSTEMS & GEOLOGIC STRUCTURES

HONOKANE NUI, EAST BRANCH

SOURCE: KOKALA CORPORATION

SCALE IN FEET

SHT 2 OF 2
nance for continued ditch operation. Two man teams are necessary for safety. The tasks of these men are to provide all necessary minor structural repairs to the flumes and other facilities to maintain the mule trails, maintain and clean the intakes, maintain the ditch banks from weeds and encroaching tree root growth, remove algae from the ditch when it becomes an operational nuisance to system operation, operate the gates to control the flow into the specified irrigated areas, operate and deliver the recording data of measurement of ditch flow.

2) To provide an efficient Ditch operation in the future, the following are recommended:
   a) Enter into contract with the Ditch Company or in the event of acquisition, employ or contract the present experienced ditchmen.
   b) The redwood flumes, when declared inoperable, within the Kohala section should be replaced with prestressed concrete flumes since the ones which have been constructed have proven their durability and should last much longer than redwood counterparts.
   c) Maintenance of poisoning of the banks should be continued to reduce the manpower requirements. However, water quality should be assured in this operation and controlled by the proper responsible agency.
   d) Ditch lining in areas planted with large ironwood trees alongside has shown a serious structural damage and the tree roots extending into the ditch section are constricting the flow. A long-term solution would be to remove the trees and permanently remove the problem and thereby increase the flow capacity of the ditch. It is understandable that due to the economic problems of the sugar operation, a maintenance policy and program was implemented that could not justify a long-term capital improvement program to reduce maintenance operations.
   e) As mentioned above, the condition of the concrete lining of the open-ditch sections is fair to poor. There are numerous locations where the lining has been severely damaged by root growth of trees abutting the ditch as noted in (d) above. The repair of the concrete lining should be included in the duties of the operation and maintenance program and only after the tree root growth problem is under control. In this approach, the following would be accomplished:
      1. The tree root growth problem will be permanently resolved and thereby reduce the rate of damage to the lined ditch and reduce maintenance.
      2. The reconstruction of the damaged lining of the ditch will reduce leakage and increase delivery efficiency.
   f) Service Road for Ditch (through plantation area). Field inspection confirmed that a service road along side the ditch would make the ditch maintenance operation more efficient. The existing topography along the ditch do not make feasible a continuous maintenance road abutting the ditch. Also, it is noted that there is no maintenance road along the ditch which abuts private property, i.e. Kahei Homesteads and Kokoiki
Homesteads. For capital improvement budget estimate purposes, the length of ditch, exclusive of existing abutting cane roads, gulches, and tunnel sections, was identified and an estimate made for constructing such a road.

3) To increase the low flows and also the capacity of the ditch, the following is recommended and is covered in the recommended capital improvement program:
   a) Construct a horizontal drill hole in Honokane Nui as shown in Map III-4a. The purpose of this drill hole would be to confirm the existence of a high level dike storage compartment above the ditch. Such storage would be used to augment the low flow and offset well pumping in dry periods.
   b) Replace the existing flumes and intakes of the Awini Section of the ditch to increase flows and the capacity of the ditch.

POWER SOURCES

EXISTING CONDITIONS

There are presently two primary suppliers of electrical power serving the North Kohala district. The first being Hilo Electric Light Company, Ltd., (HELCO) and the second, Kohala Corporation.

HELCO generates electricity through their generating plant located at the mouth of the Wailuku River in Hilo. Through a series of high voltage transmission lines, substations, and transformers, located mostly along the major highways leading into Kohala, electrical power is transmitted to the Kohala district.

The two primary voltages available along HELCO's transmission lines are 33 and 2.4 kv (kilovolts). With the use of substations and step-down transformers, electricity is supplied to residences, small businesses, government facilities (Coast Guard Station near Honoipu Landing and Kauhola Point Light House), and others requiring HELCO's electrical power.

The existing electrical power sources maintained by Kohala Corporation are those shown on Table III-3. They include the two steam turbines at the Kohala Sugar Mill and two hydroelectric plants located at Hawi and Union Mill.

The steam generating plant at the sugar mill consists of two turbines rated at 7,500 kw (kilowatts) and 2,000 kw; however, the plant has boiler capacity sufficient to generate 15,000 kw of electrical power. Kohala Corporation utilizes bagasse, a by-product of sugar cane, for fuel. Bagasse, being a combustible material, is used as the prime source of energy to evaporate water into steam; the form of energy required to turn the impellers of the turbine to generate electrical energy. The voltages made available along Kohala plantation lines are 19.5 and 2.4 kv.

On the other hand, water is used in place of steam to generate electrical energy at the Hawi and Union Hydroelectric plants. In this case, the difference between elevations at the intake
TABLE III-3
EXISTING POWER SOURCES FOR KOHALA SUGAR COMPANY IRRIGATION SYSTEM

<table>
<thead>
<tr>
<th>Unit</th>
<th>Hawi</th>
<th>Union</th>
<th>Mill</th>
<th>Mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Hydro</td>
<td>Hydro</td>
<td>Turbine</td>
<td>Turbine</td>
</tr>
<tr>
<td>Rated Kilowatts</td>
<td>350</td>
<td>500</td>
<td>2,000</td>
<td>7,500</td>
</tr>
<tr>
<td>Rated KVA</td>
<td>437</td>
<td>625</td>
<td>2,500</td>
<td>9,375</td>
</tr>
<tr>
<td>Voltage</td>
<td>2,300</td>
<td>2,300</td>
<td>2,400</td>
<td>11,500</td>
</tr>
<tr>
<td>rpm</td>
<td>514</td>
<td></td>
<td>3,600</td>
<td>3,600</td>
</tr>
<tr>
<td>Fuel</td>
<td>Water</td>
<td>Water</td>
<td>Steam from Boiler</td>
<td>Steam from Boiler</td>
</tr>
<tr>
<td>Fuel Source</td>
<td>Kohala</td>
<td>Kohala</td>
<td>Cane</td>
<td>Cane</td>
</tr>
<tr>
<td>Ditch</td>
<td>Kohala</td>
<td>Kohala</td>
<td>Bagasse</td>
<td>Bagasse</td>
</tr>
<tr>
<td>Head</td>
<td>280 feet</td>
<td>500 feet</td>
<td>200 lbs. Steam at 480 deg. F.</td>
<td>440 lbs. Steam at 650 deg. F.</td>
</tr>
<tr>
<td>Year Installed</td>
<td>1923</td>
<td>1940</td>
<td>1936</td>
<td>1966</td>
</tr>
<tr>
<td>Age, years</td>
<td>50</td>
<td>33</td>
<td>37</td>
<td>7</td>
</tr>
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</table>

*water at Kohala Ditch and at the hydroelectric plant called the “head”, acts as the source of energy to drive the impellers. The Hawi and Union Hydros are rated at 350 kw and 500 kw, respectively. The length of the hydro pipe lines are 6,075 feet for Hawi and 7,900 feet for Union. The voltage made available is 2.3 kv.*

The existing electrical facilities for the irrigation system is diagrammed on Figure III-1. As shown, the Kohala Mill steam turbine is the primary generating electrical source. Through the use of transformers (92 each), substations (3 each), bus bars, and transmission lines (45 miles), electrical power is transmitted to the pumping sites. Through a switching unit, Kohala Corporation is able to switch to Hilo Electric lines as an alternate source. Hydroelectric plants are also available and utilized to provide supplemented power when required.

Electricity generating steam turbines at Kohala Mill presently provide power to all the existing plantation wells, pumps, and Mill facilities. The Union Mill Hydroelectric plant, when receiving enough water from the Kohala Ditch, can supply electrical power to either Union #1 and Union #2 well or booster pumps. Likewise, the Hawi Hydroelectric plant can supply electrical power to Hoea well and booster system pumps and Waikane well pump. It is noted that the Hawi and Union Hydros are not continuously operating plants.

**POWER SOURCE ALTERNATIVES**

Based on the recommendation that wells would be drilled above the proposed lower service area, there will be a need to install vertical turbine deepwell pumps. In order to operate these
Kohala Mill Steam Turbines
1) 7500 KW, 9375 KVA, 11500 V
2) 2000 KW, 2500 KVA, 2400 V

Kohala Well and Pumps
Pumps: 1 @ 150 HP, 2.3 KV
1 @ 300 HP, 2.3 KV

(2.4 KV) From Hilo Electric Light Company, Ltd.

19.5 KV

LEGEND

Well and Pump
Booster Pump
Steam Turbine Generating Plant
Hydroelectric Plant
Distributing Point
Transformer or Substation
------ Primary Source
----- Alternate and Supplementary Source

Union #1
Deepwell Pump @ 250 HP, 2.3 KV

Union #1
Booster Pump @ 250 HP, 2.3 KV

Union #2
Deepwell Pump @ 250 HP, 2.3 KV

Union #2
Booster Pump @ 250 HP, 2.3 KV

Union Hydroelectric Plant
(500 KW, 625 KVA, 2.3 KV)

Hawi Hydroelectric Plant
(350 KW, 437 KVA, 2.3 KV)

Hawa Well and Pump
1 @ 300 HP, 2.3 KV

Hawa Mill
Booster Pump @ 200 HP, 2.3 KV

2.4 KV

2.4 KV

2.4 KV

2.4 KV

2.4 KV

480 V

Kazinu Booster Pumps - 2 @ 40 HP, 440 V
2 @ 75 HP, 440 V

Waikane Well and Pump @ 800 HP, 2.3 KV

2.4 KV

Source:
Kohala Corp. Base II - Map 3
Date: 6/21/75

SCHEMATIC DIAGRAM
KOHALA CORPORATION
IRRIGATION-ELECTRICAL SYSTEM
pumps, electrical or direct driven diesel engine power will be required.

Electrical power can be made available from either of the following sources: Kohala Mill's steam turbine electric generating facilities, Union and Hawi hydroelectric generating plants, HELCO's electrical lines serving the area, and a proposed diesel engine powered generator system. The latter might use methane generated from animal waste as a fuel alternative.

