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# REPORT

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## SUPERINTENDENT OF PUBLIC WORKS

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TO THE

## GOVERNOR

OF THE

TERRITORY OF HAWAII

FOR THE YEAR ENDING JUNE 30, 1913



HONOLULU:  
HAWAIIAN GAZETTE CO., LTD.  
1914

Hawaii (Hon.)

# HISTORY

OF THE

## Honolulu Water Works

From its Inception in 1847  
To December 31, 1913



Outlining the Development and Advancement of  
the System, with Plates showing Conditions Exist-  
ing in 1847, and During the Different Periods up  
to the Present Date.



HONOLULU IN 1837.





# History of the Honolulu Water Works.

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Prior to the coming of the foreigners to Oahu, most of the Hawaiians lived up the valleys where there was an abundance of water both for their domestic use and for the cultivation of the taro plant, from which poi, their national food, is made. The taro plant is an aquatic, and requires that its roots be submerged in water during the greater part of its growth. The floors of the valley were veritable networks of innumerable ponds, varying from a few square feet to an acre or more, separated by small dykes.

Honolulu was merely a small settlement of fishermen whose huts were built on the level lands skirting the Nuuanu stream and the harbor. The Chiefs and their retainers, when not living up in the valleys, lived at Waikiki where they could indulge in their favorite pastimes of surf-riding and canoeing.

With the arrival of the foreigners on the Island of Oahu in 1795 (the Hawaiian Islands were discovered in 1778), came trading. The Hudson Bay Company was established here and John Jacob Astor for a short time tried to further his fortunes on these shores. These newly discovered islands in the Pacific attracted many fortune seekers of all nationalities. Whaling was the industry that brought the majority of the vessels to Honolulu, and it was not long before the harbor was at times filled with craft of all kinds waiting their turn to take on provisions and water. Loading the ships with water was a tiresome undertaking, for in order to get the purest water possible, they had to bring it in small boats from some little distance up Nuuanu Stream.

As foreigners came and settled in Honolulu, there was a demand for a convenient water supply for domestic use, and surface wells were sunk in and about the town, many of which were found to have slightly brackish water; those who could, had water brought from the springs of Nuuanu and Pauoa Valleys. Mrs. Dr. Judd mentions sending up the valley for water; it was a long distance, but to get cool, fresh water to quench the thirst in that dry, dusty place where the Mission stood was worth almost any effort. The Honolulu of today, with its abundance of foliage and its tree-shaded streets, conveys no idea of the hot, parched, sun-beaten Honolulu of eighty years ago.

The Honorable Sanford B. Dole, speaking of Honolulu in the early days, said he remembered viewing Honolulu from the summit of Punchbowl when he was a small boy. The town looked like a checker-board; there were only streets and cross streets and a few buildings and houses dotted here and there; there were no trees except a few cocoanuts scattered along the beach, and a few Hau trees in one of the then lower sections of the town. A few years later, shortly after a water system had been installed, he again looked over the city from Punchbowl. The checker-board had vanished; the outlines of the streets were broken by trees and shrubs; gardens had sprung up around some of the homes and there was a new atmosphere of life and purpose in the whole landscape. He gazed upon the beginning of a city destined to become famous for its tropical charm and beauty.

Mr. James Hunnewell wrote an article on early wells in Honolulu in 1868. The following is taken from his paper: "The first attempt to dig a well in Honolulu was made by William R. Warren, an American, about the year 1820, in the central part of the village, as it then was, and in nearly the highest part. He went down through the yellow loam and volcanic sand some eight or nine feet to the great bed of coral that underlies the whole town. The loam caved in, making a frightfully large hole. The superstitions of the natives were aroused by some foreigners who were hostile to anything American, and the fearful hole had to be abandoned.

"The first successful attempt to dig a well was made some two years later, by Joseph Navano, a New Yorker, in his yard, afterwards owned by Stephen Reynolds, not far from the Bethel, if my reckoning is correct (and not far from my old Sandal-wood Store-house, not a vestige of which has been seen for upwards of forty years), some three or four hundred feet from the store. He went down about eighteen feet; eight or ten feet through loam and volcanic sand, and some eight feet through the coral bed, the upper surface of which was very uneven. The bottom of the coral bed was as uneven as the top, and the whole was full of cavities and channels through which the fresh water ran towards the shore.

"Through the coral the well was hewn with an ordinary American wood-axe. Near the middle of the bed, a hard projecting lump was found, which required several blows of the axe to part it from the surrounding mass, and in falling, it drew with it what at first seemed to be a knot several inches long, but on examination, proved to be a bone of the size and shape of a human thigh bone. I, with others, handled it, and at the time was of the



opinion that it was a human bone, and this opinion was strengthened by the fact that from one of the cavities before mentioned in the coral bed, the skull of a human being was taken, in good order and preservation, but darker than a new skull. It evidently had some strength in it, as it was kicked about by boys.

"The cavities did not communicate with the surface. Neither myself, or any who saw these remains, were naturalists, and the opportunity of describing and preserving these most interesting fossils was neglected.

"The second well was dug in 1822, I think on a part of the Holmes premises occupied by Captain William H. Davis, nearly opposite the main entrance of the estate now (1868) owned by Charles Brewer, Esq., and I think near the northern line of the present Fort Street. The ground here is a very little higher than where the Navano well was located, and this second well was three or four hundred yards from the first, in a northwesterly direction. The substrata proved to be the same as in the former case, and the coral was full of cavities, from which were taken a number of small bones, which I, with several others, examined and considered bones of a man's hand or foot.

"From the facts related and on reflection, I am led to the conclusion that the Islands were inhabited by man, before and during the formation of that vast body of coral that underlies Honolulu.

"Many of the present wells, especially those on the plain east of Honolulu, towards Waikiki, pass through the coral bed, which is full of cavities and cracks and is permeated with streams of fresh water from the mountains. They are usually sunk nearly to the sea-level. In one well on this plain a strong current sets constantly from the mountains to the sea."

Those who confined themselves wholly to the use of the water from surface wells became accustomed to it, and only realized its inferior quality when visitors remarked on its peculiar taste.

At first the water was lifted from the wells by buckets. One instance is recorded where a wooden pump from some old vessel was obtained and put into use. Later, the chain pump was introduced and all who could afford it had one, as a much greater amount of water could be lifted by this device than by any method previously employed. But with a greater supply of water, a longer period of labor for the operator was demanded, and this labor usually fell on the boys who, in the opinion of their parents, had plenty of time to spare; the boys, however, thought differently, and to this day you may hear some of these same boys, now grown gray, tell how they toiled at the pump in order that their elders might enjoy a refreshing bath.

At this time drip stones were used for the purpose of filtering and cooling the water. These were of stone cut in the form of an inverted cone and hollowed out. They were hung in a cool, shady spot, and the water slowly percolating through was cooled and filtered.

While the dwellers of Honolulu were well enough satisfied with their way of getting water, the shippers were not content with the slow and tedious way of supplying water to the vessels and this led to an arrangement for conducting water from a taro patch to the harbor. Mr. Thrum makes mention of this venture in his Annual of 1889.

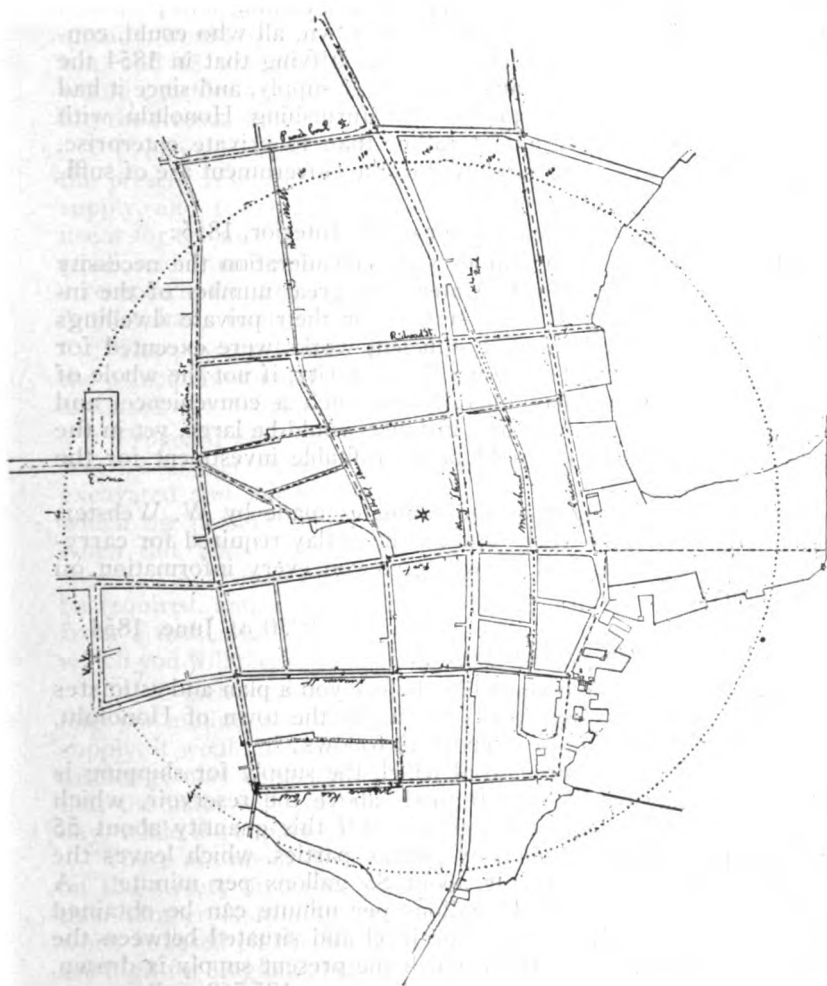
"From copies of correspondence kindly placed at our disposal the following facts relative to the introduction of the first water pipe for this port have been collected:

"During the visit of Mr. P. A. Brismade of the firm of Ladd & Company of this place, to Boston, Massachusetts, in 1838, through a representation by him that the King of these Islands was desirous of bringing water in from a considerable distance for the purpose of supplying vessels at Honolulu, Messrs. Proctor and Felt were induced to consign to Ladd & Co. fourteen reels of lead pipe weighing 8248 lbs., of inch and half-inch size, per ship Fama, October 17th, 1838. This venture, however, did not meet with the success anticipated, as in 1845 ten reels still remained on hand. An effort was made to effect a sale and close out the consignment to Dr. Judd (Minister of Interior, March 30, 1845—March 4, 1846) for the Government, but during the celebrated arbitration suit of Ladd & Co., the matter was suspended but renewed again in the summer of 1847, resulting in the disposal of it in September of that year for temporary use till iron piping could be obtained, and was laid to convey water from a taro patch back of the French Consul's (at that time "on the mauka side of Beretania street between Fort and Emma streets") to the Harbor Master's office at the foot of Nuuanu street. This was the initial effort of the present well distributed water system of Honolulu, and was the first attempt to establish a public water supply."

Meanwhile, plans were being made to bring water from Nuuanu Valley to the harbor through iron pipes, as we find from the report of the Minister of the Interior, March, 1850. (John Young, March 4, 1846, to June 6, 1857.)

"Preparations have been made to conduct water through iron pipes to the harbor in Honolulu. The pipes have been ordered and are daily expected to arrive. This is also a work of importance and cannot fail to be of great advantage to the town."





MAP OF HONOLULU IN 1847, MADE BY METCALF. THE TARO PATCH FROM WHICH WATER WAS PIPED TO HARBOR, WAS JUST ABOVE BERETANIA STREET, BETWEEN FORT AND EMMA.

The water was to be collected in a small masonry reservoir in the vicinity of what is now Bates street, and from there conducted down Nuuanu avenue through a four-inch main. This proposed work was completed in 1851. The vessels coming into port took their water from this main, and in the town, all who could, connected with it. The results were so gratifying that in 1854 the Government considered plans for a larger supply, and since it had taken the initiative, the problem of furnishing Honolulu with water fell to the Government rather than to private enterprise. The plans for this work submitted to the Government are of sufficient interest to be given in full.

From the report of the Minister of the Interior, 1855:

"I would beg to bring under your consideration the necessity of providing the town with water. A great number of the inhabitants have applied for a supply for their private dwellings and there is no doubt that if sufficient works were executed for distributing it through the town the majority, if not the whole of the residents would pay liberally for such a convenience, and although the outlay in the first instance would be large, yet in the end I feel confident it would be a profitable investment for the Government.

"I append the report of the estimates made by W. Webster, Esq., on the present works and on the outlay required for carrying them into effect, which will give you every information on the subject.

"30 of June, 1854.

"To His Excellency, John Young.

"Sir:—I have the honor to lay before you a plan and estimates for the proposed water works to supply the town of Honolulu, and with your permission, report as follows:

"*Supply.* The source from which the supply for shipping is drawn is a spring about 200 yards above the reservoir, which discharges 141 gallons per minute. Of this quantity about 55 gallons per minute is taken by private parties, which leaves the discharge into the reservoir about 85 gallons per minute. A further supply of about 45 gallons per minute can be obtained from springs nearly on the same level and situated between the reservoir and the point from which the present supply is drawn.

"These two sources would yield about 185,760 gallons per 24 hours, which would amount to nearly 31 gallons per head for a population of 6,000 people. During the dry season, however, this supply will fall off a third, which would reduce the quantity to 20 gallons per head, a quantity hardly adequate to the wants of a population in this climate.



“To augment this supply I would propose to lay a pipe from the spring named Kapena down to the site of the proposed reservoir, by which a further supply of 71 gallons per minute would be obtainable, which, together with the two sources mentioned already, would be equal to 72 gallons per head during the wet season, and 48 gallons per head during the dry season. This, I would consider an abundant supply for domestic purposes, watering the streets, washing down the houses, etc., etc.

“*Present Works.* From bad foundations and other causes, the present reservoir leaks nearly as much as the whole present supply, and I would not recommend any attempt to repair and use it for the new works. Even if repaired it would be much too small, and from being situated so near the Nuuanu road, it forms a receptacle for dust and dirt, which, besides rendering the water impure, has a tendency to fill the pipes with sediment.

“The present 4-inch main would, of course, be too small, as the principal main for the proposed works, but it can be removed and used as a distributing main in the streets of the town.

“*Proposed Works.* I would propose that a new reservoir 100 feet by 80 feet clear in the bottom by 10 feet deep, should be excavated and lined with brick work, near to the spring from which the present supply is taken. This reservoir will contain when full, about 511,250 gallons, or 97,250 more than a day's supply. A 12-inch main from the reservoir to Queen street will be required, and also distributing mains for the streets, varying from 5 inches to 3 inches in diameter, for the arrangements of which you will please refer to the accompanying plan.

“A 12-inch main will deliver at Queen street about 1,000 gallons per minute, and although this is far more than the proposed supply, it would not be advisable to use a smaller pipe, as the full discharge may be required on emergency; and another reason is, that the main will only have to do duty about twelve hours per day, while the supply to the reservoir is constant.

“There are about 500 improved lots on the Nuuanu road and on the streets through which the proposed mains will run, and this number is rapidly increasing. The estimate for the iron work is based on the latest English prices current, and the rates are high for England, but the present war may increase even these prices. The present price of casting in the United States is also high, varying, I believe, from \$50 to \$60 per ton.

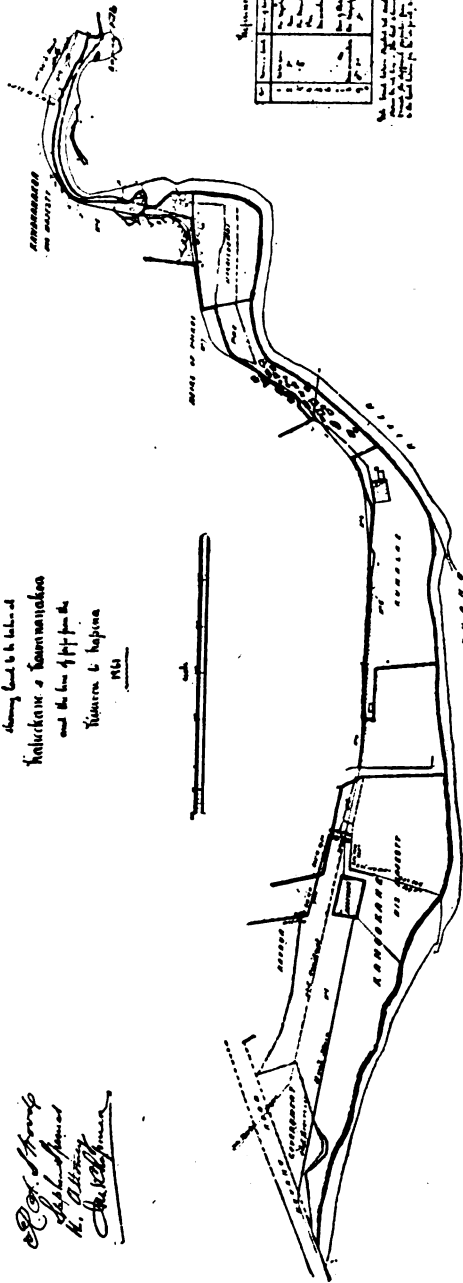
“I have assumed that the material of the present reservoir, if used in the new works, will pay for its removal and also for the fencing and finishing the slopes of the new reservoir,— items that are not included in the estimate.

Kapena Water Works

Plan

showing location of  
Kaliukawa & Kaimanawa  
and the line of pipe from the  
reservoir to Kapena  
N.G.

