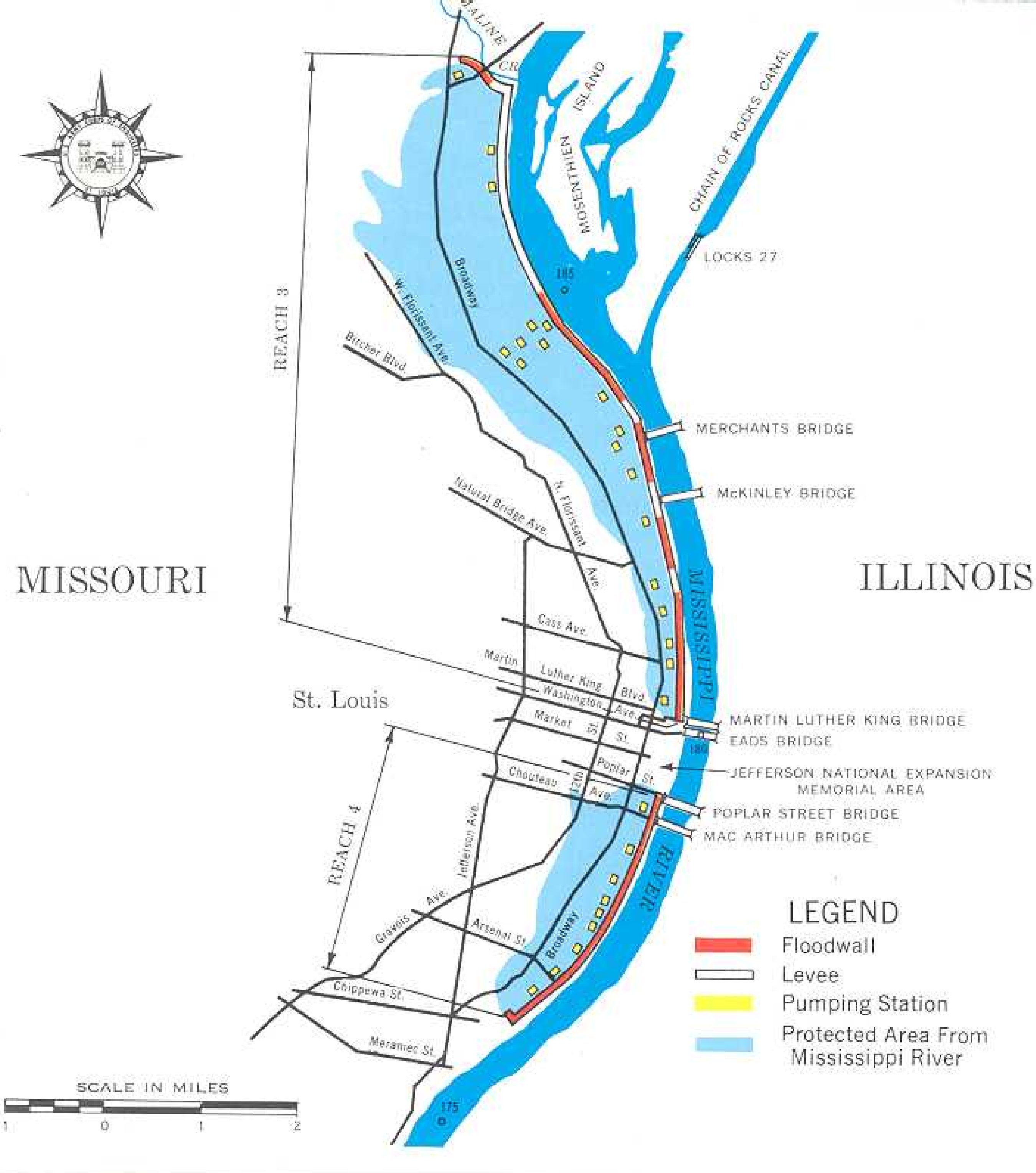
ST. LOUIS FLOOD PROTECTION SYSTEM, MISSOURI

RECONSTRUCTION EVALUATION REPORT

DRAFT

US Army Corps of Engineers
St. Louis District®

September 2004



SALINE CR.
MOSENTHIEN ISLAND
CHAIN OF ROCKS CANAL
LOCKS 27
185
REACH 3
Broadway
W. Florissant Ave.
Bircher Blvd.
MERCHANTS BRIDGE
McKINLEY BRIDGE
Natural Bridge Ave.
N. Florissant Ave.
MISSOURI
ILLINOIS
MISSISSIPPI
RIVER
Cass Ave.
Martin Luther King Blvd.
Washington Ave.
St. Louis
Market St.
12th St.
MARTIN LUTHER KING BRIDGE
EADS BRIDGE
180
Poplar St.
JEFFERSON NATIONAL EXPANSION MEMORIAL AREA
Chouteau Ave.
POPLAR STREET BRIDGE
MAC ARTHUR BRIDGE
REACH 4
Jefferson Ave.
Gravois Ave.
Arsenal St.
Broadway
Chippewa St.
Meramec St.
175
LEGEND
Floodwall
Levee
Pumping Station
Protected Area From Mississippi River
SCALE IN MILES
1 0 1 2

EXECUTIVE SUMMARY

St. Louis Flood Protection System, Missouri – Reconstruction Evaluation Report With Environmental Assessment September 2004

The Great Flood of 1993, which overtopped and breached levees along the Mississippi River and its tributaries causing widespread damage to farms and communities, sparked national concern about the reliability of many flood control systems in the region.

In 2000, the St. Louis District of the Army Corps of Engineers and the City of St. Louis entered into an agreement to share the cost of conducting a study that would analyze the condition of the flood protection system to determine what, if any, actions were needed to ensure that it functioned properly. If parts of the system were determined to be deficient, the analysis would proceed with examining the cause of the deficiency.

The draft Reconstruction Evaluation Report With Environmental Assessment and Finding of No Significant Impacts (RER/EA) presents the results of a comprehensive analysis to determine the feasibility and extent of federal interest in cost-sharing design deficiency corrections for the existing St. Louis Flood Protection System. In addition to the No Action Plan, the MVS study team analyzed four other plan alternatives, all of which included installing additional relief wells to better manage underseepage, and a one-time treatment of existing relief wells. The four alternatives differ in how to manage the risk of closure structure failure. Closure structures that are not needed any longer can have the gates removed and the opening permanently sealed. Other closure structures can either be replaced or reskinned. Alternative 1A included the replacement of the 16 most degraded closure structures and permanent closure of three closure structures. Alternative 1B included the reskinning of the 16 most degraded closure structures and permanent closure of three closure structures. Alternative 2A included the replacement of 20 closure structures and the permanent closure of 16 closure structures. Alternative 2B included the reskinning of 20 closure structures and the permanent closure of 16 closure structures

Plan 2A generates the highest average annual net benefits ($4,562,981) and is identified as the NED Plan. Plan 2A is also the Recommended Plan for this proposed project. The estimated total project cost is $11,774,200. The average annual benefits of the Recommended Plan are $5,645,981 and the estimated annualized construction cost of $1,083,000. Plan 2A has a favorable benefit-to-cost ratio (BCR) of 5.21 to 1.0.

Since Plan 2A construction work is in or immediately adjacent to the flood protection project, which itself is in an industrialized area, environmental impacts are estimated to be only one-tenth of one acre of bottomland hardwoods. In-kind mitigation will occur to offset this loss.

The public, the Corps of Engineers Mississippi Valley Division (MVD) and Headquarters (HQUSACE) offices, as well as local, state and federal government agencies will review this draft concurrently. Their comments will be considered before issuing a final reconstruction evaluation report with integrated Environmental Assessment. HQUSACE will conduct its policy review of the final RER/EA concurrently with state and agency review. After state/agency review and final policy compliance certification by HQUSACE, the RER/EA and recommendation package will be submitted to the Chief of Engineers for signature. Subsequently, the Chief of Engineer's report, and final RER/EA will be transmitted to the Assistant Secretary of the Army for Civil Works for final approval.

Pending appropriation of funds, MVS will negotiate and execute agreements with the non-Federal sponsor, the city of St. Louis, to cost-share (65 percent Federal and 35 percent non-Federal) the construction of the deficiency corrections. The sponsor will be responsible for acquiring all lands, easements, rights-of-way, relocations and disposal sites (LERRDS) for the project and would be eligible to receive credit for any compatible work against the authorized Federal plan.

ST. LOUIS FLOOD PROTECTION
RECONSTRUCTION EVALUATION REPORT
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SEPTEMBER 2004

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1. STUDY AUTHORITY

AUTHORIZATION: The original St. Louis Flood Protection authorization for construction is Public Law 84-256, 9 August 1955. This study is authorized under Section 216, Flood Control Act of 1970, Public Law 91-611, which states:

> The Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operation of projects the construction of which has been completed and which were constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures or their operation, and for improving the quality of the environment in the overall public interest.

2. STUDY PURPOSE AND SCOPE

This is the final response to the study authority as it pertains to the St. Louis, Missouri, Flood Protection Project. The purpose of this study is to evaluate the federal interest in addressing the significant potential problems in the City of St. Louis Flood Protection System. Federal participation is allowed to address design deficiencies, which is the primary emphasis of this report, or to examine the need for reconstruction due to advanced age. Engineer Circular 11-2-183, dated 31 March 2002 provides that:

> "Older projects that are properly operated and maintained by non-Federal sponsors but are no longer performing satisfactorily primarily due to their advanced age may be considered for reconstruction. The proposed work will insure that the project continues to deliver the full benefits intended by Congress at the time of authorization; will not expand or change the authorized scope, function, or purpose of the project, and is not operation and maintenance typically associated with project or corrective work required due to improper maintenance on the part of the non-Federal sponsor."

As a function of this investigation current engineering standards were utilized, original design intent was compared to existing conditions, and problems identified were categorized as advanced age, design deficiency or non-Federal maintenance responsibility. Early in the planning process it was recognized that although some project components are nearing their design life, no problems were identified that were related strictly to advanced age. An investigation of project operation and maintenance requirements has been made to assign responsibilities in order to recommend cost sharing requirements. Many of the problems were identified during the Flood of 1993, which was the first major test of the completed system. Such items included the failure of a section of the floodwall and numerous sand boils. This study also has the related purpose of evaluating a federal interest in recreation as part of a greenway on or adjacent to the flood protection system. A greenway is a natural corridor set aside for the benefit of the environment. Greenways often include hiking and biking trails for the public benefit, as well as educational and interpretive media. Potential solutions include correcting deficient items in the flood protection system, particularly with regard to underseepage controls and closure structures; and participating in a collaborative effort to improve recreational features along the flood protection system as part of a regional greenway initiative. The scope of this study does not include evaluating the feasibility of expanding the geographic area that is provided flood protection. The non-Federal sponsor for this study is the City of St. Louis, Missouri. The Metropolitan St. Louis Sewer District is responsible for internal stormwater related features, including pump stations. They chose not to be a sponsor for this study.

3. PRIOR STUDIES, REPORTS AND EXISTING WATER PROJECTS

3.1 *Flood Protection for City of St. Louis, Missouri and Vicinity*, June 1953 (CEMVS). This is the original report for the project, in which flood protection was based on the historic 1844 flood estimated at one time to be 1,300,000 cubic feet per second peak discharge.

3.2 Periodic Inspection Reports. St. Louis District has conducted periodic inspections and published findings in reports from 1973 to 2003. Volume I, published in April 1973, concluded there were design deficiencies related to closure structures. Other volumes have been produced in 1976, 1981, 1988, 1992, 1996, 1999, and 2003.

3.3 *Risk Assessment Research Program, Work Unit on Local Protection Project Performance, Function, and Workability: Final Report for City of St. Louis, Missouri, Flood Protection Project* (CEMVS-ED-HE, Dyhouse, 1994). This report presented an analysis of the level of protection provided by the St. Louis Flood Protection Project and its performance in 1993. As originally designed, the St. Louis Flood Protection System protected against a 200-year or 0.005 probability event. This was based on protecting against the estimated flow volume of the record flood of 1844, estimated to be 1,300,000 cubic feet per second, or 52 feet on the St. Louis gage.

3.4 Existing St. Louis Flood Protection Project. Project construction began in 1959 and was completed in 1974. The existing St. Louis Flood Protection System is an 11-mile-long combination of 35,614 feet of flood walls, 20,700 feet of levees, 28 pump stations, 33 road and railroad closure structures, gravity drains, and pressure sewer emergency closure gatewells. The system protects two reaches, just north and south of the St. Louis downtown central business district, separated by high ground. Reach 3, north of downtown, extends from river mile 180.2 to 187.2. It protects 2,530 acres subject to flooding. Reach 4, just south of downtown, extends from river mile 176.3 to 179.3. It protects 630 acres subject to flooding.

4. PLAN FORMULATION
4.1. Problems and Opportunities
4.1.1. Existing Conditions

The existing St. Louis Flood Protection System, shown in Figure 4-1 is an 11-mile combination of 35,614 feet of flood walls, 20,700 feet of levees, 28 pump stations, underseepage control measures, street and railroad closure structures, gravity drains, subdrains, and pressure sewer emergency closure gatewells. The project provides protection for 3,160 acres against a 52-foot Mississippi River stage on the St. Louis Gage, an estimated stage of the greatest flood of record at the time of design, the flood of 1844. Based on the draft results of the Flow Frequency Study for the Mississippi River, this stage has a current expected frequency of approximately 500 years. Flood stage is 30 feet on the St. Louis Gage. The system protects two overwhelmingly commercial and industrial reaches, just north and south of downtown St. Louis, separated by high ground.

Figure 4-1: Existing St. Louis Flood Protection System

Typical land use is shown in Figures 3 and 4.

Figure 4-2: Typical Land Use in Reach 3

Figure 4-3: Typical Land Use in Reach 4

Reach 3, north of downtown, extends from Mile 180.2 to 187.2. It protects 2,530 acres subject to flooding. Reach 4, just south of downtown, extends from Mile 176.3 - 179.3. It protects 630 acres subject to flooding. Construction of Reach 3 began in March 1959. Construction of Reach 4 began in August 1963. The project was dedicated in 1974. The original project study evaluated 5 reaches separated from each other by high ground but only reaches 3 and 4 were ever constructed. Original project costs of $79,505,200 included $1,832,500 non-Federal contribution. Project components are 29 to 44 years old.

The City of St. Louis operates and maintains the flood protection system except for the pump stations and associated stormwater management, which is the responsibility of the Metropolitan St. Louis Sewer District (MSD). Operation and maintenance guidance provided by Title 33, Part 208.10 - Flood Control Regulations, Maintenance and Operation of Flood Control Works has been complied with and the system has remained eligible for PL84-99 assistance when needed. The City of St. Louis received $125,300 PL 84-99 assistance in 1981, $700 and 1982, and $1,448,000 in 1993.

Annual Inspection records dating back to 1985 show that the City of St. Louis has received an Acceptable rating for 18 years. A minimum acceptable rating was received 11 times but corrective measures were taken to fix identified maintenance items. The last three inspections have all rated maintenance as Acceptable, the highest possible category.

Gatewells. Monsanto is the owner of an unused gatewell and 36" diameter sewer (Reach 4, Station 62+40. The City of St. Louis must work with the owner to plan and execute the removal of the gatewell and sealing of the sewer. There is an unused 42" diameter pipe and gatewell (Reach 3, Station 357+78) that was for the now demolished Ameren UE Mound plant. The City of St. Louis must work in conjunction with the owner to permanently seal the pipe.

Closure Structures. Even though the project was dedicated in 1974, the first periodic inspection was in April 1973, coincident with a flood 13.3 feet above flood stage. That report noted that the closure structures already had rust problems. For example, the report notes "a. Structural Defect. The Branch Street closure structure, C-7 (Sta. 301+42), Reach 3, has a number of badly rusted vertical structural members. It could affect the stability of the closure if not repaired." The same report lists nine other gates that have rusting problems in need of sandblasting and repainting. Unfortunately the swing gates throughout the system are constructed of corrugated metal that have areas that cannot be sandblasted or repainted because they are inaccessible. Although the Corps designed a repair for the defective closure structure, the City of St. Louis performed the repair at their expense, even though it was clearly a Corps design failure.

All of the closure structures in the St. Louis Flood Protection system are operational. However, the City of St. Louis keeps many of them closed for lack of need. There are 40 closure structures. Seven are panel type closures, where panels are bolted in place when needed and stored nearby in a shed when not needed. During June of 2001, river levels necessitated the erection of panel closures C-18 and C-19. Inspection revealed these two structures to be in good condition. Some seals need replacement. The other panel structures were not inspected. Access to panel closures is only accomplished with assistance from the City due to the large concrete blocks that lock the shed doors. It is assumed that they are also in good condition due to their protected storage in the sheds. There are 33 swinging gate closures. Of the 33 swinging gate closure structures sixteen are severely degraded, and need immediate attention. The 17 other swing gates also have rusting problems to varying degrees of severity.

Pump Stations. The 28 pump stations are operated and maintained by the Metropolitan St. Louis Sewer District (MSD). MSD is not a cost-sharing partner for this study and therefore the pump stations have not been examined for purposes of reconstruction or design deficiency concerns. All periodic inspections have found the pump stations to be operating acceptably.

Underseepage. The Mississippi River floodplain where the St. Louis Flood Protection System is located is typical in its subsurface profile. Levees extend out toward the riverfront from the bluff tie-ins on the upstream and downstream ends. The northern flank parallels Maline Creek, which flows into the Mississippi River. Deposits of clays and silts makeup the majority of the foundation for the levee and floodwall along the northern flank. As the bedrock surface drops into the ancient bedrock valley, the thick, 50 to 100 feet, sand deposits become prominent with top strata of silt, clay with some cinder fills. The thick sand deposits are exposed in the Mississippi River channel and serves as the region's alluvial aquifer. The alluvial aquifer groundwater levels reflect the river levels with some attenuation.

During high floods, water flows into the sand aquifer that is located beneath the floodplain that is protected by the levees and floodwalls. As the water flows between moderately dense alluvial sand grains, the water pressure decreases the further it is away from the seepage source, the Mississippi River. The hydrostatic pressure acts as an upward pressure force commonly referred to as uplift. The hydrostatic pressure decreases linearly as the distance to the seepage source increases. Levees and floodwalls that are close to the seepage source will have a high hydrostatic pressure beneath them. The floodplain's top strata is not as permeable as sand and offers some resistance to flow and provides static weight that is the downward force. The relationship between uplift force divided by the downward force is commonly referred to as uplift gradient. Hydrostatic uplift pressures are dependent on the flood height, aquifer thickness, aquifer permeability, and distance from the seepage source. The uplift gradient is dependent on the hydrostatic uplift pressure (force) at a particular location divided by the downward force exerted by the weight of the top strata. If the uplift gradient exceeds 0.5, seepage berms are designed and constructed to provide more weight and downward force to counteract the uplift forces. If seepage berms are not economically feasible, relief wells can be installed into the aquifer along the levee and floodwall to provide pressure release and relief by allowing the water to flow out of the aquifer. The pressure reduction in the aquifer is localized and that is the reason for a series of relief wells in a reach instead of just one. Areas that experience high hydrostatic pressure and do not have underseepage controls like seepage berms or relief wells, are likely to exhibit ground instability referred to as quick conditions (quick sand), sand boils, and/or foundation blowouts. In areas of high hydrostatic pressure, sand boils are natural groundwater flows (pressure release) exiting the ground surface carrying foundation materials to the ground surface. Cone like deposits of silt and sand are deposited adjacent to the natural groundwater conduit. Uncontrolled seepage forces can carry a tremendous amount of foundation material and undermine the levee or floodwall structure within hours of initiation. Figures 4-4 through 4-8 show the conditions that cause underseepage in flood protection projects.

Figure 4-4: Typical Stratigraphy and Hydrogeology of Normal River

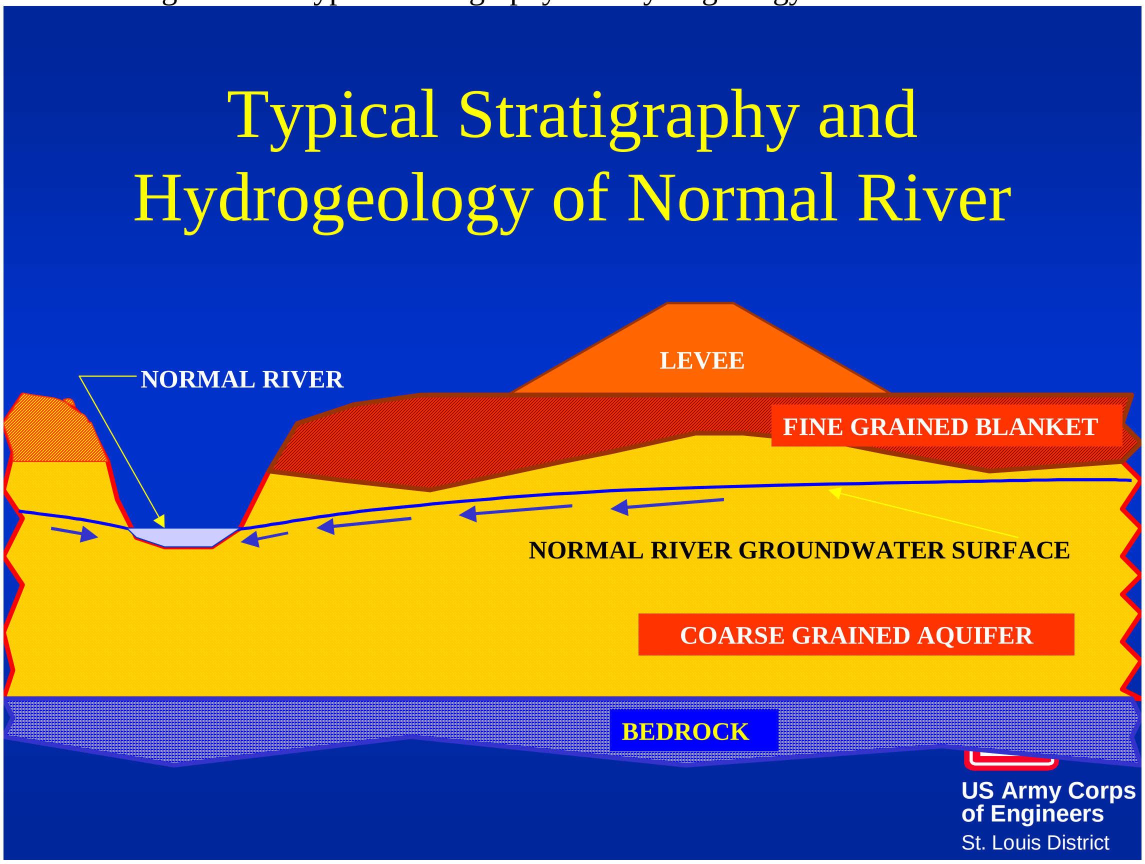


Figure 4-5: Typical Stratigraphy and Hydrogeology of a Rising River

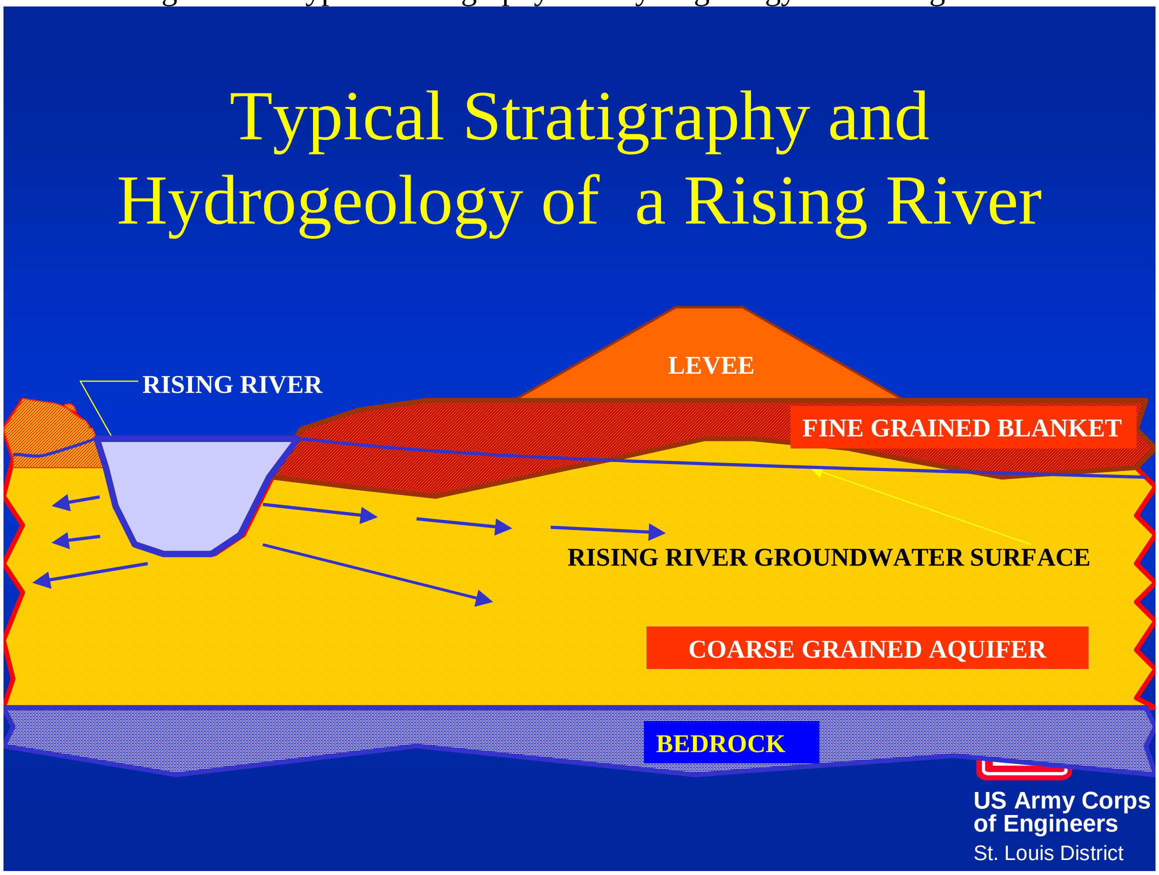


Figure 4-6: Impacts on Groundwater With Rising River

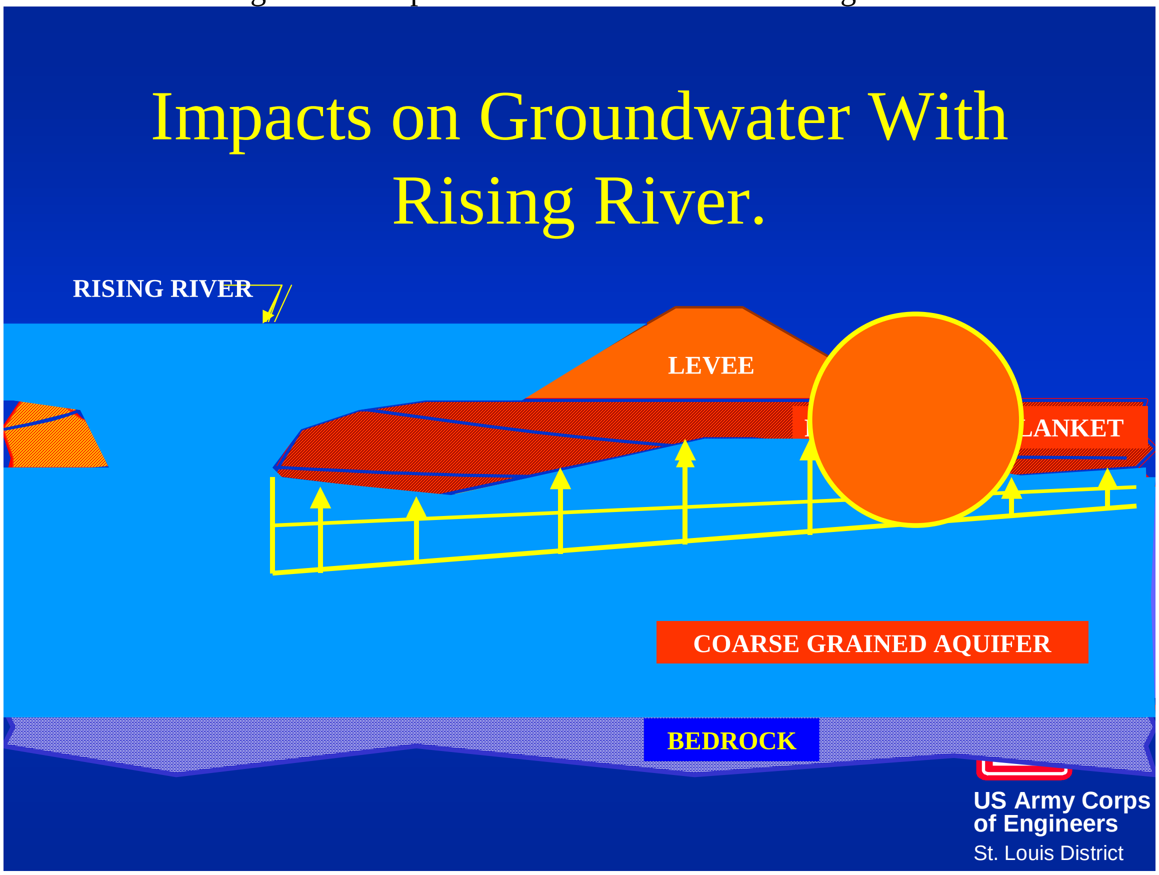


Figure 4-7: Piping in the Aquifer

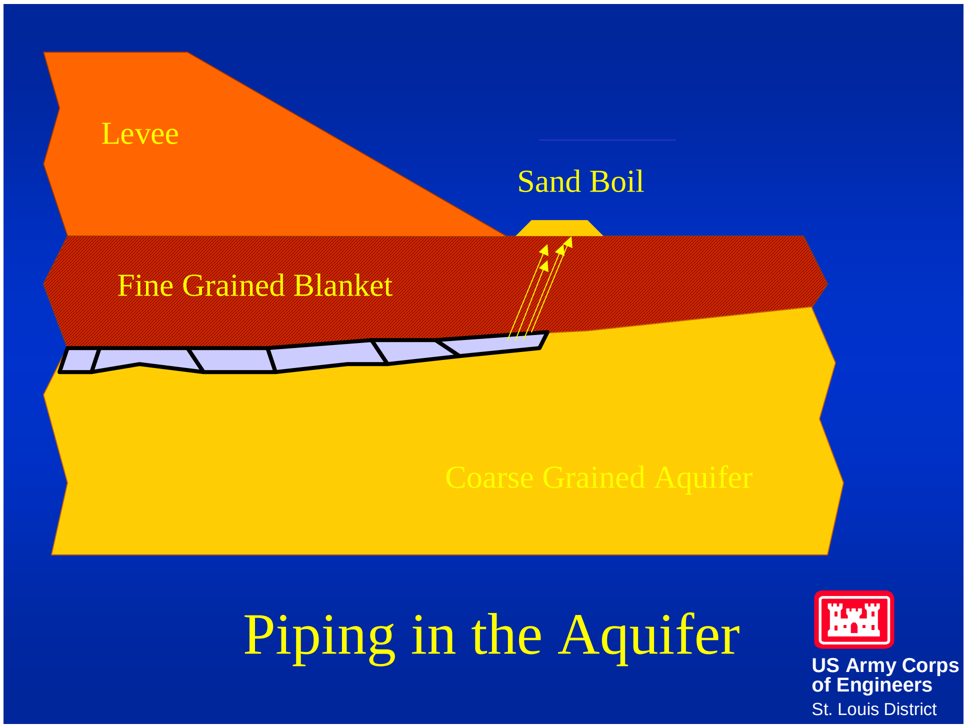
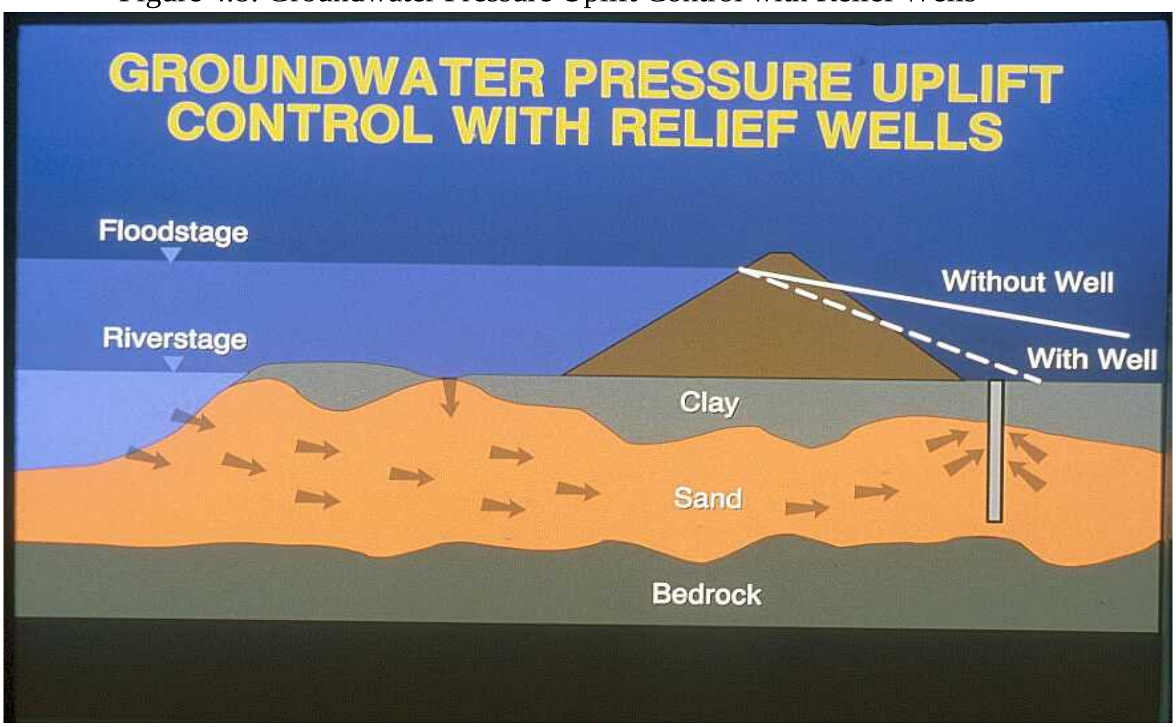


Figure 4.8: Groundwater Pressure Uplift Control with Relief Wells



During the flood of 1993, the St. Louis Flood Protection System's current flood of record, portions of the levee experienced unexpected seepage problems that had to be handled on an emergency basis. As the Mississippi River approached 49.58 feet on the St. Louis Gage on August 1, 1993, the 175-year flood level (below the design flood that today is approximately 500-year), sandboils appeared at many locations along the interior of the levee. A severe underseepage floodwall foundation blow out occurred immediately east of Riverview Boulevard. On July 22, 1993, a geyser was observed to be 4 feet high and 18 inches in diameter of seepage water and foundation material that was gushing up from underneath the floodwall monolith on the landside of the floodwall. The top of the floodwall monolith rotated riverward approximately three inches due to the loss of supporting foundation material below the floodwall. With the floodwall monolith in imminent danger of collapse from loss of foundation materials eroded away by the uncontrolled seepage, extraordinary emergency flood fight measures were required to prevent disastrous flooding of the protected area. Hundreds of tons of crushed stone were rushed to the failing floodwall monoliths and dumped over the geyser, which slowed down the flows. A crushed stone ring levee was constructed behind the failed floodwall. A reported 111 cubic yards of grout was pumped into the voids below the floodwall to stabilize it. The ensuing months after the Flood of 1993, four floodwall monoliths were demolished, the foundation replaced with a compacted clay backfill and a sheet pile cutoff wall to bedrock that completely blocks underseepage flows at this location, and the floodwall monoliths reconstructed. The quick thinking flood fight teams saved the city of St. Louis from a catastrophic breach and immediate inundation. The flood of 1993 showed that the city of St. Louis Flood Control Project has a design deficiency related to underseepage, and most likely will not function safely with floods of the design level of 52.0 feet on the St. Louis Gage because of the inadequate underseepage control features.

During the 1993 flood, when the Mississippi River was more than five feet below the design flood elevation, sandboils appeared at many locations along the interior of the levee. On July 22, 1993, a floodwall monolith failed as previously discussed due to underseepage when the Mississippi River reached 46.9 feet on the St. Louis Gage, 5.1 feet below the design flood of 52.0 feet on the St. Louis Gage. The flood of 1993 showed that the project has a design deficiency related to levee and floodwall underseepage along numerous reaches along the flood protection system, and will not function as intended because of inadequate underseepage control features.

Figure 4-9: Uncontrolled seepage gushing from under floodwall in 1993 flood

A short video of this event can be seen by going online to
http://www.mvs.usace.army.mil/pm/Project Menu/St. Louis Flood Protection/default.htm
and clicking on “Floodwall1993.mpg”

Figure 4-10 – Crushed stone and sandbags control seepage from under floodwall.

Figure 4-11 – Top of Floodwall Rotated Approximately 3 Inches Riverward.

Relief Wells. There are 110 relief wells that were originally installed in the 1950's and 1960's. The existing wells are constructed of wooden stave riser pipes and screen sections. Studies have shown that there are reductions in well efficiencies that are far greater than assumed and not self-correcting as assumed by earlier designers. The reductions of specific capacities with time can result from one or combinations of mechanical, chemical or biological processes. Sediments accumulate in the well screens and surrounding gravel pack from muddy surface waters seeping into the wells due to malfunctioning check valves. The major forms of chemical incrustation are caused by the precipitation of carbonates, sulfates, iron, and manganese compounds found in the area's groundwater. Bio-fouling, clogging of well screens, filter packs and even the natural aquifer formation adjacent to the well are caused by the activity of microscopic bacteria, molds and algae. This activity manifests itself as slimes, incrustations, and precipitation of metals and accumulation of inorganic fines. While these processes were not considered during the original design, the original designers assumed that well flow during flood events and or the simple pumping of wells at selected intervals (10 to 20 years) would restore the well's performance back to, or very close to, its original installed efficiency. Studies in 1976 following the 1973 flood indicated that the problem might be far greater than assumed in the 1960s, and that extensive redevelopment using mechanical or chemical means might be required even with natural relief well flow during a flood event. Studies conducted by the St. Louis District in the early 1990s and rehabilitation of relief wells in flooded districts following the 1993 flood confirmed that to maintain an acceptable level of relief well efficiency, an active down well program must be undertaken at regular intervals (every 8 to 10 years). This down-hole work must consist of a carefully controlled combination of chemical and mechanical redevelopment methods; a program that is well beyond any requirement originally anticipated by the original designers. In order to determine the existing condition of these wells and their current performance 69 wells were pump tested as a representative sample. This pump testing showed that 60% of the wells were performing below the recommended 80% efficiency established as the minimum acceptable performance level. The deficient well efficiency ranged between 34% and 79% with the majority falling between the range of 60-80%. Although the existing relief wells have a diminished capacity compared to when they were new, where relief wells exist today they provide some measure of underseepage protection and will remain in service unless foundation sands migrate through a broken well screen or a collapsed pipe. In floodwall reaches that have relief wells, supplemental relief wells are needed to further reduce the uplift pressures along the floodwall and levee as demonstrated by the 1993 flood. In addition, floodwall and levee sections of both Reach 3 and Reach 4 that do not have relief wells need them. This is further described in the geotechnical analysis. Without additional underseepage controls the risk of levee or floodwall failure is unacceptably high.

A short video showing iron bacteria in a relief well can be seen by going on the internet to:

http://www.mvs.usace.army.mil/pm/Project Menu/St. Louis Flood Protection/default.htm

and clicking on “Relief Well Video”.

Flood Wall Stability. The stability of two soil founded floodwall monoliths was checked. The monoliths selected for investigation are representative of other soil founded monoliths in the St. Louis Flood Protection. The monoliths checked were Reach 3, Item F-6A, Monolith 36 and Reach 4, Item F-7C, Monolith 45 (see Tables 6 and 7 of the structural section of the engineering appendix for the results of these analyses). Some of the factors of safety are below values required by current criteria. It is our opinion that these structures, as designed, are safe. No modifications to the existing floodwall monoliths are required for their stability to be adequate during a flood event. Since analysis and the current physical condition (after the 1993 flood loading) do not show that the project will fail, the floodwall monoliths are not considered to have a design or construction deficiency (reference ER 1165-2-119, paragraph 7.a. (1)). This conclusion does not however apply to underseepage control measures as discussed previously.

Hydrologic and Hydraulic Conditions. The project is intended to provide protection against a 52-foot Mississippi River stage on the St. Louis Gage, which has a current expected frequency of greater than 500 years, based on the draft results of the flow frequency study for the Mississippi River. The original design expected that protection would be against an approximately 200-year flood based on protecting against the flood of record at the time, which was the flood of 1844. This estimated level of protection was prior to completion of additional reservoirs upstream of the project in the Missouri

River and Mississippi River basins. Levee and floodwall grade freeboard is 2 feet above the water surface profile by design. The flood of record occurred during the summer of 1993 when the St. Louis gage recorded 49.58 ft. River elevations were above flood stage from 3 April to 7 October. Peak flow was estimated at 1,080,000 cubic feet per second (cfs). The frequency interval of that event was approximately 175 years. The project endured two other significant flood events; 43.3 feet on the St. Louis gage in 1973 (just as the project's construction was ending), and 41.9 feet on the St. Louis gage in 1995.

Environmental Contamination. Heavy industry has been the dominant land use in the protected area for over a century. There is one Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site, commonly known as Superfund site in the area. The Mallinckrodt, Inc. site in Reach 3 is undergoing cleanup by the St. Louis District under the Formerly Utilized Sites Remedial Action Program (FUSRAP). Ongoing remediation is expected to be complete in less than ten years. Although the risk is low, there is the potential to spread remaining surface soils containing radioactive Uranium, Radium, and Thorium onto nearby properties that have already been remediated. This recontamination would require a second round of costly cleanup. The Missouri Department of Natural Resources has an inventory of industrial sites known to have hazardous wastes. In the area protected by the St. Louis Flood Protection System are sites containing dioxin, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and the former Thompson Chemical Company site, where Agent Orange defoliant was produced from about 1950 to 1968. There are also many industrial sites protected by the flood protection system that manufacture, utilize, and store a wide variety of chemicals, such as those used in metal plating and the manufacture of surfactants. Finally, one of the regions largest wastewater treatment plants is protected by the flood protection system. Failure of the flood protection system could send millions of gallons of untreated waste into the floodplain and the Mississippi River.

National Security Considerations. The National Geospatial-Intelligence Agency (previously the National Imagery and Mapping Agency) has one of its two main facilities protected by the St. Louis Flood Protection System. The agencies mission is to provide Geospatial Intelligence in support of national security. Flooding of the NGA facility in St. Louis would have an effect on national security. The flood of 1993 inundated an inadequately protected satellite facility in south St. Louis that had to be closed. The damage was substantial enough that a new facility was constructed out of the floodplain. The Coast Guard also has facilities protected by the St. Louis Flood Protection System in Reach 4.

4.1.2. Future Without Project Conditions

The protected area has been completely developed, although some tracts are underutilized or vacant. The City of St. Louis is acquiring many parcels and promoting them for redevelopment. Piecemeal redevelopment is expected to continue. The protected area is expected to remain as a largely industrial and commercial corridor. As the flood protection system continues to age, many components of the system will reach their design life. Operation and maintenance difficulties will increase over time, especially regarding closure structures. Flood fighting could be especially difficult if underseepage issues are not addressed.

Even with proper maintenance, continued deterioration of the system and lack of correction will threaten the ability of the flood protection system to prevent interior damages from a major flood. If the city of St. Louis encounters a flood protection system failure during a major flood, billions of dollars of property are at great risk, and major transportation infrastructure can be closed or even lost. Many people live in the protected area, and thousands of people work in the protected area. The city of St. Louis will face potential loss of life, job loss, property loss, lost industrial production, and major transportation delays. The city of St. Louis and areas downstream could also incur significant environmental degradation due to the many chemical plants and a radioactive waste site in the protected area.

4.2. Project Specific Problems and Opportunities

The potential for levee or floodwall failure resulting in flood damage is a major problem. As time continues to pass without corrections being undertaken for the St. Louis Flood Protection System the probability that the project will fail continues to increase. The City of St. Louis provides routine operation and maintenance of the system and takes action to repair, as circumstances require. However, maintenance of deficient closure structures will become increasingly difficult over time and the chances of multiple failures occurring simultaneously will increase. The opportunity exists to address design deficiencies in the system now in order to prevent a future catastrophe. The FM Global insurance company has estimated that flood protection failure would cost them over $3 billion dollars in damage claims. There would also be the cost of post-failure levee system repair and environmental clean up.

During the 1993 flood the most significant concern was the failure of a concrete wall monolith on the north end of the project. The ground underneath the monolith was severely undercut due to a foundation blow out and the monolith rotated several inches. If not for immediate emergency action to contain the wall Reach 3 would have been immediately inundated, and Reach 4 would have been inundated shortly thereafter.

Figure 4-12: Rocks dumped to stop water gushing under floodwall in 1993 flood

Figure 4-13: Condition of Failed Floodwall Monolith after Flood of 1993

There were areas with sandboils that had to be ringed with sandbags; larger seepage areas had to be covered with geotextile and an 18-inch layer of rock in order to protect the integrity of the foundation. In general, the magnitude of seepage problems requiring extensive efforts was greater than anticipated. When underseepage is not properly managed it causes foundation failures that result in levee or floodwall failure, inundating what is supposed to be protected. Although the flood control system was not designed to completely prevent any sandboils from ever occurring, the project did not perform as expected in this regard.

I. Design Deficiencies

Eligibility for federal participation to modify completed projects that are now operated and maintained by local interests is defined in ER 1165-2-119, *Modifications to Completed Projects*, Paragraph 7 Modification Under Existing Authority, Local Protection Projects, sub-paragraph a. Eligible works. Work proposed must meet all of the following conditions:

> (1) It is required to make the project function as initially intended by the designer in a safe, viable and reliable manner; e.g., pass the original design flow without failure. This does not mean that the project must meet present-day design standards. However, if current engineering analysis or actual physical distress indicates the project will fail, corrections may be considered a design or construction deficiency if the other criteria are met.
>
> (2) It is not required because of changed conditions.
>
> (3) It is generally limited to the existing project features. Remedial measures which require land acquisitions or new project structures must not change the scope or function of the authorized project.
>
> (4) It is justified by safety or economic considerations.
>
> (5) It is not required because of inadequate local maintenance. Local responsibilities for maintenance of local protection projects are stated in 33CFR208.10.

