METHODS OF EARTH EXCAVATION

ON THE CHICAGO DRAINAGE CANAL.

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Methods of Earth Excavation on the Chicago Drainage Canal.

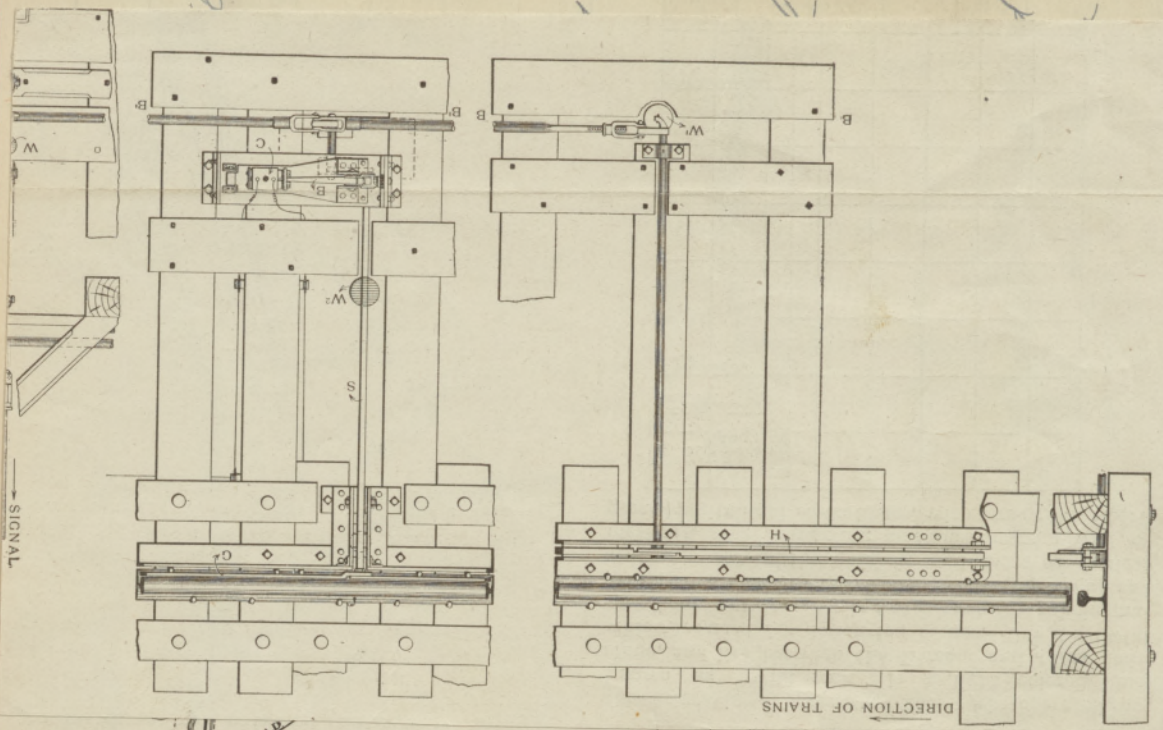
Art. 1 Introduction.

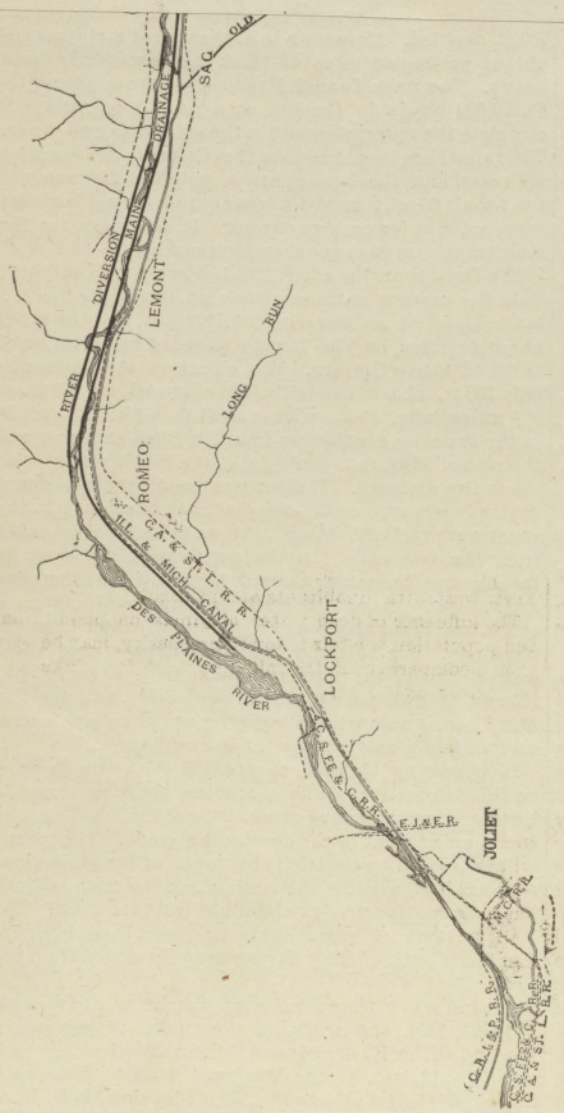
1. The Chicago Drainage Canal is to be a southern outlet of Lake Michigan by way of the Chicago River. It is intended, not only to relieve the lake from the direct discharge of sewage into it, but also to give an outlet toward the Mississippi river for the open sewer- the Chicago River. When the canal is completed, sewers may no longer discharge directly into the lake as they now do in a number of cases.