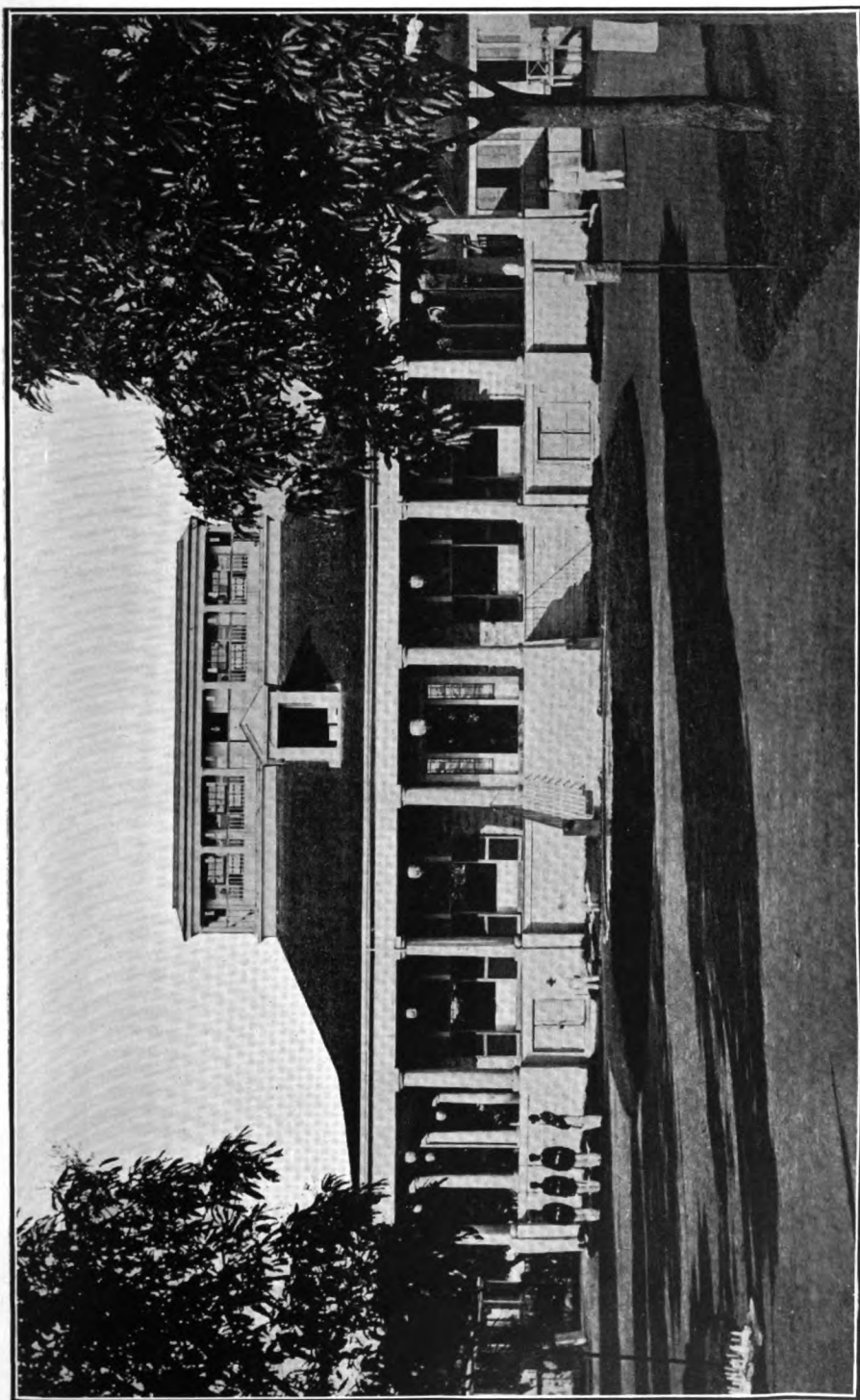
*Eng. & Archt.  
J. H. Webster  
H. H. H. H.  
H. H. H. H.*



Station	Distance from Reservoir	Height above Sea Level	Notes
1	0	100	Reservoir
2	10	95	Valve
3	20	90	Valve
4	30	85	Valve
5	40	80	Valve
6	50	75	Valve
7	60	70	Valve
8	70	65	Valve
9	80	60	Valve
10	90	55	Valve
11	100	50	Valve
12	110	45	Valve
13	120	40	Valve
14	130	35	Valve
15	140	30	Valve
16	150	25	Valve
17	160	20	Valve
18	170	15	Valve
19	180	10	Valve
20	190	5	Valve
21	200	0	Valve

*Handwritten notes:*  
Kaliukawa  
Kaimanawa

WEBSTER'S PLAN FOR RESERVOIR (BELOW JUDD STREET AND BETWEEN NUUANU AVENUE AND NUUANU STREAM),  
AND PIPE LINES FROM IT TO KAPENA SPRINGS, IN NUUANU VALLEY.



FORMER PALACE OF HAWAIIAN KINGS, ON THE SITE OF WHICH THE PRESENT PALACE (EXECUTIVE BUILDING) NOW STANDS.

"If a supply, equal to that derived from 'Kapena' were taken from the Nuuanu stream, anywhere below Kapena Falls, it would require to be passed through a filtering reservoir, and to this course there are many objections, as not only the first cost of such a reservoir is great, but there would be a continual outlay to keep it in repair besides the objection to the water for domestic purposes, even when filtered, on account of bathers, etc.

(Signed) "WM. WEBSTER, (Engineer).

"P. S.—By returns from the Water Office, I have ascertained that the greatest quantity of water supplied to the shipping in one day amounts to 18,000 gallons.

"W. W."

A detailed statement of the cost of this proposed work accompanied Mr. Webster's report, the total of which was \$68,000.

These plans were not put into operation until 1860-1861. He carried them out faithfully and within his estimate and gave good workmanship. (The Ministerial Report of 1862 states that the works cost about \$44,000, which did not include the interest on \$20,000 which had previously been borrowed for the purchase of pipe. We cannot determine, therefore, whether the estimate of \$68,000 was cut down to \$44,000, or whether the \$20,000 was included in the estimate; the latter supposition is probably the correct one.) The reservoir was situated at Kahookane below Judd street, and between Nuuanu avenue and Nuuanu stream, and was so well constructed that it was doing service up to 1895.

Such an installation demanded care and supervision, and from this time the Honolulu Water Works became a matter of great importance in Government affairs.

The contamination of the waters of Nuuanu Valley was stopped as far as possible. The Board of Health coöperated in trying to secure a pure and adequate water supply.

In order to increase the supply, it was necessary to acquire rights in the valley, and laws were enacted leading up to this. In 1860 an act was passed which gave the Government the right to condemn and acquire such water sheds and rights as were needed for the city's water supply.

Kalihi, Nuuanu, Pauoa, Makiki, Manoa and Palolo Valleys all were possible water sheds. Nuuanu Valley was nearer Honolulu than the others, and as works had already been constructed there, the Government continued the exploitation of this valley.

From 1860 to 1870 the water works office confined itself chiefly to maintaining the system built by Mr. Webster. There were some extensions of pipe lines to meet the demands of the growing

city, but no works were carried out to materially augment the supply.

During this period the Government attempted to make arrangements with the owners of land supplied with irrigation from the Kunawai spring near Liliha street, below Judd, for the purchase of their rights for the enlargement of the Water Works system, but the claims upon it made it advisable to forego this attempt.

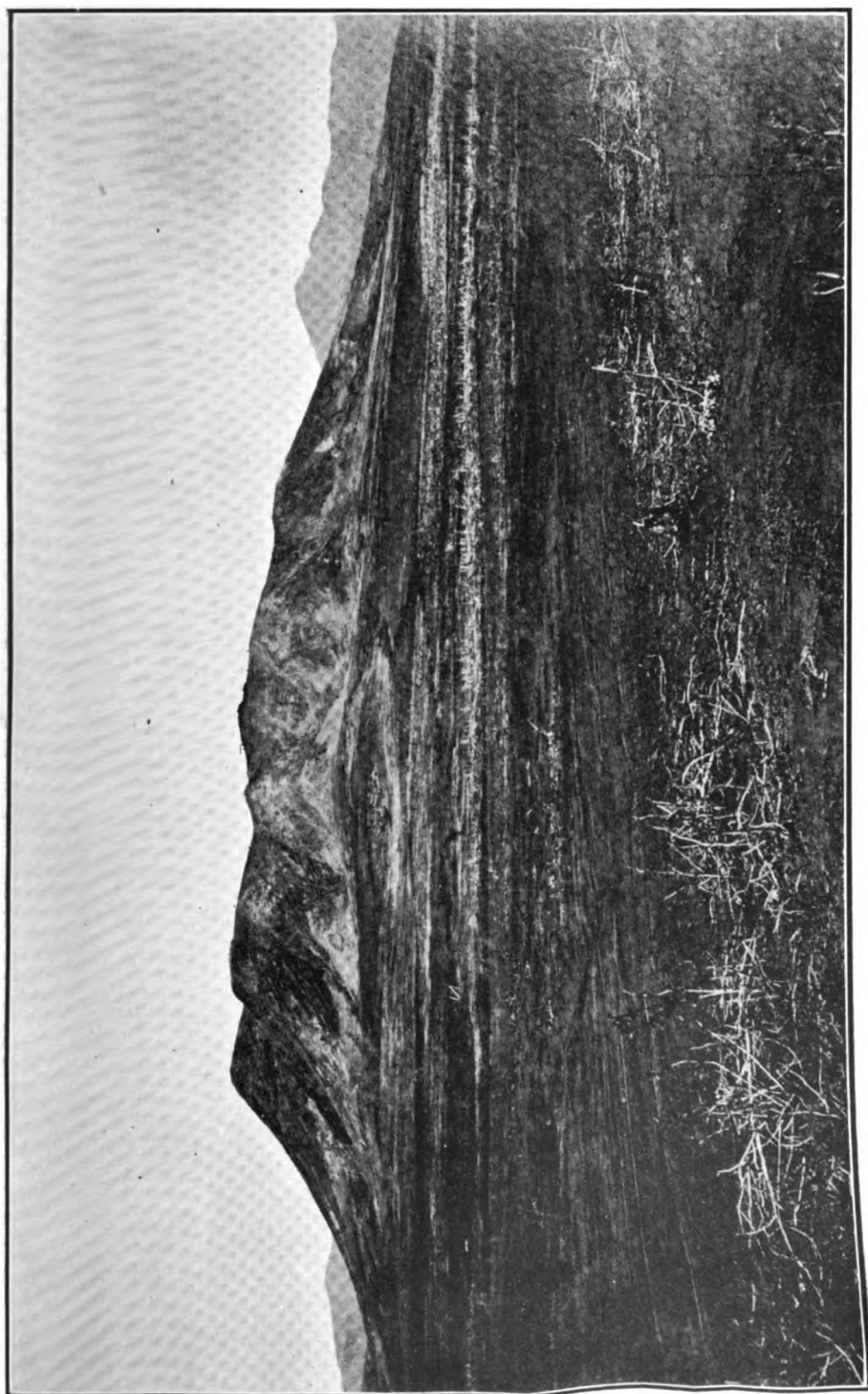
Mr. C. R. Bishop, however, controlled rights in Paki Auwai, which he agreed to sell to the Government for the sum of \$1,000. The deed was dated February 16th, 1869. The acquiring of this water gave Honolulu a good additional supply.

About this time 4720 feet of piping were laid, which served a population heretofore dependent upon other sources. The pipe varied from 7.5 inches to  $\frac{3}{4}$  inch in diameter.

It is interesting to note that the Minister of Interior, F. W. Hutchinson, April 26, 1865-January 10, 1873, shows the increase of the water receipts over the previous period to be \$3,843.09, making an interest on the outlay of about 18%.

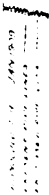
From 1872 to 1876 there was little new work of importance carried on. The revenues were increasing and the Minister of Interior in 1876 reports: "The revenue derived from this Bureau for the year 1875 was an improvement on the previous year, and gives promise of a still greater increase. This is probably the best investment in the possession of the Government."

In 1872 the office was of such importance that it was distinguished by the title of Bureau of Water Works. Up to that time the details of the work pertaining to the water supply fell to a number of sub-divisions of the Government. It was always under the Department of the Interior, but for some time the work was of such a secondary nature that its accounts were charged up to "Appropriation for Wharves." As the work grew its supervision was invested in the Clerk of the Market. In 1862 the Minister reports: "Salary of Clerk of Market and Water Supervisor, \$2400." From this it would appear that the compensation for his services in maintaining an oversight of Honolulu's water supply was \$200 a year more than his regular salary of Clerk of the Honolulu Market. In 1868 the salary of \$3600 was allowed for Road and Water Supervisor. In 1878 appropriations were made for a clerk for the Water Works, and this move to systematize the business of the office was none too soon, for at this time the Water Works began to expand and develop in a manner heretofore unparalleled. The city was extending into the plains between the centre of town and Punahou; Palama was being set-



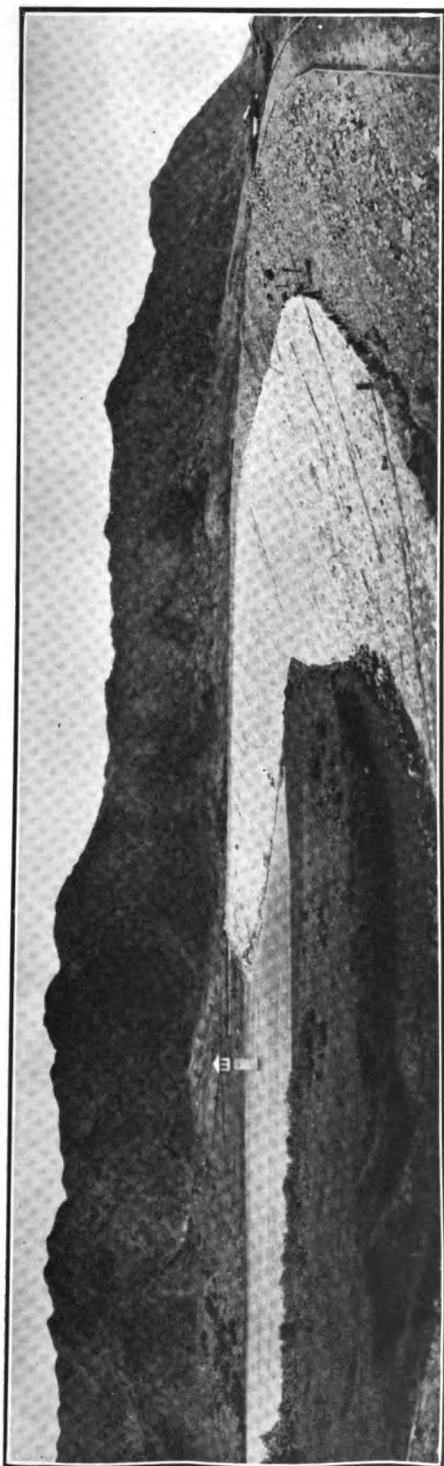
THE SLOPES OF PUNCHBOWL, FORMERLY "THE PLAINS." THE WAGON TRACK IN THE FOREGROUND OF THE PICTURE IS APPROXIMATELY THE INTERSECTION OF ALAPAI AND BERETANIA STREETS, WHERE THE PUMPING STATION NOW STANDS.

WW 69.2  
MG 68.2

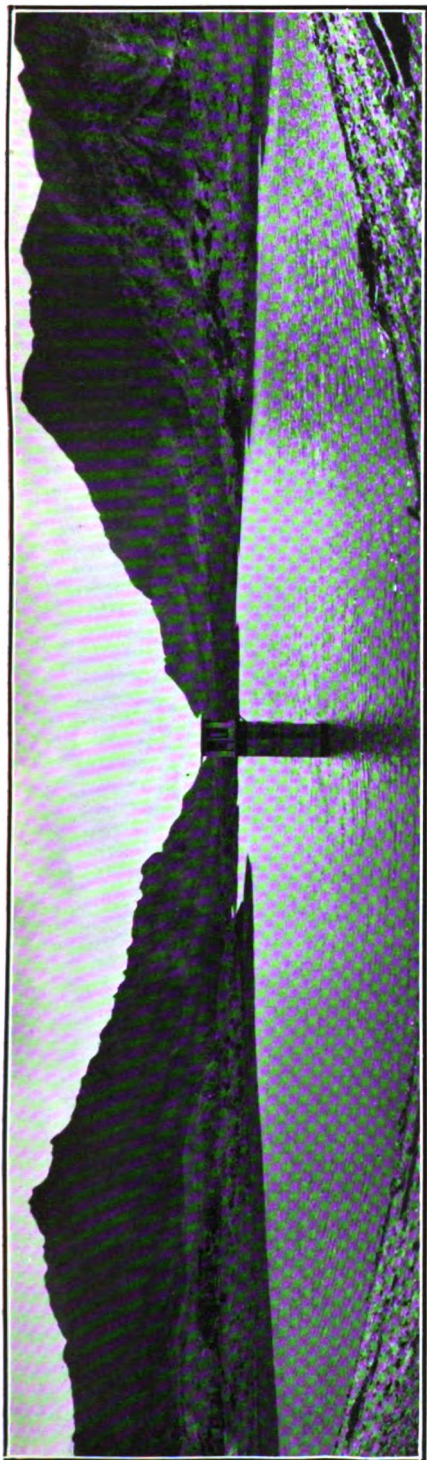








RESERVOIR NO. 4. SHOWING DAM; LOOKING EASTWARD FROM NU'UANU ROAD.



RESERVOIR NO. 4—LOOKING TOWARD THE PALL.



RESERVOIR NO. 4—LOOKING WESTWARD FROM THE SPILLWAY.

(It is interesting to note that Reservoir No. 4 is practically on the site proposed for a reservoir in 1883 and 1890.)

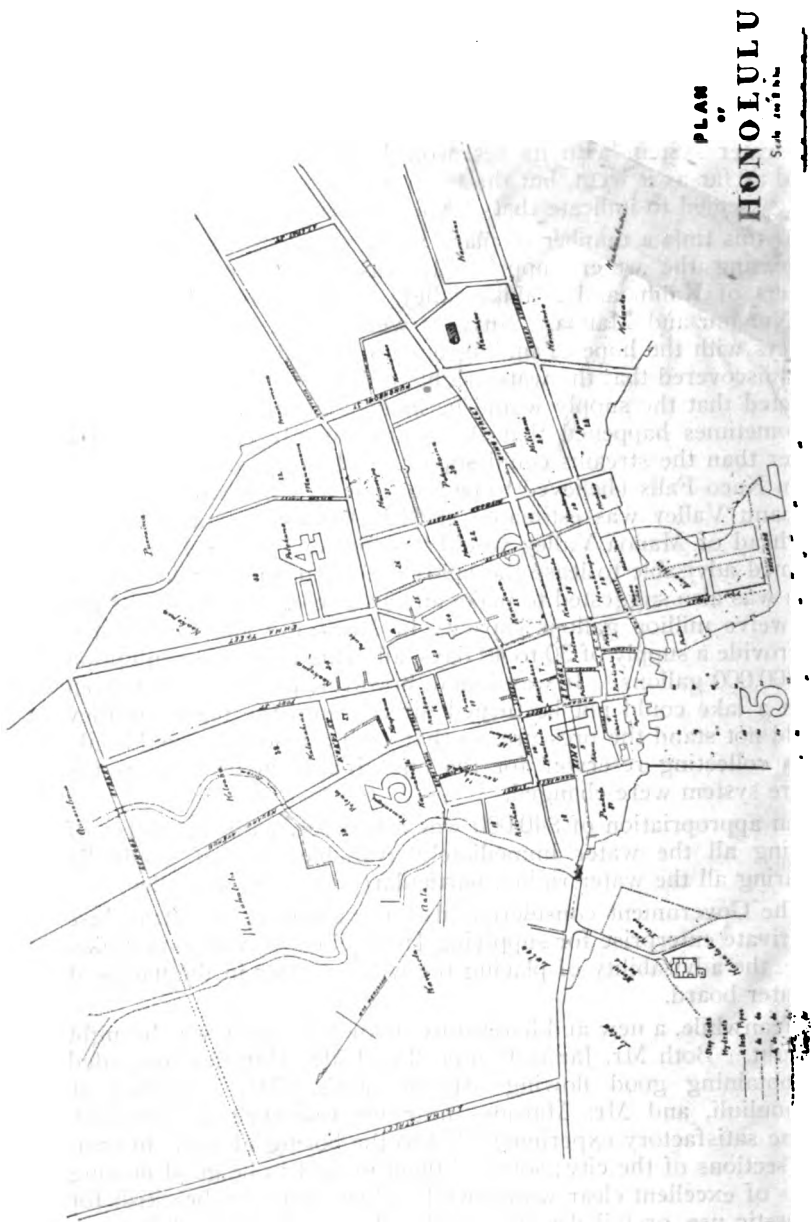
tled; and the lower slopes of Punchbowl were attracting the home-seeker. All of this increase in the city's growth demanded more water for homes and better protection against fire. New parks were to be laid out, and the streets had to be sprinkled. The old water system with its reservoir built by Webster, was still good as far as it went, but the town had outgrown it, and everything seemed to indicate that it would extend still further.

