EVALUATION OF STONE DIKE SYSTEMS AND THEIR LOCATIONS ON THE LOWER MISSISSIPPI

BY

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INTRODUCTION

The open channel method of navigation control employed on the Lower Mississippi River consists of articulated concrete mattress for bank revetment and stone dikes for contraction and secondary channel closures. Bank revetment was originally constructed of willows and timber with stone utilized for ballast. The present revetment evolved as a result of technological advances in materials and construction methods. In most instances the revetment has yielded good results with a satisfactory life expectancy. Similarly, the adoption of a stone dike design to replace the long used timber pile dike was an effort to build a structure better able to withstand the river's attack. But the results of stone dike construction have not been as satisfactory as in the case of revetment, primarily because of complications introduced by construction in flowing water and the guesswork involved in the layout and design of dike systems.

The object of dikes, when used for the benefit of navigation, is to modify the flow by using transverse structures for channel contraction or the reduction of flow in a secondary channel and guide vanes for directing the flow. Dike systems are very rarely used to control or influence high water flow for the sake of navigation, since depths are more than sufficient. It is only during low water that shoals or channel irregularities begin to present obstructions.

The purpose of the study is an attempt to evaluate stone dike systems with respect to their various locations and designs using as a parameter the frequency of structural damage or failures. These are localized or random losses of stone which threaten the structural integrity and/or the performance of a dike system. The fact that a particular dike does encounter damage does not always mean that the system as a whole has failed in its intended purpose. This type of risk is inherent in all mounded stone structures constructed in flowing water. This study will endeavor to gain some insight into any trends in failure occurrences and to eliminate some of the conjecture involved in dike system layout and design

Sixteen of the twenty-seven dike systems in the Vicksburg District were selected for study. The eleven systems omitted were either primarily of timber construction or were systems recently constructed with no available data. Data from some of the Memphis District dike systems were also used in the evaluation. Table 1 lists the Vicksburg District dike systems considered.

DESCRIPTION AND CHARACTERISTICS OF DIKE SYSTEM LOCATIONS

In order to explain the various locations, the meaning of the term "thalweg" as used in this report needs an explanation. The literal translation means "valley-way" but engineers use it to mean "channel-way" or the deeper part of a stream (5). It has also been used to describe the main thread of the current at various stages of flow regardless of depth. The latter definition will apply in this report.

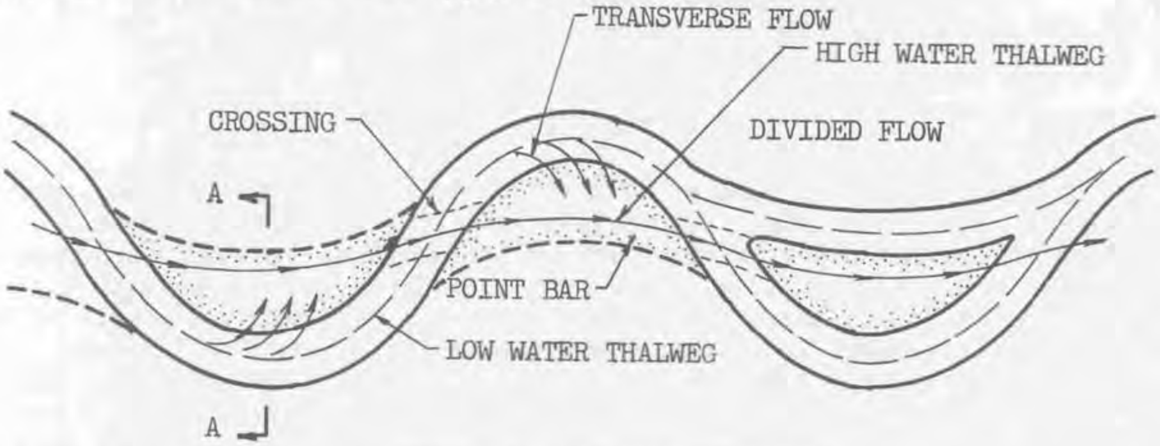


FIGURE 1 - CHANNEL GEOMETRY

Rivers tend to develop bendways by scour and erosion of the concave bank and the deposition of sediments at the convex bank. The centrifugal forces developed due to the curved flow around the bend causes an increase in the water surface elevation along the concave bank. This creates a tendency for transverse movement of bottom currents toward the convex side carrying with them the bar-building sediments. The resulting deep scour areas along the concave bank are termed pools and the sediment deposition areas develop into point bars. This occurs mainly at low and medium river stages. At this point the readers attention is directed to Figure 1 and Section A-A.

SECTION A - A

Beginning with a low stage the following sequence of events takes place in a river with reference to crossings. As a floodwave moves into a river reach the thalweg tends to straighten out and move in on the point bars. It is during these high stages that sediment is swept from point to point and through the crossings causing a sediment build-up to take place. When the floodwave crest has moved through the reach and the stage falls, the thalweg moves back into the more sinuous low water trace and the scouring of sediments deposited in the crossings commences (9).

During the higher stages the flow over point bars can cause a secondary or chute channel to develop along the convex bank leaving a divided flow situation at lower stages. Guide vanes and/or transverse dikes are constructed at the entrance and in these chutes in an effort to reduce the flow and prevent further development. Guide vanes are sometimes placed in crossings to force development of a particular channel not necessarily in harmony with the rivers natural meander sequence. This particular application will be discussed more fully further on in the report. Transverse dikes are constructed on point bars to assist in holding and consolidating sediments to prevent divided flow situations from developing. Transverse dikes can extend into crossings to contract a particular wide, shallow crossing or sometimes through error in judgement.

CLASSIFICATION OF STRUCTURAL FAILURES

There are five characteristic types of failures that may occur in mounded stone structures in flowing water.

1. Breach Failure. A dike is considered to be breached when the crown height has been reduced at a given location and usually assumes a V-notch shape. This type of failure has extended below the original bed profile in some cases and required more stone to repair than was in the initial section.