**EXISTING FACILITIES**

To include Kohala Mill's steam generating facilities, the following problems must be overcome; (1) the problem of accessibility, (2) since Kohala Mill is owned by Kohala Corporation, a means of obtaining or leasing their facilities must be agreed upon, (3) find a suitable and economical replacement for bagasse as a fuel source. This latter problem is of great concern once Kohala Corporation ceases to grow sugar cane; since bagasse will no longer be available. Other means of fuel sources, such as, manure and fiber plants have been pursued by Hawaii Biogenics, who concluded that unless a fuel source can adequately produce 65,000 pounds of steam per hour, the steam turbines should not be operated. In both the manure and fiber plants considerations, a conclusion was reached that physically and economically, it is unfeasible to maintain Kohala Mill's generating facilities.

One of the steam turbines at Kohala Mill, rated at 7,500 kw, was installed in 1966. Although the generating facility is fairly new, renovations are necessary to the enclosing structure and manual control system. The other turbine, rated at 2,000 kw, was installed in 1936. This turbine faces the same problems as the newer turbine, with the added problem of overhauling the system.

Another possible source of electrical power would be Union and Hawi hydroelectric plants. Like Kohala Mill turbines, the hydroelectric plants are old facilities; Hawi installed in 1923 and Union, 1940. For continued service, the existing water turbines and generators should be dismantled and overhauled. It is also necessary to renovate the existing structures and update the manual control system. Mr. Ray Gianini of Kohala Corporation estimated that a minimum of $20,000 and probably more will be required for renovation work. The existing penstocks at both facilities should also be replaced. Hawaii Biogenics in their study for North Kohala estimated $100,000 for penstock replacement at Hawi. Similarly, the replacement cost at Union hydro will be higher than Hawi because the penstock at Union is longer than the penstock at Hawi.

A critical problem is that these hydroelectric plants require a constant supply of water at the penstock intake — say in the neighborhood of over 5 million gallons a day to operate efficiently. Since both hydroelectric plants obtain water from the Kohala Ditch, during low flow water periods, water is not available to provide the required hydraulic pressure. Thus, during the most critical period of dry weather, no electrical power will be produced for irrigation. This problem might be overcome by relocating one of the hydro plants or locating a new plant within the proposed water system.
For the irrigation system, power distribution lines and transformers will be required. The capital cost required to upgrade the Kohala electrical facilities to meet the current standards are far too great. It involves a complete overhaul of the existing grid. Even though the operating standards might be met, the problem of solving a fuel replacement for the steam turbines and solving the water problem for the hydroelectric plants are still to be met.

HILO ELECTRIC LIGHT COMPANY, LTD. (HELCO)

HELCO, a producer of electrical power, offers another means of supplying electrical power to the proposed pump sites. HELCO makes available 33 kv and 2.4 kv along their transmission lines near the study area. On a recent trip to Hilo, it was stated by a HELCO Customer Service personnel that the use of the 33 kv transmission line is necessary to supply the required power to operate the well pumps. However, before HELCO's power can be made available, either a new substation is required after the direct tap off the 33 kv line; or possibly the expansion of the existing Hawi substation, if its maximum capacity has not been reached. For either case, the substation steps down the 33 kv to a workable 4.16 of 2.4 kv. It was also stated that only one meter is required to determine operational costs for the pumps. The placement of such a meter will be made in the substation mentioned above and energy will be metered on the primary side of the customer's transformers. For this type of meter hook-up, there will be a flat $425.00 demand charge for nonoperational months.

Like the plantation system, a HELCO hook-up will require distribution lines and step-down transformers at each pump site. According to HELCO, the customer will be responsible for the installation and maintenance of the transformers and lines, physically placed after the meter.

As shown on Table III-4, the approximately operational costs for a normal year have been calculated. Normal year calculations are made for 1,000 acre increments up to 6,000 acres. The cost calculations were based on HELCO's "Schedule P" — effective March 1, 1970. As an example, for the proposed irrigation system (6,000 acres), the approximate operating cost for a normal year is $110,000. Included within the operating costs are flat demand charges of $425/month during the periods of idleness.

DIESEL DRIVEN ELECTRIC GENERATOR

Electrical power can also be supplied from the use of diesel engine generator sets to operate the pump motors for the proposed lower service area. The set includes a battery starting diesel engine directly coupled through a shaft to an A.C. generator unit. Together, they form a system capable of generating electrical power.

The diesel generator mentioned above has options to install remote control units and disengaging clutch units. The remote control units provide a feature that enables all pumps to be operated from a centralized location. The clutch unit will be required for the proposed
Table III-4
PUMP OPERATING COSTS USING HILO ELECTRIC LIGHT COMPANY, LTD. POWER

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<tbody>
<tr>
<td>1,000</td>
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<tr>
<td>2,000</td>
<td>425</td>
<td>425</td>
<td>425</td>
<td>425</td>
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<td>425</td>
<td>425</td>
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<td>425 5,100</td>
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<td>3,000</td>
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<td>425 5,100</td>
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<td>4,000</td>
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<td>425</td>
<td>425</td>
<td>425</td>
<td>6,290</td>
<td>6,129</td>
<td>7,094</td>
<td>6,129</td>
<td>425</td>
<td>425</td>
<td>425</td>
<td>425</td>
<td>425 29,042 36.7 $791</td>
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<tr>
<td>5,000</td>
<td>425</td>
<td>425</td>
<td>425</td>
<td>8,101</td>
<td>10,031</td>
<td>8,315</td>
<td>14,534</td>
<td>9,816</td>
<td>425</td>
<td>425</td>
<td>425</td>
<td>425</td>
<td>425 62,306 220.6 282</td>
<td></td>
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<tr>
<td>6,000</td>
<td>425</td>
<td>425</td>
<td>425</td>
<td>11,693</td>
<td>17,737</td>
<td>12,242</td>
<td>14,440</td>
<td>25,998</td>
<td>16,638</td>
<td>10,044</td>
<td>425 110,917 635.7 174</td>
<td></td>
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</tbody>
</table>

Note: 1) Above costs are based on all pumps operating at once to meet water requirements. Actual operation will be more efficient by management and scheduling of pump operation to meet user requirements.
2) Monthly operational cost based on rates shown on HELCO's "Schedule P"—Effective March 1, 1970.
3) Total Annual Cost is based on a normal year.
4) Cumulative acreages 2,000 and 3,000 are pump idle years.
5) Calculations based on one meter hook-up as confirmed by HELCO.
6) Cumulative Acreages
   Require X Number of Pumps:
   2,000 — Four 1400 gpm pumps
   3,000 — Eight 1400 gpm pumps
   4,000 — Twelve 1400 gpm pumps
   5,000 — Twelve 1400 gpm pumps
   Two 1850 gpm pumps
   Four 700 gpm pumps
   6,000 — Twelve 1400 gpm pumps
   Two 1850 gpm pumps
   Thirteen 700 gpm pumps
irrigation system because of discontinuous operation of the pumps. The clutch unit allows the engine to run at no-load for maintenance purposes.

The diesel generator set can be permanently mounted on a platform or placed on portable skids or wheels. The latter possibility offers the operator a mobile unit that increases his flexibility in usage. This is of great importance when evaluating the potential irrigation system, since the electrical requirements are minimal for an average month. During the period of idleness, the diesel generator set can be utilized at another location for other purposes or they could be stored at a centralized location. When stored at a centralized location, maintenance of these sets are easier as compared to separate field locations.

The approximate operating cost for the proposed irrigation system based on a normal year is $35,200. See Table III-5. Like the HELCO operating table, the calculations for normal years are made for 1,000 acre increments up to an ultimate 6,000 acres. The diesel engine generator set operating costs were based on current diesel fuel rate of 28 cents a gallon f.o.b. North Kohala, and also, the operating of the diesel engines for 2 hours a week during months of pump idleness for engine reliability.

**DIESEL DIRECT DRIVE FOR PUMPS**

An alternate method of operating a deepwell pump can be accomplished by using a battery starting diesel engine directly connected to a right angle gear drive head of the pump. In this case, no electric pump motor is required.

Like the previously mentioned diesel driven electric generator, the diesel direct drive unit has the same options to install remote control units and disengaging clutch units.

The diesel direct drive unit can be permanently installed or placed on a movable platform for temporary periods. The permanent setup is recommended over the temporary setup since there is a problem of realigning the direct drive unit with the pumping unit for each transfer. Furthermore, when used on a temporary setup, the unit must be lifted from the platform and placed on mobile units during relocation. In order to use this equipment for other purposes, the connecting shafts must be compatible and a permanent platform is required at each site. A permanently installed unit eliminates flexibility in usage and creates difficulty during periods of maintenance. Besides a stable platform, a protective shelter will be required.

Based on current diesel fuel rates of 28 cents a gallon f.o.b. North Kohala and the operation of the diesel engines for 2 hours a week during months of pump idleness, the approximate operating cost for the proposed irrigation system is $30,600. See Table III-6. Like the other operating tables mentioned before, the calculations are based on 1,000 acre increments up to an ultimate 6,000 acres.

It is recommended that the diesel generator sets be used as the power source for the following reasons:

1) They are portable and can be used for other purposes related to agriculture.
### Table III-5

**PUMP OPERATING COSTS USING DIESEL GENERATOR SETS**

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<td>144</td>
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<td>36.7 $84.77</td>
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**NOTE:**

1. Above costs are based on all pumps operating at once to meet water requirements. Actual operation will be more efficient by management and scheduling of pump operation to meet user requirements.
2. Monthly operational cost based on current Diesel fuel @ 28c per gallon f.o.b. North Kohala and 2 hours of no load operation a week during months of pump idleness.
3. Total annual cost is based on a normal year.
4. Cumulative acreages of 2,000 and 3,000 are pump idle years.
5. Cumulative Acreages
   - Require X Number of Pumps:
     - 2,000 — Four 1400 gpm pumps
     - 3,000 — Eight 1400 gpm pumps
     - 4,000 — Twelve 1400 gpm pumps
     - 5,000 — Twelve 1400 gpm pumps
       - Two 1850 gpm pumps
       - Four 700 gpm pumps
     - 6,000 — Twelve 1400 gpm pumps
       - Two 1850 gpm pumps
       - Thirteen 700 gpm pumps
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<td>96 1,152</td>
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<td>4,000</td>
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<td>264</td>
<td>30,553 635.7</td>
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</table>

