REPORT

OF THE

Water Commission

OF THE

Territory of Hawaii

(Act 36, Legislature of 1915)

TO

HIS EXCELLENCY

The Governor of Hawaii

Honolulu, T. H.

Honolulu
Hawaiian Gazette Co., Ltd.
1917

Honolulu, T. H., January 13, 1917.

His Excellency,
the Governor of Hawaii,
Honolulu, Hawaii.

Sir:—In compliance with Act No. 36 of the 1915 legislature of the Territory of Hawaii, the following report of work accomplished with recommendations, is submitted. Attention is invited to the *Recommendations* on page 22.

Very respectfully,

G. K. LARRISON,
ARTHUR G. SMITH,
T. F. SEDGWICK,
Commissioners.

REPORT OF THE WATER COMMISSION OF THE TERRITORY OF HAWAII.

WORK ACCOMPLISHED.

Shortly after its appointment, the Commission secured the services of Mr. A. E. Chandler, member of the State Water Commission of California, one of the foremost authorities in the United States on all matters, both legal and practical, relating to water and water rights. Mr. Chandler coöperated with the Commission from May to November, 1916, and was for a month in the Hawaiian Islands, and in attendance at all the meetings of the Commission during that month. The Commission was enabled also to avail itself of the services of Messrs. R. C. Rice and R. D. Klise, experienced hydraulic engineers in the employ of the U. S. Geological Survey at Honolulu, who, together with Mr. T. F. Sedgwick, collected all data used by the Commission. sion.

Operations were divided into those pertaining to (1) *surface waters,* and (2) *artesian wells,* and were limited to quantitative and not qualitative investigations.

SURFACE WATERS.

Surface water conditions on the islands of Kauai, Oahu and Hawaii were observed on the ground by Mr. Chandler, accompanied by the Chairman of the Commission, previous to his consideration of the legal aspects relative to surface waters in the Territory.

An investigation was made of the flow of Maole Stream in Hillebrand Glen and of the relations existing between rainfall and run-off in this locality. The Maole Stream was selected as typical of the general conditions to be found on the average stream which may be used in the future to augment the water supply of the city of Honolulu.

ARTESIAN WELLS.

All investigations were limited to the Island of Oahu for the reason that operations have not yet been carried to an extent sufficient to enable a determination of artesian areas and resources on the other islands.

1. All available data relative to artesian well head elevations and rainfall records relative thereto were collected, coördinated and typical records worked up into tables and graphs.

2. All available artesian well-boring logs or records were collected, tabulated, and graphs prepared showing stratification, etc. These wells and most of the other wells in the city were tied together by careful levels and were plotted up in series to show the stratification of several vertical sections running approximately parallel to the sea and from the sea towards the mountains.

3. All available records of pumped water were collected and tabulated.

4. Measurements were made of the flow from as many flowing wells in Honolulu as were accessible; and from these and pumping records and other reliable data, estimates relative to the total draft on the artesian supply were worked out.

5. Graphs were prepared showing the excess and deficient periods of rainfall in various artesian basins, the relation existing between the rainfall and the draft on the artesian supply and the effect on same by the monthly variations in pumping.

6. Tests were made to determine the amount and radius of interference between adjacent artesian wells.

7. Measurements and tests were made and data collected to show, as far as possible, waste from artesian wells.

8. All available data relative to the dates on which the various wells in the Honolulu city area were drilled were collected and a graph prepared which shows the relation between the annual fluctuations in the artesian well heads and the number of wells drilled.

RESULTS OBTAINED.

From the data now available, your Commission believes that the following conditions exist:

1. The data relative to the relation between rainfall and run-off, obtained in Hillebrand Glen, indicate that the popular assumption of a run-off of about 50 per cent of the rainfall on such areas, is erroneous and much too high. From data now available the run-off will vary from nothing during light showers to about 35 per cent during very wet weather, with a mean of about 20 per cent of the mean annual rainfall.

The period covered by this investigation has been very

short and the work should be continued through the present wet season.

These data should now be of great value in making future flood storage estimates. While not conclusive, the data now available should prohibit any future reliance on the old assumption of 50 per cent run-off without careful field investigation.

2. Between Diamond Head and Red Hill there are apparently four separate and distinct artesian basins, and the artesian head of any one of these various basins is not appreciably influenced by the rainfall on, or draft from any other basin. It is impossible to define the exact limits of these basins on account of insufficient borings adjacent to these apparent limits. It is possible that these limits are not closely defined, but that there are areas between the basins in which the change in artesian head is gradual.

The four basins now apparent are as follows:

1. Diamond Head to somewhere between Manoa Stream and McCully Street.
2. From somewhere between Manoa Stream and McCully Street to Pauoa Stream.
3. Pauoa Stream to Kalihi Stream.
4. Kalihi Stream to Red Hill.

In these four basins, the artesian heads stood approximately and respectively on December 10, 1916:

Basin No. 1—25.0 feet above sea level.
Basin No. 2—30.0 feet above sea level.
Basin No. 3—31.0 feet above sea level.
Basin No. 4—29.0 feet above sea level.
(See Tables 1 and 2.)

3. In these separate basins the heads of, and amounts flowing from wells are perceptibly influenced by the draft from other wells located within the same artesian basin. (See Fig. 7.)

4. The draft from wells located outside of the Honolulu city area proper does not affect the artesian supply in Honolulu to any appreciable degree.

5. The artesian supply in Honolulu city area proper, between Diamond Head and Red Hill is being steadily and surely depleted on account of the draft on the artesian basins largely exceeding the supply.

Authentic records are available[1] which show that in 1882

[1] Thrum's Annual, 1882.

the artesian well heads in the basin between Moiliili and Pauoa Stream stood at 42 feet, or more, above sea level. By 1900 this head had dropped to about 34 feet. In 1904 the head was increased to about 36 feet, but during the period 1904 to 1915 fell to below 28 feet. After the heavy rains of December, 1915, and January, 1916, the head rose again to about 32 feet. Since that time it has fallen again to about 30 feet. There have been wide seasonal variations of this head, but the mean level, year by year, has dropped at an average rate of about two-fifths of a foot per year. (See Table 3 and Fig. 2.)

Authentic records[2] are also available to show that in 1882 the original artesian head stood at about 37 feet above sea level in the basin between 'Kalihi Stream and Red Hill. This head now stands at about 29 feet. The same authority[2] shows the original head in the Diamond Head-Moiliili basin to have been about 35 feet above sea level. This head now stands at about 25 feet.

The drop in head in the Kalihi-Red Hill basin was, up to 1913, at about the same rate as in the Moiliili-Pauoa basin, or from about 37 feet to about 25 feet. Since 1913 there has been a steady annual rise in this head due, from all available evidence, to the fact that there has been a considerable decrease on the draft from that basin while, during the same period, there has been an increase in the rainfall on this basin similar to that on the other Honolulu basins.

Attention is invited to the fact that even with the increased rainfall the artesian heads in all basins, except the Kalihi-Red Hill basin, have decreased—a condition which can only be explained by the annually increasing overdraft.

In 1888 there were 53 active wells in the Honolulu city area proper and about 100 on the Island of Oahu. On December 31, 1916, there were a total of about 142 wells in the Honolulu city area, of which about 109 were active—that is, either flowing or capable of being pumped; and on the Island of Oahu about 500 wells of all classes.

When all artesian wells in the Honolulu city area are flowing or being pumped at normal existing pumping plant capacity, about fifty-seven million gallons per day are being drawn from the artesian supply. It is estimated that during the period May to October, 1916, the mean daily draft from the three artesian basins between Diamond Head and Kalihi Stream was about forty million gallons. Of this amount the

[2] L. L. McCandless.

city water works department obtained but about 12.3 million gallons per day. (See Tables 20 and 21 and Fig. 8.)

6. The artesian heads vary directly with the rainfall on the catchment areas above the wells, when these heads are not influenced by pumping. (See Tables 1, 3 and 6 with Fig. 2, and Tables 1, 9 and 14 with Fig. 4.)

LEGAL QUESTIONS INVOLVED.

The Commission, with the able assistance of Mr. A. E. Chandler, has gone carefully into the questions of law relating to the ownership, use and conservation of the water resources of this Territory.

We have come to the conclusion that we do not care to recommend any legislation concerning surface waters. As is stated by Mr. Chandler in his report to the Commission dated November 4, 1916, (See pages 15 to 20), we already have a very good workable method for the determination of rights to surface waters; and the law relative thereto has been fairly definitely settled by a series of decisions. There are, it is true, several questions as yet unsettled, but we believe them to be of such a nature that they can be better determined by the courts than by positive legislation which could only attempt to define and not change vested rights in the absence of provision for compensation therefor.

Accordingly, we make no recommendation for any legislation at the present time pertaining to the diverting, developing, using, conserving, holding or wasting of surface water. The matter of the supply of potable water is provided for by Chapter 255, R. L. 1915.

We have gone very carefully into the matter of the artesian water supply in the Territory, and are agreed that, in view of the constantly increasing danger to this supply due to the steady lowering of the artesian heads, some legislation is an immediate necessity. This applies particularly to the Island of Oahu, and more particularly still to the District of Honolulu. We feel that the provisions of Chapter 269, R. L. 1915, relating to capping and waste from artesian wells on Oahu will not meet the present situation. We have, accordingly, drafted a proposed act to apply, in its terms, to the Territory at large. (See pages 21 to 23). This act will be discussed heerinafter. While the act is purposely made to apply to the entire Territory, a study of the questions pertaining to the ownership and use of artesian water in the Territory will show that its primary application and effect

will be upon the artesian supply in the City and District of Honolulu, although it will operate, we hope, to prevent actual waste from any artesian supply wherever located in the Territory.

In this Territory, artesian waters, in which term we include percolating waters in any underground water-bearing stratum, are of as vital importance as waters flowing in definite courses, either on the surface or below it; and it has been estimated by reliable authority[3] that within a period of about fifty years, should the present average annual rate of decrease in the artesian head in Honolulu, say about two-fifths of a foot per year, continue, the artesian water supply for this city will be practically exhausted.

When once the seriousness of the situation is recognized, the only question remaining is as to the best method of averting the danger and of conserving, so far as possible, our artesian supply.

It is estimated that about forty million gallons of water per day is flowing or being drawn from the artesian supply in the area between Diamond Head and Kalihi Stream; and that at least half this amount is being used for purposes other than domestic, that is, for agricultural, mechanical or other commercial purposes; and it is further estimated that the present overdraft amounts to about ten million gallons per day. These figures are necessarily approximate, but they have been arrived at after careful observation and study of the records so far available, and we believe that they are sufficiently close to furnish a basis for action. The important point is, that there is an overdraft.

Our population will undoubtedly continue to increase. In 1860, the population of the Island of Oahu was 21,275. In 1910, it was 81,993, and in 1916, it was estimated at 107,000—the population for Honolulu proper being 68,000—an increase since 1860 for the Island of over 400 per cent. The per capita consumption of water furnished by the Honolulu Water Works Department is apparently about 285 gallons per day. In 1916, 58,000 persons were served, making a total daily supply of about 16.5 million gallons, an increase of about two million gallons over 1914. Of this amount, approximately 12.3 million gallons is artesian water. The demand for artesian water for domestic consumption is bound to increase.

Against this increase in demand, it is unquestionable but that we can balance, to a certain extent, a future diminution in the use of artesian water for irrigation purposes. As the population of Honolulu grows, large areas of cultivated wet lands now

[3] Thrum's Annual, 1917, pages 147-8.

within the city limits will be filled and reclaimed, and cut into residence and business lots. Today the average visitor, accustomed to health legislation in his own city or state, wonders why we permit such large areas of irrigated lands within the limits of the city of Honolulu. Before many years, the police power of the Territory will undoubtedly require the elimination of wet land irrigation in residence districts as a sanitary measure.

These remedies, however, are in the future, and meanwhile, not only is the depletion of our artesian water supply continuing, but there appears to be an increasing tendency upon the part of the owners of land overlying artesian basins in Honolulu to discontinue their use of the water from the city mains, and to either sink new artesian wells or increase the use from existing private wells for their own purposes, agricultural, domestic and mechanical. Some check may be kept on the uses from the city mains; but under the existing statute (Chapter 269, R. L. 1915), not enough restraint can be imposed upon the owners and users of private wells. This condition requires regulation by statute. But the question of the limits to which the legislature may go is not wholly free from difficulty owing to the fact that until within a comparatively few years, the tendency of the courts was against recognizing any right whatsoever to restrict the use of subterranean waters except such as flowed in defined and recognizable channels.

There are two classes of natural underground waters—percolating waters and those which flow in defined subterranean channels. Waters in subterranean channels have always apparently been considered subject to the same legal principles as the waters of surface streams. As for percolating waters which are borne in definite water-bearing strata, the common law rule is, that such waters belong to the owner of the surface—

"..... to the owner of the freehold like rock and minerals found there. This right exists free from the usufructuary rights of others which is to be respected by the owner of an estate through which a defined stream of water is found to flow. The owner may appropriate the percolation and filtration as he may choose and turn them to profit if he can."

Our own Supreme Court has ruled (though by way of dictum only) that subterranean waters to be the subject of rights, must, like surface waters, flow in well-defined channels.

Davis v. Afong, 5 Haw. 216 (1896).

Wong Leong v. Irwin, 10 Haw. 265, 270 (1884).

The latest decision, the Afong case, was twenty years ago. Six years later, in 1902, the California Supreme Court, in the

leading case of Katz v. Walkinshaw, 141 Calif. 116, recognized the existence of the common law rule that water percolating in the ground or held there in saturation, belongs to the landowner as completely as do the rocks, sand, and other materials of which the land is composed, and therefore he may remove it and sell it or do with it what he pleases. But the court held that the analogy between the right to deal with rock and sand and the right to deal with percolating waters is not perfect. As the court said:

"If we suppose a saturated plain, one may remove and sell the sand and gravel from his land without affecting or diminishing the sand and gravel on the lands of his neighbors. If the water on his lands is his property, then the water in the soil of his neighbors is their property. But when he drains out and sells the water on his land, he draws to his land and also sells water which is the property of his neighbor. By pumping out the water from his lands he can, perhaps, deprive his neighbors of water for domestic uses, and in fact render their land valueless. In short, the members of the community, in the case supposed, have a common interest in the water. It is necessary for all, and it is an anomaly in the law if one person can for his individual profit destroy the community and render the neighborhood uninhabitable."

The paramount reason which prompted the California Court to depart from the old common law doctrine which grew up in England, where, as the Court said, percolating waters were of minor importance, was the community need for and dependence upon an artesian supply of water which the Court considered to be a *common and essential necessity*. The Court further said that—

"Such portions of the law of England as are not adapted to our condition form no part of the law of this State. This exception includes not only such laws as are inconsistent with the spirit of our institutions, but such as are framed with special reference to the physical condition of a country differing widely from our own."

It is obvious that rules which might work well in a country like England, might operate disastrously if applied indiscriminately to a country like Hawaii, where the conditions as to soil, climate, etc., are so unlike.

While water is to be defined as a mineral, the rules of law as to its use must logically vary from those applicable to coal, ore and the like. Water is a fluid, and mobile, or as one Court puts it "a fugitive." Coal and ores have a fixed and permanent place. The analogy to natural gas and oil is more apt. Although their natural use is as merchadise, the Courts have held that the Legis-

lature may impose a restriction on the waste of gas and oil by owners of land, since the owner of the surface has no property right in the gas or oil until he has actually reduced it to possession, or, if he has any property right therein, it is a right in common with the co-equal right of other landowners to take from the common source of supply, and therefore subject to the legislative power to prevent a destruction of the common property by one of the common owners.

Ohio Oil Co. v. Indiana, 177 U. S. 190.

Or, to put it another way, the owners of the surface of the land within a gas field, while they have the exclusive right on their land to sink wells for the purpose of extracting the oil and gas, have no property right therein until by the actual drawing of the oil and gas to the surface of the earth, they have reduced these substances to physical possession. In consequence of the nature of the deposits, of their transmissibility, of their interdependence, of the rights of all, and of the public at large, the State (or Territory) may lawfully exercise the power to regulate the right of the surface owners among themselves to seek to obtain possession, and to prevent the waste of the product in which all the surface owners within the area wherein the gas and oil are deposited, as well as the public, have an interest, because in the preservation of these substances, the well-being and prosperity of the entire community is largely involved.

See Townsend v. State, 147 Fed. 624.

Gas, oil and percolating water have been classed by the Courts as analogous to animals *ferae naturae,* but with this distinction, namely: that whereas the public, being absolutely the owners of such animals, the State may wholly prevent *anyone* from seeking to reduce them to possession; yet as the gas, oil and percolating water, the owners of the land above, that is the surface proprietors, can not be absolutely deprived of this right which belongs to them, without a taking of private property. The right to regulate the user in the latter case depends upon the fact that there is a co-equal right to the common supply, and that the use by one of his power to seek to convert a part of the common fund to actual possession may result in an undue proportion being attributed to one of the possessors of the right to the detriment of the others, as by waste by one or more to the annihilation of the rights of the remainder. "Hence it is that the legislative power, from the peculiar nature of the right and the objects upon which it is to be exerted, can be manifested for the purpose of protecting all the collective owners by securing a just distribution, to arise from the enjoyment by them of their privilege to reduce to possession, and to reach the like end by preventing waste."

Ohio Oil Co. v. Indiana, 177 U. S. 190 at 210.

As to the status of the municipal supply of Honolulu, it has been held that pumping by or on behalf of a municipality from an artesian basin for the purpose of furnishing water to its inhabitants for domestic purposes does not constitute an artificial taking or use as distinguished from the right enjoyed by private well owners, and that both stand upon the same basis, subject to the rule of correlative rights.

Erickson v. Crookston Water Works, etc., Co. (Minn. 1908) 17 L. R. A., N. S., 650.

We would be very glad to see a law which could be enforced, prohibiting the sinking of any more artesian wells in the Honolulu District, but such an act would, in our opinion, be unconstitutional. The farthest the Legislature may go, apparently, is to recognize the existence of correlative rights, including those of the public, to the artesian supply, and to define and prohibit waste of such water, and it is under this theory that the proposed act, submitted herewith, is drawn.

Section one of the act defines *artesian wells,* and includes pumped as well as flowing water. The present act applies only to flowing wells.

Section two provides for the effective checking of the flow from any artesian well.

Section three defines waste. The greater part of this section is based upon similar legislation on the mainland. The provision in Section three fixing the user allowed by the municipal authorities from the city mains as a basis for regulating the supply from private sources, was inserted after careful consideration and thorough discussion, and is based upon the theory of *correlative rights.* This portion of the act, of course, would be invoked only during those periods when the municipal authorities find it necessary to restrict and regulate the use of artesian water from the city mains, that is, during the dry seasons. It is obvious that if the private well owners can continue to use an unlimited amount of water at all times, there is very little to be gained from a reduction of the consumption from the city mains. Any restrictions imposed by the municipal authorities must be *reasonable,* and if at any time an unreasonable, arbitrary restriction were imposed, the owners of private wells would have their recourse to the courts. Some basis of comparative use had to be adopted, and in the opinion of the Commission and of Mr. Chandler, the one we have adopted is the most reasonable.

The other provisions of the proposed act are self-explanatory. As will be noted, we have retained in the proposed act as much as we could of Chapter 269, the present law.

REPORT AND RECOMMENDATIONS BY MR. A. E. CHANDLER OF THE STATE WATER COMMISSION OF CALIFORNIA.

Honolulu, T. H., Nov. 4, 1916.

Water Commission of Territory of Hawaii.

Gentlemen:—I have carefully considered the necessity of additional legislation regarding the appropriation and use of the surface waters of the Territory of Hawaii, and for reasons set forth herein advise that no such additional legislation be recommended.

Two general systems of water rights are recognized in the United States—that of riparian rights and that of prior appropriation. The reparian doctrine is accepted in all of the eastern states and in the western states which have both humid and arid sections—California, Kansas, Montana, Nebraska, North Dakota, Oklahoma, Oregon, South Dakota, Texas and Washington. The doctrine of prior appropriation is also accepted in the western states above enumerated, but is therein considered as governing a system of water rights inferior to the riparian right. The doctrine of prior appropriation is accepted as the exclusive doctrine in the strictly arid states—Arizona, Colorado, Idaho, Nevada, New Mexico, Utah and Wyoming.

The riparian doctrine is the common law doctrine and no legislation has been adopted in any eastern or western state codifying its principles. They have been so often before the courts of both the United States and England that legislation regarding them is deemed unnecessary.

LEGISLATION GOVERNING NEW APPROPRIATIONS.