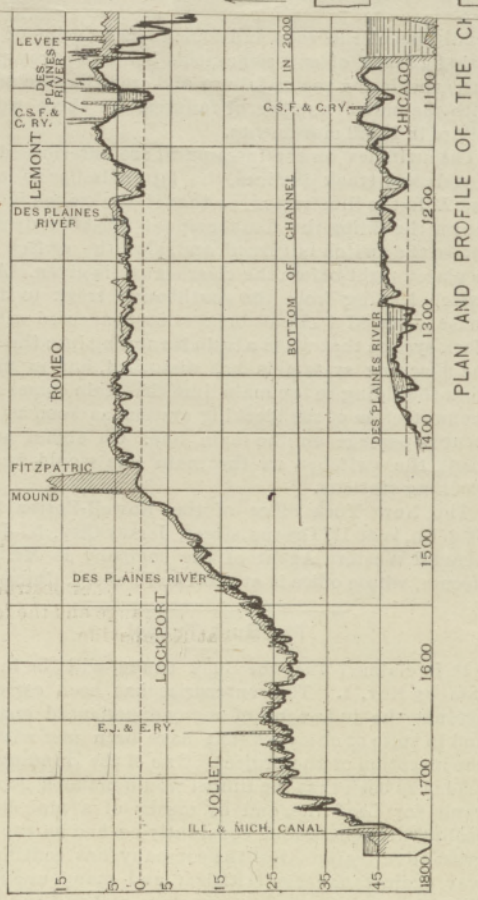
2. There will be a considerable flow of water from the lake owing to the grade of 1 in 12500. During heavy rain falls and with western winds, the Chicago River will then no longer be flushed

into the lake. The primary object of the main channel is thus to prevent contamination of the city's drinking water by the city's sewage. The canal is also intended as a navigation channel. With a depth of water of 14 feet, as being constructed, it will easily be able to accommodate all river craft, but it is likely that in the future it will be deepened so as to allow the passage of any vessel likely to reach Chicago by way of the lakes.

3 By reference to the map, between pages 4 and 5, it will be seen that the line of the canal lies close to the Des Plaines river for 25 miles of its course, and crosses it at several places. The river has been diverted, by excavation, from its natural course for a considerable distance, in order that these crossings may not occur.







PLAN AND PROFILE OF THE CH

zontal offsets; they also free the rock for blasting, so that it is thoroughly broken up by the use of about $\frac{8}{10}$ lb. of No. 2 dynamite per cubic yard. In some, if not in all, instances this channeling is sub-let by the contractor at the rate of 15 cents per square foot, making the cost about five cents per cubic yard excavated.

The broken rock, as mentioned, is sent to waste alongside the canal by derricks, the principal dimensions of which are shown in the illustrations. It is understood that wasting the rock is sublet to the Brown Hoisting

4 The canal will be a small artificial river passing about 1 000 000 cubic feet of water per minute. It will extend from Bridgeport, 6 miles from the mouth of the Chicago River, to Joliet, crossing the water shed between the Illinois and Chicago Rivers at Summit, Illinois. There are about 33 miles of excavation, of which over 10 miles is clay, 10 miles rock, hard pan, and clay, and over 12½ miles of solid rock with a slight covering of earth.

