TO: Mr. L. J. Van Mol, General Manager, 411 NSB
FROM: G. P. Palo, Chief Engineer, 607 UB
DATE: December 1, 1961
SUBJECT: REPORT ON FAILURE OF WHEELER LOCK

Approximately 436 feet of the land wall of the navigation lock at the multipurpose Wheeler project failed on June 2, 1961. The 60- by 360-foot lock, with a maximum lift of 52 feet, was part of a 650-mile waterway. A new 110- by 600-foot lock was under construction adjacent to the old lock and between it and the north riverbank. At the time of the failure a large tow, traveling upstream, had just cleared the lock so the upstream miter gate was open and the downstream miter gate closed. The water in the chamber was at elevation 555.8--near its normal maximum level.

Water cascaded over the miter sill into the lock chamber for almost four days until the needle dam could be placed to close off the upstream end of the lock. Soon after the failure, the reservoir was lowered from elevation 555.8 to elevation 549.0 to facilitate the placing of the needle dam and to reduce the head on the remaining structures. A cofferdam between the downstream approach walls was closed on June 11 and by June 15 the new and the old lock areas were unwatered. Immediately thereafter, to increase the safety of the north nonoverflow dam, foundation relief drain holes were drilled into the rock and part of the concrete for the upstream miter sill for the new navigation lock was placed against the downstream face of the dam.

It was promptly agreed that we should employ independent consultants capable of making an impartial and authoritative investigation of the failure. We were fortunate in obtaining as consulting geologist Dr. Frank A. Nickell, San Mateo, California, and as consulting engineers Mr. Lee G. Warren, Asheville, North Carolina, and Dr. John B. Wilbur, Hancock, New Hampshire.

These consultants visited the project on June 18-20, August 19-21, and October 27-29, 1961, to make on-site investigations and to review information and data accumulated by this office.
REPORT ON FAILURE OF WHEELER LOCK

The investigation disclosed that the failure of the land wall was due to sliding along a thin seam of clay, varying in thickness from one-sixteenth to three-eighths of an inch, located in a shale band in the foundation a short distance below the base of the lock wall. This seam is described in Appendix D of this report. The sequence of events leading to this conclusion is described in the following paragraphs.

Foundation investigations prior to start of construction of the new lock had included 20 NX diamond drill holes, 3-inches in diameter, at spaced intervals along the center line of each wall of the proposed new lock and three 36-inch diameter holes made with a calyx drill. The cores of the NX holes were logged by an experienced geologist in the presence of the drillers. The calyx holes were examined by a number of persons including geologists and engineers of wide experience. This examination was made by going down into the holes and inspecting the rock faces.

No record of the clay seam has been found in the reports on the original lock construction. In the new investigations before construction no evidence of the clay seam showed up in the cores of any of the NX holes and the visual inspection of the faces of the calyx holes likewise failed to reveal its existence. The clay seam was too thin to show up in the NX holes. It was not detected in the calyx holes because it has the same color as the contiguous shale and both the shale and the seam were recessed by the grinding action of the chilled shot used as the cutting medium. Accordingly, the stability of the existing land wall was evaluated on the assumption that the cores from the drill holes correctly reflected the condition of the underlying foundation, and the steps taken in constructing the new lock were predicated on the stability of the old lock wall as thus evaluated.

After the failure two weeks elapsed until the area was sufficiently unwatered so that the failure could be established as sliding within the foundation rock. During this period consideration was given to many conceivable causes including not only major weakness in the foundation or the lock wall but also such possibilities as sabotage, earthquake, and barges striking the wall. When, upon unwatering, failure was found to be sliding within the shale band, all other causes were eliminated either as nonexistent or not of major
significance and effort was concentrated on learning why the shale band had so much less shearing strength than had been expected on the basis of investigations made in advance of construction.

Foundation inspection in mid-June provided no clue to the reason for the unusual weakness of the shale band and it was decided that structural tests would be essential to learn the reason for its inadequate strength. The first step in this program was laboratory testing. The results showed strengths much above that needed to have withstood failure, but the techniques available for cutting the test samples from the foundation could not obtain a short section near the base of the shale band. It was therefore decided to attempt structural tests on the rock in place.

While steps were being taken for field tests of the strength of the foundation, rock excavation to levels below the shale band was going on in areas of the lock walls and in a 36-inch pilot hole needed to initiate excavation for the main lock discharge structure. Early in September some of these areas were pumped dry and an engineer inspecting a rock face which exposed the shale band found the thin seam of plastic clay. Steps were taken immediately to determine the extent of this clay. New 36-inch calyx holes, noted in the consultants' report, were a part of this investigation. These foundation checks, combined with facts already available, established that:

(1) The plastic clay seam existed essentially throughout the lock area.

(2) The clay seam was so nearly in a plane and so nearly horizontal that it could easily lubricate and be a sliding surface for the rock immediately above and below.

(3) Under the walls of the old lock the clay seam was at an elevation which made it particularly critical during excavation for the new lock.

This information established the reason for the failure. Accordingly, further steps to field test the strength of the shale band were dropped and the consultants were reconvened to discuss the new information and to prepare their final report.
The report of the consultants dated October 29, 1961, is attached. It is supplemented by appendices and exhibits of TVA with factual information obtained both before and after the failure. The report describes the reasons for the failure of the land wall and also describes how the two locks, each of which will include portions of the original lock and dam, are being constructed so as to be safe from sliding.

G. P. Fols

Attachment
TENNESSEE VALLEY AUTHORITY

Office of the Chief Engineer

Report No. 3-480

REPORT ON WHEELER LOCK FAILURE

Knoxville, Tennessee

November 1961
# REPORT ON WHEELER LOCK FAILURE

**TENNESSEE VALLEY AUTHORITY**

**OFFICE OF THE CHIEF ENGINEER**

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Exhibits
Wilson Dam, Alabama
October 29, 1961

Mr. G. P. Palo
Chief Engineer
Tennessee Valley Authority
Knoxville, Tennessee

REPORT ON WHEELER LOCK FAILURE

Introduction

The project at Wheeler Dam had a lock for navigation on the right or north side of the river. This lock was completed under the direction of the U. S. Corps of Engineers and put into operation by December 1, 1936. The lock operated without significant difficulty over the years since completion.

At 9:20 p.m. on June 2, 1961, when traffic was being handled normally through the lock, a sudden failure of the land wall occurred. The collapsed portion of the wall extended for a distance of 436 feet, and included the massive block of the downstream miter gate with a portion of the adjoining, lower guide wall. There was no disturbance or failure in connection with the river wall of the original lock. In consequence of this failure all river traffic, previously handled at Wheeler Dam, was interrupted.

The Tennessee Valley Authority immediately undertook investigations to determine the cause of failure and to formulate plans for reconstruction of the original lock and for continued construction of the larger, second lock located just north of the wall that failed. The Tennessee Valley Authority secured services of F. A. Nickell, geologist, Lee G. Warren, and J. B. Wilbur, engineers, as consultants to investigate and determine causes of failure. The site and progress of removal of structures that had failed, and progress in building of the new locks were inspected by these consultants on three occasions, namely, June 18-20, August 19-21, and October 27-29 (1961). During the periods between inspections by the consultants, the staff of the Tennessee Valley Authority carried out a program of additional exploration of foundation rock for both lock areas and compiled all evidence obtainable, by inspection, that might be significant in explanation of causes of failure.

Studies have now been continued to a stage at which the consultants consider that the causes of failure can be established, and replacement of lock facilities can be safely carried out.
Evidence of Failure

The staff of the Tennessee Valley Authority has assembled all observations and discussions that could be documented in order to describe the sequence of events occurring at time of failure of the lock wall.

The evidence assembled indicates that failure originated in the land wall, starting with the pintle block (No. 12), and seems to have resulted simultaneously in the collapse of the guide wall immediately downstream; this failure progressed therefrom rapidly upstream with successive failure of adjoining blocks up to, but not affecting block No. 1, for a combined length of land wall of 436 feet.

The failure, as indicated by observation and by evidence provided in the position of the several blocks of the land wall, involved lateral movement in a northerly direction (away from the river) for a distance of about 30 feet. Many of the blocks between Nos. 12 to 3 exhibited both a component of movement in an oblique downstream direction as well as rotation so that the downstream landside corner of each block came to rest farther from its original position than did the upstream landside corner of the same block.

The tearing of the lock gates from sockets and restraining devices, the overturning, breaking and cracking of individual concrete blocks, the effects of impact due to movement of the concrete blocks against bedrock of the new lock channel being constructed on the landside of this collapsed wall, as well as the disturbance in bedrock noted in proximity to the non-overflow section of Wheeler Dam have been, as mentioned, extensively documented, photographed, and investigated.

The physical demonstrations of failure indicated by evidence provided in position of the displaced blocks of the landside wall can be summarized as follows:

(a) Blocks 2 to 6 slid northward, but portions of individual blocks near the interior of the lock chamber remained in their original position.

(b) Blocks 7 to 11 slid in a northerly direction, mostly intact.

(c) Block 12 (pintle block) also moved northerly but had a greater component in an oblique downstream direction.

(d) Smaller blocks of the guide wall (Nos. 13 to 15) downstream of the pintle block (No. 12) broke extensively during disturbance and movement.

*Marginal references added by TVA to facilitate detailed study of report.
Available Reports and Information

There has been placed at our disposal a substantial amount of information.

This information includes drawings prepared in connection with design and construction of the original lock. These data, regarding investigations, interpretation and plans for the original lock, are contained in reports prepared by the U. S. Corps of Engineers. The interpretation of conditions and general adequacy of design in conjunction with construction procedures, apparently were adequate, inasmuch as the lock operated satisfactorily with no more than normal maintenance up to the time of failure.

The Tennessee Valley Authority had approval of plans for the construction of a larger, second lock located on the north side of the existing lock, in order to handle increased volume of river traffic. In preparation for the construction of the second lock, a program of foundation investigations had been carried out, including twenty NX diamond drill holes at spaced intervals along the center line of each wall for the proposed new lock, and three 36-inch calyx holes, one in the lock chamber near the dam and the others at points opposite the downstream pintle block, one on the river side and the other on the land side. The cores obtained from both NX and calyx holes were logged and results correlated for interpretation of features in, and nature of the rock in the foundation area beneath the proposed new lock. The calyx holes were inspected visually, and descriptions of observations were prepared to show the foundation features.

After the failure occurred, the Tennessee Valley Authority and the consultants recognized that conditions in the foundation should be investigated further. As a result, a systematic study and mapping of all observable bedrock features and structures were carried out. Two 36-inch calyx holes were drilled on the river side of the river wall of the original lock. A pilot, 36-inch calyx hole was drilled to a depth of 60 feet at the site of the river outlet of water to be discharged from the new lock; a 24-foot shaft to a depth of 40 feet was available for inspection where this pilot hole had been drilled.

The bedrock features revealed by this investigation have been correlated and some laboratory tests have been made on specific features in bedrock, having relation to causes of failure. Information regarding external conditions that might be connected with failure were examined, including the seismic records of stations at St. Louis and Cape Girardeau, Missouri.
Causes of Failure

The observations made at the time of failure, the movement involved in the various blocks of the landside wall, crack patterns that were carefully mapped and correlated within the individual blocks of concrete, all combined with results of geological studies regarding the foundation problems, clearly show that the failure was due to sliding of the landside wall along a weak zone in the near-surface levels of foundation rock underneath this structure.

Geological studies and drill holes show that the Ft. Payne formation at the site consists of limestone, argillaceous to crystalline, fine to somewhat coarse-grained, with a shale layer of average thickness, 0.5 ft., at a shallow depth below the base for the full length of collapsed wall. Shaley partings occasionally are found between otherwise normal succession of limestone layers. It was known from both earlier and more recent geological studies, and confirmed by our observations, that the rock layers in the area concerned have a gentle downstream and oblique dip into the hill (northwest) of about 1-1/2 degrees. Observations on the ground and in calyx holes indicated that in addition to bedding structure there are joint patterns, the most conspicuous of which also has a northwesterly trend and a vertical dip. The combination of vertical joint systems with flat-lying bedding structures allows a small amount of ground water movement at various depths throughout the foundation area.

The consultants recognize, and the staff of the Tennessee Valley Authority had indicated, the existence of the shale band (0.5 ft. average thickness) at a level slightly below the general foundation of the collapsed wall. It was clearly seen that sliding occurred on a very smooth surface near the base of this shaley band.

When the original lock was built, an open trench was excavated adjacent to the toe of the landside wall in anticipation that ultimately an additional lock would be built, adjoining the original structure. This open trench was slightly deepened and widened in the early stages of construction for the second lock. Excavation involved blasting which, while carried out with great care, had some disturbing effect on rock surrounding this trench. The records indicate that prior to failure construction progress had not reached the stage when the trench would be unwatered and cleared of debris by the Tennessee Valley Authority, and bedrock features that might have been exposed within this trench were not seen.