At this time a number of plans were considered for materially increasing the water supply. It was recommended that the waters of Kalihi and Makiki valleys be used, as well as those of Nuuanu and Manoa. Surveys were made of the two latter valleys with the hope of finding enough available water. But it was discovered that the water rights in both valleys were so complicated that the supply would be inadequate in a dry season, as it sometimes happened that the rights already called for more water than the streams could supply. The cost of piping water from Kaeo Falls (believed to be the same as Lulumahu Falls) in Nuuanu Valley was estimated at \$120,000, and to pipe it from the head of Manoa Valley would cost more. Meanwhile it was deemed advisable to lease the lands in and around Luakaha. A plan was also suggested to make an earth reservoir or lake of ten to twelve million gallons capacity in Nuuanu Valley, calculated to provide a supply of 30 to 40 days, allowing a daily consumption of 300,000 gallons. It was found, however, that the water from such a lake could not be turned directly into the mains as they could not stand the pressure, so that such a reservoir would only be a collecting reservoir for the one already in use, unless the entire system were changed.

An appropriation of \$40,000 was asked for, with the object of getting all the water immediately available, and of gradually securing all the water rights, particularly of Nuuanu Valley.

The Government considered, also, the granting of a franchise to private enterprise for supplying Honolulu with water, and likewise, the advisability of placing the whole matter in the hands of a water board.

Meanwhile, a new and heretofore unknown supply was brought to light. Both Mr. James Campbell and Mr. Marques succeeded in obtaining good flowing artesian wells,—Mr. Campbell at Honouliuli, and Mr. Marques near his residence in Punahou. These satisfactory experiments led to the boring of wells in various sections of the city; some of them proved to be good flowing wells of excellent clear water, while others were too brackish for domestic use, or failed to flow. The knowledge gained through these costly experiments was, that in and about Honolulu the



HONOLULU WATER WORKS MAP, 1878. PROBABLY AN EXTENSION OF W. BSTER'S MAP.

artesian water would not rise over 42 feet above sea level, and that, consequently, wells sunk above this level, although they might give a good supply of water if pumped, would not flow; that the waters from different wells differed greatly in mineral quality, particularly in the quantity of chlorine they contained. So, for certain localities, it appeared to be demonstrated that it would not be advisable to bore for flowing water, as the chances were that the effort would be futile. This information was valuable, although it was costly to gain.

The possibilities and limitations of artesian wells were not fully known, but the people of Hawaii and the citizens of Honolulu foresaw the reclamation of great tracts of barren waste land with its consequent increase of revenue and population. It meant the building of a railroad for better transportation facilities. It may be interesting to note here that the artesian well and railway on Oahu have made it possible to ship about eight million dollars worth of sugar annually.

Although the Government was interested in the artesian wells, it was not yet in a position to exploit them, as some of the plans for mountain supply, which had been under investigation for some time, were acted upon about the time the first well was sunk.

During this period the Makiki Valley water rights were negotiated for. The minister of the Interior states: "Under the law giving the Minister of the Interior authority to take such lands and water as are necessary for the Honolulu Water Works, I have given notice that I do, under said law, take all the water of Makiki and all lands necessary from and including Round Top and Pauoa. Commissioners have been appointed, but as yet no claims have been settled." The settlements were not concluded until 1884. The Makiki reservoir of masonry, holding 750,000 gallons, was built at this time. A reservoir was also built in Nuuanu Valley, on the Queen Emma property.

Ten miles of piping were laid, a part of which was a six-inch main from this reservoir to Judd street.

In 1880 a "Superintendent of Water Works" was appointed. He was expected to devote his energies to this office alone. Herebefore the Superintendent of Public Works, Road Supervisor, Clerk of Honolulu Market and Superintendent of Water Works were embodied in one commission, 1880-1882. Although the erection of the Nuuanu and Makiki reservoirs during the period of 1878-1888 gave Honolulu additional water, it was not sufficient, and the Government continued to look for new and economical sources of supply. Ten thousand dollars was appropriated for sinking artesian wells. One good flowing well was drilled at





Pawaa on the Waikiki road, and pipe laid from it to supply the residents at Waikiki. Another was sunk at Mililani (the present Judiciary Building grounds).

The Minister of the Interior says on this point: "Before the successful boring of artesian wells, water was obtained wholly from Nuuanu and Makiki Valleys. Large tracts of valuable lands are now exclusively used as a water shed. The water is not wholesome and is more or less dangerous to public health. Artesian well water is perfectly pure, and it is now evident that it can be obtained in quantities sufficient to supply the city. The water from these wells does not rise above five or ten feet from the surface. To supply it at a height of 100 feet above the sea level will require the adoption of a steam pumping system, which will force it to any height required. While the cost of doing this will be considerable it would be met, to a large extent, by throwing open to residents and cultivation the large tracts of valley land now used for collecting the water. The artesian wells so far throw water 42 feet above the sea level. The well at Makiki is abandoned for the present owing to the want of necessary piping. But the fact that an abundance of this water may be had makes it possible to change the water supply system with great advantage."

This period is marked by a movement for better sanitation throughout the city. In 1881 the United States Government called together an International Sanitary Congress at Washington, and Hawaii was represented by Minister Allen. The Hawaiian Kingdom had always shown a great interest in the well being of its people, and the Board of Health had been one of the active organs of the Government. Its power and efficiency is well illustrated in the treatment of the smallpox epidemic which occurred at this time. One hundred thousand dollars was appropriated for combating the disease, of which about \$97,000 was expended and the disease was successfully stamped out.

In his report for this period, the President of the Board of Health urges the necessity of a sewerage system for Honolulu, although he finds it difficult to settle on any one particular system.

He states that the odorless excavator and the filling in of the flats in the lower part of the city were doing much to make it more sanitary. He also says that experiments were carried on to drain off the contaminated surface water by a system of wells; and adds, in regard to maintaining the good health of the city: "It is very possible that some sickness is due to the quality of the drinking water; this being collected from the mountain sides and valleys is filled with vegetable matter, which diffuses through

it in finest particles. Such water is unwholesome. Water from flowing artesian wells, which is quite pure, should be substituted for this impure water. Careful investigation in other countries shows that pure drinking water is an important element in securing good health. In forcing the artesian well water through pipes by means of steam machinery, an abundant supply may be obtained for the city."

In order to purify the mountain waters, a filtering plant was constructed on the John H. Wood property in upper Nuuanu. This was the first effort to purify the mountain waters.

1882-1884. The Minister of the Interior (C. T. Gulick, August 6, 1883, to June 30, 1886) reports on Water Supply as follows: "The water supply of the City of Honolulu has claimed the attention of his Majesty's Government, not only to meet the present demands, but looking to a possible increase, not only on account of increase of population, but for the requirements of sewerage, etc., and it has consequently summoned to its assistance the best talent it could command."

Major A. S. Bender submitted a preliminary report on the Water Supply of Honolulu. His investigations were with reference to collecting and storing the mountain waters of either Nuuanu or Manoa Valleys, either of which he thought would furnish an ample supply. His plan was to erect a large earth or masonry dam which would mean the expenditure of a large sum of money. He did not estimate the total cost of the work, as he had not investigated the matter fully, but suggested that \$200,000 be asked for to commence the works. (This dam was to be on about the same site as the present No. 4 Reservoir. It is to be noted that Major Bender asked for \$200,000 with which to begin the work. Reservoir No. 4 completed has cost about \$298,000.)

The utilization of the artesian water supply was not reported upon, as Major Bender had not investigated the subject.

From 1880 to 1884 five artesian wells were sunk at public expense. They were located at Pawaa, the Palace Grounds, Thomas Square, Makiki and Mililani, at a total cost of about \$22,000. In addition to these, a well at Waikiki was purchased, so that the Water Works now controlled six wells, five of which were flowing. In 1883 complete section maps of Honolulu were made showing the existing pipe lines, reservoirs, proposed reservoirs, springs, artesian wells with other valuable data, all of which made a most reliable basis for future work.

The sanitation of Honolulu was considered again at this time, but the concensus of opinion seemed to be against the establish-



ment of a sewerage system, so that little was done in that direction.

1884-1886. The extent of the possible artesian supply was not known, but it was generally believed to be limited. In order to conserve the supply as far as possible, the following law was passed:

## LAW REGULATING ARTESIAN WELLS.

### AN ACT

#### TO PREVENT THE WASTE OF ARTESIAN WATER ON THE ISLAND OF OAHU.

Be it enacted by the King and Legislature Assembly of the Hawaiian Islands, in the Legislature of the Kingdom assembled:

SECTION 1. Every flowing artesian well on the Island of Oahu (or) that may hereafter be made on said Island, shall be capped by the owner or owners thereof in such manner as to give complete control over the flow of the water from the pipe of such well.

SECTION 2. No person having the right to the use of water from any such artesian well shall allow the same to run to waste, but may use it 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 afterward for irrigation or other useful purposes.

SECTION 3. Any person violating the provisions of Sections 1 and 2 of this Act shall upon conviction thereof, before any Police or District Court of the Island of Oahu, be fined not more than fifty dollars.

SECTION 4. For the more effectual carrying out of this Act, the Marshal and Deputy Marshal of the Kingdom and all Policemen of the Island of Oahu, may at all times of night or day enter, without warrant, any premises whereon artesian water is used.

SECTION 5. This Act shall become a law on and after its publication.

Approved on the 21st day of August, A. D. 1884.

“KALAKAUA, REX.”

This period was notable for investigations on the part of the Government to better the conditions of the city. Hawaii was coming into closer connection with foreign countries and it was expected that at the completion of the Panama Canal her commercial importance would be greatly increased. Extensive im-

provements were considered and for the Water Works in particular.

The city's water supply had become too small, and even though the present system might serve for some time to come, there was not enough for a time of drought or serious conflagration. The Chinatown fire of 1886 destroyed much valuable property, and had it not been for an efficient fire department, or had the water supply run short, the entire business section of Honolulu would have been at the mercy of the flames. The question of a sewerage system was again under consideration. Major Bender was authorized to make full investigation and to report on a system for increasing the water supply of Honolulu, and also upon a sewerage system. Mr. Van Slyke was commissioned to analyze the public drinking waters and report upon them. Besides authorizing these investigations, the Interior Department had detailed maps made showing each street and each privilege obtained from the Government.

The affairs in the Water Works Office had for some time been in disorder, and a thorough re-organization was made, the result of which placed the office on a far more satisfactory basis, and more than doubled its revenues.

The main points in Major Bender's plans for increasing the water supply were as follows:

He considered the two valleys, Nuuanu and Manoa, either of which he believed would provide sufficient water for the city's needs. Nuuanu, however, was the one decided upon as being more advantageous. Here there were two reservoir sites, one high up in the valley, which would necessitate a large dam, and the other just below the Pelly Falls at Luakaha. The latter site was chosen because, among other considerations, the rainfall there was believed to be more reliable. A part masonry dam was to be constructed which would allow a reservoir capacity of 28,000,000 gallons if the dam were 40 feet high. The water from the reservoir would be piped through the already constructed filtering tank on the Wood property. A distributing reservoir of a million-gallon capacity was to be built above the head of Emma Street, 190 feet above sea level, where it would be distributed through a system of city mains.

His plans for a sewerage system were:

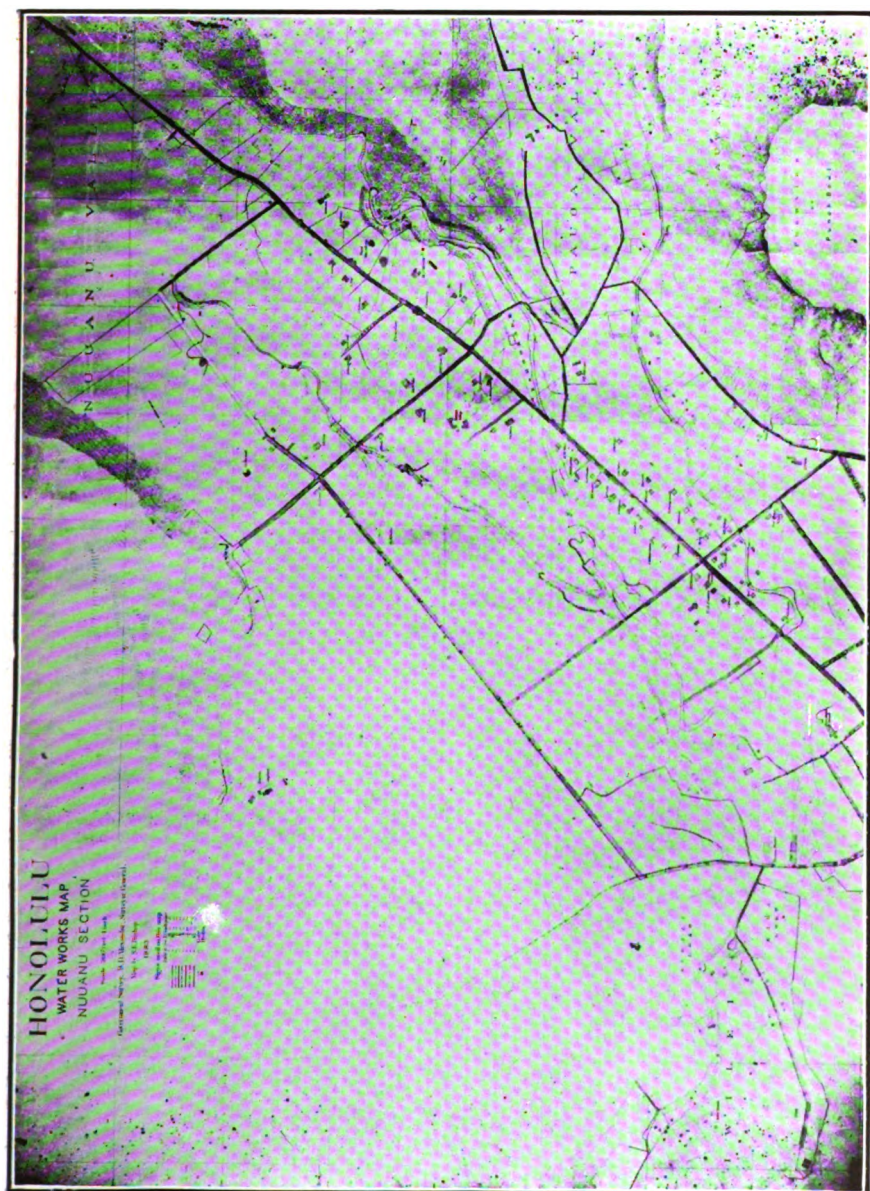
An intercepting sewer along Queen street into which the laterals would deliver, with a reservoir and pumping plant to be erected in such a location that the sewerage could be collected and pumped far enough out to sea so that it would not return.



GENERAL AND SECTION WATER WORKS MAP, 1883.



























Major Bender had not decided on the exact location for this pumping plant, but experiments had shown that from a point off the slaughter houses, refuse thrown into the sea was carried outward.

Major Bender's plans were not carried out at this time.

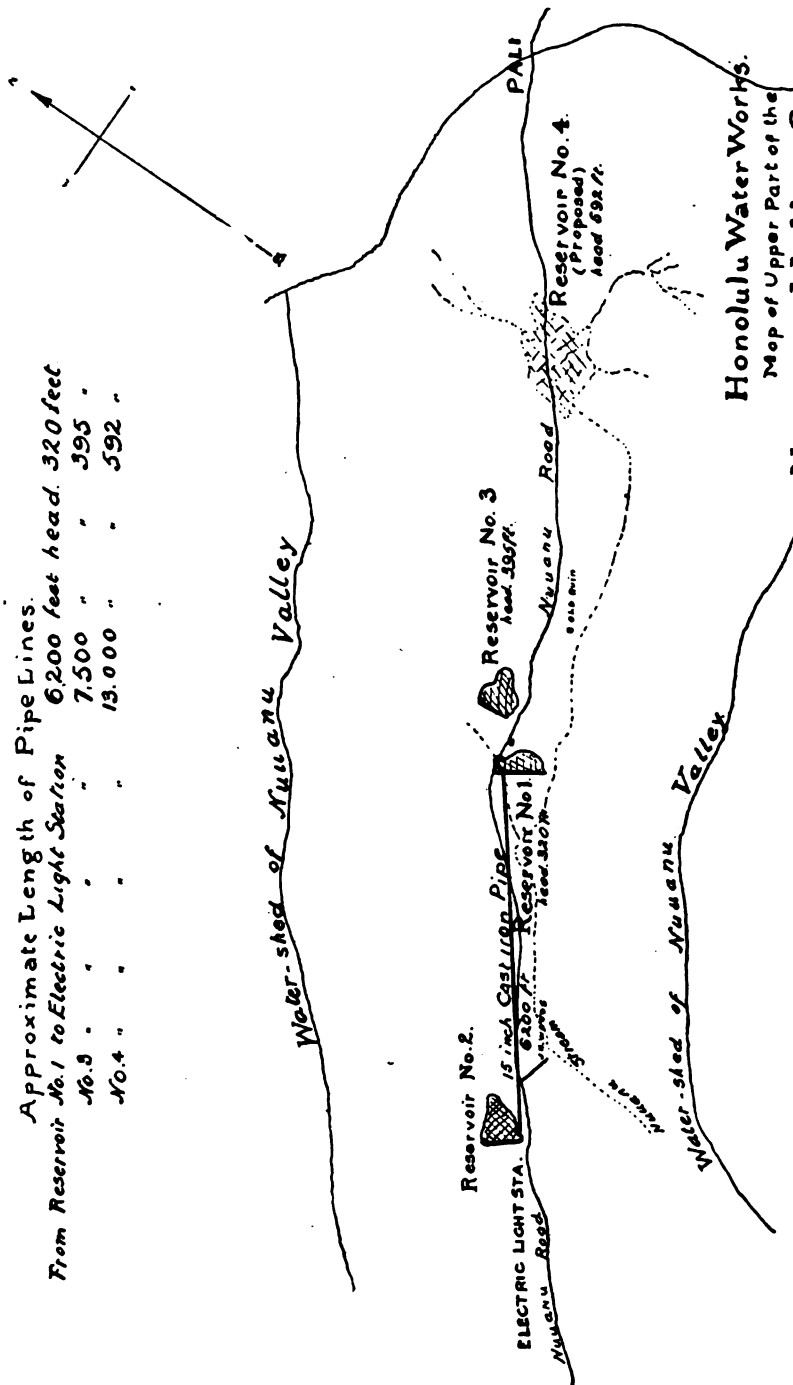
1886-1888. The year 1887 witnessed many changes in the affairs of the Government. New Ministers and officials were appointed to various Departments and Bureaus. In the Water Works Office many of the plans proposed by the previous administration were set aside. Major Bender's plans for water supply and sewerage were not deemed advisable. Instead of these, however, other plans were made for increasing the water supply and for furnishing water power for an electric plant from which the City was to be lighted. There was at this time a small electric lighting plant run by steam that they decided to discontinue on account of its expense.

