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NATIONAL DAM SAFETY PROGRAM. LOCH RAVEN DAM (MD-0002), GUNPOWDE--ETC(U)
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GUNPOWDER RIVER BASIN

GUNPOWDER FALLS, BALTIMORE COUNTY

MARYLAND

LOCH RAVEN DAM

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

(6)

National Dam Safety Program. Loch
Raven Dam (MD-0002), Gunpowder River
Basin, Gunpowder Falls, Baltimore County,
Maryland. Phase I Inspection Report.

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DEPARTMENT OF THE ARMY

Baltimore District, Corps of Engineers
Baltimore, Maryland 21203

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LEVEL II

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PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam: Loch Raven
State Located: Maryland
County Located: Baltimore County
Stream: Gunpowder Falls
Date of Inspection: 14 and 16 December 1977
Inspected By: Baltimore District, Corps of Engineers

Past performance of Loch Raven Dam shows it has withstood a storm the magnitude of "Agnes" without noticeable structural damage. However, Phase I review of the spillway capacity and structural stability of the dam has identified a spillway that is inadequate for one-half the probable maximum flood and a theoretical stability that is questionable. Concern over these two items has led to recommending the performance of an in-depth stability analysis, and a hydrology and hydraulic analysis examining the possibility of reducing the overtopping potential. The lack of design information on the structure emphasizes the need for establishing design parameters through the analysis.

In addition, it is recommended that further inspection and investigation of the spillway toe and extreme left inspection well be undertaken. A formal warning system, to alert the downstream areas of impending dangers, with established contacts and procedures should be implemented along with a system of periodic inspections and documentation.

ACCESSION for
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JUSTIFICATION Per DDC Form 50
BY on file
DISTRIBUTION/AVAILABILITY CODES
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Approved:

G. K. WITHERS
Colonel, Corps of Engineers
District Engineer

DATE: 30 Mar 78

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
LOCH RAVEN DAM MD 0002

ABSTRACT

SECTION I PROJECT INFORMATION

1.1 General:

a. Authority. The inspection was authorized by the Dam Inspection Act Public Law 92-367 and was performed at the request of the State of Maryland as the initial inspection within that state.

b. Purpose of Inspection. The Phase I inspection is an evaluation of existing engineering data and a visual inspection of the dam and appurtenances in an effort to determine if it constitutes a hazard to human life or property, and to identify the need for additional studies, investigations or analyses.

1.2 Description of Project:

a. Description of Dam and Appurtenances. Loch Raven Dam is a concrete gravity structure approximately 620 feet in length with a centrally located ungated spillway 288 feet in length. The top of dam is at elevation 248.0, about 84 feet above the streambed. The crest of the overflow section is at elevation 240.0. The base width is estimated at 114 feet.

b. Location. The dam is located on Gunpowder Falls about 9.5 miles above its confluence with the Gunpowder River, and approximately 22 miles downstream of Prettyboy Reservoir (drainage area 80 square miles).

c. Size Classification. Large (84 feet high, 72,700 Acre-Feet).

d. Hazard Classification. The potential for the loss of a number of lives in the event of a dam failure classified the dam as a high hazard.

e. Ownership. The structure is owned and operated by the City of Baltimore.

f. Purpose of Dam. The primary purpose of the dam is of water supply for the City of Baltimore. The lake also serves for recreation.

g. Design and Construction History. The present Loch Raven Dam was constructed in 1921 to provide additional storage for the City of Baltimore's water supply. It was built approximately 2000 ft. upstream of a dam constructed in 1881 by the City for water supply. No design computations were available for the existing dam, but available construction drawings revealed that the present dam was an addition to a structure built in 1912 to elevation 188.0. (See typical overflow section Appendix B).

h. Normal Operation Procedures. With the main function of the dam being delegated to water supply for the City of Baltimore, the normal operation is focused on selective level intakes. This is accomplished through 15 different gates at 4 levels. These selective intakes feed a 10-foot diameter collector system that delivers the water to the City's Montebello filtration plant. There are no means of regulating flow downstream of the dam. The only flow that passes downstream is that which exceeds the spillway crest.

1.3 Pertinent Data:

a. Drainage Area: 303 square miles.

b. Discharge at Damsite: The maximum known flood at the damsite was that produced by Tropical Storm Agnes which topped the non-overflow section of the dam by approximately 6 inches. The discharge associated with this flood is estimated to be 30,000 cubic feet per second (cfs).

The computated maximum spillway capacity is 27,000 cfs.

c. Elevation:

Top of Dam - 248.0
Spillway Crest - 240.0
Normal Tailwater (based on the crest of downstream dam) - 171.0±
Streambed at centerline of dam - 164.0+

d. Reservoir

Length of maximum pool - 7.5 miles ±

e. Storage (acre-feet)

Storage at spillway crest - 72,700 acre-feet

f. Reservoir Surface:

Reservoir Surface at spillway crest - 2,400 acres.

g. Dam:

Type: Concrete gravity
Length: 620+ ft.
Height: 84 ft. from streambed to top of dam
Top Width: 14' ±
Side Slopes: Upstream-vertical face; Downstream - spillway section 0.62H:1V ±; dam section 0.65H:1V ±
Cutoff: Upstream concrete shear key into rock foundation
Grout curtain: None

h. **Diversion and Regulating Tunnel:** The only means of regulation are the selective intakes used for the City of Baltimore's water supply. Two 48 inch low flow by-passes were originally constructed but are not operable; one has been sealed and the other is believed to be silted.

i. **Spillway:**

Type: concrete gravity uncontrolled
Length of Weir: 288 feet
Crest Elevation: 240.0

SECTION 2
ENGINEERING DATA

2.1 Design: Availability of Information. No original design information is available other than the contract drawings for the dam raising in 1921. Although these drawings have no as-built notations, they appear to be an accurate representation of the structure itself. However, information as to the excavation grades of the dam foundation is vague. Apparently, the construction of the base upon which the present dam was built was not documented, thus the actual extent of excavation and concrete placement is unknown.

Contract drawings for proposed remedial "cosmetic" treatment to the surfaces of the dam, and gate repairs, are also available. This contract is to be awarded in the near future by the City of Baltimore.

In 1968 the City contracted with the architect-engineer firm of Whitman, Requardt and Associates to evaluate the structural integrity of the dam and take concrete core samples to perform strength tests at various locations on the dam. The results of these tests were available for the inspection team. The majority of the concrete test samples were 2-4 feet from the surface and have little bearing on the overall structural strength of the dam. Two borings were taken through the toe of the overflow section of the structure into the rock foundation. The borings were available for inspection and provided some informational value, but geologic logs could not be located. A letter from the architect-engineer to the City indicated their investigation did not reveal any structural weakness or deterioration of the foundation.

2.2 Construction: Availability of Information. Drawings showing the upper portion of the dam were available for review. No drawings of the lower section and its foundation excavation limits were on file.

2.3 Operation: Availability of Information. No detailed operational data are available. Stage information is recorded and forwarded to the offices at Liberty Dam. The operation of the intake gates is based upon the water demands in the City and the water quality within the reservoir.

SECTION 3
VISUAL INSPECTION

3.1 Findings

a. General

Field inspections were accomplished on 14 and 16 December 1977. Due to heavy rainfall on the 14th, the visual inspection was limited to observation from the right abutment non-overflow section, inspection of the upper gallery, and an examination of the concrete core samples taken from the dam in 1968. A second inspection was conducted on 16 December during clear weather with frost on the ground. The downstream pool had been drained to allow inspection of the spillway toe. In addition, the abutments were inspected.

b. Dam

(1) Visual inspection revealed no noticeable misalignment along the axis of the dam. No evidence of movement at the abutments were noted.

(2) Considerable surface deterioration (spalling) of the concrete was evident on the crest and downstream face of the spillway and the upstream face of the dam in the zone of pool fluctuation. The probable cause of such deterioration is freezing and thawing and erosion of the spillway crest and downstream face. The depth of deterioration appeared to be as much as 12 to 18 inches at the worst locations, exposing temperature reinforcement. Although not showing the magnitude of deterioration as the spillway, the non-overflow section had spalling and uplifting of a gunite surfacing believed to have been placed in the 1940's.

(3) Observations in the upper inspection gallery showed some deterioration of concrete adjacent to construction joints (maximum of perhaps one-inch) but no signs of misalignment due to monolith movement. The surface of the concrete in the gallery appears sound, generally moist to wet on the upstream wall and ceiling, and moist to dry on the downstream wall and floor. Moderate to heavy efflorscence was emanating from construction joints on the upstream walls of the gallery and vertical inspection wells. Varying water depths were noted in the 3' x 3' vertical inspection wells. Six inch collector drains, located in the horizontal construction joints five feet inside the upstream face of the dam, exit into the inspection wells. Most of the drains appear to be functional as evidenced by flowing water and efflorescence at the opening to the inspection well. Water was observed flowing into the inspection well at Sta. 0+34W through a vertical joint approximately 4 feet above the gallery floor. According to the dam superintendent, this had been occuring for a number of years, often at a greater rate. However, he had not been in the inspection gallery in approximately five

years. The extreme left inspection well, Sta. 3+00E, was filled with water covering part of the gallery floor.

(4) A lower inspection gallery is contained in the base of the dam but remains filled with water. The only means of entering this gallery would be to lower the downstream pool and pumping the gallery dry. The last time such an inspection was done was 1968, when the firm of Whitman, Requardt and Associates investigated the dam.

(5) The dam is founded on a schistose gneiss which was observed to be unweathered in the two rock core borings drilled through the downstream overflow section and in outcrops on the upstream side of the right abutment. Exposed bedrock on the left abutment above the top of dam is weathered, suggesting similar rock could underlie the non-overflow section on that side. The nearly vertical joint plane on the left abutment outcrop also suggests that rock excavation to neat lines and grades, as shown on the contract drawings, were not attained during construction, or they were difficult to construct.

(6) Unweathered bedrock bonded to concrete at the rock contact, as evidenced by the borings, suggests a good foundation bond.

(7) Seepage along a horizontal construction joint was observed on the overflow section near the right side and on the non-overflow section on the upstream side of the left abutment above the pool elevation. (See photographs)

(8) Although the lower reservoir had been dewatered, on the 16th, a small pool of water still remained along the toe of the spillway. This pool was in a pocket apparently formed by the scoured rock eroded at the toe of the overflow section. The extent of scouring could not be determined. A thin layer of ice had covered the pool except for an area at the end of the concrete apron near the center of the second overflow monolith from the right abutment. Light turbidity was observed in this location.

c. Reservoir Area: No reservoir slides were noted in the general area just upstream from the dam.

d. Downstream Channel: Approximately 2000 ft. downstream from the dam is a smaller dam constructed in 1881. Severe siltation in the reservoir area of this dam has reduced its capacity significantly. This siltation presents no restriction to the spillway discharge.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Operational Procedures:

As explained in paragraph 1.2(h) the operation of the dam is now limited to selective level intakes for the use of water supply and is dependent on the City's water demands and the quality of water being withdrawn.

4.2 Maintenance of Dam:

There appears to be no established system for periodic inspections and continued evaluation of the dam. A dam superintendent performs periodic minor maintenance of gates (grease, oil, etc). As previously noted, the City is anticipating a contract in the near future for repairs to the exterior facing of the dam and the water supply gates.

4.3 Warning System:

No formal warning system is associated with the dam. The dam superintendent has radio and telephone contact with the offices at Liberty Dam.

SECTION 5
HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. Design Data

Since no spillway design data are available, the adequacy of design data cannot be determined. Assuming 3 ft. of freeboard over the spillway, a spillway design discharge is computed to be approximately 13,000 cfs. with a coefficient of discharge of 4.0.

b. Experience Data

Tropical Storm Agnes, estimated to be about a 500 year event, produced the largest flood at the damsite anyone associated with the dam could recall. This flood actually overtopped the non-overflow section by approximately 6 inches. It was reported that during Agnes, all water supply gates were closed and a stage of 248.5 was attained. This stage produced a calculated discharge of about 30,000 cfs., approximately 15% of the PMF.

c. Overtopping Potential

The estimated probable maximum flood (PMF), based on a comparison of discharge per square mile vs. drainage area for computed PMF's in the Potomac and Patuxent River Basins, is approximately 200,000 cfs. One-half of the PMF or 100,000 cfs. was used to evaluate the overtopping potential and stability of the dam. This discharge of 100,000 cfs. exceeds the maximum capacity of the spillway crest and is 7 feet above top of dam. The tailwater associated with this discharge would be at approximately 186 feet MSL.

Based on one-half the PMF discharge and stage, the spillway of Loch Raven is considered to be grossly inadequate in that it is not capable of passing one-half of the PMF without substantial overtopping. Although overtopping of a concrete gravity structure is not considered as critical as for an earthen dam, it could develop into failure. The resulting failure may be caused by erosion of the abutments, overturning created by excessive head, or sliding.

Assuming that the reservoir is maintained at spillway crest (no flood control storage), the impact of a failure at one-half the PMF on the downstream flows may not be significant since the downstream flow would be equal to the inflow. However, during a failure of the dam at spillway capacity downstream flows would be significantly increased. Any of the mentioned failures would effectively eliminate the Loch Raven Reservoir as a source of the City's water supply. Consequently, the Prettyboy Reservoir, located upstream of Loch Raven, would be negated in that its stored water could not reach the City.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations

No unusual indications of structural instability were noted. The possibility of scour beneath the downstream concrete apron should be closely observed to avoid the possible development of future problems.

b. Design and Construction Data

The available data were listed in Section 2 - Engineering Data. Since no design information or analysis are available, no evaluation is given. In order to evaluate the theoretical structural stability, an analysis based on loadings derived from hydrologic and foundation data would be required in accordance with paragraphs 2.6.1 and 4.4.4. of the "Recommended Guidelines for Safety Inspection of Dams." A preliminary stability analysis was performed to determine the need for investigations and detailed analysis. This is further discussed in paragraph 6.1e.

c. Operating Records

No operating records other than spillway stage data are available. The dam was reported to have been overtopped during Tropical Storm Agnes by approximately six inches. No apparent problems were encountered, nor developed, as a result of this event. This, coupled with the fact that the dam has been operating for 55 years under various conditions with no visible structural problems, would appear to indicate that the dam is stable under normal operating conditions.

d. Post Construction Changes

Except for sealing of the 48 inch by-pass, all changes to the dam since completion in 1922 have apparently been cosmetic.

e. Stability Analysis Performed

In the absence of a stability analysis in the existing records, a preliminary analysis to obtain a feel for the relative theoretical stability of the dam was performed as part of this Phase I investigation (see Appendix D). This analysis included calculations for overturning and sliding. The analysis does not include stress computations, as these generally are not critical for a gravity type structure.

The analysis was performed for two loading conditions, the observed flow caused by tropical storm Agnes (the maximum known flood at the damsite), and one-half the probable maximum flood. The results of this analysis indicate that the theoretical overturning resistance for the Agnes flood was barely adequate and that the section might not pass a flood of the magnitude of 1/2 PMF. The sliding analysis also indicates factors of safety which are below those set forth in the "Guidelines," but are close to those required by the State of Maryland (3.0 vs. 1.5). It should be noted that this analysis is limited to one section of the dam and is based upon sketchy knowledge of the lower portion of the dam and its foundation. Rock strength values used were based upon the type of bedrock suspected to be underlying the dam. Bedrock with similar characteristics underlies the Brighton Dam on the Patuxent River between Baltimore and Washington. A detailed study of rock strength and joint orientation for the Brighton Dam foundation yielded strength values of:

	Angle of Internal Friction	Shear Stress at 0 Normal Load (psi)
Rock to concrete	35°	24
Natural joints perpendicular to foliation	30°	22
Natural joints parallel to foliation	23°	22

The analysis performed for Loch Raven utilized the above values for a typical idealized section. There may, however, be more critical sections along the length of the dam and more critical failure planes within the height of the dam.

f. Seismic Stability

The dam is located in Seismic Zone 1. Determination of seismic hazard potential for dams in Zones 0 thru 2 is contingent upon their adequacy for static stability conditions and conventional safety margins. Without the stability analysis discussed in paragraph b. above, the theoretical seismic stability cannot be assessed.

SECTION 7
ASSESSMENT/REMEDIAL MEASURES AND RECOMMENDATIONS

7.1 Dam Assessment

The Loch Raven Dam was inspected without the benefit of design or construction data, other than contract drawings for the upper portion of the dam. Based on the visual inspection made and the operational history, the dam appears stable under normal loading conditions. Yet, uncertainties in the foundation conditions, and hydraulic and stability designs still exist. The borderline overturning resistance computed, the inability of the spillway to pass one-half the PMF, and the lack of design information accentuates a need for continued inspection and observation to assure potential problems can be detected in early stages. Further investigations and analyses should be undertaken to assure safe operation of this dam.

7.2 Remedial Measures and Recommendations

In light of the findings of this Phase I investigation, it is recommended that immediate attention be directed to the following:

a. Structures and Appurtenances:

(1) An in-depth stability analysis, as discussed in paragraph 6.1b, should be performed for an adequate evaluation of the structural stability of the dam. The need for this analysis is emphasized by:

(a) The stability analysis performed as part of this Phase I investigation which indicates marginal factors of safety.

(b) The lack of adequate foundation data to assess the sliding resistance of the rock and the uplift pressures on the dam.

(c) The lack of adequate information on the original construction (i.e., the lower portion of the dam).

(d) The guideline requirement for such an analysis for all dams in the high hazard category.

(2) A thorough analysis of the drainage basin hydrology and the hydraulics of the dam for the probable maximum flood, examining the possibilities of reducing the overtopping potential, should be performed.

(3) The downstream toe of the dam should be completely dewatered, along with the lower inspection gallery, and thoroughly inspected. In the event of excessive scouring and undermining of the toe, an evaluation of the foundation and the scouring effects will have to be made, and corrective action taken.

(4) The horizontal drains in the inspection gallery, although apparently functioning, should be cleared of efflorescent deposits to allow free draining. In conjunction with this, an investigation should be made to determine the cause of impoundment in the extreme left inspection well.

