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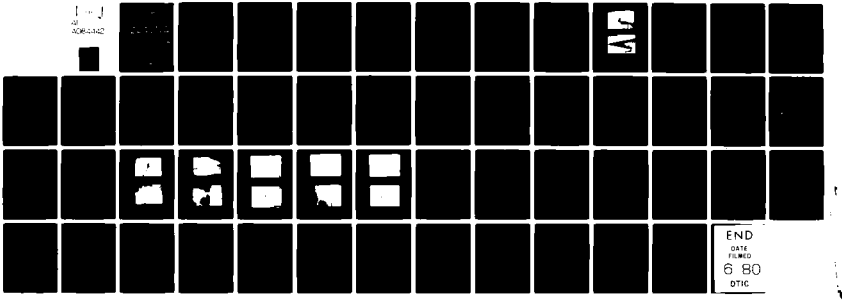

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RAPPAHANNOCK RIVER BASIN

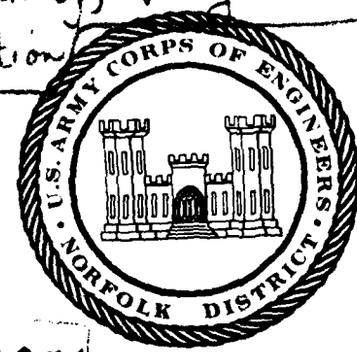
LEVEL II

Name Of Dam: EMBRY DAM
Location: STAFFORD COUNTY. VA
Inventory Number: VA 17905

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM.

Embry Dam (VA-17905). Rappahannock River Basin. Stafford County, Virginia. Phase I Inspection Report.



Boris O. Taran

Final rept.,

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PREPARED BY
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803 FRONT STREET
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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

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4. TITLE *(and Subtitle)*: Phase I Inspection Report, National Dam Safety Program, EMBRY DAM, STAFFORD COUNTY, VA	5. TYPE OF REPORT & PERIOD COVERED: Final
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7. AUTHOR(s): Boris O. Taran, U.S. Army Engineering District, Norfolk, 803 Front Street, Norfolk, VA 23510	8. CONTRACT OR GRANT NUMBER(s)
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20. Abstract

Pursuant to Public Law 92-367. Phase I Inspection Reports are prepared under guidance contained in the recommended guidelines for safety inspection of dams, published by the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general conditions of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

Based upon the field conditions at the time of the field inspection and all available engineering data, the Phase I report addresses the hydraulic, hydrologic, geologic, geotechnic, and structural aspects of the dam. The engineering techniques employed give a reasonably accurate assessment of the conditions of the dam. It should be realized that certain engineering aspects cannot be fully analyzed during a Phase I inspection. Assessment and remedial measures in the report include the requirements of additional indepth study when necessary.

Phase I reports include project information of the dam and appurtenances, all existing engineering data, operational procedures, hydraulic/hydrologic data of the watershed, dam stability, visual inspection report and an assessment including required remedial measures.

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of the Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established guidelines, the spillway design flood is based on the estimated "Probable Maximum Flood" for the region (flood discharges that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the design flood should not be interpreted as necessarily posing a highly inadequate condition. The design flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

RAPPAHANNOCK RIVER BASIN

Name of Dam: Embry Dam
Location: Stafford County
Inventory No.: 17905

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Prepared By:
Norfolk District, Corps of Engineers
803 Front Street
Norfolk, Virginia 23510

TABLE OF CONTENTS

PHASE I REPORT
NATIONAL DAM SAFETY PROGRAM

BRIEF ASSESSMENT

Name of Dam:	Embry Dam
State:	Virginia
County:	Stafford
DSGS Quad Sheet:	Fredericksburg
Stream:	Rappahannock River
Date of Inspection:	January 10, 1980

Embry Dam is a hollow slab and buttress concrete structure approximately 1070 feet long and 34.8 feet high. The dam is owned by the City of Fredericksburg, Virginia, and is used to divert water to Fredericksburg Water Plant. The dam is classified as an intermediate size with a significant hazard classification. The concrete spillway is ungated and comprises 700 feet of the dam. Six concrete gates, located on the right side of the dam, were designed to allow water into the VEPCO Canal leading to the water plant; however, only one gate can presently be operated.

Based on criteria established by the Department of the Army, Office of the Chief of Engineers (OCE), the Spillway Design Flood (SDF) appropriate to this dam is one half of the Probable Maximum Flood (PMF). The spillway will pass 20 percent of the PMF without overtopping the dam. The spillway is adjudged inadequate. The term "inadequate" is a classification used by the Corps of Engineers which indicates the dam will be overtopped by the SDF. In this case, it is not related to safety of the structure.

The visual inspection revealed that many of the slabs spanning buttresses are deteriorated along the apparent construction joint at approximately elevation 41. The dam is leaking at most of these locations. Leaks are also occurring at several slab/buttress intersections.

The inspection gallery walkway was dangerously deteriorated and, for this reason, the portion of the dam between buttresses 21 and 43 was not inspected.

It is recommended that the owner, through his professional engineers, take the following actions.

a. Analyze structural slabs to determine their ability to withstand all loading conditions up to and including 1/2 PMF.

b. Patch spalled concrete and seal cracks in slabs or otherwise reinforce slabs as indicated by further analysis. Remove silt if required.

c. Monitor seepage on the left abutment.

d. Examine upstream and downstream faces of buttresses. Repair buttresses as indicated by inspection.

e. Determine limits of siltation in front of the dam and outlet gates. Remove debris and siltation found in the vicinity of outlet gates.

f. Repair or replace the inspection gallery walkway.

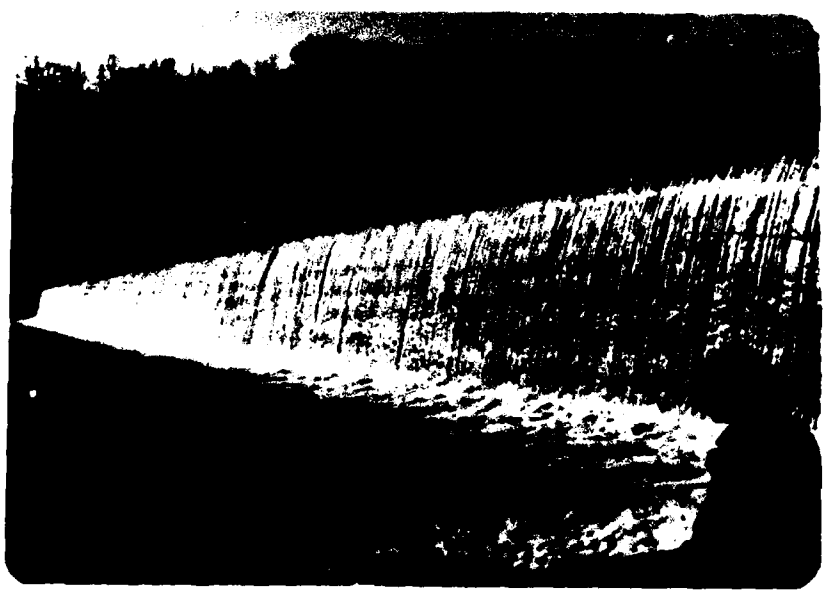
g. Install a handrail on the right abutment access walkway on top of the canal wall.

Submitted By:
ORIGINAL SIGNED BY
JOHN E. KENNEDY
for JAMES A. WALSH, P. E.
Chief, Design Branch

Approved:
Original signed by:
Douglas L. Haller
DOUGLAS L. HALLER
Colonel Corps of Engineers
District Engineer

Date: MAY 9 1980

Recommended By
Original signed by
JACK G. STARR
JACK G. STARR
Chief, Engineering Division



OVERALL VIEWS OF EMBRY DAM

JAN. 10TH. 1980

SECTION 1

PROJECT INFORMATION

1.1 General:

1.1.1 Authority: Public Law 92-367, 8 August 1972 authorized the Secretary of the Army through the Corps of Engineers to initiate a national program of safety inspections of dams in the United States. The Norfolk District has been assigned the responsibility of supervising the inspection of dams in the Commonwealth of Virginia.

