TECHNICAL REPORT NO. 8

CHANNEL STABILIZATION
INTEROCEANIC SEA-LEVEL CANAL
LOWER ATRATO RIVER PORTION, ROUTE 25
COLOMBIA, SOUTH AMERICA

by

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Committee on Channel Stabilization
CORPS OF ENGINEERS, U. S. ARMY

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Foreword

Establishment of the Committee on Channel Stabilization in April 1962 was confirmed by Engineer Regulation 15-2-1, dated 1 November 1962. As stated in ER 15-2-1, the objectives of the Committee, with respect to channel stabilization, are:

a. To review and evaluate pertinent information and disseminate the results thereof.

b. To determine the need for and recommend a program of research; and to have advisory technical review responsibility for research assigned to the Committee.

c. To determine basic principles and design criteria.

d. To provide, at the request of field offices, advice on design and operational problems.

This report of the Committee on Channel Stabilization, submitted to the District Engineer, U. S. Army Engineer District, Jacksonville, presents the requested opinions of the Committee concerning channel stabilization problems involved in evaluating the several alternate plans for handling the Interoceanic Sea-Level Canal and the Atrato River in the lower Atrato River Valley. This report was prepared by C. P. Lindner, Consulting Engineer, and embodies the opinions of the Committee. It is published by the Committee in furtherance of objectives d and a above, as being of interest to engineers engaged in channel stabilization activities.

Copies of this and other reports of the Committee on Channel Stabilization can be obtained from the U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Mississippi 39180.

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Introduction

1. On 11 March 1969, Mr. E. W. Eden, Jr., Chief of the Interoceanic Canal Studies Branch, U. S. Army Engineer District, Jacksonville, presented a paper to the Corps of Engineers Channel Stabilization Committee in which he described the physical features of the lower Atrato River and Valley and requested the Committee's opinions on channel stabilization matters in connection with the alternates being considered for the handling of the river and canal in that area. The alternative plans included: (a) Route 25A which would provide for separate channels for the canal and river with a short diversion of the river near Sautata and an additional short diversion farther downstream that would divert the river from its present distributaries to Bahia Colombia; (b) the Sautata Realinement in which the river and canal also would be carried to the Atlantic Ocean in separate channels, the river in this case being diverted from a point about 16-1/2 miles above Sautata on a direct line to Bahia Colombia; (c) the Atrato Valley Realinement in which the river and canal would occupy a single channel leading from the existing river channel at a point about 9 miles above Rio Sucio essentially on a straight line to Bahia Colombia; (d) a channel on the latter alinement for the canal only, though some local drainage would be carried thereby, with the upper Atrato River water discharged to the Pacific Ocean by means of facilities similar to those included in the Colombian Choco plan.

Description

2. The lower Atrato River occupies a channel about 50 ft deep and 1000 ft wide. As a result of the large channel section, river slopes are low as are the velocities associated therewith, except during floods of substantial magnitude. It appears that for average discharge the mean

velocities below gage 17 near Sautata are below 2 fps and the mean velocity at gage 16, about 12 miles upstream from Rio Sucio, is about 2.5 fps. Measurements made at gage 16 for a discharge of about 200,000 cfs, very close to bank-full, indicated maximum velocities on the range at the depth of the meter to be 4.5 or 5 fps. The maximum velocity so measured was only a moderate amount greater than the mean. As bank-full discharge is not far divergent from the average annual flood discharge, it is to be expected that the less frequent floods would produce velocities that are capable of eroding the riverbanks though, where the banks are tough, the erosion may be slow.

3. The valley through which the lower Atrato River flows is a wide, alluvial plain with a very mild slope toward the ocean. The banks of the river are comparatively low. The Jacksonville District has stated that the average maximum elevations as far upstream as Rio Sucio are only 5 to 10 ft above mean sea level. It is believed that the higher elevations are to be found on the natural levees. The banks, even at low water, extend above the water surface only from a very minor amount to a maximum of about 12 ft at gage 16. The floodplain is thickly covered with vegetation which reduces its effectiveness for carrying flood flows.