The failure, occurring after a long period of successful operation, would indicate that the design and construction of the original lock carried out by the United States Corps of Engineers were adequate for the bedrock conditions involved for that original structure. The
collapse of the wall, by movement along the shale band in the course of construction for the second lock, is related to a change of stability conditions of bedrock due to the operations in new construction; and, these changes include the deepening and widening of the trench at the toe of the collapsed wall which in some measure diminished the rock support.

The shale band is recognizable from other rock immediately adjoining it, according to the core recovered from NX drill holes. The almost complete core recovery, however, did not reveal any unusual weakness within the shale member. The shale appeared to have adequate physical strength to carry the loads imposed by the concrete wall that failed.

Recent 36-inch diameter calyx holes show, near the base of the shale band, a seam of clay about 1/16 to 3/8 inches in thickness, plastic in character, with virtually no frictional resistance to sliding. This clay seam, with careful search, is likewise seen in trenches now excavated and unwatered for walls both to replace the collapsed wall and for those of the new lock, and in the 24-foot shaft for river outlet, in a corresponding position near the base of the concerned shale band. This seam corresponds in dip to that of the bedding in bedrock, about 1 1/2 degrees, in a northwesterly direction. The clay seam lies below the base of the keys for blocks No.'s 8 to 12; is at levels similar to the base of keys for blocks No.'s 6 and 7; and in general, is above the base of keys for blocks No.'s 2 to 5.

A film of grout on the surface of failure under some blocks corresponded in position to this clay seam. We believe that failure occurred by movement along this clay seam. The failure apparently started with movement out of place of the pintle block (No. 12), where forces, concentrated by the miter gate, seemingly were adequate to move this block out of position. Progressive failure of each successive block in an upstream direction then followed.

We have reviewed the information available from the investigations for the original lock and the results of studies carried out by the Tennessee Valley Authority in preparation for construction of the new lock. It is obvious that at no time did observations and studies completed bring to the attention of engineers concerned the existence, or importance therefrom, of the clay seam in the shale band, although the shale band itself had been recognized in all of the studies made for both the old and new locks. The trench, deepened later in preparation of footing for final design of the common wall with the new lock, was not unwatered, and observations of bedrock features thus were not made. The inspection of 36-inch diameter calyx holes, drilled prior to the failure, indicated to the geological observers the presence and width of the shale band in question. However, due
to irregularities in the wall of the holes, the thin seam of clay was not observed. The presence of the critical, soft seam escaped recognition at any time during construction of the original and of the new locks.

The engineers, in design of the common wall of the new lock, evaluated the stability of the existing landside wall of the old lock before it collapsed. Based on cores recovered from the 20 NX drill holes, and using normal physical strengths for the shale itself, they reached a conclusion that the contemplated additional excavation for the existing trench along the toe of the landside wall was permissible.

The causes of the failure, therefore, can be summarized as due to the presence of the shale band, which also had a plastic, thin seam of clay near its base that escaped recognition, and to the resultant deficiency in the physical competency of the shale band.

The seismological stations at Cape Girardeau and at St. Louis recorded a microseism roughly corresponding to the time of failure. The interpretation, based on travel time and time of occurrence, shows that the origin of this shock lay in a general direction toward Wheeler Dam.

Design and Construction of the Two New Locks

The consultants have examined the general plans prepared for replacement of the original river lock, which will be extended in length 40 feet, and of the new lock with total length of 600 feet, being built adjoining and to the north of the area of the original lock. The conditions that resulted in failure of the original lock are eliminated in the design and construction of the two new locks at Wheeler Dam. The new footings for the confining walls of the chambers are placed on rock everywhere below the base of the shale band wherein failure by sliding occurred. All of the pinte blocks for the new locks at the downstream end are designed more conservatively and are founded on rock below the shale band to provide a substantially increased factor of safety. The removal of most of the concrete of the original lock, including the river wall which contained numerous crack patterns and was seated for a considerable portion of its length on or slightly above the shale band, eliminates this wall and its degree of stability from any future concern. The design and construction of these two new locks conform to requirements as to the section of walls and as to the depth of excavation regarding acceptable foundation rock, including:
(a) The common wall between the two new locks for the distance involved of the total length of lock replacing the original lock will have a combined base of about one and one-half times that of the landside wall that failed, and will be seated throughout this length below the shale band;

(b) The part of the central wall beyond the miter block of the new river lock will have a gravity section and be founded on bedrock below the shale band throughout. It will be more stable also because of increased crest width and resultant additional weight compared to those of the landside wall that failed. The miter block of the river wall for the new second lock will be increased in width and length for a larger degree of safety to receive stresses from the miter gate attached to it;

(c) The landside wall of the new and longer second lock will be seated on rock throughout, below the shale band. This longer landside wall has massive resistance against sliding northward, with the second lock in operation, due to the support provided by the vertical wall of rock excavated along the base of the hill and against which the concrete toe of this new landside wall abuts. The rock of the hill will be adequately drained to prevent accumulation of water from whatever source which might develop excessive unbalanced lateral force against the landside wall when the longer second lock chamber is empty;

(d) The base of the river wall of the lock replacing the original lock will be seated on bedrock below the shale layer and the pintle block of this riverside wall in its length and new position will be enlarged both as to width and in direction paralleling the lock for greater security against stresses developed by the attached miter gate, and everywhere will be founded on rock below the shale band;

(e) The walls of the two new locks are designed with conservative uplift assumptions over the entire base, and furthermore have more than the usual gravity section by virtue of crest width so that foundation drainage does not appear to be necessary. For cases when one lock is filled and the other is empty, the rock below the walls will be grouted under gravity pressure by holes carried to a depth of 15 feet below the concrete base of the walls, in order to seal to this depth existing cracks in rock which may pass water. In obvious places of vertical joints cutting across the rock below the individual blocks, special grout pipes sealed in these joints will be used;
(f) The design plan calls for a grout curtain below the heel of each wall to a depth of 30 feet, and the rock to be grouted under controlled pressures according to results obtained;

(g) In the non-overflow section of Wheeler Dam where the approach to the upstream miter gate of the second and longer lock will be located, the construction completed and plans contemplated will adequately insure stability of this portion of dam and miter sill, where shock effects from failure of the landside wall of the original lock may have been felt. The construction program includes drainage holes below the concerned section of Wheeler Dam, drilled into bedrock, a substantial additional mass of concrete for the miter sill which will rest upon the downstream face of the dam and upon rock at the toe for a distance in a downstream direction of about 60 feet, and this new mass of concrete includes in its downstream end a concrete key 15 feet wide carrying below the shale band, in addition to prestressed anchor bars inserted into holes drilled into bedrock in an upstream direction;

(h) Preparation of the bedrock and removal of the concrete blocks in proximity to the non-overflow section of Wheeler Dam by blasting are being done in a careful manner to avoid any disturbance either of the foundation bedrock or the dam itself;

(i) The remnant concrete blocks of the original lock, adjoining the upstream pintle block within the dam, according to design will be supported against outward sliding on the landside by the mass of concrete of the second pintle block, and on the river side by toe support provided by the non-overflow section of the main dam and by rock of the excavation for the riverside block. The support against inward sliding of the blocks of the river lock will be increased by a concrete slab between opposing walls on the floor of the chamber;

(j) The discharge tunnel will be lined with concrete as also the connecting 24-foot shaft in the river channel. Rock behind the lining in the tunnel and shaft will be carefully grouted under low pressure to seal the surface of contact between rock and concrete;

(k) The filling conduits to be excavated through the existing dam will be excavated carefully in a manner that will avoid disturbance of the dam;

(l) Excavation of the hill, along a vertical face, has been done in a careful manner so as not to disturb the underlying bedrock against which the hillside wall of the second lock will
rest. The wall is not designed against substantial rock load; however, this hill does not show signs of instability and is considered safe with drainage to be provided.

We are informed that 10 per cent of the concrete for the new river lock has been placed and that 95 per cent of the old concrete in the river lock has been removed. The consultants are impressed with the thoroughness of work and effort made by the personnel of the Tennessee Valley Authority in the investigation of causes of failure and in preparation of plans for reconstruction.

Frank A. Nickell

Lee G. Warren

John B. Wilbur
Mr. Berlen C. Moneymaker  
Tennessee Valley Authority  
Knoxville, Tennessee  

Dear Mr. Moneymaker:

In reply to your letter of June 20, 1961, we recorded the following disturbance at our seismograph stations on June 2, 1961.

Cape Girardeau, Missouri, slight disturbance 09h21m00s central standard time, second phase 09h21m22.3s. This disturbance was recorded in St. Louis at 09h21m49s. The vibrations are too small to distinguish phases and interpret so that from these records it is not possible to do more than say the disturbance was closer to Cape Girardeau than to St. Louis.

At Cape Girardeau, a similar disturbance was recorded at 11h38m26s p.m. (central standard time).

If I can be of additional help to you in this matter please let me know.

Sincerely yours,

[Signature]

Ross R. Heinrich

BCM:ASS
6/ 28/61 (4) G. P. Palo, 602 UB
WHEELER LOCK
Tennessee Valley Authority
AL1984 June 14, 1961
C. Quillen, Wilson Dam

Auxiliary lock land wall from upper gate.
The image shows a staircase leading down into a body of water, with concrete steps and a large concrete wall on the right side. The staircase appears to be part of a dam or a similar structure, with some debris at the base of the steps.
Auxiliary Lock, Blocks 6, 5, and 4.
Auxiliary lock, blocks 10, 9, and 8.

Pascacco Valley Authority
JULY 6, 1961
Wilson Dam
Auxiliary lock, portion of downstream face of block 2.
Auxiliary lock, blocks 2 through 6.
WHEELER LOCK

River Valley Authority

July 5, 1961

C. Quillen, Wilson

Auxiliary lock, concrete fragments downstream from block 12.
WHEELER LOCK
Tennessee Valley Authority
311 J une S, 1961

Auxiliary lock, gate leaf and guide wall (looking downsteam).
Auxiliary lock, blocks 12 and 11.

Tennessee Valley Authority
July 6, 1961

Wilson Dam
Auxiliary lock blocks 11 and 12, looking south.
Auxiliary lock bottom of block 12 (upstream side).
WHEELER LOCK
Tennessee Valley Authority
311114 June 16, 1961
C. Quillen, Wilson Dam

Auxiliary lock, crack in block 58.
Auxiliary lock, crack in blocks 59 and 60 (river wall).
Auxiliary lock river wall blocks 53, 54, and 55.
WHEELER LOCK
Tennessee Valley Authority
311092  June 15, 1961
C. Quillen, Wilson Dam

Auxiliary lock river wall blocks 55, 56, 57, and 58.
WHEELER LOCK
Tennessee Valley Authority
3L1096  June 16, 1961
C. Quillen, Wilson Dam

Auxiliary lock river wall blocks 60, 61, 62, 63, and 64.
Auxiliary lock river wall blocks 62, 63, 64, and 65.

WHEELE LOCK
Tennessee Valley Authority
31.1037, June 20, 1961
C. Guillem, Wilson Dam
APPENDIX A

DESCRIPTION OF COLLAPSED LAND WALL

WHEELER LOCK

Knoxville, Tennessee
November 1961
EXISTING WHEELER LOCK
DESCRIPTION OF COLLAPSED LAND WALL

AS OF JULY 7, 1961, FROM DETAILED INSPECTION AT SITE

The following is a general description of the visual condition, block by block, of the collapsed land wall shown on exhibits 1 through 16 and photographs in appendix B.

Block numbers used are those assigned by field force, not those on original construction drawings. Block 1 is the second block below the upper gate, which did not move, and blocks are numbered consecutively downstream, the downstream gate block being No. 12.

Blocks which are described as moved back came to rest with toe of wall against the north or land side of the trench excavated for the new lock river wall.

Cracks in the concrete of all blocks are shown on exhibits 1 through 16. In this description, cracks will be mentioned in blocks 12, 11, and 9 which are obviously due to load acting on the blocks from the downstream gate or from load transmitted from one block to another. In other blocks some keys in monolith joints were sheared off, and the front wall of the culvert was sheared off horizontally or the culvert floor was broken through vertically, involving possible load transmittal from block to block. Other breaks described were caused by the weight of the blocks when they fell on the foundation or on pieces of rock or dislodged concrete which were washed down by the rushing water in the lock chamber, coming to rest where the toppling blocks could fall on them.
The character of joints in the blocks is significant to the way the blocks were broken. All monolith joints were provided with 12- by 5-inch vertical keys. The joints were painted heavily with asphalt above elevation 493 to a thickness of about 1/8 inch.

Indications are that the chamber wall blocks were built as follows. The rock foundation was at elevation 488. At the heel and toe, key trenches 6 feet wide were excavated 4 feet into the rock and filled with concrete along with the base concrete pour to elevation 493. A vertical construction joint was introduced at 30 feet from the lock face, from elevation 493 to 511, with three horizontal 12- by 5-inch keys on the joint but no roughening for bond. The base width was 37 feet, and concrete was placed up to elevation 496 behind the vertical 30-foot joint to this base width. Then additional concrete was placed to the 53-foot block width up to elevation 496 with a vertical, unkeyed, unbonded construction joint at the 37-foot point. Then concrete was placed across this joint up to elevation 511 to make the finished back shape.

