## ENGINEERING APPENDIX

### C-1. General

This appendix documents the engineering analysis. In this appendix are attached separate reports for the Hydrology and Hydraulics and the Hazardous and Toxic Materials. Attached are the MCACES cost estimates, construction schedule, plan views, typical channel sections, typical culvert sections and plan, hydraulic control structure, and boring logs.

### C-2. Hydrology and Hydraulics

Hydraulic modeling was performed during this study; information obtained from the model was used in developing channel dimensions. Four variations of the selected channel layout were evaluated; they are the 10, 50, 100 and 200-year plans, which are referred to as C-10, C-50, C-100 and C-200. Each plan provides different levels of flood reduction. Refer to the Hydrology and Hydraulics report for complete details and the dimensions of each plan.

### C-3. Surveying, Mapping, and Other Geospatial Data Requirements

No surveys were performed for this phase of study, however, an aerial based GIS map was provided by the sponsor. The map was generated at one inch to 100 feet with two-foot contours. The map also showed buildings, streets and railroad tracks. A more recent and comprehensive topographic survey will be required in order to develop plans and specifications.

### C-4. Geotechnical

C-4.1.1. Regional and site geology

Fort Smith is located on the southern flank of the McAlester Basin, in the Arkansas Valley section of the Ouachita physiographic province. Three geologic formations, which are all Pennsylvanian age, crop out in the area. In ascending order, they are the Hartshorne sandstone, the Spadra shale and the Fort Smith formation, which consists of sandstone and sandy shale. Faulting is present in the area as is folding of the beds. These features increase in intensity southward. Groundwater generally follows the surface contours and may be found in small to moderate amounts in the residual and alluvial materials in the area. A layer of residual soil ranging up to 14 feet in thickness mantles the area; alluvial materials of varying thicknesses can be expected along major drainages of the area.

C-4.1.2. Completed exploration

In June 1999, there were a total of 23 borings drilled in the vicinity of the proposed channel alignment. Continuous standard penetration tests (SPT) were performed on the majority of the holes in accordance with procedures outlined in the Department of the Army, Engineer Manual (EM) 1110-2-1907, dated 31 Mar 72. The depth of the continuous SPTs ranged from 12 feet to 21 feet; an SPT was then performed at 3-foot intervals. Samples were obtained from each SPT for HTRW and soil classification tests. Auger borings were performed at other locations and samples were taken at 3-foot intervals for soil classification testing. When rock was encountered during the drilling

operation, the hole was core drilled into the rock for 8 feet; the boring was then terminated. Rock was not encountered on all holes, however the holes where rock was encountered ranged from 3.5 feet to 20 feet. The total depth of the holes ranged from 11.5 feet to 39 feet. A total of seven borings were drilled (MB25 – MB31) in October 1999 and monitoring wells were installed to obtain water samples for Hazardous Toxicological Radioactive Waste (HTRW) testing. See Geotechnical plates G1 – G15 for location and details on all of the boring logs.

The equipment used for the drilling operation included a Mobile B-56 drill rig, 8" outside diameter (OD) augers, 2" OD standard split spoon samplers; 3.5" OD HQ core barrels were used for rock samples. The drill operation was performed by a contract drilling company.

A local engineering firm tested the soil samples; tests included natural water contents, liquid limits and plastic limits. The soils were also visually classified in accordance with ASTM D 2487. In general the overburden consists of CL, ML, SP, SM, and CH, with clays being the most common soil type and silts being the next most common. Sands and gravels were encountered somewhat infrequently. All samples were tested for the natural moisture content, the results ranged from 7% to 37% for sands, 3% to 63% for clays and 17% to 45% for silts. Atterburg limits were performed on a total of 37 samples of the cohesive material; the plasticity indexes ranged from 5 to 59.

C-4.1.3. Preliminary stability analysis.
Based on the given soil types in the area and engineering judgment, it was determined that the excavated channel side slopes should be 1V:3H and plated with 2 feet of riprap, except where vertical walls or concrete paved slopes are to be constructed.

C-4.1.4. Excavatability analysis
The soils encountered during drilling operations will be excavated by using typical earth excavation equipment. The rock that was encountered was primarily shale with some sandstone. The rock will likely have to be removed by using continuous systematic chiseling, edging or other appropriate rock excavation methods in order to efficiently remove the material.

C-4.1.5. Potential disposal sites.
No potential disposal areas have been identified at this time. Upon project approval, the specifications will likely direct the contractor to be responsible for locating appropriate disposal areas, unless the sponsor expresses a desired location for the disposal.