1.1.2 Purpose of Inspection: The purpose is to conduct a Phase I inspection according to the Recommended Guidelines for Safety Inspection of Dams (Appendix V, Reference 1). The main responsibility is to expeditiously identify those dams which may be a potential hazard to human life or property.

1.2 Project Description:

1.2.1 Dam and Appurtenances: Embry Dam is a hollow flat slab and buttress concrete structure approximately 1070 feet long and 34.8 feet high. The crest of the dam, at elevation 64.8 feet msl, serves as a wing wall on the left side of the dam and an operating deck on the right side.

The concrete spillway (ungated) is 770 feet long with a crest elevation of approximately 52.0.

A fish ladder, with an opening of 3 square feet, is located between the spillway and the canal gates.

A 24-inch gate valve, located at the base of the spillway adjoining the canal intake structure, is located at elevation 37.6. The gate can be used to partially drain the canal.

1.2.2 Location: Embry Dam is located in Stafford County. The dam site is just upstream of Fredericksburg, Virginia.

1.2.3 Size Classification: The dam is classified as an intermediate size dam because of its maximum storage of 2400 acre feet.

1.2.4 Hazard Classification: The dam is located upstream of a few homes in Fredericksburg. Water diverted by the dam to the Fredericksburg water plant is the sole water supply for approximately 60,000 people.

Therefore, a significant hazard classification is given for this structure according to guidelines contained in Section 2.1.2 of Reference 1, Appendix V. The hazard classification used to categorize dams is a function of location only and has nothing to do with their stability or probability of failure.

1.2.5 Ownership: City of Fredericksburg, Virginia

1.2.6 Purpose: Water Supply

1.2.7 Design and Construction History: The designer is unknown. The structure was completed in 1925 and expanded in 1938 to its present size.

1.2.8 Normal Operational Procedures: Water passes automatically over the spillway. A gate above the VEPCO Canal is operated periodically to supply water to the water plant in Fredericksburg.

1.3 Pertinent Data:

1.3.1 Drainage Area: The dam controls a drainage area of about 1605 square miles.

1.3.2 Discharge at Dam Site:

Maximum flood - approximately 140,000 cfs during the 1942 flood.
Spillway pool level at top of dam - approximately 140,000 cfs

1.3.3 Dam and Reservoir Data: Pertinent data on the dam and reservoir are shown in the following table:

Table 1.1 DAM AND RESERVOIR DATA

Item	Elevation feet m.s.l.	Reservoir Capacity			
		Area, acres	Acre-feet	Watershed, inches	Length, miles
Top of dam	64.8	290	2400	.028	2.75
Spillway crest	52.0	31.2	344	.004	1.20
Streambed at downstream toe of dam	30.0±	-	-	-	-

SECTION 2

ENGINEERING DATA

2.1 Design: No original design data are available.

The dam has been inspected several times during water supply and VEPCO studies. Available information is listed below:

a. Drawing dated October 1965. Preliminary Drawing, Additions and Improvements To Existing VEPCO Dam (see Plate 2, Appendix 1 for details of existing dam). This drawing was prepared by Russel & Axon for a VEPCO expansion study.

b. Results of visual inspections performed for the Rappahannock Service Authority Regional Water Supply Study Vol. 1, Nov. 1978, are included in Appendix IV.

2.2 Construction Records: No construction records are available.

2.3 Evaluation: The available drawing prepared by Russell and Axon is adequate to perform general stability/overturning analysis, however, information is not detailed enough to properly assess cracking in the slabs. See paragraph 7.2 Recommended Remedial Measures for additional engineering study recommended.

SECTION 3

VISUAL INSPECTION

3.1 Findings:

3.1.1 General: The results of the 10 January 1980 inspection are recorded in Appendix III. At the time of the inspection, the pool elevation was 52.5 which is 0.5 feet above the spillway crest. The ground was snow covered and the weather was fair and cold. Embry dam has been inspected on several previous occasions. VEPCO studied an increase in the spillway height in 1965. Several other inspections were performed in conjunction with water supply studies. The results of only one inspection are available. This visual inspection, an excerpt from the Rappahannock Service Authority Regional Water Supply Study Vol. 1, November 1978, prepared by Russel and Axon, is reproduced as Appendix IV.

3.1.2 Dam and Abutments: The concrete inspection walkway was in extremely poor condition. Between buttresses 43 and 44 the walkway had collapsed due to deterioration of the concrete. Due to the dangerously deteriorated walkway, the portion of the dam between buttresses 21 and 43 was not inspected during this visual inspection. The north wall at the entrance to the inspection walkway is considered to be buttress zero.

(a) Buttresses

The buttresses were in generally good condition considering the age of the structure. A few significant exceptions were noted. Buttress No. 1 is cracked at the top with considerable leakage of water occurring at this location (see Photo No. 5). Surface spalling, due to exposure to water and freeze thaw cycles, is also occurring at this location.

Buttress No. 53 is cracked along the construction joint at approximately elevation 44. Concrete is spalled at the crack extending from the slab approximatley 6 feet downstream along the face of the buttress. No sign of movement along this crack was observed.

The visual inspection by Russel and Axon (see Appendix IV) indicated large spalled areas on upstream and downstream faces at buttresses leaving reinforcing exposed. Submerged upstream and downstream faces of the buttresses were not inspected by Corps of Engineer personnel.

(b) Slabs. Slabs were in fair to poor condition. Most of the slabs inspected were cracked at the mid-height construction/cold joint

and many were leaking and severely spalled with exposed reinforcing steel at the joint. (See Photo No. 7). In several locations, slab reinforcing bars were exposed for nearly the entire span length along this construction joint. Many cracks were stained with extensive orange iron colored stains. These stains may represent soil material, weathered Petersburg granite, filtering through the slab or chemicals leached from the soil. As noted in section 3.1.4 below, Petersburg granite in its most weathered form is a red iron stained clayey sand. Most slabs are calcite stained from minor seepage. No major calcite deposits were observed.

A 10-foot section of the crest slab has spalled to a depth of approximately 3 inches. This condition occurs adjacent to buttress No. 1 and extends toward the north end wall (See Photo No. 4). Discontinuity in the water flowing over the crest of the dam at buttresses Nos. 12 and 19 indicates that some deterioration of the crest slab has also occurred at these locations.

A seep was located approximately 10 feet north of the north end wall opposite the entrance to the inspection walkway. Seepage was estimated less than 1 GPM. The origin of seepage could not be determined; it may have been due to runoff.

3.1.3 Appurtenant Structures: Concrete at the intake and outlet structure is in good condition. Gates were submerged at the time of inspection and, therefore, were not inspected. The owner's representatives indicated that only one gate can be operated.

Since the walkway access to the dam along the north wall of the canal was snow covered, it was not inspected. The handrail along this access was missing.

3.1.4 Geologic Setting of the Dam Site: The dam site is located within the Piedmont Physiographic Province of Virginia. The fall line separating the hard igneous and metamorphic rocks of the Piedmont plateau and the sediments of the coastal plain is located less than two miles downstream. The fall line denotes the limit of the coastal plain sediments and generally it is characterized by a steep drop in elevation, falls and rapids. Basement rock that outcrops in the study area consists of granite and granite gneiss of Paleozoic Age. Geologic literature notes that the basement rock, Petersburg granite, may be present in any degree of weathering. Its most weathered form is a red, iron-stained, clayey, medium-grained sand. Overlying the basement rocks are sandy and clayey soils and alluvial soils in the stream valleys.

No faults were observed in the field during the dam inspection and geologic maps of the area do not show the presence of any active faults in the immediately vicinity.

