UNITED STATES

THE PANAMA CANAL
THE THIRD LOCKS PROJECT

FINAL REPORT ON MODIFIED THIRD LOCKS PROJECT

PART II - DESIGN
CHAPTER 17 - RELOCATIONS

APRIL 1944

DEPARTMENT OF OPERATION AND MAINTENANCE
SPECIAL ENGINEERING DIVISION
BALBOA HEIGHTS, CANAL ZONE

№ 7

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FINAL REPORT ON MODIFIED THIRD LOCKS PROJECT

PART II - DESIGN

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CHAPTER 17

RELOCATIONS

Introduction

17-1. When structures of the type and magnitude of the Third Locks are constructed in inhabited areas, the relocation of some existing municipal and transportation facilities is usually necessary. The Third Locks Project was no exception, particularly at Gatun where every modern service was affected. The Gatun by-pass channel is separated from the Pedro Miguel channel by Gatun Lake and Gaillard Cut, hence the relocations and structures required in the vicinity of Gatun are entirely unrelated to similar problems in the neighborhood of the Pacific Locks. In both areas, however, new or greatly increased services were needed in addition to the required relocations.

ATLANTIC RELOCATIONS

17-2. The relationship of the Gatun by-pass channel to the urban developments in the vicinity is shown in Figure 17-1. In addition to the relocations indicated, other relocations such as sanitary sewer outfalls, water mains, and channel lights and buoys were necessary. Plans were required for the interception and diversion of existing streams, the disposition of dry spoil from the locks excavation and the approach channels, and the provision of suitable backfill materials. Plate 17-1, following the text of this chapter, shows the relocations and the spoil areas in the Gatun area.

17-3. Because of the relatively congested area, all designs were interrelated. The disposition of the spoil had a major effect on practically all the other designs, and all plans in a given area were dependent on the progress of the Third Locks work and other construction being carried on concurrently in the same or in adjacent areas.

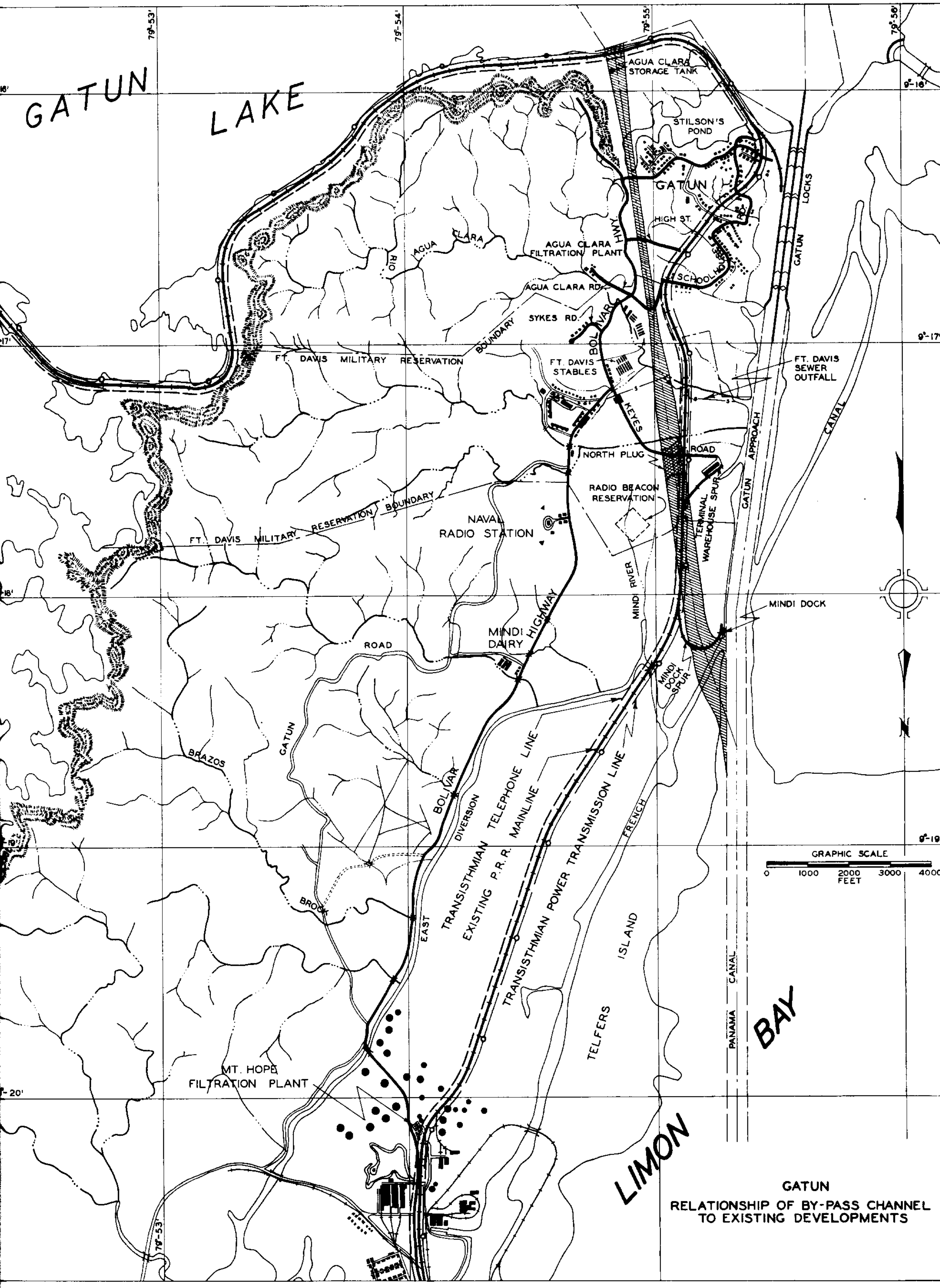
17-4. The relative importance and magnitude of the various designs rather than their chronological sequence have been used in determining the order in which the designs are described in the following paragraphs.

Panama Railroad

17-5. Figure 17-1 shows that a relocation of the Panama Railroad main line was necessary entirely to the east of the new channel because the main line was cut at both extremities of the channel for the new Gatun Locks. The developed portion of the Fort Davis Military Reservation defined sharply the eastward limit of the relocation. The existing main line within the portion to be relocated contained curves as sharp as 6° 15' and grades up to 1.31 per cent. It was desirable to improve these conditions as far as economically feasible. The existing locks, the town of Gatun, and the industrial and construction activities in the vicinity could not be cut off from rail service at any stage of the work, and temporary as well as permanent connections had to be designed to supply this service. The temporary main-line connection became known as the "Plug Crossover"; the permanent connection to the town and the existing locks was called the "Locks Crossover Spur", and the temporary and permanent connections to the Atlantic Terminal Warehouse area were known as the "Warehouse Spur Connections." It was desirable to minimize interference with the services and utilities between Fort Davis and Gatun, all of which had to be crossed by any practical alignment for the relocation. The availability of spoil from the excavations for the lock structure made possible, at minimum cost, any profile between Mindi and Agua Clara that would fulfill the other limiting conditions. Eastward from Agua Clara the two main forks of the Agua Clara River (hereinafter designated as "South Fork" and "North Fork"), and one of its tributaries seemed to offer the only feasible routes through the rugged terrain.

Selection of Route

17-6. The projection from which the preliminary estimate was prepared for inclusion of the railroad relocation in the Third Locks Project followed the South Fork, included all the essential features of the final location, and in addition contained provision for a wye track east of the new locks. The profile was a steadily ascending grade from Mindi to the summit and involved very high fills near Fort Davis and the Agua Clara Filtration Plant. The studies were suspended temporarily, and when they were resumed, the known limitations for the relocation had undergone little change. The site assumed for the bridge over the new locks was still over the upper gate bay with the resultant high profile of the main line opposite the Locks Crossover Spur take-off to facilitate a reasonable grade for that spur. Accurate topography was available only in a narrow band adjacent to and east of the lock axis, but the position of the axis had been fixed, and a closer determination of the alignment from Mindi to Agua Clara was thus possible. All likely routes from this point forward were investigated, including a line which paralleled the new locks and required a tunnel through the ridge to the



GATUN LAKE
AGUA CLARA STORAGE TANK
STILSON'S POND
GATUN
HIGH ST.
AGUA CLARA FILTRATION PLANT
RIO AGUA CLARA
HWY
SCHOOLHOUSE
AGUA CLARA RD.
SYKES RD.
BOLIVAR
GATUN LOCKS
FT. DAVIS MILITARY RESERVATION BOUNDARY
FT. DAVIS STABLES
FT. DAVIS SEWER OUTFALL
KEYES
NORTH PLUG
ROAD
RADIO BEACON RESERVATION
TERMINAL WAREHOUSE SPUR
GATUN APPROACH
CANAL
NAVAL RADIO STATION
MINDI RIVER
MINDI DOCK
MINDI DAIRY
HIGHWAY
ROAD
MINDI DOCK SPUR
GATUN
BRAZOS
BOLIVAR
DIVERSION
TRANSISTHMIAN TELEPHONE LINE
EXISTING P.R.R. MAINLINE
TRANSISTHMIAN POWER TRANSMISSION LINE
FRENCH
GRAPHIC SCALE
0 1000 2000 3000 4000
FEET
BROOK
EAST
ISLAND
TELFERS
PANAMA CANAL
BAY
MT. HOPE FILTRATION PLANT
LIMON
79°-53'
79°-54'
79°-55'
79°-56'
9°-16'
9°-17'
9°-18'
9°-19'
9°-20'
GATUN
RELATIONSHIP OF BY-PASS CHANNEL TO EXISTING DEVELOPMENTS

FIGURE 17-1

east. Comparison of all these routes with respect to cost, operating conditions, and lengths indicated the definite superiority of the projections along the Agua Clara River. Later, when accurate topography over the South Fork route became available, comparative estimates were prepared of various alignments, the most desirable being known as the "D" line.

17-7. Before studies were completed for the "D" line, consideration was given to the effect of moving the location of the bridge to either the middle or the lower chamber. Use of these crossings so lowered the required elevation of the main line at the take-off of the Locks Crossover Spur that the profile eastward of that point could be materially lowered, thereby improving operating conditions. The valley of the North Fork appeared to fit such a profile better than that of the South Fork, and additional topography was obtained to develop fully this consideration. The resultant studies produced the "N" line for comparison with the "D" line.

17-8. The feasibility of a direct route up the Brazos Brook Valley from Mount Hope to Quebrancha had been demonstrated by the engineers who relocated the Panama Railroad in 1908. The surveys were not completed because the route would have left the town and the locks at Gatun to be served by a branch line, an undesirable condition at that time. The Third Locks studies were limited originally to routes that placed the town and the locks near the main line. However, the Panama Railroad Company later proposed this short route as an alternative to those already studied, and conducted the topographic surveys necessary for a full evaluation of the route, which was known as the "S" line.

17-9. Further study of the possibilities of the North Fork route developed a refinement of the "N" line which was designated as the "N3" line. Comparison of the "D", "N3", and "S" lines showed that the initial construction cost of the "N3" line would be lower. The lengths and operating conditions for the "D" and "N3" lines were about equal, but the much shorter "S" line presented certain operating economies that required very careful consideration. An analysis of these economies was made by the Plans Section of The Panama Canal, but its report showed that they were not sufficient to outweigh the advantages of the "N3" line, and the "N3" line was selected as the basis for final location studies.[1] The three general routes are shown in Figure 17-2.

Design Standards and Other Limiting Factors

17-10. The determination of maxima for grades and curvature, whether to retain or abandon Mindi Bridge, and the position of the bridge over the new locks were all essential to the development of a final design. The first two involved the coordination of conflicting opinions. The last was dependent on several considerations besides

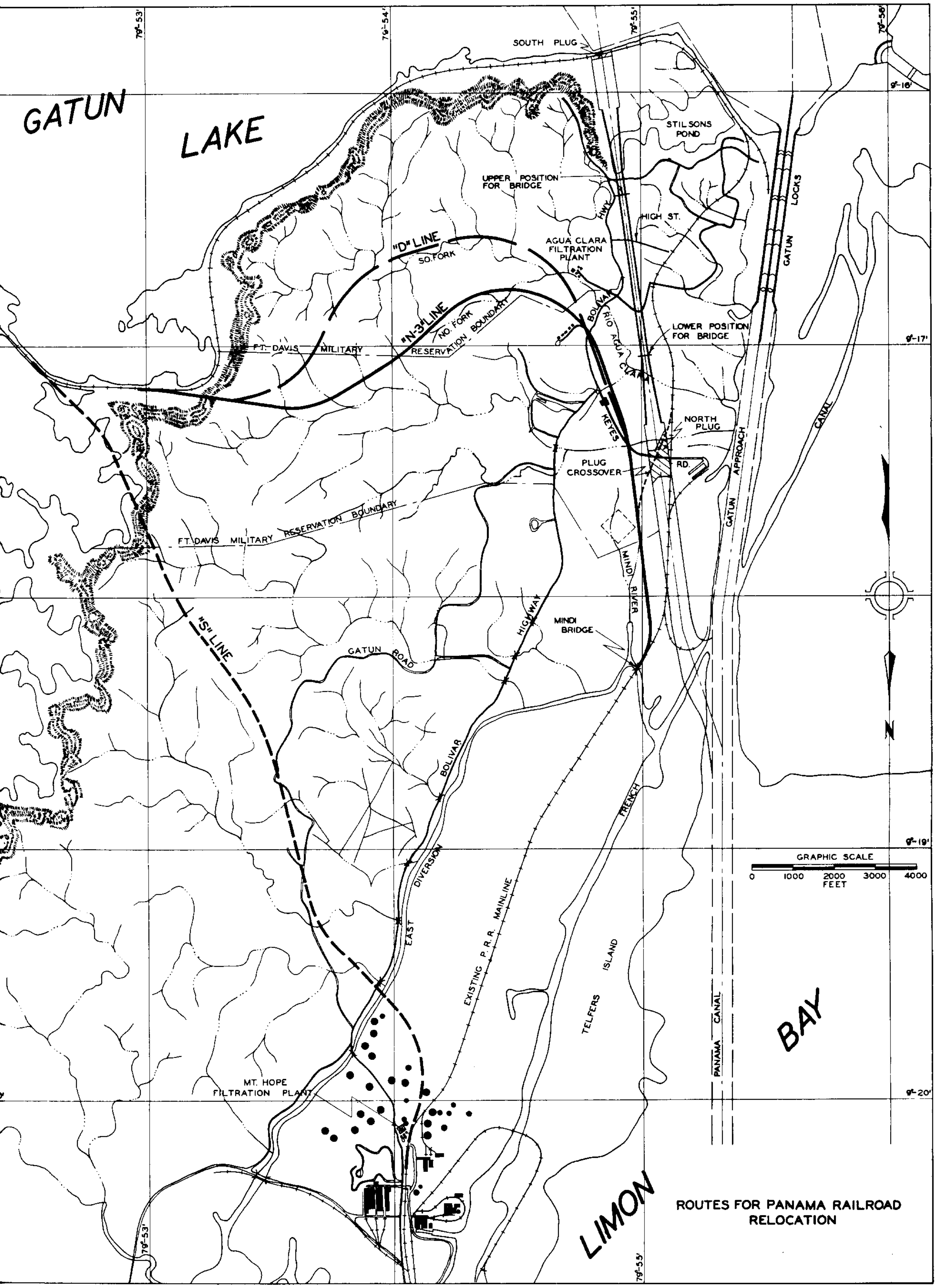

GATUN
LAKE
SOUTH PLUG
STILSONS POND
UPPER POSITION FOR BRIDGE
HWY
HIGH ST.
AGUA CLARA FILTRATION PLANT
"D" LINE
SO. FORK
"N-3" LINE
NO. FORK
RESERVATION BOUNDARY
FT. DAVIS MILITARY RESERVATION BOUNDARY
BOLIVAR
RIO AGUA CLARA
LOWER POSITION FOR BRIDGE
GATUN LOCKS
KEYES
NORTH PLUG
RD.
PLUG CROSSOVER
GATUN APPROACH
CANAL
MINDI RIVER
HIGHWAY
MINDI BRIDGE
"S" LINE
GATUN ROAD
BOLIVAR
EAST DIVERSION
EXISTING P.R.R. MAINLINE
FRENCH
TELFERS ISLAND
PANAMA CANAL
BAY
LIMON
MT. HOPE FILTRATION PLANT
GRAPHIC SCALE
0 1000 2000 3000 4000
FEET
79°-53'
79°-54'
79°-55'
79°-56'
9°-16'
9°-17'
9°-19'
9°-20'
ROUTES FOR PANAMA RAILROAD RELOCATION

FIGURE 17-2

that of its effect on the railroad location. These items are discussed in the succeeding paragraphs.

17-11. Prior to obtaining accurate topography east of the Agua Clara Filtration Plant, all projections were based on curves up to 5° and grades up to 1 per cent. Later studies were made on two bases: (1) Maximum curvature of 3° and maximum grade of 0.6 per cent; and (2) Maximum curvature of 3° 40' and maximum grade of 1 per cent with compensation of 0.04 per cent per degree of curvature. The 3° 40' curve was used only at the Mindi Bridge, where physical features limited the permissible length of tangent. Elsewhere 3° was the maximum. In every case the 1-per-cent grade produced very desirable savings in construction costs and was an improvement over the existing main-line grades. Its use also permitted almost level grades in the vicinity of the station, a condition that was not possible with the maximum of 0.6 per cent. Accordingly the second of the two bases was selected. The width of fills at subgrade level was set at 20 feet and the width of cuts at 30 feet. During construction it appeared desirable to increase these dimensions by 2 feet and to flatten the side slopes in rock cuts from 0.5^v on 1^h to 1^v on 1^h.

17-12. The original timber trestle over the East Diversion at Mindi had been replaced in 1937 by a concrete pile structure. It therefore seemed advantageous to continue the use of this bridge, even though it caused a somewhat sharper curve immediately to the south than was required by conditions elsewhere. There were two 6° and one 6° 15' curves in the section of the main line to be relocated. Nevertheless, for the sake of comparison, studies were made of alignments that would require a new bridge or otherwise would reduce the curvature. Any of these alignments was estimated to increase by more than $50,000 the cost of the relocation, and would require the consolidation of the foundations for the fills over the long stretches of swamp land to be traversed. Investigations were conducted as to the possibility of consolidating the swamp material by blasting, but before the studies had progressed very far a decision was reached to retain the bridge in service.[1]

17-13. Reference has been made in the foregoing to the site originally chosen for the bridge over the new locks and to the later studies on the effect of moving the bridge location to lower lock levels. These studies included also the possibilities of tunnels under the locks. The grades and curves found necessary for the tunnels precluded their use as railway crossings, and indicated that a bridge was the most practical solution. On the basis of these studies and data on probable curvature and profiles for the Locks Crossover Spur required by the various bridge positions, the lower chamber was selected as the location for the bridge at Gatun. The exact position, midway between the pintles of the lower gates, was fixed after further research into lock operational, marine, and protection requirements.

Final Design

17-14. Pending the settlement of the above points, work had progressed towards the development of a final alignment and profile. This included an adjustment from 1 per cent to 0.75 per cent of the maximum northbound grade on the existing main line between Quebrancha and Colon, plot plans and basic design data for masonry structures, correlation of other relocations (highways, the transisthmian telephone and power lines, and drainage canals) with the railroad design, and studies and estimates for greater economy of construction costs. The final profile rose from the elevation determined by the existing Mindi Bridge on a sharp but not maximum grade until it emerged from the low hills immediately south of the bridge, then followed the gently rising slope of the adjacent plain until an increased grade was necessary for clearance at the Bolivar Highway Underpass. The profile continued on the increased grade until it reached an elevation required for a reasonable grade for the Locks Crossover Spur, and entered a grade of 0.2 per cent to allow for a station plaza and passing siding. From that point eastward the grades were dictated by the terrain, the summit being approximately at elevation 114.

Failure During Construction

17-15. Grading was started at Mindi on February 14, 1941. The profile called for heavy fills across the Fort Davis plain. The drainage canal had been laid as closely as possible to the railroad to minimize encroachment on the Fort Davis Military Reservation. The berm between the canal and the railroad averaged 18 feet in width. When the drainage canal was excavated and the railroad fills were about 6 feet below final grade, the weakness of the foundation material, in combination with the heavy fills and the narrow berm, caused a failure of about 500 feet of the railroad embankments immediately north of the overpass structure.[2,3]

17-16. The excavated channel of the drainage canal was backfilled immediately to prevent further slides. (See Paragraph 17-84.) Studies were initiated to determine the extent to which the railroad alignment in the critical area could be moved eastward and the profile lowered. Field investigation of the limits of the carbonaceous muck and laboratory studies of safe slopes in dry excavation were intensified.[4] Consideration had already been given to improving the foundations under the north approach walls of the locks by shifting the locks southward. All these investigations were accelerated and in combination with other studies, including stabilization of the muck by drainage, resulted in the adopted solution of shifting the locks 850 feet southward, excavating for the locks in the critical area to safe, dry slopes from a wet excavation top of slope (thus leaving a prism on the east side for ultimate removal by dredging), moving the railroad location somewhat to the east and lowering its profile as much as possible, and realigning the drainage canal.

Effects of Change

17-17. The new design for the main-line relocation caused correspon ing changes in the Plug Crossover, made necessary a redesign of the Locks Crossover Spur, moved the station and passing siding northward to the plai opposite Fort Davis, and eliminated the highway underpass. The lowered profile resulted in operating conditions that were not as advantageous as those obtained by the original design but were necessary to insure stabili of the line. The eastward movement of the line to obtain the required offset from the locks excavation was limited by existing structures. Offsets from two of these--the relocated Bolivar Highway and the reconstructe guardhouse--served to establish the position and direction of the tangent between the second and third curves and caused a movement northward of the second curve. The curve connecting this tangent with the undisturbed alignment beyond Agua Clara also had two points of control; namely, a larg box culvert that had been constructed at an early date to carry the drainage canal under the railroad, and a minimum offset from the most westerly of a group of new, concrete quarters. Attempts to compound the original curve to fulfill the new conditions did not prove satisfactory. A new, simple curve was computed that passed through the points of control and whose central angle was adjusted so that the forward tangents of the original and the new curves were parallel and the following curve was affected only to a small extent.

Branch Lines and Access Spurs

17-18. Access spurs to connect the tracks on the locks backfill with the main-line system presented problems that are discussed for each case in the following paragraphs. Maxima of 1.5 per cent for operating grades and of 12° for curves were adopted. These maxima were used only when absolutely necessary. On two occasions the maximum operating grade was exceeded because of severe limiting conditions.

Plug Crossover

17-19. To insure continuous operation of the Panama Railroad it was necessary to reroute the railroad over the location of the north plug to be left in place between the dredged channel and the locks excavation. Only light grading was involved on the main-line relocation from Mindi Bridge south to the point where the crossover would be located, so a connection from the relocation at this point across the north land plug to the existing main line in the vicinity of the Fort Davis Station could be made with comparative ease. Until the completion of the Locks Crossover Spur, this connection would continue to serve all installations west of the new channel, even after routing of the transisthmian service over the relocated main line. Hence, the take-off for the crossover had to be arranged through a turnout. The alignment for the crossover offered no special problems other than the choice of direction at the land plug so as to obtain a curve that would not increase excessively the width of the land plug. Profile limitations were established by the elevations of the main-line relocation at the north and the existing main line at the south. The elevation of Keyes Road, where a grade crossing was desirable, fixed the profile of the connection within narrow limits at that point. Its profile north of Keyes Road was adjusted to meet the lowered main-line profile in June 1941, and later was raised several feet to improve subgrade drainage.

Temporary Connections

17-20. With increasing knowledge of the strength properties of the carbonaceous muck, design slopes were progressively flattened until it was apparent that the safety of the existing main line opposite the southwest corner of the north land plug would be endangered by the excavation for the locks before the Plug Crossover could be put into service. The construction of the grade for the portion of the Plug Crossover lying west of the new locks channel was accordingly expedited and a temporary connection was devised to join this portion with the main line to the north of the land plug. Differences of elevation rather than horizontal curvature considerations controlled the desirable length of this connection. A tangent to the curve of the Plug Crossover at a convenient point and the position of a #10 turnout from the main line were determined. The curve connecting the two tangents so fixed was made as flat as possible. The profile was limited again by the terminal elevations and the grade of Keyes Road where the temporary connection crossed it.

Warehouse Spur Connection

17-21. On the east bank of the Canal opposite Fort Davis the United States Army maintained a large warehouse as a general supply depot for military installations on the Atlantic side. Rail service was supplied by a spur from the Panama Railroad main line which would be severed by the excavation for the north approach channel. At the time that studies and plans for the railroad relocations were under way, Army authorities developed plans for the expansion of this depot. Originally these plans contemplated a new terminal on the east bank of the new channel with a slip from the channel so that deep-draft vessels could unload directly into the warehouses and avoid loading and unloading of freight cars. Thus the first studies for the replacement of the existing spur involved not only the necessary trackage but also depot layouts that could be serviced from the limited positions possible for the tracks. This scheme was abandoned later in favor of expansion on the original site. Studies for a spur track to service this area were complicated by provisions for a near-by spoil area to accommodate about 1,000,000 cubic yards of carbonaceous muck. To obtain this volume in the limited area available, the highly plastic spoil was restrained by compacted earth dikes that, combined with the spur embankment, resulted in a satisfactory solution to the problem.

17-22. Army plans for the expansion at the original site began to be definite about the same time that the contractor decided to handle the carbonaceous muck by wet methods and to spoil it north of Mindi Bridge. With the area no longer necessary for the spoil bank, a redesign of the Warehouse Spur was desirable. Preliminary layouts of the expanded depot were received, modifications recommended, and the alignment and grade of the spur were redesigned to permit the use of its lower end as a ladder track for spurs to the additional warehouses. The requirement that the ladder-track portion be on a tangent introduced sharper curves than would have been necessary otherwise. These curves, together with the necessity of keeping the ladder-track portion at a low elevation and on level or easy grades, resulted in operating grades in excess of the established maximum, this being one of the two exceptions mentioned in Paragraph 17-18.

17-23. The foregoing deals with the Warehouse Spur Connection as designed for construction under the excavation contract and for operation during the excavation and early masonry construction periods. Under the subsequent masonry contract, placement of the approach fills to the swing bridge, after the completion of its abutments, would bury the existing main line just south of the original Warehouse Spur turnout, and impede access to Gatun proper and to the spur from the Gatun side. Several alignments that would eliminate this condition were analyzed as to cost and operating factors. The most favorable alignment departed from the existing main line just north of the junction of the main line and the Locks Crossover Spur, passed to the north under the bobtail span of the bridge, crossed the existing main line a short distance north of the original turnout, and rejoined the previously constructed spur so as to use the maximum amount of track in place. Alignment and profile problems were mostly concerned with clearances, both horizontal and vertical, where the alignment would lie on backfill close to the lock wall. The new take-off from the main line was originally designed as a turnout, but later studies realigned a portion of the main line and eliminated the turnout as a permanent feature. The construction of the track for this final connection would have to be in two steps. First a construction turnout from the main line and a temporary connection would have to be built, and then the temporary connection would be replaced. The construction turnout would run under the bobtail span and northward to a point from which a temporary connection back to the main line could be made from the east. Such a connection would handle Gatun traffic when the approach fills to the bridge were begun. Sufficient tail track would remain beyond the undisturbed original turnout for the Warehouse Spur so that trains could switch back onto it. The replacement of the temporary connection after the completion of the Locks Crossover Spur would have to be done at a time when the Atlantic Terminal Depot could be isolated from rail connection for a short time. The alignment just discussed is shown on Figure 17-3. The temporary hookups are not shown.

Locks Crossover Spur

17-24. As indicated in Paragraph 17-5, the Locks Crossover Spur is designed to provide a permanent connection for rail service to installations lying between the two sets of locks. Up until the time that the locks were moved 850 feet southward, the take-off had been from the passing siding, and the spur approached the bridge from the southeast. This direction was dictated by the difference in elevation when the bridge was at higher levels, and later by the permissible degree of curvature. The greater offset between the bridge and the main line provided by the shift in both of these structures made access from the north not only possible but desirable. However, a take-off was necessary from the main-line track instead of the station or the passing siding. The difference in elevation was overcome by placing this turnout far enough to the north so that a grade of 1.50 per cent would not be exceeded. Since this grade was considerably in excess of that on the adjacent main line, the alignment of the spur had to be adjusted to allow for the increasing difference in elevation of the subgrades. The embankments for the first 2000 feet of this line, where it was roughly parallel to the main line relocation, were constructed from locks spoil under the excavation contract. The balance of the grading east of the new locks will be done under the masonry contract, since the fills overlay the backfill against the lock walls.