**C-5. Civil Design**
C-5.1. Site selection and project development
Site visits and preliminary cost comparisons were performed by the Project Delivery Team (PDT) in order to help facilitate selection of the most feasible channel layout. Consideration was given to existing bridges, buildings, utilities and roads that would be impacted by the selected plan. Other plans were not selected because they required excavation through an existing landfill and wetland mitigation. Other concerns were, the

channels were longer, less hydraulically efficient and posed a greater negative impact to local businesses. The alternate channel routes are presented on plates G1-G3. Also, the possibility of constructing a covered channel was discussed but not thoroughly evaluated due to the feasibility of constructing an open channel and additional costs associated with construction of a covered channel. The National Economic Development (NED) plan, C-10, is an excavated channel, which flows through the city of Fort Smith, Arkansas, which will drain into the Arkansas River; the plan is presented on plates C-1 through C-3. The federal interest limit of the proposed channel is approximately 2.3 miles long with varying depths and a portion of it is located along an old railroad easement. The majority of the channel will have a trapezoidal cross-section with 1V:3H side slopes plated with riprap. The riprap will be placed at an elevation, which is consistent with a 2-year flood event. The channel was laid out in a manner that was hydraulically functional while minimizing the need to remove or relocate existing homes, businesses and other structures. However, at various locations along the proposed channel, it will not be feasible to construct a trapezoidal channel due to real estate limitations. At these locations, a vertical concrete wall will be used and a concrete paved trapezoidal channel will be used. A combination of the 100yr and 10yr plans, C-100/C-10, is presented on plates C-4 through C-6.

The proposed channel alignment will cross several existing streets thereby creating the need for box culverts and bridges. The alignment will also require five railroad crossings. Traffic at each bridge or culvert location will be rerouted until it is deemed feasible to use the newly constructed crossing. Based on information obtained by the contract A-E firm, one of the impacted railroads will not require temporary access during the construction of the new crossing. However, temporary access will be required for the three main line railroad tracks during the construction of the new crossings. The fifty-foot right-of-way along either side of the traffic is sufficient to construct a temporary shoofly. Although, the involved railroad companies have provided concurrence on our initial proposal, a formal agreement with all involved entities will be established upon project approval.

There are also several existing storm drains including the P Street storm sewer that will intersect the proposed channel alignment. This sewer and collector drains will collect water independently of the proposed channel in reaches 1-3. Where the proposed channel alignment crosses the main sewer line or the collector drains, the existing line will be cut in order to daylight to the new channel. These lines will remain in operation after completion of the channel by flowing into the completed channel. This will allow some of the runoff to continue to be collected by the existing drains. New headwalls and pipe extensions will also be used as required. Plates C-1 and C-2 show the location of the storm sewer in relation to the proposed channel. The storm sewer is made of concrete and ranges in size from 105" to 138" in diameter with varying sizes of collector drains which tie into the sewer line at various locations within reaches 1-3. If the project goes to construction, the plans and specifications will clearly identify the location of the sewer line and will also instruct contractors to implement procedures that will avoid damage to the existing sewer line during excavation procedures.

During the initial stages of the study, it was believed that the existing pump station located near the Arkansas River would need to be upgraded to increase its capacity to handle coincident flooding. An A-E firm performed a study to determine the most practical methods of increasing the capacity of the flood control pump station. However, after further review by Hydraulic engineers, it was determined that coincident flooding will not be a problem, therefore a new/upgraded pump station would not be necessary for this project.

The upstream Federal limit of the project is at the upstream end of reach 4. However the two upstream reaches (reaches 5 and 6) will be constructed as a betterment. A cost estimate is required for the Federal interest portion of the project (reaches 1 - 4). Thus, this portion includes the estimated cost of a wing wall that would have been constructed where the existing storm sewer would have transitioned into the open channel. Since an open channel will be constructed though all of the reaches, this headwall will not actually be required although its cost will reduce the sponsor's share of costs for the betterment.

The project location is in an urban area with sparse vegetative cover; therefore no significant amount of clearing is anticipated.

C-5.2. Real Estate.
This project will require the acquisition of real estate in order to construct the flood reduction channel, which includes construction right of way. Also, real estate acquisition is required for permanent road relocation and temporary railroad access during construction. Where possible, a construction easement width of 25 feet will be used. The sponsor identified city owned land that would be available for use as a temporary lay down area during construction. This land was previously credited for the construction of the Fort Smith Levee. Refer to Plate C-1 for the location of this area.

C-5.3. Relocations.
Utilities located in the vicinity of the project were identified, by using existing as-built drawings that were provided by the sponsor. Sanitary sewer, potable water, gas and telephone lines will have to be removed and relocated in order to construct the channel.

**C-6. Structural Requirements.**

C-6.1 General.
Work includes the 15% preliminary structural design for highway, city street, and railroad crossings of the proposed May Branch drainage channel for C-10, C-50, C-100, and C-200. Preliminary designs were also done for the concrete retaining walls and bottom in the restricted width section of the channel and the hydraulic control structure. For safety purposes, a 6' chain link fence will be installed along the top of the retaining wall. The work also includes the type and extent of repairs required to restore the "P" Street storm water sewer to a good condition.

