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NEW ZEALAND.

LAND-DRAINAGE METHODS IN AMERICA

AND RELATIVE MATTERS (REPORT ON), BY J. B. THOMPSON, CHIEF DRAINAGE ENGINEER, LANDS AND SURVEY DEPARTMENT, NEW ZEALAND.

Laid on the Table of the House of Representatives by Leave

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REPORT ON VISIT TO DOMINION OF CANADA AND UNITED STATES OF AMERICA IN CONNECTION WITH METHODS OF LAND-DRAINAGE IN THOSE COUNTRIES.

SIR,— 24th June, 1921.

In accordance with your instructions to inquire into the latest methods of land-drainage in practice in the above countries, and to select suitable up-to-date plant for prosecuting work in this Dominion, I departed from Auckland on the 6th May, 1920, and returned on the 24th March last. I have advised you from time to time of the several places visited and my impressions of the works seen in progress, and now propose to as briefly as possible condense this matter, and also deal with items coming under special headings.

LOCALITIES VISITED.

Dominion of Canada.—I successively visited the Provinces of British Columbia, Alberta, Manitoba, and Ottawa, and got in touch with the various authorities controlling drainage. I found that these provinces were on the eve of embarking on very extensive operations, but that the greater portion of the land to be drained came within the category of periodically flooded lands. There did not appear to be any extensive areas of the class of country I desired to see, such as muck and peat lands; and, after discussing the subject very fully with Mr. Dawson, Chief Irrigation Engineer, Calgary; Mr. Bowman, Provincial Drainage Engineer; the Manitoba Drainage Commissioners, Winnipeg; and Mr. E. S. Drake, Director of Reclamation Service, Ottawa, I decided that my best field of observation would be in the United States of America, seeing that our conditions were more similar.

I, however, took the opportunity of inspecting levee works along the Fraser River, British Columbia; drainage of irrigated lands in Alberta; drainage of gumbo lands in Manitoba; and operations being conducted on peaty country in Ontario. All this work was being operated by dipper dredges, walking-dippers, and drag-line excavators. Very excellent work was being done, but none of it under as wet conditions as usually prevail in New Zealand. Maintenance, I found, was more or less a dead-letter, and this, the authorities informed me, was still an unsolved problem. With the exception of the machine maintenance of irrigation ditches near Calgary, I saw no mechanical means for cleaning.

For the construction of all classes of large ditches, hand labour has been superseded by machinery of various classes, and of these, walking-dippers and drag-lines are much in favour and doing excellent work.

Special facilities were afforded me of seeing the work of several dipper and clam-shell dredges operating at Toronto and Montreal, but these machines were generally too large for our operations in this Dominion.

In connection with river-protection works, it was noted that rock-filled cribbing was in general use and proving very satisfactory. This form of protection owes much of its popularity to the nearness of lumber-supplies.

United States of America.—I proceeded from Montreal, Canada, to Washington, D.C., and presented my credentials to His Excellency the British Ambassador and the Secretary of State, and was at once placed in touch with the officers of the Drainage Investigations Branch of the Department of Agriculture. These gentlemen immediately prepared an itinerary covering all the main drainage projects in several States, and either accompanied me thereto or else made arrangements for me to meet engineers at the several points. Drainage operations were inspected in the following States: Minnesota, Wisconsin, Michigan, Illinois, Iowa, Ohio, North Carolina, Missouri, Arkansas, Louisiana, Indiana, Kentucky, Tennessee, Florida, and California. The methods used for reclamation were closely observed, and much learned from the various eminent engineers and authorities met with. Very great importance is attached to the necessity for bringing to profit all flooded and swamp lands, as it is recognized (as in New Zealand) that probably the richest land is the swamp area.

My observations as regards respective qualities convinced me that there is no better swamp area in America than can be found in New Zealand; but the area in the former country is quite staggering. This, of course, is very obvious. In the United States the wet areas are approximately as follows: Swamp, 66,000,000 acres; periodically overflowed, 31,000,000 acres; tidal marsh, 4,000,000 acres. Probably three-fourths of these lands are timbered, and in many instances cut over.

THE DRAINAGE MOVEMENT IN CANADA AND THE UNITED STATES OF AMERICA.

The benefits and results attending the drainage of flooded and swampy lands in both Canada and the United States of America have opened the eyes of the public and authorities to the great potential value of the still-undeveloped areas, and a strong and insistent movement has been on foot for the systematic attack of all projects which appear on examination to be practicable.

Canada.—Provincial aid has been enlisted in Canada, and several of the provinces have—like Manitoba, for instance—enacted legislation in the direction of land-drainage. Under the enactment the Provincial Government undertakes the work, and issues debentures, and may also invest certain moneys in the same. Repayment is spread over terms of from twenty to thirty-five years.

The Dominion Government has also a Department which controls certain areas throughout, and prepares them for settlement.

United States of America.—At present there is no State or Federal aid, as in Canada, but certain States have enacted legal machinery in the interests of landowners. This legislation varies somewhat in each State, but is generally on the lines of our own Land Drainage Act, 1908. The Federal Government has under the Department of Agriculture a most valuable branch of drainage investigations. Its functions are, as its title indicates, to explore every aspect of drainage of wet areas, surveys, hydraulics, soil-surveys, schemes, and the financial and costs side. This branch of drainage investigations is most valuable, and although it does no actual construction work, yet it covers all schemes in progress, carries on experiments thereon, issues bulletins, and advises engineers and the general public as to best procedure, practice, &c. Its publicity department is proving most valuable, and is much sought.

Public agitation is now directed towards gaining State aid in the various projects of the future, as it is held that the State is equally concerned with the individual in the advancement and increased productiveness of the country. Again, many projects are too large for the successful financing and carrying-out of operations without State assistance.

Legal Machinery: Drainage Districts.

Petitions.—In both Canada and the United States the procedure is much the same as in New Zealand. All petitions for forming drainage districts in Canada must be signed by a majority of the landowners; while in the United States it varies in different States, some requiring the petition to be signed by a majority of the landowners, others by the owners of a majority of acres, and in some instances a petition signed by three landowners is sufficient.

Objections.—The usual machinery for hearing objections is much as laid down in our own Land Drainage Act.

Classification.—Great care is taken in this connection, and every endeavour made to assess the benefits likely to accrue. Classification varies from an acreage basis to, say, five different classes of benefits. In some States the various highways, railroads, &c., may be assessed for likely benefits.

Finance.—This may be effected in several ways: (1) By issue of provincial debentures (as in Canada); (2) each landowner pays his share of cost in cash, in advance of construction; (3) by the issue of certificates; (4) by the issue of bonds. Of these, (1) and (4) are the most practicable and in general favour.

The Canadian debentures have a currency of not less than twenty nor more than thirty-five years. In the United States the bonds usually extend over a period of from ten to twenty years; but it should be noted that these represent private issues.

Comparison.—Comparative analyses of the several Land Drainage Acts in the United States with the New Zealand Land Drainage Act, 1908, shows the latter to be much in accord, but it does not offer the same variety of classification.

Considering the Act respecting land drainage of Manitoba, it is found similar in many respects to the Swamp Drainage Act, 1915, of New Zealand, but the latter has several features much in advance of the former as regards resumption of lands, construction of roads, &c. In fact, the Swamp Drainage Act, 1915, has several features which appealed strongly to the authorities in Canada and the United States, and copies are desired by those advocating State assistance.

General Practice.

In considering a new project in either country, extensive engineering surveys, data as regards precipitation and run-off, and other details are called for, and it is only after deliberate analysing of all information and finance proposals that the works should proceed. This is the approved method, but it is not general. Engineers complain that the layman does not appreciate the necessity for spending money on collection of data, and this especially applies to land-drainage. Large sums of money are expended in the assembling of data considered necessary for power-installations, dams, &c., and business people realize the necessity.

In the United States much of the way is cleared for the drainage engineer, as practically the whole of the States are covered by meteorological and hydrographic surveys. The precipitation, run-off, gauging of all streams, their velocities, and so on, are available, and thus a drainage coefficient is at once known for a particular district. This data enables the engineer to design with some measure of exactitude such channels, outfalls, and laterals as will meet the requirements of the area he is dealing with.

This points markedly to the disadvantages engineers in New Zealand labour under, due to a complete absence of systematic observations of precipitation and run-off. Flood discharges of our rivers and streams are sadly wanted, and can be only arrived at under largely supposititious conditions, and the employment of formulæ which lead to indifferent approximation. Actual observations extending over a period of years are essential. To assist the Land Drainage Branch in this matter several flow-recorders and current-meters were obtained, and will shortly come to hand.

Classes of Drainage.

Drainage may be said to come under one or the other of the following headings: (1) Gravity drainage; (2) salt-marsh drainage; (3) drainage by means of pumping. Fortunately, the major portion of the swampy areas in the United States can be reclaimed by gravity drainage. This also applies to New Zealand. All the above classes were closely looked into and deductions made.

Gravity System.—This consists of the excavation of channels, outfalls, laterals, and sub-laterals leading to some arranged point or points of final discharge. The necessary tide and flood gates forming a component of the scheme are constructed either of timber or concrete. Generally the same system is world-wide, but many small features—in the aggregate large—were observed, and will be utilized as opportunities occur in our own practice.

Salt-marsh Drainage.—The amount of work done in this connection is quite trifling compared with gravity drainage proper. The systems closely resemble each other, but much greater precision has to be observed, and these undertakings are rather shied at. Their success depends on a good range of tides being available, secure, impervious levees, and really good tide-gates or sluices. Observations made on ground lead one to the conclusion that, given a good range of, say, 8 ft. between mean low- and mean high-water marks, marsh land at, say, mean level can be successfully dealt with. The drainage of areas with less range than above mentioned has not been an unqualified success by any means, and has in some cases been subsequently assisted by pumping.

Drainage by Pumping.—Very considerable areas throughout the United States have been reclaimed by pumping. The Mississippi Valley offers many examples of areas of from 1,000 acres up to 7,000 acres. Apparently the latter area is a good size to handle. In Louisiana several drained tracts were visited, and the inspection was very satisfying.

In North Carolina a very large tract, now known as New Holland, but locally as Lake Matamaskeet, was visited, and proved most instructive. The total watershed, comprising lake and foothills, is about 100,000 acres. The lake, originally 3 ft. to 5 ft. deep, is to be drained completely, and was at date of visit practically non-existent. The pumping plant is capable of handling 1,800 cusecs, and comprises the latest centrifugal pumps, which are steam-driven. The pumping plant cost £50,000; annual maintenance, £10,000.

Areas were also visited in Sacramento Valley, California, it being observed that the general lay-out of pumping plants and areas was similar to those seen in Louisiana. The majority of schemes have low pumping-heads. In addition, the huge pumps in use in New Orleans, known as the wood-screw pump, were seen. They are 12 ft. in diameter, and have a capacity of 800 cusecs each. These pumps are for low heads, and came into use during times of continued heavy rains, and control the drainage of many miles of country surrounding New Orleans.

Exceptional precautions have to be taken in designing pumping units and lay-outs. The practice universally adopted is for the engineer to prepare all hydraulic data, amount of power available, the special features of the job, &c., and then invite quotations from manufacturers of pumps for a suitable installation. This results in obtaining guaranteed efficiency plants. The practice of allowing the civil engineer to design the plant is entirely discouraged, and rightly so. Great development has taken place in connection with low-lift pumps, and is ever increasing.

Tile Draining.—In many parts of the United States tile draining is rapidly coming to the front, and its use has been most successful. Open ditches are a disability to any farm, and their maintenance is a continual worry and expense. Then again, a smooth tile will discharge water with much less friction than is possible with an open ditch. Open ditches formerly 6 ft. deep have been replaced with tiles of 48 in. diameter, and then the old ditch backfilled. There can be no doubt of the advantages of the system. Pipes of 36 in. diameter were observed running 75 per cent. bore.

Tiles are variously of clay, cement, vitrified sewer-pipe, or segmental block. Necessarily, this system is very expensive as to first cost, but, on the other hand, maintenance is eliminated, and the absence of open ditches can be appreciated.

Tile-laying machines are extensively used, and are generally very efficient. For backfilling of trenches various machines or horse scrapers are used.

Tile costs are shown in accompanying sheets of costs data.

Excavation of Channels and Ditches.

The excavation of all ditches is performed—for at least 90 per cent.—by machinery. The following machinery is standard practice:—

Floating dipper dredge	¾ to 8 cubic yards capacity.
Floating grab or clam-shell dredge	¾ to 6 ,,
Dry-land dipper excavator	½ to 2 ,,
Dry-land grab excavator	¾ to 2 ,,
Drag-line scraper excavator	¾ to 3 ,,
Hydraulic suction dredge	10 in. to 24 in. suction and delivery.

Dipper Dredges.—Floating dredges of dipper type are undoubtedly the best diggers of stiff clay seen, and are deservedly popular on account of their performances as to output and economy. Fully 80 per cent. of drainage-channel excavation in the eastern States is done by dippers of various makes. The bucket capacity varies from ¾ cubic yards to 8 cubic yards, but in general ditch-work the average would be about 2-cubic-yards capacity. Their performances were noted under conditions such as exist in New Zealand. The heaviest dredges were seen at work in the Everglades, Florida, but they were engaged in excavating coralline limestone from large canals.

Clam-shell Dredges.—In the west (California) the grab or clam-shell floating dredge is the favourite, and does remarkably good work. Machines fitted with booms 240 ft. long and carrying

6-cubic-yard buckets were seen in operation in the Sacramento Valley. They were engaged mainly on levee-work. These machines cost about $190,000 in San Francisco, and are really for very large jobs.

Walking-dredges, Dipper Type.—Laterals and sub-laterals are excavated by so-called walking-dredges. Some of these straddle the ditches, while others move back as the excavation progresses. They are of dipper, grab, clam-shell, and drag-line types. Fast work is done in favourable conditions, but it is somewhat ragged compared with hand labour, but good berms are left. All types were observed in use, and it may be stated that they all have their weak points and have frequent stoppages for repairs. However, they are much favoured by many contractors, and should fulfil many of our requirements in New Zealand.

Drag-line Scraper Excavators.—These are deservedly popular machines, and are in varied design, capacity, and power. They are extensively used for levee-building and the enlargement of rivers, streams, and channels. They provide an excellent berm, and have generally a wide range of operation. They are also good for clean-out work. Some contractors are disciples of the "drag-line," just as others pin their faith on the "dippers." Certainly, these machines must appeal to any one desiring efficiency and a wide range of operation.

Hydraulic Suction Dredges.—These are used for special jobs, such as building levees of large size along rivers, but are not by any means in general use on drainage of swamps. The cost of a 10 in. suction dredge in New Zealand would be about £18,000.

Operating-costs of various Machines.—Operating-costs vary very much, and it is not proposed to traverse this question, with the exception of providing herein a schedule of costs data provided me by the Department of Agriculture, Washington, D.C. These figures are representative of typical bids or tenders accepted in various States.

General.—A close study was made of the various machines in operation, and exhaustive inquiries made of the owners, operators, and supervising engineers as to efficiency, application, and economy of the various types and makes. This was particularly necessary in view of the purchases for New Zealand. Much assistance was given in this respect by the various consulting drainage engineers, big contracting companies, and the Chief of Drainage Investigations. Some of the contracting firms possess as many as forty machines of different types. The conclusion arrived at is that dipper dredges, walking and drag-line excavators are best suited to New Zealand drainage conditions.

Drainage Excavation Costs, Period 1919–20.

Analysis of attached U.S.A. Costs-sheet.—Some fifty-six contracts are listed, representing typical work by various classes of floating dredges, walking-dippers, drag-line excavators, &c. The highest cost is 1 dollar (4s. 2d.) per cubic yard for an improvement work of 12,173 cubic yards extending over a distance of 2·1 miles. The lowest cost is 11 cents (5½d.) per cubic yard for excavating 1,059,640 cubic yards extending over a distance of 13·25 miles. The average cost of the whole of the fifty-six contracts works out at 22·78 cents (11½d.) per cubic yard. For comparative purposes it is necessary to exclude from the cost-sheets all small and extremely large works. The average cost of ordinary-sized jobs, therefore, is worked out as being at the rate of 15·8 cents (8d.) per cubic yard.

New Zealand Dredging-costs.—Our average costs covering the same period as those above is 6·99d. per cubic yard, and for the period 1920–21 amounts to 8·12d. per cubic yard. It will thus be seen that the comparative costs are identical.

Annual Maintenance of Ditches.

It is an astonishing fact that neither in Canada nor in the United States has the question of maintenance been solved. This subject has exercised the minds of all engineers and controlling authorities, and they expressed surprise that this item received so much practical attention in New Zealand.

Annual maintenance of drainage ditches is considered an absolute necessity in America by all engineers who design such projects, and they feel that the benefit at first derived is very soon discounted by allowing ditches to deteriorate. Some of the districts carry out maintenance, but others neglect it.

It would appear that the comparatively short currency of some of the bonds is in cases largely responsible for the neglect to strike a maintenance rate in addition to the rate and sinking funds necessary to extinguish the original bonds. The result of non-maintenance has been largely instrumental in inducing engineers to make ditches over size, and thus meet silting, erosion, and vegetation in this manner. This does not appear thoroughly satisfactory, as many of these ditches become choked with all classes of vegetation, and are theoretically much beyond the cross-section necessary, and have not sufficient water to keep them scoured out under normal conditions. It therefore frequently happens that the retirement of the original bonds heralds a new issue to re-excavate the old ditches.

The annual growth of vegetation in Canadian and American ditches does not appear to be so great as in New Zealand. Practically all the well-known vegetation, such as cat-tails (raupo), convolvulus, saw- (cutty-) grass, duckweed, &c., were observed, and, so far, no light machine has been designed that will successfully and economically deal with it. The various engineers met did not consider it at all advisable to place heavy expensive machines in competition with hand-cleaning of ditches at the price the work could be man-handled in New Zealand. This is correct in so far as it goes, but the trouble is to have sufficient labour at the right period in New Zealand.

It is confidently expected that some of the walking-dredges now coming to hand for New Zealand will help to solve the question, as lessons learnt from their use may result in the design of a lighter type. A good cleaning-machine was observed in Alberta, and is also in use in the Imperial Valley, California. It runs on three wheels and straddles the ditch, and its mountings consist of a set of buckets placed transversely. Unfortunately, it is hardly suited to peaty ditches, as it requires a hard shoulder to bite on. The cost of this machine is about $11,000 in America.

It was observed that annual maintenance is better taken care of in New Zealand than in America. In provinces in Canada, such as Manitoba, where the drainage operations are conducted by the State, maintenance is considered as being absolutely necessary, and a special rate is struck for the purpose.

Projects run by land companies are in a bad position as regards maintenance, the settler being at the mercy of the company.

Sedimentation.

No greater attention is paid to this feature than is the case in New Zealand, and the same problems of silting of lower reaches of ditches and the slacking-off of grade due to light material being carried down-stream are to be witnessed everywhere. Even on very flat gradients the light silt is carried down-stream; and it should be noted that there was not observed in America anything to approach in lightness of weight the pumice soil encountered in much of the Auckland District. The fine silt of the Mississippi River resembles certain of the New Zealand rivers, such as the Clutha and the Taieri.

The general practice is to dredge silt-traps throughout all large ditches, and it is only in rare cases that any attempt is made to catch silt in "paddocks." This can be done where it is possible to obtain an area at a very low price, or where a town is affected and a higher price would be justified.

Siltation is met by dredging in America, and will have to be so met in New Zealand, together with the aid that silt-traps afford.

Erosion of Ditches.

Erosion of banks of ditches and canals appears to be a world-wide evil, and generally is met by designing wide berms, easy slopes, and making the channel over size. Easy slopes would appear on the face of it to be the remedy, but frequently they weather more rapidly than, say, ½-to-1 slopes do. American engineers take this into consideration, but the universal aim is to obtain 1-to-1 slopes. As a matter of fact this is not by any means always obtained, and neither are the wide berms. Few swamp-drainage channels can be seen in America presenting better banks, berms, and slopes than is the case in New Zealand.

It is recognized that these points are extremely important, but it is only by utilization of special plant that broad berms can be obtained. Drag-line excavators provide quite the best class of berm, outside of dredges fitted with long-range booms or jibs, and suction dredges which place hydraulic fills. The toe of berm should not be within a 1-to-1 slope line drawn from the edge of base of ditch.

Erosion of Hill-land and Control of Hill-water.

Much attention is being paid to this question, as undoubtedly much of the silt that reaches the ditches is composed of water-borne silt from the hills. This is particularly the case in light loamy soils. This problem has been largely tackled in the Carolinas and Georgia by means of terracing, and has been most successful. It should be noted that this is not done altogether to prevent sedimentation of drains, but rather to save the top soil and fertilizer of the cultivated land from being washed away either into ditches or on to the grassed bottom lands. In the latter instance the pasturage is for the time being quite lost. This control system is obviously not one of the direct functions of the drainage authority, although it has been advanced by engineers as being of utmost necessity in many projects.

Flood Protection.

The above subject being of great importance, opportunity was taken to learn as much as possible of the measures taken in the United States to meet flooding conditions.

Rivers.—The levees along the Mississippi, Sacramento, and other rivers were closely observed, and the nature and manner of constructing same noted. Construction by such means as hydraulic dredges, long-range clam-shell dredges, tower excavators, drag-line excavators, and last, but not least, horse scrapers and graders, each play their part. The Mississippi levees were visited in many places between St. Louis and New Orleans. The operations on the above major rivers cover the field of best practice.

The very extensive flood-prevention works of the Miami Conservancy District were visited, as they provide quite the most elaborate flood storage-basin system in America. It is a liberal education to have the opportunity of seeing all the ramifications of this project, and at the same time have it personally explained by those in charge. The scheme will cost some £5,000,000, and its main objective is to protect the City of Dayton, Ohio, and its population of 250,000. Complete sets of plans, specifications, and research data were obtained for reference.

Tide, Sluice, and Lock Gates.

Every opportunity of viewing the various types of gates in use was taken advantage of, and the several engineers were most obliging in supplying data and plans. One of the most satisfactory gates seen was of the " butterfly " type, and is used in New Orleans. It can be opened under a head of 14 ft. with ease, and is simply operated.

Concrete Overfalls, Flumes, and Spillways.

In view of the probable installation of overfalls, flumes, and spillways to break grade in the drainage ditches of New Zealand, a point was made of inspecting as many as possible of these in the United States. The information gleaned at first-hand will be most valuable and useful.

Highways.

In view of the future expansion of the main-highway systems of New Zealand, considerable attention was paid to observing the various classes of concrete roads in the United States. From several of the State Highway Commissions were obtained complete standard specifications and plans of all classes of roads; and, in addition, the Bureau of Public Roads, Washington, D.C., was good enough to provide its own standard requirements.

Quite a variety of highway formation obtains, and into its construction machinery very largely enters, and, in fact, is quite superseding the old methods. Construction of concrete roads is not undertaken on swamp land until many years of consolidation render it safe to do so. Unequal settlement of the roadways through swamps would soon ruin any paved formation such as concrete.

Comparison of the Muck and Peat Soil of the United States with that of New Zealand.

To see any considerable area of peat lands similar to those of New Zealand it is necessary to visit the States of Minnesota, Wisconsin, Michigan, and Florida. Here can be seen all the typical characteristics such as saw- (or cutty-) grass, maiden-cane, cat-tails (raupo), Sphagnum moss, ash-residue, and so forth. Wet and cultivated peat lands present all the well-known features seen in New Zealand. The Everglades, Florida, bear a close resemblance to the Hauraki Plains in New Zealand, but, of course, are enormous in area, comprising, as they do, some 5,000,000 acres. One feature is quite distinct, though, and this is the substratum of coralline limestone. We in New Zealand are fortunate indeed in not having this substratum, but in place thereof clay of varying quality. The peat depths seen in the several States are much shallower than in New Zealand, and range from a few inches to, say, 10 ft., and this applies particularly to the Everglades, Florida. The fact of these peat areas being of a consumable nature is causing much anxiety in so far as the Everglades country is concerned, seeing that the coralline limestone is immediately underlying same. Probably grassing and the maintenance of a fairly high water-table will ensure immunity from fire.

These genuine swamp areas are classed as " muck " and peat," the former containing a fair proportion of silt, while the latter is pure vegetable matter. Both characteristics can be seen in most New Zealand swamps. A conclusion is arrived at that the " muck " and " peat " soils of both countries are similar in character and productivity, but that much better pasture can be seen on the drained swamp areas of New Zealand. Acre for acre, the American swamp lands are no better drained, nor responsive, than those of New Zealand.

Comparison of Alluvial Swamp Lands of United States and New Zealand.

No land was seen in the United States of America to exceed in quality that of the alluvial swamp areas of New Zealand, and it may be mentioned that the Hauraki Plains area, together with Rangitaiki Plains, stand out as object-lessons in the way of both pasture and stock-carrying capacity.

Much attention is given to the question of the water-table in swamp lands, and exhaustive experiments are being continuously carried out as to point of saturation, &c. It is recommended that this field be explored in New Zealand, as first-hand knowledge is now available for its conduct.