4. Depth-integrated sediment samples taken near gage 16 during discharges that varied from 130,000 to 167,000 cfs indicated a total suspended-sediment load varying from 390 to 780 ppm. Visual observation on 20 February 1969, when the river was at a low stage, revealed a sediment-laden river with a distinct muddy plume in the ocean beyond the major distributary. It was believed that the suspended-sediment content at that time near Rio Sucio could have been between 200 and 300 ppm. A bed-load sample taken near the mouth of the river was composed essentially of fine-grained material, 90 percent finer than a 200-mesh sieve. As far as the Committee is aware no other bed-load samples have been taken or analyzed.

5. Core borings of importance to this report were taken only along Route 25A, although a number of probings were made east of this route and the river. According to the District's report to the Committee, the "borings indicated the Atrato alluvium to be composed of soft generally gray inorganic silts slightly sandy to a depth of about 50 ft with underlying

gray inorganic silts with clay." Except for possibly the 20 or 25 ft of peat encountered in three of the borings, nearly all of the material was smaller than a standard 200-mesh sieve. Discussion brought out the fact that in the three farthest downstream borings a sandy lense or stratum was encountered, and that except for these and the peat cover, the material was plastic. Despite the reportedly low, undrained shear strength of the samples, the banks both above and below water are comparatively steep; in fact, on one of the cross sections exhibited, the upper part of one bank was essentially vertical for about 20 ft, and the above-water banks observed at Rio Sucio were vertical or nearly so. The fact that the borings were not close to the riverbank may be significant, however.

6. Except for the stretch extending from near Rio Sucio to the lower end of the cutoff below the mouth of Rio Teguerre, the lower Atrato does not manifest the sinuosity common for low-slope streams in flat, delta type floodplains. This may be due to the comparative youth of the floodplain, to the normal low velocity in the stream, and to the erosion-resistant characteristic of the soil. It seems apparent that meandering of the river downstream from the cutoff has been extremely slow. It was noted, however, that once the cutoff was opened it developed rapidly, indicating that where soil and slope conditions are such as to increase the erosive capability, more rapid bank caving can take place than has occurred on most of the lower Atrato River. It is worthy of note, however, that where meandering has been most intense, the amplitude of the bends is not in excess of 4 miles.

Questions and Replies

7. In his presentation to the Committee, Mr. Eden asked certain specific questions which will be repeated below, followed by discussion where needed and the opinions of the Committee. In order to avoid repetition, it may be stated that wherever bank stabilization is required, the articulated concrete mattress as employed on the Lower Mississippi River is the type that is recommended for the lower Atrato area, because the river and the projected excavated channels are deep and the banks of the

river and any channel to be excavated will be almost entirely underwater at all times. Accordingly, a mattress that can be placed underwater to great depths is required.

Diversion of the Atrato River
into a separate outlet channel

8. Question a. "In your opinion, will the diversion channel meander to the extent that it is possible the sea-level canal prism would be re-entered or recaptured? Can you comment on the certainty of this event--could recapture be anticipated within project life (50 years)? ... when should they (bank stabilization measures) be provided?"

9. Question b. "Will bank stabilization measures be required along the sea-level canal prism if the Atrato River is diverted? If required, what type would be recommended?"

10. Question c. "Recognizing that it is difficult to make quantitative estimates of the maintenance requirements of the sea-level canal, could the Committee indicate qualitatively the impact of the diversion of the Atrato River on maintenance requirements of the sea-level canal? Can erosion due to wave wash be anticipated of such severity as to require revetment?"

11. Route 25A.

a. Reply to Question a. The contiguity of both the river and the diversion near Sautata to the canal makes imperative the provision of revetment on the entire west bank of this diversion channel and on the riverbank a short distance upstream and a lesser distance downstream from the diversion. The revetment should be installed at the time of canal and diversion construction. The diversion channel that ends in Bahia Colombia will not require revetment.

b. Reply to Question b. Bank stabilization measures should not be provided along the canal prism except, perhaps, where and if the canal infringes upon the old river channel in the vicinity of Sautata, in which case protection of the plug may be required. Shoaling that may result from bank recession caused by wave wash and tidal flow can most economically be cared for by periodic maintenance.

c. Reply to Question c. As this subsection applies only to diversion of the Atrato River in a separate outlet channel, the intent of this question is not entirely clear. If, under the Route 25A plan, the river is carried down the

canal instead of diverted, the revetment requirements would be substantially increased, and the maintenance requirements, especially those resulting from the shoaling caused by the muddy freshwater-saltwater interaction, would be greatly increased. The erosion due to wave wash should be cared for by maintenance rather than prevented by revetment. Remarks given below under "Discharge of the Atrato River into the Sea-Level Canal" apply here equally well.