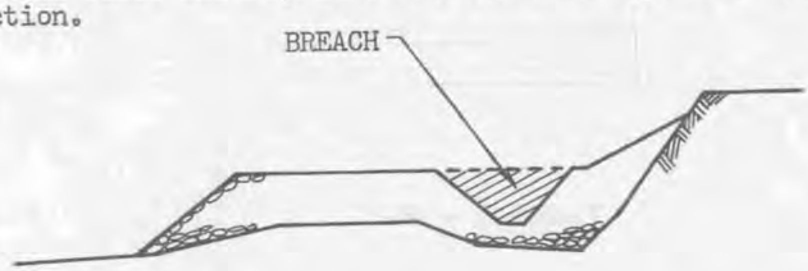


FIGURE 2 - PROFILE

2. Launch Failure. Any loss of stone from either slope which may result in a decrease in crown width but not in crown height; however, if a sufficient amount of stone is launched the consequences may be a breach failure

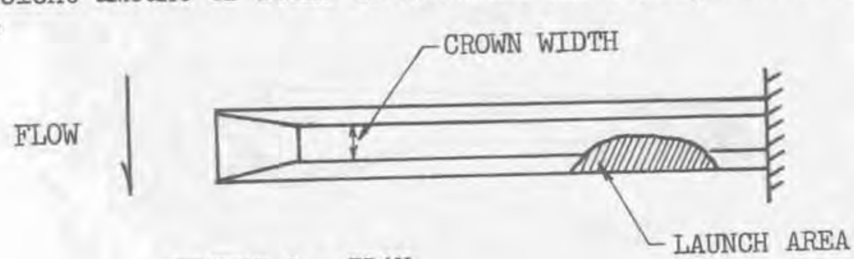


FIGURE 3 - PLAN

In the majority of occurrences the downstream slope is involved and the failure may extend along almost the entire dike length. This is especially noticeable along guide vane slopes where strong lateral flow occurs.

3. Terminal Launch Failures. This type involves the loss of stone from the outshore terminal of transverse dikes and the upstream or downstream terminals of vane dikes. They are localized and generally do not extend beyond the terminal section.

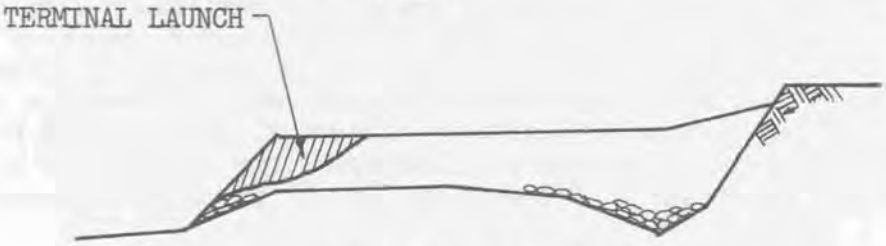


FIGURE 4 - PROFILE

4. Bank Paving Failure. This is a semi-circular or crescent-shaped failure occurring in the paved bank downstream from the inshore terminal caused by eddy current action and may lead to a flank failure if left unrepaired.

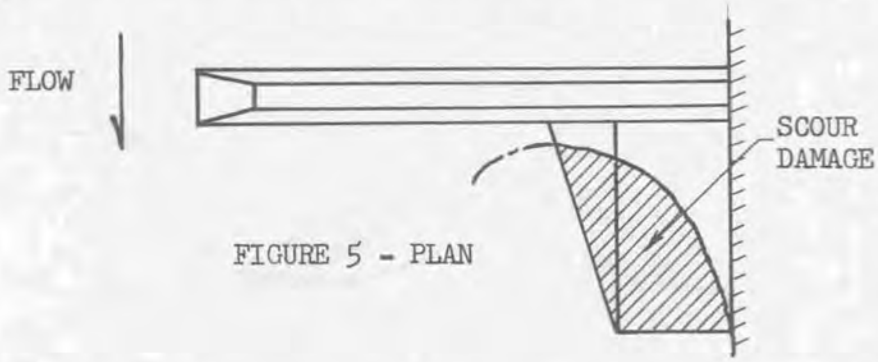


FIGURE 5 - PLAN

5. Flank Failure. This type of failure results from extensive scour damage causing a breach at the inshore terminal. High stage flows are allowed to circumvent the dike at the bankline causing further bank recession. The loss of stone from these failures is nominal as this type mainly involves bank caving.

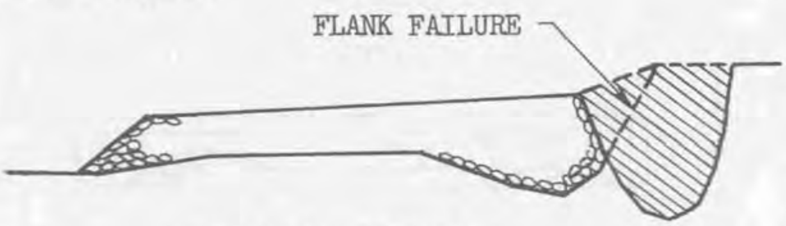


FIGURE 6 - PROFILE

RESULTS OF DATA COMPARISON

Comparison of Channel Geometry and Failure Occurrence

A comparison of channel geometry and failure occurrence in Table 2 disclosed three dominant trends:

1. Eight dike systems were located in bendways and eight in straight reaches. The straight reaches accounted for 72 percent of the failures with the bendway locations accounting for the remaining 28 percent.

2. There are three basic locations or sites: point bars (5 systems), divided flow (6 systems), and crossings (3 systems). Crossing locations had the highest failure frequency with 47 percent of the total. The lowest failure frequency was 8 percent occurring at point bar locations. The divided flow locations fell in between with 30 percent.

Although division of flow can occur across point bars at high stages, the locations labeled as such carried a percentage of flow at all stages prior to construction. The systems at Montgomery Towhead and Terrene have eliminated extreme low flows in the secondary channels but the other four locations still carry some flow at low stages.

3. Four of the systems investigated combined transverse and vane dikes. Two of these, Ben Lomond and Leland Bar, were constructed in crossings and each accounted for a high percentage of the total failures, (12.07 and 22.41 percent, resp.). The other two systems, Malone Field and Chicot Landing, which were constructed at point bar and divided flow locations had low percentages of the total failures, (0.86 and 6.03 percent, resp.).

Failure Occurrence vs. Dike System Location

The following trends were noted in Table 3:

1. Crossing locations had the highest percent of the breach, terminal launch, and launch failures (57.14, 68.57, and 37.50 percent, resp.) while point bar locations had very low percentages of the same type, (5.71, 2.86, and 12.50 percent, resp.).

2. Bank paving failures were predominant in divided flow locations, (50 percent of the total), and were much less frequent at point bar sites, (7 percent of the total).

3. The quantity of stone lost in each of the sixteen systems was tabulated and expressed as a percent of the combined total for all the systems. The three crossing locations accounted for approximately 62 percent of all stone lost and the divided flow sites followed with 26 percent. The other significant fact is that the point bar locations,(5 out of 16), contributed only 6 percent of the total stone lost.

Failure Occurrence vs. Type of Failure

The principal contrasts between type and occurrence of failures in Table 4 were as follows:

1. Breach and terminal launch failures were the most frequently occurring (35 of each type) with flank failures as the most infrequent (8 only).

