REPORT OF THE
VIRGINIA DEPARTMENT OF GAME AND
INLAND FISHERIES ON

TECHNICAL ALTERNATIVES ANALYSIS TO PROVIDE FISH PASSAGE AT EMBREY DAM

TO THE GOVERNOR AND
THE GENERAL ASSEMBLY OF VIRGINIA

SENATE DOCUMENT NO. 18

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EXECUTIVE SUMMARY

Embrey Dam is a 22' high concrete structure located just east of the Interstate 95 crossing of the Rappahannock River. The dam currently blocks anadromous fish from migrating upstream to more than 70 miles of the upper sections of the river. Virginia Senate Joint Resolution No. 296 was approved in early 1997 requesting the Virginia Department of Game and Inland Fisheries to conduct a study on the recommended methods of providing fish passage at Embrey Dam.

As a part of the study undertaken by the Virginia Department of Game and Inland Fisheries, TIMMONS, Inc. has been contracted to evaluate the technical feasibility of three previously identified alternatives for providing fish passage. The technical alternatives considered include: constructing a vertical slot fishway, breaching a portion of the dam, and removing the entire dam. To fully evaluate these options for providing fish passage, a "decision matrix" strategy was developed dividing the critical issues into technical, regulatory, and "local" categories. Issues that could be assigned specific capital and/or maintenance costs were included within a "technical decision matrix" to develop the recommendations outlined within this study. Local issues that resulted from various meetings held with federal, state, and local agencies provided input to create a "local decision matrix" of issues that have been identified for further study.

The partial and complete dam removal alternatives require that the sediment that has accumulated behind the dam be addressed. Options to address the sediment issue include full removal/hauling of the sediment off-site, and various combinations of removal, release, and stabilization of the sediment in place. The most expensive option is full removal and the least expensive option is a full release. This following financial analysis utilizes a conservative cost estimate of $4.24 million for full sediment removal to independently evaluate the three alternatives for providing fish passage.

The results of the technical decision matrix include the following:

	Fish Passage Option 1 Gravity Dam	Complete Dam Removal	Partial Dam Removal
50 year Present Worth	$ 10,200,000	$ 7,450,000	$ 7,400,000

The 50 year present worth analysis shows that either complete or partial dam removal is significantly less expensive than the most cost effective option of constructing a fish passage. The present worth of the two alternatives for dam removal are within two percent of each other. This study therefore recommends that the alternatives for either total or partial dam removal be progressed further through the regulatory process to effectively accomplish the goal of providing fish passage at Embrey Dam.

PURPOSE AND NEED FOR ACTION

History of Fish Passage

Fish passage is not a new consideration in dam construction. The impacts on migratory fishes have been recognized almost since the first blockage was created. Embrey Dam was actually constructed between 1908 and 1910 with a Kail system fish ladder in its southern abutment. The fish ladder has never been effective. In the past two decades, new emphasis has been placed on attempting to reverse the effects of dams and blockages. As part of these efforts, fish passages are being constructed, and dams are being breached or removed completely.

In 1980, Virginia and Maryland legislatures established the Chesapeake Bay Commission. The efforts of that commission to coordinate interstate planning and programs led to the 1987 Chesapeake Bay Agreement. That Agreement proposed goals and priorities that create a framework for restoring the Chesapeake Bay's resources. On December 15, 1987, representatives from Virginia, Maryland, Pennsylvania, the District of Columbia, the United States of America, and the Chesapeake Bay Commission signed the Chesapeake Bay Agreement. The goal stated in the 1987 Chesapeake Bay Agreement is to "provide for the restoration and protection of the living resources, their habitats and ecological relationships."

The Chesapeake Bay Agreement contains a commitment to "provide for fish passage at dams, and remove stream blockages whenever necessary to restore natural passage for migratory fish." Virginia Senate Joint Resolution Number 296 identifies a commitment to open 1356.75 miles of fish spawning habitat along the Bay tributaries by the year 2003. Embrey Dam currently blocks seventy miles of the upper Rappahannock River, and hundreds more miles on the Rapidan river and other tributaries. Fish Passage at Embrey Dam has been identified as a major need in reaching that goal. Figure 1 shows the river reaches that would be opened to migration by providing fish passage at Embrey Dam. A four year study (in its second year) being performed by Virginia Commonwealth University states three objectives including locating existing impediments to anadromous fishes in the Rappahannock River basin, classifying streams with respect to potential habitat quality, and developing a quantitative model of reproductive habitat relationships for anadromous clupeid fishes. This study will likely reveal many additional miles of potential spawning habitat which would be opened upon removal of Embrey Dam.

Part of Virginia State Senate Joint Resolution Number 296 directs the Virginia Department of Game and Inland Fisheries to "identify... various options, including funding needs and options, to create the fish passage." While the alternatives for providing fish passage have been defined, an evaluation of their feasibility and estimated cost is necessary to define the next step toward the ultimate stated goal of providing fish passage at Embrey Dam.

The results of the analysis of technical issues represent solutions which remove all sediment entrapped behind the Embrey Dam. The successful release of these sediments could potentially reduce the cost of both dam removal alternatives. A full release of the sediment downstream is being considered, therefore reducing the cost of disposal and/or stabilization in place. A detailed field evaluation and model has been completed to predict the fate of the sediment during a typical year and during a major storm event. The model indicates that, in a normal year, approximately 15.6 % (82,749 cubic yards) of the sediments between the I-95 bridge and Embrey Dam are scoured and transported downstream. Approximately 447,250 cubic yards will remain in place behind the dam. Sedimentation through Fredericksburg will vary from zero to approximately 0.583 inches deep. After a large flood event (similar to the major flood event in October 1942) approximately 16.6 % of the sediments between the I-95 bridge and Embrey Dam will be eroded. Sedimentation after a major flood event is estimated to produce an average layer of 0.51 inches deep in the first 7475 feet downstream of Embrey Dam and approximately 2.96 inches deep from that point through Fredericksburg. The volume of sediment predicted to be deposited in the reach of the Rappahannock through Fredericksburg is significant and will likely require dredging, which will be difficult with a thin layer over a large area. It would be easier to remove the sediment prior to removal of the dam.

To completely evaluate the impacts of the modeled sediment release, a separate impact analysis of all sediment scouring and deposition on stream biota must also be conducted. If sediment migration downstream and the scoured cross section upstream are not expected to have substantial negative biological impacts, there may be additional opportunities to reduce the estimated costs associated with both dam removal alternatives.

The regulatory issues included within the technical decision matrix include the Section 106 historic preservation, and the Section 401/404 requirements of the Clean Water Act. The section 106 requirements of historical preservation should be immediately progressed in a formal agreement between the City of Fredericksburg, the Virginia Department of Game and Inland Fisheries, and the Virginia Department of Historic Resources as one of the next steps in the process of providing fish passage. The U.S. Army Corps of Engineers (COE) should also use the results of the technical alternatives analysis to progress the environmental permitting requirements for either full or partial removal of the dam. The issues identified and listed within the "local decision matrix" can be used to begin the environmental assessment and possibly to initiate the Section 401/404 permitting process for either of these alternatives.

This report also suggests an implementation plan, schedule, and budget to progress this project to completion. The implementation plan includes the above listed issues, and suggests the following overall schedule and budget:

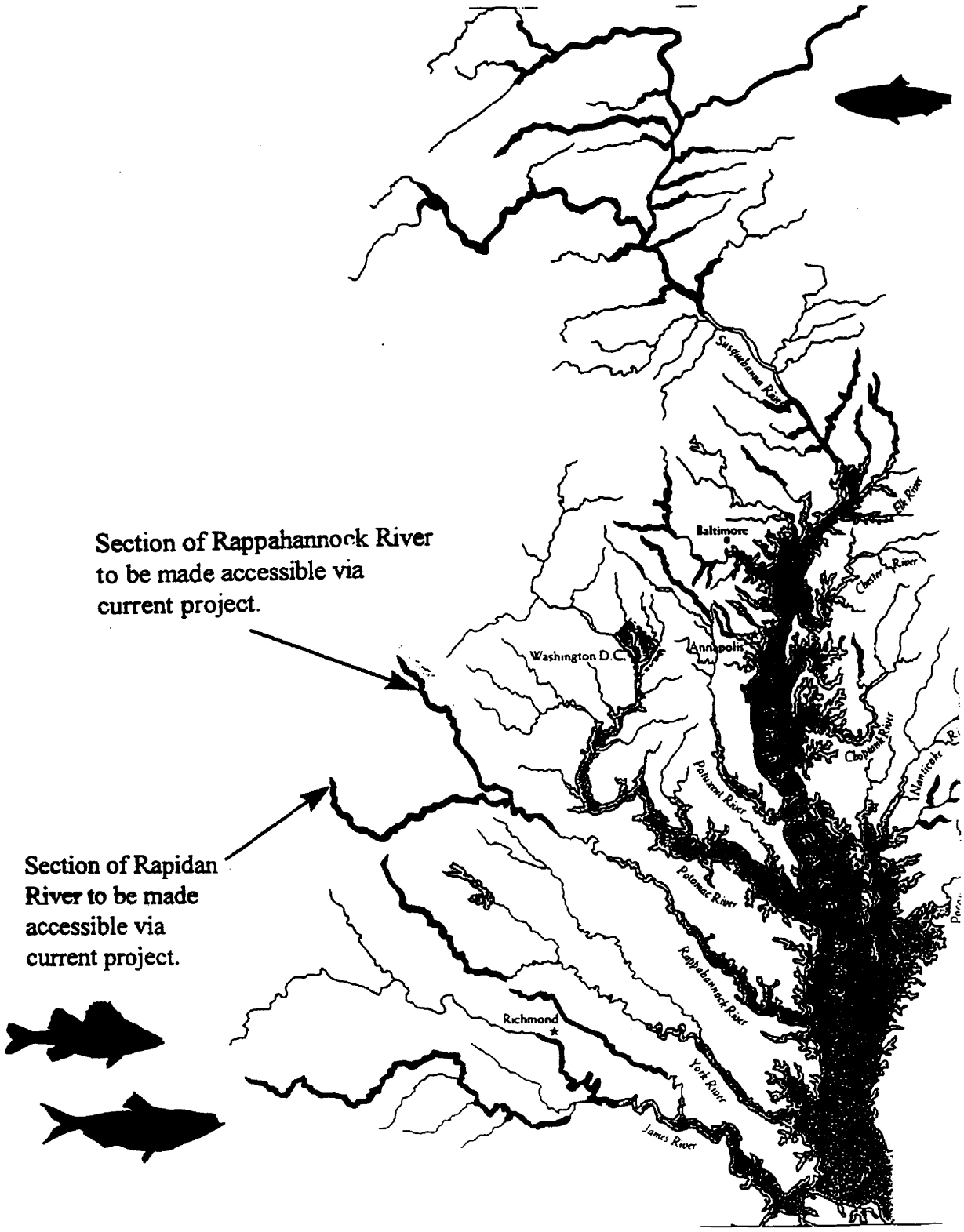
1. The environmental assessment, environmental permitting process, development of design plans and specifications, and construction process will require approximately 3 years to complete.
2. The overall cost of implementation, including design, permitting, environmental assessment and construction, will vary from $3,580,000 to $7,580,000.

Objectives of Study

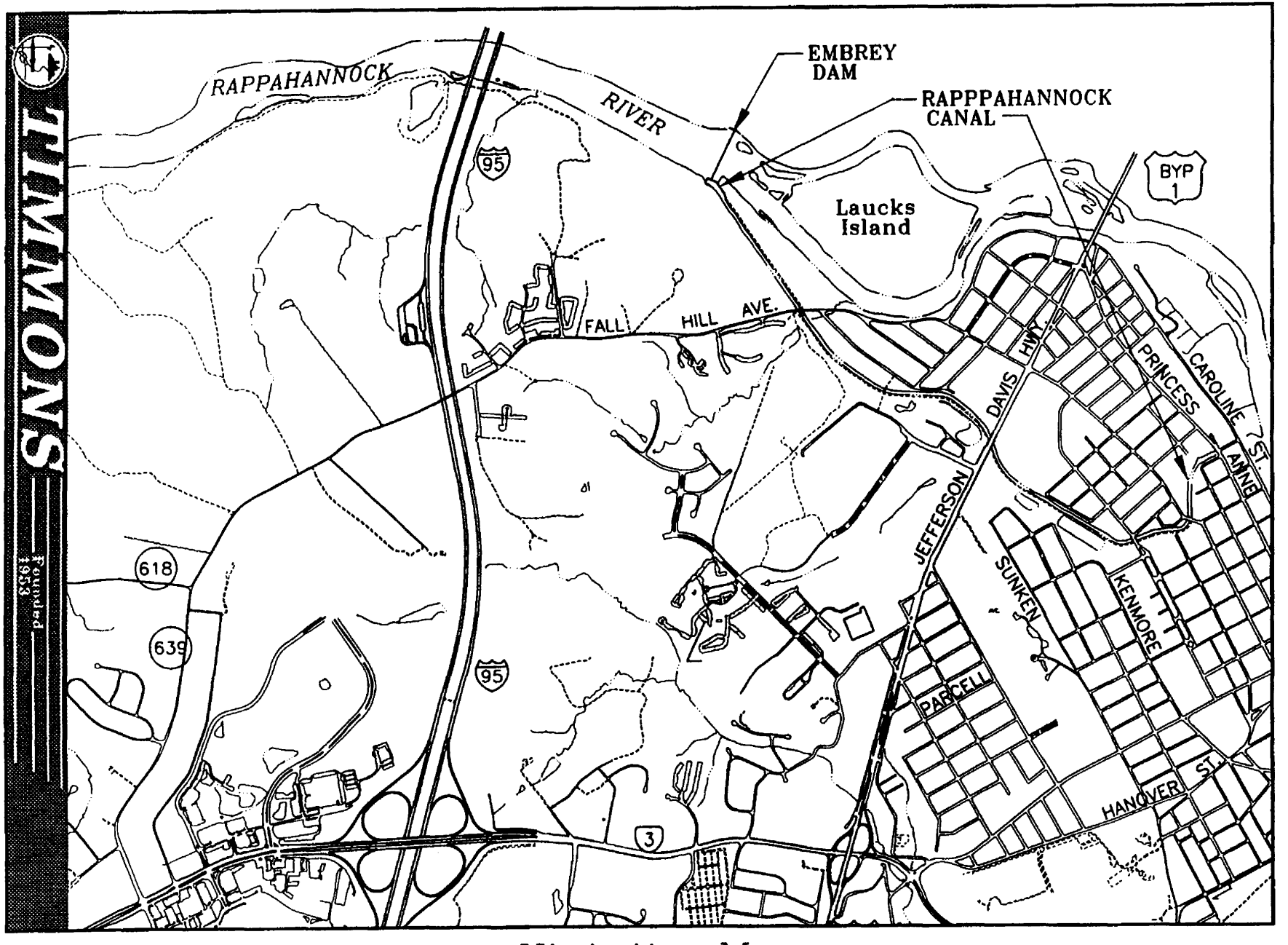
As a part of the study undertaken by the Virginia Department of Game and Inland Fisheries, TIMMONS has been contracted to evaluate the previously identified alternatives for providing fish passage with respect to technical feasibility and cost. The alternatives being considered include constructing a vertical slot fish passage, breaching a portion of the dam and removing the entire dam. The option of doing nothing is not considered an acceptable alternative because it would not fulfill the project goal. Through exploring the feasibility of each alternative for providing fish passage, this study offers estimated construction costs and assists in developing project budgets. This study will provide a method for decision making and a blueprint for progressing the project to completion.

To fully evaluate these options for providing fish passage, a "decision matrix" strategy was developed dividing the critical issues into technical, regulatory, and "local" categories. Issues that could be assigned specific capital and/or maintenance costs were included within a "technical decision matrix" to develop the recommendations outlined within this study. Local issues that resulted from various meetings held with federal, state, and local agencie,s and a public information meeting provided input to create a "local decision matrix" of issues that have been identified for further study. Regulatory issues are included in both of the matrices; if a capital cost could be included for the regulatory issue, it was included in the technical decision matrix, other regulatory issues and future planning issues are identified in the local decision matrix.

Chesapeake Bay Tributaries



(Figure 1)



Vicinity Map

(Figure 2)

EXISTING CONDITIONS

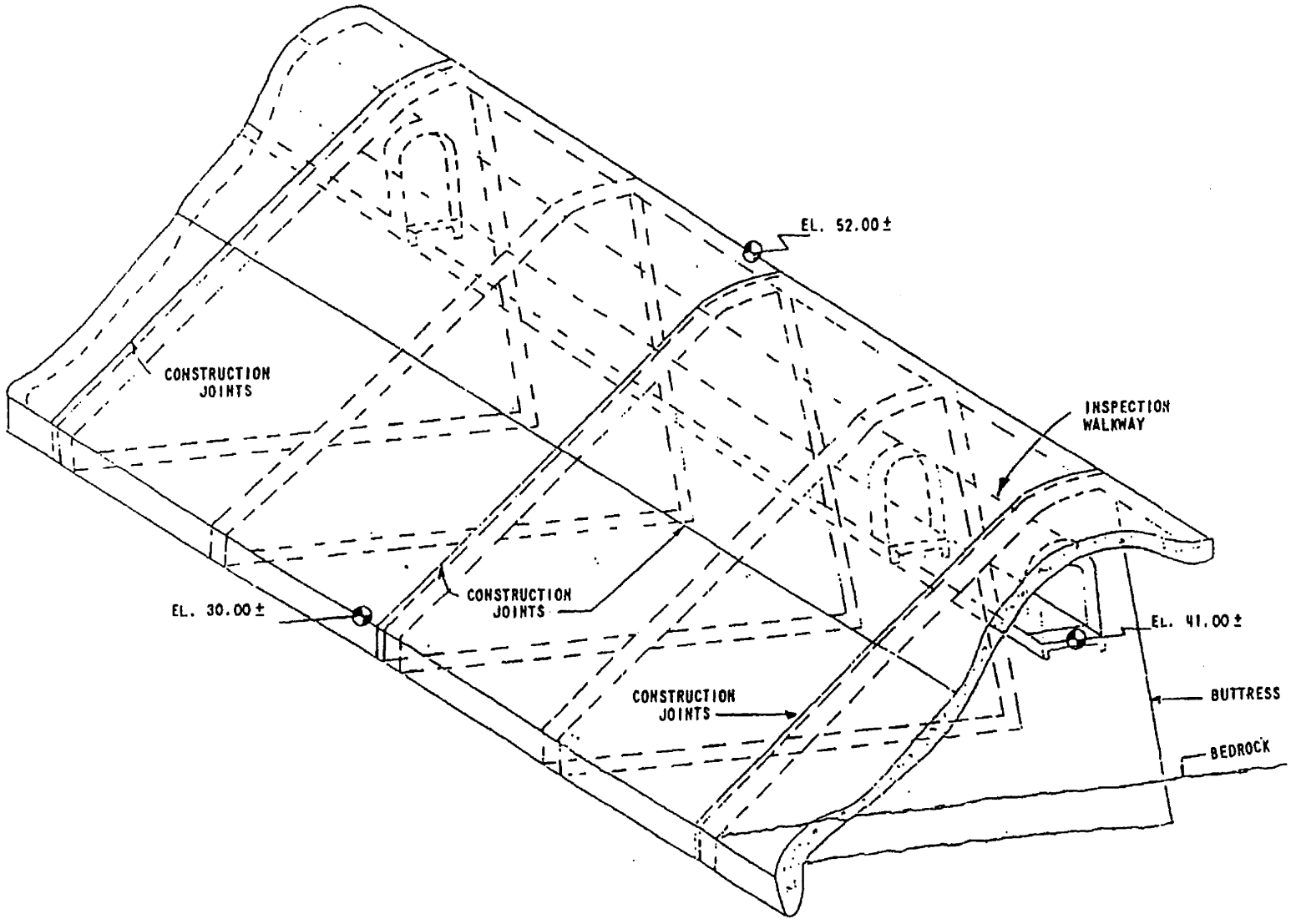
Embrey Dam is located 2.4 miles upriver of the historic center of the City of Fredericksburg (see Figure 2). The backwater from the dam extends almost to the interstate 95 bridge. The dam is owned by the City of Fredericksburg, but the majority of the dam is located in Stafford County. Only the southern end of the dam is within the limits of the City of Fredericksburg. The dam is the only major obstruction to fish migration on the Rappahannock and Rapidan Rivers. Anadromous fishes are able to migrate up to Embrey Dam, 150 miles upstream from the Chesapeake Bay, but no migration upstream of the dam is possible.

Figure 3 shows the general configuration of the dam, abutments, and beginning of the Rappahannock Canal. The dam is a concrete Ambursen dam design that uses slabs and buttresses and includes an inspection walkway through the dam and the abutments. Figure 4 shows an isometric representation of Embrey Dam. The southern abutment includes the headworks for the canal, a portion of the old canal and lock system, a gaging station used by the United States Geological Survey, and an ineffective Kail system fish ladder. While the dam is approximately 22' high, significant sedimentation has left only about 6 to 8 feet of water behind the dam. A crib dam is located just upstream of Embrey Dam. This type of dam was designed with crisscrossed timbers filled with earth and granular material. The crib dam was originally used as a source of water for Fredericksburg's hydroelectric facility. Embrey Dam was constructed to increase the level of the backwater and produce more hydroelectric power. The crib dam has been preserved by being submerged since the construction of Embrey Dam.

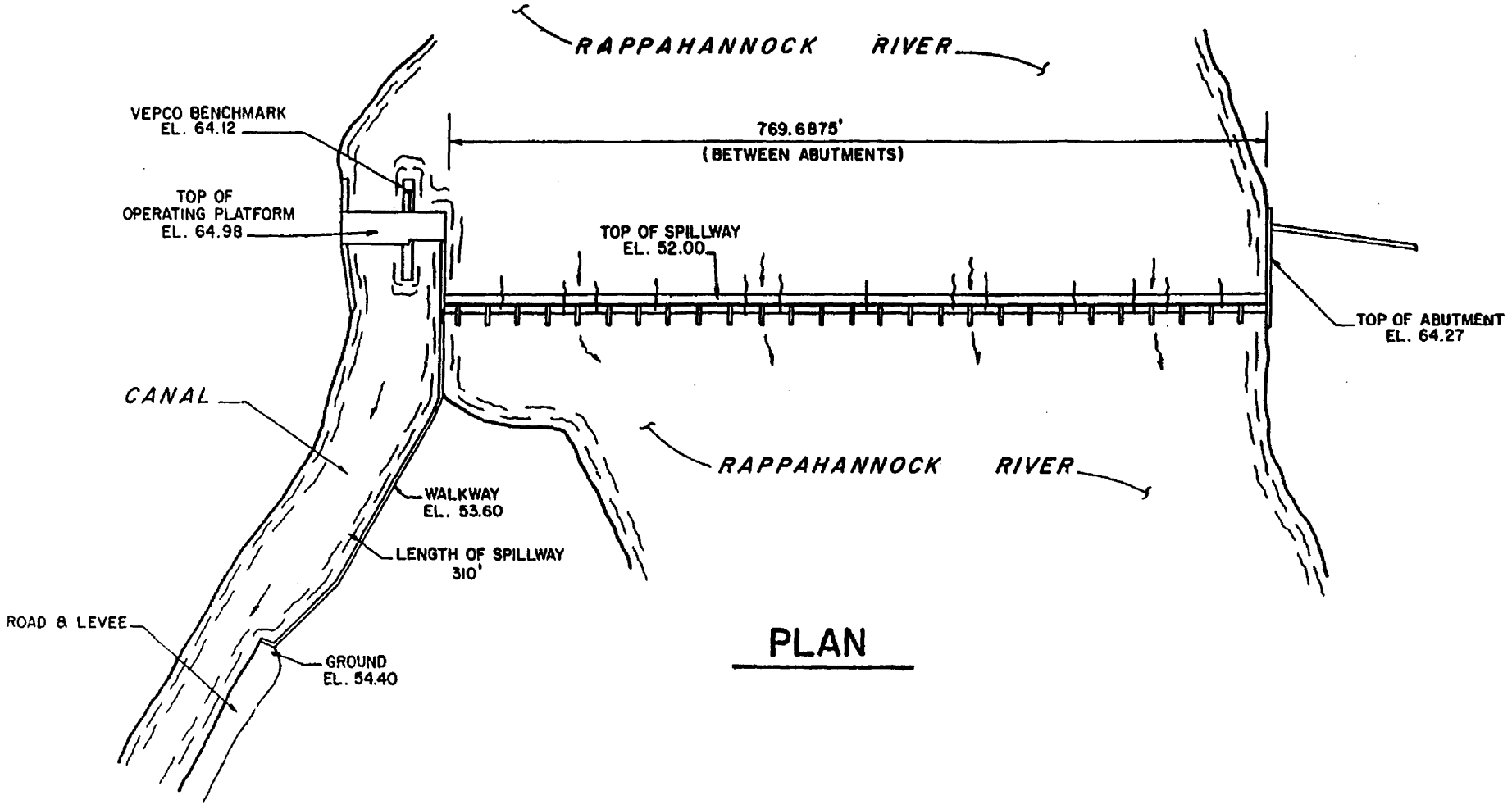
Embrey Dam is 770' long (1070' long with abutments) and the upstream slab slopes at about 38°. The foundation of the north end of the dam is significantly deeper than the rest of the dam. Before the dam was constructed, the crib dam just upstream of the area failed and the northern portion of the river was severely scoured. As a result, the river bottom in that area is low. Embrey Dam is as much as 43 feet tall in that area compared to an average height of 22'. The sloped slab is approximately 8" thick at the crest and about 1'4" thick at the heel. The buttresses are 13' 8" from center to center, and the inspection slab is at an elevation of approximately 41'.

In 1994, a report by Whitman, Requardt & Associates investigated water supply and treatment alternatives for the City of Fredericksburg. Within the report, the condition of the dam was described as relatively poor and identified the structural integrity of the dam as a concern. An inspection of Embrey Dam was recently completed for the City of Fredericksburg. A copy of the reinspection report is attached in Appendix E. The inspection included a detailed investigation of each of the 54 bays, the abutments, and the canal headworks and sidewall which are integral with the abutment. The findings from this inspection show some deterioration since the last inspection performed (1991). In particular, the rate of seepage has increased in certain areas of the dam. Portions of the inspection walkway have also deteriorated. The estimated flow in these seeping areas ranges from one or two gallons per minute to more than 30 gallons per minute. The inspection report recommends repairing the areas of seepage. In addition to the currently recommended repairs, future inspections will reveal areas in need of repair.

(Figure 4)



Isometric of Embrey Dam



Embrey Dam

(Not to Scale)

ALTERNATIVES DEVELOPMENT

This study evaluates three previously identified alternatives for providing fish passage. The alternatives being considered include constructing a fish passage, breaching the entire dam and removing portions of the dam. The option of doing nothing is not being considered an acceptable alternative because it does not fulfill the project goal.

Construction of a Fish Passage

In evaluating the feasibility of constructing a fish passage at Embrey Dam, consideration must be given to target species. Target species include American shad, hickory shad, alewife, blueback herring, and secondarily striped bass, and yellow perch. The secondary target species such as perch and bass, do not generally use fish passages. The United States Fish and Wildlife Service has recommended the facility be able to pass 150,000 shad and 1,500,000 herring during an annual migration. The Virginia Institute of Marine Science recommended twice as many of each species (300,000 shad and 3,000,000 herring). The target number for each species is based on the amount of habitat available for spawning activities.

The Virginia Department of Game and Inland Fisheries has recommended that if a fish passage is to be constructed at Embrey Dam, a vertical slot fish passage be considered. Dick Quinn, of the U.S. Fish and Wildlife Service, concurs with that recommendation. The main advantages of a vertical slot fish passage over other types of fish passages is its capacity for passing large quantities of anadromous fishes. Construction of a vertical slot fish passage is considered a viable option. Figure 5 shows a typical vertical slot fish passage.

Complete Dam Removal

Complete removal of the blockage will reestablish historic migration paths. This approach offers the only permanent, maintenance free solution to blocked migration paths. The removal of Embrey Dam along with associated sediment would restore a natural, passable watercourse. Anadromous fishes would be able to travel upstream past the City of Fredericksburg. The complete removal of Embrey Dam is also considered a viable option for providing fish passage.

Partial Dam Removal

Removing a portion of Embrey Dam would also reestablish the historic migration route. This option would consist of removing most of Embrey Dam, leaving only the last few chambers on either side of the river and the abutments. This option also results in the restoration of a natural watercourse. Leaving these sections in place, would reduce the initial cost of removal and would leave a portion of the dam for historical appreciation. There would be initial stabilization costs and recurring maintenance costs associated with the chambers left in place. Removal of a portion of Embrey Dam is also considered a viable option for providing fish passage.

The Rappahannock Canal (also known as the VEPCO Canal) flows through the City of Fredericksburg. The canal was originally used for navigation and later for hydroelectric power generation. The canal is no longer used for either of these purposes. A 36" pipe in the bottom of the canal is used to supply 6 million gallons of raw water per day to the Cossey Water Treatment Plant. Although this portion of the water withdrawn from the Rappahannock River into the canal is not expected to be necessary after the year 2000, the City of Fredericksburg has identified keeping water in the canal as one of their key concerns to be included in this study.

IDENTIFICATION OF ISSUES

All three fish passage alternatives create impacts on the river environment and the utilization of the river as a resource for water supply and recreation. Identifying these issues is critical to the evaluation of alternatives. To adequately determine all project issues, input from various government agencies, including Federal, State, and Local review agencies and public and private organizations was solicited. Prior to beginning this study, the VDG & IF distributed a notice describing the intent and scope of the study for comment. A copy of the notice is included in Appendix C. The notice identified the project as a fish passage feasibility study for Embrey Dam on the Rappahannock River. Virginia Senate Joint Resolution Number 296 was enclosed to identify the authority directing the study. The responses received assisted in identifying issues and concerns to be addressed or identified in this study. The issues enumerated in the responses included historical, environmental, and socioeconomic issues.

To fully evaluate the options for providing fish passage, a "decision matrix" strategy was developed dividing the critical issues into technical, regulatory, and "local" categories. A decision matrix using the technical issues has been created to help select the most appropriate method of providing fish passage with respect to feasibility and cost. If a capital cost could be included for the regulatory issue, it was included in the technical decision matrix. Meetings held with various federal, state, and local agencies provided input to create a similar decision matrix, which will be used to select the most appropriate method based on local and non capital regulatory issues.

The issues were developed through a series of working meeting which were held during July, August and September. The initial meeting, a kick-off meeting included The U.S. Army Corps of Engineers, the VDG & IF, TIMMONS, and GKY and Associates. This was an organizational meeting to coordinate a schedule that would provide the USACOE with a draft report with enough time to review the report and respond to TIMMONS so that responses to comments could be included in the final report.

The next working meeting was held with regulatory agencies on August 4, 1997. This meeting further defined and evaluated technical and regulatory issues that are included in the report. A similar meeting was held on August 22, 1997 with local government representatives and other agencies interested in the project. A third working meeting was conducted on September 11, 1997 which was advertised in local publications as a meeting open to the public to solicit public comment. A progress presentation was made at each of these meetings. Following the progress report, an open discussion provided insight into the issues from the various perspectives. Attendance lists for these meetings is provided in Appendix C along with related correspondence.

Following the public meeting, a draft version of the report was submitted to the USACOE and the VDG & IF. The USACOE and the VDG & IF provided comments and questions based on that report. These comments and questions were incorporated into the final report.

(Figure 5)

Bosher Dam Vertical Slot Fishway (Under Construction)

Supply of Water to Rappahannock Canal

One of the issues identified by the City of Fredericksburg is the Rappahannock Canal. Invariably, the desire was to keep the status of the canal unchanged. The flow in the canal was of concern for functional, environmental, and aesthetic reasons. The canal has been used for almost 150 years for purposes of navigation, hydroelectric power generation, and aesthetic enjoyment. Its historical value comes from both navigation and from the generation of hydroelectric power. The City of Fredericksburg's right to withdraw water for the maintenance of the Rappahannock Canal is historic. Since the beginning of hydroelectric power generation in Fredericksburg in the late 1800's, water has been diverted into the canal. River water demand has increased since then, but the withdrawal may be considered the city's right based on the historic and normal operation of the canal.

In order to evaluate how much water should be diverted into the Rappahannock Canal, the normal operations of the canal were discussed with representatives of the city. Then, to evaluate what overland flow was contributing to the canal naturally, a report by Baker Engineers was reviewed and the hydrology was revisited. Finally, field investigations were performed to evaluate the potential for canal contribution to the wetland areas adjacent to the canal.

Normal Operations of Rappahannock Canal

Water enters the canal through gates located at the southern abutment of Embrey Dam. The entrance to the canal is equipped with five gates which control the flow into the canal (See Figure 6). Two of the gates are located between the concrete wall adjoining the river and a stone wall extending perpendicular from the gates. Only one of the two gates remains open (approximately 12") during normal canal operations, with a rotation occurring between the two gates about once every 2-3 weeks. These gates supply the canal with approximately 90 cubic feet per second (60 million gallons per day) during normal operations. A 36" pipe, located on the other side of a stonewall from the two normal operation gates, runs down the canal, supplying water to Fredericksburg's Cossey Water Treatment Plant. Three other gates are located on the inland side of this pipe. Two of these gates have been bolted shut and are not operational. The third remaining gate is operational, however it is used only to flush debris from in front of the pipe and is not used during normal operation of the canal.

The outflow of the canal is controlled by gates located just upstream of Princess Anne Street (See Figure 7). The outlet for the canal consists of three 3' x 5' gates located at the bottom of the canal. One of these gates remain open approximately 6"-12" during normal operations. A 20' x 2' emergency spillway weir is located above the gates just underneath the operator's platform. Water does not flow over this weir during normal operations, but does flow through it during heavy rain. Downstream from the gate is a 16' x 16' flume followed by three 6'6" drop tubes which flow under the hydroelectric plant and outflow into the Rappahannock River. An emergency spillway channel (Mill Race) is located just downstream of the Charles Street bridge, however this spillway is not used during normal operations.

Summary of Technical Issues

This report summarizes and evaluates the technical issues identified during the course of the study. The first technical issue identified was the project goal of providing anadromous fish passage. The most pervasive issue was the status of the water in the Rappahannock (VEPCO) Canal. This issue was brought up with respect to providing water for the wetland areas near the canal, providing water for the treatment plant, and the aesthetic quality of the canal. Concerns were voiced about three water withdrawal permits just upstream of Embrey Dam which have permit conditions tied to fish passage at Embrey Dam. Much discussion took place about the effect that sediments behind the dam that have accumulated since the construction of the crib dam would have on the river environment if Embrey Dam is breached. The volume of these sediments in the pool behind the dam is estimated to be 530,000 cubic yards (Appendix F). The stability of the dam and the safety nuisance created by the dam were also identified as issues. Regulatory issues such as historical and environmental impacts have been included in the discussions. Finally, maintenance considerations have been visited as have construction issues such as removal of rubble from construction or demolition activities.

Summary of Local Issues

The local decision matrix included issues where costs could not be attributed to resolution of the issue. Mitigation of the historical aspects of Embrey Dam is important to the City of Fredericksburg. The crib dam is not required to be preserved but it is included in the local issues discussion along with the upper canal and lock system. The impacts to the historic concrete dam are also mentioned in the local issues. Recreation in the affected reach of the Rappahannock River is included from the perspectives of fishing and of canoeing and kayaking. The river is identified as a state designated scenic river. Finally, the potential for wetlands above the dam, the adjacent property rights and value and the economic development impacts are cited in the local decision matrix.

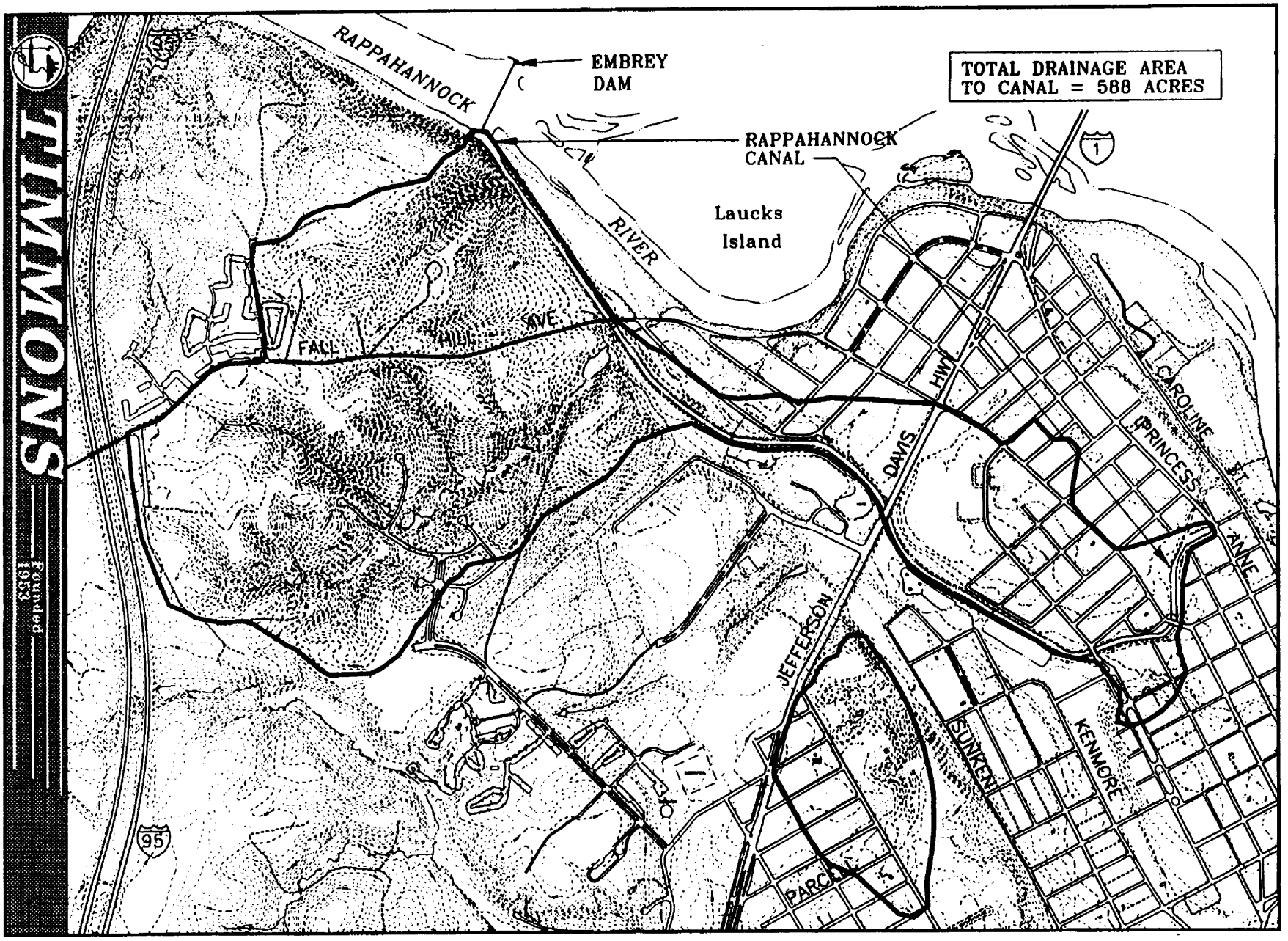
A detailed summary of each of these issues follows.

(Figure 7)

Canal Outlet Gates (Princess Anne Street)

(Figure 6)

Inlet Gates at Embrey Dam



(Figure 8)

Watershed to Canal

A preliminary HEC-RAS model was created to study to existing canal and its outlet structures. The cross sections for the model where obtained from survey data generated for the VEPCO Canal Hydraulic Inventory and Analysis for the City of Fredericksburg (Parsons Brinckerhoff Quade & Douglas, Inc.; August 1985.) The model does not include any road crossing sections and typical flow and water surface elevations were determined by field visits and an interview with a Cossey Water Treatment Plant operator. It was determined from HEC-RAS model that the water surface elevation in the canal is controlled by the gates at Princess Anne Street. Neither the flume or the drop tubes have an effect on the backwater to the canal during normal operations. A normal flow backwater elevation of approximately 48.5′ is formed by the gates at Princess Anne Street, which controls the water surface elevation the entire length of the canal.

The watershed contributing to the canal is represented in Figure 8. Approximately 588 acres of runoff contributes to the flow in the canal. This is substantial during storm events, but is not a large enough drainage basin to keep the canal flowing continuously.

The 36" pipeline on the bottom of the canal provides 6 million gallons per day (less than 10 cfs) to the Cossey water treatment plant. While this source of water will not be needed beyond the year 2000, it is a part of the estimated required flow to the canal to maintain its current characteristics and usefulness. The overall quantity of water flowing through the canal is important to facilitate flushing of the canal. Detention times in the canal of longer than one day will promote degradation of the water in the canal. The most obvious effect of longer detention times is an unpleasant odor.

There are several wetland areas adjacent to the canal. The first, Snowden Marsh and Snowden Pond, is adjacent to an office development. The runoff from this development feeds the marsh and pond. Outlet from the pond is controlled by a riser structure and flows into College Marsh and Gayle's Pond. Snowden Pond is connected to the canal by a hydraulic gate. This gate reportedly has not been used in the past several years, although the pond could be filled by opening this gate. College Marsh and Gayle's Pond, just southeast of Snowden Pond are not connected to the canal except that Snowden Pond could be filled by the canal and Snowden Pond could then fill College Marsh and Gayle's Pond. These wetland areas do not appear to be dependent on surface water flowing within the canal. The local representative for the USACOE has agreed with this conclusion.

No investigation has been performed on the groundwater conditions along the canal. If the canal is acting as a significant source for groundwater, the groundwater elevation could be impacted by the canal. If the proposed method of providing fish passage involves eliminating flow in the canal or leaving the canal dry for extended periods of time, further investigation should be performed in order to determine potential impacts to groundwater.

Sediments Upstream of Dam

Various responses and meetings conducted for this study have identified the fate of the sediments upstream of the dam as a major issue. The quantity, characteristics, and the fate of these sediments were the common concerns. As soon as the construction of the crib dam was completed in the mid 1800's, sediments began accumulating behind it. An equilibrium level of sedimentation was likely reached in the late 1800's. When Embrey Dam was constructed, the volume of sediments initially increased significantly but apparently reached an equilibrium level similar to today by the early 1900's. A study of these sediments, funded by the Environmental Protection Agency was performed by the Virginia Department of Game and Inland Fisheries and the Virginia Department of Environmental Quality. Results characterized the sediments as non-toxic to the environment (Appendix I).

Sediment Volume Calculation

The volume of sediment trapped behind the dam was estimated using the Average-End Area method and depth soundings mapped by Russell, Axon & Associates in October of 1965 (see Attachment 3). Depth measurements taken during the sediment sampling field visit conducted on July 27th 1997 generally corresponded well with the 1965 study map.

An estimate of the river bottom slope was made by projecting the elevation of the toe of the concrete dam (30.0 feet based on Whitman, Requardt and Associates *Water Supply and Treatment Alternatives* report dated October 1994) upstream to the I-95 bridge crossing where the pooling effect caused by the dam ends. The elevation of the river bottom at the bridge crossing was assumed to be 46.0 feet (Full Pool WSEL 52.0 - 6.0 feet measured depth to river bottom).