12. Sautata Realinement.

a. Reply to Question a. The Sautata Realinement diversion channel will be several miles from the canal at all points under this plan. Assuming that the soil information obtained, including the observations regarding the stability of the banks, is applicable to this route, it is considered unlikely that the diversion would capture the canal within the project life. This conclusion is based on the observed low slopes and velocities during average discharge conditions, and on the opinion that the velocities and slopes will not be sufficiently increased by the shortening, which is all within the tidal reach of the river, to substantially increase the rate of erosion. Moreover, judging from the maximum amplitude of the bends in the present river, it is unlikely that the meander pattern which may develop in the diversion channel will ever reach and intercept the canal prism. Nevertheless because of the unknowns connected with the diversion alinement and the impossibility of predicting with exactitude the action of a stream in an alluvial channel, especially one which has deviated from an existing regime, it is believed appropriate to provide for a moderate amount of bank stabilization along the diversion channel. An amount of revetment equal to about one-fourth the length of the diversion is suggested. Revetment should not be installed until a meander trace or pattern has been firmly established. It is believed that this may be 10 years after completion of the diversion.

b. Reply to Question b. The answer to this question is essentially the same as given above for the Route 25A. Revetment of the canal banks should not be provided, but periodic maintenance should suffice and be most economical. This, of course, assumes that tidal velocities will not be sufficient to cause any substantial bank erosion and meandering in the soils indicated by the borings as being present.

c. Reply to Question c. If the river is carried down the alinement indicated for the canal, the reply to this question is essentially the same as given above for Route 25A. Should the combined alinement follow the diversion channel, the revetment requirements would not be increased, but the

dredging maintenance necessitated from the source discussed below in paragraphs 17 to 19 inclusive would be enormous.

Discharge of the Atrato River into the sea-level canal

13. Question a. "If the Atrato River is permitted to enter and discharge through the sea-level canal, what in your opinion are the bank stabilization measures required? When should they be constructed?"

14. Question b. "Would you comment at least qualitatively on the impact of the Atrato River discharge on anticipated maintenance?"

15. It is assumed that these questions are intended to apply to the plan designated as the Atrato Valley Realinement or any plan in the lower Atrato Valley in which the canal and river both occupy the same channel.

16. Reply to Question a. Data presented by the District show that for the Atrato Valley Realinement plan there would be a large difference in elevation during floods between the present elevation of the river and the lower level that would occur in the combined channel at the point of diversion. Apparently a control or drop structure in the Atrato would be required. Whether or not the need for such a structure could be avoided by starting the combined channel farther downstream is a matter that would require further hydraulic study by the District. If the control structure is capable of providing an extremely high degree of flow regulation, only a very minor amount of revetment should be needed as the velocities caused by the headwater flow would be low at all times. Assuming, however, that the drop structure would provide little or no flow regulation, this plan should provide for revetment of the channel to the extent of about one-half its length. This conclusion is based on the presence of erodible lenses or layers in the borings and on the possibility that the soils along this realinement may be inferior from the standpoint of nonerodibility to those shown by the borings and by the observed riverbanks. Moreover, in any channel to be used by shipping, it is important that its length not be increased greatly and its sinuosity be restricted to that which can be easily negotiated by the ships that will transit the channel. The bank stabilizing revetment should not be installed until a meander

pattern has been established. Even though the junction of the river and the realined channel is farther upstream than the point of diversion for the Sautata Realinement, it appears that the velocities at the point of junction and downstream therefrom will be as low or lower than those in the Sautata diversion. Accordingly it can be reasonably assumed, as was suggested in the case of the Sautata Realinement, that the revetment will not be installed until 10 years after construction of the Atrato Valley Realinement.