IA. Structural Deficiencies:

The structural condition and design of the floodwall monoliths, gatewells, and closure structures must be re-evaluated. There have been three periodic inspections since the flood of 1993. An exhaustive examination of the structural features of the project was included in the periodic inspection report. The inspection reports recorded numerous deficiencies of varying degrees of severity, and proposed a recommended schedule for remediation of the deficiencies. Many of the deficiencies noted in the periodic inspection were either already a threat to the line of protection (e.g., ruptured gate seals, damaged gate girders) or had the potential to become so if not addressed (e.g., severe rusting of existing gate members). The periodic inspections did not however serve the purpose of determining a federal responsibility or interest for the documented problems.

The Government has an interest in remediation of all the structural deficiencies, but not debris removal, maintenance painting, rust removal, and minor concrete repairs, which are the responsibility of the City of St. Louis.

IB. Geotechnical Deficiencies:

Underseepage controls designed and constructed for the St. Louis Flood Protection System are not adequate for the authorized design flood level of 52.0 feet on the St. Louis Gage which is equivalent to the 500-year probability flood event and must be re-evaluated. Underseepage control measures that have been designed for this project include subsurface cutoff walls, a subsurface toe drain system, a relief well system, and piezometers. Three separate, but interrelated issues regarding relief wells as underseepage control measures have raised questions about the system's ability to perform as intended. A better knowledge of the stratigraphic conditions that contribute to underseepage has changed design criteria. Observations of actual system performance during floods since the system was originally designed and installed have underscored certain weaknesses in the design, such as assumptions regarding loss of well efficiency. These design deficiencies raise questions regarding the St. Louis Flood Protection Systems' ability to perform satisfactorily at or near its current design flood level.

The Corps of Engineers based the relief well system design on the nearby Alton to Gale, Illinois and Missouri, design documented in TM-3-430, *Investigation of Underseepage Mississippi River Levees, Alton to Gale, Illinois,* dated April 1956. At that time, the system represented the best engineering design of partially penetrating relief wells in aquifers confined by leaky blankets that would be required to be functional for a long period of time but flow infrequently. At the same time that TM 3-430 was being published, the Corps was revising design criteria. Based on extensive laboratory and fieldwork completed by the Waterways Experiments Station and during the same time frame that TM 3-430 was published, the Corps was considering using a more stringent seepage gradient. The Waterways Experiments Station published TM-3-424, *Investigation of Underseepage and Its Control, Lower Mississippi River*; October 1956 for the President, Mississippi River Commission, just 6-months after TM 3-430. The requirement of spacing the relief wells is substantially more conservative than the value used in the Alton to Gale, Illinois, design.

Additional research and flood-fight experience in the 1960s, 1970s, 1980s and 1990s, by the Corps and others outside of the Corps have shown that the original Alton to Gale seepage measures are not as conservative as the original authors believed. Another flood control project that had its underseepage design based on the Alton to Gale, Illinois and Missouri technical manual was the Bois Brule Levee, Missouri project. It seems that no effort was going to be made to redesign the entire Alton to Gale system according to the more conservative criteria described in TM 3-424 because most of the Alton to Gale system was already installed.

Additionally, the authors of the April 1956 manual TM 3-430 were well aware that they were on the leading edge of seepage control measures design and they knew that future flood events would provide data that would confirm or show the need to modify the Alton to Gale system. In the conclusions and recommendations presented in the original Alton to Gale Underseepage Design Report, the authors admit:

> 'As the levees in the St. Louis District generally have not been subjected to very high river stages and relatively few sand boils have occurred to date, the critical gradient was assumed . . .'

The authors also recommended that:

> 'The design assumptions used should be reviewed and revised as necessary to comply with actual observations and performance data obtained during future flood events.'

Observations made by the St. Louis District during flood fight efforts of 1973, 1986, 1993 and 1995 and subsequent evaluations have shown that certain areas have not performed as expected during actual flood events that are lower than the design flood levels. In some reaches along the Alton to Gale system, when the gathered piezometric data is extrapolated to design flood levels, a level of system performance is predicted that is far from acceptable. Observations made during the 1973 and 1993 flood fights show development of high uplift gradients, sand boils and heavy seepage along reaches with no in-place seepage control measures as well as reaches that do contain seepage control measures. It has been concluded that this unsatisfactory performance stems from the inadequately conservative assumptions made in TM 3-430, and limited observations of levee underseepage performance made at that time.

The performance of the St. Louis Flood Protection Project during the 1993 Flood, 1995 Flood, and conditions encountered in recent periodic inspections, demonstrated the need for evaluation, and possible remediation, of several geotechnical components of this project. The St. Louis Flood Protection Project is a system combining earth levees and concrete floodwalls. There are two basic areas of concern that have major impact on satisfactory performance of this system: underseepage and vegetation control. Vegetation control is entirely a non-federal maintenance responsibility. Slope stability, foundation stability, and through seepage at levee sections are not currently a problem.

<u>IC. Summary of Design Deficiency Problems</u>

Underseepage controls designed and constructed for the St. Louis Flood Protection System are not adequate for the authorized design flood level of 52.0 feet on the St. Louis Gage which is equivalent to the 500-year probability flood event. Inadequate underseepage controls are problems in reaches with relief wells and reaches without relief wells. The design criteria used for this flood protection system allowed for too high of allowable uplift pressure gradient. The insufficient number of relief wells combined with diminished capacity of relief wells result in inadequate underseepage controls for the flood protection system. Continuation of the present underseepage conditions has the potential to contribute to unsatisfactory performance of the flood protection system which was already experienced with the floodwall monoliths near Riverview Boulevard. Upon loading of the system to record levels in 1993, several deficiencies were noted and some had to be dealt with under extreme emergency conditions. The 1993 failure of the floodwall near Riverview Boulevard at Maline Creek was due to excessive uncontrolled underseepage. Combinations of sandbagging, ponding water, and geotextile weighted down with clean crushed stone were used to control seepage in over 20 locations. The swing gate closure structures have had rusting problems for over thirty years that began even before the project was dedicated in 1974. The gate design prevents proper sponsor maintenance since some areas that rust are inaccessible. The question as to why the Corps of Engineers did not correct all problems related to gates at that time is not known. The system was evaluated based on its response and reasons determined for its performance.

<u>II. Recreation Opportunity: North Riverfront Trail and the Confluence</u>

St. Louis 2004, a local non-profit civic organization, asked if the Corps would participate in creating a greenway along the project area in conjunction with efforts by the City of St. Louis, the Great Rivers Greenway District, and Trailnet, Inc. The portion applicable to this study is part of a larger network known as the Confluence Greenway in both Missouri and Illinois in the vicinity of St. Louis. The City of St. Louis has graded and paved a hiking and biking trail, and has drafted a North Riverfront Trail master improvements plan. The trail is along the floodwall or on top of the levee. Several non-profit and community organizations are helping to remove debris, plant native species, construct a kiosk and shelter, and improve the overall experience for trail users. However, most basic amenities are still lacking on the North Riverfront Trail. The opportunity to enhance the trail and increase the accessibility and utility of the trail should increase usage considerably.

Policy Guidance Letter No. 36, published 21 October 1992, allows for the Corps to be involved in improving recreation along the flood protection system in a variety of ways. Access, signs, interpretive media, and protection and safety measures are areas that have appeal to our potential sponsors. Chapter 17, Recreation, of EP 1165-2-1 indicates that recreation would be limited to increasing the project by 10% and must be incrementally economically justified. However, Administration guidance for the Corps of Engineers has consistently found recreation to be a low budget priority. The full recreation analysis is provided in Appendix E.

4.3.Alternative Plans.

Three basic alternative plans were used to guide the alternative development process for this study. They are (1)no action, (2) replace or reskin the 16 worst swinging gate closure structures and address underseepage, and (3) replace or reskin all swinging gate (also known as miter gate) closure structures and address underseepage. The No Action alternative assumed no action would be taken. Under this scenario the city of St. Louis would continue to perform its operation and maintenance responsibilities and maintain their standing in the P.L. 84-99 program, but no Federal action outside of the P.L. 84-99 program would be taken. The other two alternatives are deficiency correction alternatives that sought to identify actions that could be taken to correct system deficiencies. Both assume that addressing inadequate underseepage protection can be practically achieved only through additional relief wells. The difference lies in how to address the deficient swing gates. One alternative is to recondition by reskinning the existing gates in the field. The other alternative is to replace existing gates with new factory-built gates. The economic considerations of addressing deficient gates revolve around the probability of failure in addressing only the worst sixteen swing gates, or all swing gates. Since recreation is a low budget priority, it is not included in any of the alternative plans.

4.3.1. Measures Available to Address Identified Problems and Opportunities

4.3.1.1. Measures Available for Closure Structures

No Action: Steel swing gates will continue to deteriorate over time until their condition results in failure of the structure. Failure during a high water event could result in significant interior flooding. Panel closures are acceptable in their present condition.

Recondition by Reskinning: The term "reskin the gates" means removing of the skin plate sheet and the corrugated sheet and replacing with vertically spanning structural steel tees and a ¼" minimum thickness plate steel skin. Remaining steel would be sand blasted and repainted with a multi-coat paint with rubber-J-seals and steel clamping bars replaced if needed.

Replacement: Fabricate and install new steel gates with appurtenances.

4.3.1.2. Measures Available for Underseepage

No Action: Existing relief wells in the flood protection system are not providing adequate underseepage controls needed for past floods and much less than for the design flood level of 52.0 feet on the St. Louis Gage. Floodwall monoliths failed due to the lack of underseepage controls when the Mississippi River level reached 46.9 feet on the St. Louis Gage which is 5.1 feet below the design flood level of 52.0 feet. Construction of supplemental underseepage controls are needed even when the relief wells are in pristine condition. Many of the relief wells over the years have experienced a decrease in their ability to pass enough seepage water to lower the uplift pressures sufficiently to eliminate dangerously high uplift gradients that produce sand boils and instability on floodwall monoliths and levees. The existing relief wells need to be cleaned with chemical and mechanical methods to improve their performance during floods. The reaches in the flood protection system without relief wells can be expected to have severe underseepage problems undermining the integrity of the system and risking flood protection failure. The Operation and Maintenance (O&M) Manual for Reach 3, page 31, states, "…the stability of the levee and floodwall is predicated on the efficient functioning of the relief wells". Since there are an inadequate number of relief wells, the stability of the levee and floodwall is at risk. The O&M Manual states, "If the flood reaches such magnitude that local interests are unable to cope with the situation and have requested, in writing, that the Corps of Engineers take over flood fighting operations, the pumping of the underseepage relief wells will be performed by the Corps of Engineers, who will furnish and control all necessary equipment and supplies and will employ the necessary operating personnel." As such, the no action alternative implies that future floods will have underseepage problems that will require federal expense for emergency flood fighting and then post-flood repairs under the Public Law (PL) 84-99 program. Seepage during high water events will continue to create stability problems for certain reaches of the levee and floodwall. Failure of any reach of the levee will result in widespread and catastrophic flooding of the protected area.

Additional underseepage protection: The addition of relief wells, seepage berms and slurry walls were evaluated for their ability to address underseepage concerns for the system. Underseepage can be controlled by several measures but relief wells are the practical alternative. This is due to the extensive and uneconomical real estate requirements for seepage berms, construction considerations, and cost. Relief wells can be installed on existing right of way and are the least costly alternative. Seepage berms were found to be an uneconomical alternative because they can have lengths ranging from 150 ft. to 300 ft., making them unrealistic from a real estate acquisition cost standpoint in a densely developed urban area. Also, obtaining and placing suitable borrow material would be an additional complication. Installation of sheet piles or a slurry wall may be feasible from a real estate standpoint, but would be extremely costly due to utility relocations. Extreme care would need to be taken in floodwall areas to minimize harmful vibrations. Tying the sheet pile or slurry wall to the floodwall would be a very difficult technical detail and most likely would require removing part of the protection during construction and the need for temporary protection in the form of a cofferdam. Adding 70 relief wells will ensure that underseepage gradients meet Corps criteria for safety and will significantly reduce the probability of flood damage. Foundations investigations will be performed for those areas that were damaged by sand boils, subsidence, soft soil and quick conditions. The floodwall monoliths that failed had their foundations replaced with sheet pile cutoff walls and compacted clay backfill with a subdrain system located beneath the landside portion of floodwall monoliths to relieve underseepage pressures.

Improving Relief Well Performance:

A. Relief Well Maintenance and Monitoring

An evaluation of the existing relief well performance will be the initial part of this work. This evaluation will consist of measurement of total well depth to determine the presence of sediment/sand in well; air redevelopment to clean and prepare the well for testing, and performance of a pump test to measure the well specific capacity. This evaluation requires the use of an air compressor, portable generator, crane, submersible pump, and appurtenant piping and discharge. Particular care is required to prevent damage to the well screen and filter pack during this work.

B. Relief Well Rehabilitation

Rehabilitation is required where the relief well evaluation indicates significant deterioration since installation. Rehabilitation consists of a combination of mechanical processes and chemical treatments designed to clean the well and filter pack and restore well performance. Chemical treatment may use various organic acids, chelating agents, surfactants, dispersants, wetting agents, and hot water or steam. Changing environmental concerns regarding the use and concentrations of well cleaning chemicals will have a major effect on the design of a well rehabilitation program. The execution of rehabilitation is, in general: the chemical (heated or unheated) is injected into the well through a jetting tool to a prescribed concentration. The concentrated water/chemical mix is then surged to mix with the surrounding well water, and to wash through the well screen and surrounding filter pack. After surging, the water is either buffered, or allowed to return to normal pH, after which it is then removed by pumping.

C. Relief Well Replacement

Replacement consists of the design and construction of new relief wells to take the place of wells which no longer function adequately. It may also include the abandonment of damaged or non-functioning relief wells. With other similar projects, first time replacement of damaged or non-functioning relief wells ranges between 10 to 20 percent of the original number of relief wells.

4.3.2. Evaluation of Alternative Plans and Selection of Recommended Plan.

The following is a discussion of the identification of the National Economic Development (NED) plan among the proposed alternatives designed to correct a design deficiency and improve the reliability of the flood control performance of the St. Louis Flood Protection System (SLFPS). NED contributions are defined as "increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area as well as the rest of the nation. Contributions to NED include increases in the net value of those goods and services that are marketed, and also of those that may not be marketed." (*Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, p. 1, March 1983.) In accordance with Engineering Regulation (ER) 1105-2-100, dated April 2000, a comprehensive NED benefit-cost analysis is employed to assure that the value of the outputs produced (the NED benefits) by improving the performance characteristics of the St. Louis Flood Protection System (SLFPS) exceeds the value of the inputs (the NED costs) necessary to accomplish the proposed alternative.

Important assumptions used in the NED evaluation of potential alternatives for the St. Louis Flood Protection System are

(1) All benefits and costs are expressed in November 2003 price levels unless noted;
(2) Project discount rate for the evaluation of NED benefits and costs is 5.625 percent;
(3) The project base year is 2008;
(4) The St. Louis Flood Protection System is certified by FEMA as providing up to a 100-year level of protection for flood insurance purposes;
(5) Future-without-project conditions consist of the same Flood Protection System in place as under the existing condition, plus additional gate degradation and relief well loss of efficiency.
(6) The project period of evaluation is estimated at 25 years with appropriate operation, maintenance and replacement;
(7) Resources have alternative uses and consequently, opportunity costs;
(8) Individuals are risk neutral and rational economic agents; and
(9) All elevations are expressed in feet and are understood to represent "Ft. NGVD" (Feet. National Geodetic Vertical Datum).

4.3.2.1. Existing Condition

SLFPS Performance: During the Great Flood of 1993, which taxed the SLFPS with record Mississippi River stage levels, the U.S. Army Corps of Engineers, the City of St. Louis, and Metropolitan Sewer District (MSD) encountered notable concerns regarding the integrity of the SLFPS. In fact, during the Great Flood of 1993, some system concerns created problems that had to be dealt with under extreme emergency conditions. Such concerns include closure structures, relief wells, underseepage and vegetation control. Granted some performance concerns may be attributable to substandard maintenance, but some concerns are the result of a design deficiency exposed by the stresses of extremely high water flood events. Two reaches, Reach 3 and Reach 4, identify the protected project area. However, the project area is ultimately evaluated as one unit for inundation purposes because failure of the levee/floodwall combination, closure structures, relief wells, or other components would compromise the entire project area protected by the SLFPS. In the event the SLFPS would be compromised by a high-level flood frequency event, resulting in catastrophic failure, inundation damages have been estimated at upwards of $1.0 billion in the City of St. Louis. Estimates for inundation damages prevented from the Great Flood of 1993 and the 1973 Flood are $900 million and $160 million in real dollars, respectively. Failure of either Reach 3 or Reach 4 will result in widespread flooding of both Reaches.

4.3.2.2. National Economic Development (NED) Inundation Damages and Costs

The NED inundation damages and cost categories for the St. Louis Flood Protection project area include flood damages to industrial, commercial, and residential structures. Flood damages also reflect damages to contents and related (miscellaneous) flood damages associated with individual structures and area infrastructure. The NED inundation damage category of agricultural acreage was not relevant as there is no agricultural acreage within the project area. The NED inundation cost category of traffic disruption was determined to be inconsequential as the only major travel routes lie west of the project area, Interstate Highway 70 (north of the Arch Grounds) and Interstate Highway 55 (south of the Arch Grounds), and are outside the 500 year floodplain. Also, the calculation of potential NED benefits from the cessation of railroad traffic in the event of a major flood event was determined to be beyond the scope of this project. NED inundation damages and cost categories noted here are evaluated. The potential reduction in these inundation damages and costs would comprise the total NED benefits from correcting the design deficiencies of the SLFPS.

Industrial, Commercial, and Residential Inundation Damages

All industrial, commercial, and residential inundation damages are calculated using the Flood Damage Reduction Risk-Based Analysis (HEC-FDA) model. The HEC-FDA model uses data on structure types, values, and elevations along with project area hydrologic data for base year 2008 to estimate damages for flood events of different probabilities. These estimates are weighted by their probability of occurrence and converted into average annual inundation damage estimates. The risk analysis segment of the model quantifies uncertainties for relationships such as discharge-frequency, stage-discharge and stage-damage, and incorporates these risk uncertainties into economic and performance analyses of alternative flood damage reduction plans.

The model incorporates pertinent SLFPS reliability data generated through geotechnical engineering and structural engineering statistical analysis. Their analysis calculates the reliability of the SLPFS from the floodwall base to its top as a function of the reliability of the swing gates in conjunction with the reliability of the relief well system. ER 1105-2-100 (April 2000), page E: 106-107 states, “As a minimum, information shall be gathered to enable the identification of two points on the existing levee [floodwall]. The first point is the highest vertical elevation on the levee [floodwall] such that it is highly likely that the levee [floodwall] would not fail if the water surface elevation were to reach this level. This point shall be referred to as the Probable Non-Failure Point (PNP). The second point is the lowest vertical elevation on the levee [floodwall] such that it is highly likely that the levee [floodwall] would fail [if the water surface elevation were to reach this level]. This point shall be referred to as the Probable Failure Point (PFP)”.

The purpose of identifying the probable failure and non-failure points (PFP and PNP), and any quantifiable probability of unsatisfactory performance points (PUPs) between the PNP and PFP parameters, is to generate a range of water surface elevations on the SLFPS for which it is presumed that the probability of SLFPS failure increases as water surface elevation increases. The requirement that, as the water surface elevation increases the probability of failure increases, incorporates the reasonable assumption that as the SLFPS becomes more stressed, the SLFPS is more likely to fail.

The geotechnical branch calculated probable failure points due to relief well underseepage. These probable failure points are presented in Table 1.

Table 4-1
Probable Failure Points
Due to Relief Well Underseepage

Return Period	Water Surface Elevation	PUP*
1 Year		
2 Year		
5 Year	412.9	0.0001
10 Year	416.1	0.0157
25 Year	420.1	0.4520
50 Year	423.8	0.7265
100 Year	426.0	0.8154
500 Year	429.8	0.9017

**** PUP is Probability of Unsatisfactory Performance; i.e., a probability of failure at that return period / water surface elevation. Estimates for Year 2008***

For example, in Table 1 at water surface elevation 426.0 (the 100-year return period), a PUP of 0.8154 indicates there is an 81.54 percent chance the SLFPS will perform unsatisfactorily (due to relief well underseepage) given a 1 percent flood frequency event. A PUP equating to the highest flood elevation within Table 1 would be considered the PFP ONLY IF the PUP is greater than or equal to 85 percent (where ER 1105-2-100 (April 2000), page E: 107 defines 'highly likely' as "… 85+ percent confidence."). Otherwise, the PUP represents the probability of unsatisfactory performance at that water surface elevation for 2008. Conversely, a PUP (greater than zero) equating to the lowest flood elevation within Table 1 would be considered the PNP ONLY IF the PUP is less than or equal to 15 percent. This methodology to relating PUPs to PNPs and PFPs applies to all Tables within this section.

The structural branch calculated PUPs due to swing gate failure. These PUPs are presented in Table 2.

Table 4-2
Probability of Unsatisfactory Performance
Due to Swing Gate Failure

Return Period	Water Surface Elevation	PUP*
1 Year		
2 Year		
5 Year	412.9	0.0001
10 Year	416.1	0.0001
25 Year	420.1	0.0001
50 Year	423.8	0.3155
100 Year	426.0	0.5196
500 Year	429.8	0.6117

** Estimates for Year 2008*

The PUP (Probability of Unsatisfactory Performance) for the entire SLFPS is determined from these two major components, namely relief well underseepage and swing gate failure. Since failure of either of these components would result in inundation damages for the City of St. Louis, the individual PUPs were combined as a series system to determine a total system PUP. The following equation is used in calculating total system PUP estimates for 2008:

$$P(f)_s = 1- [(1-P(f)_{rw})(1-P(f)_{sg})]$$

where:

- $P(f)_s$ **= PUP for the total system (SLFPS)**
- $P(f)_{rw}$ **= PUP for the system due to relief well underseepage in the year 2008**
- $P(f)_{sg}$ **= PUP for the system due to swing gate failure in the year 2008**

The total system PUP estimates are presented in Table 3. For example, for the 100 year return period, the total system PUP equals: 1-[1-0.8154)(1-0.5196)] = 0.9113. These PUP estimates are incorporated directly into the model to calculate inundation damages for 2008.

<u>Table 4-3</u>
<u>Total System</u>
<u>Probability of Unsatisfactory Performance</u>

Return Period	**Water Surface Elevation**	**Relief Well PUP***	**Swing Gate PUP***	**Total System PUP***
1 Year	n / a	n / a	n / a	n / a
2 Year	n / a	n / a	n / a	n / a
5 Year	412.9	0.0001	0.0001	0.0002
10 Year	416.1	0.0157	0.0001	0.0158
25 Year	420.1	0.4520	0.0001	0.4521
50 Year	423.8	0.7265	0.3155	0.8128
100 Year	426.0	0.8154	0.5196	0.9113
500 Year	429.8	0.9017	0.6117	0.9618

** Estimates for Year 2008*

In accordance with hydrological and hydraulic guidelines, all inundation estimates occurring within the City of St. Louis project area are calculated from Mississippi River flood events. Thus, hydraulic and hydrologic profiles for the Mississippi River are used in the model to compute all necessary distribution curves, inundation damages and risk uncertainties. A notable factor involving inundation estimates is a north-south interceptor tunnel operated by the St. Louis Metropolitan Sewer District (hereinafter: MSD). The interceptor tunnel is approximately 7 feet (84 inches) in diameter and is located in bedrock roughly <u>60 feet</u> below ground level. The interceptor tunnel is designed to handle sewage as well as stormwater. Reach 3 and Reach 4 are separated by the high ground of the Arch Grounds, thus dividing the project area. However, the tunnel connects Reach 3 (extending north from downtown St. Louis) with Reach 4 (extending south from downtown St. Louis). If Reach 4 became inundated, floodwater would fill the interceptor tunnel, and also inundate Reach 3. Conversely, if Reach 3 became inundated, floodwater would again fill the interceptor tunnel, and would also inundate Reach 4. Engineering analysis computed an equivalent inundation level of Reach 4 via the tunnel from initial flooding of Reach 3 (via SLFPS compromise) would take 8 days, and conversely an equivalent inundation level of Reach 3 via the tunnel from initial flooding of Reach 4 (via SLFPS compromise) would take 15 days. Therefore shorter duration flood events would result in considerably less flooding via the tunnel for the Reach not initially compromised. The HEC-FDA model analysis includes an Exterior-Interior Relationship function, which defines the relationship between the flood stage on the river or exterior side of the SLFPS in relation to the flood stage in the floodplain or interior side of the levee. Guidance states if no exterior-interior relationship is specified, the assumption is that the floodplain or interior side would become inundated to the same level as the stage of the river (represented by the exterior stage/discharge function for that Reach). If, for example, the flood hydrograph volume is not sufficient to fill the interior side of the levee equal to the exterior side of the levee, then an exterior-interior relationship must be specified. For this analysis, although the Mississippi River yields sufficient hydrograph volume to inundate the compromised Reach to the same level as the stage of the river (i.e., exterior-interior stage definition is not necessary), the lengthy (8 or 15 day) duration necessary to inundate the non-compromised Reach via only the tunnel would only be sustained for a small percentage of flood events, thus an exterior-interior stage definition is necessary to reflect the majority of shorter duration flood events resulting in lower flood stage for the Reach inundated via only the tunnel). These necessary exterior-interior stages are incorporated into the HEC-FDA model analysis to properly estimate inundation damages for both Reaches from flood frequency events.

Installing a gate or valve in the tunnel was addressed as a secondary line of flood protection to possibly prevent both Reach 3 and Reach 4 from inundation if either Reach were compromised. However, installing a gate or valve in the tunnel would not be economically justified. If inundation reduction benefits are accrued by improving the primary measure of flood protection (the SLFPS) to ensure it functions properly, then there are little to no remaining inundation reduction benefits to be accrued through a secondary protection measure (e.g., a tunnel gate or valve), and justify a tunnel gate or valve, especially when the secondary measure is not used and thus unable to generate benefits unless the primary flood protection measure has failed.

Structural values are estimated using data provided by St. Louis City and existing conditions reflect 2003 price levels. Market analysis data was collected for the entire project area in 2003. Structure types and elevations are also determined from the market analysis data. Additional data sources used are historical records, and documentation from historic flood events. In accordance with ER 1105-2-100 (April 2000), page E: 102, the specific usage of depreciated replacement cost in the model is defined and followed in estimating inundation damages.

Inundation damages to the contents of industrial, commercial, and residential structures are derived via the model from depth-damage curves as well as field interviews, surveys, inspections and review of community records. Content damage for a structure is initially assigned a base value of 50 percent of that structure’s value. Content damage is subsequently based on depth damage percentages from the base value of 50 percent.

The depth-damage curves used in the model are St. Louis District depth-damage curves. There were derived / based on actual area depth-damage surveys from historical area floods. The Depth-Damage Functions for Corps of Engineers Flood Damage Reduction Studies from the Technical Analysis and Research Division at IWR was also consulted for comparison.

Related (miscellaneous) damages are grouped into two categories (1) individual structure damages; and (2) area infrastructure damages. Related damages associated with individual structures consist of flood fight efforts (rock support, sandbagging, pumps, manpower and clean-up, most notably for *low* and *medium* costs/damage events), temporary relocation, and utility connections. Also included in individual structure damages are vehicles, camper trailers, driveways, patios, fences, and landscaping.

Related damages associated with area infrastructure consist of flood fight efforts, utility functions (water and gas mains, water and gas laterals, sewers, utility meters), professional services (police, fire, medical, National Guard), and surface level infrastructure (streets, bridges, parks, and playgrounds).

While each related damage subcategory individually represents minor potential flood damages, the aggregate of all miscellaneous flood damages for all structures and the area infrastructure reflects significant flood related damages. Data for both related damage categories are incorporated into the model to calculate related damage estimates.

The Structure Type, Number of Structures and Totals of the individual Structure Values amassed for the project, and incorporated into the HEC-FDA model, are presented in Table 4.

Table 4-4
Structure Development Totals by Structure Type
Existing Condition

Structure Type	Number of Structures	Total Structure Value
Industrial	612	$188,671,407
Commercial	733	$133,043,087
Residential	609	$15,296,964
Total	1954	$337,011,458

Low and medium cost consequences and damages. As described in the Engineering section, *low* level cost consequences are represented by a personnel/equipment/materials emergency response the threat of inundation. Management and flood fighting activities consist of placing 1400 tons of rock against select gates, and the 24 hours per day efforts of 10 personnel to monitor problem areas for 21 days during the flood frequency event, as well as the removal of rock and equipment afterward. *Medium* level cost consequences are represented by a lower cantilever failure due to a rock berm either not being placed in time or performing unsatisfactorily. Significant displacement of a cantilever section is estimated to result in 526 acre-feet of floodwater entering the protected area, assuming extraordinary flood fighting efforts to stop the floodwater leakage takes two days. The 526 acre-feet of floodwater data is incorporated into the HEC-FDA model to compute inundation damages using risk uncertainties. Also, for *medium* level cost consequences, 1900 tons of rock are placed against problem area gates, and the 24 hours per day efforts of 20 personnel for 21 days are necessary. High level cost consequences would be varying degrees of inundation of the protected area based on the flood frequency event. Using industry costs for placement and removal of rock as well as November 2003 personnel billing costs, *low* and *medium* cost consequences are presented in Table 5.

Table 4-5
Low and Medium Cost Consequences
Existing Condition

Average Annual Damages	Number of Personnel	Number of Days	Tons of Rock	Placement and Removal of Rock	Personnel
Low	10	21	1,400	$35,000	$151,200
Medium	20	21	1,900	$47,500	302,400

The existing average annual industrial, commercial, and residential inundation damages from the model for the project area are presented in Table 6. Average annual damages, under the existing condition, are based on inundation of structures completed through 2003, given protection by the present SLFPS. Average annual damages include all damage categories yielding damages based on model results, specifically industrial, commercial, and residential damages. All NED inundation damage and cost categories addressed above are combined to calculate total average annual damages. Total average annual damages, under the existing condition, are estimated at $3,105,881 for Reach 3 and $2,881,847 for Reach 4, totaling $5,987,725.

Table 4-6
Total Average Annual Damages
Existing Condition

Average Annual Damages	Industrial	Commercial	Residential	Total
Reach 3	$1,413,394	$1,565,013	$124,060	$3,105,881
Reach 4	$1,155,367	$1,631,785	$94,283	$2,881,847
Total	$2,568,760	$3,196,796	$218,342	$5,987,725

4.3.2.3. Future-Without-Project Condition

Even with proper scheduled maintenance, continued deterioration of the SLFPS and lack of correction will threaten the ability of the flood protection system to prevent interior damages from a major flood. If the City of St. Louis experiences a flood protection system failure during a major flood, inundation damages have been estimated at upwards of $1.0 billion dollars in the City of St. Louis. The City of St. Louis will face loss of life, job loss, property loss, and lost industrial production. The City of St. Louis, specifically the downtown area, would also incur significant environmental degradation due to the many chemical and industrial plants as well as a radioactive waste site located within the protected area. Failure of the SLFPS would inundate areas that have nuclear contaminants, superfund sites, and industries such as plating factories. Thus it is imperative to sustain the SLFPS to top performance levels and avert such environmental consequences.

Industrial, Commercial, and Residential Inundation Damages

Again, all industrial, commercial, and residential inundation damages are calculated using the Flood Damage Reduction Risk-Based Analysis (HEC-FDA) model. The future-without-project average annual industrial, commercial, and residential inundation damages from the model for the project area are presented in Table 7. Average annual damages, under the future-without-project condition, are based on inundation of structures completed and estimated to be completed through 2008, given protection by the future-without-project SLFPS. Average annual damages include all damage categories yielding damages based on model results, specifically industrial, commercial, and residential damages. All NED inundation damage and cost categories addressed above are combined to calculate total average annual damages. Total average annual damages, under the future-without-project condition, are estimated at $3,112,071 for Reach 3 and $2,883,111 for Reach 4, totaling $5,995,182.

Table 4-7
Total Average Annual Damages
Future-Without-Project Condition

Average Annual Damages	Industrial	Commercial	Residential	Total
Reach 3	$1,416,274	$1,568,099	$124,278	$3,112,071
Reach 4	$1,156,276	$1,632,216	$94,204	$2,883,111
Total	$2,572,550	$3,200,316	$218,482	$5,995,182

Total average annual damages (Reach 3 AND Reach 4) by flood frequency event under Existing and Future-Without-Project conditions are presented in Table 8.

Table 4-8
Total Average Annual Damages
(Reach 3 and Reach 4)
by Flood Frequency Event
Existing and Future-Without-Project Condition

Return Period	Existing Condition	Future-Without-Project Condition
1 Year	$0	$0
2 Year	$0	$0
5 Year	$0	$0
10 Year	$0	$0
25 Year	$729,299	$730,208
50 Year	$1,254,434	$1,255,996
100 Year	$1,638,872	$1,640,913
500 Year	$2,365,120	$2,368,065
Total	$5,987,725	$5,995,182

4.3.2.4. Future-With-Project Condition

Four potential future-with-project condition alternatives are evaluated as follows.

(1). Alternative 1A: Replace swing gates at 10 locations, permanently close swing gates at 6 locations, redevelopment and rehabilitation of the existing 110 relief wells with chemical and mechanical methods, install 70 new relief wells, and perform foundation investigations of damaged areas. The estimated construction first costs are $7,013,100.

(2). Alternative 1B: Reskin swing gates at 10 locations, permanently close swing gates at 6 locations, redevelopment and rehabilitation of the existing 110 relief wells with chemical and mechanical methods, install 70 new relief wells, and perform foundation investigations of damaged areas. The estimated construction first costs are $7,121,000.

(3). Alternative 2A: Replace swing gates at 20 locations, permanently close swing gates at 13 locations, redevelopment and rehabilitation of the existing 110 relief wells with chemical and mechanical methods, install 70 new relief wells, and perform foundation investigations of damaged areas. The estimated construction first costs are $10,238,000.

(4). Alternative 2B: Reskin swing gates at 20 locations, permanently close swing gates at 13 locations, redevelopment and rehabilitation of the existing 110 relief wells with chemical and mechanical methods, install 70 new relief wells, and perform foundation investigations of damaged areas. The estimated construction first costs are $10,285,500.

Implementation of project Alternative 1A or Alternative 1B would reduce the total system PUP estimates for 2008 significantly, although residual probabilities of unsatisfactory performance would still exist due to either relief well underseepage or swing gate failure.

Any changes in the PUPs due to relief well underseepage for 2008, as calculated under the future-with-project condition given Alternative 1A or Alternative 1B, are presented in Table 9.

Table 4-9
Probability of Unsatisfactory Performance
Due to Relief Well Underseepage
Alternative 1A or Alternative 1B
Future-With-Project Condition

Return Period	**Water Surface Elevation**	**PUP***
1 Year		
2 Year		
5 Year	412.9	0.0001
10 Year	416.1	0.0001
25 Year	420.1	0.0001
50 Year	423.8	0.0001
100 Year	426.0	0.0001
500 Year	429.8	0.0001

** Estimates for Year 2008*

Any changes in the PUPs due to swing gate failure for 2008, as calculated under the future-with-project condition given Alternative 1A or Alternative 1B, are presented in Table 10.

Table 4-10
Probability of Unsatisfactory Performance
Due to Swing Gate Failure
Alternative 1A or Alternative 1B
Future-With-Project Condition

Return Period	Water Surface Elevation	PUP*
1 Year		
2 Year		
5 Year	412.9	0.0001
10 Year	416.1	0.0001
25 Year	420.1	0.0001
50 Year	423.8	0.0022
100 Year	426.0	0.0150
500 Year	429.8	0.1201

** Estimates for Year 2008*

Again, the PUP (Probability of Unsatisfactory Performance) for the entire SLFPS is determined from these two major components, namely relief well underseepage and swing gate failure. The same equation is used in calculating total system PUP estimates for 2008:

$$P(f)_s = 1 - [(1-P(f)_{rw})(1-P(f)_{sg})]$$

where:

$P(f)_s$ = PUP for the total system (SLFPS)
$P(f)_{rw}$ = PUP for the system due to relief well underseepage in the year 2008
$P(f)_{sg}$ = PUP for the system due to swing gate failure in the year 2008

The total system PUP estimates for 2008, as calculated under the future-with-project condition given Alternative 1A or Alternative 1B, are presented in Table 11.

Table 4-11
Total System PUP*
Alternative 1A or Alternative 1B
Future-With-Project Condition

Return Period	Water Surface Elevation	Relief Well PUP*	Swing Gate PUP*	Total System PUP*
1 Year				
2 Year				
5 Year	412.9	0.0001	0.0001	0.0002
10 Year	416.1	0.0001	0.0001	0.0002
25 Year	420.1	0.0001	0.0001	0.0002
50 Year	423.8	0.0001	0.0022	0.0023
100 Year	426.0	0.0001	0.0150	0.0151
500 Year	429.8	0.0001	0.1201	0.1202

** Estimates for Year 2008*

Implementation of project Alternative 2A or Alternative 2B would effectively reduce the PUPs due to relief well underseepage to zero (0.0001, a 1 in 10,000 probability), effectively reduce the PUPs due to swing gate failure to zero, (0.0001, a 1 in 10,000 probability) and thus the total system PUP estimates to 0.0002 (a 2 in 10,000 probability), as presented in Table 12.

Table 4-12
Total System PUP*
Alternative 2A or Alternative 2B
Future-With-Project Condition

Return Period	Water Surface Elevation	Relief Well PUP*	Swing Gate PUP*	Total System PUP*
1 Year				
2 Year				
5 Year	412.9	0.0001	0.0001	0.0002
10 Year	416.1	0.0001	0.0001	0.0002
25 Year	420.1	0.0001	0.0001	0.0002
50 Year	423.8	0.0001	0.0001	0.0002
100 Year	426.0	0.0001	0.0001	0.0002
500 Year	429.8	0.0001	0.0001	0.0002

** Estimates for Year 2008*

4.3.2.5. General Accounts

According to ER 1102-2-100, there are four accounts established to facilitate evaluation and display of the effects of alternative plans (1) national economic development (NED); (2) environmental quality (EQ); (3) regional economic development (RED); and (4) other social effects (OSE). These four accounts encompass all significant effects of a plan on the human environment as required by the National Environmental Policy Act (NEPA). They also encompass social well being as required by Section 122 of the Flood Control Act of 1970. The EQ account shows effects on ecological, cultural, and aesthetic attributes of significant natural and cultural resources that cannot be measured in monetary terms. The OSE account shows urban and community impacts and effects on life, health, and safety. The NED account shows effects on the national economy and is the only required account. The RED account shows the regional incidence of NED effects, income transfers, and employment effects.

National Economic Development Analysis

The National Economic Development (NED) account describes that part of the NEPA human environment that identifies beneficial and adverse effects on the economy. Beneficial effects in the NED account are increases in the economic value of the national output of goods and services from a plan, the value of output resulting from external economies caused by a plan, and the value associated with the use of otherwise unemployed or under-employed labor resources. Adverse effects in the NED account are the opportunity costs of resources used in implementing a plan. These adverse effects include implementation outlays, associated costs, and other direct costs (ER 1105-2-100).

The NED plan reasonably maximizes net national economic development benefits, consistent with the federal objective. Alternative plans, including the NED plan, should be formulated in consideration of the following four criteria (1) completeness; (2) effectiveness; (3) efficiency; and (4) acceptability.

While there is only one benefit standard, there are three benefit categories that reflect three different responses to a flood hazard reduction plan. During the economic analysis, all of which is contained within this section, all three of the following benefit categories are considered:

Inundation Reduction Benefit. If floodplain use is the same with and without the plan, the benefit is the increased net income generated by that use. If an activity is removed from the flood plain, this benefit is realized only to the extent that removal of the activity increases the net income of other activities in the economy.

Intensification Benefit. If the type of floodplain use is unchanged but the method of operation is modified because of the plan, the benefit is the increased net income generated by the floodplain activity. No Intensification benefits are accrued under the future-with-project condition.

Location Benefit. If an activity is added to the floodplain because of a plan, the benefit is the difference between aggregate net incomes, including economic rent, in the economically affected area with and without the plan. No Location benefits are accrued under the future-with-project condition.

As mentioned, all three of the benefit categories are considered in the determination of net NED average annual benefits. The following tables display the alternative plans, average annual benefits generated for each category of benefit, average annual costs, and NED average annual benefits.

The NED benefits are determined by subtracting a potential plan's total average annual costs to the total average annual costs associated with the future-without-project scenario. The average annual implementation costs for each potential plan are then subtracted in order to determine net NED benefits for each potential plan.

Environmental Quality, Regional Economic Development and Other Social Effects

Environmental Quality (EQ) Regional Economic Development (RED), and Other Social Effects (OSE) issues are addressed in the Environmental Impacts section of the Environmental Impacts Study (EIS).

Other social effects that are addressed by these flood damage reduction plans include (1) the reduction in human suffering associated with being flooded and being surrounded by family, friends and neighbors that are flooded; (2) the reduction in shock and personal disruptions created by being flooded; (3) an increased sense of personal security; and (4) the reduction in potentially dangerous situations resulting from increased emergency (including police, fire and medical) service response time.

4.3.2.6. Benefit and Cost Analysis

Direct Flood Damage Reduction Benefits. The NED plan reasonably maximizes average annual net national economic development benefits, consistent with a federal objective for maximizing economic benefits. Alternative plans, including the NED plan, should be formulated using four criteria; (1) completeness; (2) effectiveness; (3) efficiency; and (4) acceptability.

All the proposed Alternatives, Alternative 1A, Alternative 1B, Alternative 2A, and Alternative 2B, are evaluated to properly define the NED curve and identify the NED plan.

Tables 13 through 20 are produced from HEC-FDA model results.

The Annual Performance and Equivalent Long Term Risk for all SLFPS project alternatives for Reach 3 and Reach 4 are presented, under the future-without-project and future-with-project conditions, in Table 13 and Table 14. For example, the probability or risk of a SLFPS exceedance over the next 50 years for Alternative 2A for Reach 3 is estimated at 5.44 percent.

Table 4-13*
Annual Performance and Equivalent Long term Risk
Future-With-Project Condition: Reach 3

Project Alternative	Annual Performance (Expected Annual Probability of Design Being Exceeded)	Equivalent Long-Term Risk (Probability of Exceedance Over the Indicated Time Period)		
		10 Years	25 Years	50 Years
Without-Project	0.079	0.5772	0.8838	0.9865
Alternative 1A	0.003	0.0388	0.0942	0.1796
Alternative 1B	0.003	0.0388	0.0942	0.1796
Alternative 2A	0.001	0.0111	0.0276	0.0544
Alternative 2B	0.001	0.0111	0.0276	0.0544

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Table 4-14*
Annual Performance and Equivalent Long Term Risk
Future-With-Project Condition: Reach 4

Project Alternative	Annual Performance (Expected Annual Probability of Design Being Exceeded)	Equivalent Long-Term Risk (Probability of Exceedance Over the Indicated Time Period)		
		10 Years	25 Years	50 Years
Without-Project	0.079	0.5802	0.8858	0.9870
Alternative 1A	0.003	0.0388	0.0942	0.1796
Alternative 1B	0.003	0.0388	0.0942	0.1796
Alternative 2A	0.001	0.0111	0.0276	0.0544
Alternative 2B	0.001	0.0111	0.0276	0.0544

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Conditional Probability of Design Non-Exceedance for all project SLFPS Alternatives for Reach 3 and Reach 4 are presented under the future-with-project condition. For example, in Table 15, the probability of non-exceedance for the 0.2 percent (500 year) flood event for Reach 3 given Alternative 1A (e.g. the probability of Alternative 1A containing the 0.2 percent flood event for Reach 3) is estimated at 50.63 percent. This can also be stated as "the reliability of Alternative 1A containing the 0.2 percent flood event for Reach 3 is estimated at 50.63 percent."

Table 4-15*
Conditional Probability of Design Non-Exceedance
Future-With-Project Condition: Reach 3

Project Alternative	Conditional Probability of Design Containing Indicated Event					
	10 %	**4 %**	**2 %**	**1 %**	**0.4 %**	**0.2 %**
Without-Project	0.6656	0.2925	0.1366	0.0716	0.0305	0.0118
Alternative 1A	0.9997	0.9952	0.9736	0.9187	0.7332	0.5063
Alternative 1B	0.9997	0.9952	0.9736	0.9187	0.7332	0.5063
Alternative 2A	0.9998	0.9998	0.9998	0.9981	0.9554	0.8463
Alternative 2B	0.9998	0.9998	0.9998	0.9981	0.9554	0.8463

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Table 4-16*
Conditional Probability of Design Non-Exceedance
Future-With-Project Condition: Reach 4

Project Alternative	Conditional Probability of Design Containing Indicated Event					
	10 %	**4 %**	**2 %**	**1 %**	**0.4 %**	**0.2 %**
Without-Project	0.6656	0.2925	0.1366	0.0716	0.0305	0.0118
Alternative 1A	0.9998	0.9959	0.9760	0.9213	0.7352	0.5064
Alternative 1B	0.9998	0.9959	0.9760	0.9213	0.7352	0.5064
Alternative 2A	0.9998	0.9998	0.9998	0.9981	0.9554	0.8463
Alternative 2B	0.9998	0.9998	0.9998	0.9981	0.9554	0.8463

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Industrial, Commercial, and Residential Inundation Damages

Expected Annual Inundation Damage Reduced and Distributed for all SLFPS project Alternatives for Reach 3 and Reach 4 are presented, under the future-with-project condition, in Table 17 and Table 18.

Table 4-17*
Expected Annual Inundation Damage Reduced and Distributed
Future-With-Project Condition: Reach 3

Project Alternative	Expected Annual Damage			Probability Damage Reduced Exceeds Indicated Values		
	Total Without Project	Total With Project	Damage Reduced (Benefits)	0.75	0.50	0.25
Alternative 1A	$3,112,071	$394,345	$2,717,726	$2,017,540	$2,648,288	$3,399,233
Alternative 1B	$3,112,071	$394,345	$2,717,726	$2,017,540	$2,648,288	$3,399,233
Alternative 2A	$3,112,071	$188,638	$2,923,703	$2,131,601	$2,863,053	$3,779,637
Alternative 2B	$3,112,071	$188,368	$2,923,703	$2,131,601	$2,863,053	$3,779,637

***** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Table 4-18*
Expected Annual Inundation Damage Reduced and Distributed
Future-With-Project Condition: Reach 4

Project Alternative	Expected Annual Damage			Probability Damage Reduced Exceeds Indicated Values		
	Total Without Project	Total With Project	Damage Reduced (Benefits)	0.75	0.50	0.25
Alternative 1A	$2,883,111	$338,984	$2,544,127	$1,897,870	$2,482,313	$3,168,920
Alternative 1B	$2,883,111	$338,984	$2,544,127	$1,897,870	$2,482,313	$3,168,920
Alternative 2A	$2,883,111	$160,833	$2,722,278	$1,995,417	$2,666,853	$3,495,635
Alternative 2B	$2,883,111	$160,833	$2,722,278	$1,995,417	$2,666,853	$3,495,635

***** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Expected Annual Inundation Damage Reduced and Distributed for all SLFPS project Alternatives, totaling Reach 3 and Reach 4, are presented in Table 19, under the future-with-project condition.