5. All material excavated on the drainage canal is classified as "solid rock" or "glacial drift." Solid rock includes "all rock found in its natural bed, even though it may be so loosened from the adjacent underlying rock that it can be removed without blasting." Glacial drift includes "the top soil, earth, muck, sand, gravel,

clay, Land pan, boulders, fragmentary rock displaced from its original bed, and any other material that overlies the bed rock."

6 The writer spent a week upon the canal in studying the methods of earth excavation. The results of his observations are given below. It was intended to illustrate the text with numerous photographs, but owing to the failure of a photographer to keep his agreement, this can not be done.

Art. 2. Loosening Earth.

7. A variety of methods are employed in loosening the earth ready for removal, varying with the contractor's preference or with the condition of the material. The several methods will be described.

8. With Pick and Shovel. The earth on the

canal is loosened by hand in only two places. In one of these, the ground was originally covered with a moderate growth of timber. On account of the roots of the tree and stones of all sizes, plows can not be used to advantage. On this section, the earth is loosened with pick and shovel, and removed in wheelbarrows. Many large boulders have to be shattered with giant powder before they can be removed. The wheelbarrows have an average haul of 200 feet passing over an elevation of 15 feet.

The barrows are run on plank tracks, ten barrows being used simultaneously on each track. The barrows are loaded by men in the pit, the motorman not helping. The wheelbarrows are used for removing material varying from muck or fine gravel to stones as heavy as one man can conveniently handle. The heavier

stones are removed on "drags" which are simply strongly built platforms made from two inch plank with cleats on top.

9. On this section, there are 2000 barrows, 2000 picks and shovels, and 250 teams. The men receive $1.50 a day, and men with teams $3.50. In this connection it should be noted that the contractor was offered an inducement to furnish work to a large number of Chicago's unemployed, and he accepted the offer. It is probable that the Trustees of the Sanitary District paid the men directly and gave the contractor a percentage for superintendence and furnishing tools, etc.

10. On another section, the very soft silt or loam is loaded with shovels into cars holding about 1½ yards. These cars run on a very temporary tramway, and are drawn by mules (8 cars to the

load on the level for each two-mule team). The cut at this point varies from 3 to 5 feet. The ground here is not quicksand, yet it appears to be nearly a liquid earth. It transmits pressure very much as water does. At one point after the bottom of the channel had been brought to grade, the bottom of the cut was forced up owing to the removal of the earth.

11. By Explosives. Dynamite and giant-powder are used in breaking up all stones and rocks which can not be handled by two men. These explosives are also used to a limited extent in grubbing trees. At one point a very hard shale is blasted with giant powder preparatory to removal by steam shovel. Blasts of giant-powder are placed about 6 feet below the surface and as often as are necessary to shatter the shale.

12. On account of the great danger in handling nitro-glycerine, the use of liquid explosives is forbidden by the specifications. It is required that explosives shall be stored not less than 600 feet from the work, or from any other magazine for explosives, or from any dwelling.

13. By Plows. In a number of places, the gravelly soil, also in a few places the black loam, is loosened by heavy plows drawn by from 2 to 12 mules, one man driving and two handling the plow. In the gravelly soil, which varies from fine sand through all kinds of gravel up to rocks too heavy for two men to handle,- the two men, one guiding and the other throwing his weight on the plow, are unable to keep it in the ground for more than a few feet at a time. After the soil is loosened, it is removed

by wheel scrapers, wagons, and drags.

14. By Steam Drag Shovel. This is something of a novelty in earth excavation. The apparatus consists of a Lidgerwood Cable; a 60 H.P. Boiler, three winding drums controlled by levers, and a 2½ yard shovel propelled by cables. The earth where this apparatus is working is very soft and ordinary methods probably could not be used to advantage. Six men are employed with this apparatus: one to control the levers which regulate the motion of the drums; two to give signals (one near the shovel and the other on top of the spoil bank); a fireman; a workman; and the foreman in charge.

The boiler and engine are on a temporary track behind the spoil bank. The two towers which support the cables are also on temporary tracks on opposite sides of the channel. The shovel has three

cables attached to it, two behind and one in front. It can be pulled forward, backward, or dumped, by steam power. This cable way works very well when the shovel is not obstructed by stumps, roots of trees, or boulders. The latter are most troublesome, since usually their location can not be known in time to avoid an accident. When all works well, the capacity of this drag shovel is between 250 and 300 cu. yds per 10 hours.

