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Alternatives Analysis Memorandum
Alternatives Development and Initial Screening
McMicken Dam Fissure Risk Zone Remediation Project
Contract FCD 2002C011, Work Assignment No. 1

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4 June 2003
AMEC Job No. 2-117-001066

Bobbie Ohler, P.E.
Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009-6399

Dear Ms. Ohler:

Re: Alternatives Analysis Memorandum
Alternatives Development and Initial Screening
McMicken Dam Fissure Risk Zone Remediation Project
Contract FCD 2002C011, Work Assignment No. 1

Transmitted herewith are eight copies of the final Initial Screening memorandum for the McMicken Dam Earth Fissure Risk Zone Remediation Project. The memorandum presents the list of alternatives, and the initial screening of those alternatives, developed for mitigating the earth fissure risk zone at the south end of McMicken Dam. In response to Flood Control District of Maricopa County review comments, the memorandum includes more detailed discussions of the potential environmental consequences associated with the alternatives considered. The memorandum also presents alternatives that are recommended for further consideration, in particular more detailed cost analysis and risk assessment.

Should you have any questions, please do not hesitate in contacting the undersigned.

Respectfully submitted,

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TABLE OF CONTENTS

Page

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

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1.0 INTRODUCTION

This draft memorandum, which was prepared jointly by AMEC Earth & Environmental, Inc. (AMEC) and Stantec Consulting, Inc. (Stantec), presents the list of alternatives, and initial screening of those alternatives, developed for mitigating the earth fissure hazard at the south end of McMicken Dam. Specifically, this memorandum addresses rehabilitation and modification concepts, including remedial construction to isolate or allow abandonment of the section of the dam that is located within the identified fissure risk zone. The concepts were developed at a reconnaissance level of detail only to allow the initial screening to be completed. The list of alternatives and the alternatives analysis process is intended to satisfy the US Army Corps of Engineers (USACOE) 404b(1) process, including consideration of potential environmental and land use impacts.

This draft memorandum was prepared as the initial task of the alternative analysis being completed for the Flood Control District of Maricopa County, herein referred to as the District. The alternative analysis is being conducted for the District in accordance with the McMicken Dam Fissure Risk Zone Remediation (FRZR) Project, Work Assignment 1 of Contract FCD 2002C011 between AMEC and the District.

2.0 FISSURE RISK ZONE

AMEC previously completed an initial study (AMEC, 2002)[1] to determine if earth fissures are present within the shallow foundation soils supporting McMicken Dam, and to define the hazard zone along the southern end of the dam. The study concluded that there exists a high probability that earth fissures are present beneath the dam between Stations 58+00 and 65+00. Based on the results of the initial study, the southern end of McMicken Dam was zoned based on the earth fissure hazard. However, subsequent to completion of the initial study, a supplemental study was undertaken to further define the hazard. The field component of this study has been completed, and a task to analyze survey and other data to quantify horizontal strains has recently been initiated. Based on the results of the study to date, the southern end of McMicken Dam was rezoned, including areas both upstream and downstream.

The present zoning is depicted on Sheet 1, including low, moderate and high hazard zones. The high hazard zone extends from Stations 56+00 to 75+00 along the dam, and the moderate hazard zone extends from Stations 75+00 to 105+00 along the dam. The high and moderate hazard zones generally straddle the dam from about Station 65+00 to about Station 95+00, with the zone trending north-northeast. North of Station 95+00 the zone turns to trend north-northwest, and south of Station 65+00, the zone trends to the south.

[1] References are listed at the end of this memorandum.

For purposes of this study, the three hazard zones are defined as follows:

High Hazard - Region where earth fissures have been field identified. Distinct possibility that earth fissures are present in the alluvial foundation soils under the dam. Multiple lines of evidence are present, including close proximity of documented fissures trending towards the embankment. Indications also include significant density of seismic refraction anomalies and photo-lineaments, some of which are coincidental or parallel to trends of known fissures. The occurrence of fissures also correlates with the suspected region of considerable horizontal strain, as indicated by the settlement profile along dam crest and interferometry.

Moderate Hazard - Region where moderate density of photo-lineaments and reduced number of seismic anomalies have been detected. Settlement profiles and interferometry indicate the possibility of tensile strains. The probability of open fissures present in close proximity to the base of the embankment is low, but continued strain could produce future fissuring to the surface along photo-lineaments.

Low Hazard - Portion of dam alignment and adjacent areas lacking in significant numbers of intersecting photo-lineaments and seismic anomalies, coupled with interferometric and crest settlement profile data indicating the lack of appreciable horizontal strain.

3.0 EVALUATION WEIGHTING AND CRITERIA

The evaluation criteria developed are listed in Table 1. An initial listing was prepared and discussed during a meeting with AMEC, Stantec, District and Arizona Department of Water Resources (ADWR) personnel on 5 December 2002. Consensus regarding the evaluation criteria, and the weighting of those criteria, was reached during the meeting; however, in applying the criteria to the various alternatives being screened the need for minor modifications became apparent. These included addition of the criterion "opportunities for additional benefits" and deletion of the criterion "potential to withstand vertical differential movement". The listing in Table 1 presents the primary criteria applied to the alternatives considered in this memorandum.

The evaluation criteria considered most important, being assigned a relative weight factor of 100, are performance and failure consequences. The performance criteria include reducing the risk to the District and the public, and providing flood protection comparable to that presently provided by McMicken Dam. The presence of the fissure risk zone requires mitigation to reduce the risk. Segmenting or abandoning the southern section of the dam may accomplish the first criterion, but at the expense of the second criterion. The next four performance criteria in Table 1 directly address the modification goals listed below, and it is necessary to evaluate the relative ease of repair and the redundancy offered by the alternatives. The failure consequence evaluation criteria include loss of life, loss of property, facility damage and environmental damage.

The next most highly weighted evaluation criteria include the time required to implement the alternative and the capital cost of the alternative, each of which were assigned a relative weight factor of 60. Operations and maintenance cost, right-of-way cost if the purchase of additional land is required either for a new structure or a new spillway, and the cost of mitigation of any newly acquired land were included in a separate cost category. This category was considered less important than capital cost and was assigned a weight factor of 40. Detailed cost estimates were not developed for each of the alternatives; however, relative costs were considered based on estimates for similar types of alternatives prepared by URS Corporation for White Tanks FRS No. 3 (URS, 2002b). Time and schedule for implementation of the alternative also were considered relatively important because of the hazard associated with the fissure risk zone.

Environmental considerations were also considered important and assigned a relative weight factor of 50. The environmental considerations listed in Table 1 are the basic factors that require assessment as part of the USACOE 404b(1) submittal that may be required for the FRZR project. However, the impacts of the alternatives are essentially the same for most of the environmental considerations listed in Table 1. Only impacts to waters of the U.S. and historic properties (cultural resources) were considered in the evaluation, since the different alternatives may have a variable impact on these criteria. A more detailed discussion of environmental considerations is presented in Section 5. Similarly, with the exception of potential enhancements, the impacts of the alternatives are essentially the same for the land use criteria listed in Table 1. This is in large part because all of the alternatives can be constructed within the District's existing right-of-way.

The remaining criterion, potential enhancements, was included with the category of opportunities for additional benefits. This category and the category "capability of being accommodated in future plans" were considered significantly less important, with both categories being assigned a weight factor of 25. Finally, aesthetics or the visual appearance of the alternative was considered least important, being assigned a relative weight factor of 10.

4.0 ALTERNATIVES CONSIDERED

4.1 Overview

The lists of modification alternatives developed are presented in Tables 2 and 3. An initial listing was prepared and discussed during a meeting with AMEC, Stantec, District and Arizona Department of Water Resources (ADWR) personnel on 5 December 2002. Consensus regarding the evaluation criteria was reached during the meeting, however, in the initial screening of the various alternatives, the need for minor modifications became apparent, including the deletion of "multiple segments" because of the relatively small size of the subbasin upstream of the high hazard fissure risk zone. It was also agreed to delete the system alternatives of new embankment, roller compacted concrete (RCC) structure and soil cement structure at the present location of McMicken Dam, since these alternatives would require removal of the existing dam. This additional construction would increase the cost and the construction time relative to constructing new structures upstream and downstream. With this exception, the listings in Tables 2 and 3 present the alternatives being screened, as considered in this memorandum.