In order to install the electric plant, two cisterns or small reservoirs were built in Nuuanu Valley, one located at Luakaha, and a second one near the Half-way House. A branch pipe line was put in to connect them up and deliver water to the electric plant. A Lafell turbine wheel and an electric dynamo were installed. The venture, although not favorably received when proposed, proved a great success, and led to recommendations for the construction of three reservoirs, one to be located at Luakaha, of 2,000,000 gallons capacity; another of 1,150,000 gallons capacity at the Half-way House; and a third of 5,000,000 gallons capacity, below the electric light house plant, to receive the waters after they had passed the wheel. This system was to serve the double purpose of increasing the storage capacity of the water system, and furnishing water power for the electric plant.

It was again proposed to utilize the five artesian wells by connecting them with proper mains to supply the lower sections of the city and Kapiolani Park. These wells had been sunk for five or six years and were doing only partial duty. The Makiki well had been idle during this time; the wooden casing in the shaft was rotting away and needed to be replaced. As this well did not flow, it must be pumped if used at all. It was proposed to use the water from Makiki Valley to run a water wheel, which would be connected with the pump. It was estimated that this well had cost the Government about \$13,000, and there had been no returns. The cost of putting it into commission would be about \$4000.

# Approximate Length of Pipe Lines.

From Reservoir No. 1 to Electric Light Station	6,200 feet head. 320 feet
No. 3 . . . . .	7,500 " " 395 "
No. 4 . . . . .	13,000 " " 592 "



Scale 2000 feet to one inch.

Honolulu Water Works.

Map of Upper Part of the

Nuuanu Valley System.

Reduced from the Official Map by

May, 1920. G. F. Allard, C.E.

It was decided to make every effort to secure the control of all the water rights possible in Nuuanu Valley. Mr. S. E. Bishop was given the work of making a complete survey of the valley, locating each ditch, the amount of water to which it was entitled, the area of land the right irrigated, and the name of the owner of the right.

The sources of supply under the control of the Honolulu Water Works at this time were: the Makiki stream, Kapena Stream and spring, Nuuanu Stream and Luakaha, and the artesian wells at Thomas Square, Palace Grounds, Mililani, Pawaa and Waikiki.

The revenue of the Water Works Office was increased about \$4000 annually, by the abolishing of the free water privileges which had been in existence for a long time.

The old system of water rate charges was not altogether satisfactory, and a new schedule was proposed, based on the pressure and the size of pipe delivering the water.

*1888-1890.* It was during this period that the three reservoirs previously recommended were constructed in Nuuanu Valley (No. 3 was not completed until the following period). The plans proposed in the previous period were changed somewhat, resulting in the present reservoirs, known as Nos. 1, 2 and 3. No. 1, at the electric light station, had a capacity of 23,304,211 gallons; No. 2, at Half-way House, 7,301,690 gallons, and No. 3, near Luakaha, 10,712,300 gallons, at a total cost of about \$28,900. (Later estimates give the capacities of these reservoirs to be: No. 1, 21,304,211 gallons; No. 2, 7,301,639 gallons, and No. 3, 10,712,130 gallons; total, 39,317,980 gallons.) These served for the electric light plant as well as for the water supply. In addition, a fourth reservoir was planned for higher up the valley, which would greatly increase the storage capacity and furnish more power. This plan for a fourth reservoir, however, was not at that time carried out. The accompanying print shows the plans proposed and partly adopted.

Several times Honolulu had suffered from droughts, but the one of 1889 was especially severe, very little rain falling from November 16, 1888, to April 24, 1889, and it was confronted with the possibility of a water famine. Every effort was put forth by the Water Works Bureau to get sufficient water for the actual needs of the city.

The people were notified to use water sparingly, and irrigation regulations were insisted upon, so that all could be justly served; water inspectors were set to work and more than 500 leaky taps



were repaired. Every possible source of mountain supply was drawn upon, and their output augmented to the limit. The Superintendent of Water Works says: "During the months of February, March and April, I concentrated the water courses of Nuuanu Valley into the main stream by means of ditches (one being between 800 and 1000 feet in length), and caused the beds of the streams to be cleared of all undergrowth, fallen trees, etc. This proved to be of material assistance in making available what water there was. .

"I also turned my attention to increasing the volume of already existing springs and re-opening others which were at this time, and had been for years, extinct, and were only known to me from their mention in legend, song or story handed down by Hawaiians of former days. For this purpose I visited each valley connected with our water system, or capable of being connected."

The five artesian wells were doing but limited duty on account of the smallness of their mains, delivering only 400,000 gallons per day, instead of several millions, of which they were capable with proper mains. The drought became alarming and a fire engine was attached to the artesian well at Thomas Square and water pumped to Makiki reservoir. The experiment proved satisfactory, and an appropriation of \$3000 was made to pump artesian water for the city supply. This, however, was not needed, as the rain fell and Honolulu was again free to use its accustomed allowance of water. This experiment demonstrated the fact that the most efficient way of using the artesian wells was by pumping, and that the expense was within reasonable limits.

The drought, with its consequent shortage of water, led to investigations which brought out valuable data on water supply, such as the measurements of the capacity of springs and streams, and the recording of the rainfall. (The rain gauges were set up in Nuuanu Valley.)

The filters installed on the Wood property in 1880-82 had proved undesirable, and it was now proposed to introduce the Hyatt filter, with a capacity of 3,000,000 gallons daily, at a cost of about \$50,000. Such a plant to filter Nuuanu water was felt to be absolutely necessary for the protection of public health.

Considerable attention was paid at this time to the taking up and cleaning of pipes, which had become very necessary. In one instance a 4-inch pipe in use for 25 years was found so heavily incrustated that a 1-inch pipe could not be put through it.

Maps were made showing the city mains already existing, and a complete system of new mains was laid out, bringing in terri-

tory heretofore without Government water. This was deemed necessary in order to develop the water system on some sort of systematic basis to meet the ever-increasing demands of the city.

The inspection during the drought brought about the recommendation that meters be installed so that the actual amount of water used could be accurately gauged, furnishing a correct basis for water charges.

The control of all springs and water rights in Nuuanu Valley and the removal of all squatters therefrom was strongly urged, and that similar steps be taken with reference to Kalihi, Pauoa and Manoa Valleys.

The status of the Bureau of Water Works at this time is given by the Superintendent of Water Works, as follows:

"At present the Bureau is in the most prosperous condition it has ever been in. Its estimated revenue is at the rate of \$43,000 per annum. The total outlay since its institution in permanent works, improvements, and general expense of management has been \$653,898.80. The amount of revenue received during the same period has been \$601,343.06. So that the Bureau represents a net outlay of only \$57,555.74 to the Government to establish it in its present state of efficiency, against which is to be set off the free supply of water to all Government offices and works till 1886, and a supply of water free as a part of the subsidy to the mail steamers. The original cost of the working plant (reservoirs, pipe lines, buildings, etc.) was \$321,760.85 as nearly as can be ascertained from all reliable data, while the estimated value of the works as a whole at this date is \$875,000, including the rental value of the power it furnishes to the Electric Light Works. It has a supply drawn from a catchment area of 1790 acres in Nuuanu Valley alone, which, with an average rainfall, estimated to be at that elevation, at least 100 inches per annum, could give an available yearly supply of 1,700,000 gallons, allowing that only 40 per cent. of the total rainfall (the amount estimated by competent observers in Europe, America and Australia) is available for supply; one-eighth of that having been again deducted for loss by evaporation and percolation during storage. The reservoirs at present completed and in use by the Bureau have a total capacity of 30,081,790 gallons for storage, and to this will be added 40,000,000 gallons on the completion of the reservoir mentioned as now being in course of construction. This gives a supply sufficient for a city of 50,000 inhabitants, allowing 70 gallons per capita per diem—a fair estimate, according to the best authorities.

"In addition to the above statements should be reckoned the enormous saving to the Government in the cost of power to the Electric Light Works (175 H. P.), now furnished from our water supply, but for which, if furnished by steam, the fuel alone would cost at least \$8000 per annum without taking into account wear and tear of engines, etc., and other expenses usually required under such circumstances.

"If the projected increase in storage capacity and the increase in the size of the mains be established, and the filtering and pumping plants be procured, according to the plans detailed above, we shall have a system of water works superior to that of most cities, and second to that of no city in the world, for capacity and supply per capita, and facility for distribution, or concentration at any given point, and able to fill the utmost demands made on it in case of fire, even if the city should more than double its population."

*1890-1892.* The policy followed in these years was a continuation of that laid down under the previous administration. There were no extensive works carried out, although plans were suggested and considered for material improvement and extension.

The casing of his Majesty's well at Waikiki had been defective, and the head of water lowered to such a point that it failed to deliver water in sufficient quantities for the residents it served. It was estimated that it would cost so much to re-case the well that it would be better to sink a new one. A well 940 feet deep was drilled on the property of Queen Liliuokalani at Waikiki. An abundant flow of water was obtained, and although it had a marked mineral taste, it was thought at that time that it could be used. It was run into the mains for short periods when needed.

In 1891 a severe drought again visited Honolulu in the spring and summer, and as during the previous shortage of water, everything was done to get sufficient water. The streams and springs were made to deliver all the water they were capable of. The total mountain water supply of June 6th and 7th of this year was 915,642 gallons, and on August 28th of the same year 1,542,405 gallons, while the normal daily consumption of water at this time was estimated at 3,000,000 gallons. The Superintendent of Water Works says: "Had it not been for the artesian supply, meagre though it was, Honolulu would have had one of the greatest scourges that can befall a country or community—a water famine. \* \* \* If a fire had occurred in the city during this dry weather nothing could have saved it."

A fire engine was again attached to Thomas Square well, and the pumping continued for 47 days, at a cost of \$38.10 per day of 14 hours.

This re-occurrence of a prolonged drought emphasized the necessity of providing amply for such emergencies. Previous plans were reconsidered and new ones advanced, the most important of which were:

The construction of Reservoir No. 4 in Upper Nuuanu Valley, with a capacity of about 300,000,000 gallons, for which it was maintained that there would be sufficient water (or, as an alternative, a smaller reservoir lower down); small reservoirs in Makiki, Manoa and Kalihi Valleys; the erection of a pumping plant capable of lifting 3,000,000 gallons daily from artesian wells, and the installation of a small pump at the Makiki well.

Efforts were made to bring about the introduction and erection of the Hyatt Filter, but for various reasons it failed.

Among other items that deserve mention are the investigations that were being made in connection with studying the watersheds. More rain gauges were set up; and the measurements of streams and springs carried out with the object of determining the water available.

*1892-1894-1895.* It was during these years that Hawaii became a Republic, and although there were many changes in administrative affairs, it is interesting to note that the Water Works Bureau adhered pretty closely to the plans laid out during previous administrations.

In 1893 a drought again visited the city, and the well at Thomas Square again came to the relief of the situation; in 1894 there was another shortage of water, and for the last time a fire engine was called into service at this well.

The Makiki well all of this time had been idle. In 1893 a steam pumping plant was finally installed. On testing, it delivered 1,500,000 gallons into the reservoir in 24 hours. During the drought of 1894 it was put into steady service, and so well did it tide the city over the dry season, that it was accepted that proof enough had been given that pumping was the best way of meeting the discomforts of a possible water famine in the future.

Steps were at once taken to arrange for the installation of a pumping plant that would deliver at least 3,000,000 gallons daily. The site finally chosen was on the corner of Beretania and Alapai Streets. The contract for sinking two, 10-inch artesian wells at this place was awarded to McCandless Brothers. The Honolulu Iron Works was awarded the contract for erecting the

pumping plant. A reservoir connected with the pumping plant was to be erected on the slope of Punchbowl hill near the line of Alapai Street.

*1896-1899.* In 1895 a cholera epidemic broke out in Honolulu. The Board of Health, with the coöperation of the public, adopted stringent measures for its eradication. The mountain water was shut off as far as possible, and artesian water substituted because of its being less subject to contamination. Fortunately, the Beretania Pumping Plant had been completed and was delivering about 3,000,000 gallons of water daily.

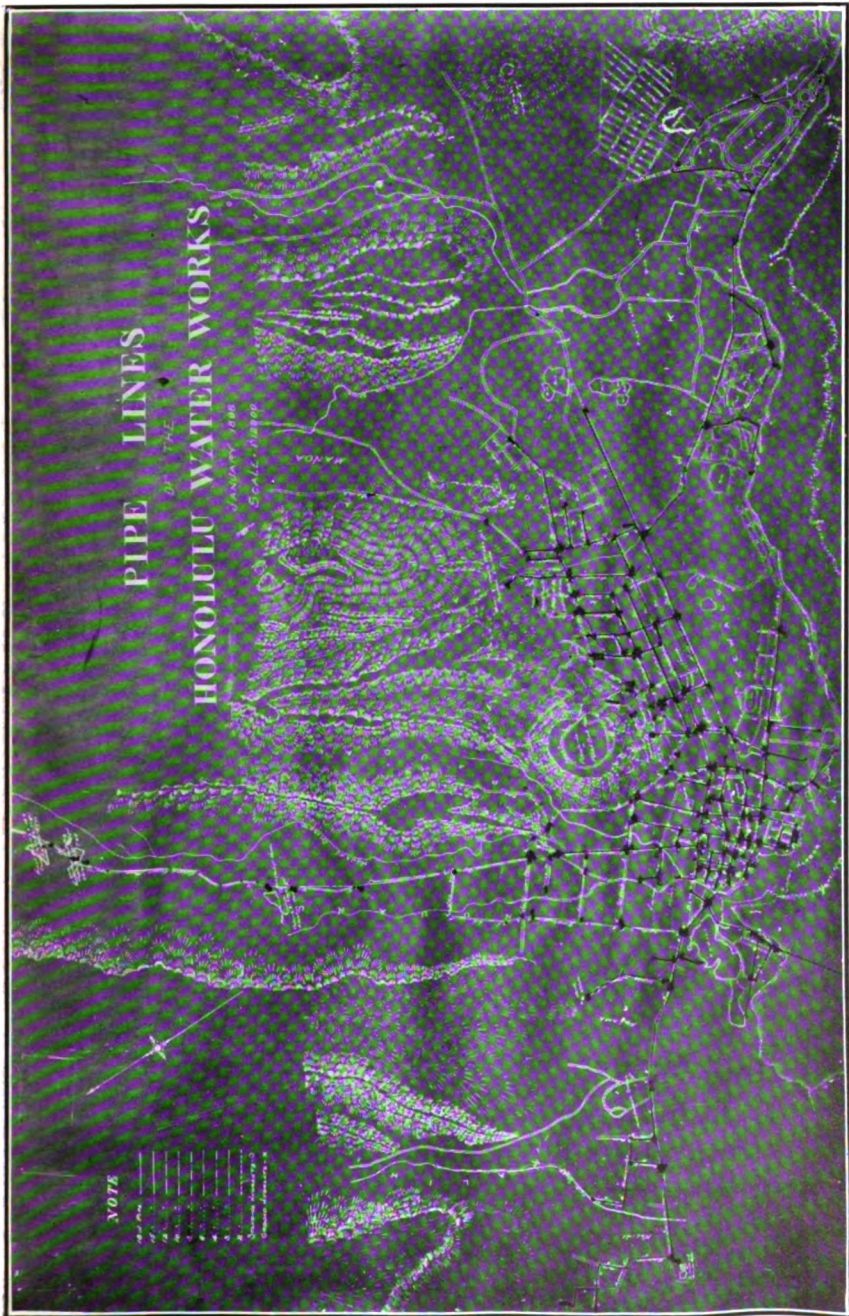
Analyses of drinking waters were made and every precaution to insure pure drinking water was taken. The sanitary condition of the city was investigated, and many districts menacing to public health were cleaned. The cholera was effectively combated. It led to the immediate agitation for a city sewerage system, and Mr. Frank Dodge was sent abroad to examine into the best modern systems adopted in other countries, and on his recommendation, Mr. Rudolph Hering was engaged to lay out plans for a sewer system. These plans corresponded in the essential features with the plans proposed by Major Bender. It was not until the latter part of 1899 that the system was put into operation. During 1899 three 12-inch artesian wells were sunk near the Kamehameha Schools and contracts let for the erection of a 5,000,000-gallon pumping plant. In December of the same year the bubonic plague appeared, and the Board of Health again took drastic measures, and again they urged the filtering of the mountain waters.

*1900-1904.* The Hawaiian Islands were annexed to the United States in 1898, but the Territorial laws did not go into effect until 1900. The Office of Public Works at this time became a Department of the Government, and an assistant superintendent was appointed. The Bureau of Water Works had grown to such an extent that it required a full staff of assistants to carry out its various lines of work.

In 1900 the Kalihi Pumping plant was in working order and Diamond Head reservoir (at an elevation of 150 feet, capacity of 876,000 gallons) was completed.

In the early part of this year a disastrous fire occurred in the Chinese section while attempting to burn some plague-infected buildings, and had it not been for a good water supply the entire city would have been in danger.

Honolulu was expanding in all directions. The Kaimuki tract was opened up, and for its water supply two artesian wells were



THE ONLY MAP FOR 1898 THAT COULD BE FOUND, WAS ONE IN WHICH THE PIPE LINES WERE INDICATED BY STRINGS HELD IN PLACE BY PEGS, THE PEGS APPEARING IN THE PHOTO AS BLACK DOTS.



sunk, and a pumping plant with a capacity of 3,000,000 gallons daily was installed, near the Kapahulu and Waialae roads. The water was pumped to a reservoir built on an elevation near Telegraph Hill. The Palolo Land Company, whose lands were adjacent to the Kaimuki Tract, arranged to get water from this pumping plant.