2. Breach and launch failures have the highest average amount of stone lost per failure while flank failures have by far the lowest average loss per failure. Flank failures are normally more of a bank recession problem.

Longitudinal Profile Design vs. Number of Failures

There are three types of longitudinal profiles that have been used in dike design. Dike systems having the same crest elevation at the outshore terminals of all structures in the system are considered to have a level profile. The outshore crest elevations in a stepped-up system increase in the downstream direction and in a stepped-down system the elevation decreases downstream. The systems having these profiles are listed in Table 5.

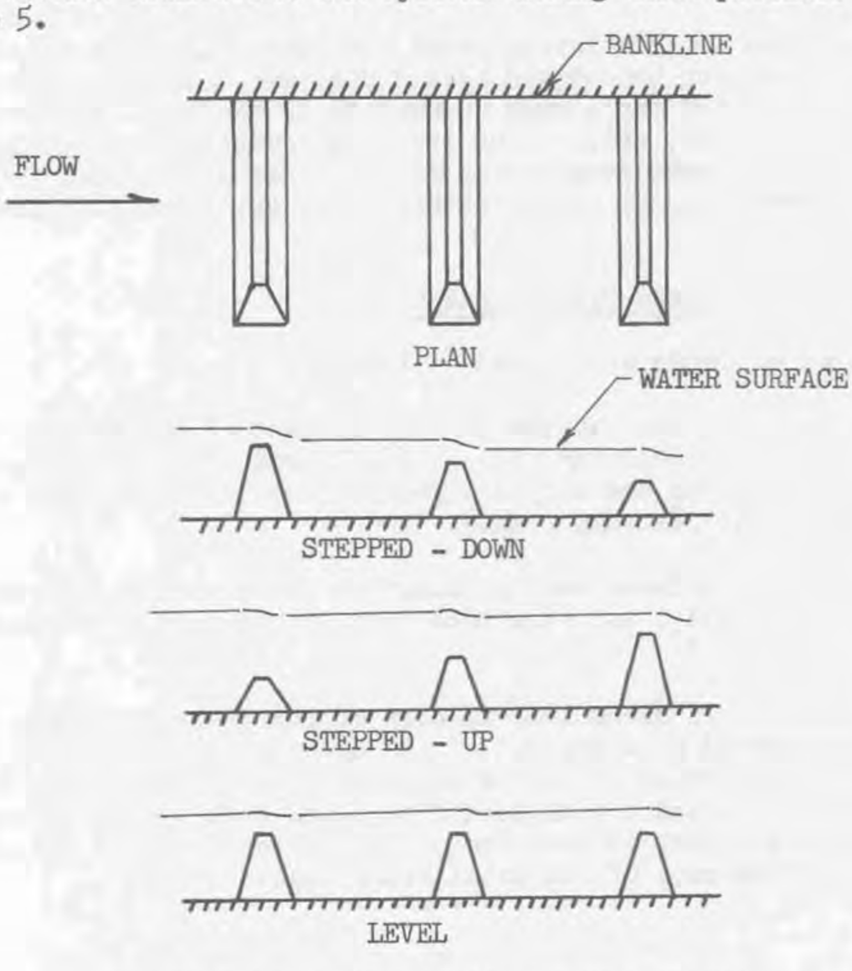


FIGURE 7 - LONGITUDINAL PROFILE DESIGN

No definite trend could be found concerning the effectiveness of the various profiles with reference to failures. It has been generally believed that the stepped-down design is more efficient in trapping sediment due to a particular flow pattern set up by such a design. Therefore, the systems using this type of profile should have more fill and most likely less failures. The systems using this technique had at least four recorded failures and as high as eleven. Stepped-up systems varied even more. The Island 84 dikes are stepped-up from datum elevation 0 (avg. low water plane) on the upstream dike to an elevation of +25 ft. (above datum) on the downstream dike. This system has no recorded failures and excellent deposition of fill. On the other hand the Baleshed Dike System is stepped-up from a -28 ft. (below datum) to a +13 in the downstream direction and has had at least seventeen failures and only very moderate fill. Again, the only trend is in the location of the system with respect to the low water thalweg. Three of the Baleshed dikes are located in the approximate path of the low water thalweg while all the Island 84 dikes are located in a natural deposition area.

FAILURE ANALYSIS WITH RESPECT TO DIKE SYSTEM LOCATION

Crossing Locations

In comparing the classified failures, it is apparent that the breach and launch-type are the most frequent and result in higher losses of stone. These types occurred predominantly at the crossing locations. The guide vanes at Ben Lomond and Leland Bar were placed diagonally in the crossing for the purpose of forcing the low water channel to follow one particular bankline contrary to natural river tendencies. These systems experienced excessive scour and stone loss. They also did not reduce the flow in the intended channel until assisted by other structures. It became necessary to reinforce the original guide vane system at Ben Lomond with transverse dikes upstream. Upon completion of the transverse structures a moderate amount of fill began to accumulate in the system. This had the effect of forcing the crossing downstream beyond the last guide vane, (see Figure 8).

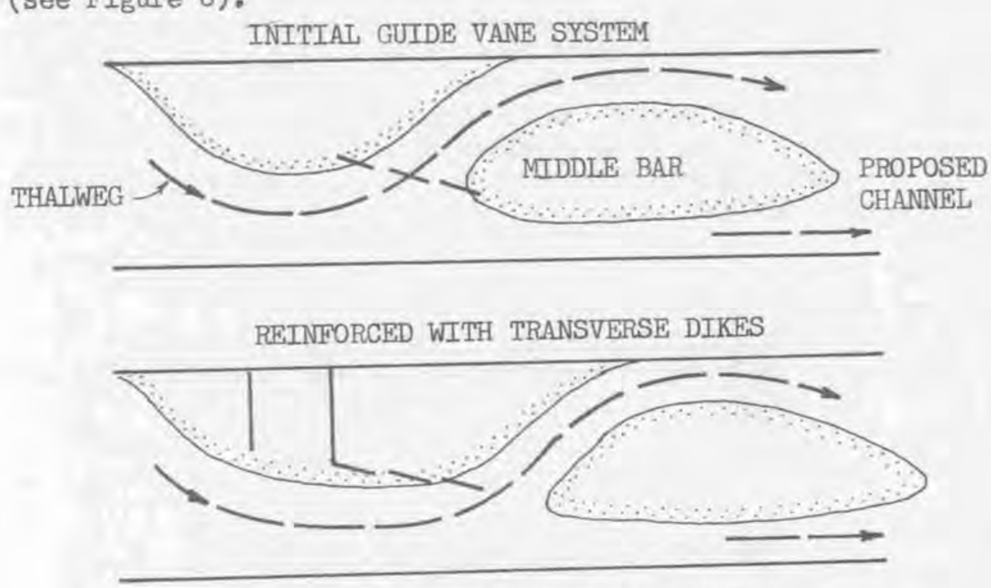


FIGURE 8 - BEN LOMOND VANE DIKES

As the vane system was extended downstream, similar scour patterns developed. Deep scour holes formed in the vicinity of the upstream and downstream terminals of the new vanes causing heavy stone losses and it was obvious that more transverse structures would be required for reinforcement.