The doctrine of prior appropriation, so far as the United States are concerned, is an outgrowth of the early mining days. The land upon which gold was discovered and claims staked out belonged to the United States. By custom early established, notices were posted upon the claims so staked. When later it came necessary to divert water for use on the mining claims, the practice of posting notices became customary for the appropriating of water also. It was not until this practice had been in vogue many years that legislation governing water appro-

priation was adopted. The first legislation along this line passed in any western state was generally copied from a California statute of 1872 (Section 1410 to 1442 of the California Civil Code) which provided that the notice should contain certain data, that it should be recorded in the county recorder's office within ten days of posting and that construction work should be commenced within sixty days of posting of notice and prosecuted to completion with reasonable diligence, in which case the right of appropriation would have a priority as of the date of posting notice.

Under the early appropriation statutes as above outlined, no public officer was obligated to give any attention to the steps taken by an appropriator after the posting of notice. The result was that hundreds of notices were recorded and no further action taken regarding the diversion, but this could not be ascertained on any given stream without an actual field examination. Likewise, where construction work was undertaken and properly prosecuted, the appropriator had to so establish by witnesses in case of conflict. The first state to remedy such defects was Wyoming, where in 1891 the office of state engineer was created and he was given jurisdiction over all new appropriations of water. Under the Wyoming statute any one wishing to divert water applies to the state engineer on a printed form, furnished by the state, on which must be set forth information descriptive of the proposed diversion. If in the opinion of the state engineer there is water from the desired source available for appropriation and if the proposed diversion will not be detrimental to the public welfare, he approves the application and specifies the date on or before which construction work must commence, the date on or before which construction work must be completed, and the date on or before which the water appropriated must be applied to beneficial use. The approved application, or permit, is subject to cancellation if the designated steps are not taken by the dates specified, unless the state engineer grants an extension of time for good cause shown. Under the Wyoming statute the state engineer has a record from start to finish not only of all the appropriations made since the passage of the statute, but also of the status of the construction work in connection with appropriations. The system thus inaugurated was adopted by Nebraska in 1895, by Idaho and Utah in 1903, by Nevada, North Dakota, Oklahoma and South Dakota in 1905, by New Mexico in 1907, by Oregon in 1909, and by California and Texas in 1913.

LEGISLATION REGARDING ADJUDICATION OF WATER RIGHTS.

As litigation over water rights was treated as any other action in regard to real property, A could sue B, B sue C, C sue A, and so on to a number of independent suits limited only by the possible combinations of the number of ditches from a stream. By the Colorado statutes of 1879 and 1881, the state was divided into districts and a procedure adopted for the adjudication of all the rights to the use of the waters of a stream within a district in a single action in the district court—special provision being made for the taking of testimony before referees. The weakness of the Colorado method was (and is) that the state was not represented in the adjudications and most of the earlier decrees were excessive, that is, not only were the amounts of water decreed not based upon beneficial use but very often a ditch was given an amount equivalent to many times its capacity.

Wyoming in 1890-91 sought to improve upon the Colorado method by providing a board of control, composed of the state engineer and four division superintendents, and giving it authority to make determinations of existing rights. In accordance with the provisions of the Wyoming statute, actual surveys of ditches and irrigated land are made under the direction of the state engineer, and the evidence regarding priority of right is presented by the claimant on a single form called "proof of appropriation." After the survey is completed for an entire stream and all of the "proofs" assembled, the latter, at a time and place duly advertised, are thrown open to public inspection. If a claimant desires to contest the claim of another, a hearing before the division superintendent is held after notice properly given. At such hearing stenographic reports are made of the testimony submitted. The board of control, with the surveys, proofs and testimony before it, makes a determination of the priority and amount of each appropriation and issues certificates in accordance therewith. Such determination is final, unless an appeal is taken to the courts. Nebraska in 1895 and Nevada in 1903 adopted the Wyoming method of determining rights.

Idaho and Utah in 1903 adopted legislation providing for surveys and assembling of hydrographic data by the state engineer to be used in a regular court action to be brought against all claimants to the waters of a stream. Similar legislation was adopted by North Dakota, Oklahoma, and South Dakota in 1905, and by New Mexico in 1907.

The Wyoming method is generally spoken of as the "administrative method" and the Colorado and Idaho method as the

"court method." Although the administrative method has given by far the more satisfactory results and the Nebraska Supreme Court and the Wyoming Supreme Court have upheld the validity of such procedure, there has been constant opposition to its introduction in other states on the ground that it is not a judicial method. Oregon accordingly in 1909 combined the two by following the Wyoming method in detail to the determination of rights by the board of control, and by providing also that such determination must be immediately presented to a circuit court, with the surveys, "proofs" and evidence upon which it is based, to be affirmed or modified after consideration by the court in a comparatively simple proceeding.

The Oregon statute has been before the Supreme Court of Oregon a number of times and its provisions have been upheld. The statute has the further distinction of having been upheld, as for as the method of adjudicating rights is concerned, by the United States Supreme Court in the recent case of Pacific Live Stock Co. v. Lewis, 36 Supreme Court Rep. 637. Nevada changed to the new Oregon procedure in 1915 and the California Water Commission is now recommending its adoption in California.

OFFICIAL APPORTIONMENT OF WATER.

The real goal of modern water right legislation is the apportionment of water among those entitled to its use. Before this can be done, however, the rights must be determined by some method as above outlined. The new rights must be likewise properly controlled so that they will fall into their proper place in the system.

The Colorado statutes of 1879-1881 provided for the appointment of water commissioners in each district to divide the waters of a stream in accordance with the court decrees. The new statutes in all of the western states enumerated above as adopting other phases of the new legislation have included provisions for the apportionment of water patterned after those of Colorado.

In the order of their importance, the three main features of legislation concerning rights to the use of water by appropriation are:

1. Apportionment of water among those entitled to its use;
2. Adjudication of rights;
3. Control of new appropriations.

GENERAL COMMENT ON THE NEW LEGISLATION.

The list of states given above indicates that the new legislation is adapted to all kinds of topographic, hydrographic, and climatic conditions. As shown, it has been adopted in North Dakota on the north, New Mexico on the south, Nebraska on the east and Oregon on the west. The water "claims" under the supervision of the state engineer, or water board, range all the way from that of the small individual ditch irrigating a few acres to that of the United States Reclamation Service projects, some of which irrigate upwards of one hundred thousand acres. All uses are likewise included and equally well cared for under the new system.

Although the new legislation is often called the water "code," it is not a codification of legal principles, but rather a specification of an administrative procedure to care for property rights which are based upon recognized principles established by early custom and crystalized by court decrees. It no more attempts to change basic principles than does the introduction of a modern office filing system or proper auditing methods change the underlying principles of business law. Each is designed to assure order and efficiency and to eliminate waste and friction.

THE SITUATION IN THE TERRITORY OF HAWAII.

A study of the legislation adopted in the Hawaiian Islands shows that only one of the three main points enumerated above has been covered. By its act of 1860 creating the office of Commissioner of Private Ways and Water Rights, Hawaii anticipated any such legislation in the western states by practically twenty years. Although many cases have been appealed from the commissioners to the supreme court, the validity of the procedure seems never to have been questioned, and, as the functions of the commissioners are now vested in the circuit judges, no doubt as to its validity now exists.

Aside from the old diversions to irrigate kuleanas there are probably not many streams of the Territory the waters of which are claimed by two private parties, and far fewer where the waters are claimed by three or more private parties. One of the principal reasons for introducing the new procedure for the adjudication of rights in the western states, as outlined above, was to do away with the multiplicity of suits. On account of the few diversions from the Hawaiian streams the reason does not exist here.

So far as the adjudication of the water rights appurtenant to the kuleanas are concerned, there appears to be no good reason for changing the adopted procedure. Such rights depend upon ancient user or upon prescription. In a great number of cases they are rights to use the waters of an old ditch for certain periods of time and not the right of individual diversions from the stream, as is the case in the western states. In the latter the problem is to determine the quantum and priority of the right so that a basis of apportionment may be decreed. In most cases in the Hawaiian Islands, not only has the basis of apportionment been long recognized, but water has been divided in accordance therewith. In such cases the problem is to determine the basis, so recognized and followed, from the testimony submitted, and it is unnecessary for the Territory to make surveys and attempt to fix the quantity of water beneficially used on each kuleana. There have been, and probably will be, cases where the distribution of water is on the area basis and not the time basis. Such cases can be effectively handled under the existing legislation.

The 1860 statute and its amendments do not specifically provide for the supervision of the apportionment of the water in accordance with the decree, but the Supreme Court in the early case of Davis v. Afong, 5 Haw. 216, 218, said, "We think the legislature did not intend to compel parties to establish their rights in one forum and oblige them to resort to another forum to have their rights enforced or protected."

As a matter of practice the commissioners very often appointed a luna auwai to supervise the division of the water. There is no need of legislation on this point.

In regard to new diversions, where one wishing to divert does not own the land traversed by the stream, the right must be purchased or leased, whether the owner is the Territory or private party. An excellent illustration of this is the number of contracts executed by the Waiahole Water Company, Ltd., in securing the right to divert water from the windward to the leeward side of Oahu. There is certainly no need of legislation to control new diversions.

As stated in the introduction, it is my opinion that no further legislation need be adopted by the Territory of Hawaii regarding the diversion, control or use of the surface waters.

Respectfully submitted,

A. E. CHANDLER.

AN ACT

RELATING TO THE USE OF WATER FROM ARTESIAN WELLS.

Be it Enacted by the Legislature of the Territory of Hawaii:

Section 1. An artesian well, for the purposes of this act, is hereby defined to be an artificial well or shaft which is sunk or driven to an artesian stratum or basin, and through which water is raised or carried to or above the surface of the ground by natural pressure or gravity, or through which water is or may be raised or carried to or above the surface of the ground by artificial means.

Section 2. An artesian well which is not capped, cased, equipped or furnished with such mechanical appliance as will readily and effectively arrest and prevent the flow of any water from such well, is hereby declared to be a public nuisance. The owner, tenant, or occupant of the land upon which such well is situated, or any person in charge of such well, who causes, suffers, or permits such public nuisance, or suffers or permits it to remain or continue, is guilty of a misdemeanor; and any person owning, possessing or occupying any land upon which is situated an artesian well, or any person in charge of such well, who causes, suffers, or permits the water to unnecessarily flow from such well, or to go to waste, is guilty of a misdemeanor.

Section 3. For the purposes of this act, waste is defined to be causing, suffering or permitting the water in any artesian well to reach any porous substratum before coming to the surface of the ground, or to flow from such well upon any land, or directly into any stream, or other natural water-course or channel, or into the sea or any bay, lake or pond, or into any street, road or highway, unless to be used for beneficial purposes; provided, that this section shall not be so construed as to prevent the beneficial use of such water by direct flow, or from storage reservoirs served by such wells, for irrigation, domestic and other useful purposes, except for driving machinery, provided, however, that such water may be used for driving machinery in case it be utilized afterwards for irrigation or other useful purposes. The use of any water, for domestic or garden irrigation purposes, from an artesian well within the area which is or may be served by the water works of any city, county, or city and county, in an amount greater than, or at a time period other than, that

fixed for domestic or garden irrigation use of water from such water works by rule or regulation prescribed by or under the authority of the board of supervisors or other constituted authority of such city, county, or city and county, is also declared to be waste within the meaning of this act.

Section 4. Each day's continuance of such waste after notice by or under authority of the board of supervisors or other constituted authority of any city, county, or city and county, shall constitute a new offense under this act.

Section 5. Any person boring, or causing to be bored, an artesian well shall keep a complete and accurate record of the depth and thickness of the different strata penetrated and, within ninety days after the last day of boring, shall file such record in the office of the superintendent of hydrography of the Territory of Hawaii.

Section 6. Any person violating any of the provisions of this act shall be guilty of a misdemeanor, and shall, for each offense, upon conviction thereof, be fined not less than $25.00 and not more than $500.00.

Section 7. Any authorized representative of any city, or county, or city and county, or any authorized representative of the superintendent of hydrography of the Territory of Hawaii, may at all times enter without warrant the premises where an artesian well is situated, or artesian water used, in order to make measurements of the flow of water from such well and the amount of such water beneficially used.

Section 8. Chapter 269 of the Revised Laws of Hawaii, 1915, relating to artesian wells, Oahu, is hereby repealed.

Section 9. If any section, subsection, sentence, clause or phrase of this act is for any reason held to be unconstitutional, such decision shall not affect the validity of the remaining portions of this act. The legislature hereby declares that it would have passed this act, and each section, subsection, sentence, clause and phrase thereof, irrespective of the fact that any one or more other sections, subsections, sentences, clauses or phrases be declared unconstitutional.

Section 10. This act shall take effect from and after the date of its approval.

RECOMMENDATIONS.

We recommend that the proposed act submitted herewith (See pages 21-22) be passed by the 1917 Legislature of the Territory of Hawaii.

We also recommend that sufficient funds be included in the appropriations for the Division of Hydrography for the biennial period beginning July 1, 1917, to allow that Division to continue the work of collecting data and making investigations relative to the artesian supply of Honolulu, and of underground waters in general, in the Territory of Hawaii.

G. K. LARRISON,
ARTHUR G. SMITH,
T. F. SEDGWICK,
Commissioners.

APPENDIX

RELATION BETWEEN RAINFALL AND ARTESIAN WELL HEADS.

TABLE 1. ARTESIAN WELL HEADS, ISLAND OF OAHU.

This is a tabulation of all monthly well heads on selected artesian wells from April, 1910, to December, 1916, collected by Mr. T. F. Sedgwick, Statistician, Department of Public Works, and by the Water Commission of Territory of Hawaii.

TABLE 2. ARTESIAN WELL HEADS, HONOLULU CITY AREA.

This table of comparative weekly well heads on over 40 wells in Honolulu city area during July to December, 1916, is the result of an investigation by the Water Commission to determine more definitely than heretofore, the boundaries of the separate artesian basins in the vicinity of Honolulu; also to secure information regarding variation of well heads in each basin.

With few exceptions, weekly well heads in each basin show a remarkably close agreement. These few exceptions are among the earliest wells sunk, which are of small bore. Undoubtedly, either the casings are defective—permitting artesian water to waste below ground—or the small casings have become choked by incrustations which have partially sealed these wells.

Weekly well heads in the Moiliili-Pauoa Stream basin agree very closely with those of Oahu College well, Punahou, which may be taken as standard for this basin.

(1) Well heads observed prior to July, 1916, are given in table "Artesian well heads, Island of Oahu."
(2) Well heads observed prior to July, 1916, are given in table "Artesian well heads, Oahu College."
(3) Compiled from daily well head record furnished by Honolulu Rapid Transit & Land Co.
(4) Compiled from daily well head record furnished by Honolulu Iron Works Co.

TABLE 3. ARTESIAN WELL HEADS, OAHU COLLEGE.

This is the longest and most complete record of artesian well heads available in Honolulu city area. From 1899 to 1904, the

TABLE 1.- ARTESIAN WELL HEADS, IN FEET, ISLAND OF OAHU.