15 The channel is not completely excavated by this shovel. Next to the banks, and around stumps, and very large boulders, the earth must be excavated by some other means. When the cut has stood for a considerable time, in order that it may dry, it is probable that the material remaining above grade, may be removed without difficulty by either wheel scrapers or wagons.

16 By Railway Grader. A "New Era" railroad grader is used by one contractor in loosening a black loam. The motive power is 12 horses, 8 in front and 4 behind. This apparatus consists of a very large plow mounted on wheels, with an inclined elevator for transferring the earth to wagons. The grader was running almost continuously while 15 teams with wagons were kept very busy (hotting when not loaded) in removing the earth. The maximum haul was a half mile, the load being a little less than a yard.

17. When all was working well, they were handling 60 to 75 cu. yds per hour. But occasionally a small boulder would interfere either with the cutting plow, or the elevator, and cause considerable delay. Five men are required: a Foreman, Two drivers, and Two men to handle the levers. Three men assist in unloading the wagons. This makes, with the fifteen

men with wagons, twenty-three men, with forty-two horses, required to run the grader.

18. By Milroy Dredge. This machine works practically on the same principle as the steam shovel, except that it wastes the material on the spoil banks without re-handling by hand, or otherwise. The shovel proper is a four jointed clasp shovel with capacity of one cubic yard. It is however never full. The shovel is carried on a 98-foot cantilever beam which has both horizontal and vertical motion. The cables and dumping apparatus are used as in the ordinary steam shovel.

19. This dredge can not be used to advantage in soils where coarse gravel and stones are found. It was doing good work in black loam, underlaid with clay which gave little resistance to loosening. The capacity of the dredge is about 375 cu. yds.

per 10 hours. The earth was wasted within reach of the 98 foot boom. This appears to be an economical method of excavating near the banks of the channel, since the earth is handled but once.

20. The boiler used is 50 H.P. burning from 3 to 4 tons of coal daily. Four men are required to work the dredge, one to manipulate the levers, a fireman, a laborer, and the foreman who continually watches the shovel and gives signals for handling it.

21. By Steam Shovels. The great bulk of earth excavated on this canal will be loosened by steam shovels of the ordinary type. The chief reason for this is undoubtably because they can be used in almost any material except solid rock. They are used in loam, clay, muck, sand, gravel, hard pan and shale. Work may be pushed forward very rapidly with steam shovels. The width of the

channel is excavated in strips as wide as the reach of the shovel will allow. The shovels rest on a temporary track, and, with but one exception, move forward in a direction parallel to the line of the canal. The one exception had a Lidgerwood Cableway, instead of a railway train to remove the material. Steam shovels excavate from 550 to 1000 cu. yds. in 10 hours. This great variation is chiefly due to the methods used in removing the material. From seven to nine men are employed on each shovel: a foreman, fireman, man to manipulate levers, man to dump shovel, man to signal engineer of locomotive as to the proper position of train for removal of material, and two to four men for removing and laying track, working jack screws which lift front part of shovel frame from the track when it is in use. In working shale, two more men are required

to do the blasting.

22. By Hydraulic Dredge. This apparatus is a very large hydraulic pump. It is capable of discharging an 18-inch stream of liquid mud which sometimes contains rocks weighing 25 lbs; but ordinarily it is desirable that the dredge should discharge only sludge. It is claimed however that it can handle any material except solid rock. The dredge rests on a flat-boat. The cutting tool and inlet-pipe have considerable horizontal motion in front.

23. The cutting tool is in the form of a cylinder 3 feet in diameter and four feet long, with 12 knives on the surface of the cylinder. This cutting tool, which weighs 1½ tons, may work under 20 feet of water, and is now working under a maximum depth of 13 feet, i.e., down to the rock. One trouble

with the working of the dredge has been that an attempt has been made to hug the rock too closely, with the result that the cutting tool is lost or torn loose from its bearings. Then considerable time is lost in fishing out and replacing the cutter.

24. The capacity claimed by the foreman is 6000 cu. yds. per 24 hours. This dredge works day and night. The boiler is 500 H.P. Seventeen men are employed on the dredge during the full 24 hours. The discharge pipe was less than 400 feet long. The ground where the dredge was working is very soft and yielding, being in fact but little different from a slough.

25 There is but one hydraulic dredge working on the canal, but another was being built at Willow Springs. This dredge can be used to advantage only when not obstructed by rocks

boulders, stumps, logs, etc. It could not be used in many of the gravelly soils along the canal. A hydraulic dredge costs between $25,000, and $30,000. They are built where they are needed.