The situation at the Leland Bar vanes was very similar with the structures attempting to force the crossing downstream. Essentially the same type scour patterns and failures occurred.

The Baleshed system consists of five transverse dikes with the two downstream structures extending into a crossing. Stone dumping operations were extremely difficult due to high current velocities and construction was halted prior to completion with a recorded stone overrun of over 100 percent on dike no. 5.

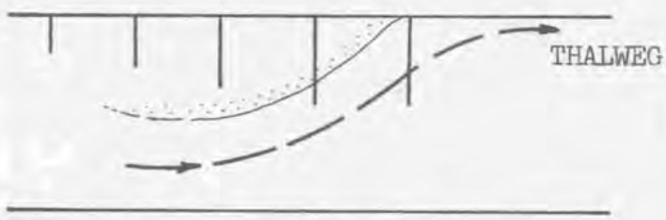


FIGURE 9 - BALESHED DIKE SYSTEM

Dikes constructed in or very near crossings are subject to attack by the river over the complete hydrograph. This attack becomes more severe shortly after the flood peak has passed. At this time scour commences to deepen the crossing until equilibrium is reached at some lower stage. Sediment deposits during high stages are not permanent or sufficient to protect the structures.

Divided Flow Locations

Dike systems constructed in secondary channels for the purpose of flow reduction usually extend from bank to bank similar to a rockfill dam or weir. In this situation there are two shoreline terminals per dike which are susceptible to damage. While this probably accounts for the high occurrence of paving failures in divided flow locations,(50 percent of the total), it also suggests that this is the main structural weakness of dikes in these situations

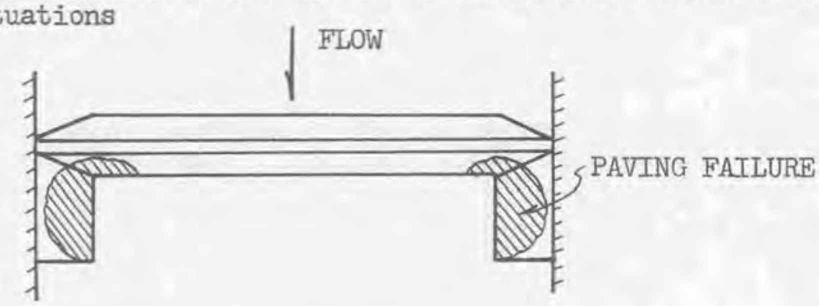


FIGURE 10 - TYPICAL FAILURE PATTERN

Point Bar Locations

Dikes constructed at point bar locations are subject to attack only over peak hydrograph periods when the main current moves in on the bars for a short period of time. Consequently, these locations had less recorded damage. The only failures were at or near the terminals. Most outshore terminals had some scour but not as excessive as at other locations,(crossings, divided flow, etc.). The inshore terminals developed typical scour patterns causing stone launching and an occasional flank failure. There was no evidence of excessive damage along the body of the dikes.

It is apparent that the earlier sediment deposition commences, and if a sizeable volume remains during all stages, there is much less chance of failure since the structure would be protected by sediment build-up. When this has happened the locations have been point bar areas where the flow velocity is slackened naturally and the dike system works with the river.

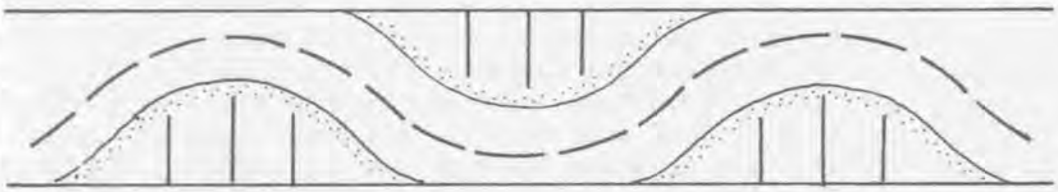


FIGURE 11 - PROPER DIKE SEQUENCE

A similar conclusion was reached by Fairley and Easley (3) in their evaluation of timber pile dikes constructed on the Lower Mississippi from 1927 to 1937.

> "Permeable pile dikes are useful in the Lower Mississippi River only at locations where they will act in conjunction with the natural developments in the reach, in contracting and guiding the channel into a desirable alignment. They are not structurally capable of resisting the direct attack of the current, as in chute closures or attempts to force the channel into a completely new location."

Examination of the dike systems included in the report revealed trends in agreement with the stone systems considered in this report. The dike systems constructed at point bar locations accumulated heavy sediment deposits and accelerated point bar development or assisted in consolidating the small bars in the area into a well-developed point bar. In no instance were there any failures recorded. The systems located in pools or crossings had little or no fill with heavy damage and in some cases were destroyed.

Fairley and Easley (3) quote the Memphis District Engineer from "Memorandum Regarding Dike Design" (April 1935) as saying:

> "I believe that our structure is much better than our technique in its use. A study of the effect of the individual dikes by reason of

and location with respect to the thread of the current and the location of the system with respect to the entire river should be studied closely."

