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Engineering Notes On Hawaii

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BROOKLYN ENGINEERS' CLUB.

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No. 43.

ENGINEERING NOTES ON HAWAII.

BY ARTHUR S. TUTTLE, Mem. B. E. C.

PRESENTED NOVEMBER 13, 1902.

The Hawaiian Islands, comprising the territory of Hawaii, extend in a southeasterly direction from latitude $22^{\circ} 15' N.$ and longitude $160^{\circ} 30' W.$ to latitude $18^{\circ} 55' N.$ and longitude $154^{\circ} 50' W.$ Commencing at the north, the principal islands of the group are Niihau, Kauai, Oahu, Molokai, Lanai, Maui, Kahoolawe, and Hawaii; there are a few additional ones of insignificant size lying still further to the north and west.

Owing to their position, the islands have a commercial and strategic position by no means insignificant, lying as they do in the path of almost every line of steamers crossing the Pacific. Statistics for the year ending June 30th, 1901, show that 662 steamers, war vessels and sailing vessels made the ports of Honolulu and Hilo, over 90% of the number entering the former. The advantage to the United States of ownership of these islands, in connection with the development and control of our new possessions in the far East, is very great, permitting of the maintenance here of a base of supplies and a naval repair yard.

There are no incorporated cities on the islands, and the territorial government is conducted entirely from Honolulu, this place having been recognized as the capital since the days of Kamehameha I, the first monarch of the group, whose reign began in 1795. Here is clustered the greatest population, probably aggregating 45 000, Hilo, on Hawaii, ranking second. A movement to establish city, town

and county organizations has recently been recommended by the United States Senate Committee.

Recent statistics concerning the area, elevation, and population of the islands show the following:

Islands.	AREA.		Highest elevation. Feet.	Population. 1900.
	Square miles.	Acres.		
Niihau	97	62 000	800	
Kauai	544	348 000	4 800	20 730
Oahu	600	384 000	4 030	58 510
Molokai	261	167 000	4 958	3 120
Lanai	135	86 000	3 400	
Kahoolawe	69	44 000	1 427	
Maui	728	466 000	10 032	24 800
Hawaii	4 015	2 570 000	13 825	46 840
Total	6 449	4 127 000		154 000

The population is classified approximately as follows:

Race.	Male.	Female.	Total.
Caucasians	16 200	12 800	28 500
Hawaiians	15 700	14 200	29 900
Part Hawaiian	4 000	3 900	7 900
Japanese	47 600	13 600	61 200
Chinese	22 300	3 500	25 800
Negroes	200	100	300
South Sea Islanders	300	100	400
Total	106 300	47 700	154 000

Since these statistics were collected there has been an importation of Porto Ricans and Italians for work on the plantations; but, as neither class of labor has proven satisfactory, it is not likely that they will constitute a permanent part of the population. Of the Caucasians, probably 14 000 are Hawaiian born and largely of American parentage, while about 2 500 more were born in this country.

Climate.—Since 1884 a daily record has been kept at the office of the Weather Bureau in Honolulu, to show the rainfall, atmospheric pressure, temperature, humidity, and direction and force of the wind. In 1890 the systematic collection of records at various points throughout the islands was begun, and the last reports indicate that the rain-

fall is recorded at eighty stations and that more or less complete meteorological observations are being made regularly at 5 points, in addition to the Honolulu station. Besides these records there are a large number of others which are not reported, nearly every ranch and plantation having at least one gauge in use. Rainfall on the islands presents all of the phenomenon usually found on large land surfaces, being low at the coast on the windward side, increasing with the elevation towards the cool high summits in the interior, and diminishing as the lee or southwestern coast is approached. Most of the readings are taken at the lower elevations, which are usually the populated sections, but a few are available for points well up on the slopes, the highest being at 4 000 ft. elevation at Kilauea, Hawaii. The records of normal rainfall show an annual range of from 8.5 ins. at elevation 15 ft. above the sea, at Olowalu, on the leeward side of Maui, to 190 ins. at elevation 1 250 ft. at Kaumana, on the windward slope of Mauna Kea, Hawaii.