College Hills, in Manoa Valley, was divided into building lots, and obtained its water supply from the Oahu College artesian well.

An electric road was built up Pacific Heights and property opened for the home-seeker. The water supply for these residents was taken from Pauoa Valley and piped to a reservoir on the Heights. All of these enterprises, with their provision for water supply, were at first carried on by private capital, but later the Government took over the Kaimuki Pumping Plant, and arranged to supply College Hills with water from Makiki Valley. Building was stimulated in other sections of the city, but they were within the limits of the Government water supply.

The contract for the Kalihi reservoir was let in 1904 and work begun. The Diamond Head reservoir was connected to the Kaimuki pump, increasing the efficiency of the water supply at Waikiki.

Among the recommendations made during this period were the construction of Reservoir No. 4 in upper Nuuanu Valley, the filtering of the mountain waters, and a sanitary control of the water supply, which would necessitate a periodical analysis and examination of drinking waters.

*1905-1906-1907-1908.* In 1905 work on the much-agitated upper Nuuanu reservoir was begun (Reservoir No. 4), and the Kalihi reservoir was completed. This reservoir not only greatly increased the Palama and Kalihi supply, but afforded better service to the high buildings in the business center. Its capacity is 3,200,000 gallons.

The Makiki Dam was begun in September, 1906. This dam forms a reservoir of about 800,000 gallons capacity.

Honolulu was again visited by a dry season, although not as severe as those of 1889 and 1894. In April, 1906, it was necessary to call upon the assistance of the Oahu College pumping plant to tide over the shortage, and a fire engine was put to work for a short time to pump from the low to the high-level service.

The Water Works Office at this time recommended the installation of the high-lift pump belonging to the Government then lying in storage at the Honolulu Iron Works. The plan was to

place it in the vacant lot adjoining the Beretania Street Station. This, however, was not done until 1910.

In connection with pumping, it is interesting to note the change from the use of coal to fuel oil at this time. Experiments were conducted at the Beretania Station which showed an economy of 27% in favor of oil.

Mr. Robert A. Duncan made a series of valuable analyses and investigations as to the condition of the waters used for domestic purposes. His work led to the condemnation of some surface wells and in general did much to impress upon the public the necessity of a pure water supply.

Recommendations were made to erect a reservoir in Kalihi Valley, with the object of supplying the residents of this higher level, and of collecting the waters of the valley and conducting them to the Kalihi reservoir, situated on the slopes back of the Kamehameha Schools.

A proposal was made to the Government for the purchase of the water sources of Pauoa Valley, but no definite terms of agreement were arrived at.

*1909-1910.* It fell to the incoming Superintendent of Public Works at this period to complete the Nuuanu dam and reservoir (No. 4), which had been begun in 1905, but for various reasons was still unfinished. The work was concluded June 30, 1910. This reservoir was the greatest single work of this kind undertaken by the Government up to this time, and its completion marked the conquest of Nuuanu Valley—a conquest of 60 years. This reservoir is capable of storing 625,000,000 gallons of water; and it cost \$298,563.38. The work was done by citizen labor. It is interesting to compare figures relating to this dam with those of other dams, such as Wahiawa:

	Wahiawa Dam.	Nuuanu Dam.
Maximum height above stream bed .....	106 ft.	79 ft.
Length on crest .....	430 ft.	2,497 ft.
Width on crest .....	20 ft.	10 ft.
Total width on base up and down stream .....	580 ft.	336 ft.
Inner slope .....	4.1	3.1
Outer slope .....	3/4.1	2.1
Width of dam at water line .....	60 ft.	60 ft.
Total yardage of earth....	141,303 cu. yds.	261,340 cu. yds.

Total yardage rock fill ...	26,000 cu. yds.	13,000 cu. yds.
Total of all fill.....	167,303 cu. yds.	274,340 cu. yds.
Concrete .....	4,581 cu. yds.	1,697 cu. yds.
Area of rip rap.....	32,000 sq. ft.	159,075 sq. ft.
Clearing on dam site.....	13,193 sq. yds.	11 acres
Clearing reservoir basin—		
all trees and shrubbery..	3½ acres	35 acres
Spillway .....	9,200 cu. yds.	8,600 cu. yds.
Total cost .....	\$242,483.88	\$298,563.86

Besides storing 625,000,000 gallons of water, the water from Reservoir No. 4 augments the power for the city electric light plant.

Plans were proposed whereby the water from Reservoir No. 4 could be utilized for the development of more electric power to be used for pumping artesian water at the several pumping stations, so reducing the cost of pumping.

In February, 1910, two 12-inch artesian wells were successfully drilled in the vacant lot next to the Beretania Pumping Station, and the high-lift pump that had been in storage for a long time was installed. This gave the city an additional supply of about 3,000,000 gallons, which could be distributed to the high, as well as the low-level service.

Plans were considered for utilizing the surplus artesian water from the Honolulu Rapid Transit and Land Company, Hawaiian Electric Company and the Honolulu Iron Works by delivering it to the city mains. At this time, work was commenced on the new Kaimuki Reservoir on Telegraph Hill.

Researches were begun in 1909 to ascertain the limits of the artesian water supply, and information obtained upon this subject was embodied in a special report. Efforts were made to collect systematic records of the rainfall in the water-shed area, and accurate measurements of the discharge of the springs and streams therein.

A small laboratory was fitted up for the examination and analysis of public and private drinking waters, looking toward the establishment of a systematic sanitary control of the actual and possible sources of Honolulu's water supply for the protection of the public health.

*June 30, 1910-June 30, 1912.* The new reservoir at Kaimuki was completed and greatly relieved the water situation for that section. The old reservoir, long inadequate, was abandoned.

This reservoir was the first reinforced concrete reservoir built by the Government. It has a capacity of 750,000 gallons, and was built at a cost of about \$22,000. The top of the reservoir was sealed over except for the necessary vent holes. On account of its situation on Telegraph Hill, 300 feet above sea level, commanding a view from Koko Head to Barber's Point, it was proposed to provide seats and benches and make it accessible to the public.

The College Hills district had frequently been troubled by turbid surface water, which mixed with the clear Makiki Spring water. To obviate this, an electric pump was installed at the Makiki Pumping Station, by which arrangement the artesian water pumped into the Makiki Reservoir by the Beretania pump, and from the Makiki well by the old pump, could be distributed to the College Hills district, so augmenting the spring water supply, and eliminating the objectionable surface water. The cost of installing this electric plant was about \$6829.

The old Kaimuki pump, purchased from the Kaimuki Land Company, had been pumping for both Kaimuki and Waikiki and working continuously at full capacity. If a breakdown had occurred, both sections would have been greatly inconvenienced. To relieve this overworked pump, two 12-inch artesian wells were sunk near the Kaimuki Pumping Station and arrangements made for installing an electric pump. The main leading to the reservoir was replaced by an 18" pipe.

The increased amount of building in the Punahou and College Hills districts necessitated an increased water supply. Punahou had been supplied chiefly by the Beretania and Makiki pump water, but the long-distance delivery and the increasing demands upon it by other nearer sections of the city, made a severe tax on the Beretania pump, and to relieve it two 12-inch artesian wells were sunk near the Marques property and plans made for connecting an electric pump.

With the high-lift pump at Beretania Street, and the electric pumps at Kaimuki and Punahou, these sections of the city would be fortified against shortage of water by the disabling of any one of these pumps. For a number of years the Water Works had been working towards such a reinforcement.

While there were good general rains in the winter of 1910-11, the period from the summer of 1911 on, was very dry, and it was owing only to the good pumping installation that consumers were not seriously inconvenienced by a water shortage.

In 1911 a few cases of cholera appeared in the city, which led to a close investigation of the water supply. Fortunately, for Honolulu, most of the drinking water is artesian water and is notably pure, so that there is little danger of the spread of such diseases through the drinking water supply.

On account of the warm climate, and owing to the fact that the majority of the homes in the residence districts of the city have generous yards and gardens, the amount of water consumption is high—two or three times higher than the consumption in many other cities. Including the water used by manufacturers, the Honolulu consumption amounts to about 350-400 gallons per day, per capita. In order to ascertain the comparative cost of delivering water to the public, letters were sent out to a number of cities in the United States and foreign countries. Comparing the figures, it was found that the Honolulu Water Works delivered water at a very low rate, among the lowest—about 6½ cents per 1000 gallons.

The work with special reference to artesian supply was continued. Monthly records were kept showing the rise and fall of the artesian level. The investigations showed that the artesian level had been gradually falling at the rate of about .4 to .5 of a foot annually. During the period 1910-1912 the artesian level stood at about 28 to 30 feet above sea level. The investigations led to the estimate that about 35,000,000 gallons of water were being drawn daily from the artesian wells within the city limits, and that only approximately 25,000,000 gallons daily can be drawn without permanently lowering the artesian level.

*June 30, 1912, to June 30, 1913.* The work of conserving the artesian supply was continued. The old law of 1884 (somewhat revised), concerning artesian wells, was put into force and many heretofore uncapped wells were properly capped. It was found difficult to determine the exact significance of certain wordings of the law, and consequently the extent of the Government's authority according to this law. One important question arose as to what constituted "waste" in connection with the discharge waters of certain manufacturies using water from their own wells, the discharge waters being of good quality and fit to be delivered into city mains. The total amount of these discharge waters from the manufactories of the city was about 4-5 million gallons per day—equal to about one-third of the amount pumped by the Government for the public supply.

A bill, providing for greater control by the Government over the artesian wells, was presented to the Legislature and passed with some modifications, but failed to become a law.

Lack of rain resulted in excessive drought both in the uplands and lowlands; the mountain supply fell short and all the pumps were worked to the limit of safety; it was necessary to restrict irrigation for the entire city to four hours a day, and inspectors were sent out to enforce the restriction regulations.

The shortage of water brought up again the question of meters. A bill, providing for the installation of meters, was introduced into the Legislature of 1909, notwithstanding there was considerable opposition, and the bill passed and became law—Act 112.

An appropriation of \$100,000 had previously been made for the purchase of the Booth water rights in Pauoa Valley, but the purchase had never actually been made. The Government again investigated the water rights of the valley and made careful surveys.

Water rights in Palolo Valley were purchased by the Government from the Palolo Land and Improvement Company for \$40,000, and additional appropriations of \$25,000 and, later, \$15,000 were made for the installation (pipe line, reservoir, etc.) necessary to deliver water to the higher levels of Palolo Hills. The water comes from springs at the base of Palolo Crater, and is a good clear water. The discolored surface water from the crater was side-flumed to a point below the intake, so separating the spring and surface water. Pipes were laid to conduct the water to a concrete reservoir on Wilhelmina Rise. Besides this water right, the purchase included an old water system comprising springs, concrete reservoir, and some pipe line. The concrete reservoir had been built by one Philip Milton in the early '80's with the idea of irrigating some of the lower lands.

The discolored surface water in the Palolo Crater was examined and it was found that a treatment with lime and either alum or clay would render it unobjectionable.

Venturi meters for measuring the amount of water pumped were installed at the Kalihi, Beretania and Kaimuki Pumping Stations. These meters do away with the old method of measuring the amount of water pumped by piston displacement.

An electric pump, intended for the Punahou plant, was temporarily installed at the Kaimuki Pumping Station and attached to the two new wells. It is capable of delivering 1,500,000 gallons per day and cost \$6829.

A concrete reservoir was built on one of the higher elevations of Alewa Heights to receive water from the Nuuanu Reservoir. It has a capacity of 480,000 gallons and cost \$5040 first, re-construction, \$6125. Total, \$11,165.



During the period extensive additions were made to the pipe lines throughout the city.

*June 30, 1913.* Palolo Hill Concrete Reservoir built; capacity, 425,000 gallons; cost, \$12,198.

A concrete reservoir with a capacity of 725,000 gallons was built on Rocky Hill to supply the lower College Hills section. Water is pumped into it by an electric pump at Punahou attached to the two artesian wells near the Marques property. The reservoir was built at a cost of \$17,900.00.

In recounting the work accomplished during these different periods, little mention has been made of the constant work of the laying and re-laying of pipes, and the general repairs of all kinds, which represent in themselves a great deal of labor and the necessary expenditure of large sums of money.

The use of plenty of water in a tropical city is not only desired for comfort, but necessary for the public health. The amount of water per capita allowed for people living in temperate and colder latitudes would be wholly insufficient for the tropics. In the early development of the Honolulu Water System some engineers estimated that 70 gallons per capita would be ample for a tropical city like Honolulu, since 60 gallons was considered a liberal supply for cities in the United States and Europe. Today Honolulu uses over five times that, or three times the amount used in many cities in the United States.

The area of the present limits of Honolulu, say, from Fort Shafter to Ocean View, in colder climates would support a population of 300,000 or more, but under tropical conditions it could not comfortably support more than half that number. The city's present population is about 55,183, and its daily consumption of water (exclusive of crop irrigation) is more or less 20,000,000 gallons, including water for manufacture, etc., of which the Honolulu Water Works supplies from 12 to 15 million gallons. It is probable that in twenty or thirty years, Honolulu will have increased its population to 100,000; and at the present rate of consumption, such a city would require 45,000,000 gallons of water daily. The Water Works Bureau has, therefore, the double duty of looking forward to future requirements as well as of providing for present needs.

The following is a list of the Ministers of Interior and Superintendents of Public Works, who were responsible for the inception, development and advancement of the Water Works System of Honolulu:

#### MINISTERS OF INTERIOR.

Dr. G. P. Judd.....	March 30, 1845, to March 4, 1846.
John Young 2nd.....	March 4, 1846, to June 6, 1857.
Lot Kamehameha.....	June 6, 1857, to December 24, 1863.
G. M. Robertson.....	December 24, 1863, to Feb. 18, 1864.
C. G. Hopkins.....	February 18, 1864, to April 26, 1865.
F. W. Hutchinson.....	April 26, 1865, to January 10, 1873.
E. O. Hall.....	January 10, 1873, to February 17, 1874.
H. A. Widemann.....	February 17, 1874, to October 31, 1874.
W. L. Moehonua.....	October 31, 1874, to December 5, 1876.
J. Mott-Smith.....	December 5, 1876, to July 3, 1878.
S. G. Wilder.....	July 3, 1878, to August 14, 1880.
J. E. Bush.....	August 14, 1880, to September 27, 1880.
H. A. P. Carter.....	September 27, 1880, to May 20, 1882.
Simon K. Kaai.....	May 20, 1882, to August 8, 1882.
J. E. Bush.....	August 8, 1882, to July 26, 1883.
W. M. Gibson, ad interim.	July 26, 1883, to August 6, 1883.
C. T. Gulick.....	August 6, 1883, to June 30, 1886.
W. M. Gibson.....	June 30, 1886, to October 13, 1886.
L. Aholo.....	October 13, 1886, to July 1, 1887.
L. A. Thurston.....	July 1, 1887, to June 17, 1890.
C. N. Spencer.....	June 17, 1890, to September 12, 1892.
C. T. Gulick.....	September 12, 1892, to Nov. 8, 1892.
Geo. N. Wilcox.....	November 8, 1892, to January 13, 1893.
Jno. F. Colburn.....	January 13, 1893, to January 17, 1893.
Jas. A. King.....	January 17, 1893, to October 16, 1899.
Alexander Young.....	October 27, 1899, to June 14, 1900.

#### SUPERINTENDENTS OF PUBLIC WORKS.

J. J. McCandless.....	June 14, 1900, to April 30, 1901.
J. H. Boyd.....	May 4, 1901, to December 6, 1902.
H. E. Cooper.....	December 6, 1902, to Nov. 17, 1903.
C. S. Holloway.....	November 25, 1903, to October 31, 1907.
Marston Campbell.....	November 1, 1907, to October 31, 1912.
H. K. Bishop.....	November 1, 1912, to May 2, 1913.
J. W. Caldwell.....	May 2, 1913, to .....

## STAFF OF HONOLULU WATER WORKS.

## Superintendent of Water Works.

2 Clerks.

7 Inspectors.

1 Foreman.

4 Tappers and Helpers.

4 Assistant Tappers.

2 Reservoir Keepers.

1 Shipping Tender.

1 Assistant Shipping Tender.

1 Chief Engineer for pumps.

*Beretania Pump.*

3 Engineers.

3 Firemen.

3 Oilers.

*Kalihi Pump.*

3 Engineers.

3 Firemen.

*Kaimuki Pump.*

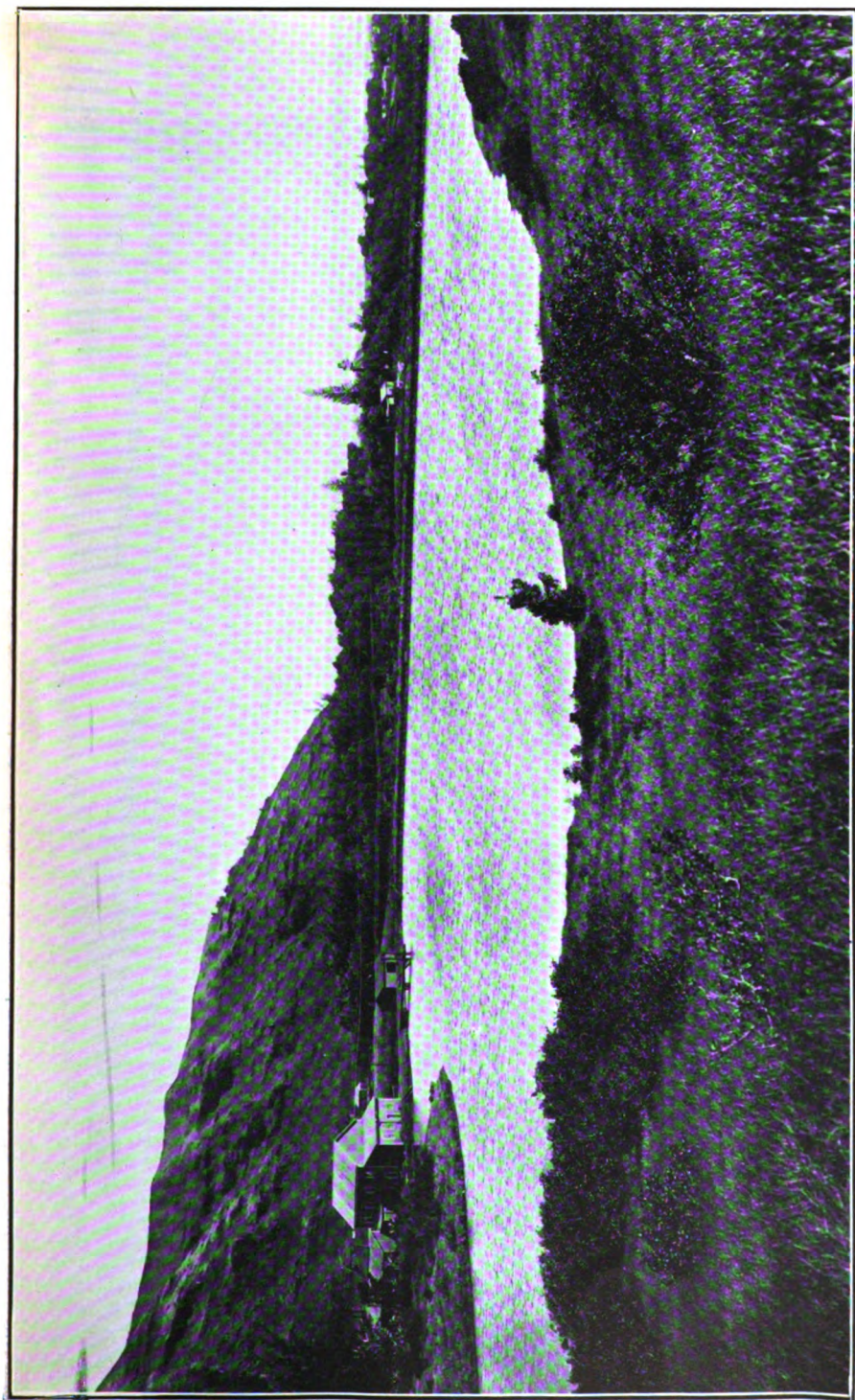
3 Engineers.