17-25. The center line of the bridge coincides with the center line of the spur on the bridge. The alignment west of the bridge was originally designed as an 8° curve with the forward tangent practically parallel to the axis of the locks. The following 6° curve terminated in a #7 turnout to make the connection to the existing main line through Gatun. This portion of the alignment crossed Spoil Areas IV and V. Between these two spoil areas lay a narrow valley whose floor elevation varied from 10 to 20. It was planned to fill the valley to elevation 35 and to superimpose the spur embankment upon this fill, using natural slopes for the embankment. However, during the early construction of Spoil Area IV, there were indications that weak foundations obtained in the valley and the original contract drawings called for this portion of the embankment to be built with 1^v on 2^h slopes on the east side and 1^v on 3^h slopes on the west side. The progress of the excavation was such that the construction of this embankment, originally proposed for completion under the masonry contract, was added to the excavation contract. Investigations of the extent and depth of the carbonaceous muck in the valley led to the conclusion that these slopes alone would not stabilize the fill. Use of a 10° curve in place of the previous 8° curve brought the line closer to the locks, placed it where the muck was shallow, and permitted blanketing of the muck between the newly constructed Jadwin Road (the main access to

Gatun during the locks construction period) and the west edge of the fill. Since the whole line moved eastward, it joined the existing main line to the east of Jadwin Road and resulted in a more desirable condition than that which existed previously. The foundations under the fill were consolidated by blasting.[5] Since the approach to the bridge from the east side of the locks also crosses an area of carbonaceous muck, consolidation of that fill will likewise require special methods. Foundation problems are more fully discussed in Chapter 5 of this report.

Access Spurs

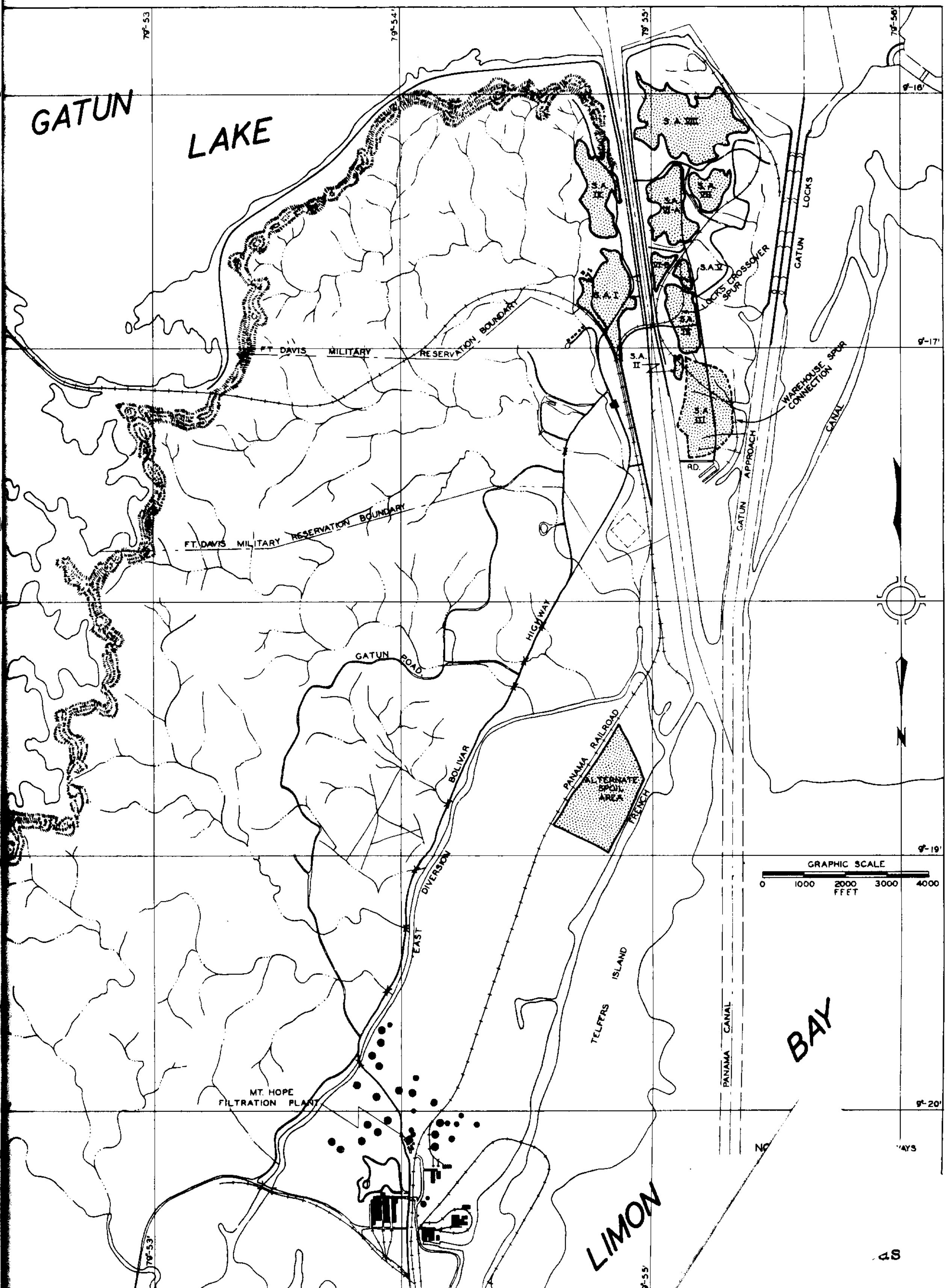
17-26. Access spurs are designed to connect the system of tracks on the backfill for the locks with the main system of the Panama Railroad. In conformity with similar facilities at the existing locks, only one spur (the West Access Spur) was originally considered. The west side was chosen because of the short connection required from the Warehouse Spur in its final position and because it would provide a complete system of interconnecting tracks for the two sets of locks. A 2.10-per-cent grade had been found necessary for the tracks on the backfill of the new locks, and it was the limiting grade for the access spur. The only problem in the design of the West Access Spur was the selection of a turnout position from the Warehouse Spur that would not exceed this profile limitation.

17-27. Facilities for dry-dock shops and other services opposite the upper chamber on the east side of the locks were added to the general plans at a later date. The East Access Spur was devised for direct rail access to this plant from the Panama Railroad. No particular difficulty was experienced in overcoming the alignment requirements, but considerable study was required to obtain a crossing at grade with a projected road connection from Bolivar Highway to the service road on the lock backfill without exceeding the profile limitations. The difficulty was finally overcome by using the spur profile that most closely fulfilled the conditions and adjusting the highway profile to meet it.

Structures

17-28. The railroad overpass originally required at the intersection of the main-line relocation and Bolivar Highway relocation was eliminated when the railroad profile was lowered in conjunction with other measures taken following the failure of the embankment. The bridge over the new locks is described in Chapter 15 of this report.

17-29. In all alignment studies, provision was made for a new station to serve Gatun and Fort Davis. The position finally chosen was dictated by the profile for the final design of the main-line relocation. The general plan of the existing station at Gatun was adopted for basic design as the type best adapted to use. Following completion of the general


GATUN
LAKE
79°-53'
79°-54'
79°-55'
79°-56'
9°-16'
9°-17'
9°-19'
9°-20'
S.A. VIII
S.A. IX
S.A. VII-A
S.A. VII
S.A. V
S.A. I
S.A. IV
S.A. II
S.A. III
LOCKS CROSSOVER SPUR
GATUN LOCKS
FT. DAVIS MILITARY RESERVATION BOUNDARY
WAREHOUSE SPUR CONNECTION
CANAL
GATUN APPROACH
RD.
GATUN ROAD
HIGHWAY
BOLIVAR
EAST DIVERSION
PANAMA RAILROAD
ALTERNATE SPOIL AREA
FRENCH
GRAPHIC SCALE
0 1000 2000 3000 4000
FEET
TELFERS ISLAND
PANAMA CANAL
BAY
MT. HOPE FILTRATION PLANT
LIMON

design by the Special Engineering Division, the Office Engineering Division prepared the detailed designs for the station proper while the Special Engineering Division prepared the grading and exterior service details.

17-30. Box and pipe culverts sufficed to take care of all stream crossings and side drainage, and no major drainage structures were required by the various railroad relocations. Minimum diameters of 30 inches were used for pipe culverts to avoid stoppage by debris, and the permissible head on all culverts was limited to 2 feet. Drainage areas were surveyed for greater accuracy in determining the runoff. Storm intensities based on a 40-year frequency were used to compute culvert sizes.

Spoil Areas and Backfill Provisions

17-31. Deep, steep-sided ravines or wide, flat, relatively marshy plains were present on both sides of the locks. Distribution of the spoil in the topographic irregularities would improve considerably the adjacent drainage and create useful areas for construction activities. It was advantageous to extend these improvements as far as possible from the locks without materially adding to the cost because of excessively long hauls. In addition, spoil from the locks represented the only inexpensive source of materials for the heavy railroad fills between the Mindi hills and Agua Clara. Allowance for reasonable swell factors in the excavated materials was necessary to determine the volume of spoil that could be accommodated in the various areas available. Segregation into stock piles containing only rock or only earth was necessary to meet the backfill requirements. It was desirable that the volume of these stock piles be such that the maximum improvement of the original topography would be obtained after the removal of the stored backfill. Detailed designs of the spoil areas at Gatun are shown in the contract drawings.[6]

17-32. The earliest design for the spoil areas included all the sites finally developed, and in addition contemplated placing spoil on both sides of the railroad relocation to the north as far as Mindi. When the position of the north land plug had been definitely fixed, the amount of dry excavation was reduced, and the need was eliminated for any spoil banks north of the north land plug other than the railroad fills. The original contract drawings were based on the disposal of approximately 11,500,000 cubic yards of dry excavation (5,000,000 cubic yards of earth and carbonaceous muck, and 6,500,000 cubic yards of rock). Swell factors of zero for earth and muck and of 40 per cent for rock were used originally, but during construction it was observed that the rock broke down under the action of the excavation and hauling equipment to a much greater extent than had been anticipated, and the swell factor was reduced to 20 per cent. In addition to the railroad and highway embankments, 9 spoil areas were used. The divisions between these 9 areas were natural topographic features or existing roads and railroads. The design of each spoil area is discussed separately in the following paragraphs. General locations and relation to the Third Locks channel are shown in Figure 17-3. The spoil areas are shown also in Plate 17-1.

Spoil Area I

17-33. At its northern extremity, Spoil Area I was little more than a widening of the railroad fill at approximately the same elevation. As the railroad swung eastward to Agua Clara, the width of the spoil area increased until its eastern limit was defined by proximity to the filtration plant. Its southern limit was a range of hills and its western limit a safe distance from the locks excavation, as determined by the shear strength of the material upon which the spoil was to be placed. The northern third of its length was designed to be of earth, part of which would be reclaimed for backfill and for the construction of the railroad and highway approaches to the bridge across the new Gatun Locks. The remaining portion, below elevations varying from 35 to 65, was to be composed of mixed earth and rock and was designed to remain as a wide, useful expanse after reclaiming rock backfill stored above these elevations on the southern and eastern portions. Backfill needs for the left north approach wall and the lower east chamber were originally estimated to be about 1,000,000 cubic yards of rock. Sufficient space was allowed between the stock pile, which rose 50 feet above the lower spoil surface, and the eastern limits of the spoil area to permit the construction of a road to the Agua Clara Filtration Plant. These general features were retained throughout the entire period of design, but the details varied considerably from time to time. When the limits of the carbonaceous muck were accurately defined and flatter excavation slopes in that material had been adopted, the western limits of the southern half of the area were moved eastward. The decision not to backfill most of the left north approach wall reduced the required rock storage by nearly 50 per cent, thus decreasing both the area and the height of the rock stock pile. In the final stages of the excavation, a large deposit of carbonaceous muck was encountered that had not been disclosed by previous drilling. At this time Spoil Area I was one of the few remaining areas not nearly completed, so that the muck could be disposed of most readily in that area. The entire southern third, (above the material already in place), was used for that purpose. It was also apparent then that not enough rock remained to be excavated to bring the rock stock pile to its designed shape. Accordingly, the base of the area was completed as closely as possible to the design, and the field forces determined the area and the height of the rock stock pile. Approximately 1,200,000 cubic yards of all classes of excavation were contained in the area in its final form. Rock excavated by the masonry contractor will be stored temporarily above the present stock-pile material in sufficient quantity to overcome the backfill deficiency.

Spoil Area II

17-34. Spoil Area II was located in a small pocket between the locks excavation and the grade of the existing railroad to the west of the north approach wall and north of the Fort Davis Station. It was to contain 113,000 cubic yards of earth and would be used principally to make adjacent bridge-approach fills for the railroad and highway on the west side. Relocation of the locks southward destroyed its useful proximity. Meanwhile, the presence of deep tongues of carbonaceous muck both north and south of the spoil area was disclosed by subsurface explorations, so that it became unsafe to load the area as heavily as was originally intended. About 22,000 cubic yards of earth that already had been placed in the bank were allowed to remain in place. A portion of this will be reclaimed for use as impervious backfill in the vicinity of the right north approach wall.

Spoil Area III

17-35. Spoil Area III was designed to contain approximately 1,000,000 cubic yards of carbonaceous muck estimated to lie within the limits of the dry excavation. This material would take several years to consolidate and was valueless as backfill. A separate spoil bank, enclosed by dikes of good earth, was selected west of the Plug Crossover between Keyes Road and the low hills occupied by the Gatun Silver Camp. The dikes were necessary to restrain the very plastic muck, and conformed to the alignment of the Warehouse Spur. They served also to support Jadwin Road as originally aligned north of the Silver Camp. Channels through the west dike permitted continuous draining of the impounded muck. The flow line through these channels would have been raised by flashboards as the height of the impounded fill rose. Provision was also made for the final surface to drain through high-level culverts under the railroad spur and the road.

17-36. As an alternate to the area occupied by Spoil Area III, a portion of the disposal grounds for suction-dredge spoil, north of Mindi Bridge, was set aside in the event that the contractor preferred to excavate the muck by wet methods. This proved to be the contractor's preference. Consequently Spoil Area III was abandoned, and an improvement in the alignment of Jadwin Road was possible. Near the end of the excavation, a part of the muck not removed by wet methods was disposed of within the area originally covered by Spoil Area III.

Spoil Area IV

17-37. Spoil Area IV occupied an area west of the new channel which was bounded by the existing railroad, Jadwin Road, Schoolhouse Road, and the alignment of the Warehouse Spur. Most of this ground, including the profile of Jadwin Road, varied from elevation 10 to elevation 20, but the other bounding features were from 10 feet to 30 feet above the higher lev Elevation 65 was chosen for the top of the spoil bank on the railroad sid This height was attained immediately back of the houses along Schoolhouse Road and was maintained for some 1200 feet northward. The drainage from the top was westward toward Jadwin Road. Before construction began it became known that the valley adjacent to Schoolhouse Road was underlain with a deep stratum of carbonaceous muck and could not be loaded heavily at its edge. The design was changed so that the spoil bank was raised only to an average elevation of 30 feet at the north edge of the valley. This top elevation was extended northward until a position was reached where it was believed safe to bring the bank to its full height, which was reduced to elevation 62. To compensate somewhat for the loss in volume thus occasioned, a natural depression north of the high bank was filled in to an average elevation of 25. This new fill extended some 300 feet farther north to close against a low ridge. The slopes of the high bank toward the railroad and Jadwin Road were originally designed to be natural slopes for the spoil, with the toes kept back about 50 feet from the center line of the railroad and the near edge of Jadwin Road. At the same time that the fill height was reduced on the Schoolhou Road end, a slope of 1^v on 3^h was designed for the face toward Jadwin Road

17-38. It was intended that the northern, low portion of the spoil area be constructed of earth, that the remainder of the area below the level of the railroad subgrade be of mixed earth and rock, and that only rock for subsequent use as backfill be stored above this level. The Lock Crossover Spur and the Bolivar Highway Connection passed over the spoil area, but at lower elevations than the top of the high bank. The backfill reclaiming was designed to remove all the material between the spur track and the locks to the elevation of the backfill, to remove enough between the spur and the highway to ensure clear vision for vehicular traffic, and to grade north of the highway to the general level of the highway subgrade.

17-39. Late in 1941 it was determined that the houses in the valley adjacent to and north of Schoolhouse Road would be removed in time to permit the excavation contractor to fill this valley and complete the fill for the Locks Crossover Spur between Spoil Areas IV and V. The earlier conception had been that this work would be done by the masonry contractor in connection with backfill and general landscaping in the vicinity. The design of the spoil area was revised to extend the low, southern portion across the valley to connect with Spoil Area V and upon this to build the railroad fill. The top elevations of this portion were revised to agree with the final backfill grades in the vicinity. Drainage of the pocket thus created was accomplished by a pipe culvert under the Locks Crossover Spur and on top of the pavement of the abandoned portion of Schoolhouse Road. In this manner, firm foundations were obtained and the old concrete road surface below the culvert could serve as a spillway for the heavy flow. A ditch, parallel and adjacent to Jadwin Road and intersecting Schoolhouse Road, was designed to pick up this drainage and the runoff from Spoil Area V and carry them to a natural channel under Jadwin Road.

17-40. The decision to backfill only a portion of the right north approach wall, thereby reducing the amount of backfill to be reclaimed from Spoil Area IV, and the movement of the Locks Crossover Spur eastward to obtain better foundation conditions, necessitated reconsideration of the manner in which backfill material would be reclaimed. Construction of the portion of the spoil area from which backfill would be taken had been completed and excess material was available. The redesign of the final shape of the bank retained all the desirable features of the original design except that north of the highway connection it left a mound of rock for which there is no immediate use. As finally designed and constructed, Spoil Area IV contained about 1,318,000 cubic yards of spoil. Very little earth was used in its construction.

Spoil Area V

17-41. Spoil Area V filled a valley between the existing railroad, Schoolhouse Road, and Jadwin Road. The original designs called for a top elevation of 65 feet. This was later lowered so that it would correspond roughly to the elevation of the adjacent railroad subgrade, and was sloped upward to the west to reach the subgrade of the Locks Crossover Spur. The slope downward from the spur subgrade to Jadwin Road was 1^v on 3^h. The eastward movement of the spur changed the grading of this portion of the area to follow that of Jadwin Road and permitted the use of a 1^v on 2^h slope for the railroad fill. The addition of a road along the eastern edge of the area to give access to a permanent building in the northeast corner, formerly served from Schoolhouse Road, involved minor changes in the drainage and elevations in the vicinity. As finally designed, Spoil Area V contained about 201,000 cubic yards of mixed spoil.

Spoil Area VI

17-42. This spoil area occupied rough terrain west of and adjacent to the new locks between Stations 117 and 147 on the lock axis. It was bounded on the north by a bend in Schoolhouse Road, on the west by the railroad main line and buildings along Schoolhouse Road, on the south by Bolivar Highway, and on the east by the excavation for the locks. High Street was located on a ridge that traversed the spoil area from east to west and divided the spoil area into two distinct parts. The treatment and history of the two parts of the area are so different that separate discussion of them is warranted.

17-43. The portion south of High Street was known as Spoil Area VI-A. Its bounding features, except to the west, were all above elevation

100. Two streams ran through it in deep ravines that joined at its western extremity at approximately elevation 25 and flowed under the railroad in a box culvert. The area to be filled averaged 1700 feet in length from north to south and 700 feet in width. The western edge of the area was limited by the location finally selected for Jadwin Road, which determined the elevations and the shape of the spoil area.

17-44. The original design filled the valleys at the southern end to the approximate elevations of Bolivar Highway. The layout consisted of a series of terraces that sloped northward to the general elevation of the grading around the High Street houses. The grade of Jadwin Road was lower throughout most of its length than the elevations established for the spoil bank, and the toe of the higher spoil was maintained at 50 feet from the near edge of the road. West of Jadwin Road, in the northwest corner of the area, the spoil sloped downward to meet the elevations of the railroad subgrade. Material placed in the area below the profiles of Jadwin Road and the railroad was to be a mixture of earth and rock. Above these elevations, and covering most of the area east of Jadwin Road, the spoil rose to elevation 140 and was to be entirely of clean rock. The toe of the eastern face of the spoil bank where it rose above the natural ground was kept back 100 feet from the top of the locks excavation.

17-45. A sanitary sewer that was exposed along the western edge of the area was relocated to protect it from damage during the placement of the spoil. A storm sewer that discharged at a low elevation into the upper valley was picked up at a convenient manhole, and pipe was laid to carry it to the east side of Jadwin Road, thence along Jadwin Road to a point midway of the area, where the water could be carried under the road and discharged to the west into the area occupied by Spoil Area VII. Manholes along this storm sewer were constructed with catch-basin tops so that the sewer would also carry off surface water. Surface collection north of the point where the storm sewer turned west was carried to the northern end of the area, passed under Jadwin Road in a pipe culvert, and was eventually disposed of through a high "glory-hole" inlet into the existing box culvert under the railroad.

17-46. The design of the area was later modified to eliminate the stored rock and to use a more gradual slope from south to north for the higher portion of the bank. This created a flat area some 15 acres in extent, at a convenient level and close to the locks, for the plant of the masonry contractor and for ultimate development by The Panama Canal as a site for a community center and additional quarters. The south end against High Street was modified to provide a greater distance from the houses to the high portion of the area. The construction followed the designs very closely, except that the eastern face was moved to within 25 feet of the top of the locks excavation. Approximately 1,750,000 cubic yards of mixed spoil were accommodated.

The surface of the spoil area will be modified by backfill reclaiming only in the southeastern corner where stored earth will be borrowed for use as top dressing.

17-47. Spoil Area VI-B, north of High Street, also covered rough terrain through which ran a low-level stream that discharged into a culvert under the railroad embankment. To ensure free runoff around the houses on High Street, the spoil was designed to be placed to elevation 80 at the east face and to elevation 75 at the west face. The bank was extended northward at these same elevations to the maximum limit permitted by a bend in Schoolhouse Road. The toe of the east face was kept back 100 feet from the top of the excavation for the locks. The west face was back far enough from the railroad to permit the collection of the drainage from the spoil area between the toe of the bank and the railroad. This ditch flowed northward to pass under Schoolhouse Road in a pipe culvert, and then turned westward to pass under the railroad through a culvert that discharged into Spoil Area IV. The material in the bank was to be mixed earth and rock.

17-48. The spoil bank was constructed entirely of earth with the toe of the east face 25 feet from the top of the locks excavation. The proximity to the cut slope was to avoid pocketing surface drainage. Subsequent changes in the design of the lock walls necessitated cutting back this slope, so that the finished face was a continuation of the cut slope of the locks excavation. The top was redesigned to provide a parking area at elevation 95 to serve the observation platform in the southeast corner, and to slope westward and northward from elevation 85 at the foot of the parking fill to elevation 75 along the railroad and at the bend in Schoolhouse Road. From here, the slope dropped to natural ground at elevation 50 about 200 feet farther to the north.

17-49. The spoil area contained about 260,000 cubic yards of earth. All but about 30,000 cubic yards will be reclaimed for backfill purposes. Reclaiming will be accomplished in the following manner: Beginning on a line 200 feet north of and parallel to the center line of High Street and using a 1^v on 2^h slope to reach the elevation of the lock wall at that point, all stored and natural earth will be removed above the elevations of the lock wall and between the excavation for the locks and Spoil Areas IV and V northward to where the natural ground is below these elevations. This material will be used for backfilling and landscaping west of the lower chamber and the north approach wall. Its removal will prepare sites for machine shops, wash rooms, parking, and other areas needed at the locks.

Spoil Area VII

17-50. This spoil area lay west of Spoil Area VI and filled a valley bounded by Schoolhouse Road on the east and north, by the railroad on the northwest, by Lighthouse Road on the southwest, and by Bolivar Highway on the south. The limiting terrain sloped from elevation 150 along Bolivar Highway to elevation 85 at the railroad. Two streams, one from the southwest and the other from the southeast, converged to pass under the railroad in a single box culvert at approximately elevation 30. Two houses were located in the northwest corner at elevations lower than the railroad subgrade and were scheduled to be removed at an early date. Accordingly, the first design ignored these houses and called for the fill to be brought to the subgrade level at the railroad, to slope gently for 280 feet to elevation 85, to rise to elevation 90 in the next 10 feet, to slope for 250 feet to elevation 95, and thence to rise at a slope of 1^v on 6.5^h to elevation 145. Above this elevation the slope was variable until elevation 148 was reached behind the houses along Bolivar Highway. The faces of the slopes were parallel to the railroad for most of their length, but above elevation 100 part of the face of the 1^v on 6.5^h slope turned to the southeast to form a series of terraces facing Schoolhouse Road. Surface-water collection was generally in a northeasterly direction, and drainage from the upper half of Spoil Area VI-A, which discharged from the subsurface pipe onto Spoil Area VII at its most easterly point, was added to the normal drainage from Spoil Area VII. It was planned to carry all this surface water to the railroad and dispose of it into natural channels beyond the railroad through a new high-level culvert.

17-51. The sudden and large expansion of civilian personnel that took place on the Canal Zone in 1940 and 1941 required that the dwelling houses remain in service. Stability analyses of the railroad fill indicated that it would not support the full height of the fill as proposed. Consideration was given to placing a low fill on the other side of the railroad grade. The final design of the spoil area did not make use of that stabilizing device but took the following form.

17-52. The fill adjacent to the railroad was lowered to elevation 65 (which was lower than the ground around the lower of the two houses) to form a pocket into which all the surface drainage would come. Here the water entered a vertical "glory-hole" inlet into the original culvert under the railroad. At the back of this pocket, approximately 100 feet from the center line of the railroad, the fill rose at a 1^v on 2^h slope to elevation 82. It then sloped upward on a 2-per-cent grade to elevation 95, then on a 1^v on 1.5^h slope to elevation 125. Above this it rose gently to close against the natural ground under Bolivar Highway at elevation 128.

17-53. About 744,000 cubic yards of spoil, mostly rock, was contai in the bank, none of which will be reclaimed as backfill. The development of Spoil Area VII created ground for future expansion of the quarters area served by Schoolhouse Road.

Spoil Area VIII

17-54. Spoil Area VIII converted an arm of Gatun Lake into an extensive area for use of succeeding contractors and for the future development of the town. Stilson's Pond, as it was called, lay south of the town of Gatun and had been isolated from the main body of Gatun Lake by the fill for the main line of the railroad. Stilson's Pond formed a drainage basin for a watershed of some 110 acres which was bounded on the north by the ridge along which ran Bolivar Highway, on the east by the excavation for the locks, and on the south by the hills of the East Ridge. It was maintained at the elevation of Gatun Lake by a 4-foot diameter equalizing culvert under the railroad fill. This culvert had been built on solid ground at approximately elevation 50, although the general level of the bottom was considerably below this and at one point dropped to elevation 12. An exposed sanitary outfall sewer was located along the northern edge of the spoil area. The contractor was required to protect this sewer.

17-55. The original design called for spoil to be placed to elevation 90 at the railroad and to rise toward the east to elevation 110 on a slope of 0.2 per cent. From a ridge created at elevation 110, the surface of the spoil sloped downward to elevation 100 at a point about 100 feet west of the locks excavation. Drainage of the surface was to have been accomplished by high-level culverts under the railroad. On the north side and near the center of its length, a mound of spoil rose above the general level of the surface to form a wide bench at elevation 145 against Bolivar Highway. This bench was created to assist the fulfillment of long-range planning by The Panama Canal for replacement of certain recreational units.