The maximum rainfall record for a year, of which the writer has knowledge, occurred at Nahiku, Maui, and was 400 ins. The dry season of 1901 in Hawaii marked a drought of unusual severity, and was followed in December by a storm which seemed to center at Laupahoehoe, on the north coast, where the precipitation aggregated over 41 ins. during 28 hours, the measuring gauge having been located at 500 ft. elevation; this was a purely local storm, but the one of March, 1902, swept along the entire windward coast of Hawaii, and registered the maximum at elevation 2 000 ft. at Paanilo, where the rainfall for 8 days was 87.91 ins.

One of the most intense Hawaiian storms of record occurred on March 18th, 1902, at Luakaha, back of Honolulu, elevation 850 ft.; here the precipitation was 12.7 ins. in 11 hours and 55 minutes, the maximum rate noted having been 5.55 ins. in 55 minutes.

An analysis of the records along the westerly end of the north coast of Hawaii shows that, during the months, May to October, the rainfall is from 30% to 40% less than in the remaining six months, and that there is an increase in rainfall with increase in elevation above the sea, probably not averaging more than 3.5 ins. per annum per 100 ft.

Within the limits of Honolulu, records are kept at no less than 8 points, located at elevations between 10 ft. and 80 ft. above tide; the

HAWAIIAN SUGAR PLANTER'S EXPERIMENT STATION AT HONOLULU.

OLD TRAM CAR LINE OF HONOLULU, RECENTLY LARGELY SUPPLANTED BY A MODERN OVERHEAD TROLLEY.

longest of these dates back to 1874 without interruption. Although separated by small distances, they show a variation in the average annual record ranging from 22.94 to 39.53 ins.

In a recent article on "Meteorology in Hawaii," by Professor Curtis J. Lyons, Territorial Meteorologist, it is stated that the mean annual temperature at Honolulu is 74° , with an annual variation of not more than $\frac{1}{2}^{\circ}$, and that there is a probability that no point on the coast has a temperature of more than 1° lower. The average monthly variation at Honolulu is from 70° in January to 78° in July and August, with an extreme monthly range of from 54° to 88° and a daily range of from 50° to 90° . With increase in elevation on the islands there is a fall in temperature, probably averaging 1° per 300 ft. The percentage of saturation or humidity at Honolulu averages 72 per cent.

This delightful climate is due to the position of the Islands with reference to the return polar currents, the trade winds, which blow over them, prevailing at the islands for about 270 days per year.

Applying the rule of decrease of temperature with increase in elevation, it will be noted that temperatures below freezing might be expected at the higher elevations on Maui and Hawaii, and on the latter island snow caps can usually be seen on the crests of Mauna Kea and Mauna Loa.

The Soil.—The geological structure of the islands is entirely of basalt. The volcanic agency by which they were formed seems to have first manifested itself at the northerly end of the group, where the old craters are difficult of definition; the action has now ceased at all of the islands except Hawaii, the largest and southernmost. Here there are two volcanoes, Mauna Loa and Kilauea, which are periodically active; at the latter there is always more or less evidence to show that the quiescent stage may be but a brief one. It is probable that the seaward slopes from the craters were originally about uniform, and ranged up to, perhaps, 15%, but the heavy rainfalls on the summits have caused more erosion here than at the coast, cutting away the surface and furrowing it with deep gulches, and, finally, as on Oahu, reducing the junction of the opposite sides of the tops of the craters to a ragged knife-edge or saw-tooth appearance.

The disintegrated material of the higher elevations is washed downward and deposited on the lower slopes, producing here a deeper

and richer soil and a less broken surface for development than does the uplands.

The small streams which form on the mountain tops are usually dissipated in the porous formation before they reach the sea, and the larger ones have cut gulches with very steep sides and with depths ranging up to over 2 500 ft. While the uplands have the advantage of increased rainfall, they lack the evenness of surface, the desirably higher temperature for growing crops, the richness of soil, and the facilities for transportation and shipment of the lowlands.