C-6.2 Design Items.
C-6.2.1 Highway, Street, and Railroad Crossings.

Clayton Expressway (State Highway 225) – bridge
Kansas City Southern RR at Sta. 13+75 - culvert
(used by Arkansas and Missouri Railroad)
Kansas City Southern RR at Sta. 28+25 – culvert
(used by Arkansas and Missouri Railroad)
Union Pacific RR at Sta. 33+70 – culvert
(leased to Fort Smith Railroad which is a subsidiary of Pioneer Railroad)
Arkansas and Missouri RR at Sta. 34+75 – culvert
Union Pacific RR at Sta. 36+50 – culvert
(leased to Fort Smith Railroad)
6th Street at Sta. 41+45 – bridge
Midland at Sta. 58+00 – culvert
Greenwood at Sta. 76+75 – culvert
Concrete Retaining Walls and Channel Bottom from Sta. 82+30 to Sta. 86+35
(17-feet height)
Arkhola Service Entrance at Sta. 86+10 – bridge
"O" Street at Sta. 92+00 – culvert
Grand at Sta. 119+05 – culvert

C-6.2.2 Hydraulic Control Structure.
This design includes one type of channel hydraulic control structure: a slide gate control structure with motor operators and concrete box culvert through the Arkansas River levee. Refer to plates C-10 and C-11.

C-6.2.3 Repair of "P" Street Storm Water Sewer.
An inspection of the entire length of the North "P" Street storm sewer was performed. It included digital still pictures with station numbering of typical conditions and damaged areas. The type and extent of repairs required to restore the sewer to good condition include replacing the flow line for the entire length of the pipe, replacing mortar, repairing exposed aggregate, patching spalled areas and sealing roof and wall cracks.

C-6.3 Waterway Opening at Structures.
Waterway openings were determined by hydraulic modeling for C-10, C-50, C-100, and C-200 as presented in the Hydrology and Hydraulics Report.

C-6.4 Design Parameters/Specifications.

Highway and Street Crossings. Design of highway and street crossings are in accordance with the latest edition of "Standard Specifications for Highway Bridges" of the American Association of State Highway and Transportation Officials (AASHTO) with HS20 traffic loading for highway bridges and H20 traffic loading for city streets and 0.05G seismic acceleration. Geometric design will be in accordance with the AASHTO Green Book "A Policy on Geometric Design of Highways and Streets". In lieu of design, Arkansas State Highway and Transportation Department (AHTD) standard designs were used.

Railroad Crossings. Design of railroad crossings were to be in accordance with the latest edition of the American Railway Engineering Association "Manual for Railway Engineering" for Cooper E80 live loading. In lieu of design, Union Pacific railroad standard Designs were used. The railroads, which were contacted, Arkansas-Missouri, Kansas City Southern, and Fort Smith Railroad (Union Pacific) all agreed that the design parameters for the railroads should conform to the standards for Union Pacific crossings.

Channel Hydraulic Control Structure. Design of the channel hydraulic control structure was done in accordance with Corps of Engineers policies and procedures including EM 1110-2-2705, Structural Design for Closure Structures for Local Flood Protection Projects, 31 March 1994 and EM 1110-2-2105, Design of Hydraulic Steel Structures, 31 May 1994.

Roadway Width of Crossings. Clayton Expressway - 44 feet plus 8 foot bicycle path, other bridges 36 feet plus 1'-7" sidewalks on both sides. Culvert street crossings 27 feet minimum width plus 7 feet each side to guard rail, wider street crossings according to city master street plan. Side slopes at culvert crossings 4 foot horizontal to 1 foot vertical.

C-6.5. Alternatives Considered.

Bridge or Culvert. A comparative analysis based on cost and recommendations of the owners was made in order to determine whether to use a bridge or culvert at typical locations. All railroads involved requested to use concrete box culverts based on future maintenance costs. Bridges were selected at Clayton Expressway, 6th Street, and service access to Arkhola storage area. Concrete box culverts were selected at all other locations.

Cast-in-Place or Pre-cast Concrete. A cost analysis made between cast-in-place and pre-cast concrete showed cast-in-place concrete construction to be more economical.

Substructure. Steel H-pile bents with concrete cap were compared with concrete bents with spread footings on the basis of cost and resistance to scour and steel H-pile bents with concrete cap were selected.

**C-7. Electrical and Mechanical Requirements.**

The feasibility study includes functional design requirements, technical design criteria and engineering services for relocation of all utilities above ground and underground within the project boundary that will interfere with the new channel system. It also includes a hydraulic control structure with motorized slide gates and all the utility connections required to operate the slide gates. Gates will be locally controlled from a motor control panel or remotely from a remote control station located in the city engineering office on Garrison Avenue.