3 Firemen.

1 Oiler.

*Makiki Pump.*

2 Engineers.



RESERVOIR NO. 1, NUUANU VALLEY—AT ELECTRIC LIGHT STATION.





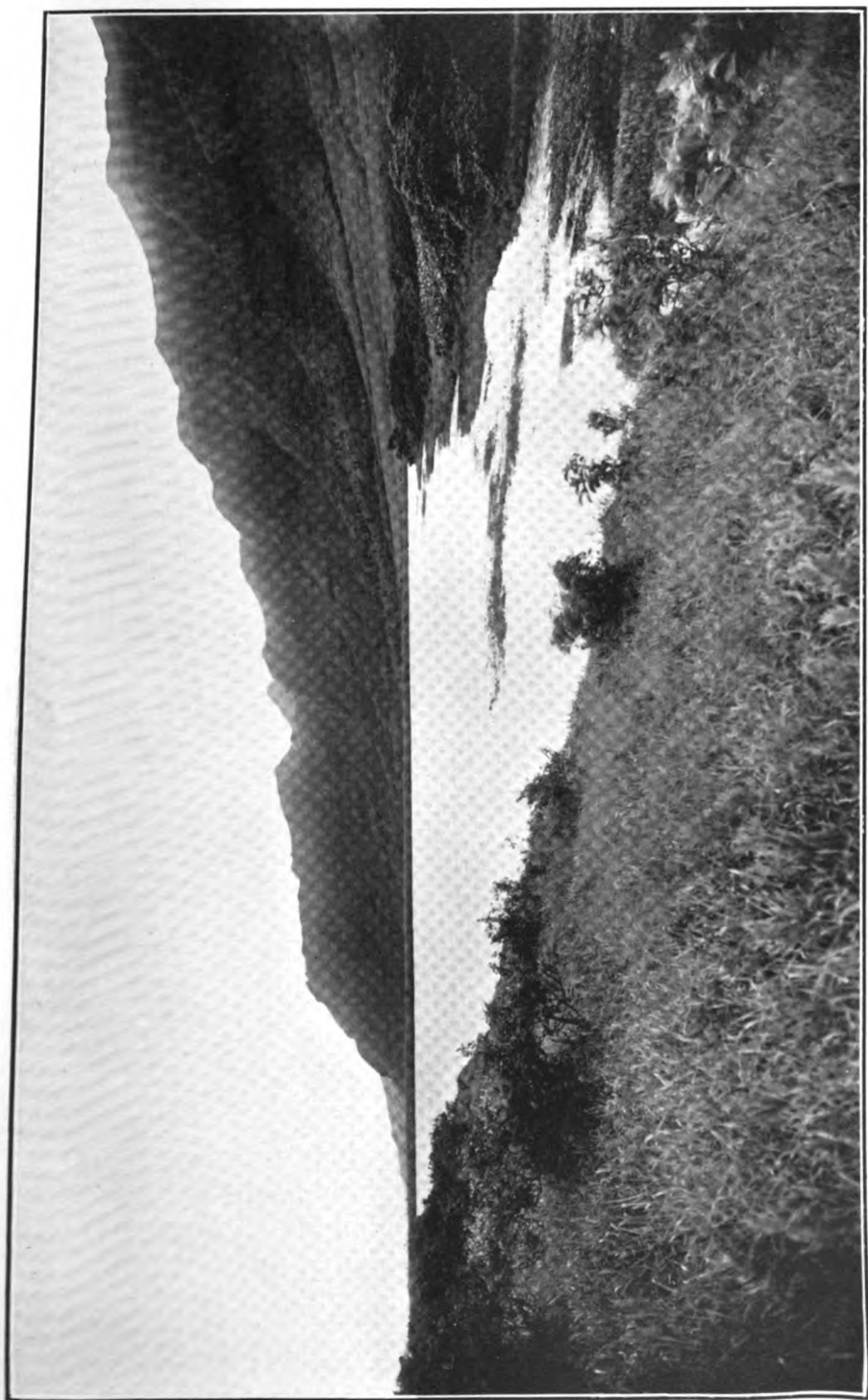
AIR CHAMBERS AT THE END OF 30" LOCK BAR PIPE LINE AT NO. 1 RESERVOIR.



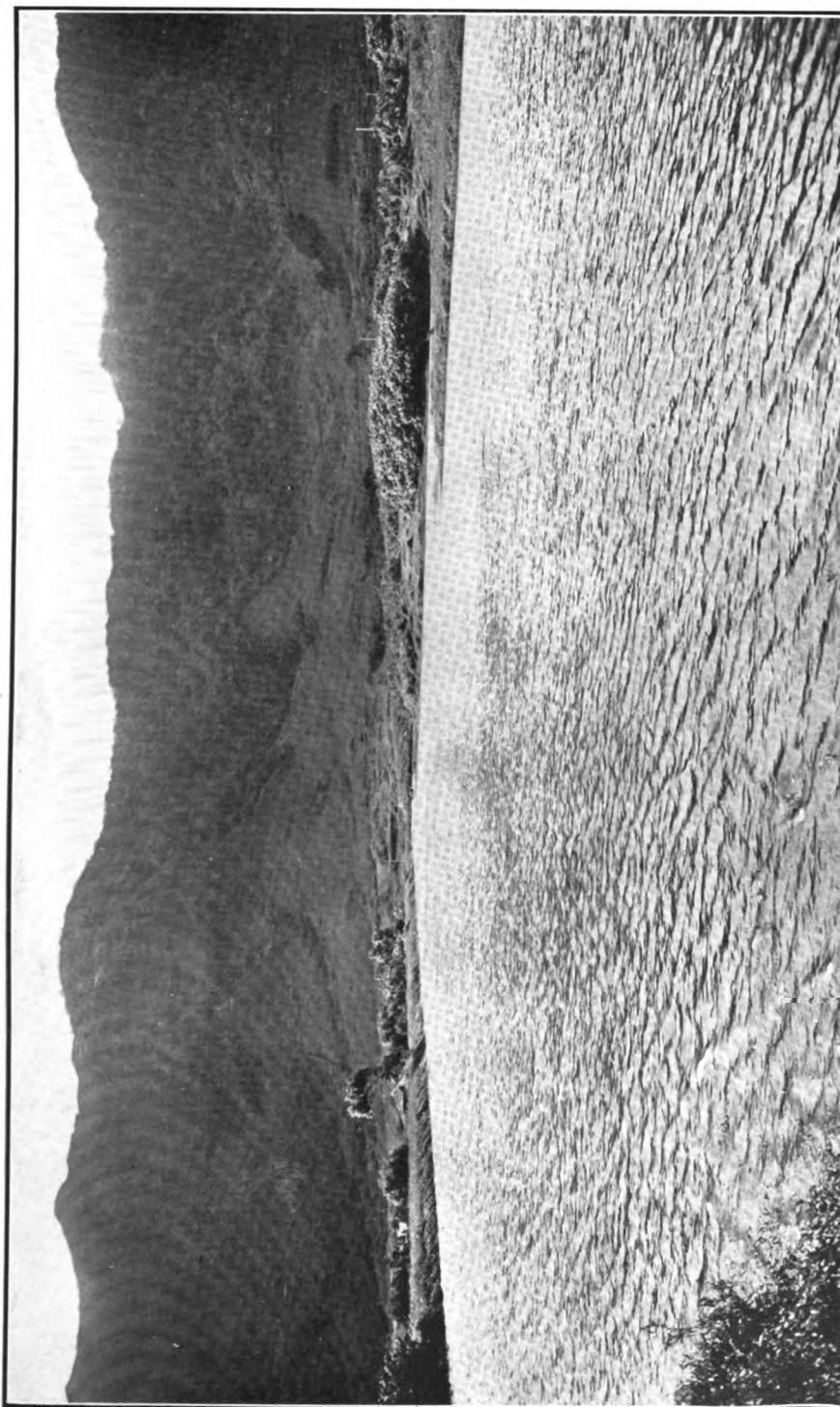


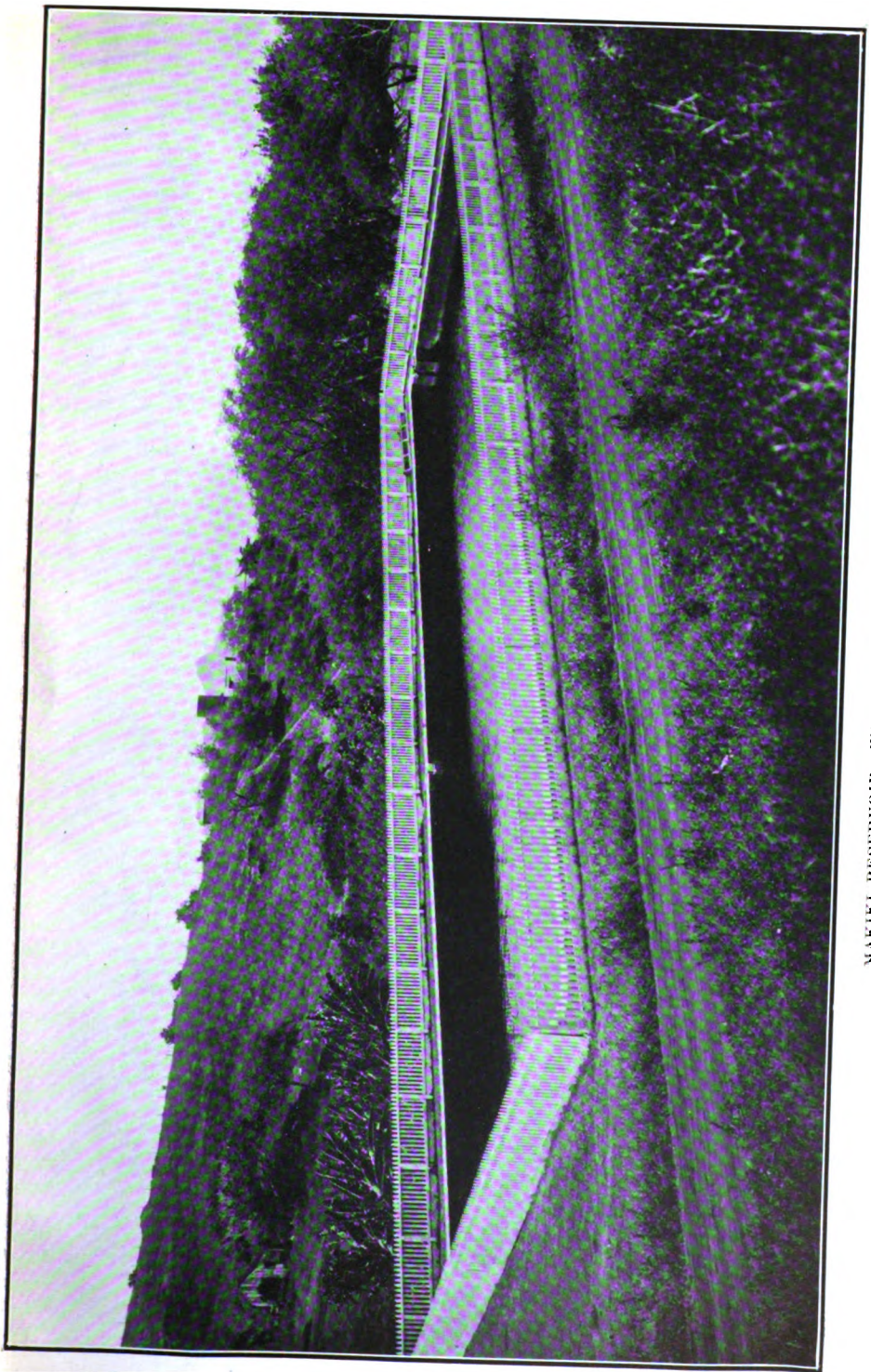
8" DISCHARGE PIPE FROM 30" LOCK BAR PIPE LINE AT NO. 1 RESERVOIR.





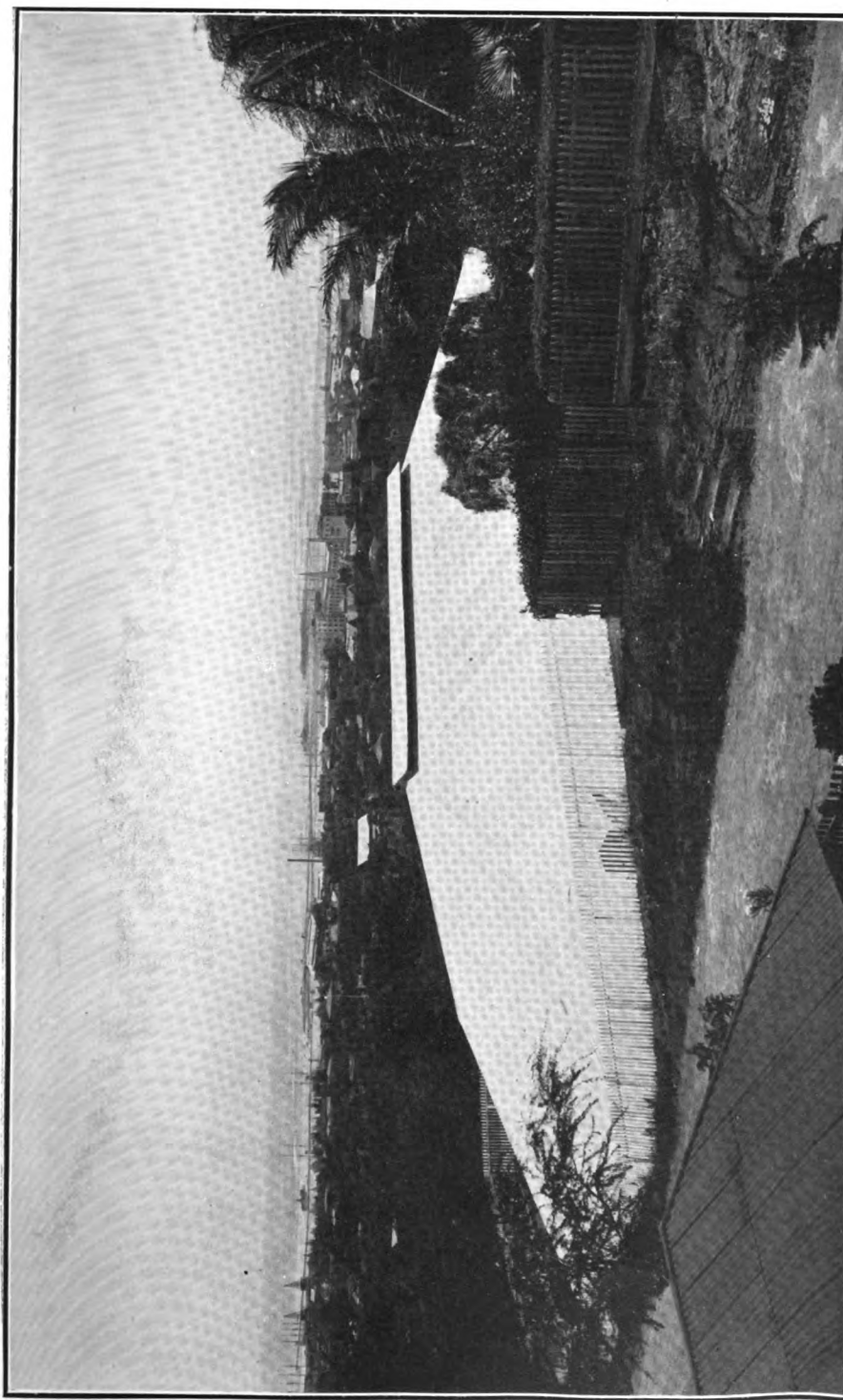
RESERVOIR NO. 2, NUUANU VALLEY, NEAR HALF-WAY HOUSE.