**NOTE:**
1) Above costs are based on all pumps operating at once to meet water requirements. Actual operation will be more efficient by management and scheduling of pump operation to meet user requirements.
2) Monthly operational cost based on current Diesel fuel @ 28c per gallon f.o.b. North Kohala and 2 hours of no load operation a week during months of pump idleness.
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   Require X Number of Pumps:
   2,000 — Four 1400 gpm pumps
   3,000 — Eight 1400 gpm pumps
   4,000 — Twelve 1400 gpm pumps
   5,000 — Twelve 1400 gpm pumps
   Two 1850 gpm pumps
   Four 700 gpm pumps
   6,000 — Twelve 1400 gpm pumps
   Two 1850 gpm pumps
   Thirteen 700 gpm pumps
2) During non-operating periods, the standby cost is minimal.
3) The operating cost is comparable to diesel direct drive and below that of power supplied by HELCO.
4) Units can be transported to a central location for storage and maintenance and reinstalled with no difficulty in alignment.
5) While plantation power is cheaper it was eliminated because:
   a) No fuel.
   b) Steam turbines must be replaced.
   c) Existing facilities must be overhauled to meet present standards.
6) They might readily be converted to methane or propane.
RECOMMENDATIONS FOR A CAPITAL IMPROVEMENT PROGRAM

PROPOSED IRRIGATION SYSTEM WITHIN THE POTENTIAL DEVELOPMENT AREA (See Map III-3)

ASSUMPTIONS

Sources.
Assumptions for a capital improvement program for the proposed irrigation water transmission system are outlined below:
1. Kohala ditch average flow (1928-1960)
2. Basal ground water pumpage when ditch flow must be supplemented
3. Minimum ditch flow of 10 mgd

Demand.
1. Major crops are sorghum, corn, forage or pasture
2. Consumption of 1,000 acre increments based on 85% of pan deficit at Puakea
3. Application based on sprinkler model

System.
1. Use Kohala ditch with improvements
2. Use existing pipelines, wells and reservoirs where possible
3. Use new pipelines, wells, pumps and reservoirs as required by increments

Increments.
1. Start with core development
2. Add 1,000 acre increments as proposed

Miscellaneous.
1. Pumps powered by diesel generator sets
2. Cost estimates based on 1973 levels
3. No inflation factor

Based on the above assumptions, recommendations for a capital program for the proposed irrigation water transmission system are outlined below:

KOHALA DITCH

1) Awini Section — Replace flumes and intakes.
2) Awini Falls to Niulii Section — Construct horizontal drill hole and appurtenances in Honokane Nui.
3) Kohala Section.
   a) Replace redwood flumes with prestressed concrete flumes.
   b) Construct maintenance road along ditch where feasible.
UPPER SERVICE ZONE

Secure rights to use three existing Kohala Plantation's overhead irrigation feeder lines:

1) 30-inch pipe off the Kohala Ditch from the intersection of Kehena and Kohala Ditch to Mahukona-Hawi Highway.
2) 24-inch pipe off the Kohala Ditch and along the Hawi side of Hawi 3 Reservoir to Mahukona-Hawi Highway.
3) 24-inch pipe off the Kohala Ditch and running along Kynnersley Road down to the Union Mill wells and pumps.

LOWER SERVICE ZONE

1) Acquire rights to use Kohala Plantation’s Reservoir No. 5 and the Union 1 and 2 wells, pumps, booster pumps, motors and appurtenances.
2) Construct or install wells, pumps, motors, diesel generators, transmission lines, earth reservoirs and appurtenances for the service irrigation system in increments serving approximately 1,000 acres each. The incremental and cumulative capital costs are tabulated in Table III-7.
<table>
<thead>
<tr>
<th>COST ITEMS</th>
<th>1000Ac.</th>
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<th>4000Ac.</th>
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<td>a) Flumes</td>
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<td>b) Intakes</td>
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<td>Horiz. Drill</td>
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<tr>
<td>Hole &amp; Appurtenances</td>
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<td>3. Kohala Ditch-Kohala Section</td>
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<tr>
<td>a) Replace Redwood Flumes</td>
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<tr>
<td>w/Prestressed Conc. Flumes</td>
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<tr>
<td>b) Maintenance Road along ditch</td>
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<td>7. Open Earth Reservoir</td>
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<td>100,000</td>
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<td><strong>INCREMENTAL TOTAL</strong></td>
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<td>$868,000</td>
<td>$905,000</td>
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<td><strong>CUMULATIVE TOTAL</strong></td>
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<td>$1,926,000</td>
<td>$2,984,000</td>
<td>$4,026,000</td>
<td>$5,521,000</td>
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*Replacement Cost not function of increments but of flume's estimated life.
FINANCIAL AND ORGANIZATIONAL CONSIDERATIONS REGARDING THE WATER SYSTEMS FOR THE DISTRICT OF NORTH KOHALA

GENERAL INTRODUCTION

GENERAL BACKGROUND

The past and present water requirements for the North Kohala area have been satisfied by the Kohala Sugar Co. for agricultural purposes and the County of Hawaii for domestic use. With the inevitable closure of sugar operations by Kohala Corp., a wholly-owned subsidiary of Castle & Cooke, Inc., it is apparent that if the agricultural base for economic viability is to continue, an economical source of agricultural water is essential. It appears that no one single agricultural water user can justify the entire expense of an agricultural water system capable of furnishing water at an economical rate. Therefore the collective use of various agricultural ventures of a single water system would be in the best interests of each user as well as contributing to the economic viability of North Kohala.

FINANCIAL CONSIDERATIONS

PURPOSE

The basic purpose of this section of the Kohala Water Resources Development and Management Plan-Phase II report is to accumulate and classify the costs identified by the water use model created for a normal year. The schedules presented represent this data. Graphic presentation of this data will more vividly point up the financial considerations (See Figure 1-2 & 1-3). Finally this report will draw conclusions and related solutions to financial problems as they relate to hydrology, engineering and basic organization.

GENERAL APPROACH

The basic approach is similar to that of a score keeper who merely accumulates the financial data as developed by the designers of the model.

In order to help evaluate, the dimension of time was added to the 1000 acre unit approach for development of the model to help compare incremental cost increases due to added acreage with expected revenue based on the increasing demand for water. It is important to note that the timing of the introduction of 1000 acre units could be decelerated or accelerated but the costs and revenue presented per accumulated acreage would remain valid.
ASSUMPTIONS

Revenue is based on the selling rate of $50.00 per million gallons which is considered a price at which most agricultural bulk water users can operate profitably. The volume of water sales, referred to as demand, is taken from the normal year model as previously presented.

Expenses are classified in three categories:
  Operating Expenditures — see Schedule 2
  Capital Costs — see Schedule 3
  Depreciation — see Schedule 4

OPERATING EXPENDITURES — SCHEDULE 2

Labor expense is a direct function of manning levels which resulted from estimates of Mr. Dale Sproat, Foreman of Kohala Ditch Co., the management of Kohala Corp., and confirmed by consultants Akinaka and Bowles. The number employed ranges from a caretaker crew of 6 regular full-time to a full complement at the 6000 acre irrigation level of 15 regular full-time employees. For example, as the delivery capacity of the Kohala ditch is approached the planned pumping operations would be activated to make up water deficits between irrigation demand and ditch delivery. This situation would require additional staff to operate and maintain the diesel generator sets and pumps. Another program of ditch improvement is planned as 4000 acres are irrigated. This program would require a crew of 4 regular full-time employees. An additional benefit of this program is that capital expenditures will be reduced. Commencing at the 2000 acre level 5 summer temporary hires are budgeted not only to continue the present practice but to provide extra labor at a time when maintenance projects can more easily be accomplished due to the reduced ditch flow.

Administrative Expense includes lease rental expense for office and maintenance yard, office supplies and material, all vehicle operation, office equipment lease rental, travel and promotion, and utilities for office and maintenance yard.

Fuel for diesel generator sets relates directly to the amount of water that must be pumped from basal ground water to supplement the ditch flow as demand exceeds ditch flow. The costs were generated by Akinaka, see Preceding Section for detailed information.

Maintenance pumps and generators costs are based on estimates from Bowles and Akinaka. This includes regular preventative maintenance as well as complete overhauls as usage requires. Labor costs for this function are included in labor, therefore the majority of the cost is parts, material and supplies.

Stables include the cost of feed, training and purchases of mules for transportation of men and material. The estimates are derived from the experience of Kohala Ditch Co.

Professional Services is the approach assumed to keep staff overhead at a minimum in order to help maintain fixed overhead at a low level. Professional Services such as accounting and
audit, hydrology, engineering, and legal-counsel are assumed to be contracted for on an as required basis.

Miscellaneous expenditures are the amounts considered sufficient to meet expenses unknown at this time and various contingencies. The amounts were computed by assuming that approximately 90% of the expenses with regard to the Normal Year Model are accurate. Ten percent of the known expenses was taken to be the Miscellaneous expenditure.

CAPITAL COSTS — SCHEDULE 3

The assets now in use in the Kohala ditch operation that are considered necessary by Akinaka and Bowles are valued at their estimated book value at 1-1-75 as shown on the property ledgers of Kohala Sugar Co./Kohala Ditch Co.

Improvements to the ditch system, the purchase of wells and pumps, and the installation of the integrated water distribution system are completely based upon cost estimates furnished by Akinaka. Note that generally improvements, acquisitions and installation are predicated on water demand of 1000 acre units as they are introduced rather than the annual time frame.

An alteration in the schedule for the improvements to the Awini section of the ditch was made with the consent of Bowles and Akinaka. The delay of the expenditure from the 2000 acre level to the 4000 acre level is economically justifiable because source development becomes critical thereby saving the time value in the payment of capital costs without materially affecting the water system.

After consultation with State officials and private financial institutions an interest rate of 6% simple interest per annum was applied to Capital expenditures. This assumes that some type of debt financing, such as revenue bonds, is secured.

DEPRECIATION — SCHEDULE 4

The assets now in use in the Kohala ditch operation and considered necessary in the model are taken at the book value at 1-1-75 and depreciated straight-line basis over the estimated useful life of the asset without regard for obsolescence. This is a departure from the asset life as determined by Kohala Sugar Co./Kohala Ditch Co. where the termination of certain leases became the prime factor to determine useful asset life.

The new assets, improvements to the ditch, basal pumping system, and distribution system are depreciated on a straight-line basis over the useful life of the asset as presented by Akinaka from manufacturers’ estimates and confirmed by Bowles.