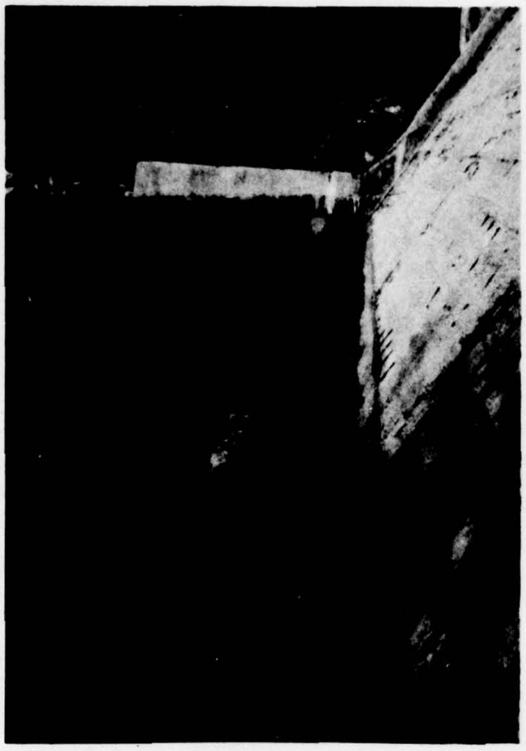
(5) The 48-inch by-passes should be restored, or other means provided, to facilitate drawdown capabilities and the ability to drain the reservoir.

b. Operation and Maintenance Procedures:

(1) A formal warning system with established contacts and procedures should be implemented.

(2) A formal system of periodic inspections and documentation should be implemented to insure that deterioration is monitored.

APPENDIX A
PHOTOGRAPHS

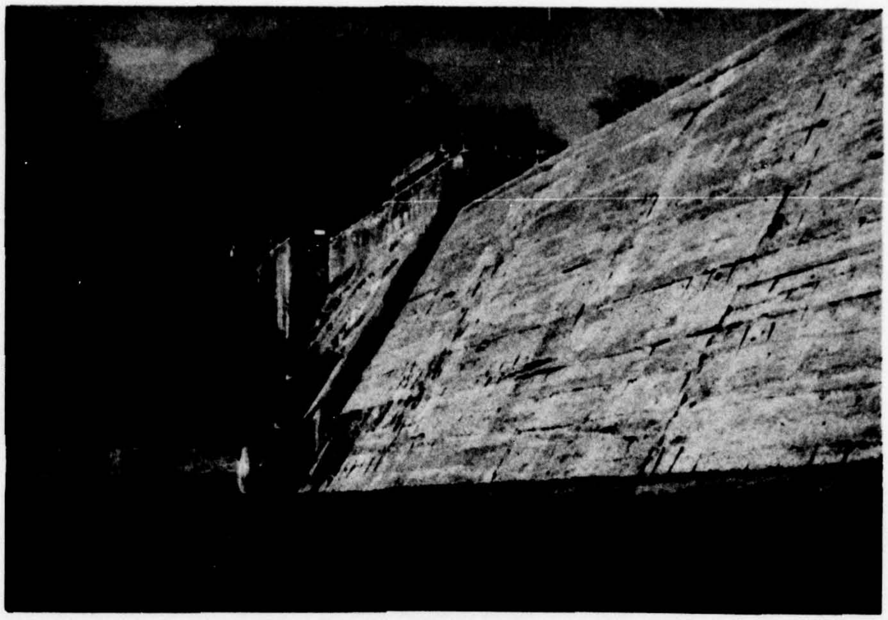


Concrete Deterioration Along Crest of Overflow Section

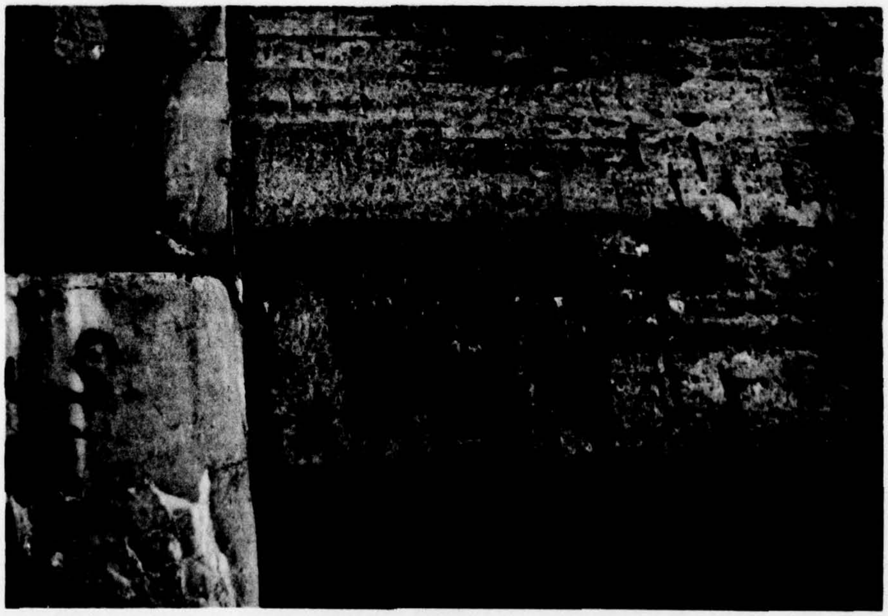
Concrete Deterioration of Face of Overflow Section. Note plugged 48" By-pass on Right Wingwall.

Concrete Deterioration of Face of Spillway

Lock Raven Dam
Baltimore, MD

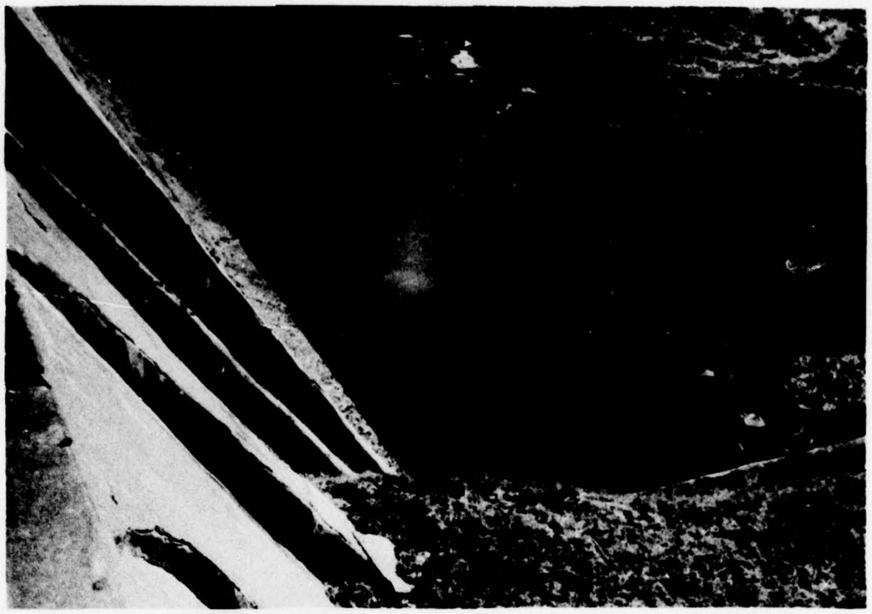


Seepage on Right Side Downstream Face of Spillway



Seepage on Right Side Downstream Face of Spillway

Lock Raven Dam
Baltimore, MD



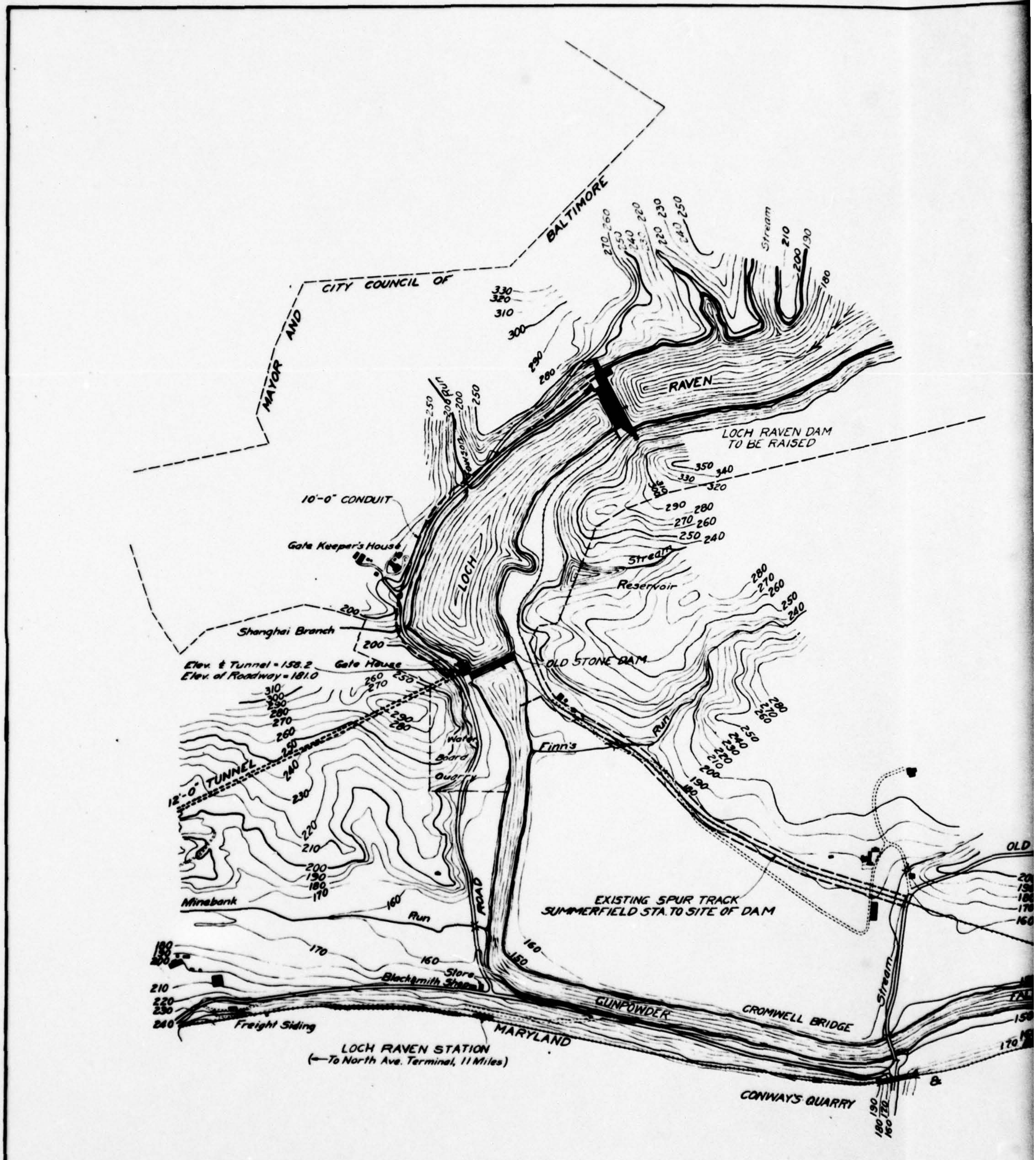
Downstream Face Right Abutment

Downstream Face Left Abutment

Typical Examples of Gunite Surface Deterioration

Lock Raven Dam
Baltimore, MD

APPENDIX B
PLANS


MAYOR AND CITY COUNCIL OF BALTIMORE
LOCH RAVEN
LOCH RAVEN DAM TO BE RAISED
10'-0" CONDUIT
Gate Keeper's House
Shanghai Branch
Elev. ℄ Tunnel = 158.2
Elev. of Roadway = 181.0
Gate House
OLD STONE DAM
Stream
Reservoir
Run
Finn's
Water Board Quarry
12'-0" TUNNEL
Minebank Run
ROAD
EXISTING SPUR TRACK SUMMERFIELD STA. TO SITE OF DAM
Store
Blacksmith Shop
Freight Siding
GUNPOWDER
CROMWELL BRIDGE
Stream
MARYLAND
LOCH RAVEN STATION
(←To North Ave. Terminal, 11 Miles)
CONWAYS QUARRY
OLD
DRAWN
TRACED

APPROVED

James W. Armstrong
FILTRATION ENGINEER

Wm. A. Megraw
WATER ENGINEER

CHIEF ENGINEER OF BALTIMORE

CITY OF BALTIMORE.
DEPARTMENT OF PUBLIC IMPROVEMENTS,
WATER DEPARTMENT.

RAISING LOCH RAVEN DAM

LOCATION PLAN

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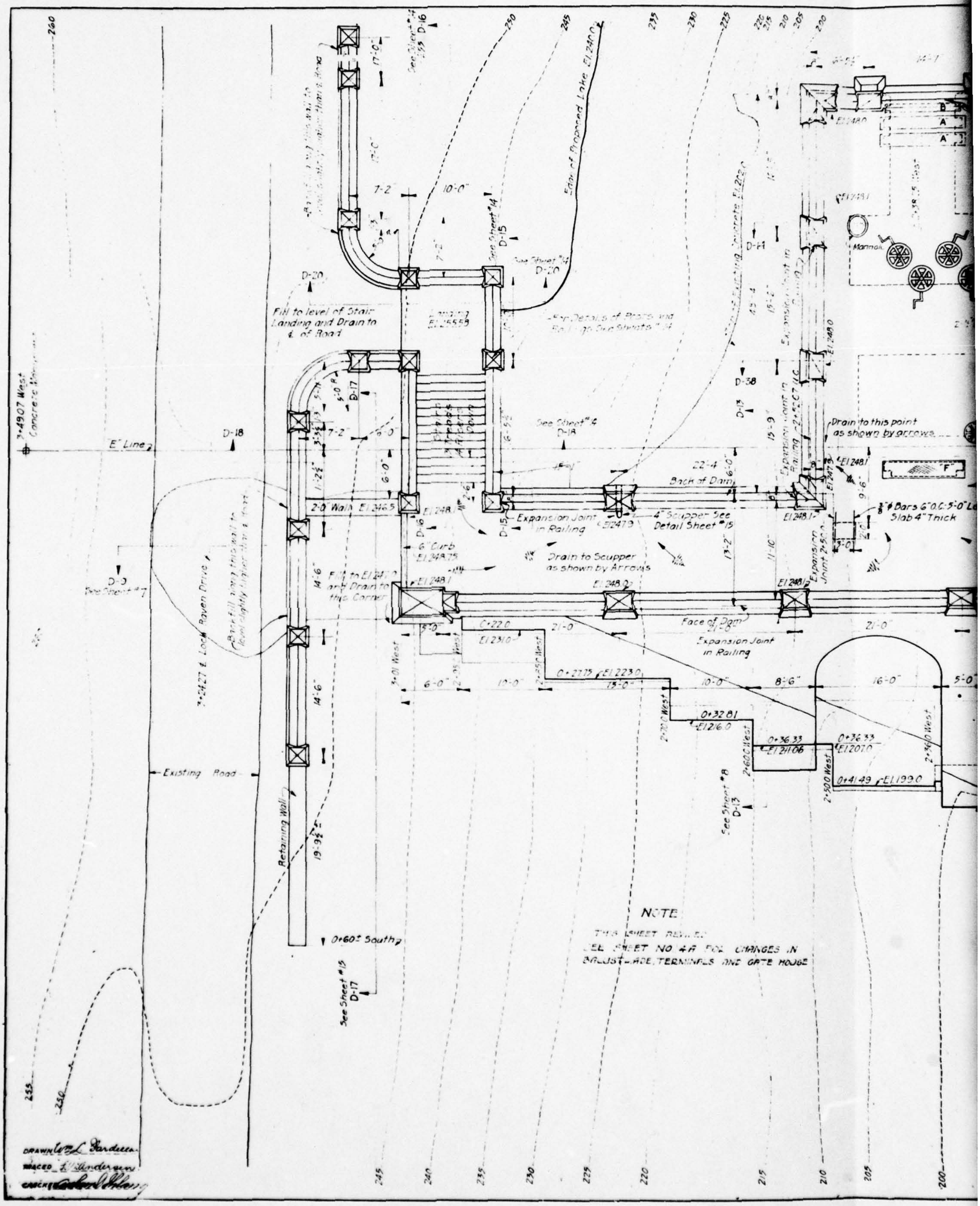