The alternatives included in Table 2 are system alternatives, which could employ the components included in Table 3. For example, a new homogeneous embankment dam could utilize a geosynthetic to protect against flow through embankment cracks resulting from shrinkage and/or settlement, or the new embankment could be designed as zoned earthen embankment and provide the same protection. The purpose in separately identifying components is that the process allows comparative evaluation of these components primarily on the basis of cost, their impact on time and schedule, and other specific criteria. The system alternatives generally involve structures requiring a more spatial consideration and have varying potential direct impacts on the environment, land use and other factors, independent of the components used in the systems.

4.2 System Alternatives

Two general categories of alternatives were developed: 1) modifications to prevent breaching of the dam due to seepage along or through an earth fissure, and 2) modifications to replace the function of the existing dam within the identified fissure risk zone of the dam. With the exception of the first two alternatives, the primary list of alternatives, as included in Table 2, includes the broad categories of rehabilitate the existing structure, abandon the existing structure and replace it with a new structure located within the watershed, and segment the existing structure.

Within the context of this study, rehabilitation infers modification of the existing structure. Rehabilitation could include constructing a new earthen embankment, constructing a new RCC or soil cement structure or constructing an upstream blanket. The new structures could be constructed upstream or downstream of the existing dam. Conceptual cross sections of these alternatives are presented in Figures 1 through 7. Rehabilitation could also include augmenting the existing dam by treating the existing embankment and foundation soils to prevent seepage, including grouting the foundation soils, filling existing cracks and fissures where present and constructing a grout curtain.

Abandonment includes construction of a new dam or diversion within the watershed located upstream of the existing dam. The new dam would impound runoff from the watershed immediately upstream of the new dam, and the diversion would divert the runoff to the unmodified northern section of the dam. These alternatives were considered because the watershed area directly impacting the southern end of the dam in the high hazard fissure risk zone is much smaller (about 9 square miles) in comparison to the total watershed above McMicken Dam (about 259 square miles). The alternatives grouped as part of this category include construction of a dam extension that will separate the southern section of the dam from the northern section so that the runoff volume contributed to the southern section of the dam by the much larger northern watershed is removed. Preliminary locations of these features are shown on Sheet 2, assuming only the section of the dam south of the high hazard zone is abandoned.

The final group of alternatives also includes segmenting the dam by constructing a dam extension, again because of the relative size of the watershed above the southern section of the existing dam. However, for this group of alternatives the runoff from the immediate watershed above the southern section of the dam would be impounded by the existing dam structure. Depending on the location of the dam extension and the volume of runoff to be impounded, rehabilitation of the existing southern section of the dam may or may not be required. The other alternative considered is segmentation of the dam with complete or partial removal of the segmented southern section of the existing dam and containment of flow in a basin.

4.3 Component Alternatives

The goals of the modification include:

1. Provide protection against flow through shrinkage or settlement induced cracking of the embankment of the existing dam or a new dam.

2. Prevent erosion or wetting induced collapse of the Holocene foundation soils from affecting the existing dam or a new dam, and

3. Provide protection against erosion caused by flow through an earth fissure located in the Pleistocene foundation soils from affecting the existing dam or a new dam.

A specific list of construction components, as presented in Table 3, was developed since many of the systems could employ the same or similar components to achieve these goals. The components are grouped to address each of the above goals. The third goal would need to be met only if the dam extension or any new structure were located inside of the fissure risk zone. Conceptual cross sections of the component alternatives are presented in Figures 8 through 12.

Design components that could provide protection against flow through embankment cracking include a geomembrane (HDPE or other plastic material, or a bituminous material) placed near the upstream face of a new earthen embankment, or an RCC or soil cement structure. The upstream face of a new earthen embankment could include a hard protective cover (fiber reinforced concrete, articulated pavement blocks, soil cement or RCC). However, because of the possible subsidence- or settlement-induced cracking of these hard elements, these components would require a geosynthetic cutoff, which can tolerate appreciable deformation and cracking, to protect against flow through the cracks. Similar to the present McMicken Dam, a homogeneous embankment could be constructed and a center cutoff/drain installed through the embankment. Based on the concerns about central cutoffs/drains that are present in existing structures (development of voids, re-cementation of the soils after placement, etc.), the material forming the central cutoff would be a flowable backfill. Because of the relative stiffness of the flowable backfill, a geosynthetic cutoff would be required. Finally, the new embankment could be constructed as a zoned earthen embankment, with a central core, upstream and downstream filter zones and a positive drainage system.

To prevent erosion or wetting of the Holocene foundation soils from affecting the structure, a trench cutoff could be constructed through this deposit and extend a short distance into the underlying Pleistocene soils. Implementation of this component alternative would need to ensure that all relatively permeable native soils, including more granular less cemented Pleistocene deposits are removed from the cutoff trench. The alternative would require a geosynthetic cutoff and flowable backfill. A similar system could be constructed in a trapezoidal ditch extending a short distance into the Pleistocene soils. The ditch would be configured large enough so that native backfill could effectively be used, but a geosynthetic cutoff would be required. Either a central cutoff or a zoned embankment, if constructed, could be extended through the Holocene soils, requiring their removal. Removal of the Holocene soils, which have a relatively high erosion and settlement potential, would be the most positive component alternative.

5.0 ENVIRONMENTAL CONSEQUENCES

5.1 General

The alternatives will have varying environmental consequences, with the consequence primarily being dependent on the location of the alternative and the location of the borrow materials that will be required to construct the alternative. In general, the rehabilitation alternatives will have the least impact since they will be constructed adjacent to the existing McMicken Dam. The impacts of alternatives 3L, 3M and 3N will be temporal and related only to access requirements during construction, since they do not include new structures. Alternatives 3B, 3E and 3H will require new construction downstream of the existing dam, however, it is likely that the borrow source for construction materials will be located upstream of the existing dam within the impoundment area. Alternatives 3A, 3D, 3G, 3J and 3K will require new construction immediately upstream of the existing dam, with the required borrow source also likely to be located within the impoundment area. The abandonment and isolation alternatives will require new construction within the impoundment area at locations removed from the existing dam and, thus, will have a somewhat greater impact on the environment. At the present conceptual level of design for the initial screening process, detailed estimates of the areas of impact have not been made. General discussions of the potential environmental impacts associated with the alternatives are presented in the following sections.

5.2 Air Quality

The alternatives would have minimal direct and indirect adverse impacts on air quality as a result of local construction traffic and activities. Dust suppression measures will be implemented during construction to minimize adverse effects on local air quality. Minor adverse impacts would result from construction vehicle and equipment emissions. None of the alternatives, once constructed, include any point source emissions.

5.3 Water Quality

McMicken Dam presently has a low flow channel designed to carry runoff to the principal outlet works. The dam rehabilitation alternatives would not result in significant alteration to this channel, unless it were to be used as a borrow area. The dam isolation and abandonment alternatives could include construction of a new section of low flow channel connecting to the existing low flow channel. Flow in the new channel would occur for limited period of time during or immediately following a storm event. The affect to water quality is expected to be temporary and minimal.

5.4 Threatened and Endangered Species

Special status species include plants and wildlife that, because of their scarcity or documented declining population in the state have been placed on lists of endangered, threatened, proposed, candidate or otherwise sensitive status. The McMicken Dam project is located within the Agua Fria watershed (ID #15070102) in Maricopa County. According to the Arizona Department of Game and Fish Heritage Data Management System, three special status bird species, three special status mammal species, three special status plant species, two special status reptile species, and one special status fish species occur in this watershed, as listed in the table below. The special status fish, the Sonora sucker, is of no concern because there are no perennial streams or lakes in the McMicken Dam project.