The Selection of Drainage Machinery and Supplies for New Zealand.

The foregoing ground covered by this report was necessarily a prelude to the consideration of the most suitable types of drainage machinery for use in carrying out the various undertakings of the Hon. Minister of Lands in New Zealand. Weight had of necessity to be given to the important factors of transport, not only overseas, but—what was more serious—transport in the Dominion. Then, again, the demands called for machines of latitude and flexibility, which might be called universal in their application to the several operations. They must be capable of undertaking either small or fairly large jobs. Ultimately, after most careful consideration of the several types, a selection was made, competitive quotations obtained and analysed, and a cabled recommendation forwarded to the Dominion as regards certain machines. Authority to enter into contracts being received, the several contract documents were prepared and completed with the greatest care. The whole of the transactions were carried out direct with the manufacturers on the basis of a f.a.s. price, New York.

The following contracts were entered into, together with requisitions for spares, &c. :—

1 Bay City Dredge-works—	$
One walking-dredge	11,600·00
One dipper dredge	9,000·00
	20,600·00
2. Bucyrus Company—	
Two gasolene excavators at $22,020 each	44,040·00
3. Monighan Machine-works—	
Two walking-excavators at $21,150 each	42,300·00
4. Michigan Dredge Company—	
One walking-dredge	15,239·00
5. Rood Construction Company—	
One walking-dredge	21,315·00
6. American Steel Dredge Company—	
Two oil dippers at $20,250 each	40,500·00
Two steam dippers at $16,250 each	32,500·00
Two steel hulls at $7,500 each	15,000·00
7. (Not placed.)	
8. Bucyrus Company—	
Three steam-shovel drag-line excavators at $19,725 each, and one set of spares, $2,850	62,025·00
9. Ingersoll-Rand Company—	
Complete gasolene-driven rock-drilling equipment	32,606·50
10. Fate-Root-Heath Company—	
Two petrol locomotives at $2,850 each, and one set of spares, $473·49	6,173·49

Requisitions issued.

1. Bay City Dredge-works : Spare parts	642·00
2. Michigan Dredge Company : Spare parts	862·20
3. Monighan Machine-works : Spare parts	1,689·35
4. Sanborn Company : Flow-recorders	314·10
5. Commercial Camera Company : Photostat, &c	1,435·50
6. Bucyrus Company : Spare parts	2,637·00
7. W. and E. Gurley : Current-meter, &c.	214·95
8. Fate-Root-Heath Company : One petrol locomotive	2,850·00
9. Bay City Dredge-works : Spare parts and extras	727·13
10. Sullivan Machinery Company : Drills and spare parts	1,277·10
11. Michigan Dredge Company : Spare parts	679·35
12. Ingersoll-Rand Company : Spare parts	1,845·17
	$347,472·74

The foregoing represent quite the most up-to-date plants available, and all are standard equipment. No single item is experimental ; all are in common and daily use in the United States. They are all up to their work and proven out. Necessarily, there will be breakdowns and stoppages, however well handled ; but allowance must also be made for delays in first instance due to machines having crews who are entirely new to this class of plant. The crews will have to master each machine ; and, outside of structural failure, it lies entirely with the personal element to operate the machine as it should be operated. Everything depends on the operator, as he will undoubtedly have a good tool in his hands.

The internal-combustion plants are intended for localities where, on account of transport difficulties, coal-delivery is difficult.

The Bureau of Public Roads, Department of Public Roads, Washington, D.C., very courteously attended to the inspection and passing of each plant at the factory, but our contracts cover replacement of any structural defects that occur within three months of erection in the Dominion.

The various machines, &c., had to come under such weights as we could handle and transport at this end, and this is limited. Machines of greater capacity than that selected would have been beyond our means of local transport and handling.

Proposed Distribution of Machinery and Supplies.

Consideration.—In the past the Lands Department has been forced to open up further construction works on several areas owing to the success attending the Hauraki Plains drainage. Attempts have uniformly been made to let contracts for the major works, but have failed on account of no contractors possessing the necessary machinery ; and no doubt labour troubles have contributed. The Department was thus compelled to undertake its own operations, and as far as possible procured machinery for the purpose. Such operations have been very successful, considering the lack of plant in comparison with the many projects involved. A visit to similar works in the United States has resulted in the choice and purchase of plant calculated to allow of greater concentration on certain areas, and the following proposed distribution of such plant is recommended:—

Plant-distribution.—Hauraki Plains: One Rood walking land dipper dredge; One Wilson walking land dipper dredge; two Bucyrus caterpillar drag-line excavators; two steam dipper dredges, 1½-yards capacity. Rangitaiki Plains: One Bay City walking dipper land dredge, 1-yard capacity; two Monighan walking drag-line excavators. Kaitaia area: One Bay City dipper dredge; one Priestman grab-dredger (from England). Waihi area: One steel dipper dredge (oil-driven), with steel hull. Poukawa area: One steel dipper dredge (steam-driven). Hikurangi area: Three Bucyrus steam-navvies convertible to drag-lines; two petrol locomotives; seven gasolene-driven air-compressor and receiver units, with jack-hammers and steel drills, &c.

Spare parts will be allocated to various machines, and as each plant arrives it will be conveyed to its approved destination. This distribution will materially accelerate work and hasten completion of main projects, and thus release plant from time to time for other undertakings.

Photographs of these machines will be found appended hereto.

Office.—The No. 3 photostat will be installed as soon as a suitable room is available. This outfit is a fine one, and has innumerable purposes of application. It is proposed to do much work of direct reduction of all descriptions of plans, not only for the Land Drainage Branch, but for the two District Offices and the Standard Survey Branch. Plans of 36 in. by 48 in. can be reduced to sizes of 18 in. by 24 in. and smaller, and portions of plans can be photostated to various scales. All classes of documents can also be readily copied, and, in fact, there are a-thousand-and-one ways where time and money can be saved.

The operation of this machine is a most suitable occupation for a young woman. Quite a feature of this machine's use is the reduction of plans for binding in atlas form for either file or field use. This application is general throughout the United States. A report on the scope of the instrument by the Taft Commission to Congress is attached hereto.

Two flow-recorders and one current-meter were purchased for use in connection with investigations of this branch. It is unnecessary to state that these instruments are absolutely essential, and should form part of the scientific equipment of any engineering office.

The Future of the Land-drainage Movement in New Zealand.

Past History.—In the initial stages of the movement comparatively small areas of swamp lands were being drained by community or private enterprise working under the Land Drainage Act. The reclamation of large areas could not well be financed without Government aid, and finally parliamentary sanction was obtained to the proposed development of what was then known as the Piako Swamp, but now as the Hauraki Plains. An enabling Bill was brought down for this particular area, and later for the Rangitaiki Plains area, and the results obtained by the drainage operations called forth applications from many districts for similar aid.

The old procedure of individual empowering Bills was then decided to be too cumbersome, and the Government of the day decided to bring down a measure which would enable it to handle subsequent applications. This measure was finally placed on the statute-book as the Swamp Drainage Act, 1915, the Hon. Minister of Lands being the administrative authority.

The Future.—To date, the drainage operations carried out under Government control have resulted in bringing previously useless swamp land to profit, and expectations have been more than realized. These operations are incomplete as regards present undertakings, and there are many areas untouched which it will pay to take in hand.

One cannot be too enthusiastic in the matter of land-reclamation, and the watching of seemingly irreclaimable areas coming to profit is very heartening. There is a big field of undeveloped possibilities in New Zealand that can be best carried out by the Government under its own Swamp Drainage Act, 1915, or by community enterprise working under the machinery of the Land Drainage Act, 1908.

There are many purely swamp areas throughout the Dominion, perhaps small individually, but large in the aggregate, which must, in the ordinary course of events, be reclaimed. Then come the large tracts of marsh lands on the foreshores of the coast. The periodically flooded bottom lands in the flood-plane slopes of rivers is another avenue for development. Fortunately, gravity drainage governs the larger proportion of future possible reclamation projects. Installation of low-lift pumps will be necessary to deal with certain of the areas. Generally, the field is a broad one, and offers every inducement for investigation.

There will without doubt come a time when necessity will demand intensive cultivation of swamp and marsh areas; holdings will become smaller, and the necessity for close drainage of same will arise. To meet these conditions tile drains will be required, in sizes of 6 in. and upwards. Their use has been most successful, and they will eventually largely replace open ditches, which occupy so much land.

Investigations necessary.—It is recognized in Canada and in the United States that practical assistance by the respective Governments is required in the direction of providing reliable data for information of Drainage Boards, settlers, and engineers, and to this end there exists an investigation staff. The Drainage Investigations Bureau of the United States is a most valuable branch of the Federal Government, and might well be adopted as a model for requirements in New Zealand and elsewhere.

Recommended Field of Investigation in New Zealand.—Although practically all officers of the Land Drainage Branch are construction men, yet it should be possible to incorporate with their duties some measure of investigational research, provided junior assistance is given them in the way of avoiding the personal daily round of visits to the various instruments, recorders, test-pits, &c. It is suggested that the time is ripe to undertake local investigations in regard to the following: Precipitation (rainfall); run-off; evaporation; soil-moisture; subsidence of drained land; flow of water in artificial canals and ditches; saturation; water-table research.

At present our means of determining the run-off of any particular watershed are meagre, and the approximate deductions arrived at unreliable.

This branch should be in a position to offer sound advice to drainage districts upon these most important questions, for upon it depends the size of ditches necessary to accommodate storm-water, the spacing of same, and the depths necessary to enable as low a water-table as possible being maintained. The value of such work would be greatly enhanced by the issue of bulletins from time to time.

In the event of the foregoing recommendations regarding drainage investigations being approved, it is not suggested that they take effect immediately, but rather that the principle be affirmed and action taken as soon as conditions return to normal.

CONCLUSION.

General.—The visit to the United States has been most educational, both practically and professionally, and it would not be possible within this report to bring out the technical phases of the works inspected.

The drainage-work done in New Zealand does not suffer by comparison with that of the United States—in fact, the finish of our work, both as to ditches, sluices, bridges, and general utility, is not surpassed. As to expedition, there is no doubt that this feature is more prominent in America. There dredges up to 6-yards capacity are not uncommon, while those of 2½-yards capacity are quite common. There there is no problem of transport, because railways are everywhere, and contractors can move plant more easily two thousand miles than we can one mile. The same applies to lumber, coal, &c. Repairs are quickly effected, due to engineering-works being readily reached for repairs, and so forth. Then, again, there are many large firms of contracting drainage engineers with plants innumerable. One firm has thirty-five floating dredges alone, and many own fleets of from ten to fifteen dredges. Other contractors concentrate on dry-land dredges. Thus the availability of floaters, walking-dippers, and drag-line excavators has quite displaced hand-labour, and no difficulty exists in putting a job through expeditiously.

Within our resources we have done remarkably well, and have no just cause for disappointment. It should not be overlooked that it is one thing to drain a district, but quite another to also form all the roads throughout that district and bridge and culvert them. No areas were seen in America under one authority that embraced so many operations as we have to undertake. Here we take the raw land and develop it in all directions, and ultimately settle it. In the States one authority drains the land and another roads it. An exception exists in the case of the Everglades, Florida, where the State is largely handling this project. The waterways through same are its main concern.

Drainage has not yet been reduced to an exact science, and the recasting of original schemes is going on daily in the United States, and will so continue. The general fault has been in ditches of too small capacity and the subsequent shrinkage of land. As land subsides, it must be followed up by deepening the drains. It is a slow process, and time is the essence of success with this class of work. Half of the operations seen in the United States consisted of redigging.

A cool consideration of the facts, together with personal observation, shows the settler on the swamp lands of New Zealand as occupying an equally favourable position with his fellow-settlers overseas.

Personal.—In conclusion, the very hearty reception and facilities afforded your responsible officer cannot be overrated, as it was thus possible to meet the most eminent drainage engineers and authorities in Canada and the United States. These gentlemen supplied a very large quantity of literature and data, and arranged visits of inspection to the many works under their control.

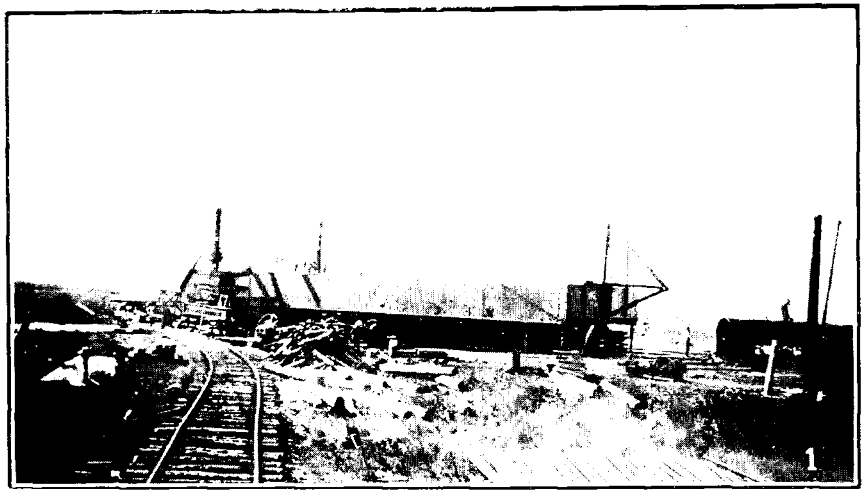
Mr. S. H. McCrory, Chief of Drainage Investigations, Washington, was very largely instrumental in making the visit the success it was, and his valuable assistance is hereby acknowledged. In the appendix hereto will be found a list of gentlemen whose interest was freely and generously given.

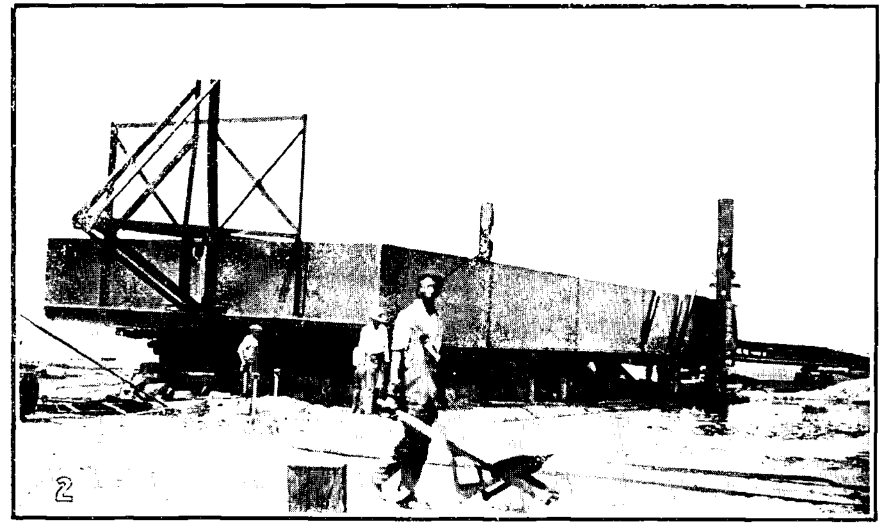
The attached plates are self-explanatory.

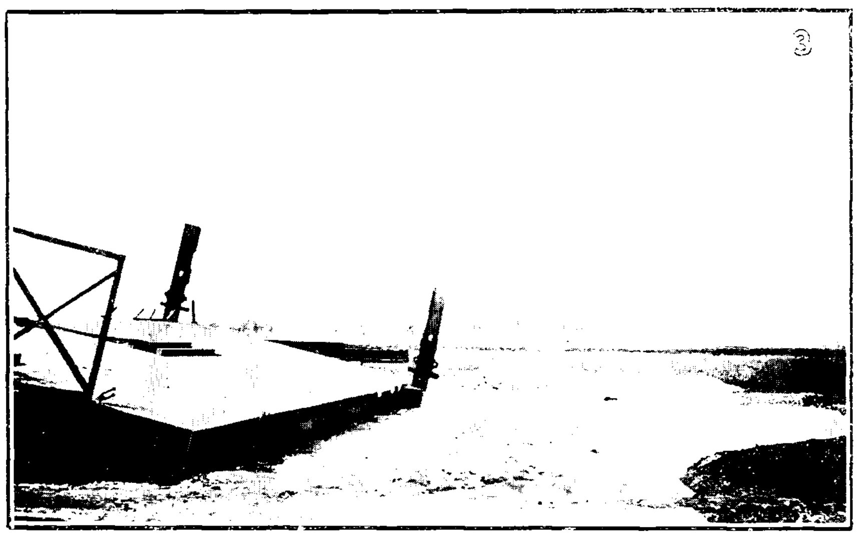
I have, &c.,

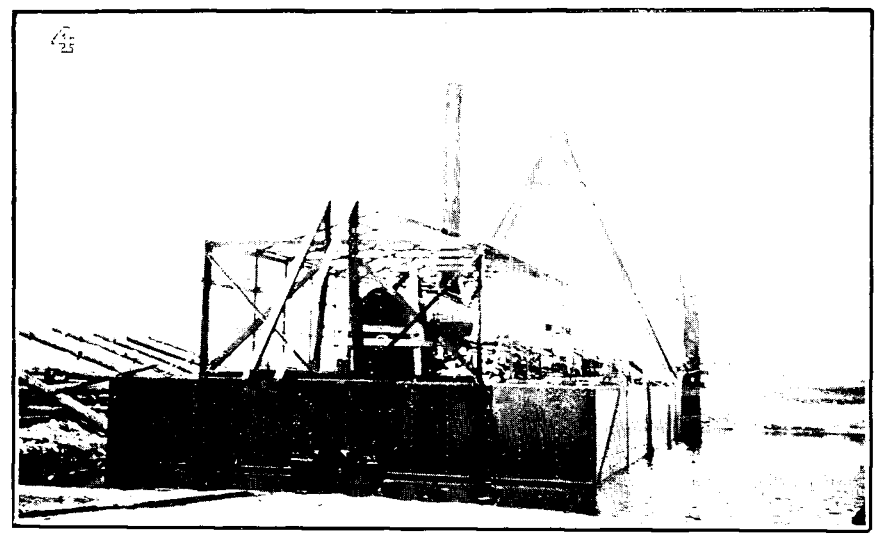
J. B. THOMPSON,
Chief Drainage Engineer.

The Hon. Minister of Lands, Wellington.

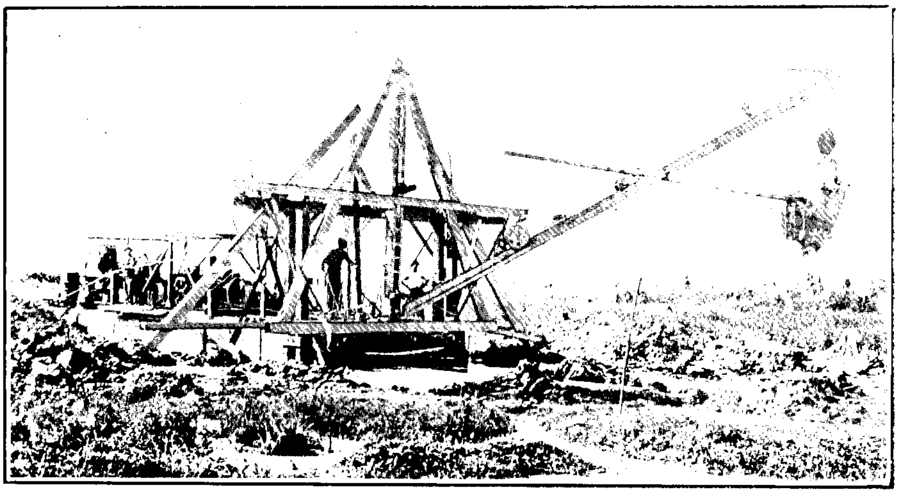






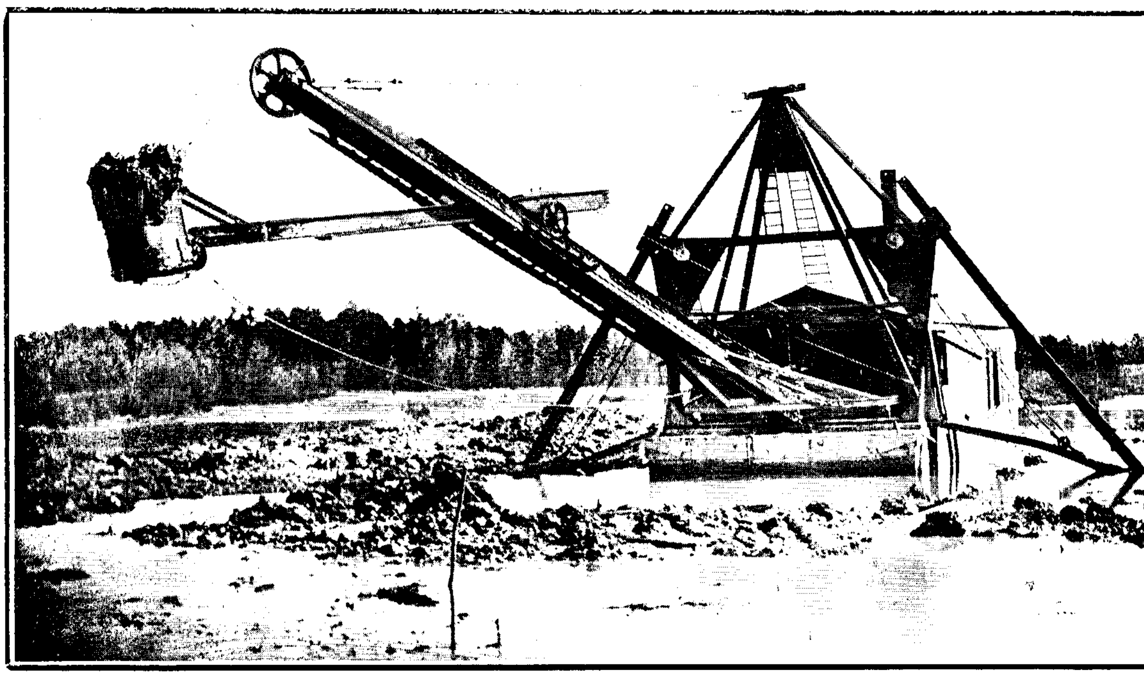


STEEL HULL.
(Two purchased for New Zealand Government.)



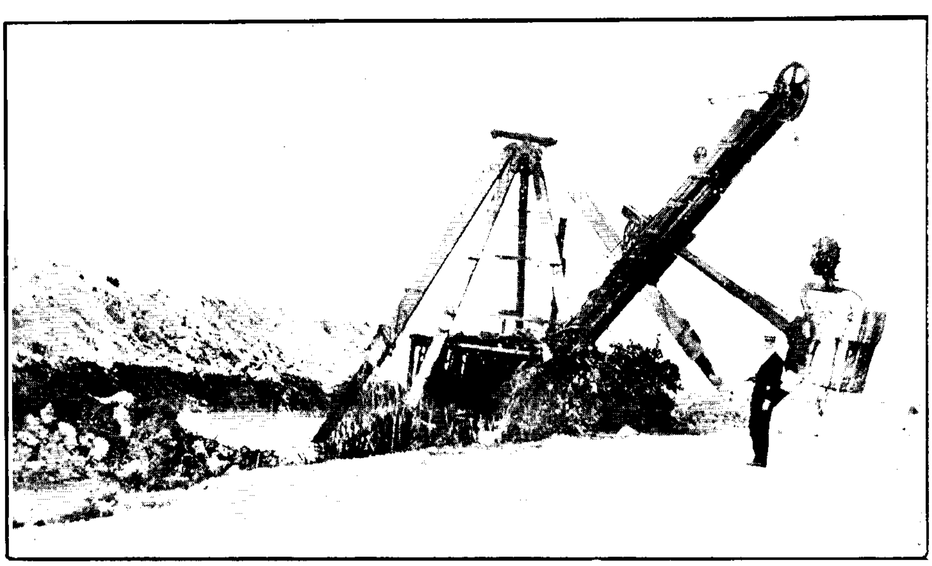
Light Dipper Dredge.

(One purchased for New Zealand Government.)