Using the Average-End Area method, the assumed river bottom slope, average elevations of the top of the sediment at 500 feet cross sections, and the river width at these cross sections, the total volume of sediment behind the dam was estimated to be 530,672 cubic yards or 329 acre-feet.

Alternatives for Sediment Removal

One option of disposing of the sediments behind the dam is to allow a full downstream release. Conversations with Scott Carney, the Floodplain Coordinator of Pennsylvania, indicate similar situations in Pennsylvania are resolved by dam removal including releasing accumulated sediment downstream. The sediment load associated with this release is a generally a small portion of the normal year sediment load. Figure 9 shows a visual representation of the comparative sediment load carried over Embrey Dam by a large storm event versus normal flow.

The quantity of sediments, and the sensitivity of the downstream areas may dictate that the sediments be removed prior to or in conjunction with dam removal. If necessary, options for removal and disposal of the sediments include hydraulic or mechanical dredging and disposal in a suitable location. The following disposal options are outlined in a report by GKY and Associates in Appendix F.

1. Hydraulically dredge the entire volume of sediment and pump the sediment to a disposal site located within 1 mile of the dredging operation.

Quantity of Flow in Canal

Based on field observations and the report entitled VEPCO Canal Hydraulic Inventory and Analysis for the City of Fredericksburg (Parsons Brinckerhoff Quade & Douglas, Inc.; August 1985), a typical flow of 90 c.f.s. has been concluded for the Rappahannock Canal. Normal operations for the canal system were determined by field observations and an interview with a Cossey Water Treatment Plant operator. The normal operation of the downstream gates (at Princess Anne Street) include the opening of one of the gates at the bottom of the canal approximately 6"-12". This procedure allows water to flow through the gate with a normal water surface elevation just below the emergency spillway weir located above the gates underneath the operator's platform. This operation was simulated and confirmed using the HEC-RAS model of the canal system. Under this scenario, the turnover time for the 77 acre-ft of water in the canal is 10.4 hours.

Method of Supplying Water to the Canal

Two methods of supplying water to the canal were considered. The first was a mechanical pumping system. This option was quickly ruled out due to high operation and maintenance costs. The selected option is to construct a pipe upstream along the banks of the river to a point upriver where the water surface elevation will provide the required head to supply the quantity of water. If the canal is required to have 90 c.f.s. of flow during normal operation, then 3,600 L.F. of 72" pipe is required to provide water to the canal.

To minimize costs, the minimum required pipe size required to transport sufficient water to the canal to achieve the desired characteristics within the canal was evaluated. An alternative scenario was developed in which the canal system has a flow of only 40 c.f.s. and a downstream gate opening of 4.5". The turnover time for the canal turns out to be 24 hours. This turnover time is adequate to keep the water in the canal from stagnating and losing its aesthetic qualities. Because the depth of flow in the canal is primarily a function of the downstream gate, reducing the flow from 90 cfs to 40 cfs will require opening the gate slightly less than the current normal operation. The uppermost point in the water surface is affected just over 4 inches by reducing the flow to 40 cfs. This will not cause a significant impact on the aesthetic quality of the canal.

If the canal is required to have only 40 c.f.s. of flow during normal operation, then 3,600 L.F. of 54" pipe is required. The cost estimates (provided in the evaluation of alternatives) for both full and partial removal of the dam assume that the canal will require a typical flow of 40 c.f.s. during normal operations, thus requiring a 54" relief pipe.

2. Mechanically dredge the entire volume of sediment and truck the sediment to a location within 12 miles of the dredging operation.
3. Hydraulically dredge part of the sediment and pump the sediment to a disposal site located within 1 mile of the dredging operation.
4. Mechanically dredge part of the sediment and place the sediment along the banks of the river.
5. Let sediment pass downstream

GKY and Associates performed a field visit to the Embrey Dam site on July 23, 1997 to collect samples of the sediment trapped behind the dam. Using the City of Fredericksburg Water Treatment Plant staff's boat, representatives collected sediment samples at six different locations upstream of the dam. These samples were submitted to *TIMMONS* on July 25, 1997 for analysis by their soils laboratory. In general, the sediment appeared to be composed of silty sands and clayey silts. Classification of the sediments using the Unified Soil Classification System (USCS) showed the samples to be SP, SM, and ML type soils. The engineering characteristics of these types of soils are generally:

1. Good to fair shearing strength when compacted and saturated
2. Very low to medium compressibility when compacted and saturated
3. Only fair workability as a construction material
4. Generally not recommended for use in canal sections, foundations, or as roadway fill

It should be noted that the samples collected only characterize approximately the first two feet of sediment on the bottom of the river. The depths measured during the field visit generally corresponded well with soundings made by Russell, Axon & Associates in October of 1965. This suggests that the sediment trapped by the dam has been and continues to be in a state of equilibrium. A report prepared by GKY and Associates, provided in Appendix F, characterizes the sediments behind the dam .

For the purposes of this study, it is assumed that the sediments will need to be excavated and disposed of as part of any dam removal scenario. The fate of these sediments under the options involving removing the dam were modeled using HEC-6; an analysis of the modeling results is provided in Appendix F. The results of the fate transport study should be assessed with respect to the river reach involved to evaluate the impacts to the river environment.

(Figure 9)

Normal Flow (Top) and High FlowEvent at Embrey Dam

Historical

Whenever federal funds or federal permitting is involved for a project, requirements of Section 106 of the National Historic Preservation Act must be addressed. The history of Fredericksburg is generally centered around colonial times and the Civil War. Embrey Dam, however, offers a different perspective on the history of the City. Fredericksburg was a thriving trading center and transportation hub based at the fall line of the Rappahannock River. Fredericksburg was on the technological forefront of hydroelectric power generation with the conversion of the crib dam from navigation to a hydroelectric facility and with the construction of Embrey Dam to increase the output of the hydroelectric power plant.

The historical value of Embrey Dam is not limited to its uses. The structure itself has historical significance. Embrey Dam, built by the Fredericksburg Water Power Company between 1908 and 1910, is an Ambursen dam. Patented by Nils S. Ambursen in 1903, the Ambursen dam design uses slabs and buttresses. Through each buttress, an archway provides access to an inspection walkway that allows access the entire length of the dam. This design was not used extensively and few representative dams are remaining.

The crib dam, located just upstream of Embrey Dam, is an example of another type of dam construction. An artists sketch of the crib dam is provided in Figure 10. Crib Dams are characterized by crisscrossed timbers and rock fill, a technology that is no longer used. Because of the materials used in their construction, these dams cannot endure prolonged exposure. The crib dam is relatively intact because it has been submerged since the initial filling of the pool behind Embrey Dam. Generally, the crib dam is submerged beyond view. During long dry periods, if the water level drops low enough and the water is clear in the pool, the general shape of the crib dam can be seen from the southern abutment.

Both Embrey Dam and the crib dam have historical value and are part of significant chapters in the history of the City of Fredericksburg. By removing Embrey Dam, this portion of Fredericksburg's history cannot be fully appreciated. If a portion of Embrey Dam were to remain after construction, the Ambursen dam could be seen and appreciated. However, the crib dam would quickly deteriorate. A report by Douglas W. Sanford of the Center for Historic Preservation of Mary Washington College entitled *An Assessment of the Embrey Dam Area* states that "unknown underwater archaeological resources including dams, mill site components, sunken vessels, other fishing traps" may be present in the vicinity. Mary Washington's report calls for full Phase I testing of the floodplain along the northern bank and for consideration of identifying and preserving underwater historic resources.

Upstream Water Withdrawal Permits

Throughout the course of this study, Spotsylvania and Stafford County referred to withdrawal permits either existing or pending approval which would be impacted by providing fish passage at Embrey Dam.

Three upstream water withdrawal permits, City of Fredericksburg's Motts Run, Stafford County's Rocky Pen, and Spotsylvania County's Hunting Run, will be affected by this project. While none of the intake structures are in or are proposed to be in the pool above Embrey Dam, permit conditions become effective when fish passage is provided at Embrey Dam. Once anadromous fishes are able to migrate upstream of Embrey Dam, the flow in the river becomes critical during the normal migration period.

The three withdrawal points are subject to the minimum flowby requirements defined within the permits. The following section is an excerpt from Spotsylvania's permit:

> Paragraph 14(d) : Spotsylvania County shall maintain the flowbys as specified in the DEQ permit. Except as provided in paragraph 14(e) below the DEQ permit and the Corps flowby conditions are unified. Spotsylvania County is only authorized to withdraw water at either intake when the natural flow (minus the withdrawals) in the Rappahannock and/or Rapidan Rivers. The permit conditions for flowbys are summarized as follows:
>
> | | * | ** | *** | |
> |---|---|---|---|---|
> | March through May: | 100% / | 60% / | 40% | of the mean annual flow |
> | June : | | 60% / | 40% | of the mean annual flow |
> | July through February : | | 40% / | 20 % | of the mean annual flow |
>
> * If, during the term of the permit, Embrey Dam is breached to allow anadromous fish passage, and storage remaining in the Hunting Run Reservoir is over 91% full for March, 94% full for April, and 97% full for May.
>
> ** If Embrey Dam is not breached, and the storage remaining in Hunting Run Reservoir is less than the provisional storage levels specified in the DEQ permit, and above the emergency volume defined in the DEQ permit. Flowbys may be decreased to this percentage of the MAF minus the withdrawal.
>
> *** Same as ** except remaining storage in Hunting Run Reservoir is less than the emergency storage levels specified in the DEQ permit and the County's mandatory water conservation measures are in effect.

The requirement for fish passage is a legal requirement of the Code of Virginia. The method of fish passage does not affect the permit condition. Safe yield determinations associated with the eventual impact of fish passage have been considered. Therefore this issue should not influence the recommended method of providing fish passage.

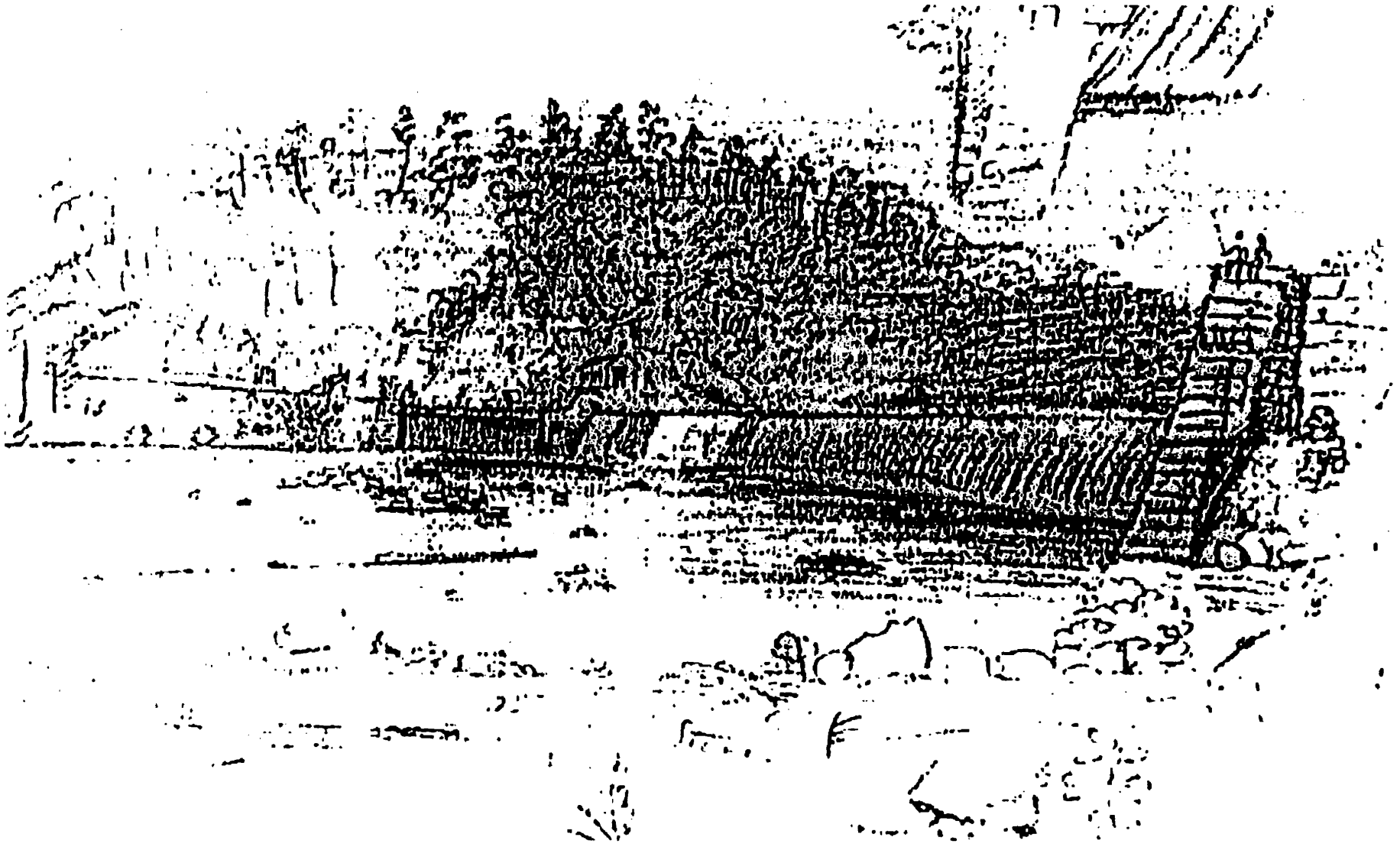
A meeting was held with the Virginia Department of Historic Resources on September 4, 1997 to discuss potential impacts to historic properties. The Mary Washington report has been accepted by the Department of Historic Resources and the public information meeting provided the opportunity for public comment on the alternatives. Table 1 provides a summary of the requirements to satisfy Section 106 of the National Historic Preservation Act if either of the alternatives are progressed

Table 1
Historical Preservation Requirements

Method of Providing Fish Passage	Requirements for Historic Preservation
Construction of a fish passage	No adverse impacts to concrete dam or crib dam. No further Action Required.
Removal of Entire Dam	The adverse impacts to the concrete dam and crib dam would need to be mitigated through additional field investigations outlined in the agreement between City and DHR, Additional study required.
Removal of Portion of Dam	The adverse impacts to both the concrete dam and the crib dam would need to be mitigated by thorough documentation.

The regulatory issues included within the technical decision matrix include the Section 106 historic preservation, and the Section 401/404 requirements of the Clean Water Act. The section 106 requirements of historical preservation should be immediately progressed in a formal agreement between the City of Fredericksburg, the Virginia Department of Game and Inland Fisheries, and the Virginia Department of Historic Resources as one of the next steps in the process of providing fish passage. This process has been initiated with the U.S. Army Corps of Engineers.

(Figure 10)



1863 Civil War Sketch of 1855 Crib Dam

(Figure 11)

Deteriorating Walkway Inside of Dam

Stability of Dam

The long term stability of Embrey Dam was found to be an issue during the course of this study. Several inspections have been performed recently and the results generally summarize that, although the stability of the dam is not an immediate threat, Embrey Dam is in need of substantial repairs in order to assure long term stability.

In 1978, Russel & Axon characterized the condition of the dam as having leaking surfaces and joints. Dewberry and Davis, in 1990 described the condition as cracking, spalling, deterioration of concrete and exposure of reinforcing. The most detailed inspection report provided by the City of Fredericksburg was completed in 1991 by representatives of the City of Fredericksburg. The report detailed cracks and spalling in each chamber. The report estimated the rate of flow in chambers exhibiting seepage.

In 1994, Whitman, Requardt & Associates listed spalling, leakage, cracking and further deterioration of the inspection walkway. While this report was part of an evaluation for water supply and treatment alternatives and not required for dam certification, it included an assessment of the condition of the dam. Whitman, Requardt and Associates concluded that the dam was in relatively poor condition and stated that the structural integrity of the dam is a concern. Figure 11 shows an example of the condition of the inspection walkway.

TIMMONS, Inc. performed a detailed inspection of Embrey Dam on August 21, 1997. There are 54 chambers in Embrey Dam. These chambers are separated by buttresses. Twelve chambers exhibiting more seepage than estimated in the 1991 report were noted in the report by *TIMMONS*. The state of deterioration in the remaining chambers generally agreed with the 1991 report. The amount of cracking and spalling was not quantified in most of the chambers. Deterioration was moderate to significant over the six year interval.

If Embrey Dam is to remain in place, substantial structural repair work must be performed. The latest inspection report calls for some minor repair work, however, to assure long term stability, significant steps must be taken. Cost estimates for these repairs are included in the Evaluation of Alternatives section of this report.

Public Safety

Several agencies involved in the research for this study have expressed concern about the public safety aspects of Embrey Dam. The City of Fredericksburg budgets funds for operation and maintenance of Embrey Dam. A significant part of these funds is geared toward safety concerns. Embrey Dam provides an attractive nuisance by offering a secluded gathering place for teenagers and young adults. There have been a number of deaths associated with Embrey Dam. There is evidence of trespassing and alcohol consumption in the area of the dam. The door to the north abutment has been removed forcibly. The dam is believed to be a popular gathering place for minors and young adults. The area was not designed for public access and lacks safety measures such as railings and stairs. The northernmost inspection walkway slab was removed to attempt to reduce the number of trespassers on the inspection walkway. Figure 11 shows how trespassers have placed trees across the missing slab to accommodate access to the walkway. There is no security patrol at the abutments access and trespassing is prevalent.

The operation and maintenance costs associated with efforts to keep the area safe or to discourage trespassing is a significant cost that is included in present value cost estimates for each of the alternatives evaluated in this report.

EVALUATION OF ALTERNATIVES

The main project goal is to provide anadromous fishes passage through Embrey Dam. This study evaluates the technical feasibility of the previously identified alternatives for providing fish passage. Each alternative is developed with respect to feasibility and cost, and the resolution of critical outstanding issues. The evaluation is intended to provide a recommended course of action based on technical issues. The alternatives considered include: constructing a vertical slot fishway, breaching a portion of the dam, and removing the entire dam. To fully evaluate these options for providing fish passage, a "decision matrix" strategy was developed dividing the critical issues into technical, regulatory, and "local" categories. Issues that could be assigned specific capital and/or maintenance costs were included within a "technical decision matrix" to develop the recommendations outlined within this study. Local issues that resulted from various meetings held with federal, state, and local agencies provided input to create a "local decision matrix" of issues that have been identified for further study. Regulatory and local issues are identified in the evaluation, but those listed in the local decision matrix are not included in the recommendations.

Construction of a Fish Passage

The Virginia Department of Game and Inland Fisheries has recommended that if a fish passage is to be constructed at Embrey Dam, a vertical slot fish passage be considered. Dick Quinn, of the U.S. Fish and Wildlife Service has concurred that a vertical slot fish passage would be the most appropriate type of fish passage for Embrey Dam. Vertical slot fish passages function in varying headwater and tailwater levels. The Gatehouse Double Vertical Slot Fish Passage at Turner's Falls on the Connecticut River is a vertical slot fish passage which has proven to be effective at passing large quantities of anadromous fishes. In 1993, 10,098 American shad passed at this facility. A similar passage is being constructed at Bosher Dam in Richmond, Virginia. The target species along the Rappahannock River (American shad and blueback herring) are the same in these projects. The success of the fish passage at Bosher dam will be another good indication of the effectiveness of vertical slot fish passages.

Specific design issues of a fish passage are beyond the scope of this report. Studies performed by the Virginia Department of Game and Inland Fisheries will provide necessary information to properly design a fish passage. The location of the fish passage on Embrey Dam needs to be evaluated based on existing river conditions. Field sampling using fish shocking techniques will reveal the most common approach path to the dam and where the most advantageous location is for a proposed fish passage. In addition to determining the preferred approach of migratory fish, the headwater and tailwater curves must be analyzed to design the invert of the entrance and exit channels. The attraction water system is another aspect of the design of any fish passage. River flows will have to be evaluated and appropriate range of attraction water flow will need to be determined.

Adjacent Property Rights / Value

Certain property issues will arise if the selected method of fish passage includes the removal of all or part of Embrey Dam. If the dam is removed, the pool above the dam will revert to its original characteristics. The rights of upstream property owners need to be evaluated, and the "viewshed" of the property also will change. The evaluation of this change is highly subjective. The view after dam removal would be a river versus the current view of a pond. This could impact the state designation as a wild and scenic river. The change is expected to be a positive impact.

A more material issue which would require resolution is the status of the land which will be reclaimed if the waterway reverts back into a river. The owners on either side of the pool currently own waterfront property. The headpond of Embrey Dam is a navigable water and is therefore owned by the Commonwealth of Virginia. The upstream and downstream reaches of the river have been studied during the preparation of this report. Based on those evaluations, the river is expected to reduce to a width of approximately 500 to 600 feet to the Interstate 95 bridge. The ownership of the reclaimed land must be resolved.

The county boundary would also be in question. The Spotsylvania / Stafford County boundary is the southern shoreline. If the river width is reduced, a certain portion of Stafford County will be on the south side of the river. Additionally, Spotsylvania County would lose river frontage along the affected reach of river. The current county boundary would no longer be the shoreline.

Another aspect of the project is the effect on the Rappahannock as a state designated scenic river. The viewshed will be altered from a backwater condition to a flowing river condition. A letter from Richard Gibbons is included in Appendix C and asks questions regarding the ultimate state of the affected reach of river.

Recreation

Canoeing and kayaking along the reach of the Rappahannock River by Embrey Dam currently requires portaging around the dam. Access is difficult, and the safety of these activities is questionable. Also, there are several areas within Fredericksburg that are open to the public. Old Mill Park, Falmouth Beach, and City Dock Park are adjacent to the Rappahannock River downstream of Embrey Dam. These downstream areas will not be significantly altered by any of the three alternatives.

The river reach from the Interstate 95 bridge to Embrey Dam will be subject to a change in flow patterns if Embrey Dam is removed. Embrey Dam is not designed to be a flood control structure so the quantity of flow in the river will not be affected. Because the permanent pool would be removed, river levels above the structure would be somewhat lower in all flood events. The downstream reach of river will not be significantly affected.

Virginia Department of Game and Inland Fisheries

Embrey Dam Fish Passage Study
Local Decision Matrix

TIMMONS

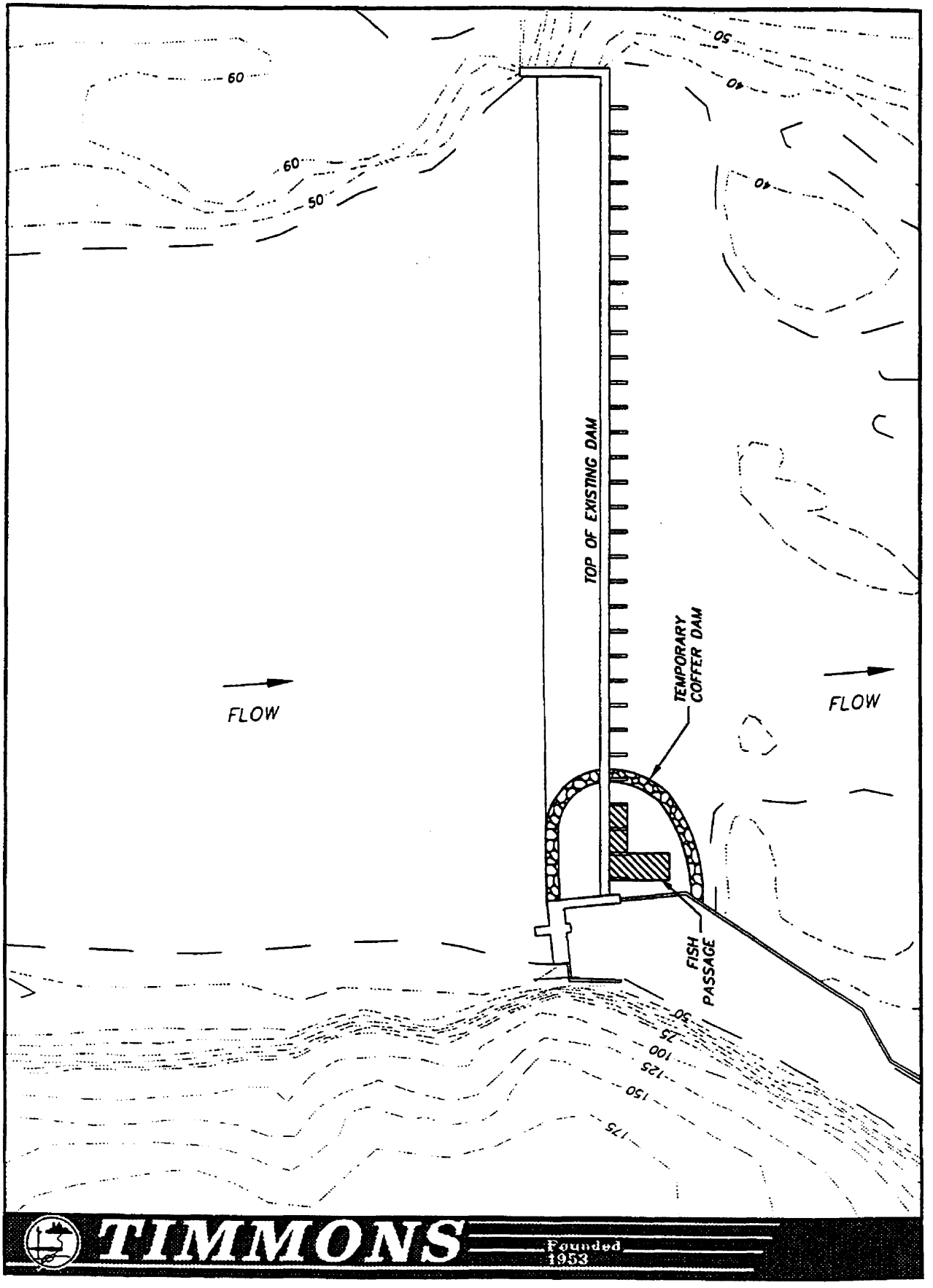
Issue	Fish Passage	Partial Dam Removal	Complete Dam Removal	Do Nothing
Historical Crib Dam	Not affected.	Will need to be removed because dewatering will cause deterioration. Section 106 process requires documentation.	Will need to be removed because dewatering will cause deterioration. Section 106 process requires documentation.	Not affected.
Historical Upper Canal Locks	Not affected.	Will provide opportunity to expose original canal and locks.	Will provide opportunity to expose original canal and locks.	Not affected.
Historical Concrete Dam	Creation of Gravity Dam means impacts would need to be mitigated through thorough documentation.	The impacts would need to be mitigated through thorough documentation.	The impacts would need to be mitigated through additional field investigation outlined in agreement between owner and DHR. Additional study required.	Not affected.
Fishing Recreation	Target and some non-target species and population pass with vertical slot fishway. All species pass with elevator.	All species would be able to pass. No limit on population.	All species would be able to pass. No limit on population.	No passage for any fish.
Canoe Kayaking Recreation	The dam is an existing safety hazard; portage is required to pass.	This alternative eliminates portage and may provide additional canoe/whitewater possibility, although abutments may be a safety hazard. Additional studies required.	This alternative eliminates portage and may provide additional canoe/whitewater possibility. Additional studies required.	The dam is an existing safety hazard; portage is required to pass.
State Designated Scenic River	No significant change to river front utilization or viewshed.	Additional river front utilization and impacts on scenic river will need to be evaluated. Additional studies required.	Additional river front utilization and impacts on scenic river will need to be evaluated. Additional studies required.	Not affected.
Sediment Impact on Downstream Flooding, Habitat, Recreation, and Navigation	Not affected.	Additional sediment transport study is required to adequately address impacts.	Additional sediment transport study is required to adequately address impacts.	Not affected.
Wetlands Upstream of Dam	Not affected.	Opportunity to stabilize existing sediment along new river banks with wetland vegetation.	Opportunity to stabilize existing sediment along new river banks with wetland vegetation.	Not affected.
Adjacent Property Rights/Value	Not affected.	Property rights, including new boundaries, of adjacent landowners must be addressed.	Property rights, including new boundaries, of adjacent landowners must be addressed.	Not affected.
Economic Development Impact	Additional studies required.	Additional studies required.	Additional studies required.	Not affected.

Virginia Department of Game and Inland Fisheries

Embrey Dam Fish Passage Study
Technical Decision Matrix

TIMMONS

Issue	Fish Passage	Partial Dam Removal	Complete Dam Removal	Do Nothing
Allow anadromous fish to travel upstream	Target and some non-target species and population pass with vertical slot fishway. All species pass with elevator.	All species would be able to pass. No limit on population.	All species would be able to pass. No limit on population.	No passage for any resident or anadromous fish.
Supply of water to Rappahannock Canal	Not affected by construction because dam remains in place.	Requires either mechanical pumping or extending intake upstream.	Requires either mechanical pumping or extending intake upstream.	Not affected because dam remains in place.
Upstream water withdrawal permits	Permit condition addressing withdrawal during migration season would be in effect.	Permit condition addressing withdrawal during migration season would be in effect.	Permit condition addressing withdrawal during migration season would be in effect.	Not affected.
Sediments upstream of dam	Not affected.	Sediments would need to be released, excavated or stabilized. Additional study required.	Sediments would need to be released, excavated or stabilized. Additional study required.	Not affected.
Stability of dam	Dam remains in place and would require repair and annual maintenance.	Although sections of the dam are removed, sections of dam left in place would require repair and annual maintenance.	Entire dam, abutments, and entrance to canal are removed.	Dam remains in place and would require repair and annual maintenance in accordance with recertification inspection.
Public Safety	Dam remains in place and would require continued safety measures by City.	Sections of dam left in place would require continued safety measures by City.	Entire dam , abutments and entrance to canal are removed.	Dam remains in place and would require continued safety measures by City.
Historical	No adverse impacts to concrete dam or crib dam.	The adverse impacts to both the concrete dam and crib dam would need to be mitigated by thorough documentation	The adverse impacts to the concrete dam and crib dam would need to be mitigated through additional field investigations outlined in agreement between VDGIF, City, DHR, and USACOE. Additional study required.	Not affected
Environmental	Section 404/401 permitting process.	COE may require additional studies before completing Section 404/401 permitting process.	COE may require additional studies before completing Section 404/401 permitting process.	Not affected
Maintenance requirements	Operation and monitoring of fishway, maintenance of dam, and intake gates for canal	Maintenance for remaining portions of dam and canal intake pipeline.	Maintenance for canal intake pipeline	Maintenance of existing dam, and intake gates for canal
Construction/ Rubble Removal	Construction would require extensive cofferdam to construct fish passage Existing dam would need to be stabilized Rubble removal and work in river bottom minimal	Construction would require extensive cofferdam to remove breached sections Sections to remain would need to be stabilized Rubble removal and work in river bottom extensive	Construction would require extensive cofferdam to remove dam, canal headwalls and sidewalls, and abutments Rubble removal and work in river bottom extensive.	No capital construction



Fish Passage

(Figure 12)

Methods and Cost of Fish Passage Construction

Construction of a vertical slot fish passage to provide fish passage achieves the project goal with the least amount of change in the existing dam. However, the dam is deteriorating and is in need of significant repair and stabilization. Recent inspections have recommended patching of areas that exhibit leakage. However, if the dam is to remain, long term stability is a concern and will require major repairs. The cost of this repair is considered within the overall cost for this alternative. The options for repairing the dam to ensure long term stability include transforming the dam to a gravity dam, reinforcing and repairing areas throughout the dam, or performing partial repairs to critical areas.

Included within each of the following options is the cost of constructing a fish passage. Several methods have been used for estimating fish passage construction cost. The U.S. Fish and Wildlife Service has used a price per vertical foot for many of their estimates; a range of $50,000 to $150,000 per vertical foot is expected.

A vertical slot fish passage is scheduled to be completed by the end of January 1998 at Bosher Dam in Richmond, Virginia. This project gives an indication of expected range of construction prices provided by contractors. The actual design and construction cost for Bosher Dam is expected to be approximately $ 1.5 million. Because Embrey Dam is approximately twice as high as Bosher Dam, construction costs are expected to be significantly higher. The length of the passage required is approximately doubled. The construction access will be more difficult at Embrey Dam. The cost of the attraction water system is not significantly changed. Demolition and excavation are not as difficult at Embrey Dam as at Bosher Dam.

Preliminary construction cost estimates for a fish passage at Embrey dam are approximately $3.5 million. Downstream migration would be achieved by providing a flume over the crest of the dam. This cost estimate does not include construction costs of repairing and stabilizing the dam. The costs for dam modifications depend on the method of stabilization and repair selected.

Option 1 - Gravity Dam

One viable option to repair Embrey Dam is to transform the existing buttress dam into a gravity dam and construct a fish passage around the dam (See Figure 12). A gravity dam would be formed by placing approximately 12,000 C.Y. of concrete and 80 tons of reinforcing steel inside the bays of the dam (from Whitman, Requardt, Oct. 1994), thus sealing existing leaks and creating a much more stable structure. The long term safety and stability of the dam is now dependent on the structural integrity of the slabs and the buttresses. By transforming the existing dam into a gravity dam, the weight of the concrete would maintain the stability of the dam. The recommended construction sequence is as follows:

- Close all the upstream gates to the canal and open the downstream gates to drain the canal..
- Breach the concrete sidewall along the northern end of the canal system, open all the upstream canal gates and divert the river through the canal headgates and through the breached wall.
- Install a coffer dam around the existing dam and dewater the dam area.
- Place concrete and reinforcing steel as required for gravity dam using coffer dam as causeway for construction entrance (See Figure 13).
- Construct fish passage

- Remove coffer dam and close canal gates, draining canal.
- Reconstruct the concrete sidewall along the northern end of the canal system.
- Open canal gates and return to normal operating procedures for the dam.

The fifty year present worth of this option of fish passage in conjunction with transforming the dam into a gravity dam is $10.2 million.

Option 2 - Reinforce and Repair Embrey Dam

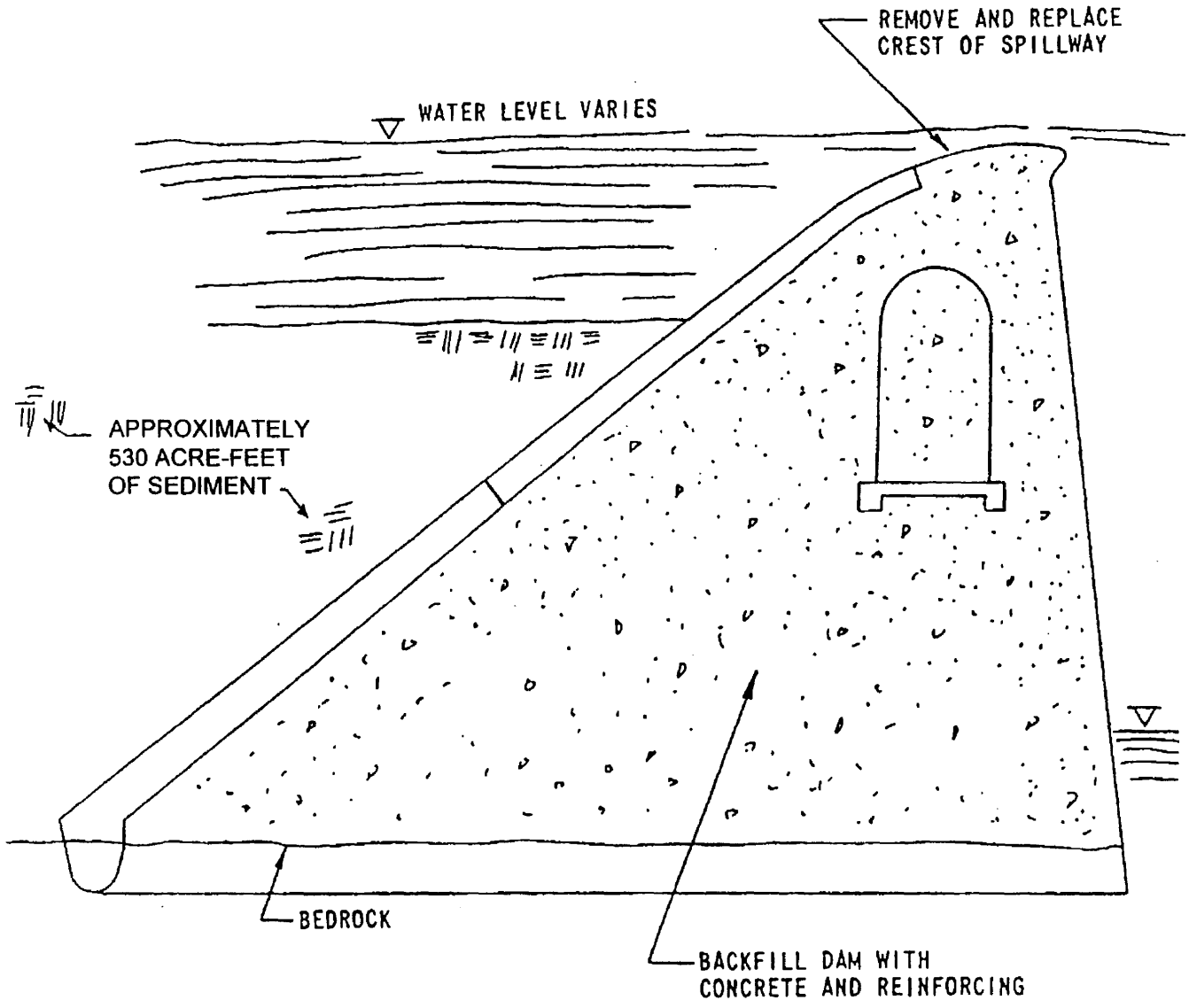
The option of reinforcing and repairing Embrey Dam is discussed in the Water Supply and Treatment Alternatives (Technical Memorandum No. 4, Embrey Dam Evaluations) report buy Whitman, Requardt and Associates, October 1994. The following description of this process was taken directly from the Whitman, Requardt report;

> *The second possible method of repair is to reinforce the weak and deteriorated areas using concrete restoration techniques. Generally, this method of repair would include but may not be limited to:*
>
> - *Diverting the flow over the crest by use of the existing canal, siphons, temporary upstream cofferdams and downstream dikes, or combinations of some or all of these methods as previously described, so that repairs may be constructed over the entire length of the dam.*
> - *Selectively remove deteriorated and weak concrete by using concrete saws and impact hammers so only sound concrete remains and rust reinforcing steel is exposed.*
> - *Remove the rust from the exposed reinforcing steel and apply a corrosion inhibitor. Replace the reinforcing steel as required.*
> - *Replace the cut out concrete with polymer modified cementitious mortars and fill the cracks with epoxy injected grouts.*
> - *Install a sprayed on epoxy waterproof membrane on the upstream face of the concrete slab after dewatering and dredging around the upstream face of the dam.*
> - *Demolish and rebuild the inspection walkway using cast-in-place concrete construction or precast slabs. Expansion joints should be installed as required to control expansion and contraction due to thermal effects.*
> - *Repair the existing deteriorated lateral buttress supports.*
>
> *Judging by the condition of Embrey Dam, selective repair may be expected on all the primary components of the dam. Prior to finalizing this alternative, a thorough inspection of the dam is required to determine the soundness of the existing concrete and to define the limits and extent of the work so contract documents can be prepared.*

The Whitman, Requardt report had an estimated construction cost of $3.912 million for reinforcing and repair of the dam and the construction of a fish passage. The fish passage had an estimated cost of $500,000, and a periodic repairs cost of $500,000 for every five years. A new cost of $4.53 million has been estimated based on the cost of the proposed fish passage, the construction of the cofferdam around the dam, and a present day estimate of all related construction costs. The same periodic repairs cost of $500,000 is still recommended every five years.

The fifty year present worth of this option of fish passage in conjunction with reinforcing and repairing Embrey Dam dam is $19.6 million.

(Figure 13)



Gravity Dam

Table 2
Fish Passage Construction Cost Estimate

Fish Passage				
22 Vertical Feet at $100,000/V.F.		$	3,500,000	
	15 % Contingency =	$	525,000	
	Total =	**$**	**4,025,000**	
Gravity Dam:				
Concrete (12,000 C.Y.)		$	3,000,000	
Cofferdam		$	250,000	
$ 227,625 Rock Fill (1,300 L.F. x 126 S.F. = 6,070 C.Y.)				
$ 20,000 Membrane (Material and Installation)				
Demolition		$	75,000	
Equipment		$	400,000	
	15 % Contingency =	$	558,750	
				Total + Fish Passage
	Total =	**$**	**4,283,750**	$ 8,308,750
	Yearly Maintenance =		**$20,000**	
Reinforce and Repair Dam:				
Concrete		$	71,000	
Cofferdam		$	250,000	
$ 227,625 Rock Fill (1,300 L.F. x 126 S.F. = 6,070 C.Y.)				
$ 20,000 Membrane (Material and Installation)				
Demolition		$	60,000	
Concrete Repair		$	700,000	
Waterproofing		$	190,000	
Dredging		$	90,000	
Equipment		$	380,000	
	Contingency =	$	261,150	
				Total + Fish Passage
	Total =	**$**	**2,002,150**	$ 6,027,150
	Yearly Maintenance =	**$**	**100,000**	
Partial Repairs to Dam:				
Cofferdam		$	250,000	
$ 227,625 Rock Fill (1,300 L.F. x 126 S.F. = 6,070 C.Y.)				
$ 20,000 Membrane (Material and Installation)				
Concrete Repair		$	400,000	
Equipment		$	252,000	
	Contingency =	$	135,300	
				Total + Fish Passage
	Total =	**$**	**1,037,300**	$ 5,062,300
	Yearly Maintenance =	**$**	**120,000**	

Option 3: Perform Partial Repairs

The option of partial repairs to Embrey Dam is discussed in the Water Supply and Treatment Alternatives (Technical Memorandum No. 4, Embrey Dam Evaluations) report buy Whitman, Requardt and Associates, October 1994. The following description of this process was taken directly from the Whitman, Requardt report;

> *This alternative is similar to reinforce and repair alternative. However, rather than repair the entire structure, this alternative would repair only the most critical elements such as the slab joints, the buttress leaks and the bulkhead leaks. This alternative would serve as a stopgap approach that allows the City more time to perform permanent repairs ... Yearly inspections and repairs would be required to determine the adequacy of the temporary repairs and address additional damages.*

The Whitman, Requardt report had an estimated construction cost of $2.08 million for partial repairs to the dam (which did not include the construction of a fish passage) and a periodic repairs cost of $100,000. A new cost of $3.57 million has been estimated based on the cost of the proposed fish passage, the construction of the cofferdam around the dam, the partial repair of the dam, and a present day estimate of all related construction costs. The same periodic repairs cost of $100,000 is still recommended.

The fifty year present worth of this option of fish passage in conjunction with performing partial repairs on Embrey Dam is $19.5 million.

Least Expensive Method of Fish Passage Construction

Table 2 outlines the construction cost estimates of the three types of dam repairs. These costs were inserted into Table 3 which estimates maintenance costs over the next fifty years. The fifty year cash flow table was then used to derive a fifty year present worth for each option. The gravity dam option is the most economical dam repair alternative based on a fifty year life expectancy of the dam. The present worth of this option is $10.2 million.