3.2 Evaluation: Based on the visual inspection, the dam requires immediate repairs to prevent further deterioration. Spalled concrete at construction joints in slabs will lead to deterioration of exposed reinforcing. This deterioration could lead to failure of slabs. The hazard from flooding is not severe since the likelyhood that more than one slab would fail simultaneously is extremely remote. Nevertheless, an emergency would develop since the water supply for approximately 60,000 people depends on the integrity of Embry Dam.

Siltation in front of the gates to the canal also poses a threat. Debris could be wedged in the operating gate during gate opening which would prevent closing this gate. This could lead to minor localized flooding along the canal.

Seepage occurring near the north end wall is minimal and poses no threat to the structure at this time.

SECTION 4

OPERATIONAL PROCEDURES

4.1 Procedures: The Rappahannock River automatically flows over Embry Dam. The structure is a run-of-the-river dam. At present, one gate on the right side of the dam is opened about four inches to supply water to the VEPCO Canal that supplies the City of Fredericksburg water system. A fish ladder with a 3 foot by 3 foot opening allows some water to pass downstream. There is no other outlet to pass water downstream and no means of dewatering the reservoir.

4.2 Maintenance: The City of Fredericksburg is responsible for maintaining the Embry Dam. Personnel visit the site periodically and maintenance is performed as needed.

4.3 Warning System: At the present time, there is no warning system or evacuation plan in operation.

4.4 Evaluation: The dam does not require an elaborate operational and maintenance procedure. However, an annual maintenance and inspection program should be initiated to help detect and control problems that may occur. It is apparent that past maintenance has been minimal. A warning system should be developed and posted so that responsible personnel will know what to do in an emergency.

SECTION 5

HYDRAULIC/HYDROLOGIC DESIGN

5.1 Design: None was available.

5.2 Hydrologic Records: None were available.

5.3 Flood Experience: The maximum flood occurred in 1942 when an estimated peak of 140,000 cfs was recorded at a USGS gage about 2 miles upstream of the dam. It is estimated that the dam was overtopped for a short time during the peak flow.

5.4 Flood Potential: The performance of the dam during the 100 Year Flood, 1/2 PMF, and PMF were evaluated. The 100 Year Flood was provided by the Flood Plains Section of the Army Corps of Engineers. The PMF was provided by the Weather Bureau.

5.5 Reservoir Regulation: Pertinent dam and reservoir data are shown in Table 1.1.

Water passes automatically over the spillway except in extreme low flow conditions. Periodically one gate above the VEPCO Canal is opened 4 inches to supply water to the Fredericksburg water system.

The storage curve was developed by use of U. S. Geological Survey Quadrangle Maps. Rating curves were developed for both spillway and nonoverflow sections of the dam.

5.6 Overtopping Potential: The probable rise in the reservoir and other pertinent information on reservoir performance is shown in the following table:

Table 5.1 RESERVOIR PERFORMANCE

Item	Normal	Agnes	100 Year Year (C)	1942	1/2 PMF	PMF (d)
Maximum Elevation feet msl	53	61.0(a)	63.9	66.0(a)	72	88
Maximum Discharge cfs	1600	107,000	127,000	140,000	278,000	556,000
Tailwater ft msl	33	49.9(a)	52	54(b)	65(b)	82

(a) High water marks
(b) Developed from backwater computation
(c) The 100 Year Flood has one chance in 100 of being exceeded in any given year.
(d) The PMF is an estimate of flood discharges that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

5.7 Reservoir Emptying Potential: There is no outlet to permit dewatering of the reservoir.

5.8 Evaluation: Based on the size (intermediate) and hazard classification (significant), the recommended Spillway Design Flood (SDF) is 1/2 PMF to the PMF. Because of the risk involved in this project, the SDF is the 1/2 PMF. The spillway will pass 20 percent of the PMF before the dam is overtopped. The SDF will overtop the dam by 7.2 feet.

Conclusions pertain to present day conditions. The effect of future development on the hydrology has not been considered.

SECTION 6

DAM STABILITY

6.1 Stability Analysis: Due to the rapid rise in tailwater during high river flow at Embry dam, the most critical conditions for overturning stability will occur during normal or near normal conditions. A preliminary check of dam stability was performed. Conservative assumptions were made for this analysis. Silt was assumed to be level with the spillway crest; low allowable stresses for concrete bearing were used; conservative residual sliding coefficients were developed from test results performed on Petersburg granite for a project in the Richmond area. These calculations, summarized in Table 6.1, indicate that the dam is stable. Even though the factor of safety for sliding failure is low, it is acceptable since it is based on conservative assumptions. This analysis was based on the "Approximate Section Thru Present Dam" indicated on the drawing prepared by Russell, Axon and Associates (Plate 2) and the visual inspections of 10 January 1980. Buttresses were assumed to be keyed into rock as indicated by the drawing.

No original calculations are available.

6.2 Foundation: Numerous bedrock outcrops were exposed in the downstream river channel, upstream river bluffs, and abutments. Petersburg granite is exposed in the left and right abutments and throughout much of the river bed. The rock is slightly to non weathered, light gray fine grained granite. Observed joints have a steep dip and a northwest trend.

Alluvium deposits consisting of material ranging from clay to boulders were overlying the bedrock on the flood plain.

6.3 Evaluation: Since construction reports are not available for review, a proper determination of the foundation conditions is not possible. Plate 2, however, shows that the dam is founded on granite.

No settlement was noted along the dam alignment during the visual inspection. Observed joint alignments within the bedrock were not oriented to facilitate potential sliding. Joints at the site appear to be continuous, closed, slightly to nonweathered, without infilling materials. Very little seepage was noted during the inspection. The potential for seepage does exist because of the upstream-downstream strike of the observed joints and the possibility that the dam overlies some weathered bedrock.

STABILITY ANALYSIS

ANALYSIS DONE ON X FULL SECTION ___ PARTIAL SECTION
LOCATION OF SECTION TYPICAL SECTION THROUGH BUTTRESSES
ANALYSIS PREPARED BY NORFOLK DISTRICT CORPS OF ENGINEERS

LOADING CASE	ELEV. HEAD WATER	ELEV. TAIL WATER	ΣV	ΣH	$\frac{\Sigma H}{\Sigma V}$	LOCATION RESULTANT FROM TOE	% BASE IN COMPRESSION	FACTOR SAFETY SLIDING	FOUNDATION PRESSURE	
									TOE	HEEL
1	52.0	33.0	551^K	395^K	0.72	15.5	100%	2.0	112^{PSI}	50^{PSI}
2	56.0	41.0	595	404	0.68	14.4	100	2.1	136	39