Table 4-19*
Expected Annual Inundation Damage Reduced and Distributed
Future-With-Project Condition
Total for Reach 3 and Reach 4

Project Alternative	Expected Annual Damage			Probability Damage Reduced Exceeds Indicated Values		
	Total Without Project	Total With Project	Damage Reduced (Benefits)	0.75	0.50	0.25
Alternative 1A	$5,995,182	$733,330	$5,261,852	$3,915,410	$5,230,602	$6,568,154
Alternative 1B	$5,995,182	$733,330	$5,261,852	$3,915,410	$5,230,602	$6,568,154
Alternative 2A	$5,995,182	$349,201	$5,645,981	$4,127,019	$5,729,906	$7,275,273
Alternative 2B	$5,995,182	$349,201	$5,645,981	$4,127,019	$5,729,906	$7,275,273

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Costs

Average annual costs are subtracted from NED average annual benefits generated by each project alternative to determine net NED average annual benefits for each project alternative. The total average annual construction costs estimate includes construction costs, annual operation, maintenance and replacement costs, real estate costs, and all applicable contingency costs. All costs are annualized using the estimated project evaluation period of 25 years and a project interest rate of 5.625 percent.

Construction First Costs and Interest During Construction

Construction first costs and interest during construction are determined for all project alternatives. In calculating interest during construction, interest is charged for each year funds are expended during the construction period because of the time value of money and project construction preventing alternative uses of the funds. A three-year construction period is assumed for Alternative 1A and Alternative 1B, and the mid-year convention is used. A five-year construction period is assumed for Alternative 2A and Alternative 2B, and the mid-year convention is used.

Average annual costs are subsequently calculated for construction first costs as well as operations, maintenance, and replacement costs. Construction first costs, interest during construction, average annual operation, maintenance, and repair costs for all project alternatives are presented in Table 20.

Table 4-20*
Construction and Investment Costs

	Alternative 1A	**Alternative 1B**	**Alternative 2A**	**Alternative 2B**
Construction First Costs	$7,013,100	$7,121,000	$10,238,000	$10,285,500
Interest During Construction	$607,600	$616,900	$1,536,200	$1,543,200
Total Investment	$7,620,700	$7,737,900	$11,774,200	$11,828,800
Average Annual Investment	$575,100	$583,900	$888,500	$892,600
Average Annual Operation, Maintenance, and Repair Costs	$177,600	$177,600	$194,500	$194,500
Total Average Annual Investment	$752,700	$761,500	$1,083,000	$1,087,100

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

4.3.2.7. SUMMARY

All average annual NED benefits and construction related costs have been calculated in the evaluation of all project Alternatives designed to correct a design deficiency and improve the reliability of the flood control performance of the St. Louis Flood Protection System, Mississippi River, St. Louis, Missouri.

The *Expected Value and Probabilistic Values of Net Benefits* for all project Alternatives are presented in Table 21. The expected average annual net benefits for Alternative 1A are estimated to be $4,509,152 and the benefit-cost ratio is 6.99. The expected average annual net benefits for Alternative 1B are estimated to be $4,500,352, and the benefit-cost ratio is 6.91. The expected average annual net benefits for Plan 2A are estimated to be $4,562,981, and the benefit-cost ratio is 5.21. The expected average annual net benefits for Plan 2B are estimated to be $4,558,881, and the benefit-cost ratio is 5.19. Alternative 2A generates the highest expected annual net benefits, at $4,562,981, and is recommended as the NED plan.

Table 4-21*
Expected Value and Probabilistic Values of Net Benefits
Future-With-Project Condition

Project Alternative	Expected Annual National Economic Benefit and National Economic Benefit				Probability Net Benefit Exceeds Indicated Amount		
	Benefits	Costs	Net Benefits	Benefit-Cost Ratio	0.75	0.50	0.25
Alternative 1A	$5,261,852	$752,700	$4,509,152	6.99	$3,486,639	$4,513,489	$5,711,249
Alternative 1B	$5,261,852	$761,500	$4,500,352	6.91	$3,479,835	$4,504,680	$5,700,103
Alternative 2A	$5,645,981	$1,083,000	$4,562,981	5.21	$3,528,262	$4,567,369	$5,779,428
Alternative 2B	$5,645,981	$1,087,100	$4,558,881	5.19	$3,525,091	$4,563,265	$5,774,235

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

The differences in the expected annual net benefits for all project Alternatives presented in Table 21 are minor. However, it is important to note that, although Alternative 1A does have lower average annual costs and robust net benefits and benefit-cost ratio, Alternative 1A does not effectively reduce the PUP estimates to zero, as does Alternative 2A. Therefore, the differences in Table 21 illustrate that the residual probabilities of unsatisfactory performance from Alternative 1A would result in decreased reliability of the SLFPS. In fact, it is interesting to note that even for the NED recommended Alternative 2A, where PUP estimates are effectively reduced to zero, the uncertainties for inundation evaluation relationships (such as discharge-frequency, stage-discharge and stage-damage calculated via Monte-Carlo iteration) in the risk analysis segment of the model yield a reliability of Alternative 2A containing the 0.2 percent flood event for either Reach 3 or Reach 4 to be estimated at approximately 85 percent (please see Table 15 and Table 16). This differs significantly from Alternative 1A, where the residual probabilities of unsatisfactory performance (i.e., residual PUP estimates significantly greater than zero) combined with the uncertainties for inundation evaluation relationships in the risk analysis segment of the model yield a reliability of Alternative 1A containing the 0.2 percent flood event for either Reach 3 or Reach 4 to be estimated at approximately 50 percent (please see Table 15 and Table 16).

The Expected Value and Probabilistic Values of Benefit-Cost Ratio for Alternative 2A, the recommended NED plan, are presented in Table 22. The Expected Benefit-Cost Ratio for Alternative 2A is estimated at 5.21.

Table 4-22
Expected Value and Probabilistic Values of Benefit-Cost Ratio, National Economic Development, Alternative 2A

Project Alternative	Expected Benefit-Cost Ratio	Probability Benefit-Cost Ratio > 1	Probability Benefit-Cost Ratio Exceeds Indicated Amount		
			0.75	**0.50**	**0.25**
Alternative 2A	5.213	0.98	4.03	5.22	6.60

4.3.2.8. SENSITIVITY AND INCREMENTAL ANALYSIS

Sensitivity analysis

Reach 3 and Reach 4. Please recall the north-south interceptor tunnel connecting Reach 3 and Reach 4. If one Reach is compromised, due to the lengthy (8 or 15 day) duration necessary to equally inundate the non-compromised Reach via only the tunnel and the small percentage of flood events for which such an inundation duration would be sustained, sensitivity analyses for Reach 3 and Reach 4 are performed separately for all Alternatives, with Benefits, Costs, and Net Benefits computed.

Benefits. Benefits have already been computed separately for Reach 3 and Reach 4 (please see Table 17 and Table 18 above).

Costs. For Alternative 1A (replace gates at 10 locations and permanently close gates at 6 locations), there are 5 gates in Reach 3 and 5 gates in Reach 4 to be replaced, and 2 gates in Reach 3 and 4 gates in Reach 4 to be permanently closed. For Alternative 1B (reskin gates at 10 locations and permanently close gates at 6 locations), there are 5 gates in Reach 3 and 5 gates in Reach 4 to be reskinned, and 2 gates in Reach 3 and 4 gates in Reach 4 to be permanently closed. For Alternative 2A (replace gates at 20 locations and permanently close gates at 13 locations), there are 9 gates in Reach 3 and 11 gates in Reach 4 to be replaced, and 6 gates in Reach 3 and 7 gates in Reach 4 to be permanently closed. For Alternative 2B (reskin gates at 20 locations and permanently close gates at 13 locations), there are 9 gates in Reach 3 and 11 gates in Reach 4 to be reskinned, and 6 gates in Reach 3 and 7 gates in Reach 4 to be permanently closed.

Average annual costs are subsequently calculated for construction first costs as well as operations, maintenance, and replacement costs. All construction and investment costs for all project Alternatives, for Reach 3, are presented in Table 23. These same construction and investment costs for all project Alternatives, for Reach 4, are presented in Table 24.

Table 4-23
Construction and Investment Costs
Reach 3

	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 2B
Construction First Costs	$1,357,100	$1,378,500	$1,918,500	$1,925,700
Interest During Construction	$117,600	$119,400	$287,900	$288,900
Total Investment	$1,474,700	$1,497,900	$2,206,400	$2,214,600
Average Annual Investment	$111,300	$113,000	$166,500	$187,100
Average Annual Operation, Maintenance, and Replacement Costs	$77,700	$77,700	$88,500	$88,500
Total Average Annual Investment	$189,000	$190,700	$255,000	$255,600

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Table 4-24
Construction and Investment Costs
Reach 4

	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 2B
Construction First Costs	$1,552,500	$1,575,800	$2,334,300	$2,347,000
Interest During Construction	$134,500	$136,500	$350,300	$352,200
Total Investment	$1,687,000	$1,712,300	$2,684,600	$2,699,200
Average Annual Investment	$127,300	$129,200	$202,600	$203,700
Average Annual Operation, Maintenance, and Replacement Costs	$99,900	$99,900	$106,100	$106,100
Total Average Annual Investment	$227,200	$229,100	$308,700	$309,800

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

The *Expected Value and Probabilistic Values of Net Benefits* for all project Alternatives, for Reach 3, are presented in Table 25. The expected average annual net benefits for Alternative 1A are estimated to be $2,528,726 and the benefit-cost ratio is 14.38. The expected average annual net benefits for Alternative 1B are estimated to be $2,527,026, and the benefit-cost ratio is 14.25. The expected average annual net benefits for Plan 2A are estimated to be $2,668,703, and the benefit-cost ratio is 11.47. The expected average annual net benefits for Plan 2B are estimated to be $2,668,103, and the benefit-cost ratio is 11.44.

Table 4-25
Expected Value and Probabilistic Values of Net Benefits
Future-With-Project Condition
Reach 3

Project Alternative	Expected Annual National Economic Benefit and National Economic Benefit				Probability Net Benefit Exceeds Indicated Amount		
	Benefits	**Costs**	**Net Benefits**	**Benefit-Cost Ratio**	**0.75**	**0.50**	**0.25**
Alternative 1A	$2,717,726	$189,000	$2,528,726	14.38	$1,955,302	$2,531,158	$3,202,860
Alternative 1B	$2,717,726	$190,700	$2,527,026	14.25	$1,953,988	$2,529,456	$3,200,707
Alternative 2A	$2,923,703	$255,000	$2,668,703	11.47	$2,063,537	$2,671,270	$3,380,154
Alternative 2B	$2,923,703	$255,600	$2,668,103	11.44	$2,063,074	$2,670,669	$3,379,394

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

The *Expected Value and Probabilistic Values of Net Benefits* for all project Alternatives, for Reach 4, are presented in Table 26. The expected average annual net benefits for Alternative 1A are estimated to be $2,316,927 and the benefit-cost ratio is 11.20. The expected average annual net benefits for Alternative 1B are estimated to be $2,315,027, and the benefit-cost ratio is 11.11. The expected average annual net benefits for Plan 2A are estimated to be $2,413,578, and the benefit-cost ratio is 8.82. The expected average annual net benefits for Plan 2B are estimated to be $2,412,478, and the benefit-cost ratio is 8.79.

Table 4-26
Expected Value and Probabilistic Values of Net Benefits
Future-With-Project Condition
Reach 4

Project Alternative	Expected Annual National Economic Benefit and National Economic Benefit				Probability Net Benefit Exceeds Indicated Amount		
	Benefits	Costs	Net Benefits	Benefit-Cost Ratio	0.75	0.50	0.25
Alternative 1A	$2,544,127	$227,200	$2,316,927	11.20	$1,791,532	$2,319,155	$2,934,597
Alternative 1B	$2,554,127	$229,100	$2,315,027	11.11	$1,790,062	$2,317,253	$2,932,191
Alternative 2A	$2,722,278	$308,700	$2,413,578	8.82	$1,866,266	$2,415,899	$3,057,015
Alternative 2B	$2,722,278	$309,800	$2,412,478	8.79	$1,865,415	$2,414,798	$3,055,621

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

In summary, the net benefits and benefit-cost ratio for all project Alternatives remain robust with Reach 3 and Reach 4 being economically evaluated separately. Conditional Probability of Design Non-Exceedance have already been computed separately for all project SLFPS Alternatives, for Reach 3 and Reach 4 (please see Table 15 and Table 16 above).

Incremental analysis

Although the St. Louis Floodwall Protection technically functions as a system, the swing gates component and the underseepage component are evaluated incrementally.

- Assumption 1: The Underseepage Component is assumed to perform/protect from inundation *perfectly*, while the Swing Gates Component is evaluated.
- Assumption 2: The Swing Gates Component is assumed to perform/protect from inundation *perfectly*, while the Underseepage Component is evaluated.

Assumption 1: Swing Gates Component

The swing gates component is comprised of all swing gates at all 33 locations along both Reach 3 and Reach 4 (see description in the Structural Engineering section of Appendix D).

Probability of Unsatisfactory Performance (PUP). The structural branch calculated PUPs due to swing gate failure. All PUPs due to swing gate failure, as calculated under both the future-without-project and future-with-project conditions for all Alternatives, are presented in Table 27.

Table 4-27
Swing Gate PUP
Future-Without-Project and Future-With-Project Conditions

		Future-Without-Project Condition	**Future-With-Project Condition: Alternatives 1A & 1B**	**Future-With-Project Condition: Alternatives 2A & 2B**
Return Period	**Water Surface Elevation**	**Swing Gate PUP***	**Swing Gate PUP***	**Swing Gate PUP***
1 Year				
2 Year				
5 Year	412.9	0.0001	0.0001	0.0001
10 Year	416.1	0.0001	0.0001	0.0001
25 Year	420.1	0.0001	0.0001	0.0001
50 Year	423.8	0.3155	0.0022	0.0001
100 Year	426.0	0.5196	0.0150	0.0001
500 Year	429.8	0.6117	0.1201	0.0001

** Estimates for Year 2008*

Benefits. Tables 28 and Table 29 are produced from HEC-FDA model results.

Conditional Probability of Design Non-Exceedance for all project SLFPS Alternatives are presented, under the future-without-project and future-with-project conditions, in Table 28. For example, the probability of non-exceedance for the 0.2 percent (500 year) flood event for Reach 3 given Alternative 1A (e.g. the probability of Alternative 1A containing the 0.2 percent flood event for Reach 3) is estimated at 50.65 percent. This can also be stated as “the reliability of Alternative 1A containing the 0.2 percent flood event for Reach 3 is estimated at 50.65 percent.”

Table 4-28*
Swing Gate Component
Conditional Probability of Design Non-Exceedance
Future-Without-Project and Future-With-Project Conditions

Project Alternative	Conditional Probability of Design Containing Indicated Event					
	10 %	4 %	2 %	1 %	0.4 %	0.2 %
Without-Project	0.9821	0.7576	0.5629	0.4524	0.3604	0.2707
Alternative 1A	0.9998	0.9960	0.9761	0.9214	0.7352	0.5065
Alternative 1B	0.9998	0.9960	0.9761	0.9214	0.7352	0.5065
Alternative 2A	0.9999	0.9999	0.9999	0.9982	0.9549	0.8438
Alternative 2B	0.9999	0.9999	0.9999	0.9982	0.9549	0.8438

Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years

Expected Annual Inundation Damage Reduced and Distributed for all SLFPS project Alternatives under the future-with-project condition, are presented, in Table 29.

Table 4-29*
Swing Gate Component
Expected Annual Inundation Damage Reduced and Distributed
Future-With-Project Condition

Project Alternative	Expected Annual Damage			Probability Damage Reduced Exceeds Indicated Values		
	Total Without Project	Total With Project	Damage Reduced (Benefits)	0.75	0.50	0.25
Alternative 1A	$2,842,435	$732,831	$2,109,603	$1,631,221	$2,111,632	$2,672,003
Alternative 1B	$2,842,435	$732,831	$2,109,603	$1,631,221	$2,111,632	$2,672,003
Alternative 2A	$2,842,435	$351,737	$2,490,698	$1,925,898	$2,493,093	$3,154,694
Alternative 2B	$2,842,435	$351,737	$2,490,698	$1,925,898	$2,493,093	$3,154,694

Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years

Costs. The swing gates component is comprised of all swing gates at all 33 locations along both Reach 3 and Reach 4. Alternative 1A consists of replacing swing gates at 10 locations and permanently closing swing gates at 6 locations. Alternative 1B consists of reskinning swing gates at 10 locations and permanently closing swing gates at 6 locations. Alternative 2A consists of replacing swing gates at 20 locations and permanently closing swing gates at 13 locations. Alternative 2B consists of reskinning swing gates at 20 locations and permanently closing swing gates at 13 locations. Average annual costs are subsequently calculated for construction first costs as well as operations, maintenance, and replacement costs. All construction and investment costs for all project Alternatives are presented in Table 30.

Table 4-30
Swing Gate Component
Construction and Investment Costs

	Alternative 1A	Alternative 1B	Alternative 2A	Alternative 2B
Construction First Costs	$2,029,00	$2,102,800	$4,250,400	$4,285,900
Interest During Construction	$175,800	$182,200	$637,800	$643,100
Total Investment	$2,205,500	$2,285,000	$4,888,200	$4,929,000
Average Annual Investment	$166,400	$172,400	$368,900	$371,900
Average Annual Operation, Maintenance, and Replacement Costs	$17,400	$17,400	$34,400	$34,400
Total Average Annual Investment	$183,800	$189,800	$403,300	$406,300

***** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

The *Expected Value and Probabilistic Values of Net Benefits* for all project Alternatives are presented in Table 31. The expected average annual net benefits for Alternative 1A are estimated to be $1,925,803 and the benefit-cost ratio is 11.48. The expected average annual net benefits for Alternative 1B are estimated to be $1,919,803, and the benefit-cost ratio is 11.11. The expected average annual net benefits for Plan 2A are estimated to be $2,087,398, and the benefit-cost ratio is 6.18. The expected average annual net benefits for Plan 2B are estimated to be $2,084,398, and the benefit-cost ratio is 6.13.

Table 4-31
Swing Gate Component
Expected Value and Probabilistic Values of Net Benefits
Future-With-Project Condition

Project Alternative	Expected Annual National Economic Benefit and National Economic Benefit				Probability Net Benefit Exceeds Indicated Amount		
	Benefits	**Costs**	**Net Benefits**	**Benefit-Cost Ratio**	**0.75**	**0.50**	**0.25**
Alternative 1A	$2,109,603	$183,800	$1,925,803	11.48	$1,489,100	$1,927,655	$2,439,204
Alternative 1B	$5,357,632	$189,800	$1,919,803	11.11	$1,484,461	$1,921,649	$2,431,604
Alternative 2A	$5,863,184	$403,300	$2,087,398	6.18	$1,614,051	$2,089,406	$2,643,878
Alternative 2B	$5,863,184	$406,300	$2,084,398	6.13	$1,611,732	$2,086,403	$2,640,078

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

In summary, the net benefits and benefit-cost ratio for all project Alternatives remain robust when only the Swing Gate Component is economically evaluated. Conditional Probability of Design Non-Exceedance for all project SLFPS Alternatives are also comparable to evaluation results for the entire floodwall protection system (please see Table 28 above).

Assumption 2: Underseepage Component.

The underseepage component is comprised of 110 existing relief wells in the future without project condition, or 110 existing relief wells rehabilitated and 70 new relief wells in the future with project condition, at locations throughout both Reach 3 and Reach 4 (see description in the Geotechnical Engineering section of Appendix D).

Probability of Unsatisfactory Performance (PUP). The geotechnical branch calculated PUPs due to underseepage failure. All PUPs due to underseepage failure, as calculated under both the future-without-project and future-with-project conditions for all Alternatives, are presented in Table 32.

Table 4-32
Underseepage PUP
Future-Without-Project and Future-With-Project Conditions

		Future-Without-Project Condition	Future-With-Project Condition: Alternatives 1A & 1B	Future-With-Project Condition: Alternatives 2A & 2B
Return Period	**Water Surface Elevation**	**Underseepage PUP***	**Underseepage PUP***	**Underseepage PUP***
1 Year				
2 Year				
5 Year	412.9	0.0001	0.0001	0.0001
10 Year	416.1	0.0157	0.0001	0.0001
25 Year	420.1	0.4520	0.0001	0.0001
50 Year	423.8	0.7265	0.0001	0.0001
100 Year	426.0	0.8154	0.0001	0.0001
500 Year	429.8	0.9017	0.0001	0.0001

** Estimates for Year 2008*

Benefits. Table 33 and Table 34 are produced from HEC-FDA model results.

Conditional Probability of Design Non-Exceedance for all project SLFPS Alternatives are presented, under the future-without-project and future-with-project conditions, in Table 33. For example, the probability of non-exceedance for the 0.2 percent (500 year) flood event for Reach 3 given Alternative 1A (e.g. the probability of Alternative 1A containing the 0.2 percent flood event for Reach 3) is estimated at 73.92

percent. This can also be stated as "the reliability of Alternative 1A containing the 0.2 percent flood event for Reach 3 is estimated at 73.92 percent."

Table 4-33*
Underseepage Component
Conditional Probability of Design Non-Exceedance
Future-Without-Project and Future-With-Project Conditions

Project Alternative	Conditional Probability of Design Containing Indicated Event					
	10 %	4 %	2 %	1 %	0.4 %	0.2 %
Without-Project	0.6704	0.3522	0.2201	0.1454	0.0696	0.0277
Alternative 1A	0.9999	0.9999	0.9998	0.9956	0.9159	0.7392
Alternative 1B	0.9999	0.9999	0.9998	0.9956	0.9159	0.7392
Alternative 2A	0.9999	0.9999	0.9999	0.9982	0.9549	0.8438
Alternative 2B	0.9999	0.9999	0.9999	0.9982	0.9549	0.8438

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Expected Annual Inundation Damage Reduced and Distributed for all SLFPS project Alternatives under the future-with-project condition, are presented, in Table 34.

Table 4-34*
Underseepage Component
Expected Annual Inundation Damage Reduced and Distributed
Future-With-Project Condition

Project Alternative	Expected Annual Damage			Probability Damage Reduced Exceeds Indicated Values		
	Total Without Project	Total With Project	Damage Reduced (Benefits)	0.75	0.50	0.25
Alternative 1A	$5,597,186	$407,386	$5,189,800	$4,012,941	$5,194,791	$6,573,351
Alternative 1B	$5,597,186	$407,386	$5,189,800	$4,012,941	$5,194,791	$6,573,351
Alternative 2A	$5,597,186	$351,737	$5,245,450	$4,055,971	$5,250,495	$6,643,837
Alternative 2B	$5,597,186	$351,737	$5,245,450	$4,055,971	$5,250,495	$6,643,837

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

Costs. The relief well component for all four alternatives consists of redevelopment and rehabilitation of the existing 110 relief wells with chemical and mechanical methods, installing 70 new relief wells, and performing foundation investigations of damaged areas. Average annual costs are subsequently calculated for construction first costs as well as operations, maintenance, and replacement costs. All construction and investment costs for all project Alternatives are presented in Table 35.

Table 4-35
Underseepage Component
Construction and Investment Costs

	Alternative 1A	**Alternative 1B**	**Alternative 2A**	**Alternative 2B**
Construction First Costs	$5,983,800	$5,986,500	$5,987,900	$5,990,200
Interest During Construction	$518,400	$518,600	$898,500	$898,800
Total Investment	$6,502,200	$6,505,100	$6,886,400	$6,889,000
Average Annual Investment	$490,700	$490,900	$519,700	$519,900
Average Annual Operation, Maintenance, and Replacement Costs	$160,700	$160,700	$160,700	$160,700
Total Average Annual Investment	$651,400	$651,600	$680,400	$680,600

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

The *Expected Value and Probabilistic Values of Net Benefits* for all project Alternatives are presented in Table 36. The expected average annual net benefits for

Alternative 1A are estimated to be $4,538,400 and the benefit-cost ratio is 7.97. The expected average annual net benefits for Alternative 1B are estimated to be $4,538,200, and the benefit-cost ratio is 7.97. The expected average annual net benefits for Plan 2A are estimated to be $4,565,050, and the benefit-cost ratio is 7.71. The expected average annual net benefits for Plan 2B are estimated to be $4,564,850, and the benefit-cost ratio is 7.71.

Table 4-36
Expected Value and Probabilistic Values of Net Benefits
Future-With-Project Condition

Project Alternative	Expected Annual National Economic Benefit and National Economic Benefit				Probability Net Benefit Exceeds Indicated Amount		
	Benefits	Costs	Net Benefits	Benefit-Cost Ratio	0.75	0.50	0.25
Alternative 1A	$5,189,800	$651,400	$4,538,400	7.97	$3,509,255	$4,542,765	$5,748,294
Alternative 1B	$5,357,632	$651,600	$4,538,200	7.97	$3,509,100	$4,542,565	$5,748,040
Alternative 2A	$5,863,184	$680,400	$4,565,050	7.71	$3,529,861	$4,569,440	$5,782,048
Alternative 2B	$5,863,184	$680,600	$4,564,850	7.71	$3,529,707	$4,569,240	$5,781,795

**** Price level: November 2003; Discount Rate: 5.625%; Base Year: 2008; Evaluation Period: 25 years***

In summary, the net benefits and benefit-cost ratio for all project Alternatives remain robust when only the Underseepage Component is economically evaluated. The Conditional Probability of Design Non-Exceedance for all project SLFPS Alternatives is also comparable to evaluation results for the entire floodwall protection system (see Table 33).

5. DESCRIPTION OF THE SELECTED PLAN

5.1. Plan Components

Alternative 2A is the Selected Plan, which is also the National Economic Development (NED) Plan. This plan will replace swing gates at 20 locations, permanently close gates at 13 locations, mechanically and chemically correct the existing 110 relief wells, and add 70 new relief wells. Twelve of the 20 closure structure locations for replacement use single gates, eight of the closure structures are double gates; therefore the total number of swing gates to be replaced is 28. Construction will include planting of bottomland hardwoods to mitigate for the one-tenth of an acre of impact.

5.2. Design and Construction Considerations

The study team conducted geotechnical, structural, design and cost analyses to determine the optimal recommended plan. Anticipated underseepage conditions and closure structure failure probabilities were key factors driving the need for, and characteristics of, the proposed deficiency corrections.

5.3. LERRD Considerations

LERRD is the acronym for Lands, Easements, Relocations, Rights of Way, and Disposal areas. On flood control projects the non-Federal sponsor is required to provide LERRD as a portion of its cost sharing requirements. The city of St. Louis owns a permanent easement 25-feet-wide on both sides of the flood protection system for operation and maintenance. The city of St. Louis will not need new land acquisition or new easements to address the deficiency corrections. Rights of entry may be needed to traverse private property with surveying or construction equipment.

5.4. Operation and Maintenance Considerations

Upon completion of the selected plan, the city of St. Louis will be responsible for Operation, Maintenance, Repair, Rehabilitation and Replacement (OMRR&R) of the project. The new closure structures will be considerably easier to maintain than the existing closure structures, which had areas inaccessible for cleaning and painting and hastened gate deterioration. The new closures will also be sturdier than the existing closure structures, which will lead to longer component life. The increased number of relief wells and additional relief well maintenance requirements will cost more than the existing system, but is necessary to insure underseepage control.

5.5. Plan Accomplishments

The Selected Plan will correct design deficiencies in the existing St. Louis Flood Protection System. This will greatly reduce the probability of system failure, which would result in flooding of about 3160 acres of mostly industrial and commercial land.

5.6. Summary of Economic, Environmental and Other Social Effects

The Selected Plan has average annual net benefits of $4,562,981 and a substantial benefit-to-cost ratio of 5.21 to 1.0. Environmental impacts are negligible, with an estimated one-tenth of one acre of bottomland hardwoods impacted, which will be offset with the planting of the same amount of bottomland hardwoods.

6. PLAN IMPLEMENTATION

6.1 Institutional Requirements, Plan Responsibilities, and Cost Sharing

Federal laws and regulatory precedents have established the traditional basis for federal and non-federal responsibilities in the construction and operation and maintenance of Federal water projects. The basic principle governing the development of specific cost-sharing policies is that, whenever possible, the cost of services produced by water projects should be paid by their direct beneficiaries. The traditional first cost of construction for the Recommended Plan and the currently estimated breakdown of Lands, Easements, Rights of Way, Relocations, and Disposal areas (LERRD), credit work, and cash contributions are displayed in Table 6.1. Cost sharing is based on Public Law 99-662, the Water Resources Development Act of 1986, as amended. The Water Resources Development Act of 1996 amended cost-sharing for flood control projects to 65% Federal, 35% Non-Federal for construction. Operation, maintenance, repair, replacement, and rehabilitation of the project are 100% non-Federal responsibilities.

Table 6.1. Cost-Sharing Allocation for the Recommended Plan
(October 2004 Price Level)

	Federal	Non-Federal	Total
PED	$929,000	$310,000	$1,239,000
Construction			
5% Cash		$512,000	$512,000
LERRD		$0[1]	$0
Additional Cash	$5,725000	$2,762000	$8,487,000
Total	$6,655,000	$3,583,000	$10,238,000

1/ The total non-Federal LERRD requirements for the recommended plan are estimated to be $0, since the non-Federal sponsor has a permanent easement for the existing project.

6.2. Remaining Work and Time Schedule

After the final report receives review and approval by the Mississippi Valley Division and the Chief of Engineers, the St. Louis District will begin design efforts and create plans and specifications for the first item of construction. Since the project is authorized no further authorization is required from Congress. Concurrently the Chief of Engineers will request approval to sign a Project Cooperation Agreement from the Assistant Secretary of the Army for Civil Works, and include construction funds for this project in the annual budget request. Upon receiving approval and construction funding, the Corps of Engineers and the city of St. Louis will execute the Project Cooperation Agreement. The draft schedule has preconstruction engineering and design continuing through fiscal year 2006, followed by project construction in fiscal years 2007 and 2008. Following completion of project construction, or any separable units, local interests would be responsible for continuing appropriate operation and maintenance.

6.3. Views of Non-Federal Sponsor.

As shown by the signing of the Design Agreement and contribution of funds to the reconstruction evaluation effort, the local sponsor continues to strongly support the current study investigation. The sponsor's preferred project alternative is Plan 2A (the identified NED/EQ and Recommended Plan).

7. SUMMARY OF COORDINATION, PUBLIC VIEWS AND COMMENTS

The St. Louis has coordinated with the U.S. Fish and Wildlife Service and Missouri Department of Conservation with respect to plant and animal species of concern, and the Natural Resources Conservation Service about potential conversions of land to nonagricultural use. The cultural resources compliance work has included initial consultation with the Missouri State Historic Preservation Office staff.

From its outset, basic environmental considerations have been an integral part of the study's plan formulation process. The report's Environmental Assessment (EA) and Draft Finding of No Significant Impact (FONSI) in Appendix A serve to inform the reviewer of the project's environmental concerns, which are minimal.

In addition to coordinating with the city of St. Louis, the FM Global insurance company has shown considerable interest in the condition of the existing flood protection system since they insure manufacturing plants protected by the system. Grace Hill neighborhood Services and Trailnet, Inc. have met with the Corps of Engineers in relation to their desire for improved recreation facilities along the North Riverfront Trail that is on the levee or adjacent to the floodwalls of the flood protection system.

8. RECOMMENDATIONS

I recommend that Plan 2A, consisting of replacement of all closure structures, the installation of new relief wells, and a restoration of existing relief wells, be authorized for implementation to provide flood control improvements for the city of St. Louis, Missouri. Plan 2A is the National Economic Development Plan and the Environmental Quality Plan. This is contingent upon such discretionary modifications as deemed necessary by the Chief of Engineers, and funding requirements satisfactory to the Administration and Congress. The estimated total project cost, based on October 2004 price levels, is $10,238,000. This recommendation is made with the provision that prior to implementation, non-federal interests will agree to comply with the following requirements:

(1) Enter into an agreement to provide, prior to execution of the project cooperation agreement, 25 percent of design costs;

(2) Provide during construction, any additional funds needed to cover the non-Federal share of design costs;

(3) Provide all lands, easements, and rights-of-way, including suitable borrow and dredged or excavated material disposal areas, and perform or ensure the performance of all relocations determined by the Government to be necessary for the construction, operation, and maintenance of the project;

(4) Provide or pay to the Government the cost of providing all retaining dikes, waste weirs, bulkheads, and embankments, including all monitoring features and stilling basins, that may be required at any dredged or excavated material disposal areas required for construction, operation, and maintenance of the Project;

(5) During construction, provide a cash contribution equal to 5 percent of total project costs, and any additional costs as necessary to make the total non-Federal contributions at least 35 percent but not to exceed 50 percent of total project costs allocated to flood damage reduction and 50 percent of the total project costs allocated to recreation.

b. Provide the non-Federal share of that portion of the costs of mitigation and data recovery activities associated with historic preservation that are in excess of one percent of the total amount authorized to be appropriated for the project, in accordance with the cost-sharing provisions of the agreement;

c. For so long as the project remains authorized, operate, maintain, repair, replace, and rehabilitate the completed project, or functional portion of the project, at no cost to the Government, in accordance with applicable Federal and State laws and any specific directions prescribed by the Government;

d. Give the Government a right to enter, at reasonable times and in a reasonable manner, upon land which the non-Federal sponsor owns or controls for access to the project for the purpose of inspection, and, if necessary, for the purpose of completing, operating, maintaining, repairing, replacing, or rehabilitating the project;

e. Comply with Section 221 of Public Law 91-661, Flood Control Act of 1970, as amended, and Section 103 of the Water Resources Development Act of 1986, Public Law 99-662, as amended, which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof until the non-federal sponsor has entered into a written agreement to furnish its required cooperation for the project or separable element;

f. Hold and save the Government free from all damages arising from the construction, operation, maintenance repair, replacement, and rehabilitation of the project and any project-related betterments, except for damages due to the fault or negligence of the Government or the Government's contractors;

g. Keep and maintain books, records, documents, and other evidence pertaining to costs and expenses incurred pursuant to the project to the extend and in such detail as will properly reflect total project costs for a minimum of three years after completion of the accounting for which such books, records, documents and other evidence are required;

h. Perform, or cause to be performed, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements of rights-of-way necessary for the construction, operation, and maintenance of the project; except that the non-Federal sponsor shall not perform such investigations on lands, easements, or rights-of-way that the Government determines to be subject to the navigation servitude without prior specific written direction by the Government;

i. Assume complete financial responsibility for all necessary cleanup and response costs of any CERCLA- regulated materials located in, on, or under lands, easements, or rights-of-way that the Government determines necessary for the construction, operation, or maintenance of the project;

j. To the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERLA;

k. Prevent obstructions of, or encroachments on, the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) that might reduce the flood control, hinder its operation and maintenance, or interfere with its proper function, such as any new development on project lands or addition of facilities that would degrade the benefits of the project;

l. Comply with the applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public law 91-646, as amended by title IV of the Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17), and the Uniform Regulations contained in 49 CFR part 24, in acquiring lands, easements, and rights-of-way, and performing relocations for construction, operation, and maintenance of the project, and inform all affected persons of applicable benefits, policies, and procedures in connection with said act;

m. Do not use Federal funds to meet the non-Federal sponsor's share of total project costs unless the Federal granting agency verifies in writing that the expenditure of such funds is authorized.

n. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable federal labor standards requirements including, but not limited to, 40 U.S.C. 3141-3148 and 40 U.S.C. 3701-3708 (revising, codifying and enacting without substantive change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.) and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c)).

o. Provide and maintain necessary access roads, parking areas, and other public use facilities, open and available to all on equal terms.

The recommendation contained herein reflects the information available at this time and current departmental policies governing formulation of individual projects. It does not reflect program and budgeting priorities inherent in the formulation of a national civil works construction program or the perspective of higher review levels within the executive branch. Consequently, the recommendation may be modified before it is transmitted to the Congress as a proposal for authorization and implementation funding. However, prior to transmittal to the Congress, the non-Federal sponsors, the States, interested Federal agencies, and other parties will be advised of any significant modifications and will be afforded the opportunity to comment further.

C. KEVIN WILLIAMS
COL, EN
Commanding

APPENDIX A

ENVIRONMENTAL ASSESSMENT
WITH
DRAFT FINDING OF NO SIGNIFICANT IMPACT

ENVIRONMENTAL ASSESSMENT
WITH
DRAFT FINDING OF NO SIGNIFICANT IMPACT

PROPOSED RECONSTRUCTION OF THE
FLOOD PROTECTION SYSTEM

CITY OF ST. LOUIS, MISSOURI

I. Introduction

A. Project Location The St. Louis Flood Protection system is located in the City of St. Louis, Missouri, and extends for about 11 miles along the right descending bank of the Mississippi River, between river miles 187.2 and 176.3 above the mouth of the Ohio River. The confluence with Maline Creek (river mile 187.2) demarks the system's northern limit, and Chippewa Street approximates its southern limit (river mile 176.3).

The existing flood protection system is a combination of concrete floodwalls (35,614 feet) and earthen levees (20,700 feet), along with 28 pump stations, 110 relief wells, various street and railroad closure structures, gravity drains, and pressure sewer emergency closure gatewells. About 3,160 acres of industrial and commercial development are protected from Mississippi River flooding by the system. This protected area consists of two reaches, just north and south of downtown St. Louis, separated by high ground (Figure EA-1). Reach 3, north of downtown, extends from river mile 187.2 to 180.2. It protects 2,530 acres subject to flooding. Reach 4, just south of downtown, extends from river mile 179.3 to 176.3. It protects 630 acres subject to flooding.

Besides providing protection against flooding from the Mississippi River, the system also removes drainage from the flood-protected bottomland (the "interior") resulting from rainfall, run-off, and seepage. A series of 28 pump stations located along the floodwall/levee remove interior drainage and send it to the river. The City of St. Louis has operation and maintenance responsibilities for the flood protection system. The exceptions are the pump stations, gravity drains, and emergency closure gatewells, which are operated and maintained by the Metropolitan St. Louis Sewer District (MSD).

B. Current Problems With groundbreaking in 1959 and project completion in 1974, project components are 25 to 40 years old. Some components are nearing their design life expectancy. During the flood of 1993, which at its peak attained a height less than the project's design, a short section of the flood protection system failed. Quick, extensive emergency actions by the City of St. Louis, MSD, and St. Louis District of the Corps of Engineers prevented a large portion of the City of St. Louis from flooding. Significant potential problems identified with the project during 1993 include under seepage, foundation piping (which caused the failure in 1993), insufficient freeboard, pipe crossing, and toe drains and relief wells. The St. Louis District is completing a Reconstruction Evaluation Study to examine whether or not problems with the system are due to design or construction deficiency, lack of maintenance, or advanced age.


MALINE
CR
MOSENTHIEN
ISLAND
CHAIN OF ROCKS CANAL
LOCKS 27
REACH 3
Broadway
W. Florissant Ave.
Bircher Blvd.
185
MERCHANTS BRIDGE
McKINLEY BRIDGE
Natural Bridge Ave.
N. Florissant
Ave.
MISSOURI
ILLINOIS
MISSISSIPPI
Cass Ave.
Martin
Luther King
Blvd.
Washington
Ave.
Market
St.
St.
St. Louis
MARTIN LUTHER KING BRIDGE
EADS BRIDGE
180
JEFFERSON NATIONAL EXPANSION MEMORIAL AREA
Poplar
St.
Chouteau
Ave.
12th
POPLAR STREET BRIDGE
MAC ARTHUR BRIDGE
REACH 4
Jefferson Ave.
RIVER
Gravois
Ave.
Arsenal St.
Broadway
Chippewa St.
Meramec St.
175
SCALE IN MILES
1
0
1
2
LEGEND
Floodwall
Levee
Pumping Station
Protected Area From Mississippi River

Figure EA-1

C. Project Purpose The purpose of this study is to evaluate the federal interest in addressing the significant potential problems in the City of St. Louis Flood Protection System. Federal participation is allowed to address design deficiencies, which is the primary emphasis of this study, or to examine the need for reconstruction due to advanced age.

D. Limits of Scope The scope of this study does not include evaluating the feasibility of expanding the geographic area that is provided flood protection. The geographic scope of the area addressed in this document is the St. Louis Flood Protection System (floodwall, levee, gates, pump stations, etc.), the areas protected from flooding in reaches 3 and 4, and aquatic areas bordering the area of protection, specifically Maline Creek and the Mississippi River.

II. Project Authorization The flood protection project was authorized for construction by Public Law 84-256, 9 August 1955. Construction began in 1959 and was completed in 1974.

III. Description of Existing Environment

A. Topography and Geology The City of St. Louis is built upon the remnants of an upland surface that rises gently away from the Mississippi River to an average elevation of 550 feet NGVD. The flood plain of the river on the west (right descending) bank does not generally exceed one mile in width. Most land protected from flooding by the floodwall/levee ranges in elevation from about 410 to 420 feet NGVD. Ground elevations along the floodwall/levee are about 410 feet NGVD at the northern end of the structure, and about 405 feet NGVD at the southern end.

In the floodplain, unconsolidated surface materials include naturally deposited alluvium and man-made fill in the form of cinders, concrete rubble, and domestic and industrial waste. Alluvium is composed of a bottom layer of coarse gravels with some cobbles and boulders overlain by thicker sections of sand. The top stratum of naturally deposited materials consists of 10 to 30 feet of silts and clays. Consolidated materials lying below surface materials include the Pennsylvanian Formations, consisting of shales, sandstones, and clays, and thick limestone deposits of Mississippian Age. Man-made fills vary in thickness from 5 to 60 feet.

B. Land Cover Much of the bottomland in the flood-protected area is urban, and consists of primarily industrial and commercial areas. Some residential areas are intermixed. Cropland is absent, including riverside of the floodwall/levee. Grassy areas or abandoned fields occur on formerly developed sites. Forested areas are typically narrow and linear, and occur mainly along the margins of the Mississippi River and Maline Creek.

C. Socioeconomic Resources While the flood-protected area is not large, it represents a significant portion of the heavy industrial and manufacturing base in St. Louis. These activities employ numerous people. The area also includes some residential neighborhoods. Commercial development also exists, and some attracts tourism, such as Laclede’s Landing. Farming does not occur in the flood-protected area or on the riverside of the floodwall/levee. Railroads service industry within the protected area, and tracks often parallel the floodwall/levee on the interior side. Many of the flood plain industries rely on the Mississippi River to receive and/or ship goods and commodities. Some commodities are moved via aerial facilities that cross over the flood protection system to the river, whereas trucks move other goods. Interstate 55/70/64 crosses the Mississippi River between reaches 3 and 4 via the Poplar Street Bridge. The North Riverfront Trail is a greenway consisting of a walking and biking trail, and is located on or adjacent to the flood protection system.

D. Prime Farmland No farmland exists within the flood-protected area, or riverside of the floodwall/levee. Four types of soil occur within a 200-foot wide buffer around the floodwall/levee, according to the digital soil survey of the City of St. Louis and St. Louis County (NRCS 1998). They include, in decreasing order of abundance, "Urban land, bottom land, 0-3 percent slopes" (57 %), "Fishpot-urban land complex, 0-5 percent slopes" (12%), "Blake-Eudora-Waldron complex" (10%), and "Urban land, upland, 0-5 percent slopes" (9%). "Water" constitutes the remaining area in this buffer (10%). None of these soils are considered by the Natural Resources Conservation Service as prime for the production of crops, except for the "Blake-Eudora-Waldron complex", which is prime only if it is protected from flooding or not frequently flooded during the growing season (Benham 1982).

E. Hydrologic Conditions As originally designed, the St. Louis Flood Protection System protected against a 200-year or .005-probability event. This was based on protecting against the estimated flow volume of the record flood in 1844, estimated to be approximately 1,300,000 cubic-feet-per-second, or 52 feet on the St. Louis gage. However, the hydrology of the Mississippi River basin has changed considerably since project authorization. Even at the current height of protection, St. Louis District hydrologic engineers estimate that the flood protection system might well provide protection against 500-year or greater events. Interior drainage is handled by a series of natural drainage ways, ditches, and pump stations. As part of the levee system, relief wells are located landside of the levee to help relieve hydrostatic pressure by allowing ground water to flow to the ground's surface. This flow is carried to the nearest pump station along the landside toe of the floodwall/levee via an existing shallow surface ditch or underground collector system.

F. Surface Water Resources Other than the Mississippi River and Maline Creek, there are no surface water resources within the project area in the bottomland. Any surface tributaries that historically traversed the flood-protected area have long since been enclosed within underground conduits.

G. Ground Water Resources Unconsolidated alluvial and glacial materials of the Mississippi River floodplain contain an aquifer that changes in response to variations in the level of the Mississippi River, rainfall-infiltration, and man-induced ditching and pumping. In contrast to surface water flow, groundwater flow in the aquifer is a relatively slow process since the groundwater must move through these unconsolidated materials. Thus, groundwater levels vary primarily with seasonal and long-term variations in river levels, rainfall, and groundwater pumpage. Under normal circumstances, groundwater in the bottoms flows slowly into the Mississippi River. Under high Mississippi River levels, groundwater movement can reverse itself and flow toward the "interior". The highest groundwater levels are achieved when rainfall is above average and river levels are high and of long duration.

When Mississippi River stages are elevated high enough, groundwater will flow up the 110 existing relief wells located in reaches 3 and 4 and reach the ground's surface. Relief well flow is then directed to the nearest pumping station to be pumped into the Mississippi River. Industrial contamination of the groundwater aquifer is a possibility given past and present industrial development.

H. Hazardous, Toxic, and Radioactive Waste Heavy industry has been the dominant land use in the flood-protected area for over a century. The Missouri Department of Natural Resources has an inventory of industrial sites known to have hazardous wastes. The area protected by the St. Louis Flood Protection System has sites containing dioxin, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and the former Thompson Chemical Company site, where Agent Orange defoliant was produced from about 1950 to 1968. There are also many industrial sites protected by the flood protection system that manufacture, utilize, and store a wide variety of chemicals, such as those used in metal plating and the manufacture of surfactants. In Reach 3, PAHs and VOCs were encountered in groundwater pumped from a few existing relief wells during testing by the District in 1999-2000. Finally, one of the region's largest wastewater treatment plants is protected by the flood protection system. Failure of the flood protection system would send millions of gallons of untreated waste into the floodplain and the Mississippi River.

