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**Phase 1 Inspection Report: National Dam Safety Program.  
Mississippi - Kaskaskia - St. Louis Basin. Lac Marseilles Dam, St.  
Francois County, Missouri**

Woodward-Clyde Consultants, Chicago, Illinois

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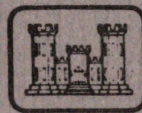
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# MISSISSIPPI-KASKASKIA-ST. LOUIS BASIN

LAC MARSEILLES DAM  
ST. FRANCOIS COUNTY, MISSOURI  
MO 30282

## PHASE 1 INSPECTION REPORT NATIONAL DAM SAFETY INSPECTION



United States Army  
Corps of Engineers  
... Serving the Army  
... Serving the Nation

**St. Louis District**

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PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

JANUARY 1981





**DEPARTMENT OF THE ARMY**  
**ST. LOUIS DISTRICT, CORPS OF ENGINEERS**  
**210 TUCKER BOULEVARD, NORTH**  
**ST. LOUIS, MISSOURI 63101**

REPLY TO  
ATTENTION OF

SUBJECT: Lac Marseilles Dam (MO 30282)

This report presents the results of field inspection and evaluation of the Lac Marseilles Dam. It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED:

**SIGNED**

Chief, Engineering Division

**01 APR 1981**

Date

APPROVED BY:

**SIGNED**

Colonel, CE, District Engineer

**03 APR 1981**

Date



**LAC MARSEILLES DAM**  
St. Francois County, Missouri  
Missouri Inventory No. 30282

**Phase I Inspection Report**  
**National Dam Safety Program**

Prepared by

**Woodward-Clyde Consultants**  
Chicago, Illinois

Under Direction of  
St Louis District, Corps of Engineers

for  
Governor of Missouri  
January 1981



## **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 not to provide a complete evaluation of the safety of the structure nor to provide a guarantee on its future integrity. Rather the purpose of the program is to identify potentially hazardous conditions to the extent they can be identified by a visual examination. The assessment of the general condition of the dam is based upon available data (if any) and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify the need for more detailed studies. In view of the limited nature of the Phase I studies no assurance can be given that all deficiencies have been identified.*

*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 any data which may be available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action removes the normal load on the structure, as well as the reservoir head along with seepage pressures, 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 frequent inspections can unsafe conditions be detected, so that corrective action can be taken. Likewise continued care and maintenance are necessary to minimize the possibility of development of unsafe conditions.*



PHASE I REPORT  
NATIONAL DAM SAFETY PROGRAM

Name of Dam	Lac Marseilles Dam
State Located	Missouri
County Located	St Francois
Stream	Unnamed Tributary of Big River
Date of Inspection	10 November 1980

Lac Marseilles Dam, Missouri Inventory No. 30282, was inspected by Richard Berggreen (engineering geologist), Leonard Krazynski (geotechnical engineer), and Sean Tseng (hydrologist). The dam is an earth and rockfill dam constructed for recreational purposes within the surrounding residential development.

The dam inspection was made following the guidelines presented in the "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed by the Chief of Engineers, U.S. Army, Washington, D.C., with the help of federal and state agencies, professional engineering organizations, and private engineers. The resulting guidelines represent a consensus of the engineering profession. These guidelines are intended to provide for an expeditious identification of those dams which may pose hazards to human life or property, based on available data and a visual inspection. In view of the limited scope of the study, no assurance can be given that all deficiencies have been identified.

The St Louis District, Corps of Engineers (SLD) has classified this dam as having a high hazard potential. The hazard zone length estimated by the SLD extends approximately four miles downstream of the dam. Within this zone are several occupied homes and a sewage treatment plant. Due to the proximity of the downstream residences, it is recommended that 100 percent of the Probable Maximum Flood (PMF) should be used as the spillway design flood. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible for the region.

Lac Marseilles Dam is in the intermediate size classification based on its maximum height of 67 ft. Its reservoir storage volume is about 2400 ac-ft. The intermediate dam classification includes dams between 40 and 100 ft in height, or having storage capacities between 1000 and 50,000 ac-ft.



Our inspection and evaluation indicate that the dam is in generally good condition. The slopes of the dam indicate no signs of any movement or instability. There was no observed seepage through the dam with the water surface only a few feet below the spillway crest elevation. Our hydrologic analyses indicate that the existing spillway will safely pass the 100 year flood and 96 percent of the PMF. A flood event with the intensity of 100 percent of the PMF would only overtop a portion of the embankment by 0.1 ft for a period of less than 1 hour. Our analysis assumes that the existing 18-in. diameter pipe outlet facility is inoperative at the time of flooding. During overtopping, this pipe would, in any case, be capable of discharging only about 40 ft<sup>3</sup>/sec. The crest of the dam is 50 ft wide, is traversed for its entire length by an asphalt-paved roadway and the materials on the downstream slope are not highly susceptible to erosion. The spillway discharge channel is underlain by bedrock at shallow depth, is located in a good position with respect to the main dam embankment and discharges the flow into a separate adjacent drainage valley.

The dam was constructed without a set of plans or "as built" records, but we understand that its construction was observed and directed by a professional engineer.

The geometry of the dam section and the properties of the materials used are not on record. Neither are seepage and stability analyses for the dam, as constructed.

Based on our evaluation of the information obtained from the visual inspection and other available information described in this report, the following specific recommendations are made for Lac Marseilles Dam:

1. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" should be performed and made a matter of record. Such analyses should consider appropriate loading conditions, including seismic loads, and should be made by an engineer experienced in the design and construction of earth and rockfill dams.
2. Determine the feasibility of a practical warning system to alert downstream residents in the event that unsafe conditions develop at this dam.
3. It is recommended that a periodic inspection and maintenance program be initiated for this facility. This program should include but not be limited to the following:

- a. Checking for evidence of slope instability such as cracks, deformation on the dam face or settling of the dam crest;
- b. Checking the amount and turbidity of seepage, if any;
- c. Maintaining the spillway discharge channel free of potential obstructions;
- d. Evaluation of the condition and an assessment of the need for repair of the sluice gate mechanism in the pipe outlet facility at the dam.

This program should be under the guidance of an engineer experienced in the design, construction and maintenance of earth and rockfill dams.

It is recommended the owner take action on these items without undue delay.

WOODWARD-CLYDE CONSULTANTS



Richard G. Berggreen  
Registered Geologist



Leonard M. Krazynski, P.E.  
Vice President



**OVERVIEW**  
**LAC MARSEILLES DAM**

**MISSOURI INVENTORY NUMBER      30282**



PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM  
LAC MARSEILLES DAM, MISSOURI INVENTORY NO. 30282  
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12. Discharge channel area in lower left of photo. Channel flows on exposed bedrock for most of its length. Note that discharge is routed well away from toe of embankment. Looking east.
13. Typical structures in downstream damage zone. Located about 1 mile downstream of dam.

#### B Hydraulic/Hydrologic Data and Analyses

#### C Design Data for Lac Marseilles Dam

**PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM  
LAC MARSEILLES DAM, MISSOURI INVENTORY NO. 30282**

**SECTION 1  
PROJECT INFORMATION**

**1.1 General**

- a. **Authority.** The National Dam Inspection Act, Public Law 92-367, provides for a national inventory and inspection of dams throughout the United States. Pursuant to the above, an inspection was conducted of Lac Marseilles Dam Missouri Inventory Number 30282.
  
- b. **Purpose of Inspection.** "The primary purpose of the Phase I investigation program is to identify expeditiously those dams which may pose hazards to human life or property... The Phase I investigation will develop an assessment of the general condition with respect to safety of the project based upon available data and a visual inspection, determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted" (Chapter 3, "Recommended Guidelines for Safety Inspection of Dams").
  
- c. **Evaluation criteria.** The criteria used to evaluate the dam were established in the "Recommended Guidelines for Safety Inspection of Dams," Engineering Regulation No. 1110-2-106 and Engineering Circular No. 1110-2-188, "Engineering and Design National Program for Inspection of Non-Federal Dams," developed by the Office of Chief of Engineers, Department of the Army, and "Hydrologic/Hydraulic Standards, Phase I Safety Inspection of Non-Federal Dams," prepared by the St Louis District, Corps of Engineers (SLD). These guidelines were developed with the help of several federal agencies and many state agencies, professional engineering organizations, and private engineers.



## 1.2 Description of Project

- a. **Description of dam and appurtenances.** Lac Marseilles Dam is an earth and rockfill dam impounding a lake for recreational purposes within the surrounding residential development. The dam crest varies in elevation from 844.9 to 846.5 ft, and is capped by a paved asphalt roadway (Fig. 3A). The spillway is an uncontrolled, roughly trapezoidal excavation in natural soil and bedrock in the right (north) abutment. The spillway crest is also covered by the asphalt roadway. Discharge through the spillway is directed away from the toe of the dam and into the downstream drainage way of the adjacent Lac Capri. An intake tower for a pipe outlet facility is located near the left abutment. It consists of a square concrete inlet tower constructed in the lake and an 18-in. diameter iron pipe crossing through the embankment and discharging into a channel near the junction of the left abutment and the embankment. The gate for this outlet is located at the tower.

The upstream slope of the dam is covered by large riprap. A concrete boat-mooring wall has been built along the central third of the upstream face. Together, the riprap and concrete wall provide excellent wave erosion protection.

- b. **Location.** The dam is located on an unnamed tributary of Big River, in Sec 29, T37N, R4E, on the USGS Bonne Terre 7.5-minute quadrangle map. It is a part of the Terre Du Lac residential community south of Missouri State Highway 47 approximately 4 mi southeast of Bonne Terre, St Francois County, Missouri (Fig. 1).
- c. **Size classification.** The dam is classified intermediate size based on its height of 67 ft and storage capacity of approximately 2400 ac-ft. The intermediate size classification includes dams from 40 to 100 ft in height or having storage capacities from 1000 to 50,000 ac-ft.
- d. **Hazard classification.** The St Louis District, Corps of Engineers (SLD), has classified this dam as having a high hazard potential; we concur with this classification. The damage zone length estimated by the SLD extends approximately four miles downstream. Located within this estimated damage zone are a sewage treatment plant and several occupied dwellings. The

potential for loss of life and property could be high in the event of sudden failure of the dam.

- e. **Ownership.** The dam is reportedly owned by the Terre Du Lac Property Owners Association, 409 Champs Elysees, Terre Du Lac, Bonne Terre, Missouri 63628. Correspondence should be sent to the attention of the president of the association (currently Mr Leonard Britzke).
- f. **Purpose of dam.** The lake impounded by the dam is used for recreational purposes by the adjacent residential community.
- g. **Design and construction history.** Construction reports were not available for Lac Marseilles Dam. All information on the construction was obtained from interviews with Mr Scott Kern, engineer for the Terre Du Lac Development, Mr Leonard Britzke, president of the Terre Du Lac Property Owners Association, and Mr James Bennett, a former engineer of Terre Du Lac Development and currently a consulting engineer (James Bennett & Associates, P.O. Box 232, Farmington, Missouri 63640).

Specifications for the construction of the dam were supplied by Horner & Shifrin Consulting Engineers, St Louis, Missouri, who prepared a preliminary design for the dam. The dam was constructed in 1971 by Fred Weber Inc., St Louis, Missouri.

The preliminary design for the dam furnished to us by Horner and Shifrin indicates a zoned embankment cross-section composed of an impervious core, two zones of filter materials both upstream and downstream and outer shells composed of rockfill. Both the upstream and downstream slopes are shown at an inclination of 2(H) to 1(V). An upstream cofferdam was to be incorporated into the finished dam embankment. This section is reproduced in Appendix C. Also enclosed in Appendix C is a set of specifications. The specifications assign considerable and wide-ranging authority to the Engineer in many critical matters including borrow areas, material selection and processing, material placement and compaction, rock blasting, foundation preparation and many others. This authority at the time of construction was apparently exercised by Mr Bennett.

Mr Bennett indicated to us that during construction considerable modification of the preliminary design was made, although no "as built" drawings could be located at Terre Du Lac Property Owners Association, or obtained from the original designer. The changes identified by Mr Bennett were:

1. Both the upstream and downstream slope inclinations were made flatter. (The survey carried out as part of our inspection indicates that the downstream slope inclinations ranged from 2 (H) to 1 (V) to 2.6 (H) to 1 (V). The exposed portion of the upstream slope-a vertical distance of about 9 to 10 ft - had inclinations of 3.6 (H) to 1 (V) at the boat bulkhead, and 2 (H) to 1 (V) on either sides of the bulkhead).
2. A 25-ft wide horizontal bench was constructed on the upstream slope, approximately half way up between the toe and the crest of the dam. This bench is located above the elevation of the junction between the cofferdam and the main embankment.
3. Filter material was only used downstream of the impervious core, in one zone of filter. This was not a processed or imported material, but rather an on-site borrow soil which was judged to be too coarse for use in the impervious core. The thickness and gradation of this filter material are not known.
4. The material used for the impervious core was broken-down and compacted on-site shale. Compaction of the core was accomplished with sheepsfoot rollers. Compaction test records could not be located. Compaction of the remainder of the embankment was accomplished by traffic with loaded scrapers.
5. Rockfill material was used on the upstream slope. The rockfill particle sizes ranged from about ½ to 2 ft.
6. Random borrow was used on the downstream slope, consisting mostly of rock fragments with variable amounts of fine particles.

During excavation of the cut-off trench, a fault was noted near the north (right) abutment between the underlying Derby-Doerun Dolomite and Davis Shale.



Two water pressure tests were carried out in the fault zone and were apparently judged satisfactory. The construction site was also inspected on several occasions by personnel from Missouri Geological Survey. Copies of their reports are enclosed in Appendix C.

- h. **Normal operating procedures.** No operating records or formal operating procedures were found for this facility. Flood flows can be passed through the gated pipe outlet facility and over the uncontrolled spillway at the right abutment. At the time of the visual inspection, the pipe outlet was flowing at approximately 20 gal/min, apparently due to some inadvertent damage to the sluice gate mechanism.

### 1.3 Pertinent Data

- a. **Drainage area.** 0.69 mi<sup>2</sup>
- b. **Discharge at damsite.**
- |   |                           |
|---|---------------------------|
| Maximum known flood at damsite                      | Unknown                   |
| Warm water outlet at pool elevation                 | N/A (Not Applicable)      |
| Diversion tunnel low pool outlet at pool elevation  | N/A                       |
| Diversion tunnel outlet at pool elevation           | N/A                       |
| Gated spillway capacity at pool elevation           | N/A                       |
| Gated spillway capacity at maximum pool elevation   | N/A                       |
| Ungated spillway capacity at maximum pool elevation | 2370 ft <sup>3</sup> /sec |
| Total spillway capacity at maximum pool elevation   | 2370 ft <sup>3</sup> /sec |
- c. **Elevations (ft above MSL).**
- |   |                |
|---|----------------|
| Top of dam                                | 844.9 to 846.5 |
| Maximum pool - design surcharge           | N/A            |
| Full flood control pool                   | N/A            |
| Recreation pool                           | 838.7          |
| Spillway crest (gated)                    | N/A            |
| Upstream portal invert diversion tunnel   | N/A            |
| Downstream portal invert diversion tunnel | N/A            |

Streambed at centerline of dam	Unknown
Maximum tailwater	N/A
Toe of dam at maximum section	778.7
<b>d. <u>Reservoir.</u></b>	
Length of maximum pool	2600 ft
Length of recreation pool	2500 ft
Length of flood control pool	N/A
<b>e. <u>Storage (acre-feet).</u></b>	
Recreation pool	1900
Flood control pool	N/A
Design surcharge	N/A
Top of dam	2400
<b>f. <u>Reservoir surface (acres).</u></b>	
Top of dam	89
Maximum pool	89
Flood control pool	N/A
Recreation pool	75
Spillway crest	75
<b>g. <u>Dam.</u></b>	
Type	Rockfill and compacted soil
Length	1185 ft
Height	67 ft
Top width	50 ft
Side slopes	Downstream, 2.0(H) to 2.6(H) to 1(V); Upstream unknown.
Zoning	Compacted shale core. Filter zone downstream. Random fill shell downstream, rock fill upstream.
Impervious core	Compacted shale. Dimensions unknown.

Cutoff	Compacted shale excavation into shale bedrock.
Grout curtain	Unknown, probably none.

h. **Diversion and regulating tunnel.**

Type	None
Length	N/A
Closure	N/A
Access	N/A
Regulating facilities	N/A

i. **Spillway.**

Type	Uncontrolled, trapezoidal notch, excavated in soil and weathered rock. Crossed by asphalt-paved road.
Length of weir	130 ft (at elev 844.9)
Crest elevation	838.7 ft (MSL)
Gates	None
Downstream channel	Unlined drainage from spillway down right abutment to drainage way of adjacent Lac Capri.

j. **Regulating outlets.**

18-in. diameter iron pipe with gate upstream in inlet tower structure. Gate was leaking estimated 20 gal/min at time of inspection. Discharge capacity calculated at approximately 40 ft<sup>3</sup>/sec.



## SECTION 2 ENGINEERING DATA

### 2.1 Design

Preliminary design drawings have been furnished by Horner and Shifrin, Inc. of St Louis, Missouri. A typical section is enclosed in Appendix C. This design was substantially modified during construction.

### 2.2 Construction

The dam was constructed in 1971 by Fred Webber, Inc. Modifications to the design were described to us by Mr James Bennett and are summarized in Section 1.2g of this report. Records of construction procedures, testing, or "as built" drawings could not be located.

### 2.3 Operation

There are no records of flow history over the spillway. The 18-in. diameter outlet pipe was reported to have a slightly damaged sluice gate and a discharge from this pipe (approximately 20 gal/min) was noted during our visual inspection.

### 2.4 Evaluation

- a. Availability. Engineering data for the Lac Marseilles Dam as constructed, were obtained through personal interviews described in Section 1.2g of this report.

We were furnished with a copy of the preliminary design cross-section prepared by Horner and Shifrin in January 1969. We were also furnished with copies of some preliminary stability analyses by the same firm prepared in October 1968, as part of the preliminary design work. On the basis of information obtained from Mr Bennett, it appears clear that the preliminary

design was not implemented during construction. The design was modified so extensively that in effect an almost entirely and different dam embankment was constructed. The preliminary stability analyses are not applicable either to the geometry or to the material strength properties of the dam as-built.

- b. **Adequacy.** The available engineering data and information is insufficient to evaluate the design of the Lac Marseilles Dam. For the dam as constructed, seepage and stability analyses comparable to the Guidelines requirements are not on record. This is a deficiency which should be rectified. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record. These analyses should be performed by an engineer experienced in the design and construction of earth and rockfill dams.
- c. **Validity.** The information obtained from Mr Bennett appears to be valid and is in agreement with those features of the dam which could be observed during the visual inspection in the field. Mr Bennett is a professional engineer and was present at the site during the period of construction. He was not able to furnish us with any written records concerning the construction of this facility, nor were any such records available from other sources.

## 2.5 **Project Geology**

The dam site is located on the northern flank of the Ozark structural dome. The regional dip is to the north. The bedrock in the area is mapped on the Geologic Map of Missouri (1979) as Cambrian age Elvins Group, probably Derby-Doerun Formation (Fig. 4).

