MEMORANDUM concerning the application of the Siphonic Sand Trap as a practical means of solving the bed load problem at the heading of the main canal diverting from the Rio Grande, Maverick County Water Control and Improvement Dist. No. 1, Eagle Pass, Texas


The inspection of the canal at the head works early, July, 1955, together with a study of the record of deposit in the channel, nature of the bed load and other information relative to the problem lead to the conclusion, after due consideration, that the solution of this problem would require a new approach.

Our experimental work, for more than 20 years, both in the laboratory and field, has permitted us to study various types of sand trap devices suitable under different conditions of channels and the nature of bed load material to be handled. We have not been concerned with suspended load from the standpoint of trapping it out as it is well recognized that the most practical method of handling such a case is to reduce the velocity of the flow in the channel to a very low limit and allow the material to settle on the bed and later be removed by means of a suitable device. For the main Maverick County canal it is possible that for the total load carried about 50 percent is of the nature of suspended material. The conventional types of sand traps, such as vortex tubes, riffle deflectors, guide vanes, grizzlies, pipe sluices, etc., will in all probability not possess very high efficiency when applied to this problem. The new vortex tube installation in Lateral No. 2 of this District no doubt will throw some light as to the practicability of this type of device when operating under somewhat similar conditions as persist at the heading of the main canal. This tryout should yield some valuable information.
Since it is assumed that a large percentage of the total load carried in the canal is of a suspended nature, then any device that tends to disturb the flow will cause some of the bed load to be lifted and thus increase the amount in suspension which is of course contrary from the standpoint of improving the efficiency. To have the vortex tube perform properly it is necessary to have the velocity over the lip of the tube at substantial rate to produce the required rotation in the tube. For ordinary sand, 50 mesh or coarser, we find the necessary velocity to be from 4 to 6 feet per second. Because of the nature of the bed load in the main canal, as would be classified as very fine, some of this bed load will pass over the tube and not be captured. Just what proportion this would be is not known.

The riffle deflector type of sand trap in all probability would not be especially effective because of the deflection of the currents over the riffles. The fineness of the material to be trapped would be stirred, due to the action of the riffles, thus putting more of the bed load in suspension and lost on downstream. A certain percentage of the bed load moving downstream toward the riffles will be caught and deposited in the outlet from the structure. Some years ago we installed an experimental riffle-deflector-vortex tube sand trap in the Sheep Creek Ditch, near Morrill, Nebraska, which gave satisfactory results, channel about 16 feet wide, 125 second foot capacity, and the bed load consisting of very fine sand. In the Rio Grande Canal, near Del Norte, Colorado, San Luis Valley, is a set of three pipe sluices suitable located in the bed of the channel, arch-pipe outlets controlled by means of 3' x 3' slide gates. Discharge from these outlets approximates about 100 second-feet. This arrangement has been very effective in trapping out the heavy bed load. The material is very coarse sand and some gravel.
All these various types of sand trap devices are, of necessity, placed on the bed of the channel, and for the most part cause disturbance to the flow. However, the pipe sluice appears to be relatively free from such action but vulnerable to the possibility of clogging due to waterlogged material dragging along the bottom of the channel. The Rio Grande installation appears to be more or less immune from this danger. To accommodate such devices in the Maverick County main canal necessitates the dewatering of the site of installation, shutting out the canal from service, construction of possibly a sand dam upstream from the site, and other precautions needed during the construction of the job. The extra material piled up in the upstream section of the canal, to construct a sizeable sand dam, will be washed into the new excavated area, in which the sand trap has been built, when the dam is broken and the canal put back into service. This particular feature of the installation has been given considerable thought, and should the excessive amount of material deposited into the excavation be great enough, the device could be completely overloaded and swamped before the new device could recover and get into action. Whether such would be the actual happening is merely a conjecture, however there is a possibility of such an occurrence.