OTHER ASSUMPTIONS

Taxes were neither computed nor included in the financial schedules. The tax areas are: real property, gross excise, public utility, state income and federal income. The basis upon which
the decision to eliminate taxes was made is that with the creation of the entity to provide the water service the necessary steps could then be taken to ensure a tax exempt status, if not permanently for at least a ten year period.

Water lease rents were also deliberately excluded. The Kohala Ditch Co. presently pays approximately $30,000.00 annually to the Estate of Bernice P. Bishop and $8,000.00 annually to the State of Hawaii. The assumption in this instance is that arrangements will be made in both cases to eliminate the water rental payments in order to reduce the operating overhead of the Ditch Co. The limited users (farm lots and Hawaii Biogenics) cannot absorb the costs during the transition period.

**STRESS MODEL CONDITIONS**

The basic assumption thus far has been the condition of a normal year with its calculated source availability and demand usage. In order to add to the comprehensive nature of this report a stress model condition was created for the period of a year. This stress year is a condition where the ditch flow is reduced due to existing source availability and where user demand is increased due to the lack of normal precipitation.

The solution as presented here is to use additional basal ground water to satisfy the water deficit. This solution naturally involves added incremental costs to water due to the necessity of pumping. The pumping mainly consists of fuel consumption and maintenance costs to a lesser degree.

Assuming a stress year when 3000 acres are under irrigation, the stress demand would be 4249 million gallons with stress ditch flow at 5028 million gallons. In spite of the apparent surplus, ditch flow is inadequate for 5 months. A water deficit of 768 million gallons would exist, representing additional pumping costs of approximately $40,000.00.

Assuming a stress year when 6000 acres are under irrigation, the stress demand would be 8498 million gallons with the stress ditch flow remaining at 5028 million gallons. The water deficit now increases to 4115 million gallons which would cost an additional $210,000.

It becomes obvious that another source of water to make-up stress period water deficits that does not require pumping is necessary to maintain a cost equilibrium. If high level ground water storage became available in quantities up to 4,000 mg, its release into the ditch system could reduce or solve the pumping cost problem.

**FINANCIAL CONCLUSIONS — OPERATING STATEMENT — SCHEDULE 1**

It is concluded that selling agricultural water at $50.00 per million gallons does not generate sufficient revenue to cover all costs incurred in the normal year model. Conversely, if water reflected costs as presented at the 6000 acre level, for example, the sales price of water would be approximately $125.00 per million gallons.
Note that revenue is almost equal to Operating Expenditures at 4000 acres and thereafter revenue slightly exceeds operating expenses, all in a normal model year.

The stress model cost increase compounds water costs thereby emphasizing the need of high level ground water storage release into the ditch system which could minimize to a large extent basal ground water pumping costs.

The primary solution to economic feasibility of the North Kohala Water Resources Development and Management Plan lies with capital costs and related depreciation.

Under the model conditions set forth in the normal year model and reflected in Schedule 1, the project is feasible only when a higher rate is charged for water service.

**ALTERNATIVE FINANCIAL SOLUTION — OPERATING STATEMENT — SCHEDULE 5**

As commercial ventures require equity capital, a solution to the financial situation here rests with sources of capital to replace the heavy debt funding arrangement. There are two general sources for funding: Government and Private participation.

Governmental funding in the form of general obligation bond grants from the State of Hawaii and the County of Hawaii is a possibility. Federal government financing without interest must be investigated. It appears that some governmental mix in participation may result.

Private participation may be expected in two areas. First, the water users could be expected to pay an assessment by acreage in much the same manner as assessments are in an improvement district on the municipal level of government. Secondly land owners may be encouraged to invest in the project seeing that the land to benefit would be their own. As water becomes available to the land the economic value of the land naturally increases thereby increasing the lease rent charged. An example might be the rate charged for dry land pasture as compared to the rate that could be charged if the pasture were irrigated thereby substantially increasing its carrying capacity.

The end result of this open funding arrangement would be a Governmental/Private joint participatory funding. This could be extended to the joint control of policy and general management of the entity created to provide water service. See the Organizational Considerations directly following for further details.

The success of the development of high level ground water storage and release to minimize basal ground water pumping costs has three very critical effects on financial considerations:

1) The operating costs can be materially reduced in a stress year;
2) The operating costs can further be reduced in a normal year;
3) It would delay and reduce capital expenditures regarding wells, diesel generator sets and pumps.
The high level ground water potential must be explored and evaluated as soon as possible. In evaluation, a comparison of capital expenditures regarding high level and basal ground water must be made in terms of reliability of source and its ultimate effect on the cost of water. Finally, if debt service and related depreciation are removed through alternative financing and the substitution of expensive basal ground water with cheaper high level ground water, the water project would be financially sound.

ORGANIZATIONAL CONSIDERATIONS

PURPOSE

The basic purpose of this section of the Kohala Water Resources Development and Management Plan-Phase II report is to conceptually present an entity which will effectively serve the agricultural water needs of the district of North Kohala. In view of the foregoing sections involving the resource and its potential, engineering and financial considerations, and most important the welfare of the population of North Kohala a water cooperative is proposed which hereafter shall be referred to as the North Kohala Water Cooperative. The governing body of this cooperative shall be referred to as the Council.

CERTAIN PURPOSES

The North Kohala Water Cooperative Council would be organized and its function would be to fulfill the following purposes:

1) The operation and maintenance of existing irrigation works.
2) The reconstruction, repair or improvement of existing irrigation works.
3) The construction or purchase of works or parts thereof for the irrigation of lands within the operation of the district.
4) The construction, reconstruction, repair or maintenance of a system of diverting conduits (dams, tunnels, ditches, flumes, wells, pipelines, etc.) from a natural source of water supply to the point of individual distribution primarily for irrigation purposes.
5) The execution and performance of any contract authorized by law with any department of the federal government or of the State of Hawaii or the County of Hawaii for reclamation and irrigation purposes.
6) The performance of all things necessary, within the law, to enable the Cooperative to exercise the powers granted it by act of legislation.

CERTAIN POWERS

In order to fulfill the purposes for which it would be created the North Kohala Water Cooperative Council would be granted the following additional powers:
Kohala Water Resources Management & Development Plan — Phase II
Schedule 1
Operating Statement

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<th>Year</th>
<th>1000 Acres</th>
<th>2000 Acres</th>
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<th>5000 Acres</th>
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<th>6000 Acres</th>
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<td>1981</td>
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</tbody>
</table>

Revenue

- $50.00 per Million Gals. × 1194 Million Gals. = $59,700
- $50.00 per Million Gals. × 2388 Million Gals = $119,400
- $50.00 per Million Gals. × 3582 Million Gals. = $179,100
- $50.00 per Million Gals. × 4776 Million Gals. = $238,800
- $50.00 per Million Gals. × 5970 Million Gals. = $298,500
- $50.00 per Million Gals. × 7164 Million Gals. = $358,200

Total Revenue = $358,200

Expenses

- Operating Expenditures — see Schedule 2
- Capital Costs — Interest — see Schedule 3
- Depreciation — see Schedule 4

Total Expenses = $1,791,000

Total Annual Income/(Deficit) = $(3,913,190)
## Kohala Water Resources Management & Development Plan — Phase II
### Schedule 2
#### Operating Expenditures

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Labor</td>
<td>$87,216</td>
<td>$115,128</td>
<td>$117,924</td>
<td>$141,060</td>
<td>$174,180</td>
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<td>$185,352</td>
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<td>4,600</td>
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<tr>
<td>Materials &amp; Supplies</td>
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<td>4,000</td>
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<td>8,000</td>
<td>10,000</td>
<td>12,000</td>
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<td>12,000</td>
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<td>90,000</td>
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## Kohala Water Resources Management & Development Plan — Phase II
### Schedule 3
### Capital Expenditures & Capital Costs

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<tr>
<td>Capital Expenditures</td>
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<td>$164,141</td>
<td>$971,141</td>
<td>$1,707,141</td>
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</table>

### Existing Facilities:
- **Flumes — Awini Section**: $17,955
- **Flumes — Kohala Section**: $96,186
- **Other facilities, equipment & tools**: $20,000
- **Total**: $134,141

### Improvements — Ditch, Awini Section
- $33,300
- $50,000
- $50,000
- $50,000
- $50,000
- $50,000
- $16,700
- $300,000

### Improvements — Ditch, Kohala Section
- $30,000
- $73,000
- $40,600
- $16,800
- $160,400

### Wells, pumps & motors with diesel generator sets
- $568,000
- $568,000
- $568,000
- $584,000
- $1,143,000
- $3,431,000

### Distribution System
- $166,000
- $168,000
- $233,000
- $849,000
- $302,000
- $1,718,000

### Total Annual Expenditures
- $164,141
- $807,000
- $736,000
- $834,300
- $1,483,000
- $1,535,600
- $66,800
- $50,000
- $50,000
- $16,700
- $5,743,541

### Accumulated Capital Expenditures
- $164,141
- $971,141
- $1,707,141
- $2,541,441
- $4,024,441
- $5,560,041
- $5,626,841
- $5,726,841
- $5,743,541

### Working Capital Requirement
- **Estimated Revenue**: $59,700
- $119,400
- $179,100
- $238,800
- $298,500
- $358,200
- $358,200
- $358,200
- $358,200
- $358,200
- $2,686,500

### Operating Expenses
- $120,216
- $178,504
- $212,176
- $241,571
- $292,640
- $329,071
- $329,071
- $329,071
- $329,071
- $329,071
- $2,690,462

### Total Annual Requirement
- $60,516
- $59,104
- $33,076
- $2,771
- $(5,860)
- $(29,129)
- $(29,129)
- $(29,129)
- $(29,129)
- $(29,129)
- $(3,962)

### Accumulated Working Capital Requirement
- $60,516
- $119,620
- $152,696
- $155,467
- $149,607
- $120,478
- $91,349
- $62,220
- $33,091
- $3,962

### Total Accumulated Capital
- $224,657
- $1,090,761
- $1,859,837
- $2,669,908
- $4,178,048
- $5,579,061
- $5,747,503

### Total Annual Capital Costs
- **Interest at 6 percent per annum**: $13,479
- $65,445
- $111,599
- $161,814
- $250,442
- $340,831
- $343,091
- $344,343
- $345,595
- $344,850
- $2,321,489
**Kohala Water Resources Management & Development Plan — Phase II**

**Schedule 4**

**Depreciation Summary**

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<td>Other facilities, equipment &amp; tools</td>
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<td><strong>Improvements — Ditch, Kohala Section</strong></td>
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<tr>
<td><strong>Wells, pumps &amp; motors with diesel generator sets</strong></td>
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<td>46,054</td>
<td>69,081</td>
<td>93,174</td>
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**Kohala Water Resources Management & Development Plan — Phase II**

**Schedule 5**

**Alternative Operating Statement**

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<td><strong>Revenue — see Schedule 1</strong></td>
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<td>$238,800</td>
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<td>$358,200</td>
<td>$358,200</td>
<td>$2,686,500</td>
</tr>
<tr>
<td><strong>Expenses — Operating Expenditures — see Schedule 2</strong></td>
<td>120,216</td>
<td>178,504</td>
<td>212,176</td>
<td>241,571</td>
<td>292,640</td>
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<td>329,071</td>
<td>329,071</td>
<td>329,071</td>
<td>2,690,462</td>
</tr>
</tbody>
</table>
1) To purchase and/or generate and sell electric power to the agricultural water users of the Cooperative for purposes of irrigation and other uses.