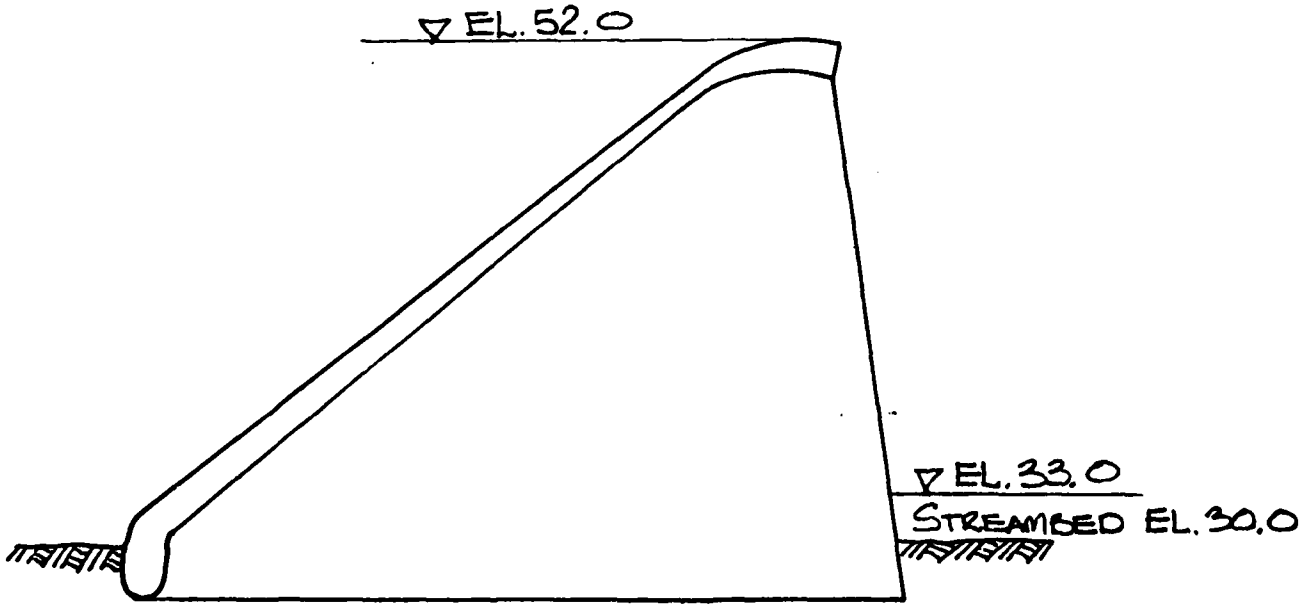


TABLE 6.1

Our Phase 1 visual inspection indicates that Embry dam is stable with regard to overturning and sliding failure based on the conditions observed 10 January 1980.

Questions regarding cracking in the slabs and other conditions noted in the structure cannot be resolved without further study. Additional analysis and investigations are beyond the scope of this report. See Section 7, Assessment/Remedial Measures.

SECTION 7

ASSESSMENT/REMEDIAL MEASURES

7.1 Dam Assessment:

Corps guidelines indicate the appropriate Spillway Design Flood (SDF) for an intermediate size and significant hazard dam is 1/2 PMF. The spillway will pass 20 percent of the PMF and 40 percent of the SDF without overtopping the dam. The SDF will overtop the dam by 7.2 feet. The spillway is adjudged as inadequate.

Cracks, spalling, and concrete deterioration in the slabs are serious problems that must be corrected soon. This condition seems to be the result of poor construction practice since cracking is concentrated in the vicinity of construction joints in the slab.

Siltation in front of the canal gates is excessive and could jam the only remaining gate which can be operated. The owner's representatives stated that the spillway section of the dam was silted nearly to the spillway crest. The State Water Control Board took soundings several years ago, approximately 75' upstream of the dam near the dam centerline. These informal soundings showed silt levels approximately ten to fifteen feet below the spillway crest.

7.2 Recommended Remedial Measures:

7.2.1 The owner, through his professional engineers, should immediately investigate the ability of the existing slab to carry imposed loads up to and including the 1/2 PMF. This can be accomplished by measuring the size and spacing of exposed reinforcing steel. Calculations should be performed using a reduced cross sectional area of steel where appropriate. To evaluate concrete strength, cores should be taken and analyzed for strength and durability. Soundings should be taken to determine the extent of siltation on the dam. Silt loads should be included during analysis of slabs. Portions of the dam not inspected between buttresses 21 and 43, should be inspected. Additional study or repair indicated by this inspection should be accomplished as appropriate.

7.2.2 It may be worthwhile to determine whether orange stains on slabs and buttresses are due to rusting of reinforcing or soil deposits at the dam site. If the staining is due to native soils, the dam may be in better condition than previously thought.

7.2.3 Spalled concrete in slabs should be patched. Severe cracks should be sealed. It is recommended that the owner's Professional Engineer contact a factory representative of a company experienced in epoxy injection type repair of cracks in concrete hydraulic structures to examine possible methods for repairing the slabs.

7.2.4 Upstream and downstream faces of buttresses should be examined by the owner's Professional Engineers during periods of low flow or by divers. Buttresses should be checked for spalled concrete noted in the Nov. 1978 inspection by Russel and Axon (Appendix IV). A qualified geologist should inspect rock foundations during low flow. If the buttresses or foundations are deteriorated, a new stability analysis should be performed by the owner's Professional Engineer. Necessary repairs should be accomplished.

7.2.5 Leaks at buttresses should be sealed.

7.2.6 Siltation, upstream of the gates to the old VEPCO canal, should be examined by divers and/or soundings should be taken. Excessive siltation poses a threat to operation of the gate and, therefore, siltation and debris in the vicinity of the gate should be removed.

7.2.7 The concrete inspection gallery walkway should be repaired and/or replaced.

7.2.8 A handrail should be installed on the walkway on top of the canal wall access to the right abutment. Public access to the dam should be eliminated by installing gates on the left and right abutments as required.

7.2.9 Seepage on the left abutment should be monitored regularly. A significant increase in flow might indicate that remedial foundation treatment would be required in the future.

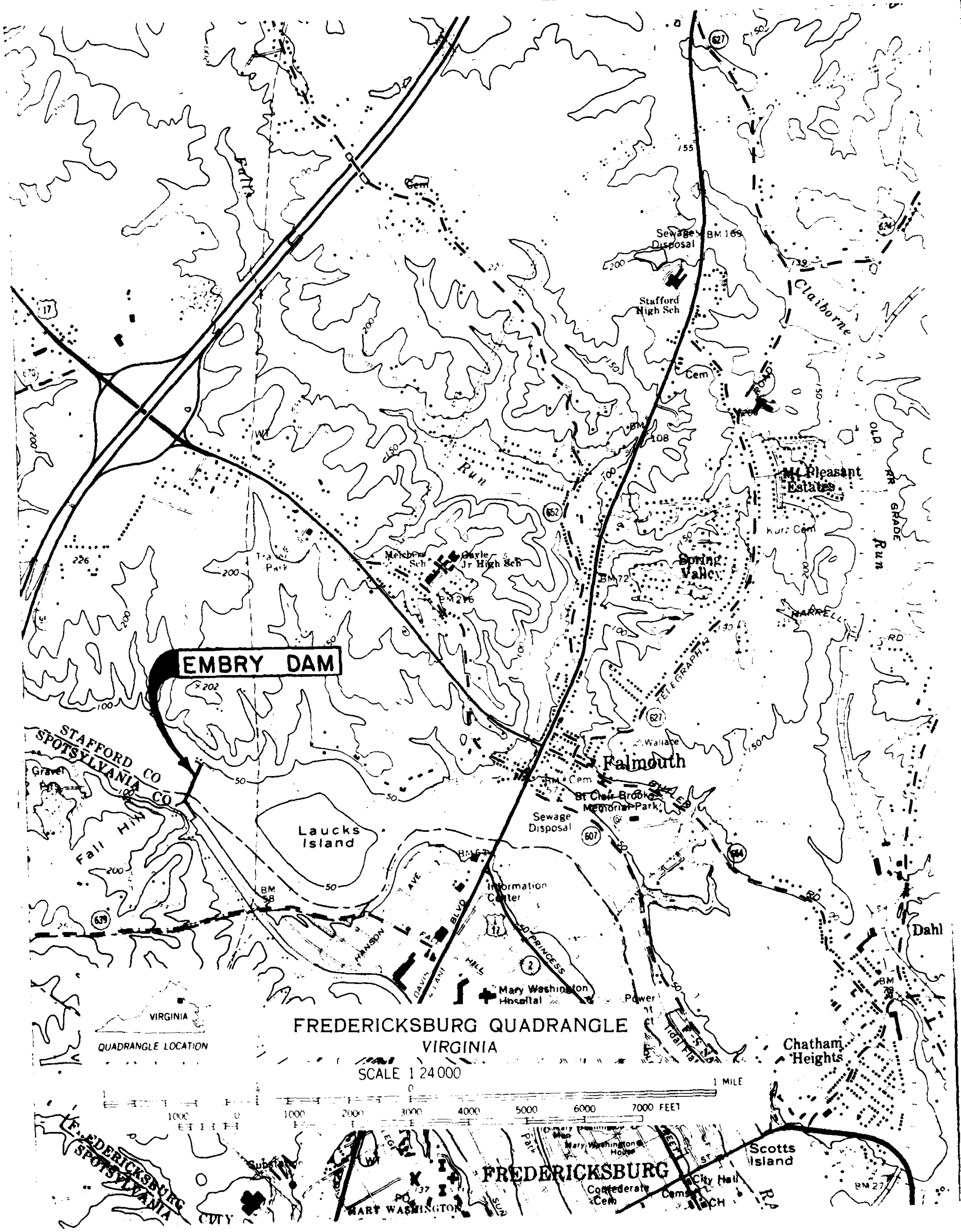
7.2.10 It is recommended that a formal emergency procedure be prepared, prominently displayed, and furnished to all operating personnel. This should include:

1) How to operate the dam during an emergency.