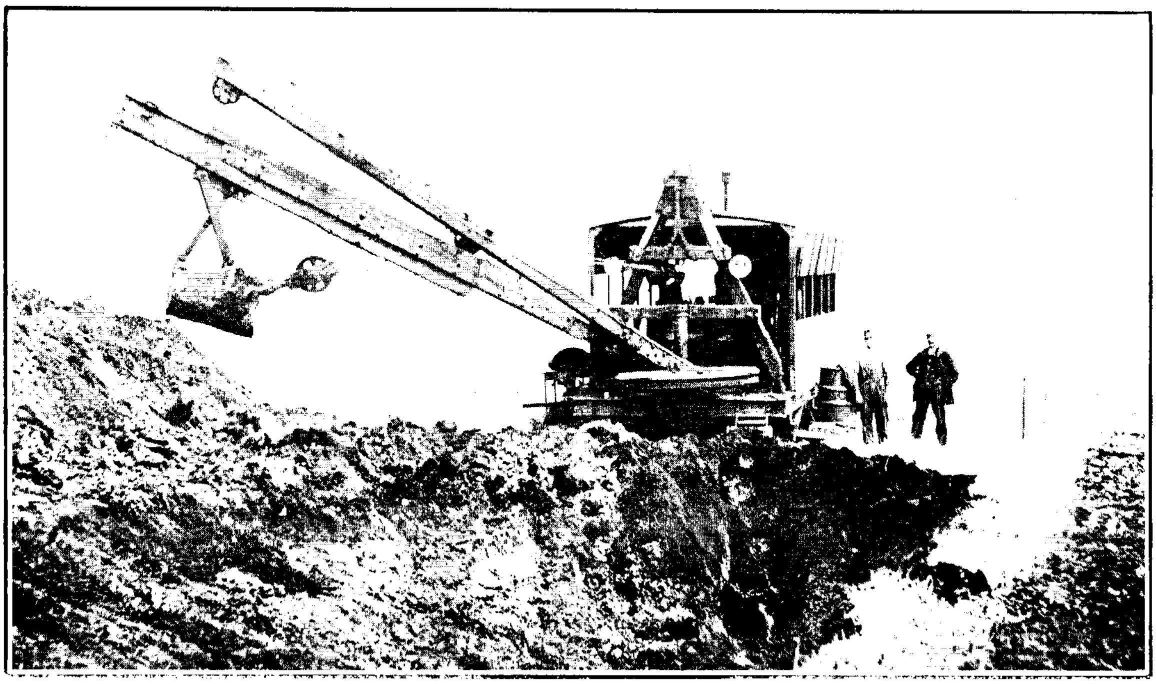


Dipper Type Dredge ($1\frac{1}{2}$ cubic yards).

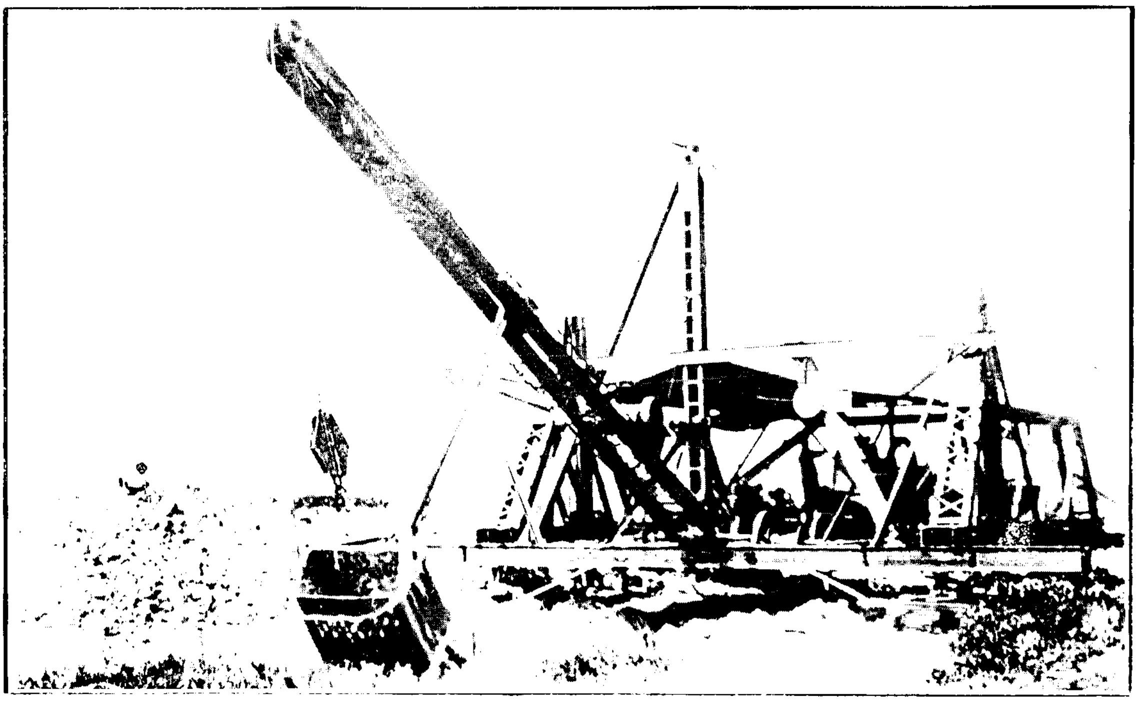
(Four purchased, without hulls, for New Zealand Government.)



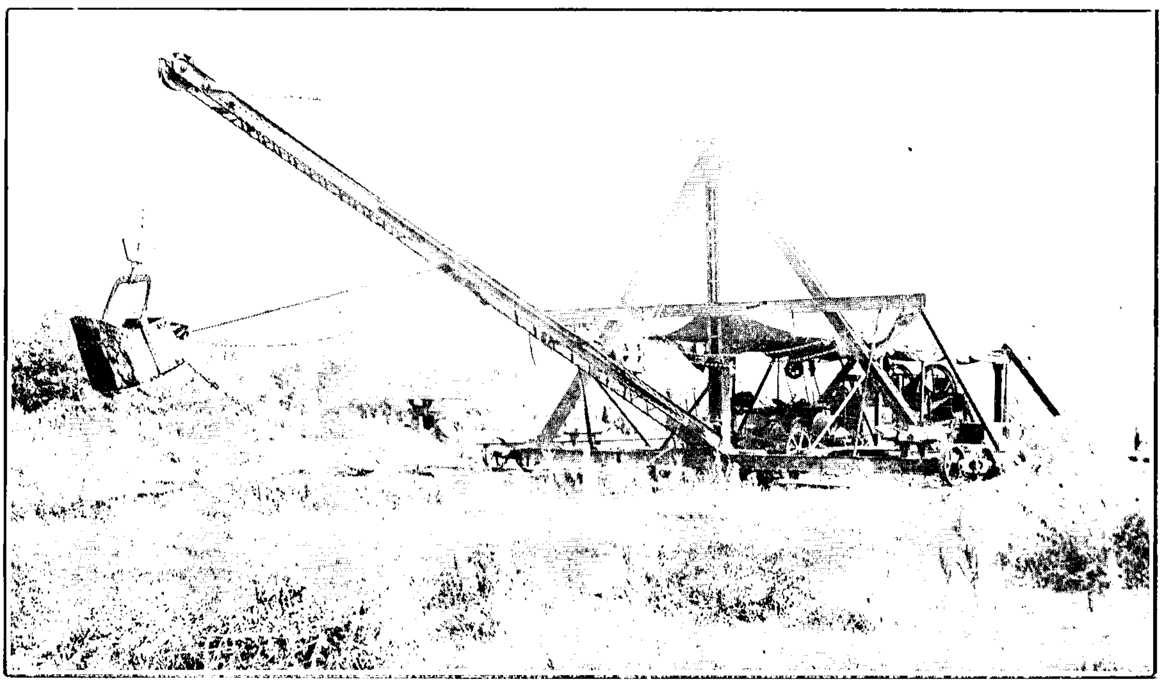
Dipper Dredge ($1\frac{1}{2}$ cubic yards).



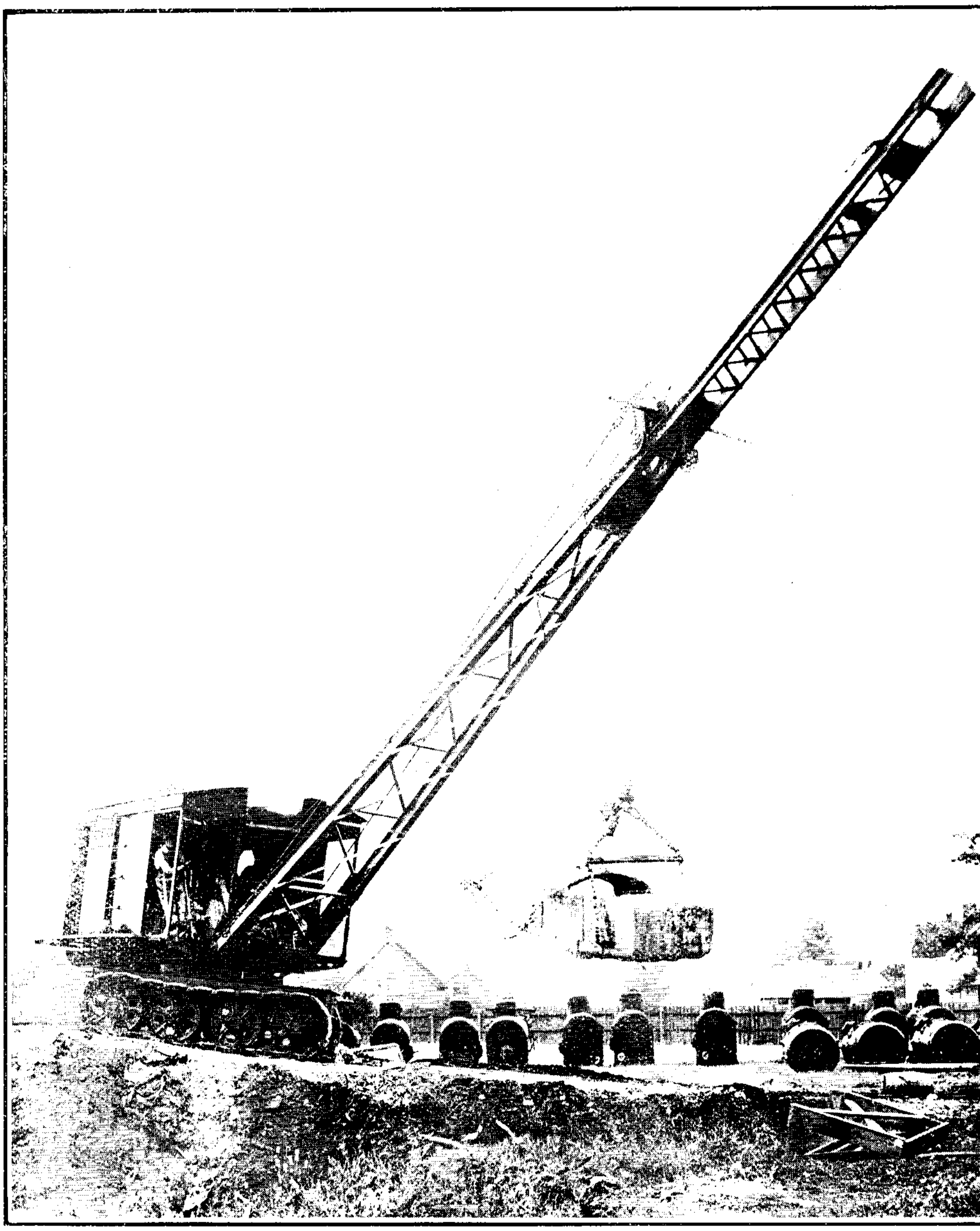
WALKING LAND DIPPER (1½ CUBIC YARDS).
(One purchased for New Zealand Government.)



WALKING LAND DIPPER (1½ CUBIC YARDS).
(One purchased for New Zealand Government.)



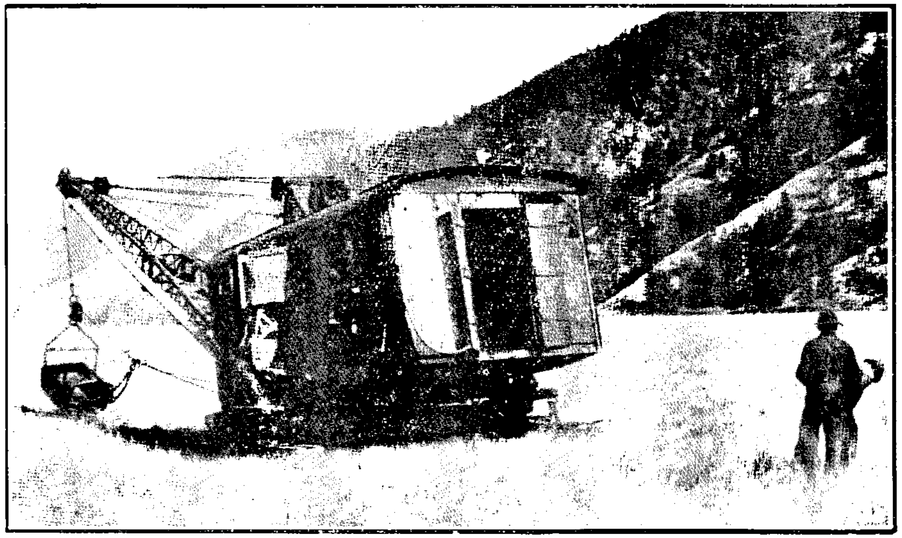
WALKING LAND DIPPER (1½ CUBIC YARDS).
(One purchased for New Zealand Government.)

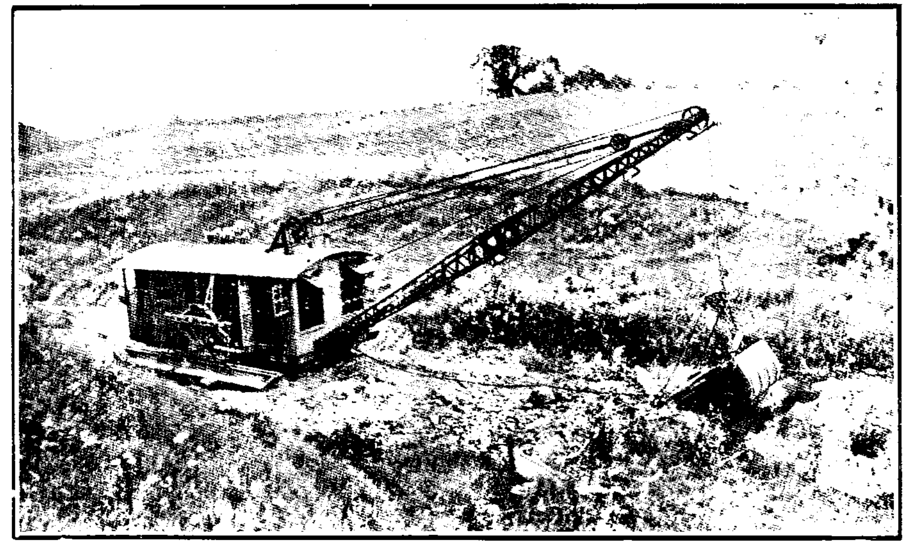


Drag-line Excavator with Extension Boom.

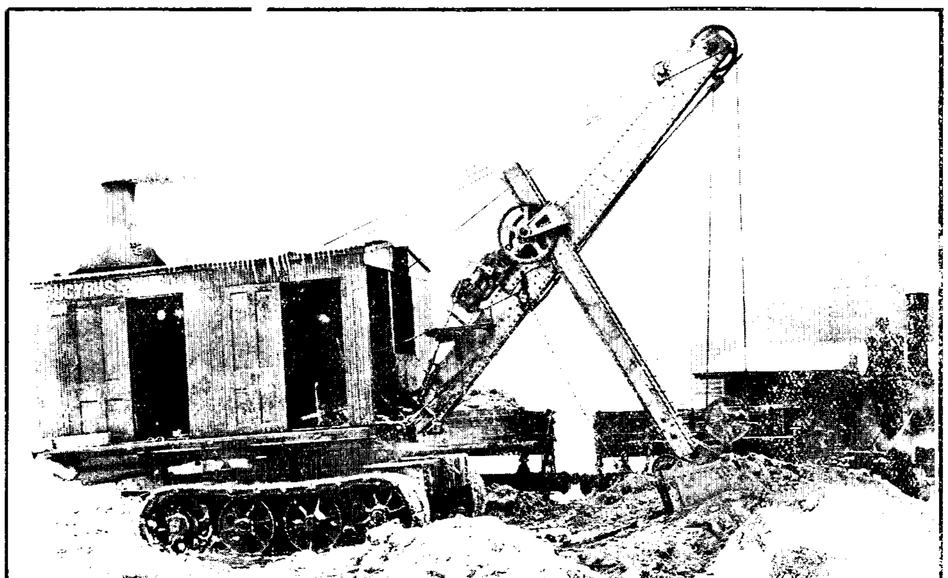
(Two purchased for New Zealand Government.)

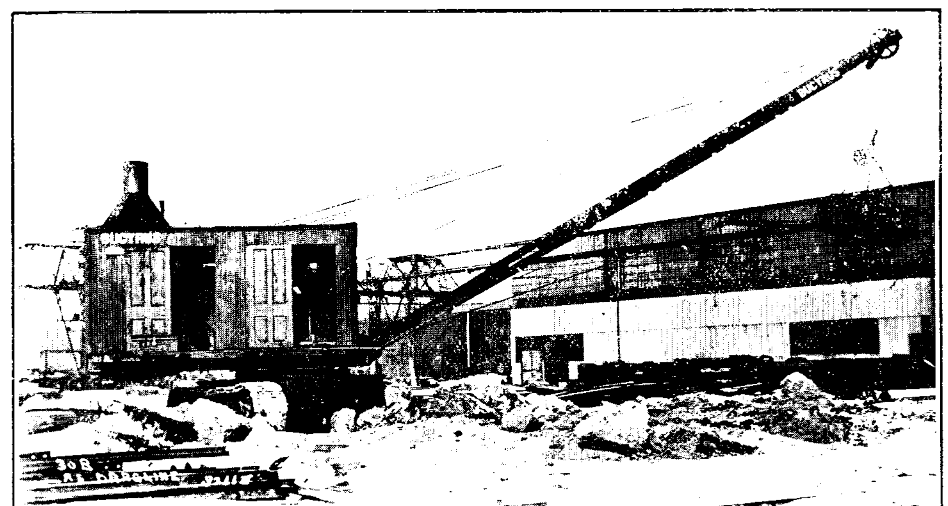
Walking Drag-line Excavator.



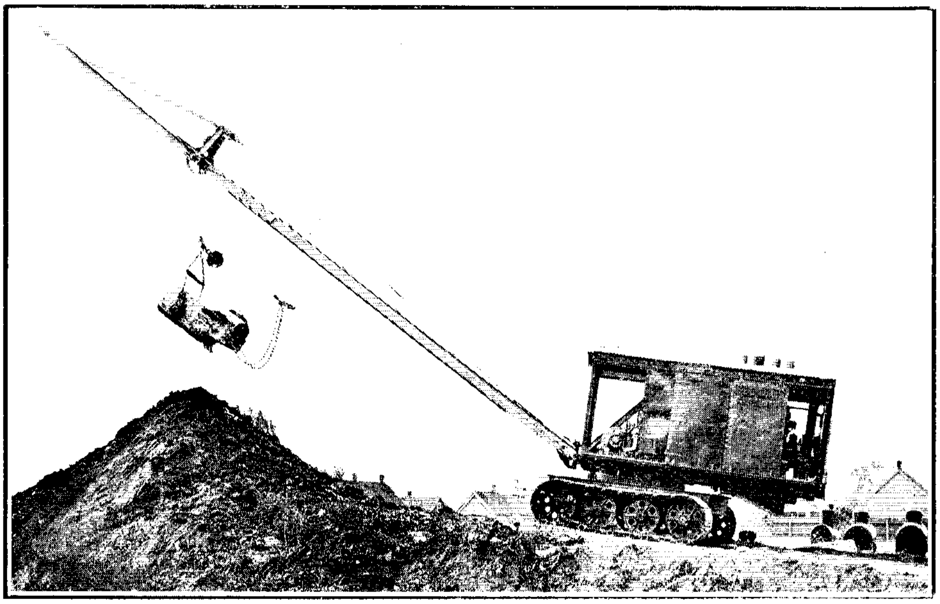


Walking Drag-line Excavators.
(Two purchased for New Zealand Government.)



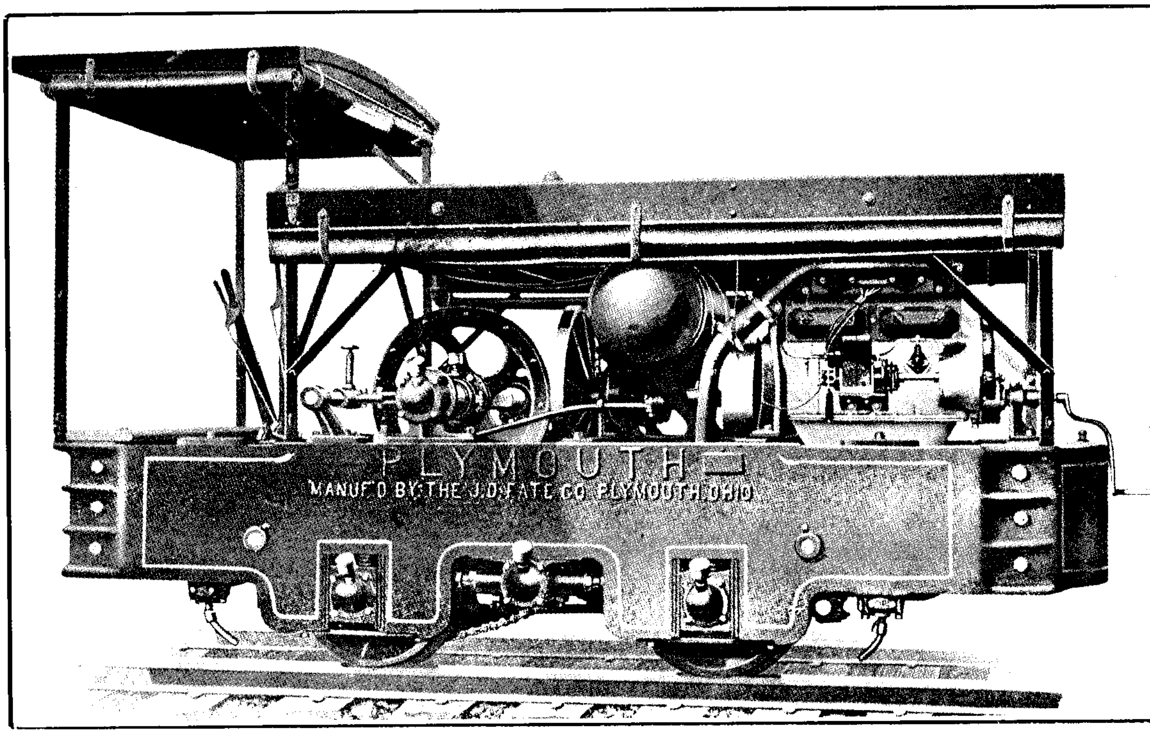


Steam Shovel (convertible to Drag-line).
(Three purchased for New Zealand Government.)



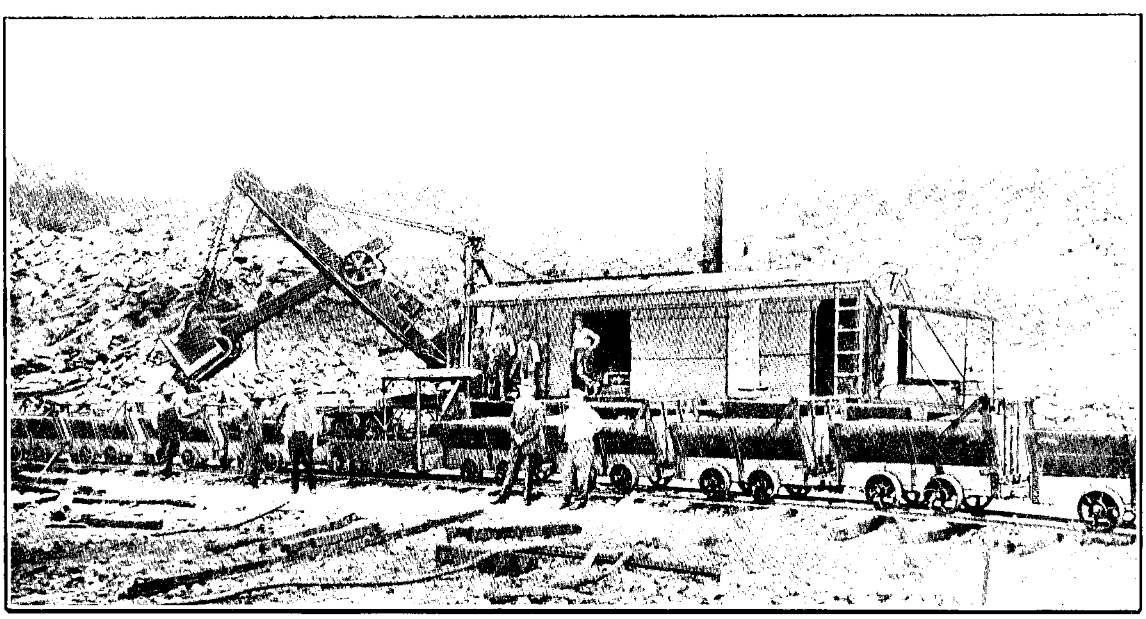
Drag-line Excavator, showing Extension Boom.

General Application of Rock-drilling Plant.