Special Status Species that may exist in the McMicken Dam Project Area

Species	Common Name	Latin Name
Bird	Western burrowing owl	*Athene cunicularia hypugaea*
Bird	Black-bellied whistling duck	*Dendrocygna autumnalis*
Bird	Bald eagle	*Haliaeetus leucocephalus*
Mammal	Greater western mastiff bat	*Eumops perotis californicus*
Mammal	Cave myotis	*Myotis velifer*
Mammal	Pocketed free-tailed bat	*Nyctinomops femorosaccus*
Plant	Arizona agave	*Agave arizonica*
Plant	Toumey agave	*Agave toumeyana var bella*
Plant	Yellow spine prickly pear	*Opuntia phaeacantha var flavispina*
Reptile	Sonoran desert tortoise	*Gopherus agassizii*
Reptile	Mexican garter snake	*Thamnophis eques megalops*

It is not expected that the special status species are present at the locations of the alternatives, all of which are within an area of limited acreage. However, it will be necessary to survey the preferred alternative project area to assess it for presence of any of the other special status species and/or their habitat. If encountered, a mitigation plan for the preferred alternative will need to be developed that includes local access/haul routes during construction, the area where new structures will be constructed and areas from where any on-site construction materials are borrowed.

5.5 Traffic/Transportation

Once constructed, the alternatives would not have an adverse impact on local traffic and transportation patterns. During construction, the impact would be temporal and very minor, particularly since it is presently anticipated to borrow the vast majority of the required construction materials (embankment fill, aggregate for roller compacted concrete and soil for soil cement) from on-site sources adjacent to the dam.

Offsite access to construction areas will be from either Olive Avenue or Greenway Road. The District does not have a dedicated right-of-way access from Olive Avenue, although there is a well-established unpaved road to the southern end of McMicken Dam from Olive Avenue. Olive Avenue is the road to White Tanks Regional Park, and use of it for access to McMicken Dam could require traversing State lands. There is a District gated access to McMicken Dam on Greenway Road, however, this road is located about 3 to 4 miles north of where it is anticipated most construction activities will occur.

5.6 Historic Properties (Cultural Resources)

According to the AZSITE database for the state of Arizona, there has been one relevant cultural resource survey conducted adjacent to the general McMicken Dam project area. The survey was conducted in January and February of the year 2000 and covered 3,343 acres west of the dam (Potter and Garrotto, 2000). Of particular interest is the result that a number of significant sites were discovered directly west of the southern end of the dam on state land. However, it is presently planned to site all of the alternatives within the District right-of-way and not on state land. In addition, the surveyors evidently extended beyond their project area, as several sites were recorded as being within the Trilby Wash Basin on District property. Once the preferred alternative is selected, it will be necessary to conduct a 100 percent pedestrian survey of the area of potential effect, including local access/haul routes during construction, the areas where new structures will be constructed and areas from where any on-site construction materials are borrowed. If any potentially significant cultural resources can be located, a treatment plan developed for their mitigation will be developed.

5.7 Prime and Unique Farmland

Information on the soil characteristics was obtained from the Soil Survey of Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona (NRCS, 1986) and the Soil Survey of Maricopa County, Arizona, Central Part (NRCS, 1977). According to those soil surveys, within the areas adjacent to McMicken Dam where the proposed alternatives would be located, the soil texture can be generally characterized as a loam or a sandy loam. This combination of soil types is generally considered by NRCS to be prime farmland when irrigated or when adequate water supply is available. However, the alternatives will be located on District property and would not traverse or affect any areas of prime and unique farmland

5.8 Waters of the U.S. (Section 404 Impacts)

Since remediation alternatives are concerned ultimately with preventing or controlling the flow of surface runoff into, through and beneath McMicken Dam via existing and potential earth fissures, it is highly likely that there will be impacts to jurisdictional waters of the U.S. within and adjacent to the portions of McMicken Dam subject to remediation activities. The Trilby Wash Basin, an impoundment created by McMicken Dam to control surface water runoff emanating from the White Tank Mountains to the west is likely to be jurisdictional waters of the U.S. Any activities requiring discharge of dredge or fill within Trilby Wash Basin or its tributaries probably will require a Clean Water Act (CWA) Section 404 Permit from the USACOE. Actions requiring discharge of dredge or fill within washes down-gradient from McMicken Dam and cut-off in the upstream direction by the dam, such as borrow areas for construction materials or new structures, may not require a CWA Section 404 Permit, depending upon the results of jurisdictional delineation. Generally, the dam rehabilitation alternatives will have less of an impact on waters of the U.S. than the dam abandonment and dam isolation alternatives because they will be constructed adjacent to the existing dam. However, the borrow area or areas that will be required for any of the alternatives involving new structures may have a larger impact than the new structures, depending on the quantity of borrow material required.

6.0 HYDROLOGIC ANALYSIS

6.1 Watershed

The McMicken Dam total watershed area is approximately 259 square miles in size. Hydrologic analyses of the watershed were conducted by the USACOE in 1953; Sergent, Hauskins and Beckwith (SH&B) in 1983; and the District in 1987, with an update in 1996. The inflow hydrograph to the dam developed by the UASCOE was based on their Standard Project Storm (SPS). The inflow hydrograph to the dam developed by SH&B and the District was based on the Probable Maximum Precipitation (PMP). The PMP was estimated by the District using the procedures presented in Hydrometeorological Report No. 49, herein referred to as HMR-49 (Hansen and Others, 1984). The resulting PMP for the 72-hour general storm was determined to be 15.7 inches.

The portion of the total watershed area contributing runoff directly to the fissure risk zone of the dam south of about Station 110+00 is approximately 9 square miles in size. Hydrologic analyses were conducted for that portion of the total watershed in accordance with the methodologies presented in the Flood Control District of Maricopa County Drainage Design Manual (FCDMC, 1995), herein referred to as the Hydrology Manual. Watershed modeling was conducted for the 100-, 200- and 500-year, 6-hour storm event as well as for the PMF using the USACOE HEC-1 computer program, version 4.1. Inflow hydrographs were estimated for the purpose of evaluating three alternatives. The alternatives are focused on the high hazard fissure risk zone, approximately from Stations 56+00 to 75+00.

6.2 Hydrologic Parameters

6.2.1 General

The physiographic characteristics of the fissure zone watershed are highly varied. The majority of this area lies within the White Tank Mountain County Regional Park. The terrain in that portion of the watershed is steep and rugged with elevations ranging from 1,600 to over 4,000 feet. The watercourses are generally steep and well defined and flow from west to east in long narrow valleys. Near the park boundary, the terrain changes abruptly to a relatively steep piedmont terrace with a distributary network of channels.

6.2.2 Watershed Delineation

Watershed delineation was performed using USGS 7.5-Minute Series Quadrangle Maps. On the piedmont terrace, circa 2002 aerial photography was used to supplement the topographic maps in areas lacking sufficient detail for watershed delineation. Because of the nature of distributary areas, there is generally some degree of uncertainty associated with the watershed delineation. For the purposes of this analysis, it was assumed that the watershed delineation is appropriate for all return periods, including the PMF. The fissure zone watershed was subdivided into three subbasins as shown on Sheet 2. Subbasin 1A corresponds to the area contributing runoff directly to the high hazard zone and is approximately 0.56 square miles in size. Subbasins 2A and 2B lie within the moderate and low hazard zones and are approximately 6.2 and 2.1 square miles in size, respectively.

6.2.3 Rainfall Statistics

Rainfall statistics for the fissure zone watershed for the 100-, 200- and 500-year return periods were obtained from the NOAA Atlas 2, Arizona (NOAA, 1973). The statistics from the NOAA Atlas were analyzed to develop the rainfall depth-duration-frequency table using the PREFRE computer program. The point rainfall depth for the 200-year return period is estimated graphically by plotting the point rainfall depths for the 25-, 50-, 100- and 500-year return periods on probability graph paper. The 6-hour rainfall depths for the 100-, 200- and 500-year, 6-hour storms are 3.34, 3.43 and 4.16 inches, respectively. The Maricopa County 6-hour local storm rainfall distribution consists of five dimensionless storm patterns that are a function of watershed area. The rainfall distribution used for this analysis was interpolated from those patterns based on the total watershed area of approximately 9 square miles. The 6-hour point rainfall depths for each return period are areally averaged over the watershed area using the depth area reduction factors presented in the Hydrology Manual.

The 6-hour local storm PMP is the critical storm for the fissure zone watershed and is estimated using the procedures presented in HMR-49. The rainfall distribution is determined using the criteria in Table 4.7 of HMR-49. The 6-hour local storm PMP is 12.9 inches. The rainfall intensity for the 15 minutes of maximum rainfall is 25.6 inches per hour.