Technical design criteria for relocating utilities and constructing motorized gate structures shall at a minimum comply with the requirements of the following criteria, latest edition.

1. NFPA 70: National Electric Codes
2. ANSI C2: National Electrical Safety Codes
3. IES Reference and Application: Lighting Handbook

**C-8. Hazardous and Toxic Materials.**
Subsurface explorations were performed in the project location to assist in determining the most feasible channel layout. No significant HTRW concerns were identified in the proposed channel location. Refer to plates G1, G14-G15 and the HTRW report for details on the subsurface exploration results.

**C-9. Construction Procedures and Water Control Plan**
The construction of the box culverts will be sequenced in order to minimize the impact on the local traffic patterns. Some streets along the "P" street drainage channel may be required to be temporarily closed during construction or permanently closed. Sequencing the installation of the box culverts will allow vehicular traffic to be rerouted around the local and collector streets during construction. Also, barriers will be installed near the edge of the excavated channel at locations where the channel intersects an existing road. The major arterial and/or collector streets, including Clayton Expressway, Greenwood Avenue, Grand Avenue, and Midland Avenue will require the box culverts to be installed in sections and traffic detoured around construction or that traffic be rerouted to parallel streets during construction.

It is anticipated that the bridges, hydraulic control structure, railroad crossings and the box culverts will be constructed by using the adjacent in-place soil as a natural cofferdam. Groundwater and rainwater will have to be considered during construction of these features. A combination of ditches, well points, sumps or pumps will need to be used for removal of water from the excavations for satisfactory completion of the work. Erosion control measures will also be put in place to minimize the erosion on the excavated slopes and all adjacent land that may have been stripped of vegetation.

**C-10. Operation and Maintenance**
The sponsor will need to be responsible for annually traversing the entire length of the channel and looking at the condition of the channel bottom and side slopes and concrete structures. The sponsor will also need to semi-annually examine the slide gate for damages. The gate stem and operating mechanism will be lubricated and the gate will be opened and closed several times to distribute the lubrication and confirm that the gates will operate as designed. Debris and plant growth that interfere with gate operation will be removed. The sponsor will need to ensure that the earthen side slopes are mowed four times per year; undesirable weeds and woody growth will be removed by herbicides or cutting. The concrete structures will also need to be inspected annually for damage and deterioration and repaired immediately to prevent further damage to the structure. The sponsor will need to be responsible for repair to any damaged sections of the riprap. Removal of plant growth within the riprap will also be the responsibility of the sponsor.

**C-11. Access Roads**
This project is located within the city of Fort Smith and in most cases it will be feasible to use the existing public city streets for transporting of miscellaneous construction equipment and hauling of excavated material, debris and miscellaneous construction materials. Additionally, a substantial portion of the project site will have sufficient construction easements along the top banks of the excavated channel. It is likely that these temporary access roads can remain functional after completion of the project, provided that periodic maintenance is performed.

**C-12. Cost Estimates**
The baseline cost estimate (C-100/C-10) for the selected plan (essentially a 100-Year level of protection) representing the scope of work was developed using the MCACES in the Civil Works Work Breakdown Structure format. The estimate reflected the recent steel and petroleum products price increases to the month of March 2004. Quantities were calculated and provided by the Designers in the District. The cost estimate for each feature was escalated to the mid point of construction using the most current indices for Civil Works Construction Cost Index System (CWCCIS) EM 1110-2-1304 dated September 30, 2003. Contingencies in the range of 10% to 20% depending on the risk and uncertainties were applied to the estimate. The cost estimate for 10-year plan was developed in the similar manner. For specific cost information refer to the MCACES cost estimate.

**C-13. Schedule for Design and Construction**
The schedule for construction is attached at the end of the engineering appendix. The design schedule has not been developed, but will be completed prior to completion of the Feasibility Phase.

**C-14. Plates, Figures, and Drawings**
Plates included in the engineering appendix include the plan view of the selected channel, typical cross sections of the channel, typical culvert plan and details, hydraulic control structure details, plan of borings, boring logs, and other structural details.

**C-15. Data Management.**
During the feasibility study, data was compiled and maintained in project folders for each discipline involved.

**C-16. Use of Metric System Measurements.**
The city administration specifically requested that the project be designed in English units and they requested that the Little Rock District pursue obtaining any waivers required. The site surveys, which were developed in English units, were provided to the Little Rock District by the city as part of their work in-kind cost sharing percentage. Converting these survey drawings from English to Metric would have created an extra work effort for the design team resulting in a higher cost for the customer and lower customer satisfaction. Documentation from the project files indicate that the waiver request was submitted and approved by the Headquarter, U.S. Army Corps of Engineers.