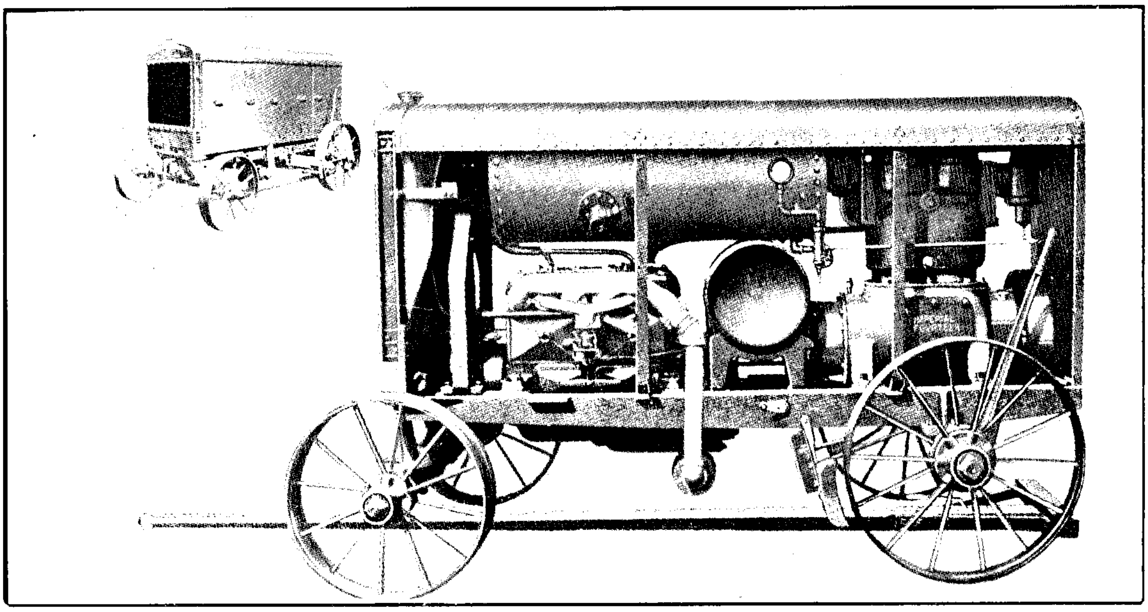


Gasolene Locomotive (3 tons).

(Three purchased for New Zealand Government.)

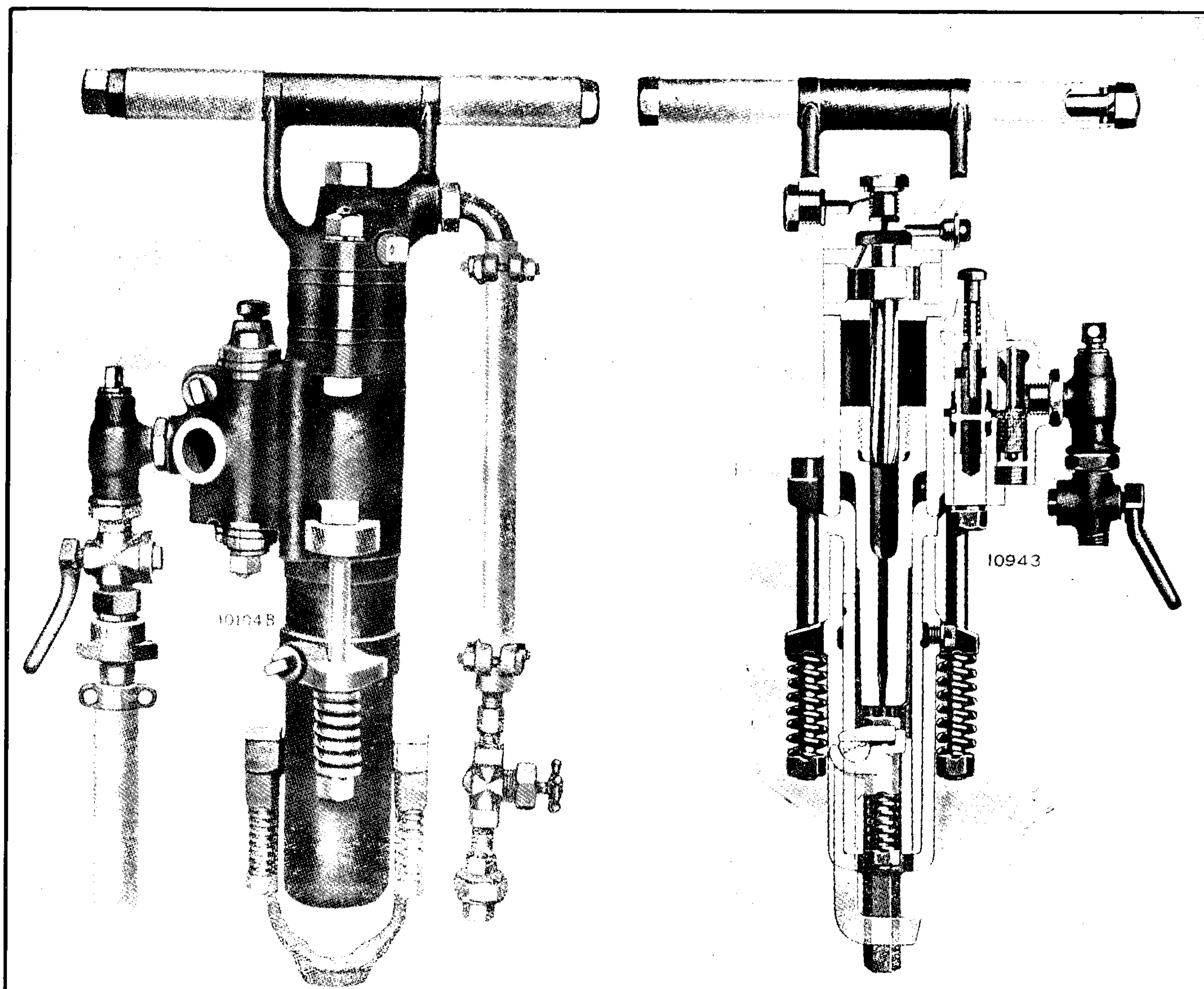


Application of above Locomotive.

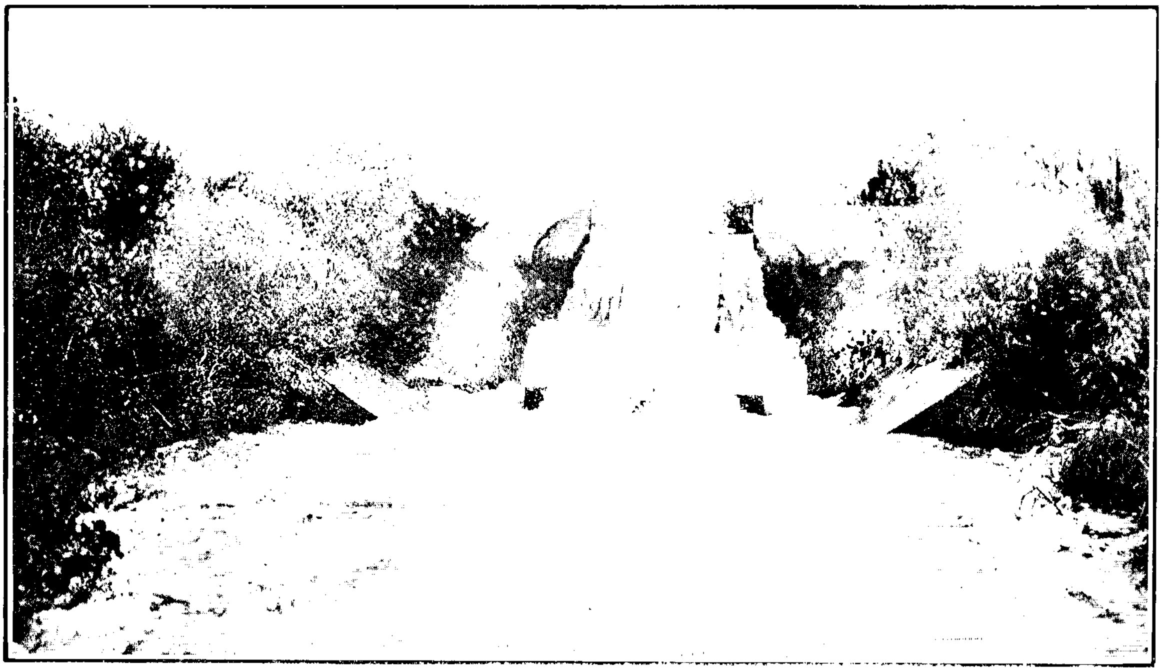


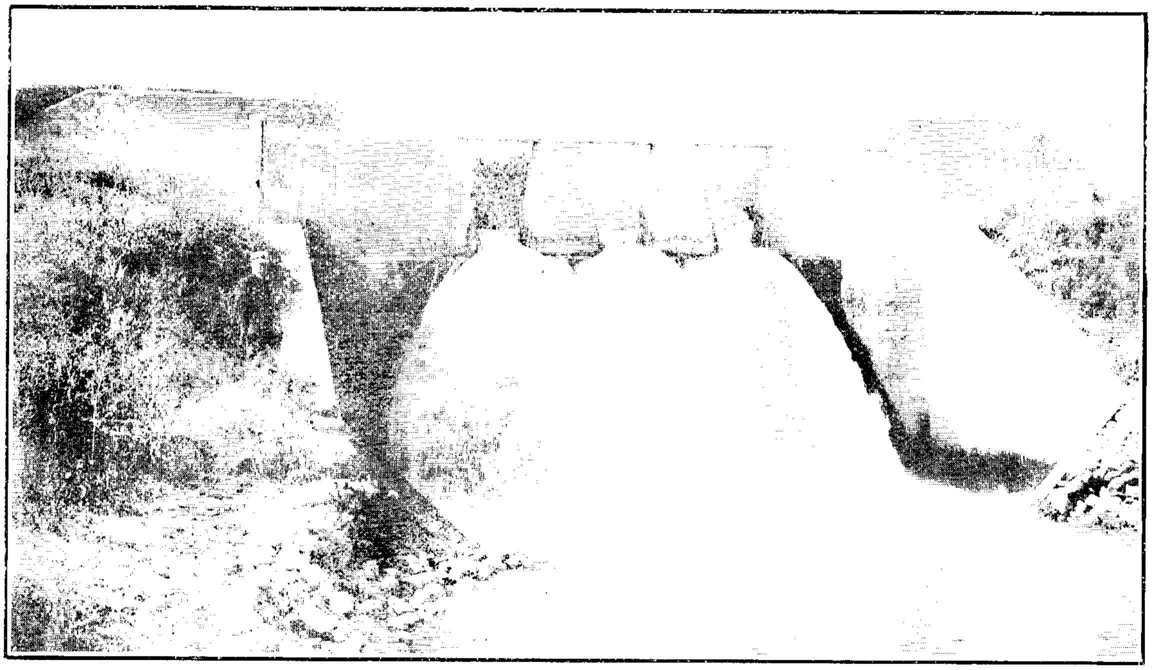
Gasolene Air compressor.

(Three complete heading outfits purchased, comprising seven units.)

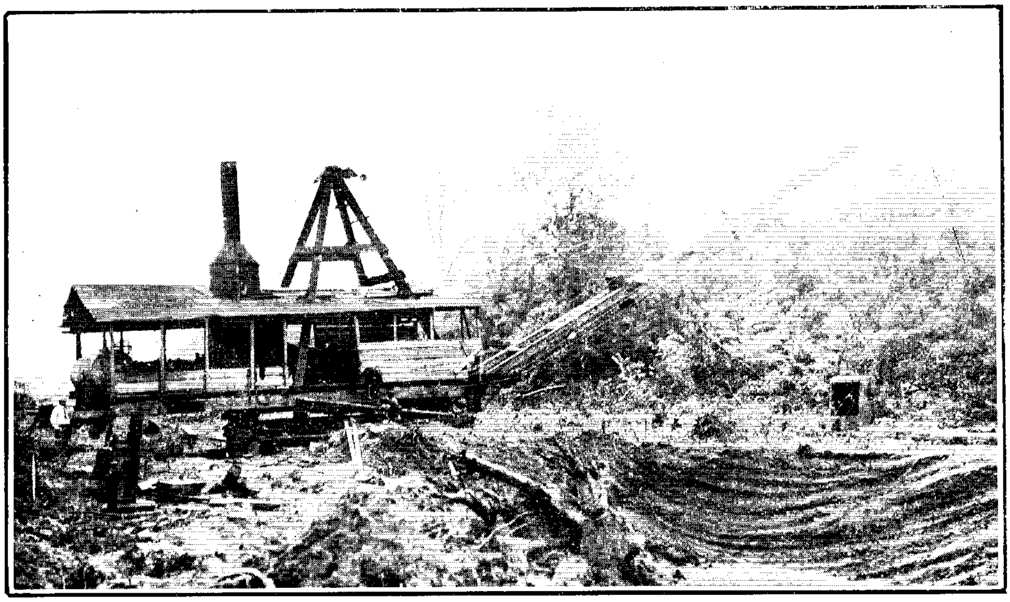


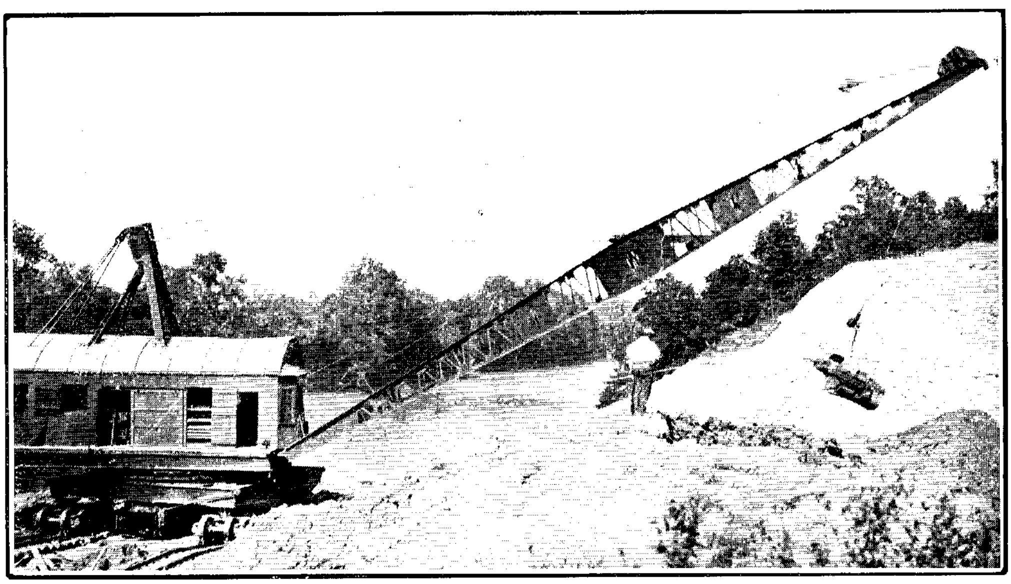
Air Rotator Drills.

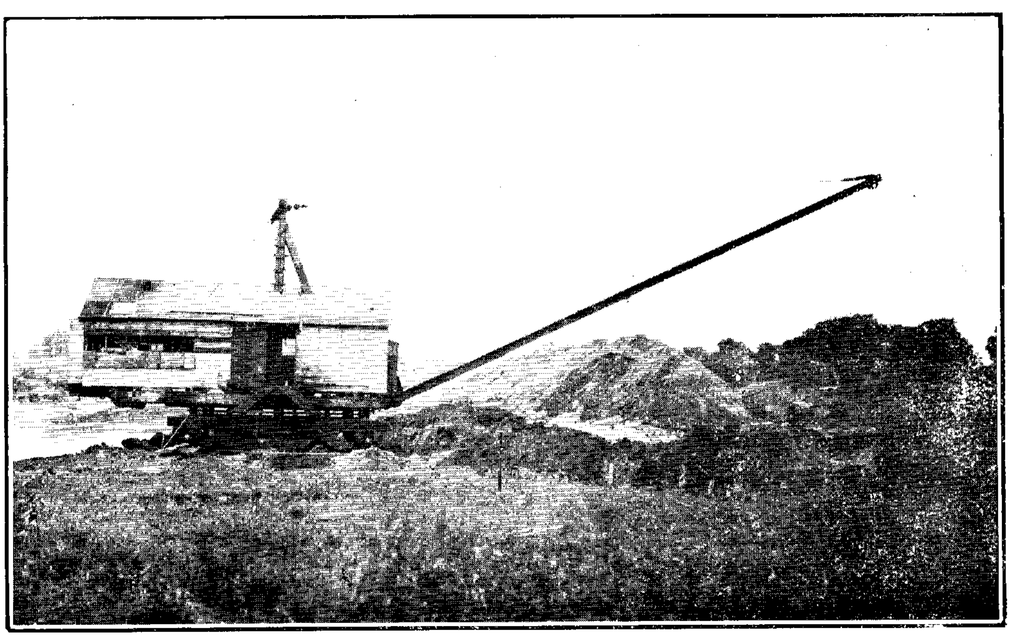




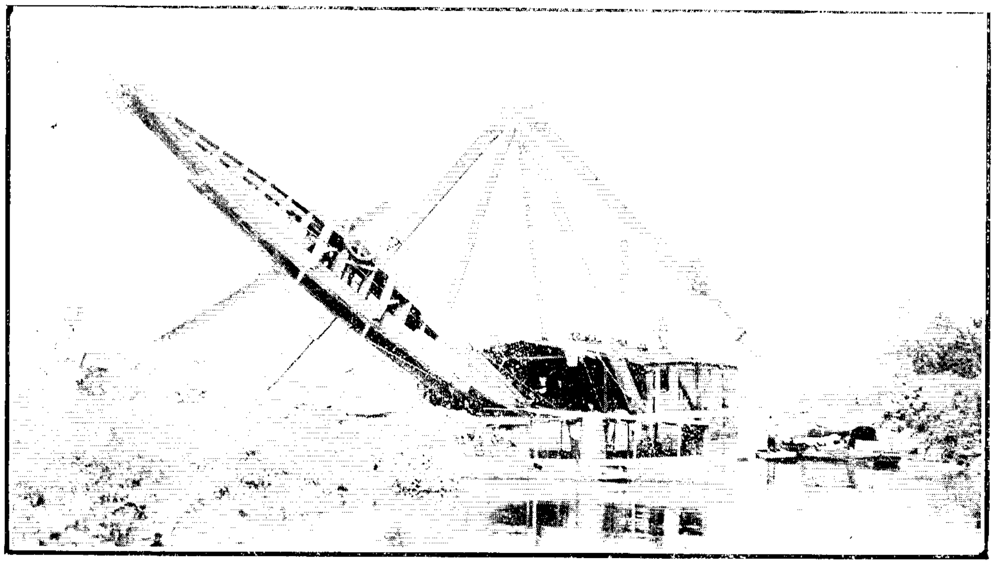
Types of Overfalls on Ditches.

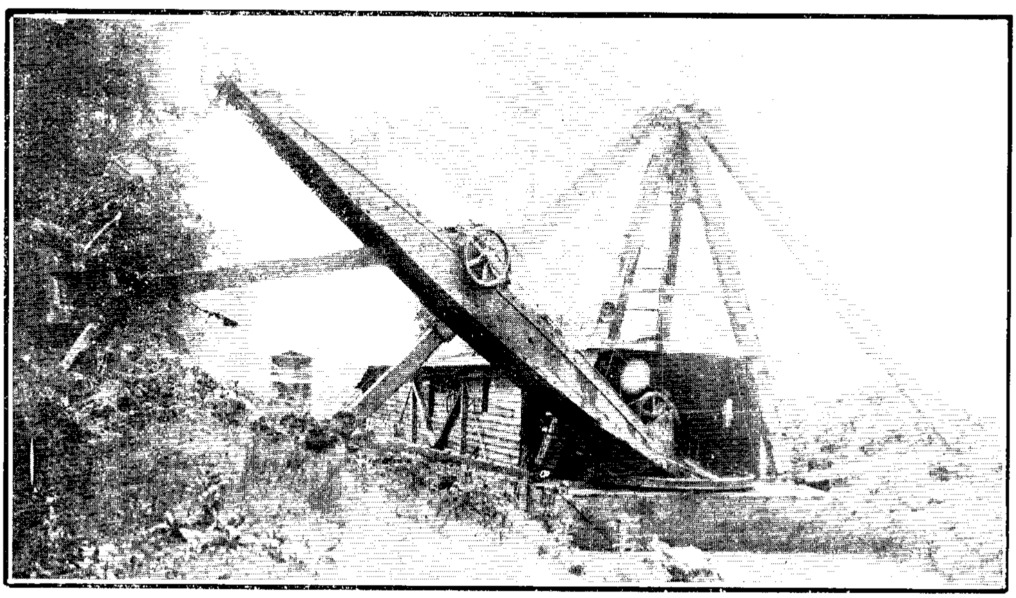


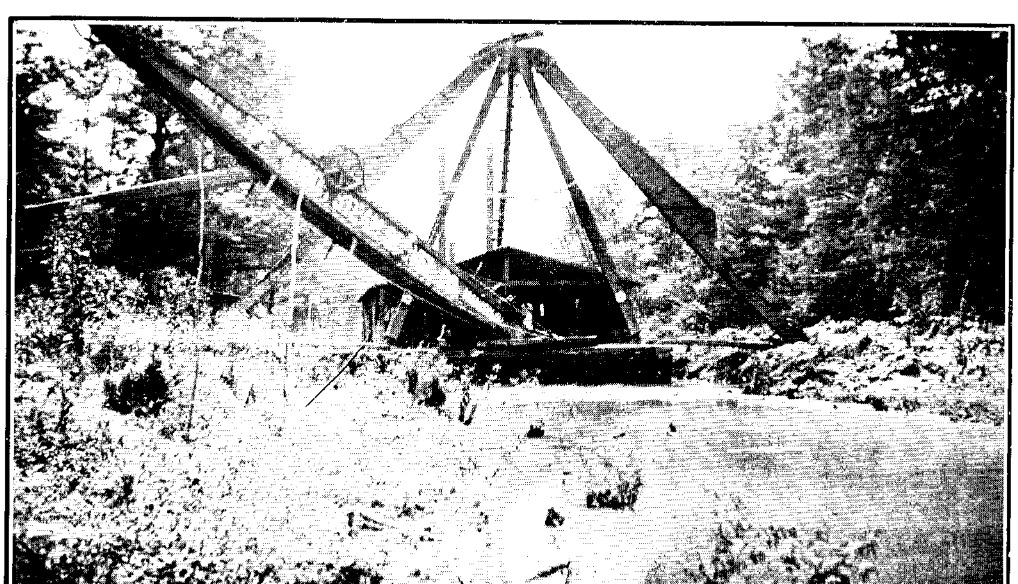




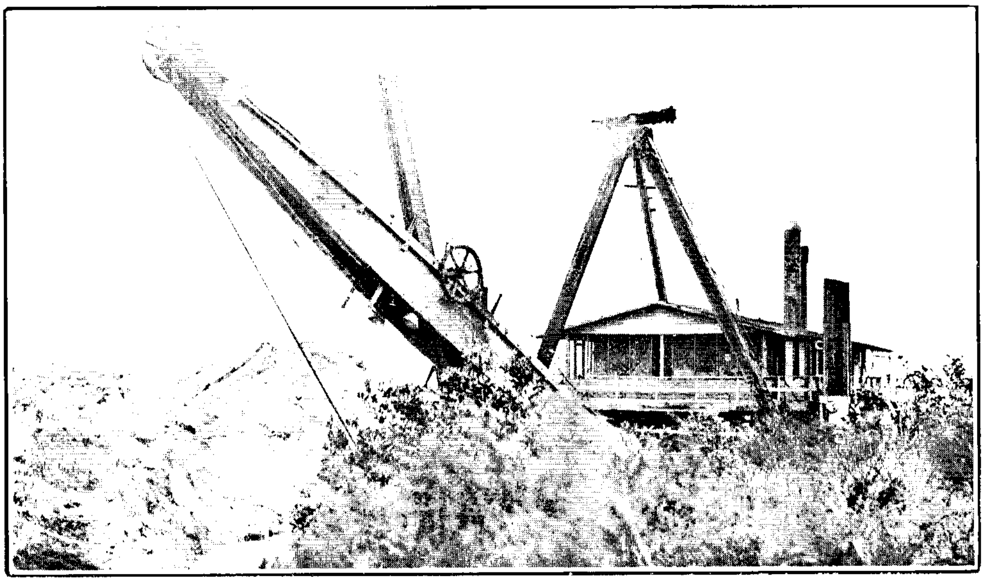
DRAG-LINE EXCAVATORS.



