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A thesis on the improvement of western waterways

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THESIS

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There is no subject that falls within the province of the engineer's art, that presents greater difficulties and more uncertain issues than the improvement of rivers. Ever subject to important changes in their regimen, as the regions by which they are fed are cleared of their forests and brought under cultivation, one century sees them deep, flowing with an equable current, and liable only to a gradual increase in volume during the seasons of freshets; while the next finds their beds a prey to sudden and great freshets, which leave them, after their violent passage, obstructed ~~and~~ by ever shifting bars and bends. Besides these revolutions brought about in the course of years, every obstruction temporarily placed in the way of the current every attempt to guard one point from its action by any artificial means, inevitably produces some corresponding change at another, which can seldom be foreseen, and for which the remedy applied may prove but a new cause of harm. Thus, a bar removed from one point may gradually form lower down;

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one bank protected from the currents force transfers its action to the opposite one, on any increase of volume from freshets, widening the bed and frequently giving a new direction to the channel. Owing to these ever varying causes of change, the best weighed plans of river improvement sometimes result in complete failure.
The object in all river improvements is to obtain a channel as near as practicable uniform in section, or gradually increasing from the source to the mouth, having sufficient capacity to carry off flood-water without overflowing, with a velocity that shall not endanger the stability of the banks. Thus it will be seen that the engineering works for the improvement of the upper portion of a river will consist chiefly of excavations to remove shoals and other obstructions, and to widen narrow parts, regulating dykes to contract wide shallows, diversions of the channel, and works for stopping useless branches.

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The work of excavating the bed of a river for the purpose of deepening its channel consists mainly of dredging. This operation may be performed by hand, by steam, or by means of the current itself. When performed by hand, an implement called a spoon is employed. It consists of a pole, having at one end an iron ring steeled on the forward edge, to which a leathern bag is attached. The end of the pole is held by a man, and the ring is hung by rope tackle capable of being wound up by means of a crab. The man who holds the pole directs the forward edge of the ring against the bottom while the spoon is being dragged along by the winding up of the rope. When the spoon arrives beneath the crab, it is hauled up and its contents emptied into a barge. In cases where the depth of water does not exceed 6 ft, this system of dredging may be employed with advantage as it is both effective and cheap, it having been ascertained that the labor and cost of the operation are not much greater than in sim-

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ilar excavations on dry land. When, however, the depth is great recourse must be had to the dredging machine With a steam dredging machine, the cost of excavating is about the same as that of similar operations on dry land. A steam dredger of 16 horse-power will, under favorable circumstances, raise about 100 cub. yds. an hour.

The most economical means of removing the materials of the bed of a river when they consist of mud, sand, or light gravel, is the employment of the current for that purpose. The operation is performed by means of a kind of movable dam, usually consisting of a framework covered with boards attached to a boat. The boat is moored in the stream, and the dam lowered to within a few inches of the bottom. The water-way being thus greatly contracted, the velocity of the current over the bed is proportionately increased, and this increased velocity will scour the bed to a considerable depth in a short time. From 30 to 70 cub. yds. may be excavated in this way in a day and at a cost of only about $.05 per yd.

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It must be borne in mind that this mode of dredging acts only by displacing the materials of the bed, leaving them free to be deposited elsewhere It can not therefore be applied where a necessity exists for the removal of the materials disturbed.
When the bed is composed of rock, recourse must be had to blasting.
When the shallowness of a river is caused by excessive width, the defect may be remedied by a regulating dike or longitudinal embankment. These dikes may be constructed either of dry stone or of wattled piles and gravel.
When built of stone, they should have a slope of about 1 to 1. The latter mode of construction is, however, the more usual. In this case the piles should have a diameter of not less than one-twentieth of the length; they should be driven into the ground in a double row to a depth equal to twice that of the water; the distance between the rows should be once and a half the depth of the water and the distance of the piles apart, longitudinally, should be equal to the depth of the water.

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After being tied together transversely, the rows of piles are wattled with willow twigs, and the space between filled up with gravel. The construction of dikes not only increases the depth by forcing the water to flow through a narrower channel, but the velocity of the water being thereby increased, the bed is scoured out until a sufficient depth is reached to establish equilibrium between the current and the materials of which the bed is composed. This consequence of erecting a dike must be carefully calculated beforehand, and the amount of contraction duly apportioned to the results. It may be remarked here that the only certain means of permanently deepening the bed of a river is the construction of continuous longitudinal embankments. Dikes built in the same as those described above are used to stop up side branches. In this case, they are thrown across the upper end of the stream from bank to bank. The effect of stopping up a branch is to throw a larger body of water