If the surface were less porous, and stream flow were in surface channels, irrigation could be readily and cheaply resorted to and the conditions for agricultural development would be ideal. In most instances the irrigation supplies are obtained from sub-surface sources and from depths ranging up to 800 ft. below tide.

Owing to lesser age it would naturally be expected that there would be a decrease in richness of the soil in the islands toward the south, and as a matter of fact there are large tracts of undecomposed bare lava rock on Maui and Hawaii.

The exports for the year ending June 30th, 1901, and their value, were as follows:

Article.	Quantity.	Value.
Sugar.....	690 879 234 lbs.	\$27 093 923.41
Hides and skin.....	1 864 100 "	76 994.66
Rice.....	549 475 "	22 527.00
Coffee.....	2 620 169 "	311 897.27
Raw wool.....	819 734 "	110 184.94
Molasses.....	93 820 galls.	4 615.00
Honey.....		9 770.00
Fruit.....		78 167.65
Curios.....		1 696.00
Sundries.....		346 654.50
Total value.....		\$28 054 430.43

The valuable forests of sandal wood, which first opened up the island trade, were almost wholly cut off early in the century. The table shows that the wealth of the island lies entirely in its agricultural resources, and that the culture of sugar cane is the most important industry.

The Sugar Industry.—There are 55 sugar plantations on the islands, each having areas under cultivation ranging in size from 300 to 12 000 acres, and probably aggregating between 175 000 and 200 000 acres.

About one-half the area is approximately evenly divided between the Islands of Kauai, Oahu and Maui, and the remaining half is on Hawaii. Nine of the plantations are located on Kauai, 9 on Oahu, 11 on Maui, and 26 on Hawaii. Nine of the number are owned by individuals, and probably have a value of over \$2 000 000; the remaining 46 are controlled by companies, and are capitalized for \$113 490 500, of which amount \$68 394 500 has been paid in.

The stock investment in plantations in the various islands, not including the value of those not incorporated, is as follows:

Kauai.....	\$10,125,000
Oahu.....	19,302,000
Maui.....	23,527,500
Hawaii.....	15,440,000

As plantations are developed, the acreage is increased from year to year, until all of the adjoining land which is suitable for cane cultivation has been brought into requisition; some of the younger plantations have prepared plans for immense additions, and in a few years will probably be larger than any now existing.

The growing season for a crop of sugar cane in Hawaii has a duration of 18 months, and the planting season begins in July; a single ratoon or second crop is usually raised from the same seed, and then the land is left for a time to fallow.

By reason of more suitable temperature and richer soil the cane thrives best near sea level, and most of the plantation lands are under 1 500 ft. in elevation, the highest reaching up to 2 800 ft. It has been commonly assumed in Hawaii that a crop requires an irrigation water supply at the rate of 1 000 000 galls. per 100 acres per day (corresponding with a rainfall of 134 ins. per annum) during the period of maximum growth, which is also coincident with the season of minimum rainfall; this estimate is believed by the writer to be over-liberal and to include a large percentage of leakage through ditches in a porous formation. Practically all of the cane grown in Kauai, Oahu and Maui is irrigated more or less abundantly, while in Hawaii irrigation is extensively resorted to on only one plantation; on the latter island, the writer is informed that a rainfall of 65 ins. well distributed through the year is all that is required to produce a fair crop, although by no means as great as when irrigation is used. The lack of development of irriga-

tion on this island is due partly to the fact that the rainfall in the sugar belt is usually sufficient to produce the crop, and partly to natural difficulties in the way of developing a water supply.

Such statistics as are available for 1901 indicate that the yield of sugar during that year was about as follows:

Kauai.....	2.5 tons (2 000 lbs.)	per acre of	cane land.
Oahu.....	3.3	“	“ “ “ “
Maui.....	2.7	“	“ “ “ “
Hawaii.....	1.75	“	“ “ “ “
Average for all islands.	2.3	“	“ “ “ “

The minimum yield, it will be noted, is on the island where the lands are unirrigated, and the maximum is on Oahu, where irrigation is most extensively resorted to.