Resolution of Issues

The technical decision matrix offers summary statements about each of the identified technical issues. The option of installing a fish passage accomplishes the project goal of providing passage for anadromous fishes. The construction of a fish passage addresses many of the project issues by not changing the current state of the dam. The water in the Rappahannock Canal and the sediments behind the canal would not be affected by this option.

Under this option, the water withdrawal permits for the existing Motts Run, and the proposed Rocky Pen, and Hunting Run will be affected. The minimum instream flow requirements spelled out in the permit and discussed previously will be in effect. The existing structures are only slightly altered; therefore the historical value of the existing structures is not reduced. Conversations with the Virginia Department of Historic Resources have revealed that construction of a fish passage would not be considered a historical impact. However, converting Embrey Dam to a gravity dam would require extensive documentation.

While the headpond would remain unaffected so that property rights would not be an issue, the dam is deteriorating and is in need of repair. Both the remaining structure and the new fish passage will require recurring maintenance. The City of Fredericksburg will bear the burden of this maintenance. In addition, the nature of the dam creates an attractive nuisance that poses a hazard to trespassers. This liability also concerns the City. Another disadvantage of this option is that recreation would not be enhanced.

While this option fulfills the project goal, it does not address certain other issues and considerations. The construction costs of this option, summarized in Table 3, are substantial and recurring maintenance costs are increased because of routine maintenance required for the passage.

Table 3
50 Year Present Worth Analysis
Assumed Inflation = 3.0 %

Year	Fish Passage			Remarks
	Option 1 Gravity Dam	Option 2 Reinforce and Repair Dam	Option 3 Partial Repairs to Dam	
0	$ 8,308,750	$ 6,027,150	$ 5,062,300	Capital Outlay
5	$ 115,927	$ 579,637	$ 695,564	Operation & Maintenance
10	$ 134,392	$ 671,958	$ 2,731,040	Full repair for option 3
15	$ 155,797	$ 778,984	$ 934,780	
20	$ 180,611	$ 3,670,289	$ 1,083,667	Second full repair for option 2
25	$ 2,393,461	$ 1,046,889	$ 1,256,267	
30	$ 242,726	$ 1,213,631	$ 4,932,561	Second Full repair for option 3
35	$ 281,386	$ 1,406,931	$ 1,688,317	
40	$ 326,204	$ 6,628,950	$ 1,957,223	Third full repair for option 2
45	$ 378,160	$ 1,890,798	$ 2,268,958	Operation & Maintenance
50				
Present Worth	$ 10,208,750	$ 19,591,450	$ 19,526,600	

Appendix F. An evaluation of these results with respect to impacts to the biota must be performed. It is likely that some dredging will be required if this alternative is chosen.

Table 5
Cost of Sediment Disposal Alternatives

Option	Cost	Considerations
Hydraulic Dredging of Entire Volume	$4.24 million	Disposal site within 1 mile
Mechanical Dredging of Entire Volume	$6.89 million	Disposal site within 12 miles
Hydraulic Dredge ½ Volume	$2.12 million	Disposal site within 1 mile
Mechanically Dredge ½ Volume	$2.915 million	Disposal site within 1 mile
Release of Sediment Downstream	Unknown	Further study needed

For the purposes of this study, it is assumed that the sediments will require excavation and disposal. Additional study is necessary to identify a suitable location for disposal of sediment within one mile of the project site. A cost of $4.24 million is included for the construction cost estimate for removal of the dam.

Methods and Cost of Removing Embrey Dam

The complete dam removal option requires a full breach of the dam followed by the removal of the dam, the dam abutments and the existing headrace, and the option of removing the sediment behind the dam. This option also requires the construction of a temporary causeway (which will act as coffer dam) during demolition and the construction of a relief pipe to supply water to the existing canal system (See Figure 14). The recommended construction sequence is as follows:

- Close all the gates to the canal and drain the canal.
- Breach concrete sidewall along the northern end of the canal system, then open all canal gates and divert the river through the canal headgates and through the breached wall.
- Breach the upper half of the three northern most slab panels as shown in Figure 14.
- Grade a temporary diversion channel in the upstream sediment layer toward the breached section of the dam.
- Remove the silt and crib dam from behind the dam, if required.
- Construct a temporary causeway along the upstream side of the dam for construction access.
- Demolish the concrete dam working from the north side to the south side of the dam.
- Removal all logs, concrete, masonry and steel to a depth of 12" below the existing river bottom.
- Reestablish river flow by removing the causeway.
- Construct relief pipe for water supply to the canal.

Complete Dam Removal

The complete removal of Embrey Dam would reestablish historic migration upstream of the dam. While the removal of Embrey Dam would create certain issues which need to be resolved, the complete removal of the dam is a permanent solution that would reduce recurring maintenance costs. The removal of Embrey Dam is considered an option for providing fish passage.

Upon removal of Embrey Dam, the river water surface elevation will drop too low to provide water to the canal. In order to assure that water can be supplied to the canal, a pipe would be constructed along the river bank, upstream approximately to the interstate 95 bridge to carry water into the upper end of the canal. The amount of flow through the canal becomes very important when evaluating the alternatives for supply water to the canal if Embrey Dam is to be removed. The cost estimates for both full and partial removal of the dam will assume that the canal will require a typical flow of 40 c.f.s. during normal operations, thus requiring a 54" pipe constructed along the banks approximately 3600 feet upstream. A summary of estimated costs for each of the pipe options is provided in the following table.

Table 4
Estimated Costs of Rappahannock Canal Pipeline

Pipe Diameter	Flow Provided to Canal	Estimated Construction Costs
72"	90 cfs	$900,000
54"	40 cfs	$700,000

Another requirement of removing Embrey Dam is to evaluate the environmental impacts of the ultimate fate of the sediments behind the dam.

A preliminary cost estimate has been developed for several options for removing the sediment from behind the dam. A detailed sediment study including cost estimates for the following options prepared by GKY and Associates is included in Appendix F:

1. Hydraulically dredge the entire volume of sediment (530,000 C.Y.) from behind the dam at a cost of approximately $4.24 million (530,000 C.Y. x $8/C.Y.) This would include mobilization, dredging, and pumping the sediment to a disposal site located within 1 mile of the dredging operation.
2. Mechanically dredge the entire volume of sediment at a cost of approximately $6.89 million (530,000 C.Y. x $13/C.Y.) This would include mobilization, dredging, and trucking the sediment to a location within 12 miles of the dredging operation.
3. Hydraulically dredge part of the sediment (265,000 C.Y.) onto the river banks at a cost of approximately $2.12 million (265,000 C.Y. x $8/C.Y.) This would include mobilization, dredging, and pumping the sediment to a disposal site located within 1 mile of the dredging operation.
4. Mechanically dredge part of the sediment (265,000 C.Y.) onto the river banks at a cost of approximately $2.92 million (265,000 C.Y. x $11/C.Y.) This would include mobilization, dredging and placement of the sediment to a location along the banks of the river.
5. Breach the dam and release the sediment downstream. A detailed sediment transport modeling study has been performed and results are summarized in

Table 6
Removal of Entire Dam Cost Estimate

Complete Dam Removal - TIMMONS, 1997

River Control		
Concrete Removal from Dam (2,500 C.Y.)	$	500,000
Removal of Abutments (2,000 C.Y.)	$	350,000
Demolition/Blasting	$	300,000
Crib Dam Removal and/or Transport	$	175,000
Causeway	$	200,000
$ 175,000 Rock Fill (800 L.F. x 126 S.F. = 3,740 C.Y.)		
$ 25,000 Membrane (Material and Installation)		
Temporary Diversion Dike	$	50,000
Diversion Pipe for Canal	$	700,000
$ 600,000 3,600 L.F. of 54" RCP		
$ 100,000 Endwalls, Butterfly Valves, Misc.		
New Headworks and Bulkhead for Canal	$	125,000
Subtotal =	**$**	**2,400,000**
15% Contingency =	**$**	**360,000**
Estimated Construction Cost =	**$**	**2,760,000**
Excavation of Sediments (Appendix F) =	**$**	**4,240,000**
Total Estimated Cost of Complete Removal of Dam =	**$**	**7,000,000**
Yearly Maintenance of Diversion Pipe =	**$**	**10,000**

Resolution of Issues

The technical decision matrix offers summary statements about each of the identified technical issues. The complete removal of Embrey Dam would require construction of a 54" relief pipe approximately 3600 feet upstream of the location of the dam to supply adequate water to the canal. Also, if the dam were to be removed, the fate of the sediments must be addressed.

Under this option, the water withdrawal permits for the existing Motts Run, and the proposed Rocky Pen, and Hunting Run will be affected. The minimum instream flow requirements spelled out in the permit and discussed previously will be in effect. The stability and safety concerns about Embrey Dam are solved with the option of removing the Entire Dam. Recreation in the area is enhanced by opening the river to canoeing and kayaking.

The historical value of Embrey Dam and the crib dam are not quantifiable costs. If preservation of the crib dam is desired, significant additional cost will be incurred. The cost of preservation of these dams can be estimated. The cost of preserving a portion of Embrey Dam is described in the option of removing a portion of Embrey Dam. Phase I testing should be performed in the sediments along the north side of the river if Embrey Dam is to be removed completely or partially. Property rights of upstream owners would also have to be addressed.

Full Breach Option

(Figure 14)

Partial Breach

(Figure 15)

Partial Dam Removal

Removal of a portion of Embrey Dam would address many of the same issues that removal of the entire dam would. However, the stability of the remaining portions of the dam would still need to be addressed. The same assumptions and design criteria are used for the sediments behind the dam and for the water supply pipe.

Methods and Cost of Partial Dam Removal

The partial dam removal option requires a partial breach of the dam followed by the removal of the dam and the option of removing the sediment behind the dam. This option also requires the construction of a temporary coffer dam during demolition and the construction of a relief pipe to supply water to the existing canal system (See Figure 15). By leaving three chambers in place at each end of the dam. The historical significance of Embrey Dam can be appreciated. Stabilization of these sections will be a cost during construction, maintenance of these sections will be a recurring cost.

The following is a procedure for the option of removing a portion of the dam

- Breach to upper half of three slab panels near the northern end of the dam, as shown in Figure 15.
- Grade a temporary diversion channel in the upstream sediment layer toward the breached section of the dam.
- Remove the silt and crib dam from behind the dam, if required.
- Construct a temporary causeway along the upstream side of the dam for construction access.
- Demolish the concrete dam working from the north side to the south side of the dam.
- Remove all logs, concrete, masonry and steel to a depth of 12" below the existing river bottom.
- Reestablish river flow by removing the causeway.
- Leave three bays and the endwalls on each side of the dam.
- Provide bracing and repairs to stabilize the remaining portions of the dam.
- Construct relief pipe for water supply to the canal.

The cost estimate for the partial dam removal is provided in the following table. The same cost estimates for removal of the sediment from behind the dam apply for the partial dam removal as discussed in the complete dam removal option.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The options for providing fish passage at Embrey Dam include constructing a fish passage facility, removing Embrey Dam completely, or removing a portion of Embrey Dam. Issues which have been raised can be addressed with any of these options. The options with the lowest initial capital outlay are complete and partial dam removal. Either of these options allows for anadromous fish passage. As discussed in the Evaluation of Alternatives, water can be maintained in the Rappahannock Canal under either of these scenarios by constructing a water intake upstream near the Interstate 95 bridge.

The upstream water withdrawal permits will be affected by either of these options. It is inevitable that the localities will have to contend with the permit condition. Because the method of passage does not affect the conditions, no further consideration to these permits need be given to select the alternative.

The stability of the dam is an issue that needs to be considered if a portion of the dam is to be left in place. Public safety, also will be an aspect of the final design of any scenario, but merits special consideration if a portion of the dam is to remain.

Impacts on downstream areas will be a critical issue in evaluating the possibility of a sediment release. Downstream habitat, and navigation channels could experience increased sediment deposition. In order to evaluate the potential release of sediments through a dam breach, a sediment fate transport study has been performed; a summary is included in Appendix F. If the projected release of the sediments is determined to be acceptable, the cost of disposing of the sediments could be greatly reduced. This issue must be evaluated based on potential impacts to biota in the river reaches above and below the dam as well as the aesthetics and safety related to the scouring of the sediments, and the deposition of the sediments in downstream reaches.

By leaving a portion of the dam in place, the appreciation for the historical significance of the dam can be enhanced. Leaving three chambers on each side of the dam would not impede the river flow and should not pose a significant threat to canoe and kayak travel on this reach of the river. The process of Section 106 of the National Historic Preservation Act has been initiated with the U.S. Army Corps of Engineers. Measures to be taken in each potential method of providing fish passage should be submitted to the Virginia Department of Historic Resources.

The 50 year present worth analysis, provided in Table 8 shows that either complete or partial removal is significantly less expensive than the most cost effective option involving constructing a fish passage. The fifty year present worth of the two options involving complete or partial dam removal are identical within the limits of accuracy of this report. Based on the information contained in this report, the cost difference of the alternatives of providing fish passage by removing Embrey Dam or by removing a portion of Embrey Dam are insignificant.

TABLE 7
Removal of Portion of Dam Cost Estimate

Partial Dam Removal - TIMMONS, 1997

River Control	$	100,000
Concrete Removal from Dam (2,300 C.Y.)	$	460,000
Demolition/Blasting	$	180,000
Crib Dam Removal	$	175,000
Causeway	$	200,000
$ 175,000 Rock Fill (800 L.F. x 126 S.F. = 3,740 C.Y.)		
$ 25,000 Membrane (Material and Installation)		
Temporary Diversion Dike	$	50,000
Diversion Pipe for Canal	$	700,000
$ 600,000 3,600 L.F. of 54" RCP		
$ 100,000 Endwalls, Butterfly Valves, Misc.		
Repair of Abutments	$	200,000
Subtotal =	**$**	**1,965,000**
15 % Contingency =	**$**	**294,750**
Estimated Construction Cost =	**$**	**2,259,750**
Excavation of Sediments (Appendix F) =	**$**	**4,240,000**
Total Estimated Cost of Partial Dam Removal =	**$**	**6,499,750**
Yearly Maintenance of Remain Portion of Dam =	**$**	**10,000**
Yearly Maintenance of Diversion Pipe =	**$**	**10,000**

Resolution of Issues

The technical decision matrix offers summary statements about each of the identified technical issues. The partial removal of Embrey Dam would require construction of a 54" relief pipe approximately 3600 feet upstream of the location of the dam to supply adequate water to the canal. Also, the fate of the sediments would need to be addressed.

Under this option, the water withdrawal permits for the existing Motts Run, and the proposed Rocky Pen, and Hunting Run will be affected. The minimum instream flow requirements spelled out in the permit and discussed previously will be in effect. The stability and safety concerns about Embrey Dam should be a part of the design criteria for construction plans to remove a portion of the dam. Recreation in the area is enhanced by opening the river to canoeing and kayaking.

The historical value of Embrey Dam and the crib dam are not quantifiable costs. If preservation of the crib dam is desired, significant additional cost will be incurred. The cost of preservation of these dams can be estimated. The cost of preserving a portion of Embrey Dam is offset by the savings on demolition costs. Some maintenance costs will be associated with the sections of dam left in place. Phase I testing should be performed in the sediments along the north side of the river if Embrey Dam is to be removed completely or partially. Property rights of upstream owners would also have to be addressed.

Suggested Implementation Plan

The following is a suggested procedure for implementation of the selected technical alternative and a preliminary schedule:

1. Select method of fish passage (dam breach has been recommended).

2. Evaluate impacts to biota and river based on results of the sediment fate study. Evaluate potential for sediment release in lieu of dredging to minimize construction cost of dam breach alternatives.

3. Develop formal agreement for historic resource preservation and/or mitigation.

4. Prepare environmental assessment for selected alternative, including impacts of sediment release on downstream river and habitats.

5. Prepare and submit Joint Permit Application to VMRC, DEQ, and U.S. COE to initiate Section 10, 401, and 404 permitting process.

6. Secure funding and develop contract documents for selected alternative.

7. Construction of selected alternative.

Preliminary Schedule

Task	Suggested Schedule
Feasibility Study	Complete
Sediment Fate Transport Study	Complete
Historic Resource Preservation/Mitigation Agreement	3 months*
Environmental Assessment	6-12 months*
Environmental Permitting Process	6-18 months*
Construction Documents and Specifications	6 months
Construction	6-12 months

*Can be completed concurrently

Preliminary Budgets for Implementation Plan

Environmental Assessment	$100,000.00
Permit Application and Negotiations	30,000.00
A/E Services for Construction Documents	350,000.00
Inspection	100,000.00
Construction	7,000,000.00**
Total Budget	$7,580,000.00

** Favorable results from the Environmental Assessment could reduce the cost by approximately $4,000,000.

Table 8
50 Year Present Worth of Fish Passage Options
Inflation = 3.0 %

Year	Fish Passage Option 1 Gravity Dam	Complete Dam Removal	Partial Dam Removal	
0	$ 6,813,750	$ 7,000,000	$ 6,500,000	Capital Outlay Costs
5	$ 115,927	$ 57,964	$ 115,927	Maintenance Costs
10	$ 134,392	$ 67,196	$ 134,392	Maintenance Costs
15	$ 155,797	$ 77,898	$ 155,797	Maintenance Costs
20	$ 180,611	$ 90,306	$ 180,611	Maintenance Costs
25	$ 2,393,461	$ 104,689	$ 209,378	Maintenance and Repairs required
30	$ 242,726	$ 121,363	$ 242,726	Maintenance Costs
35	$ 281,386	$ 140,693	$ 281,386	Maintenance Costs
40	$ 326,204	$ 163,102	$ 326,204	Maintenance Costs
45	$ 378,160	$ 189,080	$ 378,160	Maintenance Costs
50				
Present Worth	$ 10,208,750	$ 7,450,000	$ 7,400,000	

Recommendations

1. The recommended option for providing fish passage at Embrey Dam is to remove all or part of the dam. The fifty year present value for either of these options is equal within the limits of accuracy of this report. The option of breaching the dam should be progressed through the next phases of the project.

2. A sediment fate and transport study has been performed to evaluate potential migration of sediments. An environmental assessment should be performed to evaluate impacts to the biota in the affected river reaches. If sediment migration downstream is not expected to have substantial negative impacts on stream habitat, there may be opportunity to reduce substantially the cost estimates contained in this report. If it is not feasible to allow the sediments to migrate downstream, disposal sites within a one mile radius should be evaluated for capacity and suitability.

3. The U.S Army Corps of Engineers is required under Section 106 of the National Historic Preservation Act to evaluate preservation of historic properties. Requirements of historical preservation should be addressed in a formal agreement between the City of Fredericksburg, the Virginia Department of Game and Inland Fisheries, the Virginia Department of Historic Resources, and the U.S. Army Corps of Engineers as a portion of the next step in the process of providing fish passage.

APPENDICES

SENATE JOINT RESOLUTION NO. 296

Requesting the Department of Game and Inland Fisheries to conduct a study on providing fish passage at Embry Dam.

Agreed to by the Senate, February 4, 1997
Agreed to by the House of Delegates, February 14, 1997

WHEREAS, the Commonwealth, as part of the multi-jurisdictional Chesapeake Bay Agreement has committed to efforts to restore the living resources of the Chesapeake Bay and its tributaries, including a commitment to "provide for fish passage at dams, and remove stream blockages whenever necessary to restore natural passage for migratory fish"; and

WHEREAS, the Commonwealth and the other Bay states have committed to opening 1356.75 miles of fish spawning habitat along the major Bay tributaries by the year 2003, to seek necessary funding and to committing resources to reach the goal; and

WHEREAS, providing fish passage at Embry Dam would provide hundreds of miles of additional fish spawning areas and has been identified as a major need in order to reach the fish passage goal; and

WHEREAS, increased spawning areas for migratory fish species, including rock fish, shad and herring are not only vital to restoring important living resources of the Bay and its tributaries but also to providing stimulus to local and state economies through recreational and commercial fishing opportunities; and

WHEREAS, sediment has accumulated behind Embry Dam and the dam's physical condition is deteriorating; and

WHEREAS, providing fish passage at Embry Dam will require preliminary study and coordination between the City of Fredericksburg, the Department of Game and Inland Fisheries and numerous other local, state and federal agencies; and

WHEREAS, it is critical to take immediate action to begin the process of determining the steps to take and the feasibility of various options for providing fish passage at Embry Dam and to do so in a manner that assures that the local impact of such options will be considered; now, therefore, be it

RESOLVED by the Senate, the House of Delegates concurring, That the Department of Game and Inland Fisheries be requested to undertake a study on providing fish passage at Embry Dam. The study shall be conducted in close association with the City of Fredericksburg and shall strive to include all necessary local, state and federal agencies to identify: (i) previous studies relevant to providing fish passage at Embry Dam; (ii) any further study needs; (iii) steps necessary to achieve fish passage at Embry Dam; and (iv) various options, including funding needs and options, to create the fish passage.

All agencies of the Commonwealth shall provide assistance to the Department of Game and Inland Fisheries for this study, upon request.

The Department of Game and Inland Fisheries shall complete its work in time to submit its findings and recommendations to the Governor and the 1998 Session of the General Assembly as provided in the procedures of the Division of Legislative Automated Systems for the processing of legislative documents.

Appendix A

Virginia Senate Joint Resolution Number 296

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Sources for Reports

Andrew McGilvray: Report numbers 1, 2, 3, 5, 6, 7, 11. City of Fredericksburg. Department of Public Works.

L. Alan Weaver: Report Numbers 4, 8, 10. Virginia Department of Game and Inland Fisheries.

U.S. Geological Survey.: Report Number 9

Appendix B

Bibliography of References

Friends of the Rappahannock
" To conserve, protect, and educate"

P. O. Box 7254
Fredericksburg, VA 22404
Phone/Fax (540) 373-3448

Mr. Alan Weaver
Fish Passage Coordinator
Va. Department of Game and Inland Fisheries
12108 Washington Highway
Ashland, VA 23005

April 1, 1997

Dear Mr. Weaver,

As a result of the Embrey Dam Fish Passage meeting in January, Friends of the Rappahannock has been meeting individually with members of the Fredericksburg City Council, City Staff, Stafford County Staff, and the Stafford County Board of Supervisors to present summaries of information obtained at the meeting and to solicit further concerns/interests regarding restoration of fish passage at Embrey Dam. The meetings have been quite productive, and we are encouraged by the general tone of cooperation that has prevailed.

These meetings have revealed a number of key issues that need to be investigated before substantial progress can be made on the fish passage effort. The purpose of this letter is to summarize these issues and to request that you include them in your study of fish passage alternatives commissioned by the General Assembly.

Key Issues for Fish Passage Study

- **Water in the VEPCO Canal.** The City has been very clear that they desire to keep water in the VEPCO canal, for aesthetic reasons as well as to maintain the hydrology of the Snowden Wetlands. The key question at this point is to determine the estimated cost of keeping water in the canal, and the best method to do so. We request that your study investigate and estimate costs for the following alternatives:
    1. Feasibility and cost of running a pipe upriver to generate sufficient pressure head to feed water into the canal.
    2. Feasibility and cost of using a wing dam to divert a portion of river flow into the canal or restoring Lock 1 and the canal for the same purpose.
    3. Feasibility and cost of mechanical pumping alternatives.

  A corollary need that will factor into each of these questions is the determination of *the minimum flow needed in the canal* to keep it aesthetically pleasing (ie. not stagnant).

- **Sediment behind the Dam.** The fate of the 700 acre feet of sediment behind the Dam is a critical issue for both the City and Stafford County. The following specific issues need to be addressed:
    1. A *sediment fate and transport study* needs to be conducted to determine what would happen to the sediment if it were released into the river, and the near and long term effects of such a release. This should include various release scenarios ranging from full release of all sediment to slow release using methods such as hydrosuction. The analysis should also include the effect of various seasonal flow regimes and how they would effect sediment transport. Ultimately, the study should address the extent of downriver impacts that would be associated with different release scenarios.

Appendix C

Correspondence

County of Spotsylvania

Founded 1721

May 13, 1997

County Administrator

L. KIMBALL PAYNE, III

P.O. BOX 99
SPOTSYLVANIA, VIRGINIA 2255
Voice: (540) 582-7010
Fax: (540) 582-9308
TTY: (540) 582-3594

Mr. L. Alan Weaver
Fish Passage Coordinator
Department of Game and Inland Fisheries
12108 Washington Highway
Ashland, Virginia 23005

Dear Mr. Weaver:

Thank you for the opportunity to comment on the draft scope of services related to the fish passage feasibility study for Embrey Dam on the Rappahannock River. At this time, I have only one comment.

On the first page of the draft in the background section, there is a sentence that states "In the near future, the dam will no longer be needed as a drinking water supply as Fredericksburg will jointly be obtaining water from Motts Run Reservoir with Spotsylvania County." That statement is not completely accurate. Fredericksburg and Spotsylvania will obtain water from either the Rappahannock River (directly or water originally released from Hunting Run Reservoir) and from the Motts Run Reservoir.

Thank you for the opportunity to comment. I wish you the best of luck on the feasibility study.

Sincerely,

L. Kimball Payne

L. Kimball Payne, III
County Administrator

JR

C.M. Williams
Stafford
City Admin

LKPIII:pb
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2. The feasibility and cost associated with *the dredging/removal of sediment* behind the Dam.

- **Effects of Dam Removal on Upriver Water Withdrawal Permits** ←
  Stafford County has expressed concern regarding the effect of the removal of Embrey Dam on future water withdrawals from the river at Rocky Pen Reservoir. Their permits states that if Embrey Dam is removed, no withdrawals will be permitted during March through May when the river is less than 100% of normal flow. We request that the DGIF study assess flow records to determine historically the prevalence of such flows during the March through May period, and the potential impact, if any, on the Rocky Pen Run reservoir.
- **Historic Preservation**
  The crib dam behind Embrey Dam is of historical significance. The study should address costs associated with preservation of a section of the crib dam for historical interests. The Department of Historic Resources should be consulted for costs of proper documentation/preservation measures for Embrey Dam, if deemed warranted.
- **Fish Passage Analysis by Scenario**
  We request that the following fish passage scenarios be evaluated in terms of 1) feasibility, 2) cost, 3) effectiveness in passing fish, 4) environmental impact, and 5) corollary issues such as safety hazards (e.g. from keeping the dam, or from dam debris in river)
  1. Complete removal of Dam, dredging/removal of sediment, maintenance of water in canal, preservation of portion of crib dam.
  2. Partial removal of Dam, partial dredging/removal of sediment, stabilization of remaining sediment/dam, maintenance of water in canal, preservation of portion of crib dam.
  3. Options 1 and 2, but with a) full release of sediment or b) slow release of sediment (hydrosuction).
  4. Installation of fish ladder, reinforcement of Dam, including ongoing maintenance costs.

In summary, cost and feasibility data are the key types of information that the localities (and potential grantors) need in order to move forward on the fish passage issue. I would like to emphasize that the assessment of the *corollary issues* (e.g. water in the canal, sediment issues, water permit issues) is critical at this point. These are of greatest concern to the local jurisdictions, and they pose significant financial questions. We encourage you to work closely with the City and Stafford County in your study, so as to most accurately address these issues.

Thank you for your consideration of these requests. I look forward to continuing to work with you to achieve restoration of anadromous fish passage at Embrey Dam.

Sincerely,

John P. Tippett
Executive Director

~~Bill Fruit~~

cc: Price Smith, VDGIF
John Kaufmann, VDGIF
Ed Steinkoenig, VDGIF
Hal Wiggins, Corps of Engineers
Senator Edd Houck
Bill Greenup, Mayor City of Fredericksburg
Marvin Bollinger, Fredericksburg City Manager
C.M. Williams, Stafford County Adminsitrator
Gordon Shelton, Fredericksburg City Council
Bob Boss, Stafford County

JFW will send note to Houck + RFP

✓ Kimball get address

Friends of the Rappahannock
"to conserve, protect, and educate"

P. O. Box 7254
Fredericksburg, VA 22404
Phone/Fax (540) 373-3448

Mr. Alan Weaver
Fish Passage Coordinator
Va. Department of Game and Inland Fisheries
12108 Washington Highway
Ashland, VA 23005

May 21, 1997

Dear Mr. Weaver,

Thank you for the draft scope of work for the VDGIF fish passage feasibility study at Embrey Dam. This letter is in response to your request for comment on the scope of work.

We are very pleased with the scope of work, and appreciate your inclusion of the needs I cited in my April 1 letter. The final product of an analysis by scenario will be a key tool in the decision process to follow the study.

The only addition we would have at this point is that VDGIF coordinate closely with the Corps of Engineers in order to assure that the issues are addressed in a way that meets federal permitting requirements. A meeting early in the process with the Corps would be very important in designing studies that are complementary.

Thank you for your good work.

Sincerely,

John P. Tippett
Executive Director

County of Stafford

STAFFORD COUNTY VIRGINIA
PROGRESS SINCE 1664

1300 COURTHOUSE ROAD
P. O. BOX 339
STAFFORD, VIRGINIA 22555-0339

PHONE: (540) 659-8603
FAX: (540) 659-7643
METRO: (703) 690-8222

COUNTY ADMINISTRATOR
C. M. WILLIAMS, JR.

May 14, 1997

Mr. L. Alan Weaver
Fish Passage Coordinator
Virginia Department of Game and Inland Fisheries
12108 Washington Highway
Ashland, VA 23005

Subject: Embrey Dam

Dear Mr. Weaver:

Thank you for sending me the information regarding the proposed Fish Passage Feasibility Study for Embrey Dam. The draft Scope of Services appears satisfactory.

As you know, the Rappahannock River is within the boundary of Stafford County. It is also anticipated that the river will provide water for the Rocky Pen Run Reservoir. That reservoir will be a major source of drinking water for county residents. Therefore, we are interested in participating in the study as it proceeds to a final recommendation.

I look forward to working with you on this regional project.

Sincerely,

C. M. Williams, Jr.
County Administrator

CMWJr:SC:cao

(north end) may be the logical part to be left in place. This option would also help to preserve other historic resources on City owned property, such as Hunter's Iron Works and its power canal.

5. The City is anxious to remove the dam and has obtained strong Congressional support in this regard. As a consequence, the option to reinforce and maintain the existing dam should certainly be studied but should not be of primary concern.

If you have any questions, please don't hesitate to call.

Very truly yours,

Marvin S. Bolinger
City Manager

Marvin S. Bolinger
City Manager

Beverly R. Cameron
Assistant City Manager

City of Fredericksburg
P.O. Box 7447
Fredericksburg, VA 22404-7447
Telephone: 703 372 1010
Fax: 703 372 1158

May 23, 1997

L. Alan Weaver
Fish Passage Coordinator
Department of Game and Inland Fisheries
12108 Washington Highway
Ashland, VA 23005

RE: Embrey Dam, Fredericksburg

Dear Mr. Weaver:

The City staff has examined the scope of work for the Embrey Dam Fish Passage Feasibility Study. The document appears to be quite thorough and the resulting study should be useful to all concerned. I offer the following comments for your consideration:

1. The **Background** section indicates the Embrey Dam is 22 feet high. Our research has revealed that there is considerably more concrete at the dam's northern end. The river bottom in this area was very poor for the earlier crib dam and a flood in 1889 caused this end to give way. The rush of water scoured out the riverbank and the Embrey Dam builders had to remove an enormous amount of rubble and dig deep to find a suitable foundation area. As a consequence, the concrete dam is as high as 43 feet in this area.

2. The **Scope of Services** section identifies water in the VEPCO Canal as a key issue. It should be noted that the original canal lock that first watered this canal is extant as is a large portion of its related canal. Certainly repairs will be needed and piping required where it has been obliterated, but some of the original canal may be reusable.

3. Also under **Scope of Services** are historic preservation items. It should be noted that the 1850s crib dam was in disrepair when the 1910 dam was built. If preservation of a portion of the crib dam proves infeasible, extensive photo documentation may be a reasonable alternative before it collapses.

4. If a portion of Embrey Dam is to be retained, the section where the most concrete exists

Project Narrative for
Technical Alternatives Analysis and Feasibility Study
for Providing Fish Passage at Embrey Dam
City of Fredericksburg, Virginia

The purpose of this study is to conduct a technical alternatives analysis for providing fish passage at Embrey Dam. The study will complete a field inspection of the dam site to document existing conditions, inspect the key issues regarding safety, the VEPCO Canal, existing sedimentation, and historic preservation alternatives, and to collect relevant field information to assist in completing the alternatives analysis. We will also review all previous correspondance, historical analysis performed by Mary Washington College, FERC and water withdrawal permits, plans, and technical studies that have been prepared for the Embrey Dam and prepare a summary of the information that is relevant to completing a technical alternatives analysis.

A draft scope of services was prepared for this study by the Virginia Department of Game & Inland Fisheries (VDG&IF). The draft scope was sent to area municipalities for comment, and was revised to include key issues to examine during this study including:

-Maintaining water in the VEPCO Canal.
-Existing sediments behind the dam.
-Effects of possible dam removal on upstream water withdrawal permits.
-Preservation of historic properties including the Embrey Dam and the existing crib dam located just upstream.

This study will prepare an overview of all potential alternatives for providing fish passage through the Embrey Dam site including the alternative of no action. Reduce the alternatives to prepare a detailed analysis and decision matrix to evaluate all practical alternatives. The alternatives that will be developed in detail will include:

-complete removal of dam
-partial removal of dam
-providing a fish passage through a reinforced section of the dam

The alternatives analysis will evaluate each alternative on the basis of feasibility, cost, effectiveness for providing fish passage, cursory review of environmental and historical impacts, safety, relative impacts from sediment, and other key issues identified during the field investigation. This study will utilize existing data only and will not include field topographical survey, dam safety inspection, Minimum Instream Flow studies for the river, or a detailed sediment transport study for each alternative. A decision matrix will be developed as a presentation tool to promote discussion regarding the project.

U.S. Army Corps of Engineers
Fredericksburg Field Office
10789 Columbia Drive
Fredericksburg, Virginia 22407
Phone: (540) 898-3568
(FAX) (540) 898-3589

FAX TRANSMITTAL COVER

DISTRIBUTION

TO: Peter Stokely (USEPA), Janet Norman (US FWS), John Stremple (NMFS), Valerie Ford (VDEQ), John Kaufman (VDGIF) Ed Stein Koenig (VDGIF)

FROM: Hal Wiggins Dick Gibbons (VDCR), Kirk Havens (VJMS) Heather Wood (VMRC), Tim Darcy (J.K Timmons)

DATE: July 16, 17, 1997

No. of Pages (including header) 12

Comments: Re: Technical Alternatives Analysis and Feasibility Study for Providing Fish Passage at Embry Dam.

DISTRIBUTION:

The Corps is soliciting comments at this time for preliminary plans to provide Fish passage at Embry Dam in Fredericksburg, VA. A Section 404 and Section 10 permit is required for the work in the Rappahannock River associated with the work.

Dates available for a meeting in Fredericksburg are July 29, July 31, Aug. 4, Aug 6, Aug 7, or Aug 8. Please let me know as soon as possible what days are available.

Hal Wiggins

DRAFT

Fish Passage Feasibiltiy Study for Embrey Dam

Contracting Agency: **Virginia Department of Game & Inland Fisheries**
4010 West Broad Street
P.O. Box 11104
Richmond, VA 23230-1104

Project Location: Embrey Dam on the Rappahannock River just downstream of I95

Period of Contract: Single Project Services

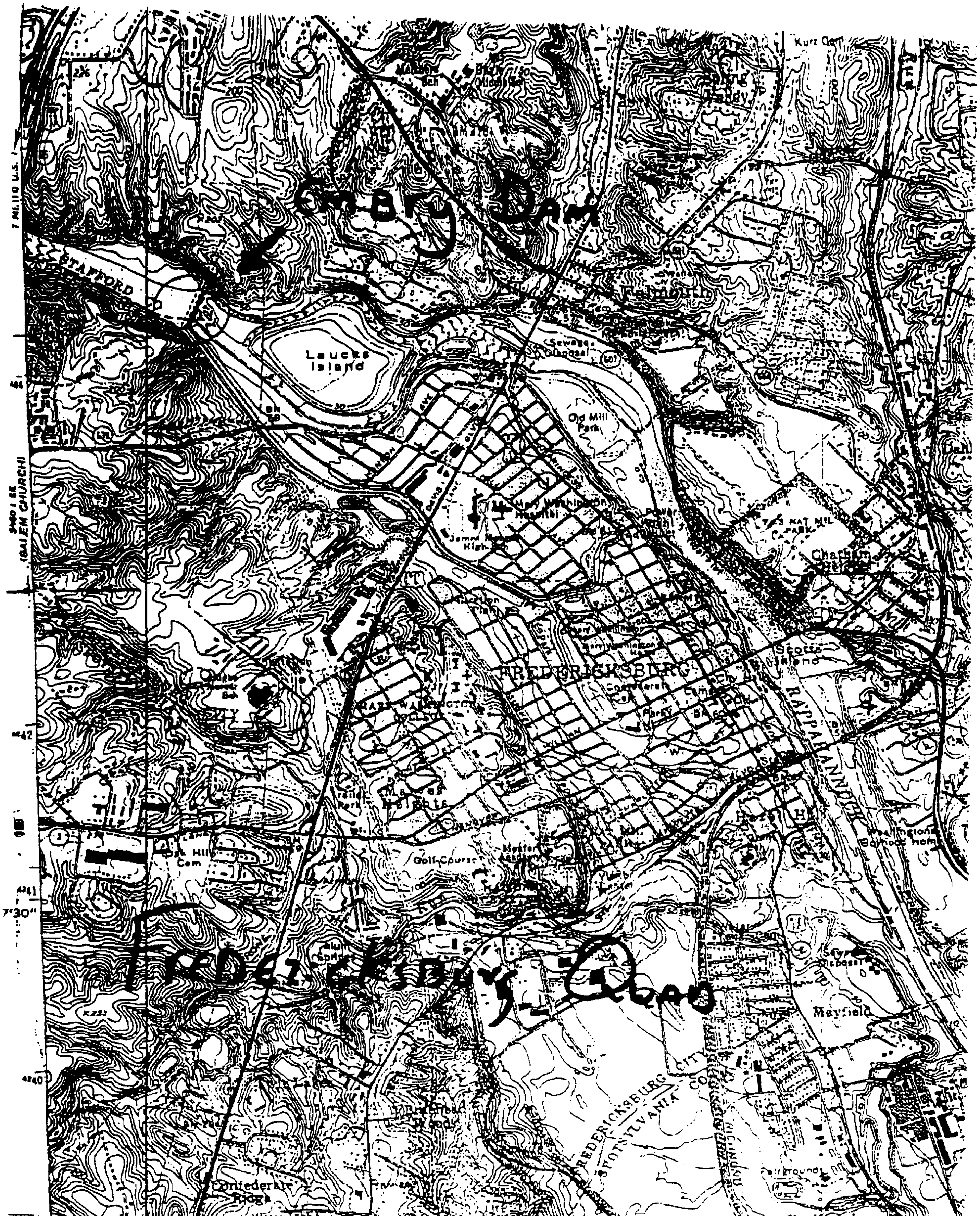
I. **Purpose**: The Virginia Department of Game and Inland Fisheries has been directed by Senate Joint Resolution No. 296 (Attachment A) to conduct a feasibility study for providing fish passage for anadromous fishes at Embrey Dam on the Rappahannnock River. Services requested include, but are not limited to investigations, studies, reports, synthesis of existing information, cost analyses and other required engineering services as needed to accomplish the project.

II. **Background**: Embrey Dam currently supplies drinking water for the City of Fredericksburg. The dam also supplies water to the old VEPCO canal. In the near future, the dam will no longer be needed as a drinking water supply as Fredericksburg will jointly be obtaining water from Mott's Run Reservoir with Spotsylvania County. Embrey Dam is 22 feet in height and is approximately 1000 feet in length. The dam is an Amberson dam and was constructed circa 1910. There is also a crib dam located just upstream of Embrey Dam that was constructed circa 1858.

The dam effectively blocks anadromous fish access to 70.6 miles of potential spawning habitat on the Rappahannock River mainstem alone as well as approximately 105 miles of major tributaries. The target fish species for passage are the river herring, which is a collective term for blueback herring and alewife, American shad and hickory shad. These fishes ascend Virginia's coastal streams each spring for the purpose of spawning and are found at the base of Embrey Dam each spring. The migratory run and spawning period for these species begins in late February and may extend until early June. Juvenile fish down migrate in the summer and fall.

The Virginia Department of Game and Inland Fisheries (VDGIF) conducted a sediment study in 1995 with assistance from the Virginia Department of Environmental Quality and Mary Washington College is completing a Phase I historical and archeological reconaissance of the dam and its environs for VDGIF. The City of Fredericksburg completed two engineering studies of the dam, one in 1990 and one in 1994. Study reports are attached for your convenience.

III. Scope of Services: The engineering firm shall provide services for a complete feasibility study and cost analysis for providing fish passage at the dam as well as


Embrey Dam
STAFFORD
Laucks Island
Falmouth
Old Mill Park
FREDERICKSBURG
RAPPAHANNOCK
Scotts Island
Golf Course
Fredericksburg Quad
Mayfield
FREDERICKSBURG CITY
SPOTSYLVANIA CO
Confederate Ridge
Fairgrounds
7'30"

3) Options 1 and 2 but with a) full release of sediment or b) slow release of sediment (hydrosuction).

4) Installation of fishway, reinforcement of dam, including continuous maintenance costs.

Fees: The fee for services shall be negotiated on a lump sum basis considering the Scope of Service required, the man hours required for each level/discipline, and the labor rates agreed upon during the initial negotiations.

addressing any potential impacts fish passage may have on other resources. The services shall include, but not be limited to the following: Synthesis of existing information and studies, evaluations, analysis, recommendations, cost and time estimates, reports, preplanning studies, engineering, planning and surveying services necessary to 1) study the dam site and its environs and identify the most cost effective approach to providing fish passage, 2) conduct a sediment fate and transport study (if dam is to be removed or breached), 3) recommend feasible methods for continued provision of water for the VEPCO canal if the dam were removed/breached, and 4) determine the effects on local historic properties if the dam is altered (e.g. removed).

Key issues to examine during this study that have been identified by various parties with vested interests are as follows:

1) Water in the VEPCO canal
   a) Feasibility and cost of extending a pipe upriver to a location with sufficient head to water the canal.
   b) Feasibility and cost of constructing a wing dam to divert river flow into the canal or restoring Lock 1 and the canal for the same purpose.
   c) Feasibility and cost of mechanical pumping alternatives.
   d) Determine minimum flow requirements for all scenarios.

2) Sediments behind the dam (shown to be non-toxic in 1995 study by VDGIF).
   a) Fate and transport study to include analysis of potential release scenarios and impacts on downstream resources.
   b) Feasiblity and cost of dredging/removal of sediment.

3) Effects of possible dam removal on upstream water withdrawal permits.

4) Preservation of historic properties including Embrey Dam and the old crib dam just upstream of Embrey Dam.