The vertical jointing in these blocks indicates a change in design plans during construction. In all blocks concrete above elevation 511 was placed across the 30-foot vertical joint below.

The disrupted block 14 of the lower guide wall indicates that it was built as follows: The rock foundation was generally about elevation 488, the same as for the chamber wall. At the heel, but not at the toe, a trench 4 feet wide was excavated 2 feet into the rock and filled with concrete along with the base concrete pour to elevation 492, the floor of the culvert. At the back wall of the culvert a vertical construction joint
without bonding provisions was introduced from rock to the culvert floor. A 4-foot-thick vertical wall was placed just behind the culvert from rock to elevation 502, the culvert roof. The 4-foot front wall of the culvert was placed from culvert floor to roof. A 4-foot lift of concrete was placed across these walls to elevation 506 to form the culvert roof. This construction resulted in the culvert's being surrounded by 4-foot slabs, with a smooth vertical face 4 feet behind the culvert from rock to elevation 506. Then, apparently from a change in plans, concrete was placed from rock to elevation 506 behind this face to make the finished back shape, with no bonding on the vertical joint. Concrete above elevation 506 was placed across the vertical joint below. Another vertical joint was introduced 5 feet behind the lock face from elevation 506 to 520. All vertical joints had no keys or bonding provisions. Parts of blocks 13 and 15 were similarly jointed. Horizontal construction joints in all blocks generally had rough 12- by 5-inch longitudinal keys 4 to 5 feet on centers. The joints were treated by cement "grout" slushing, frequently quite heavy, sometimes with excess cement. In many places the joints show lack of scarifying or green-cutting in preparation for a succeeding lift, and many keys indicate an excess of grout remaining in keyways, these features combining to lessen shear resistance.

The concrete was made with river gravel. In general, the concrete quality can be called fair to good for mass concrete.

The front and back faces of all blocks in both land and river walls have a general random pattern of old surface cracks a few feet in length. These cracks can usually be seen in the photographs from traces of efflorescence on them. In the following description these minor cracks will normally not be mentioned.
Block 1

This block did not move from its original position. It is reported that surveys show the downstream end actually moved back \(3/16\) inch. The chamber face shows nothing significant beyond minor surface cracking typical of all blocks in both the river and the land walls.

On the back of the block a large segment was broken off the downstream corner by block 2 moving back. The break extends from elevation 521 down to rock, angling on the downstream end from the 521-526 vertical step to the 496-501 step. The entire back step elevation 496 and below broke off. All the lower steps to and including elevation 521 broke angularly back to near the center of the block. A small corner is broken off the 546-551 step, and additional corners at 526 and 531, where block 2 is in contact with and is supported by block 1.

Block 2

The heel key is in its original position with front culvert wall on it.

The front wall of the culvert to elevation 502 is in its original position with only the downstream upper corner broken off. Elevation 502 joint sheared off at the downstream end. The face of block broke off diagonally from this corner to elevation 521 construction joint about 10 feet from upstream end, the break sloping back to the culvert roof.

The culvert floor is intact in its original position with a vertical break at the back from rock to culvert floor.

The remainder of the block moved back and is still standing, supported by jamming on unmoved block 1 and on toppled block 3. Without these supports the block would topple forward as did blocks 3 to 6.
The back wall of the culvert is intact in the moved position and the culvert roof practically so, with the meeting back joint tight and sound.

The front face of the block is badly spalled from elevation 502 to 531.

The standing portion of the block is unbroken and looks intact from the back, and has no significant cracks.

Block 3

The entire heel key in to the culvert is in its original position up to elevation 493 with only the downstream upper corner broken off. Elevation 493 joint sheared off.

The culvert floor broke vertically near the front from rock to the culvert floor. The entire block behind this break moved back, with the culvert floor and back wall essentially intact in the moved position. The culvert floor broke again vertically at the back down to rock.

The front wall of the culvert sheared off at the joints elevations 493 and 502 and broke vertically at the port into two pieces. The upstream half turned upside down and moved back about 20 feet. The downstream half turned over so lock face is up and slid back about 20 feet.

The main part of the block that moved back broke off in a varying fashion. For about 10 feet at the downstream end it broke back from the culvert roof to elevation 511 as described below for block 5. The remainder broke roughly at elevation 502 out to the back face. The culvert roof is intact on the toppled block. The block toppled and slid forward,
coming to rest on rubble below and on the downstream corner of the top of the front culvert wall of block 2. This upper part of the block from elevation 502 to top 560 is intact and projects upward and far out over the chamber floor.

Block 4

This block moved back with the adjacent blocks, but did not topple forward until 2 days after the rest of the wall.

The heel key has a small part of its upstream end and a little in the trench bottom in its original position; the rest of it is gone. The face of the block is generally spalled from elevation 502 to 531.

The culvert floor broke vertically near the front from rock to the culvert floor. The entire block behind this break moved back, with the culvert floor and back wall intact in the moved position. The culvert floor broke transversely near the upstream end.

The front wall of the culvert sheared off at joints elevations 493 and 502 and broke vertically at the port into two pieces. The downstream half moved back about 20 feet and tilted back at about 45 degrees and is now the main support for the toppled block. The upstream half turned lock face up and slid back about 20 feet.

The main part of the block that moved back broke and toppled forward. It broke at the level of the culvert roof elevation 502 back 6 feet, then diagonally to the vertical construction joint at 30 feet from the lock face, then separated on the vertical joint above elevation 508.1, then separated
out to the back face on construction joint elevation 511. The culvert roof is intact on the toppled block. The toppled block fell on rubble of rock and broken concrete below it, breaking again at construction joint 531 and again at elevation 556, and coming to rest on the chamber floor.

**Block 5**

The heel key is essentially gone from its original position. The downstream half is lying under toppled block 6. The upstream half turned lock face up and slid back about 20 feet.

The culvert floor broke vertically along the center of culvert from rock to the culvert floor. The entire block behind this break moved back, with the culvert floor and back wall intact in the moved position.

The front wall of the culvert sheared off at joints elevations 493 and 502, turned over so the lock face is upward and slid back intact about 25 feet. When the upper part of the block toppled and fell on the wall, the wall was broken through at the wall port near the downstream end.

The main part of the block that moved back broke and toppled forward. It broke at the level of the culvert roof back to the vertical construction joint, separated on the vertical joint up to elevation 508½, then diagonally out to the back face at elevation 511. The culvert roof is intact on the toppled block. The toppled block slid down on the culvert floor and the rubble in front of it, then broke again diagonally from elevation 531 upstream to 546 downstream, coming to rest face down on the rubble on the chamber floor.
Block 6

The entire heel key is intact in its original position up to elevation 493, including a small corner of culvert floor at the downstream end.

The concrete from elevation 488 to 493 broke essentially vertically at the back of the key. The monolith joint in the key is tight between blocks 6 and 7.

The culvert floor broke vertically at the front from rock to the culvert floor. The entire block behind this break moved back, with the culvert floor and back wall intact in the moved position.

The condition of the rest of the block is identical with that described for block 5, except that the break in the upper part of the block occurred at the shelf at elevation 541. Also, the upper part separated on construction joint elevation 549 and the piece above 549 broke into two pieces vertically. The entire assembly above elevation 541 was moved about 25 feet downstream.

Block 7

The entire heel key is intact in its original position up to elevation 493.

The concrete from elevation 488 to 493 broke vertically at the back of the key from elevation 488 to 491 and then sloping toward lock face to elevation 493 joint which sheared off. The monolith joint in the key is tight between blocks 7 and 8.

The remaining entire block moved back as a unit. The culvert floor, back wall, and roof are complete but cracked. The back wall has a new crack
at the roof line, no displacement. The floor is broken vertically at the front corner down to rock.

The front wall of the culvert broke completely through horizontally at construction joints elevations 493 and 502, the culvert roof. The wall broke into two pieces by a vertical break through it at the upstream edge of the wall port. The downstream half remains in place, displaced several inches toward chamber at top. The upstream half split diagonally from the front edge of culvert floor to the lock face at elevation 502. The inner piece slid into the culvert, the outer piece fell into the lock chamber with lock face up. This break could have been caused by toppling block 6. There are deep spalls over the entire block face below elevation 511.

The face of this block shows several major cracks. There are old cracks all across the block at elevations 522 and 556. At elevation 541 there is a construction joint with an old ragged appearance; the joint could be loose. Near the downstream end there is a vertical spalling-type crack angling back from the face toward the monolith joint from elevation 522 to 541. Below elevation 537 the crack developed from an old crack; from elevation 537 to 541 the crack is new; above elevation 541 a 5-foot-high spall popped off.

The back of the standing block shows a horizontal break at step elevation 506, otherwise no significant cracks.

**Block 8**

The heel key broke off irregularly. The upstream half is in its original position, complete below rock elevation 488, then sloping toward lock
face to elevation 493 joint which sheared off. The downstream few feet moved back intact with the block. The portion between has a varying diagonal break from down in key trench to joint elevation 493. This block might be cited as showing most nearly a typical diagonal tension break near the base.

The remaining entire block moved back as a unit and remains standing. The culvert floor, back wall, and roof are complete but cracked and broken. The back wall has a new crack at the roof line, no displacement. The floor is broken vertically at the front corner down to rock. The front wall portion below elevation 492 moved out toward chamber, leaving over a foot of open break at the floor level. The front wall below top elevation 502 apparently started to fall out and stopped. The top of it is displaced over a foot at the front corner of culvert roof. With the deep lock face spalls above elevation 502, there is little bearing area left at elevation 502 at the front of culvert, daylight showing through in places.

The front wall of the culvert broke completely through horizontally for the full length of the block at construction joint elevation 502. The construction joint elevation 493 broke completely through for the upstream half of the block, but remained tight and unbroken over the downstream half. The wall broke into two pieces by a vertical break through it at the downstream edge of the wall port. There are bad spalls over the entire block face from elevation 511 to rock.

The face of the block has an old crack at elevation 522 all across the block, otherwise no significant cracks.
The back of the standing block shows a horizontal break at step elevation 506, otherwise no significant cracks. Three steps have small upstream corners broken off.

In front of blocks 8 and 9 the top 3-foot-thick layer of the rock of the lock chamber floor moved about 1 foot out over the heel trench, suggesting that it bonded to the wall and tried to move with it.

Block 9
The entire block moved back as a unit, including all of the heel key. The key cracked diagonally from elevation 490 at the downstream end to elevation 484 at about 12 feet from the upstream end.

The culvert floor, walls, and roof are complete but cracked and broken. The back corner of the roof has a 3-inch open break starting upward toward the back of block. The back corner of the floor has a 1/2-inch crack starting vertically downward. The front corner of the floor has an open break varying from 6 inches upstream to 12 inches downstream. At the culvert roof the front wall shows a 3-inch offset toward the chamber on the elevation 502 joint, similar but less than block 8.

The front wall of the culvert is essentially intact below elevation 502; the bottom joint elevation 493 is tight and unbroken; the top joint elevation 502 is broken completely through the wall for the full length of the block. There are bad spalls on the block face above and below the joint at elevation 502.

The block has a 1-foot bulkhead slot 2 feet wider than the culvert, from the culvert floor to the top of the block, at the downstream block joint;
the bulkhead fell and closes the culvert. About 1948 a floating mooring bitt recess was drilled into the block behind the lock face at about 5 feet from the downstream end. The corner of the block is broken completely loose, cracking open for the full height from the near corner of the bulkhead slot to the back of the circular mooring bitt recess. (The face slot of the mooring bitt recess was provided with curved steel armor, set in with concrete backing. Above elevation 520 this concrete backing surprisingly is sound and tight to armor and wall.)

The face of the block shows only old minor surface cracking.

The back of the block has a new crack all across the block. It is just above the elevation 526 step across the downstream half of block, then angles down to just above the 521 step and extends to the upstream end of block. The downstream corner spalled off from elevation 521 to 549. Otherwise, the back shows no significant cracks.

**Block 10 - The Downstream Valve Block**

The entire block moved back intact, including the entire heel key. There are no breaks in the heel key or on the outside face of the front wall of the culvert.

In the culvert the valve is jammed in closed position by differential wall movements. There is a 1-inch crack in the front corner of the floor, starting vertically down. There are old narrow cracks in the front and back corners of the roof, the back one proceeding vertically upward in the corner of the valve pit. The back wall of the valve pit has an old horizontal crack at elevation 511 and a new spalling one at elevation 509.
The face of the block is completely free of any cracks. The back of the block shows only old minor surface cracking.

**Block 11**

The entire block moved back intact, including the entire heel key. There are no breaks in the heel key or on the outside face of the front wall of the culvert.