1910 - 1916

REFERENCE PLANE IS MEAN SEA LEVEL

NAME OF WELL		GOVERNMENT STABLES	MO HOP	LUNG DO WAI	SING LOY	OAHU COLLEGE	BERETANIA PUMPING STATION	HONOLULU RAPID TRANSIT	Y. M. C. A.	OAHU RAILROAD AND LAND CO.	Y. AHIN	YOUNG HOTEL GARDEN	NEW PRISON	FT. SHAFTER	DAMON	WAIMALU	PEARL CITY	WAIPAHU	HONOULIULI	WAIALUA	KAHUKU	HAUULA
Well No.		27	42	50	57	62½	72*73	81	88A	95	100	110	110A	116½	119	172	199	234	273			
1910	Apr.	30.77	24.79	24.00	30.77	30.50				30.10	29.31	28.00			25.90	21.90	18.50	19.20	20.30			
	May	3024	2439	23.65	30.24	29.75				29.72	28.51	27.53			25.85	20.82	18.05	1882	20.20			
	June	29.90	23.80		29.90	29.70				28.62		27.53			25.45	20.90	18.00	18.75	20.20			
	July					29.68																
	Aug.					29.75																
	Sept.					30.35						28.20			26.25	22.30	18.70	19.50	21.20			
	Oct.	29.90	24.12	23.94	30.40	30.40				29.62	29.51	28.30			27.00	23.26	19.37	21.62	25.00			
	Nov.	29.50	25.05	24.85	31.05	30.80				29.15	29.65	28.05			27.05	21.95	18.15	19.02	21.69			
	Dec.					31.10																
1911	Jan.	31.00	25.89	25.95	31.45	31.50				30.22	31.07	29.50			28.30	24.32	21.35	22.42	24.49			
	Feb.	31.20	24.09	24.10	32.40	32.00				30.50	31.96	31.23			28.85	25.10	21.40	23.42	25.90			
	Mar.	32.18	25.34	25.10	32.64	32.55				31.20	32.56	31.43			29.15	24.32	21.45	22.72	24.39	11.85	14.78	20.57
	Apr.	32.00	25.00	24.80	32.50	32.45				32.52	31.97	30.43			28.75	23.90	20.95	22.22	23.39	11.98	14.79	20.88
	May					32.00																
	June	31.70	25.09	24.90	31.95	31.95	31.96			31.92	31.86	30.13			28.30	23.34	20.50	21.92	22.89	11.98	14.82	20.68
	July	31.40	25.24	25.00	31.96	31.70	31.75			31.72	31.82	30.03			28.11	23.12	20.25	21.32	22.89	12.00	14.79	20.60
	Aug.	31.10	24.50	24.28	31.48	31.15	31.22			30.32	31.36	29.83			27.33	22.27	19.65	20.22	21.00	12.44	14.77	20.50
	Sept	31.10	25.05	24.87	31.20	31.10	30.98			31.30	31.24	30.00			27.15	22.15	20.05	21.00	21.94	12.26	14.82	20.60
	Oct.	30.85	25.10	24.90	31.38	30.90	31.01			31.50	31.43	29.33			27.23	23.12	19.70	20.40	21.50	12.41	15.14	20.81
	Nov.					30.85	30.74															
	Dec.					31.45	31.04															
1912	Jan.	31.30	26.20	26.10	31.85	31.40				31.90	31.89	29.68			27.42	22.75	19.25	20.67	22.27	12.52	15.18	21.27
	Feb.	30.91	24.95	24.65	31.45	31.40				32.20	31.77	28.95			27.42	22.37	19.55	21.80	22.30	12.47	15.14	21.15
	Mar.	31.00	25.38	25.20	31.60	31.50				32.10	31.73	28.73			27.60	22.47	19.45	21.22	22.29	12.42	14.75	20.80
	Apr.	30.66	25.14	24.98	31.14	31.03				31.44	31.50	29.18			27.38	22.42	19.20	20.42	21.89	12.14	14.98	20.96
	May	30.10	24.03	23.85	30.61	30.50				31.00	30.82	28.78			26.46	21.08	18.10	1935	20.84	12.02	14.03	20.37
	June	29.45	24.10	23.92	29.85	29.85				30.42	29.97	28.29			25.96	20.53	18.19	18.60	20.18	11.97	14.14	19.96
	July	28.80	24.65	24.41	29.25	29.35				29.47	29.67	27.38			25.62	20.22	17.45	18.22	19.79	11.72	14.06	19.37
	Aug.	28.65	23.47	23.15	28.98	28.92				29.52	29.21	27.33			25.25	19.92	17.15	18.12	19.36	11.62	14.08	20.08
	Sept.	28.17	22.99	22.70	28.50	28.47				29.22	28.97	27.13			25.16	19.62	16.95	17.92	19.02	11.46	13.81	19.57
	Oct.	28.10	23.06	22.80	28.40	28.30				28.82	28.56	27.18			24.88	19.95	16.90	17.63	18.89	11.45	14.13	
	Nov.	28.22	24.51	24.35	28.65	28.52				29.04	29.02	27.53			25.34	20.92	17.10	18.12	19.65	11.47	14.48	19.76
	Dec.	28.50	25.71	25.45	29.24	29.25				29.57	29.61	28.27			26.17	21.22	18.49	19.22	20.89	12.12	14.52	20.26
1913	Jan.	28.66	25.22	25.01	29.24	29.20	29.36			29.72	28.47	28.03			25.70	20.82	17.86	17.67	20.84	12.16	15.52	20.76
	Feb.	28.35	23.46	23.35	28.84	28.95	29.06			29.50	28.71	27.69			25.29	20.55	17.41	18.57	20.44	11.95	15.48	20.96
	Mar.	28.10	23.52	23.18	28.60	28.60	28.59			29.07	28.81	27.07			25.05	19.97	16.25	17.82	19.55	11.72	14.95	20.40
	Apr.	27.95	24.05	23.73	28.35	28.47	28.50			29.00	28.77	27.08			25.00	20.03		17.80	19.69	11.62	14.04	19.82
	May	28.22	23.87	23.72	28.55	28.66	28.44	28.88		29.32	29.22	27.23			25.48	20.97		19.41	21.29	11.68	14.12	19.96
	June	28.65	24.75	24.65	28.93	29.00		29.04		29.67	29.47	27.53			25.70	20.97	18.05	18.90	20.79	11.63	14.42	20.14
	July		23.70	23.45	28.52	28.55		29.04		29.00	29.17	27.00			25.26	20.22	17.25	18.00	20.19	11.55	13.90	19.48
	Aug.	27.85	22.74	22.45	28.30	28.30	28.95	28.58		28.92	28.82	27.63			25.37	20.88	17.55	18.22	20.00	11.62	13.94	19.52
	Sept.	27.75	22.70	22.40	28.01	28.05		28.54		28.97	28.66	27.03			24.80	19.97	16.95	18.15	19.44	11.52	14.22	19.63
	Oct.			22.10		27.80		28.00							25.40	20.72	17.40	18.00	20.19		15.18	19.60
	Nov.	27.70		24.22	28.37	28.35	28.00	28.46		29.00					25.80	21.39	17.92	18.82	20.36	11.91	15.12	20.31
	Dec.	28.10		25.30	28.78	28.68	28.53	28.75		29.27		27.85			25.96	21.47	18.05	19.02	20.99	12.45	14.72	20.62
1914	Jan.	28.35		24.50	28.66	28.47	28.60	28.83		29.19		27.88			27.00	21.28	17.95	19.32	21.89	12.03	14.81	20.26
	Feb.	28.15		23.26	28.75	28.57	28.72	28.92		29.14		27.93			26.55	21.62	18.25	19.52	21.59	11.82	14.22	20.16
	Mar.	28.36		23.33	28.84	28.72	28.12	29.00		29.10		27.11			26.57	22.95	18.10	19.37	21.61	12.08		20.90
	Apr.	28.66		23.95	29.10	29.20	28.84	29.04		29.60		28.40			26.35	21.68	18.50	1988	21.29	12.04	14.77	21.14
	May	28.30		23.78	28.78	28.72		29.00		29.37		28.13			26.35	21.10	18.02	19.37	21.15	11.96	14.96	21.60
	June	28.00		24.35	28.51	28.39	28.53	28.75		28.91		27.73			26.00	20.52	17.75	18.52	20.73	11.95	14.14	21.32
	July	27.55		23.65	28.00	27.90	27.95	28.42		28.52		27.13			25.79	19.88	16.95	17.62	19.19	12.18	14.28	21.56
	Aug.	27.20		24.73	27.88	27.66	27.70	27.83		28.44		27.20			25.42	19.70	16.95	17.40	18.84	12.02	14.81	21.30
	Sept.	27.70		24.27	28.19	27.85	27.65	28.08		29.00		27.98			26.15	21.47	18.22	19.69	21.61	13.07	16.02	22.63
	Oct.	27.75		23.25	28.08	28.10	28.08	28.25		28.90		27.38			25.95	20.27	17.50	18.17	19.47	12.57	15.30	22.26
	Nov.	28.00		24.55	28.41	28.40		28.58		29.30		27.48			26.31	21.15	17.85	18.27	1989	12.44	15.62	22.51
	Dec.	28.80		24.60	29.49	29.10	29.40	29.16		30.24		28.13			27.75	23.72	20.20	21.32	23.35	13.93	16.72	23.76
1915	Jan.	28.80		24.35	29.50	29.40	29.50	29.50		30.10		28.00			27.31	21.82	18.55	1942	20.94	12.22	16.12	22.42
	Feb.	28.90		25.00	29.52	29.30		29.42		30.39		27.90			27.02	21.70	18.58	19.82	21.02	12.32	15.99	22.09
	Mar.	28.23		23.68	29.19	29.10		29.16		29.64		28.03			26.65	20.97	18.19	18.94	20.11	12.12	14.93	21.08
	Apr.	28.44		24.35		29.15	29.05	29.25		29.84		28.18			26.98	22.22	19.25	20.86	22.94	12.45	16.27	22.76
	May	28.70		22.85		28.80	28.95	29.08		29.74		28.03			26.49	21.02	17.79	18.76	20.11	11.82	15.60	22.56
	June	28.20		23.09		28.55		28.83		29.34		27.73			26.06	20.38	17.75	18.52	19.95	11.74	14.85	21.31
	July	28.00		23.89		28.45	28.37	28.67		29.10		27.53			25.95	20.22	17.25	18.12	19.45	12.06	14.85	21.76
	Aug.	27.50		22.25		27.90		28.17		28.64		27.08			25.70	19.76	16.75	17.62	18.79	1207	14.68	21.16
	Sept.	27.30		22.43		27.75	27.62	28.00		28.49		26.87			25.80	19.92	16.61	17.32	18.64	11.85	14.72	20.42
	Oct.	27.25		22.95			27.75	27.92		28.29		26.93			25.65	20.38	16.90	17.22	18.56	11.85	15.27	20.88
	Nov.			24.39				28.83	28.45	29.47	29.37		30.43		27.61	22.82	19.55	22.52	24.02	12.62	15.02	21.63
	Dec.			24.55		29.35		29.50	29.07	30.89	30.08		29.60	28.00	28.05	23.47	20.20	22.37	24.79	13.47	16.02	22.09
1916	Jan.			24.60		30.90		31.17	31.20	31.89	32.17		32.15	29.92	31.15	26.52	23.65	26.55	29.44	13.56	17.12	23.32
	Feb.			24.60		31.90		31.83	31.85	33.39	32.44		33.80	30.78	31.15	27.22	24.35	27.47	29.34	13.35	17.02	23.36
	Mar.			24.60		32.42		32.17	32.53	33.84	33.82		34.24	31.81	31.06	26.05	23.22	24.77	26.59	13.02	16.26	22.82
	Apr.			24.55		31.95		32.25	32.20	33.44	33.42		33.25	29.78	30.00	25.15	21.65	24.17	25.24	13.02	16.02	21.76
	May			24.55		32.30		32.25	32.40	33.10	32.72		33.45	29.88	30.25	25.17	21.35	23.72	25.24	13.12	15.52	21.68
	June			25.00		31.65		32.21	31.80	32.50	32.57		33.20	29.48	29.75	24.55	22.05	23.37	24.59	13.02	15.02	21.26
	July			24.80		30.90		31.67	31.05	31.35	31.40		32.25	28.98	29.15	23.32	20.85	21.95	23.24	12.97	14.72	21.21
	Aug.					30.45	30.58	31.17	30.60	31.33	31.24		32.05	28.79	28.65	22.88	20.27	21.74	22.90	13.12	14.52	20.76
	Sept	28.34		23.91		30.10	30.39	30.25			31.00		31.23	28.71								
	Oct.	28.27		23.76		29.95	29.85	30.00			30.85		31.14	28.70			19.41	20.74	22.24	13.18	14.45	20.61
	Nov.	28.11		23.87		29.85	29.80				30.45		30.98	28.61	28.79	22.03	19.52	20.88		13.57	15.00	20.85
	Dec.	28.24		24.66		30.49	30.04				30.92		31.28	28.95	28.98	23.78	20.76	22.60	24.14	13.52	15.89	21.30

NOTE.- Monthly record for Honolulu Rapid Transit & Land Co. compiled from daily observations furnished by the Company.

TABLE 2.- # ARTESIAN WELL HEADS IN HONOLULU AREA

COLLECTED AND COMPILED BY

THE WATER COMMISSION OF THE TERRITORY OF HAWAII. (ACT 36 SESSION LAWS OF 1915)

Reference plane for well heads is mean sea level.

DIAMOND HEAD TO MOILIILI

NAME OF WELL	SING LOY, near Kapahulu Road	LUNG DO WAI, 12 inch casing	LUNG DO WAI [1], north of No. 51	LUNG DO WAI, rice mill yard	LUNG DO WAI, in rice mill	LUNG DO WAI, near Japanese cemetery
WELL No.	37	51	50	51½	7	52
WEEK BEGINNING						
JULY 16, 1916						
23						
30						
AUGUST 6						
13						
20						
27						
SEPTEMBER 3						
10						
17			23.91			
24						
OCTOBER 1						
8			23.76			
15			23.27	23.04		
22		23.15	23.31	23.11	21.84	
29						23.71
NOVEMBER 5		23.90	23.87	23.74		24.22
12	23.00	24.06	24.05	23.89	22.70	24.31
19	23.23	24.38	24.34	24.29	22.98	24.60
26	23.41	24.64		24.62	23.21	24.73
DECEMBER 3	23.63	24.66			23.22	25.01
10	23.95	25.04				25.29
17						
24						
31						

MOILIILI TO PAUOA STREAM

NAME OF WELL	SING LOY, Beretania St.	SING LOY, north of No. 10, Artesian Street	MRS. SASS, known also as "Weedons" and "Artesian Ice Works" – Artesian St.	G. ROBERTSON, Bingham St.	COL. C. SPRECKLES, Bingham St.	OAHU COLLEGE [2], Wilder Ave.	HON. H.A. WIDEMANN, makai of "The Macdonald"	G.P. WILDER, head of Anapuni St.	W. HOOGS, Makiki St., rear of "The Romany"	JOHN II ESTATE, corner King and Kalakaua Ave.	"GENERAL GRANT," makai King St., opp. Bureau of Agriculture and Forestry	HAWAIIAN ELECTRIC CO. STABLES, Young St.	"VIDA VILLA," Young St.	ARCHIE YOUNG, Young St.	C.M. COOKE, Kinau St.	MRS. C P WARD, King St., opp. Thomas Square	QUEEN'S HOSPITAL, near laundry	BERETANIA ST. PUMPING STATION [1]	H.R.T. & L. CO [1] [3], Alapai St.	"GOVERNMENT STABLES" [1], King St., Judiciary Bldg. grounds	HONOLULU IRON WORKS [4], foundry	I-I. S.N. CO., Bishop wharf	Y.M.C.A [1], Alakea St.
WELL No.	55	58	34	61	14	62½	15	68	67	5½	66	35	24	24½	78	25	94	72-73	81	27	87	87½	88A
WEEK BEGINNING																							
JULY 16, 1916						31.20													32.00				
23						31.10													31.75				
30						30.90													31.67				31.05
AUGUST 6						30.80						14.24			31.02			30.58	31.50				
13				30.84	30.75	30.63	30.63	30.40											31.42		15.86		
20	30.61	30.66		30.67		30.57			30.60	30.51	30.64	14.05					30.48		31.25				
27	30.47	30.49			30.57	30.45	30.49	30.51	30.41	30.49	30.51	14.16			30.64	30.38	30.45						30.60
SEPTEMBER 3	30.36	30.35		30.38	30.41	30.40	30.33	30.42	30.38	30.34	30.36	14.14			30.51	30.28	30.32	30.39	31.00	28.58	16.2		
10	30.30	30.33	30.33		30.37	30.27	30.30	30.41	30.33	30.40	30.29				30.54	30.24	30.33		30.50	28.56	15.8		
17	30.27	30.27	30.30	30.30	30.34	30.19	30.26	30.28	30.27	30.23	30.28	14.02	19.25	30.26	30.40	30.13	30.19		30.50	28.34	15.9		
24	30.17	30.18	30.16	30.22	30.24	30.10	29.74	30.19	30.15	30.17	30.18		19.20	30.15	30.28	30.01	30.08		30.20		16.1		
OCTOBER 1	29.96	29.98	29.94	30.04	30.06	29.95	30.01	30.06	30.02	30.01	30.01	13.79	19.07	30.00	30.16	29.86	29.95		30.25	28.27	16.0		
8	29.94	29.95		29.98	30.00	29.85	29.91	29.97	29.94	29.91	29.93		19.00	29.96	30.10	29.75	29.77		30.16	28.09	15.8		
15	29.89	29.89	29.86	29.94	29.94	29.77	29.94	29.91	29.86	29.87	29.93	13.67	18.95	29.85	30.02	29.74	29.79		30.16	28.10	16.2		
22	29.79	29.80	29.80	29.83	29.85	29.71	29.78	29.84		29.77	29.80	13.57	18.91	29.81	29.97	29.69	29.78	29.85	30.16	27.97	15.8	30.23	
29	29.69	29.69	29.69	29.75	29.79	29.63	29.70	29.76		29.68	29.70	13.51	18.87	29.70	29.90	29.58	29.70	29.77	30.00	28.02	16.0	29.55	
NOVEMBER 5	29.88	29.89	29.87	29.94	30.04	29.70	30.18	29.87		29.80	29.88	13.45	18.87	29.87	30.01	29.72	29.83	29.80	29.50	28.11	14.7	29.79	
12	29.89	29.92	29.90	29.93	29.96	29.78	29.90	29.84		29.83	29.90	13.57	18.87	29.91	30.07	29.76	29.89	29.86	29.83	28.12	14.9		
19	29.88	29.92	29.88	29.96		29.83	29.90	29.99		29.88	29.94	13.53		29.88	30.06	29.77	29.89	29.92	30.00	28.30	14.9	29.42	
26	29.94	29.96	29.94	30.00	30.00	29.81	29.93	29.74		29.86	29.92	13.51		29.92	30.08	29.79	29.77	30.12	30.00	28.19	15.3	29.13	
DECEMBER 3	30.00	30.01	30.01	30.04	30.04	29.94	29.96	30.02		29.91	30.00	13.47	18.95	30.00	30.15	29.87	29.98	30.04	30.00	28.24	13.5		
10	30.14	30.17		30.18	30.20	29.95	30.08	30.11		30.04	30.11		19.01	30.12	30.18	29.97	30.08	30.12	30.08	28.32	14.3	29.37	
17						30.20													30.17		14.0		
24						30.20													30.42				
31						3049													30.50				

PAUOA STREAM TO KALIHI STREAM

NAME OF WELL	THOMAS FOSTER, School and Nuuanu Ave	O.R. & L. CO. [1], round house	HAWAIIAN PINEAPPLE CANNERY, Iwilei	KAUMAKAPILI CHURCH, rear	Y. AHIN, east of group, Auld Lane	Y. AHIN, west of No. 97, Auld Lane	Y. AHIN, west of No. 98, Auld Lane	Y. AHIN [1], west of No. 100, Auld Lane	KAMEHAMEHA SCHOOL, old well on Houghtailing Road	Y. AHIN "No. 5", Houghtailing Road	KINGS No. 1, 734 Mokauea St.	KINGS No. 2, opp. 1781 Kanaanu St.	NEW PRISON, Puuhale Road – Kalihi	BISHOP ESTATE, mauka of Libby McNeill & Libby Cannery – Kalihi	L. WILCOX, off King St. mauka of Poi Factory, Kalihi
WELL No.	31	95	95½	33	97	98	99	100	103	105	107	108	110A	110B	111
WEEK BEGINNING															
JULY 16, 1916					31.93	31.95	31.92	31.95							
23					31.82	31.85	31.84	31.88							
30	31.79	31.35			31.54	31.55	31.56	31.58							
AUGUST 6					31.51	31.52	31.53	31.57							
13	31.42				31.48	31.31	31.50	31.48							
20				31.43	31.18	31.21	31.24	31.38							
27	31.18	31.33		31.25	31.23	31.25	31.27	31.25							
SEPTEMBER 3	31.06		31.33	31.22	31.17	31.21	31.21	31.19							
10	30.98		31.21	31.07	31.01	31.03	81.06	31.06		31.15		13.35			
17	30.99		31.21	31.07	31.03	31.07	31.04	31.05	30.78		31.03		31.37	31.03	31.16
24			31.18	30.98	30.95	30.98	30.99	30.97	30.81	30.99	31.08	13.32	31.23	30.85	31.16
OCTOBER 1	30.68		31.21	30.85	30.80	30.82	30.86	30.82	30.70		31.05	13.33	31.14	30.89	31.05
8	30.61		31.21	30.80	30.76	30.80	30.80	30.98	30.60	30.78	30.94	13.36	31.06	30.82	30.98
15	30.58		31.18	30.72	30.67	30.69	30.71	30.69	30.56		30.83	13.31	31.00	30.75	30.96
22	30.58			30.67	30.61	30.64	30.65	30.65	30.49	30.56	30.71	13.30	30.87	30.64	30.82
29	30.47			30.64	30.63	30.62	30.64	30.64	30.48	30.56	30.69	13.30	30.94	30.65	30.80
NOVEMBER 5	30.56		31.01	30.68	30.65	30.64	30.66	30.65	30.50	30.58	30.76	13.33	30.98	30.68	30.86
12	30.62			30.81	30.77	30.78	30.81	30.80	30.64	30.72	30.93	13.33	31.17	30.85	31.06
19	30.65		31.18	30.81	30.75	30.75	30.81	30.80	30.63	30.71	30.91	13.34	31.15	30.83	30.95
26	30.56		31.16	30.84	30.78	30.80	30.82	30.82	30.68	30.80	30.97	13.53	31.19	30.85	30.99
DECEMBER 3	30.75		31.16	30.94	30.88	30.91	30.93	30.92	30.76	30.88	31.03	13.22	31.28	30.95	31.11
10	30.72		31.18	31.07	31.01	31.04	31.05	31.05	30.87	31.06	31.12		31.40	31.08	31.16
17				31.27				31.25							
24															
31															

KALIHI STREAM TO MOANALUA.

NAME OF WELL	PACIFIC GUANO & FERTILIZER CO., King St.	FORT SHAFTER [1], Electric Pump	MR. DAMON [1], Moanalua
WELL No.	111½	116½	119
WEEK BEGINNING			
JULY 16, 1916			
23			
30			
AUGUST 6			
13			
20			
27			
SEPTEMBER 3	29.98	28.82	
10			
17	29.87	28.83	
24	29.73	28.71	
OCTOBER 1	29.70	2870	
8	29.62	28.60	
15	29.53	2823	
22	29.44	2841	
29	29.43	28.40	
NOVEMBER 5	29.64	28.61	
12	29.72	28.82	28.79
19	29.62	28.72	28.76
26	29.79	28.76	
DECEMBER 3	30.10	28.95	28.98
10	30.24	29.20	
17	30.54		29.55
24			
31			

TABLE 3.-

ARTESIAN WELL HEADS, IN FEET ABOVE MEAN SEA LEVEL, OAHU COLLEGE, PUNAHOU

1899 – 1916

DATE	1899	1900	1901	1902	1903	1904
JAN.		34.25	34.00	33.95	35.06	33.93
FEB.	35.75	34.05	34.37	33.80	35.25	34.80
MAR.	–	33.75	34.30	34.05	34.85	35.85
APR.	35.3	34.50	34.00	34.10	34.75	36.30
MAY	35.2	33.60	–	33.85	34.65	35.86
JUNE	35.1	33.53	32.85	33.50	34.18	35.40
JULY	34.6	33.26	33.40	33.40	33.80	
AUG.	34.4	32.90	–	33.10	33.30	
SEPT.	34.2	32.85	33.20	32.95	33.10	
OCT.	34.2	33.19	33.12	32.95	33.30	
NOV.	–	33.63	33.56	33.90	33.34	
DEC.	34.85	34.00	34.05	34.57	33.40	