Specifically, the final product of this study will be an analysis of fish passage at Embrey Dam outlining several scenarios. The following scenarios will be evaluated in terms of 1) feasibility, 2) cost, 3) effiectiveness of passing anadromous fishes, 4) environmental impacts, and 5) corollary issues such as safety hazards (e.g. keeping the dam, or dam debris in the river after removal): , recreational and historic values

1) Complete removal of dam, dredging/removal fo sediment, maintenance of water in the canal, preservation of portion of crib dam.

2) Partial removal of dam, partial dredging/removal of sediment, stabilization of remaining sediment/dam, maintenance of water in the canal, preservation of portion of crib dam.

We recommend that the proponent for a project involving a beach of the Dam consider the removal of the sediment retained by the Dam either through mechanical and/or hydraulic dredging or a gradual release of sediments into the river so as to meet state water quality standards. We look forward to assisting the City and all interested parties in the development of a plan to address the removal of the sediment retained by the Embry Dam.

Another issue that is being addressed is Section 106 of the National Historic Preservation Act (NHPA). Section 106 of the NHPA requires licensing or permitting federal licensing agencies (like the Corps) to consider the effects of their undertakings (Corps permit) on historic properties and to consult with the Virginia Department of Historic Resources (VDHR). At this time, preliminary comments from the VDHR on a draft report of the Embry Dam (Enclosure 3) indicates the VDHR concurs with the findings in the report that the 20th-century concrete Dam and the 19th-century crib Dam are significant structures eligible for listing on the National Register of Historic Places. The VDHR further agrees with the report that the assessment of the Dam as a significant historic structure should not impede the proposed project (i.e. the construction of a fish passageway at the site by the Virginia Department of Game & Inland Fisheries). During a review of a potential fish passage project at Embry Dam, the Corps will coordinate with the VDGIF, VDEQ, and VDHR and weigh the historic significance of the Dam against the value of restoration of anadromous fisheries in the Rappahannock River. Other issues that will be addressed related to fish passage and a possible breach are safety/navigational issues that may be associated with the removal of a partial structure (i.e. Crib Dam and/or Embry Dam).

In addition to our regulatory role, I met in June 1996 with Fredericksburg City Manager Marvin Bolinger. The purpose of the meeting was to discuss flood control and other water, environmental, and related land resource needs the City may have, including fish passage on the Embry Dam. At this time, we are awaiting a reply from the City concerning any assistance the Norfolk District can provide regarding the aforementioned topics.

DEPARTMENT OF THE ARMY
NORFOLK DISTRICT, CORPS OF ENGINEERS
FORT NORFOLK, 803 FRONT STREET
NORFOLK, VIRGINIA 23510-1096

REPLY TO
ATTENTION OF:

January 17, 1997

Northern Virginia Regulatory Section
(Rappahannock River)

Honorable Herbert H. Bateman
Representative in Congress
c/o Mr. John Goolrick
4712 Southpoint Parkway
Fredericksburg, Virginia 22407

Dear Mr. Goolrick:

This is in reference to your request of December 23, 1996 regarding information concerning State Senator Houck's fish passage project at the Embry Dam and the role of the Corps of Engineers in this project.

In August 1992, Mr. Hal Wiggins of my staff met with representatives from the City of Fredericksburg, U.S. Fish and Wildlife Service, the Virginia Department of Environmental Quality, and the Virginia Department of Game & Inland Fisheries to discuss fish passage issues related to the Embry Dam on the Rappahannock River. It was determined at that time that a Department of the Army permit would be required for work involving any dredging and/or construction associated with the breaching of Embry Dam. Formal comments were provided to the City concerning our regulatory role in the fish passage project (Enclosure 1).

Since that time, several of the issues related to a breach of the Dam have been addressed. We are currently concluding a permit action in which the County of Spotsylvania and the City of Fredericksburg will jointly share a new water intake on the Rappahannock River near Motts Run. The current water supply intake structure on the Embry Dam will therefore eventually be abandoned, thus the City will no longer depend on the Embry Dam for their water supply.

Further, we concur with the findings in the report provided by the Virginia Department of Environmental Quality (Enclosure 2) that the sediment study data indicates that characteristics of the sediments retained by the Embry Dam are comparable to other sediments upstream and that the potential for these sediments to be considered a hazardous waste is minimal. However, we would caution that water quality degradation associated with a sudden and substantial release of sediment into the water column which would occur from breaching the Dam is a concern to us.

The Free Lance-Star

SATURDAY
MAY 31, 1997

Tearing down the Embrey Dam

Getting job done will require lots of money and patience

By ROBERT BURKE
Staff Reporter

A drive to remove the Embrey Dam is gaining support among Fredericksburg area localities.

But that's unlikely to speed up seven years of studies planned by the U.S. Army Corps of Engineers.

It's going to be a long process—and it ought to be, said Robert Ogle of the corps planning office in Norfolk.

Taking the dam down isn't as simple as dropping a few sticks of dynamite in the right places.

"There's a lot of things to look at," he said. "It's not just boom, you remove the dam."

The city, for example, wants to be sure that water can reach the Rappahannock Canal and adjacent marshes and ponds. And it wants old canal locks from the city's industrial past preserved.

There's also the issue of how to handle the tons of sediment behind the dam's 23-foot-high wall. And there's the matter of exactly how to take the dam down.

"I don't think we're going to permit something that's going to leave a big pile of rubble out in the river," said Hal Wiggins of the corps' local office.

And the biggest question: Who is going to pay for it?

"When you've got all of these things, you've just got to go in and study them," Ogle said.

The dam was built around 1910 and is deteriorating. Supporters of removing it hoped that might

FILE photo

Getting rid of the Embrey Dam will be a slow, bureaucratic process, officials say.

If I may be of some assistance, please let me know.

Sincerely,

Robert H. Reardon, Jr.
Colonel, U.S. Army
District Commander

Enclosures

Copies Furnished (w/out Encl):

City of Fredericksburg, Fredericksburg
State Senator Ed Houck, Spotsylvania
U.S. Fish & Wildlife Service, White Marsh
National Marine Fisheries Service, Oxford
Virginia Department of Environmental Quality, Woodbridge
Virginia Department of Game & Inland Fisheries, Richmond
Virginia Department of Historic Resources, Richmond

speed the process, but Ogle said no.

If the dam is a hazard, that's the state and the city's problem, he said. He downplayed the potential for the dam to break.

"It's just a small dam, really. During a flood, [it's] almost submerged. If it failed while it's submerged . . . you wouldn't even feel the effect."

Area localities can begin the process by asking the corps for help. Those who want the dam removed are trying to get as many localities involved in the request as possible.

Fredericksburg has already passed a resolution; Stafford and Spotsylvania counties are expected to soon, said Fredericksburg Mayor Bill Greenup.

When all three have approved separate resolutions they'll send a letter to the corps, Greenup said.

Sen. John Warner wants the dam gone, too, and has promised to use his influence on key Senate committees to make it happen.

Ogle said studies on the project could begin as early as this fall if Warner can get money for them in the corps' 1998 budget. The fiscal year for federal agencies begins Oct. 1.

Corps planners would first do a yearlong study to determine if there's a federal interest in the project. The corps would pay for this study. It would cost about $100,000 and include an agreement on paying for the next step, called a feasibility study.

That takes three years and would include evaluating the environmental impact of the project.

The corps would pay half the cost of the feasibility study, which could run around $1 million, Ogle said. The rest would presumably come from the localities, he said.

At this point, Ogle said, the corps could estimate the project's total cost.

Last comes three years of engineering and design work. The corps would pay 75 percent of this expense, which Ogle said varies depending on the project.

Ogle did say the process could be accelerated if the state Department of Game and Inland Fisheries goes ahead with a study on fish passage at the dam.

The corps could borrow from some of that work, Ogle said.

Getting the state involved is critical in helping to pay for the project, said City Manager Marvin Bolinger. While the dam belongs to the city, the river is a state and national asset, he said.

Greenup said that while Stafford and Spotsylvania support the idea of removing the dam, "I think that they do want to take a look at to what extent each one of them would benefit" before they agree to help pay for studies.

The city currently draws its drinking water from behind the dam, but it has agreed to build a new water plant with Spotsylvania. That project makes the dam expendable.

The Free Lance-Star
FREDERICKSBURG, VIRGINIA
WEDNESDAY, MAY 21, 1997

OPINION

EDITORIALS

Friend of the Rappahannock

Sen. John Warner is suddenly becoming one of the best friends the Rappahannock River has ever had. The senator, who carries a big stick on a committee that oversees public works projects, says he will do what he can to expedite the removal of the Embrey Dam, which has impeded the river's flow since 1910.

What's more, the senator says he would like to see at least part of the river officially designated as wild and scenic by the federal government.

River rats say those kinds of things all the time, but it is uncommon for a U.S. senator to get out front and lead the way on an issue involving the environment.

Apparently his zeal comes from the fact that Sen. Warner—who fishes for pleasure—recognizes a beautiful stretch of water when he sees it.

As for the politics involved, Sen. Warner has figured out that the Embrey Dam doesn't have a lot of support—literally or figuratively. It is an old, crumbling structure that needs to come down.

Once the dam is gone, shad and other migratory fish will be able to get upriver each spring to their migratory spawning grounds, and canoeists and kayakers will be able to paddle all the way down the free-flowing stream from the Blue Ridge Mountains to Fredericksburg, where the Rappahannock becomes a tidal river.

The dam is 34.8 feet high and 1,070 feet long. If a U.S. senator can give the 87-year-old structure a push, he will display the kind of power that's useful to his constituents.

Sen. Warner, a Republican, took his stand in defense of the river on Saturday during a meeting with representatives of the governments of Fredericksburg and Stafford County, the Department of Game and Inland Fisheries, the U.S. Army Corps of Engineers and Friends of the Rappahannock. The meeting about the dam was called by Democratic state Sen. Edd Houck, a leader in efforts to preserve the upper Rappahannock.

Sen. Warner, careful not to steal all the thunder, said he wants local government officials and citizens to get behind the dam-removal effort before he starts cutting through red tape and seeking money for the early stages of the job.

TOM PRICE / Staff photographer

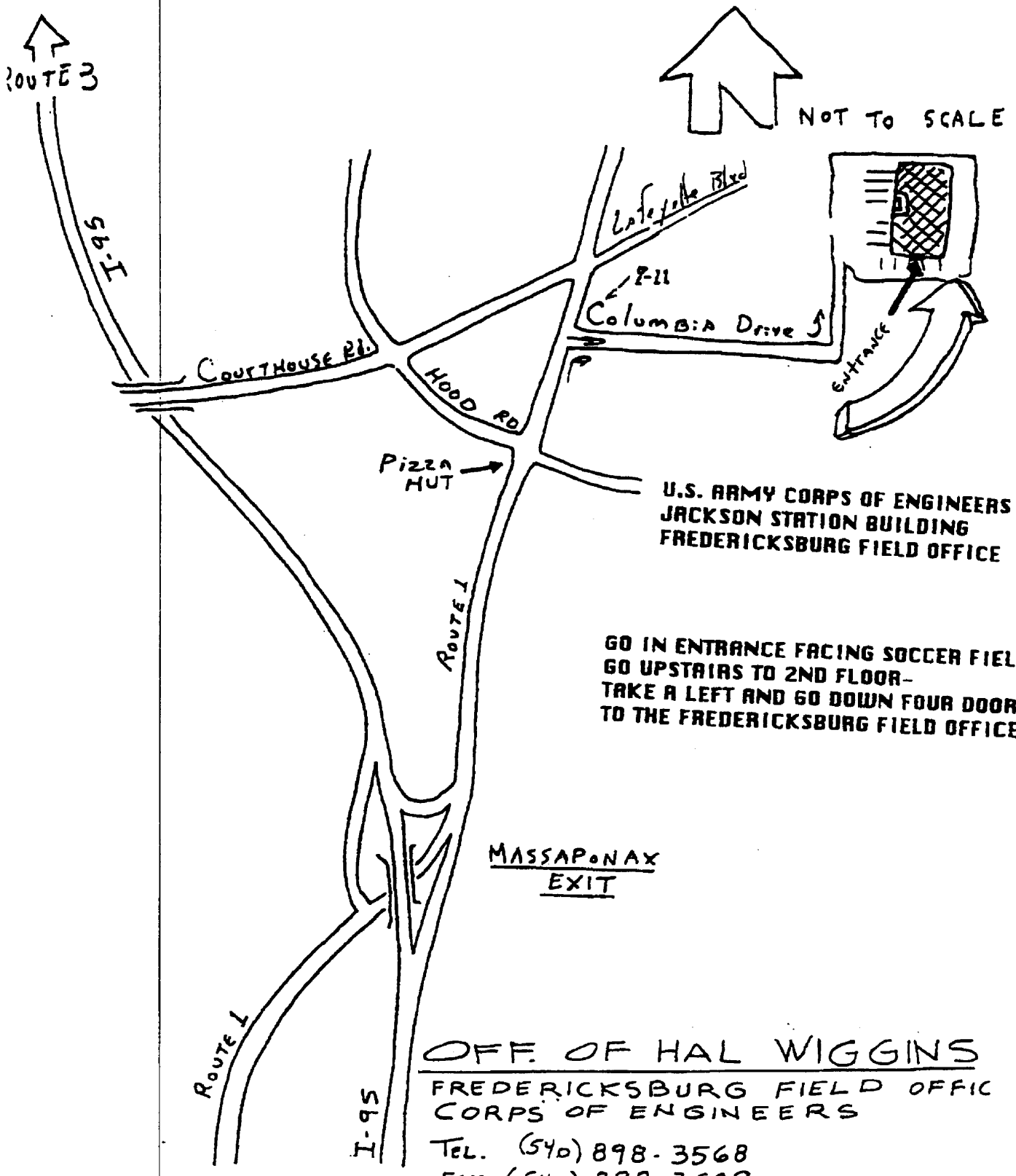
After getting a close look at the Embrey Dam over the weekend, U.S. Sen. John Warner, R-Va., said he will work for federal funds to remove it from the Rappahannock River.

Unfortunately, a Corps of Engineers representative said Saturday that his agency will need seven years to study any proposal to remove the dam. Sounds awfully bureaucratic, doesn't it?

Nature could intercede before then. One tropical storm or hurricane might be all that's needed to end the dam, which can be seen from Fall Hill Avenue not far upstream from the Falmouth Bridge.

The City Council commissioned a study that determined that no homes would be inundated if the dam broke, but anyone fishing or sightseeing downstream could drown in a wall of water. That safety factor lends a sense of urgency to the issue that could give Sen. Warner a stronger hand to play in Washington.

Because the river bed is in Stafford County, the Board of Supervisors will also have a say in the proposed demise of the Embrey Dam. Supervisors ought to raise any concerns they have, but they should do it as quickly as possible because Sen. Warner is ready to dip a big paddle in the water.



OFF. OF HAL WIGGINS
FREDERICKSBURG FIELD OFFIC
CORPS OF ENGINEERS
TEL. (540) 898-3568
FAX (540) 898-3589

U.S. Army Corps of Engineers
Fredericksburg Field Office
10789 Columbia Drive
Fredericksburg, Virginia 22407
Phone: (540) 898-3568
(FAX) (540) 898-3589

FAX TRANSMITTAL COVER

TO: Distribution: Peter Stokely (USEPA), Rob Hals: (USFWS), John Nichols (NMFS) Valerie Rourke (VDEQ), John Kaufman (VDGIF) Ed Steinkoenig (VDGIF), Dick Gibbons (VDCR), Kurk Havens (VIMS), Heather Wood (VMRC), Jonathan Phillips (VDCR), Tim Davey (JKT)

FROM: Hal Wiggins

DATE: July 24, 1997

No. of Pages (including header)

Comments:

Distribution:

The meeting for the Fish Passage Project on Embry Dam will be Monday August 4, 1997 at 10:00 Am. in the Fredericksburg Field office. A map is enclosed to the USACE Fed. Reg. office.

Hal Wiggins

Embry Dam Fish Passage Meeting

August 4, 1997

Name	Organization	Tele #
Hal Wiggins	Corps of Engineers	(540) 898-3568
John Tippett	Friends of the Rapp.	(540) 373-3448
HEATHER WOOD	VA. MARINE RESOURCES COMM.	757-247-8028
Kirk Havens	Va. Inst. of Mar. Sci	804-684-7386
CARL HERSHNER	VIMS	804-684-7387
Joan C. Crowther	DEQ-NVRO	540-583-3828
John Kauffman	Dept Game & Inland Fisheries	804 296-4731
Alan Weaver	Dept. of Game & Inland Fisheries	(804)752-5504
JON PHILLIPPE	DCR - DIV. OF DAM SAFETY - REG I	(540)347-6420
ROB KELSEY	U S FISH & WILDLIFE SERVICE	(410) 573-4527
Tim Davey	Timmons	(804) 379 613C
Richard G. Gibbain	DCR (Conservation & Recreation)	804-786-4132

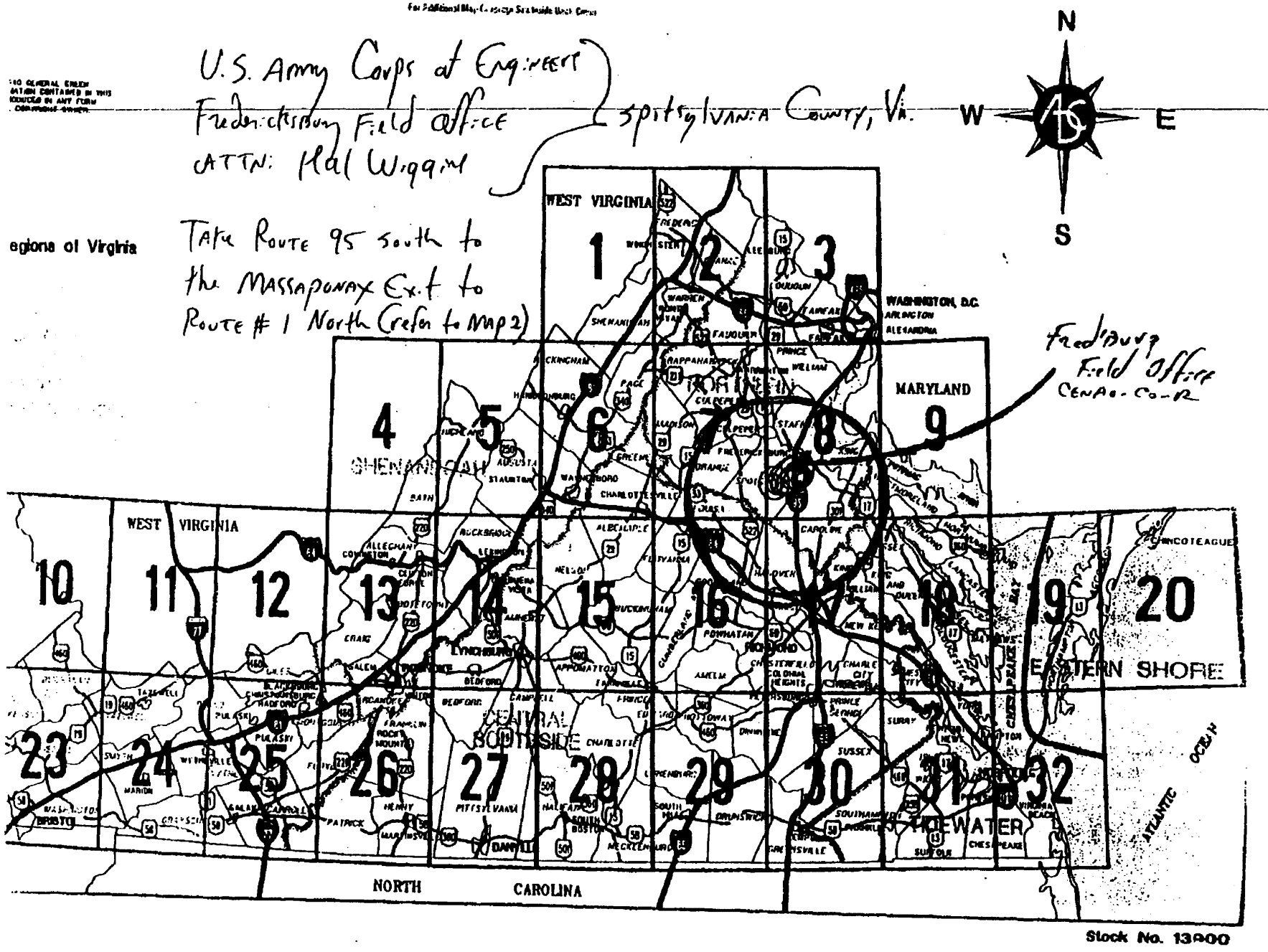
INDEX TO MAP SHEETS

U.S. Army Corps of Engineers
Fredericksburg Field office
ATTN: Hal Wiggins

Spotsylvania County, Va.

Take Route 95 south to the Massaponax Exit to Route #1 North (refer to map 2)

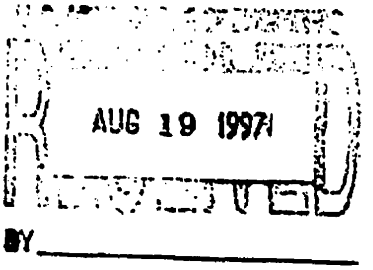
Fredburg Field office
CENAO-CO-R



Stock No. 13900

George Allen
Governor

.y Norton Dunlop
Secretary of Natural
Resources



Kathleen W. Lawrence
Director

COMMONWEALTH of VIRGINIA

DEPARTMENT OF CONSERVATION AND RECREATION

203 Governor Street, Suite 326

TDD (804) 786-2121 Richmond, Virginia 23219-2010 (804) 786-2556 FAX: (804) 371-7899

August 15, 1997

Mr. Hal Wiggins
U. S. Army Corps of Engineers
Fredericksburg Field Office
10789 Columbia Drive
Fredericksburg, Virginia 22407

Dear Mr. Wiggins:

Subject: Feasibility Study for Providing Fish Passage at Embrey Dam

The Department of Conservation and Recreation supports the goal of providing fish passage at the Embrey Dam on the Rappahannock River. This will specifically provide for enhanced recreation upstream for the citizens of Virginia.

The Fish Passage Feasibility Study for the Embrey Dam should include an assessment of several additional areas or issues. As you are aware, the Rappahannock is a state-designated Scenic River. The designation begins at river headwaters near Chester Gap and extends downstream to the Maysfield Bridge in Fredericksburg. This designation means that important scenic, recreational, and other natural resources exist in the river and along the corridor.

The study, as it currently defined, does not adequately take into account impacts or potential impacts on recreation and scenic values of the river. Several important factors concerning boating need to be addressed in each of the study alternatives; one is the quality of the recreation experience associated with each of the actions. What type of whitewater experience will the removal or partial removal of the dam create in the river? Will one of the alternatives produce an enhanced experience? The second factor concerns the considerations that need to be addressed for each alternative in order to provide a SAFE boating experience.

On the aesthetic values of the river -- what will be the impact of each of the alternatives on the river and river corridor aesthetic qualities? Each course of action will have a negative short term impact by the alteration of the pool of water now currently in the river because of the dam. The edges of the river will re-establish over time, and revegetation will take place. It is important to know the duration of impacts and if one course of action has fewer scenic consequences than another.

The College Of
WILLIAM&MARY

Wetlands Program

Virginia Institute of Marine Science
School of Marine Science
P.O. Box 1346
Gloucester Point, Virginia 23062
804/ 642-7380, FAX 804/ 642-7179

August 11, 1997

Mr. Hal Wiggins
U.S. Army Corps of Engineers
Fredericksburg Field Office
10789 Columbia Drive
Fredericksburg, VA 22407

Dear Hal:

This letter is in response to your request for our comments following the 4 August 1997 Technical Alternatives Analysis and Feasibility Study for Providing Fish Passage at Embrey Dam meeting that Dr. Carl Hershner and I attended.

Due to the large sediment load that the Rappahannock River presently receives, it is possible that a release of sediment from behind the dam may not have a significant adverse impact on the downstream fisheries resource if the release is timed not to coincide with certain critical life stages of the fish. However, to better understand the extent of the impact that a sediment release would have on the Rappahannock River, it will be necessary to determine the amount of sediment to be released and its possible downstream distribution .

The Virginia Institute of Marine Science has conducted much research on sediment modeling and the fishery resource of the Rappahannock River and would be interested in assisting as this project develops. Should you have any additional questions, please do not hesitate to contact me.

Sincerely,

Kirk J. Havens, Ph.D.
Department of Resource Management & Policy

C: Ms. Heather Wood, VMRC

Embry Dam Meeting : August 22, 1997

Name	Organization	Tele #
Hal Wiggins	Corps of Engineers	(540) 898-3568
Erik Nelson	CA of Fredericksburg	540 372-1179
John Tippett	FOR	540-373-3448
Ed SHARP	F.O.R.	540 373-3448
John Kauffman	VDGIF	804 296-4731
Alan Weaver	VDGIF	(804) 752-5504
C M Williams Jr	Stafford County	540/659-8605
DOUG FAWCETT	CITY OF FREDERICKSBURG	540.372.1023
Ken Turner	VDGIF	(540) 367-8311
CH BRAWLEY	GKY & ASSOCIATES	(703)-642-5080
Ed Steinkuehler	VDGIF - Fbrg	(540) 899-4169
Bruce Boyer	Spotsylvania County	(540) 898-2053
Tim Dewey	Timmons	(804 379 6136

Consultation with the City of Fredericksburg is recommended to determine what future uses may be made of the river, canal and corridor. The removal of the impoundment may result in the addition of lands to the floodplain that could be used for recreation or education. There should be a careful analysis of proposed alternatives to ensure that none preclude the region's ability to use the river, the canal, and the corridor's attendant resources for future recreation, education, and economic development.

The crib dam behind the Embrey Dam is an important historical feature, along with the canal and some of its related constructed features. A careful study should be done to determine if a portion of the crib dam and the Embrey dam could be saved and developed for educational purposes. This could involve some plan to retain water between the two dams and to develop walkways on or around the features. The Virginia Department of Historic Resources is the source of technical assistance for historic preservation projects.

This project should be coordinated with the Rappahannock Scenic River Advisory Board; Mr. John D. Mitchell is Chairman. He can be reached by phone at (540) 371-2030 or by mail at 1025 Hillcrest Terrace, Fredericksburg, Virginia 22405.

I appreciate the opportunity to participate in the scoping and planning for the fish passage project. The end result should be enhancement of the river and its resources.

Sincerely yours,

Richard G. Gibbons
Environmental Program Manager

RGG/br

cc: Ron Hedland
John R. Davy, Jr.
John D. Mitchell, Chairman
Rappahannock Scenic River Advisory Board

DEPARTMENT OF THE ARMY
NORFOLK DISTRICT, CORPS OF ENGINEERS
FORT NORFOLK, 803 FRONT STREET
NORFOLK, VIRGINIA 23510-1096

October 1, 1997

REPLY TO
ATTENTION OF:

Northern Virginia Regulatory Section
(Rappahannock River)
92-8628-45

Mr. Tim Davey
Timmons & Associates
711 N. Courthouse Road
Richmond, Virginia 23236-4099

Dear Mr. Davey:

This is in reference to our review of your draft "Fish Passage at Embry Dam" report prepared on September 15, 1996. Our preliminary technical comments were provided to you on September 25, 1997.

We are pleased with the efforts conducted by all parties in the preparation of the report and this effort in general. It is significant that local, state and federal government can work together in close coordination and cooperation to insure that all public interest factors are considered with this important effort.

As you know, we met on two occasions with the interested and affected public to discuss your study. The Virginia Institute of Marine Science and the Virginia Department of Conservation and Recreation provided written comments (enclosed) on the project.

At this time, we are coordinating the historic assessment report entitled "An Assessment of the Embry Dam Area" with the Virginia Department of Historic Resources (VDHR). We anticipate that the VDHR will concur with the conclusions and recommendations in the report and our findings. In addition, please find enclosed former correspondence provided by the Corps to Congressmen Bateman and the City of Fredericksburg. This correspondence should be included in the report.

We look forward to working with you closely to address the comments contained in the draft report. In addition, we would like to meet with you and our planning division staff to discuss additional steps involved with the reconnaissance study conducted by the Corps.

CHESAPEAKE BAY FOUNDATION

Resource Protectio
Environmental Educatio

September 22, 1997

Mr. Timothy M. Davey, P.E.
Timmons
711 N. Courthouse Road
Richmond, VA 23236

Dear Mr. Davey:

We would like to submit this letter of comment for inclusion in the final report to the Virginia General Assembly regarding the removal of Embry Dam as required by Senate Joint Resolution 296 (SJR 296). The Chesapeake Bay Foundation (CBF) is the largest private non-profit organization dedicated to the protection and restoration of the Chesapeake Bay. We appreciate the effort by Timmons to incorporate public comments into the final report through the information meeting held in Fredericksburg on September 11, and the inclusion of comment letters in the final report.

CBF has identified a set of nine "indicators" or benchmarks of ecosystem health that help to direct our efforts toward achieving our goal of a healthy Bay. One of the indicators is migratory fish, with the quantitative goal of 1,500 additional river miles opened for upstream migration of fishes such as American shad, hickory shad, river herring and striped bass by the year 2005. To that end, the complete removal of Embry Dam, near Fredericksburg, Virginia, would be a significant step toward our goal.

According to the decision matrix presented by Timmons at the September 11 public meeting, the complete removal of the dam will incur an estimated maximum $7.5 million over 50 years. While there remains some concern regarding the fate of sediments residing behind the dam, the complete removal of the dam is clearly the best option for achieving fish passage and relieving the City of Fredericksburg of the long-term costs of liability insurance and maintenance associated with the dam. Further study is needed to determine the best option for disposing of sediment behind the dam which, while apparently non-toxic, could impact downstream resources such as shellfish beds.

Once again, we appreciate this opportunity to comment on this study, and look forward to the next steps to providing passage for migratory fish on the Rappahannock River.

Sincerely,

Robert D. Brumbaugh, Ph.D.
Fisheries Scientist

Joseph H. Maroon
Virginia Executive Director

100 West Plume Street # 336
Norfolk, Virginia 23510
757.622.1964, fax 757.622.7861

Headquarters Office: 162 Prince George Street, Annapolis, Maryland 21401, 410.268.8816, fax 410.268.6687
Maryland Office: 164 Conduit Street, Annapolis, Maryland 21401, 410.268.8833, fax 410.280.3513
Pennsylvania Office: 214 State Street, Harrisburg, Pennsylvania 17101, 717.234.5550, fax 717.234.9632
Virginia Office: 1001 E. Main Street, Suite 710, Richmond, Virginia 23219, 804.780.1392, fax 804.648.4011

DEPARTMENT OF THE ARMY
NORFOLK DISTRICT, CORPS OF ENGINEERS
FORT NORFOLK, 803 FRONT STREET
NORFOLK, VIRGINIA 23510-1096

October 1, 1997

REPLY TO ATTENTION OF:
Northern Virginia Regulatory Section
(Rappahannock River)
92-8628-45

Cara Harbecke Metz
Virginia Department of Historic Resources
221 Governor Street
Richmond, Virginia 23219

Dear Ms. Metz:

The Corps of Engineers has been in the process of working with the Virginia Department of Game & Inland Fisheries their consultant and other interested and affected parties to review a project involving fish passage at the existing Embry Dam on the Rappahannock River in Stafford County, Virginia.

In June 1997 an historic assessment report entitled "An Assessment of the Embry Dam Area "completed by the Center for Historic Preservation (CHP) was conducted and revised. The report contains the findings and recommendations for three alternatives for providing fish passage at the Embry Dam. The Corps of Engineers concurs with the conclusions and recommendations in the report.

In accordance with Section 106 of the National Historic Preservation Act, your comments on the historic assessment report (enclosed) and concurrence with us is requested. If you have not commented on the report within 30 days of the receipt of this letter we will assume that you concur with the conclusions and recommendations in the report. Ultimately, we would like to meet with you and discuss a possible Memorandum of Agreement (MOA) between you, the Corps, and the Virginia Department of game and Inland Fisheries for handling historic properties based on the alternative chosen.

Thank you for your attention to this matter. The Norfolk District fully appreciates the opportunity to fulfill the requirements of Section 106 of the National Historic Preservation Act regarding effects of Corps authorized undertakings on properties included in or eligible for the National Register of Historic Places.

Should you have questions, please call Mr. Hal Wiggins at (540) 898-3568 at our Fredericksburg Field Office.

Sincerely,

Hal Wiggins (for)

Bruce F. Williams
Chief, Northern Virginia
Regulatory Section

Enclosure

Copies furnished (w/o encl):

Virginia Department of Game & Inland Fisheries, Richmond
State Senator Edd Houck, Fredericksburg
City of Fredericksburg, Fredericksburg
Virginia Department of Environmental Quality, Woodbridge
Friends of the Rappahannock, Fredericksburg
Corps of Engineers, Planning Division, Norfolk

SIGN IN SHEET

Bill Greene, City of Fredericksburg
Hal Wiggins USACE
Joan C. Crowther DEQ NVRO
John P. Fitzgerald FOR
Elden James RRBSC
Ted Hoover Senator Va
John Whitfield King George, VA.
Joni L. Whitfield Sierra Club-
Edward J. Sharp. F.O.R.
Mary Becelia Sierra Club
John VAN Hoy Stafford County, FOR
David B. Tanner Fredericksburg-
Scott Howson City of Fredr
Erik F. Nelson City of Fredericksburg
Stephen Sanders FOR
Bob Burke Free Lance-Star
Robert Brumbaugh - Chesapeake Bay Fndtn 100 W. Plume Suite 336 St. Norfolk 23510
Ed Stenkienitz VDGIF Fbrg
Jon Phillippe DCR Dir of Dam Safety Warrenton, Va.
Alan Weaver VDGIF Fish Passage Coordinator Ashland, VA

If you have any questions, please call Mr. Hal Wiggins at (540) 898-3568.

Sincerely,

Hal Wiggins (FAV)

Bruce F. Williams
Chief, Northern Virginia
Regulatory Section

Enclosure

Copies Furnished (w/o encl):

State Senator Edd Houck, Fredericksburg
Virginia Department of Game and Inland Fisheries, Richmond
City of Fredericksburg, Fredericksburg
County of Stafford, Stafford
National Park Service, Fredericksburg
Mary Washington College Center for Historic Preservation, Fredericksburg
Corps of Engineers, Planning Division, Norfolk

Virginia Department of Game and Inland Fisheries

Embrey Dam Fish Passage Study
Technical Decision Matrix

TIMMONS

Issue	Fish Passage	Partial Dam Removal	Complete Dam Removal	Do Nothing
Allow anadromous fish to travel upstream	Target and some non-target species and population pass with vertical slot fishway. All species pass with elevator.	All species would be able to pass. No limit on population.	All species would be able to pass. No limit on population.	No passage for any resident or anadromous fish.
Supply of water to Rappahannock Canal	Not affected by construction because dam remains in place.	Requires either mechanical pumping or extending intake upstream.	Requires either mechanical pumping or extending intake upstream.	Not affected because dam remains in place.
Upstream water withdrawal permits	Permit condition addressing withdrawal during migration season would be in effect.	Permit condition addressing withdrawal during migration season would be in effect.	Permit condition addressing withdrawal during migration season would be in effect.	Not affected.
Sediments upstream of dam	Not affected.	Sediments would need to be released, excavated or stabilized. Additional study required.	Sediments would need to be released, excavated or stabilized. Additional study required.	Not affected.
Stability of dam	Dam remains in place and would require repair and annual maintenance.	Although sections of the dam are removed, sections of dam left in place would require repair and annual maintenance.	Entire dam, abutments, and entrance to canal are removed.	Dam remains in place and would require repair and annual maintenance in accordance with recertification inspection.
Public Safety	Dam remains in place and would require continued safety measures by City.	Sections of dam left in place would require continued safety measures by City.	Entire dam , abutments and entrance to canal are removed.	Dam remains in place and would require continued safety measures by City.
Historical	No adverse impacts to concrete dam or crib dam.	The adverse impacts to both the concrete dam and crib dam would need to be mitigated by thorough documentation.	The adverse impacts to the concrete dam and crib dam would need to be mitigated through additional field investigations outlined in agreement between VDGIF, City, DHR, and USACOE. Additional study required.	Not affected.
Environmental	Section 404/401 permitting process.	COE may require additional studies before completing Section 404/401 permitting process.	COE may require additional studies before completing Section 404/401 permitting process.	Not affected.
Maintenance requirements	Operation and monitoring of fishway, maintenance of dam, and intake gates for canal.	Maintenance for remaining portions of dam and canal intake pipeline.	Maintenance for canal intake pipeline.	Maintenance of existing dam, and intake gates for canal.
Construction/ Rubble Removal	Construction would require extensive cofferdam to construct fish passage Existing dam would need to be stabilized. Rubble removal and work in river bottom minimal.	Construction would require extensive cofferdam to remove breached sections Sections to remain would need to be stabilized. Rubble removal and work in river bottom extensive.	Construction would require extensive cofferdam to remove dam, canal headwalls and sidewalls, and abutments. Rubble removal and work in river bottom extensive.	No capital construction.

Appendix D

Decision Matrices

Appendix E

Reinspection Report

Virginia Department of Game and Inland Fisheries

Embrey Dam Fish Passage Study
Local Decision Matrix

TIMMONS

Issue	Fish Passage	Partial Dam Removal	Complete Dam Removal	Do Nothing
Historical Crib Dam	Not affected.	Will need to be removed because dewatering will cause deterioration. Section 106 process requires documentation.	Will need to be removed because dewatering will cause deterioration. Section 106 process requires documentation.	Not affected.
Historical Upper Canal Locks	Not affected.	Will provide opportunity to expose original canal and locks.	Will provide opportunity to expose original canal and locks.	Not affected.
Historical Concrete Dam	Creation of Gravity Dam means impacts would need to be mitigated through thorough documentation.	The impacts would need to be mitigated through thorough documentation.	The impacts would need to be mitigated through additional field investigation outlined in agreement between owner and DHR. Additional study required.	Not affected.
Fishing Recreation	Target and some non-target species and population pass with vertical slot fishway. All species pass with elevator.	All species would be able to pass. No limit on population.	All species would be able to pass. No limit on population.	No passage for any fish.
Canoe/Kayaking Recreation	The dam is an existing safety hazard; portage is required to pass.	This alternative eliminates portage and may provide additional canoe/whitewater possibility, although abutments may be a safety hazard. Additional studies required.	This alternative eliminates portage and may provide additional canoe/whitewater possibility. Additional studies required.	The dam is an existing safety hazard; portage is required to pass.
State Designated Scenic River	No significant change to river front utilization or viewshed.	Additional river front utilization and impacts on scenic river will need to be evaluated. Additional studies required.	Additional river front utilization and impacts on scenic river will need to be evaluated. Additional studies required.	Not affected.
Sediment Impact on Downstream Flooding, Habitat, Recreation, and Navigation	Not affected.	Additional sediment transport study is required to adequately address impacts.	Additional sediment transport study is required to adequately address impacts.	Not affected.
Wetlands Upstream of Dam	Not affected.	Opportunity to stabilize existing sediment along new river banks with wetland vegetation.	Opportunity to stabilize existing sediment along new river banks with wetland vegetation.	Not affected.
Adjacent Property Rights/Value	Not affected.	Property rights, including new boundaries, of adjacent landowners must be addressed.	Property rights, including new boundaries, of adjacent landowners must be addressed.	Not affected.
Economic Development Impact	Additional studies required.	Additional studies required.	Additional studies required.	Not affected.

DAM SAFETY PROGRAM

DEPARTMENT OF CONSERVATION & HISTORIC RESOURCES
Division of Soil & Water Conservation
203 Governor Street, Suite 206
Richmond, Virginia 23219-2094

REINSPECTION REPORT FOR CLASS 1 AND CLASS II IMPOUNDING STRUCTURES

Reference: Impounding Structure Regulations, Chapter 3, Virginia Soil and Water Conservation Board

1. Project Information:
   a. Name of Impounding Structure Embrey Dam
   b. Inventory Number 17905 Other Name (if any) _____
   c. Name of Reservoir Rappahannock River
   d. Purpose of Reservoir Divert water to the Fredricksburg Water Treatment Plant

2. Location of Impounding Structure:
   a. City/County Stafford Magisterial District n/a
   b. Located 3500 feet/miles upstream/downstream of Highway Number I-95
   c. Name of River or Stream Rappahannock River
   d. Latitude 38°19' Longitude 77°29'

3. Ownership:
   a. Owner's Name City of Fredricksburg
   b. Mailing Address P.O. Box 7447
      Fredricksburg, VA
   c. Telephone (703) 372-1023

4. Owner's Engineer:
   a. Engineering Firm/Engineer Samuel E. Saunders, P.E.
   b. Virginia Number 14532
   c. Mailing Address 711 N. Courthouse Rd.
      Richmond, VA 23236
   d. Telephone (804) 794-3550

h. 1.2.8 Normal operating procedures, changes _____ no __X__ yes. If yes, describe:

Two gates (alternating every 2-3 weeks) used to divert water into the Rappahannock Canal.

i. 1.3.1 Drainage area; change ___X___ no _____ yes. If yes, describe:

j. 1.3.2 Discharge at dam site; changes ___X___ no _____ yes. If yes, describe:

k. 1.3.3 Dam and reservoir data, changes ___X___ no _____ yes. If yes, describe:

7. Provide a narrative describing any changes in the impounding structure from the Phase I Inspection Report, Section Two - Engineering Data:

a. 2.1 Design change ___X___ no _____ yes. If yes, describe:

b. 2.2 Construction, change ___X___ no _____ yes. If yes, describe:

c. 2.3 Evaluation change ___X___ no _____ yes. If yes, describe:

8. Provide reinspection observations of the impounding structure and appurtenances; Phase I Inspection Report, Section 3 - Visual Inspection.

a. Reinspection date August 21, 1997

b. Reinspection by Samuel E. Saunders, III, P.E.; Lance J. Koth, P.E.; Brad Jones

c. General observations Clear, 85°; Pool elevation was 52.5' MSL ± (approximately 0.5' above spillway crest); Tailwater was 31.0' MSL ±.

5. Phase 1 Inspection Report:

a. Phase 1 Inspection Report Prepared By Norfolk District, Corps of Engineers

b. Phase 1 Inspection Report date: September, 1997

6. Provide a narrative describing any changes in the impounding structure from the Phase I Inspection Report, Section One-Project Information:

a. 1.2.1 Description of dam and appurtenances, changes ____ no __X__ yes

If yes, describe: The gates are operable to divert water into the Rappahannock Canal.

b. 1.2.2 Location, change ____X____ no _____ yes. If yes, describe:

c. 1.2.3 Size classification, change ___X___ no _____ yes. If yes, describe:

d. 1.2.4 Hazard, classification, change ___X___ no _____ yes. If yes, describe:

e. 1.2.5 Ownership, change ___X___ no _____ yes. If yes, describe:

f. 1.2.6 Purpose of dam, change ___X___ no _____ yes. If yes, describe:

g. 1.2.7 Design and construction history, changes ___X___ no _____ yes. If yes, describe:

b. 4.2 Maintenance, changes ___X___ no _____ yes. If yes, describe:

_____

_____

c. 4.3 Warning system, changes _____ no ___X___ yes. If yes, describe:

Property owners to be included in Emergency Action Plan.