After personally inspecting the conditions at the head of the main canal, nature of the bed load, velocity of flow, the general scheme of regulation, and outlet channel from the head works to the river, I was more or less led to the conclusion that some new scheme of meeting the problem of correcting the bed load menace would have to be devised. At our Eagle Pass conference last July the possibility of a siphon type of sand trap was briefly discussed. At that time the problem was too new to visualise the layout of such a device suitable to meet the existing conditions at the head of the canal. After giving more thought to such a scheme, a general plan was sketched to show limiting sizes and dimen-
sions of such a structure together with some study of physics and hydraulic relations involved in such a problem. An over-all layout of such a siphonic sand trap, believed suitable for application to the Maverick County Canal, is shown in the accompanying drawings. Following the general idea of such a structure, an experimental model was prepared on a scale ratio of 1 to 5 to demonstrate the siphonic action and also to permit the study of the relative dimensions involved. This model was set up in the hydraulic laboratory and tested with very satisfactory results. Two features that were especially observed in these tests were the action of the siphon related to the effective head and the relative dimensions of the taper of the header that spans the channel. For a particular difference in head the approximate upward flow in the suction pipes can be calculated, and since all these pipes are of the same diameter and under identical suction head, the discharge of each pipe into the header will be the same. On this assumption the taper of the header was designed such as to have a constant velocity of flow toward the outlet and which of course would be the upward velocity in each of the suction pipes. The tests appear to be consistent in this respect. Since there are seven suction pipes, each one adds one-sevenths of the total flow or 14.2 percent, whereas the model tests indicate the percentage to be 12.4. This agreement is considered to be within reasonable limits, and a slight change in the taper can therefore be made accordingly in designing the prototype structure. Preliminary observations were made as to the ability of the tubes to pick up the bed load from the bed of the channel. In the model the suction tubes are of glass which permits noting the travel of sand upward in the tube. Sand on the bed was quickly taken into the tube covering an action area of about three inches in diameter for an effective head of about 0.5 feet. On the basis of similitude, this would indicate good suction for a full scale structure over an area of say a couple of
square feet at an effective head of 2.5 feet. For an effective head of 5 feet or more the suction effect would be quite wide and very vigorous. Coarse sand and pea gravel, 3/8-inch size, for a 0.5 foot effective head, was readily removed. Tests so far on the model have been very satisfactory.

Attention now to drawings A and B. These sketches are not intended to show details or exact dimensions, and are to be considered only in giving a conception of the nature of the installation and to serve as a means of explaining its operation, advantages and disadvantages. Drawing A shows an elevation with bridge spanning across the channel which supports the header from which is suspended the suction pipes, also an indicated sand bed. Drawing B shows an end elevation, relative taper size of the header and mechanism for controlling the position of the end of the suction pipes. The suction pipes are attached to the lower side of the header at the proper spacing and alignment. The transition section from a 6-inch pipe to an opening of 4 x 12 inches in the bottom of the header is shown in drawing A, upper left. The lifting mechanism is a simple windless affair operated by a crank which through a suitable gear ratio turns the winding drum. This grooved drum would be about 6 or 7 inches in diameter and wide enough to accommodate about 10 feet of cable or about 6 turns of the drum. On the side of the drum gear would be a graduated arbitrary scale of ten divisions to permit the operator to determine the approximate elevation of the end of the suction pipe. The cable, 3/16" galvanized steel, of ample strength, passes over the sheave wheel at the end of the angle iron support, and thence down to the point of attachment to the pipe. Intermediate in the suction pipe is a pliable rubber sleeve, 6 inches inside diameter, and 6 feet long. Drawing B shows the suction pipe in a vertical position and dotted line in a horizontal position. By means of the windlass and indicating scale the end of the pipe can be set to any
position between the vertical and horizontal as shown at A, B, C, D or E. A front elevation of the windlass is shown in drawing A. This drawing also shows the outlet end of header with leg of siphon extending downward into a standpipe. Such a standpipe could be of sheet metal, or built up of good quality concrete blocks. The foundation should be of ample strength to support such a structure. At the base of the standpipe would be a 3 x 3-foot slide gate adjusted by a hand wheel at the top. The height of the standpipe should exceed the maximum canal water surface by at least one foot. The gate to be adjusted by hand wheel at top and a foot bridge provided from the bank to reach the gate wheel. At the end of the header, horizontal section, is the priming vacuum pump. It will be noted an auxiliary siphon, say 6 inches in diameter, leading from the canal into the bottom of the standpipe. To attain the minimum suction head for priming the header it will be necessary to close the slide gate (assuming there is sufficient water depth in the standpipe to submerge the outlet end of the auxiliary siphon) and by means of the vacuum pump prime the auxiliary. The water in the standpipe will rise to the elevation of the water surface in the canal. This being accomplished, the pump is then attached to the header and the air within exhausted. The header and the several suction pipes now being full of water, it will only be necessary to open the slide gate and the main siphon will come into action. The water in the standpipe will be lowered to the water surface elevation in the outlet channel to the river. An effective head of one foot on the main siphon should cause a discharge of about 4 sec. ft., and when operating under a head of 5 feet, the flow should approximate about 10 sec. ft. The rate of discharge can be regulated by means of the slide gate.