NOTE

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SEE SHEET NO 4A FOR CHANGES IN
BALUSTRADE, TERMINALS AND GATE HOUSE

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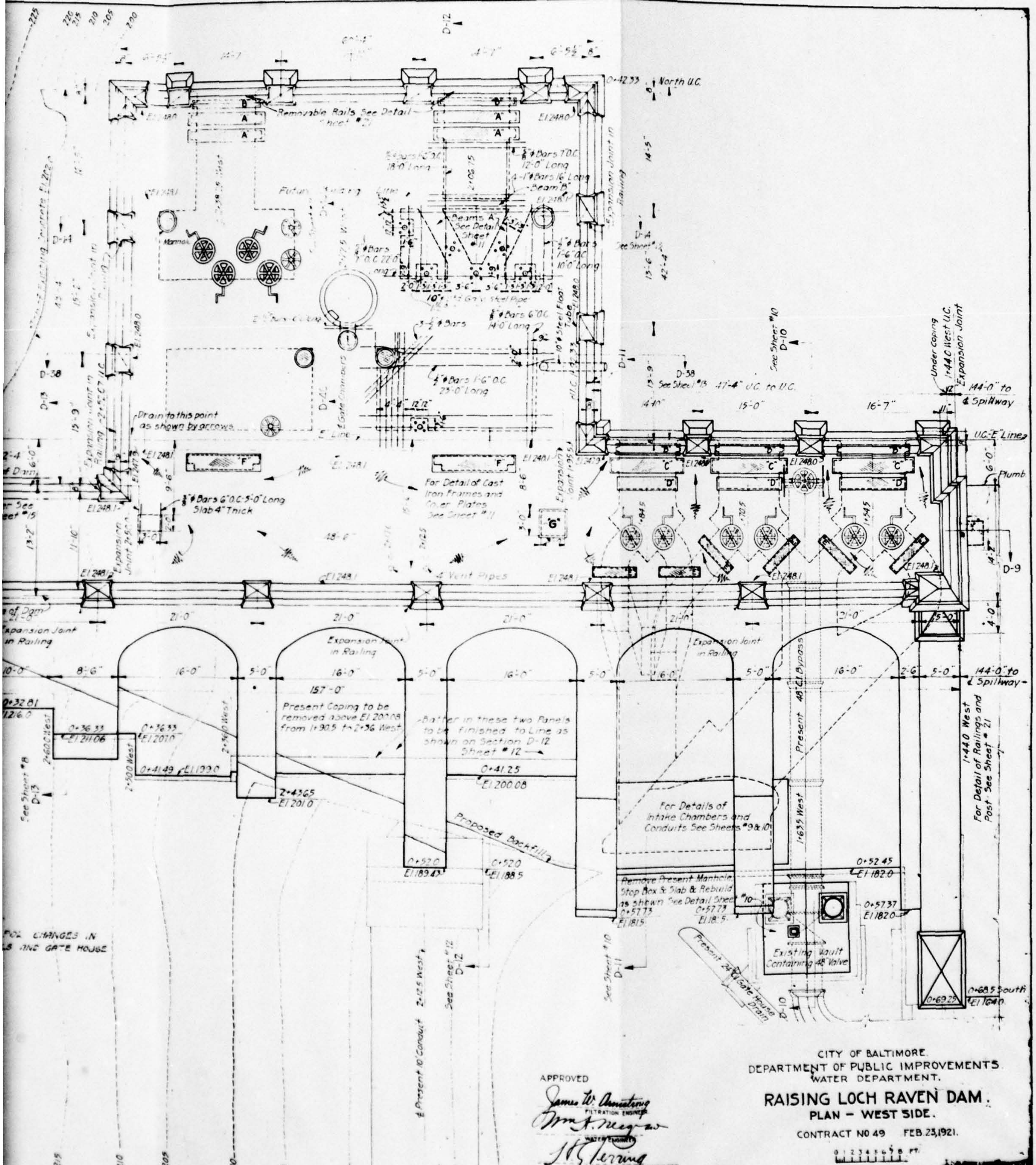


APPROVED

James W. Armstrong
FILTRATION ENGINEER

Wm A. Megraw
WATER ENGINEER

...Perring
CHIEF ENGINEER OF BALTIMORE

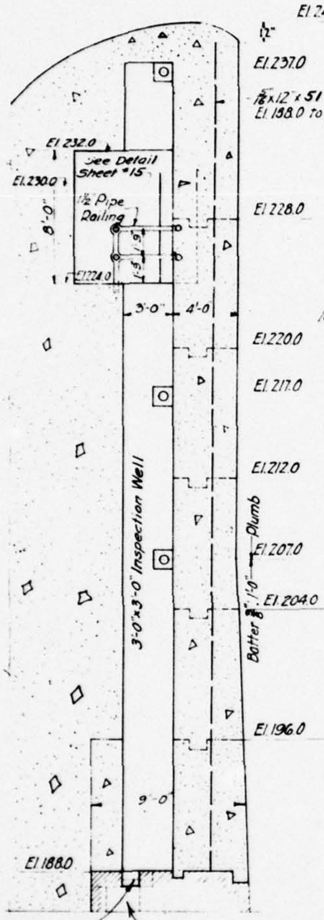
CITY OF BALTIMORE.
DEPARTMENT OF PUBLIC IMPROVEMENTS.
WATER DEPARTMENT.

RAISING LOCH RAVEN DAM.

PLAN – WEST SIDE.

CONTRACT NO 49 FEB. 23, 1921.

0 1 2 3 4 5 6 7 8 FT.

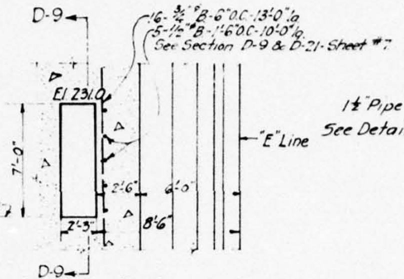


Concrete to be cut so as to make a groove 1'-3" wide by 12" deep below El 188.0 to provide for a connection between wells.

Present 2'x3' well.

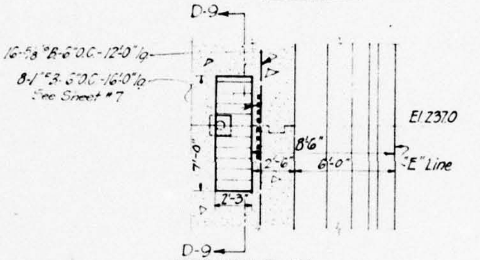
SECTION D-22

See Sheet #7



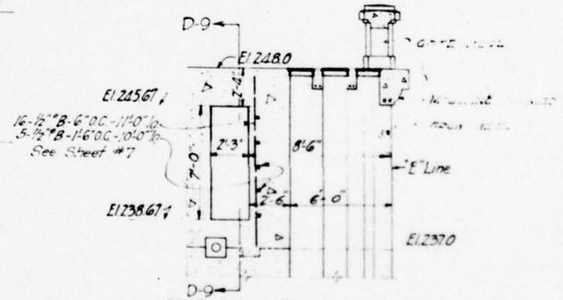
SECTION D-23

See Sheet #7



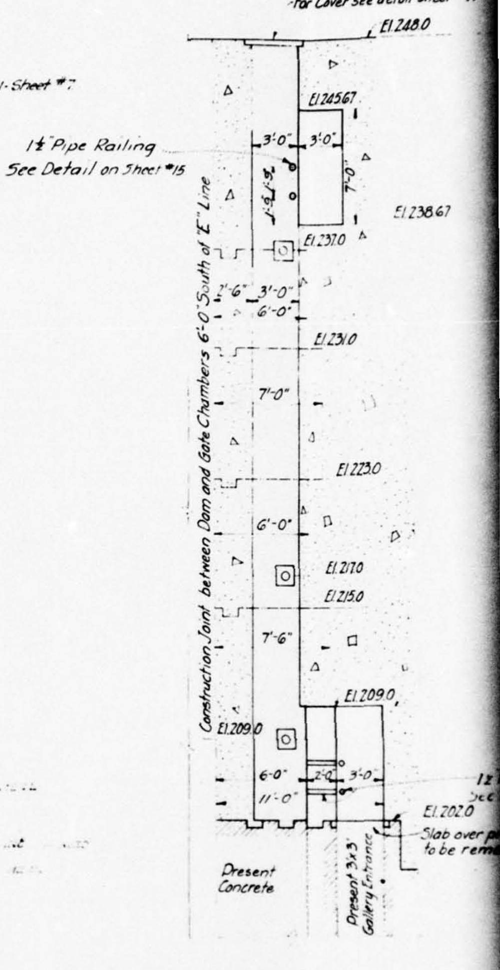
SECTION D-24

See Sheet #7



SECTION D-25

See Sheet #7



SECTION D-26

See Sheet #7

NOTE: FOR REVISIONS AFFECTING THIS SHEET SEE SHEETS No. 4R, 5R & 21R

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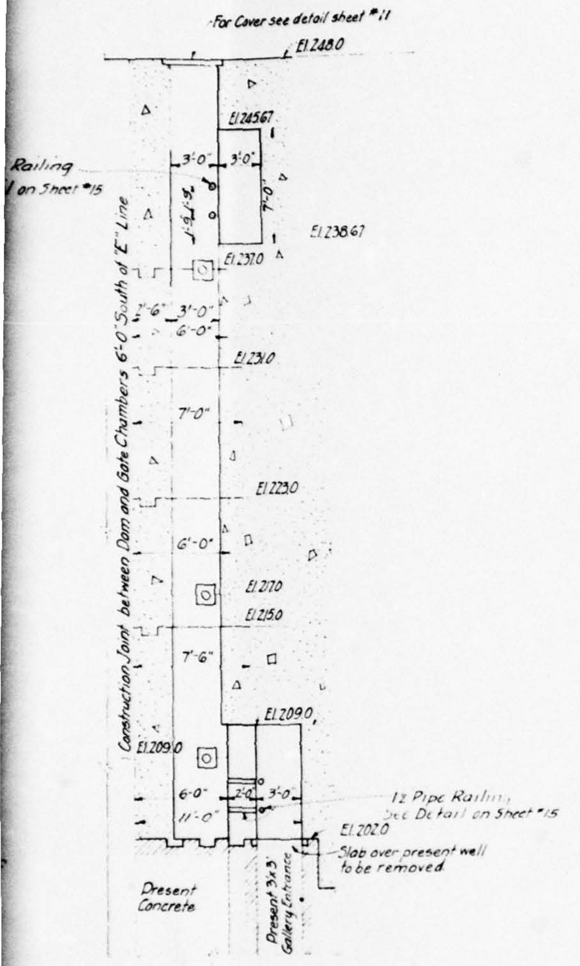
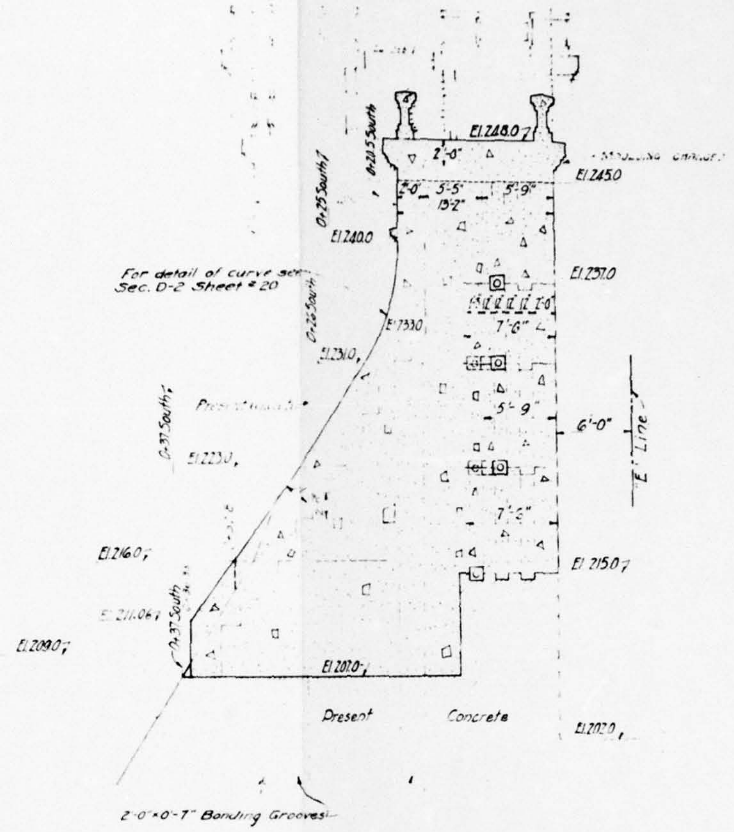
CHECKED J. Bowling



SECTION D-26

See Sheet #7



SECTION D-13

See Sheet #4

NOTE: FOR REVISIONS AFFECTING THIS SHEET SEE SHEETS NO. 4A 5A & 21A

APPROVED
James W. Armstrong
FILTRATION ENGINEER
WATER ENGINEER
CHIEF ENGINEER OF BALTIMORE

CITY OF BALTIMORE.
DEPARTMENT OF PUBLIC IMPROVEMENTS.
WATER DEPARTMENT.

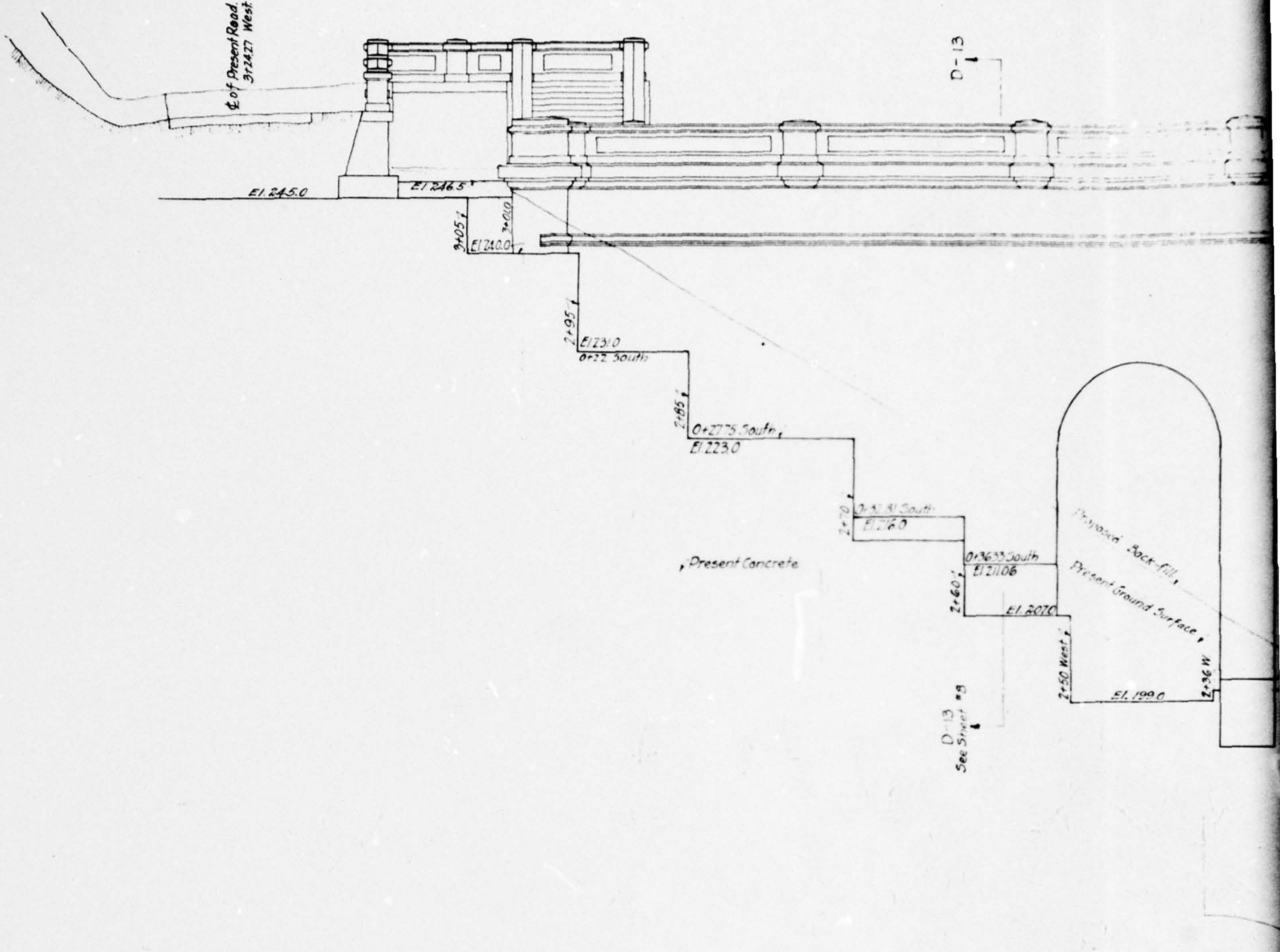
RAISING LOCH RAVEN DAM.

SECTIONS - WEST SIDE.

CONTRACT NO. 49 FEB 23 1921.
SCALES AS SHOWN

SHEET NO. 8 OF 2
DRAWING NO.

2



NOTE

THIS SHEET REVISED
SEE SHEET NO. 5A FOR CHANGES IN
BALUSTRADE TERMINALS AND GATE HOUSE

SOUTH ELEVATION-WES

For Dimensions see Sheet

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CHECKED Arthur E. Ray

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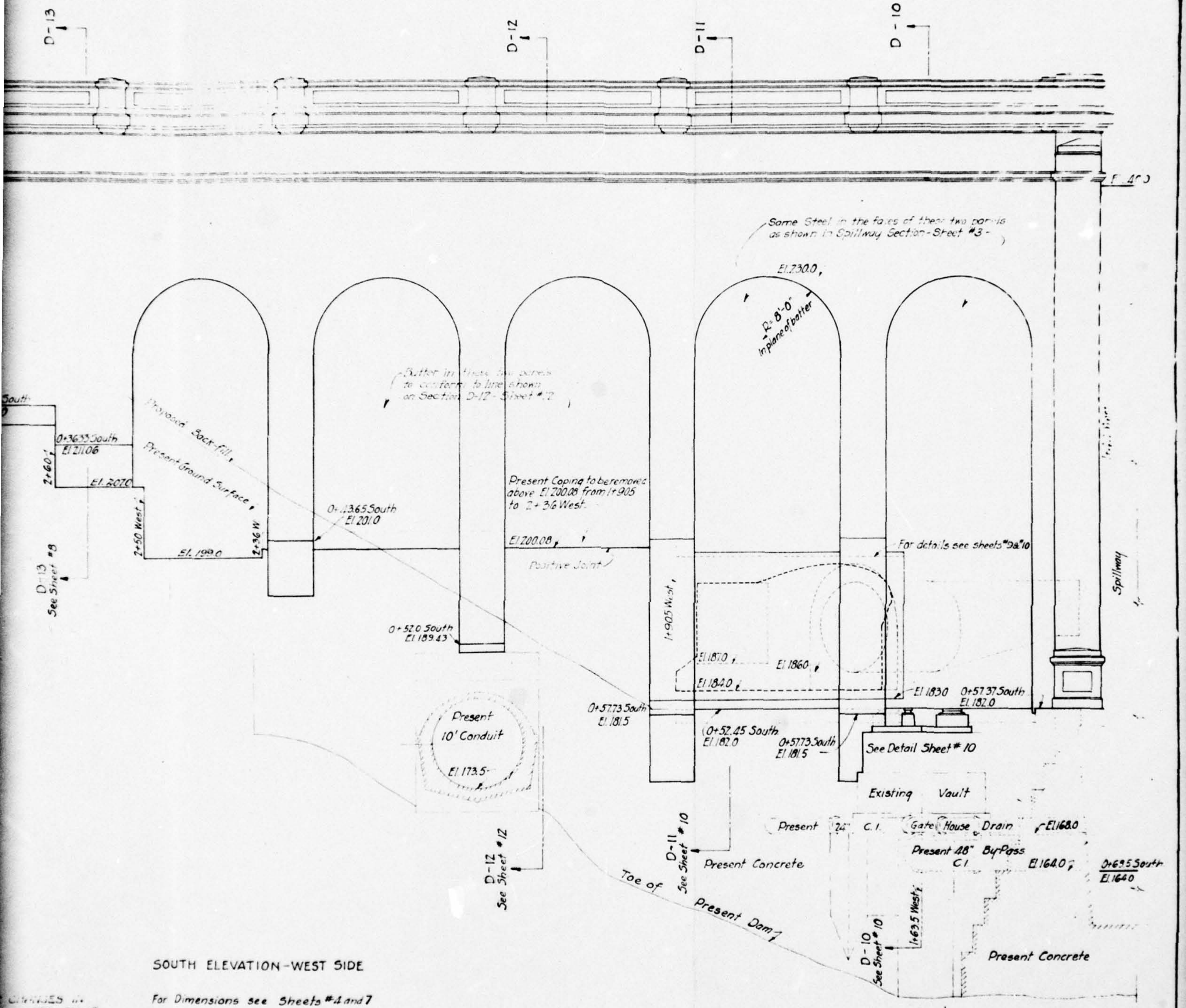