There is one Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, commonly known as Superfund) site in the area. The St. Louis Downtown Site, owned and operated by Mallinckrodt, Inc., is in Reach 3 and undergoing cleanup by the St. Louis District under the Formerly Utilized Sites Remedial Action Program (FUSRAP). Ongoing remediation of soils contaminated with radioactive materials is expected to be complete in less than ten years.

I. Biological Resources Because the flood-protected area is highly developed, there are no significant biological resources landside of the floodwall/levee. Terrestrial biological resources occur riverside of the floodwall/levee. Woody vegetation consisting of trees and shrubs grows along Maline Creek and the Mississippi River, mainly north of the Merchants Street Bridge. To the south of this bridge, forest along the left descending bank is lacking. Forest along the river has relatively low ecological importance because it is narrow and fragmented, and this is due to the close proximity of the floodwall/levee to the river, and the historic and current industrial land uses adjacent to the structure. This forest and the abandoned lands along the floodwall/levee serve as the primary wildlife habitat in the project area, and most wildlife species are adapted to human disturbance. Due to the highly developed nature of the project area, a relatively high proportion of plant species are non-native. The Mississippi River is an aquatic resource of major significance, and provides habitat to numerous species of invertebrates, fish, and birds. Wetlands subject to Section 404 of the Clean Water Act are present within the project area. They are limited in extent, and generally include forested areas riverside of the floodwall/levee, and scattered relatively small depressions landside of the structure that impound water (consisting of rainfall and local runoff) on a temporary basis, as a result of excavation or diking activities associated with development.

J. Threatened and Endangered Species In compliance with Section 7(c) of the Endangered Species Act of 1973, as amended, the St. Louis District requested that the U.S. Fish and Wildlife Service (USFWS) provide a listing of Federally threatened or endangered species, currently classified or proposed for classification, that may occur in the vicinity of the St. Louis Flood Protection System. In a letter dated June 10, 2003 from the Marion, Illinois, suboffice, the USFWS provided a list of 8 species for the vicinity of the proposed project area. They include the bald eagle (*Haliaeetus leucocephalus,* threatened), least tern (*Sterna antillarum,* endangered), gray bat (*Myotis gricescens,* endangered), Indiana bat (*Myotis sodalis,* endangered), pallid sturgeon (*Scaphirhynchus albus,* endangered), pink mucket pearly mussel (*Lampsilis abrupta*, endangered), scaleshell (*Leptodea leptodon*, endangered), and running buffalo clover (*Trifolium stoloniferum*, endangered). The letter also stated that no designated critical habitat for any of these species currently occurs in the project area.

In a letter dated March 31, 2003, the Missouri Department of Conservation (MDOC) reported that the state's Heritage Database includes records of six state-listed threatened or endangered species that may occur in the vicinity of the project area. They include the state and federally endangered pallid sturgeon, the state and federally endangered interior least tern, the state endangered and federally threatened bald eagle, the state endangered peregrine falcon (*Falco peregrinus*), the state endangered lake sturgeon (*Acipenser fulvescens*), and the state endangered paddlefish (*Polyodon spathula*). No additional resources of concern, such as sensitive communities, were identified by MDOC. Information describing each of these federally- and state-listed species follows.

Federally Listed Species

<u>Bald eagle</u> Bald eagles winter along the major rivers of Illinois and Missouri, and at scattered locations some remain throughout the year to breed. Perching and feeding occurs along the edge of open water, from which eagles obtain dead fish. The Mississippi River is a focal point for wintering eagles, especially upriver of the project area in the vicinity of Alton. Nesting has been observed on islands near the confluence with the Illinois River, upriver from Alton.

<u>Least tern</u> No known nesting habitat of the least tern occurs within the study area or adjacent reach of the Mississippi River, but recent nesting colonies have been recorded from southern Illinois in Jackson and Alexander Counties (Herkert 1992). Nesting areas are sparsely vegetated sand and gravel bars within a wide, unobstructed river channel. Nesting locations usually are at the higher elevations and away from the water's edge. The least tern has occasionally been observed across from St. Louis at Horseshoe Lake in Madison County, Illinois, during spring migration in recent years (McMullen 2001). This bird forages for small fish in shallow water areas along the river and in backwater areas, such as side channels and sloughs.

<u>Gray bat</u> Gray bats are presently known from only several counties in west-central and extreme southern Illinois; the species' historical distribution includes Madison county (Herkert 1992). Gray bats roost in caves year around, but no caves occur in Madison County. Winter caves are deep and vertical, and provide a large volume below the lowest entrance to act as cold air traps. A much wider variety of cave types are used during spring and fall transient periods.

In summer, maternity colonies prefer caves that act as warm air traps or that provides restricted rooms or domed ceilings that are capable of trapping the combined body heat from thousands of clustered individuals. Summer caves, especially those used by maternity colonies, are nearly always located within a kilometer of rivers or reservoirs over which they feed. Except for brief periods of inclement weather in early spring and possibly late fall, adult gray bats feed almost exclusively over water along river or reservoir edges.

Indiana bat Indiana bats also winter in caves or mines (Herkert 1992), but none of these features are known in the vicinity of Madison County. Females use trees in the summer months as nursery roosts, and forage for insects in the tree canopy. Trees preferred for maternity roosting in Illinois have included dead individuals with shaggy or loose bark, and diameters at breast height (dbh) often greater than 10 inches. Species have included slippery elm, American elm, northern red oak, white oak, post oak, shagbark hickory, bitternut hickory, cottonwood, silver maple, green ash, white ash, and sycamore (Hofmann 1994). Live shagbark hickory trees with loose bark or cavities are also used. Males have been known to roost in shingle oak, sassafras, and sugar maple (Hofmann 1994).

Pallid sturgeon This fish is found in the Mississippi River downstream of its confluence with the Missouri River. The entire stretch of river below the mouth of the Missouri River is considered potential habitat. Little is known of its habitat preferences. Pallid sturgeon are most frequently caught over a sand bottom, which is the predominant bottom substrate within the species' range on the Missouri and Mississippi Rivers. Pallid sturgeons have been found in water 1.2 to 7.6 meters deep with velocities of 0.33 to 90 centimeters per second (USFWS 1993). These data probably better reflect where data have been collected rather than actual habitat preferences. Recent tag returns have also shown that the species may be using a range of habitats in off-channel areas, including tributaries, of the Mississippi River.

Pink mucket pearly mussel This species is known from the lower Mississippi and Ohio River systems, and is found in large rivers with substrates of sand and gravel (Cummings and Mayer 1992).

Scaleshell This mussel is known from the Mississippi and Ohio River systems, and lives in large rivers with mud bottoms (Cummings and Mayer 1992).

Running buffalo clover This plant, a native clover of Missouri, is believed to have originally inhabited the ecotone between open forest and prairie in the eastern and central U.S. (MDC 2003, USFWS 1992). The species apparently depended on grazing and disturbance by large animals such as the buffalo for population viability (MDNR 2003, WVDNR 1998), and partial shading also appears to have been an important component of its original habitat (WVDNR 1998). Current habitats include disturbed bottomland meadows (USFWS 2003) and areas with rich moist soils that are subjected to mowing, trampling, or grazing, especially disturbed areas in woodlands (MDC 2003). In addition to two natural sites in Missouri, the plant is known from St. Louis where it was observed on an unattended load of topsoil (MDC 2003).

State Listed Species

Peregrine falcon This bird nests in downtown St. Louis (McMullen 2001), and a successful nest was reported from the I-270 bridge over the Mississippi River in 1996 (USDOT 2000), about three miles north of the northern limit of the study area. The peregrine falcon occurs as a rare migrant in Illinois from early April to mid May, and early September to November. Nests are usually located on rock ledges, bluffs, vertical escarpments, river gorges, and watergaps with precipitous cliffs; however, tree sites and city buildings may also be used. Peregrines hunt over waterways, wetlands, and open fields where they feed almost exclusively on birds in flight.

Lake sturgeon In Illinois, this fish is known from the Mississippi River, and has been recorded since 1980 from the reach adjacent to Madison County (Herkert 1992). The lake sturgeon inhabits lakes and large rivers, and occurs on the bottom usually in relatively deep water (4-9 meters) over substrates consisting of mud, sand, and gravel (Herkert 1992).

Paddlefish In Missouri, this fish historically inhabited large, free-flowing rivers, such as the Mississippi, Missouri, and Osage, but overharvest and habitat destruction have led to its decline (Pfleiger 1997). It feeds on microcrustaceans and insect larvae that are filtered from the water with its long, gill rakers. It spawns in large, free-flowing rivers over gravel bars.

K. Recreation An asphalt trail (10.6 miles long) currently exists along the riverfront in St. Louis. Most of this trail is within the study area, but the portion north of Maline Creek is outside the study area. The area surrounding the trail varies greatly, from urban warehouse district, industrial trucking and railroad yards, to semi-natural areas that serve as wildlife habitat. The trail travels through a part of St. Louis' industrial beginnings and along the edges of many old St. Louis neighborhoods. The trail follows the margin of the river, at times on the west side (landside) of the floodwall, or along the east side (riverside) of the floodwall, or on top of the levee where it travels for much of its length. The trail surface and preliminary signing and striping have been completed. Very few trail amenities or safety features have been installed along the trail. There are no connections yet developed between the trail and surrounding neighborhoods. The limited number of openings in the floodwall and access roads to the levee define how access to/from adjacent neighborhoods and cultural and historic sites can be routed. The Gateway Arch, part of the National Park Service's Jefferson National Expansion Memorial, is located along the Mississippi River on relatively high ground in between the flood-protected reaches 3 and 4.

L. Aesthetics Aesthetics of the project area are variable, and depend on location. Landside of the floodwall/levee, the project area is not aesthetically attractive because of the high degree of industrial development. The "greenway" occurring along the floodwall/levee is more pleasant, and is considered to be an amenity of the riverfront trail. From the trail, view corridors to the east are present, and include the Mississippi River, especially from atop the levee. Aesthetically unpleasant aspects of the trail include littering and illegal dumping of trash, and vandalism of recreation facilities. The Gateway Arch and surrounding park-like grounds attract visitors from around the world.

M. Historic Properties Based upon information recorded and observed in surviving nineteenth century written records, we know that much of the St. Louis Riverfront Project Area has been occupied, on a more or less on a continuing basis, for at least 1,000 years. Prior to the arrival of the Europeans toward the end of the seventeenth century, the area was home to various Native American groups. The most significant prehistoric occupation of the area occurred between 800-900 years ago, when groups of villagers representing the Mississippian Culture established a large settlement within the project area. These people constructed at least 27 large, ceremonial mounds on the high ground overlooking the Mississippi River. The modern City of St. Louis was an outgrowth of a small trading post established by French merchants in the spring of 1764. Shortly after the arrival of the first steamboat to the fledgling village in 1817, the population of the area increased dramatically and by 1850, the City of St. Louis was one of the fastest growing urban centers in the United States. Factories and warehouses, supplying all manner of goods to western-bound emigrants, soon supplanted and replaced the residential dwellings of the original French settlers along the riverfront. Today, railroad lines, highways, and commercial structures transect the riverfront area. During the mid- 1960s, the St. Louis Floodwall was built to protect the central core of the urban center from the effects of potentially catastrophic flooding from the Mississippi River.

N. Air Quality Six criteria pollutants are addressed in the National Ambient Air Quality Standards, and they include particulate matter, sulfur dioxide, ozone (or smog), carbon monoxide, lead, and nitrogen dioxide. Air quality trends during the period 1992-2001 for the St. Louis MO-IL metropolitan statistical area include a statistically significant decrease in concentration of sulfur dioxide, and no change in the levels of nitrogen dioxide, ozone, or particulates (USEPA 2002). The region is in attainment for all pollutants, with the exception of ozone. From 1991-2003, the entire region was considered to be in “moderate” non-attainment for ozone. In January 2003, the area’s status was reclassified as “serious” non-attainment, but in May 2003 it was determined to meet the one-hour ozone standard (USEPA 2003b). In April 2004, the St. Louis area was designated by the USEPA as a moderate non-attainment area for the eight-hour ozone standard (East-West Gateway 2004).

O. Noise Noise is generated at many of the project area’s industrial and commercial areas. Transportation-related noise, such as that created at railroads, major highways, and water-borne facilities, is also common.

III. Future Without Project (No Action) The protected area has been completely developed, although some tracts are underutilized or vacant. The City of St. Louis is acquiring many parcels and promoting them for redevelopment. Piecemeal redevelopment is expected to continue. The protected area is expected to remain as a largely industrial and commercial corridor. As the flood protection system continues to age, many components of the system will reach their design life. Operation and maintenance difficulties will increase over time, especially regarding closure structures. Flood fighting could be especially difficult if underseepage issues are not addressed. Even with proper maintenance, continued deterioration of the system and lack of correction will threaten the ability of the flood protection system to prevent interior damages from a major flood. Public safety will continue to be jeopardized. These assessments are reflected in Table EA-1 under the No Action column.

If the City of St. Louis experiences a flood protection system failure during a major flood, inundation damages have been estimated at upwards of $1.0 billion dollars in the City of St. Louis. Many people live in the protected area, and thousands of people work in the protected area. The city of St. Louis would face potential loss of life, job loss, property loss, and lost industrial production. The city of St. Louis and areas downstream would also incur significant environmental degradation due to the many chemical plants and a radioactive waste site in the protected area. Failure of the flood protection system would inundate areas that have nuclear contaminants, superfund sites, a sewage treatment plant, and industries such as plating factories. These contaminants would be redistributed within the floodplain and carried into the Mississippi River. Effects of a flood protection system failure are not reflected in Table EA-1.

IV. Alternatives Considered and Recommended Plan In addition to "doing nothing", which is considered the "No Action" alternative, four plans or action alternatives were formulated to address the problems associated with the flood protection system. All action alternatives assume the need for 70 new relief wells and the mechanical correction of the existing 110 relief wells. Of the 40 closure structures, the seven panel type closures function properly and will not require any corrections. Only the 33 swinging gate closure structures are considered for corrective action.

Alternative 1A: Replace swing gates at 10 locations, permanently close swing gates at 6 locations, mechanically correct the existing 110 relief wells, add 70 relief wells.

Alternative 1B: Reskin gates at 10 locations, permanently close swing gates at 6 locations, mechanically correct the existing 110 relief wells, add 70 relief wells.

Alternatives 1A and 1B would address only the swing gates in the worst condition, and allow the remaining swing gates with rusting problems to deteriorate. Six of the worst sixteen gates can be permanently closed due to lack of need. The other ten would be reskinned or replaced. The assumption with these alternatives is that the risk of failure is low enough on the remaining gates that it would be an economically prudent choice, even with the possibility of future flood fight funding and P.L. 84-99 funding being needed.

Alternative 2A: Replace swing gates at 20 locations, permanently close gates at 13 locations, mechanically correct the existing 110 relief wells, add 70 relief wells.

Alternative 2B: Reskin gates at 20 locations, permanently close gates at 13 locations, mechanically correct the existing 110 relief wells, install 70 new relief wells.

Alternatives 2A and 2B would address all the swing gates on the flood protection system. Thirteen gates would be permanently closed due to lack of need. The other 20 gates would be replaced or reskinned. These alternatives reduce the risk of failure, prevent the city of St. Louis from enduring extraordinary operation and maintenance costs, and reduce the future outlay of flood fight dollars and P.L. 84-99 funding.

Alternative 3: No Action.

The recommended plan is Alternative 2A, which generates the highest expected annual net benefits. The main report includes further details about each of the action alternatives, as well as information considered during selection of the recommended plan.

VI. Environmental Effects of the Alternatives Considered and Recommended Plan

Table EA-1 displays a summary of probable impacts to environmental, social, and economic resources in the project area for the Recommended Plan and each of other three action alternatives, i.e. 1-A, 1-B, and 2-B. Note that the four action alternatives differ only slightly with one another with respect to type and degree of impact. Figures EA-2 through EA-5 display the location of proposed new relief wells (red symbols), from north to south.

A. Topography and Geology The recommended plan and the other action alternatives would affect topography minimally. Installation of the proposed new relief wells would require the creation of a swale (shallow ditch) or subsurface collector system along the landside toe of the floodwall/levee to direct relief well water to the nearest pump station. No other changes to topography, such as fills, are proposed. Installation of proposed relief wells would require drilling down into unconsolidated alluvial materials and any man-made fills already in place, creating temporary holes.

B. Land Cover Changes to land cover resulting from implementation of the recommended plan or any of the other alternatives would be negligible. A very small area (0.1 acre) of forest would be removed along the landside toe of the levee along Maline Creek to install two proposed relief wells.

C. Socioeconomic Resources The recommended plan and the other alternatives would not adversely affect any socioeconomic resources. Flood damage reduction and safety would improve, as well as operations and maintenance of the flood protection system. The project would provide temporary employment.

D. Prime Farmland No prime farmland is expected to be impacted by the recommended plan or any of the other three action alternatives. Similarly, none of the action plans would cause an irreversible conversion of farmland to nonagricultural use. The St. Louis District has coordinated this project with the St. Louis office of the Natural Resources Conservation Service, and that agency concurs with this determination (Skaer 2004). The St. Louis District was not required to submit any Farmland Conversion Impact Rating (Form AD-1006 to the NRCS) to the NRCS.

E. Hydrologic Conditions The recommended plan and the other action alternatives would correct the potential hydrologic problem of floodwaters seeping into the protected area when the Mississippi River is high. On the other hand, during elevated river stages, groundwater would flow up within the existing and proposed new relief wells to the ground's surface. This relief well water would be collected and directed to the nearest pump station. This would be accomplished using a surface swale, or a subsurface collector system, located along the landside

Table EA-1. Summary of probable environmental, social, and economic impacts of the No Action and Four Action Alternatives. (0 = no change, – = adverse effect, + = beneficial effect; one sign = minor effect, two = moderate effect, three = major effect), * = recommended plan

Impacts	No Action	Alt. 1-A	Alt. 1-B	Alt. 2-A*	Alt. 2-B
ENVIRONMENTAL					
Terrestrial Resources	0	–	–	–	–
Wetland Resources	0	0	0	0	0
Aquatic Resources	0	0	0	0	0
T & E Species	0	0	0	0	0
Geology and Soils	0	0	0	0	0
Hydrology	0	0	0	0	0
Water Quality	0	0	0	0	0
Climate	0	0	0	0	0
Erosion and Sedimentation	0	0	0	0	0
Air Quality	0	–	–	–	–
Noise	0	–	–	–	–
Hazardous and Toxic Materials	0	0	0	0	0
Agricultural Resources	0	0	0	0	0
SOCIAL					
Land Use	0	0	0	0	0
Cultural Resources	0	0	0	0	0
Environmental Justice	0	0	0	0	0
Flood Damage Reduction	– – –	++	++	+++	+++
Aesthetics	0	–	–	–	–
Public Facilities	0	0	0	0	0
Public Services	0	0	0	0	0
Safety	–	+	+	+	+
Recreation	0	0	0	0	0
ECONOMIC					
Employment	0	+	+	+	+
Tax Values	0	0	0	0	0
Property Values	0	0	0	0	0
Community Cohesion	0	0	0	0	0
Displacement of People	0	0	0	0	0
Displacement of Businesses	0	0	0	0	0
Disrupt of Comm. Growth	0	0	0	0	0
Disrupt of Regional Growth	0	0	0	0	0
Operations and Maint.	– –	+	+	++	++

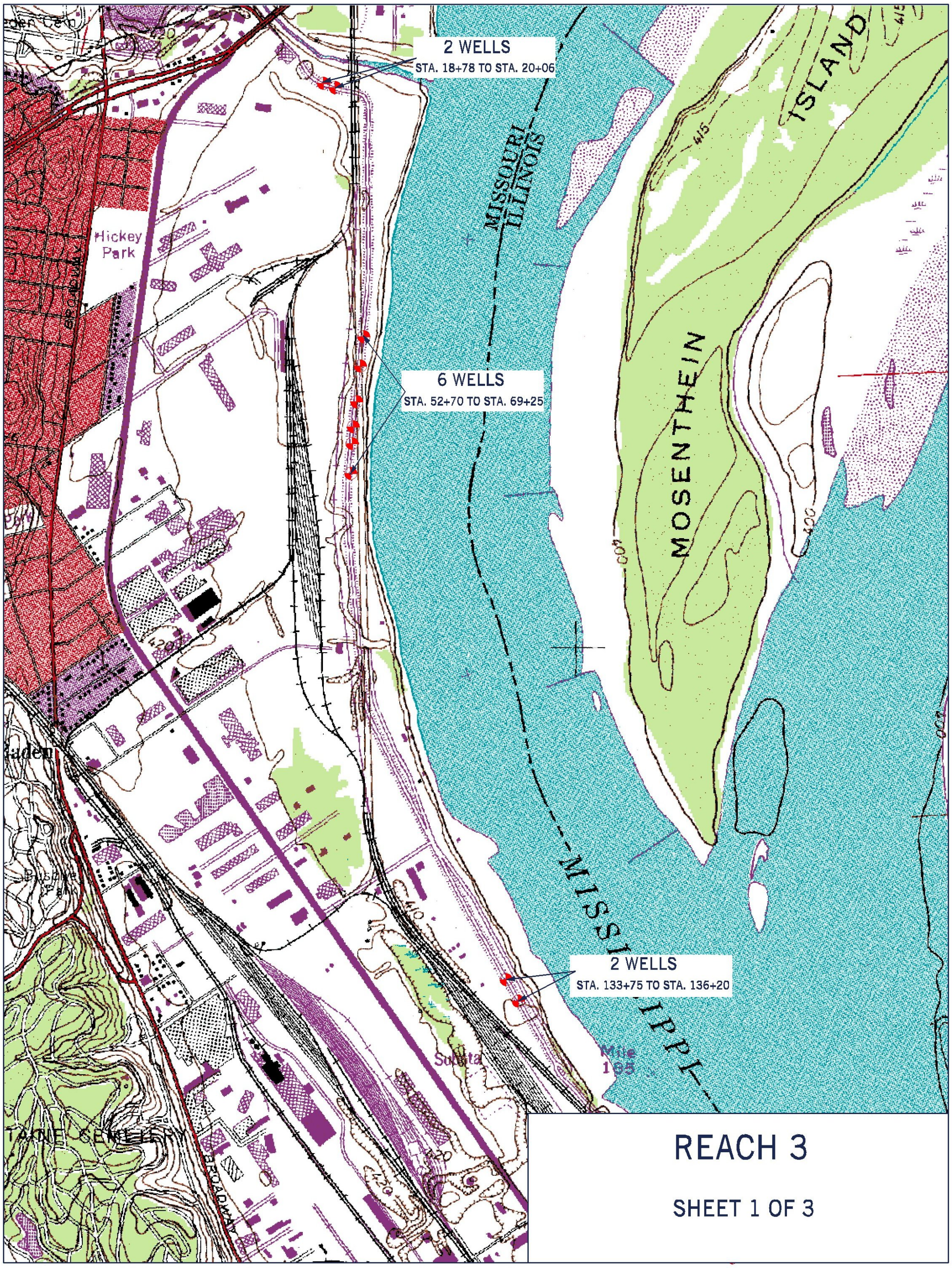

2 WELLS
STA. 18+78 TO STA. 20+06
6 WELLS
STA. 52+70 TO STA. 69+25
2 WELLS
STA. 133+75 TO STA. 136+20
MISSOURI
ILLINOIS
ISLAND
MOSENTHEIN
MISSISSIPPI
Hickey Park
Mile 185
REACH 3
SHEET 1 OF 3

Figure EA-2

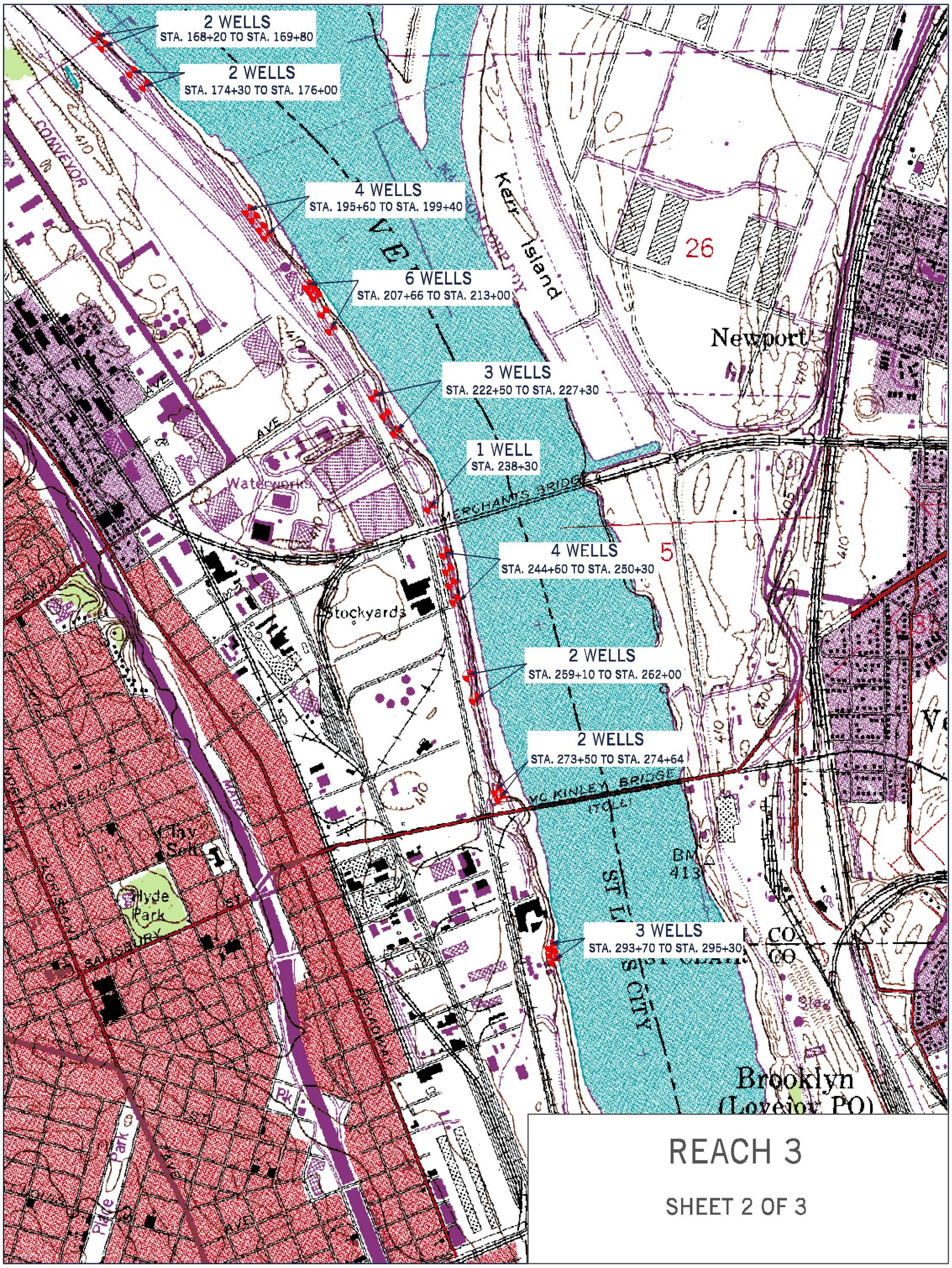
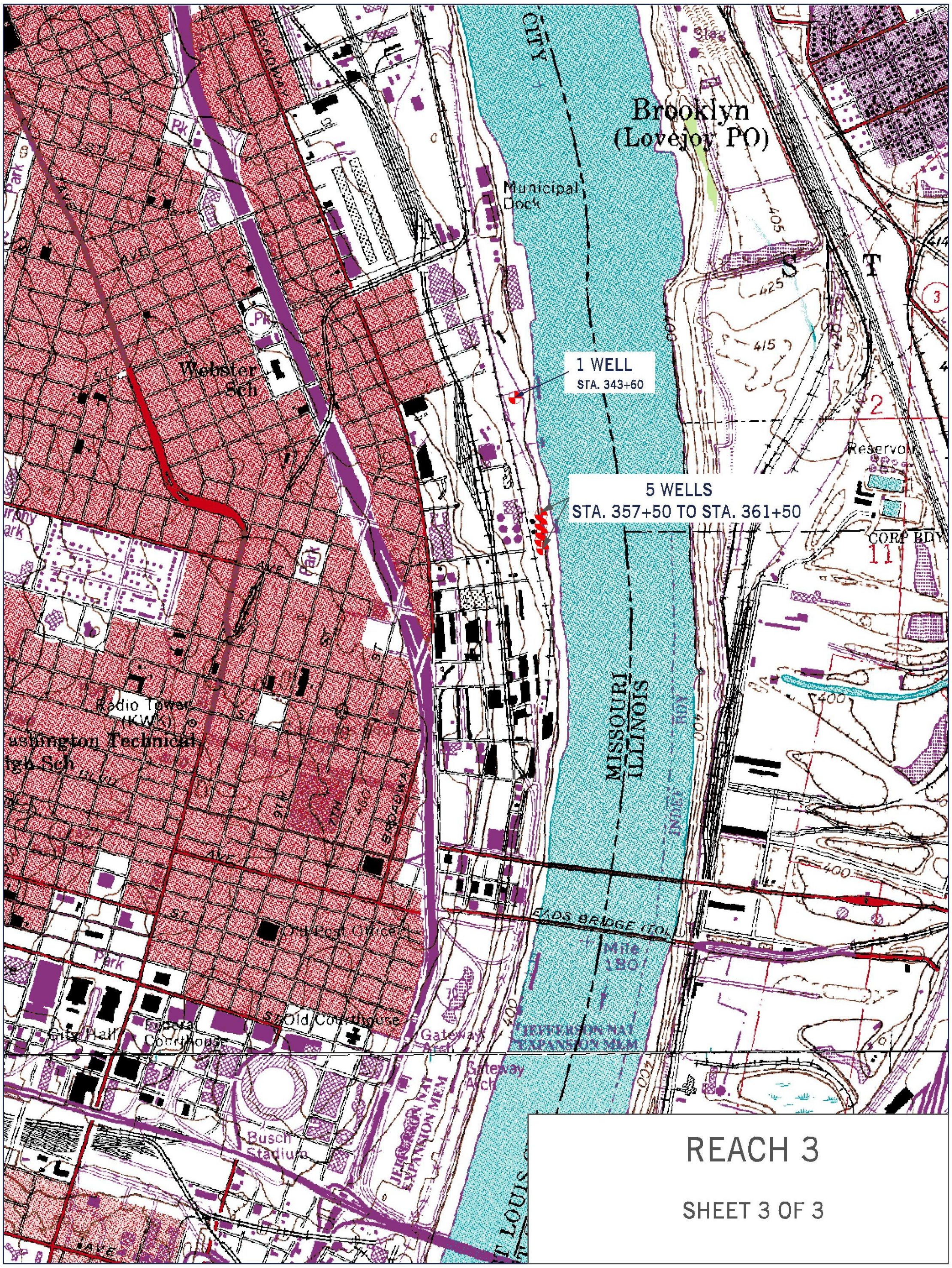

2 WELLS
STA. 168+20 TO STA. 169+80
2 WELLS
STA. 174+30 TO STA. 176+00
4 WELLS
STA. 195+60 TO STA. 199+40
6 WELLS
STA. 207+66 TO STA. 213+00
3 WELLS
STA. 222+50 TO STA. 227+30
1 WELL
STA. 238+30
4 WELLS
STA. 244+60 TO STA. 250+30
2 WELLS
STA. 259+10 TO STA. 262+00
2 WELLS
STA. 273+50 TO STA. 274+64
3 WELLS
STA. 293+70 TO STA. 295+30
Kerr Island
Newport
Waterworks
Stockyards
Hyde Park
Brooklyn
(Lovejoy PO)
REACH 3
SHEET 2 OF 3

Figure EA-3



Brooklyn
(Lovejoy PO)
Municipal Dock
Webster Sch
1 WELL
STA. 343+60
5 WELLS
STA. 357+50 TO STA. 361+50
Reservoir
CORP BDY
MISSOURI
ILLINOIS
Radio Tower (KWK)
EADS BRIDGE (TOLL)
Old Post Office
Old Courthouse
City Hall
Federal Courthouse
Gateway Arch
JEFFERSON NAT EXPANSION MEM
Busch Stadium
REACH 3
SHEET 3 OF 3

Figure EA-4

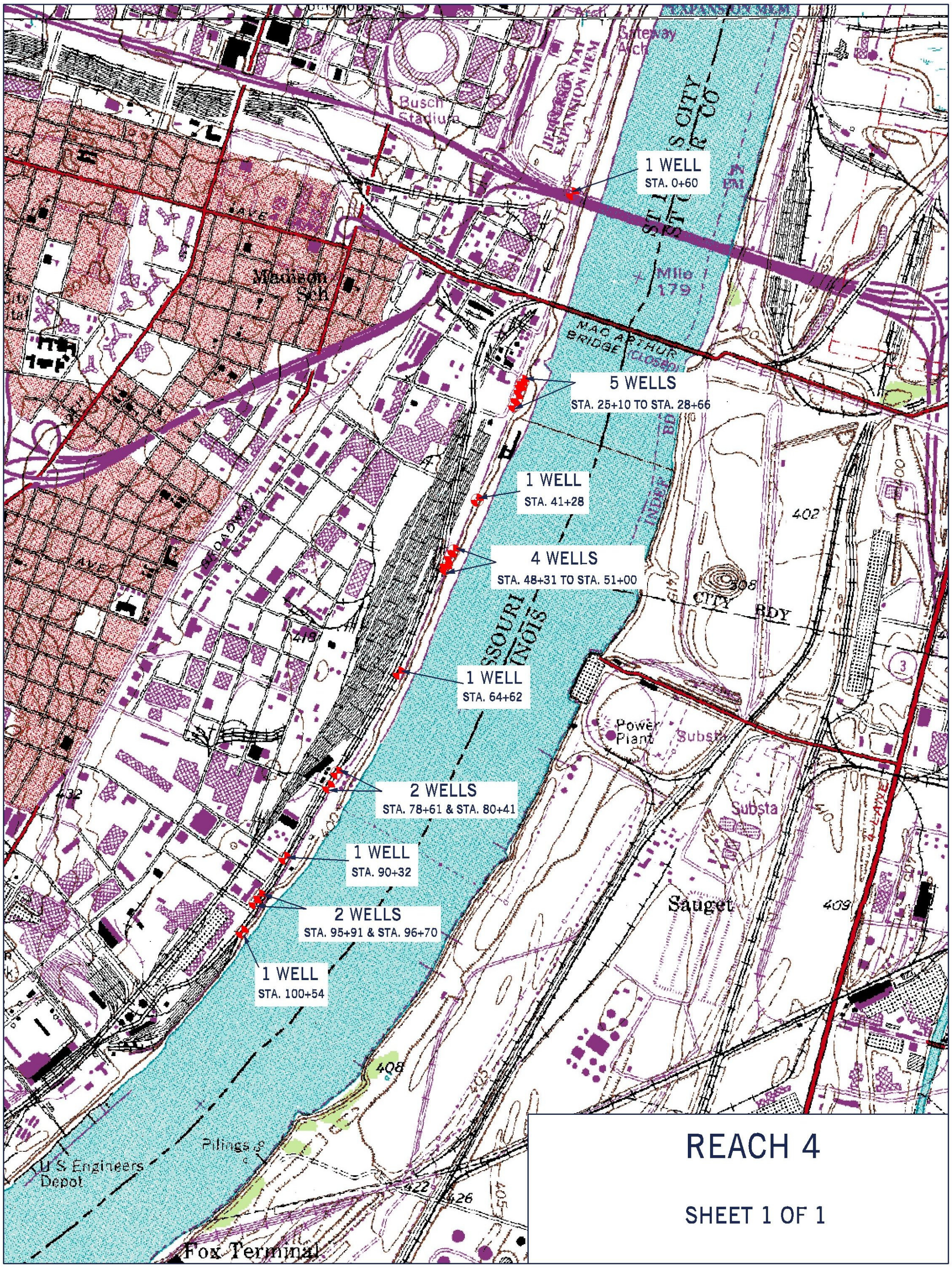

1 WELL
STA. 0+60
5 WELLS
STA. 25+10 TO STA. 28+66
1 WELL
STA. 41+28
4 WELLS
STA. 48+31 TO STA. 51+00
1 WELL
STA. 64+62
2 WELLS
STA. 78+61 & STA. 80+41
1 WELL
STA. 90+32
2 WELLS
STA. 95+91 & STA. 96+70
1 WELL
STA. 100+54
REACH 4
SHEET 1 OF 1

Figure EA-5

toe or base of the floodwall/levee. These measures would prevent relief well water from spreading out into the flood-protected area.

F. Surface Water Resources No work is proposed within Maline Creek or the Mississippi River, nor any wetlands located riverside or landside of the levee/floodwall. The recommended plan and the other action alternatives are not expected to adversely affect water quality of either the creek or river. No authorization is required under Section 404 of the Clean Water Act or Section 10 of the 1899 Rivers and Harbors Act.

G. Ground Water Resources All of the action plans would increase the number of relief wells located along the landside toe of the floodwall/levee from 110 to 180. These relief wells would penetrate the ground to a depth of no greater than 90 feet. The bottoms of these wells would be located in the unconsolidated materials located above bedrock. Installation of the proposed new wells would not affect the groundwater aquifer located in these unconsolidated materials.

H. Hazardous, Toxic, and Radioactive Waste During the installation of the proposed new relief wells, drilling materials would be monitored and tested to determine if any contaminants of concern are present that might require such materials to be considered a special waste. Similarly, during the well installation process and subsequent testing, groundwater obtained during drilling and pumping would be monitored and tested to determine if contaminates of concern are present in the water. Since the District encountered contaminated groundwater in 1999-2000 in the vicinity of a few existing relief wells in Reach 3, the District will apply for and obtain a Section 401 water quality certification from the Missouri Department of Natural Resources for the treatment and disposal of groundwater should contaminants be found in pumped groundwater once construction commences.

I. Biological Resources The recommended plan includes the removal of an estimated 0.1 acre of bottomland forest. The affected area consists of trees, shrubs, and saplings along the landside toe of the levee along Maline Creek, where several relief wells are proposed for installation. Affected tree species include mulberry, box elder, and honeysuckle. According to Corps planning guidance (ER 1105-2-100), adverse impacts to bottomland hardwood forests are to be mitigated in-kind, to the extent possible. The natural resource agencies, including the Missouri Department of Conservation and U.S. Fish and Wildlife Service, will be requested to comment on whether mitigation for this 0.1-acre loss is appropriate. No wetlands would be affected by the recommended plan. Areas where barren ground surfaces are created would be seeded with a mixture of grasses and returned to pre-project conditions.

J. Threatened and Endangered Species The following describes the recommended plan's probable effect on federally-listed species.

Bald eagle: Trees that would need to be removed as part of this proposed project are confined to a small area (about 0.1 acre) located along the landside toe of the levee along Maline Creek near its confluence with the Mississippi River. These trees are not large enough to be used as nesting trees or foraging perches. Therefore, the project is unlikely to affect this species.

Least tern: The proposed project is unlikely to affect this species because no known nesting occurs in the adjacent reach of the Mississippi River, and no proposed work would occur in or along the river's channel as part of this project.

Gray bat: As there are no known winter or other seasonal caves in the vicinity of the proposed project area, it is unlikely that the project will adversely affect this species.

Indiana bat: No trees suitable as roosting habitat (living trees with loose bark, dead trees with cavities) are present in the area to be cleared along Maline Creek. Therefore, the proposed project is unlikely to affect this bat.

Pallid sturgeon: The pallid sturgeon is unlikely to be affected because the proposed project would not occur in or along the Mississippi River's channel.

Pink mucket pearly mussel: Because there is no proposed work in or along the Mississippi River, the butterfly mussel is unlikely to be affected.

Scaleshell: Since there is no proposed work in the Mississippi River, the butterfly mussel is unlikely to be affected.

Running buffalo clover: Because the flood-protected area is highly developed and nonagricultural, natural habitats of this species, such as bottomland meadows or woodlands subject to trampling or grazing, are not present. However, since it appears that this plant is opportune in its habits (it has been found in St. Louis on an abandoned load of topsoil), the plant might be present within the project area. A survey for the presence of this plant in the areas of proposed new relief well construction and rehabilitation of existing relief wells will be necessary prior to initiation of such construction activities.

Among the state-listed species, the peregrine falcon is unlikely to be affected because known nesting sites are not near the proposed project. The lake sturgeon is unlikely to be affected because no work is proposed in the Mississippi River. Similarly, since no work is proposed in the Mississippi River, nor would water quality of the river be impaired, the paddlefish is unlikely to be affected by the recommended plan.

It is the St. Louis District's opinion that the proposed project will not adversely impact any of the federally- and state-listed threatened or endangered species that might occur in the project area. With regard to the running buffalo clover, a field survey will be conducted in areas proposed for new relief well construction as well as relief well rehabilitation to determine if this plant is present, before any construction commences. The action would not affect any critical habitat of any of these species. The USFWS will be given an opportunity to review this EA and comment on this Biological Assessment of expected effects on species of concern.

K. Recreation The proposed closure of the 13 swing gates would not affect the riverfront hiking and biking trail. Installation of the proposed new relief wells also would not adversely affect use of this trail.

L. Aesthetics The aesthetics of the project area would be adversely impacted slightly as well as temporarily by construction activities. Areas where barren ground surfaces are created would be seeded and returned to pre-project conditions.

M. Historic Properties Original construction-related ground disturbance related to the placement of the St. Louis Floodwall undoubtedly damaged or destroyed a number of potentially significant archaeological / architectural remains. Despite this, our analysis of nineteenth century records and original (late 1960's), construction-related, drawings and photographs suggest that potentially significant archaeological features may still remain intact within the proposed ROW limits of the proposed St. Louis Floodwall Improvements.

Given the fact that any excavations associated with the proposed relief well installation project will occur in close proximity to the existing floodwall, it is recommended that the required historic properties investigations (survey / subsurface archaeological testing / potential archaeological data recovery) be performed immediately in advance of construction related to the proposed floodwall project. The specific nature and scope of the on-site historic properties investigations will be developed in concert with senior Missouri Department of Natural Resources archaeologists and applicable Native American tribal representatives prior to the conduct of any fieldwork. The schedule, type, and extent of these investigations will be mutually agreed to in a formal Memorandum of Agreement, signed by both the Commander of the St. Louis District, the Missouri State Historic Preservation Officer, and, if applicable, the Keeper of the Advisory Council on Historic Preservation.

N. Air Quality The recommended plan would have short-term effects on air quality. The effects would be restricted to exhaust and dust from construction activities. These impacts would cease once construction was completed. The trees removed from along Maline Creek would be chipped rather than burned to minimize air quality impacts.

O. Noise The recommended plan is not expected to significantly affect the noise levels in the study area. Noise impacts would be temporary and caused by construction activities and machinery.

P. Relationship of the Proposed Project to Land-Use Plans The proposed project, which is to restore a fully functional flood protection project to the City of St. Louis, is consistent with local land uses, and with the original purpose of the flood control project.

Q. Adverse Effects Which Cannot Be Avoided The tree removal from along the levee at Maline Creek is necessary to install several proposed relief wells. Other unavoidable impacts include noise, dust, and exhaust generated by construction equipment.

R. Short-Term Use Versus Long-Term Productivity The recommended plan does not represent a short-term use of the environment, but a long-term or permanent solution to many problems with the original project. Current conditions could lead to a catastrophic levee failure and damage to lives, property, and livelihoods of many people. The areas of impact, for the most part, have been utilized by the original project and the reconstruction of the project would not affect any previously undisturbed areas.

S. Irreversible or Irretrievable Resource Commitments Aside from the commitment of funds, labor and construction materials for construction, there would be no irreversible or irretrievable resource commitments.

T. Cumulative Impacts In addition to proposed work at the St. Louis Flood Protection System, the St. Louis District, Corps of Engineers, has undertaken rehabilitation and reconstruction activities of existing flood protection systems at six other locations along the Mississippi River. These include, from north to south, Wood River (Madison County, Illinois), Chain of Rocks (Madison County, Illinois), East St. Louis (Madison and St. Clair Counties, Illinois), Prairie du Pont (St. Clair and Monroe Counties, Illinois), Bois Brule (Perry County, Missouri), and Cape Girardeau (Cape Girardeau County, Missouri). Construction has started at two projects (Chain of Rocks, East St. Louis), but the others are in the planning/approval stage. Relief well rehabilitation and installation of new relief wells are construction features common to all these projects, except for Cape Girardeau. The Corps is the sole agency or entity doing this kind of work on flood protection systems along the Mississippi River. All projects are expected to give rise to temporary adverse impacts to air quality and noise. Construction work by others in the vicinity of the St. Louis Flood Protection System is likely to occur concurrently with the proposed work (if approved and funded), and is likely to include a variety of industrial, commercial, or transportation-related activities at single locations. No significant cumulative impacts on the environment have been identified.

VII. Relationship of Recommended Plan to Environmental Requirements

TABLE EA-2. Relationship of Plan to Environmental Requirements

Guidance	Degree of Compliance
Federal Statutes	
Archaeological and Historic Preservation Act, as Amended, 16 U.S.C. 469, et seq.	PC[1]
Clean Air Act, as Amended, 42 U.S.C. 7609	FC
Clean Water Act, as Amended 33 U.S.C. 466 et seq.	FC
Endangered Species Act, as Amended, 16 U.S.C. 1531. et seq.	FC
Farmland Protection Policy Act, 7 U.S.C. 4201, et seq.	FC
Federal Water Project Recreation Act, as Amended, 16 U.S.C. 4601, et seq.	FC
Fish and Wildlife Coordination Act, as Amended, 16 U.S.C. 4601, et seq.	PC[2]
Land and Water Conservation Fund Act, as Amended, 16 U.S.C. 4601, et seq.	FC
National Environmental Policy Act, as Amended, 42 U.S.C. 4321, et seq.	FC
National Historic Preservation Act, as Amended, 16 U.S.C. 470a, et seq.	PC[1]
Executive Orders	
Flood Plain Management, E.O. 11988 as amended by E.O. 12148	FC
Protection of Wetlands, E.O 11990 as amended by E.O. 12608	FC
Protection and Enhancement of the Cultural Environment, E.O. 11593	PC[1]

Analysis of Impacts on Prime or Unique Agricultural Lands in Implementing NEPA, CEQ Memorandum, August 11, 1980.	FC

FC = Full Compliance, PC = Partial Compliance
1 - Full compliance will be attained after all required archaeological investigations, reports, and coordination have been completed
2 - Full compliance will be attained upon completion of coordination with USFWS

VIII. Issues and Concerns

A. Hazardous and Toxic Wastes Hazardous and toxic wastes consisting of polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) were encountered in groundwater pumped from a few of the 110 existing relief wells of the flood protection system during testing in 1999-2000. There is the potential that these contaminants would be encountered again in groundwater obtained during the proposed rehabilitation of existing relief wells and installation of new relief wells. During the construction process, groundwater obtained from initial pumping will be monitored and tested to determine if any contaminates of concern are present. Should they be found, the District will apply for and obtain a Section 401 water quality certification from the Missouri Department of Natural Resources for the treatment and disposal of contaminated groundwater.