2) To acquire, construct and lease ditches, dams, plants, transmission lines, and other power equipment and the necessary property and rights thereof and to operate, improve, repair and maintain the same, for the generation and transmission of electrical energy, used in the operation of pumping plants and irrigation systems of the Cooperative.

3) To sell the surplus of any electrical energy over and above the requirements of the district to private or public corporations, the County of Hawaii or individuals, on such terms and conditions as the Council shall determine.

4) To construct, repair or maintain a system for the bulk sale of surplus water, considered over and above the agricultural needs of the Cooperative, to the County of Hawaii for domestic purposes.

5) To assume, as principal or guarantor, any indebtedness to the United States under the federal reclamation laws, on account of Cooperative lands.

6) To set rates for the sale of all water developed in the Cooperative system to the agricultural bulk users who are Cooperative members as well as surplus water to non-Cooperative members for agricultural or domestic use.

7) To enter into contracts with individuals, public and private corporations, the State of Hawaii, the County of Hawaii or whomever else as necessary to carry out the above powers and foregoing purposes.

WATER COOPERATIVE CONCEPT

The water Cooperative concept is common to the Hawaiian agricultural system. The sugar plantations initiated the system by the creation of a privately incorporated water company to develop and manage the water resource. The only modification is that the Cooperative concept as proposed here is a joint effort between government and various agricultural ventures. With the forthcoming situation in North Kohala when sugar production ceases in 1975, the use of the Water Cooperative is of prime consideration for the following reasons:

1) The Kohala Ditch Co., a wholly-owned subsidiary of Kohala Corp., plans to cease operations within 5 years.

2) As the one-user sugar operations cease, multi-user agricultural ventures seem apparent.

3) The sources of the water for Cooperative use are located primarily within the using area.

4) The potential sources located outside of North Kohala's boundaries could not be economically used by the district in which they are located.

5) The determination of the use of water resources in North Kohala must first be considered for the areas use before transmission to other areas.

6) The financial investment by government(s) as well as by private sources creates the need for participation in the development and management of the resource.
NORTH KOHALA WATER COOPERATIVE
ORGANIZATIONAL DIAGRAM

COUNCIL
Appointee, State Dept. of Agriculture
Appointee, State Dept. of Land & Nat'l Resources
Appointee, County of Hawaii
Elected, Wateruser Representative
Elected, Landuser Representative
Elected, District Representative
Appointee, Mgr. of No. Kohala Water Cooperative

General Manager

Prof. Services (contracted outside)
Accounting
Hydrology
Engineering
Legal

Adm. Dept.
Chief

Office Clerk

Operations Dept.
Foreman

Ditch Maint.
Chief

Ditchman
Chief

Pumpman
Chief

Pumpman

Ditch Improv.
Chief

Ditchman
Improv.
Therefore the formation of the North Kohala Water Cooperative with its Council to implement certain purposes and certain powers is the recommended course of action.

The Organizational Diagram attached presents a visual conception of the proposed entity which would implement the water plan. The membership of the Council has brought together the diverse interests, qualifications, and resources to deal with the water situation.

**COUNCIL MEMBERSHIP**

1) That the Director of the State of Hawaii, Department of Agriculture, appoint a member of the Department of Agriculture to be his personal representative.

2) That the Director of the State of Hawaii, Department of Land and Natural Resources, appoint a member of the Department of Land and Natural Resources to be his personal representative.

3) That the Mayor of the County of Hawaii appoint a member to be his personal representative.

4) That the water users of the Cooperative elect a representative with one vote equal to one million gallons of water purchased. The term of his service on the Council would be one calendar year.

5) That the land users of the Cooperative elect a representative with one vote equal to 100 acres of land used. A land user is defined generally as an individual or entity who through fee title or lease agreement or other such legal arrangement has the right to the use of the land during the term of his service on the Council, which term shall be for a period of one calendar year.

6) That the Political District of North Kohala elect a representative to serve on the Council for a term of two years to coincide with the election and service of the districts elected official to the State of Hawaii, House of Representatives. The qualifications for election being those of a State Representative.

7) That the Manager of the North Kohala Water Cooperative, who is appointed by a majority of the Council shall serve as a member and chairman of the Council as long as his contractual agreement with the Council permits.

**MEMBERSHIP CONSIDERATIONS**

1) The inclusion of the State of Hawaii appointees is primarily made due to the financial commitment of the State of Hawaii towards funding capital improvements. Also important is the expertise in the areas of agriculture and resource management that these departments can contribute.

2) The inclusion of the County of Hawaii appointees is primarily made to give the local government a first hand opportunity in dealing with its own problems and solutions. In addition, a voice in a situation where County funds are involved.
3) The Wateruser Representative is required to present and represent the needs of the various agricultural waterusers who are large quantity consumers without consideration of the amount of land irrigated.

4) The Landuser Representative is required primarily to present and represent the needs of the various agricultural ventures with acreage the criteria without consideration of the amount of water consumed.

5) The elected District Representatives inclusion is necessary for the electorate of the region, its political parties and organizations, to provide participation with regards to daily operations, and future development which will have the greatest single impact on the area since the institution of the plantation system.

6) The Manager of the North Kohala Water Cooperative is one of the vital keys to the success of the Kohala Water Resources Management and Development Plan. In his position he would be most aware of the problems and alternative solutions. He would be the only full time Council member and in addition his contract accepted by a majority vote of the Council would qualify him for the position of Chairman.

COOPERATIVE STAFFING

The proposed organization was created to staff the functions proposed by the Phase II plan and as such detailed job descriptions are appropriate for the upcoming Phase III. However general classifications description are:

1) Council. To provide the North Kohala Water Cooperative with guidance and general management policy towards fulfilling its purposes as provided. Furthermore to authorize capital expenditures, and approve plans for development or expansion of the water system, and finally to approve the Cooperatives annual operating budget.

2) General Manager. To take full charge and full responsibility of the North Kohala Water Cooperative under the guidance of the Council and to implement the plans as set forth by the Council. To set operational policy and operational working procedures. To coordinate Cooperative water development and use with current and potential water users, the County of Hawaii, the State of Hawaii and any other necessary individuals or parties.

3) Administration Department. To administer services with regards to accounting, clerical and secretarial, purchasing, and personnel record keeping under direction of the General Manager.

4) Operations Department. To implement daily plans with regards to water service including the operations of maintenance, water delivery, and system improvement.

5) Professional Services. To provide technical services regarding accounting, hydrology, engineering and legal, on an as needed contractual basis, in order to keep overhead expenses at a minimum.
LABOR AND EQUIPMENT POOL

It is recommended that Cooperative members pool their labor and equipment resources to undertake various ditch improvement or maintenance projects on a contract basis.

PHASE III

Assuming the Phase II concept of the North Kohala Water Cooperative is accepted, further definition of purposes and powers must be made so as to finally provide a detailed basis upon which the Cooperative can be established, which may require an act of legislation. In addition the personnel function of job descriptions must be completed as well as the review and finalization of compensation scales.
INTRODUCTION

In evaluating the water needs of North Kohala, it is necessary to review present land use and also its future pattern so far as is known or can be forecasted. Immediate plans being processed by the Kohala Task Force must be reviewed as well as probable developments over a longer range period. This consideration involves land as a basic resource, and its use as influenced by not only physical characteristics such as topography, climate, existence of facilities and availability of water, but also by demographic, i.e., social and economic factors. These factors enter into and contribute to the happiness and prosperity of the residents in any community and in turn, create a demand for water.

Also contributing towards an orderly development and preserving environmental quality are the existing governmental land use and planning and zoning controls — State Land Use Commission and County Planning Department regulations.

The following paragraphs summarize the findings of previous investigations over the years by others. These findings have been used to create the estimate of current and future water needs of North Kohala as contained earlier in this report.

NORTH KOHALA DISTRICT

The administrative district of North Kohala occupies the northwestern tip or cape of the island of Hawaii and contains an area of approximately 80,000 acres or 125 square miles out of a total area of about 4,000 square miles for the island. Compared with the district of Honolulu, which extends from Red Hill to Makapuu Head, the district of North Kohala contains one and one half times the area of the district of Honolulu.

SOURCES OF INFORMATION

For a study of the district in greater detail, a system of zones, sections and parcels established by the Tax Map Office and, which have long been familiar to users of their Tax Maps, have been followed. See Map V-1.

For sources of information, recognition has been made of the existence of studies and publications by those many government departments concerned with general plans and matters dealing with agriculture. In focusing on North Kohala district, the past records and current base maps made available by Kohala Corporation have been invaluable. For goals of the North Kohala area, wherever possible, the consensus of those concerned with them have been researched and accepted as guidelines. We are indebted to those, in both the public and private sector, who have assisted us and have furnished complementary data.
STATE LAND USE ACREAGES, NORTH KOHALA.