SOUTH ELEVATION-WEST SIDE

For Dimensions see Sheets #4 and 7

CHANGES IN
ND GATE HOUSE

APPROVED
James W. Armstrong
FILTRATION ENGINEER
Wm. A. Megraw
WATER ENGINEER
CHIEF ENGINEER OF BALTIMORE

CITY OF BALTIMORE
DEPARTMENT OF PUBLIC IMPROVEMENTS
WATER DEPARTMENT

RAISING LOCH RAVEN DAM

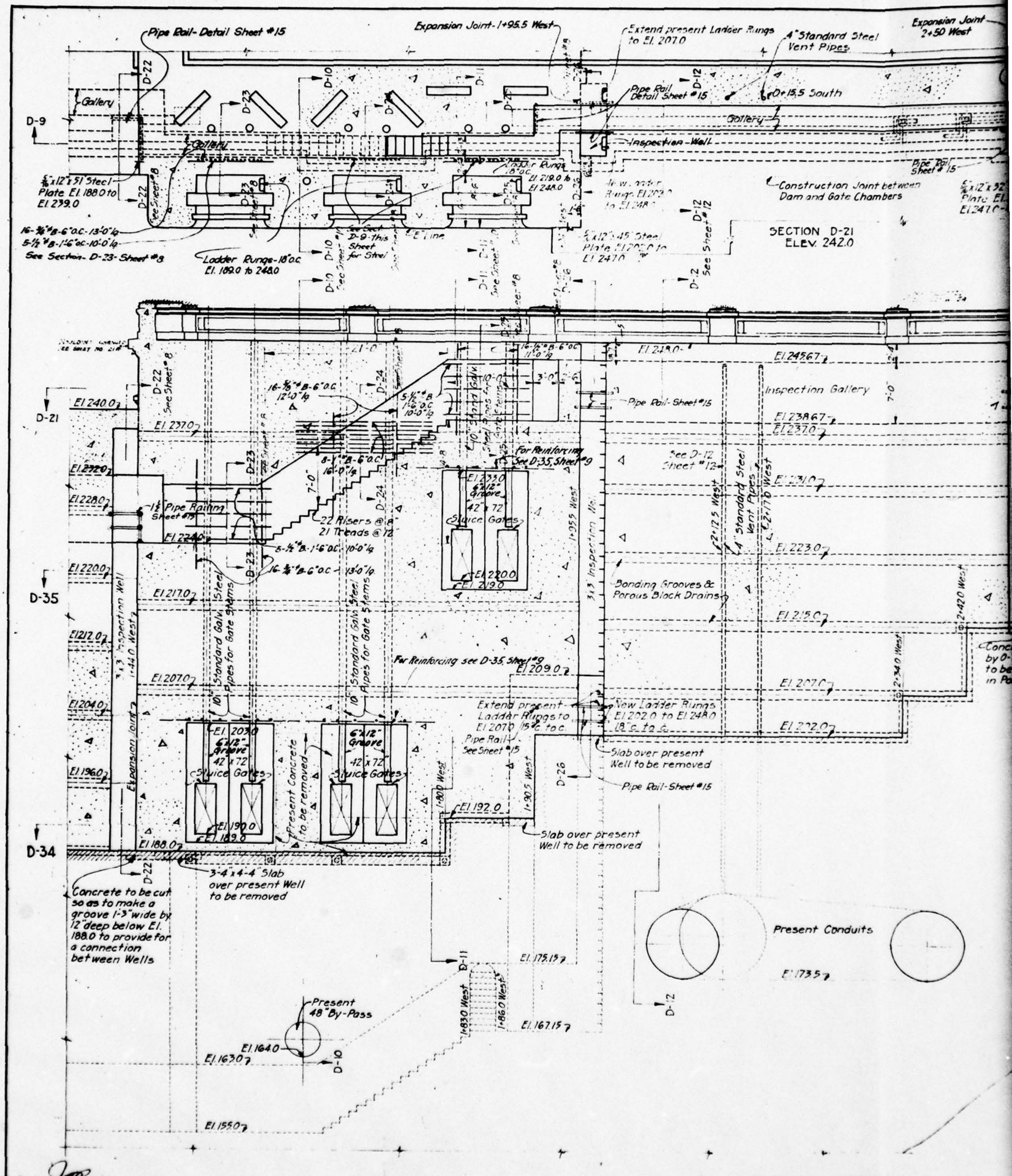
SOUTH ELEVATION - WEST SIDE.

CONTRACT NO 49 - FEB. 23, 1921

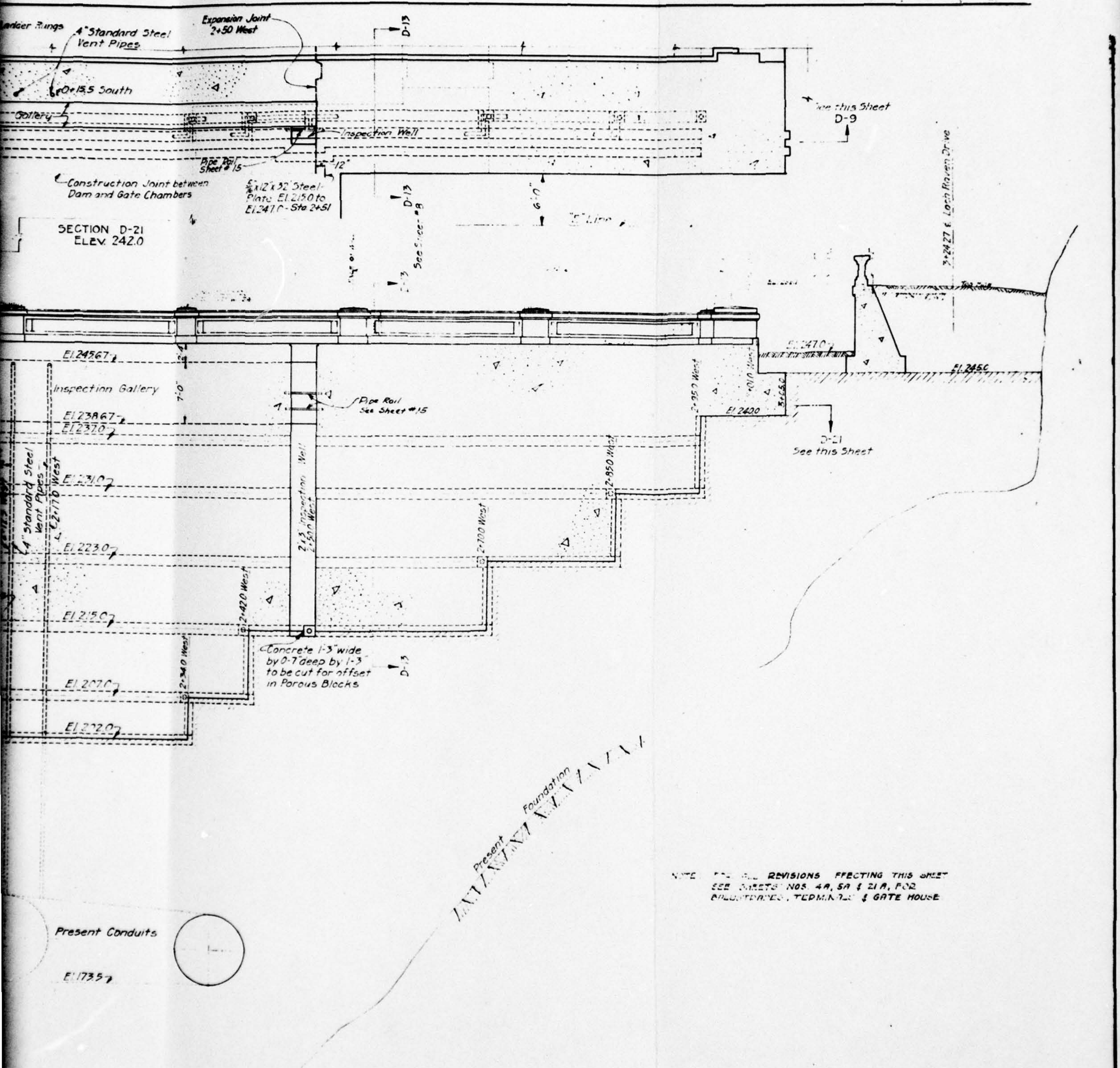
0 1 2 3 4 5 6 7 8 9 10 FT.

SHEET NO 5 OF 28
DRAWING NO 434-F

2



LONGITUDINAL SECTION D-9
WEST SIDE



NOTE: FOR ALL REVISIONS AFFECTING THIS SHEET SEE SHEETS NOS. 4A, 5A & 21A, FOR BALUSTRADES, TERMINALS & GATE HOUSE

LONGITUDINAL SECTION D-9
WEST SIDE

APPROVED

James W. Armstrong
FILTRATION ENGINEER

Wm. A. Megraw
WATER ENGINEER

H. G. Perring
CHIEF ENGINEER OF BALTIMORE

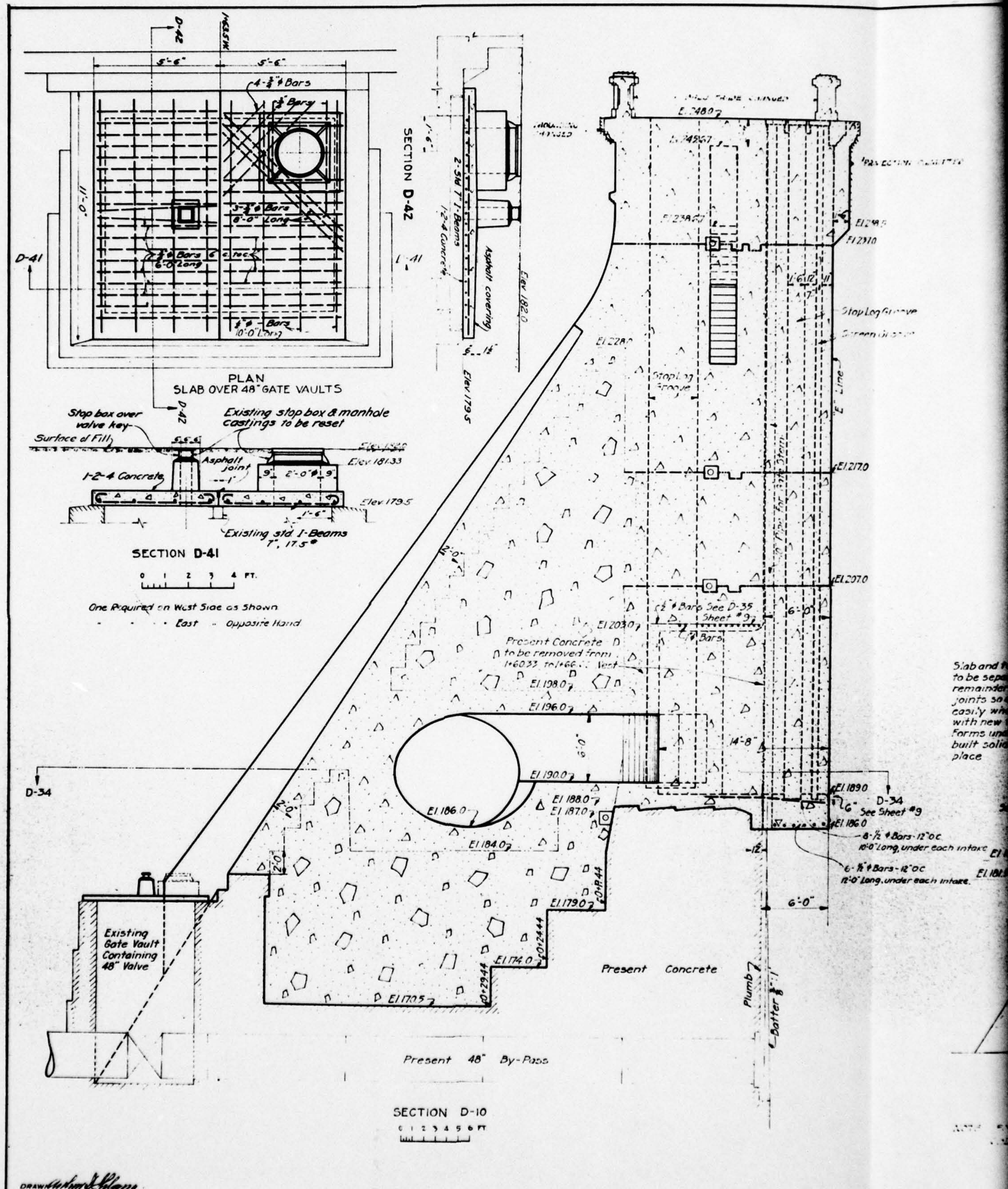
CITY OF BALTIMORE
DEPARTMENT OF PUBLIC IMPROVEMENTS
WATER DEPARTMENT

RAISING LOCH RAVEN DAM.
SECTIONS - WEST SIDE.
CONTRACT NO. 49 . FEB.23,1921

0 1 2 3 4 5 6 7 8 9 10

SHEET [redacted]

2



PLAN
SLAB OVER 48" GATE VAULTS

SECTION D-42

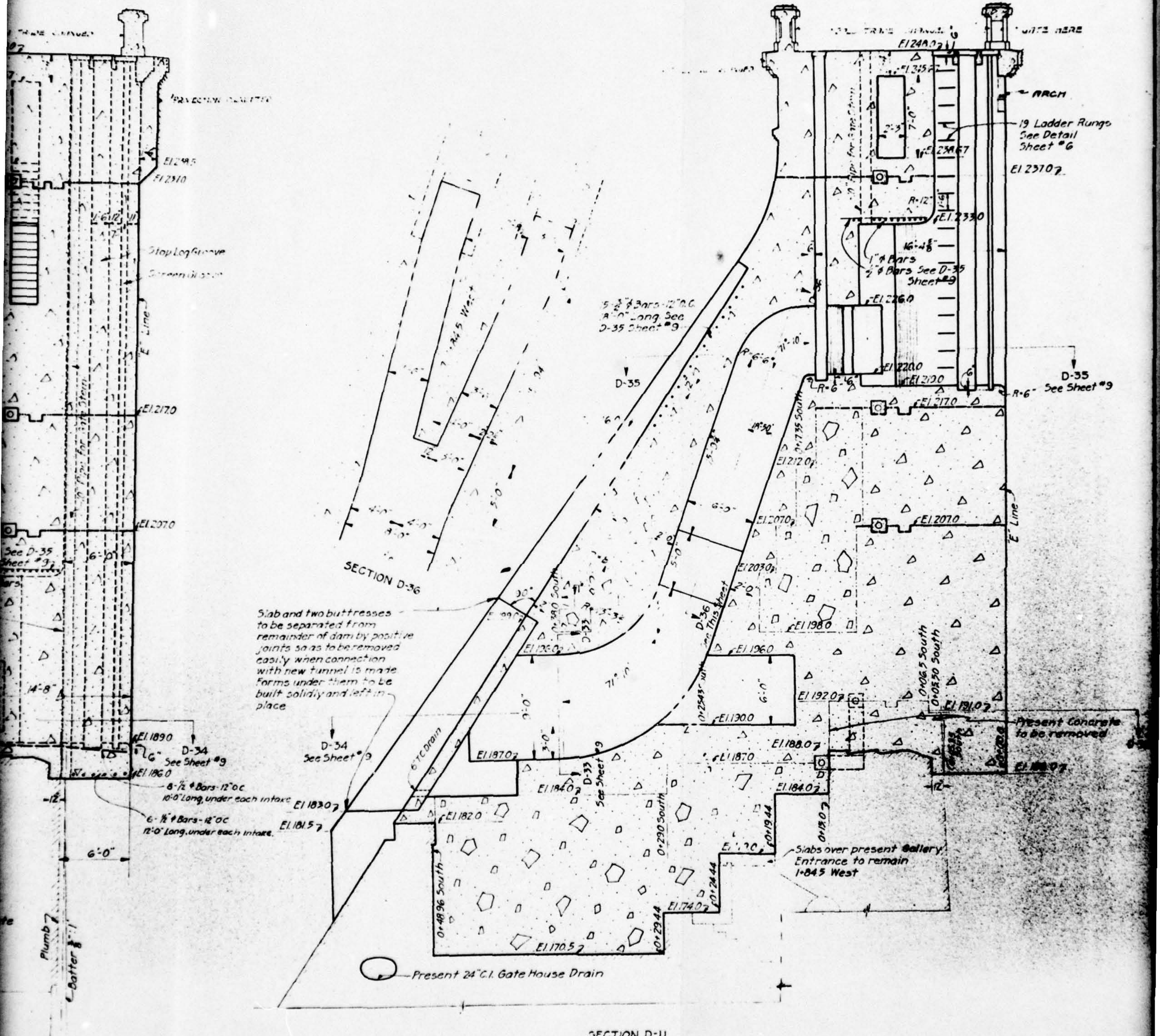
SECTION D-41

One Required on West Side as Shown
" " East " Opposite Hand

SECTION D-10

DRAWN
TRACED
CHECKED Wm. L. Tardella

1



SECTION D-11

0 1 2 3 4 5 6 FT.