B. Floodplain Management Executive Order 11988 outlines the responsibilities of Federal agencies in the role of floodplain management. Each agency shall evaluate the potential effects of actions on flood plains, and should avoid undertaking actions that directly or indirectly induce growth in the floodplain or adversely affect natural floodplain values. Engineer Regulation 1165-2-26 states:

The Corps is required to provide leadership and take action to
- Avoid development in the base flood plain unless it is the only practicable alternative;
- Reduce the hazard and risk associated with floods;
- Restore and preserve the natural and beneficial values of the base flood plain.

The Corps is required to follow the general procedures listed below to address the requirements of Executive Order 11988.

a. *Determine if the proposed action is in the base flood plain.*

The St. Louis Flood Protection System is in the base flood plain of the Mississippi River. It protects 3,160 flood plain acres.

b. *If the action is in the base flood plain, identify and evaluate practicable alternatives to the action or to location of the action in the base flood plain.*

Due to the nature of this project, there are no alternatives located outside of the base flood plain. The project involves rehabilitation and reconstruction of a flood control system that is already in place. Therefore all alternatives are located within the base flood plain.

c. *If the action must be in the flood plain, advise the general public in the affected area and obtain their views and comments*.

The general public will be advised about the project and their views and comments will be requested as part of the project's public review process. Comments will be addressed in the reconstruction evaluation report.

d. *Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the base flood plain will affect the base flood plain, impacts resulting from these actions should also be identified*.

Beneficial and adverse impacts have been described in this Environmental Assessment. No actions are proposed outside the base flood plain that would affect the base flood plain.

e. *If the action is likely to induce development in the base flood plain, determine if a practicable non-flood plain alternative for the development exists*.

Improvements to the existing flood protection system are not likely to induce development in the base flood plain beyond what already exists.

f. *As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the "no action" alternative*.

The "no action" alternative of doing nothing to fix the existing flood control system is possible, but it would not address the problems facing the system and the risk to life and property from flooding if the system were not to perform adequately. The most viable method to minimize adverse impacts is to implement the reconstruction project.

g. *If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings*.

The Corps of Engineers will advise the general public in the affected area through the public review process.

h. *Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order*.

The study's reconstruction evaluation report recommends Alternative 2A as the plan most responsive to the planning objectives.

IX. Literature Cited

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X. Environmental Assessment Preparers

The St. Louis District staff members responsible for preparing this document are as follows:

Mr. Tim George, Ecologist
Dr. Terry Norris, District Archaeologist
Mr. Mark Alvey, Geotechnical Engineer
Ms. Kathy Fox, Geotechnical Engineer
Mr. Pat O'Donnell, Project Manager

XI. Coordination, Public Views, and Responses

The St. Louis has coordinated with the U.S. Fish and Wildlife Service and Missouri Department of Conservation with respect to plant and animal species of concern, and the Natural Resources Conservation Service about potential conversions of land to nonagricultural use.

As part of the reconstruction evaluation report, the Environmental Assessment and Draft Unsigned Finding of No Significant Impact are being sent to the following elected officials, agencies, organizations and individuals for review and comment. All responses will be filed with this document.

Elected Officials:

Honorable Christopher "Kit" Bond (MO- Senate)
Honorable James Talent (MO-Senate)
Honorable William L. Clay (MO- House- 1st District)
Honorable Richard Gephardt (MO- House- 3rd District)

Federal Agencies:

Department of Agriculture, Natural Resource Conservation Service
Fish and Wildlife Service
Environmental Protection Agency, Region VII
Federal Emergency Management Agency

Missouri State Agencies:

Department of Conservation
Department of Natural Resources
Historic Preservation Agency

Organizations and Individuals:

Sierra Club
The Nature Conservancy
City of St. Louis
Metropolitan St. Louis Sewer District

To assure compliance with the National Environmental Policy Act, Endangered Species Act and other applicable environmental laws and regulations, coordination with these agencies will continue as required throughout the planning and construction phases of the proposed project.

DRAFT FINDING OF NO SIGNIFICANT IMPACT

RECONSTRUCTION OF FLOOD PROTECTION SYSTEM
CITY OF ST. LOUIS
MISSOURI

I. I have reviewed and evaluated the documents concerning the reconstruction project for the flood protection system located in the City of St. Louis, Missouri.

II. As part of this evaluation, I have considered:

a. Existing Resources and the No-Action Alternative.

b. Impact to Existing Resources with all formulated plans, including the Recommended Plan.

III. The possible consequences of these alternatives have been studied for physical, environmental, cultural, social and economic effects, and engineering feasibility. My evaluation of significant factors have contributed to my finding:

a. The reconstruction project will correct design deficiencies in the original design of the city's flood protection system, will maintain the original level of protection, and will be accomplished by rehabilitation of existing gates and relief wells, closure of unneeded gates, and installation of new relief wells.

b. There would be no significant effects to the geology or topography of the project area.

c. Inducement of development in the flood plain would not result from this project.

d. Federally listed endangered and threatened species would not be adversely impacted.

e. There would be no adverse impacts to cultural resources.

f. There would be no effect to farmland, nor any conversions of land to nonagricultural use.

g. There would be no appreciable degradation to the physical environment (e.g., noise, air quality, and water quality) due directly to the reconstruction project.

h. No significant adverse impacts to the aesthetic value, social, or recreational resources would result.

i. The proposed project would not impact any wetlands.

j. No adverse effects to health and safety of the public are expected from potentially contaminated groundwater generated by construction activities.

k. The "no action" alternative was evaluated and determined to be unacceptable as there is a public health and safety issue unless the design deficiencies are corrected.

IV. Based on the disclosure of impacts contained within the Environmental Assessment, I find no significant impacts to the human environment are likely to occur as a result of the proposed project. The proposed action has been coordinated with the appropriate resource agencies and the public, and there are no significant unresolved issues. Therefore, an Environmental Impact Statement will not be prepared prior to proceeding with the proposed reconstruction project for the City of St. Louis' flood protection system, Missouri.

____________________	__________________________
Date	C. Kevin Williams Colonel, U.S. Army District Engineer

APPENDIX B

COST ESTIMATES

ST. LOUIS FLOOD PROTECTION
RECONSTRUCTION EVALUATION REPORT
DESIGN DEFICIENCY ESTIMATE

Designed By: ST. LOUIS DISTRICT, COE
Estimated By: ST. LOUIS DISTRICT, COE

Prepared By: GREGORY DYN

Preparation Date: 09/21/04
Effective Date of Pricing: 10/01/04

Sales Tax: 0.0%

This project is assumed to be acomplished with two contracts, one for the relief wells and one for the gate replacement. The prices for the relief wells are current contract costs and include all contractor markups and mobilization, therefore markups for overhead and profit do not appear as seperate line items in the estimate.

SUMMARY REPORTS SUMMARY PAGE

DETAILED ESTIMATE DETAIL PAGE

BACKUP REPORTS BACKUP PAGE

* * * END TABLE OF CONTENTS * * *

** PROJECT OWNER SUMMARY - Level 1 (Rounded to 100's) **

	QUANTY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
11 Levees and Floodwalls			6,984,000	1,189,000	8,173,000	
30 Planning, Engineering, & Design			991,000	247,800	1,238,800	
31 Construction Management			661,000	165,300	826,300	
TOTAL ST. LOUIS FLOOD PROTECTION			8,636,000	1,602,000	10,238,000	

** PROJECT OWNER SUMMARY - Level 2 (Rounded to 100's) **

	QUANTY UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
11 Levees and Floodwalls					
11 01 Levees		4,156,500	623,500	4,780,000	
11 02 Floodwalls		2,827,500	565,500	3,393,000	
TOTAL Levees and Floodwalls		6,984,000	1,189,000	8,173,000	
30 Planning, Engineering, & Design					
30 01 Planning, Engineering, & Design		991,000	247,800	1,238,800	
TOTAL Planning, Engineering, & Design		991,000	247,800	1,238,800	
31 Construction Management					
31 01 Construction Management		661,000	165,300	826,300	
TOTAL Construction Management		661,000	165,300	826,300	
TOTAL ST. LOUIS FLOOD PROTECTION		8,636,000	1,602,000	10,238,000	

** PROJECT OWNER SUMMARY - Level 3 (Rounded to 100's) **

	QUANTY UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
11 Levees and Floodwalls					
11 01 Levees					
11 01 01 Rehab/Replace Exist Relief Wells		1,398,500	209,800	1,608,300	
11 01 02 New Relief Wells		2,380,000	357,000	2,737,000	
11 01 03 Underseepage Remediation		378,000	56,700	434,700	
TOTAL Levees		4,156,500	623,500	4,780,000	
11 02 Floodwalls					
11 02 01 Demolition		192,000	38,400	230,400	
11 02 02 New Gates		2,287,200	457,400	2,744,600	
11 02 03 Gate Closure		170,300	34,100	204,400	
11 02 04 Miscellaneous Items		116,000	23,200	139,200	
11 02 05 Mobilization and Demobilization		61,900	12,400	74,300	
TOTAL Floodwalls		2,827,500	565,500	3,393,000	
TOTAL Levees and Floodwalls		6,984,000	1,189,000	8,173,000	
30 Planning, Engineering, & Design					
30 01 Planning, Engineering, & Design					
30 01 1 Planning, Engineering, & Design		991,000	247,800	1,238,800	
TOTAL Planning, Engineering, & Design		991,000	247,800	1,238,800	
TOTAL Planning, Engineering, & Design		991,000	247,800	1,238,800	
31 Construction Management					
31 01 Construction Management					
31 01 1 Construction Management		661,000	165,300	826,300	
TOTAL Construction Management		661,000	165,300	826,300	
TOTAL Construction Management		661,000	165,300	826,300	
TOTAL ST. LOUIS FLOOD PROTECTION		8,636,000	1,602,000	10,238,000	

** PROJECT OWNER SUMMARY - Level 4 (Rounded to 100's) **

	QUANTY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
11 Levees and Floodwalls						
11 01 Levees						
11 01 01 Rehab/Replace Exist Relief Wells						
11 01 01 5 Redevelop and Pump Test	103.00	EA	309,000	46,400	355,400	3450.00
11 01 01 10 Rehabilitate Exist. Wells	63.00	EA	409,500	61,400	470,900	7475.00
11 01 01 15 Replace Wells	20.00	EA	600,000	90,000	690,000	34500
11 01 01 20 Pilot Holes for New Wells	20.00	EA	80,000	12,000	92,000	4600.00
TOTAL Rehab/Replace Exist Relief Wells			1,398,500	209,800	1,608,300	
11 01 02 New Relief Wells						
11 01 02 5 New Relief Wells	70.00	EA	2,100,000	315,000	2,415,000	34500
11 01 02 10 Pilot Holes for New Wells	70.00	EA	280,000	42,000	322,000	4600.00
TOTAL New Relief Wells			2,380,000	357,000	2,737,000	
11 01 03 Underseepage Remediation						
11 01 03 5 Foundation Repair			378,000	56,700	434,700	
TOTAL Underseepage Remediation			378,000	56,700	434,700	
TOTAL Levees			4,156,500	623,500	4,780,000	
11 02 Floodwalls						
11 02 01 Demolition						
11 02 01 5 Remove Existing Gates			138,900	27,800	166,700	
11 02 01 10 Dispose of Existing Gates			53,100	10,600	63,700	
TOTAL Demolition			192,000	38,400	230,400	
11 02 02 New Gates						
11 02 02 5 Fabrication			1,985,500	397,100	2,382,600	
11 02 02 10 Painting			95,100	19,000	114,100	
11 02 02 15 Installation			176,800	35,400	212,200	
11 02 02 20 Testing			29,800	6,000	35,700	
TOTAL New Gates			2,287,200	457,400	2,744,600	

	QUANTY	UOM	CONTRACT	CONTINGN	TOTAL COST	UNIT
11 02 03 Gate Closure			170,300	34,100	204,400	
11 02 04 Miscellaneous Items			116,000	23,200	139,200	
11 02 05 Mobilization and Demobilization			61,900	12,400	74,300	
TOTAL Floodwalls			2,827,500	565,500	3,393,000	
TOTAL Levees and Floodwalls			6,984,000	1,189,000	8,173,000	
30 Planning, Engineering, & Design						
30 01 Planning, Engineering, & Design						
30 01 1 Planning, Engineering, & Design			991,000	247,800	1,238,800	
TOTAL Planning, Engineering, & Design			991,000	247,800	1,238,800	
TOTAL Planning, Engineering, & Design			991,000	247,800	1,238,800	
31 Construction Management						
31 01 Construction Management						
31 01 1 Construction Management			661,000	165,300	826,300	
TOTAL Construction Management			661,000	165,300	826,300	
TOTAL Construction Management			661,000	165,300	826,300	
TOTAL ST. LOUIS FLOOD PROTECTION			8,636,000	1,602,000	10,238,000	

** PROJECT INDIRECT SUMMARY - Level 1 (Rounded to 100's) **

	QUANTY UOM	DIRECT	FIELDOFC	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
11 Levees and Floodwalls		6,398,600	112,100	188,300	254,300	30,700	6,984,000	
30 Planning, Engineering, & Design		991,000	0	0	0	0	991,000	
31 Construction Management		661,000	0	0	0	0	661,000	
ST. LOUIS FLOOD PROTECTION		8,050,600	112,100	188,300	254,300	30,700	8,636,000	
Contingency							1,602,000	
TOTAL INCL OWNER COSTS							10,238,000	

** PROJECT INDIRECT SUMMARY - Level 2 (Rounded to 100's) **

	QUANTY UOM	DIRECT	FIELDOFC	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
11 Levees and Floodwalls								
11 01 Levees		4,156,500	0	0	0	0	4,156,500	
11 02 Floodwalls		2,242,100	112,100	188,300	254,300	30,700	2,827,500	
TOTAL Levees and Floodwalls		6,398,600	112,100	188,300	254,300	30,700	6,984,000	
30 Planning, Engineering, & Design								
30 01 Planning, Engineering, & Design		991,000	0	0	0	0	991,000	
TOTAL Planning, Engineering, & Design		991,000	0	0	0	0	991,000	
31 Construction Management								
31 01 Construction Management		661,000	0	0	0	0	661,000	
TOTAL Construction Management		661,000	0	0	0	0	661,000	
TOTAL ST. LOUIS FLOOD PROTECTION		8,050,600	112,100	188,300	254,300	30,700	8,636,000	
Contingency							1,602,000	
TOTAL INCL OWNER COSTS							10,238,000	

** PROJECT INDIRECT SUMMARY - Level 3 (Rounded to 100's) **

	QUANTY UOM	DIRECT	FIELDOFC	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
11 Levees and Floodwalls								
11 01 Levees								
11 01 01 Rehab/Replace Exist Relief Wells		1,398,500	0	0	0	0	1,398,500	
11 01 02 New Relief Wells		2,380,000	0	0	0	0	2,380,000	
11 01 03 Underseepage Remediation		378,000	0	0	0	0	378,000	
TOTAL Levees		4,156,500	0	0	0	0	4,156,500	
11 02 Floodwalls								
11 02 01 Demolition		152,300	7,600	12,800	17,300	2,100	192,000	
11 02 02 New Gates		1,813,600	90,700	152,300	205,700	24,900	2,287,200	
11 02 03 Gate Closure		135,100	6,800	11,300	15,300	1,900	170,300	
11 02 04 Miscellaneous Items		92,000	4,600	7,700	10,400	1,300	116,000	
11 02 05 Mobilization and Demobilization		49,100	2,500	4,100	5,600	700	61,900	
TOTAL Floodwalls		2,242,100	112,100	188,300	254,300	30,700	2,827,500	
TOTAL Levees and Floodwalls		6,398,600	112,100	188,300	254,300	30,700	6,984,000	
30 Planning, Engineering, & Design								
30 01 Planning, Engineering, & Design								
30 01 1 Planning, Engineering, & Design		991,000	0	0	0	0	991,000	
TOTAL Planning, Engineering, & Design		991,000	0	0	0	0	991,000	
TOTAL Planning, Engineering, & Design		991,000	0	0	0	0	991,000	
31 Construction Management								
31 01 Construction Management								
31 01 1 Construction Management		661,000	0	0	0	0	661,000	
TOTAL Construction Management		661,000	0	0	0	0	661,000	
TOTAL Construction Management		661,000	0	0	0	0	661,000	
TOTAL ST. LOUIS FLOOD PROTECTION		8,050,600	112,100	188,300	254,300	30,700	8,636,000	
Contingency							1,602,000	
TOTAL INCL OWNER COSTS							10,238,000	

** PROJECT INDIRECT SUMMARY - Level 4 (Rounded to 100's) **

	QUANTY	UOM	DIRECT	FIELDOFC	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
11 Levees and Floodwalls									
11 01 Levees									
11 01 01 Rehab/Replace Exist Relief Wells									
11 01 01 5 Redevelop and Pump Test	103.00	EA	309,000	0	0	0	0	309,000	3000.00
11 01 01 10 Rehabilitate Exist. Wells	63.00	EA	409,500	0	0	0	0	409,500	6500.00
11 01 01 15 Replace Wells	20.00	EA	600,000	0	0	0	0	600,000	30000
11 01 01 20 Pilot Holes for New Wells	20.00	EA	80,000	0	0	0	0	80,000	4000.00
TOTAL Rehab/Replace Exist Relief Wel			1,398,500	0	0	0	0	1,398,500	
11 01 02 New Relief Wells									
11 01 02 5 New Relief Wells	70.00	EA	2,100,000	0	0	0	0	2,100,000	30000
11 01 02 10 Pilot Holes for New Wells	70.00	EA	280,000	0	0	0	0	280,000	4000.00
TOTAL New Relief Wells			2,380,000	0	0	0	0	2,380,000	
11 01 03 Underseepage Remediation									
11 01 03 5 Foundation Repair			378,000	0	0	0	0	378,000	
TOTAL Underseepage Remediation			378,000	0	0	0	0	378,000	
TOTAL Levees			4,156,500	0	0	0	0	4,156,500	
11 02 Floodwalls									
11 02 01 Demolition									
11 02 01 5 Remove Existing Gates			110,200	5,500	9,300	12,500	1,500	138,900	
11 02 01 10 Dispose of Existing Gates			42,100	2,100	3,500	4,800	600	53,100	
TOTAL Demolition			152,300	7,600	12,800	17,300	2,100	192,000	
11 02 02 New Gates									
11 02 02 5 Fabrication			1,574,400	78,700	132,200	178,500	21,600	1,985,500	
11 02 02 10 Painting			75,400	3,800	6,300	8,500	1,000	95,100	
11 02 02 15 Installation			140,200	7,000	11,800	15,900	1,900	176,800	
11 02 02 20 Testing			23,600	1,200	2,000	2,700	300	29,800	
TOTAL New Gates			1,813,600	90,700	152,300	205,700	24,900	2,287,200	

** PROJECT INDIRECT SUMMARY - Level 4 (Rounded to 100's) **

	QUANTY UOM	DIRECT	FIELDOFC	HOME OFC	PROFIT	BOND	TOTAL COST	UNIT
11 02 03 Gate Closure		135,100	6,800	11,300	15,300	1,900	170,300	
11 02 04 Miscellaneous Items		92,000	4,600	7,700	10,400	1,300	116,000	
11 02 05 Mobilization and Demobilization		49,100	2,500	4,100	5,600	700	61,900	
TOTAL Floodwalls		2,242,100	112,100	188,300	254,300	30,700	2,827,500	
TOTAL Levees and Floodwalls		6,398,600	112,100	188,300	254,300	30,700	6,984,000	
30 Planning, Engineering, & Design								
30 01 Planning, Engineering, & Design								
30 01 1 Planning, Engineering, & Design		991,000	0	0	0	0	991,000	
TOTAL Planning, Engineering, & Desig		991,000	0	0	0	0	991,000	
TOTAL Planning, Engineering, & Desig		991,000	0	0	0	0	991,000	
31 Construction Management								
31 01 Construction Management								
31 01 1 Construction Management		661,000	0	0	0	0	661,000	
TOTAL Construction Management		661,000	0	0	0	0	661,000	
TOTAL Construction Management		661,000	0	0	0	0	661,000	
TOTAL ST. LOUIS FLOOD PROTECTION		8,050,600	112,100	188,300	254,300	30,700	8,636,000	
Contingency							1,602,000	
TOTAL INCL OWNER COSTS							10,238,000	

** PROJECT DIRECT SUMMARY - Level 1 (Rounded to 100's) **

	QUANTY UOM	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
11 Levees and Floodwalls		421,100	81,300	30,200	0	5,866,000	6,398,600	
30 Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
31 Construction Management		0	0	0	0	661,000	661,000	
ST. LOUIS FLOOD PROTECTION		421,100	81,300	30,200	0	7,518,000	8,050,600	
Field Office Overhead							112,100	
SUBTOTAL							8,162,700	
Home Office Overhead							188,300	
SUBTOTAL							8,351,000	
Profit							254,300	
SUBTOTAL							8,605,300	
Bond							30,700	
TOTAL INCL INDIRECTS							8,636,000	
Contingency							1,602,000	
TOTAL INCL OWNER COSTS							10,238,000	

** PROJECT DIRECT SUMMARY - Level 2 (Rounded to 100's) **

	QUANTY UOM	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
11 Levees and Floodwalls								
11 01 Levees		0	0	0	0	4,156,500	4,156,500	
11 02 Floodwalls		421,100	81,300	30,200	0	1,709,500	2,242,100	
TOTAL Levees and Floodwalls		421,100	81,300	30,200	0	5,866,000	6,398,600	
30 Planning, Engineering, & Design								
30 01 Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
TOTAL Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
31 Construction Management								
31 01 Construction Management		0	0	0	0	661,000	661,000	
TOTAL Construction Management		0	0	0	0	661,000	661,000	
TOTAL ST. LOUIS FLOOD PROTECTION		421,100	81,300	30,200	0	7,518,000	8,050,600	
Field Office Overhead							112,100	
SUBTOTAL							8,162,700	
Home Office Overhead							188,300	
SUBTOTAL							8,351,000	
Profit							254,300	
SUBTOTAL							8,605,300	
Bond							30,700	
TOTAL INCL INDIRECTS							8,636,000	
Contingency							1,602,000	
TOTAL INCL OWNER COSTS							10,238,000	

** PROJECT DIRECT SUMMARY - Level 3 (Rounded to 100's) **

	QUANTY UOM	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
11 Levees and Floodwalls								
11 01 Levees								
11 01 01 Rehab/Replace Exist Relief Wells		0	0	0	0	1,398,500	1,398,500	
11 01 02 New Relief Wells		0	0	0	0	2,380,000	2,380,000	
11 01 03 Underseepage Remediation		0	0	0	0	378,000	378,000	
TOTAL Levees		0	0	0	0	4,156,500	4,156,500	
11 02 Floodwalls								
11 02 01 Demolition		130,200	36,800	-14,700	0	0	152,300	
11 02 02 New Gates		199,900	29,000	10,400	0	1,574,400	1,813,600	
11 02 03 Gate Closure		0	0	0	0	135,100	135,100	
11 02 04 Miscellaneous Items		57,400	0	34,600	0	0	92,000	
11 02 05 Mobilization and Demobilization		33,600	15,500	0	0	0	49,100	
TOTAL Floodwalls		421,100	81,300	30,200	0	1,709,500	2,242,100	
TOTAL Levees and Floodwalls		421,100	81,300	30,200	0	5,866,000	6,398,600	
30 Planning, Engineering, & Design								
30 01 Planning, Engineering, & Design								
30 01 1 Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
TOTAL Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
TOTAL Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
31 Construction Management								
31 01 Construction Management								
31 01 1 Construction Management		0	0	0	0	661,000	661,000	
TOTAL Construction Management		0	0	0	0	661,000	661,000	
TOTAL Construction Management		0	0	0	0	661,000	661,000	
TOTAL ST. LOUIS FLOOD PROTECTION		421,100	81,300	30,200	0	7,518,000	8,050,600	
Field Office Overhead							112,100	
SUBTOTAL							8,162,700	

** PROJECT DIRECT SUMMARY - Level 3 (Rounded to 100's) **

	QUANTY UOM	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
Home Office Overhead							188,300	

SUBTOTAL							8,351,000	
Profit							254,300	

SUBTOTAL							8,605,300	
Bond							30,700	

TOTAL INCL INDIRECTS							8,636,000	
Contingency							1,602,000	

TOTAL INCL OWNER COSTS							10,238,000	

	QUANTY	UOM	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
11 Levees and Floodwalls									
11 01 Levees									
11 01 01 Rehab/Replace Exist Relief Wells									
11 01 01 5 Redevelop and Pump Test	103.00	EA	0	0	0	0	309,000	309,000	3000.00
11 01 01 10 Rehabilitate Exist. Wells	63.00	EA	0	0	0	0	409,500	409,500	6500.00
11 01 01 15 Replace Wells	20.00	EA	0	0	0	0	600,000	600,000	30000
11 01 01 20 Pilot Holes for New Wells	20.00	EA	0	0	0	0	80,000	80,000	4000.00
TOTAL Rehab/Replace Exist Relief Wells			0	0	0	0	1,398,500	1,398,500	
11 01 02 New Relief Wells									
11 01 02 5 New Relief Wells	70.00	EA	0	0	0	0	2,100,000	2,100,000	30000
11 01 02 10 Pilot Holes for New Wells	70.00	EA	0	0	0	0	280,000	280,000	4000.00
TOTAL New Relief Wells			0	0	0	0	2,380,000	2,380,000	
11 01 03 Underseepage Remediation									
11 01 03 5 Foundation Repair			0	0	0	0	378,000	378,000	
TOTAL Underseepage Remediation			0	0	0	0	378,000	378,000	
TOTAL Levees			0	0	0	0	4,156,500	4,156,500	
11 02 Floodwalls									
11 02 01 Demolition									
11 02 01 5 Remove Existing Gates			95,000	15,200	0	0	0	110,200	
11 02 01 10 Dispose of Existing Gates			35,200	21,600	-14,700	0	0	42,100	
TOTAL Demolition			130,200	36,800	-14,700	0	0	152,300	
11 02 02 New Gates									
11 02 02 5 Fabrication			0	0	0	0	1,574,400	1,574,400	
11 02 02 10 Painting			55,400	9,700	10,400	0	0	75,400	
11 02 02 15 Installation			120,900	19,300	0	0	0	140,200	
11 02 02 20 Testing			23,600	0	0	0	0	23,600	
TOTAL New Gates			199,900	29,000	10,400	0	1,574,400	1,813,600	

** PROJECT DIRECT SUMMARY - Level 4 (Rounded to 100's) **

	QUANTY UOM	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
11 02 03 Gate Closure		0	0	0	0	135,100	135,100	
11 02 04 Miscellaneous Items		57,400	0	34,600	0	0	92,000	
11 02 05 Mobilization and Demobilization		33,600	15,500	0	0	0	49,100	
TOTAL Floodwalls		421,100	81,300	30,200	0	1,709,500	2,242,100	
TOTAL Levees and Floodwalls		421,100	81,300	30,200	0	5,866,000	6,398,600	
30 Planning, Engineering, & Design								
30 01 Planning, Engineering, & Design								
30 01 1 Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
TOTAL Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
TOTAL Planning, Engineering, & Design		0	0	0	0	991,000	991,000	
31 Construction Management								
31 01 Construction Management								
31 01 1 Construction Management		0	0	0	0	661,000	661,000	
TOTAL Construction Management		0	0	0	0	661,000	661,000	
TOTAL Construction Management		0	0	0	0	661,000	661,000	
TOTAL ST. LOUIS FLOOD PROTECTION		421,100	81,300	30,200	0	7,518,000	8,050,600	
Field Office Overhead							112,100	
SUBTOTAL							8,162,700	
Home Office Overhead							188,300	
SUBTOTAL							8,351,000	
Profit							254,300	
SUBTOTAL							8,605,300	
Bond							30,700	
TOTAL INCL INDIRECTS							8,636,000	
Contingency							1,602,000	
TOTAL INCL OWNER COSTS							10,238,000	

11 01. Levees	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT

11. Levees and Floodwalls

11 01. Levees

11 01 01. Rehab/Replace Exist Relief Wells

Assumptions:
There are 110 wells in the drainage district of which 7 wells are destroyed or damaged and will have to be replaced leaving 103 wells to pump test. Assume that 20% of the remaining wells will need to be replaced.

Redevelop and Pump Test Relief Wells - 103ea
Rehabilitate Relif Wells (chemical & mechanical rehab) - 63ea
Replace Relief Wells - 20ea

*Costs for these items are based on the current Geotech AE contract as well as other recent contracts awarded in the St. Louis District. (includes all contractor markups)

	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
TOTAL Redevelop and Pu	103.00	EA			0	0	0	0	309,000	309,000	3000.00
TOTAL Rehabilitate Exi	63.00	EA			0	0	0	0	409,500	409,500	6500.00
TOTAL Replace Wells	20.00	EA			0	0	0	0	600,000	600,000	30000
TOTAL Pilot Holes for	20.00	EA			0	0	0	0	80,000	80,000	4000.00
TOTAL Rehab/Replace Ex					0	0	0	0	1,398,500	1,398,500	

11 01 02. New Relief Wells

The new relief wells are recommended based on underseepage problems that ocurred during the flood of 1993.

*Costs for these items are based on the current Geotech AE contract as well as other recent contracts awarded in the St. Louis District. (includes all contractor markups)

	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
TOTAL New Relief Wells	70.00	EA			0	0	0	0	2,100,000	2,100,000	30000
TOTAL Pilot Holes for	70.00	EA			0	0	0	0	280,000	280,000	4000.00
TOTAL New Relief Wells					0	0	0	0	2,380,000	2,380,000	

11 01. Levees	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
11 01 03. Underseepage Remediation											
During the 1993 flood, foundation soils in many areas expeinced damage. These areas were either temporarily or permanently repaired. Before the construction of the relief wells a Foundation Investigation will be done to determine the extent of these damages. Assume 10% of the relief well cost for the potential repair of these damaged areas.											
11 01 03 5. Foundation Repair											
USR Foundation Repair	1.00	LS		0.00	0	0	0	0	378,000	378,000	378000
TOTAL Foundation Repai					0	0	0	0	378,000	378,000	
TOTAL Underseepage Rem					0	0	0	0	378,000	378,000	
TOTAL Levees					0	0	0	0	4,156,500	4,156,500	
11 02. Floodwalls											
11 02 01. Demolition											
11 02 01 5. Remove Existing Gates											
Assume 8hrs per gate to remove and prep the opening for permanent closure. Total Closure Structures = 33ea Closure Structures w/Single Gate = 22ea Closure Structures w/Double Gates = 11ea Total Gates = 44ea											
MIL PM Outside Steel Workers-Foreman	352.00	HR	X-STRSTEEL	1.00	17,093	0	0	0	0	17,093	48.56
MIL PM Outside Steel Workers - 2ea	704.00	HR	X-STRSTEEL	1.00	33,482	0	0	0	0	33,482	47.56
MIL PM Outside Laborers, (Semi-Skilled)-2ea	704.00	HR	X-LABORER	1.00	27,831	0	0	0	0	27,831	39.53
MIL PM Outside Equip. Operators, Heavy	352.00	HR	X-EQOPRHVY	1.00	16,584	0	0	0	0	16,584	47.11
MAP PM CRANE,HYD,S/P,RT,4WD,20T/70'BOOM	352.00	HR	C75GV002	1.00	0	13,434	0	0	0	13,434	38.16
MAP PM WELDER, 300 AMP, STICK & WIRE FEED, TRLR MTD	352.00	HR	W35LC004	1.00	0	1,755	0	0	0	1,755	4.99
TOTAL Remove Existing					94,990	15,189	0	0	0	110,179	

11 02. Floodwalls	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
11 02 01 10. Dispose of Existing Gates											
Assume gates to be hauled to a scrap yard in the St. Louis vicinity for salvage. Assume a day per gate for loading and hauling to the scrap yard for disposal. (crane, operater and laborers 1/2 time only) 44ea x 8hr/ea = 352hrs Assume the existing gates to weigh 75% of the new 393,600lb x .75 = 295,200lb Use a salvage value of $.05/lb											
MIL PM Outside Laborers , (Semi-Skilled)-2ea	352.00	HR	X-LABORER	1.00	13,916	0	0	0	0	13,916	39.53
MIL PM Outside Equip. Operators, Heavy	176.00	HR	X-EQOPRHVY	1.00	8,292	0	0	0	0	8,292	47.11
MAP PM CRANE,HYD,S/P,RT,4WD,20T/70'BOOM	176.00	HR	C75GV002	1.00	0	6,717	0	0	0	6,717	38.16
MIL PM Outside Truck Drivers, Heavy *	352.00	HR	X-TRKDVRHV	1.00	13,022	0	0	0	0	13,022	37.00
EP PM TRK,HWY, 46,000 GVW, 6X4, 3 AXLE	352.00	HR	T50FO018	1.00	0	12,284	0	0	0	12,284	34.90
EP PM TRLR, 50 TON, DETATCHABLE GOOSENECK, 3 AXLE, 8'6"W X 24" L	352.00	HR	T45EA007	1.00	0	2,606	0	0	0	2,606	7.40
USR PM Steel Salvage	295200	HR		0.00	0	0	-14,760	0	0	-14,760	-0.05
TOTAL Dispose of Exist					35,230	21,607	-14,760	0	0	42,077	
TOTAL Demolition					130,220	36,796	-14,760	0	0	152,256	
11 02 02. New Gates											
There are 20 closure structures that will require gate replacement. The structures are comprised of 20 single leaf gates and 8 double leaf gates for a total of 28 gate leaves to be fabricated and installed.											
11 02 02 5. Fabrication											
Fabrication costs are an average based on recent St. Louis District Contracts for various types of gated structures. Fabrication costs considers recent increases in raw material cost and delivery to the jobsite. - Use $4.00/lb											
USR PM Fabricate New Gates	393600	LB		0.00	0	0	0	0	1,574,400	1,574,400	4.00
TOTAL Fabrication					0	0	0	0	1,574,400	1,574,400	
11 02 02 10. Painting											
Assume a 5 coat vinyl paint system.											
L CIV PM Struct steel projects, metal prep, brush-off blast	15000	SF	APTSD	250.00	7,635	1,337	1,050	0	0	10,022	0.67

11 02. Floodwalls	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
CIV PM Ctg & paints, V-106D, light red oxide, vinyl paint (2-coats)	30000	SF	N/A	0.00	0	0	3,900	0	0	3,900	0.13
CIV PM Ctg & paints, V-766E, w/ added abrsv, gray, vinyl paint (3-coat	45000	SF	N/A	0.00	0	0	5,400	0	0	5,400	0.12
L CIV PM Structural steel , 1 coat, paint, spray, heavy size, appl only	75000	SF	APTSD	200.00	47,715	8,348	0	0	0	56,063	0.75
TOTAL Painting					55,350	9,684	10,350	0	0	75,384	
11 02 02 15. Installation Assume installation and alignment to take 2day/ea leaf. 28 leaves x 16hrs = 224hrs											
MIL PM Outside Steel Workers-Foreman	448.00	HR	X-STRSTEEL	1.00	21,754	0	0	0	0	21,754	48.56
MIL PM Outside Steel Workers - 2ea	896.00	HR	X-STRSTEEL	1.00	42,613	0	0	0	0	42,613	47.56
MIL PM Outside Laborers , (Semi-Skilled)-2ea	896.00	HR	X-LABORER	1.00	35,422	0	0	0	0	35,422	39.53
MIL PM Outside Equip. Operators, Heavy	448.00	HR	X-EQOPRHVY	1.00	21,107	0	0	0	0	21,107	47.11
MAP PM CRANE,HYD,S/P,RT ,4WD,20T/70'BOOM	448.00	HR	C75GV002	1.00	0	17,097	0	0	0	17,097	38.16
MAP PM WELDER, 300 AMP, STICK & WIRE FEED, TRLR MTD	448.00	HR	W35LC004	1.00	0	2,234	0	0	0	2,234	4.99
TOTAL Installation					120,896	19,331	0	0	0	140,227	
11 02 02 20. Testing It is assumed that 2 structures per day can be tested. 20 structures @ 2/day = 10days or 80hrs * Erection Technician is assumed to be an employee of the gate fabricater and rate considers all incidental expenses.											
L MIL PM Outside Steel Workers-Foreman	80.00	HR		0.00	16,000	0	0	0	0	16,000	200.00
MIL PM Outside Steel Workers	80.00	HR	X-STRSTEEL	1.00	3,805	0	0	0	0	3,805	47.56
USR PM Erection Technician	80.00	HR	X-STRSTEEL	1.00	3,805	0	0	0	0	3,805	47.56
TOTAL Testing					23,609	0	0	0	0	23,609	

11 02. Floodwalls	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
TOTAL New Gates					199,856	29,015	10,350	0	1,574,400	1,813,621	

11 02 03. Gate Closure

Gates will be removed and openings permantly closed at 13 Closure structures. Openings are to be closed with reinforced concrete. Wall thickness varies per location.
Pricing for this item is based on recent contract for similar work. Reference Festus Railroad Closure and Closure structures for the Valley Park project. $550/cy - 25% for OH&Profit = $440/cy

Quantities -
C-5 = 38cy
C-6 = 11cy
C-8 = 26cy
C-12 = 20cy
C15 = 19cy
C-17 = 12cy
C-24 = 44cy
C-27 = 19cy
C-29 = 41cy
C-30 = 43cy
C-31 = 13cy
C-32 = 11cy
C-36 = 10cy

Total reinforced concrete required for closure = 307cy

11 02. Floodwalls	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
USR PM Reinforced Concrete	307.00	CY		0.00	0	0	0	0	135,080	135,080	440.00
TOTAL Gate Closure					0	0	0	0	135,080	135,080	

11 02 04. Miscellaneous Items

Widths and heights very by structure. For estimating purposes assume an average opening width of 25' and gate height of 15'.

Assumptions -
Four joints per structure will require new backer rod and joint sealant.
Use 500 lbs of structural steel per gate for misc. items

11 02. Floodwalls	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
RSM PM Waterstop, rubber, center bulb, 1/4" thick, 6" wide (20ea x 25')	500.00	LF	ACARCARP1	18.13	1,255	0	1,785	0	0	3,040	6.08
B MIL PM Remove old caulking & sealant (4ea@15' x 20ea)	1200.00	LF	AMABBRIC1	10.00	5,201	0	0	0	0	5,201	4.33

11 02. Floodwalls	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
L MIL PM Caulking & sealants, backer rod, polyethylene, 1/2" dia(4ea@15' x 20ea)	1200.00	LF	AMABBRIC1	43.00	1,209	0	36	0	0	1,245	1.04
L MIL PM Caulking & sealants, butyl rubber filler, 1/2" x 3/4" (4ea@15' x 20ea)	1200.00	LF	AMABBRIC1	20.00	2,600	0	720	0	0	3,320	2.77
B MIL PM Install New J-Seals (3ea@15' x 20ea)	900.00	LF	SIWSE17	10.00	8,651	0	25,200	0	0	33,851	37.61
L MIL PM Misc. Structural Steel	10000	LB	SIWSE17	25.00	38,447	0	6,900	0	0	45,347	4.53
TOTAL Miscellaneous It					57,363	0	34,641	0	0	92,004	

11 02 05. Mobilization and Demobilization

Assume a day to mobilize and setup at each site. (33ea x 8hr = 264) Use a day to demob from the last site for a total of 272hrs.

11 02. Floodwalls	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
MAP PM AIR COMPR, 375 CFM, 100 PSI (ADD HOSES & ATTACHMENTS)	272.00	HR	A15XX010	1.00	0	585	0	0	0	585	2.15
MAP PM SANDBLASTER, 3 TON CAP, W/HOSE (ADD 450CFM COMPR & NOZZLE COST)	272.00	HR	A20CM013	1.00	0	432	0	0	0	432	1.59
MAP PM AIR HOSE, 1.25", 100',HARDROCK (USE AS DRILLING ACCESSORIES)	272.00	HR	A20XX003	1.00	0	22	0	0	0	22	0.08
MAP PM WELDER, 300 AMP, STICK & WIRE FEED, TRLR MTD	272.00	HR	W35LC004	1.00	0	157	0	0	0	157	0.58
MAP PM CRANE,HYD,S/P,RT,4WD,20T/70'BOOM	272.00	HR	C75GV002	1.00	0	2,788	0	0	0	2,788	10.25
EP PM TRK,HWY, 46,000 GVW, 6X4, 3 AXLE	272.00	HR	T50FO018	1.00	0	9,492	0	0	0	9,492	34.90
EP PM TRLR, 50 TON, DETATCHABLE GOOSENECK, 3 AXLE, 8'6"W X 24" L	272.00	HR	T45EA007	1.00	0	2,013	0	0	0	2,013	7.40
MIL PM Outside Equip. Operators, Heavy *	272.00	HR	X-EQOPRHVY	1.00	12,815	0	0	0	0	12,815	47.11
MIL PM Outside Laborers, (Semi-Skilled) *	272.00	HR	X-LABORER	1.00	10,753	0	0	0	0	10,753	39.53
MIL PM Outside Truck Drivers, Heavy *	272.00	HR	X-TRKDVRHV	1.00	10,063	0	0	0	0	10,063	37.00
TOTAL Mobilization and					33,631	15,490	0	0	0	49,121	

11 02. Floodwalls	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
TOTAL Floodwalls					421,069	81,301	30,231	0	1,709,480	2,242,082	
TOTAL Levees and Flood					421,069	81,301	30,231	0	5,865,980	6,398,582	

30 01. Planning, Engineeri	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
30. Planning, Engineering, & Design											
30 01. Planning, Engineering, & Design											
30 01 1. Planning, Engineering, & Design In addition to the normal PED costs this estimate considers the cost to complete a Damaged Foundation Investigation to determine any foundation damage that may need to be repaired previous to the installation of the new relief wells.											
USR Planning, Engineering and Design	1.00	LS		0.00	0	0	0	0	991,000	991,000	991000
TOTAL Planning, Engine					0	0	0	0	991,000	991,000	
TOTAL Planning, Engine					0	0	0	0	991,000	991,000	
TOTAL Planning, Engine					0	0	0	0	991,000	991,000	

31 01. Construction Manage	QUANTY	UOM	CREW ID	OUTPUT	LABOR	EQUIPMNT	MATERIAL	SUPPLIES	UNIT PRC	TOTAL COST	UNIT
31. Construction Management											
31 01. Construction Management											
TOTAL Construction Man					0	0	0	0	661,000	661,000	
TOTAL Construction Man					0	0	0	0	661,000	661,000	
TOTAL Construction Man					0	0	0	0	661,000	661,000	
TOTAL ST. LOUIS FLOOD					421,069	81,301	30,231	0	7,517,980	8,050,582	

** CREW BACKUP **

						**** LABOR ****		**** EQUIP ****		TOTAL
SRC	ITEM ID	DESCRIPTION	NO.	UOM	RATE	HOURS	COST	HOURS	COST	COST
	ACARCARP1	1 carpnter			PROD =	100%			CREW HOURS =	28
MIL	B-CARPNTERL	Carpenters	1.00	HR	45.49	1.00	45.49			45.49
	TOTAL					1.00	45.49	0.00	0.00	45.49
	AMABBRIC1	1 brklayr			PROD =	100%			CREW HOURS =	208
MIL	B-BRKLAYR L	Bricklayers	1.00	HR	43.34	1.00	43.34			43.34
	TOTAL					1.00	43.34	0.00	0.00	43.34
	* APTSD	2 paintss + 1 Air Compressor, 375 Cfm			PROD =	100%			CREW HOURS =	435
MIL	A15XX010 E	AIR COMPR, 375 CFM, 100 PSI	1.00	HR	12.53			1.00	12.53	12.53
MIL	A20CM013 E	SANDBLASTER, 3 TON CAP, W/HOSE	1.00	HR	8.90			1.00	8.90	8.90
MIL	A20XX003 E	AIR HOSE, 1.25", 100',HARDROCK	2.00	HR	0.42			2.00	0.83	0.83
MIL	B-LABORER L	Laborers, (Semi-Skilled)	1.00	HR	39.53	1.00	39.53			39.53
MIL	B-PAINTSS L	Painters, Structural Steel	2.00	HR	43.86	2.00	87.71			87.71
	TOTAL					3.00	127.24	4.00	22.26	149.51
	SIWSE17	2 strsteels			PROD =	100%			CREW HOURS =	490
MIL	B-STRSTEELF	Structural Steel Workers	1.00	HR	48.56	1.00	48.56			48.56
MIL	B-STRSTEELL	Structural Steel Workers	1.00	HR	47.56	1.00	47.56			47.56
	TOTAL					2.00	96.12	0.00	0.00	96.12

ITEM ID	DESCRIPTION		
0 5 0. Overhead Items - PM			
11 01 01. Rehab/Replace Exist Relief Wells			
11 01 02. New Relief Wells			
11 01 03. Underseepage Remediation			
11 02 01. Demolition			
11 02 02. New Gates			
* APTSD	2 paintss + 1 Air Compressor, 375 Cfm	PROD = 100%	CREW HOURS = 435
11 02 03. Gate Closure			
11 02 04. Miscellaneous Items			
ACARCARP1	1 carpnter	PROD = 100%	CREW HOURS = 28
AMABBRIC1	1 brklayr	PROD = 100%	CREW HOURS = 208
SIWSE17	2 strsteels	PROD = 100%	CREW HOURS = 490
11 02 05. Mobilization and Demobilization			
30 01 1. Planning, Engineering, & Design			
31 01 1. Construction Management			

** LABOR BACKUP **

SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	**** TOTAL **** HOURS
MIL	B-BRKLAYR	Bricklayers *	25.48	0.0%	35.0%	8.94	0.00	43.34	HR	07/01/03	17.13	208
MIL	B-CARPNTER	Carpenters	28.64	0.0%	35.0%	6.83	0.00	45.49	HR	06/25/03	22.87	28
MIL	B-LABORER	Laborers, (Semi-Skilled) *	23.78	0.0%	35.0%	7.43	0.00	39.53	HR	03/02/04	12.50	435
MIL	B-PAINTSS	Painters, Structural Steel *	26.93	0.0%	35.0%	7.50	0.00	43.86	HR	06/25/03	15.95	870
MIL	B-STRSTEEL	Structural Steel Workers *	26.54	0.0%	35.0%	11.73	0.00	47.56	HR	06/25/03	24.06	980
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	25.27	0.0%	35.0%	13.00	0.00	47.11	HR	03/02/04	23.41	1248
MIL	X-LABORER	Outside Laborers, (Semi-Skilled)	23.78	0.0%	35.0%	7.43	0.00	39.53	HR	03/02/04	9.72	2224
MIL	X-STRSTEEL	Outside Steel Workers *	26.54	0.0%	35.0%	11.73	0.00	47.56	HR	06/25/03	31.09	2560
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	22.73	0.0%	35.0%	6.31	0.00	37.00	HR	03/02/04	19.23	624