The Derby-Doerun Formation consists of thin- to medium-bedded dolomite with beds of glauconitic siltstone and shale. The borrow area at the toe of the dam and the material in the dam embankment contain both weathered dolomite and glauconitic shale fragments. There appeared to be relatively little chert, which characterizes the overlying Potosi Formation. There was no evidence of springs or solution activity in the bedrock exposed at the toe of the dam.

The soil exposed in the vicinity of the dam is a reddish-tan to yellow-olive, gravelly silty clay (CL). It appears to be the weathering product of the dolomite and

glauconite-shale bedrock. The exposed soil profile appeared to be relatively thin, approximately 5 ft or less, but may have been disturbed by grading operation for the residential development or dam construction. The soils in this area are mapped on the Missouri General Soils Map (1979) as Peridge-Cantwell-Gasconade Association.

The dam is located near the north end of the Simms Mountain Fault Zone (Fig. 4). However, the scale of the map, 1 inch equals 8 miles, does not allow for precise location of the mapped fault trace. The fault zone has a mapped length of approximately 42 mi and trends northwest-southeast. Displacements on the faults are typically up to the south. The Cabanne Fault is mapped approximately two miles north of the dam site. This fault trends roughly east-west, has a mapped length of approximately 12 mi and has an indicated displacement up to the south. These faults, like most others in the Ozark region, appear restricted to the Precambrian and Paleozoic formations. They are not considered to be in a seismically active area and are not considered to pose a significant hazard to the dam.

During the excavation of the cutoff trench for this dam a fault was noted near the right (north) abutment between the units of Derby-Doerun Dolomite and Davis Shale. Copies of reports concerning this feature are enclosed in Appendix C.

The dam is located approximately 107 miles northwest of the line of epicenters for the very large New Madrid earthquakes which occurred in 1811 and 1812. A recurrence of an earthquake of the magnitude of the New Madrid events could possibly cause damage at the dam, but a study of this aspect of risk was beyond the scope of this Phase I inspection.

## SECTION 3 VISUAL INSPECTION

### 3.1 Findings

- a. **General.** A field inspection was made of Lac Marseilles Dam on 10 November, 1980. Mr Scott Kern, engineer for the Terre Du Lac, Inc., the community developer, met with the inspection team at the dam, but did not accompany the team throughout the inspection. The inspection indicated the dam is currently in generally good condition.
  
- b. **Dam.** The embankment was constructed of local earth materials ranging from clayey soils to rock boulders (CL to GP), borrowed from the vicinity of the dam foundation. The rock fraction consists of gravel-size to boulder-size dolomite bedrock. The fine fraction of the dam appears to be a mixture of residual soil from the weathered bedrock and the products from the slaking and mechanical breakdown of the shale bedrock during construction. Relict textures in the shale fragments suggest the majority of the silt and clay materials in the embankment may be the result of these broken up, mixed and recompacted shale fragments.

The exposed surface of the dam has a mantle of gravel and rock (Photos 1 and 2; Appendix A), which appears moderately resistant to erosion. The size and the amount of rock fraction in this mantle is not uniform and is partially reflected by the non-uniform vegetation cover. The downstream face of the dam has a moderately well developed cover of grass and weeds (Photo 5), although some areas are bare (Photos 2, 6 and 12). The bare portions have experienced minor rill erosion. The bare areas are generally covered with a gravel and rock mantle.

The upstream face of the dam has large riprap erosion protection along the length of the dam (Photos 3 and 4). The central third of the dam has a concrete wall on the lake side of the riprap (Photo 4), for use as a boat mooring facility. The riprap appears to be in good condition and there is little potential for significant erosion of the upstream face of the dam.

The dam crest is about 50 ft wide and did not exhibit any evidence of disruption of the vertical or horizontal alignment. A paved asphalt road follows the dam crest alignment and no evidence of cracking could be detected (Photo 7). Some areas of apparent pavement failure have been patched (Photo 12). There was no evidence of sliding or slumping of the embankment slopes, and no evidence of sinkhole development, animal burrows or detrimental settlement.

No seepage was noted through the dam, or along the junction with the abutments. Some wet soil was noted in several areas of the bedrock exposed beyond the toe of the dam, but this seepage was very small.

c. Appurtenant structures.

1. Spillway. The spillway is a broad, roughly trapezoidal notch cut into the weathered rock at the right abutment (Photo 8). There are no gates or other control facilities in the spillway. The upstream entrance channel narrows as it approaches the spillway. An asphalt road crossing the spillway may act as a weir. The control section for the discharge capacity was determined from three survey cross sections in the spillway area (Fig. 3B). For most flows, the paved roadway will likely control erosion of the spillway. However, for high flood flows, the shallow gravelly soil along the road may be eroded, undermining the asphalt and causing the pavement to be washed away. This is not anticipated to pose a safety hazard to the embankment due to the shallow depth to bedrock and the location of the spillway in relation to the main body of the dam.

2. Low-level Outlet. A pipe outlet facility was observed at this dam, consisting of a square concrete tower near the left abutment in the reservoir (Photo 9). Discharge flows through an 18-in. dia iron pipe (Photo 10) which exits the dam near the junction of the embankment with the left abutment approximately one third of the way down the dam (el. 821 ft). The control for this outlet is at the upstream end of the discharge pipe within the concrete tower. We have been informed that due to some damage to the sluice gate mechanism the valve cannot be completely closed, resulting in a small steady discharge from the pipe. Gully erosion has occurred where this discharge



flows down the embankment-abutment contact, but is too small to be considered a safety hazard to the dam at the present time. At the time of the visual inspection, this discharge outlet was flowing at a rate of approximately 20 gal/min.

- d. **Reservoir area.** The area surrounding the reservoir is being developed as a residential community. The slopes in the drainage basin are relatively gentle, generally 5(H) to 1(V) or flatter. Grading for road and home construction has likely resulted in limited erosion and consequent siltation of the reservoir. Some wave erosion of the banks of the reservoir was noted during the field inspection (Photo 11), also contributing to siltation of the reservoir. Apparently, no depth measurements have been taken and no records could be located on rates of sedimentation in the reservoir.
- e. **Downstream channel.** The downstream channel below the spillway is a broad, ill-defined channel in soil and exposed bedrock on the right abutment (Photo 12). This channel flows west down a low ridge which separates the downstream channel from the dam embankment. The channel flows into the downstream channel below Lac Capri, a large dam in the next drainage west of Lac Marseilles.

Due to the relatively shallow depth to bedrock, no significant erosion is likely in the downstream channel. Some minor erosion was noted during the visual inspection and flyover of the site, indicating the spillway has carried flood overflow in the past.

No obstructions were noted in either the spillway or downstream channel that would reduce flow through the spillway during flood events.

### 3.2 **Evaluation**

The visual inspection of Lac Marseilles Dam indicates the dam is in generally good condition.

No cracking, slumping, sinkhole development or animal burrows were noted. There was no apparent disruption of the vertical or horizontal alignment of the dam crest and no evidence of slope instability was observed.

Minor rill erosion was noted but there did not appear to be any significant erosion of the downstream face of the dam. The downstream face is partially vegetated with grass and weeds. The erosion potential in the event of overtopping is judged to be moderate.

The upstream face of the dam appears adequately protected from wave erosion by riprap and a concrete boat mooring wall.

Significant erosion of the spillway discharge channel is considered unlikely due to the shallow depth to bedrock. Erosion of the spillway could occur during flooding and cause the paved road which crosses the spillway to be washed away, but such erosion would not be likely to pose a safety hazard to the dam due to the distance from the main embankment and the direction of the discharge flow.

## SECTION 4 OPERATIONAL PROCEDURES

### 4.1 Procedures

No records of formal operational procedures were identified at this facility. Water level in the reservoir is controlled by the ungated spillway elevation. Normal operating procedure is to allow natural drainage through the spillway.

### 4.2 Maintenance of the Dam

No records of maintenance of the dam were available. The roadway along the crest of the dam appeared well maintained. No trees were growing on the downstream slope which indicated some maintenance efforts. The riprap along the upstream face of the dam appeared well maintained.

### 4.3 Maintenance of Operating Facilities

The only facility requiring operation is the 18-in. diameter pipe outlet facility. This was not operated during the visual inspection. A discharge flow of approximately 20 gal/min was noted at the discharge end. We were informed by Mr Bennett that minor damage occurred to the sluice gate mechanism. The operation of this facility appears to have no significant impact on the safety aspects of this dam.

### 4.4 Description of Any Warning System in Effect

Our visual inspection and interviews did not identify any warning system in effect at this facility.

### 4.5 Evaluation

There is no formal maintenance program in effect at this dam. Maintenance appears to be adequate at present but it is recommended that a program of scheduled maintenance be established to assure continued safety of the dam.

The operation of the pipe outlet facility should be included in the scheduled inspection and maintenance program. The feasibility of a practical and effective warning system should be evaluated for this facility.

## SECTION 5 HYDRAULIC/HYDROLOGIC

### 5.1 Evaluation of Features

- a. Design data. No hydrologic or hydraulic design data were available for evaluation of this dam or reservoir; however, dimensions of the dam were surveyed. The survey data were supplied by James F. McCaul III and Associates of Potosi, Missouri. Other relevant data were measured during the visual inspection or estimated from topographic mapping. The maps used in the analyses were the US Geological Survey Bonne Terre (1958) and Mineral Point (1958) 7.5-minute quadrangle maps.
- b. Experience data. No recorded rainfall, runoff, discharge, or pool stage historical data were found for this reservoir.
- c. Visual inspection.
  1. Watershed. The watershed is developed as light density residential community. Much of the natural vegetation was left intact while only a small portion of the land surface was developed. The area of the reservoir is approximately 18 percent of the total drainage area of 0.69 mi<sup>2</sup>.
  2. Reservoir. The reservoir and dam are best described by the maps and photographs enclosed herewith. The primary use of this impoundment is for recreation associated with the surrounding residential development.
  3. Spillway. The spillway is partially covered by an asphalt-paved road that runs the entire length of this dam. The spillway is roughly trapezoidal in shape. The relatively steep elevation drop in the discharge channel downstream of the spillway indicates that the roadway acts as the control section for flood flows.
  4. Seepage. The magnitude of seepage through this dam is very small and not hydrologically significant to the overtopping potential.



- d. **Overtopping potential.** One of the primary considerations in the evaluation of Lac Marseilles Dam is the assessment of the potential for overtopping and possible consequent failure by erosion of the embankment. Since the spillway of this dam is paved and the depth to rock is shallow, deep erosion at the control section of the spillway due to high velocity discharge is not expected to be a major consideration. The lowest portion of the dam which is near the southeast end of the dam embankment was considered to be the top of dam for the purpose of determining the overtopping potential (el. 844.9 ft).

Hydrologic analysis of this dam for the 1 and 10 percent probability-of-occurrence and Probable Maximum Floods (PMF) were all based on initial water surface elevations equal to the spillway crest elevation. This is supported by the field survey which established that the high water mark is slightly below or at the spillway crest. The results of the analysis indicate that a flood of greater than 96 percent of the PMF will overtop the dam. The PMF is defined as the flood event that may be expected to occur from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The analysis also indicates that the spillway will pass the 1 percent probability-of-occurrence flood (100-yr flood) without overtopping the dam. The total spillway capacity at maximum pool elevation (top of dam) is 2370 ft<sup>3</sup>/sec.

The following overtopping data for the PMF ratio storms were computed for the dam:

Precipitation Event	Max. Reservoir W.S. Elev., ft, MSL	Max. Depth Over Dam, ft	Max. Outflow ft <sup>3</sup> /sec	Duration of Overtopping, hrs
50% PMF	843.0	0.0	970	0.0
96% PMF	844.9	0.0	2370	0.0
100% PMF	845.0	0.1	2550	0.8

In these analyses, the 18 in. diameter outlet pipe was assumed to be inoperative. Calculation has, in any case, shown this pipe to be capable of discharging only about 40 ft<sup>3</sup>/sec.

It should be noted that at the PMF the depth of overtopping will be about 0.1 ft and the dam will be overtopped for less than 1 hour. Furthermore, it is significant to note that the crest of the dam is wide (50 ft), the entire length of the dam is traversed by a well-maintained paved asphalt roadway and the materials on the downstream slope of the dam are not highly susceptible to erosion. It is our assessment that the combined effects of the conditions described above do not represent a significant safety hazard for this dam in the event of a PMF flood.

Input data and output summaries for the hydrologic and hydraulic analyses are presented in the attached Appendix B.

## SECTION 6 STRUCTURAL STABILITY

### 6.1 Evaluation of Structural Stability

- a. **Visual observations.** The visual inspection of Lac Marseilles Dam indicated that the dam is in generally good condition. No evidence was noted of displacement of the vertical or horizontal alignment of the dam crest or other signs of slope instability, sinkhole development, slumping, detrimental settlement or animal burrows.

No significant seepage was identified either through the dam, or at the base, or at abutments of the dam.

The spillway and discharge channel appear to be in good condition. Erosion is unlikely in either of these facilities due to shallow depth to rock. Any erosion in the spillway or discharge channel would not likely pose a safety hazard to the dam due to distance from the main dam embankment and the direction of flood flows.

- b. **Design and construction data.** No design or formal construction records were available for this dam. The preliminary design prepared by Horner and Shifrin was extensively modified during construction, but no as-built drawings were available. The sources of oral information obtained by us, as well as the available data concerning the construction of this dam, are described in Section 1.2g of this report. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available.
- c. **Operating records.** No operating records or water level records are maintained for this facility.
- d. **Post construction changes.** Post construction changes to the dam or facilities were not apparent from the visual inspection.

- e. **Seismic stability.** The dam is located in Seismic Zone 2, to which the guidelines assign a moderate damage potential. During a seismic event, liquefaction of the embankment materials is unlikely. However, without knowledge of the static stability of the dam or the soil properties of the embankment materials, the seismic stability cannot be evaluated.

## SECTION 7 ASSESSMENT/REMEDIAL MEASURES

### 7.1 Dam Assessment

- a. **Safety.** Based on our visual inspection and the evaluation of available data, the dam appears to be in generally good condition.

The slopes of the dam indicate no signs of any movement or instability. There was no observed seepage through the dam with the reservoir water surface only a few feet below the spillway elevation. Our hydrologic analyses indicate that the existing spillway will safely pass 96 percent of the PMF. A flood event with the intensity of 100 percent of the PMF would only overtop a portion of the embankment by 0.1 ft for a period of less than 1 hour (analysis assumes that the existing 18-in. diameter pipe outlet facility is inoperative at the time of flooding). The crest of the dam is 50 ft wide, is traversed for its entire length by an asphalt-paved roadway and the materials on the downstream slope are not highly susceptible to erosion. The spillway discharge channel is underlain by bedrock at shallow depth, is located in a good position with respect to the main dam embankment and discharges the flow into a separate adjacent drainage valley. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available.

- b. **Adequacy of information.** The visual inspection and the information obtained from other sources provided sufficient information to support the conclusions presented in this Phase I inspection report. However, this intermediate-size dam was constructed without a set of design plans, and as-built records are not available. The geometry of the dam section, and the description and properties of the materials used are not on record. Neither are seepage and stability analyses (static or seismic), as required by the Guidelines. This precludes a proper evaluation of the dam and is a deficiency which should be corrected.



- c. **Urgency.** The deficiencies described in this report could affect the safety of the dam. Remedial measures should be initiated as soon as practical.
  
- d. **Necessity for Phase II.** In accordance with the "Recommended Guidelines for Safety Inspections of Dams," the subject investigation was a minimum study. This study revealed that additional, in-depth investigations are needed to complete the assessment of the safety of the dam. Those investigations which should be performed as soon as practical are described in Section 7.2b. It is our understanding from discussions with the SLD that any additional investigations are the responsibility of the owner.

## 7.2 Remedial Measures

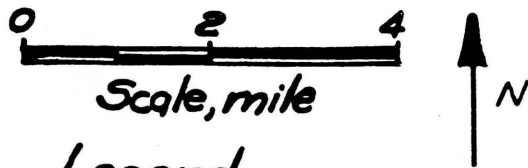
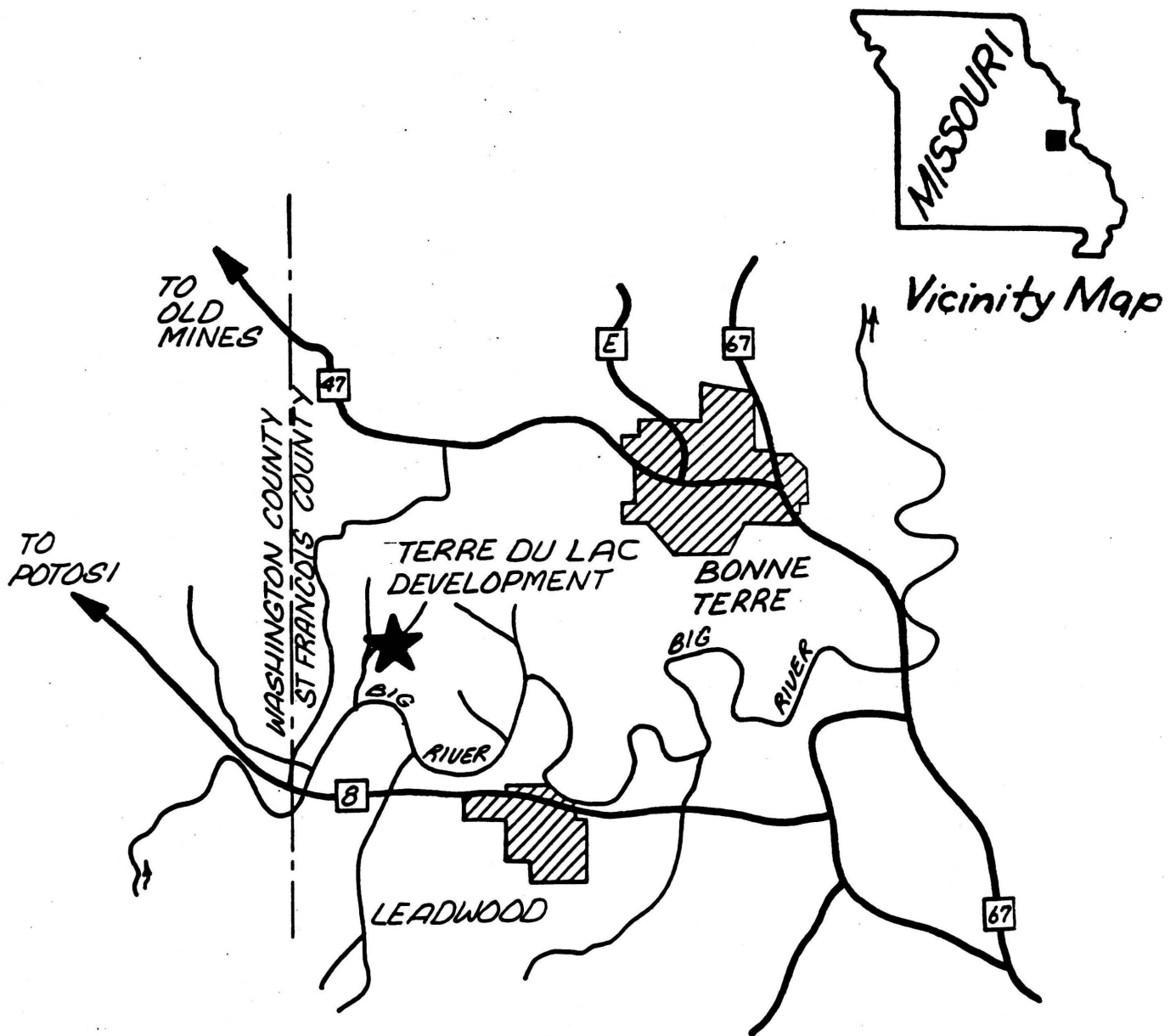
- a. **Alternatives.** There are several general options which may be considered to reduce the possibility of dam failure or to diminish the harmful consequences of such a failure. Some of these general options are:
  - 1. Remove the dam, or breach it to prevent storage of water.
  - 2. Increase the height of dam and/or spillway size to pass the PMF without overtopping the dam.
  - 3. Purchase downstream land that would be adversely impacted by dam failure and restrict human occupancy.
  - 4. Provide a highly reliable flood warning system (generally does not prevent damage but diminishes chances for loss of life).
  