JAN.		FEB.		MAR.		APR.		MAY		JUNE		JULY		AUG.		SEPT.		OCT.		NOV.		DEC.	
1908																							
										10	31.9	15	31.55	3	31.22	7	31.03	5	30.88	2	30.67	7	30.74
										16	31.85	21	31.4	10	31.1	28	30.94	12	30.85	9	30.65	14	30.77
										30	31.7	28	31.32	24	30.9			19	30.78	16	30.63	21	30.70
														31	30.9			26	30.72	23	30.61	28	30.82
																			–	30	30.73		
1909																							
4	30.70	1	30.65	1	30.87	5	31.15	3	30.88	7	30.65	5	30.57	2	30.52	6	30.27	4	30.00	1	29.88	6	29.98
18	30.61	8	30.78	8	30.90	12	31.21	10	30.72	14	30.65	12	30.60	9	30.52	13	30.15	11	29.93	8	29.90	13	30.05
25	30.70	22	30.84	15	30.90	19	31.10	17	30.67	21	30.75	19	30.55	16	30.40	20	30.12	18	29.82	15	29.89	20	30.30
				22	30.93	26	31.03	24	30.66	28	30.68	26	30.55	23	30.38	27	30.05	25	29.7	22	29.87	27	30.60
				29	31.05			31	30.65					30	30.35					29	29.85		
1910																							
3	30.70	7	31.27	7	31.18	4	30.70	2	30.20	6	29.75	5	29.95	2	29.60	6	29.80	3	30.40	1	30.35	12	31.10
10	30.83	14	31.35	14	30.90	11	30.50	9	30.15	13	29.75	11	29.90	8	29.59	13	29.92	10	30.38	7	30.50	19	31.10
17	30.95	21	31.35	21	30.85	18	30.30	16	30.00	20	29.85	18	29.80	15	29.62	20	30.10	17	30.35	21	30.80	27	31.10
24	31.10	28	31.30	28	30.85	25	30.50	23	29.90	27	29.70	25	29.68	22	29.50	26	30.35	25	30.40	28	30.90		
31	31.20							30	29.75					29	29.75			31	30.40				
1911																							
2	31.15	6	31.65	6	32.15	3	32.55	1	32.50	5	32.00	3	32.00	7	31.50	4	31.1	2	31.30	6	30.90	4	30.90
9	31.20	13	31.75	13	32.35	10	32.60	8	32.40	12	31.9	10	31.95	14	31.4	11	31.10	9	31.20	12	30.85	11	31.00
16	31.30	20	31.85	20	32.40	17	32.50	15	32.20	19	31.95	17	31.9	21	31.30	18	31.00	16	31.10	20	30.80	18	31.10
23	31.40	27	32.00	27	32.55	24	32.45	22	32.10	26	31.95	24	31.9	28	31.15	25	31.10	23	30.90	27	30.85	25	31.35
30	31.50							29	32.00			31	31.7					30	30.90			31	31.45
1912																							
1	31.45	5	31.50	4	31.53	1	31.40	6	30.90	3	30.38	1	29.70	5	29.25	2	28.90	7	28.35	4	28.25	2	28.52
8	31.55	12	31.48	11	31.60	8	31.30	13	30.80	10	30.20	8	29.60	12	29.17	9	28.90	14	28.40	11	28.35	9	28.7
15	31.60	19	31.40	18	31.58	15	31.20	20	30.60	17	30.00	15	29.48	19	29.05	16	28.75	21	28.25	18	28.3	16	28.96
22	31.65	26	31.40	25	31.50	22	31.15	27	30.50	24	29.95	22	29.38	26	28.92	23	28.55	28	28.30	25	28.52	23	29.15
29	31.60					29	31.03					29	29.35			30	28.47					30	29.25
1913																							
5	29.25	2	29.15	2	28.83	7	29.52	4	28.50	1	28.77	6	28.97	3	28.42	7	28.20	5	27.94	13	27.94	7	28.5
12	29.75	9	29.07	9	28.66	14	28.46	11	28.42	8	28.82	13	28.87	10	28.33	14	28.23	12	27.80	23	28.18	14	28.69
19	29.15	16	29.07	23	28.70	20	28.46	18	28.61	15	28.95	20	28.72	17	28.25	21	28.12			30	28.35	21	28.7
26	29.20	23	28.95	31	28.60	27	28.47	25	28.66	22	29.00	27	28.55	24	28.25	28	28.05					28	28.68
														31	28.30								
1914																							
4	28.65	1	28.65	1	28.62	5	28.90	3	29.01	8	28.60	5	28.32	2	27.85	6	27.60	4	28.00	1	28.10	6	28.52
16	28.60	8	28.69	8	28.56	12	29.00	24	28.75	21	28.54	12	28.25	9	27.79	13	27.65	11	28.20	8	28.20	13	28.75
18	28.67	15	28.70	15	28.62	19	29.00	31	28.72	28	28.39	19	28.10	16	27.70	21	27.80	18	28.15	15	28.20	20	29.00
		22	28.57	22	28.64	26	29.20					26	27.90	23	27.66	27	27.85	25	28.10	22	28.25	27	29.10
				29	28.72															28	28.40		
1915																							
3	29.45	7	29.40	7	29.20	4	29.00	2	29.10	13	28.60	4	28.50	1	28.40	5	27.8		NO RECORD		NO RECORD	27	29.35
10	29.60	14	29.35	14	29.20	11	29.00	9	29.00	20	28.58	11	28.46	8	28.20	12	27.69						
17	29.35	21	29.35	21	29.10	18	29.10	16	29.00	27	28.55	18	28.46	15	28.10	19	27.60						
24	29.50	28	29.30	28	29.10	25	29.15	23	28.95			25	28.45	22	28.00	26	27.75						
31	29.40							30	28.80					29	27.90								
1916																							
2	29.60	6	31.20	5	32.15	2	32.30	7	32.06	4	32.00	2	31.52	6	30.80	3	30.40	1	29.95	5	29.70	3	29.94
9	29.80	13	31.55	12	32.33	9	32.20	14	32.25	11	31.95	9	31.40	13	30.63	10	30.27	8	29.85	12	29.78	10	29.95
16	30.20	20	31.70	19	32.33	16	32.10	21	32.30	18	31.70	16	31.20	20	30.57	17	30.19	45	29.77	19	29.83	17	30.20
23	30.53	27	31.90	26	32.42	23	32.00	28	32.00	25	31.65	23	31.10	27	30.45	24	30.10	22	29.71	26	29.81	24	30.20
30	30.90					30	31.95					30	30.90					29	29.63			31	30.49

records were collected by Curtis J. Lyons and Robert C. Lydecker, Territorial meteorologists, respectively, and were published in the monthly weather record of the "Hawaii Territory Survey." A few additional well heads for 1899 were secured from records at Oahu College. Weekly observations from June, 1908, to December, 1916, were furnished by Mr. H. G. Wooten, pump engineer, Oahu College. A fire at Oahu College destroyed records covering the period July, 1904, to May, 1908. Fig. 2 shows this table in graph form. The graph for the period of missing records, 1904 to 1908, has been interpolated by means of a study of the monthly rainfall variation for this artesian watershed.

TABLES 4 TO 9. FIGS. 1 TO 5, which follow, have been selected to show typical artesian well and rainfall conditions on the three major artesian areas on the Island of Oahu, i.e., (1) Honolulu, (2) Pearl Harbor, and (3) Windward Oahu.

(1) HONOLULU CITY AREA.

TABLE 4. FIG. 1. MEAN MONTHLY RAINFALL ON ARTESIAN WATERSHED.

Seven of the longest rainfall records of the U. S. Weather Bureau above elevation 400 feet have been combined into a composite rainfall record to show, in a general way, the amount and monthly distribution of rainfall affecting these artesian watersheds.

TABLE NO. 4.

MEAN MONTHLY RAINFALL, IN INCHES, ON ARTESIAN WATERSHED, HONOLULU CITY AREA.

Computed From Selected U. S. Weather Bureau Records.[1]

Year	No. of rainfall records combined for mean	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1899.....	2	3.0	14.6	19.5	5.1	11.0	5.6	3.3	7.5	3.4	11.2	2.2	4.0
1900.....	2	1.9	4.5	3.4	16.2	8.8	4.9	10.4	8.7	6.4	17.6	15.2	6.1
1901.....	2–3	9.9	10.3	8.6	8.4	9.5	6.7	6.5	3.7	5.2	7.7	12.4	17.5
1902.....	4	2.1	3.1	32.6	9.9	7.4	3.0	9.8	7.7	7.5	10.4	18.8	18.0
1903.....	4	5.7	8.0	1.6	11.3	5.8	8.1	10.1	11.4	16.7	6.0	11.5	5.0
1904.....	4	14.9	27.1	8.0	11.6	5.2	5.2	9.0	7.7	4.5	8.0	8.8	8.6
1905.....	5	2.0	1.6	3.3	11.6	12.2	5.0	7.1	14.8	12.2	10.6	11.7	9.5
1906.....	5	4.7	2.7	3.6	6.5	7.2	6.0	7.9	7.7	7.3	7.4	11.7	20.7
1907.....	6	15.4	11.3	10.2	4.7	6.5	9.1	9.2	14.9	8.0	7.0	8.4	7.6
1908.....	7	3.6	13.0	12.0	7.4	7.0	9.3	4.2	10.1	10.2	4.9	4.4	10.4
1909.....	7	6.1	7.1	18.6	7.5	7.6	10.7	12.2	6.0	7.0	7.7	2.9	15.0
1910.....	7	9.4	7.6	11.0	11.1	13.5	12.3	8.1	12.7	13.9	7.0	11.8	12.4
1911.....	7	15.2	23.1	6.4	9.5	14.2	12.3	7.5	11.7	11.4	4.4	9.5	13.8
1912.....	7	2.4	8.3	12.6	9.7	7.3	4.5	6.2	8.3	4.1	13.4	11.1	12.7
1913.....	7	7.1	4.2	8.9	16.4	11.5	12.4	5.5	8.0	4.6	4.4	24.5	8.4
1914.....	7	8.3	3.9	8.4	13.5	9.1	12.4	14.4	9.8	20.3	6.7	11.0	8.7
1915.....	7	2.1	9.4	4.3	17.0	3.6	8.2	13.3	6.2	12.6	14.1	22.5	15.8
1916.....	7–5	28.2	3.6	11.6	7.6	22.2	9.8	10.6	12.6	8.4	10.8	13.6	...
Normals for watershed[2]..	...	8.8	9.4	10.6	10.5	9.4	9.2	9.0	9.7	10.5	8.3	10.5	11.4

[1] The following selected rainfall stations were used:

Name	Elevation	Length of Record From	To
Tantalus	1,665	January, 1907	August, 1916
Tantalus	1,360	August, 1901	November, 1916
Tantalus Heights	1,300	September, 1907	March, 1916
Kaliula	1,200	January, 1902	November, 1916
Upper Luakaha	1,111	January, 1905	November, 1916
Lower Luakaha	881	January, 1890	November, 1916
Electric Light Station	405	January, 1890	November, 1916

[2] Normals for watershed are mean monthly normals for the seven rainfall stations selected.

TABLE 5. FIG. 1. DEVIATIONS FROM MEAN MONTHLY RAINFALL NORMALS FOR ARTESIAN WATERSHEDS.

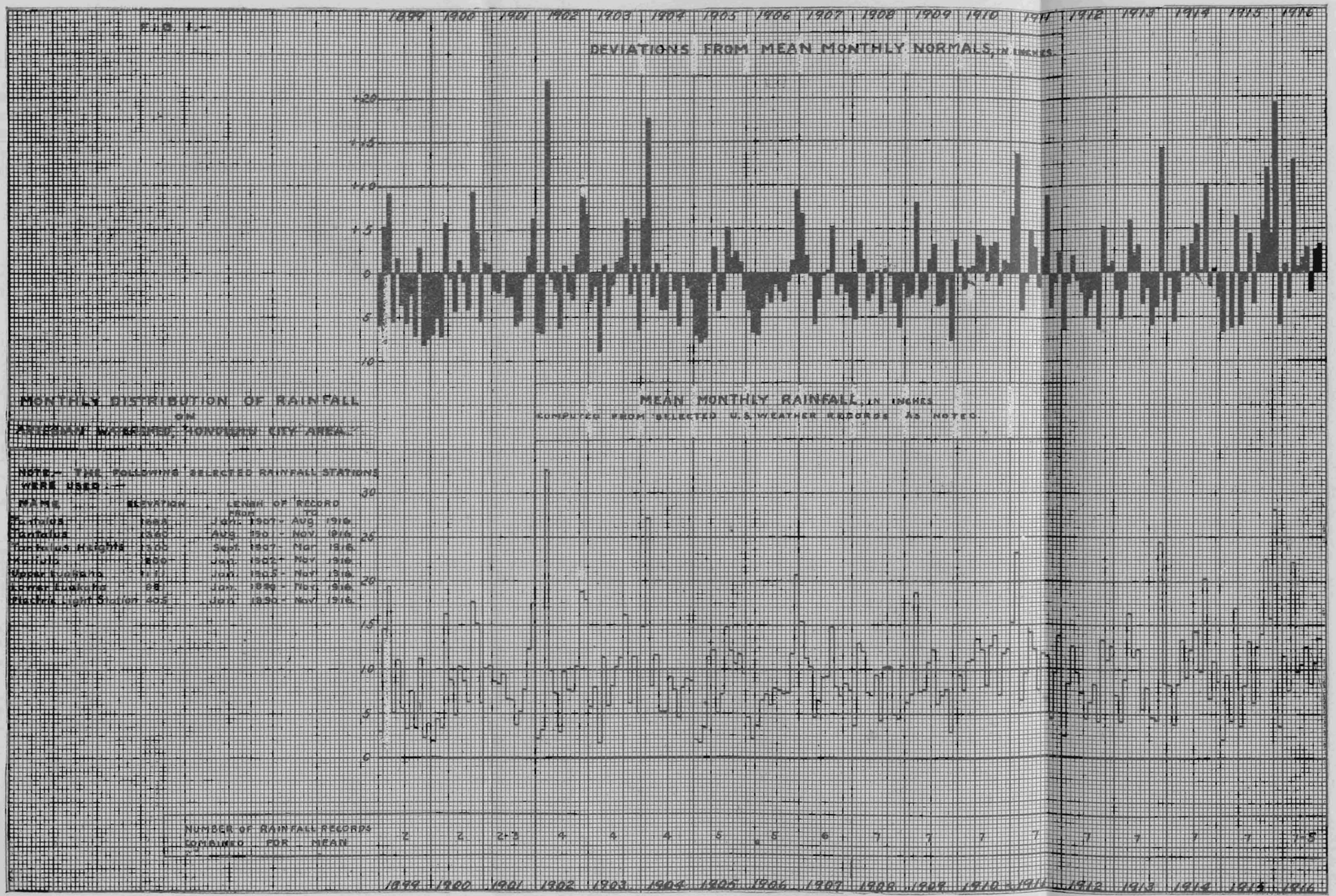
This table has been prepared from table 4. In addition to the amounts of surplus or deficient rainfall, monthly, above or below monthly normal rainfall, the table shows the periods in which the rainfall was above or below normal for the past eighteen years.

TABLE NO. 5.

DEVIATIONS FROM MEAN MONTHLY RAINFALL NORMALS, IN INCHES, FOR ARTESIAN WATERSHED, HONOLULU CITY AREA.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1899	— 5.8	+ 5.2	+ 8.9	— 5.5	+ 1.6	— 3.6	— 5.6	— 2.2	— 7.1	+ 2.9	— 8.2	— 7.4
1900	— 6.9	— 4.9	— 7.2	+ 5.7	— .5	— 4.3	+ 1.4	— 1.0	— 4.1	+ 9.3	+ 4.7	— 5.4
1901	+ 1.1	+ .9	— 1.9	— 2.1	+ .2	— 2.6	— 2.5	— 6.0	— 5.3	— .5	+ 1.9	+ 6.1
1902	— 6.7	— 6.3	+22.0	— .6	— 2.0	— 6.2	+ .8	— 2.0	— 3.0	+ 2.1	+ 8.4	+ 6.6
1903	— 3.2	— 1.4	— 9.0	+ .8	— 3.6	— 1.2	+ 1.1	+ 1.7	+ 6.2	— 2.3	+ 1.0	— 6.4
1904	+ 6.1	+17.7	— 2.6	+ 1.0	— 4.1	— 4.0	.0	— 2.0	— 6.0	— .2	— 1.6	— 2.8
1905	— 7.0	— 7.8	— 7.3	— 1.0	+ 2.9	— 4.3	— 1.9	+ 5.1	+ 1.7	+ 2.4	+ 1.2	— 1.9
1906	— 4.2	— 6.7	— 7.0	— 4.0	— 2.2	— 3.3	— 1.1	— 2.0	— 3.2	— .8	+ 1.3	+ 9.3
1907	+ 6.6	+ 1.9	— .3	— 5.8	— 2.9	— .2	+ .2	+ 5.2	— 2.5	— 1.2	— 2.1	— 3.9
1908	— 5.2	+ 3.6	+ 1.5	— 3.1	— 2.3	+ .1	— 4.7	+ .4	— .3	— 3.4	— 6.1	— 1.1
1909	— 2.7	— 2.3	+ 8.0	— 3.0	— 1.7	+ 1.4	+ 3.2	— 3.7	— 3.5	— .6	— 7.6	+ 3.6
1910	+ .6	— 1.8	+ .4	+ .6	+ 4.2	+ 3.0	— .9	+ 3.0	+ 3.4	— 1.3	+ 1.3	+ 1.0
1911	+ 6.4	+13.7	— 4.2	— 1.0	+ 4.9	+ 3.0	— 1.5	+ 2.0	+ .9	— 3.9	— 1.0	+ 2.4
1912	— 6.4	— 1.1	+ 2.0	— .8	— 2.1	— 4.8	— 2.8	— 1.4	— 6.4	+ 5.1	+ .6	+ 1.2
1913	— 1.7	— 5.2	— 1.7	+ 5.9	+ 2.2	+ 3.1	— 3.5	— 1.7	— 5.9	— 3.8	+14.1	— 3.1
1914	— .5	— 5.5	— 2.2	+ 3.0	— .3	+ 3.2	+ 5.4	+ .1	+ 9.8	— 1.5	+ .5	— 2.7
1915	— 6.7	.0	— 6.2	+ 6.4	— 5.8	— 1.0	+ 4.4	— 3.5	+ 2.1	+ 5.9	+12.0	+ 4.4
1916	+19.3	— 5.8	+ 1.0	— 2.8	+12.8	+ .6	+ 1.6	+ 2.9	— 2.1	+ 2.5	+ 3.1	

FIG. 1.—



MONTHLY DISTRIBUTION OF RAINFALL ON ARTESIAN WATERSHED, HONOLULU CITY AREA.

NOTE.— THE FOLLOWING SELECTED RAINFALL STATIONS WERE USED.—

NAME	ELEVATION	LENGTH OF RECORD FROM	TO
Punchbowl	150±	June 1907 -	Aug. 1916
Tantalus	1560	Aug. 1901 -	Nov. 1916
Tantalus Heights	1305	Sept. 1907 -	Mar. 1916
Kaiulu	800±	Jan. 1902 -	Nov. 1916
Upper Nuuanu	1.7	Jan. 1903 -	Nov. 1916
Lower Nuuanu	28	Jan. 1899 -	Nov. 1916
Electric Light Station	40±	June 1899 -	Nov. 1916

TABLE 6. FIG. 2. ANNUAL RAINFALL ON ARTESIAN WATERSHEDS.

The seven rainfall stations used to prepare table 4 were combined yearly to show (a) mean annual rainfall on this watershed; from the (b) yearly deviations from the normal annual rainfall (111.5 inches), the (c) accumulative excess (+) or deficiency (—) of annual rainfall since 1899 was prepared.

TABLE NO. 6.

ANNUAL RAINFALL ON ARTESIAN WATERSHED, HONOLULU CITY AREA.

Computed From Selected U. S. Weather Bureau Records.

Year	No. of rainfall records combined for mean	Mean yearly rainfall	Deviations of mean yearly rainfall from normal annual rainfall	Accumulated excess (+) or deficiency (—) of annual rainfall on artesian watershed, since 1899—based on normal annual rainfall
		Inches	Inches	Feet
1890.....	2	155	.....	.....
1891.....	2	91	.....	.....
1892.....	2	105	.....	.....
1893.....	2	106	.....	.....
1894.....	2	105	.....	.....
1895.....	2	111	.....	.....
1896.....	2	77	.....	.....
1897.....	2	76	.....	.....
1898.....	2	136	.....	.....
1899.....	2	91	—20.9	—1.7
1900.....	2	104	— 7.7	—2.4
1901.....	3	104	— 7.5	—3.0
1902.....	4	130	+18.8	—1.4
1903.....	4	101	—10.5	—2.3
1904.....	4	118	+ 6.9	—1.7
1905.....	5	101	—10.0	—2.6
1906.....	5	93	—18.2	—4.1
1907.....	6	120	+ 8.4	—3.4
1908.....	7	97	—14.9	—4.6
1909.....	7	110	— 1.7	—4.8
1910.....	7	132	+20.0	—3.1
1911.....	7	147	+35.6	—1.5
1912.....	7	101	—11.0	—1.1
1913.....	7	109	— 2.8	—1.3
1914.....	7	126	+15.0	— .05
1915.....	7	129	+17.6	+1.4
1916.....	5	[a] 136	+24.9	+3.5
Total for period, 27 years.....	..	3011	.....	.....
Normal annual rainfall, 27 years.....	..	111.5	.....	.....

[a] January to November record used.