_____

d. 4.4 Evaluation, changes ___X___ no _____ yes. If yes, describe:

_____

_____

10. Provide a narrative describing any changes in the impounding structure from the Phase I Inspection Report, Section 5 - Hydraulic/Hydrologic Data:

a. 5.1 Design, change ___X___ no _____ yes. If yes, describe:

_____

_____

b. 5.2 Hydrologic records, change ___X___ no _____ yes. If yes, describe:

_____

_____

c. 5.3 Flood experience, change ___X___ no _____ yes. If yes, describe:

_____

_____

d. 5.4 Flood potential, change ___X___ no _____ yes. If yes, describe:

_____

_____

e. 5.5 Reservoir regulations, change ___X___ no _____ yes. If yes, describe:

_____

_____

f. 5.6 Overtopping potential, changes ___X___ no _____ yes. If yes, describe:

_____

_____

d. Dam See Attachment 1

e. Principal Spillway: See Attachment 1

f. Emergency Spillway: N/A

g. Low Level outlet: N/A

h. Other Appurtenances: See Attachment 1

i. Reservoir Area: Sediment has not changed noticeably since 1965.

j. Downstream Channel/Area: Downstream area is stable of rocks, cobbles, boulders in stream and along banks.

k. Instrumentation: N/A

l. Evaluation/Recommendations: See Attachment 1

9. Provide a narrative describing any changes in the impounding structure from the Phase I Inspection Report, Section 4 - Operational Procedures:

a. 4.1 Procedures, changes ___X___ no _____ yes. If yes, describe:

13. If this Reinspection Report is being prepared in order to update an existing operation and maintenance certificate, describe any changes in:

a. Emergency Action Plan; change ___X___ no _____ yes. If yes, describe:

_____

_____

b. Operation and Maintenance Plan; change ___X___ no _____ yes. If yes, describe:

_____

_____

CERTIFICATION BY OWNER'S ENGINEER

I hereby certify that the information provided in this Reinspection Report has been examined by me and found to be true and correct in my professional judgment.

Signed _____ Va. Number 19532 this 19 day of SEP, 19 97
Professional Engineer

g. 5.7 Reservoir emptying potential, change ___X___ no _____ yes. If yes, describe:

_____

_____

h. 5.8 Evaluation, change ___X___ no _____ yes. If yes, describe:

_____

_____

11. Provide a narrative describing any changes in the impounding structure from the Phase I Inspection Report, Section 6 - Dam Statbility.

a. 6.1 Foundation abutments, change ___X___ no _____ yes. If yes, describe:

_____

_____

b. 6.2.1 Embankment materials, change ___X___ no _____ yes. If yes, describe:

_____

_____

c. 6.2.2 Embankment stability, change ___X___ no _____ yes. If yes, describe:

_____

_____

d. 6.3 Evaluation, change _____ no ___X___ yes. If yes, describe:

Dam has several areas with seepage, Stability does not appear to be an immediate danger. Extensive repairs are needed for long term stability.

12. Provide a narrative describing any changes in the impounding structure from the Phase I Inspection Report, Section 7 - Assessment/Remedial Measures:

a. 7.1 Dam assessment, change _____ no ___X___ yes. If yes, describe:

Three canal gates are operable.

_____

b. 7.2 Recommended remedial measures, changes ___X___ no _____ yes. If yes, describe:

Bays with exposed reinforcing bars, large cracks or honeycombing, should be repaired.

Attachment 1 - Form DS-2RR

Concrete/Masonry Dams Visual Inspection Checklist

Name of Dam: Embrey Dam | County: Stafford | State: Virginia | Coordinates: Lat 38°19'3" Long 77°29'4"

Date(s) Inspection: 09/21/97 | Weather: Cloudy | Temperature: 85°F

Pool Elevations at Time of Inspection:
±52.5' MSL (approximately 0.5' above spillway crest)

Tailwater at Time of Inspection:
±31.0' MSL

Inspection Personnel:

Lance J. Koth, P.E.

Samuel E. Saunders, III, P.E.

Brad Jones

Recorder:

Brad Jones

Attachment 1

8. Provide inspection observations.....

d. Dam: Railings have been replaced along walkway at upper end of canal adjacent to dam. Some kickplates are still missing. Access is restricted by a gate at the beginning of the walkway.

e. Principal Spillway: Principal spillway is approximately 770' of dam. Evaluation was difficult because of water passing over dam. Several spots on the spillway have irregular flow indicating spalling.

h. Other Appurtenances: Spalling in areas of the southern abutment. Some of this spalling has been repaired. Access to inspection walkway is through a hatch using an extension ladder. A more permanent access is recommended.

l. Evaluation Recommendations: Spalling, cracking, and honeycombing throughout dam should be repaired. Dam short term stability does not appear to be a threat, however long term stability remains a concern. Extensive repair is needed to stabilize dam.

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
Surface Cracks/ Concrete Surfaces	Significant spalling and cracking of the dam crest has occurred at numerous places as evidence by the discontinuity of water flowing over the crest. Most of the 55 Chambers exhibit spalling, cracking, and honeycombing at both the construction joints and across the slab. These range in severity. Refer to the enclosed tabulation of Slab/Buttress/Walkway Inspection Findings for more detail. Several of the Chambers had exposed reinforcing steel in the slab above the walkway where the concrete has spalled.	Repairs should be performed throughout structure.
Structural Cracking	Cracking observed in the slabs, inspection walkway, and buttresses of most of the chambers. Reinforcing bars are exposed in several of these chambers and the cracking/spalling extends across the entire slab in some cases.	Concrete repairs should be performed throughout the structure.
Vertical and Horizontal Alignment	No evidence of movement observed.	
Monolith Joints (Vertical)	N/A	
Construction Joints	Cracking in the slabs and buttresses has occurred primarily at the construction joints. Each of the 55 Chambers exhibit significant cracking at the joints. Refer to the enclosed Tabulation of Slab/Buttress/Inspection Findings for more detail.	Concrete repairs should be performed throughout the structure..

CONCRETE/MASONRY DAMS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
Seepage or Leakage	Significant orange colored seepage (2 GPM) was occurring through the soil approximately 10 feet east of Chamber 1.	Seepage could lead to piping of left abutment. Significant seepage occurring in several chambers. Repairs should be performed to eliminate it.
Structure to Abutment/ Embankment Junctions	Left Abutment: Cracking and spalling at junction. Evidence of abutment slab undermining. Seepage with orange color.	Repair cracking and spalling.
Drains	Pipe in Chamber 37 appears clogged.	This pipe could be a pressure relief drain which might be fed by additional collector drains laid longitudinally along base of dam, however, no plans or specifications exist. Remove material clogging drain.
Water Passages	The gates area exercised every 2-3 weeks.	
Foundation	Unable to evaluate.	

OUTLET WORKS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
Cracking and Spalling of Concrete Surfaces in Outlet Conduit	Minor Cracking and spalling was observed in the concrete surface.	Repair the spalled areas.
Intake Structure	Trash racks are littered with debris. Five gates exist to release water into the Rappahannock canal. Only three gates are equipped with a gate stem and wheel. None were operated during the inspection. According to the maintenance supervisor the two gates nearest the dam are exercised every 2-3 weeks. The pipe valve control platform which regulates flow from the canal to the Rappahannock River downstream of the Dam has no railings and access into the dam is through (by ladder) a 2' x 3' opening in the platform. The pipe valve did not have a control mechanism on it.	None.
Outlet Structures	N/A	None.
Outlet Channel	Good condition.	None.

UNGATED SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
Concrete Weir	Extents of deterioration could not be observed due to flow over the dam.	During periods of low flow the crest joints should be repaired.
Approach Channel	The approach channel was clear of debris	None
Discharge Channel	The discharge channel was observed to exist in its natural state.	None
Fish Ladder	Fish ladder is not functioning. Sections of wood are broken but some water still runs through ladder structure. A crack exists in the interior wall from the top of the arch at the access door downstream to the corner of the wall.	

INSTRUMENTATION/MISCELLANEOUS (CONTD.)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
Other: Buttresses	The concrete buttresses are cracking at joints and spalling on most of the buttresses. The downstream edge of all buttresses are covered with damp vegetation and several have spalled sections and eroded joints. All buttresses are scoured at and below the water level inside each chamber.	None. Foundations should be inspected during low flow period.
Hydrologger and Staff Gauges	There are three gauges in the vicinity of Embrey Dam. The firs is located near the I-95 bridge over the Rappahannock River and is operated by the U.S. Geological Survey. The second gauge is locate on the City's side of the Embrey Dam, at the Canal intake structure. This gauge is owned by the National Weather Service and is a hydrologger unity which is connected by telephone directly to the NWS is Sterling, Virginia. The third gauge is a staff gauge located at the City Dock and Boat Ramp downstream of the Dam.	

INSTRUMENTATION/MISCELLANEOUS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
Monumentation/Surveys	It was reported that a VEPCO elevation marker existed in the natural rock wall just upstream of the intake structure. A USGS elevation marker exists on top of the intake structure wing wall.	Locate survey monuments on and near the dam so that horizontal and vertical alignment can be checked at regular intervals.
Observation Wells	None observed	None
Weirs	None observed	None
Piezometers	None observed	None
Other: Concrete Walkway in Inspection Gallery	The concrete walkway is in poor condition. Concrete has spalled and has been scoured in all of the chambers and severely deteriorated in several chambers to the point where the walkway is missing or hanging by the reinforcing bars. Handrails are missing along entire length of walkway. Refer to the enclosed tabulation of Slab/Buttress/Walkway Inspection findings. Timber walkways have been installed in two chambers where concrete walkway had failed.	Access to Inspection Gallery has been restricted. A handrail should be installed on the downstream side of the walkway. See general recommendations. Steel door at north abutments should be replaced.
Other: Walkway along Outlet Channel	Sections of aluminum walkway kickplates are missing. Concrete walkway has been paved with asphalt or replaced with wood planking attached to original walkway supports with steel straps.	Access to area has been restricted with fencing and steel doors.
Other: Walkway along intake/outlet structures	Aluminum railings have been replaced and appear to be in good condition.	

DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
Condition (Obstruction, Debris, etc.)	The downstream channel exists in its natural state with no debris nor obstructions noted. The overbank areas are wooded.	None.
Slopes	The slopes along the Rapphannock River vary from steep to flat and are characterized by trees/brush cover and rock outcrops.	None.
Approximate No. of Homes and Population	Most of land downstream of Embrey Dam is designated flood plain. Parkland, undeveloped land a few homes are located in the downstream inundation area. See E.A.P.	None.

RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
Slopes	Reservoir area exists in natural state with topography ranging from relatively flat to steep near the inlet/outlet structure of the right abutment.	None.
Sedimentation	Sedimentation was evident on the upstream side of the dam and was reported to exist by the maintenance supervisor. Sedimentation has not changed significantly since 1965.	

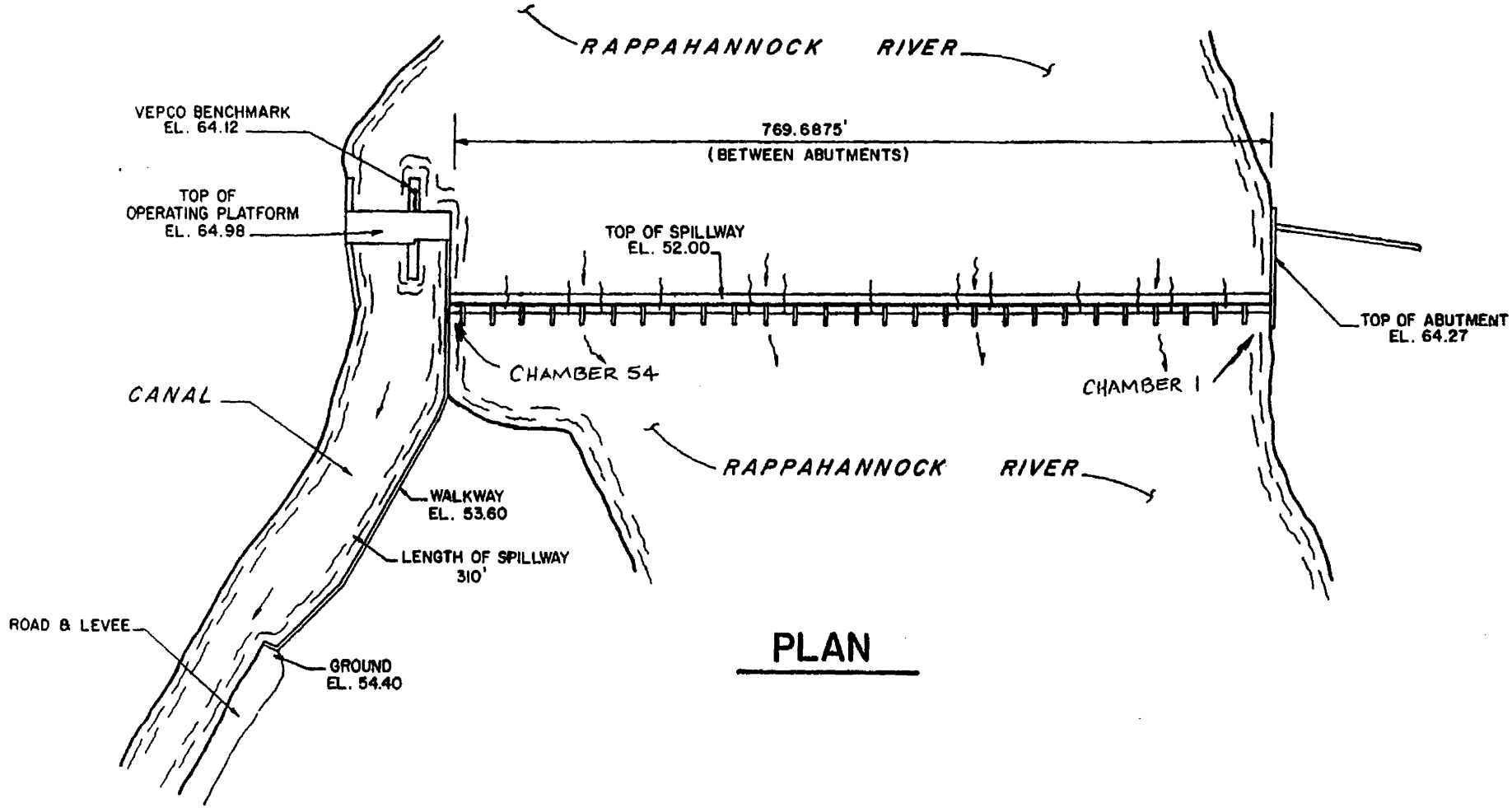
DESIGN, CONSTRUCTION, OPERATION CHECKLIST

ITEM	REMARKS
Design Reports	None available
Geology Reports	None Available
Design Computation Hydrology & Hydraulics Dam Stability Seepage Studies	None Available
Materials Investigation Boring Records Laboratory Field	None Available
Post-Construction Surveys of Dam	None Available
Borrow Sources	N/A
Spillway Plan Sections Details	N/A

DESIGN, CONSTRUCTION, OPERATION CHECKLIST

ITEM	REMARKS
Plan of Dam	Not available
Regional Vicinity Map	See Attachment 3.
Construction History	The dam was construction for Spotsylvania Power Company in the early 1900's. It is currently owned by the City of Fredericksburg.
Typical Sections of Dam	See "Preliminary Drawings, Additions, and Improvements to Existing VEPCO Dam" dated October 1965, Plat 1, Append IX in COE Phase I Report.
Hydrologic/Hydraulic Data	Not available - summaries contained in the COE Phase I Report.
Outlets - Plan - Details -Constraints -Discharge Ratings	See Fredericksburg Dam, Canal Headgates at Embrey Hydro Station October 1965 Plat 2 of COE Phase I Report.
Rainfall/Reservoir Records	None Available

(Figure 3)



Embrey Dam

(Not to Scale)

DESIGN, CONSTRUCTION, OPERATION CHECKLIST

ITEM	REMARKS
Operating Equipment Plans & Details	None available
Monitoring Systems	N/A
Modifications	None Performed
High Pool Records	None available
Post Construction Engineering Studies and Reports	See COE Phase I report for listing of studies completed. Dewberry and Davis performed a reinspection of the dam in February, 1988 and also a Water Supply and Embrey Dam Study in January, 1990, both of which have been forwarded to the Virginia Division of Soil and Water Conservation.
Prior Accidents or Failure of Dam Description Reports	See COE Phase I report for a description of the 1978 seepage problem.
Maintenance Operation Records	None Available.

Chamber No.	Slab Condition	Buttress Condition	Walkway Condition
45	Surface spalling and honeycombing accompanied by minor wet spots/seeps at slab joints. Vegetation prominent along slab at construction joint. Rebar is exposed in upper southern portion of slab.	Buttress is damp with vegetation and surface cracking at joints. Crack over south arch. Hole in south buttress (4" x 2" completely through) - spalling 4' up left of door.	Concrete surface is spalled and cracked along southern end.
44	Surface spalling accompanied by minor wet spots/seeps at slab joints. Vegetation/moss is dense at joints/cracks. Rebar is exposed at the upper construction joint. Honeycombing and cracking are also present. Rebar in top of slab exposed.	Buttress is damp with vegetation and surface cracking at joints. 4' crack at connection to slab above southern arch, spalling and cracking at bottom on north buttress.	Concrete surface is spalled.
43	Surface spalling accompanied by minor wet spots/seeps at slab joints. Vegetation prominent along slab. Spalling and honeycombing with exposed reinforcing in upper portion of slab.	Buttress is damp with vegetation and surface cracking at joints. Crack on top of south arch, holes on both buttresses where slab fell.	Walkway has fallen into bottom of chamber; temporary wooden bridge in place of walkway during inspection.
42	Surface spalling and honeycombing accompanied by minor wet spots/seeps at slab joints. Vegetation prominent along slab.	Buttress is damp with vegetation and surface cracking at joints. Crack over south arch and spalling along buttress. Crack left of north arch.	Concrete surface is spalled honeycombing and spalled 2" deep at north arch.
41	Discolored (orange stains) seepage and leaks at surface spalls at slab joints and along back wall were observed to seep at a rate of 30-40 gpm, heavier at south side, very severe spalling at joints.	Buttress is damp with vegetation and surface cracking at joints	Concrete surface is spalled, 2" deep at south arch.
40	Surface spalling accompanied by minor wet spots/seeps at slab joints. Vegetation prominent across slab. Rebar is exposed in ceiling at buttresses.	Buttress is damp with vegetation and surface cracking at joints. Spalling at south arch connection with slab, crack with no apparent spalling on lower north buttress. Spalling on both buttresses along the end of each.	Concrete surface is spalled.

Chamber No.	Slab Condition	Buttress Condition	Walkway Condition
54	Recently repaired, good condition.	Minor spalling/cracking observed.	Concrete surface is spalled.
53	Surface spalling at joints beginning to seep at estimated rate of 1 GPM. Wet spots and vegetation observed at joints midway up slab.	Very minor seepage (dripping) occurring in left and right buttresses at joints.	Concrete surface is spalled.
52	Numerous surface spalls/cracks/seeps at construction joints all dripping at an approximate rate of 2 GPM.	Surface spalling/cracking evident.	Concrete surface is spalled.
51	Minor surface spalling/cracking observed. Very minor seepage observed at the construction joints, less than 1 GPM.	Surface spalling/cracking evident.	Concrete surface is spalled.
50	Minor surface spalling observed in slab wall at the lower construction joint and is leaking less than 1 GPM. There was a 4 ft^2 spall approximately 3 in in depth, with a 1' diameter honeycomb hole near the top slab seeping at less that 1 GPM.	Surface cracking observed at joints.	Concrete surface is spalled.
49	Surface spalls observed in slab wall. Major seepage evident at the bottom of wall-concrete was damp with no running leak. Top of ramp spalled with exposed rebar.	Surface cracking observed at joints.	Concrete surface is spalled.
48	Minor spalling, seepage and vegetation observed in slab wall.	Surface cracking observed at joints.	Concrete surface is spalled, cracks forming at buttress.
47	Surface spalling accompanied by dripping at slab joints. Vegetation evident along slab.	Buttress is damp with vegetation and surface cracking at joints.	Concrete surface is spalled.
46	Surface spalling accompanied by minor wet spots and seeps at lower slab joint. Vegetation prominent along slab. 0.75 sf x 2" dry hole in upper part of slab. Upper portion of slab is relatively dry, while lower portion is rather wet.	Buttress is damp with vegetation and surface cracking at joints. Three is a crack up to 1/2" deep above archway. Spalling up to 6" deep.	Concrete surface is spalled.

Chamber No.	Slab Condition	Buttress Condition	Walkway Condition
33	Surface cracking/spalling with associated seeps and vegetation observed at joints. Some stalactites have formed. Significant orange colored seep observed at right joint between buttress and slab midway up slab. Crack and spalling has exposed several reinforcing bars on right side of slab wall.	Buttress is damp with vegetation and surface cracking at joints. Large spalled area 3 sf by 6" with rebar exposed midway up north buttress.	Concrete surface is spalled.
32	Surface cracking/spalling with associated seeps observed at joints. Orange colored seep entire length of back slab.	Buttress is damp with vegetation and surface cracking at joints. Honeycombing adjacent to walkway on south buttress. Spalling on north buttress 3' below walkway at downstream edge.	Concrete surface is spalled.
31	Some surface spalling with no seepage, relatively dry.	Buttress is damp with vegetation and surface cracking at joints. Spalling on south buttress 3' below walkway at downstream edge.	Serious spalling, surface cracking has exposed reinforcing leaving portion of walkway hanging by the reinforcing bars, and an open joint at right buttress.
30	Slab is dry and in moderately good condition with minor spalling at joints observed. Spalling and honeycombing on south side top portion. Rebar showing north side upper portion.	Buttress is damp with vegetation and surface cracking at joints. 3' x 6" crack on north buttress (cracked through to bay 29)	Concrete surface is spalled.
29	Surface cracking./spalling with associated seeps and vegetation observed at joints.	Buttress is damp with vegetation and surface cracking at joints. Left buttress has a large spall at the construction joint at the base. Right buttress has a 4" deep spall at the downstream edge. 3' x 6" crack on south buttress (cracked through to bay 30).	Concrete surface is spalled.
28	Surface cracking/spalling with associated seeps and vegetation observed at joints. A major longitudinal crack and spall midway up slab has exposed the reinforcing bar and was seeping at an approximate rate of 5 GPM. Reminder of seepage was observed occurring at left joint between buttress and slab.	Buttress is damp with vegetation and surface cracking at joints. Left buttress has a 4" deep spall at the downstream edge.	Concrete surface is spalled, crack along south end of walkway at connection to buttress.

Chamber No.	Slab Condition	Buttress Condition	Walkway Condition
39	Minor surface spalling accompanied by minor wet spots/seeps at slab joints. Vegetation evident along slab. Some honeycombing near top of slab.	Buttress is damp with vegetation and surface cracking at joints. 2" wide crack through to bay 40 in southern buttress. Some patch work done on southern buttress.	Concrete surface is spalled.
38	Minor drips and surface spalls observed. Stalactites forming from ceiling. Rebar is exposed in ceiling.	Buttress is damp with vegetation and surface cracking at joints.	Concrete surface is spalled mid eastern portion of walkway is broken rebar exposed.
37	Surface cracking/spalling observed at joints; major seepage flow (10-20 gpm) observed at buttress/slab corner joints midway up slab, with entire back wall wet with seepage. Small pipe (low level outlet of pressure relief pipe) in bottom of slab appears clogged and is dripping slightly.	Buttress is damp with vegetation and surface cracking at joints	Concrete surface is spalled.
36	Surface cracking/spalling observed at joints; wet spots/drips and small seeps observed at cracks-vegetation and minor spalling evident throughout slab. Major spall at upper construction joints with rebar exposed with heavy vegetation growth and small leaks. Rebar exposed in several areas of ceiling.	Minor spalling/seepage and vegetation evident on both buttresses above walkway and at major joints. A large spall on downstream edge about 1' below top of slab ceiling	Concrete surface is spalled heavy vegetation growth on walkway. Crack at northern end of walkway.
35	Surface cracking/spalling with associated seeps and vegetation observed at joints. Major spall at upper construction joint with rebar exposed and heavy vegetative growth and small leaks. Spalling at lower joints.	Buttress is damp with vegetation and surface cracking at joints. Honeycombed crack above north arch.	Concrete surface is spalled heavy vegetation growth on walkway. Crack at southern end of walkway.
34	Surface cracking/spalling with associated seeps observed at joints. Significant orange colored seep observed at left joint between buttress and slab 3 feet above water level. 3 gpm leakage at lower portion of south side of slab.	Buttress is damp with vegetation and surface cracking at joints. Orange stained leak midway up left buttress at slab joint. Major spalling at same location. Other spalls on right buttress with wood embedded in concrete. Spalling along buttress connection with slab	Concrete surface is spalled heavy vegetation growth on walkway. Crack at south end.

Chambe. ..	Slab Condition	Buttress dition	Walkway Condition
22	Surface spalls/cracks with associated wet spots observed.	Buttress is damp with vegetation and surface cracking at joints. South buttress has major spall downstream edge of just above water level.	Concrete surface is spalled.
21	Minor surface spalls/cracks with associated wet spots observed. Rebar is showing in ceiling at southern end.	Buttress is damp with vegetation and surface cracking at joints.	Concrete surface is spalled.
20	Minor surface spalls/cracks with associated wet spots observed.	Surface spalls, cracks, vegetation, wet spots and seeps were observed on north buttress adjacent to walkway opening. Spall on north buttress at downstream edge at walkway level.	Concrete surface is spalled. Crack along north end of walkway at connection with buttress.
19	Surface spalling and seepage was observed. Crack along upper joint on southern side.	Significant spalling, seeps, cracks and vegetation observed on both buttress walls at joint with slab. 4" x 6", 4" deep spall 3' above walkway on downstream southern edge.	Approx. 2' of east end of walkway is broken off with reinforcing bars supporting the rest of the walkway.
18	Surface cracking/spalling with associated seeps and vegetation observed at joints. Significant orange colored seep observed at left joint between buttress and slab midway up slab. Rebar is exposed in the ceiling.	Buttress is damp with vegetation and surface cracking at joints. South buttress has major spalling. North buttress has missing sections of concrete on downstream edge.	Concrete surface is spalled.
17	Surface spalls/cracks with associated wet spots were observed across the face of the slab.	Buttress is damp with vegetation and surface cracking at joints.	Concrete surface is spalled there is a crack at the joint with the right buttress.
16	Extensive surface spalling/cracking approximately 1 foot deep has exposed 3 reinforcing bars in one direction and 5 along entire slab width. Minor seepage is occurring through these cracks.	Buttress is damp with vegetation and surface cracking at joints. Spalling on downstream edge of both buttresses.	Concrete surface is spalled.
15	Extensive surface spalling/cracking has exposed 3 reinforcing bars along entire slab width. Seepage is occurring through cracks at an approx. rate of 5 gpm.	Buttress is damp with vegetation and surface cracking at joints.	Concrete surface is spalled.

Chamber No.	Slab Condition	Buttress Condition	Walkway Condition
27	Surface cracking/spalling with associated seeps, exposed rebar and vegetation observed at joints. A major longitudinal crack midway up back wall has exposed the reinforcing bar and was seeping at an approximate rate of 5 gpm. Remainder of orange colored seepage was observed occurring at left joint between buttress and slab.	Buttress is damp with vegetation and surface cracking at joints. 6"x 6" spall on north buttress 3' below walkway.	Concrete surface is spalled.
26	Surface cracking/spalling with associated seeps and vegetation observed at joints. A major surface spalling area was observed seeped at the right corner joint between the slab and buttress with orange coloring.	Buttress is damp with vegetation and surface cracking at joints. North buttress has a section missing from downstream edge. South buttress has a spall at the joint below the slab.	Concrete surface is spalled.
25	Surface cracking/spalling with associated seeps. Vegetation is very dense on slab wall at cracks. Water is dripping from cracks and joints. Rebar is exposed in the ceiling	Significant spalling, vegetation, and seepage observed on north buttress. North buttress has a section missing on downstream edge.	Walkway is severely cracked and spalled; downstream portion has broken off, reinforcing steel is exposed. Heavy vegetation growth on walkway.
24	Surface cracking/spalling with associated seeps and minor vegetation observed at joints. Orange colored seep (approx. 5 gpm) observed at left joint between buttress and slab midway up slab.	Buttress is damp with vegetation and surface cracking at joints. Both buttresses have spalled and eroding joints. South buttress has a honeycombed hole 6" deep at walkway arch. Spalling at walkway level 2' high around archway. South buttress cracked along connection with slab.	Walkway is severely cracked and spalled; downstream portion is sagging toward river suspended only be reinforcing steel.
23A	Surface cracking/spalling with associated seeps observed at joints.	Buttress is damp with vegetation and surface cracking at joints. Inter-chamber drain hole in left buttress is spalling. North buttress has section missing on downstream edge. South buttress has 6" x 8", 4" deep spall along downstream edge.	Concrete surface is spalled.
23	Minor surface spalls/cracks with associated wet spots observed. Orange colored seep observed along back wall.	Buttress is damp with vegetation and surface cracking at joints. North buttress has major spalled downstream edge of just above water level.	Approx. 1/4 of walkway has broken off and rebar is exposed through remainder of the walkway.

Chamber No.	Slab Condition	Buttress Condition	Walkway Condition
6	Extensive surface spalling/cracking has exposed 5 reinforcing bars through a 5' x 3' crack in back wall.	Buttress is damp with vegetation and surface cracking at joints. Sections of concrete have spalled off the downstream edge of both buttresses.	Significant cracks and scouring observed in walkway.
5	Extensive surface spalling/cracking has exposed 4 reinforcing bars through a 6' x 2' spall in center of slab, has caused orange staining with approx. 5-10 gpm of seepage.	Buttress is damp with vegetation and surface cracking at joints. Spall in both buttresses 2' below walkway.	Significant cracks observed in walkway at joint with north buttress. Significant surface scouring.
4	Extensive surface spalling/cracking has exposed 3 reinforcing bars through a 6' x 3' area and one reinforcing bar is exposed for the entire slab width. Approx. 10 gpm of seepage through crack. Extensive wet spots and drips were also observed in the back chamber wall, with orange staining prevalent.	Buttress is damp with vegetation and surface cracking at joints. Spalling on north buttress downstream edge.	Significant cracks and surface scouring observed in walkway.
3	Extensive surface spalling/cracking has exposed 3 reinforcing bars along entire slab width. The majority of the upstream lower concrete cross brace has spalled leaving the four reinforcing bars visible. Seepage is occurring through cracks.	Buttress is damp with vegetation and surface cracking and spalling at joints. North buttress has 12"wide, 6" deep spalling along downstream edge and a crack below the walkway.	Significant cracks and surface scour observed in walkway.
2	Extensive surface spalling/cracking with associated vegetation and seepage was observed form top to bottom across this slab. Both lower cross beams have been seriously spalled exposing the four reinforcing bars in each. Several sections of exposed rebar in top section of slab.	There is extensive spalling on the north buttress with orange stain. South buttress has 12"wide, 6" deep spalling along downstream edge.	Significant cracks observed in walkway at the joint with the north buttress.
1	Extensive surface spalling/cracking has exposed four reinforcing bars along entire slab width. Spalling is extensive along entire slab. Seepage is occurring at several of these spalled areas. Spalls and seep areas are stained orange.	Left buttress has spalled inter-chamber drain hole in left buttress. An orange colored seep is coming through drain hole in right buttress.	The majority of the walkway has deteriorated and has fallen to bottom of chamber , leaving only 2' of walkway at the south buttress. A temporary wooden bridge was in place at the time of inspection.

Chamber No.	Slab Condition	Buttress Condition	Walkway Condition
14	Minor surface spalls/crack with associated wet spots and vegetation observed.	Buttress is damp with vegetation and surface cracking at joints.	Concrete surface is spalled.
13	Minor surface spalls/cracks with associated wet spots observed. Large spalled area middle of slab (5 sf).	Buttress is damp with vegetation and surface cracking at joints. Large crack (6') on north buttress at top of downstream end.	Approx. 2' of north end of walkway is broken off with reinforcing bars supporting the rest of the walkway.
12	Surface cracking/spalling with associated seeps and vegetation observed at joints. Orange stain on north side, seepage at approx. 1 gpm.	Deep (6") spalls with seeps and vegetation observed in left buttress at joint with slab. Orange stain at lower portion of southern buttress seeping at approx. 5-10 gpm.	Concrete surface is spalled.
11	Surface cracking/spalling with associated seeps and vegetation observed at joints. Orange staining with approx. 1 gpm of seepage, honeycombing in the middle of the slab.	Buttress is damp with vegetation and surface cracking at joints. Cross braces between buttresses are moderately scoured.	Concrete surface is spalled.
10	Surface cracking/spalling with associated seeps and vegetation observed at joints. Some orange stains with approx. 1 gpm of seepage.	Buttress is damp with vegetation and surface cracking at joints. Rebar is exposed at the walkway arch in the right buttress. Cross braces between buttresses are moderately scoured.	Concrete surface is spalled.
9	Surface cracking/spalling with associated seeps and vegetation observed at joints. Orange staining with approx. 3 gpm of seepage.	Buttress is damp with vegetation and surface cracking at joints. A large spall (approx. 1" x 2" deep) with no seepage was evident on the right buttress.	Significant cracking and spalling of walkway at both edges were observed with a large crack at the joint with the south buttress.
8	Significant cracking/spalling observed along with minor seepage through them. One lower cross brace spanning the chamber between buttress walls was missing	Buttress is damp with vegetation and surface cracking at joints. The downstream crossbar is missing, while the other cross brace is severely scoured with exposed rebar.	Significant cracking and spalling of walkway at both edges were observed.
7	Surface cracking/spalling with associated seeps and vegetation observed at joints. Large spall in middle of slab with orange stain, approx. 1 gpm of seepage.	Buttress is damp with vegetation and surface cracking at joints. Spalls at downstream edge both sides below walkway.	Significant cracks observed in walkway at joint with north buttress.

Embrey Dam Fish Passage Alternatives Analysis
Sediment Issues Report

Purpose

The overall objective of this study was to conduct a technical alternatives analysis for providing fish passage above Embrey Dam. GKY&A was tasked with investigating the issues associated with the sediment accumulated behind the dam. Specifically, to make an estimate of the volume of sediment trapped behind the dam, and to assist in identifying potential methods for disposal of the sediment. This report documents GKY&A's efforts under the current scope of services. It contains documentation of data sources, descriptions of the methods used, results of the various analyses, and recommendations based on the results of the study.

Sediment Sampling Field Visit

A field visit was made to the Embrey Dam site on July 23, 1997 to collect samples of the sediment trapped behind the dam. Using the City of Fredericksburg Water Treatment Plant staff's boat, GKY&A engineers collected sediment samples at six different locations upstream of the dam. Figure 1 shows the approximate locations of the sampling sites.

The sampling was performed using a device constructed of one inch diameter metal conduit pipe. A ten foot long piece of conduit was attached to three and four foot long, one inch diameter sampling tubes using threaded compression fittings. A ball valve was attached to the opposite end of the ten foot conduit to help hold the sample in place as it was pulled up from the bottom of the river (hydraulic head caused by trapped water in the sample tube tended to push the sample out the end of the tube when the valve was not closed). Sampling tubes #4 and #8 were lost on the bottom of the river due to failure of the compression fitting.

These samples were submitted to Timmons on July 25, 1997 for analysis by their soils laboratory. Table 1 summarizes the results of the laboratory analyses. The full laboratory analysis report with grain size distribution charts appears in Attachment 1. In general, the sediment appeared to be composed of silty sands and clayey silts. The sample (#5) taken between the old timber crib dam and the concrete dam appeared to be mostly sand. Samples taken from the south side of the river (#2, #3, and #7) had a higher percentage of silts and clays, while samples taken on the north side (#1, and #6) contained more sand. Classification of the sediments using the Unified Soil Classification System (USCS) showed the samples to be SP, SM, and ML type soils. The engineering characteristics of these types of soils are generally:

1. Good to fair shearing strength when compacted and saturated

2. Very low to medium compressibility when compacted and saturated

Appendix F

G.K.Y. and Associates

Sediment Issues Report
and
Sediment Transport Modeling Study

Table 1.
Embrey Dam
Sediment Sampling Results

Sample #	Tube Length (inches)	Sample Length (inches)	D_{50} (mm)	% Gravel	% Sand	% Silt/Clay	Bulk Density Dry (lbs/ft^3)	Bulk Density Wet (lbs/ft^3)	Organic Content %	USCS Classification	AASHTO Classification	Description
1	45	22	0.141	0.0	53.2	46.8	59.9	91.6	4.9	SM	A-4 (0.0)	Brownish gray silty sand w/ trace mica
2	46.5	29		0.0	11.1	88.9	61.4	100.4	1.0	ML	A-7-5 (17.1)	Brownish gray clayey silt w// trace mica, sand
3	34.5	19		0.0	6.3	93.7	60.7	98.6	1.2	ML	A-7-5 (13.5)	Brownish gray clayey silt w/ trace mica, sand
5	35	17	0.264	0.0	93.3	6.7	47.3	87.7	2.3	SP-SM	A-3	Lt. brown silty sand w/ trace mica
6	34.75	13.5	1.01	9.3	82.3	8.4	98.4	111.1	1.8	SP-SM	A-1-b	Brown silty sand w/ trace mica and gravel
7	35	26		0.0	3.0	97.0	54.1	94.5	4.6	ML	A-7-5(18.2)	Brownish gray clayey silt w/ trace mica, sand
Average	38	21	0.472	1.6	41.5	56.9	63.6	97.3	2.6			

Notes: Based on samples collected on 7/23/97 by GKY&A
Lab tests performed on 8/1/97 by Timmons
Sample #'s 4and 8 were lost due to equipment failure
Sample # 9 was not submitted for lab tests

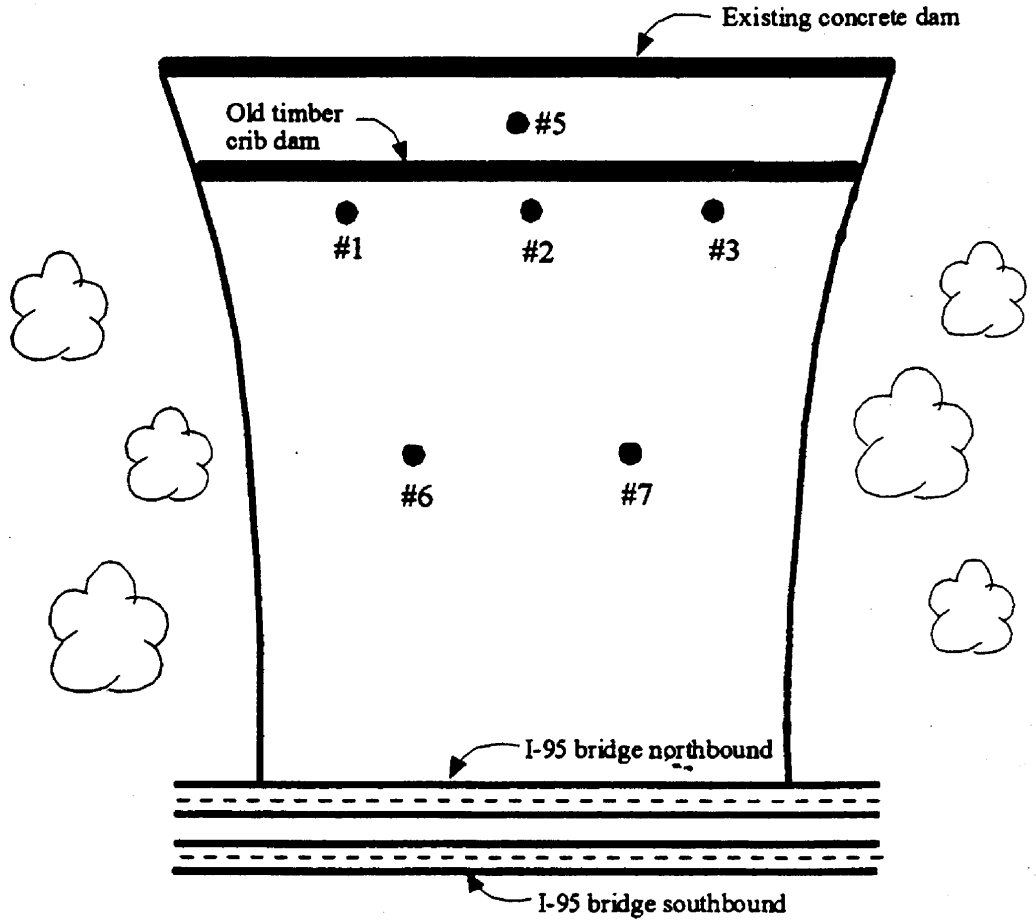


Figure 1. Sediment Sampling Locations

in the next couple of months. If a breach is scheduled prior to completion of this project, a field visit to the site will be made to document the breach.

Sediment Volume Calculation

The volume of sediment trapped behind the dam was estimated using the Average-End Area method and depth soundings mapped by Russell, Axon & Associates in October of 1965 (see Attachment 3). As stated earlier, depth measurements taken during the sediment sampling field visit conducted on July 27th 1997 generally corresponded well with the 1965 study map.

An estimate of the river bottom slope was made by projecting the elevation of the toe of the concrete dam (30.0 feet based on Whitman, Requardt and Associates *Water Supply and Treatment Alternatives* report dated October 1994) upstream to the I-95 bridge crossing where the pooling effect caused by the dam begins. The elevation of the river bottom at the bridge crossing was assumed to be 46.0 feet (Full Pool WSEL 52.0 - 6.0 feet measured depth to river bottom).

Using the Average-End Area method, the assumed river bottom slope, average elevations of the top of the sediment at 500 feet cross sections, and the river width at these cross sections, the total volume of sediment behind the dam was estimated to be 530,672 cubic yards or 329 acre-feet. Table 2 summarizes the sediment volume calculations.

Sediment Disposal Alternatives

There is a substantial amount of sediment estimated to be trapped behind Embrey Dam. Roughly half of the full pool storage volume behind the dam is taken up with sediment. Any fish passage alternative that involves partial or full removal of the dam will require addressing the issue of how to dispose of the accumulated sediment.

The laboratory tests of the sediment samples collected during the field visit to the dam revealed that the average D_{50} (median particle size) of the sediment for the three samples with measurable D_{50}'s was 0.472 mm. The other three samples had median particle sizes that were smaller than 0.075mm (opening size of a #200 sieve). The potential for movement of sediment particles can be evaluated by comparing the flow velocity in the river to the critical velocity for the beginning of motion of bed materials of a given size. The critical velocity for a given sediment particle size can be calculated using the following equation (FHWA HEC-18 Manual, *Evaluating Scour at Bridges, pp12-13*):

$$V_c = 6.19\, y^{1/6} D^{1/3}$$

where:

V_c = Critical velocity above which bed material of size D and smaller will be transported, m/s

3. Only fair workability as a construction material

4. Generally not recommended for use in canal sections, foundations, or as roadway fill

It should be noted that the samples collected only characterize approximately the first two feet of sediment on the bottom of the river.