NOTE: FOR REVISIONS AFFECTING THIS SHEET SEE SHEET NOS. 4A, 5A & 8A.

APPROVED

James W. Armstrong
FILTRATION ENGINEER

Wm. A. Megraw
WATER ENGINEER

M. G. Herring
CHIEF ENGINEER OF BALTIMORE.

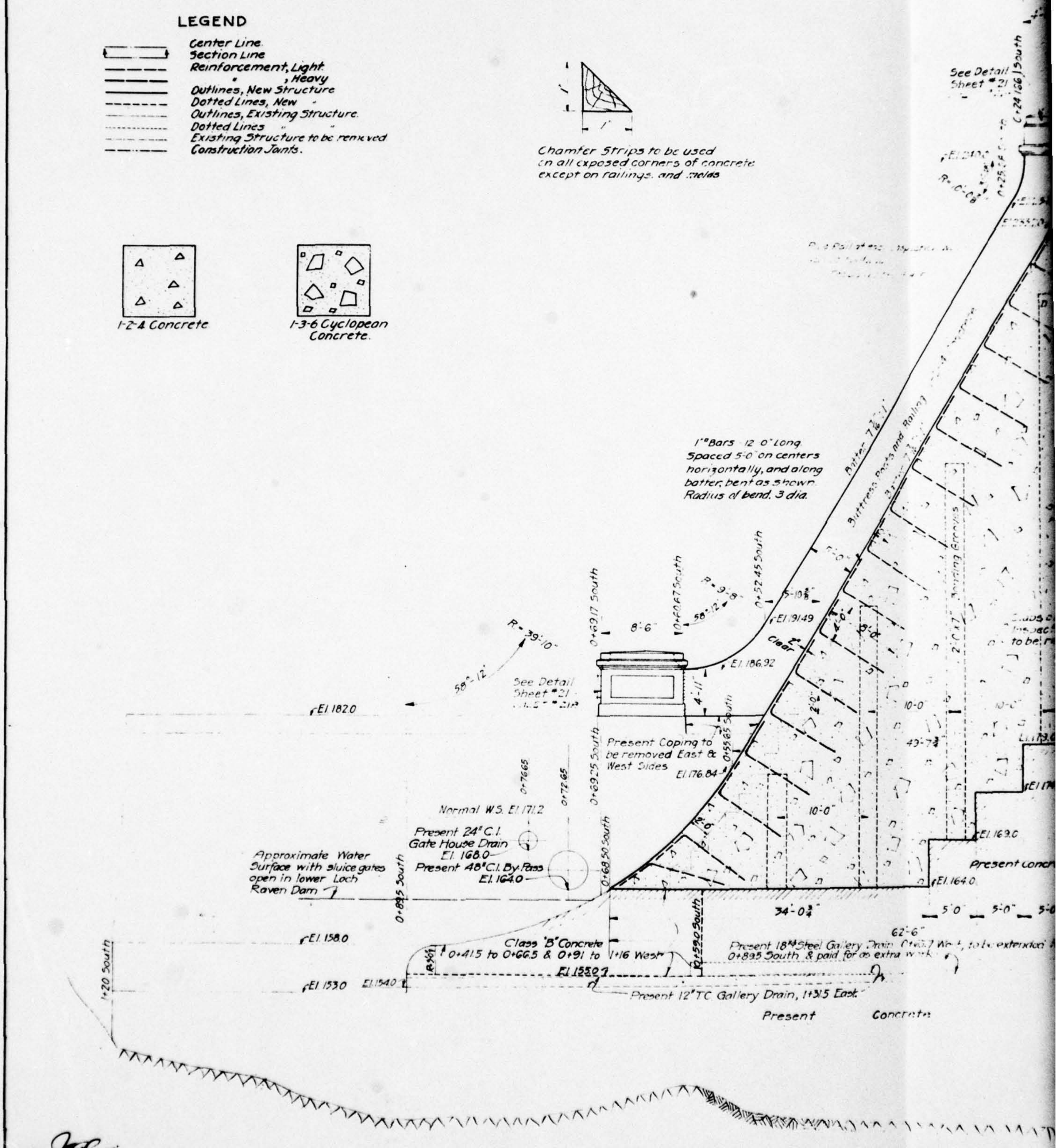
CITY OF BALTIMORE.
DEPARTMENT OF PUBLIC IMPROVEMENTS.
WATER DEPARTMENT.

RAISING LOCH RAVEN DAM.

SECTIONS – WEST SIDE.

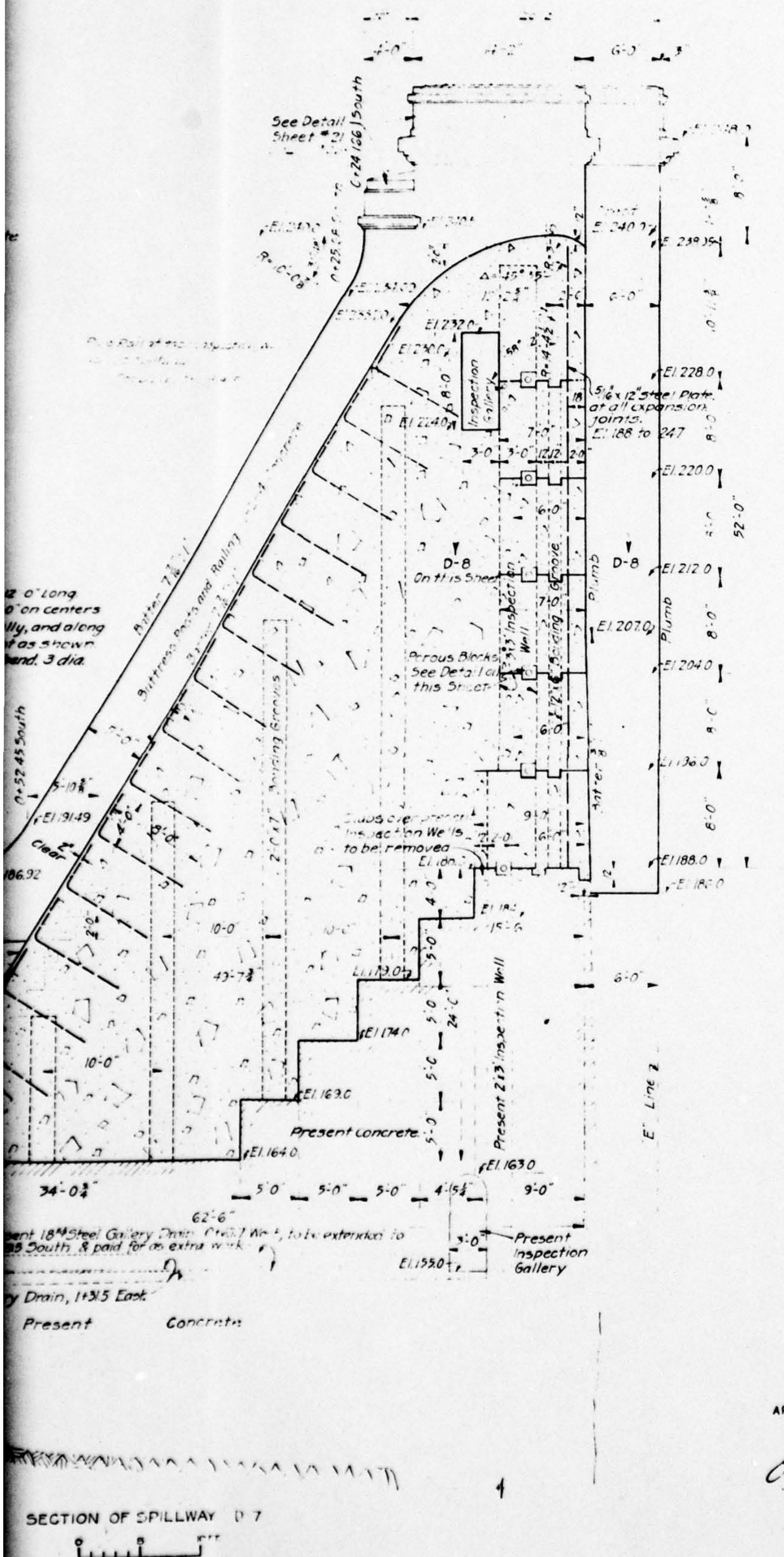
CONTRACT NO. 49 FEB. 23, 1921.
SCALES AS SHOWN.

SHEET NO.
DRAWING

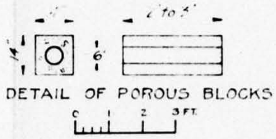


DRAWN J. E. Curling
TRACED W. W. Anderson
CHECKED Wm. L. Gadello

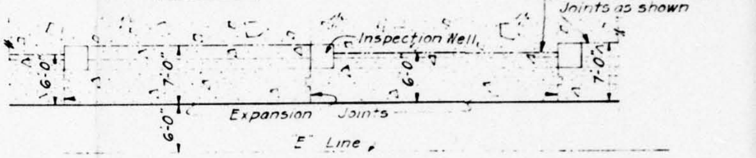
SECTION OF SPILLWAY D 7



SECTION OF SPILLWAY D 7



DETAIL OF POROUS BLOCKS



SECTION D-8
SHOWING DIVISION LINES BETWEEN
1-2-4 & 1-3-6 CONCRETE

Note:
For location of Expansion Joints and Inspection Wells on Spillway. See Sheet #1.

NOTE
FOR ALL REVISIONS AFFECTING THIS
SHEET SEE SHEETS NOS. [illegible] 5A & [illegible]

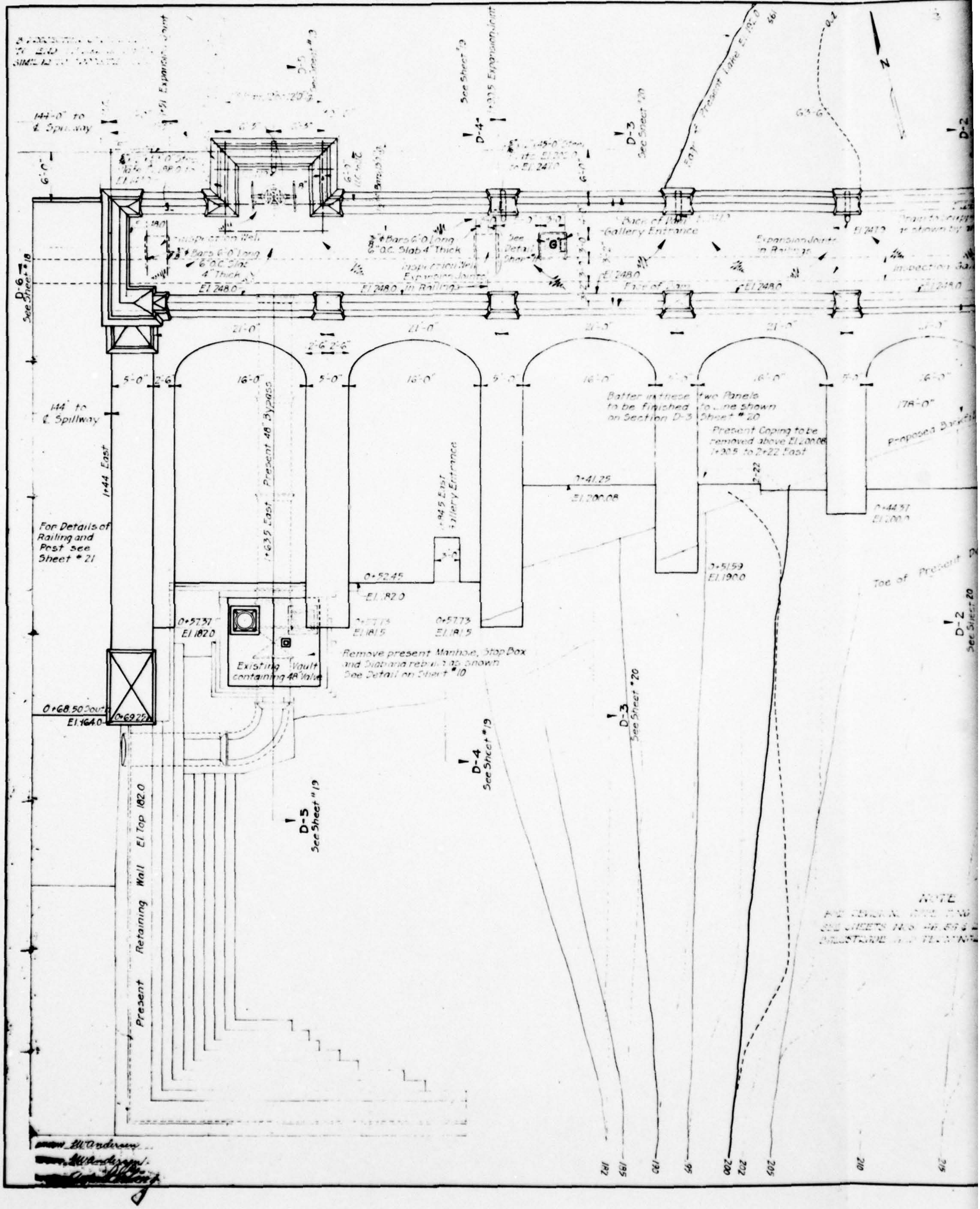
APPROVED
James W. Armstrong
FILTRATION ENGINEER
Wm. T. Magraw
WATER ENGINEER
W. Glenning
CHIEF ENGINEER OF BALTIMORE.

CITY OF BALTIMORE
DEPARTMENT OF PUBLIC IMPROVEMENTS
WATER DEPARTMENT

RAISING LOCH RAVEN DAM
TYPICAL SECTION OF SPILLWAY.
CONTRACT NO. 49 FEB. 23, 1921.
SCALE AS SHOWN

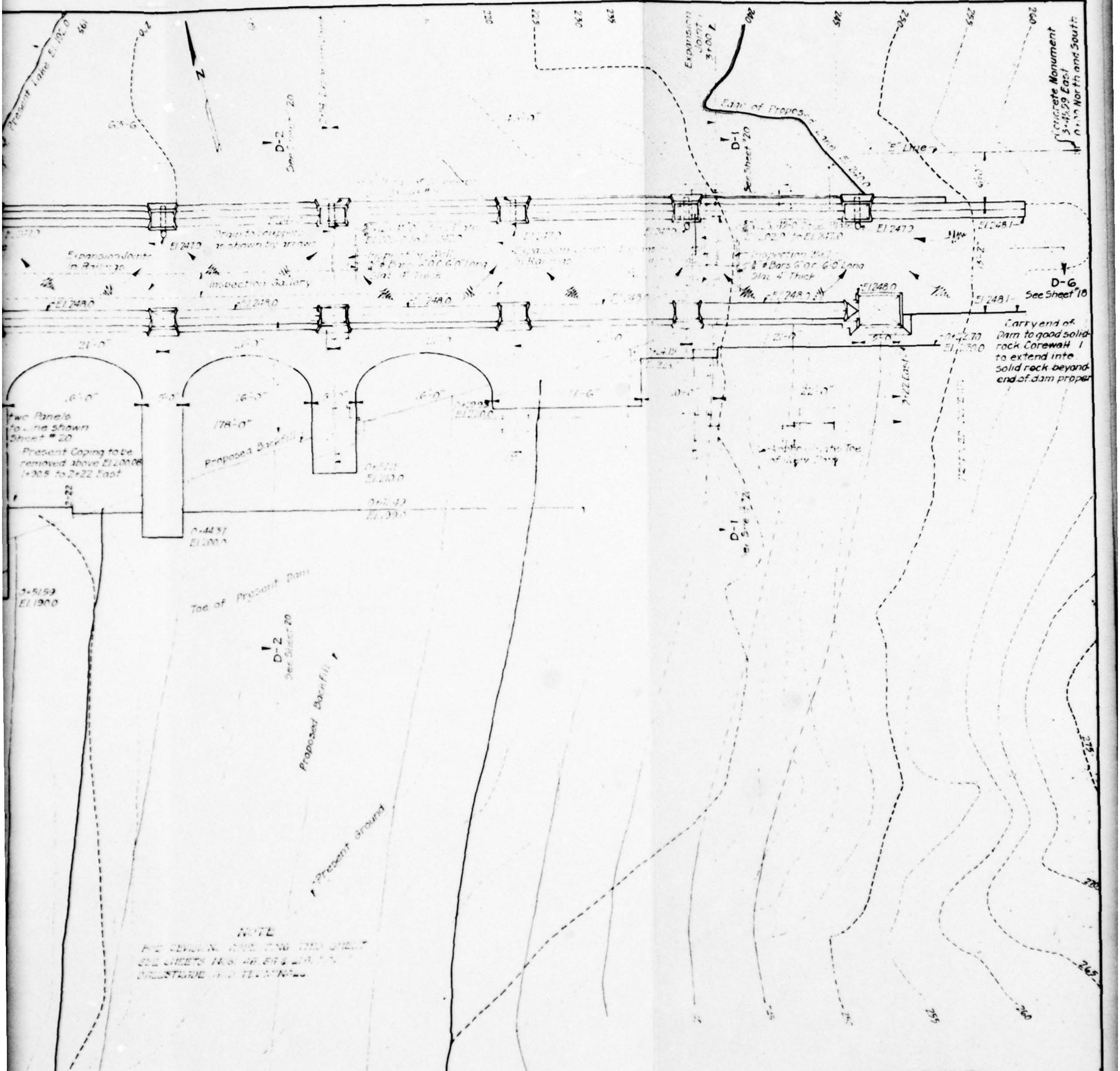
SHEET [redacted]
DRA[redacted]