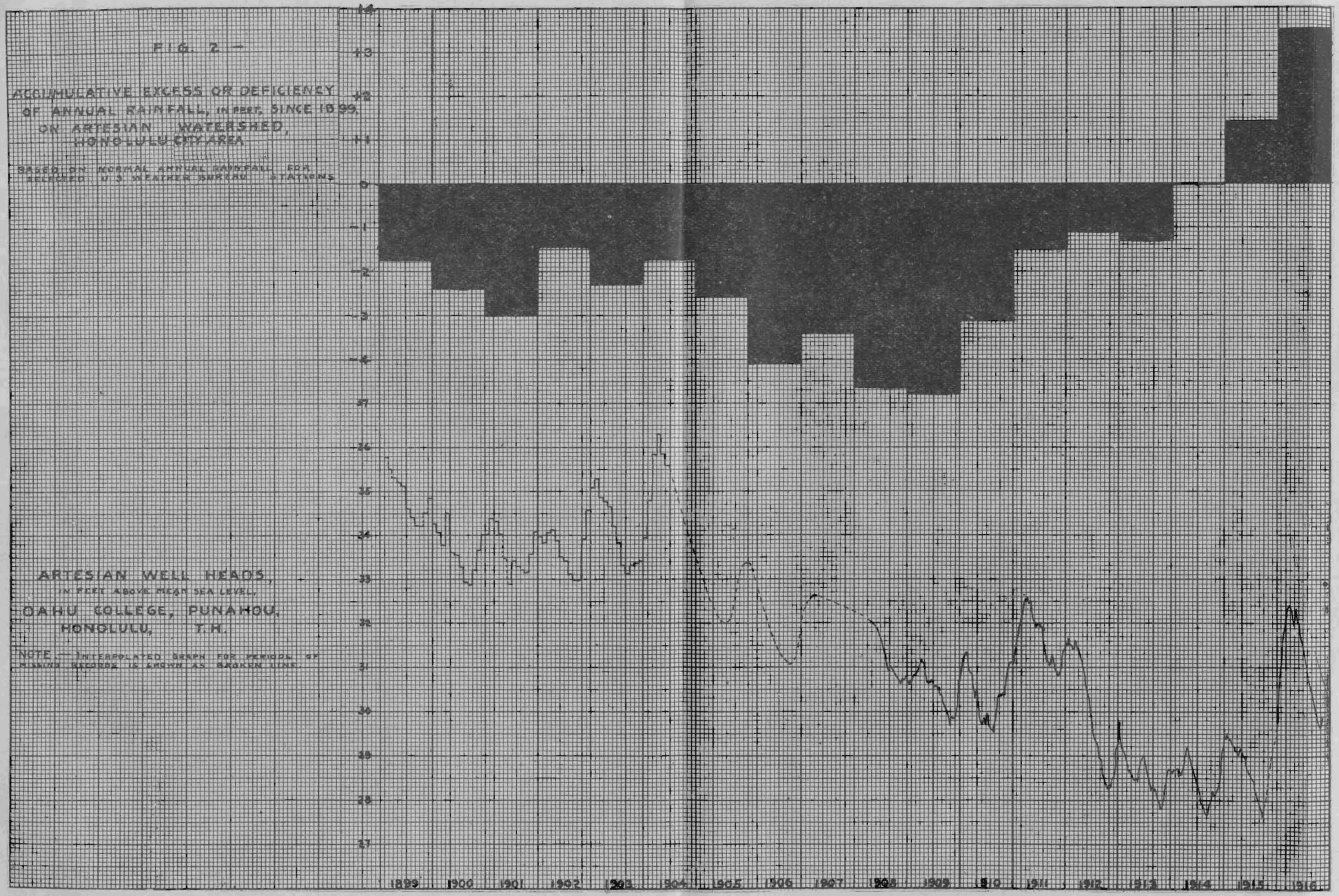
FIG. 2 —

ACCUMULATIVE EXCESS OR DEFICIENCY OF ANNUAL RAINFALL, IN FEET, SINCE 1899, ON ARTESIAN WATERSHED, HONOLULU CITY AREA.

BASED ON NORMAL ANNUAL RAINFALL FOR SELECTED U.S. WEATHER BUREAU STATIONS.

ARTESIAN WELL HEADS, IN FEET ABOVE MEAN SEA LEVEL, OAHU COLLEGE, PUNAHOU, HONOLULU, T.H.

NOTE — INTERPOLATED GRAPH FOR PERIODS OF MISSING RECORDS IS SHOWN AS BROKEN LINE.



(2) PEARL HARBOR AREA.

TABLES 7 AND 8. FIGS. 3 AND 4.

These tables and graphs, prepared similar to data in tables 5 and 6, show deviations from mean monthly rainfall normals and annual rainfall for Ewa plantation which has been selected as representative for this artesian area.

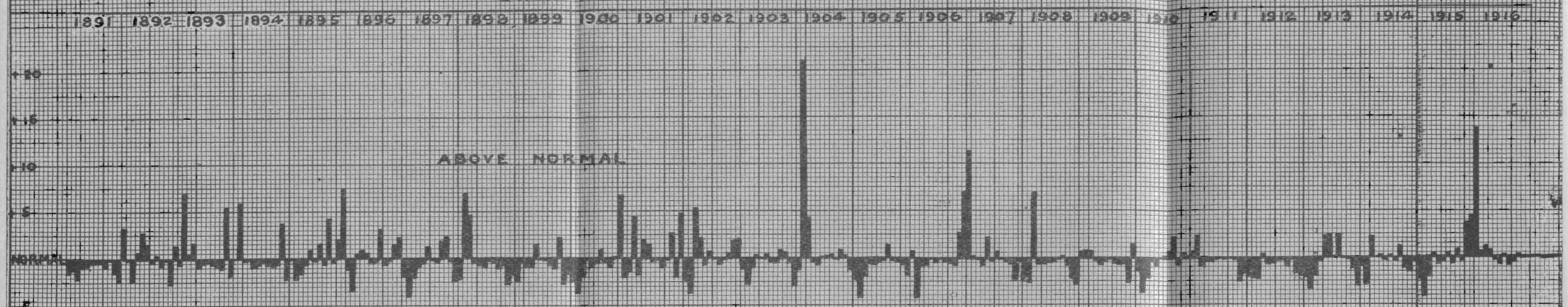
TABLE NO. 7.

DEVIATIONS FROM MEAN MONTHLY RAINFALL NORMALS, IN INCHES, EWA PLANTATION.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1891.....	— 1.5	— 1.2	— 2.1	— 0.9	— 0.8	— 0.5	— 0.4	— 0.4	— 1.0	— 0.2	— 1.5	— 2.4
1892.....	+ 3.3	— .3	— 2.5	+ .6	+ 2.7	+ 1.4	— .4	+ .3	— .9	— .3	— 2.7	+ 1.4
1893.....	— .6	+ 6.8	+ .4	+ 1.6	— .9	— .6	— .4	— .7	— .9	— 1.1	+ 5.4	— 1.8
1894.....	.0	+ 5.8	— .3	— .1	— .9	— .6	— .4	— .7	— .8	— .6	+ 3.7	— 2.2
1895.....	.0	— 2.2	— 1.6	— .6	+ .8	— .2	+ 1.5	— .6	+ 4.2	— .4	+ 2.0	+ 7.4
1896.....	— 1.2	— 3.5	+ .5	+ .8	+ .5	— .5	— .3	+ 3.1	— .7	— .2	+ 1.3	+ 2.1
1897.....	— 1.9	— 4.0	— 2.0	— .8	— .5	+ 1.2	— .1	— .4	+ 1.8	+ 2.3	— .3	— 2.4
1898.....	— 2.1	+ 6.8	+ 4.6	— .5	— .7	— .9	— .2	— .4	— 1.0	— .7	— 2.7	— 1.7
1899.....	— 2.5	— .2	— .8	— .8	+ 1.3	.0	— .1	— .7	— 1.0	+ 2.2	— 2.7	— 1.6
1900.....	— 2.4	— 3.6	— 1.8	— .1	— .9	— .5	+ .9	— .4	— 1.0	+ .1	+ 6.6	— 2.0
1901.....	— 1.3	+ 4.3	— 1.7	+ 2.0	+ 1.4	— .3	— .1	— .7	— .1	+ 2.7	— 2.0	+ 4.7
1902.....	— 2.4	— 3.6	+ 5.2	+ 2.0	— .7	+ .6	.0	— .7	.0	+ .5	+ 1.8	+ 2.0
1903.....	— 1.1	— 2.8	— 1.0	+ .3	.0	+ .4	— .4	— .5	+ .8	+ .6	— .5	— 3.0
1904.....	— 1.2	+21.0	+ 4.3	— .4	— .8	+ .1	+ .2	+ .4	— .1	+ .8	+ .3	— 1.2
1905.....	— 2.3	— 4.2	— 1.9	— .6	— .8	— .4	— .3	+ 1.3	— .3	— .4	— .7	— 1.8
1906.....	+ .7	— 4.2	— .8	— .8	.0	— .5	.0	— .4	— .6	— .8	+ 2.6	+ 7.0
1907.....	+11.2	+ .1	— .1	— .8	+ 2.1	— .3	+ .6	— .1	— .4	— .7	— 2.4	— .5
1908.....	— 2.5	— 2.6	+ 6.8	— .8	— .7	— .5	— .4	— .1	+ .1	— .9	— 2.1	— 2.8
1909.....	+ .6	+ .7	+ .6	— .4	— .8	— .3	— .2	— .6	— .8	— .6	— 2.6	+ 1.4
1910.....	— 1.4	— 3.7	— 2.1	— .4	— .8	.0	+ .2	+ .6	+ 2.2	— .8	+ .5	+ .1
1911.....	+ .6	+ 2.3	— 1.0	— .5	— .5	— .3	.0	— .3	.0	— .2	— 2.5	— 1.7
1912.....	— 2.0	— 2.1	— 2.2	+ .3	— .7	— .6	— .3	— .3	— 1.0	— .2	— 1.6	— 1.9
1913.....	— 2.1	— 3.4	— 1.8	— .4	+ 2.2	+ 2.4	+ .1	+ 2.5	.0	— .1	— 1.2	— 3.0
1914.....	— .9	— 2.9	+ 2.1	.0	+ .2	— .3	+ .1	— .4	+ 1.1	— 1.1	— 1.5	— .4
1915.....	— 2.3	— 4.0	— 2.0	+ .4	— .6	— .4	+ .5	— .6	+ .8	— .4	+ 3.8	+ 4.5
1916.....	+13.8	+ .6	+ 1.1	+ .8	— .4	— .6	+ .1	— .9	— .5	+ .4	— 2.2	
Normal monthly rainfall, for 26 years.....	2.5	4.2	2.5	.9	.9	.6	.4	.7	1.0	1.1	2.7	3.1

FIG. 3.

MONTHLY DEVIATIONS, IN INCHES, FROM NORMAL RAINFALL.
EWA PLANTATION



MONTHLY RAINFALL, IN INCHES, EWA PLANTATION
U. S. WEATHER BUREAU RECORDS

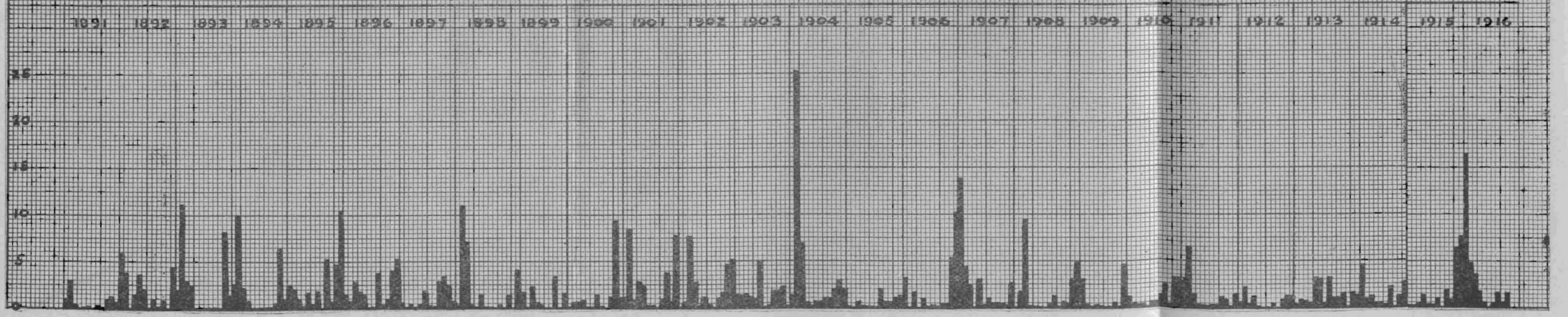


TABLE NO. 8.

ANNUAL RAINFALL AT EWA.

Computed From U. S. Weather Bureau Record.

Year	Yearly rainfall (Inches)	Deviations of yearly rainfall from normal annual rainfall (Inches)	Accumulative excess (+) or deficiency (—) since 1891, based on normal annual rainfall (Feet)
1891	6.75	—13.70	—1.14
1892	23.33	+ 2.88	— .90
1893	27.99	+ 7.54	— .27
1894	23.66	+ 3.21	— .01
1895	30.84	+10.39	+ .86
1896	22.70	+ 2.25	+1.05
1897	13.42	— 7.03	+ .46
1898	22.86	+ 2.41	+ .66
1899	13.77	— 6.68	+ .11
1900	15.39	— 5.06	— .32
1901	29.56	+ 9.11	+ .44
1902	25.41	+ 4.96	+ .86
1903	13.40	— 7.05	+ .27
1904	44.14	+23.69	+2.24
1905	7.19	—13.26	+1.17
1906	22.67	+ 2.22	+1.34
1907	29.24	+ 8.79	+2.06
1908	14.09	— 6.36	+1.55
1909	17.59	— 2.86	+1.29
1910	15.16	— 5.29	+ .85
1911	16.57	— 3.88	+ .52
1912	8.20	—12.25	— .50
1913	15.82	— 4.63	— .88
1914	16.64	— 3.81	—1.20
1915	20.40	— 0.05	—1.20
1916, Jan. to Oct.	31.19	+10.74	— .31
Total	527.98		
Normal annual rainfall for 25 10/12 years	20.45		

TABLE 9. FIG. 4. ARTESIAN WELL HEADS AT PUMPING STATIONS ON EWA PLANTATION.

These records, furnished by Ewa Plantation Company, though incomplete, are the longest available for wells outside of Honolulu city area. They are of especial value in showing the wide fluctuation in well heads in years prior to 1910.

A ready comparison of the monthly fluctuations on artesian well heads, the amounts and monthly fluctuations of artesian water pumped by Ewa Plantation, together with the periods of excess or deficiency of annual rainfall since 1891 for Ewa Plantation, is shown in Fig. 4.

From these graphs and those shown in Fig. 6, it appears that the artesian supply for Pearl Harbor area recovers most rapidly when pumping is reduced to a minimum.

TABLE NO. 9.

ARTESIAN WELL HEADS, IN FEET ABOVE SEA LEVEL, AT PUMPING STATIONS, EWA PLANTATION.

Date	STATION					
	1	2	3	5	7	10
1890						
May 8	31.5	...	...	...	...	...
1902						
February	24.6	...	25.7	22.1	26.3	...
March	24.6	...	25.7	22.1	24.3	...
1904						
March 16	30.9	...	31.2	26.4	27.1	...
April	31.6	...	31.8	27.0	27.5	...
December	26.8	...	25.7	23.8	24.7	...
1906						
November 30	18.1	...	17.3	18.4	14.2	...
1907						
January 19	25.8	...	27.1	22.5	23.9	...
February 1	26.4	...	26.9	23.6	24.4	...
1908						
April 1	26.0	...	26.5	23.4	24.1	...
1909						
February 22	23.5	...	25.4	19.4	24.0	16.7
March 18	24.0	...	25.6	20.5	24.6	16.1
1910						
January 29	24.8	...	26.0	20.6	24.7	15.8
February 13	23.9	...	24.4	18.8	23.5	15.8
June 12	21.9	23.1	23.5	16.9	21.9	15.8
September 26	24.8	20.4	25.6	15.4	24.5	16.1
November 28	25.3	19.4	24.6	18.7	23.3	15.8
1911						
January 27	26.8	22.0	27.1	22.2	24.9	16.2
February 18	27.9	22.2	27.2	21.9	26.8	16.0
March 5	27.7	22.8	28.6	22.4	27.2	16.2
July 4	24.8	18.5	26.2	20.7	22.0	15.2
September 15	25.6	16.4	25.1	19.1	22.2	14.7
December 25	24.3	19.8	25.7	20.7	24.6	14.7
1912						
January 1	25.2	20.5	26.5	20.8	24.7	15.2
February 28	25.2	19.5	25.5	21.1	23.8	15.2
July 4	22.7	19.9	23.9	17.7	22.2	14.7
September 23	21.1	19.2	22.3	16.9	20.6	14.8
December 31	22.3	21.1	25.0	18.4	22.0	15.3
1913						
February 22	21.9	16.5	23.1	16.8	20.8	15.0
May 20	23.2	18.0	24.7	19.1	22.8	15.5
July 4	22.3	17.8	24.0	18.3	21.7	15.3
September 21	21.2	16.8	22.4	18.0	20.5	15.2
November 24	22.3	17.3	24.2	18.8	21.3	15.3
1914						
January 1	22.8	17.8	24.3	19.0	22.0	15.0
February 22	23.2	18.2	24.2	18.8	22.4	15.3
April 30	21.9	17.2	23.4	17.9	21.7	15.2
July 4	21.8	18.3	24.5	17.1	21.4	15.2
September 19	21.1	17.4	23.4	17.2	20.4	14.8
November 26	21.9	17.3	23.7	19.5	23.1	15.2
December 25	25.2	21.2	26.0	22.2	24.4	15.2
1915						
January 1	25.4	20.9	26.3	22.2	24.7	15.3
February 22	22.4	18.5	24.1	20.4	21.8	15.0
July 4	20.4	16.6	23.2	17.8	20.6	14.5
August 31	20.2	15.6	23.2	17.9	20.3	15.2
November 28	24.6	20.0	25.1	20.7	25.8	15.3
December 25	24.2	19.8	24.4	19.6	22.1	15.2
1916						
January 6	25.9	22.2	26.4	22.2	24.1	15.6
January 10	26.3	22.5	28.9	22.5	24.9	15.6

(3) WINDWARD OAHU AREA.

TABLE 10. FIG. 5. ANNUAL RAINFALL, KAHUKU.

This table and graphs, prepared similar to data in tables 5, 6, 7 and 8, show the mean annual rainfall and accumulative excess or deficiency of annual rainfall at Kahuku, which has been selected as typical for the artesian basins in Windward Oahu.

TABLE NO. 10.

ANNUAL RAINFALL, KAHUKU.

Computed From U. S. Weather Bureau Record.

Year	Yearly rainfall	Deviations of yearly rainfall from normal annual rainfall	Accumulative excess (+) or deficiency (—) since 1891, based on normal annual rainfall
	Inches	Inches	Feet
1891	14.86	—20.42	—1.7
1892	36.48	+ 1.20	—1.6
1893	37.06	+ 1.78	—1.5
1894	42.95	+ 7.67	— .8
1895	35.77	+ .49	— .8
1896	27.46	— 7.82	—1.4
1897	24.09	—11.19	—2.4
1898	37.98	+ 2.70	—2.1
1899	27.33	— 7.95	—2.8
1900	38.23	+ 2.95	—2.5
1901	41.61	+ 6.33	—2.0
1902	47.83	+12.55	—1.0
1903	19.40	—15.88	—2.3
1904	75.72	+40.44	+1.1
1905	27.73	— 7.55	+ .4
1906	34.66	— .62	+ .4
1907	44.48	+ 9.20	+1.2
1908	30.23	— 5.05	+ .7
1909	41.18	+ 5.90	+1.2
1910	28.13	— 7.15	+ .6
1911	36.60	+ 1.32	+ .7
1912	20.76	— 4.52	+ .4
1913	31.31	— 3.97	+ .0
1914	37.72	+ 2.44	+ .2
1915	36.77[a]	+ 1.49	+ .4
1916	41.00[b]	+ 5.72	+ .8
Normal annual rainfall, 20	917.34		
Total for period, 26 years..			
years	35.28		

[b] April to December, 1915, only.
[a] January to November, 1916, only.

FIG. 4.