In the culvert there are indications of movement along an old crack in the front corner of the roof. There is a new 1/4-inch vertical crack in the front culvert face at 8 feet from the upstream end of block. There is a new 1/2-inch crack in the culvert floor from the above wall crack to the upstream end of block, along the front of culvert. In the back wall of culvert the elevation 493 joint shows an old crack with signs of old movement, the upper portion translated upstream 1/16 inch with respect to the lower portion. In the bulkhead slot at the upstream end of block, there is a crack across the downstream face of the slot, from elevation 511 at the front to 514 at the back.

This block has a horizontal construction joint elevation 516. On the chamber face there is a crack across the entire face of block, along the elevation 516 joint from the downstream end to the center of block, then angling down to the elevation 511 joint at the upstream end of gate recess, then roughly following elevation 511.

On the back of the block the downstream portion of all steps elevation 511 and below were broken off. The back of the block shows no significant cracks.
Block 12 - The Downstream Gate Block

The entire block moved back intact, including the entire heel key. There was some deep spalling on the face of the heel key below elevation 490. (See block 13.)

There are several bad cracks in the culvert. In the front wall: an old surface hair crack 5 feet upstream of the center of block became a 1-inch vertical break, the wall upstream of the break offset back 1 inch; a new roughly horizontal crack along the wall 3 feet above the floor in the downstream portion, branching down into two vertical ones near the center of block, all steeply vertical and of spalling nature, the wall below the crack offset back 3/4 inch; the joint at roof is loose upstream of the vertical crack, tight downstream; the bottom corner with floor is intact throughout the block. In the back wall: a new 1/4-inch vertical break near the center of the block. In the floor: a 2-inch diagonal break from the downstream back corner to the 1-inch crack in the front wall; a 1-inch break along the back corner of culvert from the upstream end to the center of block, then angling out to meet the 2-inch break. In the roof: a 2-inch diagonal break similar to the floor break from downstream back corner to the front wall break; an old transverse crack near the center of block now open 1/8 inch.

There is a new horizontal crack across the chamber face of the block, from elevation 516 at the upstream end to 511 at the downstream end, corresponding to breaks in the ends of block. There are two new vertical cracks a few feet apart near the center of the gate recess on
the front face of block from the above crack down to rock. There are no horizontal cracks on the face in the heel key or the front wall of the culvert. The horizontal joint at culvert floor elevation 492 appears loose upstream of the vertical cracks, but not displaced.

There are bad breaks in both ends of block 12. Across the upstream end there is an open break from elevation 516 at the face to 521 at the back, with the block above the break offset about 3 inches downstream. Also at the back corner of the culvert a 1/4-inch crack angling back and down; and from the face of block at elevation 494, a 1-1/2-inch break angling back and down for 5 feet, then vertically to rock. Across the downstream end there is a 3-inch open break angling from elevation 521 at the back down to the rear upper corner of the culvert, offset like the upstream break, and from this break a horizontal 1/2-inch crack out to the face of block at elevation 511, with a small offset. Also a 2-inch break from the back wall of the culvert going down to rock. The front corner of the block below elevation 511 spalled off.

On the back of the block there is a break at the elevation 521 step corresponding to the main breaks visible on the ends. There is an old small crack wandering all across the block at about elevation 533. There is an old vertical crack, now open about 1/2 inch, from elevation 531 down to rock at the center of block.

Roughness in the floor of blocks 11 and 12 shows that the culvert back wall was first cast straight and parallel to the lock face, then was removed and a new wall cast to make the culvert angle alignment.
Lower Miter Sill

The miter sill was placed independently of the lock walls with a vertical construction joint at each wall.

The joint at the river wall has long been open, now open 1/2 inch.

The joint at the land wall separated essentially cleanly and the wall moved away, leaving the sill intact.

The upstream edge of the sill and the fixtures for the gate seat were broken off when the gate went out.

The top surface of the sill was not checked for cracks.

Block 13

Blocks 13, 14, and 15 collapsed, moving generally backward and downstream, then breaking up on the interior construction joints and falling forward.

In block 13 the heel key is largely intact to elevation 492 in its original position except 10 feet of the upstream end. This piece toppled back and is lying lock face up about 25 feet back and 10 feet downstream. The deeply spalled out piece of the block 12 key is just upstream of this piece and lying the same.

The culvert floor is intact in its original position where the key remains; the upstream end broke off.

The front wall of the culvert is shattered and gone.
The 7-foot-thick back buttress wall at the upstream end of the block broke off from the main block cleanly from rock up to elevation 516 and toppled downstream.

The main portion of the block broke cleanly on three horizontal construction joints, elevations 502 (the culvert roof), 516, and 536.

The piece below elevation 502 is not identifiable.

The piece above elevation 536 to top 560 is gone. It is the piece lying face down across the channel downstream of the present lock.

The main block above elevation 502 moved back, then toppled forward, breaking at elevations 516 and 536. The piece from elevation 516 to 536 is lying face down on the rock as it fell. The piece from elevation 502 to 516 is lying face down downstream of block 12, rotated about 45 degrees counterclockwise, presumably by the water rushing through the break.

*Block 14*

The heel key is buried under rubble of large rocks but is believed to be intact up to elevation 492 since blocks 13 and 15 are so.

The entire block moved back, then toppled forward, breaking cleanly on the interior vertical and horizontal joints described in the earlier general description. This resulted in slabs as follows:

- Front wall of culvert, 10 by 4 feet, elevation 492 to 502
- Back wall of culvert 14 by 4 feet, elevation 488 to 502
- Back of block, 18 by 7 feet, elevation 488 to 506
- Roof slab of culvert, 16 by 4 feet, elevation 502 to 506
- Face of lock over culvert, 14 by 5 feet, elevation 506 to 520
The front wall of culvert was not located. The face slab over culvert is lying downstream in area of new lock. The other slabs are lying in approximately proper position in the toppled block.

The upper part of the block broke through to the back at elevation 526 when it fell, the pieces remaining together. The 7-foot back piece of the block from rock to elevation 506 broke vertically near its center when the block fell.

**Block 15**

The culvert ends 6.5 feet into this block with a wall port at the end. The heel key, culvert floor, and front wall of culvert are intact in original position to elevation 502.

The main downstream portion of the block has a width of 14 feet, the upstream 11.5 feet has a width of 23 feet enclosing the culvert portion, making a back buttress.

The portion downstream of the culvert is intact from key bottom to elevation 502 in its original position. The 11.5-foot buttress broke off from the rest of the block and fell downstream and back.

The main block above elevation 502 broke into indescribable pieces which were scattered by the rushing water, some lying 100 feet downstream in the new lock area.

**Block 16**

This is the first block of the lower guide wall. The wall was originally built to elevation 512. In 1955 additional concrete was placed to raise the wall to elevation 518.
The horizontal construction joint in block 16 at elevation 512 was completely broken off when the block was hit by the miter gate which is now leaning on this block and block 17. The downstream 13 feet of this top lift is tipped backward and caught under the gate. The rest of the lift was carried downstream into the new lock area and broken up.

The only other obvious damage to this block is that the upstream portion of the step from elevation 499 to 504 was broken off.

**Block 17**

A piece of the upstream end of the added lift from elevation 512 to 518 was broken off. Otherwise, there was no obvious damage to this block.

Block 17 and the other guide wall blocks downstream from it have recently been reinforced to serve as a cofferdam wall. Holes were drilled behind the lock face of wall through the concrete and into rock. Reinforcing bars were mortared into the holes, complete to the top of the wall.

None of these blocks show any obvious defects.
Existing location shown by "PLAN" not by A-A.
Section A-A is the existing downstream elevation and the upstream elevation is opposite head and breaker.
A majority of the spilled pieces are laying under the block.
All elevations shown are Design Elevations except those indicated as Depths, Earthen, or perforating in new recess.
Existing location shown. See Sheet 3 for details.
North of 4 door lock, beside the North Gate, East of the lower gate
In original position

Notes:

RECONSTRUCTED UPSTREAM ELEVATION

RECONSTRUCTED DOWNSTREAM ELEVATION
TENNESSEE VALLEY AUTHORITY
Office of Chief Engineer

APPENDIX B

PHOTOGRAPHS OF WHEELER LOCK AND AREA

AFTER FAILURE

Knoxville, Tennessee
November 1961
Looking east at line drill holes at southwest corner of upper miter sill ledge.
Looking south at line drill holes on north face of upper miter sill ledge.
APPENDIX C

FOUNDATION INVESTIGATION

LOCK MONOLITHS NOS. 1 - 72, INCLUSIVE

GENERAL JOE WHEELER LOCK AND DAM

TENNESSEE RIVER

Datum: All elevations given in the consultants' report, in appendix A, on TVA drawings in the appendixes, and in the exhibits have been adjusted to that of the U.S.C. & G.S. 1929 adjustment. Elevations given on all Corps drawings, etc., in this report are 0.3 foot lower based on the 1912 datum.
FOUNDATION INVESTIGATION
LOCK MONOLITHS NOS. 1 - 72, INCLUSIVE
GENERAL JOE WHEELER LOCK AND DAM
TENNESSEE RIVER
FOUNDATION INVESTIGATION, LOCK MONOLITHS Nos. 1-72, INCLUSIVE,
GENERAL JOE WHEELER LOCK AND DAM, TENNESSEE RIVER.

1. General procedure.—Paragraph 1-07 of the specifications called for the drilling of test holes in advance of excavating operations. This matter was discussed with the contractor, and due to the depth of rock cut, which in some instances was 17 feet to the bottom of the keyway, it was considered advisable to proceed with excavation to theoretical grades and proceed from there with foundation investigation. This decision was reached after a thorough study of the core borings; and, because of the specifications limiting the test holes to 20 feet, in a 17-foot cut of rock only 3 feet of the test hole would be a sample of the actual foundations. However, as the contractor started excavation in the deepest cut, which was at the lower gate bays, a careful study was made of the foundation as excavating operations advanced, and from Sta. 55A land wall, where the foundation steps up, to Sta. 430A, test holes were drilled ahead of rock removal because only a two or three-foot cut was required. In no case was it necessary to go deeper than theoretical grades except at the lower guide wall where a 2' x 4' keyway was added; in Monolith No. 81 of the cut-off wall where the rock broke in vertical seams; and a few places where rock was loosened or shattered due to heavy blasting.

2. Test holes.—After the rock cut was made and just before the foundation was prepared, a minimum of two ten-foot and one twenty-foot test and grout holes were drilled. A log of the holes was kept, and a description of the actual conditions encountered is outlined on attached plan. In cases where it was thought necessary, additional holes were drilled and all holes piped above the foundation pour for grouting.


(a) Lower Guide Wall - Monoliths Nos. 1 to 11, inclusive, Sta. 453.58 to Sta. 8003.

The overburden consisted of approximately 82 per cent mud and silt and 18 per cent loose, flat rock, varying in depth from 3 inches to 1.5 feet. The average natural rock elevation sloped from elevation 432.5 in Monolith No. 1 to Elevation 495.4 in Monolith No. 11. The river face of the rock was channeled and the rock shot out to an average elevation of 437.7. Rock was removed to a line five feet back of the land side of the wall to prevent blasting next to the concrete during construction of a future main lock. Due to the fact that this section of the wall may be used as a cofferdam for the main lock, and because the foundation generally was flat and level, it was decided to add a small keyway for stability and additional seal. Therefore, a 2' x 4' keyway was added from Sta. 8003 to the 4' x 6' keyway in Monolith No. 12. Photographs Nos. 77, 43, and 63 are typical foundation views for this section of the wall.
The foundation proper consisted of a hard, fine-grained, blue limestone underlaying a coarse-grained, gray limestone on the surface. Small deposits of quartzite were found. In some instances where the limestone was hard and flinty, the rock shattered badly from blasting. See Photograph No. 7. The rock lay in strata from 6 inches to 4 feet thick, separated by close, tight seams. A 2-inch test hole, 20 feet deep, was drilled in Monoliths Nos. 1 to 11, inclusive, but no grouting was considered necessary for this section of wall. The attached general layout sheet shows the log of test holes and seams encountered. In Monoliths Nos. 1 and 2 a small amount of surface water ran under the forms above the lock face rock ledge. This seepage was pocketed in the upstream end of the keyway and removed with a pump until the concrete being placed reached an elevation above the rock ledge and sealed off this flow. No seepage water through open seams in the rock was encountered.

(b) Land Wall Proper - Monoliths Nos. 12 to 27, inclusive, Sta. 453.58 to Sta. 56.04.

The overburden for this section of wall consists of approximately 85 per cent muck and silt and 15 per cent loose slab rock and boulders, varying from 6 inches to 3 feet in depth. The average natural rock elevation was from elevation 433.74 to elevation 436.24. The river face of the wall and a line 5 feet from the landside of the wall were channeled and the rock removed to elevation 433.84. The wall was later widened and an additional keyway added on the back side of the wall. In Monolith No. 12 the surface of the rock was a hard, close-grained limestone with a few close horizontal seams. The bottom of the foundation was a harder, finer-grained flinty, blue limestone with small deposits of quartzite speckled about its surface. The bottom of the keyway was similar to the bed. A 20-foot test hole revealed a dry hole and a satisfactory foundation. In Monoliths Nos. 13 and 14 the rock was similar to that in Monolith No. 12. In the foreground of Photograph No. 5, Monolith No. 15, is a large vertical seam. To the right of this is another. These seams are tight and appear to be well sealed. The rock, being very brittle, was shattered by blasting and shot holes are visible in Photograph No. 5. Test and grout holes shown on the attached sheet were grouted at a later date.