6.2.4 Rainfall Losses

Under present conditions the watershed is completely undeveloped. Rainfall losses were, therefore, based only on the soil characteristics within the watershed. Information on the soil characteristics was obtained from the Soil Survey of Aguila-Carefree Area, Parts of Maricopa and Pinal Counties, Arizona (NRCS, 1986) and the Soil Survey of Maricopa County, Arizona, Central Part (NRCS, 1977). According to those soil surveys, there are two basic soil textures present in the watershed. In the upper portion of the watershed, within the park boundary, the soil texture can be generally characterized as a very gravelly loam with areas of rock outcrop. In the lower portion of the watershed, the soil texture can be generally characterized as a sandy clay loam. A map of the soils as they occur within the watershed is shown in Figure 13.

Rainfall losses were estimated using the Initial Loss plus Uniform Loss Rate method with additional consideration for impervious area due to naturally occurring rock outcrop. An initial loss of 0.95 inches is used for all subbasins within the watershed. This value was estimated by the USACOE as an average value for the entire McMicken Dam watershed. Although the fissure zone watershed comprises only a small portion of the overall watershed, this value is considered appropriate given the general similarities of the fissure zone watershed to the overall watershed. Values for the Uniform Loss Rate parameter were estimated by areally averaging the hydraulic conductivity (XKSAT) for each soil map unit within the watershed. Values of XKSAT for each soil map unit are provided in the Hydrology Manual. Adjustments to the subbasin average value of XKSAT for vegetative cover were not considered in this analysis. Impervious percentages for each subbasin were estimated by areally averaging the percentage of naturally occurring rock outcrop associated with each soil map unit present in the watershed. The rainfall loss parameters for each subbasin are listed in Table 4.

6.2.5 Unit Hydrograph

Rainfall excess is routed using the S-graph method. Two S-graphs were used for this analysis. The Desert/Rangeland S-graph was used for subbasin 1A and the Phoenix Mountain S-graph was used for subbasins 2A and 2B. Application of the S-graph requires the estimation of the basin lag. The basin lag is a function of the flow path length, the flow path length from the point opposite to the basin centroid, the slope of the flow path and a coefficient representing the hydraulic efficiency (K_n) of the watershed. The flow path for each subbasin is shown on Sheet 2. The flow path length and slope for each subbasin were estimated using the USGS topographic maps. Guidance for selection of the value for K_n is provided in the Hydrology Manual. The basin lag for each subbasin along with the physical parameters, are listed in Table 5.

6.3 Results

Peak discharges and runoff volumes were computed for the 100-, 200- and 500-year storm and the PMF for each subbasin as well as for the combined area. Those results are listed in Table 6. The peak discharge for the PMF for the fissure zone watershed is 28,300 cfs with a volume of 5,200 acre-feet. The PMF inflow estimated by the District for approximately the same area (subbasin 44) is 5,800 cfs (volume was not provided). Comparisons of these results are not meaningful from a verification perspective because of the differences in the PMP. The District used the 72-hour general storm. Use of the 72-hour general storm is appropriate for modeling of the entire watershed area. However, given the nature of the dam and the differences in magnitude of the PMF inflow for the 6- and 72-hour storms, certain areas of the dam may be more sensitive to the 6-hour local storm. The inflow (peak and volume) for the 6-hour storm is higher than for the 72-hour storm. For example, if a dike were constructed isolating the high hazard fissure risk zone from the rest of the dam, the PMF inflow (330 acre-feet) would result in a maximum stage of approximately 1,357 feet assuming no release of inflow. The stage-storage relation for this condition is provided in Table 7. Similarly, if a dike were constructed isolating the entire fissure zone area from the rest of the dam, the existing storage volume to the top of the earthen embankment (elevation 1,361) is approximately 1,600 acre-feet compared to the PMF inflow of 5,200 acre-feet. The stage-storage relation for this condition is provided in Table 8.

6.4 Alternatives

Watershed hydrology is a significant issue for three alternatives, including upstream diversion, dam segmentation and segmentation with basin containment. For the purposes of this task, the investigation of those alternatives was focused on the high hazard fissure risk zone.

The upstream diversion alternative involves the construction of an extension to the existing embankment at a location just outside of the high hazard fissure risk zone (approximately station 75+00). It also includes the construction of a diversion channel that would intercept runoff from subbasin 1A and divert it to the main impoundment area north of the dam extension. The potential alignments of these features are shown on Sheet 2. The dam extension would be constructed to the full height of the existing dam, approximately elevation 1,363 feet. The diversion of the 100-year peak discharge would require a channel of approximately 20 feet in width flowing at a depth of 3 feet, assuming that the channel is fully lined.

The dam segmentation alternative involves the construction of an extension to the existing embankment to just outside of the high hazard fissure risk zone. It also includes construction of a dike within the low hazard fissure risk zone. The alignments of those features are shown on Sheet 2. The dam extension would be constructed to the full height of the existing dam, approximately elevation 1,363. The location of the segmentation dike shown on Sheet 2 is such that approximately half of the PMF inflow volume would be stored in each segment. The maximum stage would be to an elevation of approximately 1,357 feet.

The dam segmentation with basin containment alternative is similar to the dam segmentation except that the existing dam through the high hazard fissure risk zone would be removed or reconstructed to the point that it was no longer a jurisdictional structure. The design event for that alternative could be something less than the PMF. Inspection of the detailed topography shown on Sheet 2 indicates that the existing low flow channel located within the impoundment area has the potential to store nearly all of the 100-year inflow. Minimal additional excavation or berm construction would be required to store the 500-year runoff volume. The maximum stage for that alternative would be approximately elevation 1,350 feet with no additional excavation.

6.5 Implications to Alternatives

6.5.1 Probable Maximum Flood (PMF)

While the contributing watershed area to the fissure risk zone is quite small in relation to that for the entire dam, peak flows are relatively high. Due to the elusive nature of the floodplain, it is possible that during a PMF runoff event, adjoining drainage areas could break out and drain into the fissure risk zone. Due to the high peak flows, an upstream diversion channel, if designed to convey the PMF, would be very large to contain the peak flows and potential breakout flows.

Dam extension and diversion alternatives that are south of approximately Station 75+00 have the smallest contributing watershed and corresponding lower costs. However, by locating the dam extension and diversion farther north to protect the entire fissure risk zone, the resulting watershed area is much greater and the project costs will be appreciably larger.

6.5.2 Less Than PMF

Peak discharges and runoff volumes for 100- to 500-year events are approximately 16 to 23 percent of the PMF. Diversion or storage basin alternatives designed for these more frequent events will be much less costly than those designed for the PMF criteria. While diversion and storage basin alternatives do not provide the same level of flood protection as the dam, they provide as much or more than the regulatory requirement for flood control. The minimum requirement is 100-year flood protection. In order to avoid impacts on existing 100-year flood control facilities and FEMA floodplains downstream of the dam, it is recommended that alternatives be evaluated for no less than 100-year protection. Hydrologic analysis shows that 200- and 500-year peak flows and runoff volumes are not appreciably greater than the 100-year values.

It is clear that alternatives designed for 100- to 500-year floods, such as a diversion channel or a storage basin, should not consider the PMF as a contributing factor for the risk assessment. To reduce the risk of failure associated with those types of alternatives, it is recommended that the height of embankments(s) be lower than 6 feet. Sufficient freeboard should be provided to account for increases in runoff due to potential future upstream development and to account for possible sedimentation.

With the existing low flow channel along the upstream side of the dam, it may not be necessary to divert any water or to require storage above natural ground. The existing channel south of station 75+00 has sufficient volume to retain all of the runoff from the 100-year precipitation from the 0.56 square mile watershed.

7.0 SCREENING PROCESS AND ALTERNATIVE RANKINGS

The evaluation matrix presented in Table 9 was developed as the platform for the initial screening and the system alternative analysis. With the exception of the first two alternatives listed in Table 2, each of the alternatives is listed on the ordinates of the matrices. Alternative 1 (No Action) and Alternative 2 (Monitor Only) were not further considered in the screening process because they do not meet the primary criteria of reducing the risk associated with the fissure hazard. Each of the groups of evaluation criteria is listed on the abscissas of the matrices. As directed by the District, the screening process was completed with the basic premise that only the high hazard zone between Stations 56+00 and 75+00 would be mitigated.