Also during the field visit, GKY&A engineers used a 14 foot long pole with one foot markings to get a general idea of water depths at various locations between the dam and the Interstate 95 bridge crossing. Surprisingly, the depths measured using the pole generally corresponded well with soundings made by Russell, Axon & Associates in October of 1965. This would appear to suggest that the sediment trapped by the dam has been and continues to be in a state of equilibrium.

Pennsylvania Dam Breach Field Visit

At this time a field visit has not been made to any dam breach sites in Pennsylvania. However, a phone interview was conducted with Scott Carney of the Pennsylvania Fish & Boat Commission's Benner Springs Research Station. He said that his agency has been involved with nine dam breaches for fish passage over the last several years and they expect to breach four more this year. Some of the breached dams include:

1. Muddy Creek Dam in York County (6 feet high, 250 feet wide)

2. Rock Hill Dam in Lancaster County

3. Castle Fin Dam to be breached in September/October 1997 (6 feet high, 200 feet wide)

4. Williamsburg Station Dam

5. Dam (only toe of dam exists) in Central Pennsylvania (4 feet high, 50 feet wide)

He said that dam breaching is their preferred method for providing fish passage for the following reasons:

- Provides unrestricted passage for fish and boats
- Restores the riverine ecosystem
- Eliminates a potential public safety hazard to boaters and swimmers
- Eliminates operations and maintenance costs associated with other methods

Attachment 2 contains a fact sheet describing the procedure adopted by the Pennsylvania Department of Environmental Protection for facilitating the breaching of dams in Pennsylvania. As mentioned earlier, they are expecting to breach four more dams

y = Depth of Flow, m

D = Size of bed material, m

Table 3 summarizes the results of applying this equation for a bed material size of 0.472 mm (average D_{50} for sediment samples) and varying flow rates. Manning's equation was used to calculate flow velocities in the river for these same flow rates using an assumed river bed slope of 0.004571ft/ft. By comparing these flow velocities to the critical flow velocity a determination was made as to the potential for sediment movement downstream. Based on the results of this analysis it appears that sediment of this size will tend to move downstream under all flow conditions checked (500 cfs to 150000 cfs which covers the historical range of flows measured at the USGS Fredericksburg gaging station).

Given that the sediment is likely to move further downstream, there are several possible alternatives for dealing with disposal of the trapped sediment:

Alternative 1. Hydraulically Dredge Entire Volume of Sediment and Transport to a Suitable Disposal Site

Alternative 2. Mechanically Dredge Entire Volume of Sediment and Transport to a Suitable Disposal Site

Alternative 3. Hydraulically Dredge a Portion of the Sediment Volume onto River Banks

Alternative 4. Mechanically Dredge a Portion of the Sediment Volume onto River Banks

Alternative 5. Allow Sediment to Pass Downstream after Breaching

Alternatives 1 and 2 would remove the entire volume of accumulated sediment from behind the dam. These alternatives would probably be called for if the entire dam were to be breached. The material would be dredged off the bottom of the river and transported to a suitable site elsewhere. The only difference between the two alternatives is the method of dredging.

Alternative 1 uses a hydraulic dredge sitting on a floating barge to suck the sediment off the bottom of the river and pump it to a disposal site which is usually located within 1 mile of the dredging operation. The distance to the disposal site is limited because a temporary booster pump/pipeline system must be constructed to convey the material to the site. Also the particle size that can be pumped is limited to 3-4 inches in diameter (flow velocities necessary to move larger particle sizes are not practical).

Alternative 2 uses a mechanical dredge sitting on a floating barge to scoop up the sediment and either load it onto another transport barge or trucks for delivery to the disposal site. Because the material is being mechanically manipulated and trucked, there are not the same limitations on disposal site locations and sediment particle sizes. However, adequate access must be available to get the trucks close to the dredging site.

Table 2.
Embrey Dam
Sediment Volume Estimate

X-Section	Location Upstream of Dam (Ft.)	Reach Length (Ft.)	Avg. Elev. Top of Sediment	Est. Elev. of River Bottom	Depth of Sediment (Ft.)	River Width (Ft.)	Computed End Area (Ft^2)	Sediment Volume (Yd^3)
A	100		43.8	30.0	13.8	800	11040	
B	600	500	45.7	32.3	13.4	640	8585	181714
C	1100	500	45.6	34.6	11.0	580	6397	138720
D	1600	500	44.7	36.9	7.8	570	4470	100620
E	2100	500	44.3	39.1	5.2	530	2733	66701
F	2600	500	43.5	41.4	2.1	440	911	33747
G	3100	500	43.8	43.7	0.1	460	39	8804
H @ I-95	3600	500	46.0	46.0	0.0	590	0	365
Totals								530672

Notes: Assumed River Slope = 0.004571

Alternatives 3 and 4 would remove only a portion of the accumulated sediment and leave the rest in place. This would be the case if the dam were being partially breached and the river flow was being channelized through the breach area. Again, the only difference between these two alternatives is the method of dredging the material.

In either case it is assumed that a channel (approximately 300 feet wide with 3:1 sideslopes) would be dredged to direct the river flow through the partially breached dam while the remaining material would be left in place. The dredged material would be placed on the banks of the river. The material left in place (and possibly the dredged material) would probably require some sort of stabilization measures (riprap, vegetation etc.) to keep it from being eroded and transported downstream. It is estimated that these alternatives would require dredging approximately half of the estimated total volume of accumulated sediment.

Alternative 5 would allow the sediment to pass downstream after breaching the dam. As discussed earlier, preliminary calculations suggest that the sediments behind the dam will be carried downstream and deposited in reaches where the flow velocities are lower than the critical flow velocity for a given particle size. This could require dredging the material out of boat channels and other areas further downstream. In order to properly analyze this issue, a detailed sediment transport modeling study must be conducted. This level of detailed modeling is beyond the scope of this report.

Sediment Disposal Alternatives Cost Estimates

Rough cost estimates for the five alternatives just described are summarized in Table 4. A discussion of the assumptions used in developing these cost estimates follows.

Alternative 1. Hydraulically Dredge Entire Volume of Sediment and Transport to a Suitable Disposal Site ($4.24 million)

Assumptions:

1. Volume of sediment to be dredged is approximately 530,000 cubic yards.
2. Sediment disposal site will be located within 1 mile of the dredging operation.
3. Sediment material to be dredged will be 3 inch diameter or less.
4. Adequate access/easements to the dredging and disposal sites are available.
5. Costs for obtaining required permits (COE Section 404, Va. Water Protection, Erosion & Sediment Control, VPDES Storm Water etc.) are not included.
6. Unit cost for hydraulic dredging is assumed to be $8/cubic yard which includes mobilization, dredging, and delivery (pumping) to disposal site.

Estimated Cost = 530,000 yd^3 x $8/$yd^3$ = $4.24 million.

Alternative 2. Mechanically Dredge Entire Volume of Sediment and Transport to a Suitable Disposal Site ($6.89 million)

Table 3.
Embrey Dam
Potential for Sediment Movement

Flow Rate ($Ft.^3/s$)	Flow Depth (Ft.)	Flow Velocity (Ft./s)	Flow Depth (m)	Critical Velocity (m/s)	Critical Velocity (Ft./s)	Sediment Movement Predicted
500	0.44	1.95	0.14	0.35	1.14	Yes
1,000	0.67	2.58	0.21	0.37	1.22	Yes
1,500	0.86	3.03	0.26	0.39	1.27	Yes
1,750	0.94	3.23	0.29	0.39	1.29	Yes
2,000	1.02	3.41	0.31	0.40	1.30	Yes
3,000	1.30	4.01	0.40	0.41	1.36	Yes
4,000	1.55	4.50	0.47	0.43	1.40	Yes
5,000	1.77	4.92	0.54	0.44	1.43	Yes
10,000	2.68	6.50	0.82	0.47	1.53	Yes
20,000	4.07	8.59	1.24	0.50	1.64	Yes
30,000	5.19	10.12	1.58	0.52	1.71	Yes
40,000	6.16	11.36	1.88	0.54	1.76	Yes
50,000	7.05	12.42	2.15	0.55	1.80	Yes
100,000	10.68	16.41	3.26	0.59	1.93	Yes
150,000	13.62	19.32	4.15	0.61	2.01	Yes

Assumptions:

Mannings n=	0.03
Slope (ft/ft)=	0.004571
Avg. River Width=	575
Avg. D_{50}(mm)=	0.472

Assumptions:

1. Volume of sediment to be dredged is approximately 530,000 cubic yards.
2. Sediment disposal site will be located within 12 miles of the dredging operation.
3. Adequate access/easements to the dredging and disposal sites are available.
4. Costs for obtaining required permits (COE Section 404, Va. Water Protection, Erosion & Sediment Control, VPDES Storm Water etc.) are not included.
5. Unit cost for mechanical dredging is assumed to be $13/cubic yard which includes mobilization, dredging, and delivery (trucking) to disposal site.

Estimated Cost = 530,000 yd^3 x $13/$yd^3$ = $6.89 million.

Alternative 3. Hydraulically Dredge a Portion of the Sediment Volume onto River Banks ($2.12 million)

Assumptions:

1. Volume of sediment to be dredged is approximately 265,000 cubic yards (1/2 of total estimated volume - 300 foot wide channel with 3:1 sideslopes).
2. Sediment disposal site will be located within 1 mile of the dredging operation.
3. Sediment material to be dredged will be 3 inch diameter or less.
4. Adequate access/easements to the dredging and disposal sites are available.
5. Costs for obtaining required permits (COE Section 404, Va. Water Protection, Erosion & Sediment Control, VPDES Storm Water etc.) are not included.
6. Unit cost for hydraulic dredging is assumed to be $8/cubic yard which includes mobilization, dredging, and delivery (pumping) to disposal site.

Estimated Cost = 265,000 yd^3 x $8/$yd^3$ = $2.12 million

Alternative 4. Mechanically Dredge a Portion of the Sediment Volume onto River Banks ($2.92 million)

Assumptions:

1. Volume of sediment to be dredged is approximately 265,000 cubic yards (1/2 of total estimated volume - 300 foot wide channel with 3:1 sideslopes).
2. Sediment disposal site will be located within 1 mile of the dredging operation.
3. Adequate access/easements to the dredging and disposal sites are available.
4. Costs for obtaining required permits (COE Section 404, Va. Water Protection, Erosion & Sediment Control, VPDES Storm Water etc.) are not included.
5. Unit cost for hydraulic dredging is assumed to be $11/cubic yard which includes mobilization, dredging, and delivery (placement) to disposal site.

Estimated Cost = 265,000 yd^3 x $11/$yd^3$ = $2.92 million

Table 4.
Embrey Dam
Sediment Disposal Alternatives Costs

Alternative #	Description	Dredged Material Volume (Yd^3)	Dredging Unit Cost ($/$Yd^3$)	Estimated Cost
1	Hydraulically Dredge Entire Volume	530,000	8	$4,240,000
2	Mechanically Dredge Entire Volume	530,000	13	$6,890,000
3	Hydraulically Dredge Partial Volume	265,000	8	$2,120,000
4	Mechanically Dredge Partial Volume	265,000	11	$2,915,000
5	Let Pass Downstream	Uknown	Uknown	Uknown

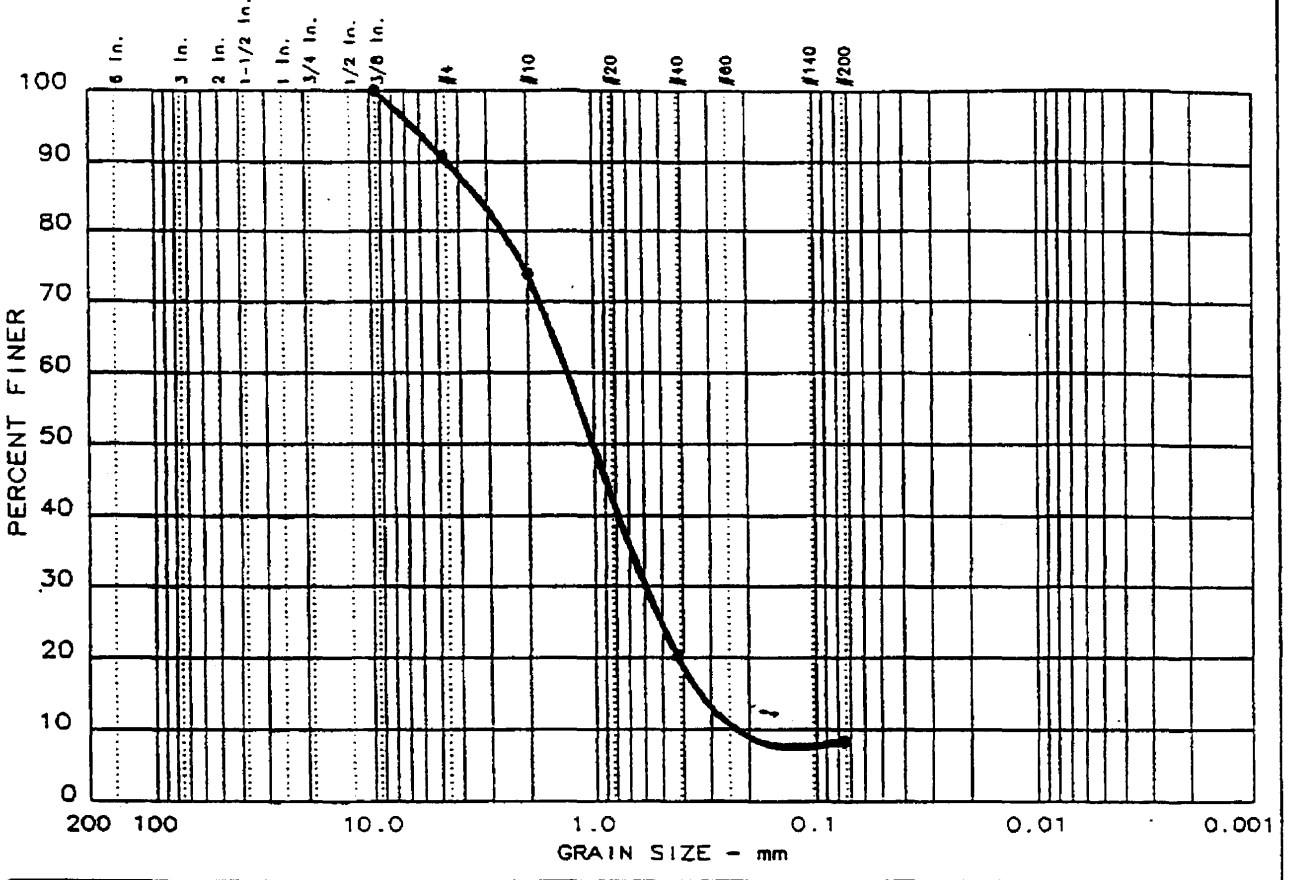
Note: See cost assumptions in report

Attachment 1.
Sediment Samples Laboratory Analysis Report

Alternative 5. Let Sediment Pass Downstream after Breaching

Without performing a detailed sediment transport modeling study, it is not possible to estimate the amount of sediment that may need to be dredged. It is likely that some dredging will be required if this alternative is chosen, possibly to clear sediment out of the navigation channels around the City docks just downstream of the dam.

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	1	0.0	9.3	82.3	8.4	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●		N/P	3.27	1.32	1.01	0.588	0.331	0.229	1.15	5.8

	MATERIAL DESCRIPTION	USCS	AASHTO
●	BROWN SILTY SAND W/ TRACE MICA AND GRAVEL	SP-SM	A-1-b

Project No.: 17372
Project: LAKE EMBRY DAM
● Location: SAMPLE TUBE #6

Date: 08-01-97

GRAIN SIZE DISTRIBUTION TEST REPORT

TIMMONS

Remarks:

LOG BOOK NO.: 17372-E

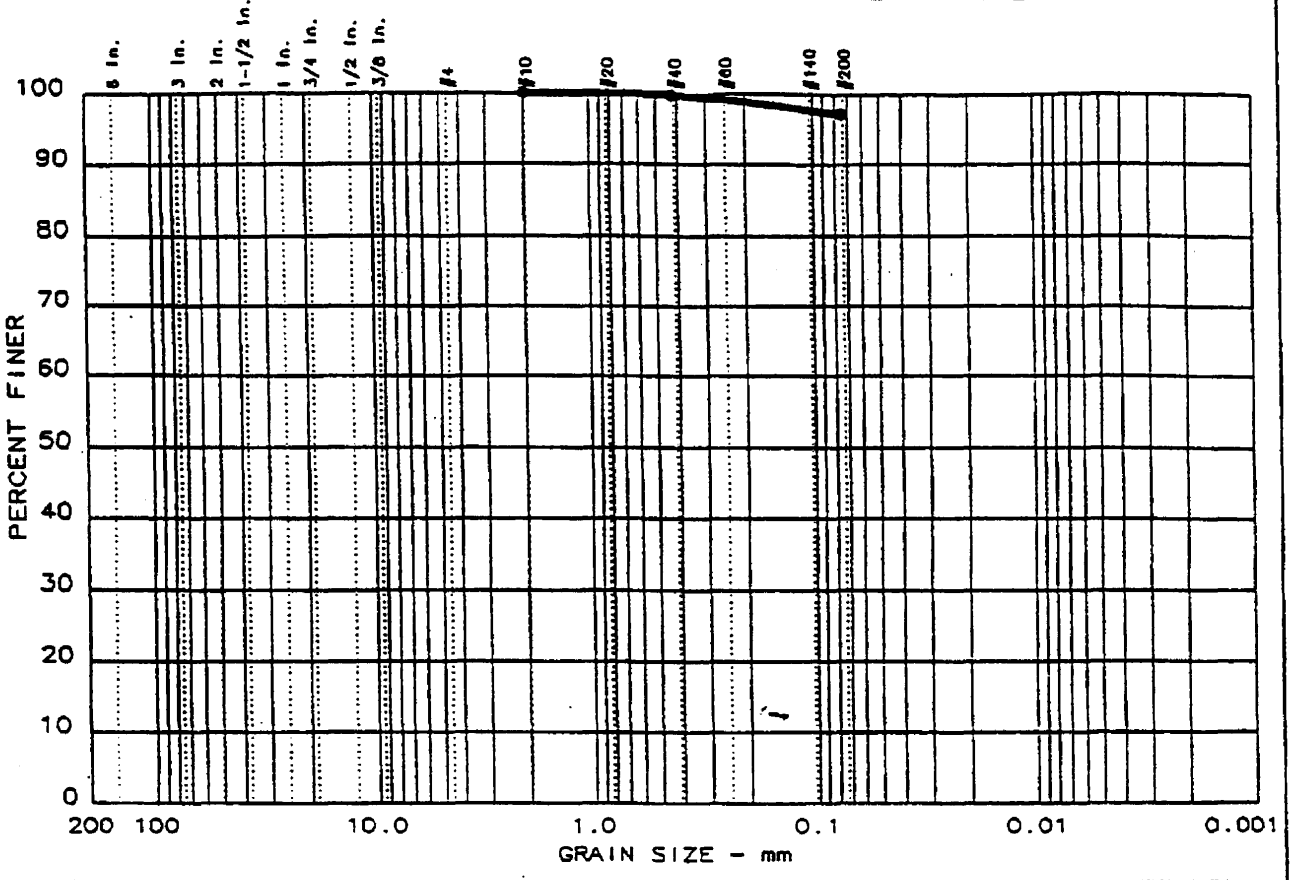
BULK DRY 98.4, WET 111.1

ORGANIC 1.8%

NMC 12.6%

Figure No _____

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	2	0.0	0.0	3.0	97.0	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	48	14								

MATERIAL DESCRIPTION	USCS	AASHTO
● BROWNISH GRAY CLAYEY SILT W/ TRACE MICA, SAND	ML	A-7-5(18.2)

Project No.: 17372
Project: LAKE EMBRY DAM
● Location: SAMPLE TUBE #7

Date: 08-01-97

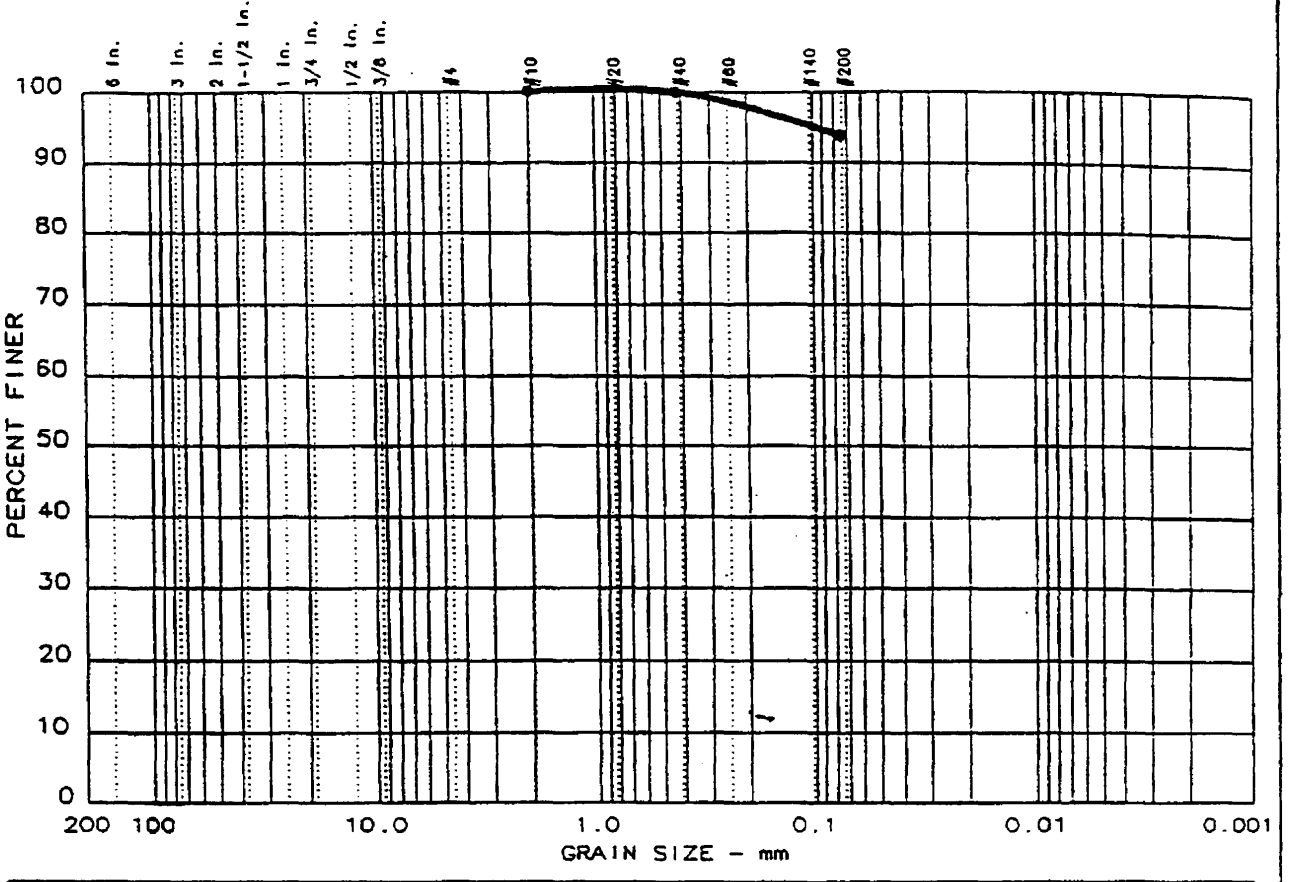
GRAIN SIZE DISTRIBUTION TEST REPORT

TIMMONS

Remarks:
LOG BOOK NO.: 17372-F
BULK DRY 54.1, WET 94.5
ORGANIC 4.6%
NMC 74.7%

Figure No. _____

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	19	0.0	0.0	6.3	93.7	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	43	11								

MATERIAL DESCRIPTION	USCS	AASHTO
● BROWNISH GRAY CLAYEY SILT W/ TRACE MICA, SAND	ML	A-7-5(13.5)

Project No.: 17372
Project: LAKE EMBRY DAM
● Location: SAMPLE TUBE #3

Date: 08-01-97

GRAIN SIZE DISTRIBUTION TEST REPORT

TIMMONS

Remarks:

LOG BOOK NO.: 17372-C

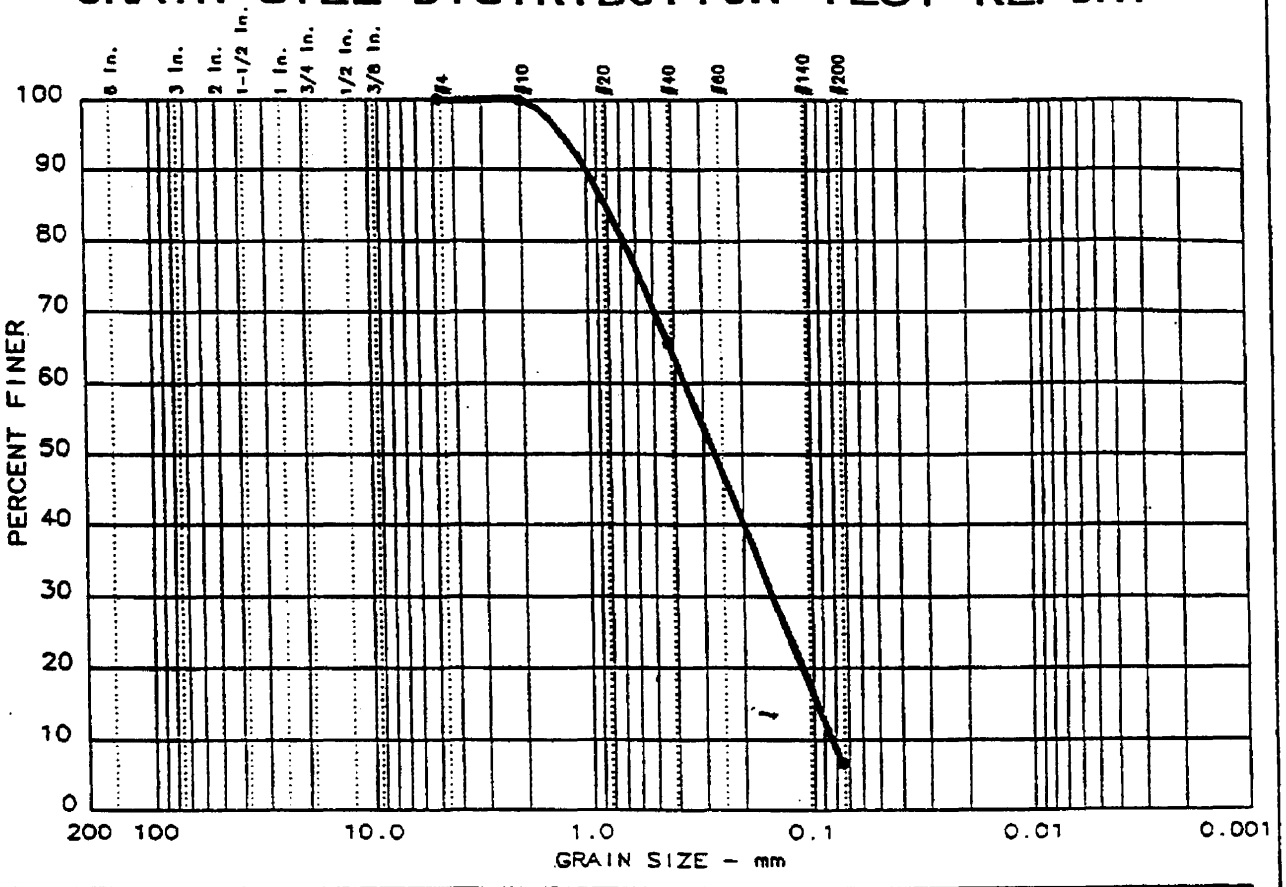
BULK DRY 60.7, WET 98.6

ORGANIC 1.2%

NMC 62.3%

Figure No. _____

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	20	0.0	0.0	93.3	6.7	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●		N/P	0.811	0.358	0.264	0.147	0.0947	0.0823	0.73	4.3

MATERIAL DESCRIPTION	USCS	AASHTO
● LT BROWN SILTY SAND W/ TRACE MICA	SP-SM	A-3

Project No.: 17372
Project: LAKE EMBRY DAM
● Location: SAMPLE TUBE #5

Date: 08-01-97

GRAIN SIZE DISTRIBUTION TEST REPORT

TIMMONS

Remarks:

LOG BOOK NO.: 17372-D

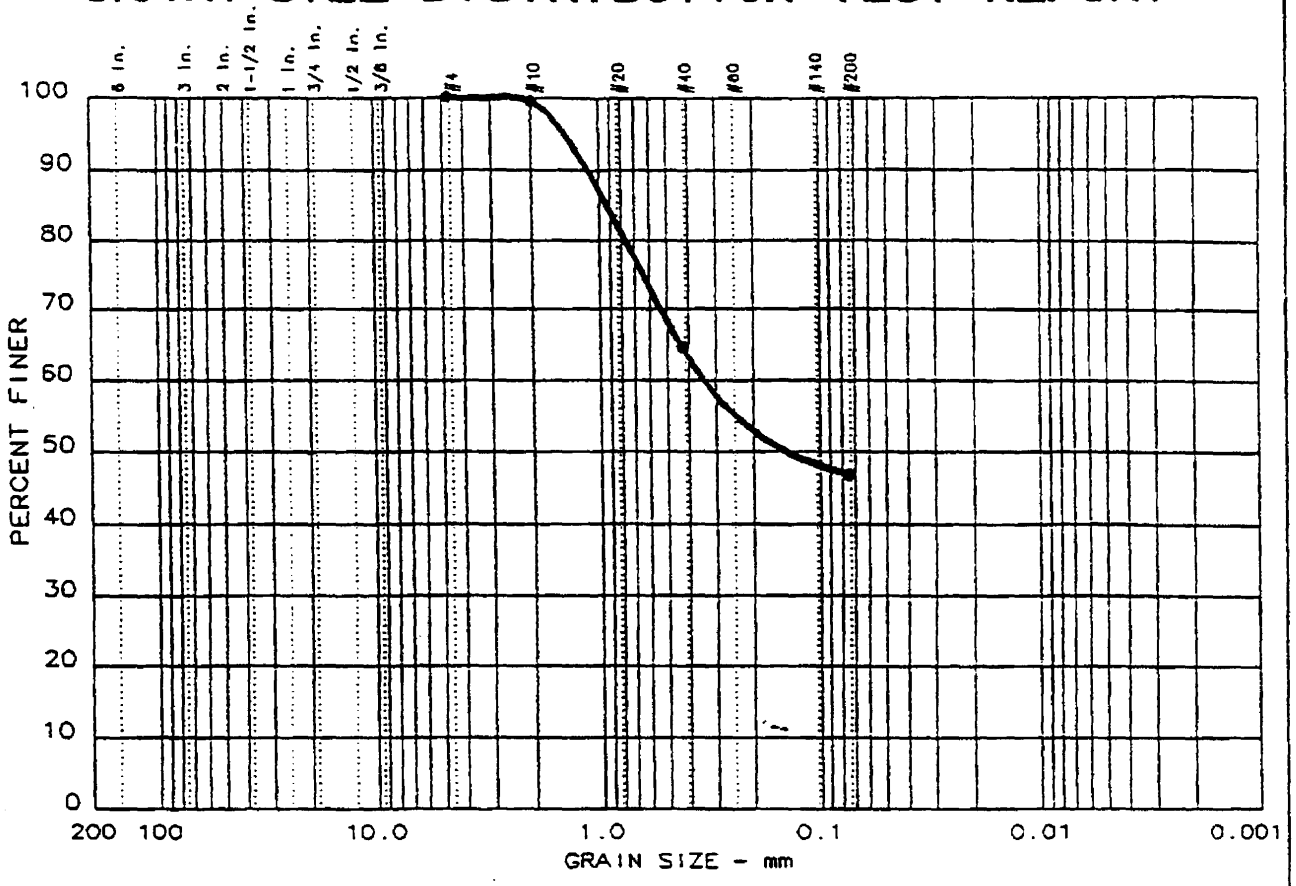
BULK DRY 47.3, WET 87.7

ORGANIC 2.3%

NMC 85.5%

Figure No. _____

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	17	0.0	0.0	53.2	46.8	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●		N/P	0.912	0.339	0.141					

MATERIAL DESCRIPTION	USCS	AASHTO
● BROWNISH GRAY SILTY SAND W/ TRACE MICA	SM	A-4(0.0)

Project No.: 17372
Project: LAKE EMBRY DAM
● Location: SAMPLE TUBE #1

Date: 08-01-97

GRAIN SIZE DISTRIBUTION TEST REPORT

TIMMONS

Remarks:

LOG BOOK NO.: 17372-A

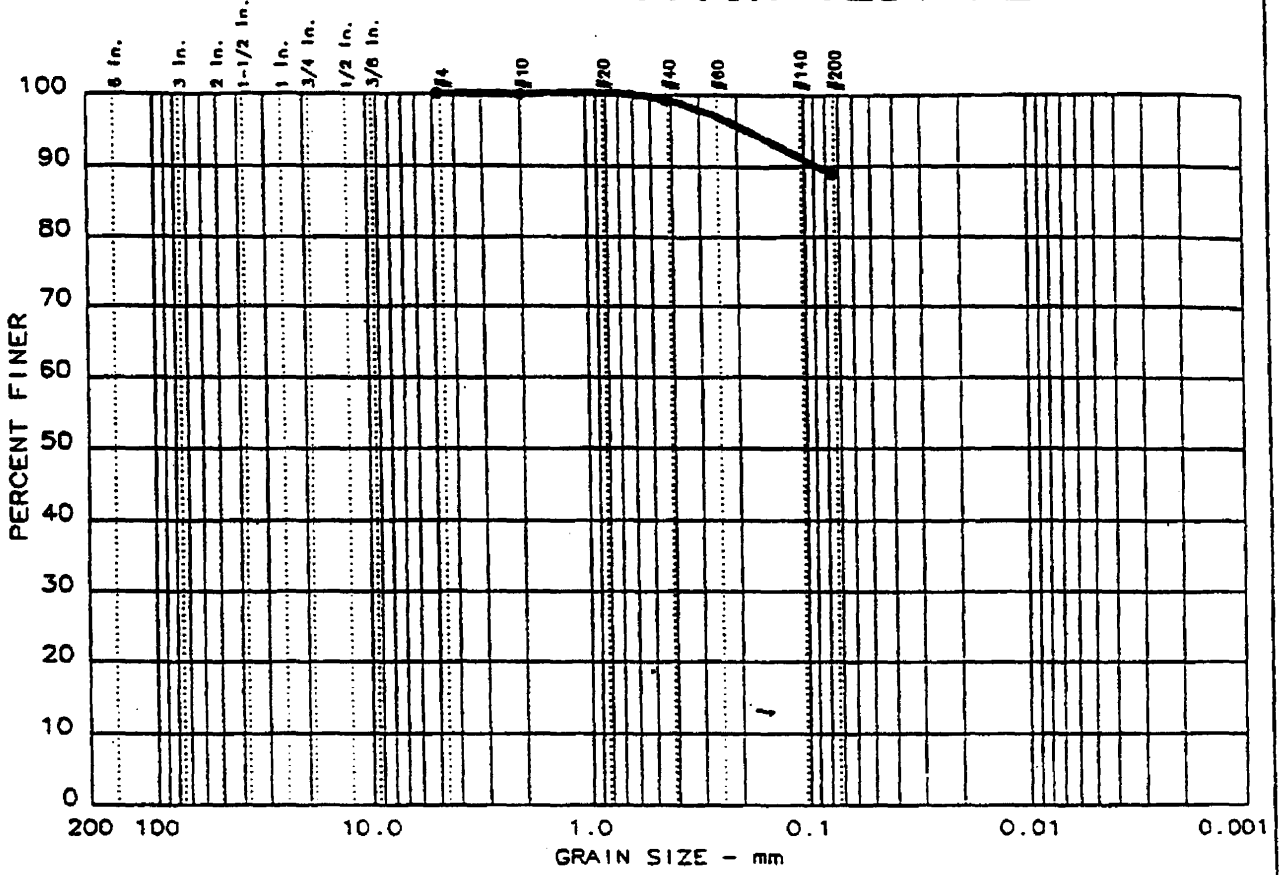
BULK DRY 59.9, WET 91.6

ORGANIC 4.9%

NMC 52.9%

Figure No. _____

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	18	0.0	0.0	11.1	88.9	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●	47	16								

MATERIAL DESCRIPTION	USCS	AASHTO
● BROWNISH GRAY CLAYEY SILT W/ TRACE MICA. SAND	ML	A-7-5(17.1)

Project No.: 17372
Project: LAKE EMBRY DAM
● Location: SAMPLE TUBE #2

Date: 08-01-97

GRAIN SIZE DISTRIBUTION TEST REPORT

TIMMONS

Remarks:

LOG BOOK NO.: 17372-B

BULK DRY 61.4, WET 100.4

ORGANIC 1.0%

NMC 63.6%

Figure No. _____

TIMMONS • 711 NORTH COURTHOUSE ROAD • RICHMOND, VA 23236-4099
(804) 794-3500 • FAX (804) 794-7639

BORING LOG

BORING NO: #6 | ELEVATION -TOP OF BORING: | DATE OF BORING:
PROJECT: EMBREY DAM
LOCATION: 34.75" TOTAL LENGTH OF TUBE
TYPE OF BORING: 13.5" SOIL IN TUBE | OBSERVER:
DRILLING CONTRACTOR:--

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
-9.5" to -13.5"	Brown Silty Coarse Sand w/ organics			Gradation between -0"- 35"
-0 to -9.5"	Brown Silty Coarse Sand			Bulk Density between -9.5" to -13.5"
--	BULK TUBE SIZE		WET WT. 150.32	BULK(WET) 301.95
	L. 5.908		DRY WT. 133.20	BULK(DRY) 285.03
	I.D. 1.054			TUBE WT. 133.94
	.3314 / 5.1548 1728	11	11.1 lb/ft³ wet	
	.2937 / 5.1548 1728	98.4	lb/ft³. dry.	

GROUND WATER DATA:

WATER LEVEL IS _____ FT. BELOW GROUND SURFACE ___ HRS. AFTER COMPLETION.

*NO. OF BLOWS 140-LBS HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
**CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

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BORING LOG

BORING NO: #7 | ELEVATION TOP OF BORING: | DATE OF BORING:
PROJECT: EMBREY DAM
LOCATION: 35.5" total Length of Tube
TYPE OF BORING: 35" total Length of Tube OBSERVER:
DRILLING CONTRACTOR: - 26" total of Soil in Tube

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
- 10' to - 26"	Brownish Grey Sandy Silt w/ mixed organics			Gradation from bottom top 3.0"
- 4" to - 10"	Brown silty coarse sand		top 4" organics	Bulk @ - 20" approx.
...	Bulk tube size L. 7.425 I.D. 1.035 .3415 1728 6.2469 .1955 1728 6.2469		WET WT. 154.92 DRY WT. 88.67 94.5 lb/ft³ wet. 54.1 lb/ft³ dry.	Bulk WET .. 348.51 Bulk DRY 232.26 TUBE WT. 193.59

GROUND WATER DATA:

WATER LEVEL IS ________ FT. BELOW GROUND SURFACE ____ HRS AFTER COMPLETION

*NO. OF BELOWS 140-LBS HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
**CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

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BORING LOG

BORING NO: # 3 | ELEVATION -TOP OF BORING: | DATE OF BORING:
PROJECT: EMBREY DAM
LOCATION:
TYPE OF BORING: 34.5 total length of TUBE | OBSERVER:
DRILLING CONTRACTOR:- 19" ± Soil in TUBE

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
- 15" to - 19"	Brownish Grey Sandy Silt			Gradation from bottom 3"
- 10" to - 19"	Brown Silty coarse SAND Mixed w/ organics			- 15" Bulk Density (WET DRY)
--	BULKTUBE SIZE L. 5.905 I.D. 1.042		WET WT. 130.27 DRY WT. 80.27	BULK WET 234.15 BULK DRY 234.15 TUBE WT. 153.88 --

$\frac{.2872}{5.0355}$ 1728 = 98.6 lb/ft³ wet.

$\frac{.1770}{5.0355}$ 1728 = 607 lb/ft³ dry.

GROUND WATER DATA:

WATER LEVEL IS _____ FT. BELOW GROUND SURFACE ___ HRS. AFTER COMPLETION.

*NO. OF BELOWS 140-LBS HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
**CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

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BORING LOG

BORING NO: #5 | ELEVATION .TOP OF BORING: | DATE OF BORING:
PROJECT: EMBREY DAM
LOCATION:
TYPE OF BORING: 35" total length of tube. OBSERVER:
DRILLING CONTRACTOR:- 19" of soil in tube

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
- 11" to - 19"	Brownish Grey Sandy S.H w/ organics		Mixed w/ organics	Sample taken from bottom 3.5"
- 4" to - 11"	Brown silty coarse sand mixed w/ organics		top 4" coarse organic	- 12" Bulk Density (WET, DRY)
	Bulk Tube Size L. 5.595 I.D. 1.036		WET WT. 108.65 DRY WT 58.56	Bulk (WET) 255.03 Bulk (DRY) 201.94 TUBE WT. 146.53
	$\frac{.2395}{4.7164}$ 1728	= 87.7 lb/ft3 wet.		
	$\frac{.1291}{4.7164}$ 1728	= 47.3 lb/ft3 dry.		

GROUND WATER DATA:

WATER LEVEL IS _____ FT. BELOW GROUND SURFACE ___ HRS. AFTER COMPLETION.

*NO. OF BELOWS 140-LBS HAMMER 30-IN. FALL. REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
**CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

MMONS • 711 NORTH COURTHOUSE ROAD • RICHMOND, VA 23236-4099
(804) 794-3500 • FAX (804) 794-7639

BORING LOG

BORING NO. 1 | ELEVATION TOP OF BORING: | DATE OF BORING:
PROJECT: EMBREY DAM
LOCATION:
TYPE OF BORING: 4" 3" total length of tube. OBSERVER:
DRILLING CONTRACTOR: 22" of Soil in tube.

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
-14" to -22"	FROM bottom of S.T. 8" Brownish Grey Sandy Silt			Excluding from bottom 3 5/8"
-2" to -14"	12" Brown Silty Coarse Sand 1" strata organics @ -18" to -17"			-13" Bulk Density (WET, DRY)
-0" to -2"	2" organics			

Bulk Tube Size
L. 4.445
I.D. 1.046

$V = A \frac{D^2}{4} \times L$

Density $= \frac{W}{V}$

WT. WET 91.84
WT. DRY 60.04

1 lb = 453.6 g
1 ft³ = 1728 in³

Bulk (WET) 204.03
Bulk (DRY) 174.26
TUBE WT. 114.19

91.84 g | 1 lb
453.6 g
.2025 lb
3.81966 in³ | 1728 in³ / ft³
91.61 lb/ft³ wet.