Pool Locations

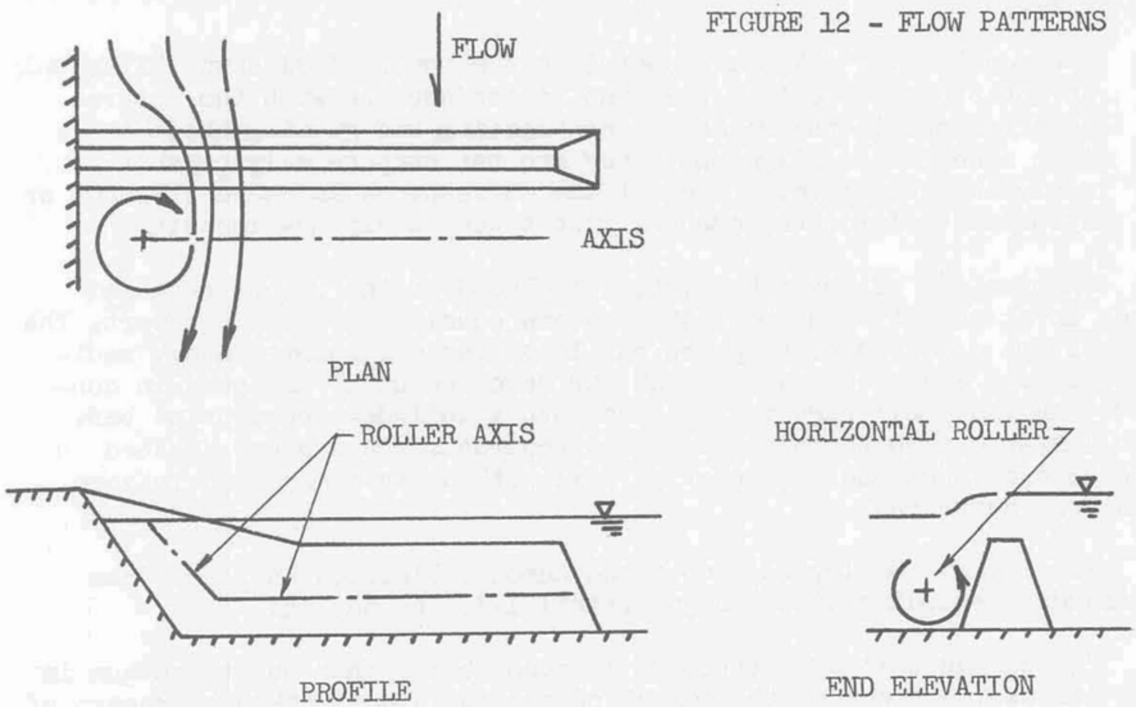
There were only two pool locations considered in the evaluation and each sustained extensive damage. Pools are not often considered for the locations of dike fields since depths for navigation purposes are not usually a problem. In some instances short transverse dikes are constructed in pools in cases of poor or unusual alignment in a bendway. Dikes constructed in pools have to endure the rivers attack at all stages as they are in a natural scour area. Caution should be excercised when placing dikes in these locations as they can easily become a navigation obstruction.

SCOUR AND STRUCTURAL DAMAGE AT DIKE TERMINALS

In principle, scour is caused by a lack of balance between the transport capacity of the flow and the sediment in motion. As the flow velocity decreases so does the transporting power of the stream allowing deposition to occur as the sediment load will be more than the stream can carry. An increase in velocity will increase the transporting capacity and if the sediment load is less than the carrying capacity, scour takes place. Dike systems cause an increase in sediment transport by contracting the cross-sectional area of the channel and increasing velocities. As previously mentioned, a major problem in connection with channel contraction has been the excessive scour in the vicinity of a dike system

Scour at Inshore Terminals

FIGURE 12 - FLOW PATTERNS



Where individual dikes tie into the bankline, a scour hole or pocket develops immediately downstream of the inshore terminal. The cause of these circular shaped scour holes is an eddy current which can be observed on the water surface at high stages. This eddy may be the result of the horizontal roller generated at the toe of the downstream slope where there is flow over the dike. As the roller approaches the shoreline, its horizontal axis may be tilted upward toward the surface following the bankline and upon reaching the surface, spreads out radially increasing its circular dimensions. Simultaneously, one must consider the surface flow around the inshore terminal crest which can cause an eddy circulating in the same direction. This is illustrated in Figure 12. It seems that the roller and surface eddy could easily amplify each other. Whatever the case may be, the eddies will remain in a particular area until the forces producing them are altered. A fall in stage to a level below that of the crown height should eliminate the causative forces and this seems to be the case judging from observations at low stages.

Flank failures normally begin with destruction of bank paving and some stone launching at the inshore terminal as a result of excessive scour. If a breach develops at the bankline, flow will concentrate through the gap and initiate bankline cutting. Since flanking usually requires the above sequence of events leading to a failure, this type does not readily occur as do the other types.

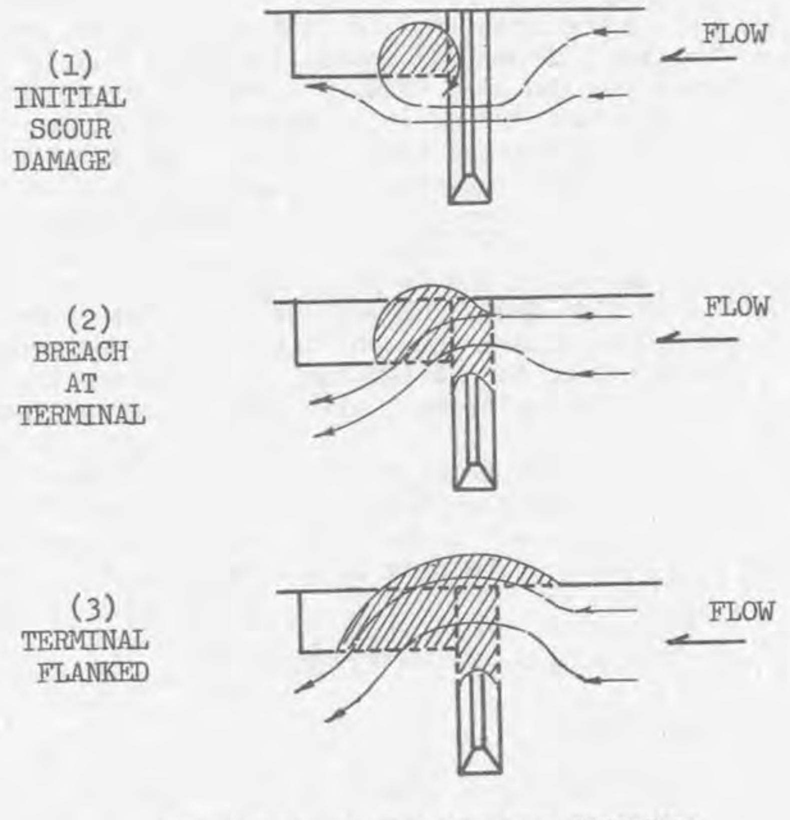


FIGURE 13 - FLANK FAILURE SEQUENCE

Outshore Terminals

The belief in the past has been that stone launched from the outshore terminal paves the scour hole and prevents further launching. Dikes have been designed with this in mind, resulting in high design elevations at the outer end. What appears more likely to the author is that as the stone is launched, the terminal approaches a flatter slope and curtails the convergence of streamlines. This has a stabilizing effect when a given slope is reached.

It was desirable at this point to see if any relationship existed between the outshore terminal height (H) and depth of scour (Ds) at the terminal.