- b. **Recommendations.** Based on our inspection of the Lac Marseilles Dam, it is recommended that the following topics be evaluated as soon as practical:
  - 1. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" should be performed and made a matter of record. Such analyses should consider all appropriate loading conditions, including seismic, and should be made by an engineer experienced in the design and construction of earth and rockfill dams.

2. Determine the feasibility of a practical warning system to alert downstream residents in the event unsafe conditions develop at this dam.
- c. **O & M procedures.** It is recommended that a periodic inspection and maintenance program be initiated for this facility. This program should include but not be limited to the following:
1. Checking for evidence of slope instability such as cracks, deformation on the dam face, or settling of the dam crest;
  2. Checking the amount and turbidity of seepage, if any;
  3. Maintaining the spillway discharge channel free of potential obstructions;
  4. Evaluation of the condition and an assessment of the need for repair of the sluice gate mechanism in the pipe outlet facility at the dam.

This program should be under the guidance of an engineer experienced in the design, construction and maintenance of earth and rockfill dams.

## REFERENCES

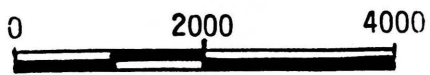
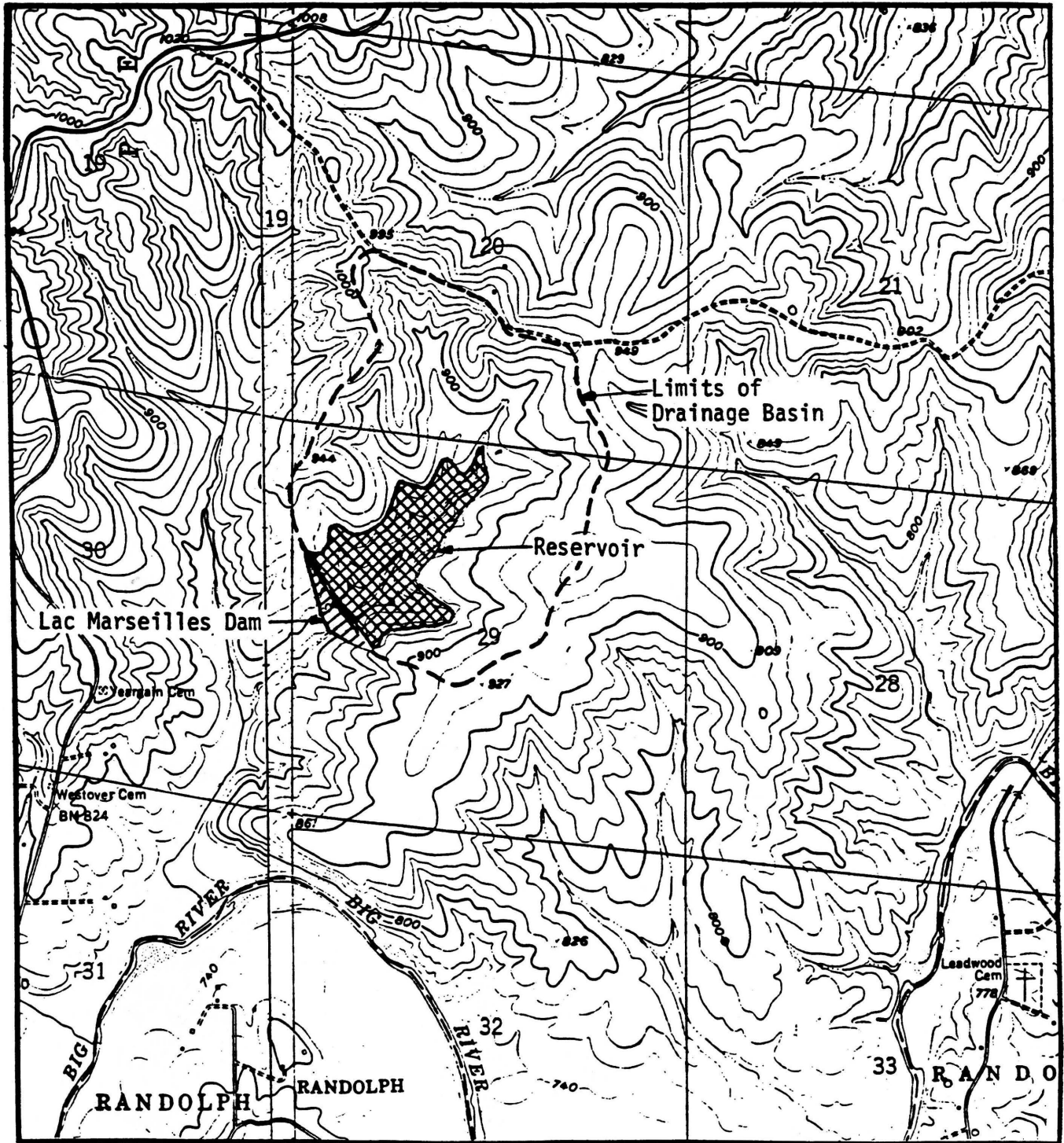
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**Legend**

-  County Line
-  State highway and Route No.
-  River or Creek
-  City or Town
-  Project location

<b>SITE LOCATION MAP</b>	
LAC MARSEILLES DAM	
MO 30282	Fig. 1



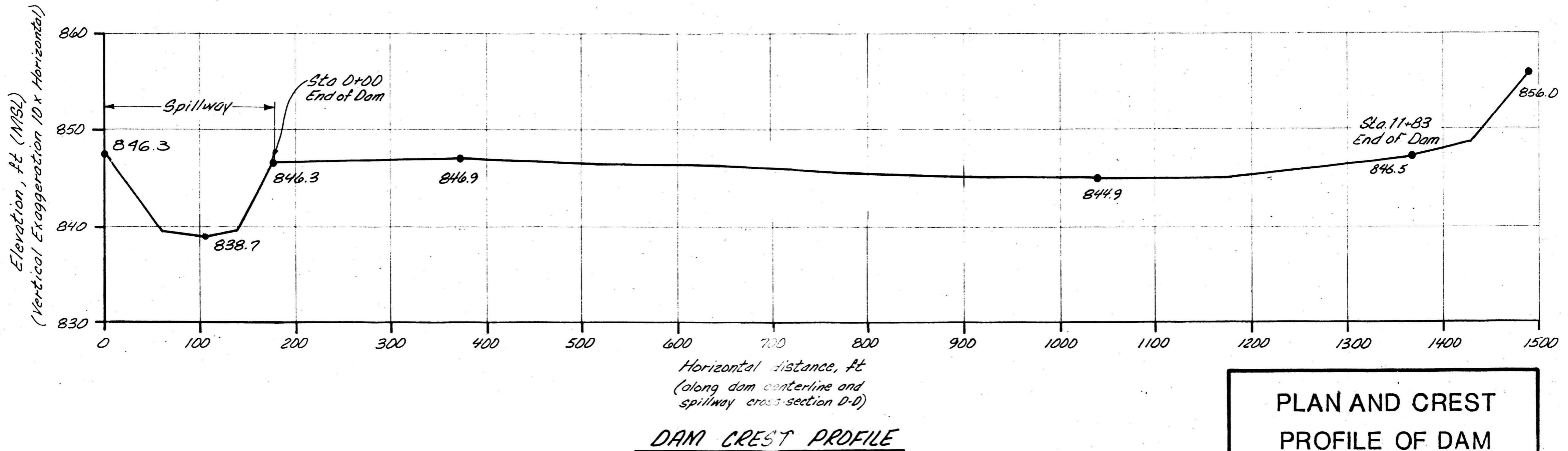
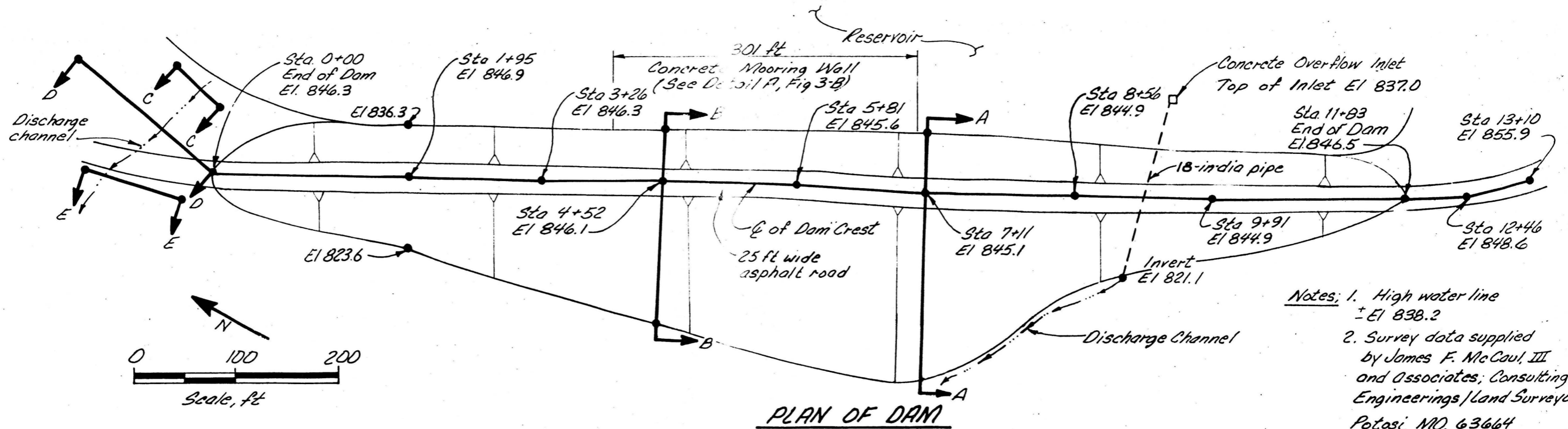
Scale, feet

NOTE

Topography from USGS  
 Bonne Terre (1958) and  
 Mineral Point (1958)  
 7.5-minute quadrangle  
 maps

<b>DRAINAGE BASIN AND SITE TOPOGRAPHY</b>	
<b>LAC MARSEILLES DAM</b>	
<b>MO 30282</b>	<b>Fig. 2</b>



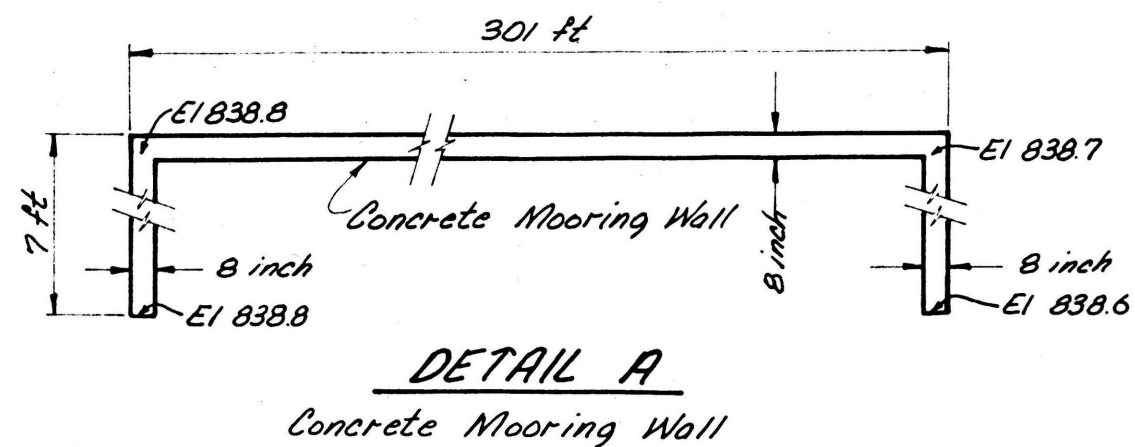
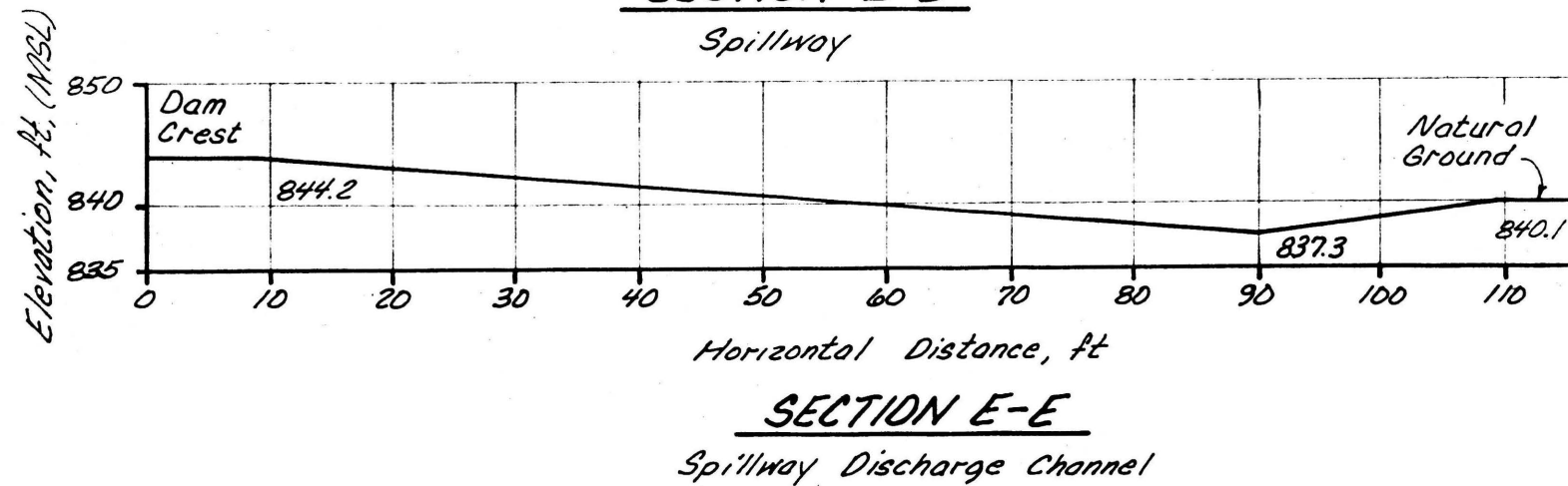
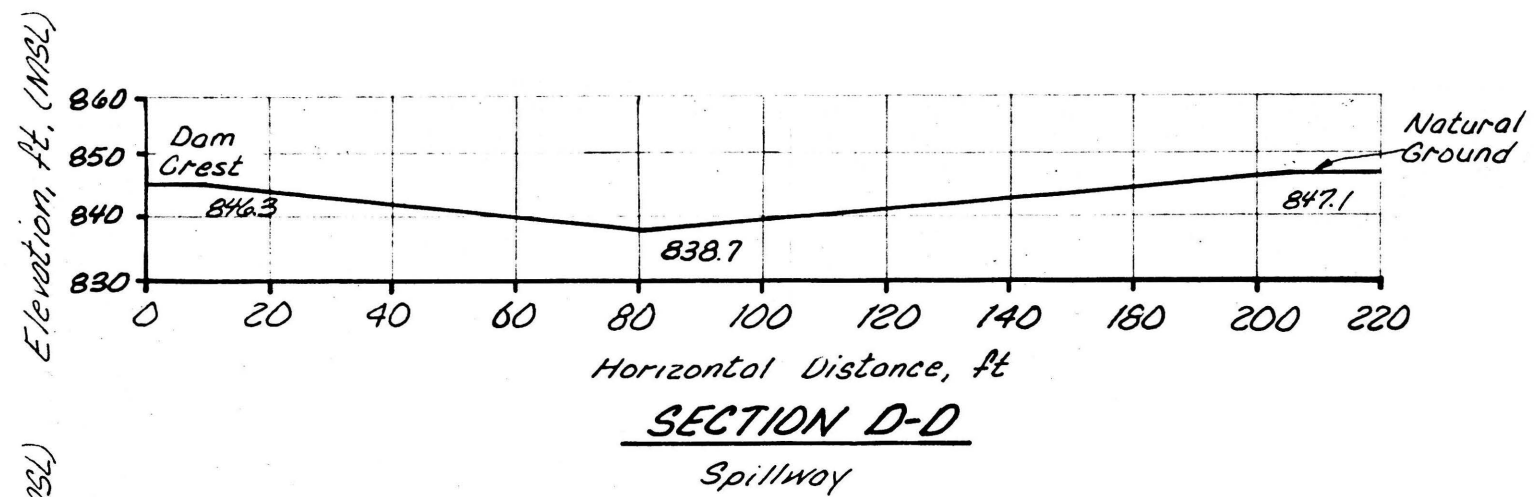
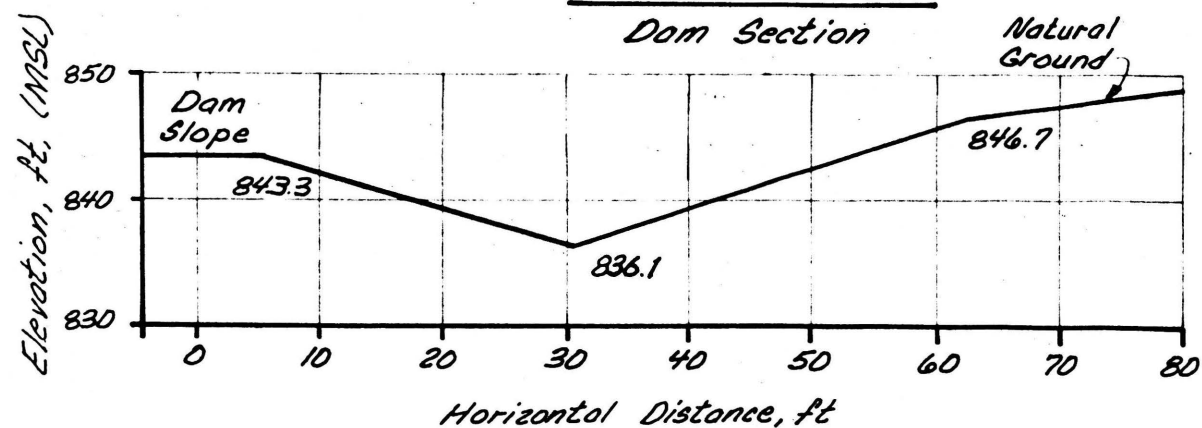
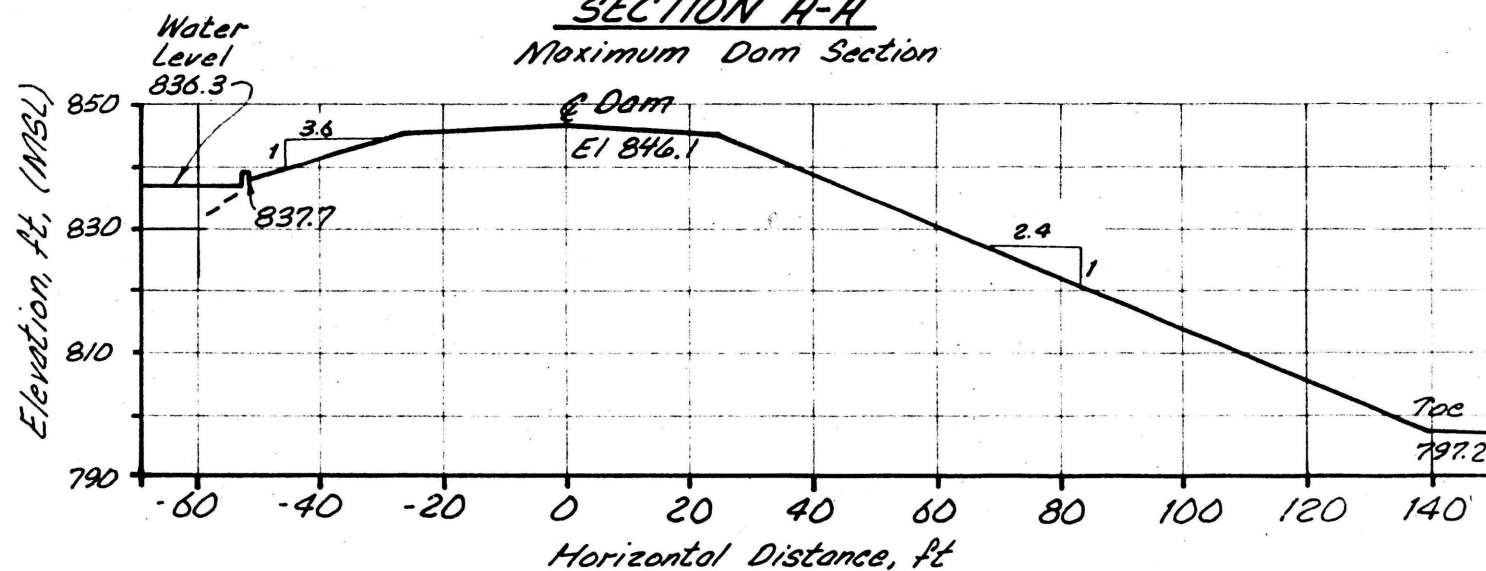
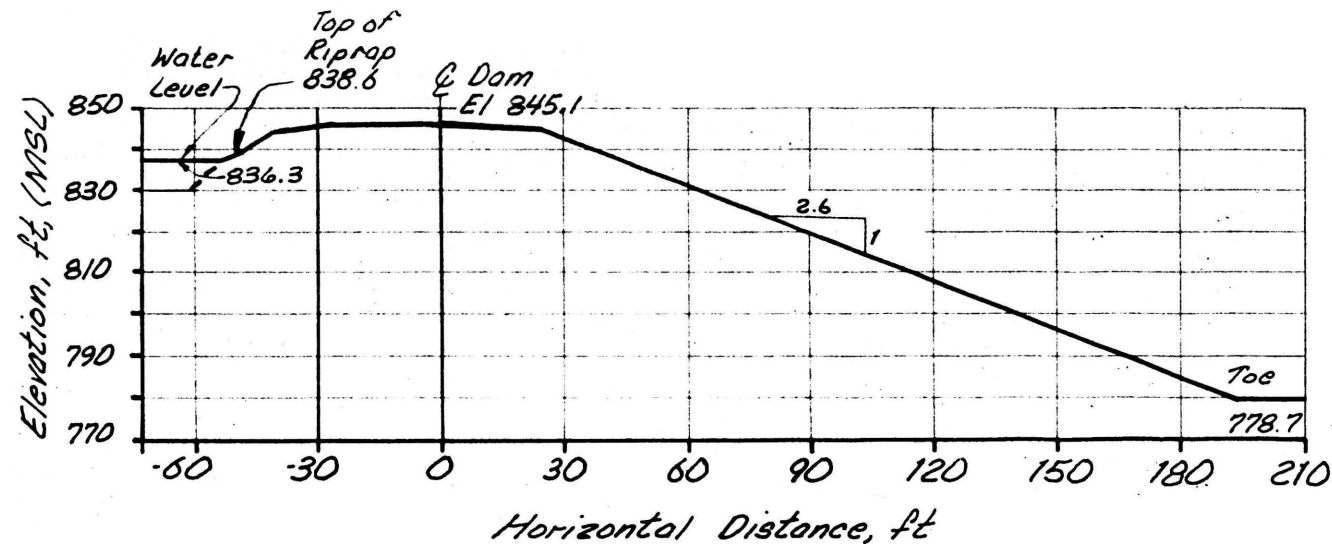