2



L.W. Andersen

L.W. Andersen



APPROVED

James W. Armstrong

CITY OF BALTIMORE
DEPARTMENT OF PUBLIC IMPROVEMENTS
WATER DEPARTMENT

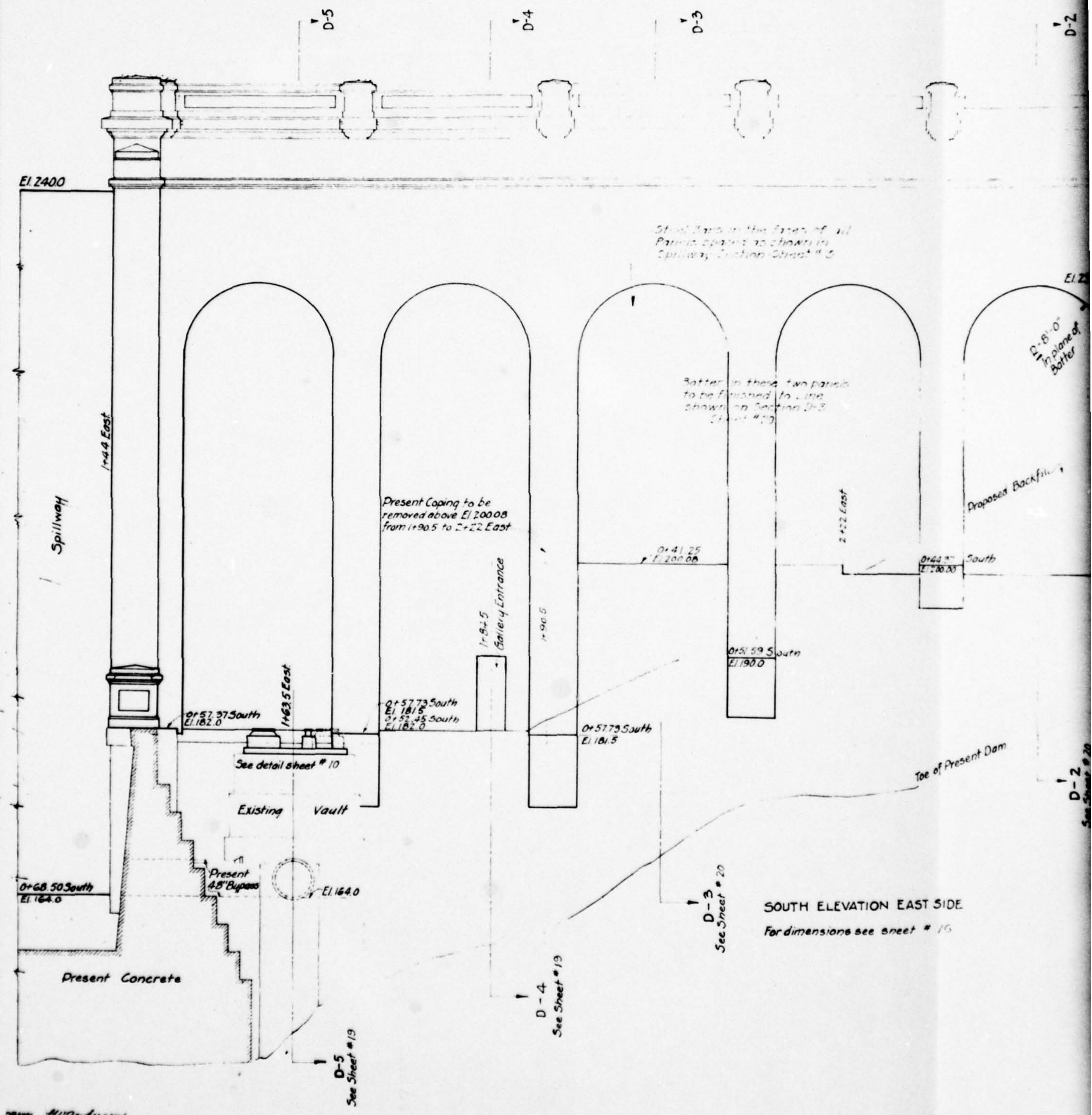
RAISING LOCH RAVEN DAM

PLAN-EAST SIDE.

CONTRACT NO 49 - FEB. 23, 1921

0 1 2 3 4 5 6 7 8 9 10 FT

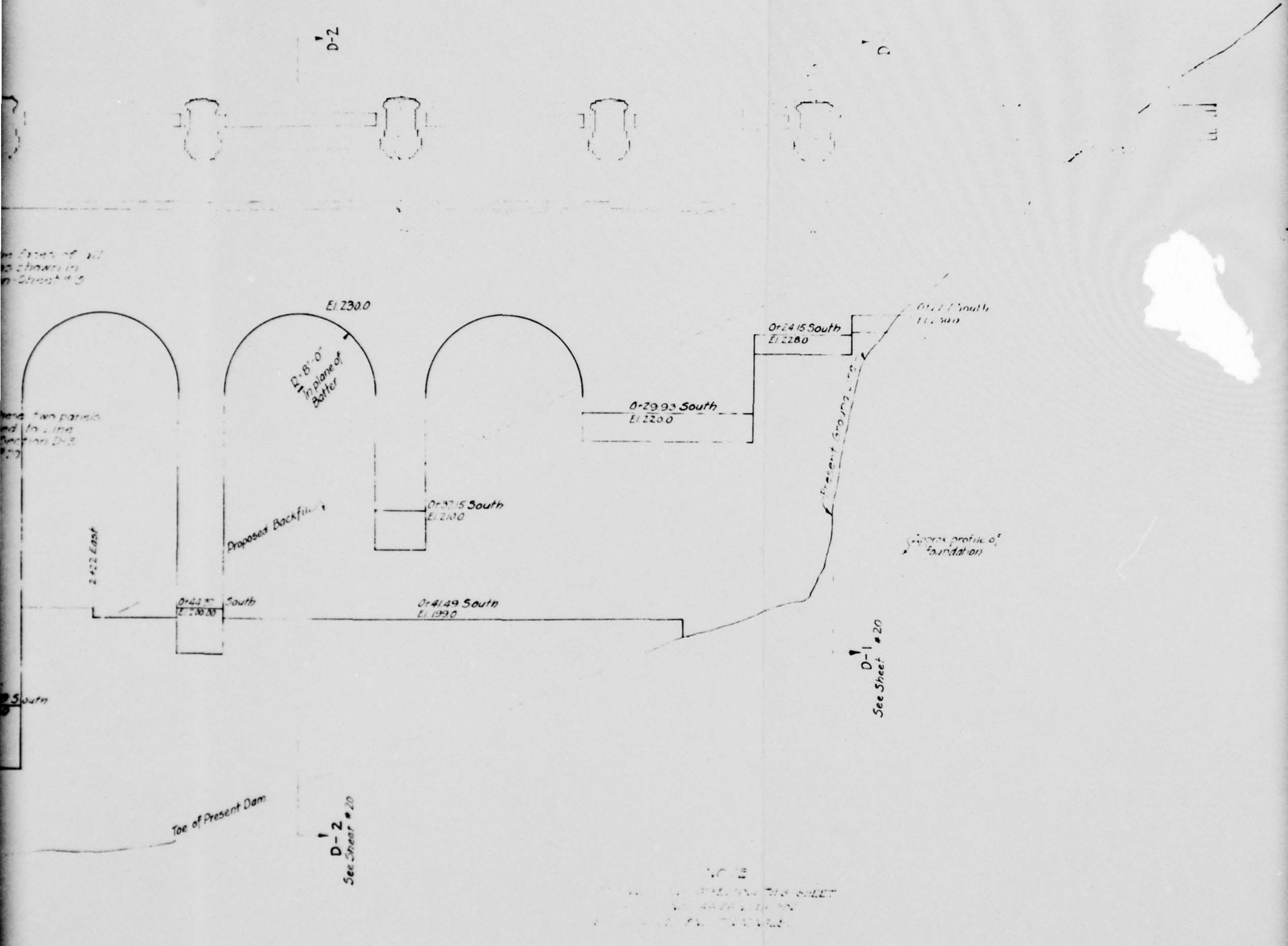
SHEET NO. [illegible]
DRAWING NO. [illegible]



SOUTH ELEVATION EAST SIDE

For dimensions see sheet # 16

DRAWN H.W.Anderson
TRACED E.Harris
CHECKED W.L. Dandella



SOUTH ELEVATION EAST SIDE

For dimensions see sheet # 16

APPROVED

James W. Armstrong
FILTRATION ENGINEER

Wm. A. Megraw
WATER ENGINEER

H.G. Perring
CHIEF ENGINEER OF BALTIMORE

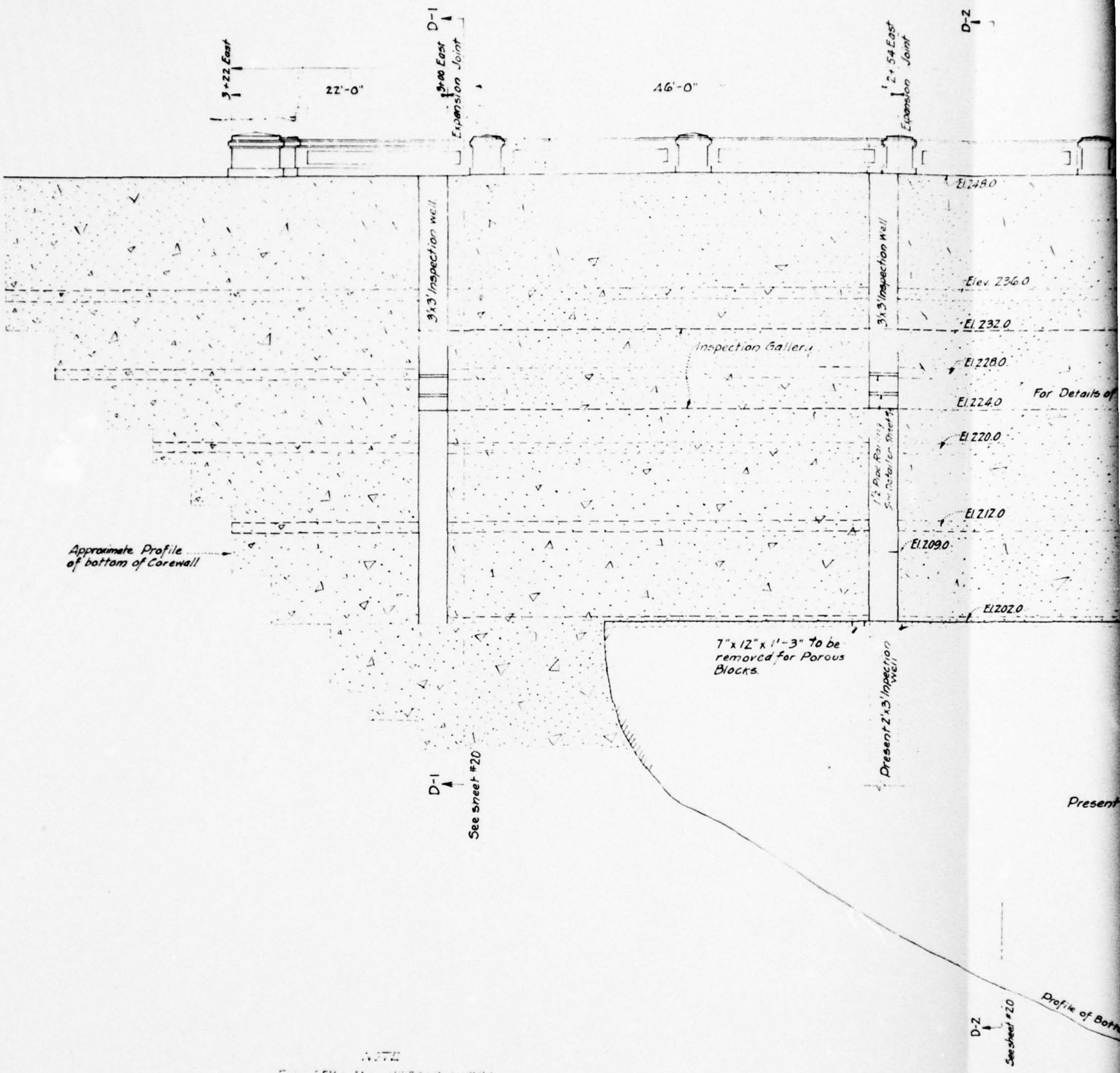
CITY OF BALTIMORE
DEPARTMENT OF PUBLIC IMPROVEMENTS
WATER DEPARTMENT

RAISING LOCH RAVEN DAM
SOUTH ELEVATION - EAST SIDE

CONTRACT NO.49 FEB.23,1921

0 1 2 3 4 5 6 7 8 FT

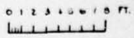
SHEET NO.17 OF 22
DRAWING NO.448-B-



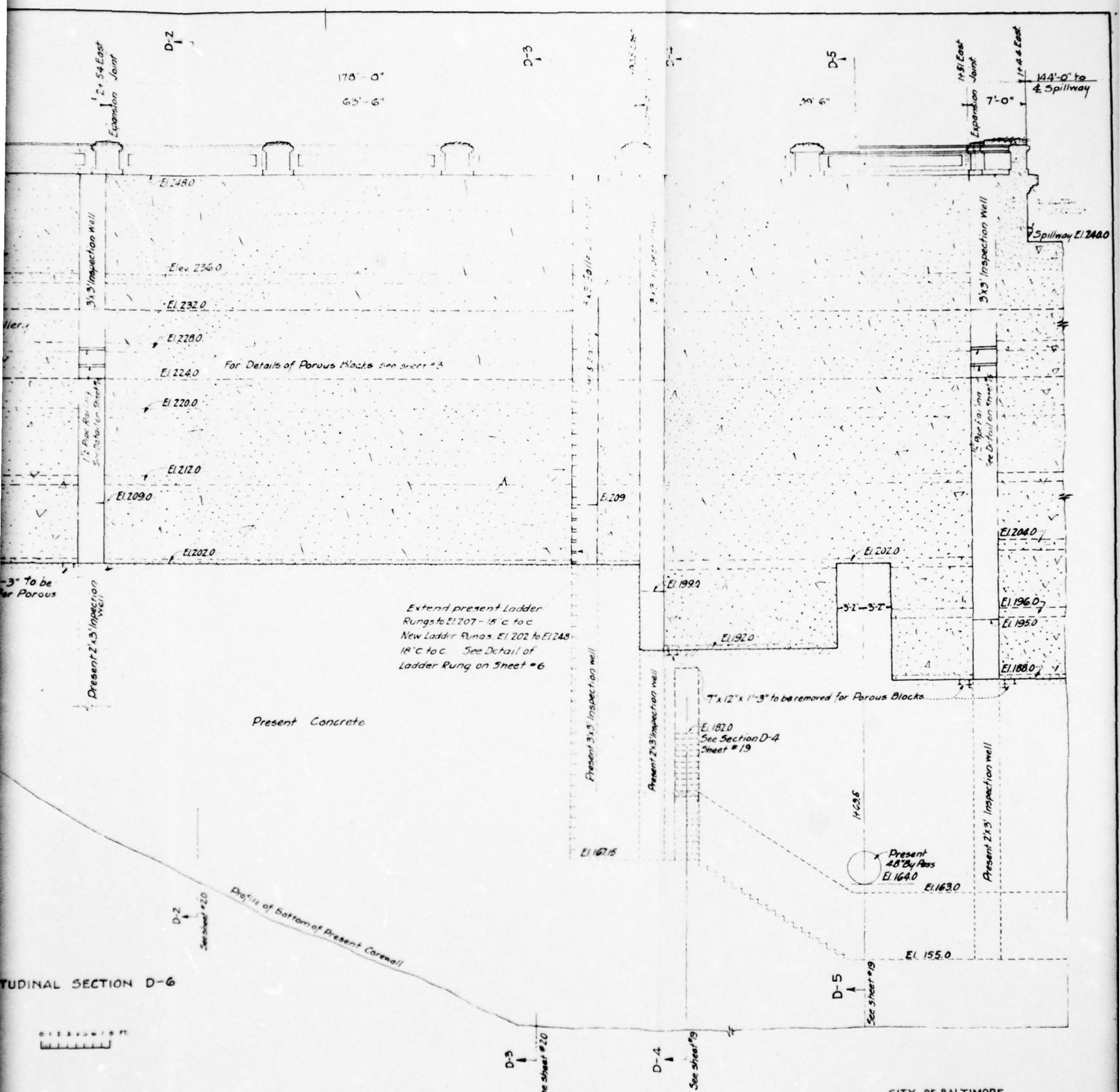
NOTE

[illegible]

LONGITUDINAL SECTION D-6



DRAWN
TRACED E. Harris
CHECKED



APPROVED

James W. Armstrong
FILTRATION ENGINEER

Wm. A. Megraw
WATER ENGINEER

CHIEF ENGINEER OF BALTIMORE.