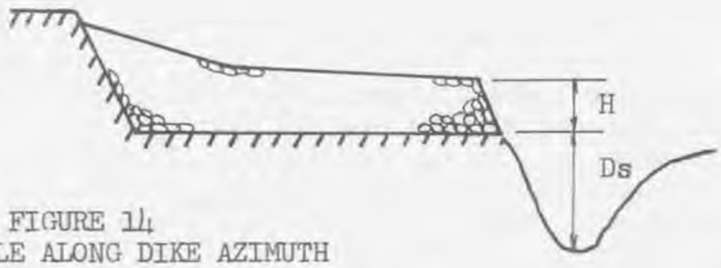


FIGURE 14
SCOUR PROFILE ALONG DIKE AZIMUTH

Data from individual dikes in both the Memphis and Vicksburg Districts were used in the investigation. The data was divided into two groups; one group for dikes in natural deposition areas and the other for dikes resisting or opposing the main flow. The readers attention is directed to Figures 15 and 16 at the end of this report. When dikes were constructed in natural deposition areas the ratio of scour depth to terminal height was about 1:1. For dikes resisting the main current the scour depth increased exponentially with an average ratio of approximately 2:1, scour depth to terminal height. From the above results it is evident that the higher a dike terminal is raised the deeper the scour. The more important point here is that these high design elevations force the river to expend a portion of its energy increasing the contracted cross-sectional area at the toe of the dike and not in the navigation channel where intended. Linder (7) sums up this point quite well with the following statement:

> "The concentration of flow lines that causes scour near the end of a dike indicates that the contraction has not succeeded in satisfactorily distributing the flow to the entire portion of the channel in which it is desired to provide and maintain the required depth".

CONCLUSIONS AND RECOMMENDATIONS

Holding Point Bars with Dikes

During high stages there is a tendency for the flow to form secondary channels across point bars which can develop into a divided flow or a braided condition (multiple channels). It becomes necessary to construct dike systems on the points to prevent this from happening. Van Frank (12) quotes the Missouri River Board of Engineers on the design of groins (dikes)

FIGURE 15

TERMINAL HEIGHT VS. SCOUR DEPTH
FOR
DIKES IN NATURAL DEPOSITION AREAS

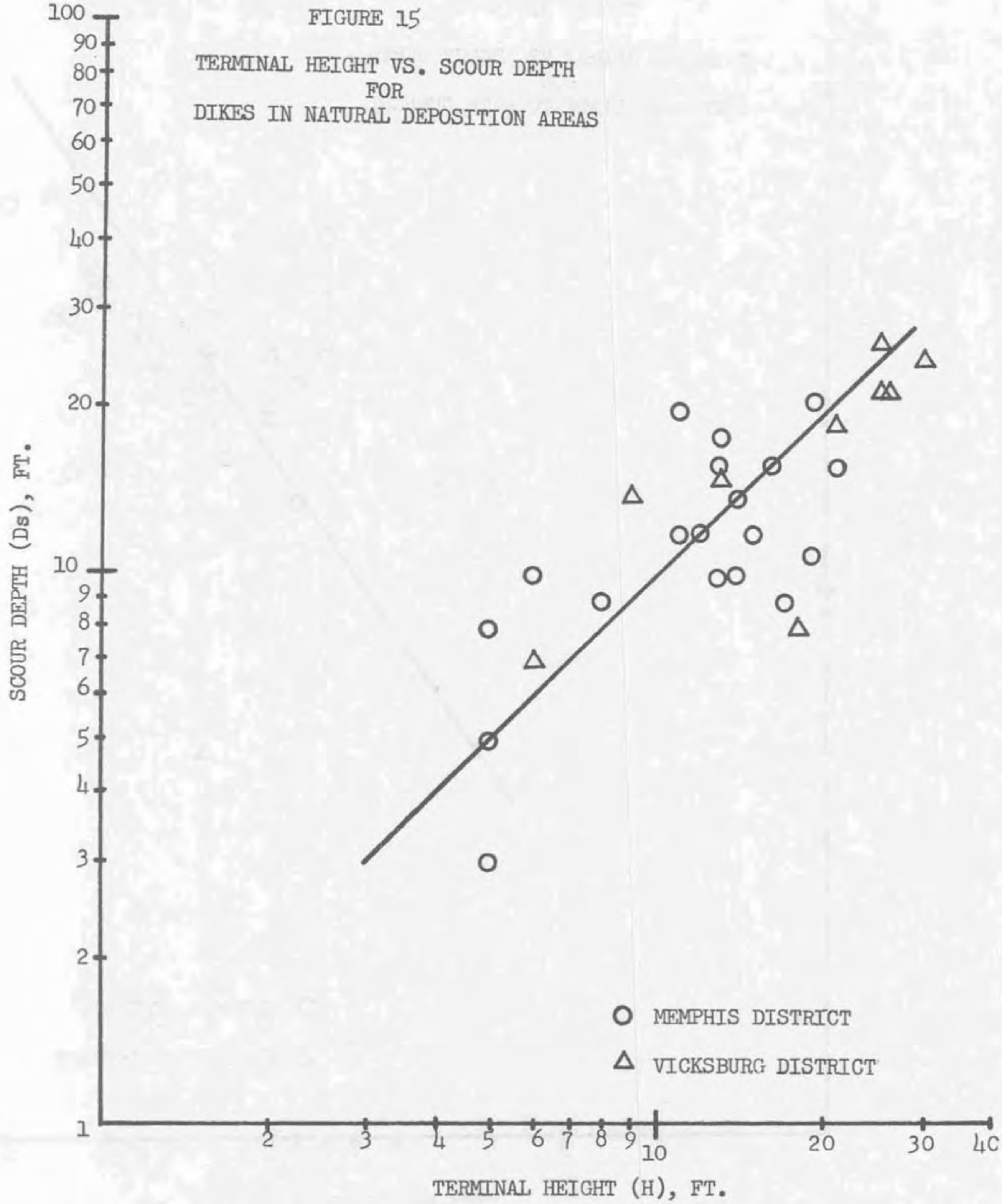
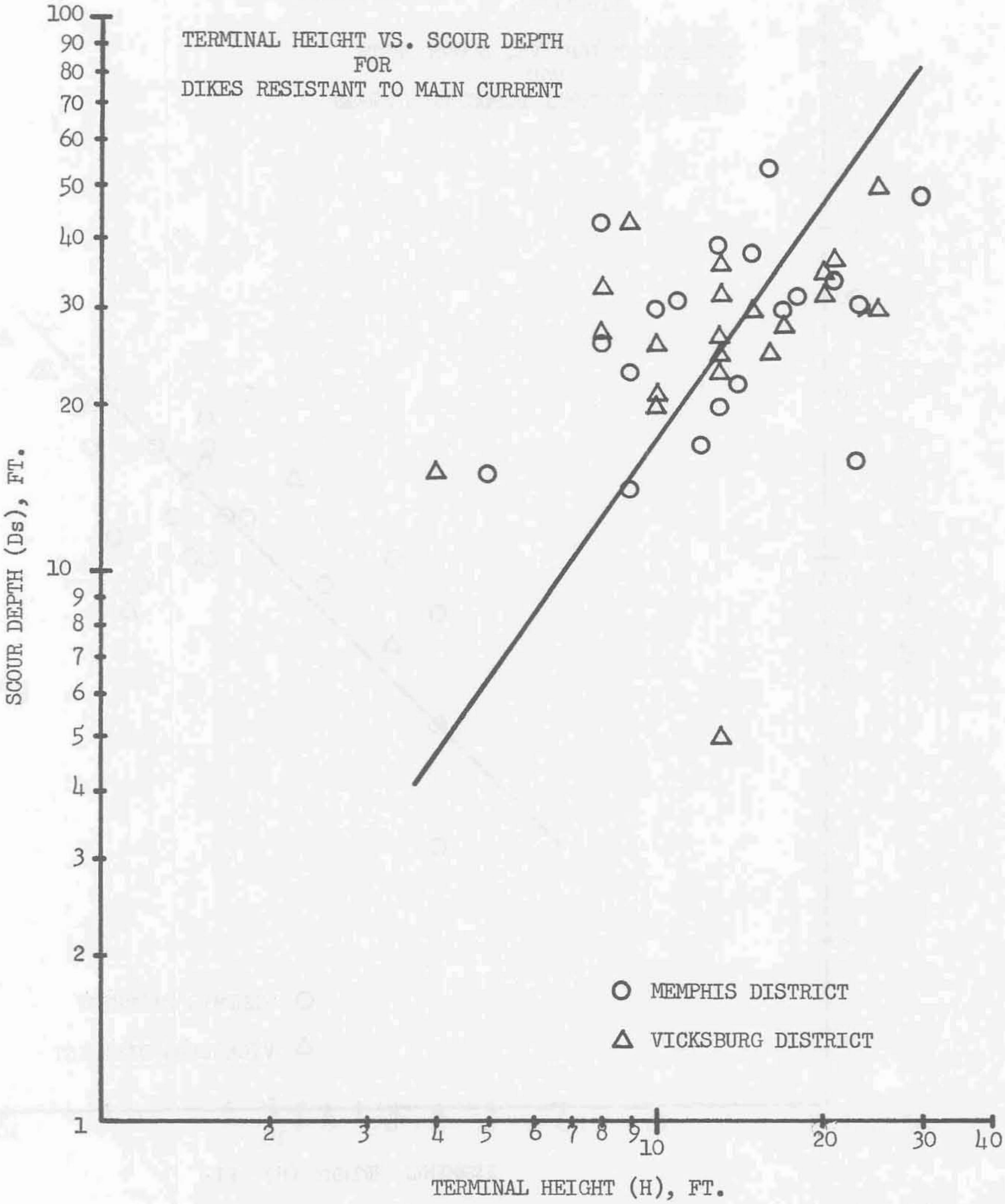