**PLAN AND CREST  
PROFILE OF DAM**

LAC MARSEILLES DAM

MO 30282

Fig. 3-A



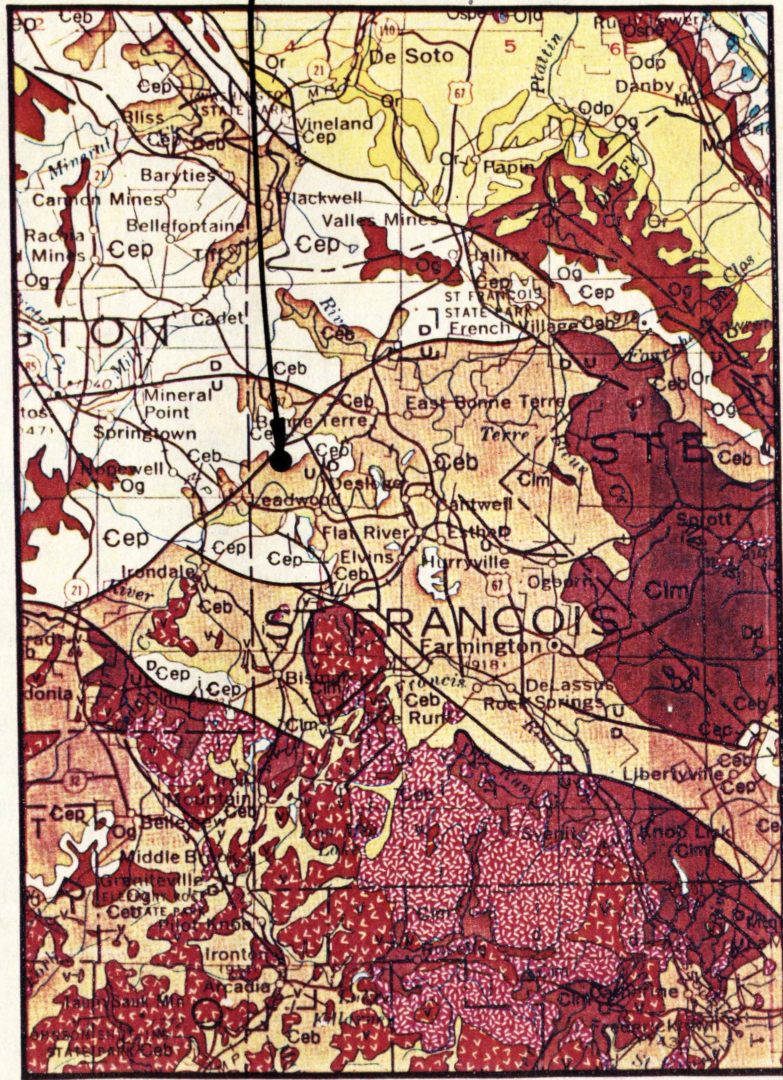
**SECTIONS OF DAM  
AND SPILLWAY**

LAC MARSEILLES DAM

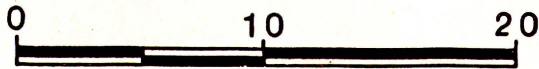
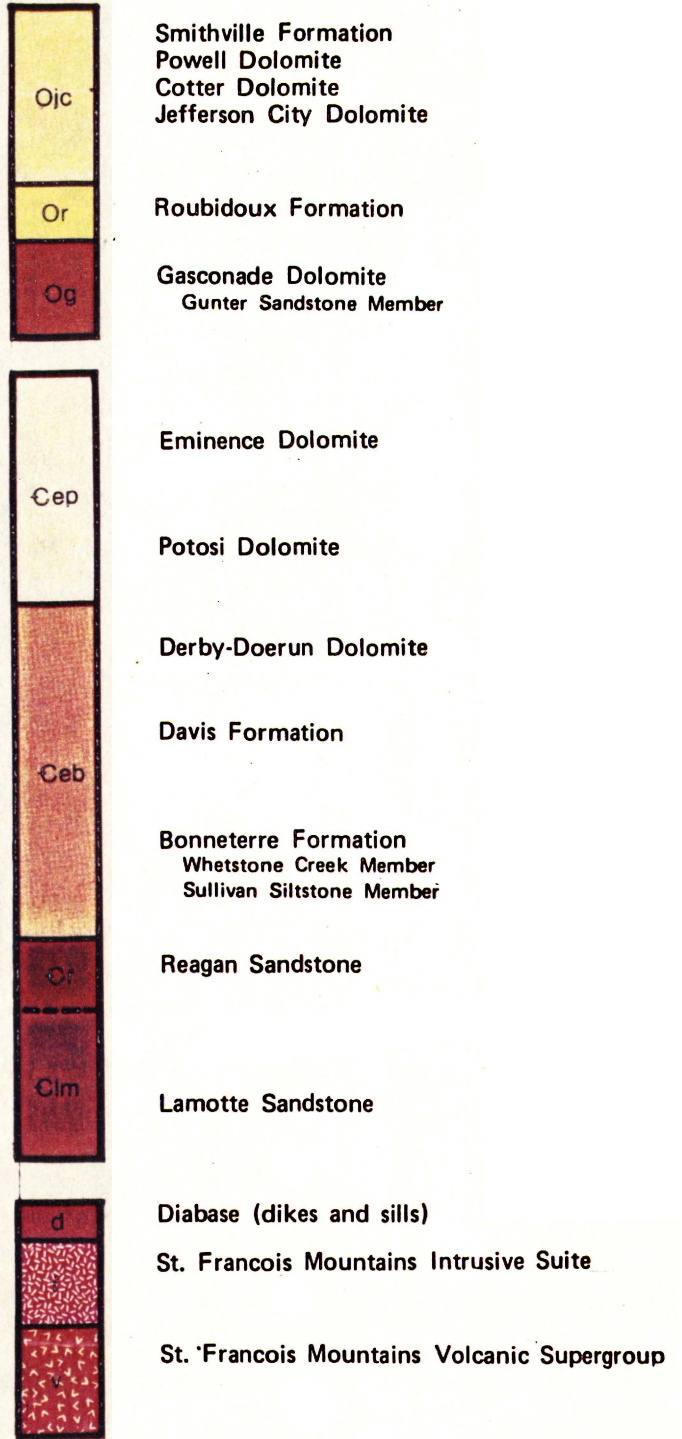
MO30282 Fig. 3-B



*Dam Location*



**Légend**



Scale, mile

**REGIONAL  
GEOLOGIC MAP**

**LAC MARSEILLES DAM**

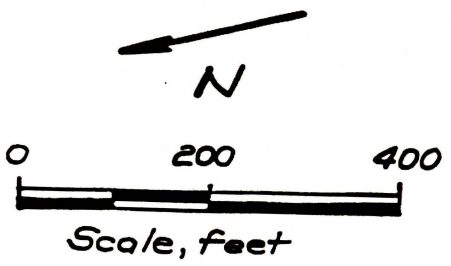
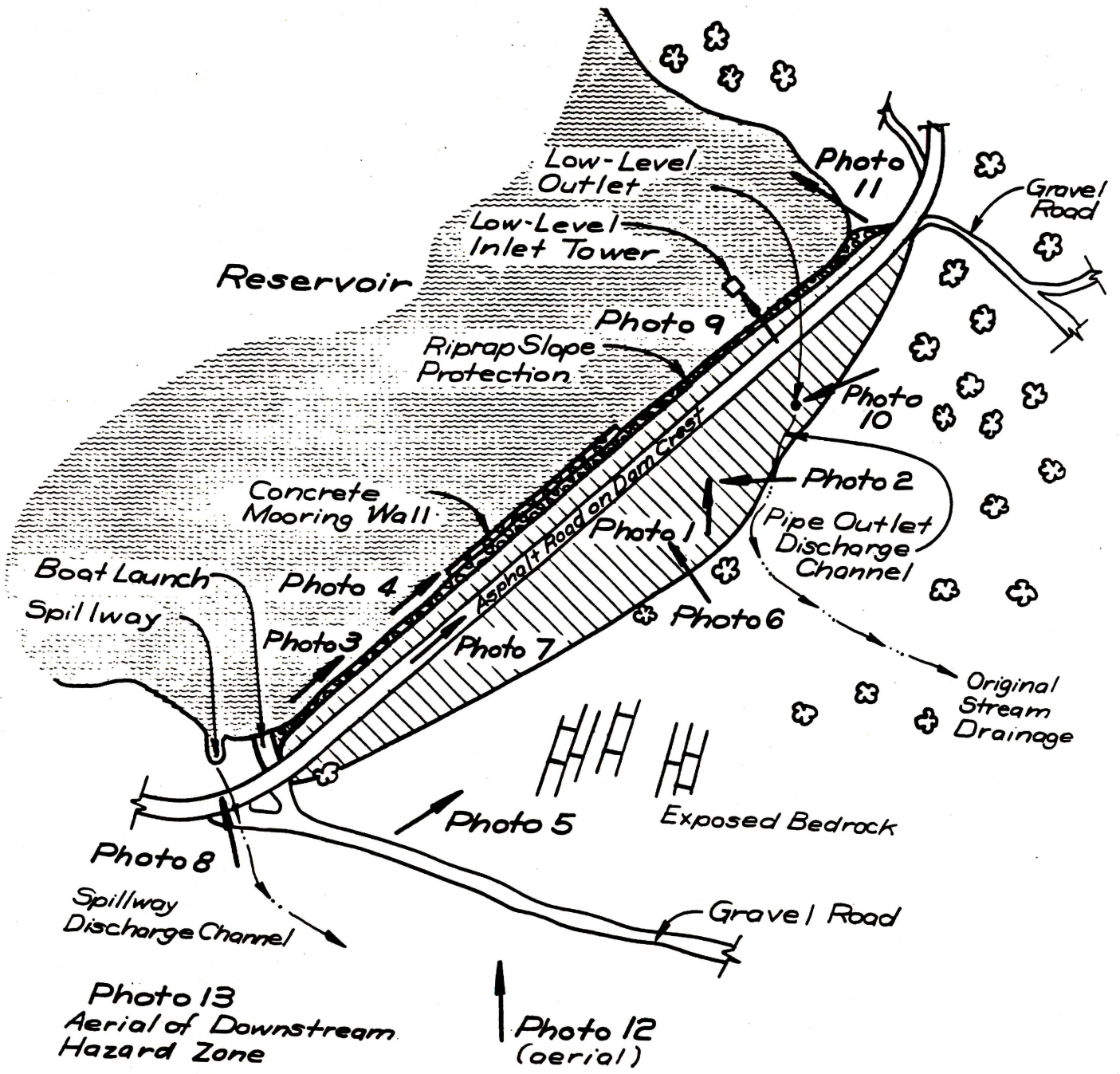
**MO 30282**

**Fig. 4**

## **APPENDIX A**

### **Photographs**





<b>PHOTO LOCATION SKETCH</b>	
LAC MARSEILLES DAM	
MO 30282	Fig. A-1



1. Stoney soil used in dam construction. View of downstream face. Lens cover for scale.



2. Downstream face of dam showing minor rill erosion and material used in construction of dam. Note also variation in density of vegetation cover. Clipboard for scale.





3. Riprap shore protection on upstream slope of dam. Looking southeast from right abutment.



4. Concrete mooring wall along center third of dam. Looking southeast.





5. Downstream slope of dam showing grass and weed cover. Looking southeast.



6. Downstream slope of dam showing scattered bare areas and minor rill erosion. Looking northeast from toe of dam.





7. Asphalt road on crest of dam. Note broad dam width and lack of any disruption of vertical or horizontal alignment. Looking southeast.



8. Spillway located at right (north) abutment. Note asphalt road across spillway. Looking east from head of discharge channel.





9. Top of concrete inlet tower for pipe outlet facility near left (south) abutment. Looking northeast from crest of dam.



10. 18-inch outlet pipe for outlet structure at left abutment. Pipe flow estimated at 20 gal/min. Looking north.





11. Wave-notched shoreline. Eroded to shallow bedrock, approximately 3 ft. Looking north from left abutment.



12. Discharge channel area in lower left of photo. Channel flows on exposed bedrock for most of its length. Note that discharge is routed well away from toe of embankment. Looking east.



13. Typical structures in downstream damage zone. Located about 1 mile downstream of dam.



## **APPENDIX B**

### **Hydraulic/Hydrologic Data and Analyses**

**APPENDIX B**  
**Hydraulic/Hydrologic Data and Analyses**

**B.1 Procedures**

- a. **General.** The hydraulic/hydrologic analyses were performed using the "HEC-1, Dam Safety Version (1 Apr 80)" computer program. The inflow hydrographs were developed for various precipitation events by applying them to a synthetic unit hydrograph. The inflow hydrographs were subsequently routed through the reservoir and appurtenant structures by the modified Puls reservoir routing option.
- b. **Precipitation events.** The Probable Maximum Precipitation (PMP) and the 1 and 10 percent probability-of-occurrence events were used in the analyses. The total rainfall and corresponding distributions for the 1 and 10 percent probability events were provided by the St. Louis District, Corps of Engineers. The Probable Maximum Precipitation was determined from regional curves prepared by the US Weather Bureau (Hydrometeorological Report Number 33, 1956 reprinted 1967).
- c. **Unit hydrograph.** The Soil Conservation Services (SCS) Dimensionless Unit Hydrograph method (National Engineering Handbook, Section 4, Hydrology, 1971) was used in the analysis. This method was selected because of its simplicity, applicability to drainage areas less than 10 mi<sup>2</sup>, and its easy availability within the HEC-1 computer program.

The watershed lag time was computed using the SCS "curve number method" by an empirical relationship as follows:

$$L = \frac{\ell^{0.8} (s+1)^{0.7}}{1900 Y^{0.5}} \quad (\text{Equation 15-4})$$

where:  $L$  = lag in hours  
 $\ell$  = hydraulic length of the watershed in feet = 6700  
 $s = \frac{1000}{CN} - 10 = 2.99$

$CN$  = hydrologic soil curve number as indicated in Section B.2e.  
 $Y$  = average watershed land slope in percent = 3.8.

This empirical relationship accounts for the soil cover, average watershed slope and hydraulic length.