17-56. Studies as to the size of the culvert openings needed, the interference of existing installations along the railroad to the placement of these culverts and the ability of the railroad fill to support the full load of the adjacent spoil led to changes in the design.[7] To relieve the pressure against the railroad fill, a basin approximately 500 feet long by 300 feet deep was left slightly to the north of the middle of the fill. This basin reduced the required area of the waterway under the railroad fill, and a liner-plate culvert, 8 feet 5-1/2 inches in diameter, was selected after comparative designs and estimates had been made of various types and methods of construction. The culvert had its flow line at elevation 79.5. As an added protection against failure of the railroad fill, dredged spoil (rock from the north approach channel excavation) was placed to elevation 52 on the Gatun Lake side for the full length of the fill and for a top width of about 700 feet. The general slope of the surface of the spoil area remained unchanged except that it was extended eastward to an elevation of 113 at the top of the face against the locks excavation. The platform against Bolivar Highway remained, but an auxiliary bench that was formed below it sloped westward from elevation 125 to elevation 95 and was located so as to allow the future extension of Jadwin Road down over the spoil to the area around the existing locks. A storage pile of clean rock suitable for backfill purposes was also added to the design at this time. This material was stacked in the southeast corner and along the southern edge to elevation 145. It measured about 400 feet in width from south to north and 800 feet in length, and rose on natural slopes above the general level of the area.

17-57. Two other changes in the design were made at a later date. The elevation of the spoil around the rim of the drainage basin and along the railroad was raised from 90 to 94. At the extreme eastern end, the spoil area was extended to meet the embankment of a haul road constructed by the contractor to elevation 100 along the top of the excavation. In this manner, pocketing of local drainage was avoided and the ultimate usefulness of the area adjacent to the new locks was increased.

17-58. The material used to create the spoil area was mostly rock. Computations of the quantities contained in it gave a volume of 4,038,000 cubic yards, but no allowance was made for subsidence into the soft bottom of the pond by the superimposed material. The shortages of material that ultimately developed during the completion of Spoil Areas I and IX may have been caused in part by this factor of subsidence.

Spoil Area IX

17-59. Spoil Area IX was not included in the original designs for disposal of the excavated materials, although it was recognized from the beginning as a possible spoil bank. It was designed and added to the other spoil areas at the request of the contractor after work had begun. This area occupied a deep depression east of the locks and opposite Spoil Area VI. The cast-iron pipe that conveyed water from the Stilson's Pond intake to the Agua Clara Filtration Plant followed the bottom of the depression. The original plans called for the valley to be filled with mixed earth and rock to elevation 95 on the west rim and to slope downward to the northeast away from the locks. Above this elevation and to the north of the center, a storage pile of clean rock was to be placed for later use as backfill. This pile sloped from elevation 135 at its western rim to carry the surface drainage toward the middle of the area, whence it flowed eastward. Another pile was located south of the middle of the area. It was designed to be of mixed earth and rock but was actually constructed of clean rock, rising to elevation 135 on its northwestern rim and sloping downward to the southeast to carry its surface drainage into the natural channel that ran along the eastern face of the whole area. An existing Army road ran southward along the western edge of the area and it was necessary to maintain traffic along this road at all times during the placement of the spoil. The design called for a top surface approximately 2000 feet long, parallel to the locks, and 1000 feet wide. The ground underneath the spoil varied in elevation from 45 to 95.

17-60. Construction of the spoil bank to the 95-foot level was carried out early in the excavation period. It did not reach the designed limits, however, but stopped about 400 feet short of the northeast extremity. In the latter stages of the work, when it again became convenient for the contractor to spoil in this area, not enough material remained to complete it as designed. The north half above elevation 95 was used in part to store some of the carbonaceous muck unexpectedly found in the lower chamber area. The south half above elevation 95 approximated the design. The base of the area to elevation 95 was extended very little beyond that completed during the first stage. It is contemplated that a portion of Spoil Area IX adjacent to the locks will be used for shops and plant in connection with the use of the lock chambers as dry docks.

17-61. The spoil area as designed contained 2,188,000 cubic yards of earth and rock. This volume was not obtained, but it will be possible to reclaim all the pervious backfill that can be hauled economically from this area. One of the portions of the spoil area that was not filled to its design grade will be used to dispose of the material excavated by the masonry contractor and not needed for pervious backfill.

Roads and Highways

17-62. Bolivar Highway was the only road between Gatun and the other towns on the Atlantic side of the Canal Zone. South of Fort Davis, the position of the highway with respect to the new locks was such that only a short piece would be of service at the conclusion of the excavation period. Two roads joined Bolivar Highway on the west: (1) Keyes Road, which was the only access to the Atlantic Terminal Depot, and (2) Schoolhouse Road, which provided an access to the north end of Gatun. Three roads joined Bolivar Highway on the east: (1) Sykes Road, which entered the military reservation near its southern boundary, (2) Agua Clara Road, at the end of which were the filtration plant and the shops for the maintenance of the municipal utilities of the Gatun Area, and (3) A newly constructed road to military installations on the heights above Gatun Lake. All these roads would be affected by the excavation for the Third Locks, and it was essential that the services they represented be maintained constantly. Their positions with respect to the new locks construction are shown in Figure 17-1 and in Plate 17-1.

17-63. During the construction period, only one road could be provided to enter Gatun from the east via the north land plug. Similarly, the swing bridge would provide only one road from the east as a permanent feature. Therefore, it was necessary to design a new network of roads for the area between the locks to replace temporarily and permanently the services performed by Bolivar Highway, Schoolhouse Road, and Keyes Road.

17-64. Highway standards in use by The Panama Canal called for 18-foot pavements with 5-foot shoulders, maximum grades of 6 per cent, and maximum curvatures of 15°. These standards were used in the design of all relocations and new roads in connection with the Third Locks, with such modifications as were found desirable to meet actual conditions and probable future needs.

Bolivar Highway

17-65. Work was in progress, as a Panama Canal improvement projec on a relocation of about 1 mile of Bolivar Highway in the vicinity of Fo Davis to by-pass the built-up area of Fort Davis for all but military traffic and to rectify the poor alignment existing within the military reservation and south of it along the shore of Gatun Lake. When it appeared that authorization of the Third Locks Project was imminent, work on the relocation was immediately halted.

17-66. Since highway traffic would increase with the inception of the Third Locks work, it was essential that the by-pass portion be completed before or soon after the arrival of the excavation contractor. An effective by-pass was created by the retention of the original tangen at the north end of the by-pass, which preserved all the construction to date, and the use of the flattest curve possible between this tangent an Keyes Road just north of its origin in Bolivar Highway. This section wa constructed with a concrete surface because its greater portion would form part of the final relocation of Bolivar Highway and because of its nearness to the site chosen for the relocation of the Fort Davis stables and motor pool.

17-67. The extension of the Bolivar Highway alignment, which would ultimately connect the between-locks area with Fort Davis and Colon, was originally designed to be a projection of the back tangent of the by-pass just described. This projection crossed over the drainag canal and under the railroad, and then turned sharply to the south to pass over the bridge across the locks. A temporary connection to Keyes Road, and a new highway called Jadwin Road which is discussed in subsequent paragraphs, created temporary access to the between-locks area from the curve just west of the overpass structure.

17-68. The shift in the position of the drainage canal and the revision in the location of the railroad that followed the failure of the railroad embankment (see Paragraph 17-15), changed the location of the bridge over the drainage canal and eliminated the overpass. The position of the permanent highway crossing of the railroad was shifted to the south and again temporarily extended westward to Keyes Road. Since the new railroad station lay north and the permanent locks crossing lay south of the grade crossing, the former curve to the south was replaced by an intersection. The permanent extension of Bolivar Highway to Jadwin Road via the bridge was given the name of "Bolivar Highway

Connection." Its general location is shown in Figure 17-4. Details of the design are shown on the contract drawings.[6] No particular problems were encountered in the design, but special treatment of the paving was necessary at the approaches to the bridge over the locks, where rapid divergence from the common center line with the railroad occurred.

Jadwin Road

17-69. The only site suitable for a laborers' camp for the new Gatun Locks lay north of Schoolhouse Road and west of the new locks channel. Plans for this camp therefore fixed the position of Jadwin Road immediately north of its intersection with Schoolhouse Road. The continuation of this alignment northward to Keyes Road was a logical step, but its exact position and its profile were affected by the location of the warehouse spur and the limits of the spoil banks originally planned for that area. The change in the location of the warehouse spur because of the abandonment of the spoil area and the contemplated expansion of the Atlantic Terminal Depot had its corresponding effect on the alignment and profile of Jadwin Road. South of Schoolhouse Road, the original design contemplated only the replacement of the portion of Schoolhouse Road that passed through the existing section for colored employees. The alignment was tortuous in order to avoid excessive excavation in the adjacent hills and to avoid the superimposition of heavy fills on a base of known structural weakness. As the design of the spoil areas in the vicinity progressed, it became apparent that by the use of a short stretch of steep grade a favorable alignment for Jadwin Road south of Schoolhouse Road could be obtained without seriously reducing the quantities of spoil to be accommodated and with the added advantage of by-passing the existing, narrow, crooked roads between the railroad and the southern limit of Gatun. The steep grade mentioned was necessary to reach the elevation of the existing railroad where such an alignment would cross it. The final alignment was developed on these bases and the vertical curves at each end of the 8-per-cent grade were made continuous so that the grade could not seriously retard traffic. The center line was established to allow ultimate widening of the pavement up to 27 feet. Across Spoil Area VI, the profile was raised enough above the level of the spoil to give adequate subgrade drainage. Panama Canal forces constructed Jadwin Road in its entirety, with a surface of bituminous macadam. The final plans were prepared by the Office Engineering Division, but were reviewed and adjusted by the Special Engineering Division to coordinate them with the designs of the spoil areas and the railroads in the vicinity. Figure 17-4 shows the final position of Jadwin Road.

Schoolhouse Road

17-70. Relocation of Schoolhouse Road was not necessary. It will be noted from Figures 17-1 and 17-4 that the general purpose originally served by Schoolhouse Road east of its intersection with Jadwin Road was both temporarily and permanently fulfilled by Bolivar Highway Connection and Jadwin Road. Between Jadwin Road and the excavation for the locks there were 5 buildings adjacent to and serviced by Schoolhouse Road. Four of these were removed during the excavation period and access to th remaining one was obtained by a road off Jadwin Road over Spoil Area V.

Sykes Road

17-71. The original designs for the railroad relocation and the drainage canal necessitated relocation farther east of a portion of Sykes Road. The grading for this section had been partially completed when the railroad and the canal alignments were modified after the failure of the railroad embankment. The revised alignment for the canal required a culvert under Sykes Road, and the final alignment for the railroad in the vicinity eliminated the interference that formerly existed, and made unnecessary the relocation of Sykes Road.

Military Road

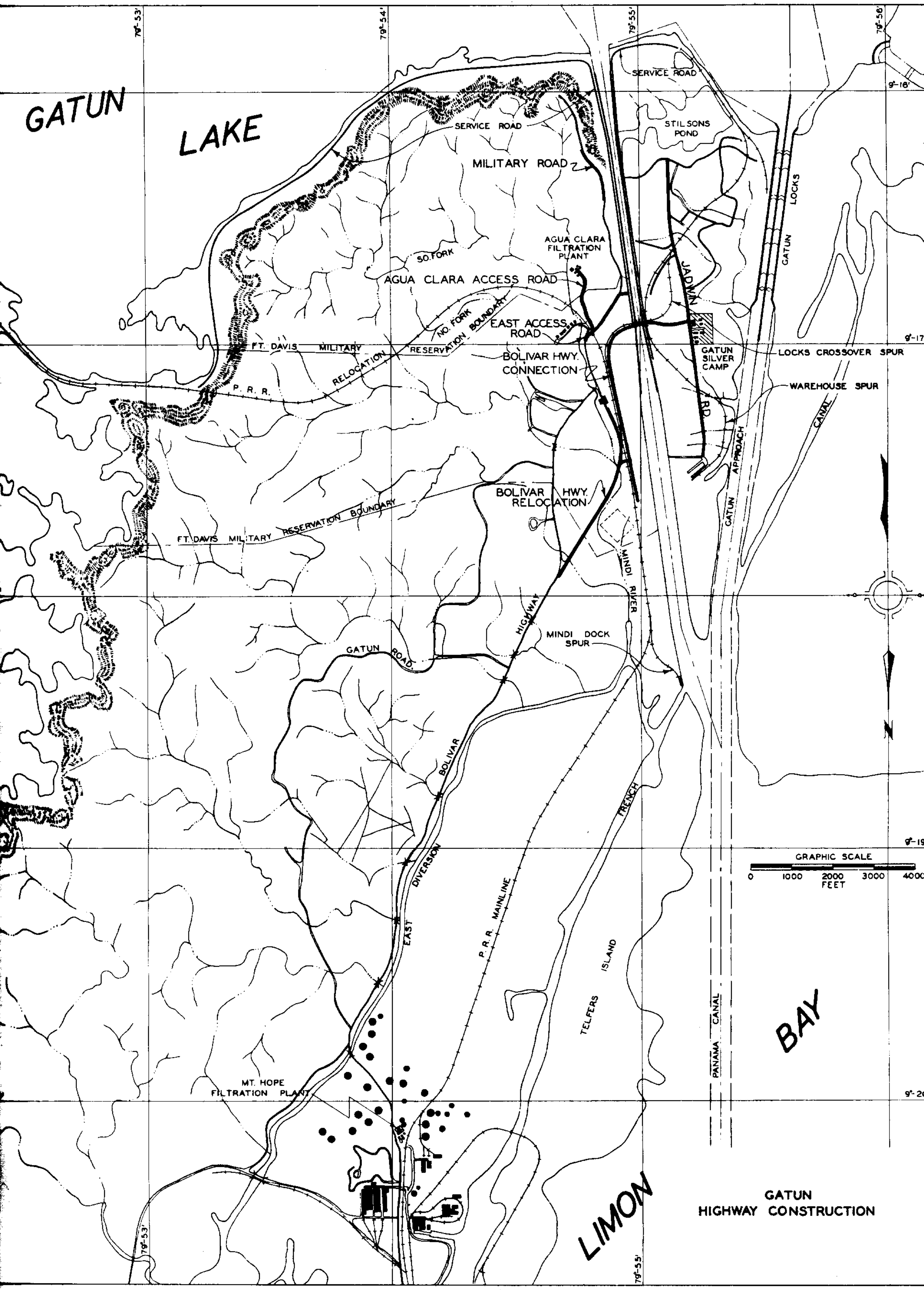
17-72. The military road leading to installations on the ridges bounding Gatun Lake branched off from Bolivar Highway at the head of Stilson's Pond. Spoil from the locks excavation would be placed into a deep gorge immediately east of the road (Spoil Area IX). It was possible for the contractor to coordinate his work and maintain access constantly to this road and this responsibility was placed upon him by the specifications. The actual temporary and permanent positions for this road were determined by the field forces guided by a very detailed study of the possibilities for various roads in the Gatun area.[8]

Agua Clara Road

17-73. Placement of spoil from the locks excavation would interfere with Agua Clara Road. Here again it was possible for the contracto to plan his activities to provide continuous access to the filtration plant, and he was so enjoined by the specifications. The design of the spoil area included an alignment for the permanent replacement of the Agua Clara Road so that the final position of this road would meet the conditions necessary to serve all interests.

Access Roads to Locks Service Roads

17-74. From the final location of the Agua Clara Road, a road designated as the "East Access Road" was designed to connect the roads



GATUN
HIGHWAY CONSTRUCTION

FIGURE 17-4

outside the locks area with the system of roads on the backfill on the east side of the new locks. Thus the crossing over the lower gates will be made available to traffic originating outside the locks area. A similar connection is contemplated for the west side of the locks, but there it will be made an integral part of the parking area and machine-shop layout to be designed for that side.

Structures

17-75. Except for the bridge over the drainage canal (see Paragraph 17-87) in connection with the Bolivar Highway relocation, no special structures were required by the highway relocations discussed above. The design of the bridge over the locks is discussed in Chapter 15.

Drainage Canal

17-76. It will be noted from Figure 17-1 that two well-defined streams, flowing generally in an east-west direction, traversed the Third Locks area within the limits of the dry excavation. It was necessary to intercept and divert these streams at an early date to permit the excavation contractor the maximum freedom from interference by surface waters. The intercepting channel had to lie to the east of the railroad relocation to avoid multiple crossings under the railroad, and to permit the most advantageous use of the terrain between the railroad relocation and the excavation for the locks for the placement of spoil. After picking up all the cross drainage, the channel either could pass under the railroad and empty into the new canal or could continue northward to empty into the East Diversion near Mindi.

Selection of Route

17-77. The Agua Clara Reservoir was the original water supply for the town of Gatun and had been created by constructing a concrete spillway across an outlet from the valley that faced north, and an earth dike across an outlet that faced west. A 36-inch cast-iron pipe, pierced this dike at the level of the valley floor, and permitted water to flow to the filtration plant. This pipe was used to lower gradually the impounded waters after the abandonment of the reservoir. The effluent from the pipe entered the natural channel of a stream that roughly paralleled the alignment of the Third Locks channel and passed between the dike and the filtration plant. This condition is shown in Figure 17-1.

17-78. Consideration was given to removing the spillway and draining the valley to avoid the periodic saturation of the railroad fills that crossed the basin, but the estimated cost rendered this scheme impractic Efforts thereafter were directed toward finding the best alignment possi in the narrow area between the railroad relocation and the built-up port of the military reservation, with the starting point of the drainage can about 200 feet south and 200 feet west of the confluence of the discharg from the 36-inch pipe and the natural channel.

17-79. The more northerly of the two streams emptied into the Can through two channels, as shown in Figure 17-1. These were formed just west of Bolivar Highway where the culvert under the highway had been built with two outlets to throw part of the discharge to the south and west, and the remainder directly west. To retain this split of the discharge meant that the section of the drainage canal would have to be increased from the intersection of Keyes Road and Bolivar Highway northward. It was therefore decided to block the southwesterly mouth of the culvert and improve the westward channel so that it could take the entir flow. This channel was designated as the "tributary ditch."

Original Design

17-80. The alignment adopted is shown by the heavy, dashed line in Figure 17-5. After passing under the railroad relocation in a due north direction, it swung northwesterly to parallel the railroad. The position of the center line was adjusted to provide a minimum berm of 15 feet between the toe of the railroad fill and the top of the drainage canal cut slope. Consequently, each shift in the location of the railroad had its corresponding adjustment of the drainage canal alignment.

17-81. The profile began at elevation 18.50. This elevation was approximately 2-1/2 feet higher than the bottom of the stream entering from the north, but slightly lower than the mouth of the 36-inch pipe. The resultant silting of the upstream portion of the bed was estimated to be unimportant, and a considerable quantity of excavation was thus saved. The first 1500 feet was on a slope of 0.1 per cent, and the following 1300 feet on a grade of 0.31 per cent to a drop structure that lowered the profile 7.5 feet. A grade of 0.04 per cent extended for 400 feet northward to a spillway located in firm material just north of the north boundary of the military reservation. The spillway lowered the profile to elevation -3.00, with the bottom of the drainage canal rising sharply below it to natural ground at approximately elevation 1.0. Past this point, the waters were free to flood over the low ground northward and reach the East Diversion through existing natural channels.

17-82. At the upper end, the ditch had a 4-foot bottom width. This increased to 5 feet at the downstream end of the 7- by 8-foot culve under the railroad relocation, and the width was increased further to 7 feet a short distance north of Sykes Road. The transitions were made

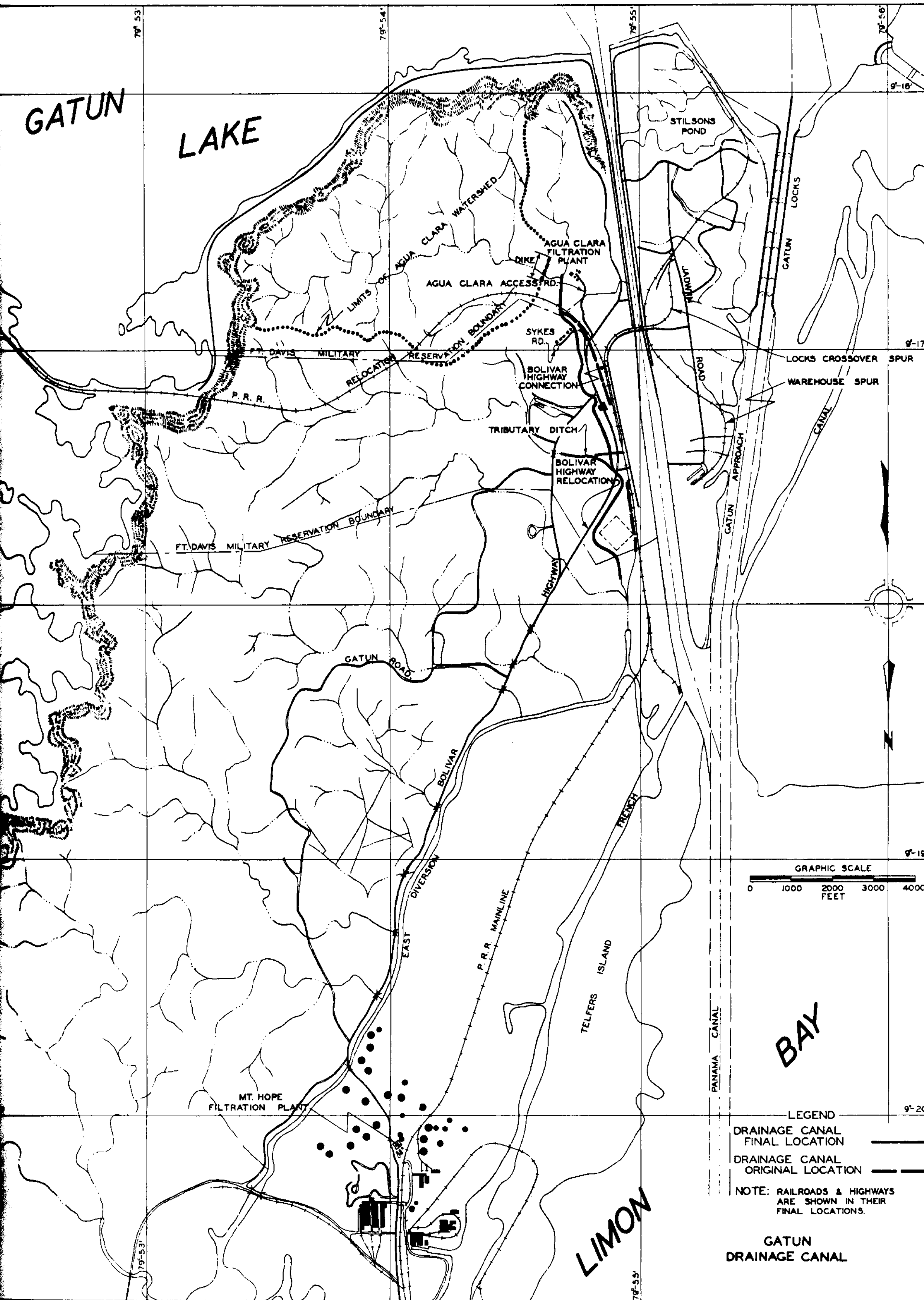

GATUN
LAKE
LIMON
BAY
STILSONS POND
AGUA CLARA FILTRATION PLANT
DIKE
AGUA CLARA ACCESS RD.
LIMITS OF AGUA CLARA WATERSHED
SYKES RD.
FT. DAVIS MILITARY RELOCATION RESERVATION BOUNDARY
FT. DAVIS MILITARY RESERVATION BOUNDARY
P. R. R.
BOLIVAR HIGHWAY CONNECTION
TRIBUTARY DITCH
BOLIVAR HIGHWAY RELOCATION
BOLIVAR HIGHWAY
GATUN ROAD
JADWIN ROAD
GATUN LOCKS
LOCKS CROSSOVER SPUR
WAREHOUSE SPUR
GATUN APPROACH CANAL
EAST DIVERSION
P.R.R. MAINLINE
FRENCH
TELFERS ISLAND
PANAMA CANAL
MT. HOPE FILTRATION PLANT
79°-53'
79°-54'
79°-55'
79°-56'
9°-16'
9°-17'
9°-19'
9°-20'
N
GRAPHIC SCALE
0 1000 2000 3000 4000
FEET
LEGEND
DRAINAGE CANAL FINAL LOCATION
DRAINAGE CANAL ORIGINAL LOCATION
NOTE: RAILROADS & HIGHWAYS ARE SHOWN IN THEIR FINAL LOCATIONS.
GATUN DRAINAGE CANAL

FIGURE 17-5

in short reaches. The tributary ditch joined the drainage canal almost at a right angle. The width of the main channel was increased at this point to 33 feet, with special paving of the banks of both channels to prevent erosion. The 33-foot width was maintained from that point to the northern end. All side slopes were 1^v on 1^h. The tributary ditch had a bottom width of 24 feet with 1^v on 1^h side slopes.

17-83. The drop structure replaced an originally designed paved section on a heavy grade. The spillway structure was designed to prevent heavy scour with possible undermining of the adjacent railroad fill and excessive silting in the sluggish tide waters of the East Diversion.

Final Design

17-84. The failure of the railroad fill with the consequent filling of the drainage canal excavation immediately adjacent, demonstrated the inadequacy of their original design. After authorization had been secured for greater encroachment on the military reservation, surveys were started to establish an alignment for the drainage canal farther to the east. The result of those field studies and of subsequent work is shown by the heavy solid line in Figure 17-5. The alignment changes began north of the culvert under the railroad at Agua Clara where the canal was carried farther northwest to obtain greater clearance from the houses along Sykes Road. A culvert under Sykes Road was designed to provide a change of direction of 72°17' and was of sufficient length to permit backfilling to original ground level where the excavation came closest to the railroad embankment and the houses. Its alignment from this point northward to the Bolivar Highway Bridge lay entirely east of Bolivar Highway instead of west of it, and followed existing water courses and depressions wherever possible. An existing 7-foot, circular-pipe culvert under Bolivar Highway at Keyes Road was utilized. Culverts on two different alignments were designed to replace this pipe at some future date, but actual experience with the heavy rains of the following wet season indicated the adequacy of the pipe and the channel in the immediate vicinity even under extreme flow conditions. The confluence of the tributary ditch and the drainage canal was redesigned to take place at a flat angle just south of the newly located highway bridge. After passing under the highway, the alignment swung eastward to pass around and behind the Radio Range Station and empty on the low ground in the vicinity of the East Diversion.

17-85. The starting profile elevation remained at 18.50, with a grade of 0.1 per cent for the first 2100 feet. A grade of 0.5125 per cent followed for 400 feet. This stretch was in excellent material and the velocity induced was not of a scouring nature. A grade of 0.27 per cent followed to the existing pipe under Bolivar Highway. The fall through this pipe and the next 100 feet of old, well-established channel lowered the elevation of the Canal from elevation 11.42 to elevation 7.40. From here to its confluence with the tributary ditch the profile grade equaled 0.134 per cent. Below this point the grade was 0.1995 per cent to approximately 700 feet from the end, where a level section was designed to check the flow before the discharging waters spread over the natural ground to reach the East Diversion through several existing channels. A drop of 6 inches in the profile at the upstream ends of the culverts under the railroad and Sykes Road permitted the placing of precast concrete tile below the profile grade for dry season flows, if pooling and consequent breeding of mosquitoes should eventually require it. Because of the firmer material traversed and the greater distance of the mouth from the railroad fill, the drop structure and the spillway were eliminated.

17-86. The 4-foot bottom width was retained only upstream of the railroad culvert at Agua Clara. A 5-foot bottom width was used from the downstream end of this culvert to the junction with the tributary ditch. From the junction to its outfall, the canal was 29 feet wide at grade. Side slopes were flattened from the original 1^{v} on 1^{h} to 1^{v} on 1.5^{h}, except for the section between the Sykes Road culvert and the junction with the tributary ditch where flatter slopes of 1^{v} on 2^{h} were used. The bottom width of the tributary ditch was reduced to 20 feet.

Structures

17-87. As indicated previously, three structures were required to carry the drainage canal under the railroad, Sykes Road, and the Bolivar Highway location. The first mentioned was a 7- by 8-foot box culvert th carries along the bottom the 16-inch cast-iron water main that serves th communities of Gatun, Fort Davis, and Fort Sherman. The second was a 7- by 7-foot box culvert built as a series of chords, with angles between them varying from 10 to 21 degrees. The third was a slab-and-girder bridge with clear span of 47 feet 7-1/4 inches, carrying a 22-foot 6-inch roadway and a 4-foot 3-inch sidewalk.