<table>
<thead>
<tr>
<th>TAX SECTION</th>
<th>URBAN</th>
<th>RURAL</th>
<th>AGRICULTURAL</th>
<th>CONSERVATION</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8,453</td>
<td>8,453</td>
</tr>
<tr>
<td>2</td>
<td>82</td>
<td>0</td>
<td>3,621</td>
<td>2,428</td>
<td>6,131</td>
</tr>
<tr>
<td>3</td>
<td>191</td>
<td>14</td>
<td>6,121</td>
<td>899</td>
<td>7,225</td>
</tr>
<tr>
<td>4</td>
<td>331</td>
<td>0</td>
<td>3,902</td>
<td>167</td>
<td>4,400</td>
</tr>
<tr>
<td>5</td>
<td>192</td>
<td>0</td>
<td>5,873</td>
<td>598</td>
<td>6,663</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0</td>
<td>5,756</td>
<td>304</td>
<td>6,060</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>8,171</td>
<td>270</td>
<td>8,441</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>11,779</td>
<td>516</td>
<td>12,295</td>
</tr>
<tr>
<td>9</td>
<td>120</td>
<td>0</td>
<td>18,976</td>
<td>485</td>
<td>19,581</td>
</tr>
<tr>
<td>TOTAL</td>
<td>916</td>
<td>14</td>
<td>64,199</td>
<td>14,120</td>
<td>79,240</td>
</tr>
</tbody>
</table>

Source: Land Use Report, 1971 (Hawaii County Planning Department)

COUNTY ZONING OF URBAN AND OTHER AREAS.

- Single family residential (RS-15): 497 Acres
- Commercial (CN-10 and CV-10): 24 Acres
- Industrial (MG-10a): 52 Acres
- Agricultural (A-1a, -3a, -5a, -20a): 62,401 Acres
- Residential-agricultural (RA-0.5a): 14 Acres
- Other: 16,261 Acres
  - Unplanned: 5,291 Acres
  - No Zone: 10,970 Acres

79,249 Acres

The County Planning Department further provides for future expansion through a "land use pattern allocation map." The best location of various land uses in appropriate relation to each other is embodied in the concept. Such planning reflects estimates of future population and its socio-economic needs. The County Planning Department in its Land Use Report, Vol. II, 1971, furnishes a following tabulation for North Kohala:

**URBAN LAND USE PATTERN ACREAGE ALLOCATION**

- Residential: 1,520 Acres
- Commercial: 152 Acres
- Industrial: 226 Acres
- Resort: 70 Acres
- Total: 1,968 Acres
EXISTING LAND USE DISTRIBUTION.

The following classification reflects actual land uses and as compiled in the County Land Use Report (1971). For convenience of comparing the preceding zoning allocations with the actual use, refer to the following table:

### EXISTING LAND USE ACREAGE DISTRIBUTION, DECEMBER 1971
### ZONING AND LAND USE PATTERN ALLOCATION, NORTH KOHALA

<table>
<thead>
<tr>
<th>LAND USE</th>
<th>LAND USE DISTRIBUTION</th>
<th>COUNTY ZONING</th>
<th>COUNTY ALLOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>545</td>
<td>497</td>
<td>1,520</td>
</tr>
<tr>
<td>Social and Cultural</td>
<td>43</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Recreation</td>
<td>44</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Commercial</td>
<td>15</td>
<td>24</td>
<td>152</td>
</tr>
<tr>
<td>Services</td>
<td>33</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Transportation</td>
<td>556</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Industrial</td>
<td>—</td>
<td>52</td>
<td>226</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>23</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Mfg. services &amp; Whsg.</td>
<td>97</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Resort</td>
<td>—</td>
<td>—</td>
<td>70</td>
</tr>
<tr>
<td>Residential-Agricultural</td>
<td>—</td>
<td>14</td>
<td>—</td>
</tr>
<tr>
<td>Agriculture</td>
<td>54,450</td>
<td>64,401</td>
<td>—</td>
</tr>
<tr>
<td>Unplanned</td>
<td>—</td>
<td>5,291</td>
<td>—</td>
</tr>
<tr>
<td>Unused Open Spaces</td>
<td>29,901</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No Zone</td>
<td>—</td>
<td>10,970</td>
<td>—</td>
</tr>
</tbody>
</table>

79,707 79,249 1,968

COUNTY'S GENERAL PLAN FOR NORTH KOHALA

The General Plan for the County of Hawaii is the policy document for the long range comprehensive development of the entire island of Hawaii. As Ordinance No. 439, it was prepared over several years and was adopted in 1971. It contains not only proposed urban land use pattern allocation, but is preceded by specific courses of action recommended by the County. These courses of action by the County are listed at the outset and as follows:
STUDY ELEMENTS

Economic Element:
- Aid the expansion of diversified agriculture
- Encourage resort facilities which are compatible
- Plan alternative uses for lands idled

Environmental Quality:
- Take action to maintain quality
- Reinforce and strengthen established standards

Flood Control and Drainage:
- Implement proposed drainage systems for the Hawi and Honomakau-Kapaau areas

Historic Sites: (See Map V-1)
- Assure protection, restoration or reconstruction of

<table>
<thead>
<tr>
<th>Site</th>
<th>Tax Map Key</th>
<th>At</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kamehameha Water Tunnel</td>
<td>5-2-02: 6</td>
<td>Waiapuka</td>
</tr>
<tr>
<td>Statue of Kamehameha I</td>
<td>5-4-05: 1</td>
<td>Kapaau Village</td>
</tr>
<tr>
<td>Mo'okini Heiau</td>
<td>5-5-05: 17</td>
<td>Puuepa 2</td>
</tr>
<tr>
<td>Apaapaa I</td>
<td>5-7-01: 10</td>
<td>Lapakahi</td>
</tr>
<tr>
<td>Koaie Settlement Complex</td>
<td>5-7-01: 22</td>
<td>Lapakahi</td>
</tr>
</tbody>
</table>

Need for further research to ascertain their value:
- Kaupalaha Heiau
  Tax Map Key: 5-2-01: 14
  At: Makapala
- Lapakahi Complex
  Tax Map Key: 5-7-01:
  At: Lapakahi

Housing:
- Aid development of housing
- Encourage Kohala Sugar to make lands available
- Encourage Kohala Sugar to provide housing

Natural Beauty:
- Honokane Valley
  Tax Map Key: 5-1-01: 4-6
  At: Awini
- Islands off Awini Valley
  Tax Map Key: 5-1-01: 13-15
  At: Awini
- Pololu Valley
  Tax Map Key: 5-1-02
  At: Pololu
Pololu Valley (Overlook) 5-2-01: 1  Pololu
Akoakoa Point 5-2-01: 7  Waiapuka
Naue Bay 5-2-01: 7,8  Waiapuka
Kapanaia Bay 5-2-01: 14  Makapala
5-2-07  Aamakao
Keokea Beach & Kalalae Pt. 5-2-01: 14-16  Makapala
Kauhola Point 5-3-07: 1  Kukuwaluhia
Upolu Point 5-5-06: 7  Kokoiki-Upolu
Old Honoipu Landing 5-6-01: 24  Puakea
Kapa Park 5-6-01: 60  Kapaa
Mahukona Harbor and Park 5-7-03: 3,4,14  Mahukona-Hihiu
Keawanui Bay 5-8-01  Puanui
Kaiopae Point 5-9-01: 6  Waiaka
Waiakailio Bay 5-9-01: 8  Kahualiili
Kawaihae-Mahukona Highway
Kohala Mountain Road

Natural Resources and Shorelines.

Public Facilities:
- Improve facilities as need arises
- Build a new gym
- Investigate a more adequate fire protection
- Encourage a central civic center and with multiple use buildings
- Implement a sanitary landfill operation
- Improve cemeteries' maintenance
- Improve County base yard facility

Public Utilities:
- Extend water system to upper area of Hawi system
- Connect Kaauhuhu-Kokoiki system to Hawi system
- Explore further sources for future needs
- Improve and replace inadequate distribution mains and storage facilities
- Study installation of sewage treatment facilities at Hawi-Kapaau

Recreation:
- Develop additional community facilities, viz. gym, youth center, and a swimming facility
- Develop Pololu Valley as a recreation area with a minimum of man-made elements
Encourage use of total area of Kapaa Beach Park
Encourage State to develop Lapakahi as historic and marine park
Encourage State to expand small boat harbor facilities at Mahukona Harbor and multi-use recreation area on adjacent lands
Encourage State to develop Upolu Point area for recreation, including access to fishing areas

Transportation:
Improve mountain route to Kohala
Improve road from Hawi to Niulii
Improve other substandard roads
Retain Upolu airfield for general aviation use

LAND USE

Agricultural:
County to help the development of new farming uses
County to help cattle industry expansion and facilities
County to help new crops such as corn, sorghum and seed crops
Macadamia and truck farming should be encouraged to grow

Industrial:
County shall identify sites suitable for future industrial activities

Multiple Residential:
"Appropriately zoned lands shall be allocated as the need" for this development increases.

Open Space:
Open space designation shall include:
Forest reserves
Watershed areas
Potential natural hazard areas
Natural areas and reserves
Open space recreation areas
Scenic vistas and viewplanes
General Use Conservation zones with compatible uses
Scientific areas, including habitats of endemic species
Resort:
   Possible development of small resort facilities at Mahukona
   Encourage development of small family-type hotels
   Encourage small-scale retreat resort development

Single Family Residential:
   County shall encourage concentration and avoid strip development
   County shall aid and encourage industry to make available residential lands in area for
   employee housing and the private market

The above is a comprehensive and long range concept of public improvements for North
Kohala with certain projects having priority over others as related to programming and financ-
ing. Since financing is dependent on tax revenues and on the economic health of the public, the
matter of creating employment opportunities deserves primary consideration.

PHYSICAL CHARACTERISTICS

North Kohala's topography may be described generally as that of a rolling terrain on the
flanks of the Kohala Mountain cone or dome which is elongated northwest-southeastward. The
land rises from sea level to over 4,000 feet elevation. Along the northerly or windward slopes,
which receives most of the rainfall, the land has been eroded and dissected with numerous
gulches and which increase in size eastward. Ocean wave action has also created a low-cliffed
volcanic coast. Pololu and Honokane Valleys, which occupy the eastern most portion and
receive the greatest amount of rainfall, are deep canyons and are accessible only by mule trails.
This feature can be seen from the Pololu Valley Lookout. The southerly slopes receive far less
precipitation, and are scored with gullies increasing in frequency toward Kawaihae. This arid
portion has relatively thin soil cover.