.1324 lb
3.81966 in³ | (1728) ft³
59.91 lb/ft³

NOTE: All SAMPLES HAVE TR. MICA

GROUND WATER DATA:

WATER LEVEL IS _____ FT. BELOW GROUND SURFACE ___ HRS. AFTER COMPLETION.

*NO. OF BLOWS 140-LBS HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D. 1.375 IN. I.D. SAMPLER 6 INCHES
**CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN

MONS • 711 NORTH COURTHOUSE ROAD • RICHMOND, VA 23236-4099
(804) 794-3500 • FAX (804) 794-7639

BORING LOG

BORING NO: # 2 | ELEVATION TOP OF BORING: | DATE OF BORING:
PROJECT: EMBREY DAM
LOCATION: 46.5 total length of tube
TYPE OF BORING: 29" of soil in tube | OBSERVER:
DRILLING CONTRACTOR:-

DEPTH	STRATUM DESCRIPTION	SAMPLE DEPTH	SAMPLE BLOWS* CORE RECOVERY**	SAMPLE DESCRIPTION
- 17 to - 29	Brownish Grey Sandy Silt 12"	Mixed w/ organics		Gradation from bottom 3.5"
- 3 to - 14	Brown Silty Coarse Sand	mixed w/ organics		- 25" Bulk Density (WET DRY)
- 0" to - 3"	organics			
	Bulk tube size L. 6.445 I.D. 1.031		WET WT. 141.77 DRY WT. 56.07	Bulk (WET) 309.04 Bulk (DRY) 253.94 Tare WT. 167.27
	$\frac{.3125}{5.3806}$ 1728	= 100.4 lb/ft³ wet.		
	$\frac{.1911}{5.3806}$ 1728	= 61.4 lb/ft³ dry.		

GROUND WATER DATA:

WATER LEVEL IS _____ FT. BELOW GROUND SURFACE ___ HRS. AFTER COMPLETION

*NO. OF BELOWS 140-LBS HAMMER, 30-IN. FALL, REQUIRED TO DRIVE 2 IN. O.D., 1.375 IN I.D. SAMPLER 6 INCHES.
**CORE RECOVERY AS PERCENT OF LENGTH OF DRILL RUN.
SEE NOTES TO BORING LOG WHICH ARE A PART OF THIS LOG.

Fact Sheet

COMMONWEALTH OF PENNSYLVANIA • DEPARTMENT OF ENVIRONMENTAL PROTECTION

BREACHING OF DAMS IN PENNSYLVANIA

The Division of Dam Safety has adopted a procedure to facilitate the breaching of dams in Pennsylvania. The procedure described below has been adopted to make it easier and more affordable for a dam owner to remove an unwanted and often unsafe dam. This will aid in the protection of public health, safety, welfare, and property downstream as well as the re-establishment of streams to their free flowing natural state. In order to qualify for this procedure, the proposed breach plan must essentially restore the stream to its natural free flowing state through the impoundment area and dam footprint area.

STEP 1

The dam owner or his/her engineer should submit to the Division of Dam Safety a plan of the proposed breach. This plan should include a plan view and cross-sections as necessary to complete the project. This plan should include dimensions, channel lining specifications, and the proposed location of the spoil area.

STEP 2

The Division of Dam Safety will do the following:

- Review the plan for proper breach sizing, re-establishment of the stream through the project area, appropriate channel protection, and properly located spoil areas.
- Conduct an Environmental Assessment for the project. If major environmental impacts are found to result from the proposed breach, a Dam Permit will be required to provide a more comprehensive review process.
- Coordinate the review of the proposed dam breach with the Pennsylvania Fish and Boat Commission and the appropriate Corps of Engineers' District Office.

STEP 3

Upon acceptance of the plan by the Division of Dam Safety, the project will be authorized under the waiver provision of Section 105.12 (a) (16) as a restoration of a stream to its natural free flowing condition. The following conditions will be stipulated:

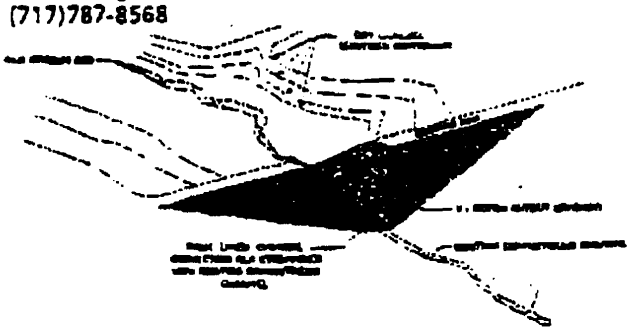
- Erosion and Sedimentation Control Plan approval by the appropriate County Conservation District.
- Notification to the Pennsylvania Fish and Boat Commission's appropriate regional office prior to construction.
- Secure Drawdown Permit if required.
- Notification of the appropriate Department Regional Office 10 days in advance of the proposed construction date.
- Submission of as-built drawings to the Division of Dam Safety within 30 days of the completion of the breach.
- Notify the local municipality 10 days in advance of the proposed construction date.

STEP 4

The Department's Regional Office shall conduct a final inspection of the site.

For more information contact:

Department of Environmental Protection
Bureau of Dams, Waterways, and Wetlands
Division of Dam Safety
P.O. Box 8554
Harrisburg, PA 17105-8554
(717)787-8568

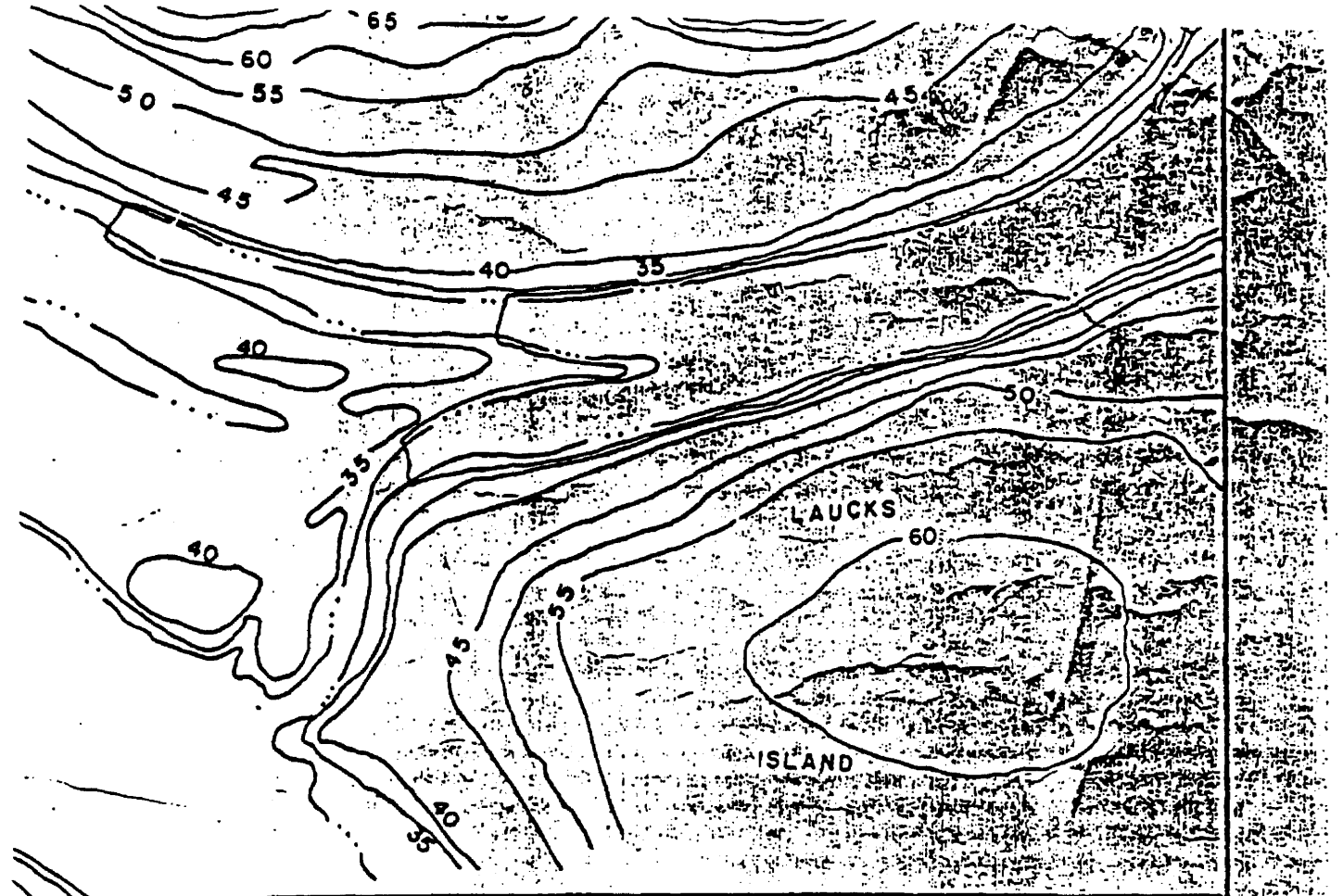


Commonwealth of Pennsylvania
Tom Ridge, Governor

Department of Environmental Protection
James M. Seif, Secretary

3760-FS-DEP____ 12/95

Attachment 2.
Pennsylvania Department of Environmental Protection
Dam Breaching Fact Sheet



NO.	DATE	DESCRIPTION	BY	CKD

REVISIONS

RUSSELL, AXON & ASSOCIATES
ENGINEERS & CONSULTANTS
DAYTONA BEACH, FLA. STAFFORD CO., VA. ST. LOUIS, MO.

FREDERICKSBURG DAM
LOCATION & VICINITY MAP WITH SOUNDINGS
FREDERICKSBURG, VIRGINIA

DESIGNED BY	FILE No. 6577-3-19 12 A	SEAL
DRAWN BY D.W.W.	SHEET No. 1	
CHECKED BY	OF 1 SHEETS	
DATE 1965	SCALE 1" = 200'	

Attachment 3.
Russell, Axon & Associates Depth Soundings Map

Embrey Dam

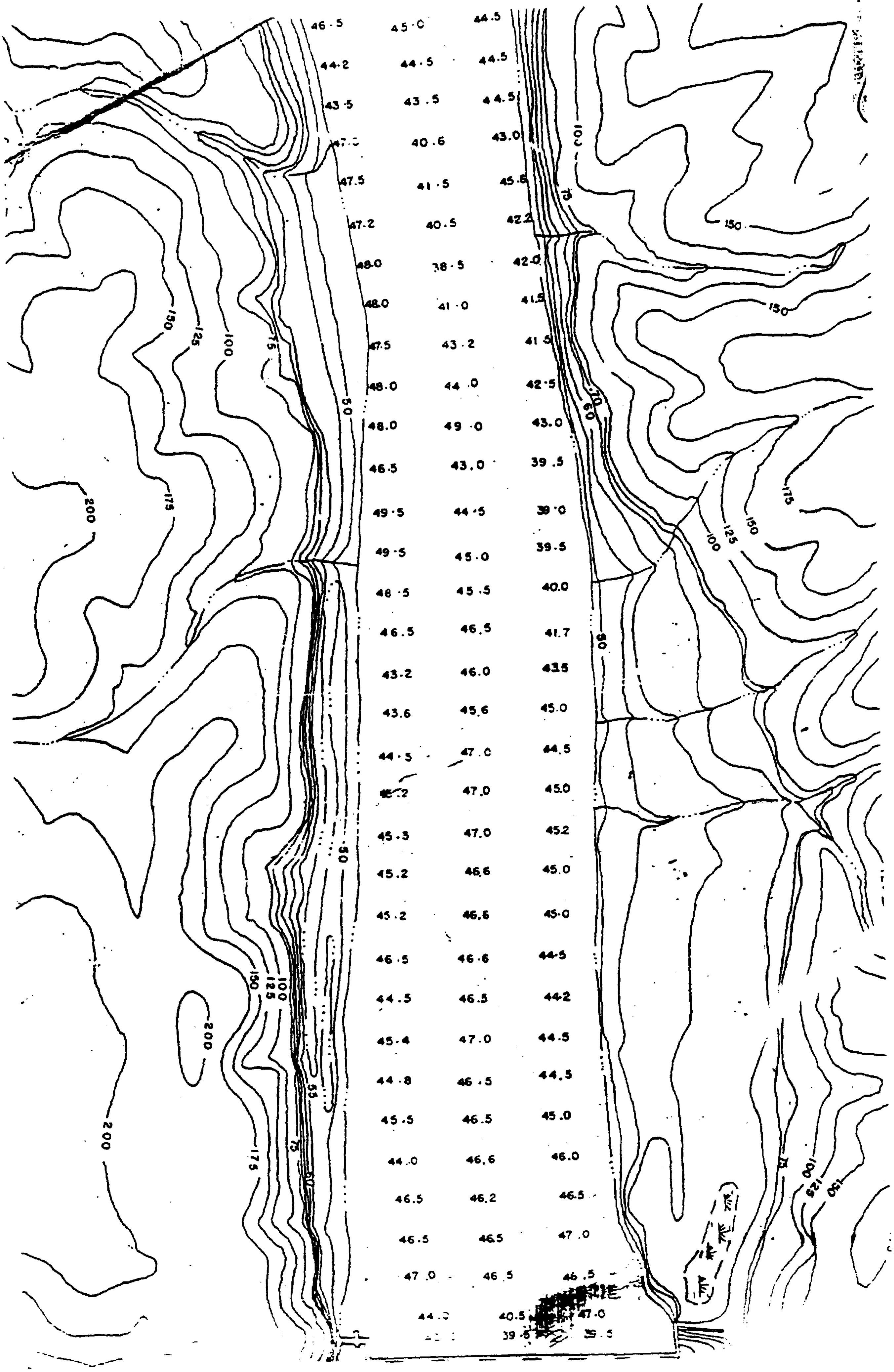
Sediment Transport Modeling Study

Virginia Department of Game
and Inland Fisheries
4010 West Broad Street
Richmond, Virginia 23230

TIMMONS, Inc.

GKY & Associates

December 5, 1997


46.5
45.0
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39.5

Flow data used in the model was taken from the USGS gaging station (01668000) located just upstream of the I-95 bridge crossing. A statistical analysis of the USGS daily flow data was performed to determine the magnitude and duration of flows that occur during a typical year. Figure 1. shows a distribution curve of daily flows for a typical year based on an analysis of flows recorded from 1907 through 1994.

The sediment size distribution used in modeling the transport of entrapped sediment was assumed to be consistent with the results of the field samples taken in July of 1997.

It should be noted that because the model does not account for local changes in bed slope between the modeled cross sections there may be some additional scouring or sedimentation that occurs along the river at various points.

Scour

There is currently no data available to estimate the amount of sediment being transported into the reservoir from upstream sources. Without having site specific monitoring data regarding the bed load moving into the reservoir under various flow rates, it is not possible to make a reasonable assumption of this sediment inflow for use in the model. Therefore it was assumed that there was no upstream sediment load flowing into the reservoir. This assumption provides for conservative results regarding the scouring of entrapped sediment because there will be no "backfilling" by upstream sediment which would serve to counteract the scouring of sediments within reservoir. Scouring of the existing channel downstream of the dam was not allowed.

Sedimentation

With regards to sediment deposition in the river below the dam, this study does not take into consideration possible deposition of sediment being carried by the river from sources upstream of the reservoir. However, depth measurements taken during a sediment sampling field visit conducted on July 27th, 1997 generally corresponded well with depth soundings mapped by Russell, Axon & Associates in October of 1965. This would appear to suggest that the sediment trapped by the dam has been and continues to be in a state of equilibrium meaning that the sediment that flows into the reservoir passes through the dam and into the downstream reach. Therefore any deposition that is currently occurring with the dam in place will probably continue to occur at a similar rate if the dam were removed. Thus the sediment deposition predicted by the model (sediment source being that which is currently trapped by the dam) would be in addition to existing deposition (from sources upstream of the I-95 bridge).

Background

Virginia Senate Joint Resolution No. 296 requested the Virginia Department of Game and Inland Fisheries (VDGIF) to conduct a study on providing fish passage at Embrey Dam near Fredericksburg, Virginia. In June of 1997, TIMMONS, Inc. was contracted to conduct a study to evaluate the technical alternatives for providing fish passage at the dam. GKY & Associates was tasked with investigating the issues associated with the sediment accumulated behind the dam. As a result of this study it was determined that a substantial portion of the overall cost for fish passage alternatives is associated with sediment removal. Therefore it was recommended that a sediment transport modeling study be conducted to estimate the potential for downstream transport of the trapped sediment if the dam were removed. The modeling study would provide information for making better estimates of the need for sediment disposal and the associated costs. This report documents the results of the sediment transport modeling study.

Modeling Approach

The study is being conducted using the Army Corps of Engineers' HEC-6 Scour and Deposition in Rivers and Reservoirs computer model. HEC-6 is a one-dimensional movable boundary open channel flow numerical model designed to simulate and predict changes in river profiles resulting from scour and/or deposition over given time periods. Generally a continuous flow record is partitioned into a series of steady flows of variable discharges and durations. For each flow, a water surface profile is calculated thereby providing energy slope, velocity, depth, and other information at each cross section. Potential sediment transport rates are then computed at each section. These rates combined with the duration of the flow, permit a volumetric accounting of sediment within each modeled reach. The amount of scour or deposition at each section is then computed and the cross section is adjusted accordingly. The computations then proceed to the next flow in the sequence and the cycle is repeated beginning with the updated geometry. Through this process, the HEC-6 model can predict the approximate spatial and temporal distribution of sediment within the modeled river reach.

For the Embrey Dam study, the river reach from the I-95 bridge crossing to a point just south of the City of Fredericksburg limits at Mayfield was modeled assuming removal of the dam. The dam removal is considered to be instantaneous because the river is expected to be diverted during dam demolition and then redirected through the breached section of the dam.

The reach was modeled using twenty seven cross sections which were created using the USGS topographic quad map, NOAA nautical charts, and depth soundings mapped by Russell, Axon & Associates in October of 1965 (Depth measurements taken during a sediment sampling field visit conducted on July 27, 1997 by GKY & A generally corresponded well with the 1965 study map). Detailed representations of these cross sections are included in Attachment 1.

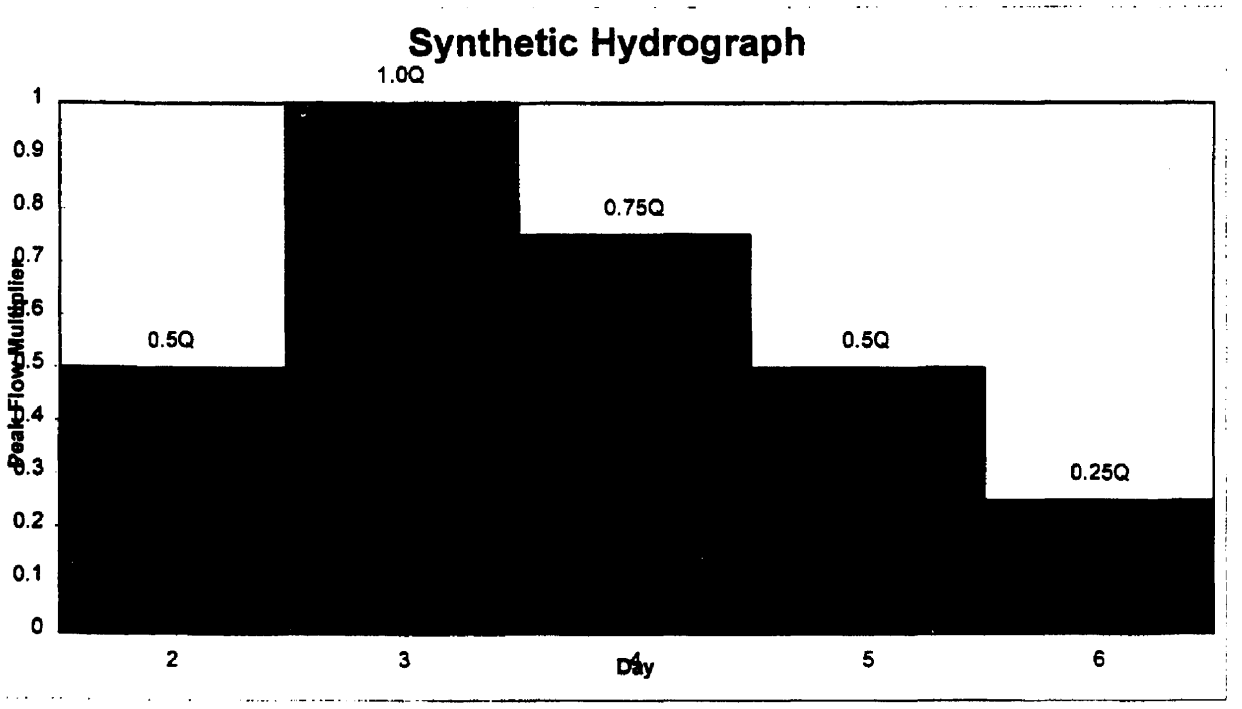


Figure 2. General Shape of Synthetic Hydrograph

A model run was also made using a 7 day hydrograph for the largest flood event (October 1942) that was ever recorded at the gaging station which had a peak flow of approximately 117,000 cfs. The hydrograph for this flow event is shown in Figure 3.

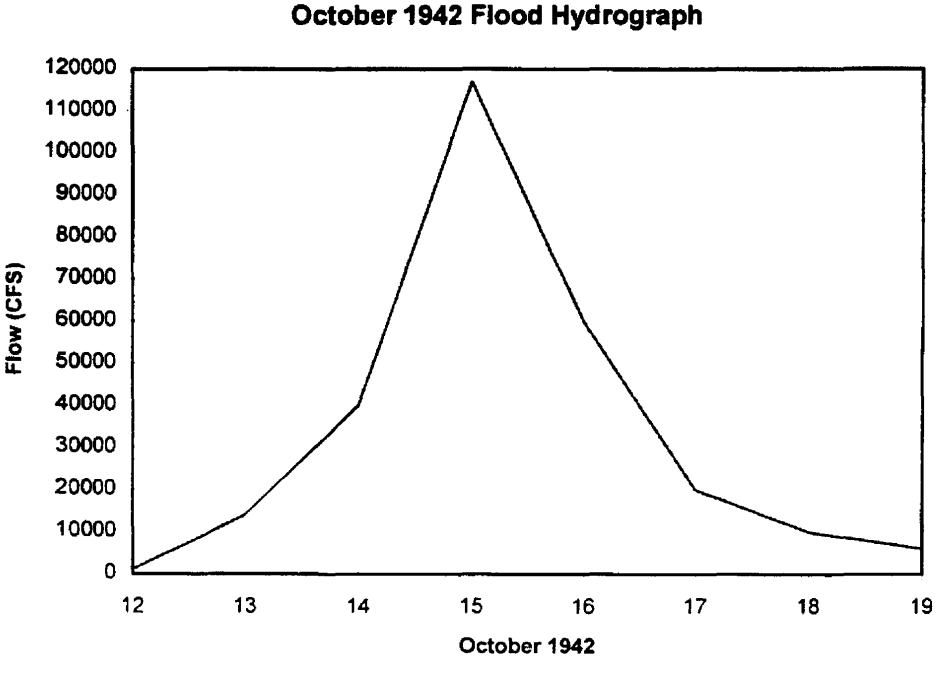


Figure 3. Hydrograph for Largest Recorded Flood Event

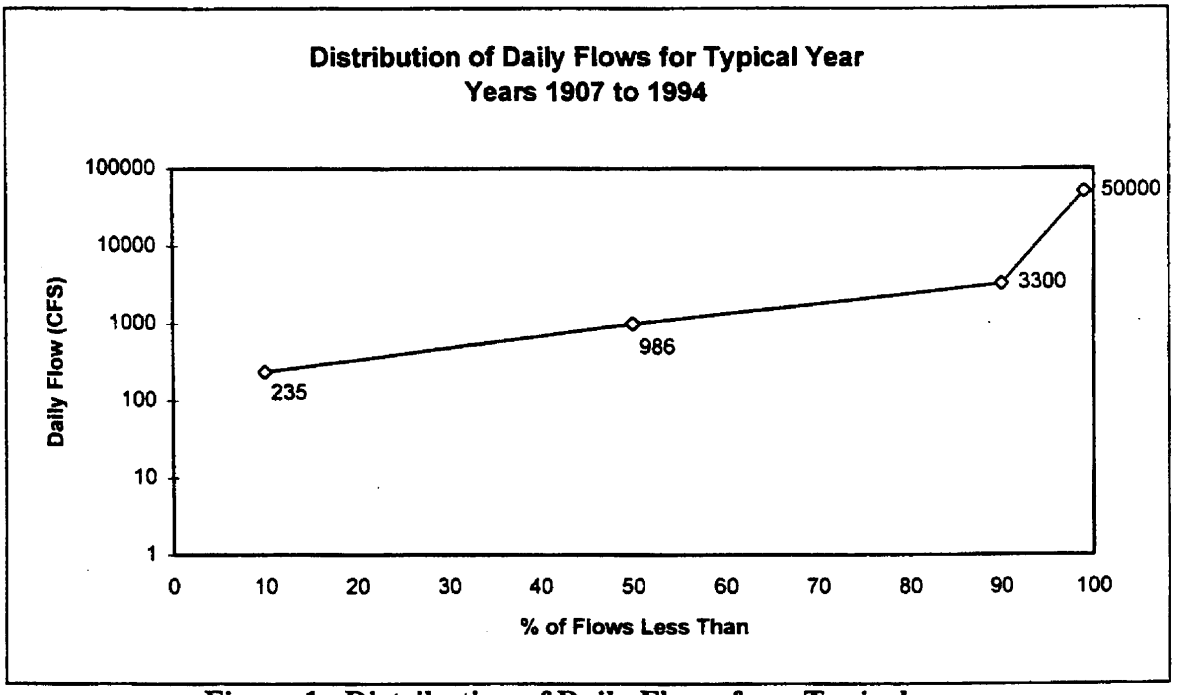


Figure 1. Distribution of Daily Flows for a Typical year

It can be seen from the curve that during the period of record:

- approximately 50 percent of the flows recorded were less than 1000 cfs
- approximately 90 percent of the flows recorded were less than 3300 cfs
- approximately 10 percent of the flows recorded were between 3300 cfs and 50,000 cfs

In order to model the sediment transport that occurs during a typical year, a combination of steady state low flows (255 days @ 1000 cfs and 75 days @ 3300 cfs) and five different 7 day synthetic hydrographs with peak flows ranging from 10,000 cfs to 50,000 cfs was used. The general shape of the synthetic hydrographs is shown in Figure 2. The hydrograph begins on day one with base flow and ends on day seven with a receding flow still slightly above base flow.

Scenario 1 - End of a Typical Year Without a Major Flood Event

The first scenario being considered is a typical year with no major flood event occurring during that year. Flows reflected in the scenario consist of 255 days of 1,000 cfs, 75 days of 3,300 cfs, and five storm events ranging from 10,000 to 50,000 cfs. Model runs numbered 1 through 7 are represented in this typical year.

The results of applying the sediment transport model using flows expected in a typical year are shown in Figures 4 and 5. Figure 4 shows the status of sediment following only dry (low flow) periods (3,300 cfs or less). Figure 5 shows the status of sediment for a typical year's flows including normally expected flows up to 50,000 cfs. The term "Transported" in each of the following scenarios refers to the sediment which passes the indicated station into the downstream reach. The term "In Transit" refers to the sediment which is temporarily deposited in the reach immediately upstream of the indicated station.

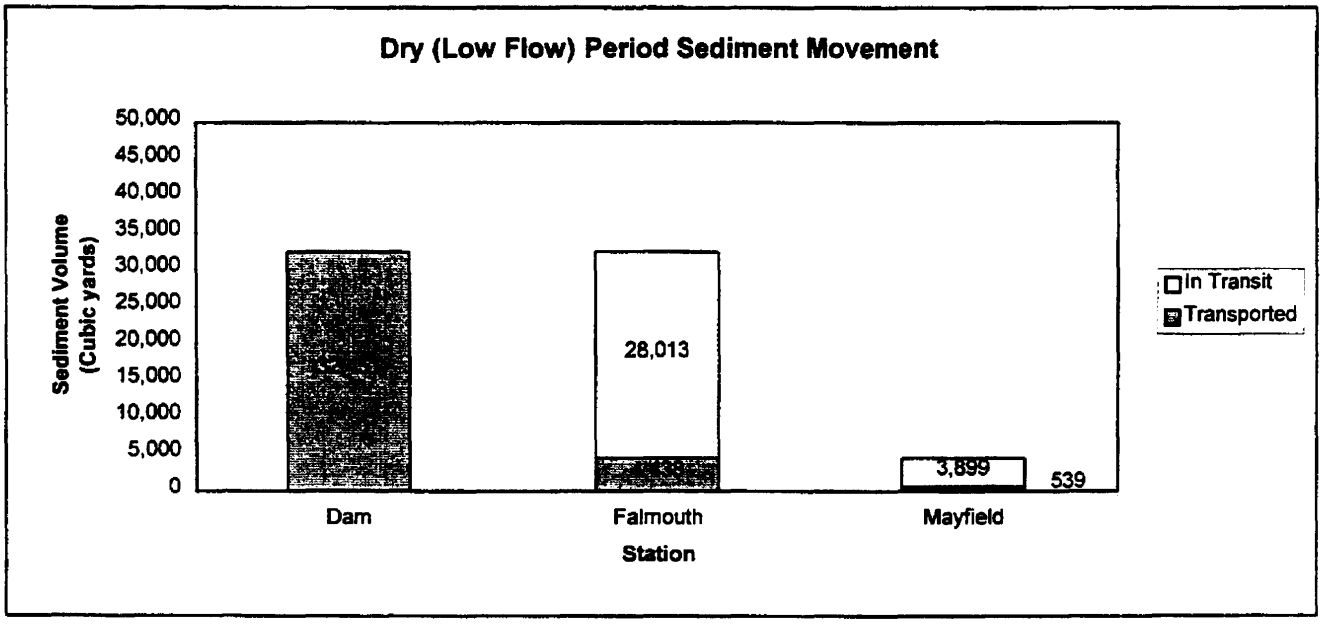


Figure 4. Sediment Movement During Dry (Low Flow) Periods

This run allows an estimate of the volume of sediment that would be transported out of the reservoir and into the downstream reach during the largest historical flood event to be made. A listing of the eight model runs made is shown in Table 1.

Model Run #	Description	Peak Flow (CFS)	Duration (Days)
1	Steady State Median Flow	1,000	255
2	Steady State 10% Exceeds Flow	3,300	75
3	Synthetic Hydrograph	10,000	7
4	Synthetic Hydrograph	20,000	7
5	Synthetic Hydrograph	30,000	7
6	Synthetic Hydrograph	40,000	7
7	Synthetic Hydrograph	50,000	7
8	October 1942 Flood Event	117,000	7

Table 1. Sediment Transport Modeling Runs

By evaluating various combinations of the results of these eight model runs, estimates of the volume of sediment being transported out of the reservoir and into the downstream reaches of the river were made.

Results

The results of the modeling efforts are expressed in terms of sediment movement through three distinct stations on the river:

- The "Dam" station corresponds to a location on the river at Embrey Dam
- The "Falmouth" station corresponds to a location on the river ~7,475 feet downstream of Embrey Dam
- The "Mayfield" station corresponds to a location on the river ~5,000 feet downstream of the City's boat dock (approximately 24,300 feet downstream of Embrey Dam)

These three stations were chosen because each one is located where a significant change in bed slope occurred and they correspond to areas of specific interest to the study (e.g. Mayfield station is close to the City's boat dock). The three reaches of the model are shown graphically in Attachment 1.

Of the twenty-seven cross sections used in the HEC-6 model, 10 were located in the reach above Embrey Dam, 10 were located between Embrey Dam and the Falmouth Station, and 7 were located between the Falmouth Station and the Mayfield Station.

Scenario 2 - Major Flood Event Closely Following Dam Breach
(Based on October 1942 Flood Event)

Figure 6 shows the results of applying the model using the hydrograph for the October 1942 flood event which had the highest recorded daily flow of approximately 117,000 cfs. It shows the volume of sediment that is transported through the indicated station to the downstream reach ("Transported") and the volume of sediment that is temporarily deposited in the reach upstream of the indicated station ("In Transit") for the historical flood event.

Scour

A major flood occurring immediately following the removal of the dam would scour approximately 16.6 % of the sediments between the I-95 bridge and Embrey Dam. The model predicts that a flood of equal magnitude to the October 1942 flood event would erode approximately 88,192 cubic yards of the sediment trapped above Embrey Dam.

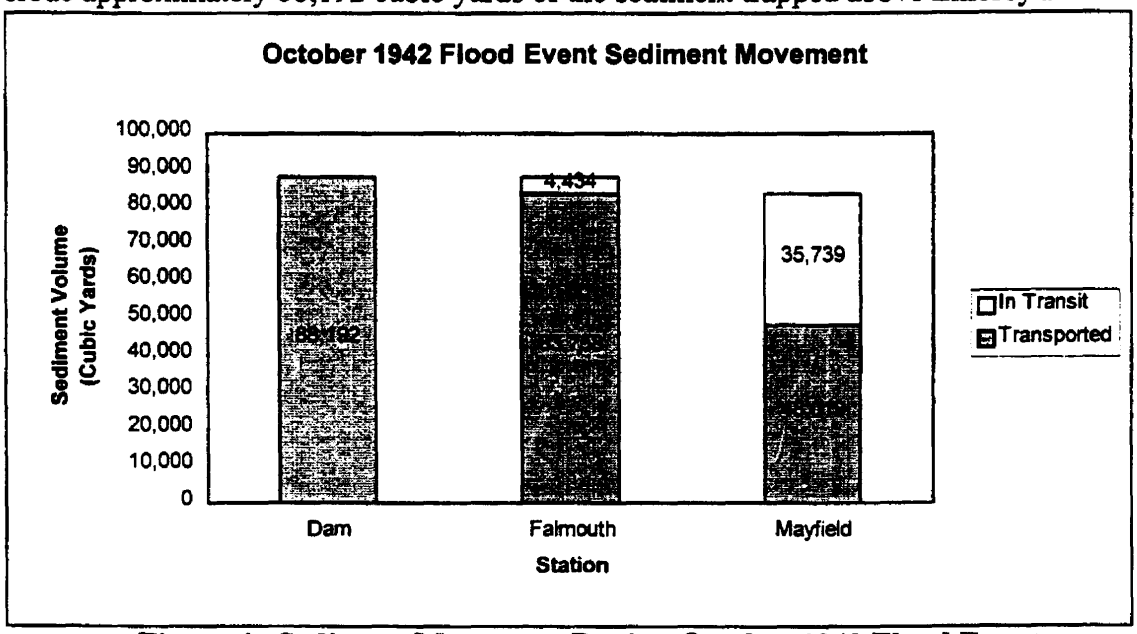


Figure 6. Sediment Movement During October 1942 Flood Event

Sedimentation

Approximately 5 % of the eroded sediment will be deposited in the 7,500 foot reach of the river between the Dam station and Falmouth station. If uniformly distributed in the reach, it will result in a 0.51 inch layer of sediment being deposited in the reach. The remaining 95 % of the eroded sediment will be transported downstream of the Falmouth station. Approximately 43 % of this eroded sediment will be deposited in the 13,300 foot reach of the river between the Falmouth station and Mayfield station. If uniformly distributed in the reach, it will result in a 2.96 inch layer of sediment being deposited in the reach. The remaining 57 % of the eroded sediment will be transported downstream of the Mayfield station.

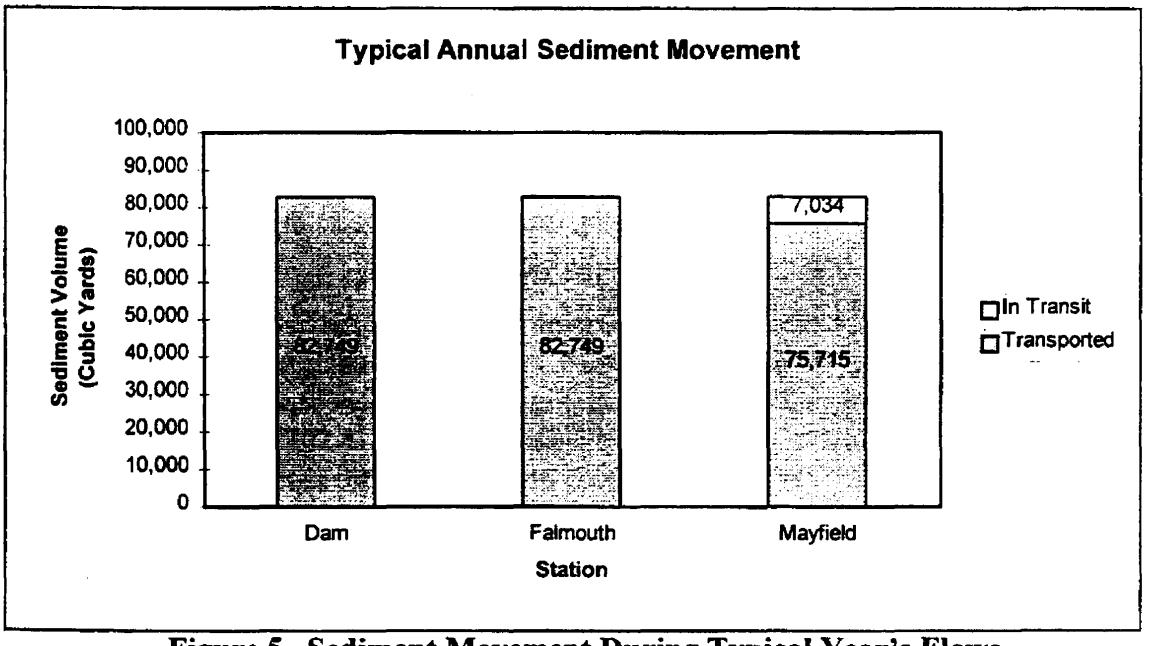


Figure 5. Sediment Movement During Typical Year's Flows

Scouring

In the first year after the removal of Embrey Dam, if no major flood event occurs, approximately 15.6 % (82,749 cubic yards) of the sediments between the I-95 bridge and Embrey Dam are scoured and transported downstream. Approximately 447,250 cubic yards will remain in place behind the dam.

Sedimentation

Based on distributing the sediment uniformly throughout the reach from the Dam station to the Falmouth station, the "In Transit" sediment is estimated to produce an average benthic layer of 0.325 inches which varies from zero inches following a storm to approximately twice the average following a dry (low flow) period. Approximately 10 % of this eroded sediment will be deposited in the 13,300 foot reach of the river between the Falmouth station and Mayfield station. If uniformly distributed in the reach, it will result in a 0.583 inch layer of sediment being deposited in the reach. The remaining 90% of the eroded sediment will be transported downstream of the Mayfield station

Scenario 3. Typical year's flows with an October 1942 type flood event (Combine Scenarios 1. and 2.)

Neglecting the effects of natural armoring and vegetative cover a conservative estimate of sediment transport under this flow scenario can be made by combining the results of flow Scenarios 1 and 2.

Scour

Approximately 32.2% of the volume of sediment trapped in the reservoir will be eroded in a 365 day period.

Sedimentation

Approximately 2.6 % of this eroded sediment will be deposited in the 7,500 foot reach of the river between the Dam station and Falmouth station. If uniformly distributed in the reach, it will result in a 0.51 inch layer of sediment being deposited in the reach. The remaining 97.4 % of the eroded sediment will be transported downstream of the Falmouth station. Approximately 25.6 % of this eroded sediment will be deposited in the 13,300 foot reach of the river between the Falmouth station and Mayfield station. If uniformly distributed in the reach, it will result in a 3.543 inch layer of sediment being deposited in the reach. The remaining 74.4 % of the eroded sediment will be transported downstream of the Mayfield station.

Scenario 4. Two typical year's flows occurring in succession

Neglecting the effects of natural armoring and vegetative cover a conservative estimate of sediment transport under this flow scenario can be made by adding the results of flow Scenario 1 for a two year period

Scour

Approximately 31.2% of the volume of sediment trapped in the reservoir will be eroded in a two year period.

Sedimentation

Approximately 10 % of this eroded sediment will be deposited in the 13,300 foot reach of the river between the Falmouth station and Mayfield station. If uniformly distributed in the reach, it will result in a 1.166 inch layer of sediment being deposited in the reach. The remaining 90% of the eroded sediment will be transported downstream of the Mayfield station.

Successive Years

Scour

In general, the sediment that is transported in a flowing river such as the Rappahannock is composed of various sizes of particles ranging from fine silts and clays to sands and gravels. As scouring of the sediment occurs, the smaller particles are picked up and transported downstream first, leaving the larger sands and gravels behind. These larger particles tend to exhibit an armoring effect on the sediment beneath them. That is, they act similar to a riprap material protecting neighboring particles from scouring. Therefore as the degradation of the bed sediment proceeds over time, there is a coarsening of the bed material which leads to a decreased rate of degradation. Because of this natural armoring process, we would expect to see a decreasing rate of scouring of the entrapped sediment over successive years which would be directly dependent upon the grain size distribution of the sediment. Thus the rate of erosion of the sediment deposit in the reservoir for successive years will be less than the rate predicted for the first year.

Also as time elapses, vegetative cover will tend to creep into the sediment overbank areas providing further resistance to scour. The timeframe for establishment of vegetation in these areas will depend upon the nutrients available in the sediment deposits, rainfall, sunlight exposure, and the method of seeding. Appendix A shows pictures of the vegetation that was established over two growing seasons upstream of the Williamsburg Station Dam (Pennsylvania) after it was breached in 1995.

Discussions with Scott Carney, the Pennsylvania Floodplain Coordinator, revealed that optimum seeding and fertilization methods would be site specific. In some instances, Pennsylvania dam breaches have not required any seeding or fertilization to establish a vegetative cover.

Sedimentation

With regards to sediment deposition in the river below the dam, this study does not take into consideration possible deposition of sediment being carried by the river from sources upstream of the reservoir. However, depth measurements taken during a sediment sampling field visit conducted on July 27th, 1997 generally corresponded well with depth soundings mapped by Russell, Axon & Associates in October of 1965. This would appear to suggest that the sediment trapped by the dam has been and continues to be in a state of equilibrium meaning that the sediment that flows into the reservoir passes through the dam and into the downstream reach. Therefore any deposition that is currently occurring with the dam in place will probably continue to occur at a similar rate if the dam were removed. Thus the sediment deposition predicted by the model (sediment source being that which is currently trapped by the dam) would be in addition to existing deposition (from sources upstream of the I-95 bridge)

In conclusion, if the sediment is not removed by dredging prior to removal of the dam, it will tend to be deposited just downstream of the dam during low flow periods and remain there until enough large flow events occur to carry it further downstream of the City. The process of natural transport of the accumulated sediment downstream may take many years.

Scenario 5. Typical year's flows with an October 1942 type flood event and another typical year's flows occurring in succession (Combine Scenarios 1. and 3.)

Neglecting the effects of natural armoring and vegetative cover a conservative estimate of sediment transport under this flow scenario can be made by combining the results of flow Scenarios 1 and 3.

Scour

Approximately 47.8% of the volume of sediment trapped in the reservoir will be eroded in a two year period.