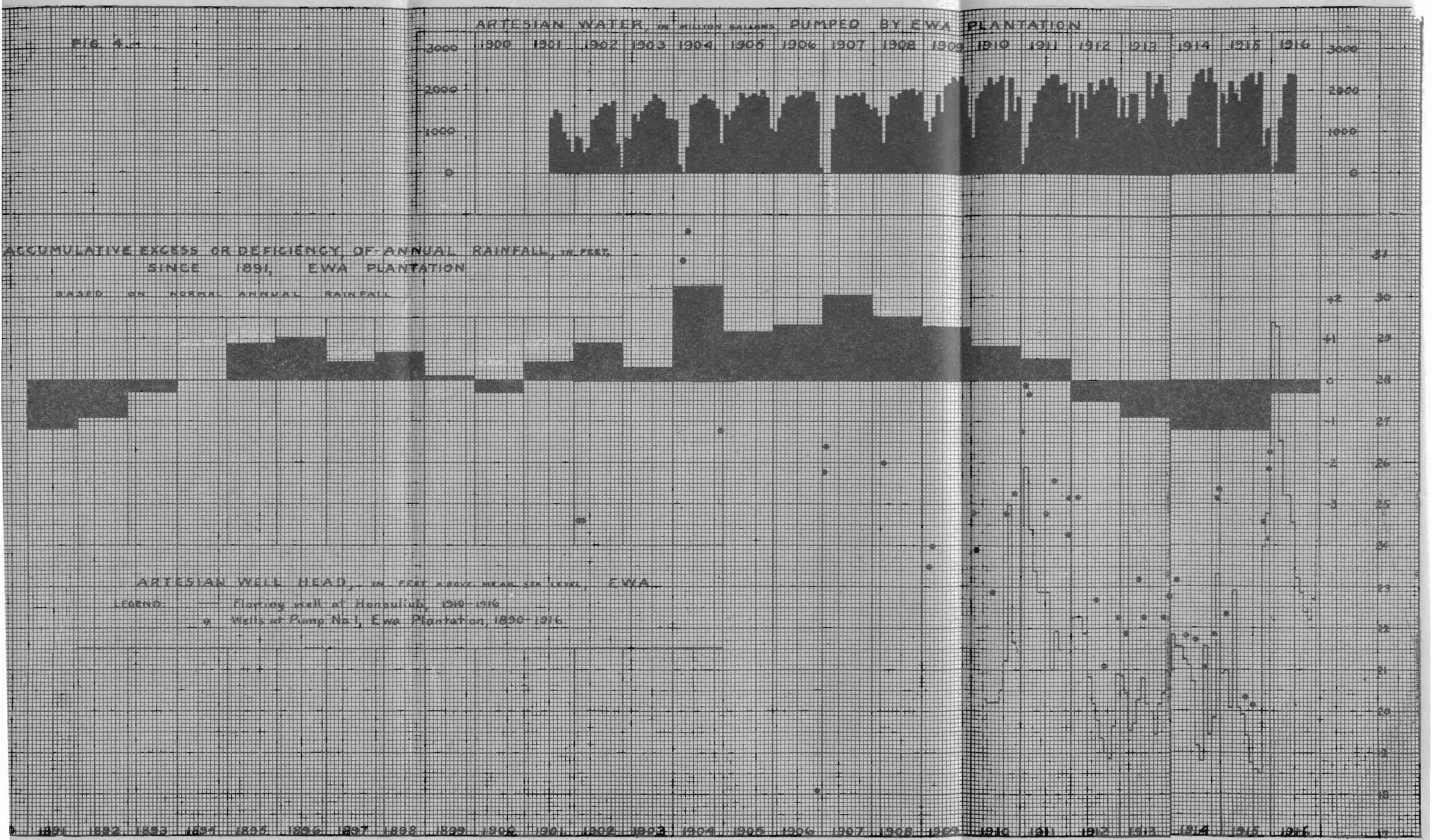

ARTESIAN WATER, in million gallons, PUMPED BY EWA PLANTATION
3000
2000
1000
0
1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916
ACCUMULATIVE EXCESS OR DEFICIENCY OF ANNUAL RAINFALL, in feet,
SINCE 1891, EWA PLANTATION
based on normal annual rainfall
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
ARTESIAN WELL HEAD, in feet above mean sea level, EWA.
LEGEND
Flowing well at Honolulu, 1910-1916
Wells at Pump No. 1, Ewa Plantation, 1890-1916
1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916

FIG. 5.

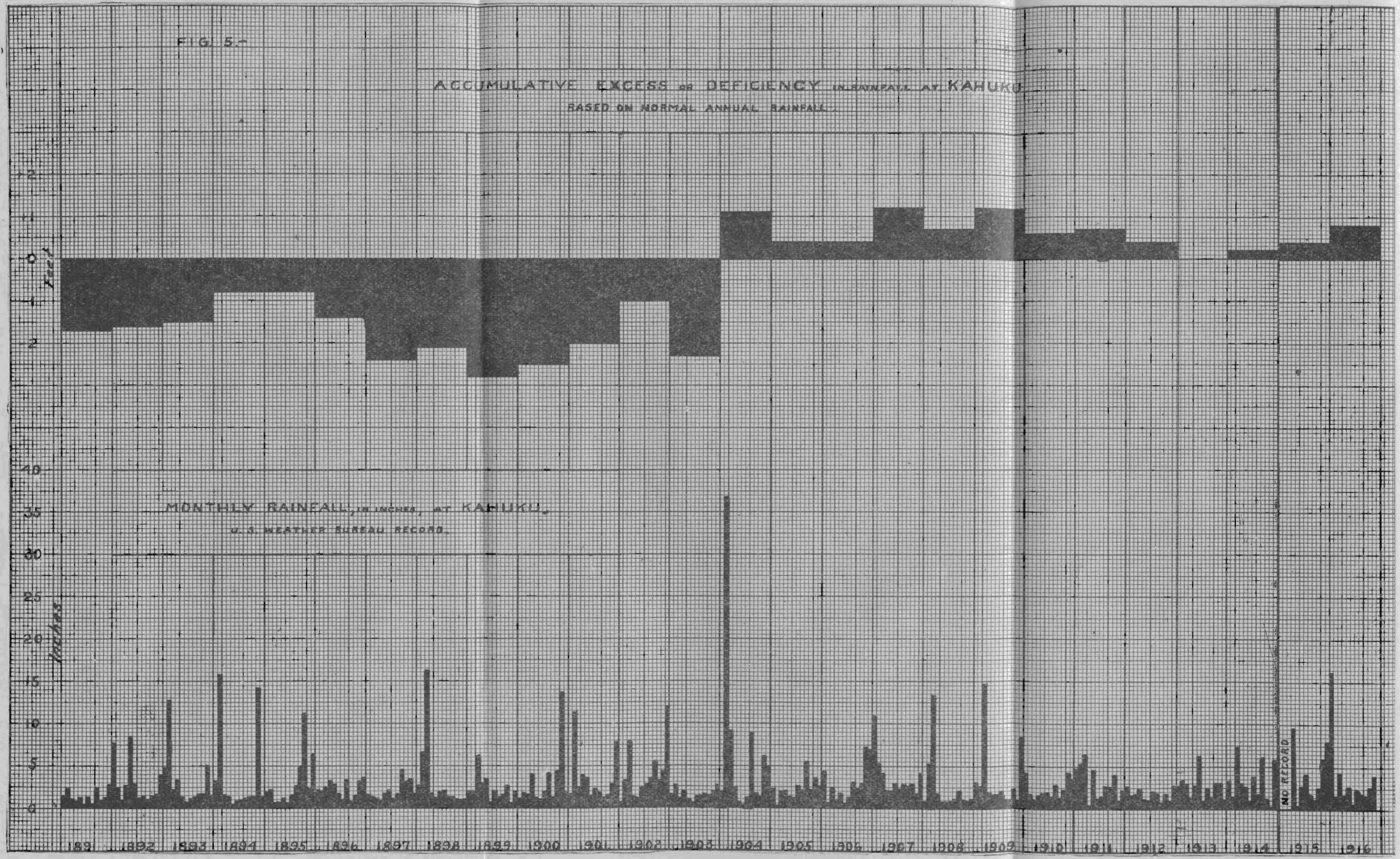

ACCUMULATIVE EXCESS OR DEFICIENCY IN RAINFALL AT KAHUKU
BASED ON NORMAL ANNUAL RAINFALL.
Feet
2
1
0
1
2
MONTHLY RAINFALL, IN INCHES, AT KAHUKU.
U. S. WEATHER BUREAU RECORD.
Inches
40
35
30
25
20
15
10
5
0
NO RECORD
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916

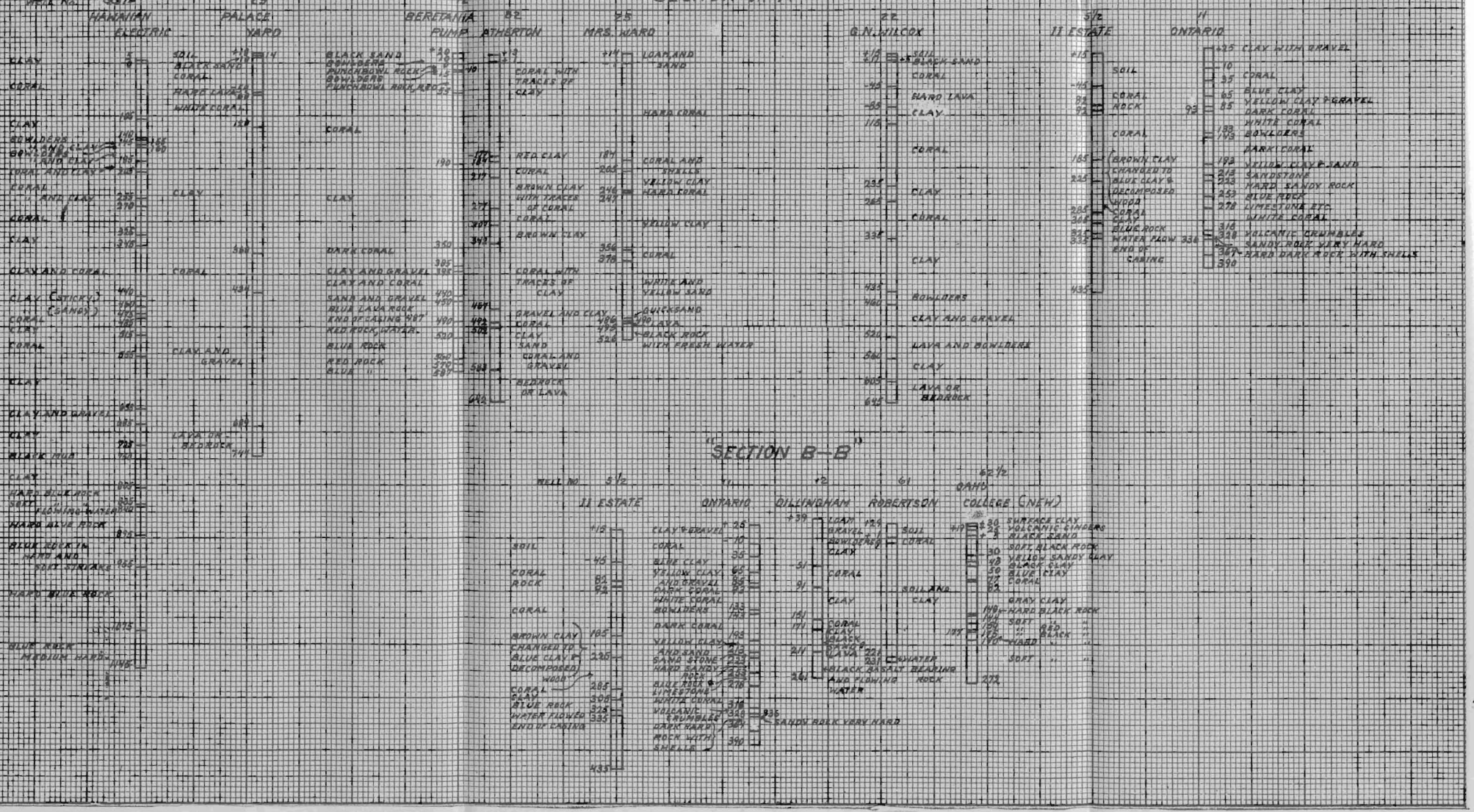
FIG. 8 a

ARTESIAN WELL LOGS

CITY OF HONOLULU

SCALE HOR.=1:12000

SCALE VERT.=1:2400



AMOUNT OF ARTESIAN WATER PUMPED ON OAHU.

TABLES 11 TO 16. FIG. 6.

These tables show the total amounts of artesian water pumped monthly and annually by the city of Honolulu and various plantations on Oahu during periods for which records are available.

In Honolulu city area the monthly draft on the artesian supply from the city pumping stations alone has steadily increased from 176 million gallons in 1905 to 392 million gallons in 1915, or an increase of 216 million gallons in ten years; in other words, the demand for artesian water served by the city for domestic and other uses has more than doubled in the past ten years.

The monthly demand for artesian water on the several plantations, unlike that for city consumption, is not steady, but fluctuates through wide limits varying from practically nothing during months of heavy rainfall to over 2,500 million gallons during the irrigating season.

TABLE NO. 11.

ARTESIAN WATER, IN MILLION GALLONS, PUMPED BY CITY OF HONOLULU.

	1904–5	1905–6	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	1912–13	1913–14	1914–15	1915–16
July	216	211	266	293	341	188	333	329	369	362	381	436
August	209	157	279	276	344	308	321	347	375	399	373	456
September . . .	208	138	272	247	309	338	277	315	354	361	322	417
October	206	176	284	257	354	341	322	314	335	380	381	406
November . . .	195	150	258	243	342	324	287	321	295	323	346	326
December	177	128	115	263	341	257	277	255	298	285	306	349
January	190	172	70	276	348	198	218	277	321	294	371	312
February	182	180	88	232	278	199	197	305	285	294	324	308
March	209	223	126	248	240	269	224	280	356	349	399	366
April	192	245	235	254	245	254	257	313	333	322	370	328
May	186	261	282	321	280	304	296	357	314	349	423	366
June	190	267	216	312	312	308	290	366	306	344	423	397
Totals	2,360	2,308	2,491	3,222	3,734	3,288	3,299	4,067	3,941	4,062	4,419	4,467

TABLE NO. 12.

ARTESIAN WATER, IN MILLION GALLONS, PUMPED BY HONOLULU PLANTATION.

	1910–11	1911–12	1912–13	1913–14	1914–15	1915–16
July	1,844	1,758	1,975	1,588	1,703	1,520
August	1,527	1,928	2,028	1,205	1,634	1,544
September	534	1,576	1,847	1,685	1,107	1,525
October	1,598	1,794	1,613	1,333	1,211	1,313
November	984	a	894	545	1,402	a
December	1,485	826	325	787	331	a
January	225	1,120	1,327	1,146	1,260	a
February	293	977	1,330	929	1,172	a
March	392	935	1,436	965	1,458	806
April	1,061	1,000	1,192	794	1,122	1,534
May	1,471	1,716	907	1,034	1,267	852
June	1,623	2,017	807	1,413	1,520	1,399
Totals	13,037	15,647	15,681	13,424	15,187	10,493

a = No pumping except small amount for domestic use.

TABLE NO. 13

ARTESIAN WATER, IN MILLION GALLONS, PUMPED BY OAHU PLANTATION.

	1904–5	1905–6	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	1912–13	1913–14	1914–15	1915–16
July	....	1,606	1,763	1,763	1,943	1,858	1,939	1,934	2,012	1,893	1,928	1,651
August	....	1,519	1,788	1,650	1,997	2,030	1,971	2,023	2,021	1,893	1,895	1,972
September . . .	....	1,596	1,748	1,621	1,794	1,960	1,222	2,007	1,899	1,926	1,288	1,888
October	....	1,736	1,796	b	1,995	1,953	1,965	1,942	1,993	1,933	1,775	1,802
November . .	....	999	b	1,574	1,800	1,865	1,424	1,893	1,937	1,394	1,838	325
December . . .	....	1,029	b	1,194	1,546	1,455	1,757	1,844	1,182	1,433	408	1,105
January	1,113	650	b	1,345	658	290	195	1,777	1,525	1,623	1,846	b
February . . .	1,177	1,387	389	1,038	352	1,269	465	1,349	1,416	1,330	1,610	102
March	1,247	1,712	830	751	658	1,958	542	1,814	1,928	1,208	1,993	1,058
April	1,338	1,750	1,646	1,224	1,650	1,832	1,246	1,749	1,740	815	1,644	1,726
May	1,453	1,816	1,682	2,035	1,769	1,976	1,955	2,013	1,300	1,314	1,477	1,150
June	1,527	1,753	1,663	1,931	1,959	1,835	1,958	1,979	1,129	1,703	1,882	1,485
Totals	7.855	17.553	13,305	16,126	18.121	20.281	16.639	22,324	20.082	18.465	19,584	14.264

b = No record. Probably no pumping except for domestic supply.

TABLE NO. 14.

ARTESIAN WATER, IN MILLION GALLONS, PUMPED BY EWA PLANTATION.

	1901–2	1902–3	1903–4	1904–5	1905–6	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	1912–13	1913–14	1914–15	1915–16
July	1,319	1,603	1,750	1,819	1,831	1,834	1,873	1,918	2,174	2,174	2,310	2,005	2,479	2,463	2,376
August	1,517	1,687	1,923	1,907	1,929	1,951	1,908	2,000	2,347	2,330	2,390	2,237	1,837	2,537	2,454
September..	1,451	1,630	1,807	1,796	1,852	1,950	1,814	1,990	2,231	1,212	2,346	2,111	2,205	2,214	2,173
October	1,003	1,752	1,712	1,768	2,019	1,950	1,931	2,036	2,373	2,300	2,129	2,323	2,410	2,589	2,480
November..	811	724	1,293	1,540	1,836	1,707	1,668	1,850	2,143	1,452	2,141	2,055	1,928	2,231	654
December...	507	120	1,293	685	1,069	100	1,508	1,950	1,332	1,830	1,632	1,328	1,324	672	1,075
January ...	910	868	1,273	1,395	982	b	1,550	1,232	874	202	1,962	1,853	1,184	1,951	25
February ..	876	818	178	1,263	1,348	b	1,347	957	1,826	614	834	1,333	1,277	1,706	283
March	482	1,425	b	1,476	1,678	1,054	706	1,336	1,979	1,226	1,912	1,982	1,358	2,290	1,363
April	611	1,237	623	1,623	1,838	1,865	1,385	1,895	2,118	1,716	1,567	1,988	1,313	1,942	2,176
May	1,302	1,492	1,639	1,937	1,881	1,800	1,832	1,497	2,335	2,022	2,193	1,210	1,914	1,782	2,415
June	1,381	1,644	1,677	1,817	1,802	1,867	1,793	2,100	2,119	2,119	1,909	1,338	2,243	2,242	2,415
Totals ...	12,170	15,000	15,168	19,026	20,065	16,078	19,315	20,761	23,851	19,197	23,325	21,763	21,472	24,619	19,889

b = No record. Probably no pumping except for domestic supply.

TABLE NO. 15.

ARTESIAN WATER, IN MILLION GALLONS, PUMPED BY WAIALUA PLANTATION.

	1914	1914–15	1915–16
July	....	1,225	1,396
August	....	1,248	1,558
September	....	774	1,666
October	....	672	1,542
November	....	804	335
December	....	271	343
January	335	583	125
February	507	853	224
March	570	1,150	530
April	1,587	912	1,150
May	773	921	483
June	1,209	1,321	1,042
Totals	4,981	10,734	10,394

Note:—Previous to January 1, 1914, records were kept in daily form, not readily accessible.

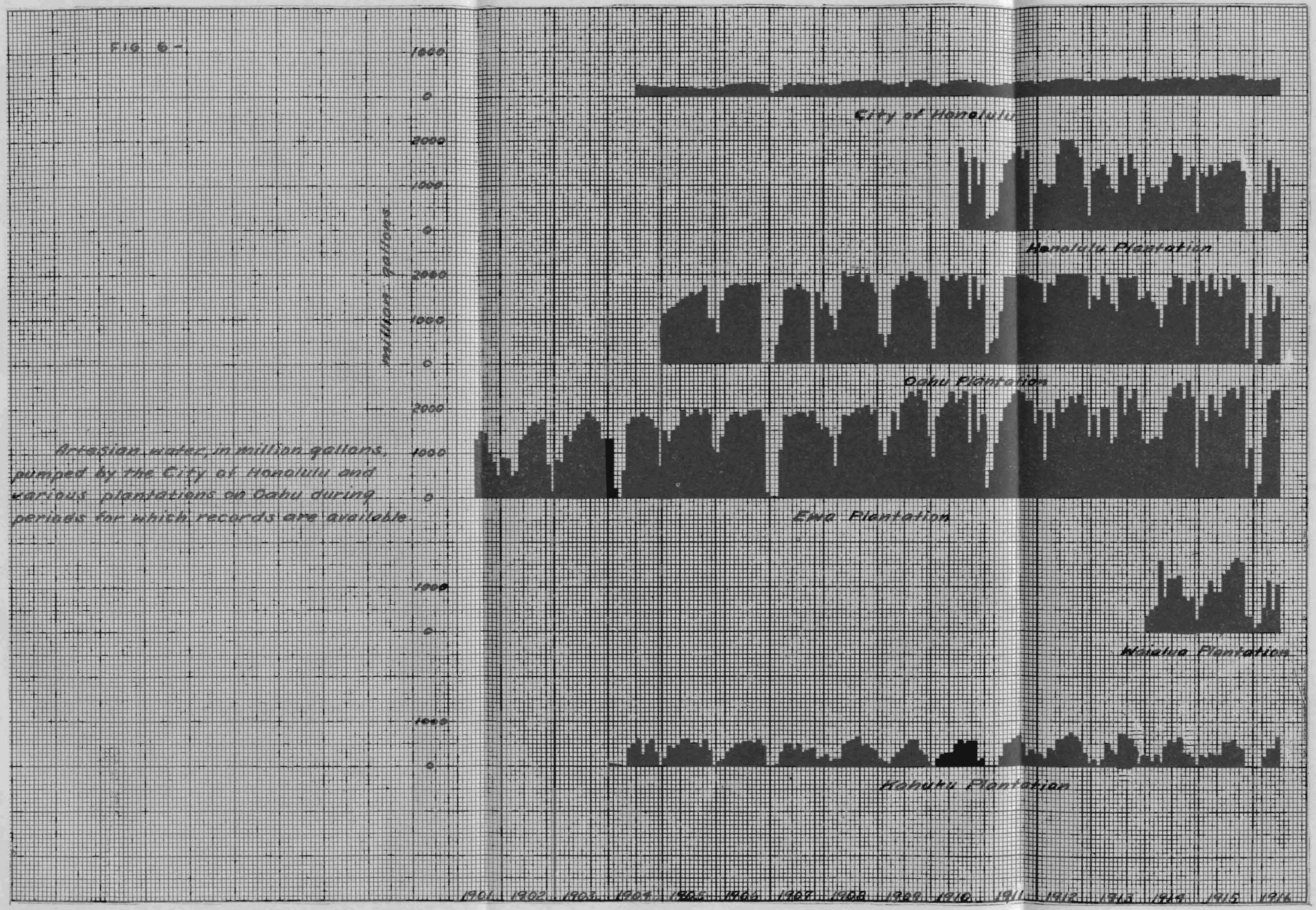


Fig. 6 -
Artesian water, in million gallons, pumped by the City of Honolulu and various plantations on Oahu during periods for which records are available.
million gallons
2000
1000
0
City of Honolulu
Honolulu Plantation
Oahu Plantation
Ewa Plantation
Waialua Plantation
Kahuku Plantation
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916

TABLE NO. 16.