2) Who to notify, including public officials, in case evacuation from the downstream area is necessary.

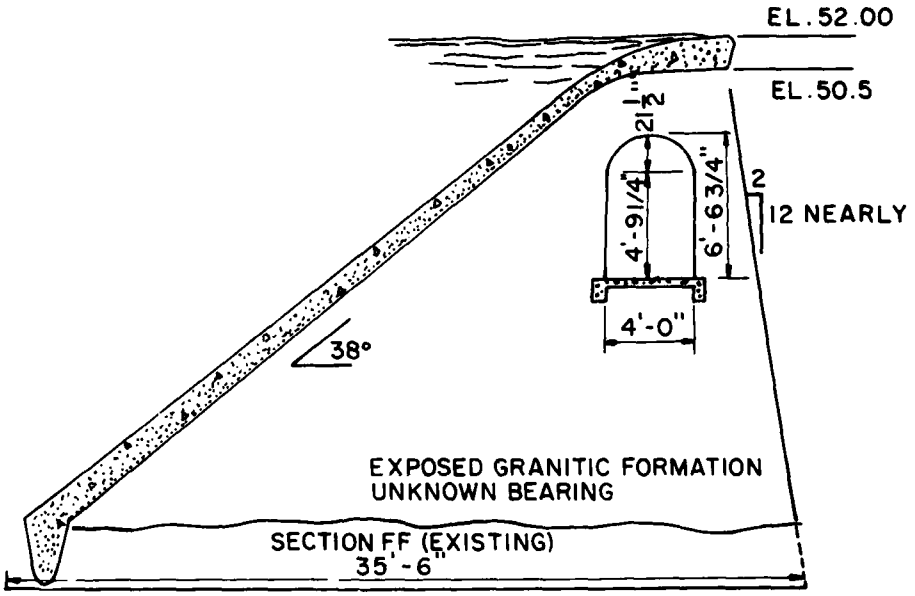
APPENDIX I

MAPS AND DRAWINGS


EMBRY DAM
FREDERICKSBURG QUADRANGLE
VIRGINIA
VIRGINIA
QUADRANGLE LOCATION
SCALE 1 24 000
1 MILE
7000 FEET
STAFFORD CO
SPOTSYLVANIA CO
FREDERICKSBURG
SPOTSYLVANIA
Laucks Island
Falmouth
Sewage Disposal
Stafford High Sch
Mt Pleasant Estates
Spring Valley
St Clair Brooks Memorial Park
Information Center
Mary Washington Hospital
Chatham Heights
Scotts Island
Dahl
City Hall
Confederate Cem
Mary Washington House
Claiborne
Run
HARRELL RD
TELEGRAPH
OLD RR GRADE
Fall Hill
Trailer Park
Melchers Sch
Gayle Jr High Sch
Kurz Cem

NOTES:

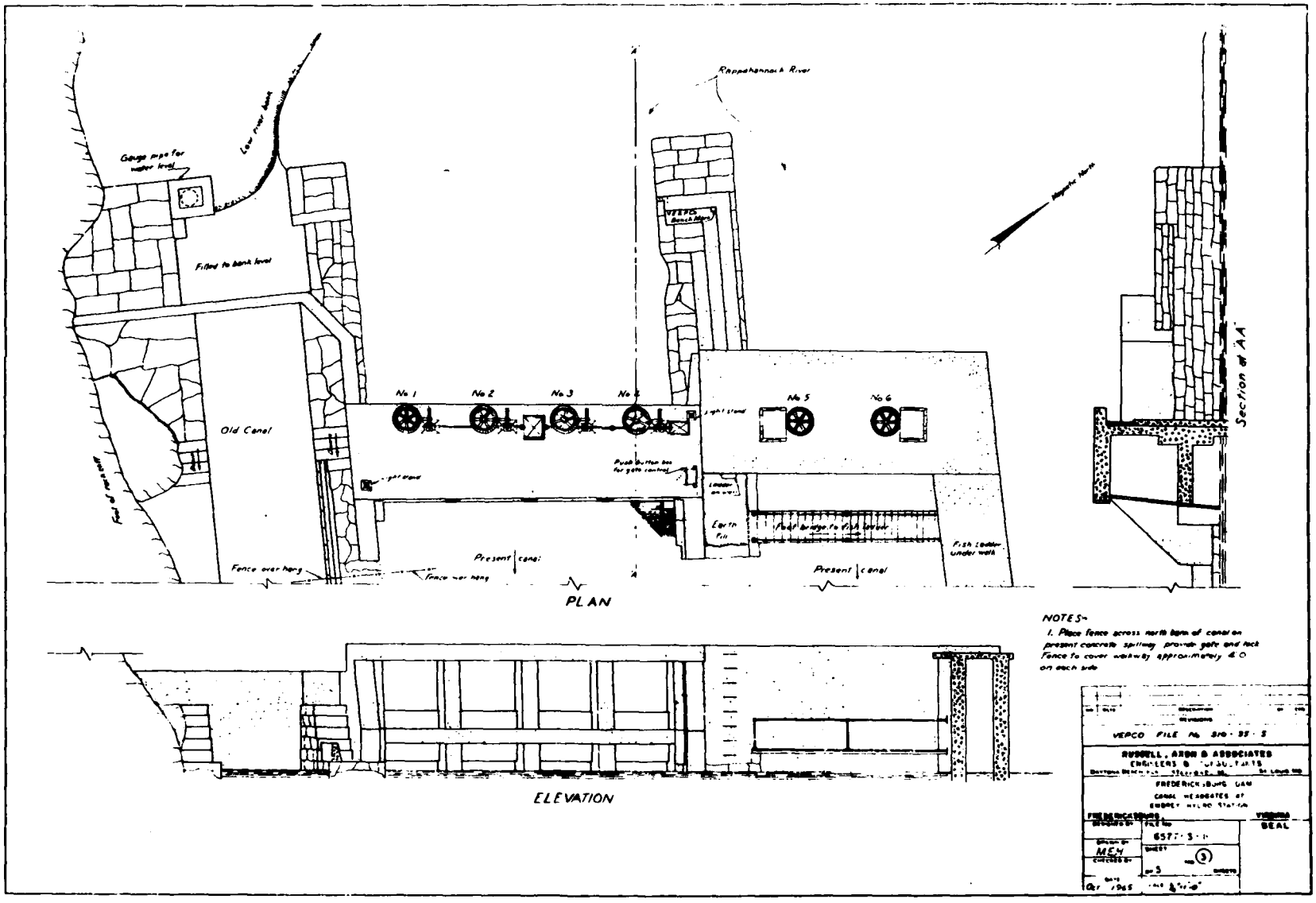
1. THE SECTION SHOWN WAS TAKEN FROM A DRAWING BY RUSSEL AND AXON ASSOC., PRELIMINARY DRAWING, ADDITIONS AND IMPROVEMENTS TO EXISTING VEPCO DAM, OCTOBER 1965.