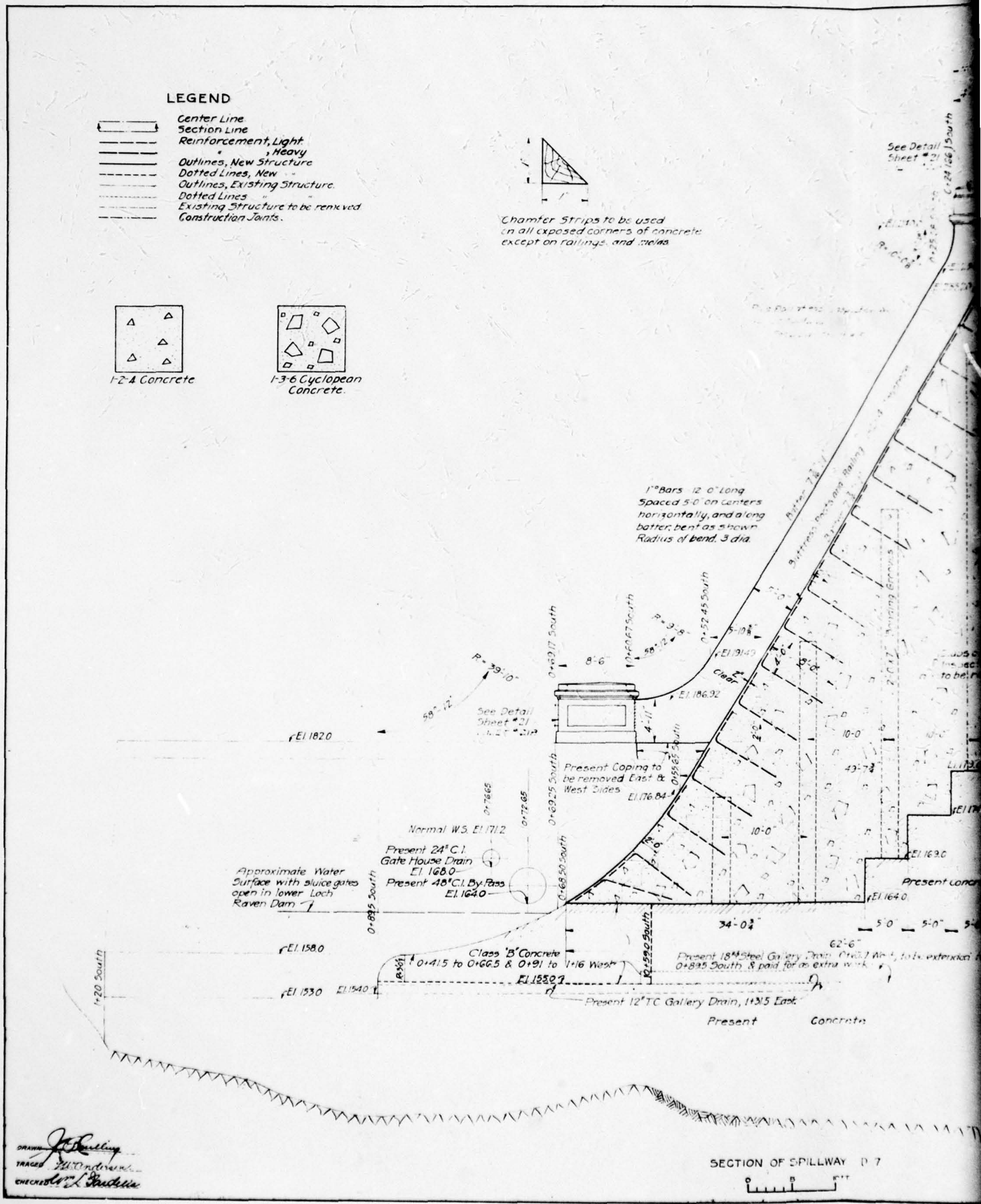
CITY OF BALTIMORE
DEPARTMENT OF PUBLIC IMPROVEMENTS.
WATER DEPARTMENT.

RAISING LOCH RAVEN DAM

LONGITUDINAL SECTION – EAST SIDE.

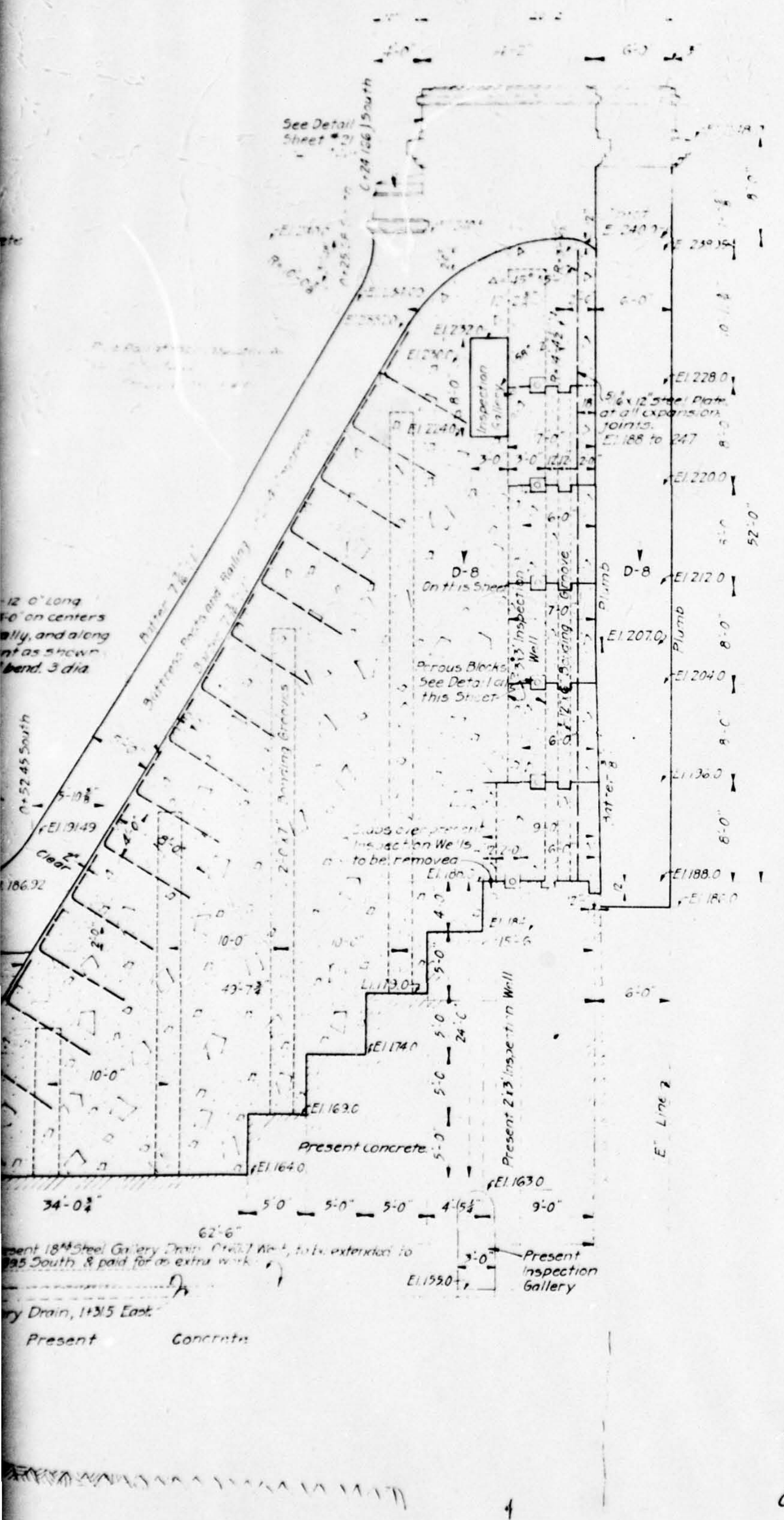
CONTRACT NO. 49 FEB. 23, 1921.
SCALES AS SHOWN

SHEET NO. 18 OF 22
DRAWING NO. 449-B-1



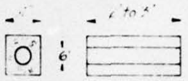
DRAWN J.E. Rulling
TRACED W. Andersen
CHECKED Wm L. Bardella

SECTION OF SPILLWAY D 7



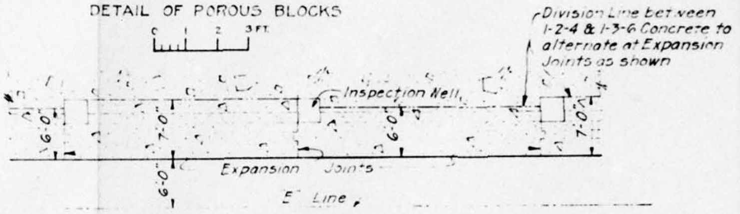
SECTION OF SPILLWAY D-7

0 5 FT



DETAIL OF POROUS BLOCKS

0 1 2 3 FT



SECTION D-8
SHOWING DIVISION LINES BETWEEN
1-2-4 & 1-3-6 CONCRETE

0 8 16 FT

Note
For location of Expansion Joints and Inspection Wells on Spillway, See Sheet #1.

NOTE
FOR ALL REVISIONS AFFECTING THIS
SHEET SEE SHEETS NOS. 48 58 & 59

APPROVED

James W. Armstrong
FILTRATION ENGINEER

Wm. T. Magraw
WATER ENGINEER

W. Conning
CHIEF ENGINEER OF BALTIMORE

CITY OF BALTIMORE
DEPARTMENT OF PUBLIC IMPROVEMENTS
WATER DEPARTMENT

RAISING LOCH RAVEN DAM
TYPICAL SECTION OF SPILLWAY
CONTRACT NO. 49 FEB. 23, 1921.
SCALE AS SHOWN

SHEET N[redacted]
DRAW[redacted]

2

APPENDIX C
CHECK LISTS

Che List
Visual Inspection
Phase 1

Name Dam Lock Raven **County** Balto. **State** Md. **ID #** Md-2

Type of Dam ______ **Hazard Category** 1

Date(s) Inspection 14 Dec '77 / 16 Dec '77 **Weather** Rain / Clear **Temperature** Upper 40's / Mid 30's

Pool Elevation at Time of Inspection 231.5 **M.S.L.** **Tailwater at Time of Inspection** ______ **M.S.L.**

Inspection Personnel:

Jim Snyder

John Tussing

Terry Clayton

Dick Royer

Bill Augustine

______ **Recorder**

OUTLET WORKS — N/A

ISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
RACKING AND SPALLING OF ONCRETE SURFACES IN UTLET CONDUIT	N/A	
INTAKE STRUCTURE	N/A	
OUTLET STRUCTURE	N/A	
OUTLET CHANNEL	N/A	
EMERGENCY GATE	N/A	

UNGATED SPILLWAY - INCORPORATED INTO DAM

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	SPILLWAY INCORPORATED INTO DAM	
APPROACH CHANNEL		
DISCHARGE CHANNEL		
BRIDGE AND PIERS		

INSTRUMENTATION N/A

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	N/A	
OBSERVATION WELLS	N/A	
WEIRS	N/A	
PIEZOMETERS	N/A	
OTHER	N/A	

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
ANY NOTICEABLE SEEPAGE	Notable Seepage was evident at two locations in the gallery.	considered minor
STRUCTURE TO ABUTMENT/EMBANKMENT. JUNCTIONS	No noticable movement	
DRAINS	Appear to be functional	periodic cleaning
WATER PASSAGES	Low flow pipes plugged	should be cleare
FOUNDATION	abutments inspected—no impairments noted Spillway slab was not inspected	dewater toe of spillway and inspec foundation.

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBERSVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	Spalling and deterioration of entire spillway was obvious Deterioration was down to reinforcing steel in some areas	resurfacing to be accomplished by City
STRUCTURAL CRACKING	No appreciable structural cracking noted	
VERTICAL AND HORIZONTAL ALIGNMENT	No displacements noted	
MONOLITH JOINTS	Satisfactory	
CONSTRUCTION JOINTS	Satisfactory	
STAFF GAGE OF RECORDER:		

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
ANY NOTICEABLE SEEPAGE	Minor Seepage @ Horiz construction joint about halfway up the right side of overflow section	Seepage considered minor.
STRUCTURE TO ABUTMENT/EMBANKMENT. JUNCTIONS	No movement noted.	
DRAINS	Drains located in horiz constr. Jts. near upstream face. Appear to be functioning. Some may be clogged w/ efflorescence. No foundation drains noted.	Clogged drains sho be cleaned.
WATER PASSAGES	Not accessable. By pass conduit plugged.	
FOUNDATION	Although downstream pool lowered – water still ponded at base of dam so toe/rock interface couldn't be inspected.	Downstream pool should be complete dewatered to allow inspection of toe.

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBERSVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	overflow section badly spalled (12 to 18 in) - Reinf (temp) exposed in some areas. Non-overflow Sect. - spalling of gunnite surfacing.	
STRUCTURAL CRACKING	None observed.	
VERTICAL AND HORIZONTAL ALIGNMENT	~~None Visible~~ No misalignment noted	Dam should be monumented for alignment.
MONOLITH JOINTS	No movement between monoliths noted	Lower gallery shou be inspected.
CONSTRUCTION JOINTS		
STAFF GAGE OF RECORDER:		

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
ANY NOTICEABLE SEEPAGE	Some seepage observed in upper gallery from construction & monolith joints. Was especially noticeable at one of The 3'x3' inspection wells about 2' above floor (location noted)	
STRUCTURE TO ABUTMENT/EMBANKMENT. JUNCTIONS	O.K. @ right abutment Seepage apparently entering (probably a g.w. source) from left abut. as observed in gallery. (static level) Both abutments appear to be adequately Keyed into rock	
DRAINS	Drains appears to be blocked as noted by water in 3'x3' wells. Should be connected and open to drain.	
WATER PASSAGES		
FOUNDATION	Some bubbles noted D/s after lower pool drained on 16 Dec. One area of possible concern was at end of apron in center of 2nd spillway monolith from right. Thin layer of ice had melted There and some light turbidity was observed.	Inspection during gunnite contract Possibly consider placement of dumbed rock @ D/s toe.

CONCR E/MASONRY DAMS

VISUAL EXAMINATION OF	OBERSVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	Concrete spalled @ crest and on D/S face Some deterioration by ice u/s @ water line.	Contact in the work by city of Baltimor to repair with gun Cracking does not a to have an effect on structural stability.
STRUCTURAL CRACKING	None observed	
VERTICAL AND HORIZONTAL ALIGNMENT	Not visually observed to be out of line	
MONOLITH JOINTS	Showed seepage as previously described	
CONSTRUCTION JOINTS	Showed seepage as previously described.	

STAFF GAGE OF RECORDER: Operable

UNGATED SPILLWA

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	Spalling in surface concrete	
APPROACH CHANNEL		
DISCHARGE CHANNEL	Some cracking of left wing wall	
BRIDGE AND PIERS		

INSTRUMENTATION

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	NONE	
OBSERVATION WELLS	WATER LEVELS measured and recorded.	Check as to why water levels are different; Are they blocked?
WEIRS	NONE	
PIEZOMETERS	NONE	
OTHER		

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Generally appear stable in vicinity of dam	
SEDIMENTATION	Silted up.	

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	much silt some debris, but not much	
SLOPES	o.k.	
APPROXIMATE NO. OF HOMES AND POPULATION		

Sheet 1

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SEE PAGE ON LEAKAGE		
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	N/A.	
DRAINS	Note functioning externally. Internal drainage through construction joints is collected in interior wells. Recommendation: Clean out drain wells.	
WATER PASSAGES	N/A	
FOUNDATION	Over flow section appears sound. Non-over flow section on weathered bedrock beneath upper left side could be seeping into joints (construction) and collected into interior wells. Recommendation - None	

Sheet 2

CONCRETE/MASONRY DAMS

ISUAL EXAMINATION OF	OBERSVATIONS	REMARKS OR RECOMMENDATIONS
URFACE CRACKS ONCRETE SURFACES	downstream face cracking and spalling. Recommendation: Resurface ~~at~~ areas of deterioration	
TRUCTURAL CRACKING	N/A	
ERTICAL AND HORIZONTAL LIGNMENT	N/A	
ONOLITH JOINTS	N/A	
NSTRUCTION JOINTS	N/A	

CHECK LIST
HYDROLOGIC AND HYDRAULIC DATA
ENGINEERING DATA

DRAINAGE AREA CHARACTERISTICS: considerable urbanization

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): 240.0 (72,700 AC-FT)

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): 240.0 (72,700 AC-FT)

ELEVATION MAXIMUM DESIGN POOL: 245.0 (assumed)

ELEVATION TOP DAM: 248.0

CREST:

a. Elevation 240.0
b. Type Concrete - ogee
c. Width
d. Length 288'
e. Location Spillover 144' either side of ℄ of dam
f. Number and Type of Gates NONE

OUTLET WORKS:

a. Type —
b. Location —
c. Entrance inverts —
d. Exit inverts —
e. Emergency draindown facilities 2 48"ϕ inoperative

HYDROMETEOROLOGICAL GAGES:
a. Type telemark
b. Location @ dam telemark to Liberty Lake
c. Records available @ Liberty Lake

MAXIMUM NON-DAMAGING DISCHARGE: unknown

APPENDIX D

ANALYSIS

BALTIMORE DISTRICT, CORPS OF ENGINEERS
PAGE ____________
SUBJECT Loch Raven Dam - Baltimore County, Maryland
COMPUTATIONS Phase I Investigation SHEET 1 OF 8 SHEETS
COMPUTED BY J.A. Tussing, Jr. CHECKED BY ____________ DATE 16 Feb 78

NARRATIVE:

The purpose of this analysis is to obtain a feel for the structural stability of Loch Raven Dam. Due to lack of specific information, assumptions concerning the foundation of the dam have been necessary. The assumed dimensions have been taken from drawings prepared by the Dept. of Public Improvements, City of Baltimore, dated Feb 23, 1921. These drawings were prepared for the raising of the dam from EL 188 to its present height. Most of the information contained on the drawings below that elevation is subject to question.

The analysis investigates the ability of the overflow section to resist overturning and sliding. No stress analysis is included as stresses are not normally critical for a gravity type concrete dam.

Two cases were considered in the analysis to obtain the loading. Case I is for the flow observed during Tropical Storm "Agnes" in 1972 - the maximum reported flow at the damsite. Case II is for one-half the "Probable Maximum Flood" (PMF).

RESULTS:

			Safety Factors		
	Pool El	Tailwater El	Overturning	Sliding @ Base	Sliding @ Rock Plane
Case I	248.5'	171.2'	1.13	2.26	-
Case II	255.0'	186.0'	1.02	1.82	1.78

CONCLUSIONS:

The factors of safety resulting from the analysis are considered to be low for a dam in the "high hazard" (as measure of potential downstream damage resulting from failure of the dam) category. Those for sliding are below the factors of safety recommended by the "Guidelines for Safety Inspection of Dams". The factors of safety against overturning are considered to be close enough to 1.0 that unknowns used in the analysis preclude a definite assessment of the dam's ability to adequately resist overturning. For example, one large unknown is the magnitude of uplift on the structure. Since there was no indication of a grout curtain or foundation drains, uplift is considered to be 100% but could be less depending upon the jointing in the foundation rock. Of the two failure modes investigated, overturning seems to be

NADB FORM 1232, 18 MAR 74

the more critical. Most authorities would agree that the resultant should fall within the middle third (or middle half on rock) of the base. The dam was probably designed for less than the flows used in this analysis. This conclusion is reached by the fact that the resultant falls outside generally acceptable limits and the fact that the present spillway is inadequate for flows exceeding that of Agnes.