ARTESIAN WATER, IN MILLION GALLONS, PUMPED BY KAHUKU PLANTATION.

	1903–4	1904–5	1905–6	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	1912–13	1913–14	1914–15	1915–16
July	...	579	489	569	491	614	494	607	593	658	727	547	531
August	...	239	483	554	323	633	600	507	667	730	722	654	598
September	...	509	384	517	338	436	624	544	519	648	575	296	451
October	...	618	610	613	417	524	346	560	189	551	460	263	399
November	...	321	327	458	137	373	263	93	327	239	57	308	d
December	...	c	c	c	197	334	79	142	252	11	153	30	d
January	50	150	79	c	267	171	d	3	235	115	204	246	d
February	15	447	123	39	116	111	140	3	166	d	127	213	d
March	c	392	283	307	141	68	254	d	417	126	245	314	184
April	c	471	421	518	166	210	285	223	332	495	71	233	424
May	381	588	498	507	493	276	369	476	620	358	434	230	401
June	525	610	520	335	560	372	478	472	598	267	581	545	637
Totals	971	4,924	4,217	4,417	3,646	4,122	3,932	3,630	4,915	4,198	4,356	3,879	3,625

c = No record. Probably no pumping.
d No pumping.

TABLES 17 AND 18. ARTESIAN WATER PUMPED FROM OAHU COLLEGE WELLS AND FORT SHAFTER WELL, RESPECTIVELY.

Aside from the records of the city of Honolulu pumping stations, these two records are the only ones kept by industrial plants, or other artesian water users in Honolulu basin.

TABLE NO. 17.

ARTESIAN WATER, IN MILLION GALLONS, PUMPED FROM OAHU COLLEGE WELLS.

Old Well—Gasoline-driven Pump.

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
1908.....	..	..	..	..	..	..	..	..	..	..	1.9	1.9
1908–9.....	2.2	1.8	1.6	2.0	1.6	1.1	1.2	1.0	0.8	1.1	1.7	1.8
1909–10.....	0.9	1.8	1.6	1.5	1.6	0.8	0.6	0.7	1.0	0.7	1.1	0.9
1910.....	1.0	1.0	0.8	1.2	1.1	0.6	..	..	..	..	..	..

New Well—Gasoline and Electrically-driven Pumps.

(For period Dec. 17, 1910, to Dec. 31, 1913, see tables given below.)

1914.....	..	..	..	..	..	..	0.7	0.7	1.0	0.8	1.1	1.1
1914–15.....	1.1	0.9	0.9	0.9	0.9	0.6	0.9	0.9	1.3	1.1	1.3	1.1
1915–16.....	0.9	1.3	1.2	0.9	0.7	0.6	0.7	0.7	1.1	1.1	1.0	0.9

1911			1912			1913		
From	To	Amt.	From	To	Amt.	From	To	Amt.
December 17	January 23	1.0	December 20	January 22	1.4	December 24	January 24	1.5
January 24	March 2	1.0	January 23	February 20	1.5	January 25	February 28	1.7
March 3	April 1	0.9	February 21	March 22	1.3	March 1	March 24	1.5
April 2	April 26	1.0	March 23	April 20	1.3	March 25	April 24	1.5
April 27	May 22	1.0	April 21	May 20	1.8	April 25	May 22	1.2
May 23	June 21	1.1	May 21	June 28	2.6	May 23	June 22	1.4
June 22	July 21	0.9	June 29	July 23	1.2	June 23	July 21	1.0
July 22	August 22	1.1	July 24	August 22	1.3	July 22	August 21	1.3
August 23	September 22	1.3	August 23	September 23	1.8	August 22	September 22	1.5
September 23	October 20	1.2	September 24	October 23	2.1	September 23	October 13	1.1
October 21	November 21	1.5	October 24	November 23	1.7	October 14	October 31	0.6
November 22	December 19	1.2	November 24	December 23	1.3	November 1	November 30	0.5
						December 1	December 31	0.6

TABLE NO. 18.

ARTESIAN WATER, IN MILLION GALLONS, PUMPED FROM FORT SHAFTER WELL.

Electrically-driven Pump.

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
1915–16.....	..	..	7.5	16	20	16	16	14	15	17	18	20
1916.....	21	22	23	21	..	..	..	..	..	..	..	..

AMOUNT OF ARTESIAN WATER FROM FLOWING WELLS ON OAHU.

TABLES 19 AND 20.

The discharge of only readily accessible flowing wells in the vicinity of Honolulu were measured. These measurements, made principally by current meter, are given in table 19. From these, together with information secured by the Water Commission, table 20 has been prepared which shows the number of wells and the present maximum daily discharge in each basin in the vicinity of Honolulu.

TABLE NO. 19.

DISCHARGE MEASUREMENTS OF FLOWING ARTESIAN WELLS IN THE VICINITY OF HONOLULU, 1916.

No. of Well	Name	Maximum Discharge in Million Gallons per Day	
		Per Well	In Basin
	Basin No. 1.		
53	A. S. Cleghorn	0.35	
54½	A. Young	2.24	
51A	do	1.24	
37	Sing Loy	.61	
38	Charles Achi	.54	
40	G. Beckley	.36	
51	Lung Do Wai	1.49	
50	do	.71	
7	do	.22	
51½	do	.48	
52	do	.35	
52½	Pua Goo Kim	.48	
42	Mow Hop	.37	
41	do	.63	
43	G. Beckley	.39	
46	Spencer	.44	10.90

	Basin No. 2.		
59	Waterhouse Trust Co.	.08	
55	Sing Loy	.70	
56	do	.76	
57	do	.51	
58	do	.31	
10	Sing Loy or "St. Lawrence"	.43	
5½	Ii Estate	1.88	
66	General Grant	.61	
23	Loon Gawk	.40	
25	Mrs. Ward	.38	
34	Mrs. Weedon	.05	
27	Government Stables	.14	
90	*Young Hotel (1915 record)	.60	
81	*Honolulu Rapid Transit	1.53	
89 & 89½	*Hawaiian Electric Co. (1915 record)	3.65	12.03
	Basin No. 3.		
97	Y. Ahin	0.85	
98	do	.60	
99	do	1.30	
100	do	1.60	
105	do	.26	4.61
	Basin No. 4.		
115	Gulick (Dowsett)	.34	
117	Damon (1911 record)	1.55	
118	Houghtailing (1911 record)	1.80	
119	Damon No. 2 (1911 record)	.84	
120	Damon (1911 record)	.51	
121	Damon-Dillingham (1911 record)	1.80	
122	Damon No. 4 Salt Lake (1911 record)	1.62	8.46

* These wells are used for industrial purposes. All other wells are used primarily for irrigation and secondarily for domestic purposes.

FIG. 7 — WELL INTERFERENCE — Y AHIN'S WELLS, PALAMA.

EFFECT ON ARTESIAN HEAD, IN FEET, OF WELLS NO'S. 100, 99, 98 AND 97, RESPECTIVELY, UNDER VARIOUS COMBINATIONS OF OPERATION.

NOTE — IN EACH GROUP, WELLS ARE ARRANGED IN ORDER FROM LEFT TO RIGHT, NO'S 100, 99, 98 AND 97, RESPECTIVELY. NUMBERS OF WELLS OPERATING (GATES WIDE OPEN) IN EACH GROUP ARE SHOWN ABOVE EACH GROUP. ALL OTHER WELLS WERE CLOSED. FIGURES BELOW THE HORIZONTAL LINE ARE THE ACTUAL WELL HEADS OBSERVED. MEAN ARTESIAN HEAD, ALL FOUR WELLS CLOSED, WAS 31.73 FEET ABOVE MEAN SEA LEVEL, JULY 19, 1916, WHEN INVESTIGATION WAS MADE.

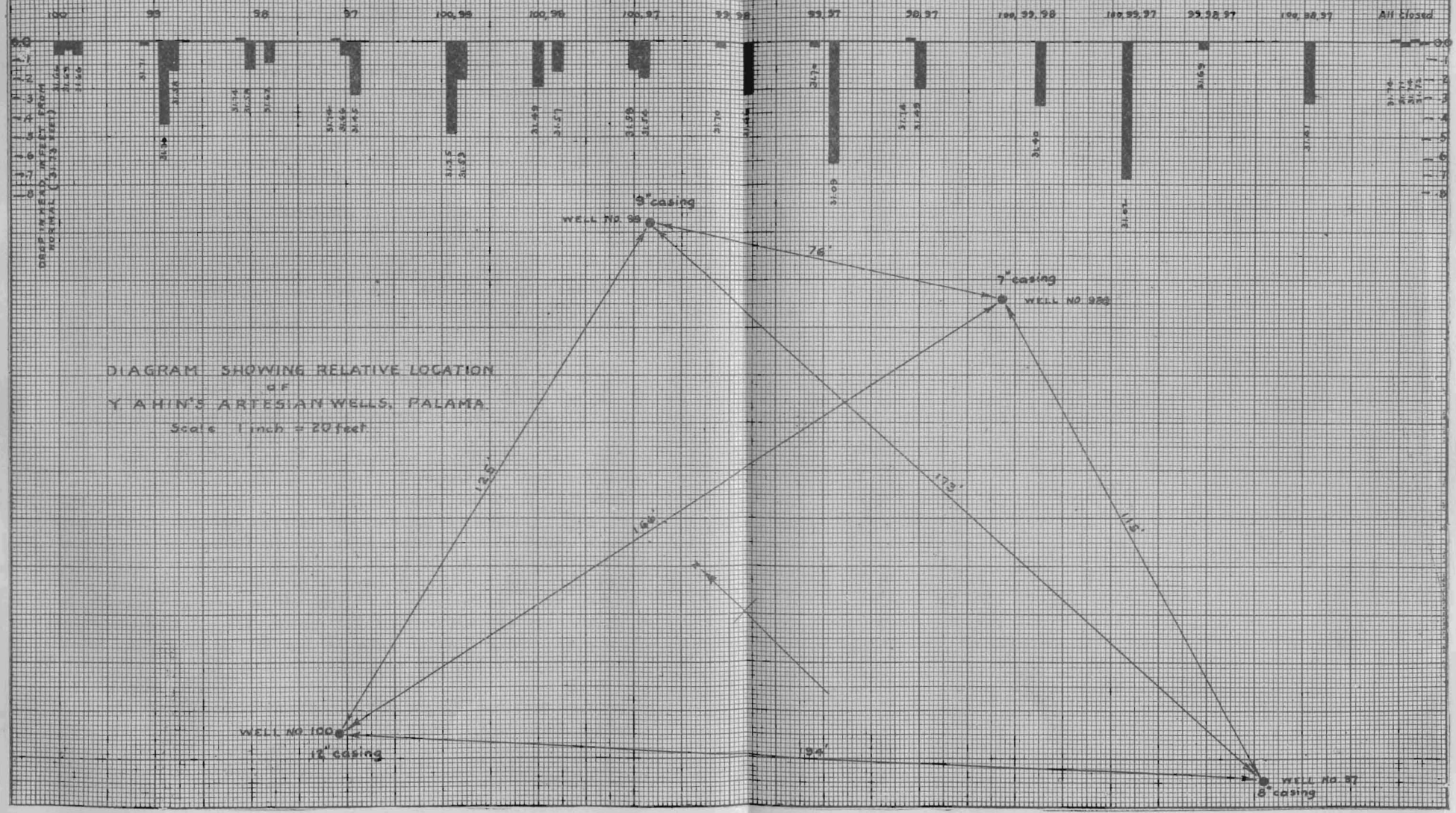


TABLE NO. 20.

MAXIMUM DAILY DISCHARGE FROM VARIOUS ARTESIAN BASINS LOCATED BETWEEN DIAMOND HEAD AND RED HILL.

Wells in Use	Wells not in Use	Discharge in Million Gallons per Day			
		By Current Meter	City Pump Records	Estimated on All Other Wells in Use	Total
		Basin No. 1			
23	11	10.90	3.25	1.3	15.45
		Basin No. 2			
54	16	12.03	4.57	5.0	21.60
		Basin No. 3			
22	4	4.61	4.48	1.1	10.19
		Basin No. 4			
10	2	8.46	0.00	1.3	9.76
109	33	36.00	12.30	8.7	57.00

Note.—Of the wells not in use, many have been covered over and abandoned. Some of these wells undoubtedly have defective casings and their water is being entirely wasted. This waste is not included in the above table.

WELL INTERFERENCE.

FIG. 7. Y. AHIN'S WELLS, PALAMA.

On July 19, 1916, a well interference investigation was made on Y. Ahin's four wells at Palama. Piezometers were installed on each, and referenced by levels to mean sea level. All wells were first closed to ascertain the normal well head. Then all possible combinations of full gate openings were made on all wells and the drop in well head observed on each closed well. The results are given in Fig. 7, together with a diagram showing the relative location of the wells. For example: The 12-inch diameter well, No. 100, distant 125, 166 and 194 feet, respectively, from wells Nos. 97, 98 and 99, when flowing wide open, drew down the head on all three wells from one-half to seven-eighths of an inch.

These wells were formerly used to supply water to an overshot wheel at Y. Ahin's rice mill. At present the water is used to irrigate cane land and for domestic water supply in the vicinity of the wells. When not needed for irrigation all wells are closed.

MISCELLANEOUS WELL INTERFERENCE.

From somewhat meagre information available it appears that in many localities where flowing wells are adjacent to large pumping plants, the flowing well heads are lowered to a measurable degree when the pumps are in operation.

Users of water from the flowing well at Waimalu, on which monthly well heads have been observed since 1910, assert that pumping station No. 4, in Waimalu Gulch, about one-half of a mile mauka of the well, affects the flow of this well considerably, and especially when the artesian well levels are low.

FORT SHAFTER WELLS, NOS. 115 AND 116½.

On September 9, 1916, when the U. S. Army (electric) pump on well 116½ (12-inch casing) was running, the head on well 115 (6-inch casing), distant about 100 feet from 116½, lowered 3¾ inches. When the electric pump was stopped the well head raised to its original height.

LUNG DO WAI WELL NO. 51.

On December 12, 1916, when Mr. Archibald Young's new well in Moiliili, sunk December 7, 1916, (10-inch casing) was flowing wide open, the artesian head of well 51 (12-inch casing), about 300 feet distant, lowered three-eighths of an inch.

PROGRESS OF ARTESIAN WELL BORING, VICINITY OF HONOLULU, SINCE 1880.

TABLE 21, compiled from information furnished by Mr. L. L. McCandless and others, shows the number of artesian wells sunk in the vicinity of Honolulu since 1880. Fig. 8 shows these data in graph form and also the graph of mean annual artesian head on Oahu College wells since 1880. Mr. Sedgwick in "Artesian Waters of Oahu"[1] in referring to the gradual fall of the artesian head, says:

"It has been difficult to find out exactly when the artesian head began to fall. Mr. Wilson, then Superintendent of Water Works, says, referring to the drought of 1889, 'The water in the Palace yard well fell during the drought 2 feet and 3 inches. Since the break-up of the drought it has regained its full

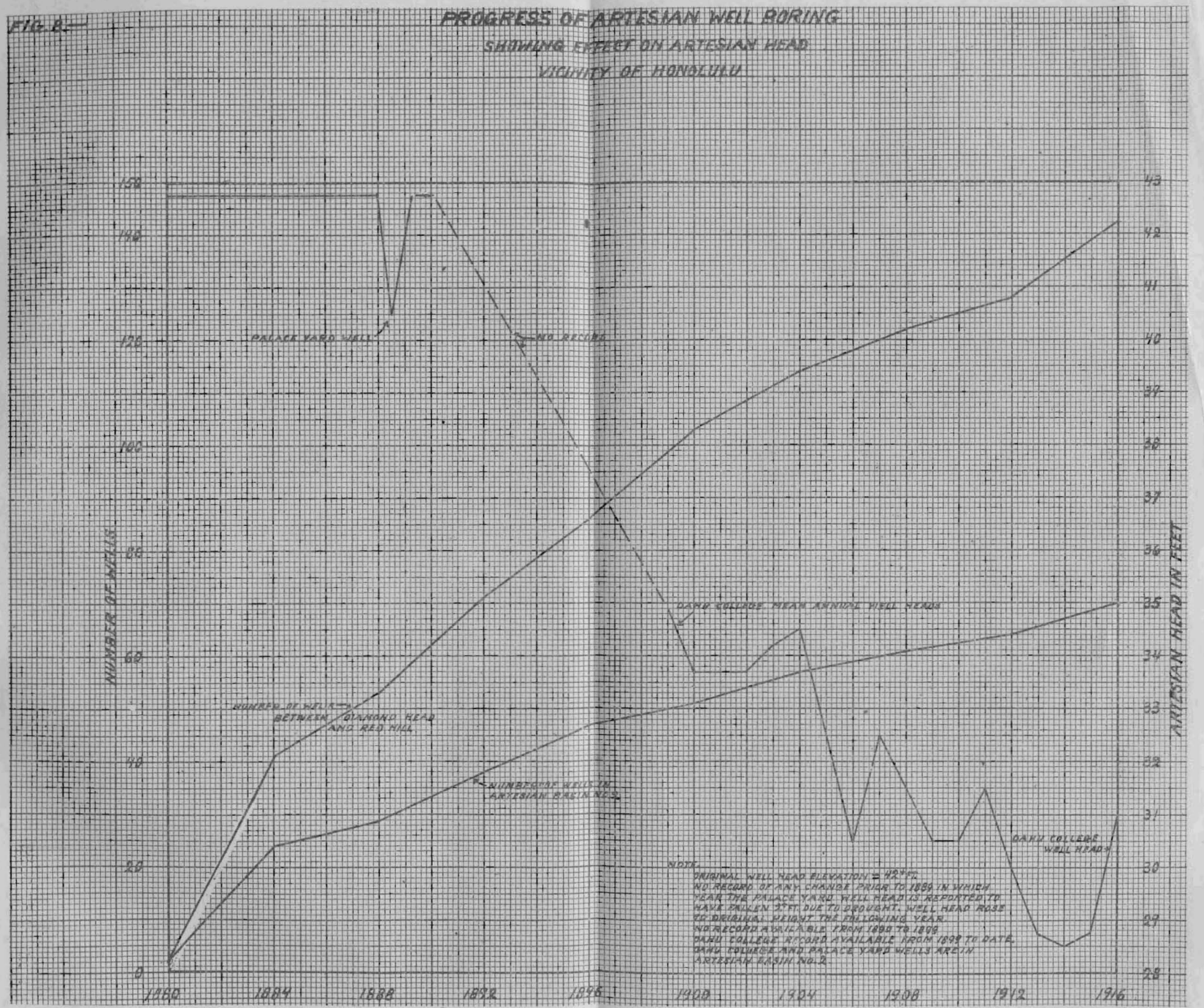
[1] Artesian Waters of Oahu, T. F. Sedgwick, Press Bul. No. 37, Hawaiian Engineering Association, Honolulu, T. H., 1913, page 12.

FIG. 8.

PROGRESS OF ARTESIAN WELL BORING

SHOWING EFFECT ON ARTESIAN HEAD

VICINITY OF HONOLULU



NOTE.
ORIGINAL WELL HEAD ELEVATION = 42 FT.
NO RECORD OF ANY CHANGE PRIOR TO 1889 IN WHICH YEAR THE PALACE YARD WELL HEAD IS REPORTED TO HAVE FALLEN 2 FT. DUE TO DROUGHT. WELL HEAD ROSE TO ORIGINAL HEIGHT THE FOLLOWING YEAR.
NO RECORD AVAILABLE FROM 1890 TO 1899
OAHU COLLEGE RECORD AVAILABLE FROM 1899 TO DATE.
OAHU COLLEGE AND PALACE YARD WELLS ARE IN ARTESIAN BASIN NO. 2.