The soils of the low windward mountain slopes in the eastern most cultivated portion have
been classed as Kohala silty clay and Ainakea silty clay loam by the U.S. Soil Conservation
Service. From 0 to 1,500 feet elevation, with an annual precipitation of 60 to 90 inches and soil
temperature of 70° F., the soil characteristics are acidic, with good natural drainage and
moderate to rapid soil permeability and effective depth of 30 inches. The substratum or parent
material is weathered lava. A good feature in the plantation fields of this area is that the dirt
service roads through the fields are passable on trucks even after heavy rains.

The soils of the low windward mountain slopes in the western most cultivated portion are
classed as Hawi silty clay. From 0 to 1,200 feet elevation, with an annual precipitation of 25 to 40
inches and soil temperature of 73° F., the soil characteristics are similar to Ainakea silty clay
loam.
These soils have good water holding capacity. Infiltration rates of these soils according to H.S.P.A. studies range from 2.2 to 3.1 inches per hour with water application rates of 2.5 inches per hour being about maximum.

These soils are old and poor in available elements and need fertilizing for the growing of crops.

The mean annual air temperature of the cultivated portion of North Kohala ranges from 70° to 76° F. The mean annual air temperature of the district ranges from 65° to 85° F. There is a 1° F decrease for every 250 feet rise in elevation.

Winds at times cause problems to farmers by damage to leafy crops and also present difficulties in obtaining uniform coverage when irrigating with sprinklers. For wind direction and velocities see the wind rose as shown in Map V-2. This is a State Department of Transportation’s study during 1966 for a wind chart at Upolu airport and shows the following:

<table>
<thead>
<tr>
<th>Wind Velocity, Knots*</th>
<th>Per cent of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 7</td>
<td>29.9</td>
</tr>
<tr>
<td>7 to 11</td>
<td>35.1</td>
</tr>
<tr>
<td>11 to 17</td>
<td>27.0</td>
</tr>
<tr>
<td>17 to 22</td>
<td>6.6</td>
</tr>
<tr>
<td>22 to 28</td>
<td>1.4</td>
</tr>
<tr>
<td>28 to 34</td>
<td>0</td>
</tr>
</tbody>
</table>

100.0

*One knot equals one nautical mile, or 6,080.20 feet per hour.

Along the coast line, this wind causes salt air and spray, which are objectionable to crops.

The rainfall is frequently uncertain and periodic droughts have caused losses to the sugar plantation and to farmers.

Landslopes in the district make cultivation less efficient than on level lands elsewhere in the State.

Lands now in cultivation occupy the northeasterly and north slope of the Kohala Mountain dome and are cut up by many deep gulches. Slope of the lands are shown in Map V-2.

Approximately 23,000 acres are located within the perimeter of cultivated lands and are classed as follows:
<table>
<thead>
<tr>
<th>Percent Slope</th>
<th>Area in Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 3</td>
<td>3,740</td>
</tr>
<tr>
<td>3 to 12</td>
<td>8,250</td>
</tr>
<tr>
<td>12 to 20</td>
<td>4,430</td>
</tr>
<tr>
<td>20 to 35</td>
<td>2,740</td>
</tr>
<tr>
<td>Gulches</td>
<td>3,840</td>
</tr>
<tr>
<td></td>
<td><strong>23,000</strong></td>
</tr>
</tbody>
</table>

Generally, lands have less slope from Hawi in a westerly direction. A sizeable acreage of the tillable lands in this vicinity have not been cultivated because of lack of water.

**POPULATION**

The district of North Kohala was populated by the native Hawaiians from the earliest periods. Kamehameha I was born and grew to manhood here. The trend of the district's total population is closely related to the degree of economic activity and, as traced from census records, is as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953</td>
<td>3395</td>
</tr>
<tr>
<td>1860</td>
<td>2632</td>
</tr>
<tr>
<td>1866</td>
<td>2345</td>
</tr>
<tr>
<td>1872</td>
<td>2086</td>
</tr>
<tr>
<td>1878</td>
<td>3299</td>
</tr>
<tr>
<td>1884</td>
<td>4481</td>
</tr>
<tr>
<td>1890</td>
<td>4303</td>
</tr>
<tr>
<td>1896</td>
<td>4125</td>
</tr>
<tr>
<td>1900</td>
<td>4366</td>
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<tr>
<td>1910</td>
<td>5398</td>
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<tr>
<td>1920</td>
<td>6275</td>
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<td>1930</td>
<td>6171</td>
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<tr>
<td>1940</td>
<td>5362</td>
</tr>
<tr>
<td>1950</td>
<td>4456</td>
</tr>
<tr>
<td>1960</td>
<td>3386</td>
</tr>
<tr>
<td>1970</td>
<td>3326</td>
</tr>
</tbody>
</table>

Source: D.P.E.D.

The above population trend reflects an earlier exodus of the native Hawaiian population away from Kohala to the urban trading centers, the establishing of sugar plantations followed by the introduction of immigrant labor, which resulted in a population increase. The latest trend reflects decreasing employment in the sugar industry.

Currently, the district is faced with the challenge of utilizing the improvements to the land and its water resources and providing continued employment for those affected by the probable phasing out of the sugar industry.

Unlike much of Hawaii, North Kohala does not have the environmental problems associated with a dense population and rapid growth. Its density is but 41 persons to a square mile. Rapid growth is not foreseeable, and environmental quality is not in immediate jeopardy.
NOTE: POSTED AREAS OF CLASSIFIED SLOPE LANDS ARE SHOWN MAINLY WITHIN CULTIVATED AREA LIMITS FOR THIS REPORT.

PLANIMETRED LAND AREA

4,304 Ac. 9.4%
9,102 Ac. 22.0%
43,735 Ac. 80.0%
16,227 Ac. 35.4%
2,928 Ac. 6.4%
3,704 Ac. 8.0%
50,000 Ac.

TOTAL LAND AREA IN KOHALA 50,000 Ac.

LEGEND

TOTAL LAND AREA N. KOHALA 50,000 Ac.

100.0%

N. KOHALA DISTRICT LAND

PLANIMETRED LAND AREA

4,304 Ac. 9.4%
9,102 Ac. 11.4%
43,735 Ac. 84.7%
16,227 Ac. 20.3%
2,928 Ac. 3.6%
3,704 Ac. 4.6%

WIND ROSE

SCALE IN KNOTS AND PERCENT OF TIME

DATA FROM STATE DEPT. OF TRANSPORTATION

LEGEND

TOTAL LAND AREA N. KOHALA 50,000 Ac.

SLOPE

- 0 to 5 percent
B - Land in gulches
C - 5 to 12 percent
D - 12 to 20 percent
E - 20 to 35 percent
Other.
### POPULATION BY AGE GROUPS, 1970
NORTH KOHALA DISTRICT

<table>
<thead>
<tr>
<th>AGE GROUPS</th>
<th>MALE</th>
<th>FEMALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABOVE 75</td>
<td>54</td>
<td>48</td>
</tr>
<tr>
<td>65-74</td>
<td>131</td>
<td>82</td>
</tr>
<tr>
<td>55-64</td>
<td>215</td>
<td>124</td>
</tr>
<tr>
<td>45-54</td>
<td>176</td>
<td>178</td>
</tr>
<tr>
<td>35-44</td>
<td>194</td>
<td>203</td>
</tr>
<tr>
<td>25-34</td>
<td>175</td>
<td>178</td>
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<td>15-24</td>
<td>244</td>
<td>235</td>
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<tr>
<td>5-14</td>
<td>389</td>
<td>367</td>
</tr>
<tr>
<td>0-4</td>
<td>168</td>
<td>165</td>
</tr>
</tbody>
</table>

**SOURCE:** 1970 U.S. CENSUS
As shown in the following graph, (Figure V-1) the present population of North Kohala is evenly distributed by age.

EMPLOYMENT OPPORTUNITIES

Creating employment opportunities, for which purpose the Kohala Task Force was set up, is very challenging and requires the concerted efforts from all who are in positions to see it accomplished. The thrust of this report is directed towards continuing the agricultural land in the collaboration of the land owners as well as farm workers, entrepreneurs with their know-how on management and production and government in carrying out its role.

The immediate problem of the Kohala Task Force is finding employment opportunities for the Kohala residents now employed by the plantation with the phasing out of sugar production. A review of the recent population trend and labor force characteristics of the North Kohala district brings out the further concern of the Kohala Task Force in encouraging diverse economic activities which would provide alternatives in gainful occupation. The 1970 Census population and labor force statistics reveal that there is a preponderance of "urban activity" oriented workers as compared with agricultural workers.

NORTH KOHALA LABOR FORCE CHARACTERISTICS, 1970

<table>
<thead>
<tr>
<th>OCCUPATION, TOTAL 1330</th>
<th></th>
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<tbody>
<tr>
<td>Professional, Technical</td>
<td>164</td>
</tr>
<tr>
<td>Managers, Except Farm</td>
<td>29</td>
</tr>
<tr>
<td>Sales Workers</td>
<td>14</td>
</tr>
<tr>
<td>Clerical</td>
<td>92</td>
</tr>
<tr>
<td>Craftsmen</td>
<td>236</td>
</tr>
<tr>
<td>Operatives, Except Transport</td>
<td>139</td>
</tr>
<tr>
<td>Transport Equipment Operatives</td>
<td>71</td>
</tr>
<tr>
<td>Laborers, Except Farm</td>
<td>64</td>
</tr>
<tr>
<td>Farm Workers</td>
<td>176</td>
</tr>
<tr>
<td>Service Workers</td>
<td>328</td>
</tr>
<tr>
<td>Private Household Workers</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INDUSTRY, TOTAL 1330</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>34</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>389</td>
</tr>
<tr>
<td>Transportation</td>
<td>12</td>
</tr>
<tr>
<td>Communications, Utilities and Service</td>
<td>6</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>10</td>
</tr>
</tbody>
</table>
Native Hawaiians had settled in such localities as Kapaa, Halawa, Makapala and Niulii and sustained themselves from the land. They also resided along the coast for fishing. The fishing activity has long ago been abandoned together with the old settlements. With the starting and growth of the sugar plantations during the past century and the opening up of homesteads during the early part of this century, the existing pattern for location of housing evolved. This changing pattern naturally influenced the zoning of North Kohala.