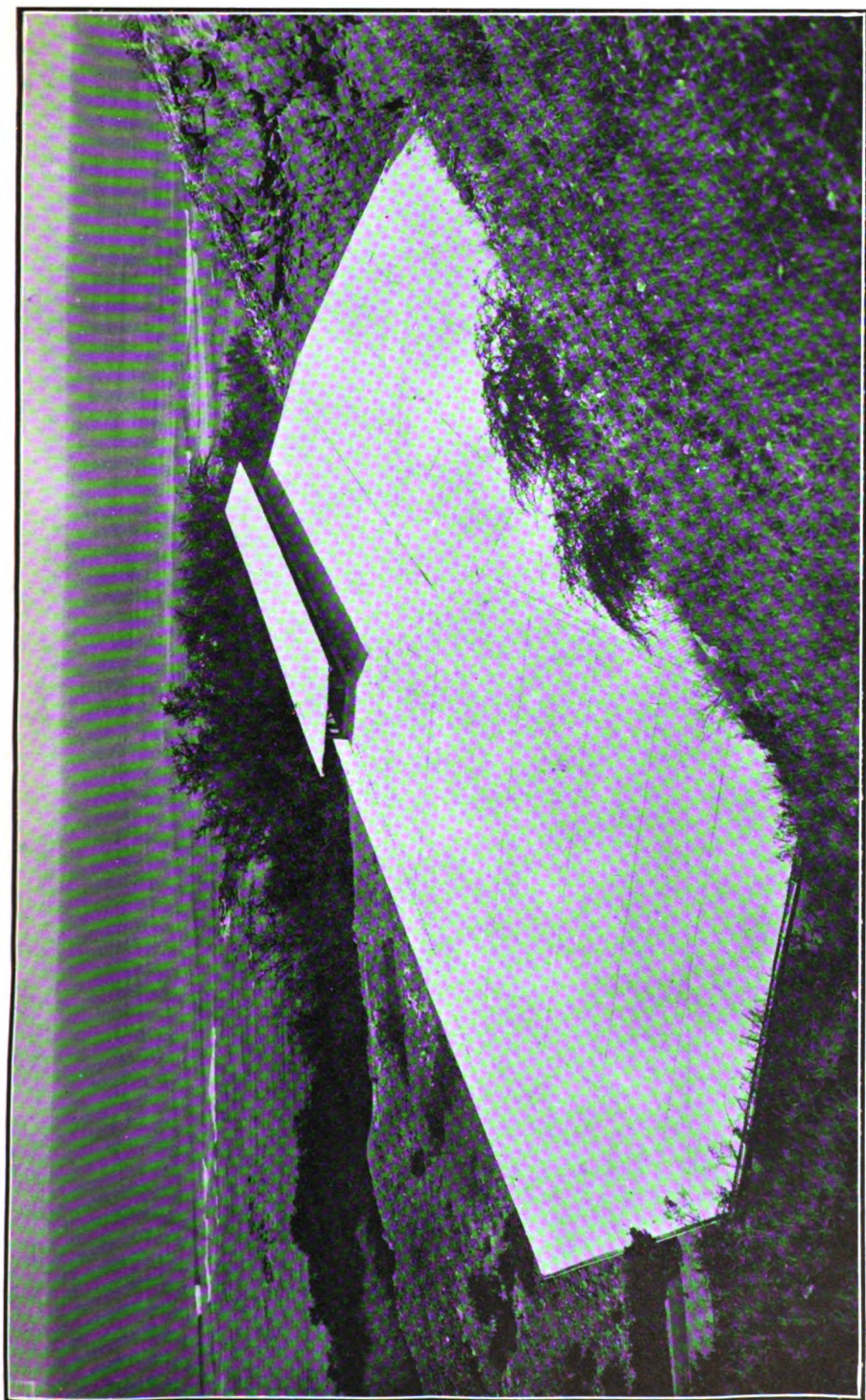




MAKIKI RESERVOIR (WITHOUT THE CONCRETE TOP).

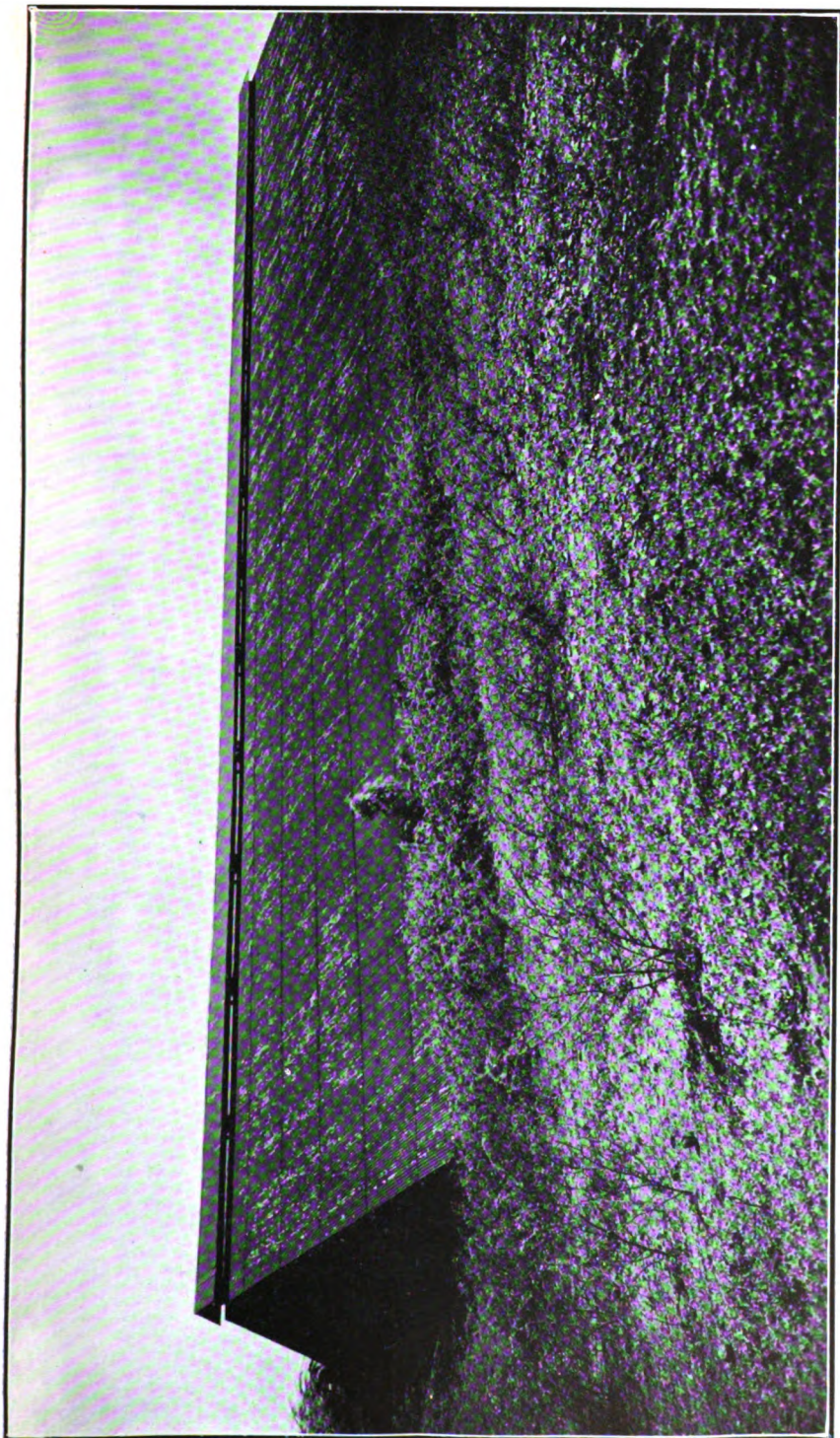






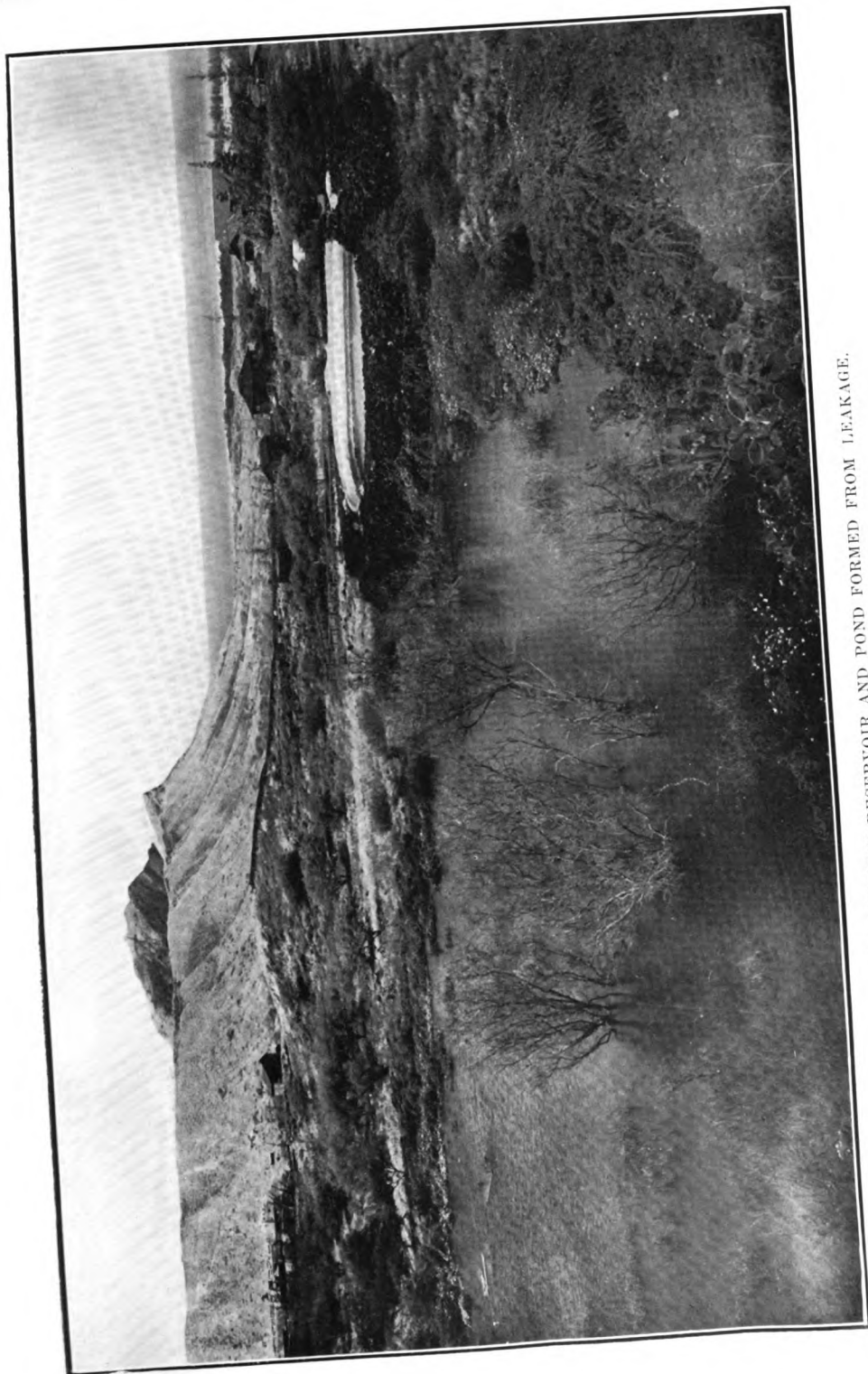
DIAMOND HEAD RESERVOIR.



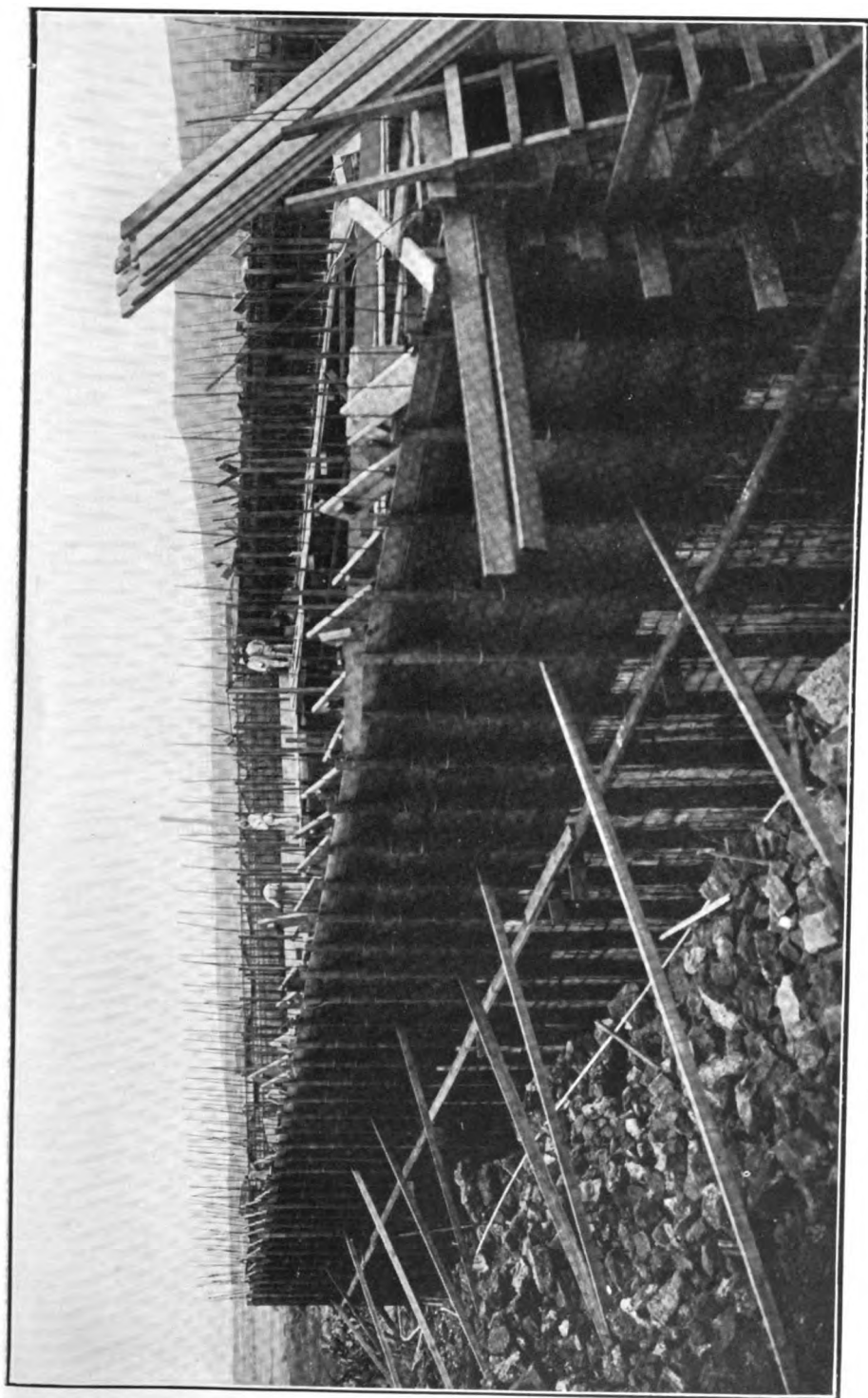


KALIHI RESERVOIR.

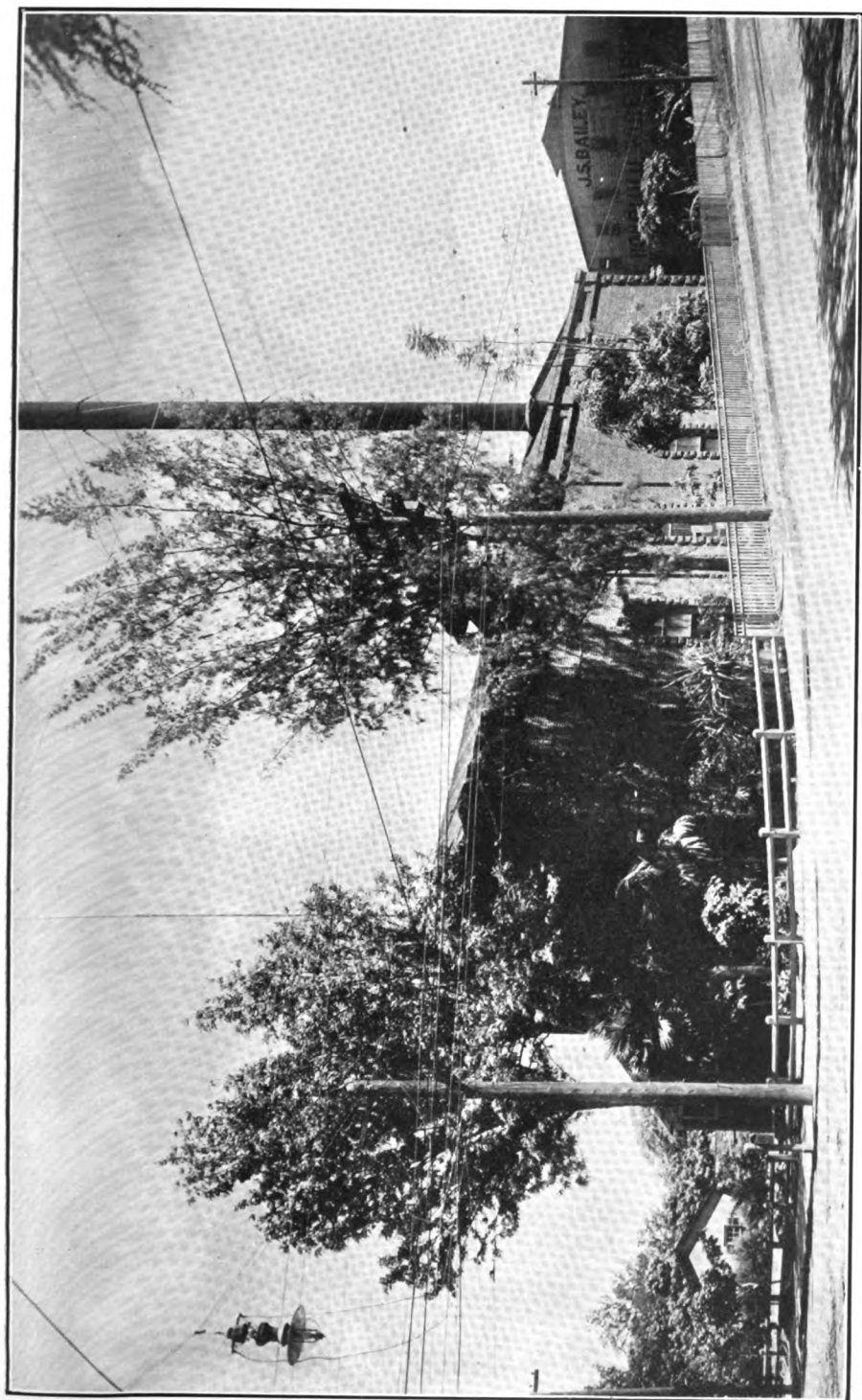




OLD KAIMUKI RESERVOIR AND POND FORMED FROM LEAKAGE.