Transisthmian Electrical Installations

17-88. Figure 17-1 shows that the transisthmian high-tension, power-transmission lines and the transisthmian telephone lines would be interrupted by the Third Locks activities. The relocation of the transisthmian telephone lines is discussed in the following paragraphs. The relocation of the power lines is so intimately associated with the desig of power requirements for the Third Locks that it is included in Chapter of this report.

Transisthmian Telephone Lines

17-89. The Canal Zone telephone system is owned by the Panama Railroad Company, but operation and maintenance are functions of the Electrical Division of The Panama Canal. The three reasons for originally laying the concrete-encased duct line along the Panama Railroad were: (1) A railroad-owned facility was located on railroad right-of-way adjacent to the tracks; (2) The only continuous land communication across the Isthmus was followed; and (3) Accessibility for maintenance was provided by the railroad tracks. Signal cables for the railroad and one of two cables owned by All America Cables and Radio Company also occupied space in these ducts. Continuity of service of these installations was vital, and both temporary and permanent relocations were required.

Selection of Route

17-90. The original studies made for the relocation of this facility retained not only the duct line method of protecting the cables but also the route originally followed. Considerable difficulty was experienced in fixing the position of the necessary manholes with respect to the railroad tracks so as to minimize the interference of telephone repair work with the operation of trains, and also to avoid the necessity of undue widening of the cuts and fills for the railroad subgrade. The Panama Railroad desired a location that would eliminate the proximity of the two structures; accordingly, other routes, outside the limits of the grading for the railroad, were investigated.[9] All were disadvantageous from the point of view of cost because of various combinations of three causes: (1) Length of route; (2) Terrain traversed; and (3) Road construction necessary for original construction and subsequent maintenance.

17-91. The Electrical Division found the use of armored cable satisfactory in similar installations. This factor, combined with the high cost and controversial features of the duct-line method, led to the decision to use armored cable and to the adoption of the following general location: From Mindi to the vicinity of the north land plug the cable follows the railroad relocation on the west and just outside the limits of the grading; from this point a temporary connection is provided across the land plug to the existing system, and at the conclusion of the new locks construction the cables will be extended on the east side through the crossover tunnels to make permanent connections to the existing system on the west side; the existing system will be used forward of the points of temporary and permanent connections, and prior to the removal of the south plug a permanent crossing of the new channel will be made in the vicinity of the plug by means of deeply embedded, submarine-type, armored cables. Because of the modification of the Third Locks program, the permanent crossings have not been constructed.

Design

17-92. The actual design of the detailed route to be followed, the type of cable to be used and the installations of the cables were carried out by the Electrical Division. The crossing of the drainage canal for the cables running to Fort Davis was effected through ducts under the sidewalks of the highway bridge. For the temporary relocation of the transisthmian lines, approximately 6000 feet of 50-pair, 19- and 16-gauge wires, quadded, lead-sheathed, band-armored, paper-insulated cable were placed about 18 inches below the surface of the ground. Placed in the same trench were the signal cables for the railroad and a 25-pair, 19-gauge, lead-covered, band-armored, paper-insulated cable to replace the former cable between the Gatun and Cristobal switchboards. About 4000 additional feet of the 50-pair cable will be required to make the permanent connection, at which time approximately 900 feet of the temporary installation will be salvageable.

17-93. Access for maintenance of the section lying between Stilson's Pond and Quebrancha along the former railroad location will be obtained by converting into a road the old railroad roadbed, from which the rail is expected to be salvaged. These roads are shown in Figure 17-4. The locks service roads to which they connect are at approximately the same elevation as the old roadbed, and the extension of them to the railroad eliminates the construction of expensive, parall roads at higher levels. Elsewhere along the route, no special construction is necessary for maintenance purposes.

Elimination of Agua Clara Filtration Plant

17-94. The Agua Clara Filtration Plant received its raw-water supply through a 20-inch gravity line from Stilson's Pond, an arm of Gatun Lake. After purification, the water was pumped to a 250,000-gallon concrete storage tank located on the ridge bounding the north shore of Gatun Lake. This 12-inch pumping line served also as the supply line for the towns of Gatun, Fort Davis, and Fort Sherman.

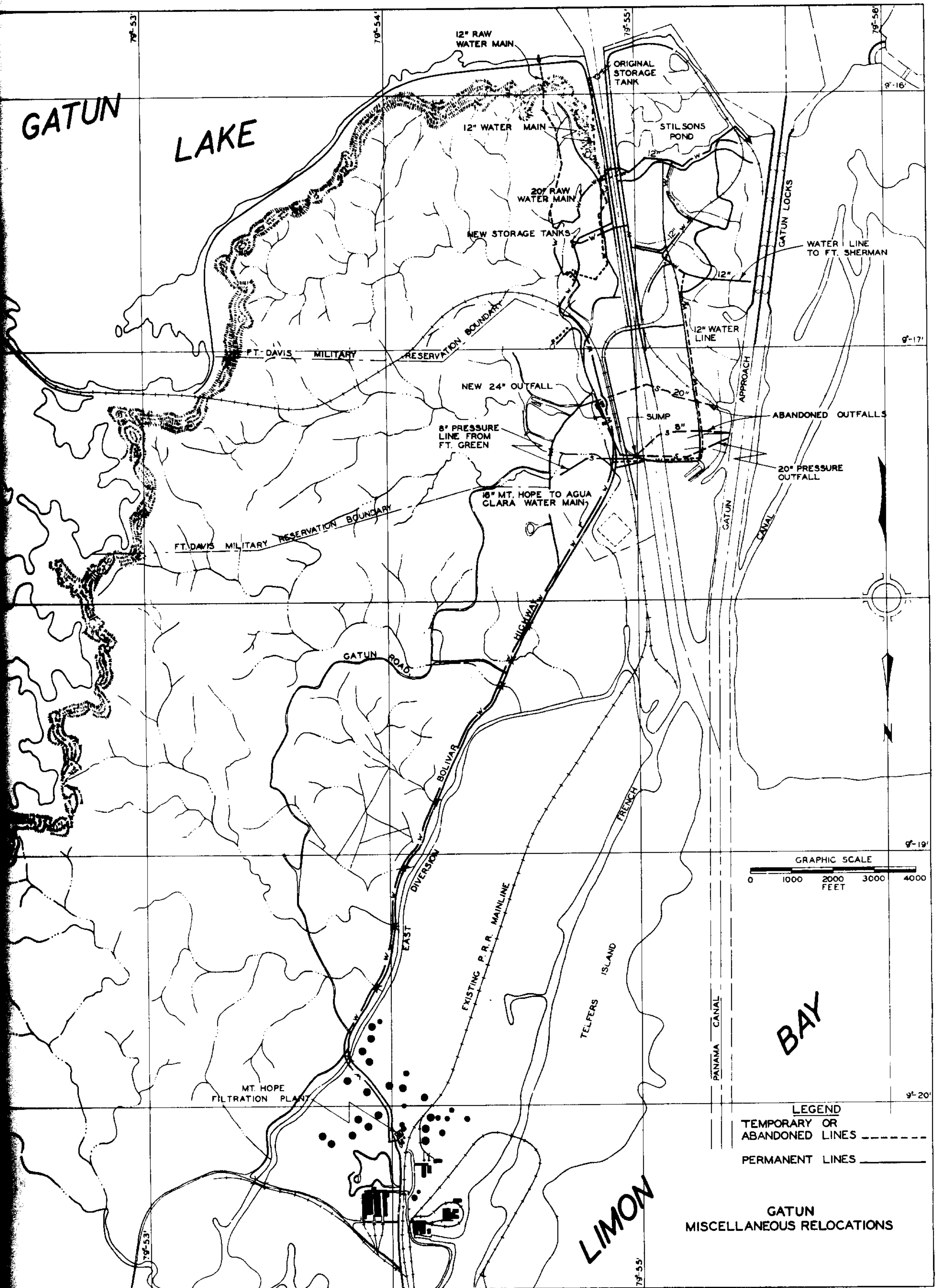
17-95. Prior to the definite plans for the Third Locks Project, designs had been completed, funds obtained in part, and work begun to eliminate the Agua Clara Plant for economic reasons. The new supply was to be a 16-inch pumping line from the Mount Hope Filtration Plant to two steel standpipes located on a hill east of the Third Locks channel and opposite the town of Gatun. Distribution to the communities served extremity and extended at this size to a tee just east of its intersecti with the existing railroad. From this tee, one 12-inch line ran southw and south to connect with the 12-inch main feeder at Bolivar Highway ne the center of the town. Another 12-inch line ran somewhat north of west joined the existing 8-inch line to Fort Sherman and continued across th existing locks to augment the Fort Sherman supply. All this was perman work. To provide for the supply during the construction period, a temp 12-inch line took off the 16-inch pumping line opposite the north land crossed the plug parallel to Keyes Road, and then went south along Jadw Road to connect with the 12-inch line to Fort Sherman. The ultimate ho will be through two 12-inch lines from the standpipes carried through crossovers under the new locks and connected with the original 12-inch feeder and the 12-inch extension of the earlier 6-inch line. One of th two 12-inch lines crossing the locks will act as the regular service ma the other will provide stand-by and emergency service. The relative positions of the temporary and permanent installations are shown in Figure 17-6.

Design

17-99. Since the original designs for this feature had been prep by the regular Panama Canal forces, there remained only the modificatio necessary to correlate them with the Third Locks designs and activities. This was facilitated by frequent consultation and by interchanging of maps and sketches to show changes desirable or contemplated in other features that would have bearing on the ultimate design of the water sy The two steel standpipes, each of 500,000-gallon capacity, were designe by the Office Engineering Division. The construction schedule require for correlation with the excavation for the new locks was met by comple of the entire installation in August 1941.

Mindi Powder Dock

17-100. The Mindi Powder Dock, used exclusively for the handling of explosives, was a small timber structure located on the east bank of the Canal, at the mouth of the old French channel, about 1-1/2 miles north of Gatun Locks. Panama Canal regulations require, for the handlin of explosives, a dock of this type in an isolated locality where large quantities of explosives can be unloaded directly from shipside into rai road cars. The alignment selected for the Third Locks channel involved the destruction of the spur track from the main line and the isolation o the Mindi Powder Dock from any feasible land connection. For this reas the relocation of the dock became necessary.



GATUN LAKE
12" RAW WATER MAIN
ORIGINAL STORAGE TANK
12" WATER MAIN
STILSONS POND
20" RAW WATER MAIN
NEW STORAGE TANKS
GATUN LOCKS
WATER LINE TO FT. SHERMAN
12" WATER LINE
FT. DAVIS MILITARY RESERVATION BOUNDARY
NEW 24" OUTFALL
SUMP
ABANDONED OUTFALLS
8" PRESSURE LINE FROM FT. GREEN
20" PRESSURE OUTFALL
16" MT. HOPE TO AGUA CLARA WATER MAIN
GATUN APPROACH
CANAL
GATUN ROAD
HIGHWAY
BOLIVAR
EAST DIVERSION
EXISTING P.R.R. MAINLINE
FRENCH
TELFERS ISLAND
PANAMA CANAL
BAY
LIMON
MT. HOPE FILTRATION PLANT
GRAPHIC SCALE
0 1000 2000 3000 4000
FEET
LEGEND
TEMPORARY OR ABANDONED LINES
PERMANENT LINES
GATUN
MISCELLANEOUS RELOCATIONS

FIGURE 17-6

Selection of Site

17-101. Four sites for the relocated dock were considered. Three of the sites were off Telfers Island and the fourth was on the new channel at a point corresponding to that occupied by the existing structure, that is, at the confluence of the channel with the French Canal. The fourth site was selected because detailed study of all sites showed that it was entirely adequate and also much cheaper than any of the others.[11]

General Design

17-102. The existing structure was 34 feet wide by 133 feet long. Experience had shown that a somewhat longer and narrower dock would be preferable. Its over-all dimensions were therefore fixed at 20 feet wide by 200 feet long, a reduction in total surface area. This width did not include any provision for railroad tracks on or adjacent to the dock. A depth of water of 26 feet at the outboard face of the dock, with underwater slopes for the dredged basin of 1^v on 2^h would give sufficient draft for all craft that might use the structure. This provision fixed the position of the outboard face of the dock with respect to the prism line of the new channel.

17-103. The location of the basin east of the channel was established to reduce dredging to a minimum commensurate with good foundations for the dock. The basin was 100 feet wide and 1500 feet long. Mooring dolphins, composed of 12 piles each and equipped with appropriate mooring hooks, were located at designated distances from the ends of the dock and at a slight angle landward from the outboard line of the dock. Efficient operation of the dock required that there be provided, in addition to the access track, a 5-car siding, a small gear shed, and a low-level launch landing. The new dock was to serve also as a general-cargo dock.

17-104. Before the location of the access track was determined, hydraulic spoil placed in the vicinity required a diversion of the Mindi River outfall. If the outfall were constructed initially, an additional structure would be required for the access track. Construction of a temporary outfall, delay in the construction of the access track, and selection of an alignment for the final outfall so that the discharge would take place through the trestle bents of the access track, eliminated the necessity for an additional structure over the outfall. The direction of flow was such that any currents set up would not disturb ships tied at the dock.

Design of Dock and Trestle

17-105. The all-concrete dock was designed for a moving live load of

400 pounds per square foot of deck. Lateral loads consisted of ship impact, assumed as 1000 pounds per linear foot, hawser pull on the bollard assumed as 25,000 pounds on each of four bollards; and wind loads on the wharf and vessels moored thereto.[12] The railroad trestle was designed for Cooper's E-45 loading with a 50 per cent allowance for impact. Lateral and longitudinal design loads were in accordance with the American Railway Engineering Association specifications for masonry structures, 1940

17-106. Five pile bents were used under the dock, and 4 pile bents were used under the railroad trestle. All bents were on 20-foot centers. The piles were precast of reinforced concrete. Those between 18 and 38 feet in length were 16 inches square, and those from 42 to 74 feet in length were 18 inches square. The outside piles in each bent were battered 1 in 6.

17-107. All concrete designs were made in accordance with U. S. Navy "Standards of Design for Concrete, No. 3YB", with the following maximum stress values:

f'_c = 3000 lb. per sq. in. (n = 10)

f_c = 1050 lb. per sq. in.

f_s = 18,000 lb. per sq. in.

v = 90 lb. per sq. in.

u = 300 lb. per sq. in. (special anchorage)

The protective cover of concrete over the reinforcing varied from a minimum of 2-1/2 inches to a maximum of 3-1/2 inches.

17-108. The dock superstructure consists of a continuous slab and girder deck of 10 spans supported on walls 8.5 feet high over the pile bents. Longitudinal curtain walls 12 inches thick extending from the deck to the pile caps are constructed on the outside of the dock to give the stiffness required for equal distribution of longitudinal bollard loads to the pile bents. All construction joints in the dock superstructure were placed at the center line of the spans to minimize eccentric pile-cap loadings during construction.

17-109. The railroad trestle consists of two reinforced concrete girders constructed in 100-foot units of five 20-foot, continuous spans supported on the pile bents. Timber crossties are placed on the tops of the girders and held in place with daps to fit a formed ledge on the girder and by hook bolts connecting the timber guard rails with the girders at every third tie. Lateral stiffness is obtained by means of concrete diaphragms at 5-foot centers between the girders. A concrete slab, 15 feet in length, under the ballast at the land end of the trestle creates a transition zone of the track roadbed from the embankment section to the trestle girders.

17-110. The foundations consist of 15 to 30 feet of muck and clay oove weathered rock that varies in thickness from 5 to 15 feet above ound rock. The piles were driven to, or within a few feet of, the ound rock. For the purpose of analysis of the bents, the piles were ssumed to be fixed at the pile cap and at a depth of 10 feet below the urface of the ground. An extensive program of core drilling and auger rilling was required to obtain the subsurface data necessary for design.

Fort Davis Buildings

17-111. A total of 66 buildings occupied the southwest corner of the ort Davis Military Reservation. Stables, garages, ships, warehouses, a aundry, the Post Exchange Motor Pool, and other services necessary to the ilitary establishment were included. Some of these structures lay within he excavation limits for the locks and the north approach channel, and thers had to be removed for the construction of works appurtenant to the ocks. It was therefore necessary to find an area within the revised imits of the reservation of sufficient extent to accommodate all these ervices. Proximity to at least one main road or street was also a equisite. Such an area existed in an undeveloped portion of the reservaion lying between the original Bolivar Highway on the east, the Bolivar ighway relocation to the north and west, and a stream on the south. his area was of relatively low relief, with enough high ground of suitable aterials to make the required fills.

evelopment of Plans

17-112. In addition to the engineering phases involved in the reocation, certain legal questions required consideration. A joint Army-anama Canal board that consisted of a legal and an engineering representaive from each of the two agencies was formed to coordinate all aspects f the problem.

17-113. The first meeting of this board resulted in the development f a definite procedure to be followed, a determination of the work entailed, he buildings to be moved, and the location of temporary land boundaries. his was followed by studies of unit costs of buildings for the purpose f appraisal, estimates of costs of relocations, utilities, and grading, nd a complete estimate of the value of existing installations, cost of oving, cost of reconstruction, and all other costs. A survey of the rea was made and topographic maps were prepared.

17-114. At a second meeting, the board considered the estimates and ata then available and made recommendations for the distribution and andling of the work.[13] These recommendations were approved by the two agencies involved. A revised estimate of all costs was prepared by the Office Engineering Division. Plans for the work were to be made in their entirety by the Army, but eventually both the Special Engineering Division and the Office Engineering Division assisted in their preparation.

17-115. Authority to begin grading operations was granted by the Army on October 9, 1940, even though many details of the work to be done and the procedures to be followed had not at that time been settled. Final authority to proceed with the entire project was given by the Commanding General, Panama Canal Department, on December 22, 1940.[14]

Post Exchange Motor Pool

17-116. Plans were made for the construction of the Post Exchange Consolidated Gas Station and Repair Shop in the vicinity of the new building area at Fort Davis. An agreement was reached between the Army and The Panama Canal with respect to the amount each organization would contribute to the construction. The costs exceeded the amount estimated, and a board of arbitration was appointed to settle a controversy that arose regarding cost distribution on the project. The Special Engineering Division was relieved of further interest in the matter.

Radio Range Station

17-117. Funds had been made available to the Army by the War Department for the relocation of the Fort Davis Radio Range Station to a site farther removed from the relocated Panama Railroad main line. The Panama Canal agreed to pay $14,750 as an equitable relocation cost to be added to these funds.

17-118. The entire relocation project, excepting the proposed Radio Range Station reconstruction, was accomplished by the regular Panama Canal operating divisions, under the inspection and supervision of the Special Engineering Division forces. It was agreed that removal and reconstruction of the Radio Range Station would be handled entirely by the Army.

Fort Davis Sanitary Sewer Outfall

17-119. A 20-inch concrete pipe outfall carrying all the sanitary sewage from Fort Davis ran westward under Keyes Road to cross the excavation for the new locks. The original design for its relocation consisted of a 24-inch gravity line that was located just east of and parallel to the drainage canal and discharged into the East Diversion. The increase in the size of the pipe was to take care of current and future expansions of Fort Davis.

17-120. Before construction started, a new development, Fort Green, had sprung up north of Fort Davis. The sewage from Fort Green was disposed of through an 8-inch pressure line that crossed the locks excavation near the north plug. Since this line would also have to be relocated, the design was reconsidered to combine all features. The position of the gravity portion was shifted eastward to the east side of Keyes Road. It ran northward to cross under the Bolivar Highway relocation at a flat angle and entered a manhole located opposite the north plug. Sewage from the relocated stables area was also brought to this manhole, out of which a 24-inch line ran westward to a sump. The 8-inch pressure line was diverted to discharge into this sump. Pumps forced the sewage from the sump through a 20-inch pressure outfall approximately 2300 feet long and discharged it into the existing Canal. The sump was located just outside the excavation limits of the new channel so that when the north plug is removed, the pressure outfall will ultimately act as a short gravity line discharging into the by-pass channel. Discarded dredge pipe was used to construct the pressure outfall.

17-121. The sump and pumping equipment were designed by the Office Engineering Division. The lines and grades for the sewer pipe were determined by Special Engineering Division field forces. The relocation is shown in Figure 17-6.

Electric Utilities Serving Fort Davis

17-122. Electric power and light source cables and telephone trunk lines serving Fort Davis either lay within or crossed the limits of the Third Locks area and hence required both temporary and permanent relocations. The same was true of Signal Corps communication cables to installations in the vicinity of Gatun.

17-123. The telephone and power cables were picked up at the intersection of Jadwin Road and the existing railroad main line, and relaid along Jadwin Road and Keyes Road to new substations and main distribution manholes at the intersection of Keyes Road and old Bolivar Highway. Connections to the existing duct systems were made from this point. The final relocation of the feeder cables will be southward from this point and through crossover tunnels in the new locks and thence west to the starting points of the temporary relocations. The Electrical Division and the Special Engineering Division collaborated in the preparation of the designs. The relocations of the Signal Corps cables were worked out by the Army, and they were reviewed and adjusted by the Special Engineering Division to conform to all projected Third Locks work.

Channel Lights and Buoys

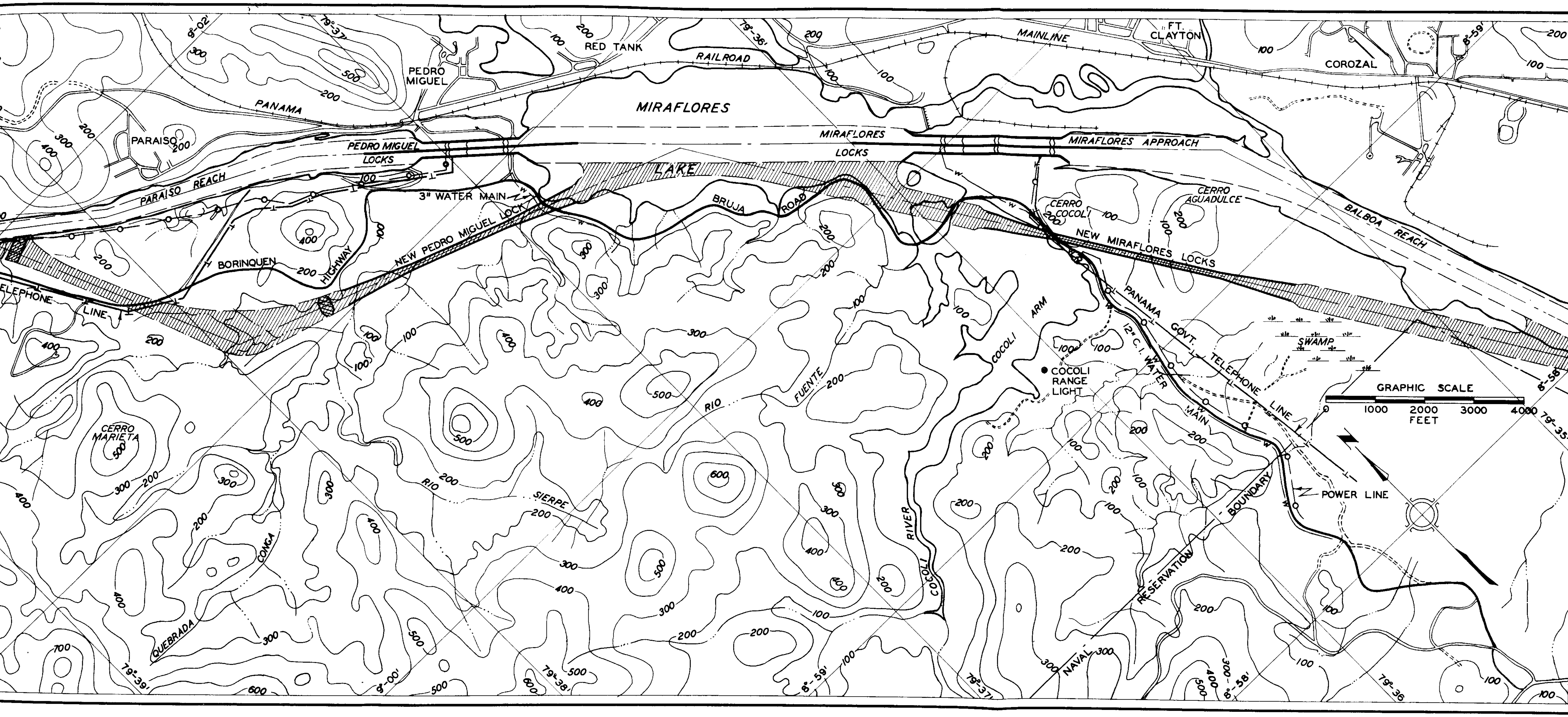
17-124. Electric lights on the banks and on floating buoys outline the Canal for night navigation. Cables running along the banks supply the electricity to the lights. Relocations of several lights and of 4000 feet of main cable were necessary to connect the new channel to the Canal.

17-125. Plans were obtained showing all lights, their connections, and the positions of the main feeder cables. The alignment and limits of the proposed new channel were superimposed on these maps, and the Lighthouse Subdivision was consulted as to a satisfactory method of achieving the relocations. By dead-ending the main feeder cables on both sides of the new channel and supplying power from the Cristobal and Gatun terminals, the unaffected lights were retained in service. Temporary buoy lights were placed over the stretch of open water. Upon completion of the Third Locks construction, the two dead ends will be picked up, extended along both banks of the new channel, and connected through the north crossover tunnel of the new locks to form again a closed circuit. All work in connection with these relocations was performed by the Lighthouse Subdivision and was coordinated with dredging operations in the vicinity.

PACIFIC RELOCATIONS

17-126. Figure 17-7 shows the relationship of the by-pass channels at Miraflores and Pedro Miguel to the existing locks and other developments in the vicinity. The features requiring relocation were: (1) Highways; (2) Water mains; (3) Electric utilities; and (4) Channel lights and buoys. Other appurtenant works that had to be provided were: (1) A railroad to connect the new locks with the Panama Railroad system; (2) Drainage diversions; (3) Earth dams to cut off the waters of Gatun and Miraflores Lakes; and (4) Disposal of excavated materials and provision of necessary backfill.

17-127. The absence of urban developments adjacent to the alignment of the new by-pass channels and locks permitted more freedom in the choice of locations than the designers had encountered at Gatun. On the other hand, the topography of the near-by terrain was very rough, and careful consideration was necessary, even in the early planning, to achieve economical designs. Temporary and permanent relocations were



PEDRO MIGUEL AND MIRAFLORES
RELATIONSHIP OF BY-PASS CHANNELS
TO EXISTING DEVELOPMENTS

FIGURE 17-7

required for every existing utility because continuity of service had to be maintained.

17-128. In every case, with the exception of the railroad, the location or relocation of a given feature at Miraflores was entirely distinct from a similar feature at Pedro Miguel. The designs of the features listed in Paragraph 17-126, except for channel lights and buoys, were influenced greatly at both lock sites by the spoil distribution. Relative importance and magnitude of the various features have been used in establishing the order in which the designs are discussed.

Spoil Areas and Backfill Provisions

17-129. Although no urban developments existed in the vicinity of the new Pacific Locks to delimit the placement of spoil, the necessity of creating construction towns near the new Miraflores Locks required that the planning for the spoil areas in that neighborhood be simultaneous with the planning for the towns.

17-130. In most cases at both locks sites, the spoil would have to be stacked against the sides of the hills and ridges adjacent to the excavations instead of filling deep ravines as at Gatun. It was, of course, of importance to design the areas so as to obtain the maximum use from the completed surfaces both during and after the construction period. This included the positioning of the spoil areas to reduce the quantities of backfill to be required and to support utility relocations, and the use of spoil to reduce the cost of grading for railroads and highways.

17-131. The variable quality of the rock, a great deal of which was unsuitable for certain types of backfill, made the provision of stock piles of the proper kinds of material a much more complicated problem than at Gatun. Since each type of rock would swell in different amounts, the excavation quantities had to be broken down into the several types to determine the volume of spoil to be accommodated at each lock site. This was particularly true at Pedro Miguel. The slopes on which the banks could be safely constructed and the height to which a given bank could be carried were in many cases determined by the quality of the underlying rock. Detailed designs of the spoil areas and backfill provisions at Pedro Miguel and Miraflores are shown in the contract drawings.[15]

Pedro Miguel

17-132. No accurate topography was available at Pedro Miguel when the first studies for disposition of spoil were undertaken, except of a comparatively narrow strip along the proposed center line. These studies determined that there was ample room for all the spoil within reasonable hauling distance from the excavations and established the limits to which it was desirable to obtain accurate topography.