The same statistics also show that the acreage cared for per laborer on each island was about as follows:

Kauai.....	4.7 acres of cane land	per laborer.
Oahu.....	3.4	“ “ “
Maui.....	3.8	“ “ “
Hawaii.....	6.8	“ “ “
Average for all islands.	5	“ “ “

These figures also show that the force of laborers required follows the same order as the tonnage of sugar produced. There is an irregularity in the number of acres cared for per man and ranging from about 3 to over 10, and also in the yield per annum at the various plantations, some of the richer plantations yielding as high as 12 tons per acre per crop, and especially favored fields giving even greater returns. On the irrigated lands there should be and is a much greater uniformity of yield than when dependence is placed entirely upon the rainfall as on the Island of Hawaii, where the great length of the cane belt, including areas so located as to have little relationship in the rainfall, is responsible for an apparent greater uniformity of yield for the entire island than is the case for the various plantations considered independently.

During the years which have elapsed since the annexation of the islands, there has been a growing scarcity of labor. In the early days of the cane industry both Chinese and Japanese labor were freely

used, but, after the overthrow of the monarchy in 1893 and the application for annexation to the United States, it was decided to shut out the Chinese, fearing that an excessive population of this race might prove an obstacle to the accomplishment of the desire.

Upon the admission of Hawaii as a territory, in 1898, the Japanese contract labor system was terminated, with the result of freeing Asiatic laborers from a legal obligation to perform work, and materially reducing the rate of immigration. This at once caused a shortage of labor and a demand for increase in pay, both of which conditions were aggravated by the development of new and large plantations which followed the assurance of a stable government.

Assuming the area of the cane lands to be 200 000 acres and that one laborer will care for 5\ acres, it would appear that the present total of 70 000 male Asiatics would be more than enough for the needs. Allowance must be made, however, for the fact that the rice fields, from which their chief food is obtained, must also be cultivated by these men; that they are the general market gardeners; that, with restraint removed, as it now is, and with cost of living for this class at such a low figure that the wage of a day will provide support for several succeeding idle ones, and that there is at present an undisputed shortage in the labor supply, it is plain that capital is placed at a serious disadvantage.

To the fact that these races have a realizing sense of their position the writer can testify after an experience with them which covered over six months, during which interval, and notwithstanding that the wages paid were higher than the men had ever before received, there were no less than three general strikes when he was informed that the trade-union idea and spirit was just as strong and far more unreasonable than here at home.

With all natural advantages for the chosen occupation of the islands and practically all of the capital invested in it and dependent upon its success, and with general conditions such that only Asiatic labor can be successfully used, it would appear that we owe it to this new dependency to open the doors to a sufficient amount of Chinese labor to relieve what is rapidly becoming an "intolerable condition." Such relief has been petitioned for in Congress, but from the present outlook there does not seem to be any prospect of securing it at an early date.

SEWAGE PUMPING STATION, HONOLULU.

MAKIKI STREET, HONOLULU. RECENTLY MACADAMIZED.

The "prevailing rate" of wages for ten hours' labor per day, on the plantations, ranges from about \$17 to \$20 per month, together with lodging, fuel and medical attendance. Skilled labor invariably commands higher prices than in the States.

Excepting only a few of the smallest plantations and which are in proximity to others and larger ones, each has its own mill, and the manufactured raw sugar is shipped either to Honolulu or Hilo for forwarding to the mainland. With but one exception, where the diffusion process is used, the manufacture depends upon milling, the usual equipment consisting of the nine roller mill.