A numerical rating system (1 through 5) was used, with the number 3 indicating the alternative generally was neutral with respect to that evaluation criterion, or to the other alternatives. A numerical rating of 4 indicates the alternative is somewhat favorable or somewhat better than the other alternatives. A numerical rating of 5 indicates the alternative is very favorable or much better than the other alternatives. Similarly, a numerical rating of 2 indicates the alternative is somewhat unfavorable or less preferred than the other alternatives, and a numerical rating of 1 indicates the alternative is very unfavorable or much less preferred. For each alternative, the scores within an evaluation criteria group are summed, normalized by the number of individual criteria within the group, and the score calculated as the product of the weighting factor for that evaluation criteria group and the normalized rating.

Ratings for each alternative for the various evaluation criteria were discussed and assigned by the AMEC project team during a meeting with representatives of the District and ADWR. Brief discussions of the ratings assigned are provided in the following paragraphs.

7.1 Performance Criteria

Generally, rehabilitation alternatives involving construction of new structures, and isolation and abandonment alternatives, are considered more favorable than the other rehabilitation alternatives (3J through 3N) since they provide a greater degree of protection (ratings of 4 and 5). Alternatives 3L through 3M are considered to not adequately protect against foundation settlement or future subsidence and earth fissuring, and are assigned a rating of 1 for these categories. Also, their performance would be difficult to monitor (rating of 1), they offer little redundancy (rating of 2) and they would be difficult to repair (rating of 2). Rehabilitation alternatives involving construction of new structures are considered to offer the largest redundancy in design (rating of 5). However, they also are considered to have a larger potential for being affected by future subsidence (neutral rating of 3) than most of the abandonment and isolation alternatives.

7.2 Failure Consequences

Concerning failure consequences, almost all of the alternatives are ranked similarly. The RCC and soil cement structure alternatives are ranked higher than the other rehabilitation alternatives because failure of these types of structures (piping failure without embankment breach) likely would involve only a small section of the structure, limiting the flood flows downstream. Isolation alternatives also ranked somewhat higher, primarily because the inflow to the southern end of the dam is significantly reduced and the freeboard is increased.

7.3 Time and Schedule

Rehabilitation alternatives generally ranked higher (neutral to favorable ratings of 3 and 4) than isolation or abandonment alternatives (somewhat unfavorable to neutral ratings of 2 and 3) because it is considered they could be constructed as quickly but likely would require less time to permit or to provide for mitigation. It is considered that Alternatives 3L through 3N likely can be constructed more quickly than Alternatives 3A through 3K, thus, the higher rating for these alternatives.

7.4 Capital Cost

There is a large variation in the capital cost ratings assigned to the alternatives. It is considered that RCC and soil cement structures would have a much higher cost and they are assigned the lowest rating of 1. New earthen embankments (Alternatives 3A and 3B, and Alternative 5A, the isolation alternative with multiple segments requiring two or more dikes) are considered to be the least expensive and they are assigned a favorable rating of 4. Alternatives 3L through 3M, which would require grouting or a similar treatment, are considered moderately expensive (rating of 2), but less expensive than the other rehabilitation alternatives. The capital cost for the other alternatives are considered to be somewhat higher (rating of 3) than constructing new earthen embankments.

7.5 Other Costs

In general, there are only small differences in the other costs ratings of the alternatives. The RCC and soil cement rehabilitation alternatives (rating of 4) are considered to require less maintenance than the other alternatives, particularly Alternatives 3J through 3L. However, Alternatives 3J through 3N are considered to require less mitigation cost (rating of 4) than the other alternatives. The two abandonment alternatives are considered to have the highest mitigation cost (rating of 4) and the three isolation alternatives are considered to have the highest right-of-way costs (rating of 2) because of the possible need for a downstream outfall channel.

7.6 Environmental Considerations

As discussed in Section 5, generally, alternatives involving construction at or near the existing McMicken Dam will have little if any impact on historic properties or waters of the U.S. and, thus, are assigned a neutral score of 3. Alternatives involving construction upstream of the existing dam, because of potential impacts to waters of the U.S., were assigned a lower rating of 2. The other potential environmental impacts discussed in Section 5 are similar for each of the alternatives.

7.7 Accommodation Capability

For this category it was assumed that future plans for McMicken Dam could include construction of an upstream channel along the length of the structure or raising the dam, and ratings were assigned based on how readily the alternative could be accommodated in either of these broad plans. The abandonment alternatives are assigned a favorable rating of 4 since both the dam and the diversion could be accommodated by either broad plan. The rehabilitation alternatives are assigned a lower rating of 2 because they are not readily accommodated by a channel plan. The isolation alternatives are assigned a neutral rating of 3.

7.8 Aesthetics

With the exception of Alternatives 5B, 5C and 3L through 3N, all alternatives were assigned a somewhat unfavorable rating of 2 since they increase the size of the existing structure. Alternatives 3L through 3N are neutral since the new construction associated with the alternatives will not be observable. Alternative 5B and to a greater extent Alternative 5C, are assigned ratings of 3 and 4, respectively, because they could result in lessening the height of or removing a section of the existing McMicken Dam.

8.0 INITIAL SCREENING

Representatives of the District, AMEC, Stantec and ADWR met on 7 January 2003 to review a draft of the initial screening of the alternatives presented in Table 9 and to discuss the results of the hydrological analyses presented in Section 5. The District established that the next level of screening and alternative analysis would consider protection of only the high hazard fissure risk zone, with consideration of expanding to include the moderate hazard fissure risk zone, and with a monitoring program to be developed for the moderate hazard fissure risk zone as part of final design. Further, the project team agreed that the isolation and abandonment alternatives provided the opportunity to develop protection for only the 500-year event, since the watershed above the high hazard fissure risk zone and the section of the dam south of this zone is relatively small. Flows from this storm event could be detained or possibly channeled downstream of the dam. The District established the criteria that the flood protection to be provided by these alternatives, at a minimum, would be the 500-year event, and would approach the ½ PMF event. Further analysis of the rehabilitation alternatives will necessarily provide protection for the presently defined PMF event --- that is, the analyses will consider rehabilitation to be consistent with the present crest elevation of the existing McMicken Dam.

Based on these criteria and the rankings of the alternatives, as presented in Table 10, the following alternatives were selected for additional analysis:

- Abandonment Alternative 4B, diversion structure located upstream of the existing dam, but within the District right of way (ranking of 1). Additional analyses of this alternative will also consider flows from both the 500-year and PMF events.

- Isolation Alternative 5C, dam extension and segmentation with modification of existing dam and possible basin containment (ranking of 2). Additional analyses of this alternative will also consider flows from both the 500-year and PMF events, and the option of basin containment and downstream channels.

- Rehabilitation Alternatives 3B and 3A (rankings 3 and 4, respectively), new embankment dam located either upstream or downstream of the existing structure, provided there is sufficient District right-of-way downstream to construct the new dam, and allow for the maintenance road. Analysis will consider either the upstream or the downstream location, but not both.

- Rehabilitation Alternatives 3E and 3D (rankings 6 and 8, respectively), RCC structure located either upstream or downstream of the existing dam, provided there is sufficient District right-of-way downstream to construct the new RCC structure, and allow for the maintenance road. Analysis will consider either the upstream or the downstream location, but not both.

- Rehabilitation Alternatives 3H and 3G (rankings of 6 and 8, respectively, also), soil cement structure located either upstream or downstream, provided there is sufficient District right-of-way downstream to construct the new dam, and allow for the maintenance road. Analysis will consider either the upstream or the downstream location, but not both.

- Isolation Alternative 5B, dam extension and segmentation with limited rehabilitation of the existing dam (ranking of 10). Additional analyses of this alternative will also consider flows from both the 500-year and PMF events, and the option of basin containment and downstream channels.

- Abandonment Alternative 4A, dam extension located upstream of the existing dam but within the District right-of-way (ranking of 11).

Thus, of the eleven highest ranked alternatives listed in Table 10, ten were selected. The only alternative not selected for further analysis is isolation Alternative 5A, dam extension with multiple segments and no rehabilitation of existing dam (ranking of 5). It was decided that this alternative incorporates minor variations of Alternatives 5B and 5C, and that analysis of the other alternatives for both the 500-year and PMF events provides essentially the same benefits.