SRC	LABOR ID	DESCRIPTION	BASE	OVERTM	TXS/INS	FRNG	TRVL	RATE	UOM	UPDATE	DEFAULT	**** TOTAL **** HOURS
0 5 0. Overhead Items - PM												
11 01 01. Rehab/Replace Exist Relief Wells												
11 01 02. New Relief Wells												
11 01 03. Underseepage Remediation												
11 02 01. Demolition												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	25.27	0.0%	35.0%	13.00	0.00	47.11	HR	03/02/04	23.41	528
MIL	X-LABORER	Outside Laborers, (Semi-Skilled)	23.78	0.0%	35.0%	7.43	0.00	39.53	HR	03/02/04	9.72	1056
MIL	X-STRSTEEL	Outside Steel Workers *	26.54	0.0%	35.0%	11.73	0.00	47.56	HR	06/25/03	31.09	1056
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	22.73	0.0%	35.0%	6.31	0.00	37.00	HR	03/02/04	19.23	352
11 02 02. New Gates												
MIL	B-LABORER	Laborers, (Semi-Skilled) *	23.78	0.0%	35.0%	7.43	0.00	39.53	HR	03/02/04	12.50	435
MIL	B-PAINTSS	Painters, Structural Steel *	26.93	0.0%	35.0%	7.50	0.00	43.86	HR	06/25/03	15.95	870
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	25.27	0.0%	35.0%	13.00	0.00	47.11	HR	03/02/04	23.41	448
MIL	X-LABORER	Outside Laborers, (Semi-Skilled)	23.78	0.0%	35.0%	7.43	0.00	39.53	HR	03/02/04	9.72	896
MIL	X-STRSTEEL	Outside Steel Workers *	26.54	0.0%	35.0%	11.73	0.00	47.56	HR	06/25/03	31.09	1504
11 02 03. Gate Closure												
11 02 04. Miscellaneous Items												
MIL	B-BRKLAYR	Bricklayers *	25.48	0.0%	35.0%	8.94	0.00	43.34	HR	07/01/03	17.13	208
MIL	B-CARPNTER	Carpenters	28.64	0.0%	35.0%	6.83	0.00	45.49	HR	06/25/03	22.87	28
MIL	B-STRSTEEL	Structural Steel Workers *	26.54	0.0%	35.0%	11.73	0.00	47.56	HR	06/25/03	24.06	980
11 02 05. Mobilization and Demobilization												
MIL	X-EQOPRHVY	Outside Equip. Operators, Heavy	25.27	0.0%	35.0%	13.00	0.00	47.11	HR	03/02/04	23.41	272
MIL	X-LABORER	Outside Laborers, (Semi-Skilled)	23.78	0.0%	35.0%	7.43	0.00	39.53	HR	03/02/04	9.72	272
MIL	X-TRKDVRHV	Outside Truck Drivers, Heavy	22.73	0.0%	35.0%	6.31	0.00	37.00	HR	03/02/04	19.23	272
30 01 1. Planning, Engineering, & Design												
31 01 1. Construction Management												

** EQUIPMENT BACKUP **

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
MAP	A15XX010	AIR COMPR, 375 CFM, 100 PSI	2.89	0.70	4.13	1.37	0.15	0.02	3.26	12.53 HR	707
MAP	A20CM013	SANDBLASTER, 3 TON CAP, W/HOSE	2.64	0.27		0.28	0.10	0.02	5.60	8.90 HR	707
MAP	A20XX003	AIR HOSE, 1.25", 100',HARDROCK	0.14	0.01					0.26	0.42 HR	1142
MAP	C75GV002	CRANE,HYD,S/P,RT,4WD,20T/70'BOOM	13.25	3.62	3.77	1.34	1.17	0.19	14.82	38.16 HR	1248
EP	T45EA007	TRLR, 50 TON, DETATCHABLE	2.36	0.80			1.78	0.30	2.16	7.40 HR	624
EP	T50FO018	TRK,HWY, 46,000 GVW, 6X4, 3 AXLE	10.95	2.01	7.91	2.63	1.49	0.25	9.65	34.90 HR	624
MAP	W35LC004	WELDER, 300 AMP, STICK & WIRE	0.81	0.18	2.31	0.64	0.03	0.00	1.02	4.99 HR	1072

** EQUIPMENT BACKUP - Level 3 **

SRC	ID.NO.	EQUIPMENT DESCRIPTION	DEPR	FCCM	FUEL	FOG	TR WR	TR REP	EQ REP	TOTAL RATE	** TOTAL ** HOURS
0 5 0. Overhead Items - PM											
11 01 01. Rehab/Replace Exist Relief Wells											
11 01 02. New Relief Wells											
11 01 03. Underseepage Remediation											
11 02 01. Demolition											
MAP	C75GV002	CRANE,HYD,S/P,RT,4WD,20T/70'BOOM	13.25	3.62	3.77	1.34	1.17	0.19	14.82	38.16 HR	528
EP	T45EA007	TRLR, 50 TON, DETATCHABLE	2.36	0.80			1.78	0.30	2.16	7.40 HR	352
EP	T50FO018	TRK,HWY, 46,000 GVW, 6X4, 3 AXLE	10.95	2.01	7.91	2.63	1.49	0.25	9.65	34.90 HR	352
MAP	W35LC004	WELDER, 300 AMP, STICK & WIRE	0.81	0.18	2.31	0.64	0.03	0.00	1.02	4.99 HR	352
11 02 02. New Gates											
MAP	A15XX010	AIR COMPR, 375 CFM, 100 PSI	2.89	0.70	4.13	1.37	0.15	0.02	3.26	12.53 HR	435
MAP	A20CM013	SANDBLASTER, 3 TON CAP, W/HOSE	2.64	0.27		0.28	0.10	0.02	5.60	8.90 HR	435
MAP	A20XX003	AIR HOSE, 1.25", 100',HARDROCK	0.14	0.01					0.26	0.42 HR	870
MAP	C75GV002	CRANE,HYD,S/P,RT,4WD,20T/70'BOOM	13.25	3.62	3.77	1.34	1.17	0.19	14.82	38.16 HR	448
MAP	W35LC004	WELDER, 300 AMP, STICK & WIRE	0.81	0.18	2.31	0.64	0.03	0.00	1.02	4.99 HR	448
11 02 03. Gate Closure											
11 02 04. Miscellaneous Items											
11 02 05. Mobilization and Demobilization											
MAP	A15XX010	AIR COMPR, 375 CFM, 100 PSI	2.89	0.70	4.13	1.37	0.15	0.02	3.26	12.53 HR	272
MAP	A20CM013	SANDBLASTER, 3 TON CAP, W/HOSE	2.64	0.27		0.28	0.10	0.02	5.60	8.90 HR	272
MAP	A20XX003	AIR HOSE, 1.25", 100',HARDROCK	0.14	0.01					0.26	0.42 HR	272
MAP	C75GV002	CRANE,HYD,S/P,RT,4WD,20T/70'BOOM	13.25	3.62	3.77	1.34	1.17	0.19	14.82	38.16 HR	272
EP	T45EA007	TRLR, 50 TON, DETATCHABLE	2.36	0.80			1.78	0.30	2.16	7.40 HR	272
EP	T50FO018	TRK,HWY, 46,000 GVW, 6X4, 3 AXLE	10.95	2.01	7.91	2.63	1.49	0.25	9.65	34.90 HR	272
MAP	W35LC004	WELDER, 300 AMP, STICK & WIRE	0.81	0.18	2.31	0.64	0.03	0.00	1.02	4.99 HR	272
30 01 1. Planning, Engineering, & Design											
31 01 1. Construction Management											

GOVERNMENT ESTIMATE WORK SHEET

ED-CE

PROJECT: St. Louis Flood Protection DATE: 20-Oct-2004

SUBJECT: Reach 3 & 4 Breakdown of MCACES FILE:

ITEM	QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT
Reach 3 -				
Replace				
Demo	9	EA	7,000.00	63,000
New Gates	9	EA	137,000.00	1,233,000
Misc.	9	EA	7,000.00	63,000
Mob and Demob	9	EA	2,300.00	20,700
Subtotal				1,379,700
Close				
Demo	6	EA	7,000.00	42,000
Gate Closure	6	EA	16,000.00	96,000
Mob and Demob	6	EA	2,300.00	13,800
Subtotal				151,800
Total Reach 3				1,531,500
Reach 4 -				
Replace				
Demo	11	EA	7,000.00	77,000
New Gates	11	EA	137,000.00	1,507,000
Misc.	11	EA	7,000.00	77,000
Mob and Demob	11	EA	2,300.00	25,300
Subtotal				1,686,300
Close				
Demo	7	EA	7,000.00	49,000
Gate Closure	7	EA	16,000.00	112,000
Mob and Demob	7	EA	2,300.00	16,100
Subtotal				177,100
Total Reach 4				1,863,400

SUBTOTAL:		$3,394,900
CONTINGENCIES: (in %)	0	($4,900)
SUBTOTAL:-------------------		$3,390,000
P.E. & D. (in %)--------------	0	$0
C.M. (in %)-------------------	0	$0
TOTAL COST		**$3,390,000**

APPENDIX C

DRAFT REAL ESTATE PLAN

Draft Real Estate Plan
St. Louis Flood Protection
Reconstruction Evaluation Report (RER)

Project Description

The St. Louis Flood Protection System is in St. Louis, Missouri. It is divided into two major reaches. Reach 3 extends from the mouth of Maline Creek at Mississippi River mile 187.2 to river mile 180.2 at Carr Street. Reach 4 extends from Poplar Street at river mile 179.2 to Chippewa Street a river mile 176.3. The City of St. Louis hereafter referred to as (City) is the local sponsor.

1. Purpose

This Real Estate Plan is in support of the Reconstruction Evaluation Report (RER), which provides a plan to address the significant potential problems in the St. Louis Flood Protection System that were identified during the 1993 Flood. Significant potential problems were identified to include under-seepage, foundation piping, insufficient freeboard, pipe crossing, toe drains and relief wells. The recommended plan would require that (20) floodgates be replaced, (13) floodgates be closed and (70) new relief wells be installed. In addition, enhancements would be made to the bike trail that runs along the levee and floodwall.

2. Lands, Easements, Rights-of-Way (LER) Required for Construction

As a result of installing new relief wells .10 acre of mitigation land is required in fee and 7.5 acres of permanent easement are required for new relief wells. The repair and closing of floodgates will require no additional land. **The City owns all the land required for the project.**

Fee

a. Fee is required for .10 acre for mitigation. A restrictive deed will be placed on the land to restrict its use for environmental purposes only. The City owns this land in fee.

Permanent Easement

b. Permanent easement is required on 7.5 acres for (70) new relief wells. The City owns permanent easement 25 feet either side the entire length of the floodwall and levee. This has been determined to be adequate to construct the relief wells. No additional land is required for the new relief wells or repair and closure of the floodgates.

Temporary Access and Staging Areas

c. The City has ample land to provide for temporary staging areas. The City will provide an

Entry Permit for these areas. At this time, sites have not been determined. There are two areas that will require access from private entities but the city requests that they obtain a right-of-entry for this purpose. They have good relationships with the entities identified and have used this method in the past.

Since the City of St. Louis already acquired all the land for the original project and no additional land is required for the reconstruction, no additional estates are necessary.

3. LER Required that is Owned by Sponsor

The City owns all of the land required for the project. The City purchased the property for completion of the Flood Protection Project in the early 1970's. The City received credit for these properties on the original project.

4. Non-Standard Estate

No non-standard estates are required.

5. Existing Federal Project within the LER Required for the Project

The original St. Louis Flood Protection project is a federal levee. The LER required for the reconstruction is within this federal project.

6. Federally Owned Land Required for the Project

No federally owned land is required for the project.

7. Navigation Servitude

Navigation servitude is not applicable to this project.

8. Map depicting the area

A project map of the area is included as Exhibit A.

9. Possibility of Induced Flooding Due to Project

No induced flooding will occur.

10. Baseline Cost Estimate

No cost estimate is required because the City owns all the property. No credit can be given since it was purchased in the early 1970's for the original flood protection project and credit has already been granted.

11. Relocation Assistance Benefits under Public Law 91-646

No persons, farms, or businesses will be displaced by this project.

12. Mineral Activity in Project Area

No mineral activity is located in the project area.

13. Sponsors Legal and Professional Capability to Acquire LER

City has acquired real property interests for the original 10.9-mile Flood Protection Levee Project that was completed in 1974. The sponsor has the in-house staff to facilitate the purchase of any property necessary from private landowners in accordance with P.L. 91-646. No private property is required for the reconstruction. A capability assessment has been completed and is shown in Exhibit B. It is for informational purposes only.

14. Zoning ordinances proposed

No zoning ordinances are proposed.

15. Schedule of Land Acquisition Milestones

Since no property needs to be acquired for this recommended plan, the sponsor will provide an entry permit and attorney's certificate before construction can begin.

16. Facility or Utility Relocations/Alterations

No facility or utility relocations/alterations are required for the project.

17. Impacts of Suspected or Known Contaminants

A Phase I HTRW Real Estate Historical Search of the properties indicated that many commercial and heavy industrial businesses are located near the area that the relief wells will be constructed. This report was provided to ED-HQ. The Phase I HTRW Test Report by ED-HQ provides requirements for health and safety during construction of relief wells.

18. Landowner Support or Opposition to the Project

No opposition is known to exist for the project. Protection of the City against flood is the most important factor for the businesses and landowners located behind the flood protection project.

19. Notification to the Non-Federal Sponsor Regarding the Risks Associated Land before Execution of the Project Cooperation Agreement (PCA)

The sponsor does not need to acquire any real estate for the project.

20. Other Real Estate Issues Relevant to the Project

None are known to exist.

This Real Estate Plan is recommended for approval as part of the Reconstruction Evaluation Report.

Thomas R. Hewlett
Chief, Real Estate Division

Real Estate Plan-Sharon Wolf-2/2/04

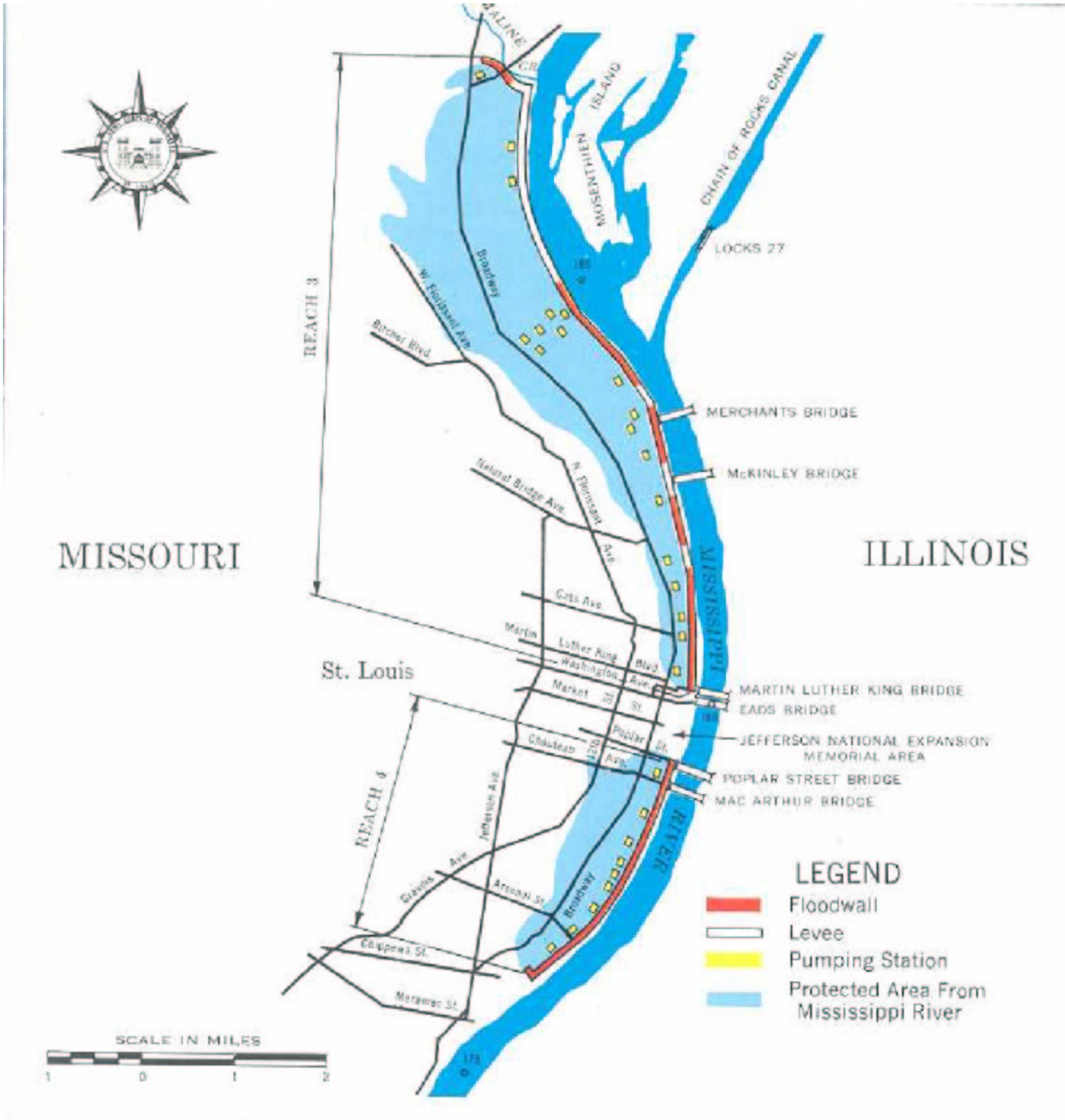
MISSOURI
ILLINOIS
St. Louis
REACH 3
REACH 4
MOSENTHEIN ISLAND
CHAIN OF ROCKS CANAL
LOCKS 27
MERCHANTS BRIDGE
McKINLEY BRIDGE
MISSISSIPPI
RIVER
MARTIN LUTHER KING BRIDGE
EADS BRIDGE
JEFFERSON NATIONAL EXPANSION MEMORIAL AREA
POPLAR STREET BRIDGE
MAC ARTHUR BRIDGE
Broadway
W. Florissant Ave.
N. Florissant Ave.
Natural Bridge Ave.
Cass Ave.
Martin Luther King Blvd.
Washington Ave.
Market St.
Poplar St.
Chouteau Ave.
Jefferson Ave.
Gravois Ave.
Arsenal St.
Chippewa St.
Meramec St.
LEGEND
Floodwall
Levee
Pumping Station
Protected Area From Mississippi River
SCALE IN MILES
1
0
1
2

EXHIBIT A

ASSESSMENT OF NON-FEDERAL SPONSOR'S
REAL ESTATE CAPABILITY

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? Yes, per discussion held with Mr. Mike Seemiller, Survey Project Coordinator, on December 30, 2003, the City of St. Louis has the legal authority to acquire and hold title to real property for project purposes.

b. Does the sponsor have the power of eminent domain for this project? Yes, the sponsor has power of eminent domain and but are not required to use it for project purposes.

c. Does the sponsor have "quick-take" authority for this project? The Sponsor does have "quick take" authority.

d. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? No, all of the land required for the project is within the City of St. Louis.

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of the Federal project including P.L. 91-646, as amended? No, the City has Real Estate Specialists who have been acquiring property for City for a number of years. They are familiar with P.L. 91-646 and the federal regulations for acquiring property. The City acquired all the property for the floodwall and levee system completed in 1974 and for other City projects since that time.

b. If the answer to II.a. is "yes," has a reasonable plan been developed to provided such training? N/A

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? Yes, as described above.

d. Is the sponsor's projected in-house staffing levels sufficient considering its other workload, if any, and the project schedule? No acquisition is required but if some would occur the City has the staff to support.

e. Can the sponsor obtain contractor support, if required in a timely fashion? Yes, the City will sub-contract engineering, appraisal and title work, if needed.

EXHIBIT B

f. Will the sponsor likely request USACE assistance in acquiring real estate? No, the

City does not have to acquire property for this reconstruction work.

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? The City's real estate staff is located at St. Louis City Hall.

b. Has the sponsor approved project/real estate schedule/milestones? No, the project schedule has not been provided to the City at this time and a real estate schedule is not required.

IV. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? The City successfully acquired all the real estate interests for the original floodwall and levee project.

b. With regard to this project, the sponsor is anticipated to be fully capable. The City has purchased numerous properties under P.L.91-646 regulations. The City is fully aware of the USACE requirements for surveying, title evidence, legal descriptions, appraisal, and negotiations but these requirements will not be necessary on this project.

EXHIBIT B

APPENDIX D

ENGINEERING ANALYSIS DOCUMENTS

Structural Evaluation

1 Introduction

a. An evaluation of the problems with the structures of the St. Louis Flood Protection System has been performed. This report details the findings. The scope of work included the portion of the structures under the supervision of the City of St. Louis (flood walls and closure structures). Metropolitan Sewer District (MSD) is not a project participant. The portion of the project under the supervision of MSD was partially evaluated as follows: pump stations were not evaluated; gatewells were evaluated from the exterior only; outlet works were evaluated as possible depending on river stage/submergence during the inspections days. This study can authorize federal funding only for those problems resulting from design or construction deficiencies. Problems associated with lack of maintenance or abandonment are the responsibility of the City of St. Louis or MSD. Note that this project is not a periodic inspection and will not repeat all information in the previous periodic inspection, nor does it replace the next regularly scheduled periodic inspection.

b. Probabilities of unsatisfactory performance for elements of the system without the project have been determined at the 1, 2, 5, 10, 25, 50, 100 and 500 year flood events. Conditional probability given unsatisfactory performance for each flood event was determined for low, medium and high levels of damage. The consequences of unsatisfactory performance at the low and medium levels have been described. Quantities of manpower and material for the low and medium damage levels were given to Cost Engineering for assessment of costs. The Economics Section will determine the costs of partial inundation for the medium damage level and the high level damage consequences (total inundation) and costs. Rehabilitation scenarios have been developed and quantities for each repair alternative estimated. Cost Engineering will evaluate the costs for the repair alternatives.

c. The St. Louis Flood Protection System has a total of 40 closure structures. Closure structures are required where an opening in the floodwall or levee allows for vehicle, rail or pedestrian travel. The openings are closed-off during highwater events with some type of gate. The St. Louis Flood Protection System has two types of gates: Swing gates and panel closures. Swing gates are steel gates that are attached with hinges and swing shut to make closure. Panel closures have aluminum panels that are erected to make closure. The only structures determined to have a design deficiency were the steel swing gates. These gates have degraded and result in significant increase in the probability of unsatisfactory performance. Other problems have been determined to be maintenance items and are the responsibility of the City of St. Louis and MSD.

2 Swing Gate Analysis.

a. The following is a description of the closure gate inspection and reliability analysis that has been performed.

b. Inspection of the swinging closure gates was performed. Original Design documents were retrieved from storage. Notes from the field inspection have been assembled in a spreadsheet together with other relevant gate information taken from the drawings and specifications (Table 1). Per the City of St. Louis, gates at thirteen locations are no longer used and could be permanently closed.

c. Inspection revealed the following:

1) Gates have been recently painted with very poor surface preparation.
2) Localized corrosion through the gage metal skin plates at the bottom of the gates and at the horizontal girders. (See Figures 1, 2 and 3.)
3) Bottom of some gates repaired. Different methods of repair used. Some repairs started but not finished. Some of the repairs have deteriorated.
4) A large percent of the gates have dirt, mud or debris on or piled around the gate bottoms. Some areas have poor drainage around the gates.
5) Many seals have cracked/torn pieces.
6) Missing strut pit covers.
7) Spalled concrete.
8) Other problems as noted in previous periodic inspection reports.

d. Of these conditions, only the problem of steel corrosion is considered a design deficiency. Other items are the responsibility of the City of St. Louis to repair/maintain.

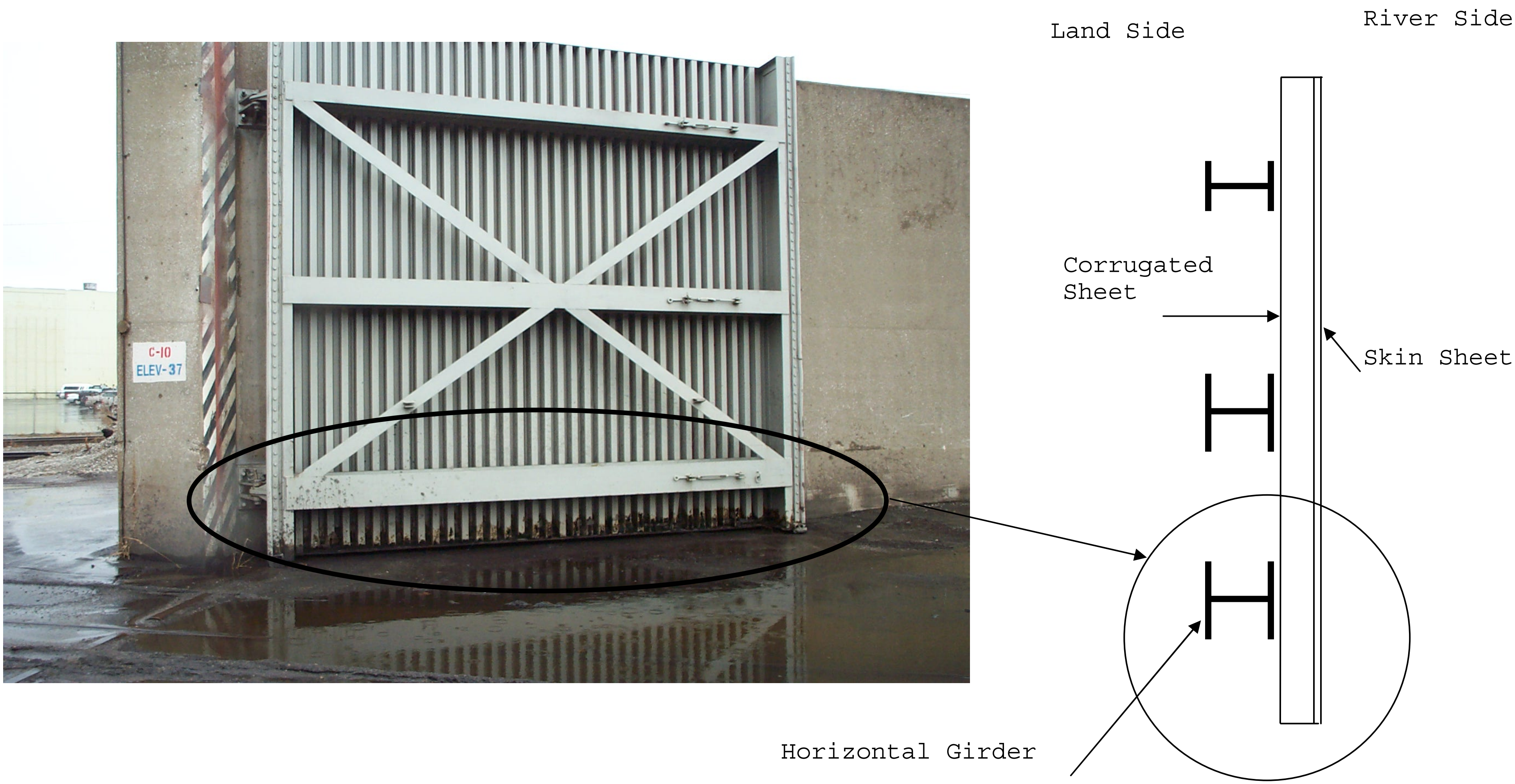

Figure 1. Typical Swing Gate and Vertical Cross Section

Figure 2. Corrosion of Sheet Metal

Figure 3. Corrosion Through Sheet at Girder

3 Design Deficiencies

a. The steel swinging closures gates for the St. Louis Flood Protection have localized corrosion problems stemming from design deficiencies. The skin plate for the gates is a double layer of 16 or 18 gage sheet steel (one corrugated and one flat). The flat sheet forms the damming surface. The corrugations of the corrugated sheet run vertically and span between horizontal girders. The space between the two layers is inaccessible for preparation and application of coatings. EM 1110-2-2105, *Design of Hydraulic Steel Structures*, states in Appendix H d(1) that the minimum skin plate thickness shall be ¼ inch and in Section 2-2b(1) that details allow for a sandblasting hose. Additionally, the industrial environment of some of the gates is highly corrosive. EM 1110-2-2105 states in Section 2-2a(1) that in severe environments additional thickness may be required. The localized corrosion has been most severe at the bottom of the gates, however, another location of corrosion is the connection of the skin sheet steel to the horizontal girders. Welding of the corrugated sheets to the girders destroyed the original coating on the skin plate side of the corrugated sheet. Lack of access made touch up coating impossible. The area between the girder and the corrugated sheet also traps moisture and dirt since seal welding all around was not possible. EM 1110-2-3400, *Painting: New Construction and Maintenance,* Section 2-4a states the importance of design for corrosion control and avoidance of crevices.

4 Analysis Format

a. The format of reliability analysis/results was coordinated with the Economics Section. Per the requirements of the economics section,

1) Probabilities of unsatisfactory performance were calculated for the "without project" condition and the repair alternatives.
2) Analyses were performed for 8 return periods (1, 2, 5, 10, 25, 50, 100 and 500 years). Water elevation mean and standard deviation at selected sites for the required return periods were provided by Hydrologic Engineering and are shown in Table 1.
3) Conditional probabilities were determined for three levels of damage when given that unsatisfactory performance has occurred.

b. The gates were considered a series system versus a parallel system since failure of one will fail the entire system. For a series system with independent variables, the reliability is the product of the individual reliabilities.

5 Variables

The variables used in the analyses are as follows:

a. *Steel yield stress*

Bending mean = 1.08(stated mean)
Shear mean = 1.10 (stated mean)
Bending coefficient of variation = 14%
Shear coefficient of variation = 15%

Distribution = lognormal
Reference: Major Rehabilitation Report No. 2 Lock and Dam No. 24

b. *Corrosion*

A local materials testing firm was employed to test metal thickness on selected gates. Means and standard deviations of percentage of material lost were calculated from the data. The effect of uniform corrosion on reducing the reliability of the gates was not as significant as the effect of localized corrosion. Localized corrosion of the corrugated sheet at the horizontal beams has, in the worst cases, changed the continuous span to simple span and changed the governing web crippling equation to free end. Field measurements showed that on some gates 17 gage material was substituted for the 18 gage material indicated on the plans. This material difference is noted in Table 1 under the heading "As Built Gage". Measurements were not taken at the localized corrosion because the surface was too rough to accurately measure and the area behind the girder flange was inaccessible.

From the measurements, for uniform corrosion:

Mean loss = 3.19 mils
Std Deviation = 4.12 mils
Distribution = lognormal
See computations for linear model with time.

For the localized corrosion of the gates other than the sixteen worst (replaced under Alternative 1) it was assumed that the current corrosion is two thirds of the original thickness and that the standard deviation is twice the standard deviation of the uniform corrosion. Thus the following:

Mean = 40.0 mils
Std Deviation = 8.24 mils
Distribution = lognormal
See computations for linear model with time.

c. *Modeling Uncertainty*

ks, a variable to account for modeling uncertainty and initial material tolerance:
Mean = 1.02
Std deviation = 0.1
Distribution = normal
Reference: Reliaibility Analyss of Hydraulic Steel Structures with Fatigue and Corrosion Degradation, March 1, 1994, WES and JAYCOR. Major Rehabilitation Report No. 2 Lock and Dam No. 24.

d. *Water Elevation*

Mean = varies by site
Std deviation = 1.0 ft
Distribution = normal
Per Hydrologic Engineering, the fetch is not long enough to apply waves.

6 Alternatives

a. Two levels of repair were investigated in addition to the “without project” condition: replace or recondition (by reskinning) selected deteriorated gates (or permanently close if location is obsolete are we sure that they will be obsolete during the project life - 100’s years.); replace or reskin all gates (or permanently close if location is obsolete). The term “reskin the gates” means removing of the skin plate sheet and the corrugated sheet and replacing with vertically spanningl structural steel tees and a ¼” minimum thickness plate steel skin.

b. These alternatives cover the range of repair approaches that are suitable for long-term solution of the problem. Repair of the lower cantilevers was not considered to be a long-term solution since the sheet steel in the upper part of the gate is also deteriorated and can not be adequately maintained. Also, the cantilever repair does not provide the moment reduction in the vertical corrugated steel span between the lower and upper horizontal girders as required by the original design.

c. The selection of which gates to included in Alternative 1 was based on the conditions observed during the field investigation. Alternative 1 includes replacement or reskinning of 10 gates (C-3, C-4, C-10, C-14, C-16, C-20, C-22, C-23, C-25 and C-26) and permanent closure of 6 gates (C-5, C-8, C-27, C-29, C-30 and C-31). Alternative 2 includes permanent closure of 13 gates (C-5, C-6, C-8, C-12, C-15, C-17, C-24, C-27, C-29, C-30, C-31, C-32 and C-36) and replacement or reskinning of all 20 other swing gates. A table of estimated quantities of materials required for each alternative was prepared for Cost Engineering.

7 Probabilities

a. Probabilities of unsatisfactory performance were calculated for the limit states for bending, shear and bearing. The selection of which gates to perform the analyses upon was made by consideration of level of deterioration and inspection of gate data for maximum loadings. For each alternative group, the selected gate is for the worst deterioration and the greatest load. Probabilities were calculated using the @RISK software to perform Monte Carlo simulation. All probabilities shown are output from 10,000 iterations. Original minimum section moduli were taken from the drawings. But 17 guage steel was substitiuted for 18 ga. Making original moduli too high.

b. The probability of unsatisfactory performance for the “without project” case is from the analysis of bending the lower cantilever of gate C-25 (Table 2). The section property used is based on the original section but with the compression flange gone due to local corrosion of the corrugated sheet at the horizontal beam. This represents the worst corrugation flange and is a conservative assumption since not all compression flanges are completely gone. Load is redistributed to adjacent corrugations. These corrugations have some level of corrosion and it is uncertain if they will carry additional load. Also, uniform corrosion causes further reduction of section. Additional capacity due to the end plates or the angle at the bottom is not accounted for in this analysis.

c. The critical result for Alternative 1 (worst gates replaced, reskinned or permanently closed) was from analysis of C-24 for bending of the lower cantilever (500 year and 100 year results shown in Table 3). This analysis models the built-up section (composed of the skin plate sheet and the corrugated sheet) as a continuous beam over the horizontal girders. Two locations for bending were considered. The maximum moment is at the middle horizontal girder. This is not the critical location because, after yielding, the moment will redistribute to a mid span section away from the localized corrosion at the girder. The critical section for bending is the bottom cantilever. Once the section is yielded there is no redundant load path. Corrosion has not progressed to the extent of creating the hinges and simple spans of the without project alternative. Both uniform and localized corrosion are modeled as linearly progressing with time. The bearing limit state was also investigated. Bearing on the lower horizontal girder did not govern (500 year and 100 year results shown in Table 4). The limit state for bearing was taken as 1.5 times the allowable load. The factor 1.5 was from comparison of allowable and LRFD load tables in a manufacturers catalog. The equation for allowable load was taken from *Structural Engineering Handbook*, 3rd Edition, Chapter 10 – Design of Cold-Formed Steel Structural Members, Equation 22b and is for web crippling with reaction away from the member end. The reaction on the lower girder was calculated using the tributary area. A shear analysis was performed but did not control the reliability for this alternative. Many of the gates in Reach 3 do not have the localized corrosion at the lower horizontal girder but they do have severe localized corrosion of the lower cantilever. The City of St. Louis has made extensive repairs to many gates either by adding plates to cover holes or repairing the entire lower cantilever. These repairs are considered temporary. The reliability model described above is thus used to represents the probability of unsatisfactory performance of all remaining gates.

d. The new or reskinned gates and permanent closures are assumed to perform satisfactorily for the 30 year economic justification period. Therefore the probability of unsatisfactory performance for Alternative 2 (all gates replaced or closed) is taken as zero.

8 Consequences

a. Three levels of consequences are considered for each alternative.

b. *Without Project Alternative*

The limit state is for bending stress in the lower cantilever equal to yield. The low level cost consequences are represented by a response to the problem before high waters arrive. Rock would be placed against the sixteen worst gates (those called for replacement in Alternative 1) immediately after the gates are closed and as the water is rising on the gates. These sixteen gates would be monitored 24 hours per day. Management and flood fighting activities would consist of placement of 1400 tons of rock before a large event, the efforts of 10 people for 21 days to monitor problems during the event and the removal of the rock after the event. The medium level cost consequences are represented by a failure of the lower cantilever because of the rock berm not being placed in time. Significant displacement of a section of the cantilever is assumed resulting in an opening with an area of 5 square feet. The head of water pushing through the opening is assumed to be 16.4’. Extraordinary flood fighting efforts are required. A crushed stone berm would be placed or other structural solution implemented but the effort to stop the leakage is made more difficult since access to the site is now through incoming flood waters. It is assumed it takes two days to perform the emergency repair and stop the flooding. Per Hydrologic Engineering, this would result in an estimated 526 acre-feet of water entering the protected area. These efforts would be in addition to the efforts stated in the low cost consequences. The total cost for the medium level consequences would be from 20 people for 21 days, 1900 tons of rock placed before and removed after the event and the limited inundation acreage. The high level cost consequences would be total inundation of the protected area. This would result from leakage causing scour and undermining a wall section.

c. *Alternative 1 With Project (Some gates replaced, some permanently closed)*
The limit state is for bending stress in the lower cantilever equal to yield, which is the same scenarios as in the without project analysis. The low level cost consequences are represented by small displacement of a section of the skin plate and minor leaking. It is assumed that the leaking is not too severe and that it is noticed and stopped before significant flooding occurs. It is assumed that 250 tons of rock is placed when the leak is noticed and removed after the flood. Monitoring and management would require 10 people for 21 days. The medium level cost consequences are represented by the same medium level consequences scenario detailed in the without project alternative above except that the effort for the sixteen worst gates is not needed. Total costs are from 15 people for 21 days, 500 tons of rock placed and removed and the limited inundation acreage. The high level cost consequences would be total inundation of the protected area.

d. *Alternative 2 With Project (All gates replaced)*
As stated above the new gates are assumed to perform satisfactorily for the 30 year economic justification period. Therefore there are no consequences or associated costs.

9 Conditional Probabilities

The conditional probabilities given unsatisfactory performance for each of the alternatives were determined from an analysis considering the condition of the structure and the likelihood of each level of consequence occurring. Component analysis results (single gate analysis) for year 2004 are summarized in Table 5.

10 System Probability for the Gates

For each flood return period considered, the probability of unsatisfactory performance and high damages for the system of gates was calculated as follows:

Without-Project Alternative:
$P(f)_{\text{gate system}} = 1-[1-(P(f)_{\text{group of 16}})(\text{High Damages Conditional Probability})]^{16} \times [1-(P(f)_{\text{group of 17}})(\text{High Damages Conditional Probability})]^{17}$

Alternative #1:
$P(f)_{\text{gate system}} = 1-[1-(P(f)_{\text{group of 17}})(\text{High Damages Conditional Probability})]^{17}$

Results for the system of gates are summarized in Table 6.

11 Panel Gates

Closure of C-1A, C-1, C-2, C-18, C-19, C-21 and C-38 is made with panel gates. During June of 2001, river levels necessitated the erection of C-18 and C-19. Inspection revealed these two structures to be in good condition. Some seals need replacement. The other panel structures were not inspected. Access to panel closures is only accomplished with assistance from the City due to the large concrete blocks that lock the shed doors. It is assumed that they are also in good condition due to their protected storage in the sheds. Todd Waelterman of the St. Louis Street Department agreed that all of the panel structures are in good condition except that the C-2 panels were stolen. The City's plan for C-2 is to make closure with sand bags.

12 Flood Wall Stability

The stability of two soil founded floodwall monoliths was checked. The monoliths selected for checking are representative of other soil founded monoliths in the St. Louis Flood Protection. The monoliths checked were Reach 3, Item F-6A, Monolith 36 and Reach 4, Item F-7C, Monolith 45 (see Tables 7 and 8 for the results of these analyses). Some of the factors of safety are below values required by current criteria. It is our opinion that these structures, as designed, are safe. No modifications to the existing floodwall or closure structures are required for their stability to be adequate during a flood event. Since analysis and the current physical condition (after the 1993 flood loading) do not show that the project will fail, the floodwall is not considered to have a design or construction deficiency (reference ER 1165-2-119, paragraph 7.a.(1)). Also, differential settlement has occurred at several places along the line of protection due to varying foundation designs. These movements are small and are not a deficiency.

13 Conclusions

This project investigated the structural design and condition of the St. Louis Flood Protection. The only structural element of the system found to be inadequate and the result of a design deficiency was the swing gates. The two deficiencies in the swing gate design are inadequate skin plate thickness and poor detailing for corrosion prevention. These deficiencies have resulted is the current inadequate structural capacity of many of the gates and degradation of all the gates will continue with time. For the without project alternative there is a high probability of unsatisfactory performance. Alternative 1 calls for replacement or permanent closure of the sixteen gates that are in the poorest condition. There is a significant probability of unsatisfactory performance for Alternative 1. Alternative 2 calls for replacement or permanent closure of all swing gates. Alternative 2 assumes satisfactory performance for the 30 year economic justification period.