In Monoliths Nos. 15, 16 and 17, the original rock surface was found to be a comparatively level, hard and coarse-grained, gray limestone. The foundation proper was of a harder, finer-grained, blue limestone. Being somewhat brittle, the rock was shattered as can be noted in Photograph No. 27 of Monolith No. 15. Several seams were discovered by test hole drilling, but later grouting operations showed these seams to be tight and, in general, the holes indicated a hard strata of blue limestone with no seepage.

The foundation for Monoliths Nos. 18, 19, and 20 was practically the same kind of limestone as encountered in Monoliths Nos. 15, 16, and 17, except possibly not as brittle. Straight, vertical faces on the keyways were maintained as shown on Photographs No. 60 and No. 133, while the rock surface was even and level. No seepage was apparent through seams, and test holes revealed a hard, tight foundation.
The foundation for the remainder of this section of wall, Monoliths Nos. 21 to 25, inclusive, consisted of a surface stone of gray, chalklike, coarse grained limestone, changing into a finer, blue, close grained limestone, in some cases very brittle and laying in shoots as shown in Photograph No. 102. The rock was very brittle and hard, and several keyway faces were lost in blasting.

In Monoliths Nos. 26 and 27, the rock was similar to that encountered in Monoliths Nos. 18 and 19. The keyway faces were maintained and a level foundation was obtained, as shown on Photographs Nos. 119 and 120. No seepage water was encountered and test holes revealed very few wet seams. All holes were grouted and results indicated a good, tight foundation.

(a) Upper Guide Wall - Monoliths Nos. 28 to 37, inclusive, and Monolith No. 72. Sta. 56.0A to 450.0A.

The overburden consisted of approximately 90 per cent mud and silt and 10 per cent flat, slab rock, varying in depth from 6 inches to 1.5 feet. The natural rock sloped from elevation 495.74 in Monolith No. 28, to elevation 493.04 in Monolith No. 37. Because of the shallow cut to the foundation base, and because of vertical cracks exposed on the natural rock surface, it was thought best to investigate the foundation before drilling and blasting. Test holes ten feet deep were drilled on the center line of the wall on 50-foot centers, and it was found that a satisfactory foundation could be secured at elevation 492.04.

The foundation material was a hard, gray, coarse grained limestone at the surface, changing to a finer grained, blue limestone at the bed.

In Monoliths Nos. 28 to 33, inclusive, and Monolith No. 72, quite a few seams were discovered, as shown on the accompanying sketch. Vertical faces were maintained on the keyway, but the rock surface was inclined to be a bit scaly, as shown in Photograph No. 162. In Monolith No. 28, where the foundation steps up to elevation 492 from elevation 489, quite a bit of the corner of the keyway was loosened by blasting, and it was necessary to remove it. Test and grout holes were piped above the foundation pour and grouted at a later date.

In Monoliths Nos. 34 to 37, inclusive, the general appearance of the rock was the same as in the remainder of the wall, except possibly not as scaly and brittle. See Photograph No. 222. Test and grout holes were piped above the foundation pour and grouted in such cases as were considered necessary.

(d) Upper Guard Wall and River Wall Proper - Monoliths Nos. 48 to 65, inclusive, Sta. 151.0A to 449.59B.
From Monoliths Nos. 43 to 55, inclusive, the overburden consisted of approximately 85 per cent mud and silt and 15 per cent flat, silty rock. In Monoliths Nos. 56 to 65, inclusive, the percentage of silty rock ran as high, in some cases, as 90 per cent, the remainder of the overburden being mud and silt with a few patches of gravel. The natural rock elevation sloped from elevation 436.5 in Monolith No. 46 to elevation 453.6 in Monolith No. 65. Both river and land faces of the wall were channeled and the wall widened due to changes in design, but no keyway added on the river side of the wall as in the case of the land wall.

In Monoliths Nos. 48 and 49, the foundation bed consisted of a fine grained, blue limestone. An excellent foundation was obtained for both blocks. However, in Monolith No. 49, where the foundation steps down from elevation 432 to elevation 439, the rock was shattered somewhat by blasting. Test holes drilled in Monolith No. 49 revealed two seams which are visible in Photograph No. 131 of Monolith No. 50. The seams were dry, however, and subsequent grouting operations proved them to be fairly tight. Photograph No. 131 also shows the excellent foundation obtained for Monolith No. 50, and the vertical faces obtained on the keyways. As also noted in the same photograph, the rock lay in layers from 2 to 4 feet in thickness.

In Monoliths Nos. 50 to 56, inclusive, during excavating operations, the rock broke to a seam approximately 5 feet to one foot below theoretical grade. Rock was removed to this seam, as shown in Photograph No. 130. Another seam was discovered in the bottom of the keyway, 4 feet below the foundation proper. Test holes revealed further seams, but as all holes were dry and seams apparently tight, the foundation was considered satisfactory. The foundation for this section of wall was probably the poorest encountered on the entire job.

In Monolith No. 57, the foundation was stepped back above the seam, and a better grade of rock was apparent. Note absence of seam in keyway picture No. 86, of Monolith No. 58, and step in foundation of Monolith No. 57 in Photograph No. 87. The foundation proper was a hard, blue grained limestone. The foundation material for Monoliths Nos. 59, 60, and 61 was a brittle, flintlike limestone, that was easily shattered by blasting.

In Monolith No. 59 a large corner of the keyway was lost as the rock broke to a vertical seam shown in Photograph No. 81. The vertical seam remaining in the foundation was tight and the rock solid. Test and grout holes were piped above the foundation pour and grouted at a later date.

The foundation for Monoliths Nos. 62 to 65, inclusive, was a hard, blue grained limestone and laying in horizontal strata. Vertical keyway faces were maintained and a very satisfactory foundation obtained. See Photograph No. 18.
(e) **Lower Guard Fall - Monoliths Nos. 66 to 71, inclusive, Sta. 449.585 to Sta. 645.08.**

A shallow overburden, consisting largely of river mud combined with a small percentage of large, loose, flat, soft limestone boulders, was removed from the surface of a hard, coarse grained limestone rock. The natural rock elevation was practically level at an elevation of 425.5 ft. The foundation proper was a hard, fine grained, blue, flintlike limestone, that shattered from blasting. Fairly good vertical faces were maintained, however. A 2-inch test hole was drilled in each of the monoliths but as this section of wall is not subject to a hydrostatic head, grouting was not considered necessary. A view typical of the condition as existed is shown on Photograph No. 53. The top of the vertical face illustrated is natural rock. No water seepage was encountered in the entire section of wall.

(f) **Lower Miter and Emergency Sills - Monoliths Nos. 42 and 43.**

The foundation material was a hard, gray, coarse grained limestone rock at the surface, which changed to a finer grained, brittle, blue limestone at the bed. The rock structure was hard, dense, and free from open seams and seepage. Vertical faces were maintained except at the walls where the rock face was broken due to heavy blasting for the walls proper. The vertical face broken on the upstream side of the miter sill, as shown in Photograph No. 237, was due to the change in design of the sills as excavation for the original sill was under way when the change was made. Test and grout holes in both sills revealed no seepage or seams, but were piped above the foundation for grouting. During grouting operations water was pumped through the relief drains in both sills to keep them open.

(g) **Upper Miter and Emergency Sills - Monoliths Nos. 40 and 41.**

The rock structure was a hard, coarse grained limestone at the surface and a finer grained, blue limestone at the bed, providing an excellent foundation for the sills. Due to the depth of the upstream rock cut, the channeling was made in two steps. The first drilling was from natural rock to elevation 435.0 ft, but the rock broke approximately 6 feet deeper due to a seam at that point. The upstream face was then stepped in 31 inches, and drilled to elevation 464.0 ft, to the bottom of the keyway. The upper cut contained several seams that can be seen in Photograph No. 211, and these seams are at approximately the same elevation as those found in the upper guide wall foundations. However, the foundation proper was good, test holes all dry and without seams except Nos. 1 and 2, where a wet seam was hit approximately 10 feet below the foundation bed. These two holes discharged no seepage water.
A portion of the downstream face broke out to the seam at the foundation level, as shown in Photograph No. 213. This rock was removed outside the sill proper and the remaining space filled with concrete to elevation 400.0, the level of the lock chamber. The foundation bed is illustrated in Photograph No. 216. Test and grout holes were drilled and grouted, as shown on the attached sketch. During grouting operations water was pumped through the relief drains to insure their clearance.

4. Grouting—all grout and test holes were piped to the top of the foundation pour and into the lock tunnel; therefore, all grouting operations were conducted at a later date. A small air driven pump was used for grouting; and if excessive grouting had been required this pump would have been impractical as only cement and water mixtures could be pumped. The amount of grout used in most cases was very small, however, and a mixture of sand, cement, and water not necessary.

5. Recommendations—No additional steps are recommended to protect this structure from seepage.

C. E. Perry,
Major, Corps of Engineers,
District Engineer.

Incls.
Dugs 02-13-10/12, 6530
Photographs 3, 5, 7, 12, 27, 45, 58, 60, 62, 65, 66, 87, 102, 118, 120, 130, 135, 162, 181, 222, 237, 241, 243, and 246.

U. S. Engineer Office,
Nashville, Tennessee.
February 15, 1935.
TENN. RIVER - CHATT. DIST.
LOCK & DAM NO. 3 - 600' LOCK
River Wall Mon. No. 57
Downstream View
June 12, 1933 Photo No. 87
TENNESSEE VALLEY AUTHORITY
Office of Chief Engineer

APPENDIX D

FOUNDATION EXPLORATION FOR
NEW WHEELER MAIN LOCK

Knoxville, Tennessee
November 1961
Role A. Elliot, Chief Water Control Planning Engineer, 603 UB

Borton C. Moneymaker, Chief, Geologic Branch, 615 UB

November 23, 1961

WHEELER LOCK--MUD SEAMS

In response to your request for a written statement describing the effort made to locate clay seams, or mud seams, at Wheeler lock, the following statement is submitted.

During the exploration work carried out in 1960, every care was taken carefully, in the presence of the drillers who supplied information not available from the cores recovered. The geologist who logged the cores was alert and included all available information in the logs. Even where slight weathering was noted and the lowest elevations of both sections weathering and slight weathering were reported in the logs prepared and issued. No filled or open cavities were found, no mud--or clay--seams were found. On basis of both the cores and x-ray request excavation, the rock in the new Wheeler lock foundation was found to be exceptionally free from such weathering effects as rock decay and solution cavities. Kelliker's report of March 1960 states that the bedding planes "show no development of weak, soft material, or clay along them." (Bottom of Page C).

The "clay seams" and "mud seams" encountered in nearly all limestone formations are thin solution cavities filled with clay. When thicker that 0.11 or 0.2, such features are more frequently referred to as "filled cavities." The origin of such seams is quite simple. The rock is disintegrated along some structure, usually a bedding plane or a joint. Subsequently, the resulting cavity becomes filled-up by moving ground water. Even to this day, no real mud seams have been found in either of the Wheeler lock sites, although they were found in both the dam site and the powerhouse site in the construction period.

The mud seams on which sliding resulted in the failure of the lead wall of Wheeler lock is an entirely different geologic feature. It represents the hydration and partial decay of pulverized shale along a tectonic fracture. At some stage of rock deformation, presumably the fault, uplift and folding resulted in a break within the shale layer known as the
"A-zone." This break is parallel to bedding planes, a short interval above the lower contact of the shale within which it was developed. The break, developed in the relaxed stress, was accompanied by movement along its surface. This movement, perhaps very slight in terms of feet and inches, was sufficient to precipitate a small amount of shale on its surface, and to provide a thin opening for the ingress of water. In the presence of water over a long period of time, the precipitated shale has been hydrated and the small amount of soluble material has been removed. In addition to the hydration and leaching of the precipitated material, some of the subjacent and superjacent materials also become similarly weathered. Thus the weathering is gradual and limited to hydration and leaching is assisted by the lack of evaporation of the iron content of the material, and by the research completed to date.

The mud seam involved in the failure of the lock wall is much too thin to have been found in its hole. In the three large-diameter holes bored by Allen and Kallberg and examined also by Harwell and Barton, the seam could not be detected visually. It has the same color as the subjacent shale, and both the shale and the seam were removed by the primary action of the chilled steel shot used as the cutting medium, which always happens in the drilling of a hole through dissimilar rocks which vary widely in their resistance to abrasion.

Although evidence of bedding plans, shingles in folded sedimentary rocks are quite common, the mud seam of Wheeler lock is, so far as I know, unique in the Tennessee Valley. It is not on a contact, but within a fairly thin shale bed. It is only partially weathered and is, chemically, a very sticky or thin mud clay. It is because of its high water content and fineness of grain, a very effective lubricant.
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INTRODUCTION

The new lock at the Wheeler project will be located adjacent to the right (north) bank of the Tennessee River at river mile 274.9. It will have a chamber 600 feet long by 110 feet wide and will be built between the existing lock and the right abutment.