The additional analyses of the selected alternatives will include developing preliminary designs and comparative cost estimates for design and construction. Additional hydrologic analyses of the abandonment and isolation alternatives will be completed to size the required new construction, including diversion channels or structures, basins and dam extensions.

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FIGURES

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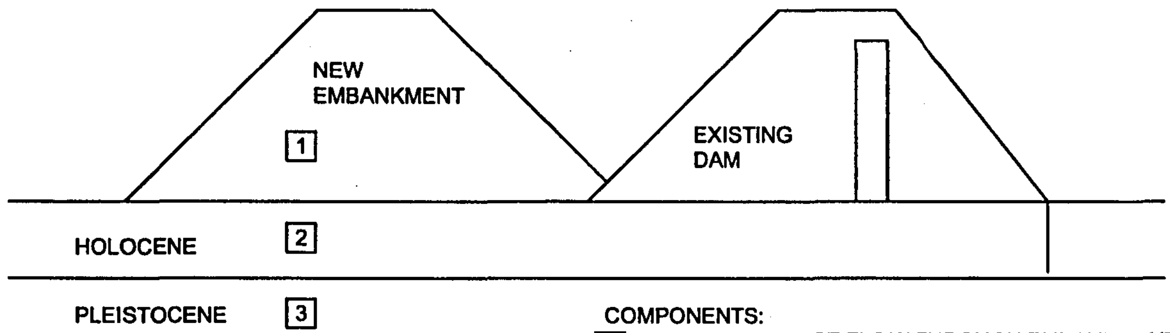

NOTE: NEW EMBANKMENT COULD BE CONSTRUCTED UPSTREAM OR DOWNSTREAM.

COMPONENTS:

1. PROTECT AGAINST FLOW THROUGH EMBANKMENT
2. PREVENT HOLOCENE SOILS FROM AFFECTING EMBANKMENT
3. PROVIDE CUTOFF IN PLEISTOCENE SOILS AND UNCEMENTED SANDS AND GRAVEL

JOB NO.	2-117-001066
DESIGN:	LH
DRAWN:	KAS
DATE:	12/2002
SCALE:	NOT TO SCALE

SYSTEM ALTERNATIVES 3A AND 3B
NEW EARTHEN EMBANKMENT

MCMICKEN DAM FRZR PROJECT
CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1

FIGURE 1

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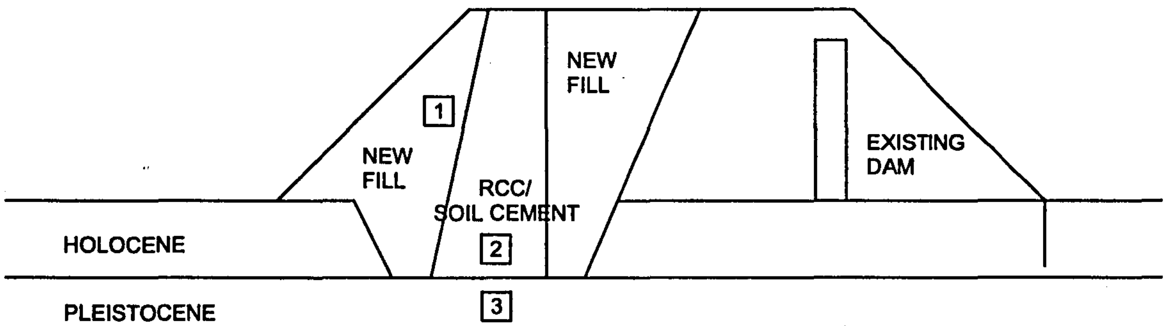

COMPONENTS:

1 PROTECT AGAINST FLOW THROUGH EMBANKMENT

2 PREVENT HOLOCENE SOILS FROM AFFECTING EMBANKMENT

3 PROVIDE CUTOFF IN PLEISTOCENE SOILS AND UNCEMENTED SANDS AND GRAVEL

JOB NO. 2-117-001066	SYSTEM ALTERNATIVES 3D AND 3G UPSTREAM RCC OR SOIL CEMENT STRUCTURE	amec
DESIGN: LH		
DRAWN: KAS		
DATE: 12/2002	MCMICKEN DAM FRZR PROJECT CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1	FIGURE 2
SCALE: NOT TO SCALE		

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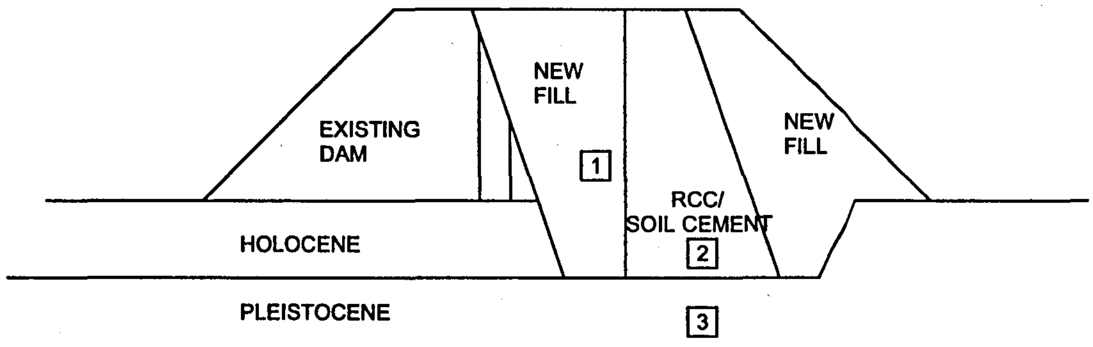

COMPONENTS:

1. PROTECT AGAINST FLOW THROUGH EMBANKMENT
2. PREVENT HOLOCENE SOILS FROM AFFECTING EMBANKMENT
3. PROVIDE CUTOFF IN PLEISTOCENE SOILS AND UNCEMENTED SANDS AND GRAVEL

JOB NO. 2-117-001066 DESIGN: LH DRAWN: KAS DATE: 12/2002 SCALE: NOT TO SCALE	SYSTEM ALTERNATIVES 3E AND 3H DOWNSTREAM RCC OR SOIL CEMENT STRUCTURE MCMICKEN DAM FRZR PROJECT CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1	FIGURE 3 amec

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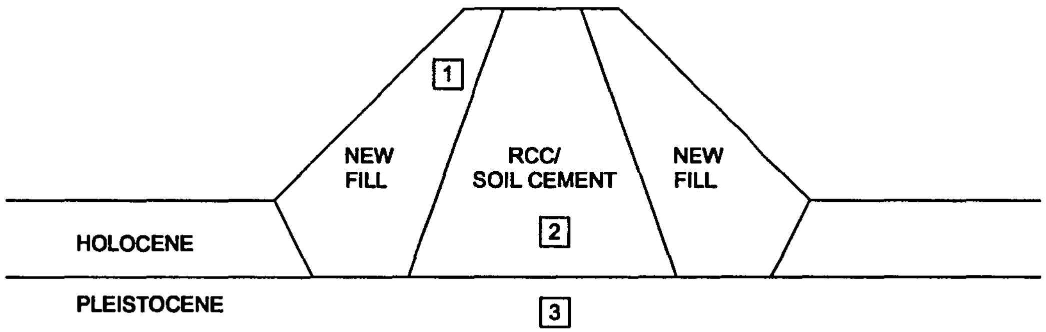

COMPONENTS:

1. PROTECT AGAINST FLOW THROUGH EMBANKMENT
2. PREVENT HOLOCENE SOILS FROM AFFECTING EMBANKMENT
3. PROVIDE CUTOFF IN PLEISTOCENE SOILS AND UNCEMENTED SANDS AND GRAVEL

JOB NO.	2-117-001066
DESIGN:	LH
DRAWN:	KAS
DATE:	12/2002
SCALE:	NOT TO SCALE

SYSTEM ALTERNATIVES 3F AND 3I
RCC OR SOIL CEMENT AT EXISTING DAM LOCATION

MCMICKEN DAM FRZR PROJECT
CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1