17-133. Following the necessary field surveys, the studies were resumed. It was soon apparent that the design of the spoil areas west of the new locks and the diversion and control of surface drainage in the same area were inseparable and would have to be considered as a single problem. It was also apparent that instead of maximum utilization of certain valleys close to the lock site, to balance the haul the spoil areas would have to extend along the north approach channel to a greater extent than originally planned.

17-134. In the areas to be occupied by the spoil banks, the underlying material in almost all cases was the Cucaracha formation. The weakness and structural instability of some phases of the Cucaracha led to very careful determinations of (1) the proper distances between the spoil banks and the cut slopes of the excavations, and (2) the permissible slopes to which the banks could be constructed without overloading the foundation material. (Slopes on the various foundation materials are discussed in Chapter 5 of this report.) The following general conditions of control were established:

> 1. The intersection with the ground surface of a slope of 1^v on 5^h whose origin was at the elevation of sound rock in the cut slope would determine the toe of the spoil bank at any point along the excavation.
>
> 2. Face slopes for the spoil banks would be 1^v on 5^h, 1^v on 4^h, or 1^v on 3^h, depending on (1) the type of rock underlying that face and (2) whether the thrust of the bank was toward a critical feature or away from it.

17-135. Rigid application of the first condition would have resulted in very ragged faces for the banks. The extreme limits for the toes were determined by the preceding conditions and by average lines that were established to smooth out the inequalities. As an added measure of safety, and to overcome the unevenness of the ground, these average lines were set back approximately 100 feet farther from the excavations. To facilitate construction and to retard the flow of surface drainage down the faces of the high banks, the faces were designed as terraces with 15-foot lifts, and the berms were made of sufficient width not to exceed the average slopes of Condition 2 in Paragraph 17-134. The actual slope assumed by the material in each lift will be its natural angle of repose, but it was assumed as 1^v on 2^h for the purpose of computation of yardage.

17-136. Because of the modification of the construction program, only a small amount of excavation was accomplished at Pedro Miguel. As now designed, the spoil areas at Pedro Miguel should require at most only slight changes to meet the contingencies that may arise when the work is performed. Figure 17-8 shows the relation of the spoil areas to each other and to the other features in the vicinity. Details of the final designs of the Pedro Miguel spoil areas are shown in Plate 17-2, which follows the text.

17-137. <u>Spoil Area PM-I</u>. A valley which will be noted in Figure 17-7 as lying east of the bend in the new channel and between the Canal and the new channel will be occupied by Spoil Area PM-I. A mass of agglomerate crosses the new channel at this point but does not extend all the way to the Canal, which in this vicinity is cut through the Cucaracha formation. Application of geological considerations established the limits of Spoil Area PM-I with respect to the two channels. Its northern limit was determined as the south bank of a diversion ditch along the toe of the hill to the north. This ditch will carry the surface runoff from the west side of the new channel during the excavation period.

17-138. For convenience in the computation of yardage, and because the two sections of the spoil bank were independent of each other, the portion east of Borinquen Highway was designated as PM-I-A and the portion west of it as PM-I-B. The road has been purposely left open to general traffic and will serve also to obtain access to the successive lifts of the spoil bank. PM-I-A will rise from elevation 130 to elevation 206, while PM-I-B will rise from elevation 100 to elevation 190. Although the strength of the underlying material would permit PM-I-A to be raised above the elevation given, the added material obtained would not compensate for the additional construction difficulties. The faces toward the channels and the diversion ditch will have slopes of 1^v on 5^h. Slopes on both sides of the road will be 1^v on 4^h for PM-I-A and 1^v on 2^h for PM-I-B, which is only 15 feet higher than the road. The south end of PM-I-A will wash out against the side of Paraiso Hill whereas both the north and south ends of PM-I-B will be confined by spurs from Paraiso Hill. Spoil Areas PM-I-A and PM-I-B together will contain about 2,202,000 cubic yards of mixed spoil, none of which will be reclaimed as backfill.

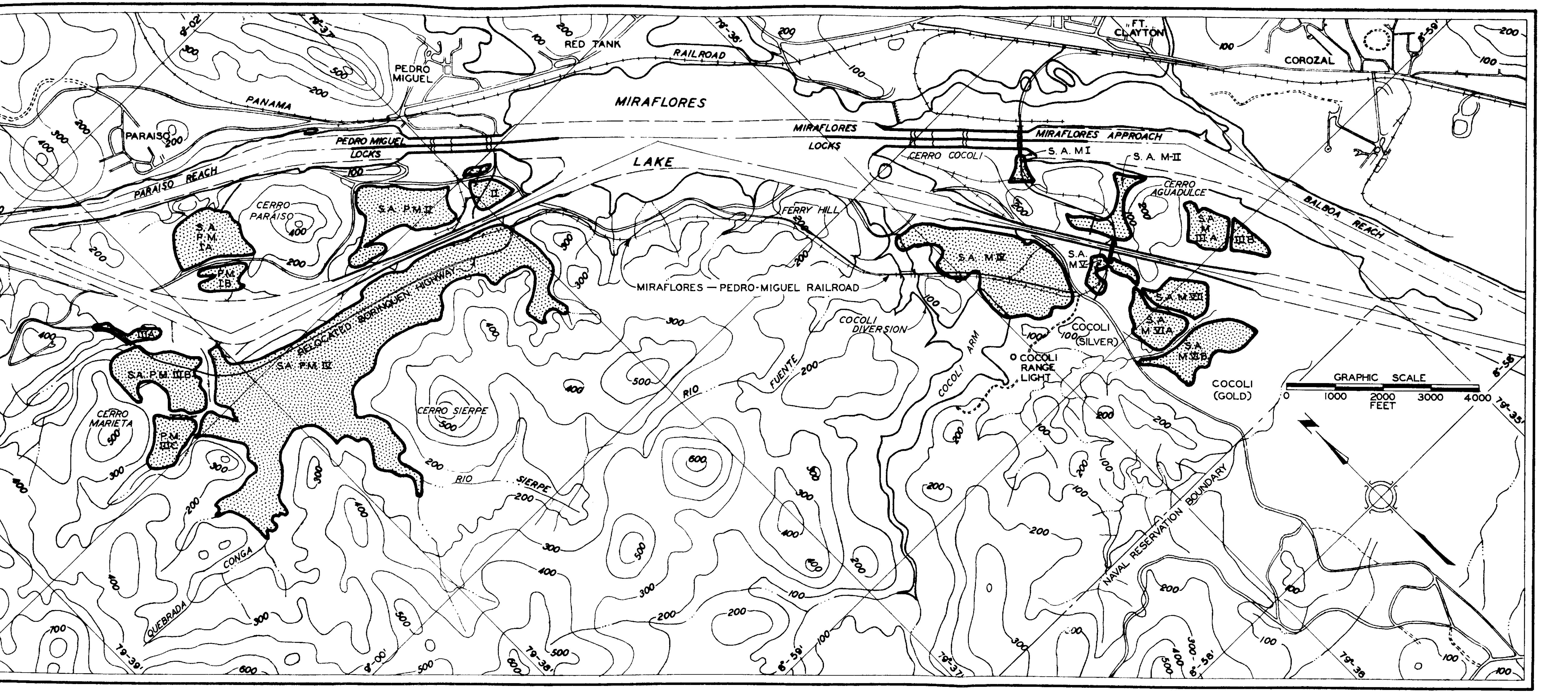
17-139. <u>Spoil Area PM-II</u>. This spoil area will rise above the swampy ground west of the existing Pedro Miguel Locks, between this structure and the new lock. The swamp had been created by using the original river valley as a spoil area for suction dredge effluent during maintenance operations in Gaillard Cut. It will be noted in Figure 17-7 that the portion of the swamp east of the new lock is encircled by Borinquen Highway. It was recognized early that the area so bounded would provide an excellent plant site for the masonry contractor if a firm foundation could be created by spoiling selected materials. This area also offered the only feasible site for storage of the materials needed for backfill on the east side of the new lock.

17-140. Little was known of the depths of the soft hydraulic spoil in the area, since early core drilling had been concerned solely with developing the elevation of top of sound rock. Allowing for a reasonable amount of subsidence, it was believed that the amount of agglomerate rock to be excavated from the lock site would be sufficient to fill this area to elevation 66 and to provide the required free-draining backfill adjacent to the east wall. Above elevation 66, a layer of mixed earth and softer rock could be placed to elevation 70 to form a firm, well-drained plant area, and to support the stock piles of selected backfill materials.

17-141. The original designs were developed on this basis. Surface drainage was diverted eastward into ditches along Borinquen Highway. In the north corner above elevation 70, mixed earth and rock was stacked to be used later for unclassified backfill outside the limit of the free-draining agglomerate. Immediately south and in contact with this unclassified spoil was a large stock pile of selected earth to be used for impervious backfill and for closing fills for railroads and highways. In the southeast corner, also above elevation 70, rose the stock pile of selected agglomerate to be used for the free-draining backfill. The face of the base course toward the lock excavation was kept back a minimum distance of 100 feet from the top of the cut slope.

17-142. The decision to create a surge basin in the area occupied by Spoil Area PM-II and the necessity to impound water with an earth dam near the southern end of the area brought about several changes in the design of the spoil bank. It was obviously desirable to construct the major portion of the dam during the excavation period. The positions of the storage piles had to be adjusted and their basal areas reduced to provide plant room in addition to space for the earth dam. The selected earth stock pile was greatly reduced in size and placed south of the earth dam, between Borinquen Highway and the slopes of the backfill of the existing locks. The rock storage was split to allow for a sufficient amount on both sides of the dam. The south portion of the rock storage occupied essentially the same location as before, and the north portion was placed above the unclassified backfill and raised to elevation 110. The south limit of the unclassified backfill storage was moved northward and the elevation of its top increased from 85 to 95 to supply the deficiency caused by the smaller basal area. A separate stock pile of derrick stone, for bombproofing adjacent to the lock walls, was stored on firm ground at the north end of the spoil area. The limits of the base course (whose top remained at elevation 70) were not affected much by these changes.

17-143. Meanwhile, investigations of the nature and extent of the hydraulic spoil had disclosed its unsuitability as foundation material for the dam and special drilling was undertaken to establish a firm foundation for the base of the dam. Because of the poor structural quality of the hydraulic spoil, it was decided to excavate it not only under the dam, but also to limits parallel to the lock excavation that would insure firm foundations under the backfill.[16]



PEDRO MIGUEL AND MIRAFLORES SPOIL AREAS

FIGURE 17-8

17-144. Since the backfill within the limits of the surge reservoir would be saturated at all times, any stable earth and rock, not necessarily free draining, could be used. The amount of agglomerate needed was therefore reduced and there was no objection to spoiling unclassified materials within the limits of the backfill. The total amount of spoil that could be placed close to the excavation for the lock was thus increased. This consideration led to a redesign of the base course of the spoil area so that a rock dike would be constructed as the first step toward covering the remaining hydraulic spoil with agglomerate rock. The dike was designed to be built at the edge of the cut slope in the hydraulic spoil, and the limits of the base course west of the rock dike were extended to within 50 feet of the top of the excavated slope for the lock.

17-145. An earth blanket, 2 feet thick, keyed into the impervious core of the dam, was designed to cover the existing ground between elevations 60 and 90 northward from the dam, and prevent leakage around the east end of the dam where it joined the backfill of the existing locks.

17-146. The amounts of backfill in the various storage piles were adjusted as closely as possible to the amounts of backfill to be reclaimed, and in this manner the maximum volume of water above elevation 70 was obtained in the surge reservoir. Approximately 1,874,000 cubic yards of spoil will be placed in the area. About 1,200,000 cubic yards will be reclaimed as backfill.

17-147. Spoil Area PM-III. This spoil area will lie west and north of the bend in the north approach channel. A spur ridge from Marieta Hill and a drainage improvement channel will divide it into three sections that have been designated as Parts A, B, and C.

17-148. Part A was designed to take advantage of a small valley lying between the relocated Borinquen Highway and a hill on the west bank of the approach channel. It will be necessary to rectify the channel of a stream that crosses this valley and Part A will help to restrain this stream in its new bed, besides offering a convenient spoiling ground. Because the area overlies agglomerate rock and the thrust of its weight is away from, rather than toward the approach channel excavation, the slopes of Part A have been designed at 1^v on 3^h. At its extreme northwestern corner, the spoil area will merge with the fills supporting the relocated highway. This portion of the spoil bank was designed to fit the final alignment and profile determined for the highway relocation. Part A will contain approximately 157,000 cubic yards of mixed earth and rock, none of which will be reclaimed as backfill.

17-149. Part B will lie along the eastern and southern faces of Marieta Hill. Its eastern limit was originally fixed by safe loading conditions above the excavation for the north approach channel, but its final position and extent have been determined by the line and grade of the relocated Borinquen Highway. Its southeast side parallels the main drainage channel which fixes the position of the toe, and will face the northern end of Spoil Area PM-IV. The entire spoil bank will be built over strata of the Cucaracha formation, and average slopes of 1^v on 4^h have been used in its design. This part of Spoil Area PM-III will contain about 2,353,000 cubic yards of spoil, none of which will be reclaimed as backfill.

17-150. Part C will form an extension of the southern face of Part B, westward from the ridge that divides them. Its southern limits are also determined by the drainage channels in the valley, and the average slope used in its design is also 1^v on 4^h. Part C can be extended farther to the west. The floor of the valley at its western extremity will be filled as part of the general scheme of diversion and control of the surface drainage. A channel cut through a low ridge connects the raised valley floor with the main outfall. Part C will contain about 890,000 cubic yards of mixed earth and rock, and none of it will be reclaimed as backfill.

17-151. Parts B and C have been designed with tops at elevation 220. The surface collection will be toward the hills into ditches formed in the spoil which will lead to a common outfall cut into the separating ridge.

17-152. Spoil Area PM-IV. Spoil Area PM-IV will lie west of the new locks and the north approach channel. Figures 17-7 and 17-8 show that the area to be covered contains many streams whose sources are in the hills above the spoil area. These streams discharge now in a common outlet that cuts across the site to be occupied by the new lock. Planning for the diversion and control of this drainage was therefore an essential part of the design of the spoil area. The effect of the drainage on the spoil area design is discussed in Paragraphs 17-267 to 17-273.

17-153. The eastern toe of the spoil area adjacent to the excavation for the new lock and channel was fixed by the safe loading conditions described in Paragraph 17-134. An average slope of 1^v on 5^h was used for this face throughout the 7500-foot length of the spoil area, despite the fact that the portions underlain by agglomerate and by the Culebra formation could have been designed for steeper slopes. The narrowness of the valley in the southern 2200 feet of the area did not permit raising the bank above elevation 145. A dike of a minimum width of 40 feet was constructed at this elevation.

17-154. The spoil sloped downward from the back of the dike against the hills to form a channel for the collection of runoff. Spur ridges projected into the dike at two points, so that ditches cutting through the spurs were necessary to provide a continuous channel for the collected runoff. As the hills receded to the west in the northern portion of the spoil area, the top of the area was widened so that the alignment of the dike roughly paralleled the contours of the limiting hills. A maximum width of 1700 feet at elevation 145 was thus obtained. The valleys upstream from the dike were filled to whatever elevations were necessary to ensure a gradient of not less than 0.15 per cent between the extreme western end of the fills and the collection ditch.

17-155. A top elevation of 145 was maintained for the southern 4200 feet of the length of the spoil area. Northward, in the wider portion of the bank, the top was gradually raised to a maximum elevation of 190. This placed the greatest concentration of spoil as close as possible to its source. At its northern end, the area ended in a face parallel to Spoil Area PM-III-B with average slopes of 1^v on 4^h. Where the top of the spoil area rose more than 15 feet above the top of the dike along its back edge, an average slope of 1^v on 5^h was used above elevation 145. Surface drainage of the wide top areas was designed to flow into the collection channel along the western edge.

17-156. The spoil area was divided into four sections, A, B, C, and D. The dividing lines were normal to the axis of the lock at definite stations along the axis. This device simplified computation of the volumes contained in the bank and permitted efficient control by the constructing agencies of haul and placement of the spoil. Part A was the most northerly section and Part D the most southerly. Free-draining backfill for the west side of the lock walls was obtained by placing agglomerate rock along the eastern face of Part C above elevation 85. This material would in all probability come from the north approach channel rather than from the lock site, because of the relatively small amount of agglomerate to be removed from the excavation for the lock proper.

17-157. The original contract drawings were based on the above design.[15] The basic design was not changed although modifications in details were required by: (1) The addition of the relocation of Borinquen Highway along the eastern face of the spoil area; (2) The provision of earth dams on the west side of the lock (at first two at widely separated positions and eventually one enclosing the gate dry dock located at the north end of the left north approach wall); (3) The changing quantities of backfill as the shape of the lock walls underwent revision; (4) The consideration that the hydraulic muck in the lock area might be excavated by wet methods rather than dry; (5) The alternate plans proposed by the contractor for the diversion of the surface drainage; (6) The continuing study of minimum requirements for the control of the surface drainage; and (7) The decision to carry the spoil placement east of the relocated highway berm to within 50 feet of the top of the locks excavation in the manner described under Spoil Area PM-II. However, the final plans for diversion of the surface drainage required a strong dike east of the highway relocation. This will be built with spoil and has been designated as Part E of Spoil Area PM-IV. When excavation at Pedro Miguel was suspended because of the modification of the Third Locks Program, a portion of the highway grade had already been built, and the use of flatter slopes in Cucaracha and overburden had increased the amounts of spoil. Accordingly, the design was reconsidered to ensure that Spoil Area PM-IV, containing about 19,128,000 cubic yards loose measure, would be large enough for all the spoil that did not go into the other areas. The design is such that adjustments will be easy even if the quantity of spoil to be accommodated should vary within wide limits. The storage above elevation 145 in Parts A and B may be reduced nearly 4,000,000 cubic yards or increased a million or more cubic yards merely by altering the top elevation. Such changes will not destroy the usefulness of the spoil area to divert and control the surface drainage.

17-158. The final design provides for the storage of agglomerate rock in the amount of 535,000 cubic yards, which is enough for the required derrick stone and for the necessary free-draining backfill. It also contemplates the ultimate removal, for use as unclassified, pervious backfill, of about 165,000 cubic yards of mixed earth and rock from the extreme south end and about 398,000 cubic yards adjacent to and north of the agglomerate storage. The resulting pockets will be formed above the elevation of the highway subgrade and will drain into the highway side ditches. The runoff from the east face above the highway will pass through culverts under the highway, thence in prepared channels to a collection ditch formed by the spoil area and the back slope of the backfill. The collection ditch empties into a low-level culvert that carries the runoff under the railroad and the West Access Road, and into the backwater of Miraflores Lake behind the left south approach wall.

Miraflores

17-159. At the start of studies for the spoil areas at Miraflores sufficient accurate topography was available to permit quick determination of the general location of the areas and accurate computation of their volumes. Additional topography was required for the studies of the construction towns, and no final determinations of the spoil areas could be made until the surveys had been completed and the two studies could go forward jointly.

17-160. Foundation conditions for the spoil areas were of little concern at Miraflores where the underlying rock was basalt in almost all cases. As will be seen in the detailed description of the individual areas, poor foundations were purely local problems.

17-161. The original planning made use of a distant area known as the Victoria Dump. As the studies progressed, it became apparent that the amount of spoil that could be placed in the Cocoli Arm of Miraflores Lake was limited only by the height to which it might be desirable to carry it, and that more distant areas would not be needed. The spoil areas for which detailed studies and designs were prepared were therefore in the immediate vicinity of the lock site. Figure 17-8 shows the interrelation of the spoil areas and their relation to the other features in the vicinity. Details of the final designs of the Miraflores spoil areas are shown in Plate 17-3, which follows the text.

17-162. Spoil Area M-I. As originally conceived, Spoil Area M-I made use of the entire area between the existing Miraflores Locks and Bruja Road for temporary storage, from the excavation for the new lock, of rock which would later be crushed for use as concrete aggregate. To obtain the needed volume, the stock pile rose 70 feet above the backfill of the old locks. Studies of the ability of the backfill to support this load resulted in the abandonment of the site for that purpose and reduced the spoil area to the fill upon which would be placed the subgrades for the highway and railroad approaches to the bridge.

17-163. At a later date, consideration was given to improving the surface drainage and increasing the utility of the area between the existing locks and the new locks by filling the valley between the backfill of the existing locks and the east slope of the Miraflores West Dam and against the east slope of the West Dam where the valley widened. The decision to reserve this space for the contractor charged with processing and furnishing Chagres River aggregate for the new locks eliminated any further consideration of spoil disposition in this area.

17-164. The spoil area was designed to be built of common excavation materials up to elevation 55, and no special care was to be taken in the placement of the spoil. The dimensions of the spoil area were sufficient to support whatever alignments the highway and railroad approaches would ultimately require. As constructed, it was built of selected overburden and was compacted throughout in the same manner as the railroad and highway fills. Slopes of 1^v on 2^h were designed for the exposed faces of the bank, because the highway and the railroad alignments followed the outer edges of the spoil bank and the fills averaged over 20 feet in height. It contained about 144,000 cubic yards of spoil.

17-165. Spoil Area M-II. This spoil area filled low ground east of the new locks opposite the upper chamber, in the valley between Cocoli Hill and Aguadulce Hill. The first design called for the toe to be placed about 100 feet east of the top of the slope of the locks excavation. From this point the bank rose on a slope of 1^v on 1.5^h to elevation 65. A rim dike, 20 feet wide, protected the excavation at this elevation against inflow of surface drainage. In addition, the top surface sloped downward to elevation 60 about 100 feet east of the dike and then dropped down in two terraces to elevation 30 about midway of the distance to the Canal. The slope from this point was rather flat to elevation 25, and was followed by a slope of 1^v on 20^h to elevation 15, or natural ground above the Canal.

17-166. This design had been dictated by the intention of building a dock at the foot of the spoil area, and the consequent necessity of providing a flat area at dock level to facilitate the unloading of supplies for the construction of the locks. Subsequent abandonment of the site for a dock made possible a large increase in the capacity of the spoil area by the elimination of the terraces and by the use of a gradual slope from elevation 60 to intersect a slope upward from the Canal of 1^v on 1.5^h.

17-167. As construction proceeded in the vicinity, it was determined that the foundation at the lower (east) end would not support so heavy a load. The small amount of material placed at that time had created a sizable mud wave. The design was modified to construct a rock dike at the lower end, using an existing old railroad bed for its outer limit. The rock dike had a minimum top width of 40 feet. Above it the spoil rose on a slope of 1^v on 3^h to elevation 45. The western end of the spoil bank was moved out to within 25 feet of the top of slope of the locks excavation, and carried up on a slope of 1^v on 1.5^h to elevation 62. The rim dike was eliminated, and between the limiting elevations of 62 and 45 the top of the spoil area sloped more or less uniformly.

17-168. The spoil area was planned to contain about 522,000 cubic yards of mixed earth and rock. This quantity included a ramp on a grade of 10 per cent from the end of the railroad cut to the level of the spoil area. The spoil area, as constructed, did not reach its full height and will serve to take some of the spoil when the work is resumed. It is not intended to reclaim any of this as backfill, but the final surface is to be used as the site for the entrance plaza, parking spaces, and maintenance shops.

17-169. Spoil Area M-III. Spoil Area M-III lay east of the new locks channel and south of Aguadulce Hill. Selected earth was to be placed to elevation 50, and above this clean rock was to be stored for later use as backfill. Some of the selected earth would also be re-used as backfill. The slopes were on the angle of repose for the material to be placed. The south toe was about 700 feet from the corresponding elevation under the hill, and the east and west toes were kept back at least 300 feet from the Canal and from the excavation for the new locks.

17-170. When excavation was begun for the south approach, the overburden was found to be very plastic silt or muck of no value for future use. An extension of Spoil Area M-III, called M-III-B, was designed south of the original area. This was triangular in shape with a rock dike along the southeast face where the underlying material was of poor quality. Behind this dike the muck was placed to elevation 50 westward to within about 300 feet of the top of the lock excavation and northward toward Part A (the original spoil area) in such a manner that a natural drainage channel between the two parts was not obstructed.

17-171. The only changes in the design of this area were to reduce the amount of selected earth in the base of M-III-A by restricting the placement to the western half of the bank, to set back the toe of the superimposed rock about 40 feet from the top of the underlying earth along the western face, and at one point to pull back the eastern face in a notch where a tongue of very soft material was present.

17-172. Construction of the spoil area followed the designs very closely. M-III-A contains about 140,000 cubic yards of selected earth, some of which will be used as impervious backfill, and 648,000 cubic yards of rock, the greater part of which will be reclaimed for use as pervious backfill. M-III-B contains about 329,000 cubic yards of mixed earth and rock. None of it will be reclaimed.

17-173. Spoil Area M-IV. Cocoli Arm, a part of Miraflores Lake west of the new lock site, was filled by Spoil Area M-IV. This body of water would have to be impounded behind a cofferdam before the north approach channel could be excavated in the dry. Cocoli Arm had a connection with the main lake through the natural valley left between the original west bank of the river and the Miraflores West Dam, and another by means of an excavated channel farther to the west. The former of these two outlets had been partially closed by the construction of Bruja Road, and there remained only a 10-foot-wide channel between the fills at the ends of the bridge. The north land plug would complete the closure. The other outlet was crossed by Bruja Road on a timber trestle bridge about 200 feet long. Accordingly, any scheme for using the lake as a spoil area had to permit the flow of the Cocoli River through this latter channel. The Cocoli Diversion, discussed in Paragraphs 17-274 to 17-276, furnished a solution to this problem and made possible the maximum development of the spoil area.

17-174. The detailed design of the spoil area was in large measure dependent on the alignments chosen for the relocation of Bruja Road and for the branch railroad to Pedro Miguel. Before these features had been definitely fixed, the eastern limit of the spoil area had been defined by the location chosen for a dike to be constructed very early in the excavation program, which would act as the cofferdam against the Cocoli Arm, and would provide for a construction road and for temporary relocations of water mains, and telephone and power lines. This dike, whose eastern edge was established 510 feet west of and parallel to the axis of the locks, had a top width of 100 feet at elevation 65 and side slopes of 1^v on 2^h. It was composed of rock mixed with earth so as to form a heavy, impermeable mass. The eastern toe did not encroach closer than 200 feet to the top of the excavation for the north approach, this offset having been established as a safe distance to avoid failure of the excavated slopes, considering the strength of the material involved.

17-175. Rough computations of the volume of spoil that could be placed to the west of the dike to given elevations and varying limits served to fix the approximate over-all dimensions that would accommodate the volume of spoil not taken care of by the other areas. The original design was developed after the alignments for the railroad and highway had been fixed. The special construction required for the support of those structures is described in Paragraph 17-235. The design called for a valley between the construction dike and the subgrade of the highway. The valley sloped from elevation 65 at the south end to elevation 55 at the north end. West of the railroad the surface sloped from about elevation 68 at the subgrade to elevation 65 along the western rim. The western edge was capable of being extended some 700 feet westward without blocking the channel of the Cocoli River.

17-176. The valley between the highway subgrade and the construction dike was selected as the site for storing rock to be recrushed for concrete aggregate. This mound, containing over 2,000,000 cubic yards, measured about 2700 by 400 feet and rose to elevation 110 from the level of the spoil area surface. This was the only portion of the spoil area that would be altered in any way by the operations of other contractors.

17-177. The design of the construction dike was later altered so that the eastern half was constructed entirely of rock and the western half of earth and rock. The east slope was changed to 1^v on 1^h, thus increasing the offset from the top of the excavation for the north approach.

17-178. After further investigations of the character of the foundation material between the dike and the north approach excavation, it was determined that this area could be safely loaded after unwatering took place. The design of this portion was altered to extend the top of the spoil at elevation 65 not closer than 200 feet from and parallel to the west prism line. The material between the dike and the natural high ground south of the emergency dam could be placed before unwatering. North of the emergency dam the material could be placed only after unwatering. An indentation in the new east face allowed for the excavation of the piston recess for the emergency dam. The previously described extension of the east face added a potential 700,000 cubic yards to the capacity of the spoil area. During the construction of this portion, it became advisable to place two rock fills that would act as French drains normal to the construction dike and would aid in the consolidation of the material actually placed. The inclusion of the rock fills was made before any large amount of spoil had been placed in the area. Four other major changes in the general design of this spoil area were made subsequently to meet conditions that developed during the excavation or because additional services were required in the area.