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into the main channel, the stream in which will be both deepened and accelerated thereby. Thus the consequences will be the same as those produced by the longitudinal dike, and they will have to be calculated in the same way. When the course of a river is so circuitous that the velocity of the current is not sufficient to prevent deposits, the bed silts up and the channel becomes too small to contain flood-water. Hence result disastrous inundations; as is the case with the Missouri River which contains immense deposits of quick-sand which greatly impede the velocity and cause it to overflow its banks for several miles on each side during high water. These floods generally occur in the Missouri every spring and do an immense amount of damage to farms lying in the course. The last one which occurred, and which was a very noted one because of the great amount of damage done was in June 1883. During this flood the Missouri was estimated to be 25 miles wide in some places.

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The damage done by one of these floods would pay for necessary improvements to prevent their recurrence according to estimates made by an able engineer. These floods may be stopped partly by embankments and partly by cut-offs as the river is very crooked in the upper part of its course. The main points to be considered in the construction of a cut-off are these: The new chanel must be made as deep as possible, for the tendency of a river is to widen rather than to deepen its channel, and this must be kept in view in the excavation of the cut-off. Another important condition is to connect the new channel with the old by a curve of a considerable radius. Unless this condition be fulfilled, the stream will not enter at all, or if it enter, will not flow freely in the new channel.
It is also an advantage to slightly curve the new channel, for the current will then keep constantly against the concave bank; whereas if the channel is straight, it will

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deviate from side to side, and thus tend to produce bends. The velocity, too, is somewhat checked by the curved channel, and ~~in~~ this will generally be an advantage. The new channel must not be opened to receive the waters of the river until the down-stream end of the old one has been completely closed. For it has been found impracticable to divert the stream into the new channel unless this be done by reason of the impossibility of throwing out the cut to a depth inferior to that of the old channel. It is also necessary to clear the bed of the new cut of all trees, reeds, or aquatic plants, as these impede the flow of the current and favor deposits.

The simplest and most effective means of protecting the adjacent land from inundations in consequence of a river overflowing its banks, is to increase, artificially, the height of the banks at those parts liable to overflow. In doing this two ~~two~~ methods have been used; one consists in building levees on each side of the

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short pickets and interlacing them with willow twigs, forming a kind of wicker-work. These constructions, which are used almost exclusively along the Mississippi, break the force of the current, and diminish its velocity near the shore, and thus cause the water to deposit its finer particles, which gradually fill out and strengthen the banks. If the banks are high, and are subject to cave in from the action of the current on their base they may be either cut down to a gentle declivity as in the last case; or else they may receive a slope of nearly 45°, and be faced with dry stone, care being taken to secure the base by blocks of loose stone, or by a facing of brush and stone laid in alternate layers. When aquatic trees are abundant, fascines are often employed. These fascines are bundles of willow twigs from 9 to 12 in. in diameter and about 12 ft. in lenght. They are laid with their length up and down the slope and are fixed to the bank by stakes.

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Works executed in this way do not, it is true, last very long, ten years being the limit of a fascine under water; but their duration is sufficient in rivers carrying much suspended matter, to give rise to depositions which eventually serve to effect the object intended in a more permanent way.

Timber sheeting may also be resorted to in some cases. This may consist either of sheet piling or of guide piles and horizontal planks. The wales of the sheet piling or the guide piles of the planking must be tied back to wooden anchoring plates firmly fixed in suitable situations. Sometimes it may be necessary to construct retaining walls to preserve the banks of a river; but such instances will seldom occur, and they will never extend beyond a very limited space.

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When the general depth of water in a river is insufficient for the draught of boats of the most suitable size for the trade on it, an improvement, termed slack-water, or lock and dam navigation, is resorted to. This consists in dividing the course into several suitable ponds, by forming dams to keep the water in the pond at a constant head; and by passing from one pond to another by locks at the ends of the dams.

The position of the dams, and the required, will depend upon the locality. In streams subject to heavy freshets, it will generally be advisable to place the dams at the widest parts of the bed, to obtain the greatest outlet for water over the dam. The dams may be built either in a straight line between the banks and perpendicular to the thread of the current, or they may be in a straight line oblique to the current, or their plan may be convex, the convex surface being up stream, or it may be a broken