APPROXIMATE SECTION THRU PRESENT DAM

SCALE: 1/4" = 1'-0"

PLATE 2



R3

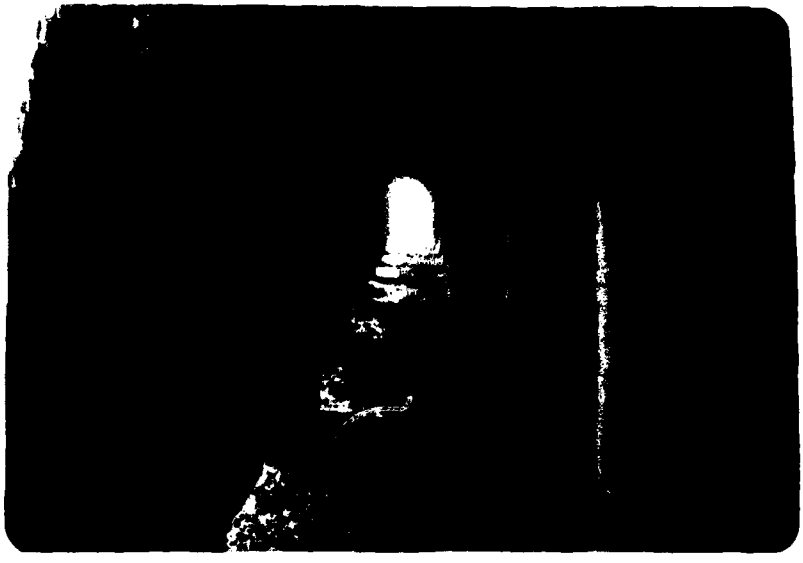


PHOTO #1 : INSPECTION GALLERY

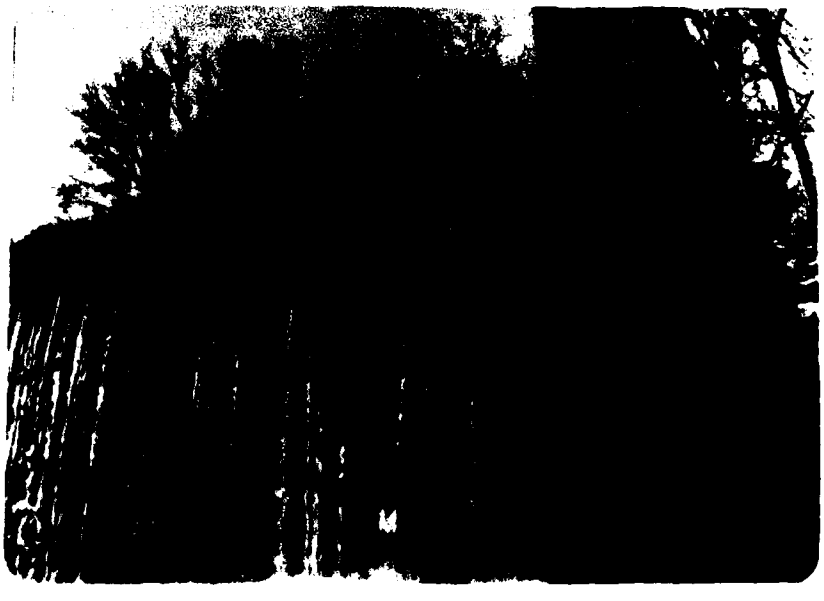


PHOTO #2: LEFT STRUCTURAL ABUTMENT

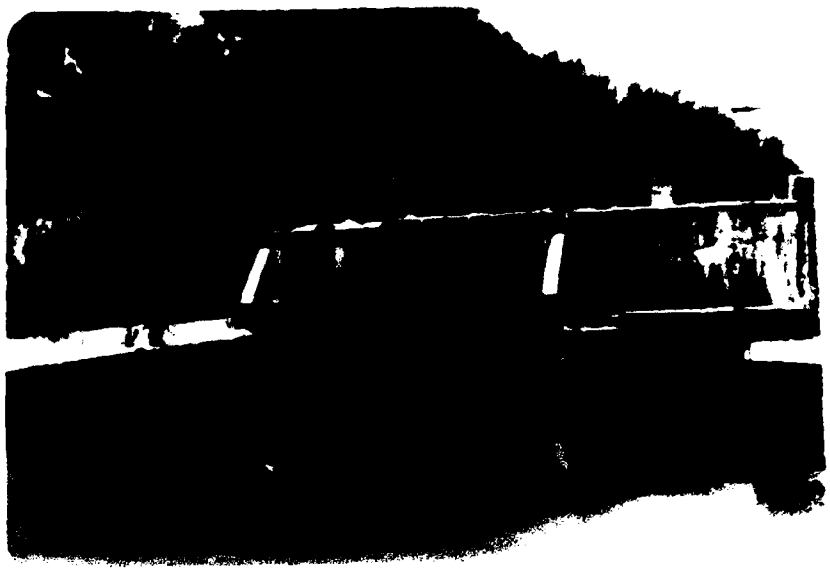


PHOTO #3: INLET WORKS TO CANAL

PHOTO #4: VIEW OF CANAL

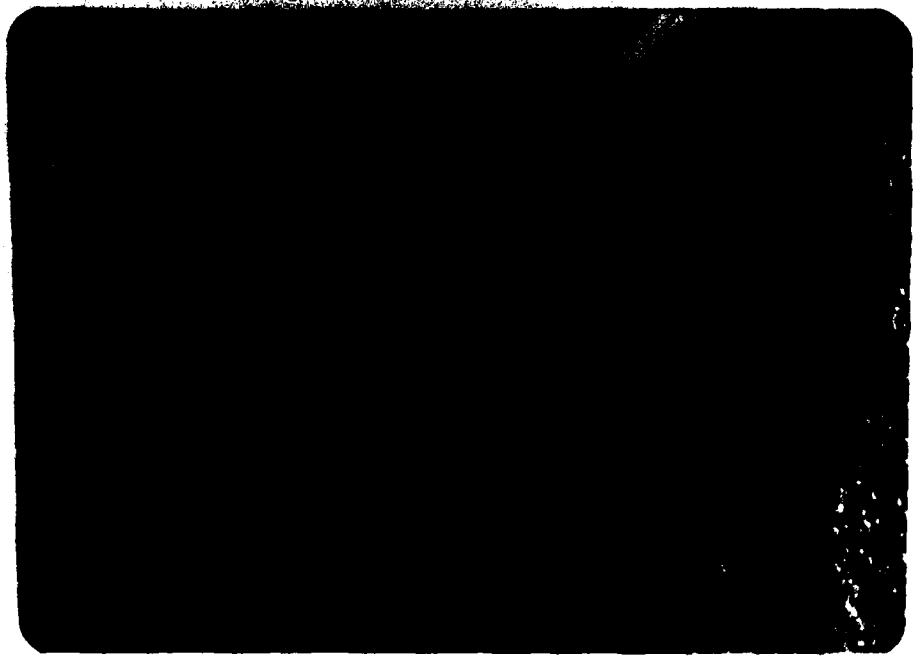


PHOTO #5 : CRACKS, LEAKS, AND DETERIORATED CONCRETE @ THE SLAB / BUTTRESS NO. 1 JUNCTION

PHOTO #6 : CRACK AT SLAB ADJACENT TO BUTTRESS NO. 14 & 15

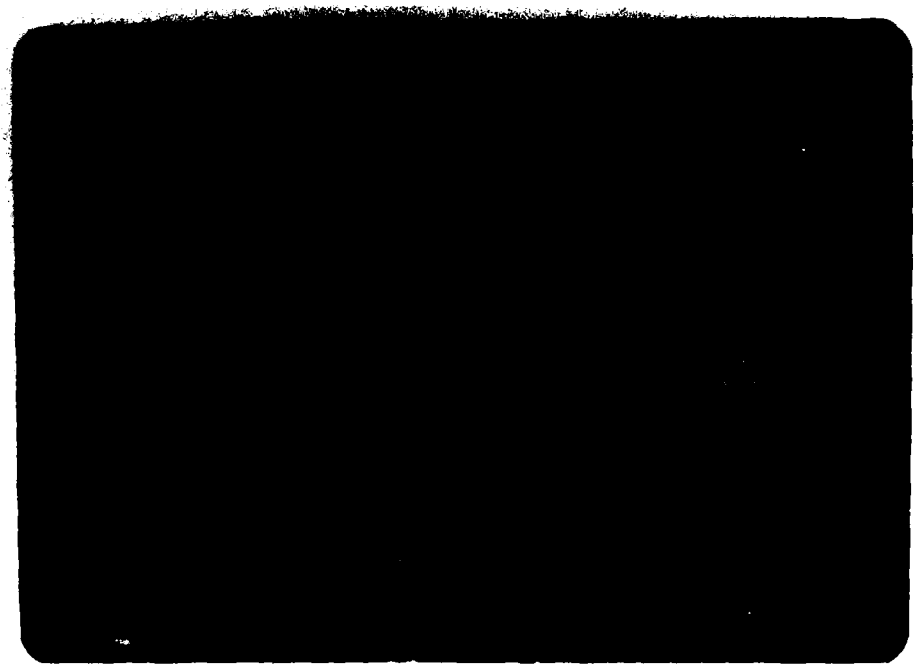


PHOTO # 7: EXPOSED REINFORCING ROD AND LEAK BETWEEN BUTTRESS NO. 14 & 15

PHOTO # 8: CRACKS AND LEAK AT BUTTRESS NO. 19

PHOTO #9: SPALLED CONCRETE IN SLAB & BUTTRESS AT BUTTRESS NO.53

PHOTO #10: HOLE THROUGH SLAB ADJACENT TO BUTTRESS NO.55

APPENDIX II

PHOTOGRAPHS

APPENDIX III

FIELD OBSERVATIONS

Check List
Visual Inspection
Phase I

Name Dam: Embry County: Stafford State: Virginia Coordinates: Lat 3819.3
Long 7729.4

Date Inspection: 10 Jan 1980 Weather: Clear Temperature: 32° ±

Pool Elevation at Time of Inspection: 52.5± M.S.L. Tailwater at Time of Inspection 31± M.S.L.

Inspection Personnel:

Corps of Engineers
Meade Stith, Structural
Jim Robinson, Hydrology
Boris Taran, Dam Safety
Leonard Jones, Dam Inventory
Jerry Swean, Geotechnical

Virginia Water Control Board
Leon Musselwhite
Ed Constantine
Hugh Gildea

City of Fredericksburg
T. F. O'Kane
Bill Judy, John McNair & Assoc.

Stith & Robinson Recorders

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SEEPAGE OR LEAKAGE	Seepage of less than 1 GPM is occurring north of buttress 0 at approximately 7+64 on PLATE 1. This may be due to runoff. The dam is leaking at many slab/buttress junctions, however, a complete inspection was not performed due to the dangerously deteriorated walkway. Many slabs are cracked and reinforcing rods are exposed due to concrete spalling. Slab spalling is generally occurring at the same location (approximately EL 41) longitudinally cross the slab. The slab is leaking at most of these locations. See Photo 7.	Slabs and buttresses should be repaired to stop leakage.
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	Left Abutment: Some seepage as listed above was noted. Right Abutment: Ties into the old canal.	
DRAINS	N/A	
WATER PASSAGES	Only one gate is presently used. Other canal headgates have not been operated since the 1940's. Gates were submerged and were not inspected.	
FOUNDATION	Slightly to non weathered granite outcrops in downstream bluffs abutments, and downstream riverbed. Granite - gray, fn grained. Joints - NW strike, near vertical dip. Downstream bluff consists of alluvium w/boulder base overlain w/sandy and clay soils.	

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS CONCRETE SURFACES	A section of the crest of the dam, approximately 10 feet long, has spalled appromimately 3" deep between buttresses 0 and 1 adjacent to buttress 1. (Buttress 0 is Sta. 7+69.75 Plate 1.) No evidence of any buttress movement was observed at buttress 1 however, considerable leakage is occurring at the top of the buttress and the top of the buttress is cracked at this location - see Photo #5. Discontinuity in water flowing over the crest of the dam occurs at buttresses 12 and 19 indicating the crest has also deteriorated at these locations.	The crest of the dam should be inspected by qualified personnel during low flow and repaired as necessary.
STRUCTURAL CRACKING	*Considerable structural cracking has occurred* in the slabs. Reinforcing is exposed at mid height of most slabs and in some cases cracks and spalling extend across the entire span. See Photo #7.	*Spalled concrete should be* patched and severe cracks should be sealed.