With the lag time thus computed, another empirical relationship is used to compute the time of concentration as follows:

$$T_c = \frac{L}{0.6} \quad (\text{Equation 15-3})$$

where:  $T_C$  = time of concentration in hours  
 $L$  = lag in hours.

Subsequent to the computation of the time of concentration, the unit hydrograph duration was estimated utilizing the following relationship:

$$\Delta D = 0.133T_C \quad (\text{Equation 16-12})$$

where:  $\Delta D$  = duration of unit excess rainfall  
 $T_C$  = time of concentration in hours.

The final interval was selected to provide at least three discharge ordinates prior to the peak discharge ordinate of the unit hydrograph. For this dam, a time interval of 10 minutes was used.

- d. Infiltration losses. The infiltration losses were computed by the HEC-1 computer program internally using the SCS curve number method. The curve numbers were established taking into consideration the variables of: (a) antecedent moisture condition, (b) hydrologic soil group classification, (c) degree of development, (d) vegetative cover and (e) present land usage in the watershed.

Antecedent moisture condition III (AMC III) was used for the PMF events and AMC II was used for the 1 and 10 percent probability events, in accordance with the guidelines. The remaining variables are defined in the SCS procedure and judgements in their selection were made on the basis of visual field inspection.

- e. Starting elevations. Reservoir starting water surface elevations for this dam were set as follows:

- (1) 1 and 10 percent probability events - spillway crest elevation, 838.7 ft;
- (2) Probable Maximum Storm - spillway crest elevation, 838.7 ft;

The 18-in. diameter low-level outlet pipe was assumed blocked or inoperable and did not pass any amount of the flood. The discharge capacity for this pipe was calculated at approximately 40 ft<sup>3</sup>/sec if operating.

- f. Spillway Rating Curve. The HEC-2 computer program was used to compute the spillway rating curve using discharge channel cross sections and conveyance characteristics.

## B.2 Pertinent Data

- a. Drainage area. 0.69 mi<sup>2</sup>
- b. Storm duration. A unit hydrograph was developed by the SCS method option of HEC-1 program. The design storm of 48 hours duration was divided into 10 minute intervals in order to develop the inflow hydrograph.

- c. Lag time. 0.82 hr
- d. Hydrologic soil group. C
- e. SCS curve numbers.
  - 1. For PMF: AMC III - Curve Number 89
  - 2. For 1 and 10 percent probability-of-occurrence events: AMC II - Curve Number 77
- f. Storage. Elevation-area data were developed by planimetering areas at various elevation contours on the USGS Bonne Terre (1958) 7.5-minute quadrangle map. The data were entered on the \$A and \$E cards so that the HEC-1 program could compute storage volumes.
- g. Outflow over dam crest. As the profile of the dam crest is irregular, flow over the crest was computed according to the "Flow Over Non-Level Dam Crest" supplement to the HEC-1 User's Manual. The crest length-elevation data and hydraulic constants were entered on the \$D, \$L, and \$V cards.
- h. Outflow capacity. The spillway rating curve was developed from the cross section data of the spillway and the downstream channel, using the HEC-2 backwater program. The results of the above were entered on the Y4 and Y5 cards of the HEC-1 program.
- i. Reservoir elevations. For the 50 and 100 percent of the PMF events, the starting reservoir elevation was also 838.7 ft, the spillway crest elevation. For the 1 and 10 percent probability-of-occurrence events, the starting reservoir elevation was 838.7 ft, the spillway crest elevation.

### B.3 Results

The results of the analyses as well as the input values to the HEC-1 program follow in this Appendix. Only the results summaries are included, not the intermediate output. Complete copies of the HEC-1 output are available in the project files.

\*\*\*\*\*  
 FLOOD HYDROGRAPH PACKAGE (HFC-1)  
 DAM SAFETY VERSION JULY 1979  
 LAST MODIFICATION 26 FEB 79  
 \*\*\*\*\*

1	A1	LAC MARSEILLES DAM NO. 30282, ST. FRANCOIS COUNTY, MISSOURI.										
2	A2	WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 80C224.										
3	A3	PROBABLE MAXIMUM FLOODS.										
4	B	288	0	10	J	0	0	0	0	0	0	0
5	B1	5										
6	J	1	2	1								
7	J1	1.00										
8	K	0	INFLOW									
9	K1	LAC MARSEILLES INFLOW COMPUTATIONS, PMF.										
10	M	1	2	0.89								
11	P	0	26	102	120	130	140					
12	T							-1	-89		0.23	
13	W2		0.52									
14	X	-1	-.05	5								
15	K	1	DAM									
16	K1	FLOOD ROUTING AND OVERTOPPING ANALYSES										
17	Y			1	1							
18	Y1	1						-838.7	-1			
19	Y4	838.7	839.4	840.0	840.4	841.0	842.0	842.7	843.4	843.8	844.9	
20	Y4	845.0	845.5	845.9	846.7							
21	Y5	0.	10.	50.	100.	200.	500.	800.	1200.	1500.	2000.	
22	Y5	2500.	3000.	3500.	4500.							
23	SA	0.	3.4	7.4	17.6	30.	44.	61.	77.5	80.	89.	
24	SA	99.										
25	SP	778.4	780.	790.	800.	810.	820.	830.	838.7	840.	844.9	
26	SE	850.										
27	SS	838.7										
28	SO	844.9	2.0	1.5								
29	SL	0.	215.	450.	640.	980.	1195.	1225.				
30	SV	844.9	845.	845.5	846.	846.5	847.	848.				
31	K	99										

Input Data  
 Various PMF Events  
 Lac. Marseilles Dam  
 MO 30282

B4

\*\*\*\*\*  
 FLOOD HYDROGRAPH PACKAGE (HFC-1)

DAM SAFETY VERSION JULY 1978  
 LAST MODIFICATION 26 FEB 79  
 \*\*\*\*\*

Output Summary  
 Various PMF Events  
 Lac Marseilles Dam  
 NO 30282

RUN DATE 81/01/04.  
 TIME 10.29.55.

B5

LAC MARSEILLES, DAM NO. 30282, ST. FRANCIS COUNTY, MISSOURI.  
 WOODWARD-CLYDE CONSULTANTS, HOUSTON JOB 80C224.  
 PROBABLE MAXIMUM FLOODS.

JOB SPECIFICATION									
NO	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
288	0	10.	0	0	0	0	0	0	0
			JUPER	NMT	LROPT	TRACE			
			5	0	0	0			

MULTI-PLAN ANALYSES TO BE PERFORMED

RTIOS = .50 1.00  
 NPLAN = 1 NRTIO = 2 LRTIO = 1

\*\*\*\*\*

SUB-AREA RUNOFF COMPUTATION

LAC MARSEILLES INFLOW COMPUTATIONS, PMF.

ISTAO	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
INFLOW	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

IHYD	IURC	IAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOV	ISAME	LOCAL
1	2	.69	0.00	.69	1.00	0.000	0	0	0

PRECIP DATA

SPFF	PMS	R6	R12	R24	R48	R72	R96
0.00	26.00	107.00	120.00	130.00	140.00	0.00	0.00

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRLE	CNSTL	ALSMX	RTIMP
0	0.00	0.00	1.00	0.00	0.00	1.00	-1.00	-89.00	0.00	.23

CURVE NO = -89.00 WETNESS = -1.00 EFFECT CN = 89.00

UNIT HYDROGRAPH DATA

TC = 0.00 LAG = .92

RECESSION DATA

STRT = -1.00 OPCS = -.05 RTICR = 5.00

UNIT HYDROGRAPH 27 END OF PERIOD ORDINATES, TC = 0.00 HOURS, LAG = .92 VOL = 1.00  
 01. 101. 211. 318. 366. 383. 319. 260. 194. 134.



5. 4. 3. 2. 1. 1. 0.

2	END-OF-PERIOD FLOW							END-OF-PERIOD FLOW							Output Summary Various PMF Events Lac Marseilles Dam MO 30282 B6
	MO.DA	HR.MM	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MM	PERIOD	RAIN	EXCS	LOSS	COMP Q	
4	1.01	.10	1	.00	.00	.00	1.	1.02	.10	145	.03	.03	.00	4.	
5	1.01	.20	2	.00	.00	.00	1.	1.02	.20	146	.03	.03	.00	11.	
6	1.01	.30	3	.00	.00	.00	1.	1.02	.30	147	.03	.03	.00	16.	
7	1.01	.40	4	.00	.00	.00	1.	1.02	.40	148	.03	.03	.00	23.	
8	1.01	.50	5	.00	.00	.00	1.	1.02	.50	149	.03	.03	.00	32.	
9	1.01	1.00	6	.00	.00	.00	1.	1.02	1.00	150	.03	.03	.00	41.	
10	1.01	1.10	7	.00	.00	.00	1.	1.02	1.10	151	.03	.03	.00	48.	
11	1.01	1.20	8	.00	.00	.00	1.	1.02	1.20	152	.03	.03	.00	54.	
12	1.01	1.30	9	.00	.00	.00	1.	1.02	1.30	153	.03	.03	.00	58.	
13	1.01	1.40	10	.00	.00	.00	1.	1.02	1.40	154	.03	.03	.00	62.	
14	1.01	1.50	11	.00	.00	.00	1.	1.02	1.50	155	.03	.03	.00	64.	
15	1.01	2.00	12	.00	.00	.00	1.	1.02	2.00	156	.03	.03	.00	66.	
16	1.01	2.10	13	.00	.00	.00	1.	1.02	2.10	157	.03	.03	.00	67.	
17	1.01	2.20	14	.00	.00	.00	1.	1.02	2.20	158	.03	.03	.00	68.	
18	1.01	2.30	15	.00	.00	.00	1.	1.02	2.30	159	.03	.03	.00	69.	
19	1.01	2.40	16	.00	.00	.00	1.	1.02	2.40	160	.03	.03	.00	70.	
20	1.01	2.50	17	.00	.00	.00	1.	1.02	2.50	161	.03	.03	.00	70.	
21	1.01	3.00	18	.00	.00	.00	1.	1.02	3.00	162	.03	.03	.00	70.	
22	1.01	3.10	19	.00	.00	.00	1.	1.02	3.10	163	.03	.03	.00	71.	
23	1.01	3.20	20	.00	.00	.00	1.	1.02	3.20	164	.03	.03	.00	71.	
24	1.01	3.30	21	.00	.00	.00	1.	1.02	3.30	165	.03	.03	.00	71.	
25	1.01	3.40	22	.00	.00	.00	1.	1.02	3.40	166	.03	.03	.00	71.	
26	1.01	3.50	23	.00	.00	.00	1.	1.02	3.50	167	.03	.03	.00	72.	
27	1.01	4.00	24	.00	.00	.00	1.	1.02	4.00	168	.03	.03	.00	72.	
28	1.01	4.10	25	.00	.00	.00	1.	1.02	4.10	169	.03	.03	.00	72.	
29	1.01	4.20	26	.00	.00	.00	1.	1.02	4.20	170	.03	.03	.00	72.	
30	1.01	4.30	27	.00	.00	.00	1.	1.02	4.30	171	.03	.03	.00	72.	
31	1.01	4.40	28	.00	.00	.00	1.	1.02	4.40	172	.03	.03	.00	72.	
32	1.01	4.50	29	.00	.00	.00	1.	1.02	4.50	173	.03	.03	.00	72.	
33	1.01	5.00	30	.00	.00	.00	1.	1.02	5.00	174	.03	.03	.00	72.	
34	1.01	5.10	31	.00	.00	.00	1.	1.02	5.10	175	.03	.03	.00	72.	
35	1.01	5.20	32	.00	.00	.00	1.	1.02	5.20	176	.03	.03	.00	72.	
36	1.01	5.30	33	.00	.00	.00	1.	1.02	5.30	177	.03	.03	.00	72.	
37	1.01	5.40	34	.00	.00	.00	1.	1.02	5.40	178	.03	.03	.00	72.	
38	1.01	5.50	35	.00	.00	.00	1.	1.02	5.50	179	.03	.03	.00	72.	
39	1.01	6.00	36	.00	.00	.00	1.	1.02	6.00	180	.03	.03	.00	73.	
40	1.01	6.10	37	.01	.00	.01	1.	1.02	6.10	181	.13	.12	.01	76.	
41	1.01	6.20	38	.01	.00	.01	2.	1.02	6.20	182	.13	.12	.01	89.	
42	1.01	6.30	39	.01	.00	.01	2.	1.02	6.30	183	.13	.12	.01	106.	
43	1.01	6.40	40	.01	.00	.01	3.	1.02	6.40	184	.13	.12	.01	130.	
44	1.01	6.50	41	.01	.00	.01	3.	1.02	6.50	185	.13	.12	.01	172.	
45	1.01	7.00	42	.01	.00	.01	4.	1.02	7.00	186	.13	.12	.01	207.	
46	1.01	7.10	43	.01	.00	.01	4.	1.02	7.10	187	.13	.12	.01	238.	
47	1.01	7.20	44	.01	.00	.01	5.	1.02	7.20	188	.13	.13	.00	263.	
48	1.01	7.30	45	.01	.00	.01	5.	1.02	7.30	189	.13	.13	.00	281.	
49	1.01	7.40	46	.01	.00	.01	5.	1.02	7.40	190	.13	.13	.00	299.	
50	1.01	7.50	47	.01	.00	.01	6.	1.02	7.50	191	.13	.13	.00	308.	
51	1.01	8.00	48	.01	.00	.01	6.	1.02	8.00	192	.13	.13	.00	312.	
52	1.01	8.10	49	.01	.00	.01	6.	1.02	8.10	193	.13	.13	.00	315.	
53	1.01	8.20	50	.01	.00	.01	6.	1.02	8.20	194	.13	.13	.00	323.	
54	1.01	8.30	51	.01	.00	.01	6.	1.02	8.30	195	.13	.13	.00	327.	
55	1.01	8.40	52	.01	.00	.01	6.	1.02	8.40	196	.13	.13	.00	329.	
56	1.01	8.50	53	.01	.00	.01	6.	1.02	8.50	197	.13	.13	.00	331.	
57	1.01	9.00	54	.01	.00	.01	6.	1.02	9.00	198	.13	.13	.00	333.	
	1.01	9.10	55	.01	.00	.01	6.	1.02	9.10	199	.13	.13	.00	334.	



	1.01	9.20	56	.01	.00	.01	6.	1.02	9.20	200	.13	.13	.00	336.
	1.01	9.30	57	.01	.00	.01	6.	1.02	9.30	201	.13	.13	.00	336.
2	1.01	9.40	58	.01	.00	.01	6.	1.02	9.40	202	.13	.13	.00	337.
3	1.01	9.50	59	.01	.00	.01	7.	1.02	9.50	203	.13	.13	.00	338.
4	1.01	10.00	60	.01	.00	.01	7.	1.02	10.00	204	.13	.13	.00	338.
5	1.01	10.10	61	.01	.00	.01	7.	1.02	10.10	205	.13	.13	.00	339.
6	1.01	10.20	62	.01	.00	.01	7.	1.02	10.20	206	.13	.13	.00	339.
7	1.01	10.30	63	.01	.00	.01	7.	1.02	10.30	207	.13	.13	.00	339.
8	1.01	10.40	64	.01	.00	.01	8.	1.02	10.40	208	.13	.13	.00	340.
9	1.01	10.50	65	.01	.00	.01	8.	1.02	10.50	209	.13	.13	.00	340.
10	1.01	11.00	66	.01	.00	.01	9.	1.02	11.00	210	.13	.13	.00	340.
11	1.01	11.10	67	.01	.00	.01	9.	1.02	11.10	211	.13	.13	.00	341.
12	1.01	11.20	68	.01	.00	.01	9.	1.02	11.20	212	.13	.13	.00	341.
13	1.01	11.30	69	.01	.00	.01	9.	1.02	11.30	213	.13	.13	.00	341.
14	1.01	11.40	70	.01	.00	.01	9.	1.02	11.40	214	.13	.13	.00	341.
15	1.01	11.50	71	.01	.00	.01	10.	1.02	11.50	215	.13	.13	.00	341.
16	1.01	12.00	72	.01	.00	.01	10.	1.02	12.00	216	.13	.13	.00	341.
17	1.01	12.10	73	.03	.01	.02	10.	1.02	12.10	217	.44	.44	.01	342.
18	1.01	12.20	74	.03	.02	.02	12.	1.02	12.20	218	.44	.44	.01	343.
19	1.01	12.30	75	.03	.02	.02	14.	1.02	12.30	219	.44	.44	.00	448.
20	1.01	12.40	76	.03	.02	.02	16.	1.02	12.40	220	.44	.44	.00	548.
21	1.01	12.50	77	.03	.02	.02	23.	1.02	12.50	221	.44	.44	.00	659.
22	1.01	13.00	78	.03	.02	.02	28.	1.02	13.00	222	.44	.44	.00	772.
23	1.01	13.10	79	.04	.02	.02	32.	1.02	13.10	223	.53	.53	.00	878.
24	1.01	13.20	80	.04	.02	.02	37.	1.02	13.20	224	.53	.53	.00	983.
25	1.01	13.30	81	.04	.02	.02	41.	1.02	13.30	225	.53	.53	.00	1039.
26	1.01	13.40	82	.04	.03	.02	45.	1.02	13.40	226	.53	.53	.00	1109.
27	1.01	13.50	83	.04	.03	.01	50.	1.02	13.50	227	.53	.53	.00	1172.
28	1.01	14.00	84	.04	.03	.01	54.	1.02	14.00	228	.53	.53	.00	1228.
29	1.01	14.10	85	.05	.03	.02	57.	1.02	14.10	229	.66	.66	.00	1278.
30	1.01	14.20	86	.05	.04	.02	61.	1.02	14.20	230	.66	.66	.00	1327.
31	1.01	14.30	87	.05	.04	.01	66.	1.02	14.30	231	.66	.66	.00	1381.
32	1.01	14.40	88	.05	.04	.01	71.	1.02	14.40	232	.66	.66	.00	1442.
33	1.01	14.50	89	.05	.04	.01	76.	1.02	14.50	233	.66	.66	.00	1500.
34	1.01	15.00	90	.05	.04	.01	80.	1.02	15.00	234	.66	.66	.00	1564.
35	1.01	15.10	91	.05	.04	.01	85.	1.02	15.10	235	.60	.60	.00	1619.
36	1.01	15.20	92	.03	.06	.02	89.	1.02	15.20	236	1.01	1.00	.00	1660.
37	1.01	15.30	93	.14	.11	.03	96.	1.02	15.30	237	1.81	1.81	.00	1744.
38	1.01	15.40	94	.39	.29	.06	113.	1.02	15.40	238	4.93	4.93	.01	2002.
39	1.01	15.50	95	.10	.09	.01	144.	1.02	15.50	239	1.31	1.31	.00	2407.
40	1.01	16.00	96	.06	.05	.01	186.	1.02	16.00	240	.81	.81	.00	3007.
41	1.01	16.10	97	.05	.04	.01	224.	1.02	16.10	241	.62	.62	.00	3607.
42	1.01	16.20	98	.05	.04	.01	243.	1.02	16.20	242	.62	.62	.00	3904.
43	1.01	16.30	99	.05	.04	.01	243.	1.02	16.30	243	.62	.62	.00	3870.
44	1.01	16.40	100	.05	.04	.01	238.	1.02	16.40	244	.62	.62	.00	3639.
45	1.01	16.50	101	.05	.04	.01	206.	1.02	16.50	245	.62	.62	.00	3228.
46	1.01	17.00	102	.05	.04	.01	181.	1.02	17.00	246	.62	.62	.00	2816.
47	1.01	17.10	103	.04	.03	.00	162.	1.02	17.10	247	.49	.49	.00	2494.
48	1.01	17.20	104	.04	.03	.00	148.	1.02	17.20	248	.49	.49	.00	2280.
49	1.01	17.30	105	.04	.03	.00	137.	1.02	17.30	249	.49	.49	.00	2073.
50	1.01	17.40	106	.04	.03	.00	127.	1.02	17.40	250	.49	.49	.00	1907.
51	1.01	17.50	107	.04	.03	.00	114.	1.02	17.50	251	.49	.49	.00	1771.
52	1.01	18.00	108	.04	.03	.00	112.	1.02	18.00	252	.49	.49	.00	1656.
53	1.01	18.10	109	.00	.00	.00	105.	1.02	18.10	253	.04	.04	.00	1557.
54	1.01	18.20	110	.00	.00	.00	99.	1.02	18.20	254	.04	.04	.00	1435.
55	1.01	18.30	111	.00	.00	.00	94.	1.02	18.30	255	.04	.04	.00	1291.
56	1.01	18.40	112	.00	.00	.00	76.	1.02	18.40	256	.04	.04	.00	1117.
57	1.01	18.50	113	.00	.00	.00	63.	1.02	18.50	257	.04	.04	.00	922.
58	1.01	19.00	114	.00	.00	.00	51.	1.02	19.00	258	.04	.04	.00	741.
59	1.01	19.10	115	.00	.00	.00	40.	1.02	19.10	259	.04	.04	.00	589.