The Ewa plantation, located on the southern slope of Oahu, and only a short distance west of Honolulu, has undoubtedly reached the most complete stage of development of any on the islands, and a description of it, largely gathered from the *Honolulu Evening Bulletin*, Industrial Edition, of November, 1901, and from the annual reports to the stockholders, shows that it embodies practically all of the best features of the Hawaiian plantations. The company was incorporated in 1890, and has a paid-up capital of \$500 000, and a bonded debt of the same amount. The plantation comprises about 7 000 acres under an approximate elevation of 200 ft.; of this area probably 6 500 acres is under cultivation, the output from which for the year ending September 30, 1902, was reported to be nearly 39 000 tons. By means of several miles of excellent dirt roads all of the cane lands are easily accessible for cultivation; the cane is hauled to the mill by a steam railroad, the equipment comprising over 30 miles of permanent track, with a few miles of portable track, six 25-ton locomotives, and 600 cane cars, each having a capacity of 6 to 7 tons. The cars are unloaded at the mill by machinery, and the cane is fed directly to the crushers. Machinery is used for ploughing and is being introduced wherever possible elsewhere to relieve the shortage in labor. The average annual rainfall at the mill for the last ten years is 20 ins., with an extreme range of from 8 ins. to 31 ins.; this plantation, therefore, depends wholly upon irrigation. Six pumping stations are maintained for this purpose, having an aggregate capacity of 67 000 000 galls. per day; the pumping engines are of the Riedler and Blake types, and are in units which range from 2 000 000 to 12 000 000 galls. per day each; the lifts are from about 100 to 220 ft. The water supply is obtained from 56 driven wells, which are about 12 ins. in diameter and reach to depths ranging from, say,

400 ft. to 800 ft. below sea level. Coal is obtained from the Canadian and Australian markets, costing about \$7 per ton at this plantation, those more remote being obliged to pay higher prices and up to over \$10 per ton.

The mill building has a steel frame covered with corrugated iron, and the floor is of concrete finished with cement. The mill has a capacity of 300 tons of sugar per day, and the equipment consists of settling tanks to hold 24 000 galls., evaporators of 600 000 galls., vacuum pans of 85-ton capacity, forty-five 30-in. to 40-in. centrifugals, and wooden tanks to store 400 000 galls. of molasses.

The operation of sugar boiling is under the direction of a chemist, who also makes analyses of the soils for the purpose of determining the fertilizer requirement.

On plantations where an upland water supply is available, the cane is sent to the mill through flumes built of a V-section, and laid on grades of upwards of 1.5 per cent. A flow of about 1.5 cu. ft. per second is required for this purpose.

Gravity cables are also used to some extent for cane transportation.

The Sugar Planters' Association maintains a station in Honolulu, where experiments are conducted to determine the relative merits of the various kinds of cane, duty of water, effect of saline water on cane growth, methods of planting, and other matters of kindred nature; here, also, fertilizers are analyzed to determine their conformity with contract specifications.

For sugar-mill purposes bagasse is almost exclusively used for fuel, and the supply seems to be just about sufficient for this use. The high price of coal and the large quantities consumed for operating pumping plants led to an investigation, in 1901, by Hon. Lorrin A. Thurston, of the possible use of oil for this purpose, attention having been attracted to the fact that coal was rapidly being supplanted in the west by this fuel. From the information thus gathered it was estimated that 4 bbls. (168 galls.) of 14° fuel oil was equivalent to 1 long ton of Australian coal, and that the former would cost \$6 delivered, as contrasted with \$10 for the latter. Following this report, negotiations were begun leading to the adoption of this fuel, and contracts for some of the plantations have been placed and the storage tanks are being erected.

The following statistics concerning the production of sugar were,

in part, furnished to the Sub-Committee of the Senate Committee on Pacific Islands and Porto Rico, which visited the islands during September last, and in part have been taken from the report of Governor Dole for the year ending June 30th, 1902.