FIGURE 4

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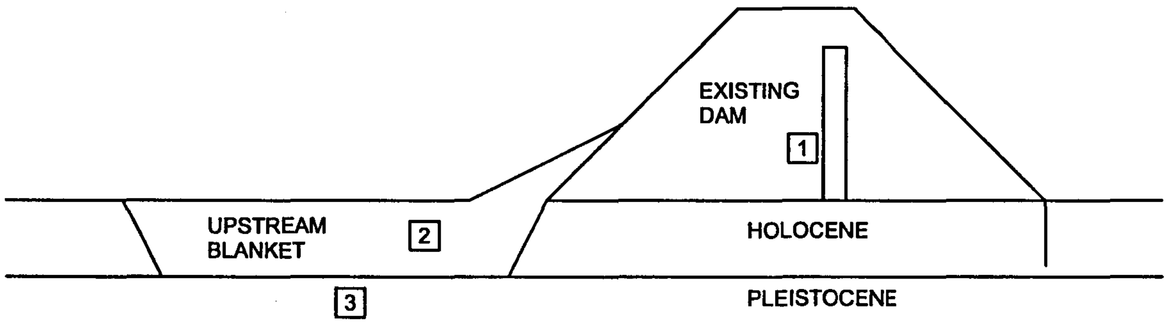

COMPONENTS:

1 PROTECT AGAINST FLOW THROUGH EMBANKMENT

2 PREVENT HOLOCENE SOILS FROM AFFECTING EMBANKMENT

3 PROVIDE CUTOFF IN PLEISTOCENE SOILS AND UNCEMENTED SANDS AND GRAVEL

JOB NO.	2-117-001066
DESIGN:	LH
DRAWN:	KAS
DATE:	12/2002
SCALE:	NOT TO SCALE

SYSTEM ALTERNATIVES 3J AND 3K
UPSTREAM BLANKET/CUTOFF

MCMICKEN DAM FRZR PROJECT
CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1

FIGURE 5

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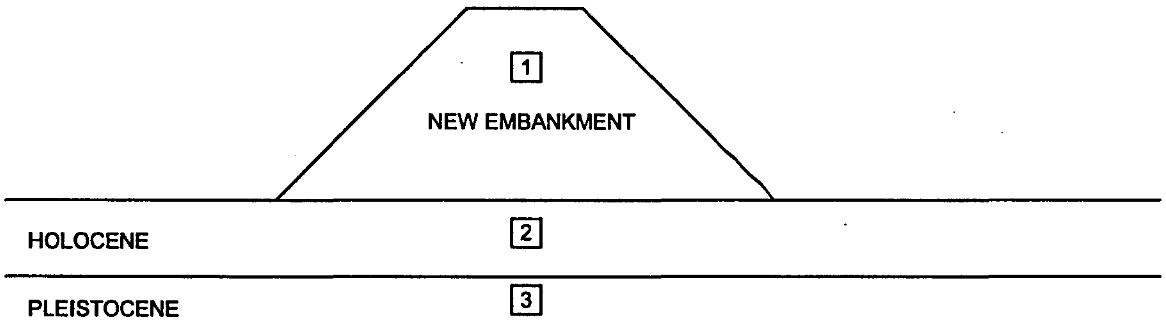

COMPONENTS:

1 PROTECT AGAINST FLOW THROUGH EMBANKMENT

2 PREVENT HOLOCENE SOILS FROM AFFECTING EMBANKMENT

3 PROVIDE CUTOFF IN PLEISTOCENE SOILS AND UNCEMENTED SANDS AND GRAVEL

JOB NO.	2-117-001066
DESIGN:	LH
DRAWN:	KAS
DATE:	12/2002
SCALE:	NOT TO SCALE

SYSTEM ALTERNATIVES 3C, 4A, 4B, 4C, 4D AND 5
NEW EARTHEN EMBANKMENT AT EXISTING DAM
LOCATION, NEW UPSTREAM DAM AND DAM EXTENSION

MCMICKEN DAM FRZR PROJECT
CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1

FIGURE 6

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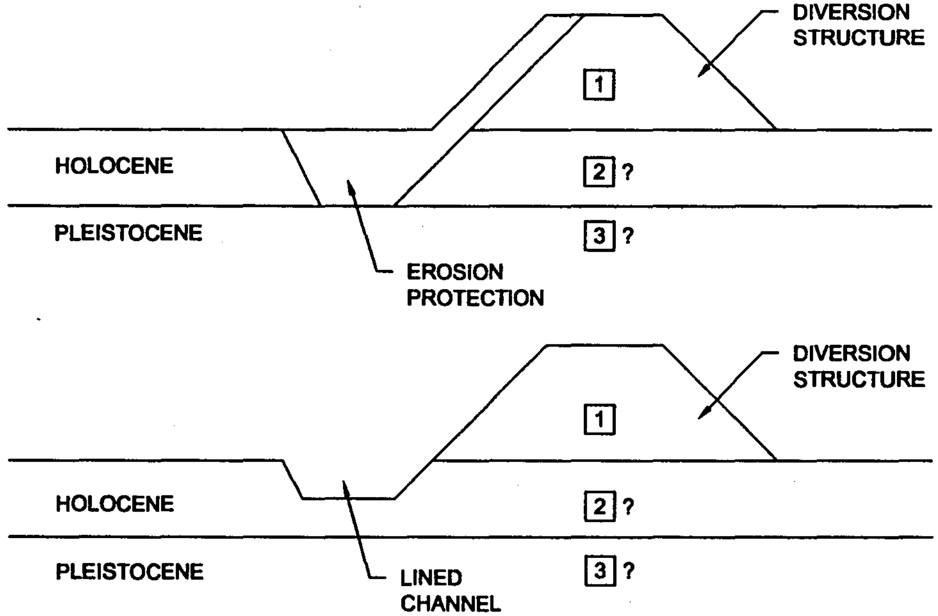

COMPONENTS:

1. PROTECT AGAINST FLOW THROUGH EMBANKMENT
2. PREVENT HOLOCENE SOILS FROM AFFECTING EMBANKMENT
3. PROVIDE CUTOFF IN PLEISTOCENE SOILS AND UNCEMENTED SANDS AND GRAVEL

JOB NO.	2-117-001066
DESIGN:	LH
DRAWN:	KAS
DATE:	12/2002
SCALE:	NOT TO SCALE

SYSTEM ALTERNATIVES 4C AND 4D
UPSTREAM DIVERSION

MCMICKEN DAM FRZR PROJECT
CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1

FIGURE
7

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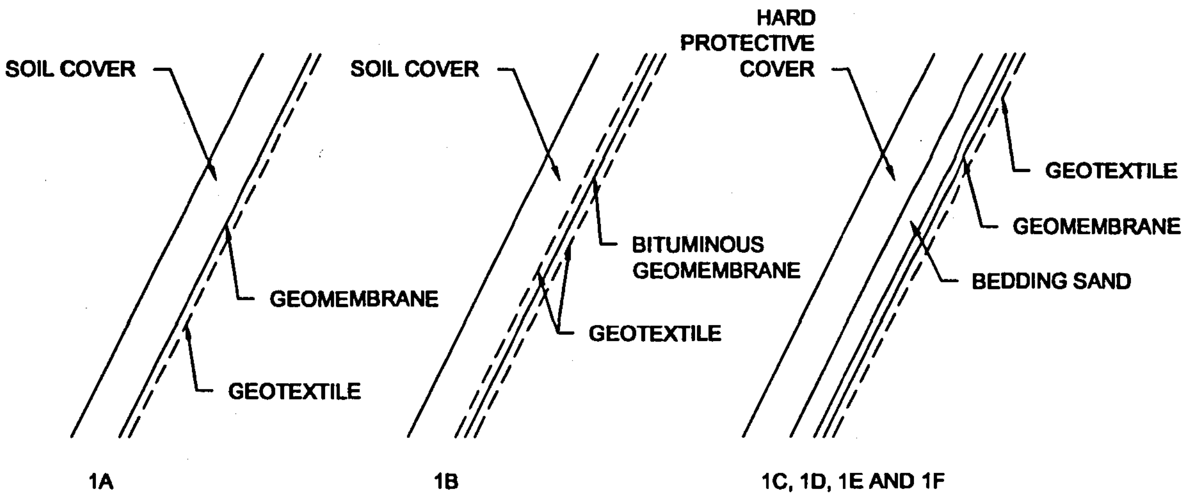