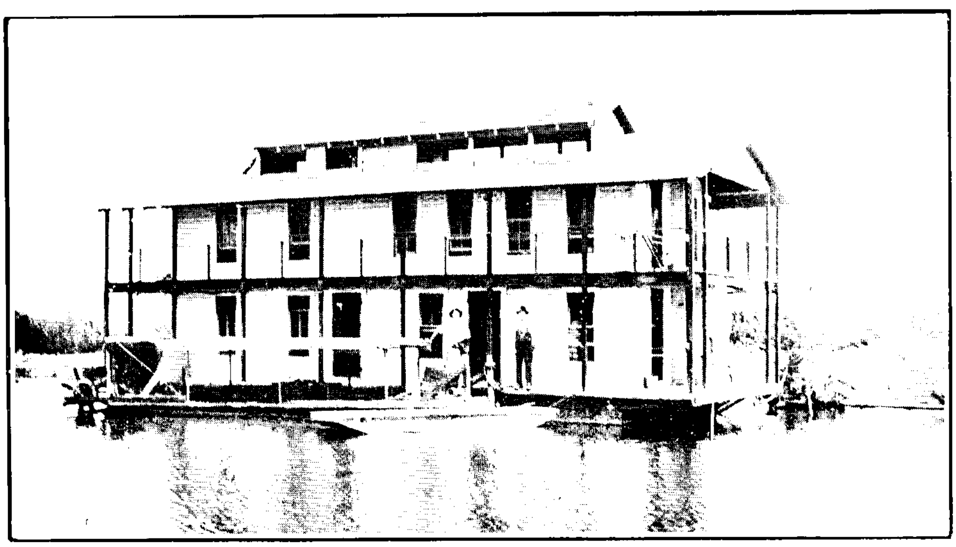


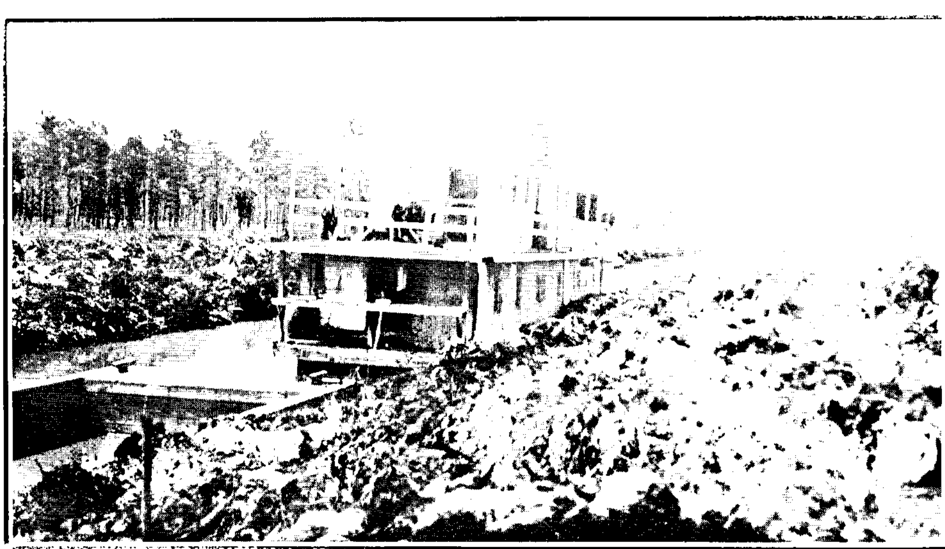


Dipper Dredges.

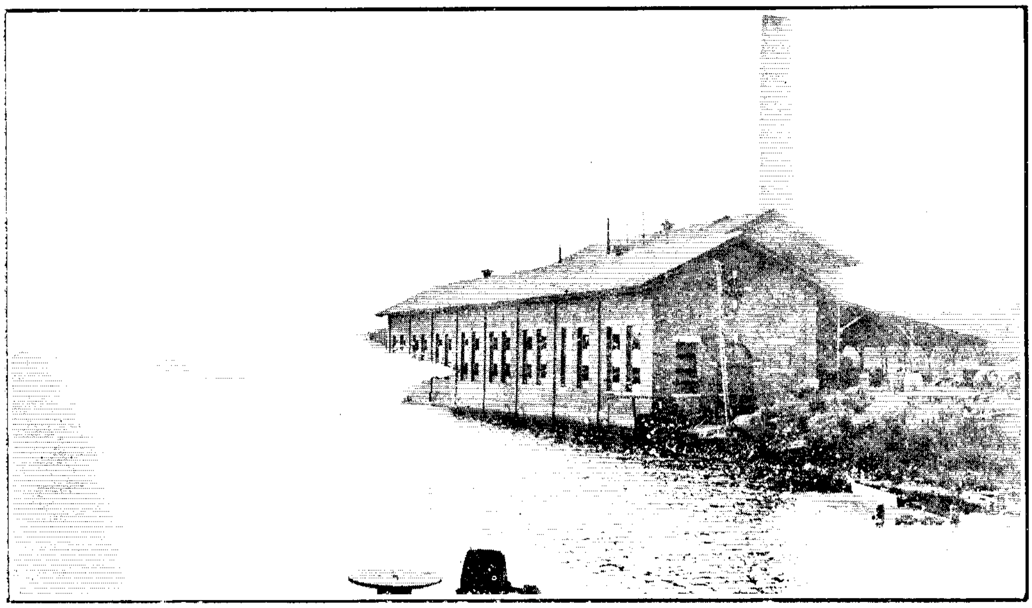


DIPPER DREDGE.

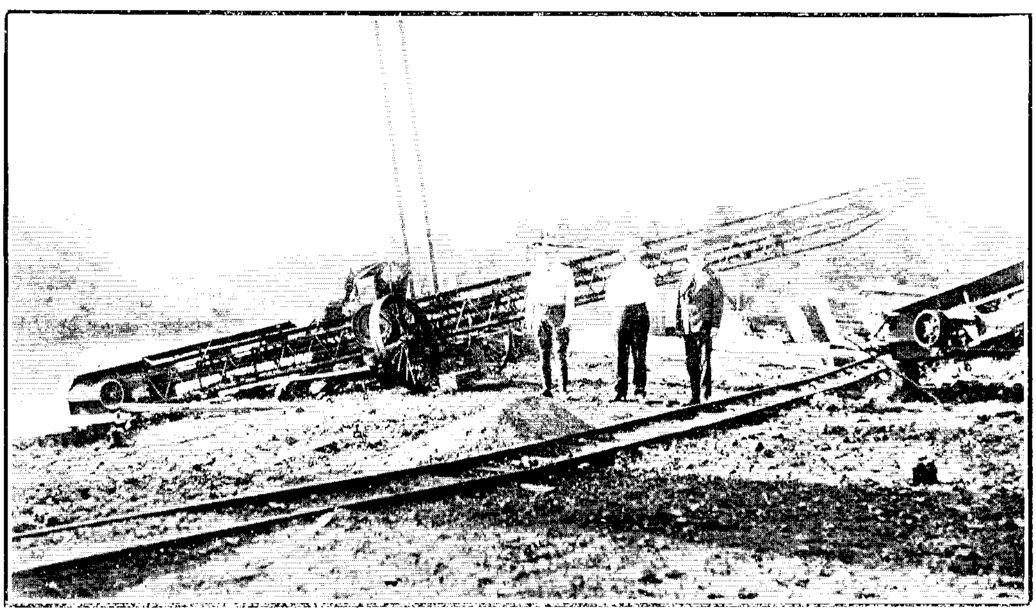




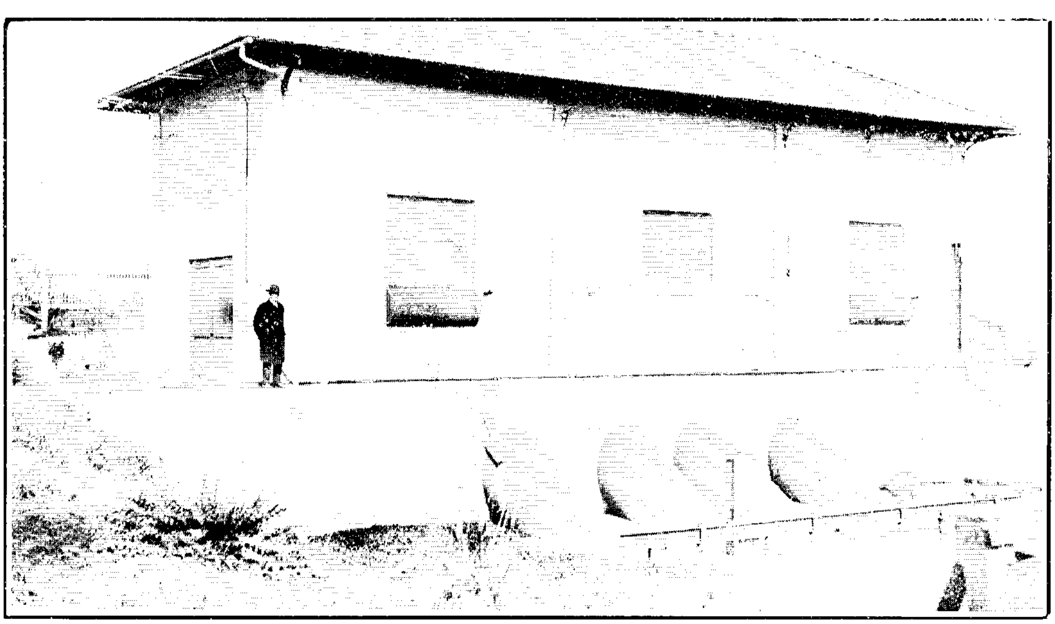
TYPES OF CABIN BOATS FOR HOUSING DREDGE CREWS.



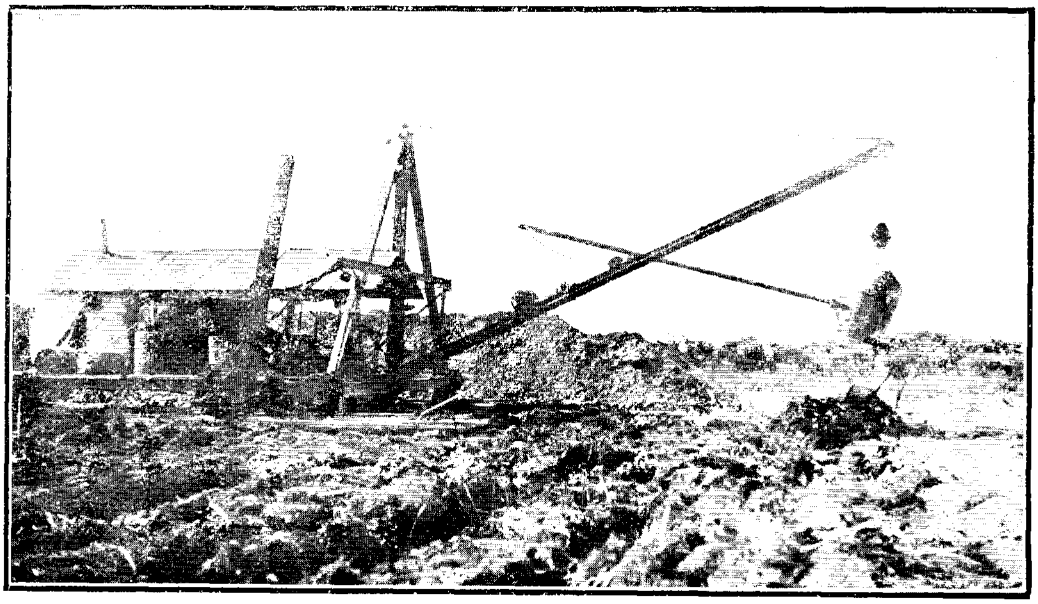
PUMPING STATION, NEW HOLLAND.

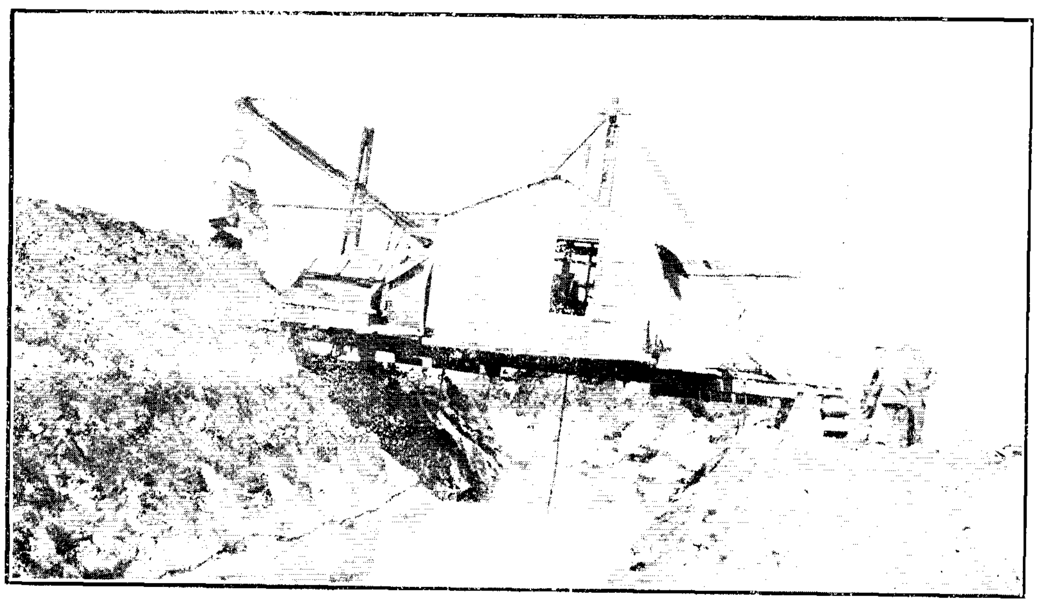


COAL ELEVATOR AT PUMPING STATION.

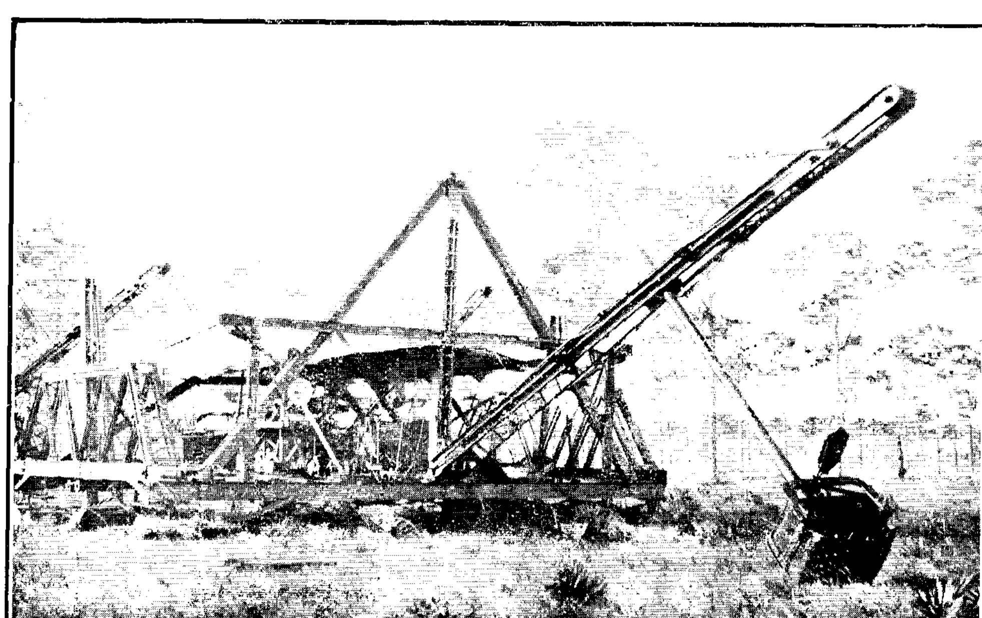


PUMPING STATION FOR 6,000 ACRES, LOUISIANA.

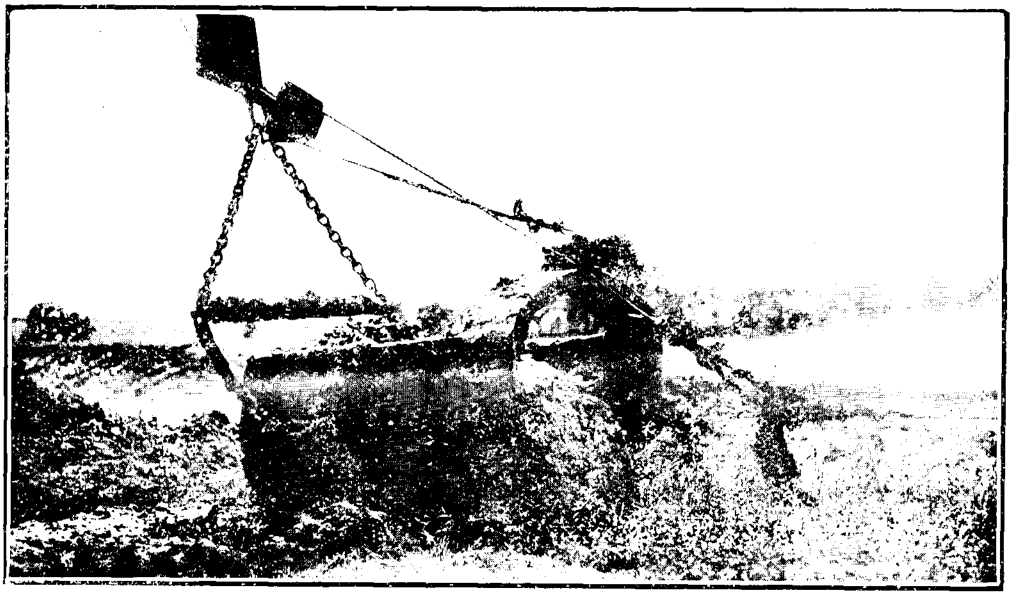




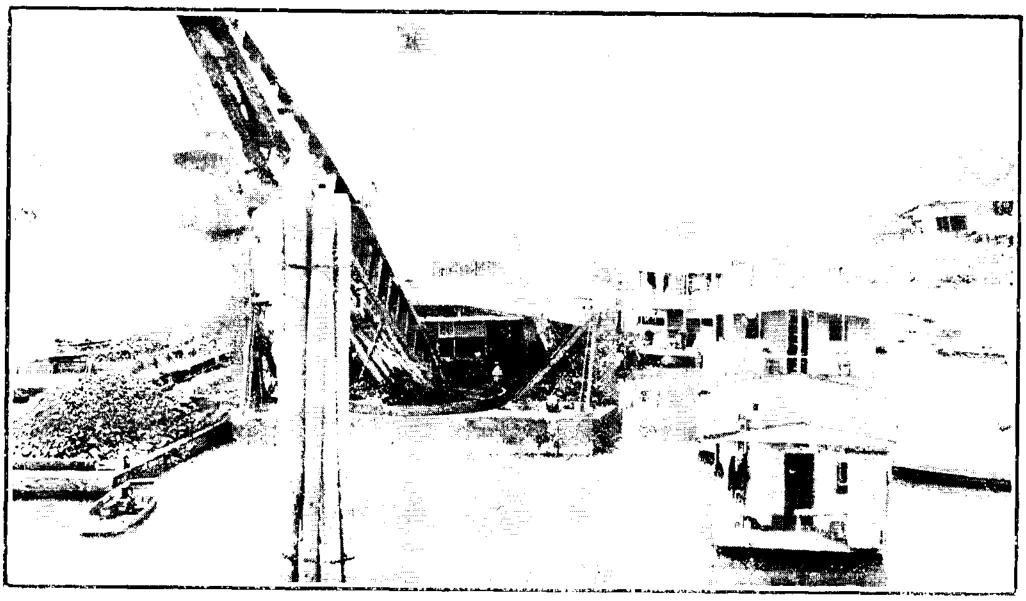
Walking Dredges.



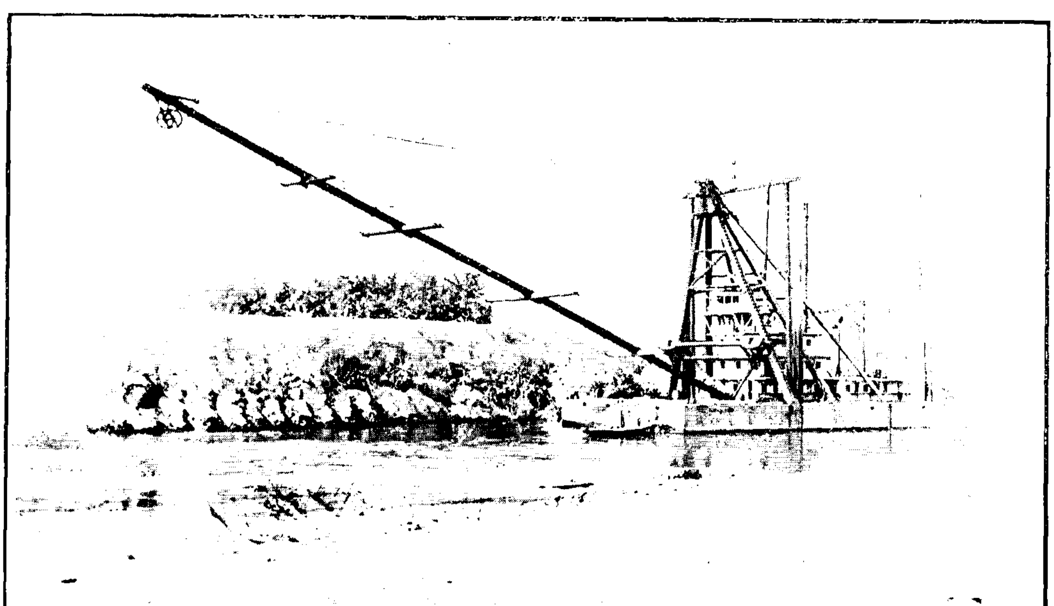
Walking Dipper Dredge.



Typical Drag line Bucket.

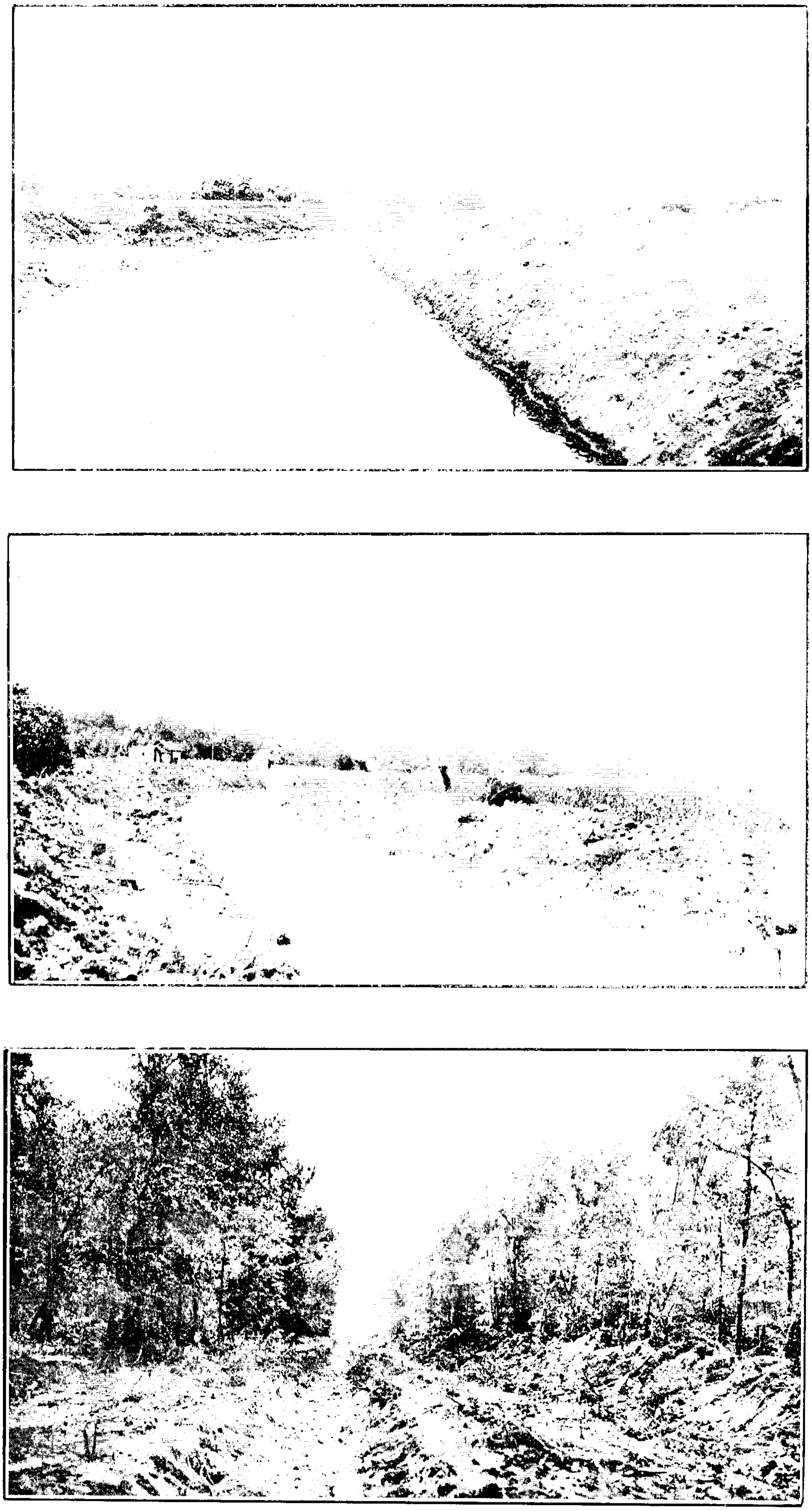


Dredging Outfit at Memphis.