During February and March, 1960, twenty-four exploratory holes totaling 1440 linear feet were drilled along the proposed alignment of the river and land walls and in the discharge area. These holes were spaced on 100-foot centers along the lock walls, while in the discharge area varied spacing was used in order to stay clear of the existing navigation channel (Exhibits 1 and 2).

GENERAL GEOLOGY

Physiography

The area surrounding Wheeler Dam lies near the southern margin of the Highland Rim section of the Interior Low Plateaus as defined by Fenneman.¹ This physiographic subdivision is characterized by a young to mature plateau of moderate relief. Between Wheeler Dam and Wilson Dam the outcrop belt of

¹ Fenneman, N. M., Physiography of the Eastern United States, pp. 415-427.
the cherty middle member of the Fort Payne formation is crossed by the Tennessee River forming the Muscle Shoals area. Because of this resistant horizon the local relief is somewhat more steep and gorge-like than the surrounding area.

**Stratigraphy**

The Fort Payne formation of Mississippian age is the only geologic unit that will be involved in the construction of the project. The total thickness of this formation in Lauderdale County, Alabama, is in the neighborhood of 200 feet. The Tuscumbia limestone, also of Mississippian age, overlies the Fort Payne. This formation probably is present in the upper part of the hill forming the right abutment well above pool level of Wheeler Lake - elevation 556. No outcrops of coarse-crystalline, slightly asphaltic, fossiliferous limestone typical of the Tuscumbia have been seen, but the red residual clay containing characteristic porous, iron-stained chert which is present in the road cuts just north of the dam is indicative of the presence of this formation at higher elevations in this vicinity. One exploration hole (5+55 DS - 60' R) was drilled through the Chattanooga shale which underlies the Fort Payne. The shale was found to be 18 feet thick, but, as it is more than 20 feet below the deepest excavation that will be required for the discharge tunnel, it will not be involved in the construction activities.

**Structure**

The regional geologic structure is controlled by the Nashville dome. The area around the Wheeler project lies on the southern flank of this dome and the regional dip is a degree or less to the south. This regional trend
is often obscured by the slight variations caused by minor local folding. This is the case at Wheeler. Here the general structure is that of a broad, extremely low anticline, the crest of which is in the middle of the river, with the axis more or less parallel to the course of the river. As a result of this minor fold the rock strata in the area of the new lock strike N 38° E and dip 1½° to the northwest.

**DETAILED GEOLOGY**

**Stratigraphy**

Various units of the Fort Payne formation are the bedrock at the site. Overlying bedrock are thicknesses of detrital and alluvial material varying from nothing to 19 feet. A brief description of the unconsolidated deposits and the subdivisions of the Fort Payne formation follows.

**Overburden** — The unconsolidated materials overlying bedrock can be divided into three categories: (1) alluvial clays and silts, (2) talus deposits, and (3) fill material. In 12 holes drilled from a barge in Wilson Lake an average of 1.6 feet of silt and clay was encountered overlying bedrock. This material represents sedimentation in relatively slack water areas which have been protected from scouring current action by the existing lock walls. In the holes drilled on the river-side of the existing lock current action has kept the bedrock bottom swept clean and little bottom sediments were encountered. Relatively minor amounts of talus materials are present at the bottom of the rock bluff north of the land wall of the proposed lock. This material has accumulated mainly from surface runoff washing debris down from higher on the hill. The majority of the overburden
that is present is the result of prior construction activity in the area. Before the existing lock and dam were built a canal was in use along the right bank of the river. Material excavated to make this canal and other debris from the construction of the lock and dam were piled in the area in which the land wall of the new lock will be built. This fill is made up of limestone slabs ranging up to a cubic yard in size embedded in a matrix of small rocks, clay and silt. The maximum thickness of fill that was encountered in the drilling was 18.6 feet; the minimum was 11.7 feet; and the average was 14.4 feet.

Fort Payne Formation -- A maximum of 88 feet of the lower portion of the Fort Payne formation was encountered in drilling hole 5+55 ES - 60'R (Exhibit 2). From examination of the cores it was possible to subdivide the Fort Payne into five distinct units of varying thicknesses. The highest unit is composed of light-gray, coarse-crystalline, fossiliferous limestone in beds up to two feet thick. The total thickness of this unit is not known but a maximum of 6.5 feet was recovered from hole 7+40-60'R. A thin, but persistent, bed of medium-gray, fine-crystalline, argillaceous limestone underlies the upper coarse-crystalline unit. This unit averaged 1.5 feet thick in the 14 holes that penetrated it. Only the holes drilled in the fill area along the land wall of the proposed lock encountered bed rock sufficiently high to penetrate these first two units. In all the holes drilled from the barge in the lake, rock either had been excavated or eroded below these two units. The next lower unit is similar to the uppermost unit being an average of 5.9 feet of light-gray, coarse-crystalline, fossiliferous limestone. The fourth unit comprises the majority
of the Fort Payne formation at the site and will, in all probability, be the unit on which the lock will be founded and through which the discharge tunnel will be driven. This unit consists of medium-gray, fine-crystalline to dense, slightly argillaceous limestone. The individual beds are a foot or less in thickness and thin shaly partings usually occur along the bedding planes. In most respects this unit is very similar to the rock which afforded the foundation for the lock recently completed at the Wilson project. From examination of the cores there appears to be one marked difference, however, in that there does not appear to be nearly as much chert in the rock at Wheeler as there was at Wilson. Two key horizons were noted in cores from all the holes drilled. Key bed "A" occurs approximately 6.4 feet below the top of the unit and consists of 0.5 foot of dark gray to black shale. Key bed "B" occurs 7 feet below "A" and consists of 0.1 foot of limestone containing small green specks of mineral glauconite. These key horizons are shown on Exhibits 1 and 2 and were used to determine the geologic structure in the lock area. The lowest unit of the Fort Payne was encountered in the one deep hole drilled and consisted of four feet of medium-gray, dense, cherty limestone. This unit will be well below any intended excavation and will not be involved in the construction of the lock.

Structure

Although the rock strata underlying the lock site are essentially horizontal, matching of key beds between drill holes indicates a dip of approximately $1\frac{1}{2}^\circ$ to the northwest. The strike of the bedding N 38° E makes an angle of 42° with the centerline of the lock - N 80° E - with
the result that there is an apparent dip downstream of 1.5' per 100'
and an apparent dip to the north or into the right abutment of 1' per
100'.

Vertical or near vertical joints are undoubtedly present in
the foundation area, but only two were encountered in the drilling.
Both of these were above foundation grade. During the construction of
Wheeler Dam a few joints in the river bed were found to have been
enlarged by solution near the surface, but these cavities narrowed to
extinction a few feet down into rock.

Physical Character of the Rock

The lock will be founded entirely on the Fort Payne formation.
Although often somewhat shaly, this formation is hard and resistant and
has ample strength to support the weight of the lock. No recent tests
have been made from rocks in the lock area for shear and compressive
strengths, but tests of samples from the dam foundation made during the
construction period give the following results. Nine specimens tested
in compression showed an average compressive strength of 23,660 pounds
per square inch and twelve specimens tested in shear were found to have
an average shear strength of 2,112 pounds per square inch. These values
are in excess of any loading that will be imposed by the structures.

In the portion of the Fort Payne formation at foundation grade
the rock is relatively thin-bedded. The bedding planes vary in spacing
from three to four inches up to a maximum of slightly over one foot.
Although these well-defined bedding planes are usually marked by a thin
shaly parting, they are tight where undisturbed and show no development of
weak, soft material, or clay along them.
Foundation Conditions

In contrast to most sites with limestone foundations that have been explored in the Tennessee Valley area, no evidence of serious foundation defects was disclosed by the drilling. No cavities were encountered in any of the holes drilled and no weathering was seen along any of the bedding planes. This marked lack of weathering effects is probably attributable to two things. In the first place, the Fort Payne formation is relatively insoluble in this area as it contains a high percentage of siliceous and argillaceous material; in the second place, during the construction of the existing lock and dam, and prior to that when the canal was excavated, the slightly weathered rock that was near the surface in the present lock area was removed and no weathering of any consequence has occurred since that time.

The zone which produced gas when encountered in drilling relief holes along the north wall at Wilson lock is present in the Wheeler lock area as well, but it is apparently sufficiently deep that it will not be encountered in the construction activity. One exploratory hole (5+55 DS 601 R) was drilled through the Chattanooga shale and encountered a show of gas at elevation 391.0 about half a foot above the base of the shale (Exhibit 2). At this location this seam is some 90 feet below the expected excavation grade. The nearest this seam would come to the surface would be in the vicinity of the discharge outlet where it would be some 45 feet below invert grade.

Construction Problems

Possible geologic problems during the construction period can be divided into three categories. Those are problems encountered during
(1) excavation, (2) grouting, and (3) tunneling. Each of these will be discussed briefly.

**Excavation** -- The foundation rock at Wheeler is very similar to that at Wilson. It is a flat-lying, thin-bedded, relatively brittle, siliceous to argillaceous limestone. If due care is not taken in spacing of blast holes and loading of the charges into these blast holes shifting along the near-horizontal bedding planes will take place as it did at Wilson, thereby necessitating the removal of otherwise sound and perfectly suitable rock. The experience gained at Wilson should prove valuable here and procedures developed during the later stages of the Wilson construction program should be followed here for optimum results.

During the construction of Wheeler Dam the final cleanup of the foundation blocks was deferred until just prior to pouring concrete. It was found that over most of the foundation if final cleanup was done too soon the exposed rock surfaces would slake and crack from alternate expansion and contraction. The only strata which is expected to disintegrate markedly upon exposure to air is key bed "A" (Exhibits 1 and 2). This thin - 0.5' average thickness - horizon was the only one to show any signs of disintegration in the cores. The other cores recovered from the exploratory holes have shown no tendency to break down after several weeks exposure to alternate wetting and drying and, from this evidence, it does not appear that cracking and slaking will be a major problem in the lock area. However, the early excavations should be watched closely to determine if this problem will arise.
Grouting -- Very little grouting should be required in the foundation area for the lock. The exploratory drilling has shown the rock to be tight and sound and no cavities were encountered. If the final foundation grade is set above the thin shale horizon of key bed "A" this undisturbed bed should serve as an adequate cutoff with no grouting required below it. The possibility is present that there may be a few vertical joints which pinch out below the key bed "A" horizon. If, upon exposing the foundation, this proves to be the case, these special areas can be treated individually as required.

Tunneling -- The major problem envisioned in driving the proposed discharge tunnel is the possible occurrence of a solution channel that would permit a heavy flow of water to enter the excavation. This possibility cannot be ruled out, but the soundness and tightness of the rock make it appear to be a remote probability. It is believed that if proper drilling, loading, and shooting procedures are followed the tunnel can be safely driven. Loading should be light enough so that any incipient vertical joints will not be appreciably widened and a drilling pattern should be used that will place the least strain on the roof. After a round is drilled and before it is loaded observations should be made to determine if excessive leakage is indicated from any of the holes. If such leakage ahead of the face is encountered grouting may be necessary before the tunnel heading is advanced.

Construction Materials

No specific investigations have been made to locate an adequate supply of suitable aggregate. The quarries furnishing aggregate to the Wilson and Colbert projects would be capable of supplying sufficient material
of suitable quality. If these sources are too distant from the project to be economically feasible, it is probable that a suitable quarry could be developed in the vicinity of Town Creek some 10 miles south of the river.

CONCLUSIONS

Exploratory drilling in the area proposed for the new lock at the Wheeler project has shown that no serious foundation problems should be encountered in the construction of the lock. Cores showed the rock to be sound and unweathered throughout. Inasmuch as the foundation rock is essentially flat-lying, thin-bedded, and relatively brittle proper care should be taken during excavation to prevent shifting of sound rock along bedding planes due to overloading of blast holes. In driving the discharge tunnel observations should be made of all drill holes in a round prior to loading to make sure that excessive flows of water will not be encountered when the round is shot. If excessive flows are noted, the area ahead of the face should be grouted before the tunnel heading is advanced.

ACKNOWLEDGMENTS

All the geologic work connected with the preliminary foundation investigations at this site was done by the writer under the direct supervision of Berlen C. Moneymaker, Chief Geologist, and the general supervision of Reed A. Elliot, Chief Water Control Planning Engineer.
EXHIBITS
NOTE:
For more detail concerning lithology see typed Geologic Record of Drill Hole.

LEGEND:
- Crystalline, fossiliferous limestone with shaly partings.
- Crystalline limestone with large chert nodules.
- Coarse crystalline, crinoidal limestone.
- Limestone with quartz-calcite nodules.
- Argillaceous limestone grading into 0.2' shale of zone "A".
- Fine-grained limestone
- 0.1' shaly parting—probable shear.
- Joints and open fractures.