Art. 3 Removal of Earth.

26. A variety of methods are employed in removing the earth after it has been loosened. The several methods will be described.

27 By Wheelbarrows. The excavation described in section 8, in which wheelbarrows are used for the removal of material, costs from 35 to 40 cents per cu. yd. The cost of excavation on another section where barrows are used is from 10 to 12 cents per cu. yd. The maximum cut in the last case is 5 feet and the earth is black loam underlaid by a soft clay.

28. By Drags. See section 8.

29. By Wheel Scrapers. The excavation where wheel scrapers are used costs from 12 to 15 cents per cu. yd. for the first 10 feet in depth, with 500 feet maximum haul.

30. By Wagons. Wagons with square boxes are used by some contractors, in place of the drags for the removal of such stones as one man can not handle. They are collected in this manner for building retaining walls.

See sections 16 and 17.

31. By Tramways with Mule Power. The tramways are built in rigid sections as long as the length of the rail. The sections are held together only by the fish plates. The track may be very quickly laid and more quickly removed. When a section is moved, the ties are left rigidly connected to the rails. The method is convenient, but it necessarily

makes a poor track

32. Contractors are required to build levees where the engineer considers they are necessary for the protection of the work during construction. On two sections the earth is hauled to the top of levees on tramways up grades varying from 6 to 10 %, the mules pulling all the time in the horizontal plane at the foot of the levee. On these grades, two cars holding 1¼ yards each make too heavy a load for any ordinary team.

33. For example take a load W on a 10% grade with a rope 40 feet long attached to the car, the levee being 25 feet high.

Fig. 1.

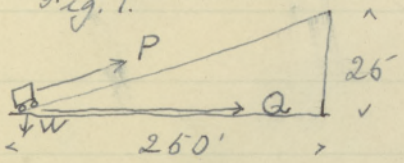


Fig. 2

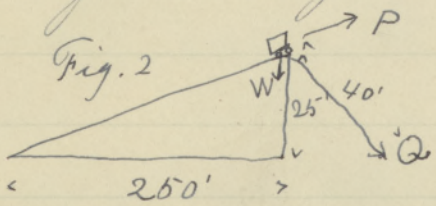
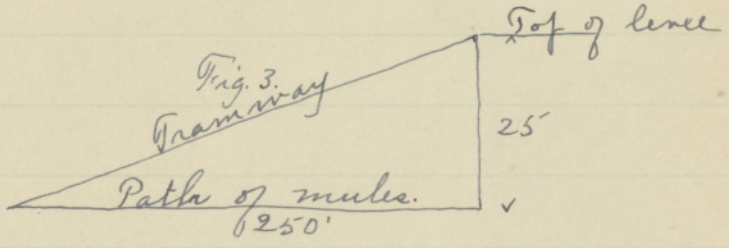


Fig. 3.



If P can raise the load acting in the direction

of the line of motion, Fig. 1, The Q acting horizontally equals 1.004 P, that is Q = 1.004 P in order to start the load at the foot of the levee. At the foot of the incline the loss of power is small, but as the loaded cars approach the top of the levee, the component of the pull which is perpendicular to the plane of the incline, becomes very considerable. This component is dead loss, since it only produces pressure on the rails. At the top of the levee Q = 1.836 P. See Fig 2. But if the friction of the rope dragging or rather grinding into the earth and the loss due to the curves not being in the same vertical plane as the track, were considered it is probable that Q = 2 P. This is not economical.

34. By Trains. As stated before the greater part of the earth to be excavated on the canal will be

loosened by steam shovels, and nearly all of this material will be removed by trains drawn by locomotives. The engines used vary from the worn-out, rickety, locomotive which can scarcely draws six tons of earth up a 3% grade, to the carefully designed, well built, freight locomotives. All the cars used are dump cars. One contractor uses the Thatcher patent dump cars, which are dumped by steam power from the locomotive. Each car has a compressed air cylinder. The cars seem to get out of order easily, and many of them have to be aided very considerably, by hand or by levers, before they will dump. The cars have a capacity of 9 cu. yds. each, but only about 7 yds. are put in them. The cars cost $400. each. Each locomotive handles from 12 to 18 cars.