FIGURE 16

TERMINAL HEIGHT VS. SCOUR DEPTH
FOR
DIKES RESISTANT TO MAIN CURRENT



on point bars:

> "Following the protection of the caving banks, it will probably be found that some of the bars on the convex side will, during higher stages, become subject to the direct attack of the current, and as soon as possible after this condition has been observed these bars must be held in place by inclined groins. These groins should theoretically be about on the same level as the bar, and should be constructed to as low an elevation as is consistent with reasonable progress in the works. A low elevation will diminish their cost, protect them from drift, and cause the least possible interference with the highwater flow of the river."

The dike system design in the above quotation pertained to timber pile structures but would be valid for stone structures also. Although drift is not a problem in stone dikes, the low elevation is desirable for the other reasons discussed in the quote.

Not enough is known of the effects of various crest elevations of dikes on point bars but the construction of a minimum dike initially would allow for easy modification at a later date. This technique is discussed more thoroughly in the next section.

Construction Procedures Should Allow for Modification

It appears that there would be a distinct advantage in constructing stone dikes in successive lifts over a period of years. By following such a plan as this, advantage could be taken of the sediment deposition accumulating in a dike field and raising the bar profile.

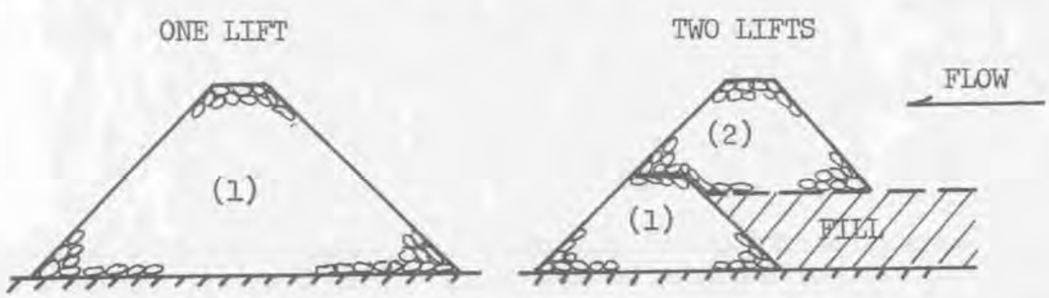


FIGURE 17 - CONSTRUCTION BY LIFTS ON POINT BARS

Such a method was mentioned by Thomas and Watt (11) in their discussion of stone dike construction in Europe:

> "This gradual construction, or experimenting with dikes, was done not only as regards their length, but also as regards their height, and when a certain depth had been reached, Submerged works were commenced, which at a later period were built higher if necessary. Remarkable amounts of deposit were thus obtained in many cases, and dikes which could only have been constructed at great cost if in deep water were built gradually, and finished on a bottom that had been raised without difficulty and at a small cost. Such results on convex banks were very rapid, but on concave banks the system gave less satisfactory results. Scour at the heads of the dikes always took place, and could not be checked except by the precautions and the methods of gradual construction just described. It was doubtless

this fact which induced German engineers to adopt and generalize in so remarkable a manner the use of submerged spurs, the other advantages of which could not have been discovered except by the experience acquired after their construction."

To briefly summarize: Dike system construction should not advance any faster than channel development. A minimum amount of dike should be constructed and after observing the effect on the channel (as this is difficult to predict) the system can be modified to suit changing conditions.