	Tons of sugar per acre harvested.
Average yield of unirrigated plantations, 1897-01, inclusive.....	3.45
Average yield of irrigated plantations, 1897-01, inclusive.....	5.82
Average yield of all plantations, 1897-01, inclusive.....	4.48
Average yield of all Oahu plantations, 1901.....	8.44
Average yield of Ewa plantation, Oahu, 1901 (highest noted).....	10.78
Average yield of Kohala plantation, Hawaii, 1901 (lowest noted).....	2.39
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Average tons of cane per ton of sugar, Oahu plantations, in 1901.....	8.62 tons
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Average cost of cultivation per ton of sugar, Ewa plantation, for 1901.....	\$24.28
Average cost of cultivation per acre, Ewa plantation, for 1901.....	265.01
Average cost of irrigation per acre, Ewa plantation, for 1901.....	35.72
Average cost of irrigation per ton of sugar, Ewa plantation, for 1901.....	3.30
Average cost of production per ton, for Oahu plantation, for 1901.....	41.13
Average cost of production per ton, for Hawaiian Sugar Company, Kauai, for 1901.....	49.00+*
Average cost of production per ton, for Oahu Sugar Company, Oahu, for 1901.....	47.00+*
Average cost of production per ton, for Ewa plantation, Oahu, for 1901.....	36.62 *
Average cost of production per ton, for Kahuku plantation, Oahu, for 1901.....	45.00+*
Average cost of production per ton, for Haiku plantation, Maui, for 1901.....	57.00+*

* Cost at mill. Investments for permanent improvements and cost of marketing not included.

	Tons of sugar per acre harvested.
Average cost of production per ton, for Paia plantation, Maui, for 1901.....	44.00+*
Average cost of production per ton, for Ookala plantation, Hawaii, for 1901.....	38.47 *
Average cost of production per ton, for Onomea plantation, Hawaii, for 1901.....	54.98 *
Average cost of production per ton, for Honokaa planta- tion, Hawaii, for 1901.....	52.50 *
Average cost of production per ton, for Hawaiian Ag. Company, Hawaii, for 1901 ..	44.11 *
Average cost of production per ton, for Kohala Sugar Com- pany, Hawaii, for 1901.....	64.00 *
Average cost of production per ton, for Hutchinson planta- tion, Hawaii, for 1901	45.00 *
Average cost of production per ton, for Kilauea Sugar Com- pany, Hawaii, for 1901.....	64 00 *
Average cost of marketing from Island of Hawaii, per ton.....	\$12.50 to \$15.00

The importance of these islands in the production of cane sugar is exhibited in the following table, showing the tonnage raised by various countries, for the year 1901-02:

Asia.....	859 130 tons.
Cuba.....	800 000 “
Hawaiian Islands.....	310 000 “
Africa.....	280 000 “
Louisiana.....	275 000 “
Brazil.....	215 000 “
British West Indies	165 000 “
United States (remainder).....	163 126 “
Australia.....	161 500 “
Argentine Republic.....	115 000 “
Peru.....	105 000 “
Mexico.....	100 000 “
Porto Rico ..	100 000 “
British Guiana.....	95 000 “
Spain	33 000 “

* Cost at mill. Investments for permanent improvements and cost of marketing not included.

From this it will be noted that Hawaii produces nearly 37% of the cane sugar of the United States (including Porto Rico), and nearly 9% of the cane sugar of the world.

Railroads.—A well-equipped railroad, having a length of 71 miles, traverses the southern, western and northern coasts of Oahu, and another is in use from Hilo, Hawaii, to the Puna plantation on the south, with a branch to Olaa plantation on the road to Kilauea. The last-mentioned road and branches, when complete, will have a length of 43 miles. There is also a short, narrow-gauge road along the extreme north point of Hawaii for the transportation of sugar from the Kohala mills to the Mahukona landing, and another similar road crosses Maui.

While the old-fashioned tram road of Honolulu is still in operation it has been largely superseded by a new trolley line, now operating on over 20 miles of single track with 85-lb. rails. Open cars are used, of a type which can be quickly changed into substantial closed ones, affording perfect protection during the most inclement weather. Most of the plantation-mill railroads are well built and maintained, but their location is usually such that they can only be used for communication with the mill which each serves.

Telephones and Telegraph.—Telephones were introduced in Honolulu and Hilo in 1882. They are in common use and have been installed in the smallest hamlets, bringing all parts of each island within reach of quick communication and at very reasonable rates, ranging, in Oahu, from \$42 to \$90 per annum. For inter-island communication the wireless telegraph system has been installed, with stations on Oahu, Molokai, Lanai, Maui and Hawaii, the longest transmission being 78 miles between Keeaumoku, Lanai and Mahukona, Hawaii. The poles used range from 125 ft. to 175 ft. in height above the ocean. The system has been put in successful use, but patent difficulties have interfered with continuity of operation.