Presently, housing is spread along a strip bordering the highways in North Kohala extending from Kokoiki Homesteads to the west and to Niulii to the east. A 1973 County housing study by planning areas follows:

<table>
<thead>
<tr>
<th>Tax Map Key:</th>
<th>Planning Area</th>
<th>Single Family Houses (Urban &amp; Agricultural) Areas</th>
<th>Vacant Parcels Within Urban Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-2</td>
<td>Niulii-Makapala</td>
<td>68</td>
<td>30</td>
</tr>
<tr>
<td>5-3</td>
<td>Halawa-Halaula</td>
<td>187</td>
<td>14</td>
</tr>
<tr>
<td>5-4</td>
<td>Kapaau-Kynnersley</td>
<td>327</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Union Mill</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Honomakau</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-5</td>
<td>Hawi-Hualua</td>
<td>239</td>
<td>16</td>
</tr>
<tr>
<td>5-5</td>
<td>Kokoiki</td>
<td>53</td>
<td>—</td>
</tr>
<tr>
<td>5-7</td>
<td>Mahukona</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>875</td>
<td>82</td>
</tr>
</tbody>
</table>

Source: U.S. CENSUS, 1970
It becomes apparent that new housing needs can be met without undue constraints and can conform to current concepts for an orderly development since such needs can be met gradually and without immediate urgency. The off-site and site development costs can be kept within reason if those vacant parcels within the present urban areas are utilized first.

DOMESTIC WATER NEEDS

Domestic water systems for North Kohala are maintained and operated by the Department of Water Supply, County of Hawaii. In its December 1971 publication entitled "Water Master Plan", the Department has proposed improvements with several goals in mind as follows: (1) provide for anticipated increase in water demand; (2) provide good quality water meeting the standards of the U.S. Public Health Service; (3) improve the system to provide adequate distribution, pressure and volume.

Presently, the Department provides water from high level tunnels, four separate systems, namely Kaauhuhu-Kokoiki, Hawi, Kynnersley-Kapaau and Halaula. Barring droughts and unforeseen increase in demand, there is a sufficient supply of water for future growth for perhaps twenty (20) years.

The present systems do not have adequate size mains to provide fire protection. Accordingly, these lines are to be replaced with larger mains. Along the highway from Upolu to Kapaau, the system will be interconnected.

There are adequate resources in North Kohala to support considerable expansion of the domestic service. In the preceding section, it was suggested that certain types of agricultural activities can best be served via the domestic system. A major historical destination point is planned for the land of Lapakahi. As shown in Map III-3, an extension of the domestic system can be incorporated to supply Lapakahi and surrounding lands. It is noted that removing inexpensive surface water from the Kohala Ditch will adversely effect the long range potential for irrigation. Because domestic users can afford higher water unit costs, it is recommended that, as the demand exceeds 0.5 mgd, well sources be installed at an elevation of about 1,000 feet along the Kohala Ditch.

FORESTRY

The State Forester in his latest report on lands zoned Conservation in North Kohala reflects the following thoughts:

1. As prime agricultural lands may become available in North Kohala, it is not conceivable that reforestation activities would take consideration over other interests.

2. Barring any change in forest composition or forest management practices, North Kohala's water quality and quantity is predicted to remain adequate. Water resource management should continue to receive top consideration.
3. Timber resource management is expected to play a very limited role. Reforestation activities, not for timber, but primarily to enhance or maintain watershed quality would be a desirable necessity. For timber purposes, forestry should take a passive role and acquire only those lands that are unwanted.

4. For recreational purposes, a minimum-development type of facilities would be highly desirable. Following are tentative proposals:
   a. Acquisition of the Kohala Ditch Trail by an appropriate agency of the State or County and assuming of responsibility for the maintenance of the ditch.
   b. Connecting the Kohala Ditch Trail with the Waipio-Waimanu Trail.
   c. Construction of trail shelters and camping facilities along the trail and within the category of wilderness type recreational development.

The value of the watershed providing runoff to the Kohala and Kehena Ditches cannot be overemphasized in viewing the long range potential of the districts. Significant alterations to the native forest environs above the ditches can materially effect the economy. It is noted that the forest cover of the Kohala Mountains has been markedly reduced in the past 70 years. It is recommended that the Task Force urge the land owners and the appropriate government agencies to create programs which will protect the integrity of these watersheds. Such programs should include the following:

1. Withdrawal of grazing as might be facilitated by providing irrigated lands makai as proposed in the Kohala Water Plan.
2. Establishing a barrier which will prevent the encroachment of exotic trees and grasses. The barrier might consist of timber planting.
3. Careful management of trails and other access to reduce the introduction of exotics.

INDUSTRIAL

The Hawaii County General Plan separates industrial development into two distinct types: (1) the sector which is service oriented and is affected by population and the level of activity of other industries; (2) the sector which is mostly influenced by outside markets. In the case of service types, emphasis is placed on proper location — close enough to population but still distant enough to avoid traffic and environmental problems.

The General Plan statements on goals, policies and standards are comprehensive and actively control existing and future industrial sites.

Industrial activity presently in North Kohala consists of sugar processing and its related activities. The sugar processing plant which is located in Halaula is situated on 52 acres of industrially zoned land.

As cited previously, for future industrial expansion there is a total acreage of 226 acres allocated to North Kohala.
RESORT

The County General Plan recognizes that North Kohala has potential for the development of small resorts, which would primarily cater to visitors seeking quiet and rest.

Since North Kohala does have areas of historical significance, improvements to access to these areas would be desirable together with such resort development. Similarly, trails for hiking, hunting and fishing should be considered not only for visitors but also for resident satisfaction.

As these potential sites become established along the leeward (west) coastline of North Kohala, it will be necessary to make a water supply available.

AGRICULTURE

Analysis by governmental agencies and as contained in the County General Plan of the general outlook for agriculture on the island of Hawaii as a whole are summarized as follows:

1. Although it is a major economic sector, agriculture faces competition from other economic activities. Sugar is the largest agricultural enterprise.
2. The number of farms has decreased both in number and total acreage.
3. Factors which point towards a continuous growth of agriculture on the island of Hawaii are:
   a. The Sugar industry has not faced extreme pressures from urbanization.
   b. Growth has taken place on the island in other forms of agriculture.
4. The land situation has to be improved in aspects of availability, taxation, and ownership or leasing.
5. The labor-housing situation has to be improved to attract workers.
6. The heavy capital requirement of water development projects forces dependency upon the State.
7. There is a great need for problem-solving research in all aspects of farming from growing to marketing — including farm loans and keeping of books, improvement of suitable varieties, achieving irrigation efficiency, disease control, mechanization, transportation, and marketing methods.

The goal by the County regarding agriculture is to protect and maintain farm lands. Policies of the County to aid agriculture are as follows:

1. Agricultural lands shall continue to receive preferential treatment. Studies shall be made of new approaches to preserve prime agricultural land.
2. Basic resources and amenities such as water and roads, shall be developed as items in the County's CIP Program.
Probably the most famous heiau in all Hawaii is found near Upolu in North Kohala. Constructed by the high priest Mookini, it played an important role in Kamehameha's march toward ruler of the Hawaiian Islands. The heiau is approximately 130 feet by 250 feet with walls 20 feet high in places. This temple is on the National Register of Historical Places.
Kalahikiola Church, dedicated in 1855, was once ranked with Kawaiahao Church. It is still in use today.

Bond House and the Boys School, erected in the 1840s by the Reverend Elias Bond, is a bit of New England attesting to the early missionaries influence. The buildings are in good repair and maintained by descendents of Reverend Bond.

The original statue of King Kamehameha I at the Kapaau civic center. It was once lost at sea.
3. Assist other State agencies on programs which aid agriculture.

The North Kohala district's major industry is agriculture. There are 62,402 acres of agriculturally zoned lands in the district, of which 2,169 acres are vacant.

The termination of sugar operations is regarded as a challenge to build a stronger diversified agriculture and economic base for North Kohala.

HISTORICAL RESOURCES

North Kohala possesses places of historical importance which need preservation and possible development. This portion of the island of Hawaii had a concentration of population long before Captain Cook's journey. Koaie village existed as early as 1300 A.D. Presently, the ahupuāa of Lapakahi is a major site for archaeological research. The "birthstones" of Kamehameha I are near Upolu Point and reputedly his family heiau is located above Hapuu Bay. Mookini Heiau was re-dedicated by Kamehameha.

The Department of Land & Natural Resources, through its Parks Division, has published "North Kohala: Preservation Master Plan for Historical Resources", July 1972. Some of these historic sites are listed herein below. Many such sites are linked with the young, growing years of Kamehameha I. Other sites are associated with the American missionary Elias Bond, or the early Chinese arrivals and later plantation workers, and the sugar and cattle industries.

The Department's master plan describes a concept for the public education and enjoyment of these historic sites. Some of these sites, which may be acquired for the general public, are proposed to be included in the State parks system and be developed. Access and enjoyment could be improved by building roads and trails to these sites from the main highway. Other sites which are being preserved by private groups are proposed to be supported in their efforts. (See Map V-1)

The more important historic sites are listed as follows:

- Lapakahi Ahupuaa
- Fishing Village Trail from Upolu Point west
- Kapaa Village, a County Park
- Kukuipahu Heiau
- Kamehameha's birthplace at Kokoiki
- Mookini Heiau
- Kamehameha Statue
- Old Halawa Village
- Kapanaina Bay and the Canoe Road
- Hale o Kaili
- Waiapuka, Kamehameha's Irrigation Tunnel
- Pololu Valley Lookout
Private historical groups are working to preserve the following:

- The Bond House
- Kalahikiola Church
- Girls Seminary
- Kapaaau
- The Kohala Ditch

**LAND OWNERSHIP**

Land ownership is shown on Map V-3. The major land owners in North Kohala are the Kohala Corporation, State of Hawaii, Bishop Estate, Richard Smart and Kahua Ranch.

The shape and sizes of parcels and the land ownership as found presently are the outgrowth of the pattern and system of land holdings of over a century and a quarter ago, since the Mahele and centuries preceding it.

Sugar plantations and ranches came into existence and land improvements have taken place to establish cultivation of sugar and raising of cattle.

These economic activities were carried out on private land as well as land on long term leases from the State. Individual fields were laid out over private as well as leased lands to fit the terrain and convenience in operations and with little need to regard property boundary lines.

Looking to the future and possible new uses and leases of such lands, there appears a definite desirability by the land owners involved to effect a land boundary adjustment through an equitable land exchange. In the Kohala Task Force's considerations, this has been a major challenge since it is no simple task.
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<th>DATE DUE</th>
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