At the time of priming the main siphon the ends of the siphon pipes should be well above the sand surface in the canal. When the suction pipes
are so located and the siphon in action, there will be no bed load withdrawn. Depth measurements from the bridge will indicate the elevation of the sand surface and the scale on the windlass gear can now be used to lower the end of the suction pipes such as to be in contact with the sand bed. When all the pipes have been adjusted it should be found that a pocket has been formed at the end of the pipe which should occur within less than one minute. All pipes now should be lowered, say two or three inches, and very shortly the sand pockets will be increased in size, both depth and diameter. The lowering of the pipes should not be rapid but rather at longer periods as the depth increases. At possibly half depth of the sand bed the width of the pockets will extend laterally and join the adjacent ones, thus producing somewhat of a trench in the sand bed across the channel. When this stage is reached any material approaching on the sand surface in between the siphon pipes will be deposited in this trench and be subject to removal through the adjacent pipes. As the depth of the pipes increases the trench gets deeper and the critical angle of the upstream slope of the trench will accommodate itself to a point further upstream such as to arrest all sand movement into the trench.

Finally, when the suction pipes are vertical, as indicated by position B, the upstream slope of the trench will be somewhat as shown in the drawing. It would be expected that the velocity of the flow in the canal would tend to swing the suction pipes such that the open end would move over a considerable area on the bed of the canal, thus increasing the intake of sand into the siphon pipe. It is recognized that there will be a considerable amount of bamboo roots and other debris moving downstream and if in sufficient quantity could foul the end of the pipe. Work is being done to perfect a simple accessory to be attached to each siphon pipe, contact switch as shown in drawing A, whereby should a pipe become fouled, a
signal light will indicate the situation and the operator can raise the end of the pipe to clear the obstruction and then reset.

After giving this type of sand trap considerable thought and discussing the matter with my colleagues, there appears to be general agreement that such a device is entirely practical, and to this I feel inclined to agree. The complete scheme is not yet fully developed, but I believe it far enough advanced to warrant definite conclusions.

The probable general design of such a structure would not involve expensive construction. The bridge to support the header would be two 9-inch channels across the canal, spliced near center of span for convenience of transportation and handling. The tapering header tube and transition sections would be 12-gage gal. steel sheet and the 6-inch motion pipes 14-gage gal. The header would be in three pieces with flange connections, as indicated in drawing A. The 6-inch rubber sleeves may have to be of special construction to provide flexibility to bend through about a 90 degree arc, and also non-collapsible for a suction head of at least 10 feet. Such a tube has been discussed with the Gates Rubber Co. of Denver and we are informed it is entirely reasonable to make such tubes. The cost has not yet been determined. These tubes would have cemented connections and fixed in place with bolted ring clamps. The cross ties, sheave supports, would be bolted to the top flange of the bridge channels and extend downstream about 7-1/2 feet from centerline of bridge and upstream about 5 feet. These ties, two for each sheave wheel, would be spaced across the bridge at about equal intervals and in plan, downstream length, would be narrowed to about 2 inches apart at the ends. The upstream lengths would be straight and provide supports for the plank floor across the canal. No detail has been worked out for the lifting windlass. The drawings show the general design of this feature of the structure.
The vacuum pump for priming should be one that would be operated by a small electric motor, probably 1/4 horse power. Because of relatively large amount of air in the header and suction connections at the time of priming, considerable work might be involved when hand operated. It is estimated that it will require at least 30 minutes for priming. The system should operate indefinitely when once primed. There are a number of details yet to be considered, and at this time this discussion is only intended to give a general over-all description of the structure and some mention as to how it would operate. The cost of such an installation has not yet been determined.