St. Louis Flood Protection

Table 1 Gate Data

																												Flood Water Elevation					
Gate #	Street	Reach	Station	Item	Type	Sill Elev.	Clear Width (ft)	Height (ft)	Top Elev.	Plan Metal Gage	Plan Metal Thickness	As Built Gage	Corrugation Spacing	Overall Sect. Depth	Width Front Corr.	Width Back Corr.	1st Beam	2nd Beam	Top or 3rd Beam	Top	Top Support	1st Beam Sect.	2nd Beam Sect.	Plan Sheet / Beam Weld	Actual Sheet / Beam Weld	Alternative 1	Other Notes	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
C-1A	Riverview	R3	07+42		Panel		10	12																			Bent seal plate. Spalled concrete base.						
C-1	Riverview	R3	07+80		Panel		56	14																			Strut pits and sill covered with asphalt.						
C-2	Railroad	R3	21+87		Panel		31	6.5																			No Panels. City will sandbag.						
C-3	Prarie	R3	210+62	F-2	Swing	419.9	24	18	437.9	16	0.0598		6	4.6	2.675	2	2.12	5.69	5.69	4.5	No			Not welded		Do nothing.	Bottom deteriorated. Debris / mud at bottom. Paint has some large flaking. Strut pits not covered.						
C-4	E. Grand	R3	221+33	L-3A	2-Swing	420.1	30	14.92	435.02	18	0.0478	17	6	4.6	2.675	2	2.42	5	5	2.5	Yes	W12x58	W12x50	Not welded		Do nothing. The City should repair bottom damaged area.	Bottom deteriorated. Some paint flaking. Lower sheet on north gate damaged. Lower beam bent.	415.5	418.9	423.8	426.7	429.8	433.2
C-5	Ferry	R3	241+73	F-3	2-Swing	422.5	30	13.71	436.21	18	0.0478	17	6	4.6	2.675	2	2.13	4.79	4.79	2	No			Some tack		Do nothing.	Deteriorated bottom. RS lower plate added to north gate. Torn seal. Open strut pits. Some paint flaking.						
C-6	Blanton	R3	290+65	F-5	Swing	425.7	20	9.9	435.6	18	0.0478		6	4.6	2.675	2	1.94	5	2.96		No			Welded		Do nothing.	Steel / seals / paint OK						
C-7	Branch	R3	301+42	F-5	2-Swing	423.1	30	12.9	436	18	0.0478	17	6	4.6	2.675	2	2.13	4.79	4.79	1.19	No			Welded		Do nothing.	Some sheets torn at beams from damage. Bottom replaced but deteriorated again. Mud / debris behind gate bottoms. North lower hinge concrete cracked. Sill missing section. Some damage to sheet.	414.1	418.1	422.8	425.9	428.6	432.1
C-8	Railroad	R3	313+11	F-6A	Swing	418.2	20	17.6	435.8	16	0.0478		6	4.6			2.1	6.25	6.25	3	No			Welded		Permanent closure.	Bottom deteriorated. Some sheets corroded through at beams. Mud / debris at bottom.						
C-9	N. Market	R3	324+43	F-6A	2-Swing	419.7	30	14.92	434.62	16	0.0598		6	4.6			2.42	5	5	2.5	Yes			Welded	Not Welded	Do nothing. City should complete bottom repair. Add gussets to north gate. Install seal?	Damaged concrete beam. South bottom replaced but not painted. South seal not fully installed on bottom. North bottom seal not installed. North bottom replacement partially completed (Used two plates and no gusset plates). Sill and strut pits covered with mud and gravel. Paint coming off in large flakes.						
C-10	Railroad	R3	332+29	F-6A	Swing	417.8	17	17.71	435.51	16	0.0598		6	4.6			2.21	6.25	6.25	3	No			Tack Weld	Welded	Replace gate.	Severely deteriorated bottom. Mud at bottom. Spalled concrete. Holes burned through sheet at lower beam tack weld.						
C-11	Madison	R3	334+32	F-6A	2-Swing	418.7	30	14.92	433.62	16	0.0598		6	4.6			2.42	5	5	2.5	Yes			Welded		Do nothing. City should complete bottom repair. Install seal.	Bottom replacement partly completed. Seals not on bottom. Mud / debris at bottom.						
C-12	Chambers	R3	336+67	F-6A1	Swing	420	17	15.5	435.5	16	0.0598		6	4.6			2	5.25	5.25	3	No			Welded		Do nothing.	Bottom replaced but severely deteriorated again. Mud / debris at bottom. Sheet at beams OK.						
C-13	Sand Co.	R3	350+80	F-6A1	Swing	417.4	17	17.5	434.9	16	0.0598		6	4.6			2.21	6.25	6.25	2.79	No			Tack Weld	Welded	Do nothing.	Bottom replaced. Seals bad. Sheet over beams OK. Spalling concrete. Sill gaps at old rails.						
C-14	Mullanphy	R3	364+38	F-6A1	2-Swing	418.9	30	14.92	433.82	16	0.0598		6	4.6			2.42	5	5	2.5	Yes			Welded		Do nothing.	Bottom steel deteriorated. Sheet at beams OK. Some mud at bottom.						
C-15	Railroad	R3	372+04	F-6A1	Swing	419.6	17	15.1	434.7	16	0.0598		6	4.6			2	5.25	5.25	2.6	No			Welded		Do nothing.	Bottom replaced. Sheet at beams OK. Debris / mub at bottom. Couldn't see bottom.						
C-16	UE	R3	379+45	F-6B	Swing	421	18	13.6	434.6	16	0.0598		6	4.6			1.85	4.75	4.75	2.25	No			Welded		Do nothing.	Bottom deteriorated. Sheet at beams OK (at bottom of lower beam about 20% through). Lower paint peeling. Bad section of seal.						
C-17	UE	R3	379+73	F-6B	Swing	422	17	12.6	434.6	16	0.0598		6	4.6			2.1	6.5	4		No			Welded		Do nothing.	Some deterioration at bottom. Sheet at beams OK. Mud / trash at bottom.						
C-18	SullivanWharf	R3	395+57	F-6C	Panel	412.5	54.5	21.9	434.4																		1 strut pocket gone. 2 pockets under asphalt?						
C-19	Poplar	R4	00+43	F-7A	Panel	412.3	78.2	21.4	433.7																								
C-20	Gratiot	R4	10+57	F-7B	Swing	415.4	18	18	433.4	16	0.0598	14/16	6	4.6			2	6	6	4	No			Welded		Do nothing.	Trash, mud behind gate. Rust coming through paint esp. at bottom. 50% of sheets are 50% deteriorated at beams.						
C-21	Chouteau	R4	16+70		Panel		54	18.3																									
C-22	Convent	R4	24+86	F-7B	Swing	414.4	24	18.71	433.11	16	0.0598	14/16	6	4.6			2	6.5	6.5	3.71	No			Welded		Replace gate.	Urgently need new bottom. Bottom replaced but deteriorated again. Sheet rusted through at many beams. Rust coming through paint.	412.9	416.1	420.1	423.8	426	429.8
C-23	Rutger	R4	30+20	S-16	2-Swing	414.7	30	18.29	432.99	16	0.0598	14/16	6	4.6			1.79	6.5	6.5	3.5	No			Welded		Replace gate.	Sheet corrosion at beams varies from 30% to 100%. Mud piled around bottoms. Bottoms deteriorated. Hole in sheet. Seal torn.						
C-24	Rutger	R4	31+02	F-7B	Swing	413.4	24	19.6	433	16	0.0598	14/16	6	4.6			2	6.5	6.5	4.6	No	W14x150	W14x136	Welded		Do nothing.	Mud at base. Half of sheet have 10%-30% deteriorated at lower beam. Paint peeling, especially at bottom. Sill covered with gravel. Seal torn.	412.9	416.1	420.1	423.8	426	429.8
C-25	Miller	R4	37+34	F-7B	2-Swing	413.4	30	19.4	432.8	16	0.0598		6	4.6			2.4	6.5	6.5	4	No	W14x74	W14x53	Welded		Replace gate.	Corrugation deterioration at beams ranges 20%-100% . Mud / trash at bottoms. Paint flaking. Sill concrete deteriorated.	412.9	416.1	420.1	423.8	426	429.8
C-26	Lesperance	R4	64+97	F-7C	Swing	416.4	17	15.79	432.19	16	0.0598		6	4.6			2	5.5	5.5	2.79	No			Welded		Replace gate.	Mud / trash at bottom. Sheet significantly rusted through at beams. Bad seal.						
C-27	Barton	R4	76+78	F-7C(1)	Swing	416.8	17	15.1	431.9	16	0.0598		6	4.6			2	5.5	5.5	2.1	No			Welded		Permanent closure.	Mud at base. Sheet rusted through at beams. Bottom deteriorated						
C-28	Barton	R4	80+27	P-19	2-Swing	417.5	30	14.4	431.9	16	0.0598		6	4.6			2.5	5	5	1.9	No			Welded		Do nothing.	Sheet at beams and bottom not severly deteriorated. Strut pit covers missing.						
C-29	Victor	R4	90+05	F-7C(1)	2-Swing	416.8	30	14.79	431.59	16	0.0598		6	4.6			2.5	5	5	2.29	No			Welded		Do nothing.	Sheet at beams and bottom not severly deteriorated.						
C-30	Sidney	R4	93+70	F-7C(1)	2-Swing	416.1	30	15.5	431.6	16	0.0598		6	4.6			2.5	5	5	3	No			Welded		Do nothing.	Sheet at beams and bottom not severly deteriorated. Sheet has deformation toward landside.						
C-31	Dorcas	R4	116+30	F-7D	Swing	419.4	20	11.6	431	18	0.0478	16	6	4.6			2	6.5	3.1		No			Welded		Permanent closure.	Mud / trash at bottom. Sheet significantly rusted through at beams.						
C-32	Arsenal	R4	122+03	F-7E	Swing	421	20	9.9	430.9	18	0.0478	17	6	4.6			1.94	5	2.96		No			Small welds		Do nothing.	Bottom deteriorated. Sheet at beams OK. Rust coming through paint especially at bottom. Heavy RS vegitation.						
C-33	COE	R4	125+66	F-7E	Swing	420.9	8	9.9	430.8	18	0.0478		8	3.096			1.94	5	2.96		No			Small welds		Do nothing.	Sheet OK at beams.						
C-34	COE	R4	126+84	F-7E	Swing	420.9	18	9.9	430.8	18	0.0478		6	4.6			1.94	5	2.96		No			Small welds		Do nothing.	Spalled abutment concrete. Damaged north vertical seal. Paint coming off in large flakes. Sheet at beams OK. Some mud at bottom.						
C-34B	Coast Guard	R4	135+00																					Some small welds		Do nothing.	Newer structure. Sheet OK at beams.						
C-35	Zepp	R4	143+40	F-7E(1)	Swing	420.7	18	9.9	430.6	18	0.0478	16	6	4.6			1.94	5	2.96		No			Small welds		Do nothing.	Torn seal. Debris / mud at bottom. Some deterioration on bottom. Many sheets corroded through or partly through at beams. Rust coming through paint.						
C-36	Potomac	R4	147+15	F-7E(1)	Swing	420.7	18	9.9	430.6	18	0.0478		6	4.6			1.94	5	2.96		No			Small welds		Do nothing.	Many sheets corroded through at beams. Some deterioration on bottom. Rust coming through paint.						
C-37	Guthrie	R4	156+23	F-7E(1)	Swing	420.6	18	9.9	430.5	18	0.0478	16	6	4.6			1.94	5	2.96		No			Small welds		Do nothing.	Sheet OK at beams. Minor rust at bottom.						
C-38	Railroad	R4	162+22		Panel		50	5																			Rail 1" above sill.						

Repair Alternatives

1) Replace or permanently close worst gates

2) Replace or permanently close all gates.

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Table 2 - Without Project 5/11/2001

Gate C-25 Reliability

Lower Section of Skin Plate - Bending

Notes:

1) Calculation of original modulus done separately.
2) Compression flange assumed completely deteriorated.
3) Original section modulus not reduced for effective areas of cold formed metal.
4) Modulus reduced for uniform corrosion during iterations.
5) Limit State taken as bending stress = F_y
6) Water deterministic (per Dave Kelly, 4/5/01)
7) Factor of Safety = $F_y/(k_s(M/S))$

Random Variables	Fy	Corrosion (mil)	k_s
Mean	35.64	3.19	1.02
Std Dev	4.9896	4.12	0.1
Value	35.64	3.19	1.02
Comments	Mean = 1.08 x (stated Fy). COV = 14%. Lognormal.	Lognormal	Normal

Constants								
Orig S (in^3/')	0.585							
Flood Event	1	2	5	10	25	50	100	500
Water El.			412.9	416.1	420.1	423.8	426	429.8
S			0.554	0.554	0.554	0.554	0.554	0.554
El. Bottom Beam			415.8	415.8	415.8	415.8	415.8	415.8
El. Sill			413.4	413.4	413.4	413.4	413.4	413.4
Depth Bottom Beam			-2.9	0.3	4.3	8	10.2	14
Depth at Sill			-0.5	2.7	6.7	10.4	12.6	16.4
Pressure Bottom Beam = w1				0.019	0.269	0.500	0.638	0.875
Pressure Sill = w2				0.169	0.419	0.650	0.788	1.025
$M = w_1(L)^2/2 + (w_2-w_1)(L)^2/6$ ('k/')				0.20	0.92	1.58	1.98	2.66
$f_b=k_s(M)/S$ (ksi)				4.38	20.29	35.01	43.76	58.88
Factor of Safety				8.14	1.76	1.02	0.81	0.61
Count Cell 1				0.000	0.000	0.000	1.000	1.000
# of trials	10000	10000	10000	10000	10000	10000	10000	10000
# of failures	0	0	0	5	59	4655	8777	9969
Prob of unsatisfactory performance	**0.0000**	**0.0000**	**0.0000**	**0.0005**	**0.0059**	**0.4655**	**0.8777**	**0.9969**

Gate C-22 Reliability

Lower Section of Skin Plate - Bending

Notes:

1) Section modulus assumed to be from 1/4" plate used for repair. No measurement taken.
2) Repair used no gusset plates to horizontal beam.
3) Limit State taken as bending stress = F_y
4) Water deterministic (per Dave Kelly, 4/5/01)
5) Factor of Safety = $F_y/(k_s(M/S))$

6) It is assumed that this lower section would be sandbagged to prevent failure.

Constants	Water El.	Orig S (in^3/')
	429.8	0.125

Random Variables	Fy	Corrosion %	k_s
Mean	38.88		1.02
Std Dev	5.4432		0.1
Value	38.88	NA	1.02
Comments	Mean = 1.08(stated Fy). COV = 14%. Lognormal.	Lognormal	Normal

Year	2001			
S	0.125			
El. Bottom Beam	416.4			
El. Sill	414.4		# of trials	100
Depth Bottom Beam	13.4		# of failures	100
Depth at Sill	15.4		Prob of fail	1.00
Pressure Bottom Beam = w1	0.838			
Pressure Sill = w2	0.963			
$M = w_1(L)^2/2 + (w_2-w_1)(L)^2/6$	1.76	'k/'		
$f_b=k_s(M)/S$ (ksi)	172.18			
Factor of Safety	0.23			
Count Cell 1	1.000			

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Table 3 - Alternative 1 Replace Worst Gates 5/22/2001

Gate C-24 Reliability
Skin Plate **Cantilever Bending** With Variable Water and Variable Corrosion

Notes:
1) Gage metal is continuous over horizontal beams.
2) Limit State taken as bending stress = Fy
3) Water Elevation is Random Variable
4) Factor of Safety = Fy/(k_s(M/S))

		Corrosion		Water Elevation by Return Period (ft)								
Random Variables	Fy (ksi)	Uniform (mil)	Localized (mil)	k_s	1	2	5	10	25	50	100	500
Mean	35.64	3.19	40	1.02			412.9	416.1	420.1	423.8	426.0	429.8
Std Dev	4.9896	4.12	8.24	0.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Value	35.64	3.19	40	1.02			412.9	416.1	420.1	423.8	426	429.8
Comments	Mean = 1.08(stated Fy). COV = 14%. Lognormal	Lognormal	Lognormal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal

Constants	
Original t LS (in)	0.0598
Original t RS (in)	0.0747
Start Date For Local Corrosion	1966
Start Date For Uniform Corrosion	1986
Flange Width (in)	9.5
Width Compressive Element (in)	6.0
El. Bottom Beam	415.4
El. Sill	413.4

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Uniform Corrosion Loss (mil)	3.2	3.4	3.6	3.8	4.0	4.3	4.5	4.7	4.9	5.1	5.3	5.5
Localized corrosion Loss (mil)	40.0	41.1	42.3	43.4	44.6	45.7	46.9	48.0	49.1	50.3	51.4	52.6
t LS Uniform (in)	0.057	0.056	0.056	0.056	0.056	0.056	0.055	0.055	0.055	0.055	0.054	0.054
t LS Local (in)	0.020	0.019	0.018	0.016	0.015	0.014	0.013	0.012	0.011	0.010	0.008	0.007
t RS Uniform (in)	0.072	0.071	0.071	0.071	0.071	0.070	0.070	0.070	0.070	0.070	0.069	0.069
Effective Comp Flange Over Beam												
λ	5.38	5.71	6.08	6.50	6.99	7.56	8.23	9.02	9.99	11.19	12.72	14.73
ρ	0.18	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.07
Eff. Length b (in)	4.57	4.51	4.45	4.39	4.33	4.27	4.21	4.15	4.09	4.03	3.96	3.90
Area (in^2)	1.60	1.59	1.58	1.57	1.56	1.54	1.53	1.52	1.51	1.50	1.49	1.48
Dist. To NA (in)	0.97	0.96	0.94	0.93	0.92	0.90	0.89	0.88	0.86	0.85	0.84	0.83
I base (in^4)	5.27	5.13	4.99	4.86	4.72	4.59	4.46	4.34	4.22	4.10	3.98	3.87
I NA (in^4)	3.76	3.67	3.59	3.50	3.42	3.33	3.25	3.17	3.09	3.01	2.93	2.85
S (in^3)	1.07	1.04	1.01	0.98	0.95	0.93	0.90	0.87	0.85	0.82	0.80	0.78
500 Year Event												
Depth Bottom Beam	14.4											
Depth Sill	16.4											
Load Length (ft)	2.0											
Pressure Bottom Beam (ksf)	0.900											
Pressure Sill Beam (ksf)	1.025											
M ('k/')	1.97											
f_b=k_s(M)/S (ksi)	22.58	23.21	23.87	24.55	25.25	25.99	26.74	27.53	28.35	29.19	30.07	30.98
Factor of Safety	1.58	1.54	1.49	1.45	1.41	1.37	1.33	1.29	1.26	1.22	1.19	1.15
Count Cell 500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
# of trials	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Prob of Unsatisfactory Performance (500 yr)	**0.0459**	**0.0558**	**0.0657**	**0.0783**	**0.0922**	**0.1092**	**0.1289**	**0.1500**	**0.1752**	**0.2021**	**0.2265**	**0.2526**
Hazard (1/year)		**0.0105**	**0.0106**	**0.0137**	**0.0153**	**0.0191**	**0.0226**	**0.0248**	**0.0306**	**0.0337**	**0.0315**	**0.0349**
100 Year Event												
Depth Bottom Beam	10.6											
Depth Sill	12.6											
Load Length (ft)	2.0											
Pressure Bottom Beam (ksf)	0.663											
Pressure Sill Bm (ksf)	0.788											
M ('k/')	1.49											
f_b=k_s(M)/S (ksi)	17.12	17.60	18.10	18.62	19.15	19.71	20.29	20.88	21.50	22.14	22.81	23.50
Factor of Safety	2.08	2.02	1.97	1.91	1.86	1.81	1.76	1.71	1.66	1.61	1.56	1.52
Count Cell 100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
# of trials	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Prob of Unsatisfactory Performance (100 yr)	**0.0051**	**0.0060**	**0.0070**	**0.0083**	**0.0104**	**0.0126**	**0.0151**	**0.0178**	**0.0228**	**0.0272**	**0.0320**	**0.0387**
Hazard (1/year)		**0.0009**	**0.0010**	**0.0013**	**0.0021**	**0.0022**	**0.0025**	**0.0027**	**0.0051**	**0.0045**	**0.0050**	**0.0070**

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Uniform Corrosion Loss (mil)	5.7	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.7	7.9	8.1	8.3
Localized corrosion Loss (mil)	53.7	54.9	56.0	57.1	58.3	59.4	59.8	59.8	59.8	59.8	59.8	59.8	59.8
t LS Uniform (in)	0.054	0.054	0.054	0.053	0.053	0.053	0.053	0.053	0.052	0.052	0.052	0.052	0.052
t LS Local (in)	0.006	0.005	0.004	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
t RS Uniform (in)	0.069	0.069	0.069	0.068	0.068	0.068	0.068	0.067	0.067	0.067	0.067	0.067	0.066
λ	17.49	21.54	28.02	40.07	70.31	286.63	NA	NA	NA	NA	NA	NA	NA
ρ	0.06	0.05	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eff. Length b (in)	3.84	3.78	3.71	3.65	3.59	3.52	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Area (in^2)	1.47	1.46	1.45	1.44	1.43	1.43	1.42	1.41	1.41	1.40	1.40	1.39	1.39
Dist. To NA (in)	0.81	0.80	0.79	0.78	0.77	0.76	0.75	0.75	0.75	0.75	0.75	0.75	0.75
I base (in^4)	3.76	3.65	3.54	3.44	3.34	3.25	3.21	3.19	3.18	3.17	3.15	3.14	3.13
I NA (in^4)	2.78	2.71	2.63	2.56	2.50	2.43	2.40	2.39	2.38	2.37	2.36	2.36	2.35
S (in^3)	0.75	0.73	0.71	0.69	0.67	0.65	0.64	0.64	0.64	0.63	0.63	0.63	0.63
500 Year Event													
f_b=k_s(M)/S (ksi)	31.92	32.89	33.89	34.92	35.99	37.09	37.56	37.71	37.86	38.01	38.16	38.32	38.47
Factor of Safety	1.12	1.08	1.05	1.02	0.99	0.96	0.95	0.95	0.94	0.94	0.93	0.93	0.93
Count Cell 500	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
# of trials	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Prob of Unsatisfactory Performance (500 yr)	**0.2842**	**0.3142**	**0.3485**	**0.3797**	**0.4156**	**0.4500**	**0.4820**	**0.5148**	**0.5430**	**0.5678**	**0.5887**	**0.6095**	**0.6290**
Hazard (1/year)	**0.0440**	**0.0438**	**0.0527**	**0.0503**	**0.0615**	**0.0626**	**0.0618**	**0.0674**	**0.0617**	**0.0574**	**0.0510**	**0.0533**	**0.0523**
100 Year Event													
f_b=k_s(M)/S (ksi)	24.21	24.94	25.70	26.49	27.30	28.13	28.49	28.60	28.71	28.83	28.94	29.06	29.18
Factor of Safety	1.47	1.43	1.39	1.35	1.31	1.27	1.25	1.25	1.24	1.24	1.23	1.23	1.22
Count Cell 100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
# of trials	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Prob of Unsatisfactory Performance (100 yr)	**0.0454**	**0.0530**	**0.0600**	**0.0675**	**0.0766**	**0.0857**	**0.0968**	**0.1046**	**0.1149**	**0.1257**	**0.1353**	**0.1442**	**0.1516**
Hazard (1/year)	**0.0070**	**0.0080**	**0.0075**	**0.0080**	**0.0099**	**0.0100**	**0.0123**	**0.0087**	**0.0116**	**0.0122**	**0.0111**	**0.0104**	**0.0087**

St. Louis Flood Protection JAZ
Table 4 - Alternative 1 Replace Worst Gates 5/22/2001

Gate C-24 Reliability
Skin Plate **Bearing** With Variable Water and Variable Corrosion

Notes:
1) Skin is continuous over horizontal beams.
2) Thickness reduced by corrosion.
3) Limit State taken as reaction = 1.5(P_a)
This is based on the difference between allowable and LRFD in manufacturer catalog load tables.
4) Water elevation is a random variable.
5) Fy mean and std deviation from LD24 Major Rehab Report No. 2.
6) Pa equation from Structural Engineers Handbook (Web Crippling, Interior Reaction).
Chapter 10 - Design of Cold-Formed Steel Structural Members
7) Factor of Safety = 1.5(P_a)/(k_s(P)).
8) Bottom beam is W14x150. bf = 15.5".
9) Reactions are based on tributary area.

				Water Elevation by Return Period (ft)							
Random Variables	Fy (ksi)	Uniform Corr (mil)	k_s	1	2	5	10	25	50	100	500
Mean	35.64	3.19	1.02			412.9	416.1	420.1	423.8	426.0	429.8
Std Dev	4.9896	4.12	0.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Value	35.64	3.19	1.02			412.9	416.1	420.1	423.8	426	429.8
Comments	Mean = 1.08(stated Fy). COV = 14%. Lognormal	Lognormal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal

Constants	
Original t LS (in)	0.0598
Start Date For Uniform Corrosion	1986
El. Middle Beam	421.9
El. Bottom Beam	415.4
El. Sill	413.4
Length Bottom Cantilever (ft)	2.0
Length Bottom Beam to Middle Beam (ft)	6.5
h (in)	4.5
N (in)	15.5
Number of webs per 12"	2

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Uniform Corrosion Loss (mil)	3.2	3.4	3.6	3.8	4.0	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.7	7.9	8.1	8.3
t LS Uniform (in)	0.057	0.056	0.056	0.056	0.056	0.056	0.055	0.055	0.055	0.055	0.054	0.054	0.054	0.054	0.054	0.053	0.053	0.053	0.053	0.053	0.052	0.052	0.052	0.052	0.052
Pa = t^2(Fy)(1.-0.00546Fy)(10.76-0.0148h/t)(1+0.007N/t)	2.57	2.56	2.54	2.53	2.51	2.50	2.49	2.47	2.46	2.44	2.43	2.42	2.40	2.39	2.38	2.36	2.35	2.33	2.32	2.31	2.29	2.28	2.27	2.25	2.24
1.5(Pa)(# Web) (k/')	7.71	7.67	7.63	7.59	7.54	7.50	7.46	7.42	7.38	7.33	7.29	7.25	7.21	7.17	7.13	7.09	7.04	7.00	6.96	6.92	6.88	6.84	6.80	6.76	6.72
500 Year Event																									
Depth Middle Beam	7.9																								
Depth Bottom Beam	14.4																								
Depth Sill	16.4																								
Load Length (ft)	16.4																								
Pressure Middle Beam (ksf)	0.494																								
Pressure Bottom Beam (ksf)	0.900																								
Pressure Sill Beam (ksf)	1.025																								
Bottom Beam Reaction (k/')	4.52																								
Factor of Safety = 1.5(Pa)(# web)/(ks)(Reaction)	1.71	1.70	1.69	1.68	1.67	1.66	1.65	1.64	1.63	1.62	1.61	1.60	1.60	1.59	1.58	1.57	1.56	1.55	1.54	1.53	1.52	1.51	1.50	1.50	1.49
Count Cell 500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
# of trials	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Prob of Unsatisfactory Performance (500 yr)	**0.0104**	**0.0107**	**0.0111**	**0.0115**	**0.0118**	**0.0122**	**0.0125**	**0.0126**	**0.0129**	**0.0133**	**0.0136**	**0.0142**	**0.0147**	**0.0153**	**0.0163**	**0.0171**	**0.0174**	**0.0179**	**0.0183**	**0.0192**	**0.0200**	**0.0213**	**0.0221**	**0.0235**	**0.0246**
Hazard (1/yr)		**0.0003**	**0.0004**	**0.0004**	**0.0003**	**0.0004**	**0.0003**	**0.0001**	**0.0003**	**0.0004**	**0.0003**	**0.0006**	**0.0005**	**0.0006**	**0.0010**	**0.0008**	**0.0003**	**0.0005**	**0.0004**	**0.0009**	**0.0008**	**0.0013**	**0.0008**	**0.0014**	**0.0011**
100 Year Event																									
Depth Middle Beam	4.1																								
Depth Bottom Beam	10.6																								
Depth Sill	12.6																								
Load Length (ft)	12.6																								
Pressure Middle Beam (ksf)	0.256																								
Pressure Bottom Beam (ksf)	0.663																								
Pressure Sill Beam (ksf)	0.788																								
Bottom Beam Reaction (k/')	3.27																								
Factor of Safety = 1.5(Pa)(# web)/(ks)(Reaction)	2.36	2.34	2.33	2.32	2.31	2.29	2.28	2.27	2.25	2.24	2.23	2.22	2.20	2.19	2.18	2.16	2.15	2.14	2.13	2.11	2.10	2.09	2.08	2.07	2.05
Count Cell 500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
# of trials	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Prob of Unsatisfactory Performance (100 yr)	**0.0035**	**0.0036**	**0.0038**	**0.0038**	**0.0039**	**0.0041**	**0.0041**	**0.0042**	**0.0045**	**0.0046**	**0.0047**	**0.0048**	**0.0049**	**0.0049**	**0.0051**	**0.0055**	**0.0056**	**0.0058**	**0.0060**	**0.0061**	**0.0062**	**0.0063**	**0.0067**	**0.0069**	**0.0071**
Hazard (1/yr)		**0.0001**	**0.0002**	**0.0000**	**0.0001**	**0.0002**	**0.0000**	**0.0001**	**0.0003**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0000**	**0.0002**	**0.0004**	**0.0001**	**0.0002**	**0.0002**	**0.0001**	**0.0001**	**0.0001**	**0.0004**	**0.0002**	**0.0002**

ST. LOUIS FLOOD PROTECTION
Table 5 - Component Analysis Summary
Probabilities of Unsatisfactory Performance

Without Project

Probabilities Based on Bending Limit of Lower Skin Plate Cantilever, C-25

			Conditional Probabilities Given Unsatisfactory Performance		
Return Period	Water Elevation	Probability of Unsatisfactory Performance	Low Damages	Medium Damages	High Damages
1 YR		0.0000	N/A	N/A	N/A
2 YR		0.0000	N/A	N/A	N/A
5 YR	412.9	0.0000	N/A	N/A	N/A
10 YR	416.1	0.0005	1.00	0.00	0.00
25 YR	420.1	0.0059	1.00	0.00	0.00
50 YR	423.8	0.4655	0.65	0.30	0.05
100 YR	426.0	0.8777	0.65	0.30	0.05
500 YR	429.8	0.9969	0.65	0.30	0.05

Alternative 1 - Replace or Permanently Close Specific Gates (16 Total)

Probabilities Based on Bearing Limit of Continuous Skin Plate, Gate C-24

				Conditional Probabilities Given Unsatisfactory Performance		
Return Period	Water Elevation	Probability of Unsatisfactory Performance For 2003	Probability of Unsatisfactory Performance For 2013	Low Damages	Medium Damages	High Damages
1 YR		0.0000	0.0000	N/A	N/A	N/A
2 YR		0.0000	0.0000	N/A	N/A	N/A
5 YR	412.9	0.0000	0.0000	N/A	N/A	N/A
10 YR	416.1	0.0000	0.0002	1.00	0.00	0.00
25 YR	420.1	0.0004	0.0010	1.00	0.00	0.00
50 YR	423.8	0.0012	0.0077	0.65	0.30	0.05
100 YR	426.0	0.0070	0.0454	0.65	0.30	0.05
500 YR	429.8	0.0657	0.2842	0.65	0.30	0.05

Alternative 2 - Replace or Permanently Close All Gates

The new gates are assumed to perform satisfactorily for the 30 year economic justification period.
There are no damage costs.

ST. LOUIS FLOOD PROTECTION

Table 6 - System Analysis Summary

Probabilities of Unsatisfactory Performance and High Damages for the Gate System

Without Project

Return Period	Water Elevation At River Mile 178.5	Probability of Unsatisfactory Performance and High Damages for the Gate System, 2003	Probability of Unsatisfactory Performance and High Damages for the Gate System, 2013
1 YR		0	0
2 YR		0	0
5 YR	412.9	0	0
10 YR	416.1	0	0
25 YR	420.1	0	0
50 YR	423.8	0.3146	0.3184
100 YR	426.0	0.5152	0.5308
500 YR	429.8	0.5827	0.6540

Alternative 1 - Replace or Permanently Close Specific Gates (16 Total)

Return Period	Water Elevation At River Mile 178.5	Probability of Unsatisfactory Performance and High Damages for the Gate System, 2003	Probability of Unsatisfactory Performance and High Damages for the Gate System, 2013
1 YR		0	0
2 YR		0	0
5 YR	412.9	0	0
10 YR	416.1	0	0
25 YR	420.1	0	0
50 YR	423.8	0.0010	0.0065
100 YR	426.0	0.0059	0.0379
500 YR	429.8	0.0544	0.2160

Alternative 2 - Replace or Permanently Close All Gates

The new gates are assumed to perform satisfactorily for the 30 year economic justification period.

There are no damage costs.

Table 7: Reach 3, Item F-6A, Monolith 36 - Stability Analysis Summary

Reach 3, Item F-6A, Monolith 36 Stability Analysis Summary		
Case I1 - Water to 3' Below Existing Top		
	Result	Requirement
Overturning - % Base in Compression	94%	100%
Bearing Pressure	FS = 2.79	FS = 3.0
Sliding	FS = 1.80	FS = 1.5
Case I2 - Water to Top		
	Result	Requirement
Overturning - % Base in Compression	65%	75%
Bearing Pressure	FS = 1.83	FS = 2.0
Sliding	FS = 1.39	FS = 1.33

Table 8: Reach 4, Item F-7C, Monolith 45 - Stability Analysis Summary

Reach 4, Item F-7C, Monolith 45 Stability Analysis Summary		
Case I1 - Water to 3' Below Existing Top		
	Result	Requirement
Overturning - % Base in Compression	99%	100%
Bearing Pressure	FS = 4.55	FS = 3.0
Sliding	FS = 2.27	FS = 1.5
Case I2 - Water to Top		
	Result	Requirement
Overturning - % Base in Compression	62%	75%
Bearing Pressure	FS = 2.66	FS = 2.0
Sliding	FS = 1.50	FS = 1.33

Geotechnical Analysis

1. Introduction

a. The St. Louis Flood Protection Project (SLFP) is a system combining earth levees and concrete floodwalls. It is comprised of two reaches: Reach 3, which is just north of downtown St. Louis, and Reach 4, which is south of downtown, with the reaches separated by high ground. Most of the floodplain is on the Illinois side of the river, such that both reaches protect long narrow tracts of land, with distances from the line of protection ranging from several hundred feet to about 2000 feet. The majority of the protected area is located in Reach 3, from Mississippi River Mile 180.2 – 187.2, protecting approximately 2500 acres. Reach 4 extends from Mississippi River Mile 176.3 – 179.2, and protects approximately 630 acres.

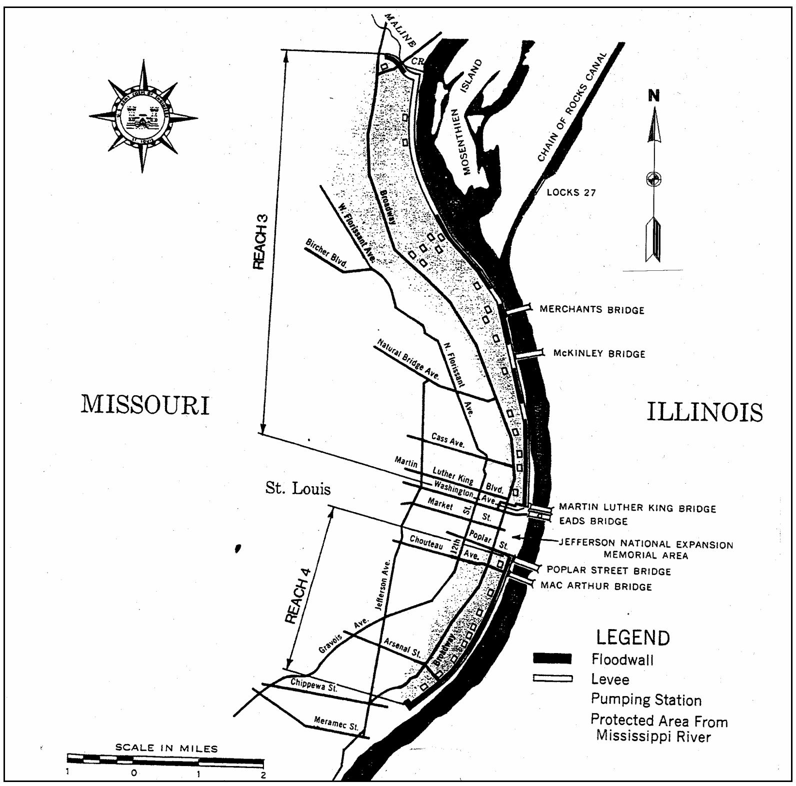


Figure 1 – Map of St. Louis Flood Protection

b. Underseepage controls designed and constructed for the St. Louis Flood Protection System are not adequate for the authorized design flood level of 52.0 feet on the St. Louis Gage which is equivalent to the 500-year probability flood event.
Underseepage control features incorporated into the original design of this project were a combination of relief wells, sheet pile cutoff walls, and a subsurface toe drainage system. Of these features, the relief wells are perhaps the most important in reducing the effects of increased head from design flood events because sheet pile cutoff walls were not used under the levee sections and were rarely used beneath the floodwall. The original design was

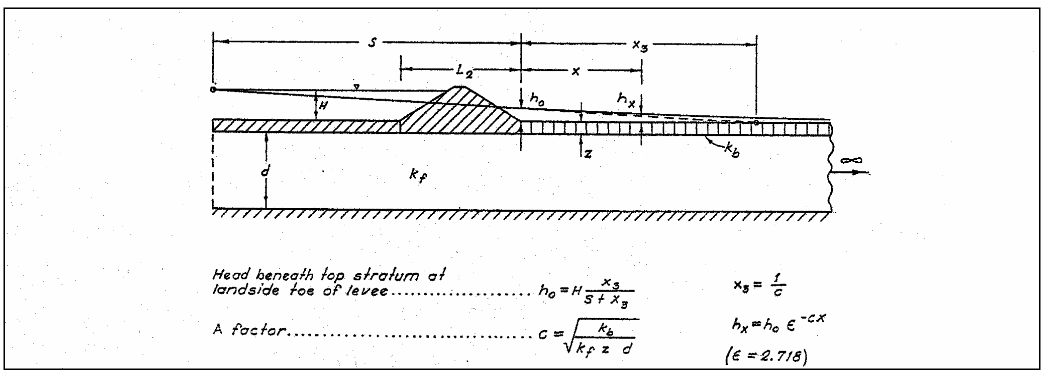
based on a critical gradient of 0.85 instead of 0.5. The original design included 34 relief wells in Reach 3 and 76 relief wells in Reach 4.

c. During the flood of 1993, which was a 175-year event, underseepage problems occurred that had to be dealt with under extreme emergency conditions. These included a blow out of the foundation resulting in a geyser of water discharging land side of the floodwall in the upper part of Reach 3 which caused the floodwall to crack and rotate, as well as soft ground in parts of Reach 3 and numerous sand boils throughout the project indicating high uncontrolled underseepage gradients.

2. <u>General Design Summary</u>

a. The original design for the SLFP was accomplished primarily in the early to mid-1960's. The need for positive underseepage relief measures was determined from guidance in "Investigation of Underseepage, Mississippi River Levees, Alton to Gale, Ill." (Reference 1).

b. The referenced investigation was a performance-based study of underseepage in Illinois levee districts from approximately Mississippi River Miles 203 to 46. Gradients and heads at the landside toe are based on a generalized section of levee (Figure 2).



<u>Figure 2 – Generalized Cross Section of Levee and Symbols for Seepage Analysis</u>

The main components of this generalized cross section are a top stratum or blanket, which is considered to be semi-pervious; an aquifer or pervious substratum that continues to an impervious base (e.g., rock); and an impervious section of levee. Flow is assumed to enter the pervious substratum at the riverbank, riverside borrow pits, or through the top stratum, and is further assumed to be horizontal and laminar; flow through the top stratum is assumed to be vertical and laminar. Of particular interest are the gradients created at the landside toe of the structure, whether it is a levee or floodwall. These are called exit gradients, and are defined as:

$$i_0 = \frac{h_0}{z} \qquad (1)$$

Where h_0 is the excess head at the levee toe
z is the effective thickness of the top stratum

These variables are functions of the net head on the levee (H); the vertical permeability (k_b) of the top stratum; the effective thickness (d) and horizontal permeability (k_f) of the pervious substratum; the ratio k_f / k_b; the distance (s) from the landside toe of the levee to the effective source of seepage; the distance (x_3) from the landside toe to the effective seepage exit; and the critical gradient (i_c) through the top stratum at the landside toe. The critical gradient is that at which sand boils or heaving of the top stratum occurs, resulting in loss of foundation material (piping), loss of shear strength, or loss of bearing capacity. It is defined as the ratio of the submerged unit weight of the top stratum to the unit weight of water:

$$i_c = \frac{\gamma'}{\gamma_w} \qquad (2)$$

Where γ' is the buoyant unit weight of soil
γ_w is the unit weight of water

Typically the critical gradient for most fine-grained or sandy fine-grained soils is between 0.80 – 0.85.

c. The generalized levee section in Figure 2 represents a confined or artesian, condition wherein excessive underseepage pressures beneath the top stratum could result in failure by piping or heave. Relief wells are designed to prevent these modes of failure. When the SLFP system was designed, an exit gradient of 0.85 was used, thus grossly underestimating the number of relief wells needed. However many years unsatisfactory flood experiences throughout the Corps of Engineers designed levee systems have shown that an exit gradient of 0.50 should have been used in accordance with Engineering Manual 1110-2-1913 (Reference 10).

d. To limit the exit gradient, relief wells must reduce uplift pressures to an acceptable, net allowable head, h_a, at the downstream toe, corresponding to an exit gradient (i_0) of 0.5:

$$FS = \frac{i_0}{i_c} = \frac{\gamma' Z_t}{\gamma_w h_a} \qquad (3)$$

$$h_a = \frac{i_c}{FS} Z_t \qquad (4)$$

Where FS is the factor of safety
Z_t is transformed thickness of the top stratum

The transformed thickness is used to simplify computations in converting a multi-layered top stratum to a single equivalent layer.

e. Once an allowable head is determined, an iterative procedure is done to determine a well spacing "a" that will accomplish this goal. There are many methods to compute well spacing and flows, based on the type of seepage source, the arrangement of wells, percent penetration of the wells, type of seepage exit, and type of top stratum. For many levees, an appropriate assumption to make is that there is an infinite line source (the river), with an infinite line of wells parallel to the line source, and an infinitely long impervious top stratum.

f. Mathematical solutions for well flows and head midway between the wells for the typical assumption above were developed by Muskat (Reference 2), and Middlebrooks and Jervis (Reference 3), for the case of no head losses in the wells. These solutions are valid for both fully and partially penetrating wells.

g. The iterative procedure was originally described in "Investigation of Underseepage and Its Control, Lower Mississippi River Levees" (Reference 4), and updated in "Design, Construction, and Maintenance of Relief Wells" (Reference 5). The procedure begins by assuming no head losses in the well (H_w), and that the head midway between the wells (H_m) should equal the allowable net head, h_a. A well penetration is assumed for the first trial well spacing, and H_m is computed by:

$$H_m = \frac{(H_1 - h_w)\theta_m}{\frac{s}{a} + \theta_a} \tag{5}$$

Where H_1 is total head corresponding to the bottom of the well and the river stage
h_w is the head corresponding to the bottom of the well and the top stratum surface
s is the distance from the center of the well to the effective seepage source
θ_m is an average mid-well uplift factor

$$\theta_m = \frac{\pi}{2}\ln\left[\frac{a}{\pi}\right] r_w$$

where r_w is well radius

$$\theta_a = \frac{\pi}{2}\ln\left[\frac{a}{2\pi}\right] r_w$$

where θ_a is average uplift factor

Various trials of well spacing are used until $H_m = h_a$.

h. Well flows are next computed for the above well spacing and penetration by:

$$Q_w = \frac{(H_1 - h_w)kD}{\frac{s}{a} + \theta_a} \quad (6)$$

Where k is horizontal permeability of the pervious foundation
D is thickness of the pervious foundation

i. Well dimensions are assumed, and hydraulic head losses in the well, H_w, are computed for the calculated flow. These must be added to the head midway between the wells, H_m, and a new iteration to determine an adjusted well spacing is made. The adjustment is made by substituting

$$h_m = H_m - H_w \quad (7)$$

into equation (5), and a new value of well spacing "a" is determined.

j. Well flows and well losses are re-calculated for the adjusted well spacing. This process is repeated until a reasonable degree of convergence for well spacing is obtained. The procedure described is for fully penetrating wells; a similar one is used for partially penetrating wells, using a slightly different assumption for head between the wells.

k. A spreadsheet can be used to do these calculations very quickly. Conroy (Reference 6) has developed a spreadsheet for this purpose.

3. Pump Tests

a. The original designers of the SLFP system made the erroneous assumption that the relief wells were essentially self-cleaning when they flowed during a flood event. Thus maintenance of the relief wells required of the City of St. Louis in the original maintenance agreement was directed toward cleaning out debris and sediment. Since then it has been determined that relief wells are not self-cleaning and require a complex carefully controlled combination of chemical and mechanical redevelopment. Such a program is well beyond any requirement originally anticipated by the relief well designers and is well beyond any interpretation of the maintenance required of the City of St. Louis. Diminished capacity of the relief well system due to plugging of the screen and filter caused by the precipitation of carbonates, sulfates, iron, and manganese compounds or bio-fouling caused by the activity of microscopic bacteria, molds, and algae adversely impacts the overall performance of the flood protection system.

b. To determine the capacity of the existing relief wells, a pump testing program was accomplished on a sample of the relief wells. The pump test program consisted of two phases: an initial pump test lasting approximately two hours, until little change in drawdown occurred; and a second phase wherein selected wells were re-tested after mechanical surging (air lifting). An initial pump test was performed on 18 wells in Reach 3. Mechanical surging was performed on 10 wells and then a second pump test was performed to measure the improvement in performance. In Reach 4, 51 wells were pump-tested, of which 14 wells were mechanically surged and retested. The results of the initial pump tests and the retests after mechanically surging are shown in Figures 3, 4 and 5 (see Reference 7).