SCALE:

1/25 0 1/5 FT.

FOUNDATION INVESTIGATIONS
NEW LOCK

GRAPHIC LOGS
OF
CALYX HOLES

WHEELER PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL, ALABAMA

KNOXVILLE 3/18/1961 9231300
**GEOLOGIC RECORD OF DRILL HOLE**

**PROJECT** NEW WHEELER LOCK

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<td>Medium-gray, medium to fine-grained, crystalline to slightly argillaceous. Rock fractured to 488.0. Slightly weathered vertical joint striking NW-SE pinching out at 483.8. Water on shaly parting at 486.5. Dark-gray, fine-grained, grades into shale.</td>
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<td>As above with shaly partings. Quartz/calcite nodules 474.2 to 473.2</td>
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**REMARKS:** Surface rock fractured to el. 485.0. Narrow slightly weathered vertical joint pinches out at el. 483.8. Some water but no apparent weathering on slightly opened shaly parting at el. 486.6. All rock below el. 483.8 is very good.

Robert W. Allen, Geologist
# GEOLOGIC RECORD OF DRILL HOLE

**PROJECT:** WEN WHEELER LOCK

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<tr>
<td>496.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ELEVATION BOTTOM OF HOLE</th>
<th>SIZE OF CORE</th>
<th>ELEVATION OF WATER GAINED</th>
</tr>
</thead>
<tbody>
<tr>
<td>471.6</td>
<td>36&quot; Calyx</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BOTTOM OF SERIOUS WEATHERING</th>
<th>BOTTOM OF ALL WEATHERING</th>
<th>DATE STARTED</th>
<th>DATE COMPLETED</th>
</tr>
</thead>
<tbody>
<tr>
<td>496.9</td>
<td>496.9</td>
<td>March 1961</td>
<td>April 1961</td>
</tr>
</tbody>
</table>

**MATERIAL** | **ELEVATION OF STRATUM** | **DEPTH FROM SURFACE** | **THICKNESS OF STRATUM** | **LENGTH OF CORE RECOVERED** | **DIP** | **DESCRIPTION** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone</td>
<td>496.9</td>
<td>0.0</td>
<td>6.9</td>
<td>6.9</td>
<td></td>
<td>-rock weathering, rock excellent. medium-gray, coarse crystalline, fossiliferous with shaly partings.</td>
</tr>
<tr>
<td>Limestone</td>
<td>490.0</td>
<td>6.9</td>
<td>1.3</td>
<td>1.3</td>
<td></td>
<td>coarse crystalline with small nodules.</td>
</tr>
<tr>
<td>Limestone</td>
<td>488.7</td>
<td>8.2</td>
<td>7.0</td>
<td>7.0</td>
<td></td>
<td>coarse crystalline with shaly partings.</td>
</tr>
<tr>
<td>Limestone</td>
<td>481.0</td>
<td>15.2</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td>fine crystalline with calcite grains.</td>
</tr>
<tr>
<td>Limestone</td>
<td>480.0</td>
<td>16.2</td>
<td>6.3</td>
<td>6.3</td>
<td></td>
<td>fine crystalline, medium to thin banded.</td>
</tr>
<tr>
<td>Limestone</td>
<td>473.7</td>
<td>23.2</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
<td>dark gray, fine grained grades into shale below.</td>
</tr>
<tr>
<td>Shale</td>
<td>473.5</td>
<td>23.4</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
<td>dark-gray, green. Key shale.</td>
</tr>
<tr>
<td>Limestone</td>
<td>473.3</td>
<td>23.6</td>
<td>1.7</td>
<td>1.7</td>
<td></td>
<td>medium-gray, fine crystalline with calcite grains.</td>
</tr>
<tr>
<td>BOTT. OF HOLE</td>
<td>471.6</td>
<td>25.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REMARKS:** No weathering. Rock excellent.

*From graphic by J.H.K.*

Robert W. Allen, Geologist
# GEOLOGIC RECORD OF DRILL HOLE

## PROJECT: NEW WHEELER LOCK

### HOLE NUMBER
7+36 D. S.

### LOCATION
85.5' Left

### ELEVATION OF SURFACE
491.6

### ELEVATION OF RIVER BED
- 

### ELEVATION OF WATER TABLE
- 

### ELEVATION TOP OF BEDROCK
491.6

### THICKNESS OF OVERBURDEN
- 

### ELEVATION OF WATER LOSS
- 

### ELEVATION BOTTOM OF HOLE
466.5

### SIZE OF CORE
36" Calyx

### BOTTOM OF SERIOUS WEATHERING
491.6

### BOTTOM OF ALL WEATHERING
491.6

### DATE STARTED
April 1961

### DATE COMPLETED
April 1961

## MATERIAL

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ELEVATION OF STRATUM</th>
<th>DEPTH FROM SURFACE</th>
<th>THICKNESS OF STRATUM</th>
<th>LENGTH OF CORE RECOVERED</th>
<th>DIP</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>491.6</td>
<td>0.0</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
<td>ROCK DRILLING</td>
</tr>
<tr>
<td>Limestone</td>
<td>491.6</td>
<td>0.0</td>
<td>7.6</td>
<td>7.6</td>
<td></td>
<td>Medium-light grey, crystalline, fossiliferous, shaly partings, 0.1 ft. shaly parting at 484.5 - probable shear zone.</td>
</tr>
<tr>
<td>Limestone</td>
<td>484.0</td>
<td>7.6</td>
<td>1.3</td>
<td>1.3</td>
<td></td>
<td>Crystalline with calcite geodes.</td>
</tr>
<tr>
<td>Limestone</td>
<td>482.7</td>
<td>8.9</td>
<td>5.7</td>
<td>5.7</td>
<td></td>
<td>Medium-fine grained, medium-thin banded.</td>
</tr>
<tr>
<td>Limestone</td>
<td>477.0</td>
<td>14.6</td>
<td>0.2</td>
<td>0.4</td>
<td></td>
<td>Dark gray, fine grained, grades into shale below.</td>
</tr>
<tr>
<td>Shale</td>
<td>476.8</td>
<td>14.8</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
<td>Dark gray-green. Key shale &quot;A&quot;.</td>
</tr>
<tr>
<td>Limestone</td>
<td>476.6</td>
<td>15.0</td>
<td>1.6</td>
<td>1.6</td>
<td></td>
<td>Crystalline with calcite geodes.</td>
</tr>
<tr>
<td>Limestone</td>
<td>475.0</td>
<td>16.6</td>
<td>8.5</td>
<td>8.5</td>
<td></td>
<td>Medium-fine grained.</td>
</tr>
<tr>
<td>BOTTOM OF HOLE</td>
<td>466.5</td>
<td>25.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REMARKS:** No weathering. Rock excellent. Thin shale zone at 466.5 will probably create overbreak during blasting -- could be source of slight amount of water.

Robert W. Allen, Geologist
TENNESSEE VALLEY AUTHORITY
Office of Chief Engineer

APPENDIX E

RESULTS OF TESTS OF FOUNDATION CORE
AND CHEMICAL ANALYSIS OF SHALE
WHEELER LOCK

Knoxville, Tennessee
November 1961
Results of Tests of Foundation Core
Wheeler Lock and Dam
Tennessee Valley Authority

1. References:
   a. Telephone conversations between the Chief, Concrete Division, U. S. Army Engineer Waterways Experiment Station and the Engineer-in-Charge, U. S. Army Engineer Division Laboratory, Southwestern on 19 and 20 July 1961.
   b. Letter from the Director, U. S. Army Engineer Waterways Experiment Station, dated 24 July 1961.

2. The following NX Cores from the vicinity of the foundation of Wheeler Lock, TVA, were received 21 July 1961:

<table>
<thead>
<tr>
<th>SWD Sample No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-1817</td>
<td>15 sections of NX core identified as &quot;A&quot;</td>
</tr>
<tr>
<td>F-1818</td>
<td>9 sections of NX core identified as &quot;B&quot;</td>
</tr>
<tr>
<td>F-1819</td>
<td>3 sections of NX core identified as &quot;compression&quot;</td>
</tr>
</tbody>
</table>

3. Twelve specimens of core marked "A" were tested for torsional shear. One half of the specimens were tested in the moisture condition as received and one-half were tested after vacuum saturation. It is noted that all but one of the specimens failed helically and sliding resistance after shear could not be obtained. Sliding resistance was determined at 100, 200, and 300 psi for the one specimen (A-7) that failed on a horizontal plane. Results of these tests are shown in Table 1 and on Plate 1. Three specimens marked "Compression" were tested for unconfined compression. Results of these tests are shown on Table 2.

4. All specimens were transported to the laboratory inundated in a tank of water. Results of moisture content determinations of the "as received" specimens and the "vacuum saturated" specimens indicated that the samples were saturated when received. This was also indicated by the fact that free water was extruded from the specimens during testing in compression.
### TABLE NO. 1

Results of Torsional Shear Tests

**HX Core Identified as "A"**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Specimen</th>
<th>Length, Inches</th>
<th>Moisture Content, %</th>
<th>Unit Dry Weight, Lbs/cu.ft.</th>
<th>Normal Load, psi</th>
<th>Modulus of Rupture in Torsion, psi</th>
<th>Sliding Resistance after Shear, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-1718</td>
<td>A-1</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>297</td>
<td>Helical failure.</td>
</tr>
<tr>
<td></td>
<td>A-2</td>
<td>3.2</td>
<td>3.2</td>
<td>159.2</td>
<td>100</td>
<td>345</td>
<td>Helical failure.</td>
</tr>
<tr>
<td></td>
<td>A-3</td>
<td>3.1</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>162</td>
<td>Helical failure.</td>
</tr>
<tr>
<td></td>
<td>A-4</td>
<td>4.8</td>
<td>3.0</td>
<td>159.4</td>
<td>100</td>
<td>409</td>
<td>Helical failure.</td>
</tr>
<tr>
<td></td>
<td>A-5</td>
<td>2.6</td>
<td>2.1</td>
<td>160.0</td>
<td>10</td>
<td>441</td>
<td>Helical failure.</td>
</tr>
<tr>
<td></td>
<td>A-6</td>
<td>4.2</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>410</td>
<td>Helical failure.</td>
</tr>
</tbody>
</table>

**Moisture Condition: As Received**

| A-7        | 7.7      | -   | -   | 10  | 184  | -   | Helical failure.                   |

**Moisture Condition: Vacuum Saturated**

| A-8        | 8.6      | 2.5  | 161.6 | 100 | 854  | -   | Helical failure.                   |
| A-9        | 5.1      | -    | -    | 10  | 375  | -   | Helical failure.                   |
| A-10       | 7.1      | 2.5  | 160.6 | 100 | 463  | -   | Helical failure.                   |
| A-11       | 6.7      | 2.5  | 160.6 | 100 | 463  | -   | Helical failure.                   |
| A-12       | 4.7      | 2.7  | 159.7 | 100 | 565  | -   | Helical failure.                   |

Remarks:

- Failed along a horizontal bedding plane; values for sliding resistance with normal loads of 100, 200 and 300 psi were all obtained from the same failure plane.
TABLE NO. 2

Results of Unconfined Compression Tests

UX Cores Identified as "Compression"

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Specimen No.</th>
<th>Specimen Diameter, Inches</th>
<th>Specimen Height, Inches</th>
<th>Compressive Strength, psi</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1729</td>
<td>6-1</td>
<td>2.15</td>
<td>6.15</td>
<td>3,085</td>
<td>Failed by splitting and crumbling in the lower 1-inch.</td>
</tr>
<tr>
<td></td>
<td>6-2</td>
<td>2.15</td>
<td>6.0</td>
<td>9,650</td>
<td>Shattered.</td>
</tr>
<tr>
<td></td>
<td>6-3</td>
<td>2.15</td>
<td>6.3</td>
<td>9,025</td>
<td>Shattered.</td>
</tr>
</tbody>
</table>
Torsional Shear Tests

Wheels: Look and Dam

Legend:
0: Moisture condition as received
•: Vacuum saturated
$: Helirol Failure
---: Horizontal Failure
x: Sliding Resistance after shear

Shear Stress, psi

Legend:
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8

Normal Load, psi

Plate No. 1
REPORT FROM
SOUTHERN TESTING LABORATORIES, INC.

