of ditches and natural streams can be obviated by observing this precaution.

Where ditches are liable to become clogged by sand bars blown in by the wind the maintenance of a grass strip a rod or more wide along each side has been found effective.

The engineer, in designing crossings for a drain, should in no case consider the building of culverts in the main line of the drain. All crossings should take the form of open bridges. In practically every case where culverts have been built the spring freshets have lifted them, and used the timbers thus released as battering rams against any structures farther down the drain.

In regard to side slopes, authorities state that the manner of excavation is an important factor. With clay sub-soil, if excavated by teams, where rapid fall exists, the sides should be given a slope of almost two to one. When under the same conditions excavation is made by a dredge, the slope may be made one to one or less. A berm of at least six feet should intervene between the ditch and the toe of the waste bank.

Methods of Excavation.—These may be dealt with under the three main subdivisions of hand labor, team labor and mechanical means.

In certain parts of the world, particularly in Europe and Asia, comparatively large contracts are executed by manual labor. In Saskatchewan unskilled labor commands so high a wage as to make it prohibitive where any other method is practicable. The supply of even unskilled labor is most irregular. In the spring or fall it is scarcely possible to obtain men for construction work owing to the large number required for the planting and harvesting of crops at this period. Manual labor is therefore the last resort for the contractor in Saskatchewan.

On certain sections of a drain drag scrapers may be used to advantage. There are nearly always some portions of a drain which are dry enough to give good footing for horses. And, if the ground is not too stony, teams will handle such excavation at almost minimum cost. If the drainage scheme consists of a fairly dry main drain tapping one large area of flooded land, teams may here be used to advantage. The majority of drains, however, cut through a succession of sloughs and intervening comparatively dry ridges. In such cases it does not pay to employ teams for the minor part of the work when a different method must be adopted for excavating the wet material. The use of team labor, therefore, in drain excavation, is greatly limited.

The handling of wet material requires machinery. On the comparatively small drains of Saskatchewan only two general types of machines will be found practicable. A light weight type of dragline excavator may be used to a limited extent, while a dredge has the most general usefulness.

There has been designed a light weight type of dragline which cuts fairly true to theoretical cross-section, and of which all the parts may be transported on wagons, an important consideration in a country of long distances and poor roads. It has a frame supported by four large wheels and when properly planked will travel over any ground that will sustain an empty wagon. As many of the slough bottoms will not support even this light weight the machine is often unable to excavate these places which must then be done by hand labor. Such a dragline has another conspicuous disadvantage. Since it is a machine of small capacity it cannot handle the large boulders so often encountered in the drainage regions of the north and fails to make any headway in hardpan. It is readily seen that a small dragline is not in any sense adequate for general drainage work, although it must be admitted that in suitable material the cost of excavation per yard is less than with any other method so far employed.

There are two types of dredge employed in drainage work, the walking and the floating dipper dredge.

The walking dredge, as its name implies, is propelled by a sort of walking motion. It consists of a rectangular framework mounted on large feet, one at each corner, and connected transversely by a light timber. This requires the members of each pair to move in the same direction, the direction being controlled by a chain which runs from each corner foot to a drum operated by the cranesman. Midway of the machine on either side is a large foot which can be moved longitudinally. Without going into further details of construction it is enough to add that the machine may be moved on these feet a distance of about six feet for each "set." It can propel itself across country at the rate of almost a mile per day. It is hard to see that the walking dredge has any advantage over the floating dredge other than its ability to travel from one drain to another, provided they are situated near together. The floating dredge must of necessity be dismantled in order to reach new work. It is obvious that the walking dredge operates with difficulty in soft material and is, therefore, not of practical use under conditions ruling in Saskatchewan.

The floating dredge is essentially a steam shovel mounted on a scow which is steadied when excavating by spud legs which are dropped vertically into the bottom of the ditch or else angle from the sides and press against the banks of the ditch. The smaller sizes of such a type require at least three feet in which to float, a condition which usually obtains in the drainage areas under discussion.

This is the most efficient type of machine yet devised for the excavation of drains. It will dig in any material (blasting is, of course, necessary for rock) and will handle boulders. In contrast to the dragline type and the walking dredge, wet ground aids rather than retards its efficiency.

Although the floating dipper dredge has been found the most satisfactory, it yet labors under great disadvantages in a northern country where drainage is in its infancy. The drains so far designed are small, having usually about a four-foot bottom and with one and one-half to one side slopes. A dredge large enough to handle any reasonable yardage, *i.e.*, not under a one-half yard machine, cannot excavate to a bottom much less than seven feet, particularly in shallow work. This means that the contractor must excavate from 25 to 100% more material than is called for by the specifications and must consequently charge more per yard for the actual pay yardage than if he were getting remuneration for his total excavation. A source of additional outlay to the northern contractor is found in the fact that fuel, laid down at the machine, costs at least three times as much as to the contractor in the States to the south. Since the work in progress at the present time lies hundreds of miles from any point carrying dredge repairs in stock there is occasionally great and costly delay when breakages occur. The supply of the needful unskilled labor is variable and of poor quality. Skilled labor for this work must be brought from a distance. The small amount of work in progress and the short five months' season make it difficult to obtain good men except at a very high wage and on practically their own terms.