17-179. The first change arose from the fact that the performance of the crushing plant which produced the aggregate storage was very much below that expected of it, and only a fraction of the total required storage would be produced at the end of the excavation period. A stock of quarry-run rock that could be crushed at any time in the future was formed by a storage pile at the southwestern corner of the spoil area. This storage pile had a top elevation of 100 against the adjacent hill and sloped gradually toward the railroad location. It was designed to contain about 400,000 cubic yards of clean rock.

17-180. The second change developed from the choice of site for the temporary construction power plant. The site selected was a low ridge along the west side of Spoil Area M-IV, about midway of its length. The changes in the design affected the surface drainage of the spoil area north of the plant and established a new western limit to avoid excessive pumping of the cooling water for the plant.

17-181. The first attempts to unwater the north approach area were unsuccessful. After blanketing the slopes of the Miraflores West Dam with clay and strengthening the north land plug with little success in reducing the inflow of water, it was determined that infiltration was through the construction dike. It was inferred that the miscellaneous material placed west of the dike had not effected a seal. An earthen dike, anchored against the spur ridge on which the power plant was being constructed and running almost due south, was devised to correct this condition. The dike had a minimum top width of 20 feet and was raised to approximately elevation 58. Its location was within the newly established limits of the spoil area.

17-182. The fourth change was imposed by the need to find a site for disposal of the large quantities of river silt from the north approach channel excavation. A dike of earth was constructed in a westerly direction from the northwest corner of the rock-storage pile described in Paragraph 17-179. Between this dike and the hills, the plastic silt was end-dumped off the rock and the dike, and was allowed to flow westward toward the Cocoli River channel.

17-183. The final volume of Spoil Area M-IV was over 5,000,000 cubic yards, exclusive of the crushed rock in the aggregate storage pile. The only reclaiming for backfill will be from the fines created by recrushing for aggregate. (See Paragraphs 17-176 and 17-179.) It is expected that the rock-storage pile in the southwest corner will be completely removed by the time the primary crushing operation has produced a sufficient quantity of rock of the proper size for recrushing as aggregate. Although the construction of those portions of the spoil that were not affected by the changes noted in the preceding paragraphs followed the original designs rather closely, certain areas that were not brought up to grade will be utilized as spoil banks for some of the material excavated when construction is resumed.

17-184. <u>Spoil Area M-V</u>. This spoil area lay west of the new locks and filled the upper reaches of the same valley within the eastern portion of which Spoil Area M-II was located. The original design kept the east face sufficiently back from the locks excavation to avoid interference with the construction of the west abutment for the swing bridge over the locks. This face rose on a slope of 1^v on 1.5^h to a rim dike, 20 feet wide, at elevation 70. The extreme western end of the area was also filled to elevation 70. The surface sloped from these two limits to form a drainage basin midway of the area that emptied into natural low ground to the south and west. The railroad and highway fills approaching the bridge pocketed some surface drainage at the western end of the area. The drainage was carried eastward to join the rest of the runoff through a ditch cut through the intervening high ground.

17-185. The position of the bridge was subsequently moved southward 143 feet. This placed a part of the subgrade for the railroad and highway in cut with fills at both ends above the spoil area. The design of the bridge was also altered to provide for a 360° swing with a consequent increase in the length of the western span and a movement westward of the west abutment. In addition, the west abutment was provided with an entrance to the machinery room at the level of the lock wall. The eastern edge of the spoil area was accordingly moved westward with slopes toward the lock which conformed to the new design of the abutment. The spoil area was raised at its eastern edge to the subgrade elevation of the railroad and highway, and was sloped so as to force the drainage westward into collection ditches parallel with Bruja Road at the western limit.

17-186. Only a small amount of earth was placed in this spoil area, although it was originally designed to contain about 122,000 cubic yards of mixed earth and rock. The contractor found the valley and the adjacent hill to the north a convenient place in which to erect the plant for crushing the rock for the aggregate stock pile. When work is resumed the area will be used as a bank for the waste from the crushing operation, and after the removal of the crushing plant as a spoil area, for the rock removed during the concrete pouring period as final trimming and preparation of the foundations for the locks are advanced. The final design calls for a cap of earth to form an impermeable surface over the expected rock spoil. One of the functions performed by this spoil area is that of separating natural drainage from esplanade drainage, consequently permitting the use of smaller underground storm-water pipes. This function would not be fulfilled if the rain falling on the surface of the spoil area were permitted to percolate through the pervious rock fill.

17-187. Spoil Area M-VI. As originally designed, Spoil Area M-VI had a top elevation that varied from 68 at its northern end to 55 at its southern end. Its top surface was approximately 900 feet wide by 1500 feet long and it contained about 1,343,000 cubic yards of selected earth. This material was stacked opposite the lower gate bay, against a low hill lying midway between the locks excavation and Bruja Road. The eastern, southern, and western limits of the spoil bank were well-defined drainage channels, the eastern and western ones joining the southern one which was known as the Quebrada Macuco.

17-188. As the excavation for the locks progressed, it became apparent that a sufficiently large quantity of selected earth would not be available. It was also determined that the foundations at the southern end of the spoil bank would not support so heavy a load. These factors, combined with the need to create additional room for probable further expansion of Cocoli townsite at a later date, led to a complete redesign of the area.

17-189. The channel of the Quebrada Macuco, eastward of Bruja Road, was realigned to lie about 700 feet farther north from the location of its original bed. The excavation involved in the realignment was very small, inasmuch as the culvert under Bruja Road had an invert elevation of 19.6 and the natural ground dropped rapidly from elevation 30 to elevation 20. North of the new channel the spoil area was called M-VI-A, and south of it, M-VI-B.

17-190. Spoil Area M-VI-A retained the former north, east, and west limits of the old area. The south toe rose on a 1^v on 2^h slope and was held about 50 feet back from the ditch excavation. The top surface had a uniform slope from elevation 68 at the north end to elevation 65 at the south end. In addition, it sloped east and west from elevation 70 along the longitudinal center line. The selected earth pocket was placed against the hill at the shallow northern end and contained about 96,000 cubic yards, of which about 60,000 cubic yards will be reclaimed as impervious backfill. The remainder of the area, of mixed earth and rock, contained about 569,000 cubic yards, none of which will be reclaimed. The construction of the spoil area followed the designs very closely.

17-191. Spoil Area M-VI-B filled the low ground between the new channel for the Quebrada Macuco and the town of Cocoli. Its width from north to south averaged 600 feet and it had a maximum length of about 1600 feet. The highest part of its top surface was at elevation 32, from which the surface sloped to the north and south to elevation 29 along the edges. On the western end it dropped on a 1^v on 2^h slope to form a ditch between this slope and the fill around some of the houses constructed by the excavation contractor. The discharge from a culvert under Bruja Road that formerly ran eastward in ground to be covered by the spoil area was carried by this ditch into the Quebrada Macuco.

17-192. The spoil area was to have a top cap of about 2 feet of earth to present a fairly smooth surface for later use. By the time the fill reached the top no more overburden was available, and the surface was topped out with fairly small rock and some earth. The area contains about 635,000 cubic yards of mixed rock and earth, none of which will be reclaimed.

17-193. <u>Spoil Area M-VII</u>. Spoil Area M-VII, located between the lock excavation and Spoil Area M-VI-A, was stacked on its northern end against a spur of Aguadulce Hill that extended to the west of the locks excavation. It was about 800 feet long and 600 feet wide and was composed entirely of selected basalt. It had a level top at elevation 70. The pervious nature of the rock did not require any sloping to ensure drainage. The western limit of the area lay against the slope of Spoil Area M-VI-A. The level of the drainage between the spoil areas was raised during the excavation period, and the capacity of the spoil bank was increased thereby. As finally designed it contained about 663,000 cubic yards of rock.

17-194. Construction followed the design rather closely, the only deviation being the construction of a haul road by the contractor about midway of the width of the area and at a somewhat lower elevation than the designed top. To compensate for this, the top elevation on both sides of the road was raised about 5 feet. Reclaiming for primary rock crushing and for pervious backfill will remove all the clean rock available in the spoil area.

17-195. Derrick-Stone Storage. When the excavation contractor improved his explosives technique and large pieces of basalt suitable for derrick stone were infrequent, derrick-stone storage became necessary. Two storage piles were therefore designed to be created by the contractor who will complete the excavation when the work is resumed. One of these will be on Spoil Area M-II in the northeast corner and the other will be on Spoil Area M-V midway of its width and south of the highway subgrade. Together they will contain about 66,000 cubic yards of rock in pieces of one cubic yard or larger. Details of these two areas are shown in Plate 17-3.

Miraflores-Pedro Miguel Railroad

17-196. A railroad to cross the Canal and serve the Army and Navy installations on the west bank south of Miraflores had been considered before, but no detailed studies had been made until the Third Locks program started. The preliminary alignment studies were based on bridge crossings of both the existing and the new lock structures, and included a rather elaborate network of tracks on the west bank of the new channel. Later studies demonstrated that the trackage to the south could not be justified by Third Locks needs. Abandonment of this track also caused a wye track to be dropped from further consideration, and only a line north to Pedro Miguel remained.

17-197. A tunnel under the locks was given preliminary consideration, but it was soon apparent that it was unfeasible because of the grades imposed by the terrain east of the existing locks. Simultaneous studies were carried on toward fixing the position of a bridge over the existing locks which would control the alignment and the grades for the railroad between the main line and the bridge. The design of this portion of the

Miraflores-Pedro Miguel Railroad is described in Chapter 15 of this report. The designs of the main branch west of the existing locks and the auxiliary spurs and tracks required to create a comprehensive system serving the existing and the new lock structures are discussed herein. Plates 17-2 and 17-3 show the relocations at Pedro Miguel and Miraflores, respectively.

Design

17-198. Since this was a branch line, subject only to intermittent traffic and light rolling loads, the design limitations were the same as those for similar tracks at Gatun, namely: 12° curves, all curves to be spiraled through not less than 60 feet, and 1.5-per-cent operating grades. To achieve this, grades were to be compensated on curves at the rate of 0.04 per cent for each degree of curvature. Vertical curves were to be of such lengths as to maintain rates of change not to exceed 0.15 feet in sags and 0.30 feet at summits. At subgrade level, fills were to be 20 feet wide and cuts 28 feet wide. Slopes of 1^{v} on 1.5^{h} for cuts in overburden and of 7^{v} on 1^{h} for cuts in sound basalt or agglomerate were established, all cut slopes to be protected by diversion ditches. Fill slopes were to be those inherent to the material involved unless special conditions made flatter slopes desirable.

17-199. The position chosen for the bridge over the new Miraflores Locks obviously would dictate the alignment, and to some extent the grades, between the two bridges. Studies were made for alignments based on the three practical positions for the bridge. The position over the north end of the upper chamber required the use of the maximum curvature and of grades approaching 3 per cent. Excavation quantities were also high, even though the line was the shortest of the three. The possibilities of a pontoon-type bridge in the north approach were also investigated briefly. Studies for the south end of the upper chamber, where the bridge deck would be at the same elevation as at the north end, indicated an improvement in alignment and the use of grades within the design limits, without too great an increase in excavation quantities. Two routes could be used to reach the position over the south end of the lower chamber, but both proved disadvantageous as to alignment, excavation quantities, and length of track when compared with the center position. Therefore, the center position was fixed as the origin of alignments for study west of the new locks.[17]

17-200. Studies had been made concurrently for a construction track that would not cross the new locks but would use the north land plug and the construction dike in Spoil Area M-IV and, if so desired, could be put into service at an early date in the vicinity of Miraflores. The investigations included the extension of this track to Pedro Miguel at a low level along the shore of Miraflores Lake, and also the connections with the alignments then projected for the permanent track that would parallel approximately the alignment of the existing Bruja Road after crossing the north land plug. These studies were carried only far enough to establish the feasibility of the alignments and profiles and the major features involved in their construction. They could have been rapidly developed into final form had the necessity ever arisen.

17-201. Of the several projections made for the permanent track west of the new locks, one skirted the south shore of the Cocoli Arm, after leaving the bridge over the new locks, and crossed the spoil area in such a direction as to require a bridge over the south end of the Cocoli Diversion channel. Its profile had been lowered to effect a grade crossing of the existing Bruja Road south of the point of beginning of the highway relocation, so that the bridge over the diversion channel could be at a relatively low elevation and of short span. From this point the alignment curved to fit the topography, remaining south and west of the Fuente River until the stream became minor in character, and climbed to reach a saddle between the drainage flowing southeast and that flowing east and north. The alignment then turned northwest toward Pedro Miguel, finding support for the descending profile on the east slopes of the hills lying west of Bruja Road. Rounding the hill at the south end of the new Pedro Miguel Lock, the alignment converged with that of the lock axis to end on the future backfill on the west side of the locks.

17-202. This alignment had the advantage of complete separation of the railroad and the highway west of the new locks. Its cost was greater, however, because of heavier grading, greater track length, minor structures, and two bridges instead of one, than an alignment that followed the highway more closely and made use of a combination railroad and highway bridge over the Cocoli River outfall. It was decided that the disadvantage of cost outweighed the advantages inherent to complete separation of the alignments. This decision resulted in the redesign of the alignment between the new locks and a point north of the saddle where the first design began to parallel Bruja Road. It was also necessary to adjust the highway alignment in order to meet the new conditions. Since the elevation to which the railroad could be brought by the time it reached the crossing of the Cocoli outfall would control the elevation of the bridge deck, the alignment of the railroad was allowed also to fix the location of the Cocoli Arm Bridge.

17-203. The sharpest curve used in the design that was carried to the original contract drawings was $8^{\circ}04'42''$, and left the bridge over the existing locks toward the south. The spiral began at the end of the bridge. This curve was followed by one of $7^{\circ}59'30''$ in the opposite direction and approaching the bridge over the new locks. A curve of 7° left the bridge over the new locks, swinging north to establish a long tangent over Spoil Area M-IV parallel to the axis of the new Miraflores Locks. A 1° curve was used to approach the Cocoli Arm Bridge and a 4° curve was used to leave it and head toward the saddle. Past this point the alignment was dictated by the terrain, but the curves used did not exceed 6°. Alignment characteristics were therefore well within the design limit. The profile between the bridges exceeded the maximum set by the design limitations because of the limited distance and the requirements for vertical curves. The Panama Railroad preferred to hold the smooth vertical curves and to accept the higher gradient. The maximum grade was used in leaving Spoil Area M-IV, across the Cocoli Arm Bridge, and also in the final stages of the climb to the summit in the saddle cut.

Changes in Design

17-204. Two changes in plans affected the design of the railroad in the vicinity of the new Miraflores Locks. The first was a shift in the positions of the gate blocks and the second a radical change in the method of operation of the swing bridge over the new locks. The effect of the first change was to alter the positions of all the possible bridge crossings, thus reopening the question of the most suitable site. Comparative alignments and estimates resulted in the readoption of the center position over the lower gates of the upper chamber, and this brought about the second change--the adoption of a 360° swing for the bridge to reduce the time the bridge would be closed to highway traffic during ship transits. The balanced spans necessary to accomplish a 360° swing moved the west abutment farther away from the axis of the locks.

17-205. The final position chosen for the bridge over the new lock was to the south of the original position so that the distance between the bridges over the new and the existing locks was increased. The central angles of the curves approaching and leaving the new locks were unchanged, but the curve approaching from the east was made 8° and the one leaving the bridge to the west was changed from 7° to 7°15'. The first change was merely for the sake of simplicity, but the sharper curve west of the bridge was required by the new position for the west abutment to avoid curvature of the track on the bridge proper.

17-206. Another change in the alignment was due to the reduction of the offset between the center lines on the Cocoli Arm Bridge from 16 feet 10 inches to 3 feet 5 inches. The railroad alignment had been adopted as the origin of dimensions, so it was expedient to retain this portion of the alignment. In the immediate vicinity of the bridge, a redesign of the railroad and the highway was necessary to achieve rapid separation of the two kinds of traffic at both ends of the bridge. This could be accomplished only by sharply reversing curves at the bridge approaches. In recognition of the greater importance of the highway as a public facility, it was decided to establish the most desirable highway alignment and make the railroad diverge from it. This was accomplished at the east end of the bridge by reversing curves, each of 5°, whose central angles were also of 5°. The intervening tangent was made long enough to obtain the desired center-line separation. At the west end of the bridge, a 5° curve to the left with a central angle of 5° established the direction of a tangent which was projected to intersect the forward tangent of the former curve to the right just west of the bridge. The curve between these two tangents was increased from 4° to 4°40' to fit the reduced length of the back tangent. The central angles of the three 5° curves were completely absorbed by their spirals. Profile adjustments were minor in nature and presented no problems.

17-207. The other changes all occurred at the northern end of the line near the Pedro Miguel Locks. The first design called for a flat curve to the left of the locks backfill, parallel to the axis of the locks. When the position of the return track was established, this alignment could not be used. Meanwhile, the decision to use a common center line for the railroad and the relocated Borinquen Highway in the cut above the south approach wall had brought about a change in the direction of the tangent for the railroad in that cut. Four curves with small central angles were required to meet the new conditions, including proper clearances from the West Access Road leading to the locks backfill off Borinquen Highway. The last two curves were of 12° each because of the space limitations. The change in the direction of the tangent through the cut above the south approach wall also involved a change from 6° to 6°30' of the curve around the last hill. Profile adjustments were minor.

17-208. Only the earthwork for the railroad was included in the original excavation contract. The construction of box culverts and the fabrication and placing of pipe culverts were added later. The modification of the excavation program eliminated from the contract the completion of the grading between the new locks and Bruja Road, and all excavation not yet performed north of Station 176+00. Grading in the vicinity of this station was limited to the placement in fill of the material to be excavated from the cut ending about Station 169+00. Since the closing fills to the bridge over the new locks had not been included in the excavation contract, there remains for completion the grading across Spoil Area M-II; that west of the new locks to Bruja Road; and between Station 170+00 and Station 210+00; and the placing of several pipe culverts. The alignment of the railroad is shown in Figure 17-8.

Access Tracks to Locks and Connecting Spurs

Locks Connecting Railroad at Pedro Miguel

17-209. The addition of the surge reservoir dam between the existing locks and the new lock at Pedro Miguel offered an opportunity of connecting the tracks on the backfills of the new and the existing locks, and in this manner facilitate the interchange of equipment and avoid duplications. A tangent was established parallel to and 25 feet to the left of the axis of the dam, looking from the new lock toward the existing locks. The center line of the return track for the new lock was projected to an intersection with this tangent. A 14° curve was used at this P.I. to reduce the quantity of fill required outside the normal limits of the backfill and of the dam, and to avoid interference with other take-offs from the return track. Although very sharp, this curvature was permissible for the type of equipment that would operate over the track. At the opposite end of the dam, a 12° curve was used whose forward tangent connects with the existing tracks on the backfill of the existing locks through a #7 frog near the north end of the locks. The profile was practically level except for a short section where a grade of approximately 1-per-cent was used to overcome the 4-foot difference in elevation between the top of the dam and the backfill of the new locks.

Interconnecting Spurs at Miraflores

17-210. The position of the main branch east of the new locks made impossible a direct connection between it and the return tracks on the backfill of the new locks, except at a cost far in excess of that warranted by the service to be received. An indirect connection could be made, however, by running northward over the backfill of the existing locks and then switchbacking into the towing track on the right north approach wall. A switch point at the end of the bridge over the existing locks, followed by a swing to the north, was not convenient because a turnout would be located where the main track lay in the pavement of a heavily traveled road. Therefore, a switchback off the main branch was adopted which ran northward to connect with the tracks on the backfill of the existing locks. A turnout to the south, with the switchpoint north of the frog to create a second switchback, was extended at a convenient point along this alignment to connect with the towing track of the new lock just north of the chain-fender recess.

17-211. The design of the take-off from the main branch was modified to improve future grade intersections with highways in the vicinity. The entire adjustment could not be made in the railroad alignment and grade, and accordingly the profiles of the highways were also modified. The final design calls for a #9 turnout from the main branch followed by a 12° curve to the left which starts a few feet back of the heel of frog. This curve is followed by a 4° curve to the right whose forward tangent is extended to connect with the tracks on the backfill of the existing locks through a #7 turnout near the north end of the locks. Forward of the 4° curve, another #7 turnout to the south forms the switchback to the new locks. A short 9°40' curve immediately follows the frog. The forward tangent of this curve ends in a curve of 200-foot radius that makes the tie to the towing track of the new locks. The sharp radius is dictated by the design of the special castings for turnouts from the towing tracks where rack and conductor slots are required. This curve will prevent main-line railroad equipment from entering the system of tracks on the east backfill of the new locks.

17-212. The connection between the main branch and the tracks serving the existing locks is known as Spur "A". Its profile is undulating for the first 400 feet to facilitate grade intersections with the highways. (See Paragraph 17-211.) Vertical curves are designed to eliminate practically all the tangent grades. Once clear of these limiting conditions, the profile fits the terrain. No difficulty was experienced in keeping the profile within the design limitations. The switchback to the new locks, known as Spur "B", has a short stretch of maximum grade as it leaves Spur "A". Most of this grade is flattened by the vertical curves at either end. Elsewhere the grades do not exceed 1.1 per cent.

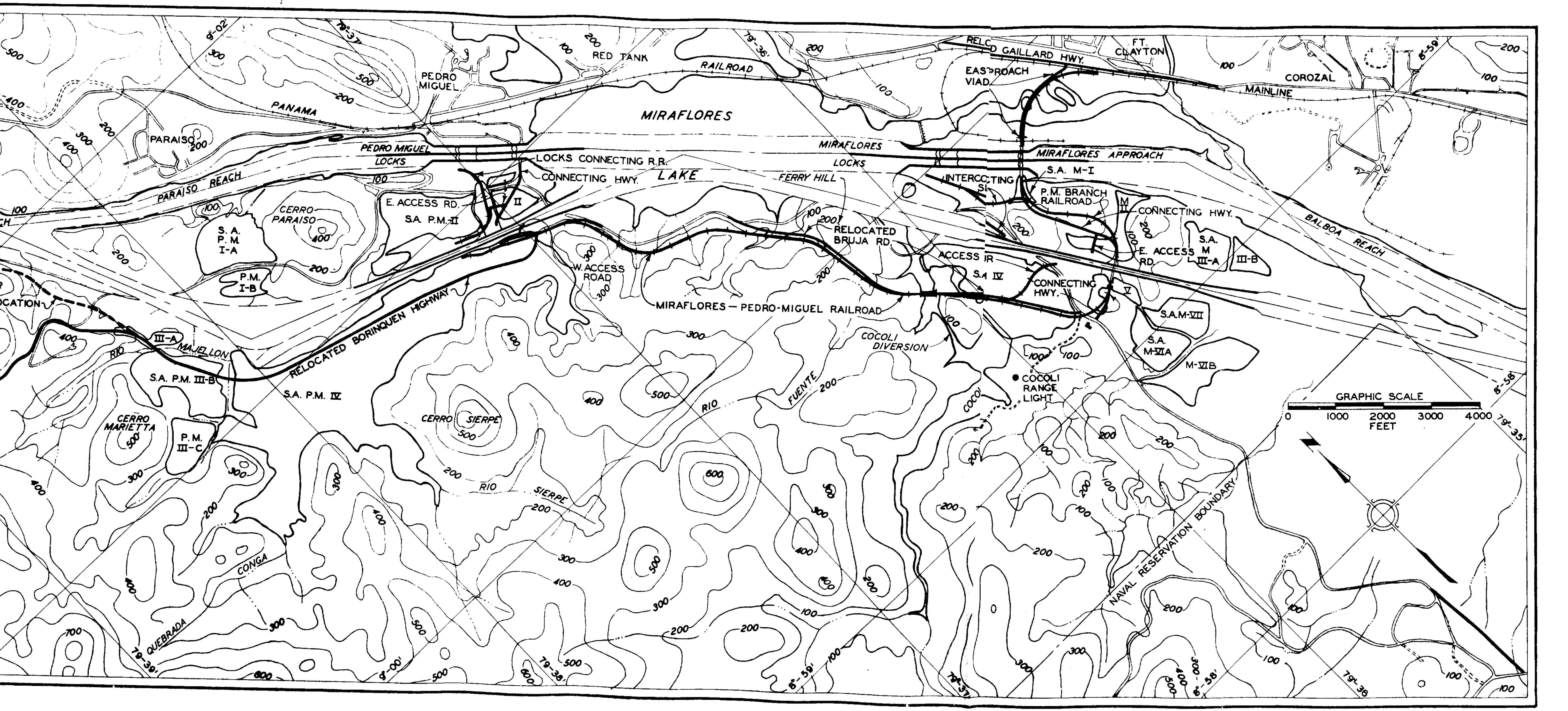
West Access Track at Miraflores

17-213. The alignment of the Miraflores-Pedro Miguel branch railroad across Spoil Area M-IV is parallel to and approximately 1000 feet away from the position of the return track on the west side of the new Miraflores Locks. For operating reasons, it was desirable to have the connection between these tracks, known as the West Access Spur, take the form of a switchback off the main branch. The difference in elevation that could exist between the two terminal points was reduced to a minimum by this alignment. The position of the connection to the return track was fixed within narrow limits by the track layout on the backfill, so that the problem became one of finding the direction of the connecting tangent that would give the other desirable alignment characteristics without the use of excessively sharp curves.

17-214. As originally designed, the track took off the main branch through a #7 turnout. About 100 feet beyond the heel of frog, a 10° curve to the left was joined by a 200-foot tangent to a similar curve to the right. The forward tangent of this second curve became the back tangent of a curve of 200-foot radius, the projection of the special turnout from the return track. At a later date, it was decided to stop the rack and conductor slot at a point which would permit the use of a standard railroad turnout to the access track instead of the special turnout required by the rack. A position was established for the point of a #7 frog that would keep the switch point clear of the rack, and the closing curve of the access track was redesigned. It became necessary to use a 12° curve instead of the original 10° curve. The profile consisted of zero grades at both ends connected by a grade of approximately 0.9 per cent. The relationship of these tracks to each other and to the other features in their vicinity is shown in Figure 17-9.

Structures

17-215. As noted earlier in this chapter, the design of the approach trestle to the bridge over the existing locks, the bridge itself, and the



PEDRO MIGUEL AND MIRAFLORES
RAILROAD AND HIGHWAY CONSTRUCTION

FIGURE 17-9

bridge to be built over the new locks are described in Chapter 15 of this report. The design of the Cocoli Arm Bridge is also described in Chapter 15.

17-216. Several box culverts were required by the location. Only one, a 7- by 8-foot box culvert under the railroad and the highway just north of the deep cut through the saddle west of Ferry Hill, was of unusual size or importance. At this location, the railroad fill rose more than 50 feet and the highway fill rose about 28 feet above the top of the culvert. Auger borings taken along the line of the culvert indicated that the foundations were capable of supporting the load without any special provisions in the design to reduce the unit load.

17-217. The original alignments for the railroad and the highway called for a complete separation of the fills, and the position of the highway was so far to the east that the new culvert had to make a direct connection to a culvert under the existing Bruja Road. When the highway was redesigned after the top of rock in the cut had been definitely established by the core drilling, it was found that the alignment could be improved by moving it westward. (See Paragraph 17-237.) There was no change in the railroad location, with the result that the two fills merged, and the length of the culvert was reduced from 290-1/2 to 231 feet. A drop inlet into the culvert was necessary to pick up the runoff between the fills.

17-218. The culvert was laid at a slight skew to the railroad center line and on a 4.1-per-cent grade to fit the ground. Its position required minor modification of the natural channel immediately upstream. The floor, walls, and deck were 1 foot thick throughout most of its length, but for the 85 feet under the heaviest portion of the railroad fill the section was thickened to 1 foot 8 inches at the floor and deck and to 1 foot 3 inches at the walls. The drop inlet rose 24 feet above the top of the deck and was fabricated from four lengths of 30-inch precast concrete pipe. A cast-iron grating, made of reinforcing rods at 6-inch centers, was placed at the top of the pipe and a check wall rose 2 feet above its level on the downstream side to impound the runoff and improve the entrance conditions. The precast concrete gutters placed along all the flow lines to the drop inlet did not prevent the carrying off of considerable fines from the slopes of the fills above the gutters. No dangerous erosion took place, however, and no fouling of the culvert occurred.