35. Another contractor employs a simple car which is dumped by hand or by a long pole used as a lever. These cars are made by the Corey Car and M'f'g Co. They work very well. Their capacity is 3 cu. yds. There are 14 or 15 cars in each train. Eight men are needed for unloading when dumped by hand, but only five when the lever is used. The cars cost $200. each

36 The track used, except by two contractors, is standard gage. The tracks are often from necessity laid on very soft yielding material. As a result cars and engines are often thrown off the track. One contractor found the ground so soft that he placed a large number of poles below the ties. He used ordinary medium weight freight locomotives, and quite often, even after the above mentioned precaution, the track would

slide out from under the locomotive. This always caused some delay, and sometimes for a considerable time. The average length of haul is one half mile.

37. On one section each steam shovel had only one train, and the shovel had to wait while the train went to unload. On all the other sections, each shovel has two trains, and some contractors have three. The third train to be used in case of accident. With the two trains, one usually waits a short time, but the cost of running a train is considerably less than that of a steam shovel.

38. By Steam Derrick. Only one of these machines is used on the canal. The derrick is practically the same machine as the Milroy dredge described in sections 18 and 19, with a cantilever beam 90 feet long. Instead of a clasp shovel, it has a

flat bucket of considerable horizontal area, suitable for catching the load from the ordinary steam shovel. The steam shovel dumps into the bucket of the derrick, and the load is then carried by the derrick to the waste bank. The derrick can not remove material as fast as the shovel can loosen it. The derrick rests on a track which runs parallel to the line of the canal and close to, and below, the bank. The cost of operation is small, only three men being required. This method of removal appears to be economical, but not as rapid as removal by trains. This objection of course becomes greater when material is taken from the middle of the canal.

39. By Wright's Inclined Tramway. With this apparatus the steam shovel dumps into cars

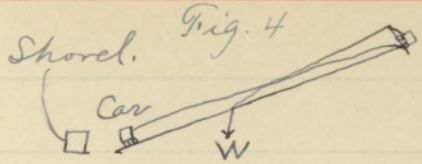


Fig. 4

which rest on an inclined tramway. The incline has a double track with two balanced cars (both being attached to the ends of a cable), and the steam shovel is kept working continuously. The stationary engine on the incline draws a car to the top where it dumps from its own weight. The car is brought back to the plane of the incline by a weight W, shown in Fig. 4. One car goes down empty while the loaded one goes up. In this way no power is lost by using brakes. Two of these inclines are in use on the canal. The method is economical and rapid.

40. By Pumping. When the material for this thesis was obtained, October 1893, the pumping required was very small. The Chicago

Drainage Canal lies close to, and between, the Illinois and Michigan Canal, and the Des Plaines river. On this account water needs neither to be pumped for any considerable distance, nor against much head. The contractors are on several sections making great sink holes, with wheel scrapers and wheelbarrows, where water will collect during heavy rainfalls, and cause great additional expense for pumping, with expensive delays in the work.

41. The pumping of liquid mud has been discussed in sections 22 to 25 inclusive.

Art. 4 Comparison of Methods.

42. There are many things to be considered in comparing the various methods of excavating earth on the canal. Work carried on with a large number of men is liable to be disturbed

by strikes, fights, and riots. When large bodies of men are collected along the canal, the saloons are many and very popular. This is an important objection to having large bodies of men concentrated on one section. On the other hand, a contractor, being well equipped with apparatus, manned by intelligent men, excavates earth faster and cheaper, and with less friction, than if the work were done by hand.

43. Under certain conditions, as have been described, special apparatus is used to advantage. When the Des Plaines river has been diverted from its original course by excavation, economy required some other method than by steam shovels. The cut was only 3 to 5 feet deep for a considerable distance. On river diversion, as the change of the river channel is called, in the

black loam and soft clay, the steam drag shovel and railway grader were used. The hydraulic dredge, at the time this data was obtained, had not proved itself to be a success; but the fact that the contractor was building another dredge similar to the one described, which was to cost between $25,000. and $30,000. shows at least that one man had confidence in this method of excavation.

44. But in the main channel, the steam shovel is without doubt the most economical and rapid instrument for loosening earth, and nearly all the earth will be loosened by it. Trains pulled by locomotives are the most economical, and rapid method of removing earth, since tracks may be laid wherever desired. Trains will remove much the greater

part of the earth in the main channel.

46. The ideal method of excavating earth as seen on the Chicago Drainage Canal is by a full complement of steam shovels, locomotives, dump cars, all on standard gage track.

End