Input Data  
Various PMF Events  
Lac Marseilles Dam  
MO 30282

B7

1	1.01	19.20	116	.00	.00	.00	32.	1.02	19.20	260	.04	.04	.00	459.
2	1.01	19.30	117	.00	.00	.00	25.	1.02	19.30	261	.04	.04	.00	388.
3	1.01	19.40	118	.00	.00	.00	21.	1.02	19.40	262	.04	.04	.00	301.
4	1.01	19.50	119	.00	.00	.00	17.	1.02	19.50	263	.04	.04	.00	251.
5	1.01	20.00	120	.00	.00	.00	15.	1.02	20.00	264	.04	.04	.00	219.
6	1.01	20.10	121	.00	.00	.00	13.	1.02	20.10	265	.04	.04	.00	187.
7	1.01	20.20	122	.00	.00	.00	12.	1.02	20.20	266	.04	.04	.00	168.
8	1.01	20.30	123	.00	.00	.00	11.	1.02	20.30	267	.04	.04	.00	154.
9	1.01	20.40	124	.00	.00	.00	10.	1.02	20.40	268	.04	.04	.00	144.
10	1.01	20.50	125	.00	.00	.00	9.	1.02	20.50	269	.04	.04	.00	136.
11	1.01	21.00	126	.00	.00	.00	9.	1.02	21.00	270	.04	.04	.00	130.
12	1.01	21.10	127	.00	.00	.00	9.	1.02	21.10	271	.04	.04	.00	126.
13	1.01	21.20	128	.00	.00	.00	9.	1.02	21.20	272	.04	.04	.00	123.
14	1.01	21.30	129	.00	.00	.00	8.	1.02	21.30	273	.04	.04	.00	121.
15	1.01	21.40	130	.00	.00	.00	8.	1.02	21.40	274	.04	.04	.00	119.
16	1.01	21.50	131	.00	.00	.00	8.	1.02	21.50	275	.04	.04	.00	118.
17	1.01	22.00	132	.00	.00	.00	8.	1.02	22.00	276	.04	.04	.00	117.
18	1.01	22.10	133	.00	.00	.00	8.	1.02	22.10	277	.04	.04	.00	116.
19	1.01	22.20	134	.00	.00	.00	8.	1.02	22.20	278	.04	.04	.00	116.
20	1.01	22.30	135	.00	.00	.00	8.	1.02	22.30	279	.04	.04	.00	116.
21	1.01	22.40	136	.00	.00	.00	8.	1.02	22.40	280	.04	.04	.00	116.
22	1.01	22.50	137	.00	.00	.00	8.	1.02	22.50	281	.04	.04	.00	116.
23	1.01	23.00	138	.00	.00	.00	8.	1.02	23.00	282	.04	.04	.00	116.
24	1.01	23.10	139	.00	.00	.00	8.	1.02	23.10	283	.04	.04	.00	116.
25	1.01	23.20	140	.00	.00	.00	8.	1.02	23.20	284	.04	.04	.00	116.
26	1.01	23.30	141	.00	.00	.00	8.	1.02	23.30	285	.04	.04	.00	116.
27	1.01	23.40	142	.00	.00	.00	8.	1.02	23.40	286	.04	.04	.00	116.
28	1.01	23.50	143	.00	.00	.00	8.	1.02	23.50	287	.04	.04	.00	116.
29	1.02	0.00	144	.00	.00	.00	8.	1.03	0.00	288	.04	.04	.00	116.

SUM 36.40 35.29 1.11 93540.  
 ( 925.11 896.11 28.11 2642.761

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME	Output Summary
CFS	3904.	1882.	616.	325.	93485.	Various PMF Events
INCHES	111.	53.	17.	9.	2647.	Lac Marseilles Dam
MM		25.37	33.24	35.01	35.01	MO 30282
AC-FT		644.32	844.34	889.23	889.23	
THOUS CU M		933.	1223.	1288.	1288.	
		1151.	1508.	1588.	1588.	B8

HYDROGRAPH AT STAINFLOW FOR PLAN 1, RTIO 1

43	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.
44	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
45	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
46	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.
47	2.	2.	2.	2.	3.	3.	3.	3.	3.	3.
48	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.
49	3.	4.	4.	4.	4.	4.	4.	4.	4.	4.
50	5.	5.	5.	6.	7.	9.	11.	14.	16.	18.
51	21.	23.	25.	27.	29.	31.	33.	35.	38.	40.
52	42.	45.	48.	57.	72.	93.	112.	121.	122.	114.
53	103.	91.	81.	74.	68.	63.	59.	56.	52.	49.
54	44.	38.	32.	25.	20.	16.	13.	10.	9.	7.
55	5.	6.	5.	5.	5.	5.	4.	4.	4.	4.
56	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.
57	4.	4.	4.	4.	4.	6.	8.	12.	16.	20.

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS  
 FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)  
 AREA IN SQUARE MILES (SQUARE KILOMETERS)

RATIOS APPLIED TO FLOWS

OPERATION	STATION	AREA	PLAN	RATIO 1	RATIO 2
				.50	1.00

HYDROGRAPH AT	INFLUW	.69	1	1952.	3704.
		( 1.791	(	99.2811	110.5611
ROUTED TO	DAM	.69	1	966.	2547.
		( 1.791	(	27.3711	72.1211

Output Summary  
 Various PMF Events  
 Lac Marseilles Dam  
 MO 30282

B9

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS  
 FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)  
 AREA IN SQUARE MILES (SQUARE KILOMETERS)

RATIOS APPLIED TO FLOWS

OPERATION	STATION	AREA	PLAN	RATIO 1	RATIO 2	RATIO 3	RATIO 4
				.95	.96	.97	.98

HYDROGRAPH AT	INFLUW	.69	1	3704.	3748.	3787.	3826.
		( 1.791	(	105.0311	106.1411	107.2411	108.3511
ROUTED TO	DAM	.69	1	2367.	2400.	2434.	2470.
		( 1.791	(	67.0211	67.9711	68.9411	69.9411



SUMMARY OF DAM SAFETY ANALYSIS

1	PLAN 1 .....		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM			
2		ELEVATION	838.70	838.70	844.90			
3		STORAGE	1902.	1902.	2418.			
4		OUTFLOW	0.	0.	2400.			
5								
6								
7		RATIO	MAXIMUM	MAXIMUM	MAXIMUM	DURATION	TIME OF	TIME OF
8		OF	RESERVOIR	DEPTH	STORAGE	OVER TOP	MAX OUTFLOW	FAILURE
9		PMF	W.S.ELEV	OVER DAM	AC-FT	CFS	HOURS	HOURS
10								
11		.50	842.44	0.00	2252.	966.	0.00	41.67
12		1.00	845.03	.13	2430.	2547.	.83	41.17
13								0.00
14								
15								
16								
17								
18								

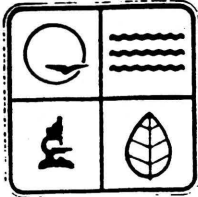
Output Summary  
 Various PMF Events  
 Lac Marseilles Dam  
 MO 30282

SUMMARY OF DAM SAFETY ANALYSIS

1	PLAN 1 .....		INITIAL VALUE	SPILLWAY CREST	TOP OF DAM	BIO		
2		ELEVATION	838.70	838.70	844.90			
3		STORAGE	1902.	1902.	2418.			
4		OUTFLOW	0.	0.	2400.			
5								
6								
7		RATIO	MAXIMUM	MAXIMUM	MAXIMUM	DURATION	TIME OF	TIME OF
8		OF	RESERVOIR	DEPTH	STORAGE	OVER TOP	MAX OUTFLOW	FAILURE
9		PMF	W.S.ELEV	OVER DAM	AC-FT	CFS	HOURS	HOURS
10								
11		.95	844.87	0.00	2416.	2367.	0.00	41.17
12		.96	844.90	.00	2418.	2400.	.17	41.17
13		.97	844.93	.03	2421.	2434.	.50	41.17
14		.98	844.97	.07	2424.	2470.	.67	41.17
15								0.00
16								
17								
18								
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22								
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24								
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33								
34								

## **APPENDIX C**

**Design Data for Lac Marseilles Dam**



January 7, 1981

Mr. Leonard Krazynski  
11 East Adams  
Suite 1500  
Chicago, IL 60603

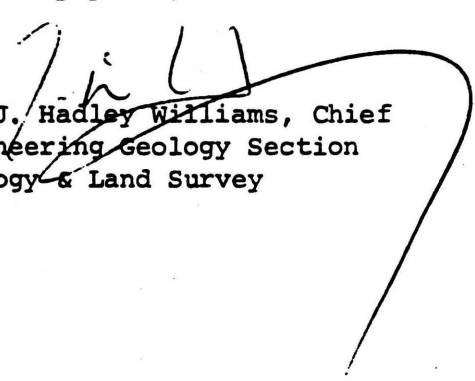
Dear Mr. Krazynski:

The attached is the only reference I have to the eastern lake. My core trench recollection of Davis shale exposure were from a visit to the development for review of their waste disposal procedures. I neglected to make a written comment for the record concerning the core trench in shale.

As I mentioned, I recall a clean trench, 15 feet or so wide, dry, and excavated into firm unweathered shale. This includes foundation and at least the lower portion of the abutments.

From my comments in the attached report, I see I was mistaken in my remarks to you about which lake experienced leakage.

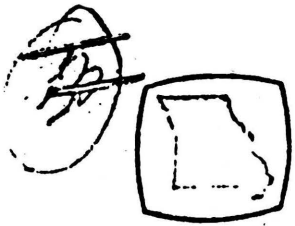
Sincerely yours,

  
Dr. J. Hadley Williams, Chief  
Engineering Geology Section  
Geology & Land Survey

MISSOURI DEPARTMENT OF NATURAL RESOURCES  
P.O. Box 250 Rolla, Missouri 65401 (314) 364-1752

Joseph P. Teasdale Governor  
Fred A. Lafser Director

Division of Geology and Land Survey  
Wallace B. Howe Director



MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

DUEHLER PARK

ROLLA MISSOURI 65401

314-364-1752

Wallace B. Howe STATE GEOLOGIST AND DIRECTOR

Larry D. Fellows ASSISTANT STATE GEOLOGIST

*Reservoir  
A. Francis 1/17*

November 10, 1971

Mr. Richard I. Bowen  
Reitz & Jens, Inc.  
Consulting Engineers  
111 South Meramec Avenue  
St. Louis, Missouri 63105

Dear Mr. Bowen:

I'm sorry to have been somewhat delayed in answering your letter. I have forgotten which lake is Lac Capri. Ed indicated that you might be in no hurry as to a reply on the particulars of that lake site, from a geologic aspect. However, I thought perhaps I would send some general information along with the idea that we could follow up with more definitive data at a later date. The area has been mapped geologically and this map is available, although it is an old report. It will be a matter of copying from the old report since it is an out of print publication.

Of the two lakes in the southeastern portion of the Terre Due Lac development, one, the western lake, is underlain by the Derby-Doerun dolomite. The eastern lake is underlain by Davis shale with faulting having occurred on the right (west) abutment. Here the Davis is faulted. Faulting has dropped the Derby-Doerun on the west so that it underlies the western lake.

The western lake underlain by massive evenly bedded Derby-Doerun dolomite, has, or at least did have, some leakage through solution enlarged joints and bedding planes of the dolomite. However, this solution enlargement is minor in my estimation and would not significantly affect water levels within the lake. It is not characterized by caves and random cavern development, but rather a network spacing of small planar openings. The rock surface profile of the Derby-Doerun at the western lake is somewhat affected by solutioning also. Consequently, it is an uneven profile with weathered dolomite making up a portion of the sub-soil profile of the overlying red clay. The red clay is a well structured, moderately permeable clay. It is low density and certainly not typical of clay in it's more commonly conceived sense. It is a kaolinite or perhaps a dehydrated halloysite with a high concentration of iron. Sodium rich dispersants would perform more successfully as sealants than bentonite. Since much of the fill of the dam for the western lake is made up of bedrock residuum and boulders, this has certainly improved the construction aspect of this lake. A dam built primarily of red clay is one where serious leakage trouble and perhaps slope failure would be expected. Therefore, the zoned construction procedures used in this dam, I think, have markedly improved it's construction and I would suspect it's performance.



Mr. Richard I. Bowen  
November 10, 1971  
Page 2

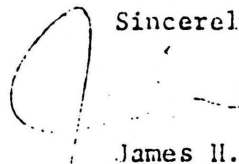
The eastern dam and lake are underlain for the most part, by a nonplastic, platy shale typical of the Davis. The weathered surface of the Davis has mixed with the overlying soil and no doubt has some plasticity. The overlying soil should be more clay-rich and thus perform somewhat better in an earthen fill than the nonplastic red clay. Faulting is of course ancient, geologically, and movement has long since ceased. I am not sure of the seismic intensity with earthquakes in the Ozarks vicinity in this area. I would suggest that you might contact Rev. Stauder, S.J. at St. Louis University for his opinion on this subject.

Water leakage through the Davis should be minor. As I recall, the core trench for the dam had been dug into firm and fresh shale. However, because of the platy characteristics of the shale, I would not be surprised to see minor seeps occurring downstream of the dam. The only hazard is that if seepage should be serious through the shale, it would be hard to cutoff. Grouting is particularly difficult and might have to be done with chemical grout. The abundance of soil cover for earthen dam construction is somewhat lacking at both sites. Therefore, I anticipate that some long distance transportation would be necessary.

I believe some considerable amount of soils investigation has been done for both of these lakes. I think Dr. Schmidt of the Civil Engineering Department at U.M.R., participated as a consultant with reference to this project. As you may know, Horner & Schifrin were also involved with Terre Due Lac. I think what grouting has been done on the western lake was completed by Red Crocker from Bonne Terre. He may have also drilled and grouted on the eastern lake. I recall seeing some AX cores laying about the site. However, I do not know the results of the drilling.

I hope that this answers, in general, your question. More detail is certainly available in our files and can be provided. Also, we can visit the lake site with you if it would be of assistance. However, because of projects being somewhat stacked up again on our calendar, it might be two to three weeks before we get there unless we happen to be working in that area.

Sincerely yours,



James H. Williams  
Geologist and Chief  
Engineering Geology

JHW/lb

## ENGINEERING GEOLOGIC REPORT ON LAC MARSEILLES AND LAC LA FITTE, TERRE DU LAC

### ST. FRANCOIS COUNTY, MISSOURI

On December 22, 1977 a brief, visual examination was made on the dams at Lac Marseilles (SW $\frac{1}{4}$ , NW $\frac{1}{4}$ , Sec. 29, T. 37 N., R. 4 E.) and Lac La Fitte (SW $\frac{1}{4}$ , NE $\frac{1}{4}$ , Sec. 28, T. 37 N., R. 4 E.).

#### LAC LA FITTE

This lake is estimated to be 50 acres in size and has a watershed of almost 600 acres. Rough field measurements show the dam to be 60' high, 50' wide, 400' long with 1 to 1 downstream slopes and 2 $\frac{1}{4}$  to 1 upstream slopes. This is a new dam and evidently much of the dam is constructed out of shale stripped from the Davis Formation. Exposures of shale can be seen in the lake basin just above the present lake level.

At the time of this examination, the lake level was 30' below the top of the dam. The spillway is 25 to 30 feet wide and is located on the east side of the dam. There will be at least 10' of freeboard.

#### SUMMARY:

This dam appears to be well built. The top of the dam is wider than most which gives it added stability.

There were a few scattered seeps at the toe of the dam. These seeps were small and not uncommon for a dam this size.

#### LAC MARSEILLES

This lake is approximately 40 acres in size with a watershed of 370 acres. The dam is about 50 to 60 feet wide at the top, and 400 feet long. The spillway is located on the west end of the dam. The floor of the spillway is 25-30 feet wide and is paved. There is a drawdown tube in the lake near the east abutment of the dam.

The dam looks stable and well constructed. There were a series of small erosion gulleys on the downstream slope. Evidently, shale was used in construction of the dam as shale is exposed in the small gulleys.

Small scattered leaks are present in bedrock joints and bedding planes on the slope downstream of the west abutment. There are also another series of small leaks that occur in the old stream channel downstream from the toe of the embankment. The leaks are marked by cattails and high brush.

The leaks are not serious nor unusual. Total estimated water flow from leaks is 40 gpm.