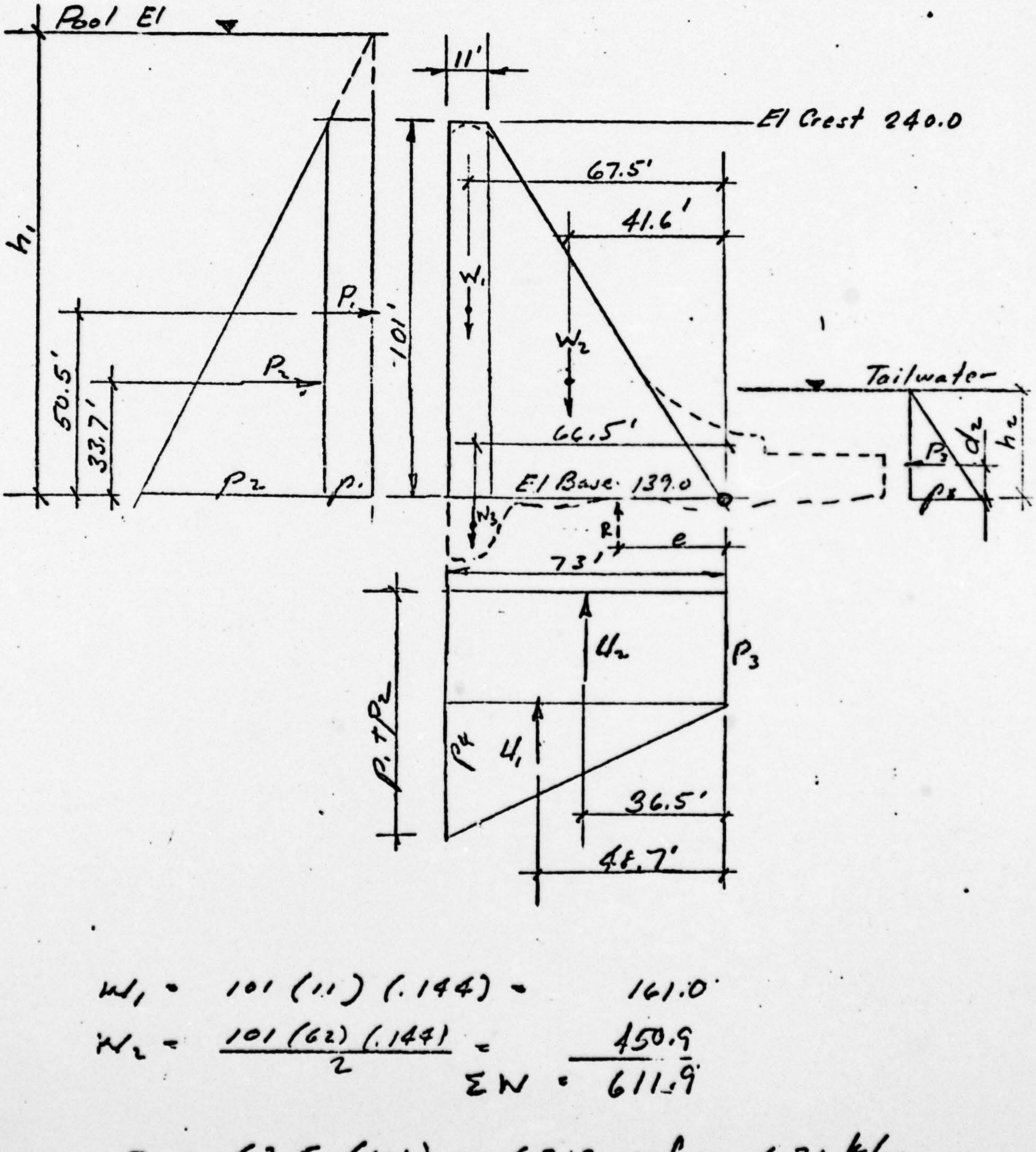
On the basis of this analysis, it is recommended that the stability of the dam be investigated further.

BALTIMORE DISTRICT, CORPS OF ENGINEERS PAGE

SUBJECT Loch Raven Dam ~ Baltimore County, Md.

COMPUTATIONS Stability Analysis (Geometry) SHEET 3 OF 8 SHEETS

COMPUTED BY H. Russing Jr. CHECKED BY J.B. DATE 8 Feb 78



$$W_1 = 101\,(11)\,(.144) = 161.0$$

$$W_2 = \frac{101\,(62)\,(.144)}{2} = 450.9$$

$$\Sigma W = 611.9$$

$$p_2 = 62.5\,(101) = 6313 \text{ psf} = 6.31\ ^{k}/_{\square'}$$

BALTIMORE DISTRICT, CORPS OF ENGINEERS PAGE

SUBJECT Loch Raven Dam ~ Stability Analysis

COMPUTATIONS Case I : Agnes Flow (Max of Record) SHEET 4 OF 8 SHEETS

COMPUTED BY HHussing Jr CHECKED BY JH DATE 8 Feb 78

- Flow over spillway at 8.5 ft. above crest.

$h_1 = 101 + 8.5 = 109.5'$

$p_1 = 62.5\ (8.5) = 531\text{ psf} = .53^{k}/\square'$

Assume tailwater @ El 171.2 (Normal downstream pool)

$$\underline{-139.0}$$

$h_2 = 32.2 \quad d_2 = \frac{32.2}{3} = 10.7''$

$p_3 = 62.5(32.2) = 2012\text{ psf} = 2.01^{k}/\square'$

$p_1 + p_2 = .53 + 6.31 = 6.84^{k}/\square'$

$p_4 = 6.84 - 2.01 = 4.83^{k}/\square'$

		H	V	d	M
P_1	$= .53\ (101) =$	$53.5^{k} \rightarrow$		$\times\ 50.5'$	$= 2703^{k'}$ ↺
P_2	$= \frac{6.32\ (101)}{2} =$	$319.2^{k} \rightarrow$		$\times\ 33.7'$	$= 10755$ ↺
P_3	$= \frac{2.02\ (32.2)}{2} =$	$32.5^{k} \leftarrow$		$\times\ 10.7$	$= 348$ ↻
U_1	$\frac{4.83\ (73)}{2} =$		$176.3^{k} \uparrow$	$\times\ 48.7$	$= 8585$ ↺
U_2	$2.02\ (73) =$		$147.5^{k} \uparrow$	$\times\ 36.5$	$= 5382$ ↺
W_1			$161.0 \downarrow$	$\times\ 67.5$	$= -10868$ ↻
W_2			$450.9 \downarrow$	$\times\ 41.6$	$= -18757$ ↻
		$\Sigma H = 340.2^{k} \rightarrow$	$\Sigma V = 288.1^{k} \downarrow$		$M_R = 29973^{k'}$ ↻
					$M_{OT} = 27425$ ↺
					$\Sigma M = 2548$ ↻

Factor of Safety against:

a. <u>Overturning</u> $= \frac{29{,}973}{27{,}425} = \underline{\underline{1.09}}$ $\quad e = \frac{2548}{288.1} = 8.84'$

<u>Resultant falls outside kern!</u> $\quad 73/3 = 24.33'$

b. <u>Sliding</u> (along base) $\quad$ Assume: $\phi = 35°$

$R = \Sigma V \tan\phi + sA \qquad s = 24\ ^{\#}/\square''$

$R = 288\ (\tan 35°) + .024(144)(73) \qquad s = .024\ ^{k}/\square''$

$R = 201.7 + 252.3$

$R = 454 \leftarrow \qquad SF = \frac{R}{\Sigma H} = \frac{454}{340.2} = 1.33 < 3.0$

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SUBJECT Loch Raven Dam. - Stability Analysis

COMPUTATIONS Case II - 1/2 Probable Max Flood **SHEET** 5 **OF** 8 **SHEETS**

COMPUTED BY Arussing Jr. **CHECKED BY** JP. **DATE** 9 Feb 78

Water surface El. @ spillway crest = 255'

Tail water El. = 186'

$h_1 = 255 - 139 = 116.0'$

$p_1 = 62.5\,(\overset{15}{\cancel{116}}-101) = 938\text{ psf} = .94\ ^{k}/_{\square'}$

$p_1 + p_2 = 6.31 + .94 = 7.25\ ^{k}/_{\square'}$

$h_2 = 186 - 139 = 47' \quad d_2 = \frac{47}{3} = 15.67'$

$p_3 = 62.5\,(47) = 2937\text{ psf} = 2.94\ ^{k}/_{\square'}$

$p_4 = 7.25 - 2.94 = 4.31\ ^{k}/_{\square'}$

		H	V	d	M
P_1 =	$.94\,(101)$ =	94.9^k →		* 50.5' =	$4,792^{k'}$ ↷
P_2 =	$\frac{6.31\,(101)}{2}$ =	319.2^k →		33.7	10,757 ↷
P_3 =	$\frac{2.94\,(47)}{2}$ =	69.1^k ←		15.7	1,085 ↶
U_1 =	$\frac{4.31\,(73)}{2}$ =		157.3^k ↑	48.7	7,660 ↷
U_2 =	$2.94\,(73)$ =		214.6 ↑	36.5	7,833 ↷
W_1			161.0 ↓	67.5	10,868 ↶
W_2			450.9 ↓	41.6	18,757 ↶
		$\Sigma H = 345^k$ →	$\Sigma V = 240^k$ ↓		$M_R = 30,710$ ↶ $M_{OT} = 31,042$ ↷ $\Sigma M = 332^{k'}$ ↷

Factor of Safety against:

a. Overturning $= \frac{30,710}{31,042} = \underline{\underline{.99 < 1.0}}$

b. Sliding (along base)

$R = \Sigma V \tan\phi + sA$

$R = 240(\tan 35°) + .024(144)(73)$

$R = 168.05 + 252.29 = 412.3$

$S.F. = \frac{R}{\Sigma H} = \frac{412.3}{345} = 1.19 < 3.0$

Conc Key would have to fail.

$R_{key} = 60^{\#}/_{\square''}(25^{\square'})(144)$

$R = 216^k$

$S.F. = \frac{628}{345} = \underline{\underline{1.82}}$

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SUBJECT Loch Raven Dam ~ Stability Analysis

COMPUTATIONS Cases I & II **SHEET** 6 **OF** 8 **SHEETS**

COMPUTED BY Hessing Jr. **CHECKED BY** MFL **DATE** 16 Feb 78

Account for conc key (W_3)

Case II

$W_3 = 13 \times 13 \times (\overset{81.5}{144-62.5}) = 13773.5 = 13.7^k$

$d_3 = 73 - 6.5 = 66.5$

Use submerged wt. since uplift has not been increased

$M_3 = 13.7(66.5) = 911^{k'}$

$M_R = 30,710 + 911 = 31621^{k'}$

$S.F._{(OT)} = \frac{31,621}{31042} = \underline{\underline{1.02 > 1.0}}$

Case I

Overturning

$M_R = 29,973 + 911 = 30,884^{k'}$

$SF_{(OT)} = \frac{30,884}{27,425} = \underline{1.13}$

$\begin{array}{r} -27,425 \ M_{OT} \\ \hline 3459^{k'} = \Sigma M \end{array}$

$\begin{array}{r} 288.1 \\ + \ 13.7 \\ \hline \Sigma V = 301.8 \end{array}$

$e = \frac{\Sigma M}{\Sigma V} = \frac{3459}{301.8} = 11.46'$

Resultant still outside middle third

Sliding @ Base

Shear key would have to fail for sliding to occur. Key provides an additional 216^k of resistance

$R = 454 + 216 = 770^k$

$SF = \frac{R}{\Sigma H} = \frac{770}{340.2} = 2.26 < 3.0$

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SUBJECT Loch Raven Dam - Stability Analysis

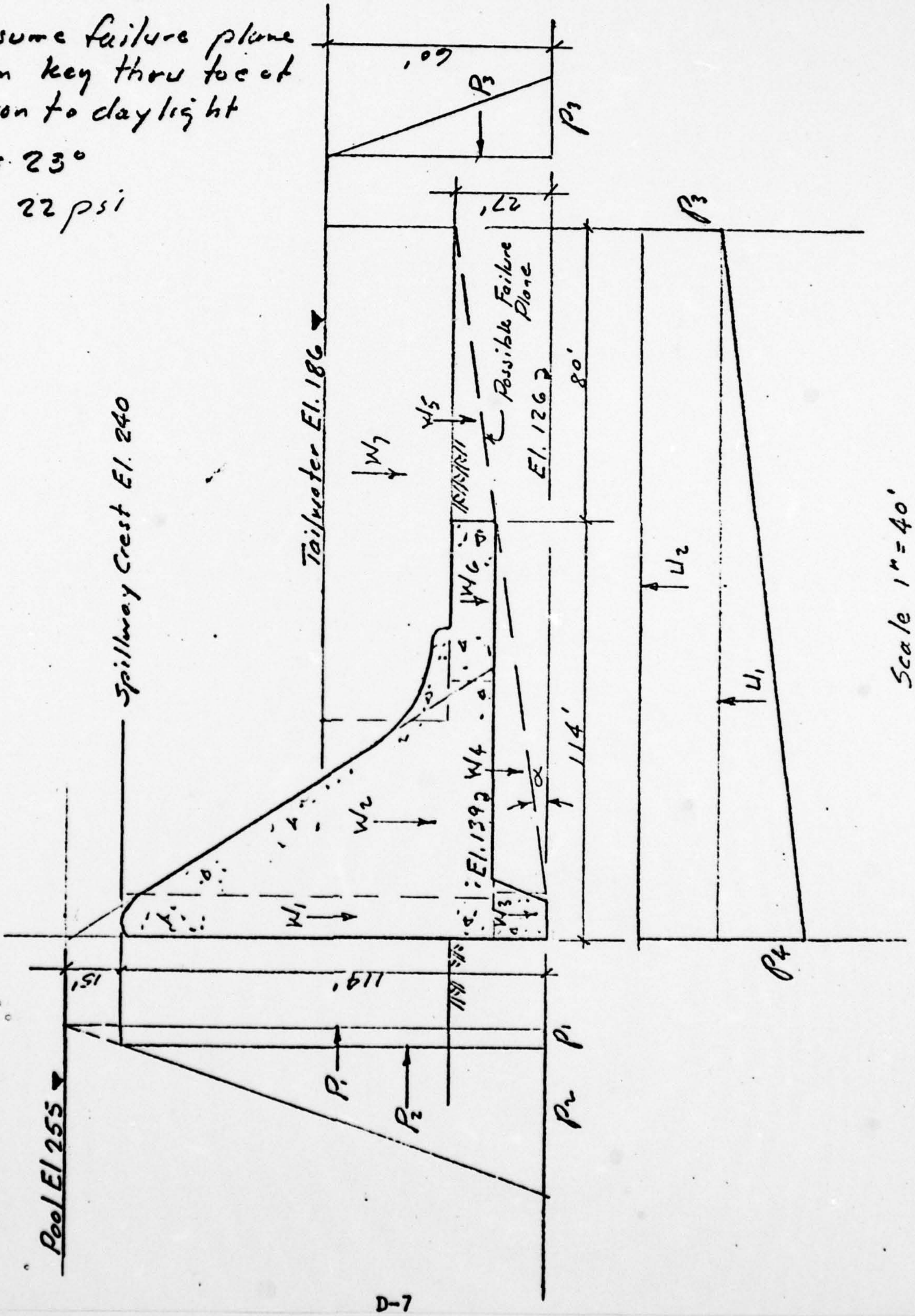
COMPUTATIONS Case II (1/2 PMF) - Sliding Stability SHEET 7 OF 8 SHEETS

COMPUTED BY H Trussing Jr. CHECKED BY MFL DATE 16 Feb 78

Assume failure plane from key thru toe of apron to daylight

$\phi = 23°$

$s = 22$ psi



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SUBJECT Loch Raven Dam - Stability Analysis

COMPUTATIONS Case II (1/2 PMF) - Sliding Stability **SHEET** 8 **OF** 8 **SHEETS**

COMPUTED BY JA Russing Jr **CHECKED BY** MFL **DATE** 16 Feb 78

$W_1 = 161.0^k \qquad 161.0^k$

$W_2 = 450.9^k \qquad 450.9$

$W_3 = 13(15)(.144) = 28.1'$

$W_4 = 15(101)(.5)(.160) = 121.2$

$W_5 = 12(80)(.5)(.160) = 76.8$

$W_6 = 12(44)(.144) = 76.0$

$W_7 = 36(135)(.0625) = \underline{303.8}$

1217.8^k

$U_1 = 4.313(194)(.5) = 418.36$

$U_2 = 3.750(194) = \underline{727.50}$

1146.9

$\Sigma V = 1217.8 - 1146.9 = 70.9^k \downarrow$

$p_1 = .0625(15) = .938^{k/'}$

$p_2 = .0625(114) = \underline{+7.125}$

$p_1 + p_2 = 8.063$

$p_3 = .0625(60) = \underline{-3.750}$

$p_4 = (p_1 + p_2) - p_3 = 4.313$

$P_1 = .938(114) = 106.9$

$P_2 = 7.125(114)(.5) = \underline{406.1}$

513.0

$P_3 = 3.75(60)(.5) = \underline{112.5}$

$\Sigma H = \underline{400.5}$

$\alpha = Tan^{-1} \frac{27}{181} = 8.48°$ say $8.5°$

$\phi = 23°, \quad s = 22^{\#/\square''}$

$A = 13 + \frac{181}{Cos\, 8.5} = 13 + 183$

$A = 196^{\square'}$

$$R = \Sigma V\, Tan(\phi + \alpha) + \frac{s A}{Cos\alpha\,(1 - Tan\phi\, Tan\alpha)}$$

$$R = 70.9\, Tan(23° + 8.5°) + \frac{.022\,(144)\,(196)}{Cos\, 8.5°\,[1 - (Tan\, 22°)(Tan\, 8.5°)]}$$

$$R = 70.9\, Tan\, 31.5° + \frac{.022\,(144)\,(196)}{Cos\, 8.5°\,(\underset{.94}{1 - .06})}$$

$$R = 43.45 + 667.9$$

$$R = 711.3^k$$

$$SF = \frac{R}{\Sigma H} = \frac{711.3}{400.5} = \underline{\underline{1.78}} < 3.0$$

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