LAB NO. 164,322

SAMPLE OF AS SHOWN

MARKED

RECEIVED FROM Tennessee Valley Authority, Knoxville, Tennessee

REPORTED TO Tennessee Valley Authority, Knoxville, Tennessee

Dr. Berlen C. Moneymaker, Chief Geologist

DATE RECEIVED AT LABORATORY 10/9/61

WLF-1  WLF-2  WLF-3

<table>
<thead>
<tr>
<th>Substance</th>
<th>WLF-1</th>
<th>WLF-2</th>
<th>WLF-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>58.08%</td>
<td>54.28%</td>
<td>55.16%</td>
</tr>
<tr>
<td>Aluminum oxide (Al₂O₃)</td>
<td>15.47%</td>
<td>20.78%</td>
<td>19.32%</td>
</tr>
<tr>
<td>Iron oxide (Fe₂O₃)</td>
<td>4.17%</td>
<td>4.30%</td>
<td>4.30%</td>
</tr>
<tr>
<td>Calcium oxide (CaO)</td>
<td>4.10%</td>
<td>2.18%</td>
<td>3.14%</td>
</tr>
<tr>
<td>Magnesium oxide (MgO)</td>
<td>4.38%</td>
<td>4.38%</td>
<td>4.48%</td>
</tr>
<tr>
<td>Calcium oxide (MnO)</td>
<td>0.012%</td>
<td>0.014%</td>
<td>0.024%</td>
</tr>
<tr>
<td>Titanium dioxide (TiO₂)</td>
<td>0.13%</td>
<td>0.04%</td>
<td>0.45%</td>
</tr>
<tr>
<td>Sodium oxide (Na₂O)</td>
<td>3.66%</td>
<td>2.72%</td>
<td>2.95%</td>
</tr>
<tr>
<td>Potassium oxide (K₂O)</td>
<td>1.97%</td>
<td>1.88%</td>
<td>2.11%</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>7.78%</td>
<td>8.29%</td>
<td>7.72%</td>
</tr>
</tbody>
</table>

WLF-1 Typical shale of "A seam", above mud seam, as recovered in cores.

WLF-2 Shale of "A seam" immediately above mud seam taken from wall of 36" hole.

WLF-3 Mud from mud seam near base of "A seam".

SOUTHERN TESTING LABORATORIES, INC.
TENNESSEE VALLEY AUTHORITY
Office of Chief Engineer

APPENDIX F

ROCK EXCAVATION

NEW WHEELER MAIN LOCK

Knoxville, Tennessee
November 1961
ROCK EXCAVATION

The general level of excavation for the new lock chamber was to elevation 490.5. Excavation of trenches for the filling and emptying culverts followed the chamber excavation and extended 6 to 8 feet lower. The north line of the south culvert cut was line-drilled to grade along its full length. From station 3 + 54 to station 5 + 92 the south line of this same culvert was drilled from approximately elevation 488.5 (bottom of original trench) to elevation 486.5 and shallow blast holes were used to create the first step of the excavation. After removal of broken rock in the cut, line drilling for the second step was done and the area blasted to grade at elevation 482.5. Farther downstream (station 5 + 92 to station 7 + 35) close line drilling to grade along the south line was done. In this area 6-foot-deep blast holes were used to make the full cut. Blasting in this area was done in May.

Along the old lock wall (station 0 + 10U to station 3 + 54D) a trench of approximately 2-foot depth remained after the general area cut was made to elevation 490.5. This trench was widened by using shallow blast to facilitate double-line drilling (adapted as an alternate to a plan for broaching decided upon earlier). Following this and starting in early May, double-line drilling was done between station 1 + 00D and station 3 + 54D. This drilling was 2-1/2 feet from the north toe of the old lock wall. From station 1 + 00D to station 0 + 10U, double-line drilling to grade was spaced 8 inches off the wall. Blast holes were not drilled to grade as was evident from the amount of trim blasting which followed. Blast holes for this excavation were usually spaced on 3-foot centers with holes as far from line drilling...
as possible to prevent breakage across the line drilling. Each blast consisted of a series of blasts separated with 17 milliseconds delay connectors. Dynamite use rate for culvert excavation was slightly in excess of 0.8 pounds per cubic yard of rock. Blasting along the lock wall for the final cut in the south culvert was done between May 12 and June 2. For drilling and blasting details, see attached print of drawing 61KL047.
TENNESSEE VALLEY AUTHORITY
Office of Chief Engineer

APPENDIX G
SEISMOGRAPH STATIONS REPORT -
SAINT LOUIS UNIVERSITY
WHEELER LOCK FAILURE

Knoxville, Tennessee
November 1961
EXHIBITS

Datum: All elevations given in the consultants' report, appendix A, on TVA drawings in the appendixes, and in the exhibits have been adjusted to that of the U.S.C. & G.S. 1929 adjustment. Elevations given on all Corps drawings, etc., in this report are 0.3 foot lower based on the 1912 datum.
Black 1 is partially supported by
Block 1 in this area.

NOTE 2
Pier 8 is shattered.
Block 2 is jammed against Block 3 in this area.

Block 1 partially supports Block 2 in this area.

Block 3 is supported here (see B-B 6/1046).

Block 2 is jammed against Block 3 in this area.

Block 1 partially supports Block 2 in this area.

Block 3 supported here (see B-B 6/1046).

NOTES:
- Block 2 concrete in these areas was broken and shattered in small pieces.
- Piece 1 remained in original position. Hatched areas show the location of pieces in other positions.
- Sheet numbers should be referred to for additional information.

CONSTRUCTION PROCESS:
- Original Position
- After Movement
- Reconstructed

SCALE: 1'-0"/100'
RECONSTRUCTED FRONT ELEVATION

RECONSTRUCTED REAR ELEVATION

NOTES:

1. Block 2 is jammed against Block 3 in this area.

2. See Note 1.

GENERAL:

- Piece 1 remained in original position.
- Hatched areas show location of pieces after movement.
- Blocks 2 and 3 are jammed against each other.
- All elevations shown are Design elevations except as noted.

SCALE: 1"=1'-0"
PLAN-NORTH WALL
Scale: "1=100'

NOTES:
- Piece 1 remained in its original position.
- Hatched areas in Sell A and plan show the.
- present position of pieces 2, 3, 4, 5, and 6.
- Pieces 7 and 9 could not be located.
- Pieces marked 'T' are either shattered and gone
down the block and covered by a mass
of small pieces.
- All elevations shown are extreme elevations and
are not intended to represent actual.
- Elevations shown are those indicated as 'Orig.' or plan showing to new-data.

Ref: Oorg 6/4/1944
Scale: "1=100'
extect as noted

AUXILIARY LOCK
EXISTING CONDITIONS
NORTH WALL
BLOCK 3
WHEELER PROJECT
TENNESSEE VALLEY AUTHORITY
ENGINEERING DEPARTMENT

FIELD OFFICE: 7/13/44
CHECKED: D. L. Stahl
APPROVED: J. W. Walker

RECONSTRUCTED FRONT ELEVATION

RECONSTRUCTED DOWNSTREAM ELEVATION

RECONSTRUCTED UPSTREAM ELEVATION

RECONSTRUCTED REAR ELEVATION
The existing Black wall is shown in its original position, except as noted.

Existing Black wall is shown in its original position, except as noted.

Some of the cracks and discontinuities in the downstream portion of the south wall are due to the non-uniformity of the existing condition. The displacement at South Wall of Culvert is shown in the plan view.

Notes:
- The existing Black wall is shown in its original position, except as noted.
- Discontinuities in the downstream portion of the south wall are due to the non-uniformity of the existing condition.
- The displacement at South Wall of Culvert is shown in the plan view.

Cranes shown here. They could not be seen further since view is only partially exposed.

All elevations with Design Elevations except those indicated by "Old," "New," or "Removed."
EXHIBIT 10

EXISTING CONDITIONS
NORTH WALL
BLOCK 9
WHEELER PROJECT
TENNESSEE VALLEY AUTHORITY

NOTES:
- The plan view shows the location of the block after movement.
- Hatched areas show position of pieces, relative to the main body of the block after movement.
- The rock shown in the upstream and downstream elevations moved with the block.
- Cracks in the culvert floor, roof, and south wall, and shown in sections A-A, B-B, and C-C, vary in size from 6" to 12".
- Breaks shown thus, ---, could not be seen further to determine their course.
- All elevations shown are design elevations except those indicated as "Original Position".

Scale 1" = 1'-0" except as noted.

AUXILIARY LOCK
FIELD OFFICE

TENNESSEE VALLEY AUTHORITY WHEELER PROJECT
11/21/74

COMM. 10-1343  K-13750  5/13/74
Under the North leaf of the lower gate

PLAN OF EXISTING LOCATION

RECONSTRUCTED FRONT ELEVATION

RECONSTRUCTED REAR ELEVATION

RECONSTRUCTED UPSTREAM ELEVATION

RECONSTRUCTED DOWNSTREAM ELEVATION

Note: All elevations are Design elevations except those indicated by "Orig." or "Perf." prior to new design.

AUXILIARY LOCK
EXISTING CONDITION
BLOCK 14
NORTH WALL

RECONSTRUCTED FRONT ELEVATION

RECONSTRUCTED REAR ELEVATION

RECONSTRUCTED UPSTREAM ELEVATION

RECONSTRUCTED DOWNSTREAM ELEVATION

Note:
① Has multicolored or colored portions which are not visible in this drawing.
② Has multicolored or colored portions which are not visible in this drawing.
③ Has multicolored or colored portions which are not visible in this drawing.
④ Has multicolored or colored portions which are not visible in this drawing.
⑤ Has multicolored or colored portions which are not visible in this drawing.
⑥ Has multicolored or colored portions which are not visible in this drawing.
⑦ Has multicolored or colored portions which are not visible in this drawing.
⑧ Has multicolored or colored portions which are not visible in this drawing.
⑨ Has multicolored or colored portions which are not visible in this drawing.
⑩ Has multicolored or colored portions which are not visible in this drawing.
⑪ Has multicolored or colored portions which are not visible in this drawing.
⑫ Has multicolored or colored portions which are not visible in this drawing.
⑬ Has multicolored or colored portions which are not visible in this drawing.
⑭ Has multicolored or colored portions which are not visible in this drawing.
⑮ Has multicolored or colored portions which are not visible in this drawing.
⑯ Has multicolored or colored portions which are not visible in this drawing.
⑰ Has multicolored or colored portions which are not visible in this drawing.
⑱ Has multicolored or colored portions which are not visible in this drawing.
⑲ Has multicolored or colored portions which are not visible in this drawing.
⑳ Has multicolored or colored portions which are not visible in this drawing.
⑴ Has multicolored or colored portions which are not visible in this drawing.
⑵ Has multicolored or colored portions which are not visible in this drawing.
⑶ Has multicolored or colored portions which are not visible in this drawing.
⑷ Has multicolored or colored portions which are not visible in this drawing.
⑸ Has multicolored or colored portions which are not visible in this drawing.
⑹ Has multicolored or colored portions which are not visible in this drawing.
⑺ Has multicolored or colored portions which are not visible in this drawing.
⑻ Has multicolored or colored portions which are not visible in this drawing.
⑼ Has multicolored or colored portions which are not visible in this drawing.
⑽ Has multicolored or colored portions which are not visible in this drawing.
⑾ Has multicolored or colored portions which are not visible in this drawing.
⑿ Has multicolored or colored portions which are not visible in this drawing.
⒀ Has multicolored or colored portions which are not visible in this drawing.
⒁ Has multicolored or colored portions which are not visible in this drawing.
⒂ Has multicolored or colored portions which are not visible in this drawing.
⒃ Has multicolored or colored portions which are not visible in this drawing.
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EXHIBIT 16

EXHIBIT 16

KEY PLAN - NORTH WALL

SECTION A-A

UPSTREAM ELEVATION

DOWNSTREAM ELEVATION

PLAN

FRONT ELEVATION

REAR ELEVATION

Notes:
The North leaf of the lower gate is presently resting upon Blocks 16 and 17 and is being held in place by Blocks 18 and 19. This is a result of the gate hitting them.
Block 17 is in its original condition with the exception of the cracks as shown.
Block 18 is in its original condition with the exception of the cracks as shown and as follows:
1. Evidently broken into small pieces, as a few small segments were found.
2. Existing location at prior Sta 994.2
3. Existing location as shown in Plan view and Section AA

AUXILIARY LOCK

EXISTING CONDITION

BLOCKS 16 & 17

NORTH WALL

WHEELER PROJECT

TENNESSEE VALLEY AUTHORITY

Scale 1/8" = 1' actual
except as noted
This crack was visible before June 8, but was opened at time of equipment removal. These cracks were not visible before movement occurred. All other cracks were not visible prior to failure of Aux. Lock. Only major cracks shown.

Scale: 1"=10'

EXHIBIT 17

MAIN LOCK

LOCATION OF BREAKS IN CHAMBER

WHEELER PROJECT

TENNESSEE VALLEY AUTHORITY

DEPARTMENT OF CONSTRUCTION

SUBMITTED: January 14, 1992
APPROVED:...

FIELD OFFICE: 2-19-91

Panel with Notes:

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DEPARTMENT OF CONSTRUCTION

SUBMITTED: January 14, 1992
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Scale: 1"=10'
TVA
WHEELER LOCK
STABILITY ANALYSIS

From computation of 3-31-59
SECTION
LAND WALL THAT FAILED

53'-0"

8'-0"
6@3'-6" 21'-0" 6@3'-9" 22'-6"

1'-6"

12@5'-0" 60'-0"

6'-0" Min

8'-6" 8'-0"

Shale layer

Excavation line
for new lock.

SECTION
LAND WALL THAT FAILED

FIGURE 2

EXHIBIT 24