Location of Dike Systems

The most important step in the design of a dike system is selecting the proper location, therefore, the interval between point or alternate bars needs to be determined. In straight reaches the deposition areas are sometimes called alternate bars due to their plan geometry. The contrast between bar sequence and channel geometry in straight and sinuous reaches is shown below in Figure 18.

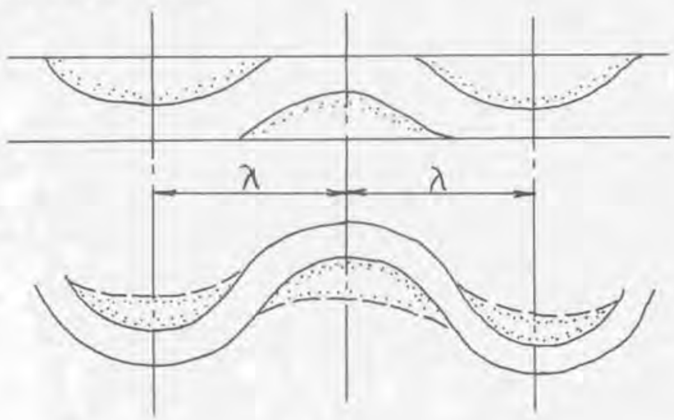


FIGURE 18

A frequency distribution analysis should determine with reasonable accuracy, the natural distance between bars (λ) in a river. The data can be obtained from hydrographic surveys and/or aerial photography. A histogram of distance between bars vs. percent occurrence can be plotted. Winkley and Robbins (14) used this method in their geometric stability analysis of the Lower Mississippi River and determined the normal bar spacing to be approximately $4\frac{1}{2}$ to 5 miles. They further stated that channel realignment or control should begin at a fixed hard point and areas of deposition should be planned according to normal bar spacing for each individual reach of the river.

Channel Improvement should be based on the evolution of the existing channel rather than on the creation of a new one. The natural tendencies toward sediment deposition should be assisted rather than forcing a change.

Inglis (5) summed up the importance of location in his comment on the origin of the Denehy T-head Groyne (dike):

"What was more important, however, was that the name of Denehy had come down, not because he had designed that groyne, but because he had had an extra-ordinary flair for placing groynes in the right position. He knew exactly where to put a groyne to induce the river to do what he wanted, he was a genius and understood the subject inside out. Many other people had used Denehy T-headed Groynes with disastrous results. There was not much design of the groyne; it was a question of where it was placed."

TABLE 1

Dike System	Year	Type	Design	Number of Dikes
Island 70	1962	Pile/Stone	Transverse	4
Smith Point	1963	Pile/Stone	Transverse	3
Montgomery Towhead	1964	Pile/Stone	Transverse	3
Terrene	1967	Stone	Transverse	3
Malone Field	1968	Stone	Transverse, Vane	2 Trans. 3 Vane
Chicot Landing	1967-68	Stone	Transverse, Vane	3 Trans. 3 Vane
Ashbrook-Miller Bend	1965	Stone	Transverse	7
Island 82-Miller Bend	1966	Stone	Transverse	8
Leland Neck	1964	Stone	Transverse	3
Leland Bar	1966 1968	Stone	Transverse, Vane	3 Trans. 5 Vane
Island 84	1965	Stone	Transverse	3
Leota	1967	Stone	Transverse	3
Wilson Point	1968	Stone	Transverse	2
Baleshed	1964	Stone	Transverse	5
Ben Lomond	1967-68 1970	Stone	Transverse, Vane	2 Trans. 5 Vane
Ajax Bar	1962	Pile/Stone Stone	Transverse	6

TABLE 2

Dike System	Channel Geometry	Type of Location	No. of Failures	Percent of Total	Failures per Dike	Stone Lost (Tons)
Island 70	Straight	Divided Flow	8	6.90	2.00	8,855
Smith Point	Bendway	Point Bar	4	3.45	1.33	4,500
Montgomery Towhead	Straight	Divided Flow	4	3.45	1.33	5,400
Terrene	Bendway	Divided Flow	4	3.45	1.33	5,600
Malone Field	Bendway	Point Bar	1	0.86	0.20	280
Chicot Landing	Bendway	Divided Flow	7	6.03	1.40	9,000
Ashbrook-Miller Bend	Straight	Pool	11	9.48	1.57	4,135
Island 82-Miller Bend	Straight	Forced Pool	5	4.31	0.63	7,410
Leland Neck	Straight	Divided Flow	1	0.86	0.33	1,500
Leland Bar	Straight	Crossing	26	22.41	3.25	46,184
Island 84	Bendway	Point Bar	0	0	0	0
Leota	Bendway	Point Bar	3	2.59	1.00	5,800
Wilson Point	Bendway	Point Bar	1	0.86	0.50	242
Baleshed	Straight	Crossing at Nos. 4&5	17	12.50	3.40	31,950
Ben Lomond	Straight	Crossing	14	12.07	2.80	31,520
Ajax Bar	Bendway	Divided Flow	10	8.62	1.67	14,900

TABLE 3

Type of Location	Percent of Total Failures	Percent of Failure Type					Percent of Stone Lost
		Breach	Terminal Launch	Launch	Bank Paving	Flank	
Crossing	47.5	57.14	68.57	37.50	14.0	25.00	62
Divided Flow	30.0	31.44	22.71	24.50	50.0	25.00	26
Point Bar	8.0	5.71	2.86	12.50	7.0	25.00	6
Pool	10.0	5.71	2.86	12.50	29.0	12.50	2
Forced Pool	4.5	0	3.00	13.00	0	12.50	4

TABLE 4

Type	Number	Percent of Total	Stone Lost (Tons)	Stone Lost per Failure	Percent of Total
Breach	35	30	64,800	1,851	36.4
Terminal Launch	35	30	49,300	1,409	27.8
Launch	24	21	43,500	1,812	24.5
Bank Paving	14	12	18,900	1,350	10.6
Flank	8	7	1,260	158	0.7
Totals	116		177,760		

TABLE 5

Dike System	Location	No. of Failures	Longitudinal Profile
Island 70	Divided Flow	8	Level
Smith Point	Point Bar	4	Level
Montgomery Towhead	Divided Flow	4	Stepped-up
Terrene	Divided Flow	4	Stepped-down
Ashbrook-Miller Bend	Pool	11	Stepped-down
Island 82-Miller Bend	Forced Pool	5	Stepped-down
Leland Neck	Divided Flow	1	Stepped-up
Island 84	Point Bar	0	Stepped-up
Leota	Point Bar	3	Stepped-down
Wilson Point	Point Bar	1	Level
Baleshed	Crossing	17	Stepped-up
Ajax Bar	Divided Flow	10	Stepped-down

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