VERTICAL AND HORIZONTAL ALIGNMENT	No evidence of movement was observed.	
MONOLITH JOINTS (VERTICAL)	N/A	
CONSTRUCTION JOINTS	Cracking in the slabs noted above has occurred primarily at construction joints.	Spalled concrete should be patched and severe cracks should be sealed.

UNGATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	Concrete has aged with some deterioration at some joints.	During low flow periods the joints should be repaired.
APPROACH CHANNEL	Little debris was observed in the reservoir.	An old wooden dam 66 feet upstream can be observed during low flow conditions.
DISCHARGE CHANNEL	The discharge channel was in good condition. Natural rock outcrops were observed across the entire channel.	None.
FISH LADDER	The fish ladder located between the ungated spillway and VEPCO Canal appeared in fair condition.	Concrete should be resurfaced where the existing surface is worn or spalled.

OUTLET WORKS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	Snow cover of about 3 inches inhibited the observation of the concrete surface.	None.
INTAKE STRUCTURE	Four 7' by 7' concrete gates were used to supply water into the VEPCO Canal. These gates have not been operated since the 1940's. Heavy rust abides on the gate stems and wheels. Observation of the gates could not be made due to water level and snow cover.	None.
OUTLET STRUCTURE	Water was passing through the closed gates (probably around the gate seals). The flow could not be determined since it was below the water's surface.	None.
OUTLET CHANNEL	The VEPCO Canal was frozen except for the first 50 feet below the gate.	None.
EMERGENCY GATE	None.	None.

INSTRUMENTATION

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	No record of any monumentation/surveys.	
OBSERVATION WELLS	N/A	
WEIRS	None.	
PIEZOMETERS	None.	
OTHER: CONCRETE WALKWAY IN INSPECTION GALLERY	The inspection walkway is severely deteriorated and between buttresses 43 and 44 has collapsed. Handrails for the walkway is also missing.	Inspection walkway should be repaired and/or rebuilt.

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	The reservoir slopes varied from mild to steep with heavy tree cover.	None.
SEDIMENTATION	The owner stated that considerable sedimentation has occurred. Some tree limbs were noted in the silt near the left abutment.	There are no means of flushing the sedimentation.

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	The downstream channel was in good condition. Natural rock outcrops were observed across the entire channel. The channel is at least 700 feet wide.	None.
SLOPES	The slopes along the channel are steep with extensive tree growth and natural rock outcrops.	None.
APPROXIMATE NO. OF HOMES AND POPULATION	Some homes are located about 1-1/2 miles downstream. The water plant served by the VEPCO Canal depends on the diversion by the Embry Dam.	None.

CHECK LIST
ENGINEERING DATE
DESIGN, CONSTRUCTION, OPERATION

ITEM	REMARKS
PLAN OF DAM	None available.
REGIONAL VICINITY MAP	No map available other than USGS quadrangle map.
CONSTRUCTION HISTORY	The dam was constructed for the Spotsylvania Power Co. in the early 1900's. No additional information is available.
TYPICAL SECTIONS OF DAM	Originals not available. See "Preliminary Drawings, Additions and Improvements to Existing VEPCO Dam" dated October 1965, Plate 1, Appendix IV.
HYDROLOGIC/HYDRAULIC DATA	Originals not available.
OUTLETS - PLAN - DETAILS - CONSTRAINTS - DISCHARGE RATINGS	Originals not available.
RAILFALL/RESERVOIR RECORDS	None available. See Fredericksburg Dam, Canal Headgates at Embry Hydro Station, October 1965, Plate 2.
DESIGN REPORTS	None available
GEOLOGY REPORTS	None available.
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	None available.