17. Reply to Question b. It was noted above that the Atrato River carries a very high suspended-sediment load. When fresh water charged with suspended and colloidal sediment mixes with salt water, a process of flocculation takes place. The flocs have a greater propensity for settlement than does the sediment in its original suspended or colloidal state. Moreover, the heavier salt water underruns the fresh water so, unless the freshwater flow is sufficient to push the salt water beyond the mouth of the stream, the salt water penetrates along the bottom with an average upstream component of flow. From oral reports received, this does not now happen in the Atrato because the shallowness over the ocean bar enables the freshwater discharge to prevent penetration. But under the Atrato Valley Realinement plan, a deep channel will be excavated into the bay. This will permit the salt water to flow upstream a considerable distance along the bottom of the canal. The flocculated sediment that settles into this bottom saline water will be trapped and will move back and forth with the tide until it deposits to form shoals. A high flood discharge may evacuate the fluff that has not already deposited, but the fluff will rapidly re-form after the flood as the process of flocculation is continuous in the area of mixing of fresh and salt water. In addition, fluff that has been evacuated from the channel during a flood or that has settled initially into the lower layers of water seaward from the mouth of the channel may be drawn back into the channel by the upstream flowing water along the bottom.

18. The seriousness of these actions so far as maintenance is concerned may be realized by reference to experience in estuary harbors. After freshwater flow averaging about 16,000 cfs was diverted into

Charleston Harbor, S. C., for example, maintenance dredging increased rapidly from a negligible amount to about 10,000,000 cu yd a year. Of this it was estimated that about 3,000,000 cu yd was carried into the harbor with the diverted fresh water. This amounts to about 50 ppm based on a dry weight of the sediment in the shoal of 20 pcf. According to recollection, this checks the concentration of the sediment reported to be present in the diverted water. The amount of dredging not accounted for by the sediment in the diverted water was attributed to bank erosion, poor dredging practices, and return from the ocean, each of which may be present to a greater or lesser extent in the Atrato Valley Realinement than in Charleston Harbor.

19. In appraising the situation for the Atrato Valley combined channel, account should be taken of the fact that the Atrato River suspended-sediment concentration is six or more times as much as that of the water diverted into Charleston Harbor and that the average discharge of the river is about six times the flow of the fresh water into Charleston Harbor. The potential maintenance from this source is so great it appears that it could prove impracticable to provide adequate maintenance for the combined channel of the Atrato Valley Realinement plan. Under this plan salt water from the Pacific as well as from the Atlantic is available for mixing with the fresh water, and the divided flow reduces the chance of, or may eliminate, flushing of the fluff from the canal. The experience in Savannah Harbor, Ga., where about 7,000,000 cu yd per year is dredged furnishes further evidence of the seriousness of this problem.

20. In the foregoing discussion it is premised that the control structure in the river above the point of diversion will not remove any substantial amount of sediment. Should it be capable of substantially reducing the sediment content, the expected maintenance of flocculated material may be estimated by reference to Charleston, Savannah, and other harbors where the problem has been studied.

Interception of the Atrato River and discharge to the Pacific through the San Juan River

21. Question. "An evaluation of the probable savings through the

Atrato River interception and diversion from its floodplain may be needed. What is your opinion as to the equitable basis for computation of the savings insofar as stabilization measures are concerned?"

22. Reply. A plan essentially in conformity with the Colombian Government's Choco Development plan is visualized here. It is assumed that the interoceanic canal layout used in conjunction with this plan will be the same as the Atrato Valley Realinement. If most of the upper Atrato River water, except occasional flood flows, is diverted to the Pacific, no revetment should be required along the canal in the lower Atrato Valley. Therefore the equitable basis for the determination of savings would be a comparison of the cost of this plan with the cost of the least expensive alternative plan.

23. With this plan as well as the Atrato Valley Realinement discussed above, the river from the point where the canal diverges from the lower Atrato River must be excavated to the outlet works of the dam or provision must be made for natural erosion of this stretch and for removal of the eroded material from the canal. Also, if flood flows are discharged into the lower Atrato, a moderate amount of maintenance to remove flocculated and deposited sediment may be required. Should it be possible to control and pass all upper Atrato flows to the Pacific, it would not be necessary to allow for excavation or erosion of the river from the dam to the canal nor should shoals caused by flocculation be anticipated.