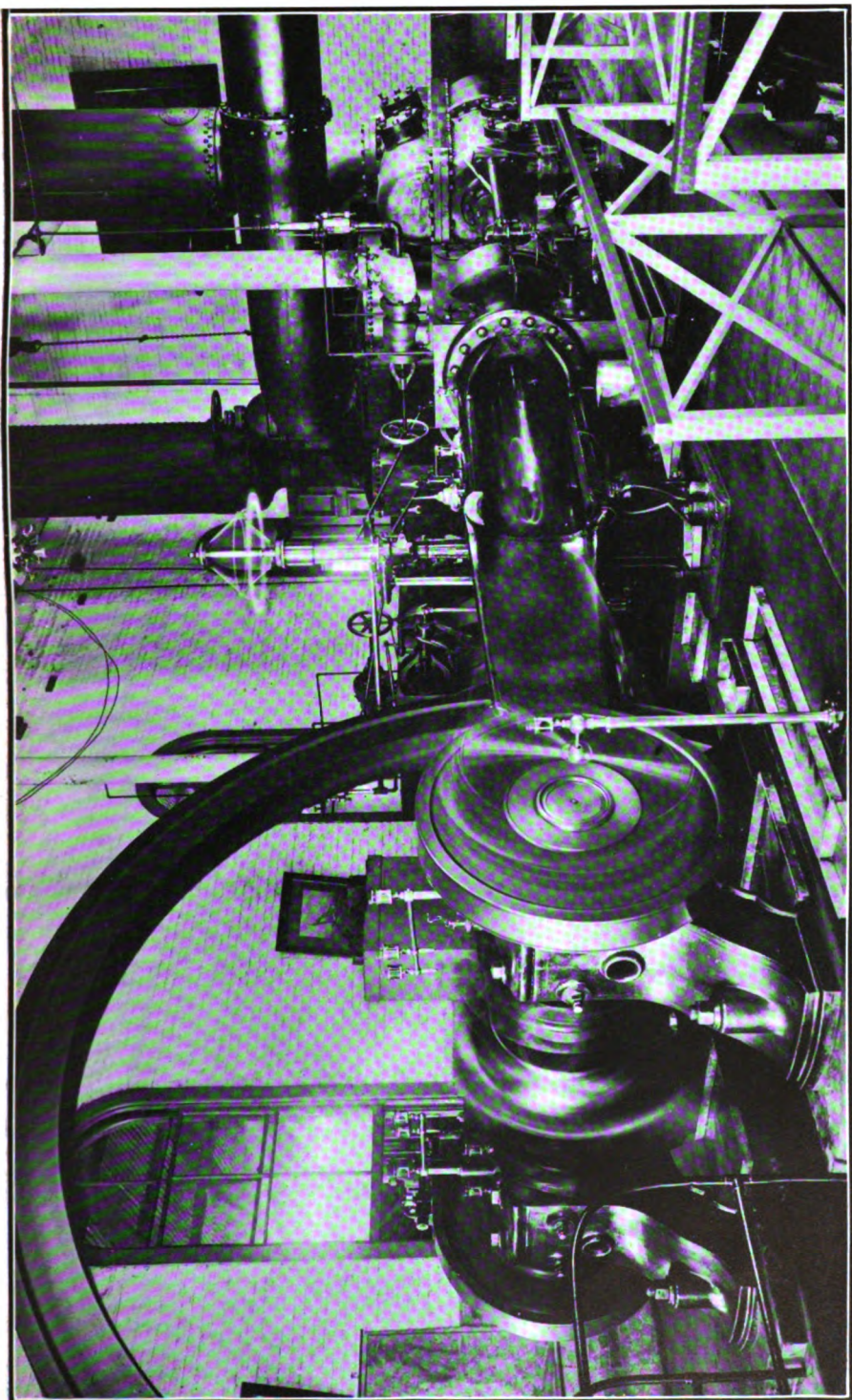


NEW KAIMUKI RESERVOIR IN COURSE OF CONSTRUCTION.

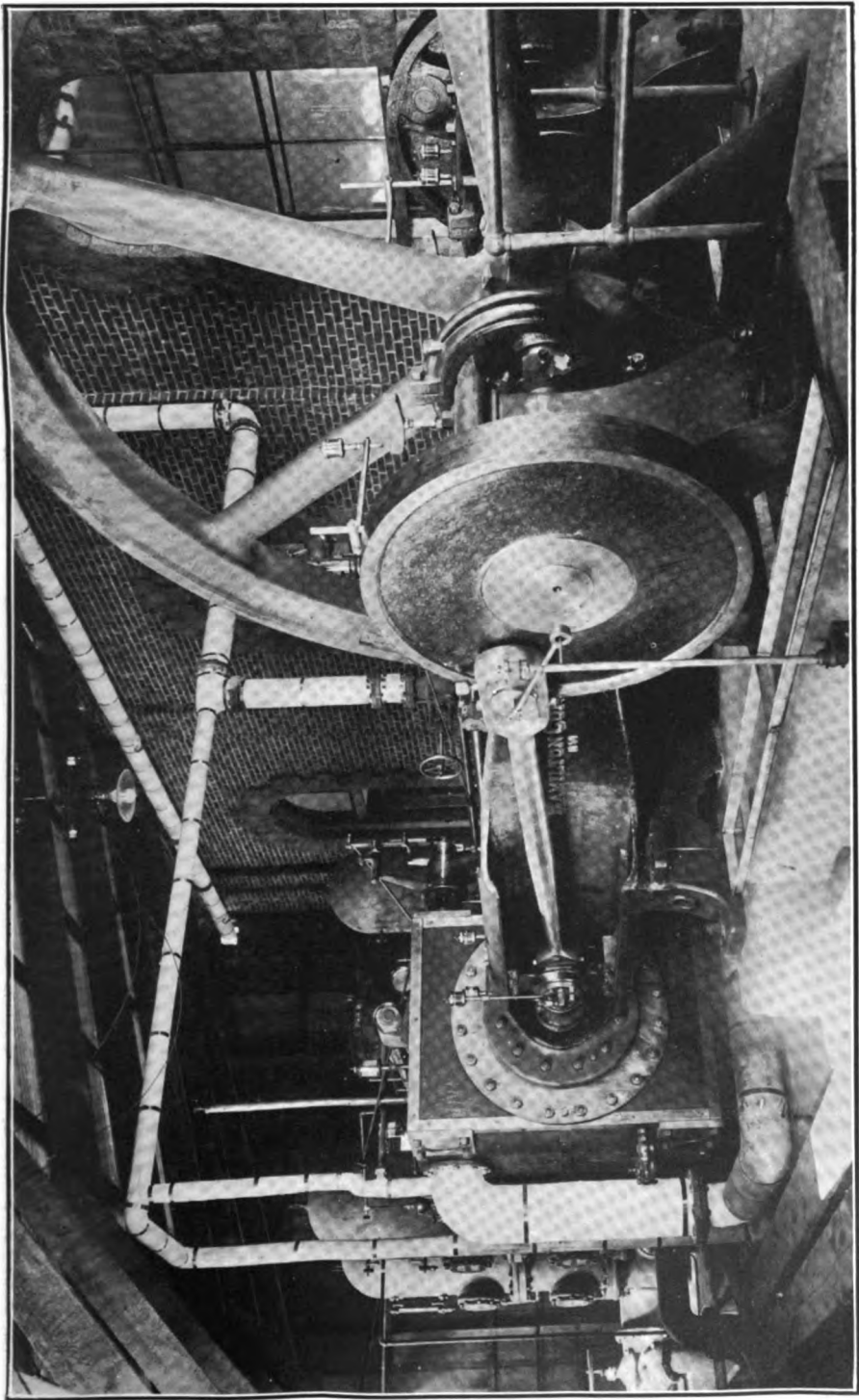


BERETANIA PUMPING PLANT.





BERTANIA PUMPING PLANT (INTERIOR).



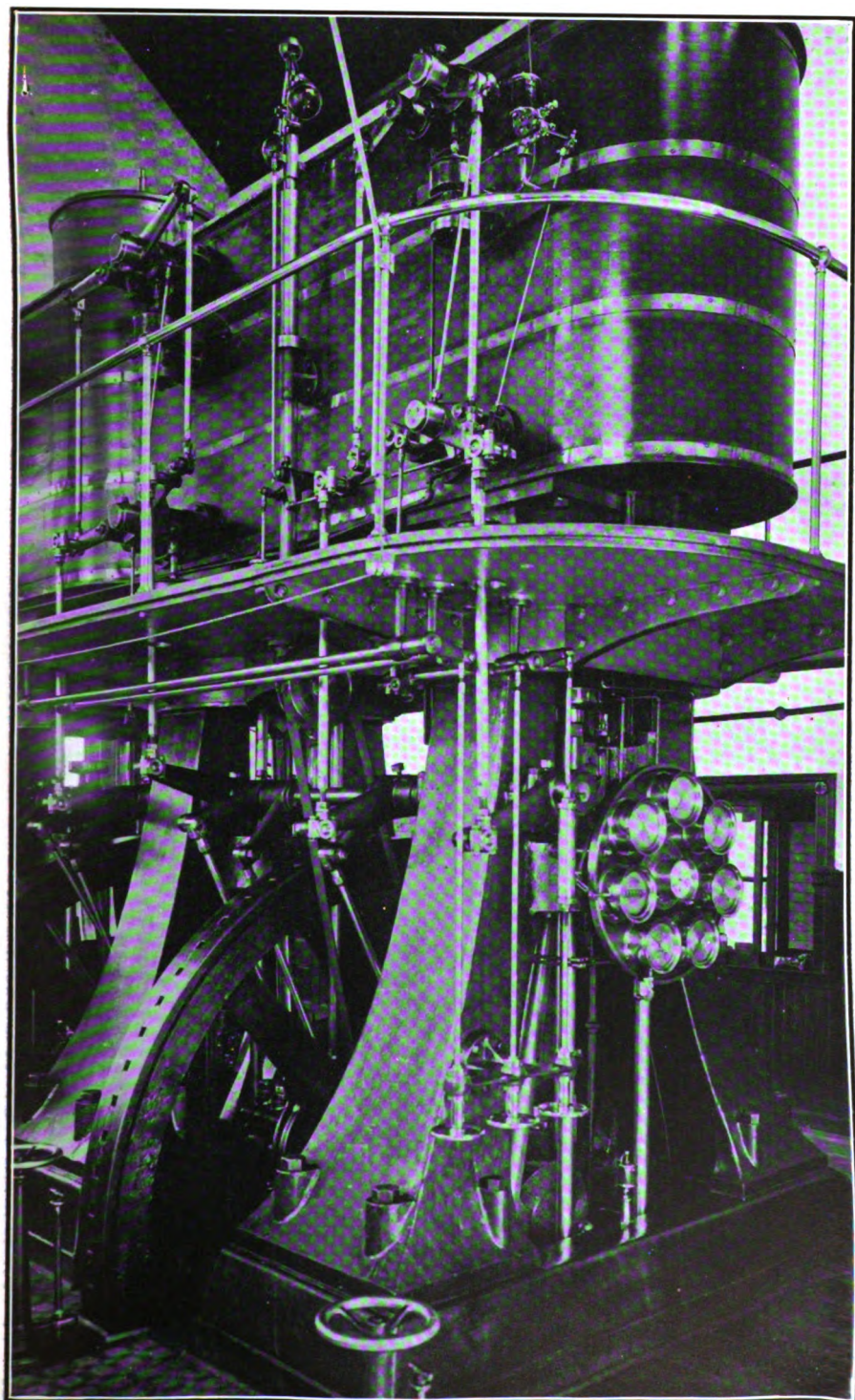
HIGH-LIFT PUMP, BERETANIA STATION.





KALIHI PUMPING PLANT.





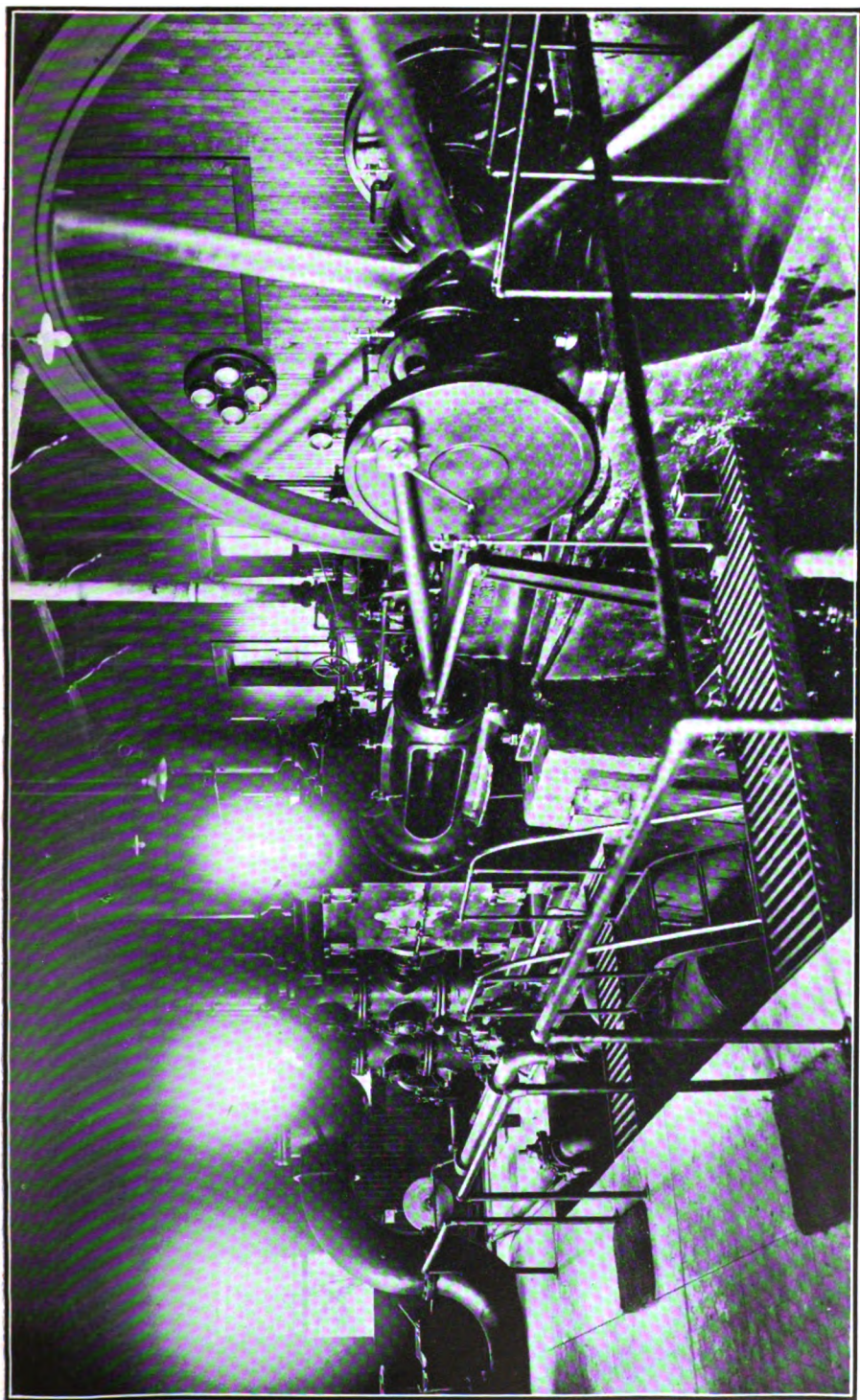
KALIHI PUMPING PLANT (INTERIOR).



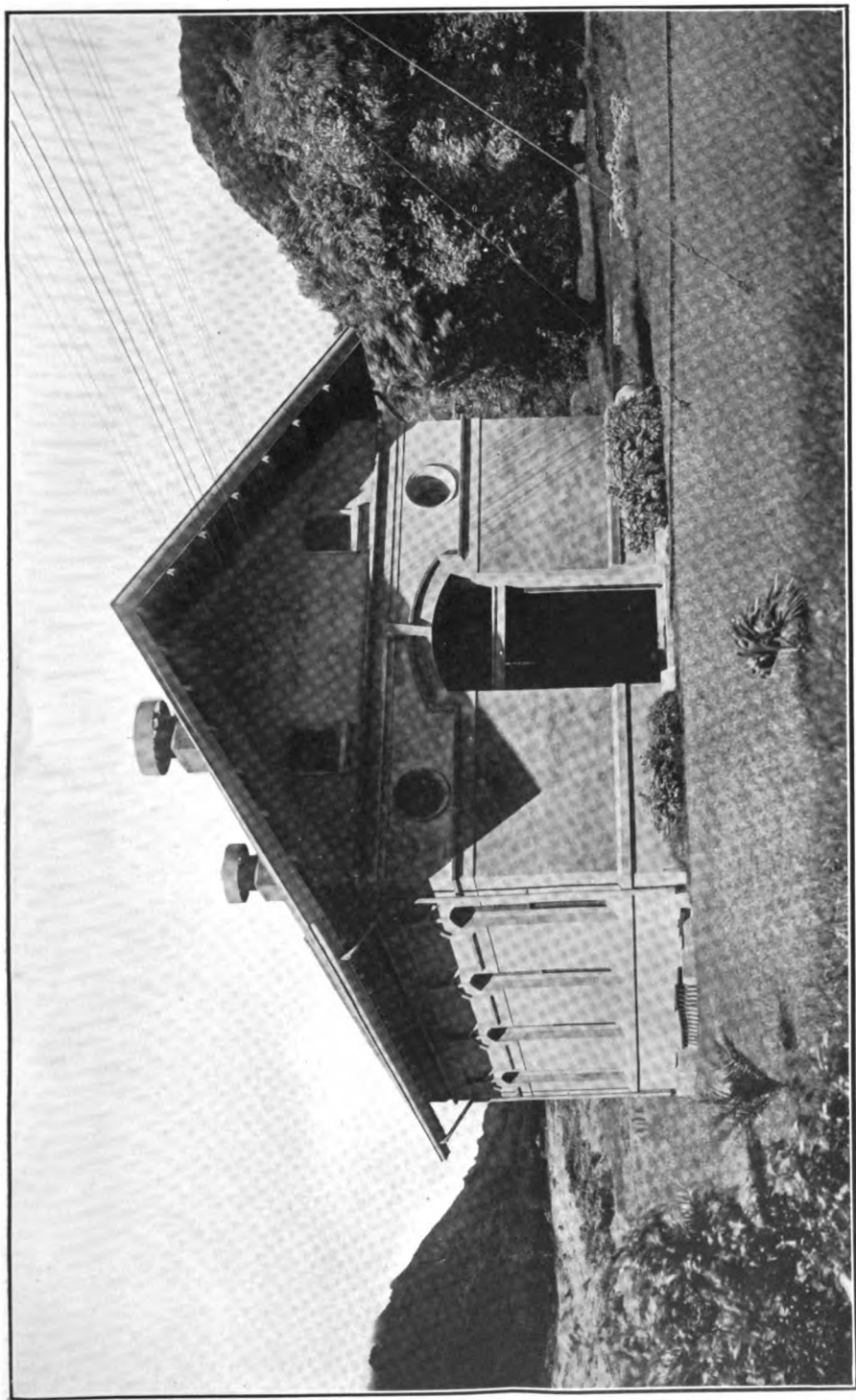


KAIMUKI PUMPING PLANT.





KAIMUKI PUMPING PLANT (INTERIOR).



ELECTRIC LIGHT STATION AT RESERVOIR NO. 1.