17-219. Another structure became necessary by the failure of a portion of the west slope of the deep saddle cut, at a time when the cut was about half completed. Correction of the slide condition led to the creation of a bench at that level of the cut and to the flattening of the slopes above and below the bench. The slide destroyed a portion of the diversion ditch along the top of the cut slope, and left a pocket of some two acres in extent that could not be diverted from the cut slope.

The normal side ditch of the railroad could not safely carry this additional flow, nor could its section be readily increased to do so. The extra runoff was carried to the bench, turned in a stilling basin, and led to the mouth of the cut in a special ditch.

17-220. At the point where the water had to be brought down the slope, the bench was too narrow to construct a normal-type stilling basin of adequate size. A design was evolved which took into account the conditions of high velocity and heavy flows but because no precedent could be found for the conditions anticipated, a model was constructed. Study and trial developed a combination of shape of basin and retarding baffles that turned the water through 85° in a horizontal plane and 37° in a vertical plane, dissipated most of the kinetic energy, and stopped the serpentine action of the flow upon leaving the basin. This last feature was essential to avoid overtopping the shallow ditch that economy dictated along the bench. The model indicated that 80 per cent of the maximum predicted runoff would safely pass the structure at all points. This was considered satisfactory, because the predicted flow was based on unusual rainfall conditions.

17-221. The structure was designed to make use of three construction materials: Grouted riprap, reinforced concrete, and precast-concrete flat slabs. The part of the diversion ditches that collected the flow at the top of the cut, and the paved ditch down the slope at a gradient of 77 per cent were of the first material. The retarding basin and baffles, the transition section from the greater depth, and the vertical walls of the basin to the normal ditch depth with sloping sides were of reinforced concrete. The ditch along the bench, for some 500 feet downstream from the basin, was paved with the slabs. These slabs were 1 foot long, 3 feet wide, and 2-1/2 inches thick, with edges and ends prepared to bond well with cement mortar.

17-222. It was found that the turbulence at the confluence of the waters from the diversion ditches required the ditches to be deepened to 3 feet to avoid overtopping in the curved sections leading to the ditch down the slope. Because of the high velocity attained by the water, the section on the slopes needed to be only 6 inches deep, but was made 18 inches deep to allow for any unusual conditions. All side slopes were 1^v on 1^h. To key this portion into the slope, the thickness of the bottom paving was increased in blocks at 12-foot intervals. The transition of the side slope on the upper side of the chute to meet the vertical wall of the basin was made in the grouted riprap section in a distance of 6 feet. The opposite side retained its 1^v on 1^h slope but the riprap was held level at a certain point to increase the depth of the paved section to 4 feet by the time the floor of the basin was reached.

17-223. The bottom of the basin on the inside under the bank had a radius of 4 feet 6 inches to effect the turn in the horizontal direction. The outside edge retained the direction of the chute to intersect at an angle of 85 degrees the outside edge, projected backwards, of the channel along the bench. The basin was roofed over for 7 feet downstream from this end, and the overhang projected 2 feet from the back wall toward the bank. The clear wall height under the roof was 3 feet 6 inches, and the roof was 6 inches thick. A baffle, 6 inches deep, hung along the edge of the roof toward the chute and the downstream end to dissipate the energy and remove the serpentine action of the effluent. In a distance of 10 feet downstream from the roofed section the outside wall dropped to 2 feet in height, and made the transition from vertical to 1^v on 1^h in the next 6 feet. The opposite side was also reduced in height to 2 feet at this same point, which was the end of the concrete. The outer wall of the basin was battered and keyed into the foundation. As an added factor of safety, a lug extended perpendicular to the chute into solid rock where the concrete began at the base of the slope.

17-224. Two slabs placed with the long dimension along the axis formed the bottom of the ditch. The side slopes were formed by the slabs placed on end, the 3-foot length being taken up in the slope length of the 2-foot depth of ditch. The paved ditch discharged into an unpaved ditch at a point where erosion would be harmless.

Roads and Highways

17-225. The highway which would be affected by Third Locks operations extended northward from Thatcher Highway to the former construction town of Empire on the west side of the Canal. Connections to the highway system on the east side of the Canal, prior to construction of Miraflores Bridge, were made via Thatcher Highway and Thatcher Ferry or over the lower gates of the Pedro Miguel Locks. Connections to the system of roads in the interior of the Republic of Panama were made by way of Thatcher Highway and a road westward from Empire. South of the Pedro Miguel lock gates the road was known as Bruja Road, to the north it was known as Borinquen Highway. Prior to 1939, traffic over these roads was light. Operations for the construction of the Third Locks and the steady increase of military traffic after 1939 made it essential to maintain the roads in service at all times.

17-226. Figure 17-7 shows that Bruja Road would be cut in three places in the vicinity of the new Miraflores Locks and that Borinquen Highway, within the limits of the new by-pass channel, either would be isolated by the excavation for the new Pedro Miguel Lock or would be destroyed by the excavation of the Pedro Miguel north approach channel. At its southern end, Bruja Road passed through a Naval reservation where traffic was subjected to certain restrictions. It was therefore desirable to relocate this part of the road outside of the reservation.

17-227. The decision to provide permanent highway bridges over the existing and the new locks at Miraflores introduced the problem of connecting the relocations on the west bank with the highway system on the east bank via these bridges.[17] Early studies were predicated on relocations through the hills to the west all the way from the south end of the new Miraflores Locks to the north end of the necessary relocation of Borinquen Highway, with complete abandonment of the existing roads within those limits except in the immediate vicinity of the new and the existing locks. These studies were made prior to any consideration of bridges over the new and the existing locks. As the planning of related features became more specific, it was apparent that the necessary relocations around Miraflores could be considered separately from those in the Pedro Miguel area. Subsequent studies proceeded on that basis.

Bruja Road

17-228. Under this title are described the relocations in the vicinity and south of the new Miraflores Locks. Bruja Road had been constructed by the Army in recent years because the crossing of the lower gates at Pedro Miguel restricted the type and size of vehicles having access to the roads to the west. It had an 18-foot pavement with narrow shoulders, and a tortuous alignment with many sharp curves and fairly heavy grades. The standards adopted for its relocation were: 20-foot pavement with 5-foot shoulders, that resulted in fill sections 30 feet wide and cut sections 45 feet wide at subgrade level; curves would not exceed 15° and this maximum would be used only where absolutely necessary; grades would be held to a maximum of 6 per cent.

17-229. South Section. The relocation of Bruja Road near its junction with Thatcher Highway had already been planned as one of the regular Panama Canal improvement projects and the designs were adopted practically without modifications. The terrain traversed permitted easy grades and curves, but it was of a swampy nature and the pavement was constructed with a Telford base. Modifications were made in the original alignment to meet conditions introduced at later dates, but the essential feature of free movement for traffic was retained.

17-230. Middle Section. The site finally chosen for Cocoli, the Pacific side construction town for the Third Locks, was south of the new Miraflores Locks site and east of Bruja Road. As the town grew and traffic increased in the vicinity, Bruja Road was widened from 18 to 27 feet within the limits of the town. No changes in grade or alignment were involved. The widening was later increased to 30 feet and was carried northward to the Pacific Area office.

17-231. Miraflores Locks Section. The studies for permanent highway crossings of the new Miraflores Locks had included a highway tunnel in addition to a bridge crossing for the railroad. The tunnel was finally abandoned in favor of a combined highway-railroad bridge, whose position with respect to the new locks had been fixed by the railroad requirements. This dictated the beginning point of the relocation of Bruja Road in the vicinity of the new locks. The first projection swung sharply to the north at the west end of the bridge, intersected the existing road at grade, and crossed Spoil Area M-IV on the construction dike to pick up the general alignment of the existing road to a point west of the outlet of the Cocoli River. From here it passed over a saddle west of Ferry Hill and ended north of the hill.

17-232. Concurrent planning for the railroad called for a crossing of the Cocoli River considerably upstream from the highway crossing and the use of a saddle farther to the west. Although this separation was desirable, the additional cost was regarded as unjustified by the amount of traffic to be expected under normal conditions, and a combined railroad and highway bridge was used to cross the Cocoli River with both alignments passing through the same saddle west of Ferry Hill.[18] (See Paragraph 17-202.)

17-233. The redesign of the highway alignment called for a 12°26' curve at the west abutment of the bridge over the new locks to effect rapid separation from the railroad. From the end of this curve, the two alignments were practically parallel over Spoil Area M-IV at 28 feet between center lines. This distance was reduced to 16 feet 10 inches in the curve just east of the Cocoli Arm bridge. Simultaneous, full capacity highway and railroad use was thus permitted on the bridge. The offset of 16 feet 10 inches was retained to a point west of the bridge to where the highway swung away to climb on a 5-per-cent grade to a level above the railroad in the cut.

17-234. The position of the highway in the cut with respect to the railroad was determined by this difference in elevation. Little was known about the subsurface conditions, since there was only one core hole in the vicinity. Based on this hole, an assumed top of rock was established throughout the whole cut. To determine a safe offset for the highway from the railroad, the horizontal components for slopes of 7^v on 1^h in rock and 1^v on 1.5^h in overburden were computed from the railroad subgrade to the highway subgrade. A constant of 20 feet was added to these distances. Plotting these offsets gave minimum positions for the highway for a given profile. Any adjustment in the profile of the highway necessitated a recheck of its alignment. Except at one or two critical points, it proved practicable to obtain greater than the minimum offsets, and as the highway left the cut it swung to the east away from the railroad and dropped on a 6-per-cent grade to rejoin the existing road.

17-235. The fill for the highway across Spoil Area M-IV was carried all the way down to the bottom of the lake, and it was built of rock with a sufficient width at elevation 60 to support earth fills with a 10-foot berm on either side. Subgrade profiles for the highway and the railroad were at the same elevation in this section except at the bridge approaches where the highway subgrade rose to bring the paving up to the top of rail.

A later revision raised the highway subgrade so as to maintain the top of highway paving at top of rail the entire distance between the bridges.

17-236. The position chosen for the Cocoli Arm Bridge was dictated partly by alignment considerations and partly by the fact that the surface topography, in the absence of any subsurface data, indicated the probable presence of adequate foundations at relatively high elevations. Cores obtained from a few exploratory drill holes revealed unexpected foundation conditions, and an extensive investigation followed to ensure the safety of the foundations. Although some slight change in the position of the bridge could have been advantageously made in view of the information thus revealed, the decision to retain the original position was justified by the actual conditions encountered during construction.

17-237. Only the grading for the highway was originally included in the contract for the excavation of the Pacific Locks. Construction of the necessary drainage structures was added at later dates. Extensive core drilling in the saddle cut disclosed a rock surface considerably lower than that assumed in the original design. Meanwhile, studies for the design of the Cocoli Arm Bridge had resulted in fixing the distance between center lines for the highway and the railroad on the bridge at 3 feet 5 inches instead of the original 16 feet 10 inches. Although the dimensions for the bridge design were based on the railroad center line, the greater importance of the highway as a public facility was recognized, and the redesigns of the highway that were made necessary by these factors improved the highway alignment at the expense of the railroad alignment. The same procedure as before was followed in fixing the new position of the highway through the saddle cut. The new critical points occurred at such positions in the cut that it was possible to keep the highway and railroad center lines closer together than formerly as they left the cut to the north. This resulted in an improved highway alignment and in the reduction of some 60 feet in the length of a large box culvert under the following fills. (Paragraph 17-217.)

17-238. Pending the completion of this relocation, traffic would continue to use the existing road. To provide for this at all stages of the excavation program, construction roads across the construction dike and from the bridge over the existing locks to the existing Bruja Road east of the new channel were made the obligation of the contractor.

17-239. The sharpest curve used in this design, except at the west abutment of the bridge over the new locks to achieve separation from and parallelism to the railroad alignment, was 4°15'. The maximum grade of 6 per cent was used at both sides of the saddle cut to reduce the excavation quantities as much as possible and to facilitate the smooth alignment obtainable at the higher elevations. The subgrade sections were designed to carry a 20-foot pavement with 5-foot shoulders. Where highway and railroad fills lay so close together that they formed drainage channels on completed fill, precast concrete gutters were required to prevent erosion of the fills. Concrete gutters were also used in the saddle cut to collect the runoff from the side of the highway toward the railroad to insure rapid runoff and minimum saturation of the cut slope below the highway. The alignment of the final design is shown in relation to other features in Figure 17-9.

17-240. The modified construction program for the Third Locks eliminated from the excavation contract the portion of the relocation that lay between the west end of the bridge over the new locks and the existing Bruja Road. Meanwhile, studies of paving details at the bridge approaches had indicated that the original alignment of this portion would result in an intersection with the existing Bruja Road that would be unsatisfactory for the majority of the traffic using it, because of the presence and superelevation of the railroad. This portion was therefore redesigned to lie to the south of the railroad. A 15° curve off the bridge abutment achieved rapid separation of the highway and railroad center lines. It was followed by a 10° curve in the opposite direction to create a right-angle approach to the existing Bruja Road. This intersection was designed to reduce traffic interference as much as possible, considering that all lanes were on the same level. The 22-foot width of pavement on the bridge was extended to the beginning of the intersection, it being considered unnecessary to provide any additional widening in the curves because of the low speeds of vehicles approaching the bridge. On the fill between the bridge abutment and the following cut, the shoulders were widened to accommodate pedestrian traffic and foundations for signals to control traffic over the bridge. The relocation of Bruja Road is shown in Plate 17-3.

17-241. Structures. The design of the Cocoli Arm Bridge is discussed in detail in Chapter 15 of this report. The only other major structure was a 7- by 8-foot box culvert, under both the highway and the railroad north of the saddle cut, that is described in Paragraphs 17-216 to 17-218 in connection with the railroad location.

Borinquen Highway

17-242. Under this title are described the relocations in the vicinity of and to the north of the new Pedro Miguel Lock. These included the relocation of the extreme northern end of Bruja Road where it would be cut by the excavation for the new lock, and the relocation of Borinquen Highway northward from that point to the north end of the north approach channel.

17-243. There were several ways in which traffic could be maintained pending the completion of the necessary relocations. A common connection to the lower gates of the existing locks could be established by temporarily routing Bruja Road across the south land plug. From this point, Borinquen Highway could be left undisturbed to where it crossed the north approach channel. From this point northward, a construction road could be readily built on the east side of the approach channel to cross finally over the north land plug and rejoin the existing road. Another solution was to depart from the existing road at the center plug and maintain a construction road on the west side of the channel during the placement of spoil to a point from which a short permanent section could be built in the hills to connect with the existing road farther to the north.

17-244. These solutions, while furnishing temporary service, left a permanent road on the west side still to be built from the south land plug to wherever the construction roads rejoined the existing highway; all of the construction outlined above would cease to be of value when the land plugs were removed and the surge reservoir filled. Those alignments were given little consideration, therefore, except to develop their possibilities as construction roads desirable for the excavation contractor. The remaining condition, namely, the construction of a permanent highway at an early date entirely on the west side of the new lock, had two possible solutions. One was to build in the hills, thus avoiding interference with contractual operations as much as possible. The other was to utilize the spoil areas to support the road where feasible, and then to seek the hills for the remaining section.

17-245. Selection of Route. Projections for the first of these two alternatives were prepared in October 1940, using 1 to 20,000 scale maps. More accurate topography would be required for definite designs; but this could not be obtained until the following dry season. Meanwhile, the concurrent development of the design of the spoil areas in the vicinity made possible studies based on the second alternative. These studies indicated the feasibility and economic superiority of this route. Two routes were possible north of the point where the spoil areas would no longer serve to support the road. One swerved eastward toward the channel and placed the road for most of the remaining distance in a bench to be cut in the slope of the channel excavation. This kept the alignment to the east of Escobar Hill. The other swung westward to pass through a saddle back of Escobar Hill. Development of this latter route was also dependent on obtaining accurate topography. A decision was therefore reached in February 1941 to proceed with detailed designs based on using the spoil areas and the bench to be cut in the channel slopes. The necessary field surveys were authorized to obtain data for a more detailed analysis in the future of the alternate alignment to the west of Escobar Hill.

17-246. Design. A 20-foot pavement requiring 30-foot fill and 45-foot cut sections with maximum grades of 6 per cent and maximum curves of 15° were the standards originally used to design the Borinquen Highway relocation. The existing road had a pavement 16 feet wide with shoulders 2 feet wide, curves up to 25°, and grades as high as 9 per cent. The relocation began on Bruja Road south of the hill at the south approach to the new Pedro Miguel Lock, rose to reach the elevation of the railroad through this same hill, crossed the railroad at grade at the north end of the common cut and then traversed the spoil areas on a rising grade. North of Spoil Area PM-III, it lay on natural ground until it entered the bench in the channel slope. It rejoined the existing road just north of this bench at the south end of the north land plug, which at this point remained at the full height of the original ground to permit a connection across it to possible construction roads on the east side of the new channel. Preparation of the subgrade to the lines and elevations shown was added to the excavation contract by addendum, the alignment and profiles being shown on two drawings at small scales and superimposed on the spoil areas as though the spoil-area surfaces were natural ground.

17-247. It was obvious that modification of the carefully designed slopes of the spoil areas would be necessary to allow for the highway grade. The study for these modifications resulted in minor changes in the alignment and profile of the highway. This new design was carried to drawings at larger scales so that the constructing forces would be furnished with greater detail than was shown on the original drawings. These drawings were never issued because of the following conditions.

17-248. Changes in Design. The addition of two earth dams (later reduced to one) and the gate dry dock on the west side of the new lock made necessary additional adjustments in the alignment and the profile. Continued studies of safe slopes in the excavation for the approach channels and the lock proper resulted in the adoption of flatter slopes in the hill at the south end of the lock, so that the highway could no longer occupy the position originally called for. The adoption of a common center line for both the highway and the railroad through this cut,and the modification of the previous alignments and profiles for both structures to achieve this purpose permitted the solution of the problem of the flatter slopes.

17-249. The changes resulting from all the above features were incorporated in a revision of one of the two contract drawings. This was included in the contract by change order. Shortly thereafter, the modification of the Third Locks construction program canceled any further work in the Pedro Miguel area and the drawings covering the relocation of Borinquen Highway were withdrawn from the contract.

17-250. Accurate topography at the northern end of the relocation had been available for some time, and studies for the route west of Escobar Hill had been undertaken. A study had also been made to adjust the alignment and profile of the route across the bench in the channel slope so as to reduce the required excavation to a minimum commensurate with safety. Comparative estimates of cost over these two routes showed that in spite of the reduction of excavation quantities for the bench line, the longer route to the west of Escobar Hill would cost some $20,000 less. This economic advantage, added to the obviously greater safety of the longer route, resulted in the decision to adopt this route for the work to be performed under future contracts.

17-251. Application of currently available unit costs to the quantities called for by the approved alignment showed that the probable cost would greatly exceed the original estimates, and that this cost would be out of line with the value of the relocation to The Panama Canal. Accordingly, the relocation was considered more nearly a replacement in kind than one governed by standards for roads of much more importance. As a result, the following were adopted: (1) A paving width of 18 feet, the fill section to remain at 30 feet but the cut section to be reduced to 43 feet; (2) A ruling grade of 8 per cent; and (3) A maximum curvature of 18°.[19] The position of the relocation in relation to other features is shown in Figure 17-9 and Plate 17-2.

17-252. Structures. The original hydraulic studies for the sizes of structures for the highway relocation required one bridge with a clear span of 60 feet and two large box culverts in addition to several pipe culverts. A restudy at a later date took into account the storage capacities of the valleys upstream and was correlated with an intensive study, made in collaboration with the excavation contractor, of the best method of diverting and controlling the runoff during the excavation period. These studies led to the adoption of fill sections at the sites of two of the structures that would be heavy enough to act as impounding dams, with box culverts operating under pressure. The bridge was replaced by a 4- by 4-foot box culvert to operate under a maximum head of 15 feet with a depressed section of the roadway, amply protected by riprapped slopes, to act as an emergency floodway for extreme runoffs. A double-barrel 10- by 10-foot culvert was replaced by a 6- by 6-foot box culvert operating under a maximum head of 21 feet. The other large box culvert was eliminated by the change in alignment to the west of Escobar Hill.

Connecting Highways

17-253. Under this title are described the design of the permanent connection between the existing locks and the new locks at Miraflores, the connection between the existing locks and the new locks at Pedro Miguel, and the access roads to future service roads for the new locks from existing or new roads on either side of the new locks. These roads are shown in Figure 17-9.

17-254. Miraflores Connecting Highway. The original plan for this connection was an extension to the south of the west end of the construction road from the bridge over the existing locks to Bruja Road east of the new Miraflores channel. As the emergency-dam designs developed for the new locks, the original plan to pass the connecting highway through the same cut was found impracticable. It was therefore decided to parallel roughly the alignment of the railroad, place the road on a bench above the railroad for a short distance, and then cut through the ridge between the railroad and the new locks and follow along the west side of the ridge until convenient to turn westward to reach the bridge over the new locks. The procedure followed in establishing the alignment where it lay close to and above the railroad was the same as that used for Bruja Road in the cut north of the Cocoli Arm bridge.

17-255. Construction of the subgrade for this alignment was added to the excavation contract, and the necessary structures were included, except for the approach fill to the future bridge. This fill will be largely supported by the backfill for the lock walls, and its construction will be done by the future masonry contractor. Slight modification of the original profile for this section was occasioned by studies to devise a smooth intersection at the bridge, where the railroad and highway alignments converge. A later decision to add a railroad spur near the existing locks also made necessary a lowering of the highway profile, by shortening the length of a vertical curve, to improve the future intersection at grade of the railroad and the highway. Construction of the grade at this point had been completed under the original plans before the change became necessary, so that the rectification remains to be accomplished. A similar change in profile of the construction road was made when a permanent pavement was laid.

17-256. The criteria used to control the design of the Connecting Highway were the same as those for the Bruja Road relocation. It was not necessary to use the maximum allowable gradient; but use of the maximum curvature of 15° was found desirable approaching the future bridge, to achieve rapid separation of the highway and railroad alignments.

17-257. Miraflores Access Roads. The East Access Road joins the Connecting Highway and the service road on the east side of the new Miraflores Locks. Starting normal to the service road near the position chosen for the central control station, it bends slightly to approach the Connecting Highway at a right angle. Its position and profile are subject to modification to fit whatever layout of entrance plaza and shops is finally adopted. The same criteria were used to control the design of this short road as were used for the Bruja Road relocation.

17-258. The West Access Road is merely a turnout from the existing Bruja Road where it approaches the lock wall near the upper gate bay. It forms a right-angle intersection with the service road at that point.

17-259. Pedro Miguel Connecting Highway. Provision for vehicular traffic to pass over the lower gates and through the lock walls so as to connect the service roads entirely within the locks enclosure was a feature common to all the new locks. At Gatun and Miraflores this same service was also performed by the overhead bridges in combination with the access roads from the external highways to the service roads. No overhead bridge is to be provided at Pedro Miguel; so the gate crossing takes on added importance since this will be the only way traffic can pass from one side of the lock to the other.

17-260. Several layouts were developed in an effort to meet all the conditions of future traffic. An analysis indicated that the greater portion of the traffic would be northbound and would pass over the gates of the new lock and of the existing locks in order to utilize this most northerly hookup between the main roads on the east and west banks of the Canal. As a result of this analysis, the alignment finally adopted took the shortest route between the two sets of gates.

17-261. A curve of 200-foot radius passed through the lock wall, the tunnel under the adjacent backfill, and continued to the end of the retaining wall required to restrain the backfill and the back slope of the cutoff dam. From here a tangent intersected the road from the gates of the existing lock. A curve of 300-foot radius was used at this point of intersection. A 7-per-cent grade rose from the level of the new lock-gate crossing to a point about 50 feet beyond the end of the retaining wall. Beyond this point the profile ran level across the spoil area. The profile dropped on a light grade after leaving the spoil area to meet the grade of the existing road.

17-262. Pedro Miguel Access Roads. The East Access Road was an offshoot from the Connecting Highway. It started about 350 feet from the end of the retaining wall, and climbed on a grade of 7.6 per cent to the top of the cutoff dam. There it turned at right angles and followed the top of the dam, and then swung north to join the service road on the east side of the new lock. The 90° bend at the top of the dam was developed as an intersection so that if it should prove desirable in the future a connection eastward could be made to the service road on the west side of the existing locks.

17-263. The West Access Road took off of the relocation of Borinquen Highway where the latter turns sharply westward to leave its common alignment with the railroad. Easy reversing curves at some distance from each other cause this access road to be in effect a continuation of the service road on the west side of the new lock.

17-264. These roads were designed for a 20-foot pavement with 30-foot subgrade sections in fill. The sharp curves and steep grades noted before were required by the limiting conditions. They are fully justified because of the slow speeds that the same limiting conditions will impose on traffic.

17-265. Structures. The only structures required by the connecting highways and the access roads were small box culverts and pipe culverts.

Diversion of Surface Drainage

Pedro Miguel

17-266. The channel for the new Pedro Miguel Lock and its north approach passed through a watershed of approximately 3000 acres. Slightly less than 90 per cent of this area lay to the west of the new channel. All the streams combined to form one channel that flowed southeastward for about 7000 feet within the limits of the excavation. The small tributaries to the east of the excavations carried water only in the wet season and were of no particular importance. Three of the streams to the west had all-year flows, and a fourth was quite large. The interception and diversion of this drainage west of the locks necessitated designs for both temporary and permanent conditions. The design diversion, at first known as the Rio Grande Diversion, was later designated the Rio Sierpe Diversion after the name of its largest tributary.

17-267. The first study for drainage diversion was made prior to the adoption of plans for disposition of spoil in the valleys and on the slopes close to the excavations. Accordingly, there was no conflict between drainage problems and spoil areas. Later, as the spoil areas became better defined, it was necessary to review the whole problem.

17-268. The total drainage to be handled was estimated at 9900 cubic feet per second. The adopted plan has been described partially under Spoil Area PM-IV (Paragraphs 17-152 to 17-157). Initial diversion of two of the all-year streams was to be effected at an early date by means of a dike that formed the western and northern toes of the high portion of Spoil Area PM-IV. Outfall for the waters so impounded would be through a ditch between Spoil Area PM-IV-A and Spoil Areas PM-III-B and PM-III-C. This ditch was 60 feet wide and the upstream invert was at elevation 125. A gradient of 0.15 per cent was used upstream and downstream from this fixed point. The gradient upstream determined the elevations to which spoil could be placed in the valleys above the dike and established the flow line of the collection ditch along the west edge of Spoil Area PM-IV. The ditch discharged into a small valley which was closed temporarily at its lower end by the extension of the dike parallel to the ditch to anchor against a low hill. The third stream that had an all-year flow emptied into this valley. Since it was desirable to provide for a 15-foot depth of water at all points, dikes were designed along the south side of the outfall ditches where the ground was too low.

17-269. The flow out of this valley, or retarding basin, during the construction period was to be through a ditch 70 feet wide cut through a saddle at the opposite end of the low hill and across the north approach channel. A temporary plug to carry the ditch until such time as the waters could flow into the excavation was left in the channel. The ditch across the channel widened to 80 feet, after receiving inflow from another stream about midway between prism lines, and discharged over low ground near the bank of the Canal. The permanent flow out of the small valley was at the southern end, after removal of a portion of the dike, and into the north approach channel through a series of baffled channels that insured dispersed flow rather than a concentrated current.

17-270. It was originally intended to carry the entire scheme to the contract drawings. Instead, only that portion which would form part of the permanent diversion (the 60-foot ditch and its side dike) was shown, and the contractor was free to determine the method of diversion beyond that point, subject to approval by the contracting officer.

17-271. The contractor first proposed a long impounding dam to extend from a point opposite the end of the north approach wall to the same hill into which was anchored the dike parallel to the 60-foot ditch.[20] The alignment of this dam followed that of the highway relocation wherever possible. A ditch was to be dug through the same saddle that was pierced by the 70-foot ditch but would flow northward against the slope of the natural ground and within the limits of the approach channel excavation. The starting elevation of this ditch was 135, which was 12 feet higher than in the scheme described before. This scheme was not approved because of its inherent construction hazards and because it would be of practically no use in the final plan for diversion.

