

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