ITEM	REMARKS
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	None available.
POST-CONSTRUCTION SURVEYS OF DAM	None available.
BORROW SOURCES	N/A
SPILLWAY PLAN SECTIONS DETAILS	N/A
OPERATING EQUIPMENT PLANS & DETAILS	None available.
MONITORING SYSTEMS	N/A
MODIFICATIONS	None performed.
HIGH POOL RECORDS	None available.
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	In depth surveys of the dam are not available. A study was performed by by Russel Axon & Assoc. in 1965 to determine the feasibility of increasing the pool to el. 64, however, copies of this report are not available. A visual inspection of the dam was performed for the Rappahannock Service Authority, Regional Water Supply Study Vol 1, Nov. 1978, see Appendix IV for the results of this visual inspection.

PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	In 1978 seepage through the dam adjacent to buttress No. 55 became severe forming a hole in the slab. (See Photo #10.) This required patching by placing bags of dry mix concrete on the upstream face until leaking stopped.
MAINTENANCE OPERATION RECORDS	None available.

APPENDIX IV

INSPECTION REPORT

(Excerpt from Rappahannock Service Authority
Regional Water Supply Study Vol. 1, Nov. 1979)

The plant seems to operate without any major problems even though the equipment and building are not in good condition.

4. Abel Lake Water Treatment Plant

Construction of the Abel Lake Water Treatment Plant is due for completion early in calendar year 1981. This plant, to be located on the Potomac Creek Reservoir, will be a 3.0 MGD rapid filtration plant expandable to 4.0 MGD with equipment and minor piping additions.

B. IMPOUNDMENT FACILITIES

Currently there are facilities throughout the RSA area forming impoundments: Potomac Creek Reservoir or Abel Lake in Stafford County; a small impoundment on the Rappahannock River formed by Embry Dam; Motts Run reservoir in Spotsylvania County supplementing flow in the Rappahannock River; Ni River Reservoir in Spotsylvania County; and the North Anna Reservoir (Lake Anna) along the southern border of Spotsylvania County. The effective water supply storage and safe yields for all but Lake Anna are determined in Section V.B.1. In this section, the structural condition of two of the facilities crucial in tapping the Rappahannock River as a major water supply source - the Embry Dam and the Motts Run Dam - are reviewed.

1. Embry Dam

Embry Dam, located directly on the Rappahannock River, is in poor condition. It is a 70 year old concrete buttress dam, approximately 770 feet long and 22 feet high, which serves principally

as a diversion structure and holding basin for the raw water intake to the Fredericksburg Water Treatment Plant. A detailed visual inspection of the dam uncovered the following deficiencies.

The concrete slab supported by the buttresses has deteriorated and the concrete quality is below average. The slab has developed cracks at several locations and water leaks through them. At several locations 80 percent of the surface area of the reinforcement has been exposed and shows signs of corrosion.

All of the 57 buttresses have deteriorated due to weather, and half of them have large spalled areas on both the downstream and upstream faces. At the larger spalled areas, water and weather have eroded away the construction joint to expose the aggregate and reinforcing steel. All the reinforcing bars show signs of corrosion, a condition which, if allowed to continue, will eventually reduce the quality and tensile strength of the steel.

The walkway, which should be approximately 5 inches thick, in several places is only 2-½ inches thick due to deterioration of the concrete. It is broken at two places, and the reinforcing bars are not continuous. The quality of concrete is poor and the reinforcing bars do not have adequate bond with the concrete. All the exposed reinforcement shows signs of corrosion. Consequently, it is dangerous to walk on this slab, since it could collapse at any time.

In general, it appears that the 70 year old Embry Dam has served its useful life span, unless it undergoes rehabilitation. With regard to stability, such condition was not possible to assess because water was overflowing the dam; final conclusions must await an opportunity to

examine the upstream and downstream faces of the dam and to conduct subsurface investigations and core-drilling studies of the existing concrete.

2. Motts Run Dam

The Motts Run Dam, an earthen structure built in 1970, is in good condition. However, there appear to be two major leaks at the construction joint between the riser and transition section to which the outfall pipe is connected. The exterior of the riser pipe, particularly at the construction joint between the riser and transition section, should be repaired to prevent deterioration of the concrete and exposed reinforcement. The repair procedures, however, cannot be finalized until there is an opportunity to examine the outside and inside surface of the riser. Also, the opening mechanisms for the gates are not working due to improper construction of the shafts and gates. The gates and mechanisms should be repaired as recommended by the Fredericksburg City Engineer.

C. DISTRIBUTION FACILITIES

Major pipe lines in the various governmental units comprising the RSA area have in general been constructed to serve the individual areas without regard to a regional attitude. However, because Spotsylvania County originally obtained water from the City of Fredericksburg, there are strong interconnections between those two units. The connection to Stafford was initially made to serve a small area around the community of Falmouth, and, at present, the 8-inch line between the two is conveying approximately 750,000 gallons per day. This represents the maximum that can be

RAYMOND INTERNATIONAL BUILDERS, INC.
SUBSIDIARY CONTRACTOR DIVISION
6925 Westfield • Pennsauken, New Jersey

E. R. Collo
Asst. Vice President
Soiltech Department

October 9, 1978

Russell & Axon
Northshore Center
1111 Northshore Drive
Knoxville, TN 37919

Attention Mr. Mahendra Butala

Subject: Emory Dam - Fredericksburg, Virginia

Gentlemen:

As requested by your Mr. Butala, last week I arranged to meet with Paul Williams of your Fredericksburg office and made a walking inspection of the structure with your Jack Roberts.

From my visual inspection, it was apparent that the majority of the disintegration and weakness in the structure is in the slabs or deck section and concentrated for the most part at either construction joints or cold joints in the concrete deck.

While there was some disintegration of the concrete buttresses in the haunch area at the slab or decks, visually this did not appear to be extensive. There was disintegration and damage to the downstream faces of the buttresses, but again this did not appear to be too extensive.

There was a fairly good flow over the crest of the dam so that no observation could be made of either the crest section or of the downstream and underwater portions of the abutments.

Before any suggestion or recommendation for repair can be made, it is necessary to have additional information on the strength and condition of the structure, particularly the strength of the concrete in the buttresses and in the slab itself. Further, it will be necessary inspect the underwater sections of the buttresses to determine the condition of the concrete and observe if there is any undercutting or scouring of the buttresses themselves or the supporting rock foundation.

We would suggest that cores be taken of the concrete and analyzed for strength and durability. We would also suggest that some form of non-destructive testing be made of the concrete deck or slabs in conjunction with the cores and further, that an underwater diving inspection be made to determine the condition of the foundation and supporting buttresses.

Depending upon the strength of the concrete and the extent of disintegration, both to location and depth, one method of repair would be to cast against the underside of the deck, spanning from buttress to buttress, reinforced concrete slab sections where the existing concrete is disintegrated, damaged and under strength. Assuming minor repairs to the abutments (the concrete being at design strength, durable and no undercutting or scour) and reinforcing approximately 25 per cent of the exposed under-surface of the slab, it is estimated that the cost of repairs would be in the vicinity of $250,000.

If we go to the opposite extreme where the entire underside of the deck has to be reinforced with a new slab and extensive repairs made to the buttresses, then costs in excess of $1 million would not be an unreasonable estimate at this time and based upon the "lack of knowledge" that we have of the structure.

I trust this information is as requested and will assist you and your client in determining the steps and procedures for restoration of this structure.

If we can be of service on the underwater investigation and coring of the concrete, we would be pleased to submit our proposal for such technical services.

Thank you for the opportunity of making this inspection and we trust to be of further service.

Very truly yours,

RAYMOND INTERNATIONAL BUILDERS, INC

E. R. Collo
Assistant Vice President
SOILTECH Department

djt
encl.
cc: Paul J. Williams
Russell & Axon
1028 Old Forge Plaza
Fredricksburg, Virginia 22401

APPENDIX V

1. Recommended Guidelines for Safety Inspection of Dams, Office of the Chief of Engineers, Department of the Army, Washington, D. C.