FIG. 9 b. –

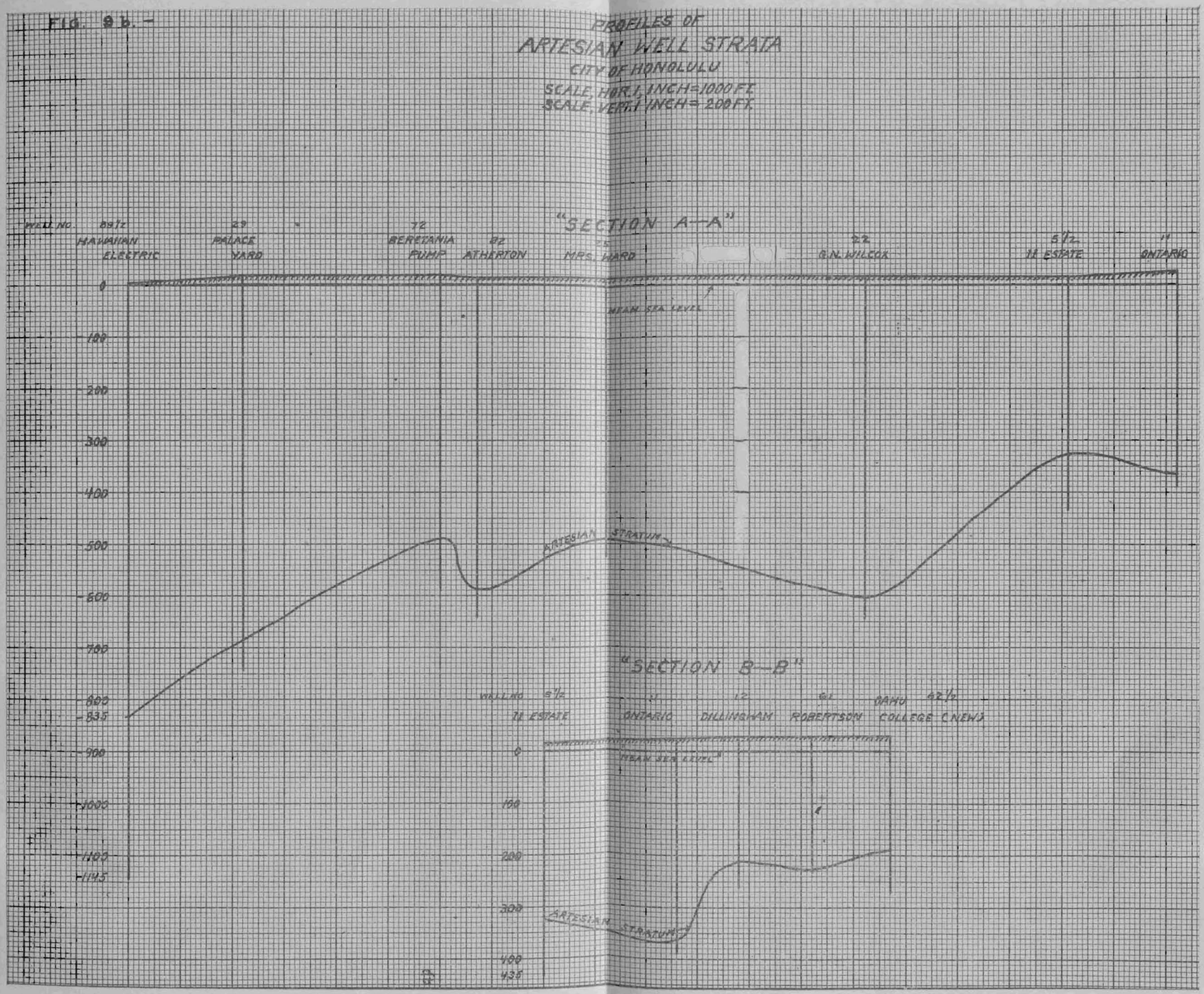

PROFILES OF
ARTESIAN WELL STRATA
CITY OF HONOLULU
SCALE, HOR. 1 INCH = 1000 FT.
SCALE, VERT. 1 INCH = 200 FT.
"SECTION A–A"
WELL NO. 8½
HAWAIIAN ELECTRIC
29
PALACE YARD
12
BERETANIA PUMP
32
ATHERTON
25
MRS. HARD
22
G.N. WILCOX
5½
H. ESTATE
11
ONTARIO
MEAN SEA LEVEL
ARTESIAN STRATUM
0
100
200
300
400
500
600
700
800
835
900
1000
1100
1145
"SECTION B–B"
WELL NO. 5½
H. ESTATE
11
ONTARIO
12
DILLINGHAM
61
ROBERTSON
OAHU COLLEGE
42½
C.N.E.W.S.
MEAN SEA LEVEL
ARTESIAN STRATUM
0
100
200
300
400
435

FIG. 10 a.

ARTESIAN WELL LOGS
CITY OF HONOLULU
SCALE HOR.=1:12000
SCALE VERT.=1:2400

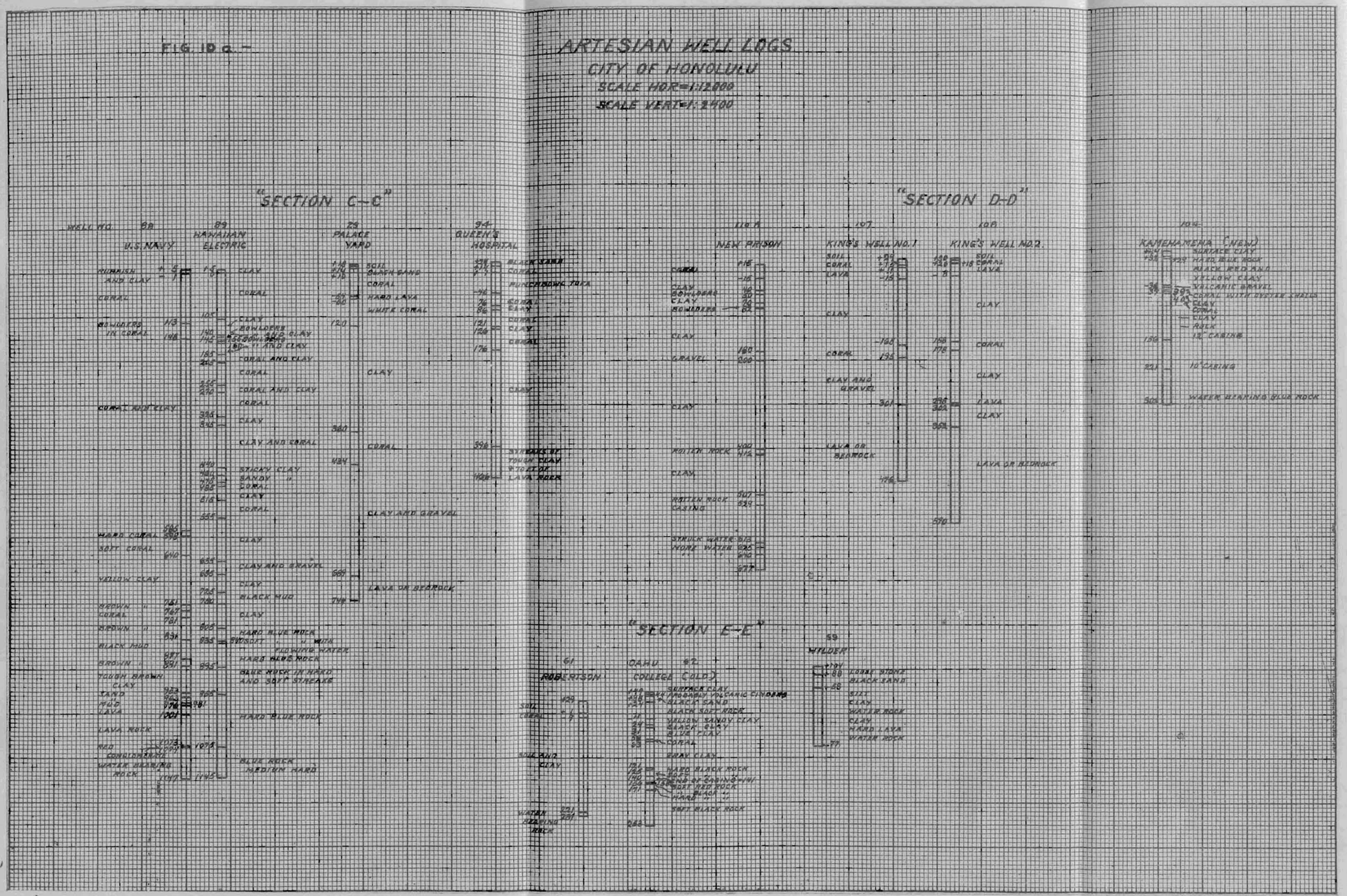
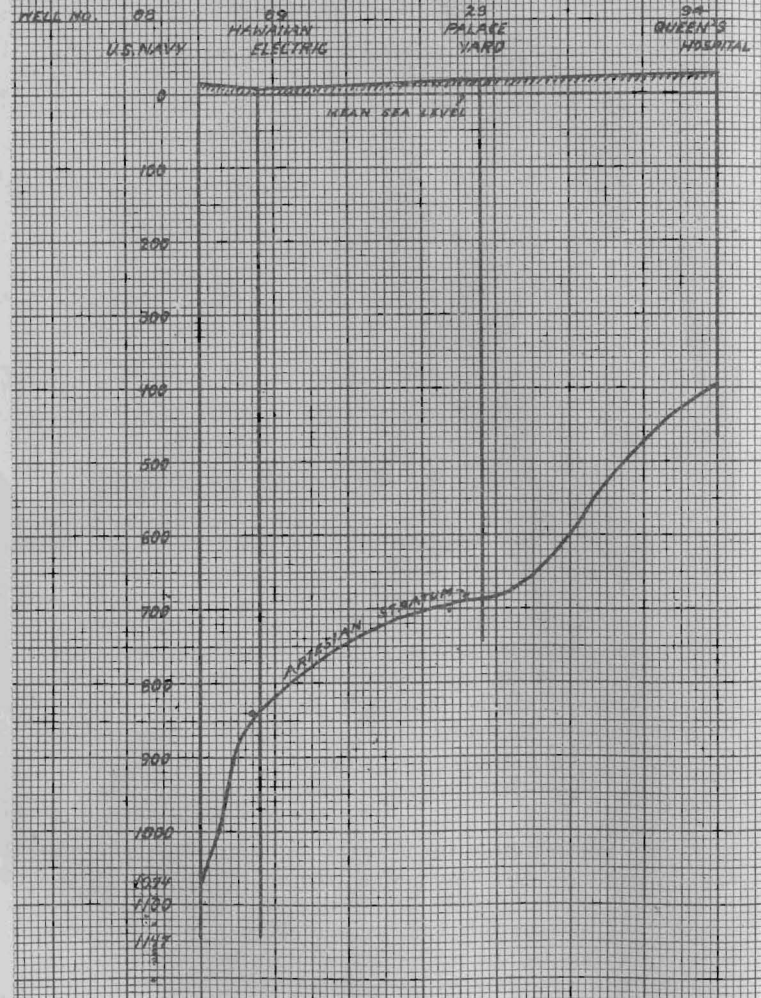


FIG. 10 b.

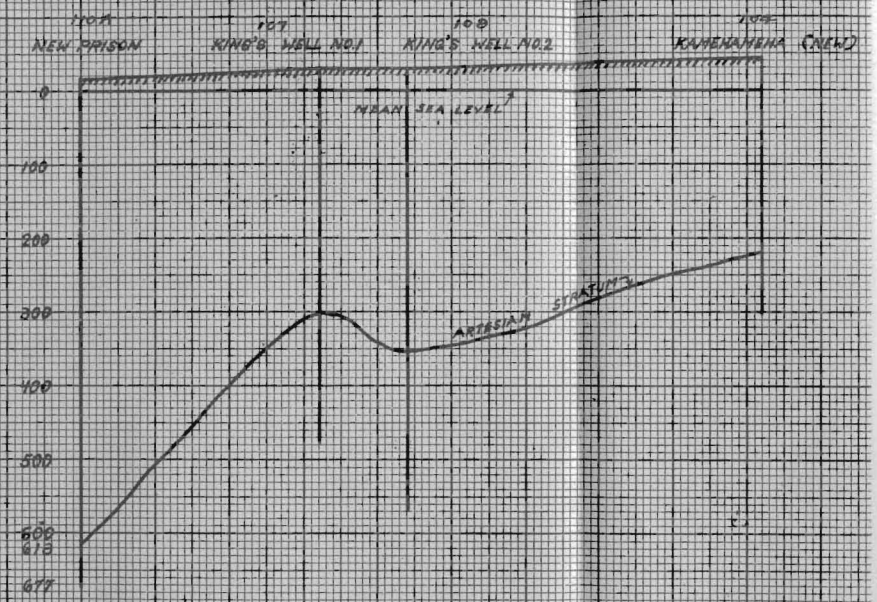
PROFILES OF ARTESIAN WELL STRATA CITY OF HONOLULU

SCALE HOR. 1 INCH = 1000 FT.
SCALE VER. 1 INCH = 200 FT.

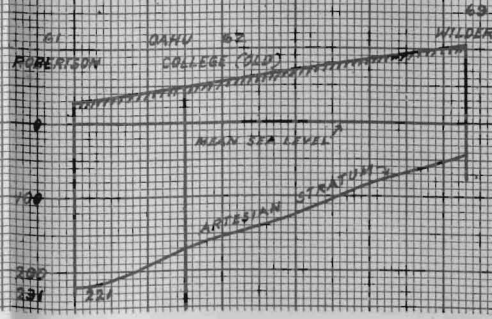
"SECTION C–C"



"SECTION D–D"



"SECTION E–E"



original height of 42 feet and 9 inches above sea level for the first time since its first fall.'"

This information, bearing upon a period for which exact data are not available, has been incorporated in the well head graph.

TABLE NO. 21

PROGRESS OF ARTESIAN WELL BORING, VICINITY OF HONOLULU.

Year	Total Number of Wells Sunk Since 1880
1880	2
1884	41
1888	53
1892	71
1896	86
1900	103
1904	114
1908	122
1912	128
1916	142

WELL LOGS, HONOLULU CITY AREA.

FIGS. 9a, 9b, 10a AND 10b.

All available logs of artesian well borings on the Island of Oahu have been collected and compiled. Those in Honolulu city area have been referenced to a common datum—mean sea level—by levels to the several wells from City of Honolulu bench marks. Figs. 9a and 10a represent typical sections in Honolulu as shown by borings. The geographic location of these sections "AA" to "EE" are shown on the map of Honolulu (Plate I) which accompanies this report. Figs. 9b and 10b, which are identical with Figs. 9a and 10a, show the trend of the artesian strata, or water-bearing rock, in the direction approximately east and west, and from the mountains to the sea.

Little interest was manifested in keeping accurate records of well borings after it became known with assurance to what depths, approximately, in different localities, wells must be sunk to insure a reliable flow of potable water. For this reason much valuable data have been lost that would assist in defining the mauka limits of the artesian watershed areas, and the dip of the

water-bearing strata, as well as contributing greatly in the study of the geologic map of the island. In a general way the few sections that have been drawn show that the artesian strata lie deepest in the valleys and toward the coast.

WASTE WATER FROM ARTESIAN WELLS.

Many artesian wells in the vicinity of Honolulu were visited to ascertain how the well owners or users conform to the provisions of the existing law regulating artesian wells. A majority of the wells visited were found properly capped and equipped with valves that could be easily opened and closed. Several wells had valves that could not be turned, and others had badly leaking service connections.

Two large industrial concerns in Honolulu utilize artesian water from private-owned wells which deliver about five million gallons per day for boiler and condenser purposes. This water is afterwards turned into storm sewers. Several other large concerns also utilize a total of about one million gallons per day for other industrial purposes and then waste this water into the sewers.

There are several wells which have service pipes equipped with small hydraulic rams that raise water to tanks for domestic supply. Discharges from the waste pipes are either turned into surface channels or used for irrigation. As the efficiency of a hydraulic ram is low, the greater portion of the artesian water supplying the ram is utilized in furnishing the power which enables the ram to elevate the water.

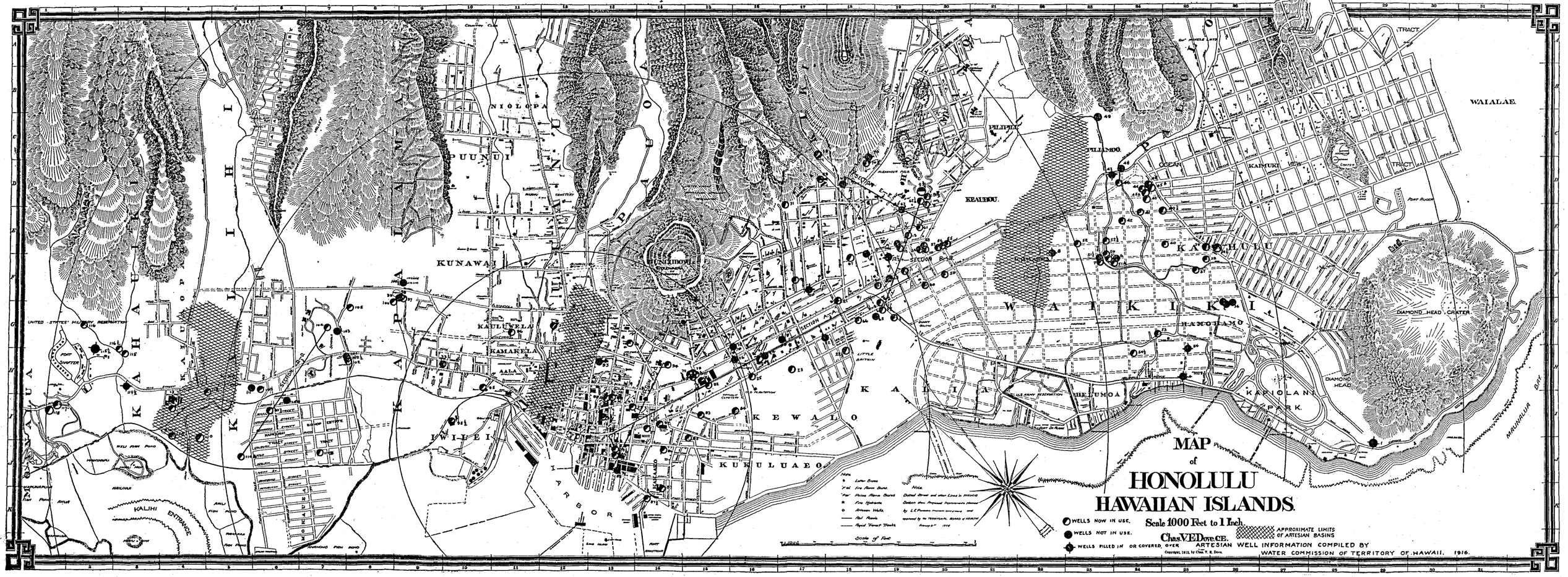
In the vicinity of Honolulu there are many flowing wells used to irrigate truck gardens, rice and taro lands. Discharge measurements made on the flow from one well used to irrigate about four acres of truck and taro land showed that about 73 per cent of the total flow was turned into a creek below the lowest taro area.

BENCH MARKS FOR ARTESIAN WELLS, HONOLULU CITY AREA.

These elevations, referenced to mean sea level, have been determined by the Water Commission by level circuits from permanent city bench marks. The list has not been included in this report, but is on file with the Superintendent of Hydrography.

LOCATION OF ARTESIAN WELLS AND BASINS, VICINITY OF HONOLULU.

PLATE 1. On this map are shown (a) the location and present conditions of all known artesian wells; (b) the approximate east and west boundaries of the sub-basins in Honolulu basin, indicated by cross-hatched lines; and (c) the sections "AA" to "EE" from which log profiles have been drawn. (See Figs. 9a, 9b, 10a and 10b).


MAP
of
HONOLULU
HAWAIIAN ISLANDS.
Scale 1000 Feet to 1 Inch.
Chas. V. E. Dove. C.E.
WELLS NOW IN USE.
WELLS NOT IN USE.
WELLS FILLED IN OR COVERED OVER
APPROXIMATE LIMITS OF ARTESIAN BASINS
ARTESIAN WELL INFORMATION COMPILED BY WATER COMMISSION OF TERRITORY OF HAWAII. 1916.
Copyright, 1913, by Chas. V. E. Dove.
NIOLOPA
PUUNUI
KUNAWAI
KAULUWELA
KAMAKELA
IWILEI
KUKULUAEO
KEWALO
KAKAAKO
KALIA
WAIKIKI
KAIMUKI
KAPAHULU
WAIALAE
KEALOHOU
PILIPILI
PILIMOO
OCEAN VIEW
KAIMUKI
HEEIA
HAMOHAMO
KAPIOLANI PARK
DIAMOND HEAD
DIAMOND HEAD CRATER
MAUNALUA BAY
HONOLULU HARBOR
KALIHI ENTRANCE
FORT SHAFTER
UNITED STATES MILITARY RESERVATION
SECTION A-A
SECTION B-B
Scale of Feet