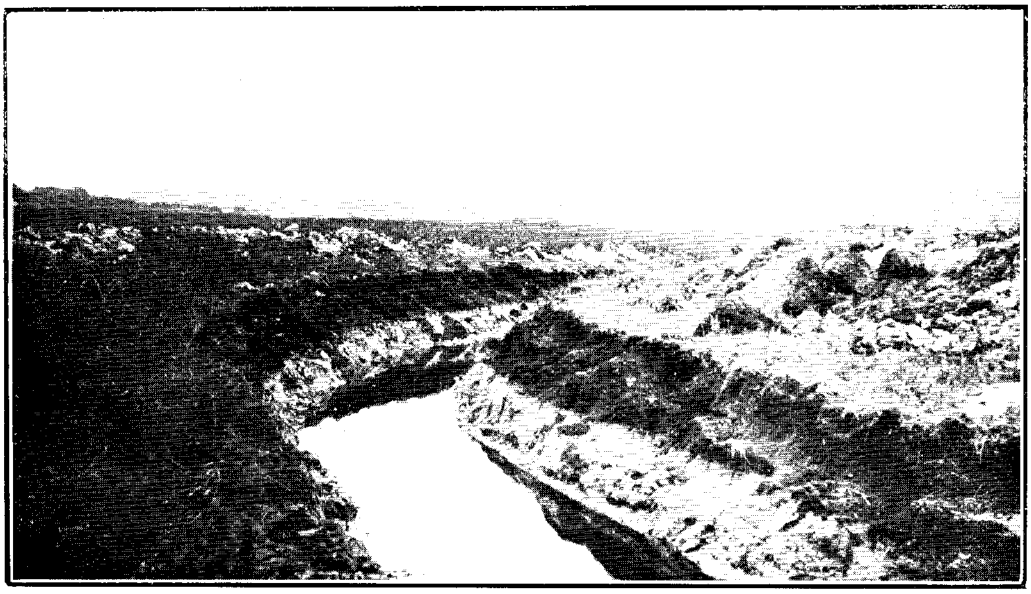


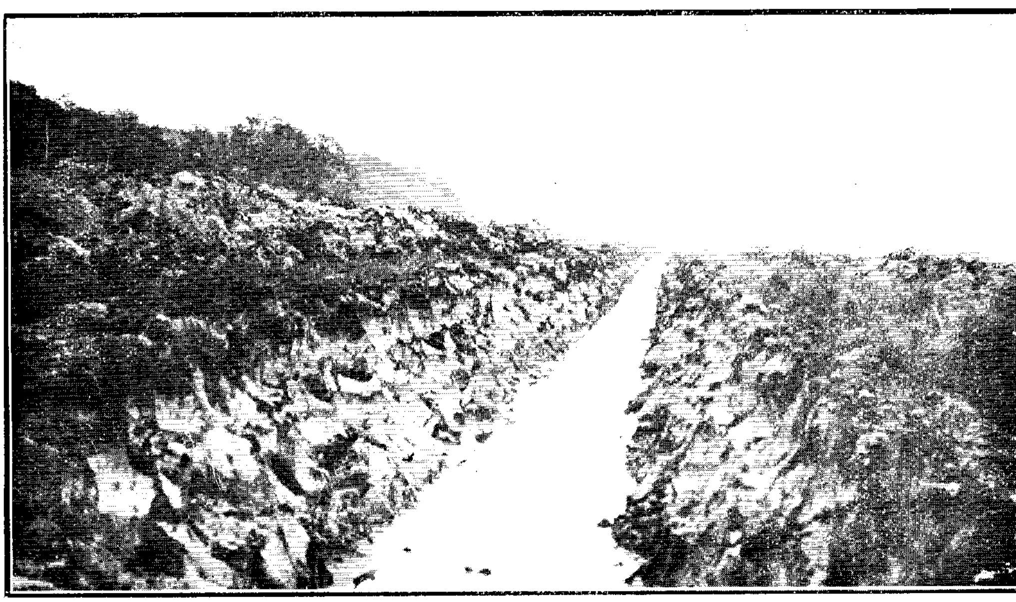
Level Construction, Sacramento River.

[illegible] IV.

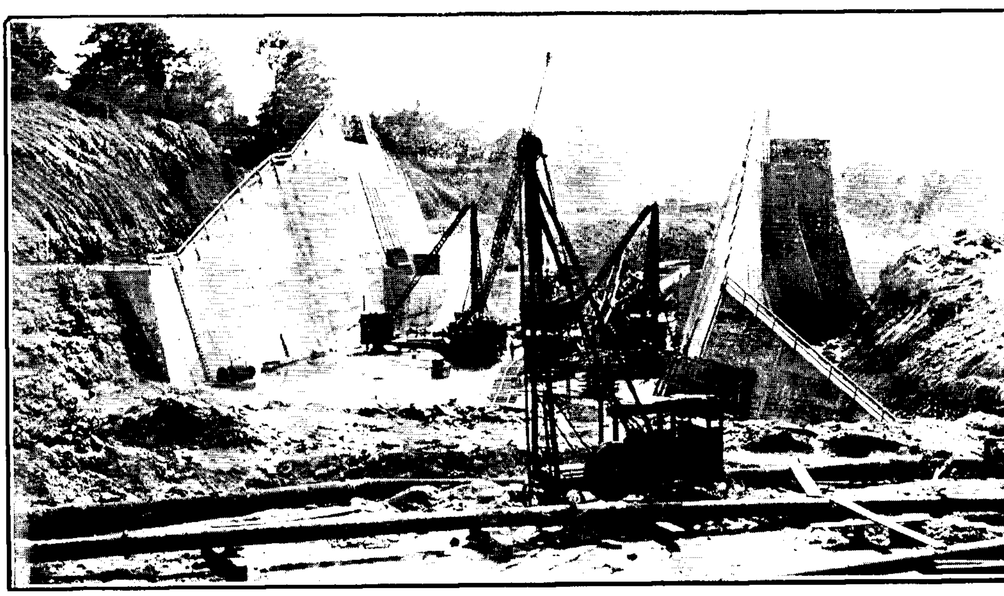


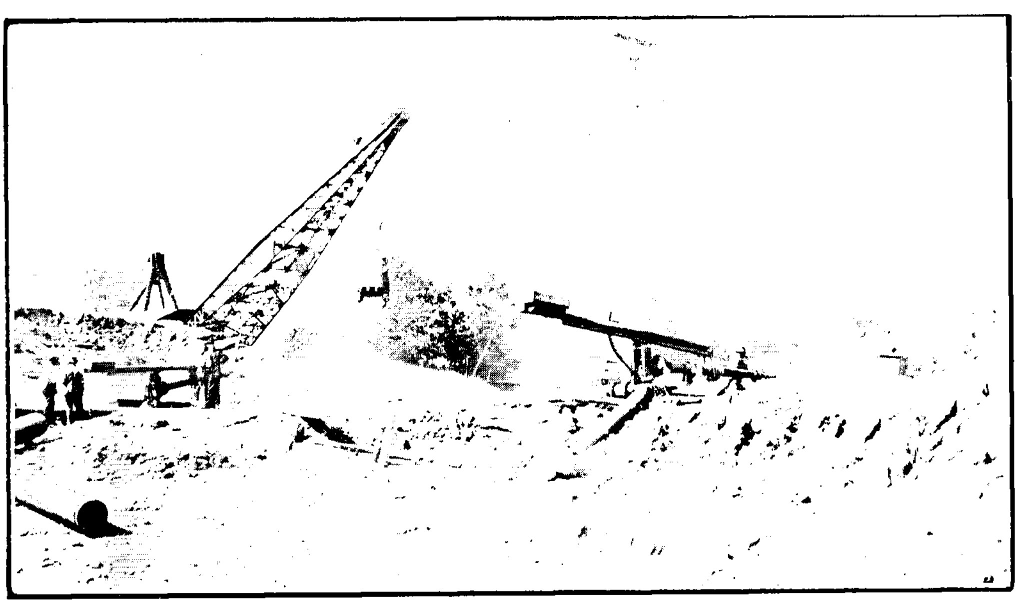
Ditch Types



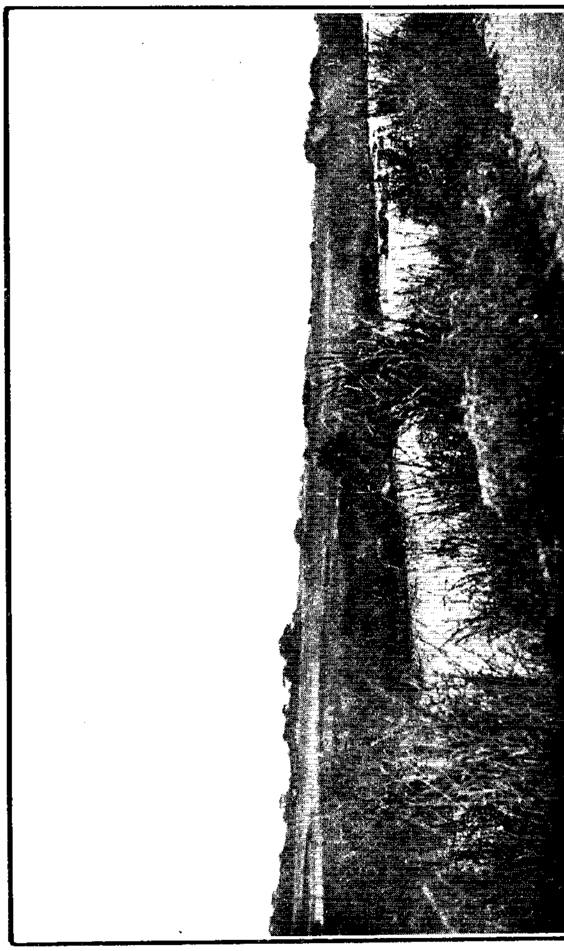


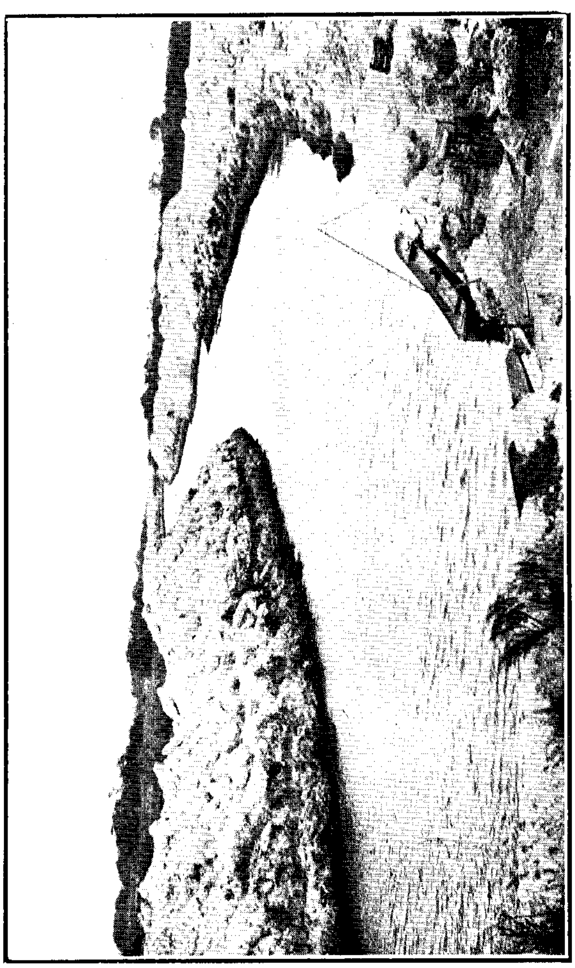
Ditch Types.

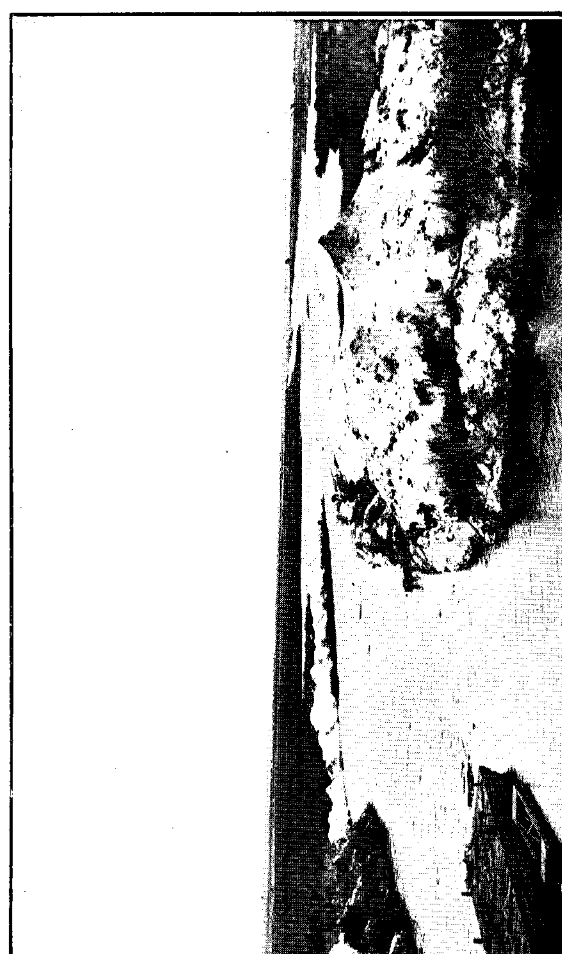




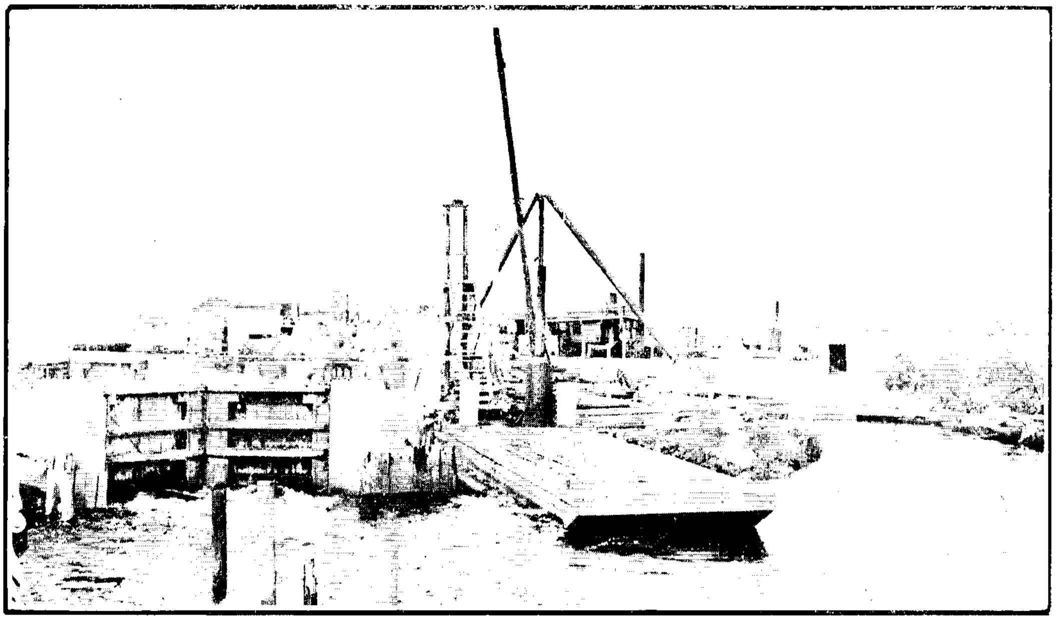
SCENES IN MIAMI CONSERVATION DISTRICT.

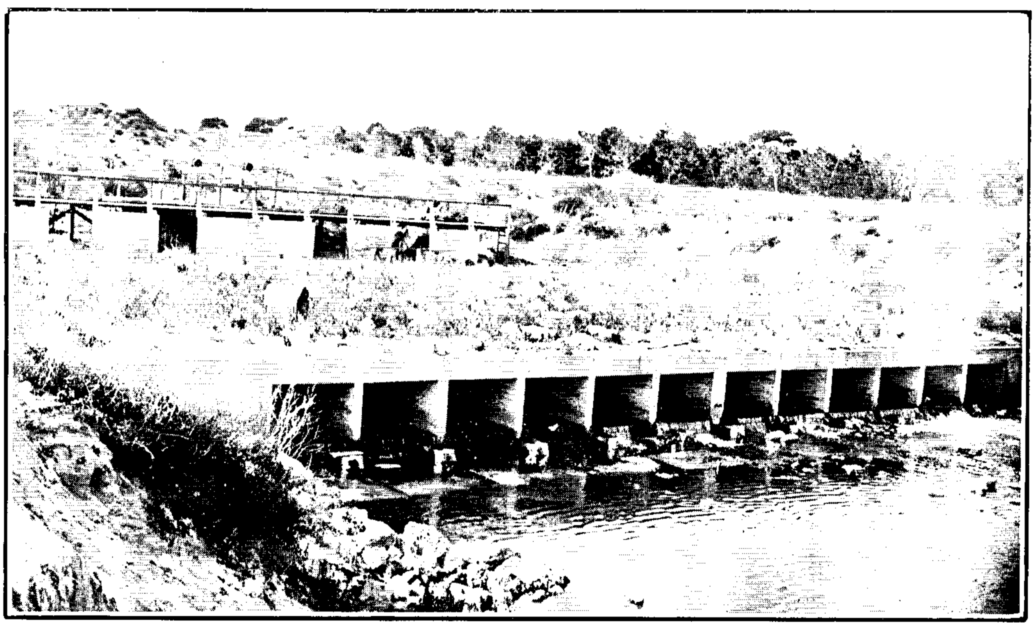




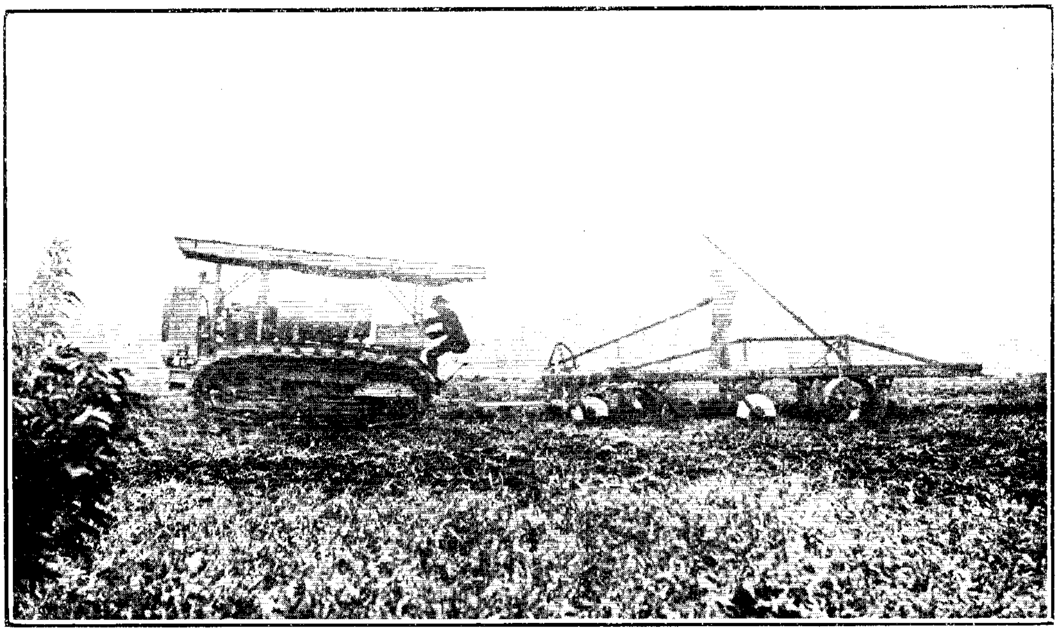


Canal Scenes on the Everglades, Florida.

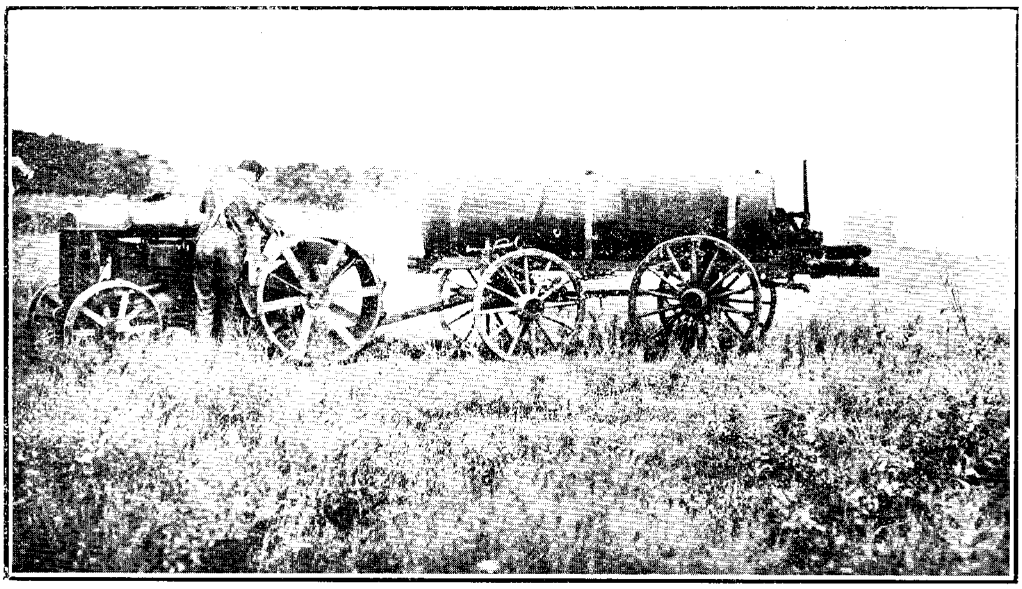




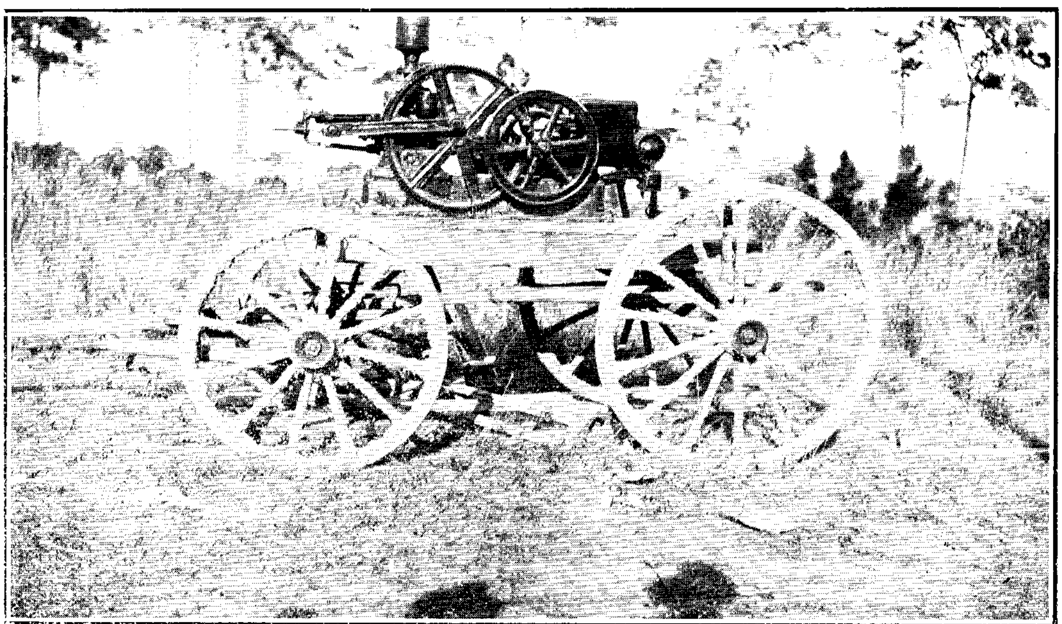
SCENES ON THE EVERGLADES, FLORIDA.