As is well known, the laying of the long-talked-of Pacific cable is about to begin, which will bring not only these islands, but also the Philippines, into closer touch with the rest of our country.

Municipal Engineering.—Honolulu and Hilo have a public water supply and sewerage system, and electric-light service; some of the smaller settlements are provided with a portion of these conveniences.

The water supply of Honolulu is in part obtained from mountain

streams and in part from deep wells; the former is a gravity supply, and the surplus head is used for generating a portion of the power used for street lighting. The total supply is about 8 000 000 galls. per day, or about 175 galls. per capita per day. This use, it should be noted, includes the irrigation of the extensive grounds which surround the typical Honolulu home, and which are invariably well stocked with every variety of tropical plant.

The sewerage system of Honolulu is in every respect a modern one, and was designed by Rudolph Hering, M. Am. Soc. C. E.; at the beginning of the present year the portion completed included nearly 40 miles of laterals and mains, ranging in size from 6 ins. to 36 ins. in diameter. The entire flow is raised a few feet at the pumping station located near the harbor, and the steel pipe outlet is intended to be carried to a depth of 100 ft. of water, where the discharge will meet currents which will take it away from the shore, although work has been temporarily suspended at a depth of 50 ft. Surface drainage is provided for by either open timber or concrete flumes.

In the district of Honolulu there are about 75 miles of roads, and those of the most populous sections, together with the main driving thoroughfares, have been macadamized. The earlier work consisted simply of a surface coat of stone, but the specifications at present in use require an 8-in. bed of $2\frac{1}{2}$ -in. stone, well compacted and covered with a layer of screenings 1 in. in thickness. Blue stone is used for curbing and cement for walks. Coral rock has been used for some of the roads, but it has proven to be exceedingly difficult and expensive to keep in repair. The harder volcanic rock is generally used, the quarrying and crushing being done with a plant owned by the Territory.

Timber, steel and concrete bridges occur frequently on the Hawaiian roads, some of them being of a very substantial character, and particularly so in the vicinity of Honolulu. The district of Honolulu has a well-organized, paid fire department, with 3 stations and an equipment comprising 1 first-class, 3 second-class, 1 third-class, and 1 fourth-class fire engines, and a chemical engine, together with other accessories in keeping, including a call system.

Docks and Harbors.—Honolulu is the only port on the islands where extensive dock facilities have been provided. There are but three harbors of importance on the islands, Honolulu and Pearl Harbor, on

CONCRETE HIGHWAY BRIDGE, HONOLULU.

PAAUHAU LANDING ON THE NORTH COAST OF HAWAII. THIS IS TYPICAL OF THE LANDINGS
ALONG THE HAMAKUA COAST.

Oahu, and Hilo on Hawaii. The latter is large, but lacks a breakwater, which will doubtless be provided shortly and will render it safe. The entrance to Pearl Harbor is barred by a coral reef, which is now being removed by the United States War Department, so as to form an entrance; the completion of this work is to be followed by the establishment of a large naval station, and it will open up a most commodious, land-locked and safe deep-water harbor.

The coast line, where protected, is fringed with a bed of coral, which extend seaward for a long distance, leaving very shallow water. Where it is exposed to the steady action of the waves driven up by the prevailing trade winds, it has been eaten into with the formation of precipitous cliffs, dropping from heights of as great as 1 700 ft. directly into deep water; here a vessel venturing too close incurs the risk of being driven upon a rocky and uninviting coast. Communication between vessels and the shore is established either by whale boats or by cables; where the former are used along a bold coast line, they deliver their cargo into a bucket operated by a crane on the shore, and after the same has been landed at the base of the cliffs it is elevated to the plateau above by a cable railway built at an angle of, perhaps, 45°, or even greater.