17-272. Obviously, the most advantageous plan to both parties concerned was one whose initial phases could be incorporated best into the final plan (thus reducing the cost to the Government), and which would represent the minimum cost to the contractor in the performance of non-pay work induced by the temporary diversion. The contractor's objection to the design plan was based on the large amount of non-pay excavation east and west of the approach channel. If this cost could be reduced, the objections would be removed. Numerous studies were made to arrive at a satisfactory solution. The final design is described in the following paragraph.

17-273. The original size of the ditches was reviewed, taking into account the reservoir action of the valleys upstream from the 60-foot ditch, with the result that the widths of the ditches were reduced from 60, 70, and 80 feet, to 4, 25, and 30 feet, respectively.[21] The adoption of this scheme left the ditch east of the north approach channel as the only non-pay item to the contractor. In this scheme the highway fill will act as a permanent impounding dam with overflow permitted for extreme runoff conditions. A permanent outfall from the small retarding basin below the highway fill will be constructed by deepening the 25-foot ditch so that its flow line lies below the top of the sound agglomerate when the higher ditch across the approach channel is no longer needed. In this manner the scouring will be minimized and the water can cascade over the benches in the cut slope of the channel.[15]

Miraflores

17-274. Although the courses of three streams were changed in the vicinity of the new Miraflores Locks during the excavation period, only the diversion of one of them was essential to the excavation for the locks structure. This was the diversion of the Cocoli River which entered the Cocoli Arm at such a point as to require a new outfall. The other two were connected with the placing of spoil and will not be dealt with further. (Diversion of the Quebrada Macuco is described in Paragraph 17-189.)

17-275. The flow from the Cocoli River could be permanently disposed of through two distinct channels. One of these channels ran southeastward through a ridge with a top at about elevation 80. It would pass under the existing Bruja Road and then turn southward to parallel the road and enter existing drainage. The portion east of Bruja Road would seriously interfere with the development of the area between it and the new locks as a plant area for the contractor and would also largely preclude the use of the low ground opposite the south end of the locks for spoil placement. The other channel would run northward through a saddle with a top at about elevation 60 and would discharge directly into the most westerly of the two original outfalls of the Cocoli Arm.

17-276. The latter was obviously the preferable route, since it interfered with nothing else and involved the minimum excavation. A few auger holes were put down to determine the character of the overburden and the approximate depth to rock. A channel 50 feet in width with side slopes of 1^v on 2^h and a level bottom at elevation 45 was selected. This profile grade was 9 feet below the normal level of Miraflores Lake. The channel had to be of sufficient capacity to prevent the formation of unfavorable currents across the ship channel in the lake.

Earth Cutoff Dams

17-277. The prime function of the earth dam east of the new Pedro Miguel Lock was to create the surge reservoir. The earth dam on the west was necessary to reduce the hydrostatic pressure that would be exerted by the waters of Gatun Lake under the sloping sides of the gate dry dock. Both dams served also to lower the ground-water table in the backfill to the south, thereby increasing the factors of safety originally introduced in the wall design assumptions and the provisions for drainage of the backfill. (See Chapter 7 of this report.)

17-278. At Miraflores, the concrete at the north end of the right lock wall will be placed to full height against a strong rock formation, thus making unnecessary any other protection against the head of Miraflores Lake. The rock on the left side at the north end was barely high enough to rise above the level of the lake and was much weaker in character. Hence an earth cutoff dam has been provided there also.

Surge-Reservoir Dam - Dam "C"

17-279. The first alignment chosen for the surge-reservoir dam extended from the lower gate bay of the new lock to the backfill of the existing locks by the shortest route. Subsurface investigations of the backfill indicated that a more impervious portion lay somewhat north of the original line. Still later, the position of the new lock was changed and the lower gate bay was moved northward. As a result the whole alignment for the earth dam shifted to the north, and reduced somewhat the capacity of the reservoir.

17-280. A few auger holes were put down in the hydraulic muck along this new center line to determine roughly its depth. A dam was then designed to rest on top of the muck,[22] with a top width of 150 feet, and side slopes of 1^v on 18^h. It was believed unlikely that a dam of this type could be built without failure during construction. This belief, combined with the great volume of rolled fill that was required, the reduction in the capacity of the surge reservoir by the very flat slopes, and the loss in utility of the area as a plant site and storage area for selected backfill, led to the abandonment of the design.

17-281. The program of auger holes was abandoned and core drilling substituted therefor. A suitable foundation was found at a not prohibitive depth. Consideration had been given already to removal by suction dredge of the hydraulic muck within the limits of the excavation for the locks. The large amount of muck to be removed under the dam also could be done most conveniently by this method. Laboratory tests established that, depending on the depth after unwatering, the muck would stand at slopes varying from 1^v on 4^h to 1^v on 9^h.[23] The muck would be removed to these slopes by both wet and dry methods with the slopes beginning at the line of intersection of a 1^v on 1.5^h slope from the shoulder of the dam and the firm foundation. The impervious core of the dam would be composed of carefully compacted material to be obtained from the excavation for the locks or near-by borrow pits. It would be placed to form a fill 20 feet wide at elevation 90 with slopes of 1^v on 0.5^h. Whatever suitable material was available would be used to complete the structure. The top would be at elevation 92 and would be 150 feet wide, this width being dictated by bombproofing considerations. Side slopes of 1^v on 3^h and 1^v on 2^h would be used on the wet and dry sides, respectively. The spoil area to elevation 70 would be placed outside the limits of the dam.

17-282. To correct the known perviousness of the backfill for the existing locks, an extension of the dam was originally designed as a cutoff wall roughly paralleling the existing locks and tying to the Pedro Miguel West Dam. It was to be built by excavating a ditch through the pervious material and by carefully backfilling with compacted fill to create a watertight diaphragm. Drilling disclosed that the rock was very low. Accordingly, the cost of such a structure was high. The final solution was an earth blanket, originally 10 feet thick but later reduced to 2 feet, whose extent and method of construction are described under Spoil Area PM-II. Plate 17-2 shows the location of Dam "C".

Gate Dry-Dock Dam - Dam "A"

17-283. The original plan for the cutoff dam on the left side called for an earth dam to connect the retaining wall at the left side of the dry-dock entrance to a hill a short distance away. Seepage through the spoil to be placed in a valley behind this hill, and through the dry-dock walls when the dock was full of water, required a second cutoff farther to the south, opposite the knuckle of the north approach, to connect with the main range of hills. This latter dam was about 1000 feet long and some 35 feet above natural ground. Little information was available as to the depth of the overburden above sound rock. The original contract plans called for both of these dams and for a large amount of extra backfill between the south end of the dry dock and the lower dam to avoid the creation of a lake of stagnant water. These dams were designated on the drawings as "A" and "B", the former being the one at the entrance to the dry dock. Dam "A" is shown in Plate 17-2.

17-284. Subsequent core drilling revealed that the sound rock under Dam "B" was lower than anticipated, thus materially increasing the volume of the rolled core. Meanwhile, continuing study also had shown that Dam "B" could be eliminated without loss of any of its functions if changes were made in the design of Dam "A" and if the probabilities of seepage from Gatun Lake through the spoil area were correctly evaluated. Adoption of such a course would greatly reduce the volume of fill to be placed and eliminate the necessity of the extra backfill at a further saving of nearly $200,000.

17-285. The design of Dam "A" was changed to make it continuous along the three outer sides of the dry dock. Keyways were used to effect seals at both ends between the rolled core and the concrete against which it abutted. The top of the dam was placed at elevation 95 with the impervious core rising from sound rock to elevation 90. The width of the core was 20 feet at the bottom and at the top. Side slopes of 1^v on 1^h in the section below natural ground were intersected by side slopes of 1^v on 0.5^h coming down from the top. The top widths of the leg at the entrance end of the dry dock and of the leg parallel to the length of the dry dock were fixed at 50 feet because of restricting conditions; but the top width of the third leg was set at 100 feet. All slopes toward the dry dock were 1^v on 3.5^h while those away from the dry dock were 1^v on 2^h except for the leg at the entrance, which had a slope of 1^v on 3.5^h on both sides. The position of all of the legs is such with respect to the finished dry dock that the paving on the sides of the dock may be placed directly on the slopes of the dam.

Miraflores Earth Cutoff Dam

17-286. Between Stations 129 and 131 on the left side of the new Miraflores Locks, the top of sound rock was found at about elevation 56, only 2 feet above the level of the lake. It dropped away rapidly to the west and was badly jointed. It also sloped downward to the south so that opposite Station 125 the top of the rock was at elevation 35 and then rose sharply to above elevation 60. To effect a positive seal against the lake waters, it was necessary to parallel the lock for about 700 feet and then turn normal to the lock wall to close against it. The center line of the dam parallel to the lock was established at 250 feet west of the axis, thus leaving space between the dam and the lock wall for the placement of free-draining backfill and for the construction of the service road off the top of the dam. The majority of the dam is of the core-trench type, the excavation being carried down at slopes of 1^v on 1^h to sound rock so as to give a width of 30 feet at the base of the dam. If suitable, the material excavated may be replaced in the trench. The shrinkage due to the rolling will require some borrow to top out. Where the dam turns toward the lock wall, the section changes from the trench type to a fill type with a top width of 20 feet and side slopes of 1^v on 1.5^h. The top remains at elevation 60 throughout its length. The dam is shown in Plate 17-3.

Water Mains

17-287. The only filtered water main at Pedro Miguel that entered the area to be occupied by the construction of the new lock was a 3-inch line serving Army outposts in the vicinity. At Miraflores, however, a 12-inch main had been laid in recent years to serve Navy and Panama Canal installations along the west bank of the canal to the south of Miraflores. This construction had been necessary to augment the supply available from an 8-inch line that crossed the Canal at Thatcher Ferry. The submarine section of this 8-inch line had required a great deal of maintenance, and when it became necessary to increase the supply the new 12-inch line had been carried across the locks at Miraflores to follow Bruja Road. Since a considerable portion of Bruja Road lay within the excavation limits for the new locks, temporary relocation of a part of the 12-inch main was necessary, and a permanent location also had to be determined. The locations of the 3-inch and the 12-inch mains are shown in Figure 17-7.

17-288. The greater demands for filtered water represented by the construction of the new locks, the additional expansion of existing Naval facilities, and the construction of new Army units would eventually require that the supply of water be further increased. This was the responsibility of the Municipal Engineering Division, and any alignment for the relocation of the 12-inch main that would meet the Third Locks needs would also serve for a main or mains of larger capacity.

17-289. Construction at Miraflores was scheduled to precede that at Pedro Miguel. Hence the study of the required relocation at Pedro Miguel could be deferred, but the relocation at Miraflores required immediate attention, even though the planning was only tentative for many of the features that might affect the relocation.

17-290. The alignment of the 12-inch main between the locks and Bruja Road brought it under the original position of the stock pile of crushed rock for concrete aggregate. The proposed relocation therefore placed the line adjacent and parallel to the locks from the north crossover to the south end of the lower chamber. Here it turned westward, just north of the north toe of Spoil Area M-I, to join with the existing line at Bruja Road. This relocation had the dual advantage of removing the line from an area to be used for the Third Locks and of producing the shortest final alignment, since from this point of junction it would ultimately be laid southward on the east side of the new locks until it could be carried in a crossover across the new structure, and then would continue westward and normal to the new locks to join the existing main along Bruja Road.

17-291. From the point of temporary junction at Bruja Road east of the new locks, a new line would be laid northward to cross the north land plug, return to the south over the construction dike in Spoil Area M-IV, and again connect with the existing main along Bruja Road. All this section would be salvaged after completion of the permanent installation.

17-292. The new main was laid in accordance with the preceding outline, but the size of the main was increased to 16 inches to provide for increased demands. The part of the main along the construction dike was placed above ground to facilitate its salvage. When the area between the locks was abandoned as a location for the crushed-rock stock pile, another 16-inch main was laid from the existing locks to connect with the recently installed 16-inch main at the north land plug, and the length of the pumping line during the construction period was reduced about 3500 feet. The Municipal Engineering Division determined the positions of all valves and special fittings.

17-293. The 3-inch line at Pedro Miguel took off from a 6-inch line in the gallery of the west wall of the locks and followed Bruja Road southward to where it left the road to serve outposts of the United States Army. The original plans for its relocation simply relaid the line so as to carry it across the south land plug instead of following Bruja Road across the excavation for the locks. When the nature and extent of the overburden in the new locks area became fully known, it was decided to remove the poor material by suction dredge. Therefore, the south land plug could not be completed until the dredge had withdrawn from the area and in the meanwhile Bruja Road, where it crossed the new locks, would have to be removed.

17-294. There were two ways in which a continuous water supply to the outposts could be maintained. One was to bring a line up from Miraflores and the other was to run to the north, thence over the center plug, and again southward to the west of the new locks. Both of these involved entirely too much expense for the value received. A conference was arranged with Army personnel responsible for the supply of potable water to outlying units, with the result that the Army undertook to obtain a supply for those particular outposts by drilling, and the Special Engineering Division was relieved of any further concern in the matter.

Electrical Facilities

17-295. The only electrical facilities that required relocation in the vicinity of the new Pedro Miguel Lock were a telephone line running northwestward to serve the Cucaracha Signal Station, and some Army Signal Corps cables. At Miraflores, partial relocation was required of similar facilities and of power lines. The Panama Government telephone lines to the interior of the Republic also required partial relocation at Miraflores to remove them from the site for the new locks. With the exception of the Cucaracha Signal Station telephone line at Pedro Miguel, all the relocations necessary to clear the site were accomplished during the excavation period, and plans for the permanent positions were completed.

17-296. The relocation problems presented at Miraflores were minor in importance compared with the expansions required by the Third Locks and the needs of construction by other agencies in the affected areas. Consequently, the relocations of electrical facilities were made by the Electrical Division of The Panama Canal and by the Army Signal Corps.

17-297. Completion of the relocation of the telephone line to the Cucaracha Signal Station was not necessary because of the modification of the Third Locks Program. Two routes have been developed for the relocation, and a final selection will be made at some later date.[24]

Channel Lights and Buoys

17-298. Bank lights and floating buoys along the west bank of the

Canal require temporary relocation during the dredging of the Third Locks channels, and permanent relocation at the conclusion of the Third Locks program in order to serve the new as well as the old waterways. Temporary relocations were made by the Lighthouse Subdivision of the Marine Division of The Panama Canal. The permanent locations were determined jointly by the Lighthouse Subdivision and the Special Engineering Division. The necessary manholes and duct lines have been provided in the new structures.

17-299. The bank light supply cable will begin at the intersection of the left bank of the Pedro Miguel north approach channel and the left bank of the Canal and will run southward along the left bank of the new channel to the north end of the left north approach wall. It will enter a gallery at that point and will be carried to the upper crossover, thence back in a gallery to the north end of the right north approach wall, and then northward along the right bank of the by-pass to connect with the existing cable on the left bank of the Canal. Beginning again at the lower end of the existing Pedro Miguel Locks, the cable will run down the left bank of the Canal, around the turn and up the right bank of the south approach to the new lock, across the new lock via the galleries in the south approach walls and the lower crossover, and thence southward along the left shore of Miraflores Lake to the new Miraflores Locks. Here it will follow again the approach walls, using the upper crossover to cross the new locks, and returning northward along the right bank of the north approach channel to connect with the cable in the gallery of the left approach wall of the existing locks. The channel in Miraflores Lake which cannot be served by bank lights will be marked as at present by lighted buoys. A similar loop will serve the bank lights south of the existing locks and the south approach channel to the new Miraflores Locks.

17-300. Only the temporary relocations in the vicinity of Miraflores have been completed. The remainder of the temporary work and all of the permanent work will be performed as required when the Third Locks work is resumed.

Conclusion

17-301. Many other studies and designs not described in the foregoing were completed, on the Pacific side as well as on the Atlantic side. Although a number of these were not translated into formal drawings, all were basic for or essential to the designs that have been discussed. To illustrate the point: In connection with the drainage canal in the Gatun area, the design of a revision of the surface drainage to relieve the periodic flooding of Fort Davis was required, and with respect to the whole problem in this area, it was necessary to determine for the Fort Davis Military Reservation a temporary boundary that would protect adequately the interests of both the U. S. Army and The Panama Canal during the construction period. Again, backfill provision has been mentioned only insofar as it affected the design of the spoil areas, but the necessary estimates of backfill quantities constituted a major task. The examples given were among the major items. There were many others of lesser importance.

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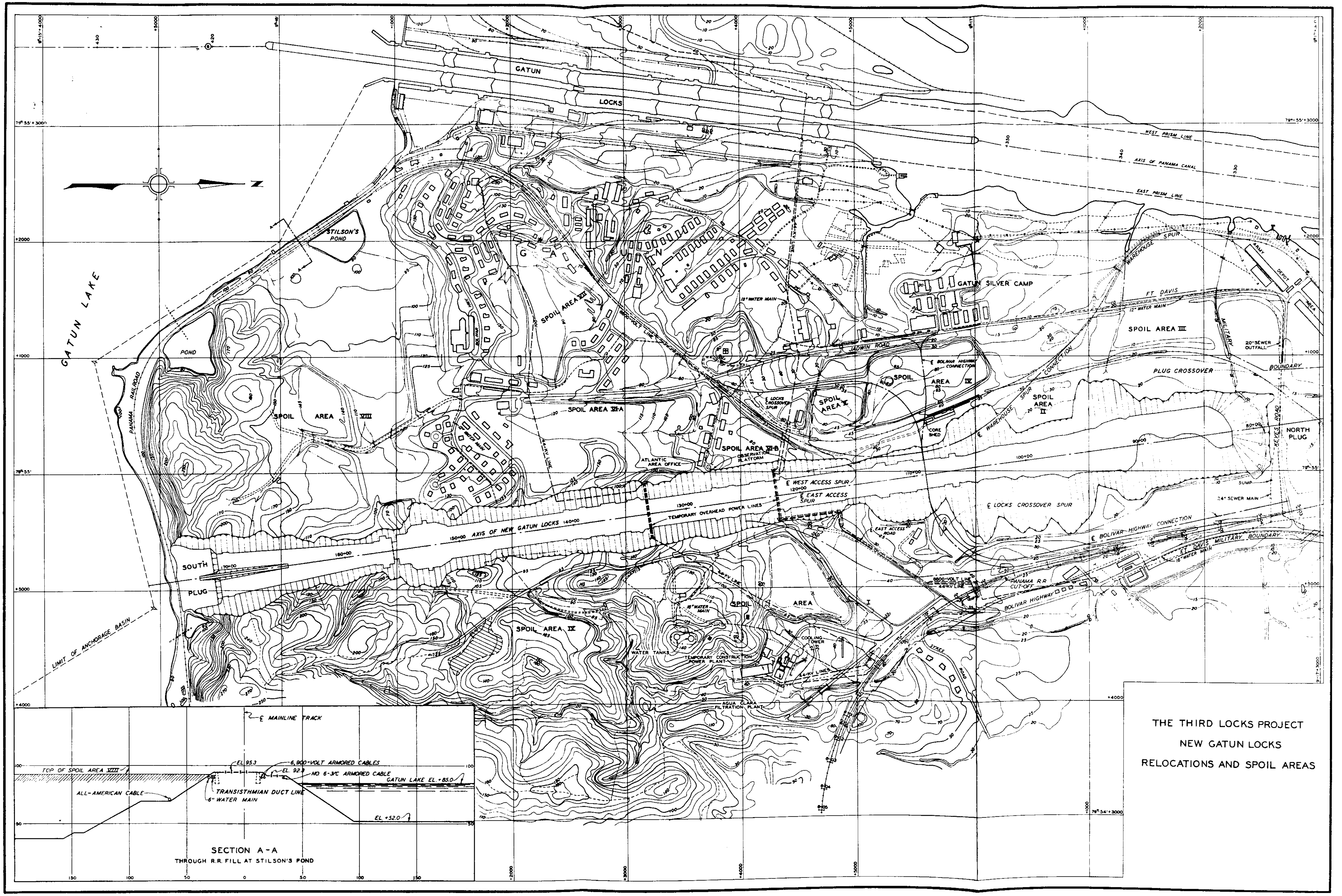
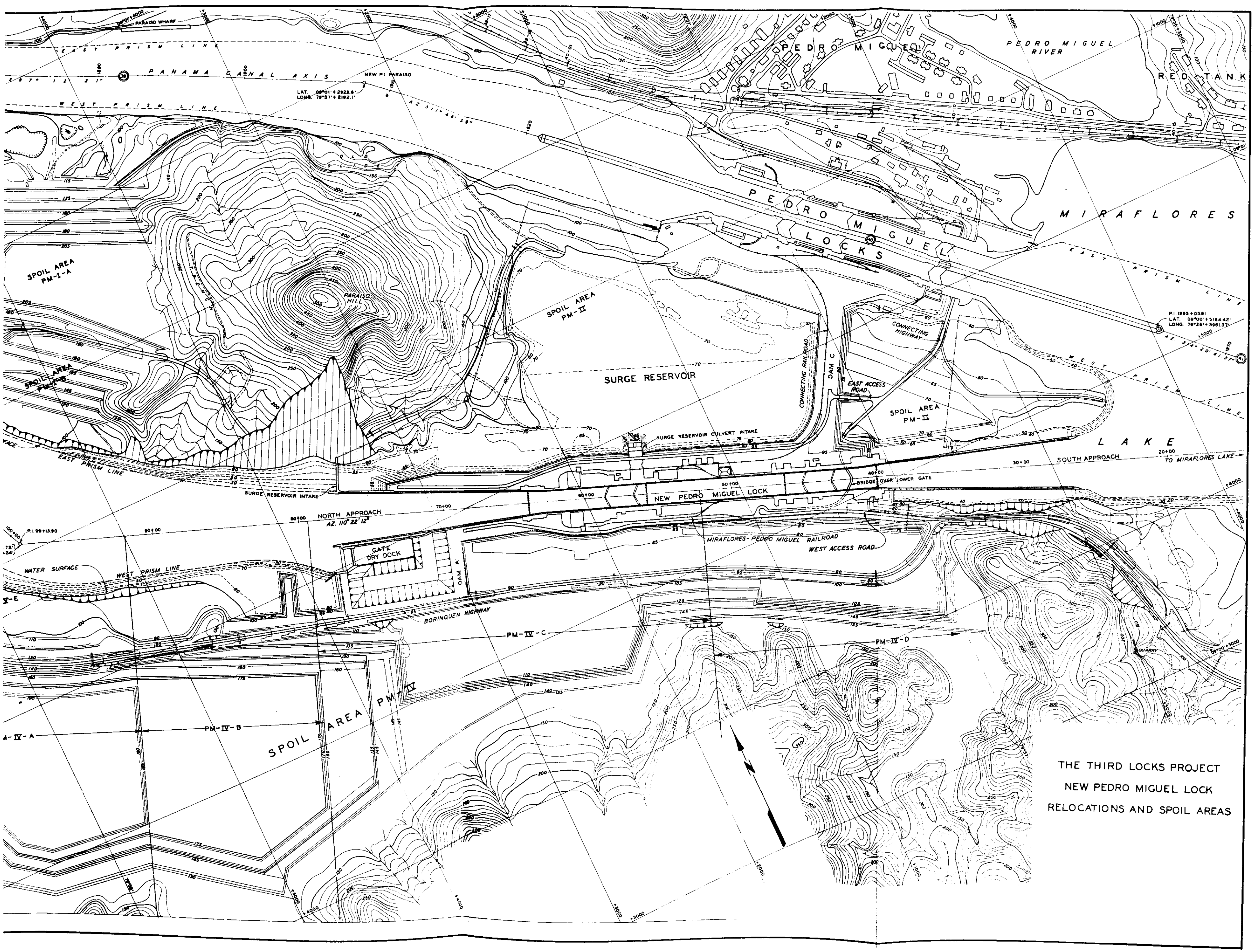
AUTORIDAD DEL CANAL DE PANAMA - CENTRO DE RECURSOS TECNICOS



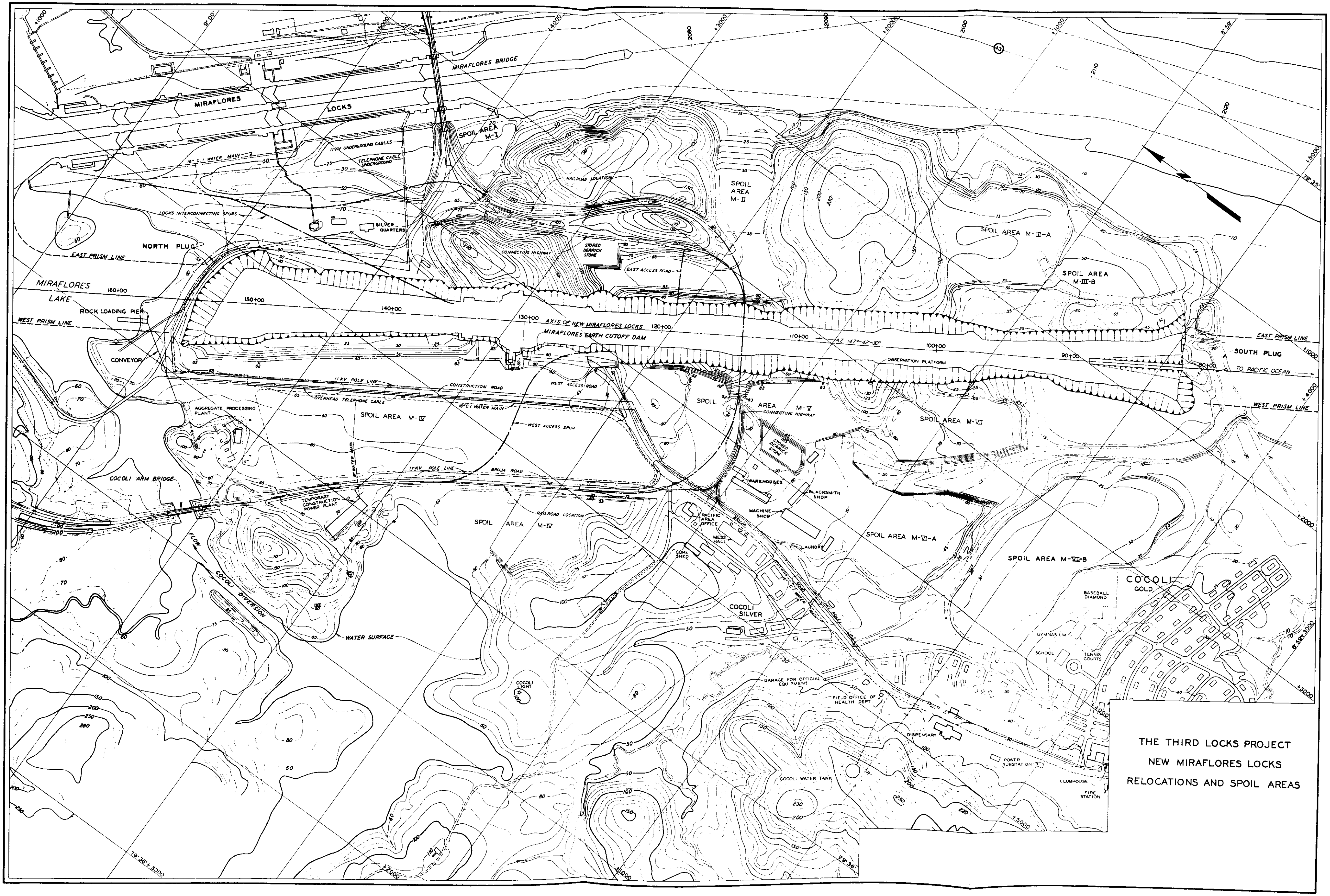
THE THIRD LOCKS PROJECT
NEW GATUN LOCKS
RELOCATIONS AND SPOIL AREAS

PLATE 17-1



THE THIRD LOCKS PROJECT
NEW PEDRO MIGUEL LOCK
RELOCATIONS AND SPOIL AREAS

PLATE 17-2



THE THIRD LOCKS PROJECT
NEW MIRAFLORES LOCKS
RELOCATIONS AND SPOIL AREAS

PLATE 17-3