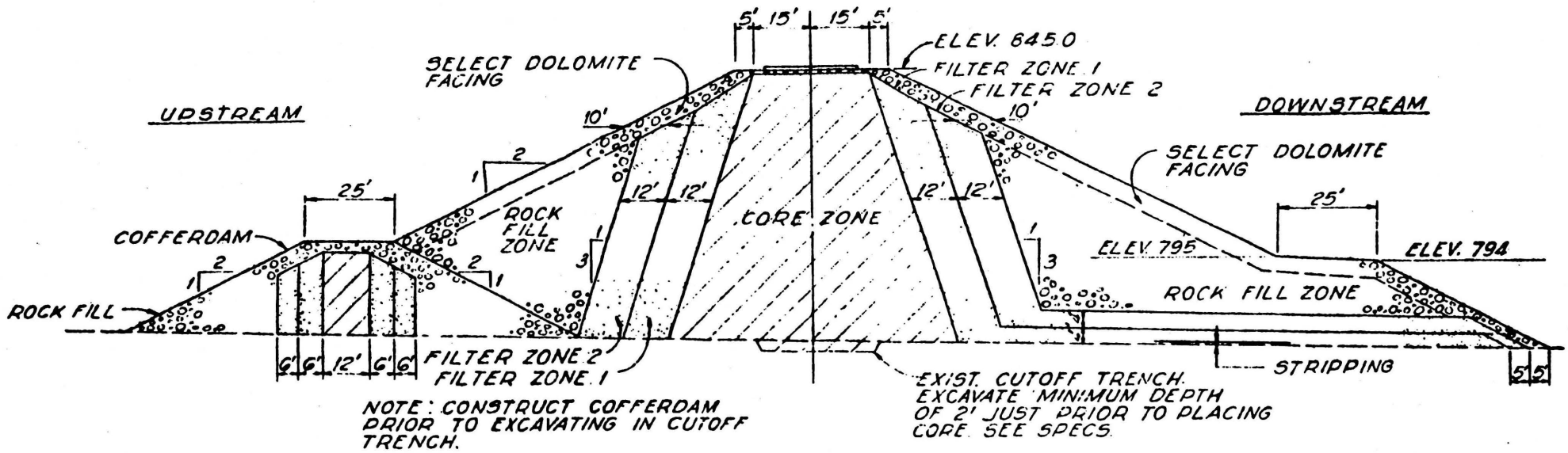
The overall condition of the dam is excellent. The wide crest of the dam enhances its stability.

RECOMMENDATIONS:

1. Flow rates from leaks should be periodically checked.
2. Erosion gulleys may eventually become deep enough to require grading. Perhaps some sort of lespedeza or stabilizing grass could be seeded on the slope to reduce erosion.

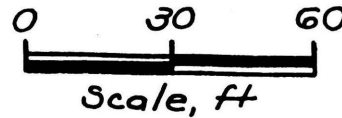
John W. Whitfield, Geologist  
Applied Engineering & Urban Geology  
Geology & Land Survey  
December 16, 1977

Quint



STA. '8+50

Note:  
 This section was reproduced from  
 Horner & Shifrin, Drawing 3 of 6,  
 Lac Marseilles Dam Profile and  
 Cross-Sections



<b>HORNER &amp; SHIFRIN PROPOSED 1969 DESIGN</b>	
<b>LAC MARSEILLES DAM</b>	
MO 30282	Fig. C-1

SPECIFICATIONS FOR CONSTRUCTION  
OF LAC CAPRI AND LAC MARSEILLES DAMS  
AND RELATED DRAINAGE FACILITIES

A. EXCAVATION

1. SCOPE

The work under these specifications shall involve the completion of the Lac Capri dam and the construction of the Lac Marseilles dam, including pipe outlets complete with gated intake structures and outlet headwalls.

2. CLEARING AND STRIPPING

In general, the area to be inundated by the lakes has already been cleared of trees; however, all areas to be occupied by permanent construction under these specifications and the surface of all borrow areas within the limits as shown on the drawings or as authorized by the Engineer shall be cleared of all trees, stumps, brush and other perishable materials. Such materials from clearing operations shall be placed in neat piles and burned or otherwise disposed of. No trees shall be cut outside of areas mentioned above without specific approval. All such trees ordered to be left standing shall be carefully protected from damage due to construction operations. Piling for burning shall be done in such a manner and at such location as to cause the least risk. Special precaution shall be taken at all times to prevent fire from spreading beyond the limits of the cleared areas. Suitable equipment shall be available at all times for use in preventing and suppressing fires. All foundation surfaces against which embankment materials are to be placed shall be stripped to a sufficient depth to remove all unsuitable materials.

3. EXCAVATION

(a) General. All excavation shall be performed in accordance with this section of the specifications to the lines, grades and dimensions shown on the drawings or as otherwise established by the Engineer. All necessary precautions shall be taken to preserve the material below and beyond the lines of all excavation in the best possible condition. Natural slopes shattered or loosened by blasting shall be taken down.

All excavation for embankment and structure foundations shall be performed in the dry. No excavation shall be made in frozen materials without approval of the Engineer.

(b) Excavation for Cut-Off Trench. The cut-off trench for the Lac Marseilles dam has been excavated. Minor modifications to the present dimensions will be required as shown on the drawings. All shale surfaces in

the cut-off trench for the Lac Marseilles Dam shall be protected from freezing and air slaking by leaving a temporary cover of two feet of unexcavated material. The final two feet of excavation in shale shall be performed during non-freezing weather. Such excavation shall be immediately followed by placement of embankment material or by the application of a protective coating of earth at least one foot in thickness. Exposed finished excavated shale surfaces shall be kept moist at all times to prevent evaporation of natural moisture in the material and such surfaces shall be protected from freezing.

(c) Rock Excavation for Pipes and Structures. Rock excavation for pipe trenches and structure foundations, shall be performed by machine or by line drilling and broaching. The spacing of such holes shall be sufficiently close to ensure the rock will break along the desired lines.

The concrete structures, and the pipeline where possible, shall be set on firm rock. The bottom rock and side walls shall be finished accurately so that construction can be performed to established line and grade. No earth or rock materials will be permitted to extend within the neat lines of the structures. Loose materials shall be removed or, if earth, moistened with water and tamped with suitable tools to form a firm foundation for the pipe.

(d) Rock Excavation for Spillway. The spillway shall be excavated through rock to the lines and grades as shown on the drawings. Accurate trimming of the rock will not be required but the excavation shall conform as closely as practicable to the established lines and grades as shown on the drawings. Loose material on side slopes above the rock shall be removed or moistened with water and compacted with suitable equipment to form a stable slope.

Rock excavation from the spillway shall be removed by blasting. Drill holes for blasting will be spaced sufficiently close to ensure the rock will break along the desired lines and to sizes which can be broken down to required gradation in the embankment with a minimum of effort. Use of heavy explosives shall be discontinued within 50 feet of the dam centerline and in other areas where in the opinion of the Engineer such heavy blasting may damage adjacent rock. In such areas rock excavation shall proceed by light blasting or by line drilling and broaching.

(e) Excavated Materials. So far as practicable, all suitable materials from excavations for cut-off trench, spillways and pipe outlet facilities shall be used in the embankments.

(f) Excavation for Borrow.

General. Earthfill materials required for construction of the dam embankments and for the upstream impervious pad along the north abutment of Lac Marseille shall be obtained from spillway excavations and from borrow areas located generally upstream of the dam sites below the normal water surface elevation as shown on the drawings.



The location and extent of all borrow pits within the borrow areas will be determined by the Engineer. The Engineer will designate the depths of all cuts in all parts of the borrow pits and may change the limits or location of borrow pits within the limits of the borrow areas in order to obtain suitable material and to minimize stripping operations. The type of operation and the equipment used in the excavation of materials from borrow pits shall be such as will produce the required distribution of the materials to be placed in the embankment.

No borrow pit shall be opened closer than 500 feet from the dam centerline. Excavated borrow pit surfaces in earth shall be graded to slopes not steeper than two on one. Excavated surfaces in rock shall be vertical or benched.

Unsuitable rock material shall be wasted as described below in "Disposal of Excavated Material." Blasting and other operations shall be such that the excavations will yield as much suitable material as practicable. Suitable material shall be excavated separately from the materials to be wasted. In excavating materials which are suitable for use in the dam, embankment depths of cut shall be used which result in the best gradation of materials for proper placement and compaction. When excavated clay materials are too wet for immediate compaction in the embankment, such materials shall be temporarily stockpiled or spread on the embankment and worked with harrow, scarifier or other suitable equipment until the moisture content is reduced sufficiently to permit them to be placed in the embankment. Should cobbles, boulders or rock fragments having average dimensions more than 6 inches be found in otherwise approved clay materials, they ~~then~~ shall be removed. Such rock materials shall be placed in the outer slopes of the embankment or wasted as directed by the Engineer.

(g) Disposal of Excavated Material. Excavated materials that are unsuitable for, or are in excess of permanent construction requirements, shall be wasted on the upstream side of the dam or in approved areas downstream of the dam site. Unsuitable impervious earth materials shall be used to pad exposed rock surfaces in the upstream areas adjacent to the dam or wasted as directed by the Engineer. Waste piles, shall be located where they will not interfere with the flow of water to or from the spillway or pipe outlet facility. Waste piles shall be leveled and trimmed to reasonably regular lines and shall neither detract from the appearance of the completed structure nor interfere with the flow of water to the spillway or pipe outlet facility.

(h) Moisture and Drainage. As far as practicable, the material to be used in the dam embankment shall be conditioned in the borrow pits before excavation. Moisture, if required by the Engineer, shall be introduced into the borrow pits by irrigation at least two days in advance of excavation operations. When moisture is introduced into the borrow pits, care should be exercised to moisten the material uniformly avoiding both excessive runoff

and accumulation of water in depressions. If the material to be excavated contains excessive moisture as determined by the Engineer, steps shall be taken to dry the material prior to placement in the embankment. Such steps may include, but shall not necessarily be limited to the following:

- (1) Excavating drainage ditches through the borrow areas;
- (2) Allowing adequate time for the open pits to air dry;
- (3) Selective excavation to secure the materials whose moisture content is closest to the optimum;
- (4) Thoroughly mixing wet material with drier material; or
- (5) Temporary stockpiling of the wet material.

To avoid the formation of pools in borrow pits, drainage ditches shall be excavated and maintained through the borrow pits where, in the opinion of the Engineer, such drainage ditches are necessary.

#### 5. BLASTING

Rock excavation in the spillway and in borrow areas except where prohibited by these specifications may be performed by blasting. Excessive charges which might tend to loosen the dam foundation or embankment will not be permitted. Once the Lac Capri dam reaches elevation 850 or the Lac Marseilles dam reaches elevation 810, blasting will be restricted to the use of light charges and will not be permitted within 1,500 feet of the dam unless specifically authorized by the Engineer. All blasting operations will be subject to the approval of the Engineer.

The transportation, handling, storage and use of dynamite and other explosives shall comply with the laws of the State of Missouri and shall be directed and supervised by a person of proven experience and ability in blasting operations working with a few trained, reliable men. Blasts shall not be fired until all persons in the vicinity have had ample notice and have reached positions out of danger therefrom.

## B. EMBANKMENT

### 1. SCOPE

The work covered by this section of the specifications consists of furnishing all plant, labor and equipment and performing all operations in connection with placing and compacting the embankment as shown on the drawings and as specified herein.

The term "embankment" as used in these specifications includes all portions of the dam as follows:

- a. Earthfill or core zones.
- b. Semi-pervious zone.
- c. Filter zone.
- d. Rockfill zone.
- e. Bedding for riprap.
- f. Riprap in the spillway and upstream slope of the embankment.

### 2. GENERAL PROVISIONS

The embankment shall be constructed to the lines and grades as shown on the drawings; however, the slopes of the division lines between zones or portions of the embankment are tentative and subject to variation by the Engineer prior to or during construction. No brush, roots, sod, or other perishable or unsuitable materials shall be placed in the embankment. The final suitability of all materials for use in the embankment will be determined by the Engineer. No embankment shall be constructed with frozen materials or on a frozen foundation.

The top of the dam shall be constructed with the edges on the construction grade and the center raised above the construction grade to provide the crown shown on the drawings. No openings through the embankment will be allowed unless specifically authorized by the Engineer. Such authorized openings shall have side slopes of the bonding surface between embankment in place and embankment to be placed not steeper than four on one. The bonding surface of the embankment in place shall be prepared as provided for embankment foundations.

### 3. PREPARATION OF FOUNDATION

No material shall be placed in any section of the embankment until the foundation for that section has been dewatered and suitably prepared and has been approved by the Engineer.

The foundation (except hard rock surfaces) for the earthfill and semi-pervious zones shall be prepared by leveling and rolling so that the surface materials of the foundation will be as compact and well-bonded with the first layer of earthfill and semi-pervious zone as herein specified for the subsequent layers of the earthfill and semi-pervious zone. Surfaces of the existing Lac Capri embankment against which earthfill and semi-pervious fill are to be placed shall first be scarrified to a depth of 6 inches to provide a surface for proper bonding with the newly-placed embankment materials. All shale foundation surfaces in the cut-off trench of Lac Marseilles dam shall be protected from air-slaking and freezing by leaving a two-foot temporary cover of unexcavated material. Finish excavation shall be made to remove such temporary cover. Surfaces upon or against which the earthfill portions of the dam embankment are to be placed shall be cleaned of all loose and objectionable material immediately prior to placing the first layer of earthfill. The surfaces of each portion of the foundation immediately prior to placing the earthfill shall have all water removed from depressions and shall be properly moistened and sufficiently clean to obtain a suitable bond with the earthfill.

#### 4. MATERIALS

(a) General. All materials required for construction of the dam including the earthfill zone, semi-pervious zone, filter zone, rockfill zone, and for riprap and bedding shall be secured from spillway excavation and from designated borrow areas. The intention is to make the best possible use of the material obtainable from these sources by proper location of materials in the embankment in accordance with the zoning as shown on the drawings and specified in the paragraph titled, "Placement." Classification of each type of material will be made in the field by the Engineer. Experience in recent work with the dolomite rock in the existing Lac Capri embankment indicates that the required particle gradation can be achieved by controlling the number of passes of compaction equipment.

(b) Earthfill or Core material. The earthfill zone of the embankment shall consist of clays and clay-shales excavated from the spillway and the designated borrow areas, reasonably free of rock fragments and cobbles.

(c) Semi-pervious zone. The semi-pervious portion of the embankment shall consist of clays and clay-shales which as excavated are mixed with considerable quantities of soft weathered dolomite rock which breaks up under rolling to form essentially a soil and which compacts without excessive voids.

(d) Filter zone. The material for the filter zone shall consist of relatively pure dolomite rock which breaks up under rolling to form essentially a soil and which compacts to a dense granular mass of the following gradational limits:

	<u>U. S. Standard Sieve Size</u>	<u>Per Cent Passing</u>
Zone 1	#4	95-100
	#20	40-80
	#50	15-45
	#100	5-25
	#200	0-15
Zone 2	3-inch	100-90
	1½-inch	90-70
	¾-inch	80-40
	⅜-inch	40-10
	No. 4	20-0

(e) Rockfill. Material for the rockfill zone shall consist of dolomite rock free of significant quantities of shale and shall be excavated from the spillway and designated borrow areas.

(f) Riprap. Riprap shall consist of rock produced from the borrow areas or spillway excavation. The rock shall be sound, durable, not weathered, and well graded in fragments from 25 to 100 pounds in weight. Bedding for riprap shall consist of rock corresponding to the requirements for filter (Zone 2) material.

## 5. PLACEMENT

(a) General. No fill shall be placed on any part of the embankment foundation until such areas have been inspected and approved. The gradation and distribution of materials throughout the compacted earth fill section of the dam shall be such that the embankment will be free from lenses, pockets, streaks, and layers of material differing substantially in texture or gradation from surrounding material of the same class. Successive loads of material shall be dumped at locations on the fill as directed or approved by the Engineer. No fill shall be placed upon a frozen surface, nor shall snow, ice, or frozen earth be incorporated in the embankment.

(b) Rate of Placement. Unless otherwise directed, the embankment shall be maintained at approximately the same level regardless of the number of types of materials being placed.

(c) Spreading. After dumping, the materials shall be spread by bulldozers or other approved means in approximately horizontal layers. The thickness of these layers before compaction shall not be more than 9 inches for materials in the earthfill, semi-pervious and filter zones. Materials in the rockfill zone shall be spread in layers not more than 18 inches in thickness prior to compaction. As soon as practicable after commencement of construction of any section of the embankment, the central portion thereof shall be raised or crowned with grades not to exceed



5 per cent so that the surface of the fill will drain freely and shall be so maintained throughout construction. If the compaction surface of any layer of earthfill or semi-pervious material is determined to be too smooth to bond properly with the succeeding layers, it shall be loosened by harrowing, or by any other approved method, before the succeeding layer is placed thereon. During the dumping and spreading processes, all roots and debris and all stones of greater than 6 inches in maximum dimension shall be removed from all embankment materials. Large stones may be blended into the downstream slope of the embankment. Roots and debris shall be disposed of in other approved locations. The entire surface of the embankment under construction shall be maintained in such condition that construction equipment can travel on any part it. Ruts in the surface of any layer shall be filled satisfactorily before compacting.

(d) Moisture Control. The materials in each layer of the fill shall contain the amount of moisture, within the limits specified below or as directed by the Engineer, necessary to obtain the desired compaction as determined by the Engineer.

(1) Earthfill and Semi-Pervious Zones. The moisture content shall be as uniform as practicable throughout any one layer of impervious materials. The upper and lower limits of moisture content shall not be more than 3 nor less than 2 percentage points, respectively, from the optimum moisture content as determined by the Engineer. Material that is too wet shall be spread on the embankment and permitted to dry, assisted by discing or harrowing, if necessary, until the moisture content is reduced to an amount within the specified limits. When the material is too dry, sprinkling each layer on the fill will be required, Harrowing, or other approved methods will be required to work the moisture into the material until a uniform distribution of moisture is obtained. Water applied on a layer of fill shall be accurately controlled in amount so that free water will not appear on the surface during or subsequent to rolling. Should too much water be added to any part of the embankment, so that the material is too wet to obtain the desired compaction, the rolling and all work on that section of the embankment shall be delayed until the moisture content of the material is reduced to an amount within the specified limits. If it is impracticable to obtain the specified moisture content by wetting or drying the material on the fill, pre-wetting or drying the material may be required at the source of excavation. If the top or contact surfaces become too dry to permit suitable bond between these surfaces and the additional fill to be placed thereon, the dried materials shall be loosened by scarifying or discing to such depths as may be directed by the Engineer. The loosened material shall be dampened to an acceptable moisture content, and shall be compacted in accordance with the applicable requirements of the paragraph entitled, "Compaction" to densities comparable to the underlying embankment.

(2) Filter Zone. The materials in the filter zone shall be saturated with water and kept in an approximately saturated condition during compaction. Jets shall not be directed at the embankment with such force that the finer materials will be washed out.

(3) Rockfill. The materials in the rockfill zone may be placed and compacted without addition of water.

(4) Riprap. Riprap shall be placed along the upstream face of both dams to the lines and thickness called for on the drawings. Riprap shall be dumped and graded off in a manner to ensure the larger fragments are uniformly distributed throughout the area to be protected. Smaller rock fragments shall be used to fill the spaces between the larger rock fragments in such a manner as will result in a compact uniform layer of riprap of the specified thickness. Bedding for riprap shall be spread without segregation over the designated areas in a uniform layer.

## 6. COMPACTION

(a) Equipment. Compaction equipment shall conform to the following requirements and shall be used as prescribed in subsequent paragraphs.