	St. Louis Flood Protection - Reach 3												July 2000
	Initial Pump Test Data											Original Construction	
												Pump Test Data	
Well #	Initial Flow Meter (Gal)	Final Flow Meter (Gal)	Initial Depth (ft)	Final Depth (ft)	Drawdown (ft)	Total Volume Water Pumped (Gal)	Duration (min)	Avg. Flow Rate (GPM)	Specific Yield (GPM/FT)	% of Original Specific Yield	% of Original Flow Rate	Flow Rate (GPM)	Specific Yield (GPM/FT)
8	1365850	1408440	24.98	37.1	12.12	42590	120	354.9	29.3	89.6	101.405	350	32.7
9	1669260	1700590	25.7	33.1	7.4	31330	120	261.1	35.3	55.4	40	650	63.7
10	1588180	1617700	26.12	31.4	5.28	29520	120	246.0	46.6	90.8	51	487	51.3
12	1417750	1447100	26.92	37.8	10.88	29350	120	244.6	22.5	54.2	75	324	41.5
15	1491680	1525880	30.8	39.75	8.95	34200	120	285.0	31.8	71.1	110	260	44.8
16	1526000	1560850	21.14	28.2	7.06	34850	120	290.4	41.1	53.4	78	370	77.1
17	1447120	1469660	21.38	24.2	2.82	22540	120	187.8	66.6	80.0	42	450	83.3
18	1756580	1803000	22.74	29.7	6.96	46420	120	386.8	55.6	70.2	97	400	79.2
19	1860510	1897360	26.32	33.16	6.84	36850	120	307.1	44.9	73.1	88	350	61.4
20	1617990	1653800	20.54	27.62	7.08	35810	120	298.4	42.1	54.2	75	400	77.7
21	1700650	1730500	20.11	28.47	8.36	29850	120	248.8	29.8	45.6	78	320	65.3
27	1469660	1491550	22.44	28.11	5.67	21890	120	182.4	32.2	60.8	66	275	52.9
28	1561060	1588180	21.46	26.26	4.8	27120	120	226.0	47.1	98.5	103	220	47.8
29	1897610	1927150	25.8	32.24	6.44	29540	120	246.2	38.2	65.9	85	290	58
30	1803060	1844580	24.2	31.9	7.7	41520	120	346.0	44.9	68.1	108	320	66
31	1730510	1748560	22.5	31.63	9.13	18050	120	150.4	16.5	77.0	84	180	21.4
32	1927260	1936000	27.9	33.29	5.39	8740	120	72.8	13.5	84.5	55	132	16
33	1844610	1860560	26.2	33.42	7.22	15950	120	132.9	18.4	61.4	55	240	30

Figure 3 – Initial Pump Test Data – Reach 3

					St. Louis Flood Protection - Reach 4								July/August 2000
	Initial Pump Test Data											Original Construction Pump Test Data	
Well #	Initial Flow Meter (Gal)	Final Flow Meter (Gal)	Initial Depth (ft)	Final Depth (ft)	Drawdown (ft)	Total Volume Water Pumped (Gal)	Duration (min)	Avg. Flow Rate (GPM)	Specific Yield (GPM/FT)	% of Original Specific Yield	% of Original Flow Rate	Flow Rate (GPM)	Specific Yield (GPM/FT)
6	1992200	1999600	25.92	32.5	6.58	7400	120	61.7	9.4	76.8	62	100	12.2
14	1936020	1943260	22.44	27.2	4.76	7240	120	60.3	12.7	82.1	48	125	15.43
15	2210980	2217680	26.52	32.86	6.34	6700	120	55.8	8.8	36.2	27	207	24.35
16	2057280	2066210	25.91	33.32	7.41	8930	120	74.4	10.0	37.5	34	222	26.75
17	2015440	2026170	25.6	33.42	7.82	10730	120	89.4	11.4	40.6	39	231	28.17
19	2123380	2152660	26.86	38.33	11.47	29280	120	244.0	21.3	63.2	139	175	33.65
20	2338510	2361250	28.44	37.71	9.27	22740	120	189.5	20.4	65.2	118	160	31.37
21	2456850	2490570	27.55	35.87	8.32	33720	121	278.7	33.5	77.3	98	285	43.31
22	2519040	2539310	25.24	32.3	7.06	20270	120	168.9	23.9	99.0	80	210	24.17
26	2630120	2654670	29.24	34.3	5.06	24550	120	204.6	40.4	79.9	51	400	50.63
27	2769940	2798870	31	36.26	5.26	28930	120	241.1	45.8	146.7	96	250	31.25
28	3031650	3063600	29.96	37.7	7.74	31950	120	266.3	34.4	85.7	82	325	40.12
29	3095000	3138500	31.7	37.33	5.63	43500	120	362.5	64.4	146.5	102	356	43.95
30	2845600	2882780	32.6	35.98	3.38	37180	120	309.8	91.7	215.7	91	340	42.5
31	3184070	3190100	32.22	36.86	4.64	9600	120	80.0	17.2	96.5	53	150	17.86
32	2926490	2955550	32.62	39.42	6.8	29060	120	242.2	35.6	90.1	76	320	39.51
33	524160	548080	32.58	38.44	5.86	23920	120	199.3	34.0	82.0	59	340	41.48
34	611220	621510	32.7	37.24	4.54	10290	120	85.8	18.9	68.7	39	220	27.5
36	2029040	2057020	30.14	39.1	8.96	27980	120	233.2	26.0	75.7	85	275	34.38
37	2594830	2607630	28.61	36.19	7.58	12800	121	105.8	14.0	50.9	47	226	27.44
39	2799000	2818410	33.18	40.72	7.54	19410	120	161.8	21.5	45.0	40	400	47.62
40	2490850	2498490	29.52	37.36	7.84	7640	120	63.7	8.1	81.2	80	80	10
41	2717520	2741030	32.63	38.75	6.12	23510	120	195.9	32.0	85.4	65	300	37.5
42	2066240	2087170	28.66	33.37	4.71	20930	120	174.4	37.0	93.7	55	320	39.51
43	2654810	2681900	30.19	37	6.81	27090	120	225.8	33.1	88.4	75	300	37.5
44	2539440	2571610	28.91	36.72	7.81	32170	120	268.1	34.3	84.8	79	340	40.48
45	2217690	2234360	28.95	37.68	8.73	16670	120	138.9	15.9	33.7	54	255	47.22
46	1943370	1966730	26.34	31.84	5.5	23360	120	194.7	35.4	93.3	97	200	37.95
47	2498540	2518950	29.66	36.5	6.84	20410	120	170.1	24.9	74.6	94	180	33.33
48	2882950	2905120	31.86	36.7	4.84	22170	120	184.8	38.2	101.8	95	195	37.5
49	3063800	3082110	31.92	38.39	6.47	18310	120	152.6	23.6	76.6	95	160	30.77
50	2955590	2979350	32.3	37.62	5.32	23760	120	198.0	37.2	105.0	102	195	35.45
53	2741220	2751030	32.16	37.9	5.74	9810	120	81.8	14.2	49.4	55	150	28.85
54	2152770	2174580	30.58	35.03	4.45	21810	120	181.8	40.8	88.8	79	230	46
55	1966760	1991660	27.8	31.2	3.4	24900	120	207.5	61.0	56.8	42	495	107.51
56	2087320	2123250	30.52	35.98	5.46	35930	120	299.4	54.8	67.5	77	390	81.25
57	2280350	2322090	31.1	37.03	5.93	41740	120	347.8	58.7	76.4	87	400	76.82
58	2361450	2384820	32.58	37.72	5.14	23370	120	194.8	37.9	102.3	97	200	37.04
59	2234400	2267440	29.7	35.85	6.15	33040	120	275.3	44.8	122.5	145	190	36.54
60	2571700	2593680	28.6	33.16	4.56	21980	120	183.2	40.2	117.2	99	185	34.26
61	2174860	2210920	30.36	37.82	7.46	36060	120	300.5	40.3	98.2	147	205	41
62	2607670	2630000	28.96	34.23	5.27	22330	120	186.1	35.3	85.9	101	185	41.11
64	1999760	2015320	28.1	32.2	4.1	15560	120	129.7	31.6	110.7	93	140	28.57
65	2322390	2338470	29.74	33.7	3.96	16080	120	134.0	33.8	104.6	81	165	32.35
66	2384960	2406850	30.88	37.13	6.25	21890	120	182.4	29.2	76.0	85	215	38.39
67	2751100	2769910	32.68	38.42	5.74	18810	120	156.8	27.3	68.5	78	200	39.84
68	2905290	2926400	32.34	37.5	5.16	21110	120	175.9	34.1	60.0	57	310	56.78
71	2979440	3023440	32.16	38	5.84	44000	120	366.7	62.8	85.9	96	380	73.08
72	2818500	2845470	28.12	34.13	6.01	26970	120	224.8	37.4	42.5	66	340	88
73	2682280	2716020	31.74	37.36	5.62	33740	120	281.2	50.0	63.8	70	400	78.43
74	2408280	2456610	30.62	36.95	6.33	48330	120	402.8	63.6	73.4	90	450	86.64

Figure 4 – Initial Pump Test Data – Reach 4

St. Louis Flood Protection - Reach 3																August 2000
	Final Pump Test Data (After Air Lifting)											Original Construction Pump Test Data		Initial Pump Test Data		
Well #	Initial Flow Meter (Gal)	Final Flow Meter (Gal)	Initial Depth (ft)	Final Depth (ft)	Drawdown (ft)	Total Volume Water Pumped (Gal)	Duration (min)	Avg. Flow Rate (GPM)	Specific Yield (GPM/FT)	% of Original Specific Yield	% of Original Flow Rate	Flow Rate (GPM)	Specific Yield (GPM/FT)	Flow Rate (GPM)	Specific Yield (GPM/FT)	% Improvement Specific Yield
9	758540	785860	38.56	44.2	5.64	27320	120	227.7	40.4	63.4	35	650	63.7	261.1	35.3	14.4
12	838020	852010	38.96	44.59	5.63	13990	90	155.4	27.6	66.5	48	324	41.5	244.6	22.5	22.7
16	911150	941070	33.78	38.7	4.92	29920	120	249.3	50.7	65.7	67	370	77.1	290.4	41.1	23.3
17	786350	812030	32.76	35.54	2.78	25680	120	214.0	77.0	92.4	48	450	83.3	187.8	66.6	15.6
20	689170	718810	32.3	39.6	7.3	29640	120	247.0	33.8	43.5	62	400	77.7	298.4	42.1	-19.6
21	812200	837870	32.84	37.88	5.04	25670	120	213.9	42.4	65.0	67	320	65.3	248.8	29.8	42.4
27	890490	911150	34.24	38.88	4.64	20660	120	172.2	37.1	70.1	63	275	52.9	182.4	32.2	15.2
29	852220	877990	34.46	38.78	4.32	25770	120	214.8	49.7	85.7	74	290	58	246.2	38.2	30.1
32	941280	952100	36.14	42.42	6.28	10820	120	90.2	14.4	89.7	68	132	16	72.8	13.5	6.4
33	878030	890570	36.67	42.2	5.53	12540	120	104.5	18.9	63.0	44	240	30	132.9	18.4	2.7

	St. Louis Flood Protection - Reach 4														August/September 2000	
	Final Pump Test Data (After Air Lifting)											Original Construction Pump Test Data		Initial Pump Test Data		
Well #	Initial Flow Meter (Gal)	Final Flow Meter (Gal)	Initial Depth (ft)	Final Depth (ft)	Drawdown (ft)	Total Volume Water Pumped (Gal)	Duration (min)	Avg. Flow Rate (GPM)	Specific Yield (GPM/FT)	% of Original Specific Yield	% of Original Flow Rate	Flow Rate (GPM)	Specific Yield (GPM/FT)	Flow Rate (GPM)	Specific Yield (GPM/FT)	% Improvement Specific Yield
15	3023580	3031610	28.44	34.64	6.2	8030	120	66.9167	10.8	44.3	32	207	24.35	55.8	8.8	22.6
16	3082190	3095060	28.46	37.48	9.02	12870	120	107.3	11.9	44.4	48	222	26.75	74.4	10.0	18.9
17	3173910	3190185	28.28	39.34	11.06	16275	120	135.6	12.3	43.5	59	231	28.17	89.4	11.4	7.6
19	497050	524100	28.26	37.76	9.5	27050	120	225.4	23.7	70.5	129	175	33.65	244.0	21.3	11.4
20	587100	610950	27.24	36.3	9.06	23850	120	198.8	21.9	69.9	124	160	31.37	189.5	20.4	7.5
37	654940	670540	30.6	37.18	6.58	15600	121	128.9	19.6	71.4	57	226	27.44	105.8	14.0	40.0
39	718860	736470	32.38	38.23	5.85	17610	120	146.8	25.1	52.7	37	400	47.62	161.8	21.5	16.7
45	3190110	3210700	31.14	35.52	4.38	22200	120	185.0	42.2	89.4	73	255	47.22	138.9	15.9	165.6
49	670630	689190	31.14	38	6.86	18560	120	154.7	22.5	73.3	97	160	30.77	152.6	23.6	-4.5
53	643540	654910	30.96	37.5	6.54	11370	120	94.8	14.5	50.2	63	150	28.85	81.8	14.2	2.0
55	3138990	3173970	32.92	36.6	3.68	34980	120	291.5	79.2	73.7	59	495	107.51	207.5	61.0	29.9
56	548270	585900	32.6	37.65	5.05	37630	120	313.6	62.1	76.4	80	390	81.25	299.4	54.8	13.3
68	621530	643500	30.66	35.68	5.02	21970	120	183.1	36.5	64.2	59	310	56.78	175.9	34.1	7.0
72	736560	758430	31.93	35.3	3.37	21870	120	182.3	54.1	61.5	54	340	88	224.8	37.4	44.6

Figure 5 – Final Pump Test Data

c. The result of the pump tests and mechanical surging in Reach 3 are as follows:

Initial Pump Test. Of the 18 relief wells which were initially pump tested, 13 had specific capacities in the range of 50-79% of original, and 5 were at 80% or better than original.

Mechanical Surging. Specific capacities were increased between 2.7-42.4% from the initial pump tests after mechanical surging.

The result of the pump tests and mechanical surging in Reach 4 are as follows:

Initial Pump Test. Of the 51 relief wells which were initially pump tested, 7 had specific capacities below 50% of original, 20 relief well specific capacities were in the range of 50-79% of original, and 24 were at 80% or better.

Mechanical Surging. The 7 wells that had specific capacities of less than 50% of original and 7 additional relief wells from the next group, which had specific capacities in the range of 50-79% of original, were selected for mechanical surging. Specific capacities were increased between 2.0-165.6% from the initial pump test after mechanical surging.

It is obvious from the above initial pump test data that the relief wells degrade with time and are not self-cleaning, as the original designers had assumed. It is also obvious from the mechanical surging efforts and retesting of the relief wells that the capacity of the relief wells can be improved using a relatively inexpensive rehabilitation effort. However, mechanical surging efforts do not restore the wells to the full capacity. To restore the wells to their full capacity, a much more complex program of chemical and mechanical redevelopment methods must be used. For these reasons it is imperative that all the existing relief wells be rehabilitated as part of the reconstruction effort and then put on a continuous maintenance program. Frequent restoration of the relief wells under a sponsored-required maintenance program will keep the wells at the required performance level. Therefore, after the rehabilitated relief wells are turned over to the local sponsor, the maintenance agreement will state that all relief wells shall be maintained on a continuous basis, giving specific maintenance requirements. It is anticipated that this rehabilitation and maintenance program will restore well efficiency to approximately 80% of their design capacity. Those wells not restored to the required efficiency will be replaced.

4. Underseepage Problems Noted During the 1993 Flood

During the 1993 flood of record (175-year event) many serious underseepage problems were noted in the SLFP system. A list of the underseepage problems is as follows:

Reach 3

a. Riverview Boulevard, Along Maline Creek, Sta. 07+05. On July 22, 1993, a foundation blow out occurred adjacent to the floodwall due to underseepage. It consisted of a geyser of water 18 inches in diameter shooting four feet up into the air. Only extraordinary flood fighting measures kept the protected areas of the City of St. Louis from being inundated. The foundation blowout had to be covered with four feet of riprap and 6-inch minus stone to slow the flow. Next the whole area had to ringed with a dike in case the rock over the foundation blowout failed. Finally 111 cubic yards of grout was pumped under the floodwall monoliths to seal the hole in the foundation. These were temporary emergency repairs only meant to last until the flood was over, then a permanent repair was made.

b. From Station 41+00 to 48+20, minor seepage was noted 4 –5 feet upslope from the toe after the crest.

c. Coal Conveyor, Sta. 166+50. A large area of extremely soft ground occurred in this area due to excessive underseepage.

d. At Station 202+15, a small (< 4 inches) sand boil was stabilized by ponding water above it with a concrete sewer pipe.

e. Merchants Bridge, Sta. 241+80. Numerous sand boils along the Merchants Bridge had to be covered with geotextile and a layer of clean rock to control the seepage.

f. At Station 258+50, a small sand boil developed near the railroad tracks upstream from the conveyor, and the owner placed sand on top. Placing relief wells in this area will control gradients that generate small sand boils.

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g. At Station 274+44, there were large subsidence areas. This was in the Salisbury Pump Station area. The subsidence problems were remediated after the flood.

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h. Angelrodt Street, Sta. 288+00. An extremely large area of sand boils existed adjacent to the floodwall that had to be covered with geotextile and an 18-inch layer of clean rock to control seepage and removal of foundation material.

i. At Station 292+14, seepage occurred. Sandbags and a PVC standpipe were placed on top to control the seepage.

j. At Station 350+70, flow of water was ringed with sandbags.

k. Mound Street, Sta. 357+25. There was a large area the size of a football field that consisted of extremely soft soil in a quick condition. If someone stepped in the soft area, that person would sink in halfway up to the knee. This area had to be covered with geotextile and an 18-inch layer of clean rock to control the underseepage.

l. Razor Wire Piezometer, Sta. 360+90. An area had very high uplift pressures landside of the floodwall. Piezometric readings indicated that the water pressure beneath the ground landside of the floodwall was at the same elevation as the flood water level on the riverside of the floodwall. This meant that there was no reduction of the seepage pressures beneath the floodwall, which represents an extreme serious condition.

m. Ashley Power Plant, Sta. 384+70. There were numerous sand boils in this area that had to be controlled by ringing the area with sand bags and flooding it.

Reach 4

n. Mill Street Pump Station, Sta. 22+22. There were numerous sand boils in this area that had to be controlled by ringing them with sand bags.

o. Service Base, Sta. 122+03 . There were numerous sand boils along the floodwall that had to be controlled by ringing them with sand bags.

As can be seen from the many serious underseepage problems that existed during the 1993 flood (175 year event), which was not even as high an event as the design event (500 year event), underseepage control measures are needed. The floodwall was designed for an underseepage critical gradient of 0.85. The design of the floodwall did not follow Corps of Engineers has determined that an underseepage critical gradient of 0.5 should be used based on many years of experience with flood events. Thus the SLFP system was incorrectly designed based on faulty information and therefore, is a design deficiency of the underseepage control system.

5. Reliability Analysis

a. The purpose of this analysis is to determine the probability of unsatisfactory performance (PUP) of the SLFP system due to underseepage. Uncontrolled underseepage beneath the flood protection system will result in sand boils or foundation blowouts that can quickly remove foundation material beneath the flood protection resulting in failure of the flood protection system. The St. Louis District used the results of land surveys, existing geotechnical exploration, the guidance presented in ETL 1110-2-328, "Reliability Assessment of Existing Levees for Benefit Determination" (Reference 8) and the results of 35+ years of flood fight experience to determine the probability of unsatisfactory performance of the existing St. Louis Flood Protection System.

b. Probabilistic underseepage analyses were completed to determine the probability of unsatisfactory performance for flood levels corresponding to the 1, 2, 5, 10, 25, 50, 100, and 500-year flood events. The probabilistic model used in these analyses is based on the Corps of Engineers traditional, deterministic method of underseepage analyses, a method that has been widely published in the Corps of Engineers' technical manuals. The St. Louis District adapted this method to an Excel spreadsheet and modified it to include random variables and a Taylor Series expansion of the performance function (the underseepage analyses). The Taylor series is a 'first-order, second moment' method which means that only the first order (linear) terms are retained and only the first two moments of the random variables (the expected value and the standard deviation) are considered. This is the method of analysis required in ETL 1110-2-547, "Introduction to Probability and Reliability Methods for Use in Geotechnical Engineering" (Reference 9). In this analysis, the standard deviation is derived by multiplying the expected value by an appropriate coefficient of variation. Those variables considered as random variables are listed below and shown in Table 1.

(1) Landside Blanket Thickness

The stratigraphy of each reach was described by Corps of Engineers borings. The natural stratigraphy in each boring was transformed to determine the z_{BL} (blanket thickness used for Q and X_3 determination) and z_T (blanket thickness used for gradient determination). This analysis utilizes a value of 90% for the coefficient of variation for z_T.

(2) Aquifer Permeability

The expected value of the aquifer permeability is typically defined by the relationship between the D_{10} size of the sand and its permeability shown on Figure 3.5, in EM 1110-2-1913, "Design and Construction of Levees" (Reference 10). Harr, in "Reliability Based Design in Civil Engineering" (Reference 11), Table 1.8.1, shows that the coefficient of variation for permeability should be taken as 90% for saturated conditions.

(3) Landside Blanket Permeability

The expected value of the landside blanket permeability, K_{BL}, is based on the value of Z_{BL} and a relationship defined by Plate 4 in DIVR 1110-1-400 "Soil Mechanics Data", Sec 8, Part 6, Item 1 (Reference 12). No other reliable data exists which measures the landside blanket permeability so this analyses utilizes a coefficient of variation of 90% for the K_{BL}.

Table 1 - Random Variables

Random Variable	Expected Value	Coefficient of Variation
Landside Blanket Thickness, Z_{BL} and Z_t	8 feet	0.90
Based on Permeability, K_f	700 x 10^{-4} cm/sec	0.90
LS Blanket Permeability, K_{BL}	2.9 x 10^{-4} cm/sec	0.90

c. In these probabilistic seepage analyses, unsatisfactory performance is defined as underseepage gradients that exceed a value of 0.85, which represents a quick condition of the foundation material. This means the seepage pressure caused by flow of water under the flood protection system is equal to the weight of the soil landside of the flood protection system. When the seepage force exceeds the weight of the soil, sand boils or a foundation blowout occur.

d. Reliability analyses were performed for the SLFP system using the methodology given in ETL 1110-2-547, "Introduction to Probability and Reliability Methods for Use in Geotechnical Engineering" (Reference 9) to determine the probability of unsatisfactory performance due to underseepage for various flood levels. The results of these analyses are shown in Table 2. In Table 2 the first column is the flood return period, the second column is the water elevation of the flood, the third column gives the probability of occurrence of the flood, and the fourth column gives the probability of unsatisfactory performance. The spreadsheet used to calculate the probability of unsatisfactory performance is shown in Figure 6. The flood of 1993 was a 175-year event. From Table 2, by interpolating between and 100-year and the 500-year flood events, a probability of unsatisfactory performance of 0.83 is obtained. Based on the major underseepage problems that occurred during the 1993 flood (listed in Paragraph 4) of a foundation blowout, soft and quick ground conditions, and a large number of sand boils, the calculated probability of unsatisfactory performance of 0.83 is entirely reasonable because we are seeing the problems that are predicted.

Table 2 - Probable of Unsatisfactory Performance Due to Underseepage

Return Period	Water Surface Elevation	Probability of Occurrence	Probability of Unsatisfactory Performance
1 Year		1	
2 Year		0.5	
5 Year	412.9	0.2	0.0000
10 Year	416.1	0.1	0.0157
25 Year	420.1	0.04	0.4520
50 Year	423.8	0.02	0.7265
100 Year	426.0	0.01	0.8154
500 Year	429.8	0.002	0.9017

6. Underseepage Remediation

To solve the problem of excessive underseepage beneath of SLFP system, additional relief wells need to be added. Based on the current guidance of relief well design, an analysis was performed to place new relief wells where the underseepage gradient equals or exceeds 0.5. A new analysis was done to examine the non-well sections of Reaches 3 and 4 of the St. Louis Flood Protection system, using the spreadsheet analysis developed by Conroy (Reference 6), subject to the current design criteria of relief well being installed if the gradient (i) is greater than 0.5. A summary of the new relief wells needed and their location based on the new analysis is given in Table 3. Based on the new analysis, a total of 46 new relief wells are required Reach 3 and 24 in Reach 4, for a total of 70 new relief wells. For both reaches, this represents a design deficiency from the original 1961 design.

Table 3 - New Relief Well Locations

REACH 3

STATION		Number of New Wells
From	To	
17.5	21.35	2
51.00	57.80	2
57.80	64.00	2
64.00	71.00	2
132.50	135.00	1
135.00	138.50	1
167.40	170.60	2
174.30	177.70	2
195.00	200.00	4
207.66	208.17	3
208.17	214.69	3
221.30	223.60	1
223.60	226.60	1
226.60	228.00	1
237.20	239.38	1
243.30	245.80	1
245.80	249.60	2
249.60	251.00	1
257.80	260.40	1
260.40	263.45	1
273.50	274.80	2
293.30	295.70	3
343.50	343.50	1
357.00	362.00	6
Total		46

REACH 4

STATION		Number of New Wells
From	To	
0.00	1.20	1
24.30	25.90	1
25.90	28.66	4
32.11	32.11	1
33.30	33.30	1
34.19	34.19	1
35.18	35.18	1
36.16	36.16	1
37.10	37.10	1
41.28	44.31	2
48.30	51.00	3
64.62	80.41	3
90.00	100.60	4
Total		24

7. Conclusion

A design deficiency has been noted on the STFP system. This design deficiency was due to incorrect criteria being used to design the original relief well system and an incorrect understanding of the function and behavior of relief wells by the Corps of Engineers. Subsequent studies by the Corps of Engineers has found that relief well systems should be designed for a critical gradient of 0.5, not 0.85, which was used for SLFP system. This design deficiency can be corrected by adding an additional 70 new relief wells. Also the Corps of Engineers thought the relief wells were self-cleaning during flood events which turned out not to be the case. Since relief wells are not self-cleaning, their capacity becomes reduced with time; thus, they cannot relieve the underseepage pressures. Because the Corps of Engineers thought the relief wells were self-cleaning proper provisions were not placed in the maintenance agreement requiring the local sponsor to periodically restore the capacity of the relief wells. To correct this design deficiently the Corps of Engineers will pump test and rehabilitate all 110 of the existing relief wells and turn them over to the local sponsor with a maintenance agreement requiring the proper specified periodic maintenance of the relief wells.

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Figure 6: Condition of Failed Floodwall Monolith after Flood of 1993


#33
#34
MH-7
CITY OF ST. LOUIS
FLOOD WALL
MONUMENT MARKER
6.5'

APPENDIX E

RECREATION ANALYSIS

APPENDIX E
RECREATION ANALYSIS

Introduction
The Flood Control Act of 1944, as amended, and the Federal Water Project Recreation Act of 1965 (Public Law 89-72) indicate the Federal Government's intent to encourage non-Federal entities to participate in recreation development at Federal water resources projects. The Corps of Engineers is authorized by Federal Law to participate with local sponsors in providing outdoor recreation facilities at water resource projects. Policy Guidance Letter No. 36 (Oct 1992) established the current policy and guidance that permits Corps participation at new non-reservoir structural flood control projects on lands within the project boundaries (project-related lands) and those lands needed for access, parking, potable water, sanitation and related development for health, safety and public access.

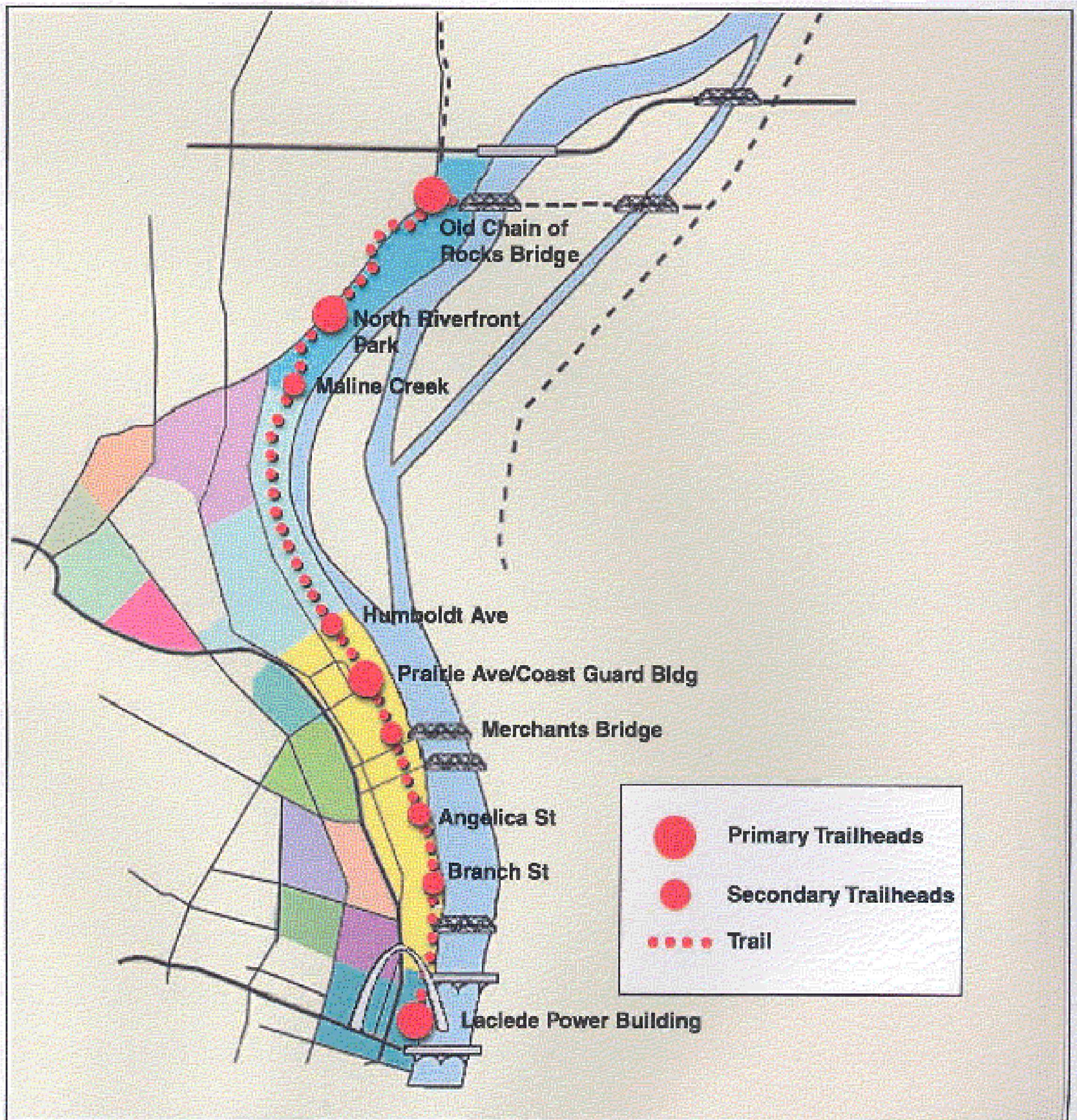
Project-related lands are defined as lands needed to allow for the proper functioning of the project. These lands have been acquired in fee title. The lands proposed for public use development at this project are considered within the project boundaries and the facilities developed on them would be eligible for Federal cost sharing.

The City of St. Louis requested that the Corps of Engineers include potential recreation amenities that could be developed along the existing Riverfront Trail in conjunction with the proposed flood control project. The St. Louis District has coordinated with the city and other trail organizations in development of the plans contained in this report.

Initial planning for the Riverfront Trail was begun in 1987. As planned, the Riverfront Trail is a 12-mile paved recreational trail that runs along the Mississippi River between the Gateway Arch/Laclede's Landing area and the Old Chain of Rocks Bridge. The trail surface and preliminary signing and striping on 10 miles of the Trail were completed in April 1999. The project portion of the trail is the lower 8.4 miles, south of Maline Creek. The Riverfront Trail provides an opportunity for users to experience historic and industrial sections of St. Louis and natural river scenery. The universal trail surface allows for walking, bicycling, jogging and roller-blading. Completion of the final two miles to the Chain of Rocks Bridge is anticipated by late summer 2003.[1]

[1] Personal Communication with Kevin Keach at Confluence Greenway

Figure 7 - Riverfront Trail

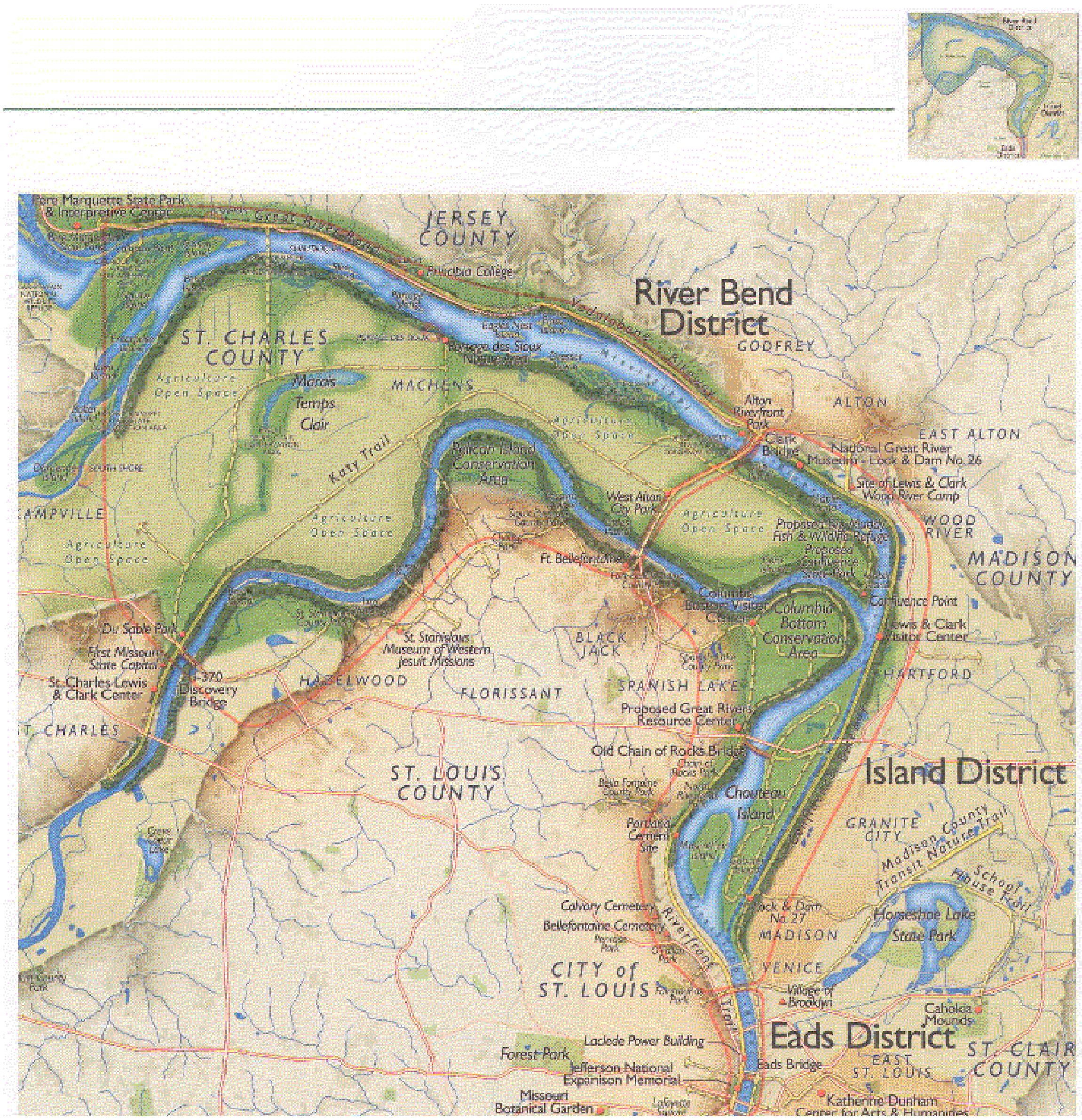


Locations of Trailheads along the Riverfront Trail

The Riverfront Trail is an integral part of the Confluence Greenway, a system of parks, conservation and recreation areas with trails along 40 miles of Mississippi and Missouri riverfront. The Confluence corridor runs on both banks between downtown St. Louis/East St. Louis, past Alton to the confluence of the Mississippi and Illinois Rivers and across to St. Charles.

The Riverfront Trail is located in two of the three development districts of the Confluence Greenway. Dense urban development and a viable working river characterize the Eads District. The Island District follows a natural stretch of the Mississippi and includes valuable conservation areas and historic resources, including the Old Chain of Rocks Bridge.

<u>Figure 8 - The Confluence Greenway</u>



The existing trail system receives mainly recreation use. Walking, jogging, bicycling and rollerblading are popular activities. Bank fishing is also popular along this stretch of the river. A survey contracted by the Confluence Greenway indicated that respondents are willing to use this trail in a substantial way. As part of this plan, connector routes will be established from neighborhoods along the trail.

Several local trail organizations have spearheaded the development of trails in the St. Louis metro area. A bi-state park and recreation district (Great Rivers Greenway, formerly the Metropolitan Park and Recreation District in Missouri and Metro East Park and Recreation District in Illinois) was established by referendum to support recreational development on both sides of the Mississippi River. Revenues generated from provisions of that referendum will be distributed according to the Master Plan currently being prepared by the park districts commissions.

2 Proposed Recreational Facilities

Proposed recreational facilities for the project portion of the trail include one primary and four secondary trailheads, and two rest stops The North Riverfront Trail when complete will link to other major regional trails and destinations as well.

The *St. Louis Riverfront Trail Enhancements Plan* (June 2001) is a conceptual plan developed for the St. Louis Planning Commission that addresses the future development and use of the trail.   Recreational facilities conceptually proposed for the entire Riverfront Trail include four primary trailheads, five secondary trailheads, and three rest stops. A site furnishings plan is currently being prepared. The *Riverfront Trail Enhancements Plan* is included as an attachment to this report.

Primary trailheads will provide substantial facilities that support sustenance and orientation needs for both regional and neighborhood trail users. These trailheads will have enough facilities to become either destinations or rest stops. Primary trailheads will include information kiosks, trash receptacles, parking lots, water fountains, bicycle racks/parking, rest rooms, concessions, emergency call boxes, native plant landscaping, benches, and picnic tables.

Secondary trailheads are meant to provide orientation and access to the trail. Secondary trailheads are not as fully developed as the primary trailheads, and therefore, do not provide some of the more expensive amenities (i.e., vehicle parking, water fountains, rest rooms). Secondary trailheads will provide information kiosks, trash receptacles, bicycle racks/parking, native plant landscaping, and benches and picnic tables.

Rest stops will provide bicycle rack/parking, picnic tables, benches/seating, a shelter, native plant landscaping and trash receptacles.

In addition, restoration of native plant communities is planned. Plantings of native trees, shrubs, vines, grasses, and wildflowers will begin to recreate natural habitat structure and components. Conditions are appropriate for wet forest, wetlands, mesic prairie and dry prairie. This feature will create bird watching opportunities along the trail as well.

3 Recreation Evaluation

The recreation analysis used the Confluence Greenway Survey to project recreational demand for the Riverfront Trail and to establish the importance of trail amenities and aesthetics to the public. In addition, a valuation of the recreational experience using the Water Resources Council's Unit Day Value method was derived for the following combined recreational activities: bicycling-walking-jogging.

4. Recreation Market Area And Demand

Market area or zone of influence is usually defined as the area from which 80 percent of the total day-use visitation can be expected to originate. Because the flood control project is of urban character, visitation expected at the trail sites would mainly be of local origin. Therefore, the city of St. Louis and the counties of St. Louis in Missouri, and Madison and St. Clair in Illinois were considered the zone of influence for this project.

Demand for trails with expanded or improved facilities is evident from the existing limited supply of facilities, the Missouri SCORPs and the Confluence Greenway survey. The population of the market area (St. Louis, St. Clair, and Madison Counties and St. Louis City) totals 1,879,527. There are 427 miles of trails in the region that may draw users from this market area. That translates to .23 mile of trail per thousand people. Trails with amenities in the St. Louis metropolitan area total 50.5 miles without including the Katy Trail (225 miles – not located in counties of the market area). That translates to .03 miles of trails with amenities per thousand people. Kansas City was used as a standard in the 1991 Missouri SCORP and it had .50 miles of trail per thousand. The 1986 Missouri SCORP projected a 1990 demand of 895 miles of bicycle trails for the East-West Gateway Region (that includes St. Charles, Franklin, St. Louis, Jefferson Counties and St. Louis City) almost twice that of the St. Louis area. In the Missouri SCORP 1996-2001[2], the top three activities rated as most important by the public included the following: 1.) Expand existing facilities; provide better maintenance and repair 2.) Develop funding sources to improve existing recreational facilities and 3.) Carry out orderly development, maintenance and expansion of outdoor recreation facilities.

The Confluence Greenway contracted a probability survey in February 2000 developed and conducted by E. Terrence Jones, a professor at the University of Missouri at St. Louis. The survey measured how often the respondents between the ages of 18 and 69 walked, hiked, jogged, and roller bladed or bicycled for pleasure; their familiarity with the Confluence Greenway initiative, their potential usage of the features of the Confluence Greenway project, how the presence of certain features affected their trail usage, and the importance they attached to doing more with the region's rivers. A professional interviewing firm conducted random telephone interviews.

[2] Missouri SCORP 1996-2001, pg 14

The survey found that of the 51 percent that would walk, hike, jog, roller blade or bike ten or more times a year (26 percent of market area population), 7 percent would use the Riverfront Trail, 10 or more times a year, 9 percent would do so 5 to 9 times annually, 11 percent 3 or more times, and 28 percent one or two times. Forty-four percent would not use the Trail. Usage of at least once a year (56 percent overall) is highest among City of St. Louis participants (72 percent) and among those 44 and under (68 percent). Many respondents may have been overestimating their future use of the Riverfront Trail, because each day they used the Riverfront Trail they would have to give up using another trail (or the street or sidewalk) they currently use or would have to increase their trail use overall. Given the paucity of trails in the City and St. Louis County, hiking/jogging/bicycling/rollerblading on streets and sidewalks may predominate, and these facilities would be close to their homes--closer than the Riverfront Trail. Nevertheless, respondents did indicate a willingness to use the Riverfront Trail in substantial numbers.

From the survey, annual visits to the trail were estimated to be 1,298,000. By county, the totals were estimated to be 693,000 for St. Louis County, 118,000 for Madison County and 146,000 for St. Clair County and 341,000 for St. Louis City. The estimates do not include any visits by persons under 18 or over 69 or by those living outside the four counties in the sample. Visitors to the region may also use the trail so their visits could be added to total use. The Arch receives almost 4 million visitors per year and the Chain of Rocks Bridge is anticipated to receive 1,466,000 visits per year when fully operational.

For percentage results (including annual visits) based on the entire sample, the sampling error, at the ninety-five percent confidence level, is approximately plus-or-minus five percent. For percentage results for each county, the sampling error is about plus-or-minus eight percent.

The projected total annual visits to the Riverfront Trail are 1,298,000. For the purpose of this study that number will be reduced by one-third because only two-thirds of the trail is within the St. Louis Flood Protection Study project boundary. The total then would be 856,680. The upper limit of visitation is further reduced to 750,000 due to limits of the Unit Day Value method indicated in the regulations.

The survey also determined the importance respondents placed on amenities and aesthetics along trails. Twenty-nine percent say that in deciding where to walk, jog, or bike, it is extremely important that there be rest rooms and water fountains located along the trail. Another 34 percent think that it is very important, 24 percent somewhat important, 9 percent not very important and 4 percent not at all important. Women (67 percent extremely or very important) and those 55 to 69 (74 percent extremely or very important) are most likely to place a high priority on this factor.

The Survey also determined that in making the same decision about where to walk, jog or bike, ten percent say having a trail which is “landscaped with plants and other interesting things to look at” is extremely important, 28 percent think it is very important, 38 percent think it somewhat important, 18 percent not very important, and 7 percent not at all important. This pattern extends across all segments of the surveyed group. In deciding where to bike, 8 percent say it is extremely important that there be a “convenient place near the trail to rent a bike,” 16 percent reply it is very important, 25 percent somewhat important, 28 percent not very important and 22 percent not at all important. There are no significant differences between groups.

In general, about fifty percent of the respondents of this statistical sample felt amenities and landscaping were extremely or very important.

Use of the trail was also analyzed by calculating use based on the capacity method. A review of the literature indicates that for urban trail systems, the average density at which users begin to feel crowded is about 50 bicycles per mile and 100 walkers per mile. Given turnovers of 12 for bicycling and 10 for walking the carrying capacity can be calculated as follows:

Bicycling Visitation. It was calculated that the trail could accommodate 378,000 bicyclists per year using the following recreation criteria for bicycling:
50 bicyclists per mile of trail;
a turnover rate of 12 per peak day (weekends and holidays);
9 peak days per peak month;
60 percent of peak month bicycling occurring on peak days; and
20 percent of annual bicycling days occurring during the peak month.

Bicycling, rollerblading, walking and jogging visitation was projected to reach capacity by the end of the fifth year after the trail amenities were fully developed. Annual visitation was projected at 20 percent of capacity the first year and 20 percent growth each additional year until the fifth year.

Walking Visitation. It was calculated that the cost-shared trail could accommodate 291,200 hikers and joggers per year using the following recreation criteria for hiking:
100 walkers/joggers/rollerbladers per mile of trail;
a turnover rate of 8 per peak day;
26 peak days in a year; and
60 percent of annual hiking visitation occurring on peak days.

Walking and jogging visitation is projected to reach capacity by the end of the fifth year after the trail was developed. Annual visitation was projected at 20 percent of capacity the first year and 20 percent growth each additional year until the fifth year.

These figures do not represent maximum carrying capacity, which would only be limited by the physical space available.

By the capacity method the walking and bicycling projected visitation figures total 669,000, which is 187,480 less than the survey total for the project section of the trail. This number will be used to determine recreation benefits because it is the more conservative and most reasonable.

The number of visitors to the trail without amenities was estimated by taking the average of the percent of respondents who felt facilities and landscaping were extremely or very important and subtracting that number from the total, i.e. 669,000 to arrive at a number of visitors who would use the trail without the proposed amenities, i.e., 334,000.

5. Recreation Displaced by the Riverfront Trail

Given the fact that the City of St. Louis has only one trail system with facilities that would be comparable to those proposed for the Riverfront Trail, i.e. Forest Park, and only one other in the county at approximately ten miles distance, i.e. Grant's Trail (visitation is estimated at 250,000); only minimal recreation displacement would be expected due to the great demand for such facilities as evident in the Confluence Greenway Survey and the Missouri SCORP figures.

6 Unit Day Values

Unit day values were developed for combined recreational activities. This methodology relies on professional judgment to assign point values to five criteria. The total points assigned are converted to a unit-day value that is then applied to the estimated visitation to derive the overall benefits. The points were assigned to the criteria as described below. These points were then converted to a Unit Day Value using point to value data for Fiscal Year 2003. The point to value data used was from the "General Recreation" activity category.

The Unit Day Value (UDV) methodology was used to estimate the recreational benefits associated with the project since use, for the purposes of this study, will be limited to 669,000 visitors and recreation benefits are not an integral part of plan formulation[3]. No amenities are presently located on or along the trail. Existing benefits for a trail without amenities were derived and subtracted from the with project benefits to determine net recreational benefits. Standard discounting and amortizing calculations were used to develop average annual discounted recreation benefits.

Unit day values for bicycling-walking-jogging without trail amenities were assessed at $4.08 and $6.17 with the addition of trail amenities.

The following table presents the UDV criteria and the points assigned.

[3] ER1105-2-100, para. E-50 b.(4)

Criteria and Evaluation Description	Points Assigned
Criteria 1 – Recreation Experience This criterion addresses the recreational opportunities and experiences available to the user. Point range: 0-30	
Walking-Bicycling-Jogging-Jogging, Without project – there are no services developed that will meet the needs of trail users; thus, length of stay on the trail may be curtailed or there may be fewer return trips.	5
Walking-Bicycling-Jogging, With project – the expected level of amenities will cause interest in the trail to increase, length of stay may increase and return trips may be more frequent – there are several general activities.	10
Criterion 2 – Availability of Opportunity This criterion accounts for competing facilities and opportunities (competition) available to the residents in the market area. Point range; 0-18	
Walking-Bicycling-Jogging, Without Project – trail use will continue but grow rather slowly	3
Walking-Bicycling-Jogging, With Project – there are several opportunities within one hour	6
Criterion 3 Carrying Capacity This criterion compares the demand for the offered experiences, the ability of the resource to support the projected visitation, and the proposed level of facility development. Point Range: 0-14.	
Walking-Bicycling-Jogging, Without Project – issues of public health and safety will limit potential use	2
Walking-Bicycling-Jogging, With Project – ultimate facilities to handle projected visitation	12
Criterion 4 – Accessibility This criterion addresses the accessibility to and opportunities/facilities with the project for all market area residents. Point range: 0-18	
Walking-Bicycling-Jogging, Without Project – good access and opportunity for use	11
Walking-Bicycling-Jogging, With Project – access and opportunity to use the project would be enhanced by connector routes	15
Criterion 5 – Environmental Quality This criterion addresses the aesthetic factors of the project area. Point range: 0-20	
Walking-Bicycling-Jogging, Without Project – aesthetic interest would be average	3
Walking-Bicycling-Jogging, With Project - there would be high aesthetic quality with no factors that exist that lower quality	6

Total points assigned and resulting Unit Day Value (FY 03)	
Walking-Bicycling-Jogging, Without Project	**24($ 4.08)**
Walking-Bicycling-Jogging, With Project	**49 ($6.17)**

7. Estimate of Recreation Costs and Benefits

The average annual costs are $172,797 ($97,797 annual cost plus estimated annual O&M of $75,000), which are offset by average annual benefits of $3,200,259. The resulting benefit-cost ratio for the recreational features is 18.5.

Recreation Activity or Facility	UDV Points	FY 2003 Gen. Rec. Benefit/Day	Visitors per Year	PV, Benefits Years 5-50	PV, Benefits Years 1-5	Annual Benefits
Walking/Bicycle/Jogging Trail No Amenities, 8.4 miles, max capacity after 5 years						
Bicycling/Walking/Jogging	24	$4.08	334,000	$21,418,204	$3,830,479	$1,574,003
Walking/Bicycle/Jogging Trail With Amenities, 8.4 miles, max capacity after 5 years						
Bicycling/Walking/Jogging	49	$6.17	669,000	$64,876,544	$11,707,702	$4,774,262
Annual Benefits Added by Amenities to Riverfront Trail						$3,200,259
Trail Amenities	Qty	Unit Cost	Total			
Primary Trailhead	1	$343,000.00	343,000			
Secondary Trailheads	4	$150,000.00	600,000			
Rest Stops	2	$75,000.00	150,000			
			$1,093,000			
Interest During Construction			$99,016			
Design Costs (for $334,000 in recreation development)			$63,000			
Contingency @ 25 %			$1,568,770			
Annualized Cost Trail Amenities			$97,797			
Optimization:						
Incremental Benefits, Addition of Trail Amenities				$4,774,262	- 1,574,003 =	$3,200,259
Incremental Costs, Addition of Trail Amenities:						
Trail Amenities, amortized over 50 years						$97,797
Additional annual OMRR&R						$75,000
Incremental benefits > incremental costs, so						$172,797
trail amenities are incrementally justified.						

Trail with No Amenities yrs 1-5	
66000	$254,338
132,000	$508,675
198000	$763,013
264000	$1,017,351
334000	$1,287,103
Total	$3,830,479

Trail with Amenities yrs 1-5	
134000	$780,902
268000	$1,561,804
402000	$2,342,706
536000	$3,123,608
669000	$3,898,682
Total	$11,707,702

B/C = 18.5

Conclusion: The demand for the Riverfront Trail with amenities and average annual benefits generated are sufficient to justify the cost-share participation and development of this project.