Sedimentation

Approximately 1.75 % of this eroded sediment will be deposited in the 7,500 foot reach of the river between the Dam station and Falmouth station. If uniformly distributed in the reach, it will result in a 0.51 inch layer of sediment being deposited in the reach. The remaining 98.25 % of the eroded sediment will be transported downstream of the Falmouth station. Approximately 19.98 % of this eroded sediment will be deposited in the 13,300 foot reach of the river between the Falmouth station and Mayfield station. If uniformly distributed in the reach, it will result in a 4.126 inch layer of sediment being deposited in the reach. The remaining 80.02 % of the eroded sediment will be transported downstream of the Mayfield station.

Conclusions

Based on the results of the eight model runs made, it appears that if the dam were removed a typical year's flows would move approximately 15.6% of the entrapped sediment out of the reservoir. Practically all of this sediment would be transported through the reach between the Dam station and the Falmouth station with some temporary deposition of sediment occurring between flood events. About 10 % of this sediment would be deposited in the reach between Falmouth station and Mayfield station with the remaining 90% moving downstream past Mayfield station.

If a large flood event (e.g. October of 1942 Flood Event) were to occur, it would tend to flush approximately 16.6 % of the sediment out of the reservoir deposit in a seven day period. Approximately 95% of this sediment would be transported through the reach between the Dam station and the Falmouth station. Then 57% of this sediment would continue to be transported through the reach between Falmouth station and Mayfield station with the remaining 43% of the material remaining in the reach. Because the event occurs over a seven day period there is probably not enough time for the material to be completely transported out of this lower reach. However, as other flow events occur they would tend to re-suspend the sediment that was deposited by this large flood event and move it downstream of the Mayfield station.

Exhibit A - Location of Stations used in Model

Scale: 1"=2000'

From Fredericksburg USGS Quadrangle Sheet

Attachment 1
Modeling Parameters

Initiation – at Dam Cross Section

Mid Point – at Dam Cross Section

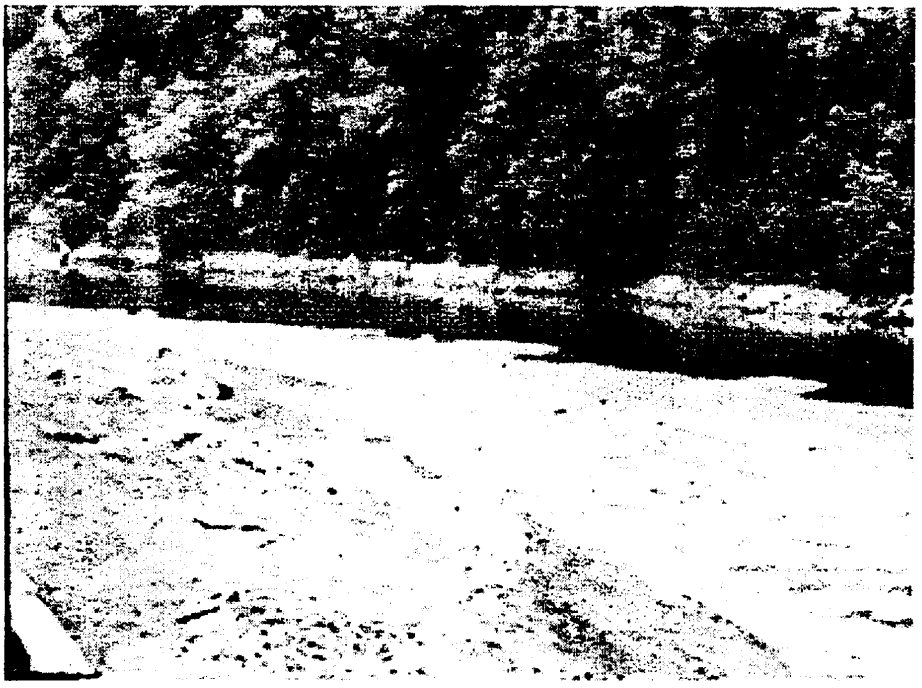
WILLIMASBURG STATION DAM DEMOLITION – 1995

Attachment 2
Williamsburg Station Dam Breach Photographs

Look upstream – two growing seasons late

At Dam Cross Section – two growing seasons later

WILLIAMSBURG STATION SEDIMENT STREAM
REGRESSION TO NATURAL STATE – 1997



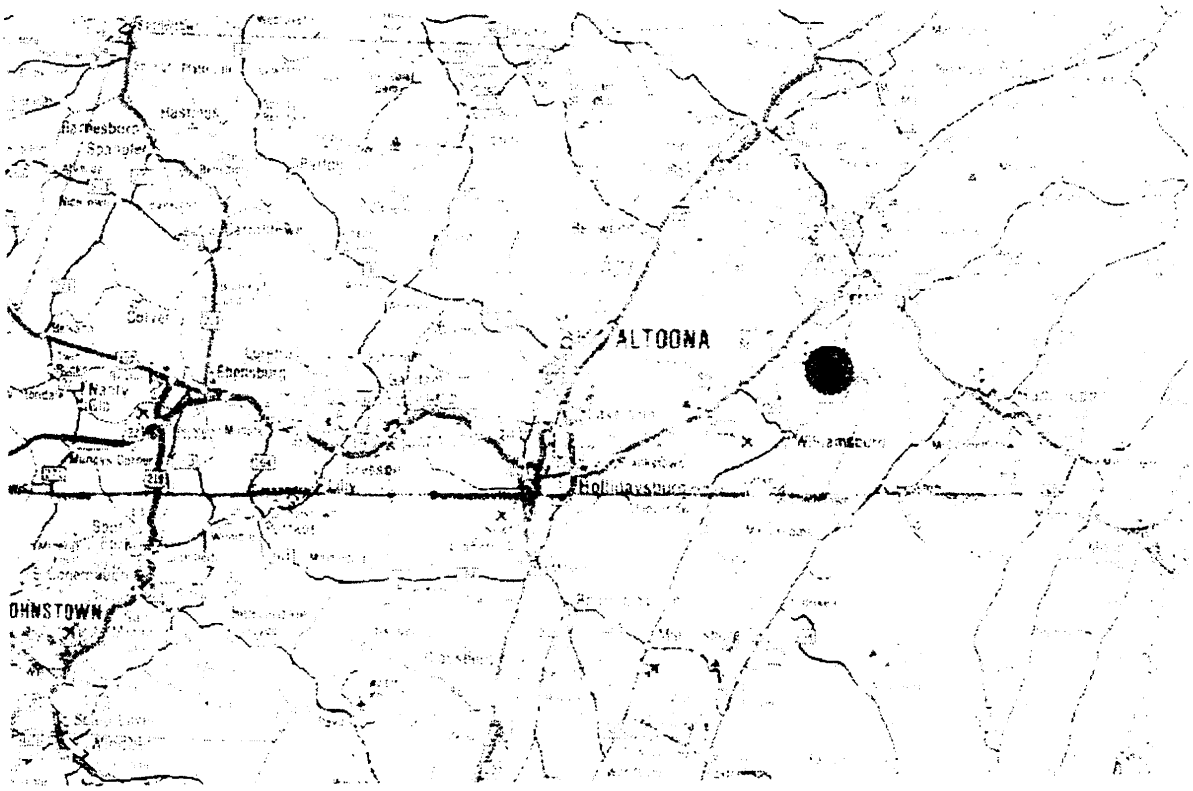
Looking upstream

Another view looking upstream

WILLIAMSBURG STATION DAM DEMOLITION – 1995

Appendix G

City of Fredericksburg Resolution 97-53



Location Map

6) exploring other opportunities and facilities which may serve to improve flood control provisions along the River;

7) preserving the water rights of the localities; and

BE IT FURTHER RESOLVED, that the Commonwealth of Virginia is hereby requested to serve as the non-federal sponsor for returning the River to its natural state working closely with the local jurisdictions of the City of Fredericksburg and the Counties of Spotsylvania and Stafford.

Clerk's Certificate

I, the undersigned, certify that I am Clerk of the Council of the City of Fredericksburg, Virginia, and that the foregoing is a true copy of Resolution 97-53 duly adopted at a meeting of the City Council held May 27, 1997 at which a quorum was present and voted.

Given under my hand and the official seal of the City.

Deborah H. Ratliffe
Clerk of Council

5/29/97
Date

Marvin S. Bolinger
City Manager

Beverly R. Cameron
Assistant City Manager

City of Fredericksburg
P.O. Box 7447
Fredericksburg, VA 22404-7447
Telephone: 540 372 1010
Fax: 540 372-1158

RESOLUTION 97-53

WHEREAS, the Rappahannock River is of vital importance to the City of Fredericksburg, the Counties of Stafford and Spotsylvania and the entire region with its beauty, economic value and recreational value; and

WHEREAS, the Embrey Dam was built in 1910 on the River to divert water to the City's water treatment plant, but has now deteriorated and has the potential to collapse; and

WHEREAS, the citizens of the area desire to remove the Embrey Dam from the Rappahannock River, particularly since the City of Fredericksburg and the County of Spotsylvania are building a new water treatment plant and the Dam will no longer be needed for water supply; and

WHEREAS, the area localities are most desirous of returning the Rappahannock River to its natural state allowing migrating fish to swim further upstream and thereby encouraging more recreational and economic opportunities;

NOW, THEREFORE, BE IT RESOLVED this 28th of May, 1997, that the City Council of the City of Fredericksburg, Virginia, does hereby join with its neighbors in the Counties of Spotsylvania and Stafford to request the Congress of the United States to provide the support and direction through the Corps of Engineers, Norfolk Division, to return the river to its natural state while at the same time:

1) ensuring that an acceptable level of water flow is maintained in the Rappahannock Canal;
2) ensuring that the abundant and critical wetland resources and vegetation located adjacent to the Rappahannock Canal, including the Snowden marsh and pond, Gayles marsh and pond, College marsh and the presettling pond adjacent to the City's Kenmore Water Plant, are preserved in their present status;
3) ensuring the preservation of historically important locks adjacent to the Canal;
4) recognizing and documenting the 1855 Crib Dam and its importance in Fredericksburg's early industrial history and water power origins;
5) considering the potential for improving and enhancing regionally important recreational areas adjacent to the River downstream from the Dam (Old Mill Park, Falmouth Beach, City Dock Park, and others);

1987 CHESAPEAKE BAY AGREEMENT

THE CHESAPEAKE BAY IS A NATIONAL TREASURE and a resource of worldwide significance. Its ecological, economic, and cultural importance are felt far beyond its waters and the communities that line its shores. Man's use and abuse of its bounty, however, together with the continued growth and development of population in its watershed, have taken a toll on the Bay system. In recent decades, the Bay has suffered serious declines in quality and productivity. ◇ *REPRESENTING* the Federal government and the States which surround the Chesapeake Bay, we acknowledge our stake in the resources of the Bay and accept our share of responsibility for its current condition. We are determined that this decline will be reversed. In response, all of our jurisdictions have embarked on ambitious programs to protect our shared resource and restore it to a more productive state. ◇ *IN* 1980, the legislatures of Virginia and Maryland established the Chesapeake Bay Commission to coordinate interstate planning and programs from a legislative perspective. In 1985, Pennsylvania joined the Commission. And, in 1983, Virginia, Maryland, Pennsylvania, the District of Columbia, the U.S. Environmental Protection Agency and the Chesapeake Bay Commission formally agreed to a cooperative approach to this undertaking and established specific mechanisms for its coordination. Since 1983, our joint commitment has carried us to new levels of governmental cooperation and scientific understanding. It has formed a firm base for the future success of this long-term program. The extent and complexity of our task now call for an expanded and refined agreement to guide our efforts toward the twenty-first century. ◇ *RECOGNIZING* that the Chesapeake Bay's importance transcends regional boundaries, we commit to managing the Chesapeake Bay as an integrated ecosystem and pledge our best efforts to achieve the goals in this Agreement. We propose a series of objectives that will establish a policy and institutional framework for continued cooperative efforts to restore and protect Chesapeake Bay. We further commit to specific actions to achieve those objectives. The implementation of these commitments will be reviewed annually and additional commitments developed as needed.

GOALS AND PRIORITY COMMITMENTS

THIS NEW AGREEMENT CONTAINS Goals and Priority Commitments for Living Resources; Water Quality; Population Growth and Development; Public Information, Education and Participation; Public Access; and Governance. ◇ The parties to this 1987 Agreement are the U.S. Environmental Protection Agency representing the Federal government, the District of Columbia, the State of Maryland and the Commonwealths of Pennsylvania and Virginia (hereinafter the "States") and the Chesapeake Bay Commission. This Agreement may be amended and attachments added in the future by unanimous action of the Chesapeake Executive Council.

Appendix H

1987 Chesapeake Bay Agreement

WATER QUALITY

GOAL: *REDUCE AND CONTROL POINT AND NONPOINT SOURCES OF POLLUTION TO ATTAIN THE WATER QUALITY CONDITION NECESSARY TO SUPPORT THE IVING RESOURCES OF THE BAY.* The improvement and maintenance of water quality are the single most critical elements in the overall restoration and protection of the Chesapeake Bay. Water is the medium in which all living resources of the bay live, and their ability to survive and flourish is directly dependent on it. ◇ To ensure the productivity of the living resources of the Bay, we must clearly establish the water quality conditions they require and must then attain and maintain those conditions. Foremost, we must improve or maintain dissolved oxygen concentrations in the Bay and its tributaries through a continued and expanded commitment to the reduction of nutrients from both point and nonpoint sources. We must do the same for toxics and conventional pollutants. To be effective, we will develop basin-wide implementation plans for the control and reduction of pollutants which are based on our best understanding (including that derived from modeling) of the Bay and its tributaries as an integrated system.

OBJECTIVES:

- ◇ Provide timely construction and maintenance of public and private sewerage facilities to assure control of pollutant discharges.
- ◇ Reduce the discharge of untreated or inadequately treated sewage into Bay waters from such sources as combined sewer overflows, leaking sewage systems, and failing septic systems.
- ◇ Evaluate and institute, where appropriate, alternative technologies for point source pollution control, such as biological nutrient removal and land application of effluent to reduce pollution loads in a cost-effective manner.
- ◇ Establish and enforce pollutant limitations to ensure compliance with water quality laws.
- ◇ Reduce the levels of nonpoint sources of pollution.
- ◇ Reduce sedimentation by strengthening enforcement of existing control regulations.
- ◇ Eliminate pollutant discharges from recreational boats.
- ◇ Identify and control toxic discharges to the Bay system, including metals and toxic organics, to protect water quality, aquatic resources and human health through implementation and enforcement of the states' National Pollutant Discharge Elimination System permit programs and other programs.
- ◇ Reduce chlorine discharges in critical finfish and shellfish areas. Minimize water pollution incidents and provide adequate response to pollutant spills.
- ◇ Manage sewage sludge, dredged spoil and hazardous wastes to protect the Bay system.
- ◇ Manage groundwater to protect the water quality of the Bay.
- ◇ Quantify the impacts and identify the sources of atmospheric inputs on the Bay system.

COMMITMENT:

TO ACHIEVE THIS GOAL WE AGREE:

- ◇ by *July 1988*, to develop, adopt and begin implementation of a basin-wide strategy to equitably achieve by the year 2000 at least a 40 percent reduction of nitrogen and phosphorus entering the main stem of the Chesapeake Bay. The strategy should be based on agreed upon 1985 point source loads and on nonpoint loads in an average rainfall year.
- ◇ by *December 1991*, to re-evaluate the 40 percent reduction target based on the results of modeling, research, monitoring and other information available at that time.
- ◇ by *December 1988*, to develop, adopt and begin implementation of a basin-wide strategy to achieve a reduction of toxics consistent with the Water Quality Act of 1987 which will ensure protection of human health and living resources. The strategy will cover both point and nonpoint sources, monitoring protocols, enforcement of pretreatment regulations and methods for dealing with in-place toxic sediments where necessary.
- ◇ by *July 1988*, to develop and adopt, as required by the Water Quality Act of 1987, a basin-wide implementation strategy for the management and control of conventional pollutants entering the Chesapeake Bay system from point and nonpoint sources.
- ◇ by *July 1988*, the Environmental Protection Agency, acting for the federal government, will develop, adopt and begin implementation of a strategy for the control and reduction of point and nonpoint sources of nutrient, toxic and conventional pollution from all federal facilities.

LIVING RESOURCES

GOAL: *PROVIDE FOR THE RESTORATION AND PROTECTION OF THE LIVING RESOURCES, THEIR HABITATS AND ECOLOGICAL RELATIONSHIPS.* The productivity, diversity and abundance of living resources are the best ultimate measures of the Chesapeake Bay's condition. These living resources are the main focus of the restoration and protection effort. Some species of shellfish and finfish are of immense commercial and recreational value to man. Others are valuable because they are part of the vast array of plant and animal life that make up the Chesapeake Bay ecosystem on which all species depend. We recognize that the entire natural system must be healthy and productive. We will determine the essential elements of habitat and environmental quality necessary to support living resources and will see that these conditions are attained and maintained. We will also manage the harvest of and monitor populations of commercially, recreationally and ecologically valuable species to ensure sustained, viable stocks. We recognize that to be successful, these actions must be carried out in an integrated and coordinated manner across the whole Bay system.

OBJECTIVES:

- Restore, enhance, protect and manage submerged aquatic vegetation.
- Protect, enhance and restore wetlands, coastal sand dunes, forest buffers and other shoreline and riverline systems important to water quality and habitat.
- Conserve soil resources and reduce erosion and sedimentation to protect Bay habitat.
- Maintain freshwater flow regimes necessary to sustain estuarine habitats, including, where appropriate, establishing minimum in-stream flows.
- Develop compatible Bay-wide stock assessment programs.
- Develop Bay-wide fisheries management strategies and develop complementary state programs and plans to protect and restore the finfish and shellfish stocks of the Bay, especially the freshwater and estuarine spawners.
- Provide for the restoration of shellfish stocks in the Bay, especially the abundance of commercially important species.
- Restore, enhance and protect waterfowl and wildlife.

COMMITMENT:

TO ACHIEVE THIS GOAL WE AGREE:

- by *January 1988*, to develop and adopt guidelines for the protection of water quality and habitat conditions necessary to support the living resources found in the Chesapeake Bay system, and to use these guidelines in the implementation of water quality and habitat protection programs.
- by *July 1988*, to develop, adopt and begin to implement a Bay-wide plan for the assessment of commercially, recreationally and selected ecologically valuable species.
- by *July 1988*, to adopt a schedule for the development of Bay-wide resource management strategies for commercially, recreationally and selected ecologically valuable species.
- by *July 1989*, to develop, adopt and begin to implement Bay-wide management plans for oysters, blue crabs and American Shad. Plans for other major commercially, recreationally and ecologically valuable species should be initiated by 1990.
- by *December 1988*, to develop a Bay-wide policy for the protection of tidal and non-tidal wetlands.
- Provide for fish passage at dams, and remove stream blockages wherever necessary to restore natural passage for migratory fish.

PUBLIC INFORMATION, EDUCATION AND PARTICIPATION

GOAL: *PROMOTE GREATER UNDERSTANDING AMONG CITIZENS ABOUT THE CHESAPEAKE BAY SYSTEM, THE PROBLEMS FACING IT AND POLICIES AND PROGRAMS DESIGNED TO HELP IT AND TO FOSTER INDIVIDUAL RESPONSIBILITY AND STEWARDSHIP OF THE BAY'S RESOURCES.*

GOAL: *PROVIDE INCREASED OPPORTUNITIES FOR CITIZENS TO PARTICIPATE IN DECISIONS AND PROGRAMS AFFECTING THE BAY.* The understanding and support of the general public and interest groups are essential to sustaining the long-term commitment to the restoration and protection of the Chesapeake Bay system and its living resources. Citizens must have opportunities to learn about that system and associated management policies and programs and must be given opportunities to contribute ideas about how best to manage that natural system.

OBJECTIVES:

Provide timely information on the progress of the restoration program.

- Assure a continuing process of public input and participation in policy decisions affecting the Bay.
- Enhance Bay-oriented education opportunities to increase public awareness and understanding of the Bay system.
- Provide curricula and field experiences for students.
- Promote opportunities to involve citizens directly in Bay restoration efforts.
- Coordinate the production and distribution of Bay information and education materials.

COMMITMENT:

TO ACHIEVE THESE GOALS WE AGREE:

- to conduct coordinated education and information programs to inform the general public, local governments, business, students, community associations and others of their roles, responsibilities and opportunities in the restoration and protection effort, and to promote public involvement in the management and decision-making process.
- to provide for public review and comment on all implementation plans developed pursuant to this agreement.
- by *March 1988*, to develop state and federal communication plans for public information, education and participation, and by *May 1988*, to develop a unified, Bay-wide communication plan.
- to promote Chesapeake Bay restoration efforts by establishing an annual Bay-wide series of Chesapeake Bay Watershed Awareness events, to include a Governor's Cup Fishing Tournament.

PUBLIC ACCESS

GOAL: *PROMOTE INCREASED OPPORTUNITIES FOR PUBLIC APPRECIATION AND ENJOYMENT OF THE BAY AND ITS TRIBUTARIES.* Interest in and commitment to the Chesapeake Bay and its tributaries are greatly affected by personal contact with that natural system. Consequently, improved opportunities for access to the shores and waters of the system are essential if public awareness and support are to be maintained and increased.

OBJECTIVES:

- Improve and maintain access to the Bay including public beaches, parks and forested lands.
- Improve opportunities for recreational and commercial fishing.
- Secure shoreline acreage to maintain open space and provide opportunities for passive recreation.
- Secure necessary acreage to protect unique habitat and environmentally sensitive areas.

COMMITMENT:

TO ACHIEVE THIS GOAL WE AGREE:

- to intensify our efforts to improve and expand public access opportunities being made available by the federal government, the states, and local governments, by developing a strategy, which includes an inventory of current access opportunities by *July 1988*, which targets state and federal actions to secure additional tidal shorefront acres by *December 1990* along the Bay and its tributaries.
- by *December 1988*, to prepare a comprehensive guide to access facilities and the natural resource system for the tidal Chesapeake Bay.

POPULATION GROWTH AND DEVELOPMENT

GOAL: *PLAN FOR AND MANAGE THE ADVERSE ENVIRONMENTAL EFFECTS OF HUMAN POPULATION GROWTH AND LAND DEVELOPMENT IN THE CHESAPEAKE BAY WATERSHED.* There is a clear correlation between population growth and associated development and environmental degradation in the Chesapeake Bay system. Enhancing, or even maintaining, the quality of the Bay while accommodating growth will frequently involve difficult decisions and restrictions and will require continued and enhanced commitment to proper development standards. The states and the federal government will assert the full measure of their authority to mitigate the potential adverse effects of continued growth. ◇ Local jurisdictions have been delegated authority over many decisions regarding growth and development which have both direct and indirect effects on the Chesapeake Bay system and its living resources. The role of local governments in the restoration and protection effort will be given proper recognition and support through state and federal resources. ◇ States will engage in an active partnership with local governments to establish policy guidelines to manage growth and development.

OBJECTIVES:

- ◇ Designate a state-level office responsible for ensuring consistency with this Agreement among the agencies responsible for comprehensive oversight of development activity, including infrastructure planning, capital budgets, land preservation and waste management activities.
- ◇ Provide local governments with financial and technical assistance to continue and expand their management efforts.
- ◇ Consult with local government representatives in the development of Chesapeake Bay restoration and protection plans and programs.
- ◇ Identify and give public recognition to innovative and otherwise noteworthy examples of local government restoration and protection-related programs.
- ◇ Assure that government development projects meet all environmental requirements.
- ◇ Promote, among local, state and federal governments, and the private sector, the use of innovative techniques to avoid and, where necessary, mitigate the adverse impacts of growth.

COMMITMENT:

TO ACHIEVE THIS GOAL WE AGREE:

- ◇ to commission a panel of experts to report, by *December 1988*, on anticipated population growth and land development patterns in the Bay region through the year 2020, the infrastructure requirements necessary to serve growth and development, environmental programs needed to improve Bay resources while accommodating growth, alternative means of managing and directing growth and alternative mechanisms for financing governmental services and environmental controls. The panel of experts will consist of twelve members: three each from Virginia, Maryland and Pennsylvania, and one each from the District of Columbia, Environmental Protection Agency and the Chesapeake Bay Commission.
- ◇ by *January 1989*, to adopt development policies and guidelines designed to reduce adverse impacts on the water quality and living resources of the Bay, including minimum best management practices for development and to cooperatively assist local governments in evaluating land-use and development decisions within their purview, consistent with the policies and guidelines.
- ◇ to evaluate state and federal development projects in light of their potential impacts on the water quality and living resources of the Chesapeake Bay, and design and carry out each state and federal development project so as to serve as a model for the private sector in terms of land-use practices.
- ◇ by *December 1988*, to develop a strategy to provide incentives, technical assistance and guidance to local governments to actively encourage them to incorporate protection of tidal and non-tidal wetlands and fragile natural areas in their land-use planning, water and sewer planning, construction and other growth-related management processes.

BY THIS AGREEMENT, we reaffirm our commitment to restore and protect the ecological integrity, productivity and beneficial uses of the Chesapeake Bay system. We agree to report in *January 1989* on progress made in fulfilling the commitments in this agreement, and to consider at that time additional commitments. The implementation strategies which will be developed pursuant to this agreement will be appended as annexes, and annual reports will include an accounting of progress made on each strategy.

December 15, 1987
(Date)

FOR THE COMMONWEALTH OF VIRGINIA

FOR THE STATE OF MARYLAND

FOR THE COMMONWEALTH OF PENNSYLVANIA

FOR THE UNITED STATES OF AMERICA

FOR THE DISTRICT OF COLUMBIA

FOR THE CHESAPEAKE BAY COMMISSION

ACKNOWLEDGMENTS

[illegible]

GOVERNANCE

GOAL: *SUPPORT AND ENHANCE THE PRESENT COMPREHENSIVE, COOPERATIVE AND COORDINATED APPROACH TOWARD MANAGEMENT OF THE CHESAPEAKE BAY SYSTEM.*

GOAL: *PROVIDE FOR CONTINUITY OF MANAGEMENT EFFORTS AND PERPETUATION OF COMMITMENTS NECESSARY TO ENSURE LONG-TERM RESULTS.*

The cooperation necessary to sustain an effective Chesapeake Bay restoration and protection effort requires a formal working arrangement involving the states and the federal government. That institutional arrangement must allow for and promote voluntary individual actions coordinated within a well-defined context of the individual responsibilities and authorities of each state and the federal government. It must also ensure that actions which require a concerted, Bay-wide approach be addressed in common and without duplication. One of the principal functions of the coordinating institution is to develop strategic plans and oversee their implementation, based on advice from the public, from the scientific community and from user groups. ◇ In addition, the coordinating body must exert leadership to marshal public support, and it must be accountable for progress made under the terms of this agreement. The coordinating body will continue to be called the Chesapeake Executive Council. The Chesapeake Executive Council shall be comprised of the Governors, the Mayor of the District of Columbia, the Administrator of the Environmental Protection Agency and the Chairman of the Chesapeake Bay Commission. The chairmanship of the Council shall rotate annually as determined by the Council. The term of the Chairman shall be one year. The Administrator of the Environmental Protection Agency shall represent the federal government and the Chairman of the Chesapeake Bay Commission shall represent its members.

OBJECTIVES:

- ◇ Continue to demonstrate strong, regional leadership by convening an annual public meeting of the Chesapeake Executive Council.
- ◇ Continue to support the Chesapeake Executive Council and provide for technical and public policy advice by maintaining strong advisory committees.
- ◇ Coordinate Bay management activities and develop and maintain effective mechanisms for accountability.
- ◇ The Chesapeake Bay Liaison Office shall provide staff support to the Chesapeake Executive Council by providing analyses and data management, and by generating reports related to the overall program. The Implementation Committee shall provide guidance to the CBLO Director in all matters relating to support for the Council and their supporting committees, subcommittees and work groups including the development of all plans and other documents associated with the Council.
- ◇ Examine the feasibility of joint funding support of the Chesapeake Bay Liaison Office.
- ◇ Track and evaluate activities which may affect estuarine water quality and resources and report at least annually.
- ◇ Develop and maintain a coordinated Chesapeake Bay data management system.
- ◇ Continue to implement a coordinated Bay-wide monitoring system and to develop a Bay-wide living resources monitoring system.
- ◇ Develop and implement a coordinated Bay-wide research program.

COMMITMENT:

TO ACHIEVE THESE GOALS WE AGREE:

- ◇ to develop an annual Chesapeake Bay work plan endorsed by the Chesapeake Executive Council.
- ◇ to continue to support Bay-wide environmental monitoring and research to provide the technical and scientific information necessary to support management decisions.
- ◇ to strengthen the Chesapeake Bay Liaison Office by assigning, as appropriate, staff persons from each jurisdiction and from participating federal agencies to assist with the technical support functions of that office.
- ◇ by *July 1988*, to develop and adopt a comprehensive research plan to be evaluated and updated annually to address the technical needs of the Chesapeake Bay Program.
- ◇ by *July 1988*, develop a Bay-wide monitoring plan for selected commercially, recreationally and ecologically valuable species.
- ◇ by *March 1988*, to establish a local government advisory committee to the Chesapeake Executive Council and charge that committee to develop a strategy for local government participation in the Bay program.
- ◇ to consider and review the feasibility of establishing an independent Chesapeake Bay Executive Board.
- ◇ by *July 1988*, the Environmental Protection Agency, acting for the federal government, will develop, a coordinated federal agency workplan which identifies specific federal programs to be integrated into a coordinated federal effort to support the restoration of the Chesapeake Bay.

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
Office of Water Resource Management
Water Quality Assessment and Planning

Peter W. Schmidt
Director

P. O. Box 10009
Richmond, Virginia 23240-0009
(804) 762-4000

Friday, April 21, 1995

Commonwealth of Virginia
Attn.: Mr. L. Alan Weaver
Department of Game and Inland Fisheries
12108 Washington Highway
Ashland, Virginia 23005

Dear Mr. Weaver:

Thank you very much for providing the completed laboratory data for your Embrey Dam Sediment Study. The data are generally low or less than the detection limit and are summarized below by **organic** Target Analytes (TALs) and by **inorganic** TALs constituents.

ORGANIC COMPOUNDS

The organic TALs including BTEX, TCLP, Total Organic Halogens and Total Petroleum Hydrocarbons were below the method detection limit in most cases and are summarized as follows:

	BTEX	VOLATILES	SEMI VOLATILES	PESTICIDES & HERBICIDES	TOX	TPH
TOTAL NUMBER OF MEASUREMENTS	24	198	216	162	18	18
NUMBER OF DETECTS	0	0	0	2	1	7

The two detects in the Toxicity Characteristic Leaching Procedure (TCLP) fractions for pesticides and herbicides were for 2,4-D at very low concentrations and are not considered significant. The one detect for TOX and seven for TPH are at low concentrations and probably represent background levels.

Appendix I

VDGIF and VDEQ Sediment Characterization Report

breaching the dam. Prior to any action to remove any part of the dam please contact the Department for assistance and guidance with the appropriate regulatory requirements.

Alan, I want to thank you very much for your hard work and perseverance in completing this portion of your very large project. If I can be of any further assistance to you please contract me directly at 804.762.4449.

Very truly yours,

R E STEWART

R.E. Stewart II
Environmental Program Planner
rstewart@freenet.vcu.edu

attachments

cc: Cynthia Sale NRO
Glenn Moore WRM
Chester Bigelow OWRM

INORGANIC COMPOUNDS

The inorganic TALs including Total and TCLP metals were below the method detection limit in most cases and are summarized in the attached tables. After review of the raw data and comparison with existing metals sediment data, two inferences can be made regarding the potential of the sediment to contain significant concentrations of TALs.

1) Data from sites located upstream from the dam were retrieved from the National EPA Water Quality database STORET and compared to the study data. The comparison was made between total concentrations because no historic TCLP data was found. The average concentrations of the study data were lower than the STORET data for all TALs. The mean Arsenic and Mercury concentrations for the study data are within two standard deviations of the STORET data. The mean Cadmium and Chromium concentrations for the study data are within one standard deviations of the STORET data. The study data and STORET data are similar.

2) Total and TCLP data for metals were compared to the Regulatory Thresholds (RT) listed in the Virginia Hazardous Waste Management Regulations, VR 672-20-10, *effective September 8, 1993*. For all observations the total concentrations were less than a factor of 20 of the RT. The factor of 20 is applied to samples which are considered 100% solid, as these sediment samples would be, to determine the potential maximum leaching concentration. In theory we postulate that all of the metal in these samples leached into the extract prepared during the TCLP analysis resulting in a TCLP concentration below the RT. Additionally the actual TCLP concentrations are below the RT and the mean of each TAL is more than two standard deviations less than the RT.

N.B. These specific STORET sites were selected for comparison to the study sites because they were located in the same basin upstream of the study site and they contained the same study data parameters. STORET contains no detailed information on site history including information on site selection. Consequently the data analysis maybe influenced by unknown site specific conditions.

In conclusion the sediment study data indicates that the characteristics of the sediments retained by the Embrey Dam are comparable to other sediments upstream and that the potential for these sediments to fail a hazardous waste characteristic as defined in VR 672-20-10 is minimal.

The Department may be concerned with water quality degradation associated with a sudden and substantial release of sediment into the water column which could occur from

RAPPAHANOCK SEDIMENT STUDY
STORET PARAMETERS FOR SITES ON RAPPAHANNOCK

otal concentrations, mg/Kg

Station	Arsenic	Cadmium	Chromium	Mercury
3-RAP006.53	6.30	0.16	25.10	0.600
	9.40	0.20	23.00	0.270
	1.70	0.17	15.10	0.100
	4.00	0.20	18.00	0.230
	26.00	0.70	29.80	0.120
	11.70	0.20	31.20	0.180
	14.50	0.26	31.10	0.200
	10.00	4.00	28.00	0.500
	4.00	1.00	28.00	0.500
3-RAP030.21	7.80	0.16	30.00	0.060
	9.60	0.20	19.40	0.200
	2.80	0.10	14.60	0.130
	15.00	0.24	64.00	0.100
	3.90	0.20	16.00	0.170
	24.00	0.70	22.10	0.100
	9.70	0.20	16.70	0.120
	5.70	0.19	19.80	0.090
3-RAP045.08	3.00	1.00	23.00	0.500
3-RAP066.54	5.00	5.00	10.00	0.300
3-RAP077.28	2.00	1.00	16.00	0.500
mean concentration	8.76	0.79	23.90	0.25

EMBREY DAM SEDIMENT STUDY
VIRGINIA DEPARTMENT OF GAME AND INLAND FISHERIES

Total concentrations, mg/Kg

Site ID	Arsenic	Cadmium	Chromium	Mercury
C-1-B	0.46	0.11	22.16	0.130
C-1-M	1.22	0.20	22.90	0.020
C-1-T	0.61	0.67	5.97	0.048
C-2-B	0.48	0.05	8.89	0.020
C-2-M	0.30	0.06	3.69	0.140
C-2-T	0.33	0.14	5.30	0.020
C-3-B	0.85	0.09	21.10	0.091
C-3-M	0.93	0.10	23.70	0.088
C-3-T	0.79	0.09	17.30	0.020
C-4-B	1.26	0.09	10.54	0.020
C-4-M	0.20	0.05	1.38	0.020
C-4-T	0.45	0.08	3.80	0.020
C-5-B	0.62	0.05	23.50	0.110
C-5-M	0.52	0.04	7.25	0.030
C-5-T	0.20	1.00	1.00	0.020
C-6-B	0.28	0.07	6.14	0.020
C-6-M	0.41	0.05	5.73	0.020
C-6-T	0.50	0.05	5.52	0.020
mean concentration	0.58	0.17	10.90	0.05
THEORETICAL MINIMUM CONCENTRATION THAT WOULD EXCEED TCLP REGULATORY THRESHOLD	100.00	20.00	100.00	4.00

EMBRY DAM CORE DESCRIPTIONS

Core #1 84 inches long Site 42

C-1-B 0-12 inches Leafy, mulch, very organic, twigs, very silty, amorphous grey, black, brown.

C-1-M 12-28 inches Very silty, sandy, clay mixed with gravel, Brown tan white mixed grain, sites unconsolidated.

C-1-T 28-84 inches Grey, black, brown, tan, unconsolidated, very fine grained to gravel.

Core #2 64 inches long Site 18

C-2-B 0-4 inches Grey-brown, amorphous clay, very silty.

C-2-M 4-20 inches Very fine grained, grey to tan to coarse grained sand, unconsolidated.

C-2-T 20-64 inches Coarse grained to gravel, unconsolidated.

Core #3 76 inches long Site 77

C-3-B 0-24 inches Grey-tan, amorphous clay wet, very silty, very fine grain sand, slightly organic, some leafs, twigs.

C-3-M 24-56 inches Very sandy, highly organic, leafy, mat type compaction. Not much degredation.

C-3-T 56-78 inches Organic, leafs, twigs, silty, fine grained sand, grading towards course grained sand, very consolidated.

Core #4 48 inches long Site 94

C-4-B 0-10 inches Highly organic, leafy twigs, very silty, highly compacted, very fine gravel sand, slightly amorphous well bound together.

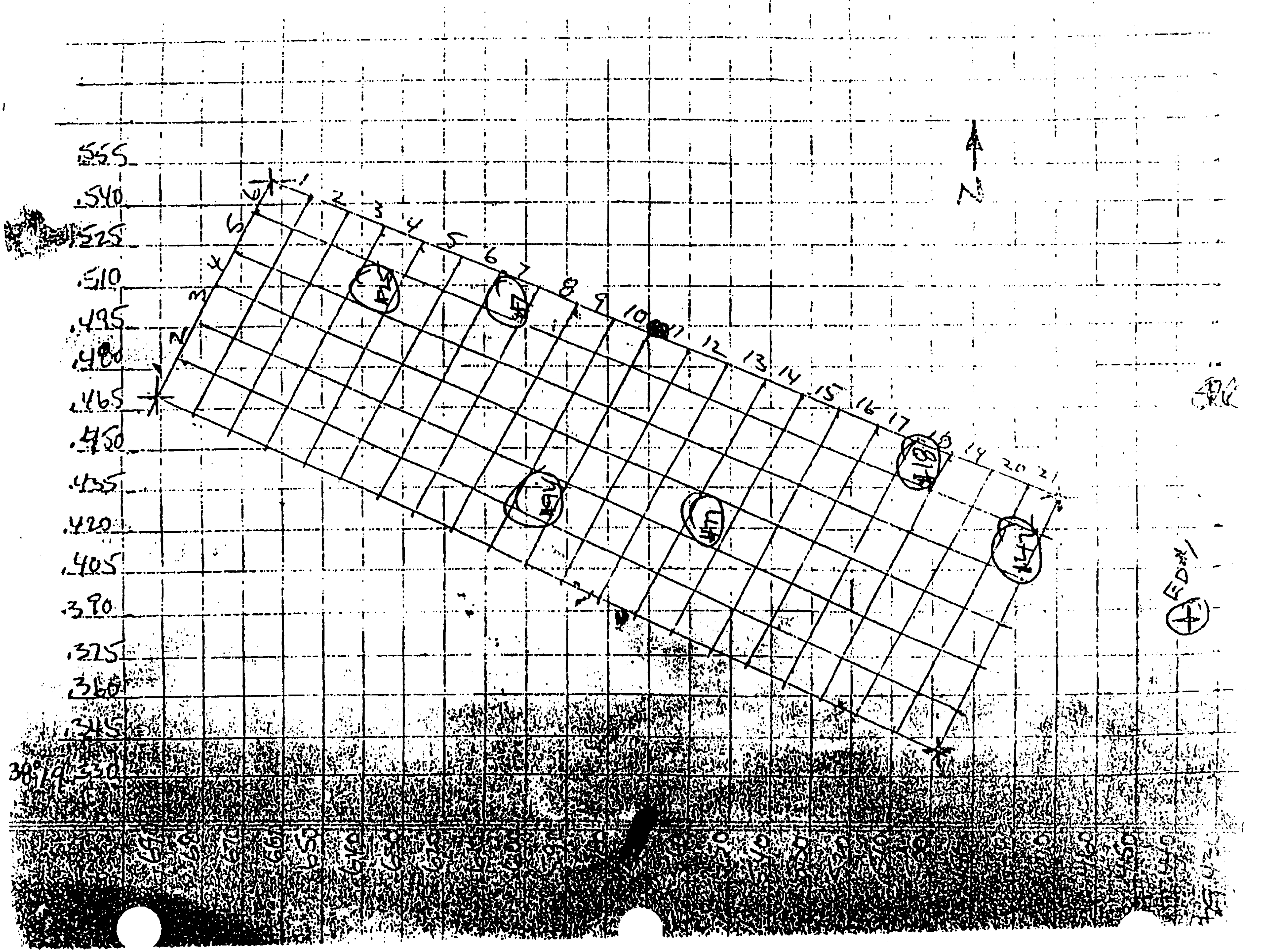
C-4-M 10-36 inches Very silty, very fine grained sand quartzite, micatious, unconsolidated.

C-4-T 36-28 inches Very fine grained sand, grading towards gravel. Full spectrum of grain size.

EMBREY DAM SEDIMENT STUDY
VIRGINIA DEPARTMENT OF GAME AND INLAND FISHERIES

TCLP concentrations, mg/L

Site ID	Barium	Chromium	Lead	Mercury
C-1-B	0.80	0.10	0.50	0.0002
C-1-M	0.63	0.10	0.50	0.0003
C-1-T	0.57	0.10	0.50	0.0002
C-2-B	0.29	0.10	0.50	0.0004
C-2-M	0.41	0.10	0.54	0.0002
C-2-T	0.30	0.16	0.50	0.0002
C-3-B	0.86	0.10	0.50	0.0002
C-3-M	0.88	0.10	0.50	0.0002
C-3-T	0.60	0.10	0.50	0.0002
C-4-B	0.74	0.10	0.50	0.0002
C-4-M	0.26	0.10	0.50	0.0002
C-4-T	0.35	0.10	0.50	0.0016
C-5-B	0.77	0.10	0.50	0.0002
C-5-M	0.35	0.10	0.50	0.0002
C-5-T	0.43	0.10	0.50	0.0033
C-6-B	0.34	0.10	0.50	0.0002
C-6-M	0.41	0.10	0.50	0.0002
C-6-T	0.25	0.10	0.50	0.0002
mean concentration	0.50	0.10	0.54	0.0005
REGULATORY LEVEL	100.00	5.00	5.00	0.2000



.555
.540
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3879330
N

Core #5 45 inches long Site 7

C-5-B 0-6 inches Very silty, slightly organic, amorphous clay, very fine grained sand.

C-5-M 6-24 inches Rubble, very sandy to gravel. Gravel grades into fine grained sand at top.

C-5-T 24-45 inches Very silty, amorphous very tight compaction with organic grading towards gravel at top.

Core #6 40 inches long

C-6-B 0-16 inches Very organic, silty, amorphous, very fine grained, sandy grading towards course gravel.

C-6-M 16-28 inches Very fine gravel sand grading towards course grained.

C-6-T 28-40 inches Course grained sand grading toward gravel at top.