(1) Tamping Rollers. Tamping rollers shall consist of a heavy duty double drum unit with a drum diameter not less than 60 inches and an individual drum length of not less than 60 inches. The drums shall be water or sand and water ballasted. Each drum shall have staggered feet uniformly spaced over the cylindrical surface such as to provide approximately three tamping feet for each two square feet of drum surface. The tamping feet shall be 7 to 9 inches in clear projection from the cylindrical surface of the roller and shall have a face area of not less than 6 nor more than 16 square inches. The roller shall be equipped with cleaning fingers, so designed and attached as to prevent the accumulation of material between the tamping feet, and these cleaning fingers shall be maintained at their full length throughout the periods of use of the roller. The weight of the roller shall not be less than 2,500 pounds per foot of linear drum length weighted. The design and operation of the tamping roller shall be subject to the approval of the Engineer who may direct such repairs to the tamping feet, minor alterations in the roller, and variations in the weight as may be found necessary to secure optimum compaction of the earthfill and semi-pervious materials. The roller shall be self-propelled or tractor drawn at a speed not to exceed 3.5 miles per hour. Self-propelled tamping rollers may be used in lieu of tractor drawn tamping rollers, provided that, by the substitution of tamping feet not to exceed twice the face area specified for the towed rollers, the foot pressure on the tamping feet of the self-propelled roller can be adjusted to approximately the foot pressure of the towed roller for the particular working condition. In no case shall the foot areas for self-propelled tamping rollers be less than those specified for the towed rollers. For self-propelled rollers, in which steering is accomplished through the use of rubber tired wheels, the tire pressure shall not exceed 40 lbs. per square inch.

(2) Rubber-Tired Rollers. Rubber-tired rollers shall have a minimum of four wheels equipped with pneumatic tires. The tires shall be of such size and ply as can be maintained at tire pressures between 80 and 100 pounds per square inch for a 25,000 pound wheel load during rolling operations. The roller wheels will carry approximately equal load in traversing uneven ground. The spacing of the wheels will be such that the distance between the nearest edges of adjacent tires will not be greater than 50 per cent of the tire width of a single tire at the operating pressure for a 25,000 pound wheel load. The roller shall be provided with a body suitable for ballast loading such that the load per wheel may be varied, as directed by the Engineer, from 18,000 to 25,000 pounds. The roller shall be towed at speeds not to exceed 5 miles per hour. The character and efficiency of this equipment shall be subject to the approval of the Engineer.

(3) Crawler-Type Tractor. Where the Engineer directs that pervious materials be compacted by a crawler-type tractor alone, the tractor shall weigh not less than 20,000 pounds and shall exert a unit tread pressure of not less than 6 pounds per square inch.

(4) Power Tampers. Compaction of material, in areas where it is impracticable to use a roller or tractor, as provided in the paragraph below shall be performed by the use of power tampers or other approved method.

(b) Earthfill and Semi-Pervious Zone. After a layer of impervious fill material has been dumped and spread, it shall be harrowed, if required, to break up and blend the fill materials. Harrowing shall be performed with a spring-tooth harrow, or other approved harrow, to a depth at least equal to the uncompacted thickness of the layer. When the moisture content and the condition of the layer is satisfactory, the lift shall be compacted by a sufficient number of passes of the tamping roller or the rubber-tire roller to bring the lift to a minimum of 95 per cent of maximum density as determined by the standard compaction test, Method A of ASTM Designation D698. A pass shall consist of the entire coverage of the area with one trip of the equipment specified. Each trip of the tamping roller shall overlap the adjacent trip not less than 1 foot. Portions of the fill which are not accessible to the roller shall be placed in 6-inch layers and compacted with power tampers to a degree equal to that obtained on the other portions of the compacted fill by rolling as specified. Dumping, spreading, sprinkling, and compacting may be performed at the same time at different points along a section when there is sufficient area to permit these operations to proceed simultaneously. When, in the prosecution of the work, excavation precedes fill to such an extent that the materials excavated cannot be placed directly in the embankment, such materials shall be stockpiled at approved locations adjacent to the work until their use is authorized.

(c) Filter and Rockfill Zones. After each layer of filter zone material has been placed and spread, the entire surface of the layer shall be compacted by sufficient coverages of the crawler-type tractor specified in paragraph to achieve the desired gradations. A minimum

of two coverages will be required for each lift of rockfill material. A coverage by tractor shall consist of one entire coverage of the surface of a layer by the treads of the tractor. Portions of the filter and rockfill zones which are not accessible to the crawler-type tractor shall be placed in six-inch layers and compacted with vibratory compactors to a degree equal to that obtained on other portions of the compacted pervious fill by the crawler-type tractor.

## C. MISCELLANEOUS

### 1. ALIGNMENT AND SETTLEMENT MARKERS

This item covers the installation of settlement and alignment markers across the dams and abutments. The markers shall be as detailed and shall be installed at the locations shown on the drawings. All markers shall be installed after the access road and all rock dumping operations have been completed.

### 2. SEEDING

(a) General. This item covers furnishing all material and performing all work required for mulching, fertilizing and seeding. The surface to be mulched, fertilized and seeded shall include all new cut, fill and backfill areas except those surfaces covered by stone surfacing and all existing unprotected slopes directly adjacent to the project area prescribed by the Engineer.

(b) Time of Seeding Seeding shall be performed within the seeding seasons listed below. The seeding work shall be prosecuted at a rate which will ensure the seeding of all completed areas within the seeding seasons. Seeding, however, shall not be performed when conditions are unfavorable for such work.

#### Seeding Seasons

Fall Seeding	15 August to 20 September
Spring Seeding	15 February to 15 April

In the event of fall seeding, the seeding of legumes shall be postponed until the beginning of the next spring seeding season. The legumes shall be broadcast over the seeded area between 15 February and 15 March.

(c) Preparation of Seed Bed. Eroded and otherwise damaged areas to be seeded shall be repaired and dressed. Immediately prior to placing mulch, all surfaces specified to be seeded shall be loosened to a depth of not more than 4 inches by disking, harrowing or by other approved methods.

(d) Mulching of Seed Bed. After the seed bed has been prepared as specified, the entire area to be seeded shall be covered with a straw mulch. The mulch shall be applied uniformly at a rate of 4,000 pounds per acre. The mulch material shall be good quality wheat or rye straw free from Johnson Grass and any other objectionable grasses or weeds. The mulch shall be spread by hand, straw spreader, or other approved equipment, and then lightly disked.



(e) Preparing Seed Bed and Mulching Outside of Seeding Season. In order to reduce erosion during non-seeding seasons, the seed bed shall be prepared and the straw mulch placed immediately after completion of the embankment. The mulch shall be lightly disked and allowed to stand until the next specified seeding season. It shall be disked again immediately prior to seeding. Any damage which has occurred during the non-seeding periods shall be repaired and additional straw placed where it has become deficient because of wind, erosion or other cause.

(f) Fertilizer. At the time of seeding, an approved 33 per cent ammonium nitrate fertilizer shall be applied, or an approved equivalent thereof in such quantity as will yield 50 pounds of nitrogen per acre. In the case of 33 per cent ammonium nitrate, the above provisions will be interpreted to required 150 pounds of fertilizer per acre. Fertilizer shall be applied by drill, or broadcast uniformly on the area. The fertilizer shall be incorporated into the soil by disking or harrowing.

(g) Seed Mixture. The following seed mixture shall be applied to the surface specified to be seeded.

Seed Mixture Per Acre

**Smooth Brome Grass (Southern Strain) . . .	20 lbs. (pure live seed)
*Alsike Clover . . . . .	3 lbs. (pure live seed)
*Ladino Clover . . . . .	1 lb. (pure live seed)
Perennial Rye Grass . . . . .	5 lbs. (pure live seed)
*Lespedeza (Korean), Unhulled . . . . .	5 lbs. (pure live seed)

\*Indicates legumes.

\*\*The smooth brome grass seed furnished shall be true Southern strain (either Achenback or Elsberry) grown in Oklahoma, Missouri, Kansas, or Southern Illinois (south of Springfield, Illinois) and from the summer harvest next preceding the date of use.

(h) Pure Live Seed Content. For each seed ingredient in the mixture, the minimum percentage (by weight) of pure live seed (percentage purity x percentage germination) shall be as listed below. All legume live seed percentages include hard seed.

Smooth Brome Grass (Southern strain) . . .	65%
Alsike Clover . . . . .	87%
Ladino Clover . . . . .	88%
Perennial Rye Grass . . . . .	84%
Lespedeza (Korean), Unhulled . . . . .	86%

All seed containers shall be tagged or labeled to show the percentages of purity and germination. By multiplying these two percentages for each ingredient, it will be determined if the above minimum requirements have been complied with. The percentage of weed seed shall not exceed that allowed by the laws of the State of Missouri. To determine the actual weights of each seed ingredient required in seed mixture, the following formula shall be used:

$$\frac{\text{Lbs. per live seed}}{\text{Actual per cent of pure live seed}} \times 100 = \text{Actual pounds of seed required}$$

Legume Seed Inoculation. The legume seed shall be properly inoculated with approved inoculant not more than 4 hours prior to seeding. The inoculant shall be applied in accordance with the manufacturer's directions.

Planting Seed. Except for separate legume seeding as specified below, the seed shall be sown over the mulch by either a hand type or power-drawn type of seeder. Immediately after sowing, the seed shall be covered by the use of a cultipacker operated parallel to the slope.

Separate Legume Seeding. Where legumes are seeded separately because of fall seeding, any portions of the seeded areas which have been damaged by rain wash or other causes shall be repaired without additional cost by redressing, remulching, refertilizing and reseeding the damaged areas, after which the legume seed shall be broadcast over the seeded areas.

## D. PIPE OUTLET CONSTRUCTION

### 1. SCOPE

The work under these specifications shall involve the construction of 18-inch diameter pipe outlets for the two lakes complete with gated intake structure and outlet headwall.

### 2. FIELD LOCATION OF CONCRETE STRUCTURES AND PIPELINE

The planned location of the pipe and structures are shown on the drawings.

The final location of the pipeline and concrete structures shall be determined in the field. The soil overburden shall be removed at the approximate location shown for the pipeline and concrete structures and the actual rock configuration noted. The position of the structure and pipeline shall then be moved horizontally and parallel to the dam centerline until each item can be constructed on firm, sound, in-place rock. The as-constructed elevations of each item, however, shall be as shown on the drawings. All final locations are subject to the approval of the Engineer.

### 3. EXCAVATION FOR PIPE TRENCHES AND STRUCTURE FOUNDATIONS

(a) General. All concrete structures and where possible all pipes shall be set on firm rock. The bottom rock and the side slopes of either rock or common materials upon or against which concrete is to be placed shall be finished accurately to established lines and grades. No material will be permitted to extend within the neat lines of the structure. Loose materials on common side slopes shall be removed or moistened with water and tamped with suitable tools and equipment to form a firm foundation for the concrete structure. If at any point in common material, material is excavated beyond the established excavation lines for any reason except by written orders from the Engineer, the over-excavation shall be filled with select materials in layers not more than 6 inches thick moistened and thoroughly compacted by tamping or rolling. This over-excavation may be filled with concrete. Rock material excavated beyond the limits required to receive the structure shall be filled solidly with concrete.

### 4. BACKFILL OVER PIPE AND AROUND STRUCTURES

Backfill above concrete pipe encasement shall consist of materials comprising the embankment. Backfill in areas beyond the lines of the embankment shall consist of earthfill materials or soil overburden removed for pipeline construction. All backfill within 2 feet of structures and at

other locations which are inaccessible to tamping rollers shall be placed in 6-inch layers prior to compaction and each layer thoroughly compacted by special rollers, mechanical tampers or other approved methods.

## 5. PIPELINE CONSTRUCTION

(a) Ductile Iron Pipe. The pipeline shall be constructed to the line and grade shown on the drawing. The pipe shall be ductile iron conforming to the requirements of ASA Standard A21.51, thickness Class 3, and shall be furnished with mechanical joint ends conforming to ASA Standard A21.11 or shall have ends designed for use as push-on joints with trade name Bell-Tite, Fastite, Tyton or equal. All ductile iron pipe shall be installed in lengths not to exceed 20 feet. The pipe shall be coated on the exterior surface with coal tar pitch varnish to which sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, not "tacky" and brittle. Lining of pipe and hydrostatic testing will not be required.

Mechanical or push-on joints shall be installed in accordance with the recommendations of the pipe manufacturer.

(b) Pipe Laying. The pipe shall be laid and maintained to the required line and grade. Proper implements, tools and facilities shall be provided for the safe and expedient execution of the work. All pipe shall be carefully placed in the trench piece by piece in such a manner as to prevent damage to the pipe. The outside of the spigot and the inside of the bell shall be wire-brushed and wiped clean and dry and free from oil and grease before the pipe is laid.

After placing the length of pipe in the trench the spigot end shall be centered in the bell and the pipe forced home. Pipe shall be laid in a straight line with the bell ends in the direction of pipe laying. No pipe shall be laid in water or in trench conditions unsuitable for proper pipelaying and jointing.

(c) Pipe Encasement. All pipe shall be encased in concrete to the minimum dimensions and with the clearances called for on the drawing. The concrete shall be placed against the firm walls and bottom of the trench. The pipe shall be securely supported in place before and during placement of concrete. The trench shall be kept dry and free of water until the concrete has set. Backfill shall not be placed until 12 hours after the concrete encasement has been completed.

## 6. CONCRETE STRUCTURES

(a) General. The intake structure and outlet headwall shall be constructed of reinforced concrete to the lines, grades and dimensions shown on the drawings and specified herein. The intake structures shall be complete with steps and a sluice gate.

(b) Steps. The steps shall be cast iron manhole steps, Tower Grove Foundry No. B-1076 or equal.

(c) Sluice Gate.

(1) Materials. A 18-inch sluice gate shall be furnished and installed. The gate shall be of the conventional rising stem type for use with a circular wall opening and shall be designed for a maximum hydrostatic head of 20 feet, an operating head of 10 feet and an unseating head of 0 feet.

The frame, slide and wedges shall be cast iron. All seat facings shall be bronze. The facings shall be attached by bolting, brazing, dovetail notching or other approved method.

Guide Angles and fasteners shall be galvanized steel. The stem shall be cold rolled steel and shall be of the size recommended by the manufacturer. Stem guides shall be of cast iron and shall be adjustable in two directions to provide true alignment of the stem. The stem bearings shall be brass on bronze bushed. Adjustable stop collars shall be provided to limit the upward and downward travel of the stem.

A handwheel lift shall be provided for gate operation. The lift shall be of cast iron with ball or roller thrust bearings above and below a cast manganese bronze lift nut flange. Adequate grease fittings shall be provided to lubricate the bearings and other moving parts. An arrow and the word "open" shall be cast on the rim of the handwheel to indicate direction of rotation to open the gate. The maximum at the rim of the handwheel shall not exceed 25 lbs. for operation of the gate.

Anchor bolts and nuts shall be galvanized steel. They shall be of the hooked-end type and must be of sufficient quantity and length to properly anchor the unit for which they are used.

(2) Installation. Installation of all parts shall be done in a workmanlike manner. The manufacturer shall supply complete installation data, instructions for adjustment, and drawings for the gate. After the complete unit has been installed and checked, the gate shall be run through one full cycle from the fully closed position to the fully open position and back again to the fully closed.

## 7. CONCRETE

(a) Materials. Concrete shall be composed of cement, sand and coarse aggregate, water, air-entraining agent, and calcium chloride as required, all well mixed and brought to the proper consistency. In general, cement, air-entraining agent, and sealing compound for curing will be accepted on manufacturer's certification of compliance with specifications requirements.



(1) Cement. Cement shall be type I, low alkali, in accordance with the "Standard Specifications for Portland Cement" of the American Society for Testing Materials, Designation C 150.

(2) Water. Water shall be free from objectionable quantities of silt, organic matter, alkalies, salts, or other impurities.

(3) Sand and Coarse Aggregate. Sand and coarse aggregate shall be furnished from any approved source. The aggregates shall conform to the "Standard Specifications for Concrete Aggregates" of the American Society for Testing Materials, Designation C 33.

(4) Air-Entraining Agent. The air-entraining agent shall conform to the provisions of ASTM Designation C 260-58T.

(5) Curing Compound. Curing compound shall be white-pigmented compound conforming to "Tentative Specifications for Liquid Membrane-Forming Compounds for Curing Concrete," ASTM Designation C 309-58.

(b) Composition. Sand and coarse aggregate shall be mixed in proportions as directed by the Engineer. The concrete shall contain not less than 6 sacks of cement per cubic yard for concrete containing 1½-inch-maximum size aggregate and 7 sacks per cubic yard for concrete containing ¾-inch-maximum-size aggregate. One per cent of calcium chloride, by weight of the cement, shall be used in all concrete placed when the weather is cold enough to require protection of the concrete from freezing. The slump of the concrete shall not exceed 3 inches. Air-entraining agent shall be used in such amount as will effect the entrainment of from 4 to 6 per cent of air, by volume, of the concrete as discharged from the mixer. When calcium chloride is being used, the portion of mixing water containing the air-entraining agent shall be introduced separately into the mixer.

(c) Batching and Mixing. The sand and coarse aggregate shall be weighed and shall be proportioned on the basis of integral sacks of cement unless the cement is weighed. Weighing equipment of the beam type may be used. The mixing time shall be at least 1-1/2 minutes. Truck mixers will be permitted only when the mixers and their operation are such that the concrete throughout the mixed batch and from batch to batch is uniform with respect to consistency and grading. Any concrete retained in truck mixers so long as to require additional water to permit satisfactory placing shall be wasted.

(d) Forms, Preparations for Placing, and Placing. Forms shall be used to shape the concrete to the required lines. The surfaces of construction joints shall be clean and damp when covered with fresh concrete or mortar. Cleaning shall consist of the removal of all laitance, loose or defective concrete, coatings, sand, sealing compound if used, and other foreign material.

The methods and equipment used for transporting concrete, and the time that elapses during transportation, shall be such as will not cause appreciable segregation of coarse aggregate or slump loss in excess of 1 inch in the concrete as it is delivered to the work. The concrete shall be delivered to the site of the work and discharge and placing shall be completed within 1-1/2 hours after introduction of the cement to the aggregate. Retempering of concrete will not be permitted. Concrete shall be vibrated until it has been consolidated to the maximum practicable density, is free from rock pockets of coarse aggregate, and closes snugly against all surfaces of forms and embedded materials. Except for the pipe encasement, exposed unformed surfaces of concrete shall be brought to uniform surfaces and worked with suitable tools to a reasonably smooth wood-float or steel-trowel finish as directed.

(e) Protection and Curing. All concrete shall be protected against injury. The concrete shall be protected from freezing by maintaining it at a temperature not less than 50 degrees F for at least 72 hours after it is placed. The concrete shall be cured by water curing or by membrane curing. If concrete is cured by water curing, the concrete shall be kept continuously moist for at least 14 days after being placed by sprinkling or spraying or by other methods approved by the Engineer. Membrane curing of concrete shall be by application of sealing compound. Sealing compound for membrane curing shall be pigmented conforming to "Tentative Specifications for Liquid Membrane Forming Compound for Curing Concrete," ASTM Designation C 309-58. The curing compound shall be applied to formed surfaces immediately after the forms are removed and to unformed surfaces as soon as free water disappears. The curing compound shall be applied in one coat in a continuous operation by spraying. Coverage shall not exceed 150 square feet per gallon.

(f) Reinforcement. Steel reinforcement bars shall be placed in the concrete where shown on the drawings. Before reinforcement is placed, the surfaces shall be cleaned of heavy flaky rust, loose mill scale, dirt, grease, or other foreign substances. Reinforcement shall be accurately placed and secured in position so that it will not be displaced during the placing of the concrete.

Reinforcement will be inspected for compliance with requirements as to size, shape, length, splicing, position, and amount after it has been placed.