Industrial Plants.—The largest undertaking of this character is the Honolulu Iron Works, which was organized in 1853 and is capitalized for \$500 000. The buildings are modern in character, occupy a site having an area of over 6 acres, and are equipped for building pumps, boilers, steel pipe and sugar-mill machinery, and for repairing vessels. The buildings include a machine shop, foundry, boiler shop, pattern shop, blacksmith shop, and coppersmith shop. From 400 to 600 mechanics are usually employed.

Forestry.—The Hawaiian trees are of varieties quite unknown here, and most of them are exceptionally hard. As already noted, it was the shipment of valued woods that marked the first era in the history of commerce with the islands, practically exhausting the sandalwood supply, which was sold in China. Where not too arid, or lacking in fertility, the lowlands along the coasts have been turned into sugar cane, while the less rugged inland areas are largely used as sheep and cattle ranches. The latter use, in particular, is largely responsible for denuding large areas of what was formerly forest lands, as the cattle break down the young trees, which would otherwise replace the old

ones as they die off. The effect of the increasing loss of forest area is shown in the drying up of what were formerly swampy areas and the running dry of streams before considered as unfailing.

Water for irrigation purposes has a higher value on these islands than anywhere else in the world, and the absolute dependence upon it and the recognition of the relationship existing between dry season run-off and the preservation of the forest area are awakening a great deal of attention to the subject of forestry. It is the common idea on the islands that the loss of woodland has resulted in a diminished rainfall, but an analysis of the rain records for many years fails to sustain the belief.

Government Land Survey.—No reference to the engineering works of Hawaii would be complete without including a reference to the Government Land Survey. In the early days of the monarchy, title to all of the lands was vested in the King, but in 1848 there was a division into four parts, one part being assigned to the Government, another to the Crown, another to the Chiefs, and the remainder to the common people, as kuleanas or homesteads. The Crown and Government lands are now merged into one, and belong to the United States; they comprise about 1 720 000 acres, or about 40% of the total area, and of this nearly 75% is either high, forest, or rugged and barren land. A part of the area is leased as cane land, but the greater part of the cane is grown on land that was originally assigned to the Chiefs.

In this division of property there was a manifest intention to give each of the Chiefs every variety of land, for the grants thus made were usually long, narrow strips extending from the sea to the summits in the center of the island; each such grant was called an ahupuaa. The kuleanas were the little patches occupied by the natives, where they raised taro for their sustenance. These lands were usually well watered and include the richest of the Territory. This division was crudely fixed, and in verifying titles it soon became necessary to call in the engineer. In 1870 a general survey was begun, using the system followed by the United States Coast and Geodetic Survey, some of the instruments used by which bureau were loaned to the Hawaiian Government. Since this date the work of the Surveyor-General has been devoted to locating and triangulating the various islands and mapping them in considerable detail, the work

being so conducted as to make it extremely valuable to all landed interests and the basis of all conveyances.

Surveying in these islands is sometimes attended with features which are pleasant, and sometimes with privations and danger to life and limb. In this work almost impassable gulches and dense jungles of swamp-land were penetrated, continued observations were made at the highest summits, where the intense cold was peculiarly trying after prolonged residence in a tropical climate, and the volcano of Kilauea was mapped under conditions far from inviting. There is given a modest account of the method used to occupy the triangulation station at Diamond Head, in a report of 1889, by Professor W. D. Alexander, who was Surveyor-General from the inception of the work up to within a recent time, in which he says that "the instruments were carried up the precipice on the inner 'makai' side of the crater in the following manner: An iron stake was driven into the rock at the top of the precipice, to which a pulley was attached with 40 fathoms of whale line. Two men then drew up the instrument boxes, one at a time, while two others climbed up with the boxes, and kept them from touching the rocks anywhere during the ascent."

The results of this work are easily accessible to all to whom it is of use, and that the skeleton work has been thoroughly done is evident by the fact that it is difficult to find a locality which is not within easy reach of a permanent monument where azimuth, altitude, and co-ordinates can be readily determined.

The work furthermore shows a conscientious care and accuracy which could only have been achieved by a body of competent men devoted both to the land of their adoption and to our own profession.

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