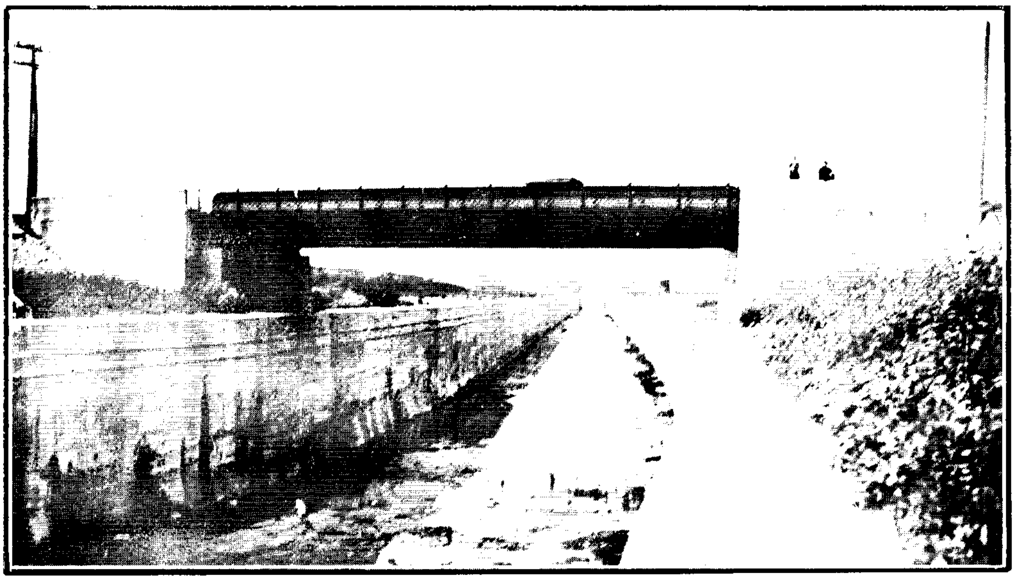
Breaking up Everglades Country.

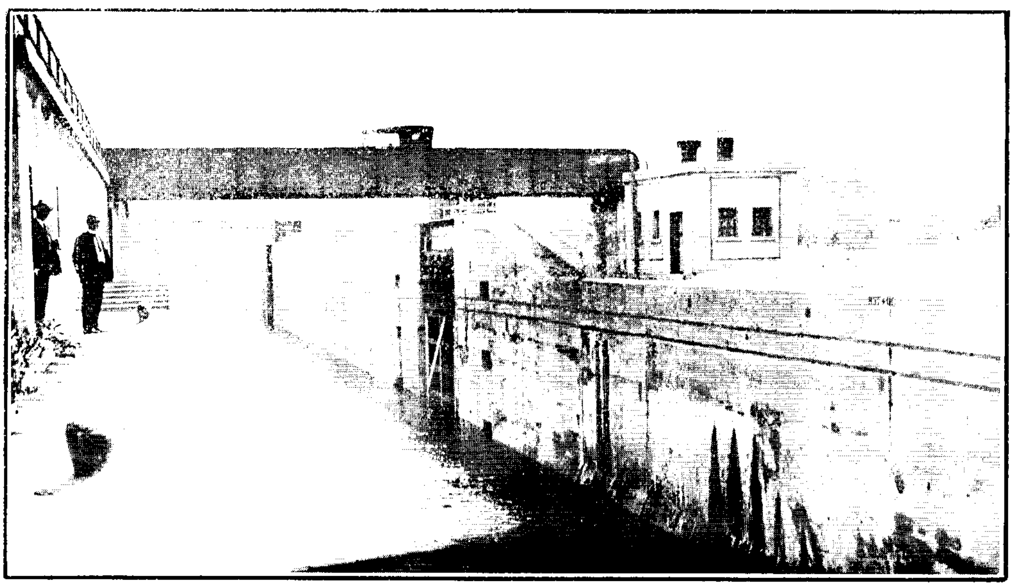


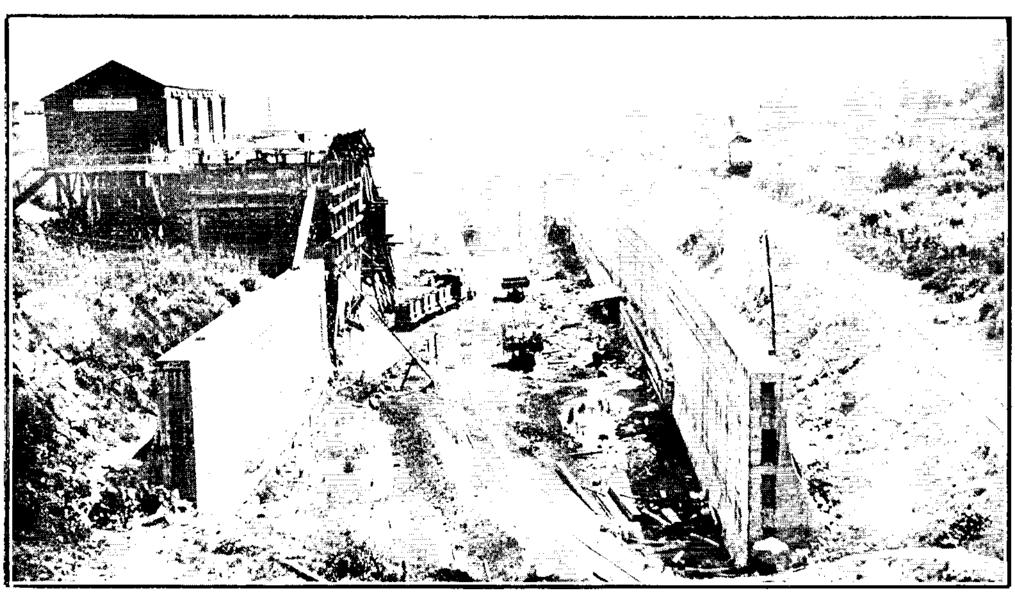
Conveying Gasolene supplies to Dredges.



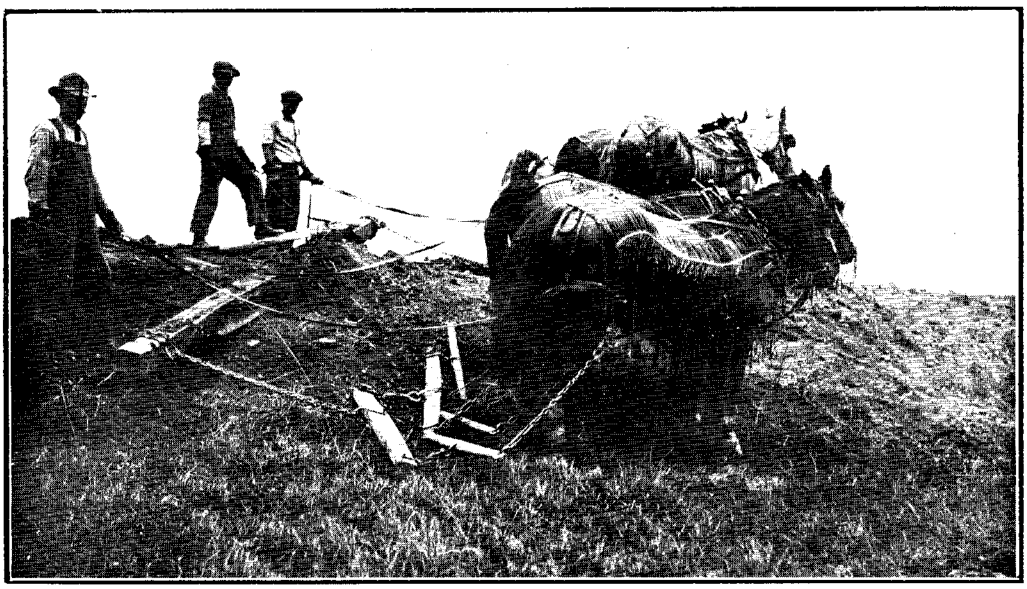
Pump for supplying Outlying Machines with Water.



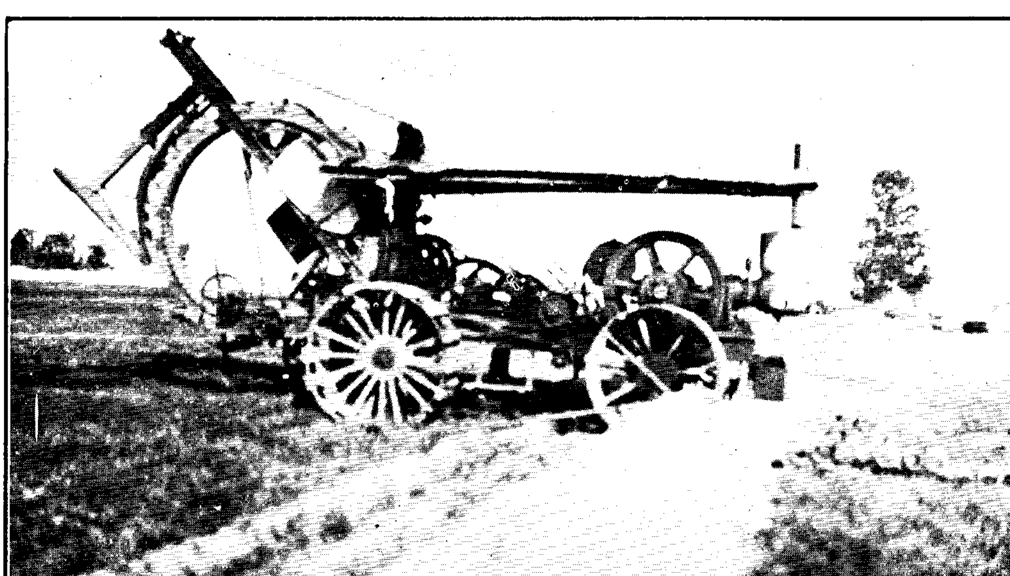




Scenes on the Calumet Sag Canal, Chicago.



Grading a Spoil-bank.



A Tile-ditcher.

APPENDIX.

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— Young, Esq., W. Palm Beach, Fla.
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B. S. Nelson, Esq., Consulting Engineer, New Orleans, Louis.
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W. O. Birket, Esq., Caruthersville, Mo.

II. COST DATA FOR DRAINAGE EXCAVATION.

United States Department of Agriculture.—Bureau of Public Roads.

T. & S. = Team and scraper work. H.D. = Hydraulic dredge. F.D.D. = Floating dipper dredge. D.L.E. = Drag-line excavator. W.D.D. = Walking dipper dredge.)

State.	Drainage District and County.	Date let.	Excavation (Cubic Yards).	Bid per Cubic Yard.	Clearing per Acre.	Length. (Miles).	Base Width.			Depth.		Side Slope.	Berm	Soil.	Remarks.	Engineer. / Contractor.
							Max.	Min.	Av.	Max.	Av.					
				Cents.												
Ill. ..	Mackinaw D.D.; McLean and Ford Cos.	29/9/19	412,677	12·78	None	11·5	35	6	..	16	9	1 : 1	6	Loam, clay ..	F.D.D., $1\frac{3}{4}$ yd., 40 ft. boom, 6-15-20-35 ft bases.	Bell & Hare, Bloomington, Ill.; N. C. McGinnis and Co., Bement, Ill.
Miss.	Pace D.D.; Bolivar Co...	8/3/20	341,700	31	Incl.	..	10	3	6	12	5	1 : 1	10	Alluvial loam ..	Arpin walking-dredge, 7 laterals 3 ft. base, balance 4-6-8-10 ft. bases.	W. W. Boone, Cleveland, Miss.; J. P. Arpin Co., Greenville, Miss.
Ill. ..	Indian Creek No. 2 D.D.; Cass and Morgan Cos.	3/3/20	1,059,640	11	Incl.	13·25	32	22	..	17·5	11	1 : 1	15	Loam and clay; some sand	F.D.D., $2\frac{1}{2}$ yd., 70 ft. boom; D.L.E., 1·12 ft. base; lateral, 12 ft., and 4 ft. base with F.D.D.	Caldwell Eng. Co., Jacksonville, Ill.; M. J. O'Mearn & Son, Beardstown, Ill.
Mo. ..	Platt River No. 1 D.D.; Buchanan Co.	25/3/20	1,495,244	Main 14	$87.12	17	22	16	18	25	17	$\frac{1}{2}$: 1	10	Gumbo and mixed clay	F.D.D. and D.L.E. M.D. 10·7 mis., 1,022,614 yd. at 14c.; M.D. 5·5 mis., 397,630 yd. at $14\frac{1}{2}$c.; M.D. 1 mis., 75,000 yd. at $15\frac{1}{2}$c.	W. B. Hazen, St. Joseph, Mo.; Land & Sampson, St. Joseph, Mo.
Ky. ..	Otter Creek D.D.; Hopkins Co.	3/4/20	107,086	22	$30	11	15	5	8	12	7	$\frac{1}{2}$: 1	8	Alluvial and gumbo	D.L.E. or W.D.D.; new work ..	J. V. Poole, Madisonville, Pa.; Church & Co., Owensboro, Ky.
Ill. ..	McCraney Ck., Subdist. Sny. Island D.D.; Pike Co.	16/4/20	319,800	30	Incl.	..	..	..	..	..	..	..	8	Alluvial ..	D.L.E., 60 ft. boom; combined ditch and levee; lev., 7 ft. hl., 3 ft. top, 2 : 1 s.s.; 8 ft. berm; bids up to 34·7c.	J. C. Chamberlin, Pittsfield, Ill.; A. V. Wills & Sons, St Louis, Mo.
Ill. ..	Garden Special D.D.; Mason Co.	20/4/20	110,000	29·5	..	..	8	6	..	10	7	1 : 1	..	Sandy loam ..	1 yd., 42 ft. span, Bay City dredge; 30,000 yd. levee at 30c., 40,000 yd. levee at 35c.; ditch-work clean out	C. H. Kreiling, Havana, Ill.; M. J. O'Mearn & Son, Beardstown, Ill.
Iowa	Indian Creek No. 3 D.D.; Cass Co.	17/5/20	750,680	12·5	Incl.	12	18	16	17	17·2	11·6	1 : 1	10	Black loam ..	F.D.D. and one dry-land excavator ..	Boyd F. Walker, Atlantic, Ia.; Lana Construction Co.
Miss.	Bolivar Co.	–/5/20	220,000	19	$52	..	..	..	..	..	..	..	..	..	F.D.D.	W. W. Boone, Cleveland, Miss.; R. H. McWilliams, Memphis, Tenn.
Mo. ..	Platte Valley D.D.; Worth and Nodoway Cos.	20/5/20	950,000	13	..	12·7	27	22	..	27	14	$\frac{1}{2}$: 1	15	Wabash loam ..	2 D.L.L.s; D.D. has 6 laterals, 4-10 ft. base	Gates & Deleuw, Conway Building, Cinn.; Chas. Reese, Parnell, Mo.
Iowa	Drainage Dist. No. 3; Montgomery Co.	28/3/20	436,000	15	Incl.	7	14	14	14	19·5	16	$\frac{1}{2}$: 1	12	Loam and sandy clay	D.L.E.	C. D. Forsbeck, Red Oak, Ia.; S. O. Briggs Co., Omaha, Nebr.
Miss.	Drainage Dist. No. 10; Bolivar Co.	5/6/20	552,700	19·5	$40	14	25	12	..	13	8	1 : 1	10	Gumbo ..	F.D.D.; 6 miles of laterals, 3 ft. to 4 ft. base, 5 ft. deep	W. W. Boone, Cleveland, Miss.; R. H. McWilliams.
Iowa	Upper Soldier Valley D.D.; Monona Co.	8/6/20	1,340,000	11·75	Incl.	..	18	4	..	16	11	1 : 1	16	Loam and silt ..	$2\frac{1}{2}$ yd., Monighan D.L.E.; 90% excav., 16 ft. and 18 ft. base. Some laterals sold at 25c. cubic yard	C. Moriarty, Sioux City, Ia.; S. O. Briggs Co., Omaha, Nebr.
Miss.	Bolivar Co.	–/6/20	5,000,000	16	..	..	..	..	..	..	..	..	..	..	Two Bay City machines	W. W. Boone, Cleveland, Miss.; R. H. Murdock, Grand Rapids, Miss.
Miss.	Bolivar Co.	–/6/20	70,000	35	Incl.	..	6	3	..	..	..	..	..	..	Bay City dredge	W.W. Boone, Cleveland, Miss.; Gaudlin & Pratt, O'Reilly, Miss.
Iowa	Drainage Dist. No. 114; Palo Atlo Co.	10/6/20	456,660	14·5	..	8	30	20	..	12	10	1 : 1 & $\frac{1}{2}$: 1	8	Loam and sand ..	F.D.D.	Guy R. Campbell, Emmetsburg, Ill.; E. D. Barr, Gibbon, Minn.

Iowa	Farm Creek D.D.; Pottawatomie and Mills	16/6/20	437,500	17·75	Incl.	7·9	10	6	..	15	12	1 : 1	10 to 15	Sandy loam ..	D.L.E.	Seth Dean, Glenwood, Iowa; E. A. Wickham, Council Bluffs.
Iowa	Pigeon Creek D.D.; Harrison Co.	18/6/20	172,700	18·75	Incl.	5·5	14	10	..	..	9	1 : 1	..	Sandy clay ..	D.L.E.	C. L. Huff, Logan, Iowa; G. W. Condon, Council Bluffs.
Nebr.	Drainage Dist. No. 5; Richardson Co.	29/6/20	604,884	14·25	Incl.	8·2	8	4	..	18	17	1 : 1	15	Wabash loam ..	D.L.E.; 15 laterals, 4 ft. base, 12 ft. deep; sold 22c. to 35c.	J. F. Relf, Falls City, Nebr.; Fred M. Crane, Omaha, Nebr.
Ohio..	Hocking Co. D.D.; Hocking Co.	3/7/20	335,012	14·3	Total $1,000	6	40	40	..	10	10	1 : 1	..	Sand, loam, clay	F.D.D.; 3 H.W. bridges to move ..	Eph. Shaw, Logan, Ohio; Gilmore Bros.
Iowa	Bear Creek No. 1 D.D.; Poweshiek Co.	7/7/20	389,663	18	$60	11·7	30	12	..	11	9	½ : 1	5	Loam and gumbo	F.D.D.; main, 359,290 yd.; 2 laterals 8 ft. base, 1 lateral 16 ft. base	Cent. Sta. Eng. Co., Muscatine, Iowa; Clyde A. Walb, La Grange, Ind.
Iowa	Bear Creek No. 2 D.D.; Poweshiek Co.	7/7/20	231,140	17·94	$60	2·5	40	35	..	11	10	½ : 1	5	Loam and gumbo	D.L.E.	Cent. Sta. Eng. Co., Muscatine, Iowa; Mathews Bros.
Ill. ..	Union No. 1 D.D.; Sangamon Co.	15/7/20	77,950	19·25	None	..	16	10	12	11	9	1 : 1	10	Clay, loam ..	Dry-land machine	J. W. Dappert, Taylorville, Ill.; U. P. Babcock, Paris, Ill.
Miss.	Straight Bayou D.D.; Humphries and Sharkey Cos.	15/7/20	1,812,000	18	Incl.	52	24	14	..	17	8	½ : 1	10	Yazoo clay ..	F.D.D.; one 60 ft. boom, one 45 ft. boom	M. H. Brewer, Silver City, Miss.; Bemidji Drainage.
Ga. ..	Cedar Creek D.D.; Jasper Co.	15/7/20	279,764	13·5 Rock $4	..	10	18	12	14	9	7·5	½ : 1	8	Clay and rock ..	1¼ yd., F.D.D.; right of way to be cleared by owner of each tract	W. D. Alexander, Charlotte, N.C.; Sigman-Reinhardt, Stanley, N.C.
Ky. ..	Mayfield Creek D.D.; McCracken, Bullard, Graves, and Carlyle Cos.	16/7/20	2,800,000	Main 14·9	$35	23	45	20	..	..	12·5	½ : 1	15	Silt, loam ..	3 yd., F.D.D. and drag lines; laterals, 436,000 yd. at 18¼c. to 25c., 44,000 yd. T. and S. at 30c.	H. A. Pulliam, Padacah, Ky.; Fred C. Morgan, Indianapolis, Ind.
Minn.	County Ditch No. 57 D.D.; Blue Earth Co.	24/7/20	81,262	18	None	1·3	8	8	8	20	14	1 : 1	5	Heavy clay ..	3 yd., Monighan D.L.; spoil banks levelled to 3 ft.	Roy Allison, Mankato, Minn.; Mulgrew & Sons, Dubugue, Iowa.
Iowa	North English River No. 9 D.D.; Iowa Co.	4/8/20	957,000	14·59	..	13·2	30	20	..	..	12	½ : 1	..	Black	..	J O. Watkins, Iowa City, Iowa; Clyde A. Walb, La Grange, Ind.
Iowa	Drainage Dist. No. 87; Wright	9/8/20	65,294	23·5	..	..	6	6	6	..	..	..	..	..	..	..
Minn.	County Ditch No. 27 D.D.; Polk Co.	2/7/20	48,594	23·4	None	8·25	..	..	3	9·8	7·4	1 : 1	5	Clay	Dry-land excavator; material to be placed on roadway and graded at $162.50 per mile; cleaning	E. J. Boyer, Crookston, Minn.; Northern Minn. Drain Co., Litchfield.
Minn.	County Ditch No. 37 D.D.; Polk Co.	2/7/20	50,658	23	None	9·75	..	..	3	11·2	6·8	1 : 1	5	Clay	Dry-land excavator; material to be placed on roadway and graded at $195 per mile	E. J. Boyer, Crookston, Minn.; M. W. Barnard & Son, Minneapolis, Minn.
Iowa	Joint D.D. No. 17 ..	28/7/20	26,810	70	None	3·71	20	8	12	4	2·5	1½ : 1	20	Clay, loam, sand	D.L.E.; cleaning-out work	F. A. MacDonald, Armstrong, Iowa; Clark Construction Co., Clinton, Iowa.
Tenn.	Cypress Creek D.D.; Fayette and Shelby Cos.	2/8/20	348,600	16·99	$35	12	18	10	14	15	8	½ : 1	8	Sandy loam ..	F.D.D.	S. W. McCleskey, Memphis, Tenn.; N. C. McGinnis & Co.
Iowa	Nishnabotna River D.D. No. 17; Page Co.	30/7/20	678,309	16·5	..	10·25	..	30	30	15·1	8·9	1 : 1	..	Alluvial silt and clay, sand	New work, F.D.D.	A. S. Van Sandt, Clarinda, Iowa; E. E. Sternberg.
In. ..	Patoka River Ditch D.D.	17/7/20	3,675,860	14·1	Incl.	11·75	80	40	..	22	17½	1 : 1	20 & 25	Clay, loam ..	About 25% of right of way must be cleared; D.L.E.	A. G. Wheeler, Princeton, Ind.; Fred C. Morgan, Indianapolis, Ind.
Ill. ..	Rochester and McLeary's Bluff Levee D.D.; Wabash Co.	7/8/20	407,000	20	$80	9·5	..	..	..	..	..	2 : 1	10	..	D.L.E., 3 yd.; levee job, average 11 ft. high, 6 ft. crown, side slopes 2 : 1 each	G. C. Harvey, Mount Carmel, Ill.
Iowa	Drainage Dist No. 187; Wright Co.	9/8/20	65,294	23·5	..	..	6	6	6	..	..	..	..	..	..	..
Ky. ..	Brush Creek D.D.; Graves and Hickman Cos.	20/8/20	291,800	17·9	Incl.	10	18	12	14	12	10	½ : 1	10	Alluvial ..	F.D.D. Contractor to be paid cash, 80% monthly	J. A. Porter, Clinton, Ky.; P. H. Porter, Clinton, Ky.

II. COST DATA FOR DRAINAGE EXCAVATION—*continued*.

UNITED STATES DEPARTMENT OF AGRICULTURE.—BUREAU OF PUBLIC ROADS—*continued*.