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line presenting an angle up
stream. The three last forms
mentioned offer a greater outlet than
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over the dam, but are more liable to
cause injury to the bed below
the stream, from the oblique
direction which the current may
receive, arising from the form of
dam at top. The cross section of
a dam is usually trapezoidal,
the face up-stream being inclined,
and the one downstream
either vertical or inclined.
When the downstream face is
vertical, the velocity of the water
which flows over the dam is
destroyed by the shock against the
water of the pond below the dam
but whirls are formed which
are more destructive to the bed
than would be the action of the
current upon it along the
inclined face of a dam. In all
cases the sides and bed of the
stream, for some distance
below the dam, should be
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current by a facing of dry stone, timber, or any other convenient construction of sufficient durability for the object in view.
The dams should receive a sufficient height only to maintain the requisite depth of water in the ponds for the purposes of navigation. Any material at hand offering sufficient durability against the action of the water may be resorted to in their construction. Dams of alternate layers of brush and gravel, with a facing of plank, fascines, or dry stone, answer very well in gentle currents. If the dam is exposed to heavy freshets, to shocks of ice, and other heavy floating bodies, as driftwood, it would be more prudent to form it of dry stone entirely, or of crib-work filled with stone; or, if the last material cannot be obtained, of a solid crib-work alone. If the dam is to be made, water-tight, sand and gravel in sufficient quantity may be thrown in against it in the upper pond.

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The points where the dam joins the banks, which are termed the roots of the dam, require particular attentcution to prevent the water from filtering around them. The ordinary precaution for this is to build the dam some distance back into the banks. The safest means of communication between the ponds is by an ordinary lock. It should be placed at one extremity of the dam, an excavation in the bank being made for it, to secure it from damage by floating bodies brought down by the current. The sides of the lock and a portion of the dam near it should be raised sufficiently high to prevent them from being overflowed by the heaviest freshets. When the height to which the freshets rise is great, the leaves of the head gates should be formed of two parts, as a single leaf would, from its size, be to unwieldy; the lower portion being of a suitable height for the ordinary manoevers of the lock:

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the upper, being used only during the freshets, are so arranged that their bottom cross pieces shall rest when the gates are closed, against the top of the lower portions. An arrangement somewhat similar to this may be made for the tail gates, when the lifts of the locks are great, to avoid the difficulty of manoeuvring very high gates, by permanently closing the upper part of the entrance to the lock at the tail gates, either by a wall built between the side walls, or by a permanent frame-work, below which a sufficient height is left for the boats to pass.

A common, but unsafe method of passing from one pond to another is that which is termed flashing; it consists of a sluice in the dam, which is opened and closed by means of a gate revolving on a vertical axis, which is so arranged that it can be manoeuvred with ease. One plan for this purpose is to divide the gate into two un-

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When the obstruction in a river cannot be overcome by any of the preceding means, as for example in those considerable descents in the bed known as rapids, where the water acquires a velocity so great that a boat can neither ascend nor descend with safety, resort must be had to a canal for the purpose of uniting its navigable parts above and below the obstruction.

The general direction of the canal will be parallel to the bed of the river. In some cases it may occupy a part of the bed by forming a dike in the bed parallel to the bank, and sufficiently far from it to give the requisite width to the canal. Whatever position the canal may occupy, every precaution should be ~~made for their~~ taken to secure it from damage by freshets.

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A lock will usually be necessary at each extremity of the canal where it joins the river. The positions for the extreme locks should be carefully chosen, so that the boats can at all times enter them with ease and safety. The locks should be secured by guard gates and other suitable means from freshets; and if they are liable to be obstructed by deposits, arrangements should be made for their removal either by a chase of water or by machinery. If the river should not present a sufficient depth of water at all seasons for entering the canal from it, a dam will be required at some point near the lock to obtain the depth requisite.

It may be advisable in some cases instead of placing the extreme locks at the outlets of the canal to the river to form a capacious basin at each extremity of the canal between the lock and river, where the boats can lie in safety.

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The last report of the Mississippi River commission speaks very favorably of such methods of improvement as I have given in this thesis. By the use of these methods many of the western rivers, such as the Missouri, Osage, Gasconade and others may be made navigable for many miles toward their source and thus greatly increase western facilities for cheap transportation. The report says of work done; "We see no reason for doubting the ultimate entire success of the improvements. On the Upper Mississippi below Des Moisne work is carried on in detached portions, and so far only at those place where navigation is most impeded; but on the Missouri only continuous work beginning at some point of stable regimen, affords any prospect of success. By doubling or trebling plants, which cannot be done under the present allotment of appropriations, the work could be done in a much shorter time without any increase of the ultimate cost."

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The report gives in detail the plans upon which the commission is at work below Cairo, the main principle being a contraction of the width of the river and the protection of the banks, to secure the scouring out of the bottom and the prevention of the formation of bars. The works have already passed beyond the experimental stage. They have received practical tests at various points on the Mississippi and Missouri Rivers, and even recent work of the commission already shows their correctness.

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