Advantages and disadvantages of the siphonic type of sand trap should be pointed out. For the Maverick County main canal it would not be necessary to close down the operation of the irrigation system. Water could be delivered without interruption and also provide a supply for the hydroelectric plant as a revenue to the District. Any structure built in the canal, such as vortex tubes or a riffle deflector type of sand trap, or some other type of device requires that the canal be put out of commission, drag line operation to excavate the site of the structure, sand dam upstream of ample height for protection and the possibility of pumping to rid the site of accumulating water. Such a structure in the canal, no doubt, would require more or less concrete for construction. The time consumed for construction would depend upon the nature of the type of sand trap built in the canal. The siphonic sand trap would eliminate many of these required items of construction and at the same time permit the canal to be in operation at all times. This should be a primary advantage. Sand trap structures on the bed of the channel tend to disturb the flow such as to result in more or less turbulence which in turn stirs up the bed load and creates a larger percentage of material
as suspended matter. Since the bed load consists of silt and fine sand the efficiency of such devices may prove to be relatively low whereas the siphonic type of trap would cause little or no disturbance and is believed capable of catching a considerable amount of suspended material. As the bed load moves into the depression scooped out by the siphon pipes the cross sectional area of the water prism is materially increased and thus the velocity is decreased. Because of the reduced velocity there will be a strong tendency for the suspended matter to settle down to a lower elevation, and some of this will move into the zone of the suction action at the ends of the pipes. Fine material on the bed of the channel downstream from the suction pipes will move slowly upstream and a portion of this will also come within the influence of the suction pipes. Some preliminary observations on the model as to the ability of the suction pipes to draw up the bed load have been made. The action for a 5 to 6 inches of suction head, appears to be very good. The lift is quite rapid and as the bed load is moved up to the end of the pipe, by means of a small scraper, the heaped up pile of medium size sand is quickly taken away. Small pebbles ranging in size from 1/8 to 1/4 inches in diameter were readily taken up by the siphon action. The flexibility of the siphon rubber hose will permit the end of the suction pipe to swing over considerable area, thus increasing the range of action. Mention has been made of the bed load moving down the slope toward the tubes. This movement will be slow but positively downward, and at the ultimate depth none of the incoming bed load will escape downstream between the tubes. As an accessory, each tube will be provided with a signal light, 50 watt, colored, to indicate whether that particular tube is in action. The light will only show when the tube is inactive.
Some of the disadvantages to the siphonic sand trap might be said to be due to the fact that roots or fibrous material may catch on the end of the suction pipe and choke off the flow. Should this occur, the signal light will immediately indicate the situation and the operator can then raise the tube by means of the windlass and clear the obstruction. If the end of the pipe is raised too near the water surface, air may eddy into the system and destroy the siphon action. Some trouble may be encountered in priming, but if a good efficient pump is provided, there should be little difficulty. It is estimated that probably it will require about half an hour to get the siphon in action. The velocity of flow through the system will depend upon the effective head and will range from 5 to 10 feet per second. The cutting action of the sand moving through the pipes and header could be appreciable. To safeguard against this occur of the metal surfaces it has been suggested that a rubber base paint could be used as a protection, or possibly have the system lined with sheet rubber, 1/8 to 3/16 inches in thickness. The menace of ice may not be a problem. The successful operation of such a sand trap device will depend very largely upon attendance, that is, the operator should be on hand and give attention should a signal light indicate trouble, otherwise the siphon should operate continuously at good efficiency. It may later be found that the cost of such a structure may prove to be a disadvantage. Should the Board of Directors, engineers, and others feel, after due consideration of this type of sand trap, that it has sufficient merit to warrant further development, then the design can be advanced to the point of estimating costs and conclusions drawn as to whether the final outlay of funds would prove this scheme to be at a disadvantage. The fact that this type of device is now in an experimental stage, with no field experience, may give the impression that time and money could be spent with the ultimate end
result of an unsatisfactory structure. With this thought in mind, it can be assumed, from model tests, that the underlying principle is sound and knowledge of hydraulic and physical laws indicate that low efficiency could come only from improper design. To lessen the doubt on this point it will be necessary to carefully investigate all the details involved in the final design and to fully understand the method of operation. It is not expected that the complete design would be prepared by a single individual, but rather the composite talent of several having particular training and knowledge covering all the features involved in such a device. My general conclusion at this time would be that there is little doubt as to the ultimate success of this type of sand trap. One of the important items of such an installation would be in the operation. If no earnest endeavor is made to maintain the full siphon action, then the device may prove to be more or less of a failure.