State.	Drainage District and County.	Date let.	Excavation (Cubic Yards).	Bid per Cubic Yard.	Clearing per Acre.	Length. (Miles).	Base Width. Max.	Base Width. Min.	Base Width. Av.	Depth. Max.	Depth. Av.	Side Slope.	Berm.	Soil.	Remarks.	Engineer. / Contractor.
Ill. ..	D.D. No. 1; Ricks and Christian Cos.	4/9/20	9,679	Cents. 35	None	4·2	6	..	4	3	2	1½ : 1 & 2 : 1	8	Black loam, clay	T. and S. Contractor to be paid in cash, 80% monthly	J. W. Dappert, Taylorville, Ill.
S. Dak.	Mud Lake D.D.; Douglas Co.	10/9/20	182,000	25	None	9	8	4	..	20	7	1 : 1	6	Clay, gumbo ..	F.D.D. and D.L.E. Contractor to be paid in cash	Western Eng. Co., Yankton, S. Dak.; Northern Minn. Dredge, Litchfield, Minn.
S. Dak.	Garder Valley D.D.; Douglas Co.	10/9/20	246,000	25	None	10	8	4	..	17	6	1 : 1	6	Black loam, clay	F.D.D. and D.L.E. Contractor to be paid in cash	Western Eng. Co., Yankton, S. Dak.; Northern Minn. Dredge, Litchfield, Minn.
Iowa	D.D. No. 55; Hardin Co.	13/9/20	268,022	25	None	8·75	20	10	14	9	7	1½ : 1	..	Loam, clay, sand	D.L.E. Contractor to be paid in warrants	W. S. Porter, Eldora, Iowa; R. J. Phelps.
Ill. ..	Whiteside and Rock Island Special D.D.; Whiteside and Rock Island Cos.	13/9/20	194,400	40 & 35	None	1·25	30	30	..	..	6	1 : 1	20	Musk, loam, sand	Levee, 142,760 cubic yd., 18,000 ft. long, 5 ft. high, 30 ft. arm; ditch, 51,600 cubic yd., 6,550 ft. long	Fred A. Snyder, Albany, Ind.
Ga. ..	Drainage Dist. No. 1; Spalding, Ga.	25/9/20	147,680	16·4	$50	6·6	14	8	..	8	5·8	½ : 1	..	Sandy loam ..	F.D.D. Contractor to be paid in cash, 90% monthly	Cecil L. Fife, Fayetteville.
Ill. ..	Bug River Special D.D.; Christian and Montgomery Cos.	1/10/20	7,404	40 & 37	None	5·5	4	2½	..	..	..	1½ : 1	..	Clay, loam ..	T. and S.; clean-out work. Contractor to be paid in cash, 80% monthly	J. W. Dappel, Taylorville.
Miss.	Christmas D.D.; Boliver Co.	7/10/20	497,526	26	Incl.	24	18	4	8 12	13	6	1 : 1	10	Alluvial loam ..	1 yd., F.F.D.; 1 road machine. Contractor to be paid in warrants	W. W. Boone, Cleveland, Miss.; Road Construction Co., Grand Rapids.
Iowa	D.D. No. 165; Kossuth Co.	7/10/20	1,149,500	14	None	7·8	50	20	30	..	10	1 : 1	..	Black loam ..	F.D.D.	G. D. Hart, Bancroft; Thomas & Swan, Algona, Iowa.
Iowa	Seven-mile Creek D.D.; Cass Co.	14/10/20	388,600	14·4	None	12	10	10	10	..	..	1 : 1	10	Black loam, clay	D.L.E.	B F. Walker, Council Bluffs.
Iowa	Drainage Dist. No. 123; Palo Alto Co.	22/10/20	54,000	20	..	3·5	8	8	8	7	5	1½ : 1	6	Sand	D.L.E. Contractor to be paid in warrants	R. H. Fuller, Emmetsburg.
Ind. ..	Wm. M. Myers et al Ditch D.D.; Miami Co.	23/10/20	30,731	22	None	2	4	4	4	11	8	1 : 1	4	Clay	W.D.D. Contractor to be paid in cash	C. P. Howard, Peru, Ind.; E. O. Deeds, Deedsville.
Ill. ..	Rock River D.D.; Henry and Whiteside Cos.	29/10/20	272,000	14·9	Incl.	6	16	8	12	18	7½	1½ : 1	10	Sandy loam ..	D.L.E. Contractor to be paid in cash, monthly	H. E. Reeves, Le Claire; Mathews Bros., Erie, Ill.
Mo. ..	J. W. McCoglan et al D.D.; Stoddard Co.	6/11/20	66,950	25·8	Incl.	6·3	..	..	..	..	..	..	..	..	Contractor to be paid in cash, monthly	A. C. Spiker, Bloomfield; J. E. Warner, Benton.
Ind. ..	Joseph Nagel et al D.D.; Jasper Co.	6/11/20	30,665	35·5	..	3	6	5	..	8·5	6	1 : 1	8	Clay	D.L.E., 1,170 cubic yards rock ..	E. D. Nesbitt, Rensselaer; A. Benema, Chicago, Ill.
Okla.	Sequoyah D.D. No. 1; Sequoyah Co.	8/11/20	288,500	16·5	Incl.	4·9	26	18	..	..	10	1 : 1	10	Alluvial ..	F.D.D. Contractor to be paid in cash..	W. L. Winter, Fort Smith; American Construction Co., Oklahoma.
Ohio..	R. V. Wright Improv. D.D.; Huron Co.	9/11/20	12,173	$1	..	2·1	..	..	..	..	..	1½ : 1	..	Muck	D.L.E. Contractor to be paid in cash..	H. P. Starbin, Norwalk.
Miss	Merigold D.D.; Boliver Co.	18/11/20	159,447	30	$30	12·6	12	4	6	8·9	5·5	1 : 1	10	..	..	W. W. Boone, Cleveland; McWilliams, Memphis.

III. COST DATA FOR TILE DRAINAGE.

United States Department of Agriculture.—Bureau of Public Roads.

(C.T. = Clay tile. Cem. T. = Cement tile. V.T. = Vitrified tile. S.P. = Sewer-pipe. S.B. = Segmental block.)

State.	Drainage District and County.	Date let.	Kind of Tile.	Diameter in Inches.	Length in Feet.	Cost per Foot.	Depth. Max.	Depth. Av.	Hauling Tile: Distance and Price per Ton.	Construction: Digging, Laying, and B.F. Cost per Foot.	Remarks.	Engineer, Contractor, &c.
						$				$		
Iowa	D.D. No. 128; Buena Vista Co.	4/5/20	Cem. T.	26	1,600	1.665	..	6·7	2 m. Delivered on site of work for prices shown	0.55	..	Contractor, H. Johnson, Albert City, Iowa; manufacturers, Cement Products Co., Spencer, Iowa.
			Cem. T.	24	3,200	1.440	..	7·2		0.60		
			Cem. T.	22	3,400	1.125	..	6·3		0.50		
			Cem. T.	20	400	0.945	..	6·1		0.45		
			Cem. T.	18	4,700	0.795	..	6·5	..	0.48		
			Cem. T.	16	800	0.645	..	5·9	..	0.30		
			Cem. T.	10	700	0.232	..	4·2	..	0.12		
			Cem. T.	8	1,260	0.15758	..	4·2	..	0.12		
Iowa	D.D. No. 79; Cerro Gordo Co.	17/5/20	Cem. T.	26	2,000	1.650	9·0	8·0	Delivered on site of work for prices shown	1.00	1 concrete headwall, 5 yd., at $25	Contractor, Christenson Const., Iowa Falls, Iowa; manufacturers, Cement Products Co., Spencer, Iowa.
			Cem. T.	24	1,500	1.175	8·0	7·0		0.67		
			Cem. T.	20	2,000	0.870	8·0	7·0		0.55		
			Cem. T.	18	2,000	0.725	8·5	6·5	..	0.40		
			Cem. T.	16	1,200	0·623	7·0	6·0	..	0·36		
			Cem. T.	15	800	0.490	6·0	5·5	..	0·33		
			Cem. T.	14	500	0.406	6·0	5·5	..	0.30		
			Cem. T.	12	3,700	0.319	9·0	6·1	..	0.305		
			Cem. T.	10	3,000	0·218	8·0	5·6	..	0.27		
			Cem. T	9	1,500	0.188	8·5	5·5	..	0.25		
			Cem. T.	8	3,100	0.146	8·0	5·1	..	0.20		
			Cem. T.	7	4,350	0.116	7·0	5·0	..	0.189		
			Cem. T.	6	7,850	0.095	7·0	4·5	..	0.173		
Iowa	Sub-district No. 9 of No. 4; Kossuth Co.	2/6/20	Cem. T.	30	500	2.985	..	5·6	Probably delivered on site of work	Included in cost per foot	6-7 in. intakes, at $15; 9-6 in. intakes, at $15; 4 manholes at $100; 1 headwall, 12 cu. yd., at $30 per yard	Engineer, G. D. Hart; contractors, Humbolt Gravel and Tile Co., Humbolt, Iowa; also furnishing tiles.
			Cem. T.	24	5,800	2.1675	..	7·0				
			Cem. T.	18	2,700	1.234	..	6·4	..			
			Cem. T.	16	2,800	1.081	..	6·7	..	..		
			Cem. T.	15	3,000	0.986	..	7·2	..	..		
			Cem. T.	14	3,500	0.9325	..	7·2	..	..		
			Cem. T.	12	2,600	0.6000	..	5·5	..	..		
			Cem. T.	10	4,600	0.549	..	6·6	..			
			Cem. T.	8	600	0.365	..	6·1	..			
			Cem. T.	7	1,482	0.315	..	5·4	..			
			Cem. T.	6	500	0.2545	..	5·7	..			
Iowa	D.D. N . 7; Bremer Co.	16/6/20	Cem. T.	22	150	1.22	..	5·8	Delivered on site of work for prices shown	0.48	..	Engineer, C. A. Cool, Waverly, Iowa; contractor, Nels. Debel; manfacturers, Mason City Cement Products Co., Mason City, Iowa.
			S.P.	22	250	1.30	..	5·5		0.48		
			Cem. T.	20	1,300	1.10	..	5·4		0.48		
			Cem. T.	18	300	0.966	..	5·8	..	0.48		
			Cem. T.	15	900	0.650	..	5·6	..	0.48		
			Cem. T.	14	..	0.4615	..	..	..	0.36		
			Cem. T	12	977	0.360	..	4·8	..	0.34		
			S.P.	12	200	0 375	..	5·1	..	0.36		

III. COST DATA FOR TILE DRAINAGE—*continued.*

UNITED STATES DEPARTMENT OF AGRICULTURE.—BUREAU OF PUBLIC ROADS—*continued.*

State.	Drainage District and County.	Date let.	Kind of Tile.	Diameter in Inches.	Length in Feet.	Cost per Foot.	Depth. Max.	Depth. Av.	Hauling Tile: Distance and Price per Ton.	Construction: Digging, Laying, and B.F. Cost per Foot.	Remarks.	Engineer, Contractor, &c.
						$				$		
			Cem. T.	10	900	0.2831	..	4·6	..	0.32		
			S.P.	10	200	0.420	..	4·6	..	0.45		
			Cem. T.	9	400	0.200	..	5·0	..	0.30		
			Cem. T.	8	..	0.180	..	..	..	0.242		
			Cem. T.	7	1,400	0.156	..	4·8	..	0.260		
			Cem. T.	6	346	0.087	..	4·5	..	0.174		
Iowa	Polk-Story D.D. No. 4; Polk-Story Cos.	19/7/20	C.T.	26	7,300	1.915	12·0	7·0	Delivered on site of work for prices shown	1.0317	..	Contractors, Mason & Twigg, Huxley, Iowa; manufacturers, Iowa Pipe and Tile Co., Des Moines, Iowa.
			C.T.	24	2,040	1.580	..	6·5		0.6317		
			S.P.	24	575	2.000	..	..		0.5317		
			C.T.	22	2,060	1.310	..	7·5	..	0.6317		
			C.T.	20	2,100	1.070	..	6·7	..	0.5317		
			C.T.	15	1,160	0.690	..	5·0	..	0.3317		
			C.T.	10	3,500	0.280	..	5·0	..	0.1517		
			C.T.	8	1,500	0.210	..	5·0	..	0.1817		
			C.T.	6	5,000	0.120	..	4·0	..	0.1017		
Ill. ..	Union D.D. No. 1; Sangamon Co.	15/7/20	S.B.	42	1,930	4.020	6·6	6·0	5 m.; $2.10	0.800	Concrete-work, 62·9 yd., at 33c. per yd.: 1 large brick c.b., $397. Prices are for low bids; contracts not let when data were obtained	Engineer, J. W. Dappert, Taylorsville, Ill.; contractor, H. T. Munson, Illiopolis, Ill.; manufacturers, Evans & Howat, Fire Brick Co., St. Louis.
			S.B.	39	5,910	3.740	6·0	5·6	5 m.; $2.10	0.625		
			S.B.	36	3,080	3.130	6·4	5·8	5 m.; $2.10	0.552		
			S.B.	30	2,597	2.410	8·5	4·8	5 m.; $2.10	0.350		
			S.B.	24	3,081	1.650	5·9	5·5	5 m.; $2.10	0.320		
Ill. ..	Sub. D.D. Embarass River; Champaign and Vermilion Cos.	17/8/20	Cem. T.	16	2,383	0.520	..	4·3	3 m.	0.294	Construction includes hauling, also constructing 2 ground wells	Engineer, W. E. Price, Tuscola, Ill.; contractor, Sam Warner, Broadlands, Ill.; manufacturer, F. W. Scanling, Chrisman, Ill.
Minn.	County Drain No. 57; Blue Earth Co.	24/7/20	Cem. T.	52	2,900	Approximate $10 per ton for weight of tile	16·7	14·3	2 m.; $1	2.20	Total tile contract, $163,000; approx., 8,200 tons	Engineer, Roy Allison, Mankato, Minn.; contractor, Frank Essel, Mankato, Minn.; manufacturers, Minnesota Pipe and Tile Co., Mankato, Minn.
			Cem. T.	48	3,900		16·3	12·3	2 m.; $1	2.00		
			Cem. T.	42	1,600	..	10·3	9·7	2 m.; $1	1.75		
			Cem. T.	40	2,200	..	9·8	8·6	2 m.; $1	1.50		
			Cem. T.	36	1,800	..	10·3	8·8	2 m.; $1	1.40		
			Cem. T.	30	3,400	..	6·9	6·3	2 m.; $1	0.74		
			Cem. T.	24	1,621	..	6·8	6·0	2 m.; $1	0.50		
			Cem. T.	20	6,235	..	7·0	6·0	2 m.; $1	0·35		
			Cem. T.	18	16,215	..	10·0	6·0	2 m.; $1	0.32		
			Cem. T.	16	11,995	..	9·5	6·0	2 m.; $1	0.29		
			Cem. T.	14	14,680	..	8·0	5·5	2 m.; $1	0.23		
			Cem. T.	12	14,270	..	7·8	5·5	2 m.; $1	0.20		
			Cem. T.	10	15,205	..	7·2	5·0	2 m.; $1	0.15		
			Cem. T.	8	32,280	..	6·8	4·5	2 m.; $1	0.10		
Iowa	Joint D.D. No. 17 ..	28/7/20	Cem. T.	34	2,000	$3.40 in place	4·0	3·0	45c. per ton mile	40c. cu. yd.	Headwall, 10 yd., $27; tile laid in open ditch, backfilled 3½ ft. over tile	Engineer. F. A. MacDonald, Armstrong, Iowa; manufacturers, Armstrong Cement Co., Armstrong, Iowa.

Minn.	County Ditch No. 63;	16/8/20	Cem. T.	6	600	Total, $8,200	6·4	5·0	10 m.; $4.50 ..	Total, $9,600	..	Manufacturers, Watertown Tile
	Lac qui Parle Co.		Cem. T.	7	600	..	4·8	4·3	Total, $2,800, with			and Const. Co., Watertown.
			Cem. T.	8	5,200	..	10·9	6·1	truck			
			Cem. T.	10	2,700	..	10·0	5·7	..			
			Cem. T.	12	3,800	..	7·4	5·3	..			
			Cem. T.	14	1,700	..	15·2	10·0	..			
			Cem. T.	18	1,900	..	11·0	8·5	..			
			Cem. T.	20	1,800	..	12·6	10·5	..			
			Cem. T.	22	2,900	..	15·8	10·0	..			
Ill. ..	Little Wabash D.D.;	25/8/20	C.T.	8	1,227	0.105	5·3	4·6	½ m. to 2½ m.;	0.30	..	A. C. Stanfield, Pana, Ill.; James
	Coles Co.		C.T.	10	4,009	0.17	7·0	6·6	$2	0.50		Shinn, Mattoon, Ill.; manu-
			C.T.	12	3,420	0.22	7·6	6·6	..	0.60		facturers. National Tile Co.
			C.T.	15	2,726	0.39	7·8	7·4	..	0.70		
			C.T.	18	11	0.60	..	4·0	..	0.35		
			C.T.	20	313	0.72	..	9·5	..	1.10		
			C.T.	24	906	1.08	..	7·7	..	0.95		
			C.T.	30	1,509	2.10	..	7·4	..	1.05		
			Cem. T.	36	2,485	3.70	..	5·0	..	1.00		
Iowa	D.D. No. 4; Webster	3/8/20	Cem. T.	12	400	0.30	6·0	5·3	2¼ m., incl. ..	0.30	..	J. L. Parsons, Ft. Dodge, Iowa.
	Co.		Cem. T.	18	2,600	0.77	9·9	7·5	..	0.70		
Iowa	D.D. No. 316; Webster	3/8/20	Cem. T.	10	370	0.24	6·9	6·7	1½ m., incl. ..	0.40	..	Elmer Johnson Callender, J. L.
	Co.		Cem. T.	10	450	0.24	5·6	5·3	..	0.25		Parsons, Chris. Krammer, Ft.
			Cem. T.	12	1,000	0.32	6·9	6·1	..	0.35		Dodge, Iowa; manufacturers,
			Cem. T.	12	600	0.32	5·0	4·4	..	0.25		Humbolt Gravel and Tile Co.,
			Cem. T.	14	900	0·46	7·6	6·7	..	0.50		Hum.
			Cem. T	16	2,300	0.65	9·7	8·1	..	0.80		
			Cem. T.	18	1,600	0.79	8·9	7·3	..	0.60		
			Cem. T.	22	1,400	1·28	10·5	9·4	..	1.30		
Iowa	D.D. No. 311; Webster	3/8/20	C.T.	8	300	0.20	5·8	5·5	3 m., incl. ..	0.25	..	J. L. Parsons, Chris. Krammer,
	Co.		C.T.	14	700	0.51	6·4	5·5	..	0.30		Lehigh Sewer and Tile Co.,
			C.T.	15	2,000	0.585	10·2	6·7	..	0.45		Ft. Dodge, Iowa.
			C.T.	15	500	0.585	6·2	5·6	..	0.35		
			C.T.	16	2,000	0.674	9·4	7·1	..	0.50		
			C.T.	20	2,100	1.047	8·7	6·6	..	0.50		
			C.T.	24	1,300	1.558	10·9	7·5	..	0.90		
Minn.	Judicial Ditch No. 6;	19/8/20	Cem. T.	6	4,710	Cost, $11.75 per ton at	..	4·4	2·5 m.; $1.40 ..	0.0985	Includes material and	H. E. Hartley, Lafayette, Minn.;
	Nicollet and Sibley		Cem. T.	7	1,400	Lafayette; freight	..	5·7	..	0.208	labour; total labour,	Roy H. Allison.
	Cos.		Cem. T.	8	2,770	rate, 5½ c. from fac-	..	5·5	..	0.197	$15,350	
			Cem. T.	9	510	tory. Total, $18,400	..	4·4	..	0.155		
			Cem. T.	10	3,550	..	..	6·0	..	0.29		
			Cem. T.	12	5,550	..	..	6·5	..	0.36		
			Cem. T.	14	1,820	..	..	6·5	..	0.40		
			Cem. T.	18	1,700	..	..	6·7	..	0.51		
			Cem. T.	20	1,300	..	..	5·5	..	0.43		
			Cem. T.	22	940	..	..	7·8	..	0.81		
			Cem. T.	24	660	..	..	8·1	..	0.98		
			Cem. T.	26	3,500	..	..	7·8	..	1.06		
			Cem. T.	30	2,900	..	9·0	7·5	..	1.20		
Minn.	County Ditch No. 84;	10/8/20	..	5	4,300	0.05	..	4·0	8 m.; $4.60 ..	0.0845	..	S. B. Gardner, J. B. Camden;
	Renville Co.			6	5,200	0.0715	..	4·5	8 m.; $4.60 ..	0.1196		manufacturers, Minn. Pipe and
			..	7	2,500	0.088	10·0	5·0	8 m.; $4.60 ..	0.156		Tile Co., Man.
			..	8	2,800	0.1055	8·3	6·0	8 m.; $4.60 ..	0.2301		
			..	10	3,200	0.165	8·0	5·8	8 m.; $4.60 ..	0.2353		
			..	12	3,100	0.242	11·7	6·7	8 m.; $4.60 ..	0.3172		
			..	15	1,900	0.352	9·5	6·2	8 m.; $4.60 ..	0.3315		

III. COST DATA FOR TILE DRAINAGE—*continued.*

United States Department of Agriculture.—Bureau of Public Roads—*continued.*

State.	Drainage District and County.	Date let.	Kind of Tile.	Diameter in Inches.	Length in Feet.	Cost per Foot.	Depth. Max.	Depth. Av.	Hauling Tile: Distance and Price per Ton.	Construction: Digging, Laying, and B.F. Cost per Foot.	Remarks.	Engineer, Contractor, &c.
						$				$		
Ill. ..	Sub. D.D. No. 1 of Pesotum, Slough, Champaign, and Douglas Cos.	17/8/20	C.T.	8	512	0.129	..	4·4	1 m., incl. ..	Total, $1,150	..	V. W. Burton, Pesotum, Ill.; Blake Thomas; manufacturers, Wm. E. D. Clay Manufacturing Co., M., Ind.
			..	10	1,050	0.182	..	4·8	..			
			..	16	2,300	0.482	..	4·9	..			
Ill. ..	Union D.D. No. 1; Kane Co.	2/9/20	C.T.	26	5,220	1.90	12·0	6.0	..	1.50	Construction cost includes hauling of tile. One bulkhead; 10 cub. yd. concrete, $400; contractor to be paid in cash	Wells Eng. Co., Aurora, Ill. Carpenter-Henderson. Streator Drain Tile Co., Streator, Ill.
			C.T.	24	1,000	1.225	8·0	6·0	..	1.00		
			C.T.	18	5,900	0.685	8·0	6·0	..	0.80		
			C.T.	16	1,000	0.53	8 0	5·5	..	0.60		
			C.T.	14	6,300	0.41	7·0	5·5	..	0.50		
			C.T.	12	2,845	0.305	7·0	5·0	..	0.50		
Iowa	D.D. No. 123; Hardin Co.	13/9/20	C.T.	36	2,900	3.75	7·8	6·5	4 m.; $2 ..	1.80	Total construction including hauling, $17,325	W. S. Porter, Eldora, Iowa. Anderson and Emper, McComb Sewer-pipe Co., McComb, Ill. Eldora Pipe and Tile Co.
			C.T.	32	5,500	2.80	7·1	6·3	4 m.; $2 ..	1.50		
			C.T.	14	500	0.45	6·8	5·2	4 m.; $2 ..			
			C.T.	12	4,500	0.36	6·8	5·2	4 m.; $2 ..			
			C.T.	10	4,400	0.26	6·8	5·2	4 m.; $2 ..			
			C.T.	8	1,000	0.17	6·8	5·2	4 m.; $2 ..			
Iowa	D.D. No. 70 ..	13/9/20	C.T.	30	4,800	2.50	7·0	6·3	5 m.; $2.50 ..	..	Cost of construction on 30 in., including hauling, $659,1.20; cost of constructing balance, $3,372.50	W. S. Porter, Eldora, Iowa. Jens A. Jensen, Eldora Pipe and Tile Co.
			C.T.	10	2,300	0.25	7·1	5·4	5 m.; $2.50 ..			
			C.T.	8	3,500	0.16	6·1	5·4	5 m.; $2.50 ..			
			C.T.	6	5,200	0.09	6·0	5·3	5 m.; $2.50 ..			
Iowa	D.D. No. 318; Webster Co.	14/9/20	Cem. T.	32	100	2.76	4·0	4·0	3½ m. ..	0.70	Contractor to be paid in warrants	J. L. Parsons, Ft. Dodge, Iowa. McHose Sand and Tile Co., Boone, Iowa.
			Cem. T.	30	2,500	2.355	4·0	4·0	..	0.70		
			Cem. T.	28	350	2.12	4·0	4·0	..	0.60		
			Cem. T.	26	1,300	1.91	4·0	4·0	..	0.60		
			Cem. T.	24	1,050	1.56	4·0	4·0	..	0.60		
			Cem. T.	18	2,065	0.75	8·2	6·5	..	0.60		
			Cem. T.	16	1,100	0.645	10 4	9·1	..	1.50		
			Cem. T.	15	1,800	0.60	11·5	8·8	..	1.00		
			Cem. T.	14	1,100	0.485	7·1	6·6	..	0.50		
			Cem. T.	12	600	0.33	7·5	7·0	..	0.50		
			Cem. T.	10	2,600	0.25	7·5	6·4	..	0.35		
			Cem. T.	8	3,260	0.158	8·6	5·7	..	0.25		
			Cem. T.	6	762	0.10	4·8	4·5	..	0.15		
			Cem. T.	26	1,500	..	10·0	8·9	..	1.60		
			Cem. T.	24	800	..	7·6	6·9	..	1.00		
Iowa	D.D. No. 287; Webster Co.	14/9/20	S.P.	34	50	2.888	8·6	6·6	5½ m. ..	2.00	Contractor to be paid in warrants	J. L. Parsons, Ft. Dodge, Iowa. Thor. Larson.
			Cem. T.	34	1,950	2.888	8·6	6·6	..	1.00		
			Cem. T.	32	7,210	2.52	9·5	7·7	..	1.25		

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