JOB NO. 2-117-001066 DESIGN: LH DRAWN: KAS DATE: 12/2002 SCALE: NOT TO SCALE	COMPONENT ALTERNATIVES 1A, 1B, 1C, 1D, 1E AND 1F BARRIERS TO FLOW THROUGH EMBANKMENT MCMICKEN DAM FRZR PROJECT CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1	FIGURE 8

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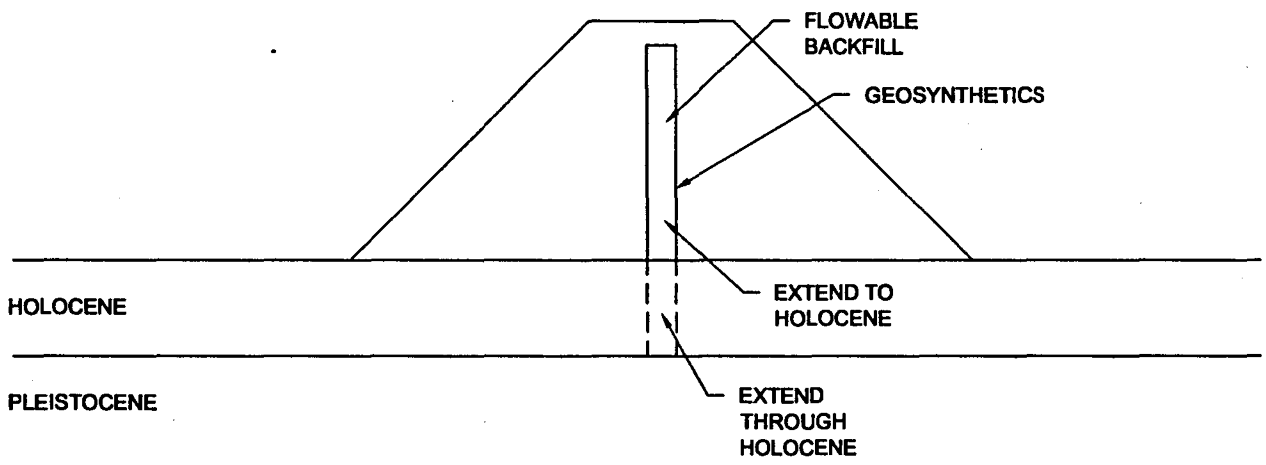

JOB NO. 2-117-001066 DESIGN: LH DRAWN: KAS DATE: 12/2002 SCALE: NOT TO SCALE	COMPONENT ALTERNATIVES 1G AND 2D CENTER CUTOFF BARRIER TO FLOW THROUGH EMBANKMENT OR THROUGH HOLOCENE SOILS MCMICKEN DAM FRZR PROJECT CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1	FIGURE 9

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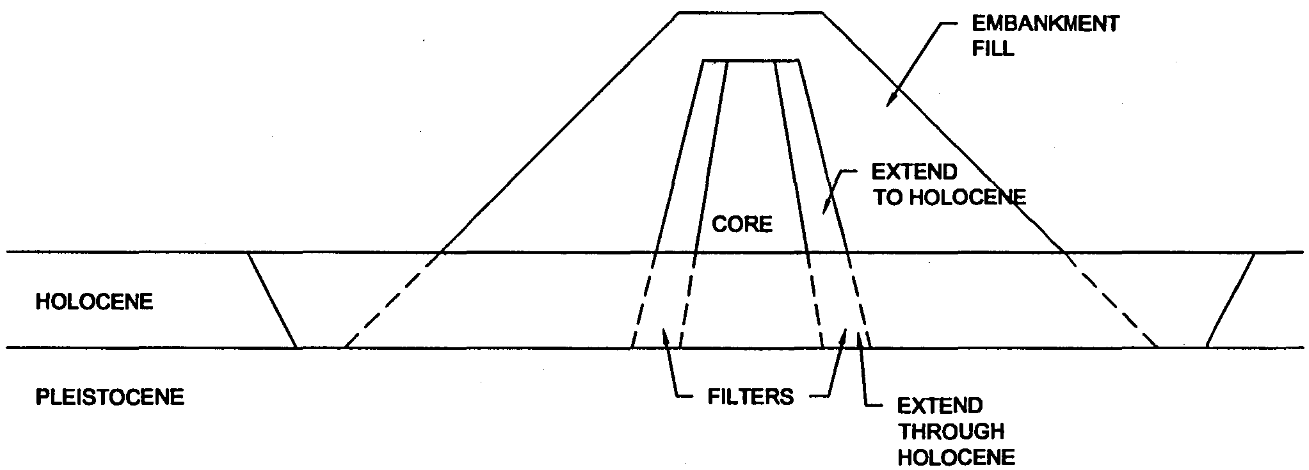
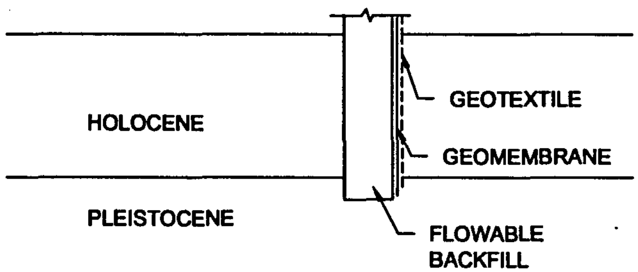
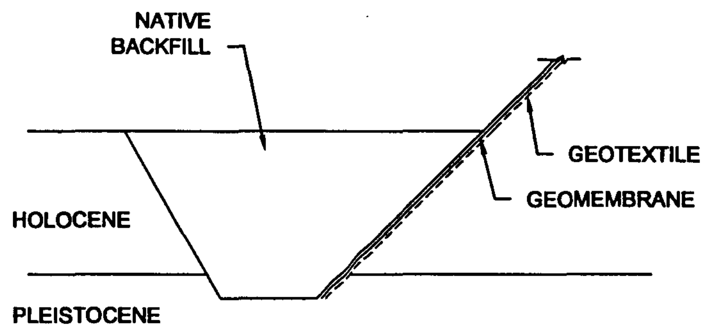


JOB NO. 2-117-001066 DESIGN: LH DRAWN: KAS DATE: 12/2002 SCALE: NOT TO SCALE	COMPONENT ALTERNATIVES 1H AND 2E ZONED EARTHEN EMBANKMENT BARRIER TO FLOW THROUGH EMBANKMENT OR THROUGH HOLOCENE SOILS MCMICKEN DAM FRZR PROJECT CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1	FIGURE 10 amec



TRENCH



TRAPEZOIDAL DITCH

JOB NO.	2-117-001066
DESIGN:	LH
DRAWN:	KAS
DATE:	12/2002
SCALE:	NOT TO SCALE

COMPONENT ALTERNATIVES 2A AND 2B
BARRIERS TO FLOW THROUGH HOLOCENE SOILS

MCMICKEN DAM FRZR PROJECT
CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1

FIGURE 11

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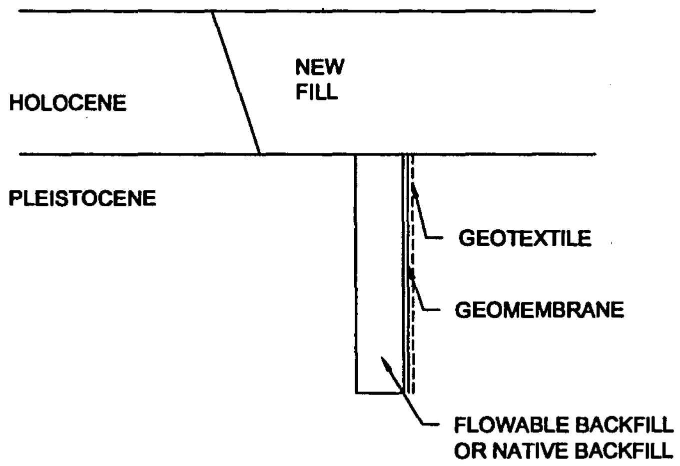


JOB NO. 2-117-001066 DESIGN: LH DRAWN: KAS DATE: 12/2002 SCALE: NOT TO SCALE	COMPONENT ALTERNATIVES 3A AND 3B PROTECT AGAINST EARTH FISSURE IN PLEISTOCENE SOILS MCMICKEN DAM FRZR PROJECT CONTRACT FCD 2002CO11, WORK ASSIGNMENT NO. 1	FIGURE 12 amec

Legend

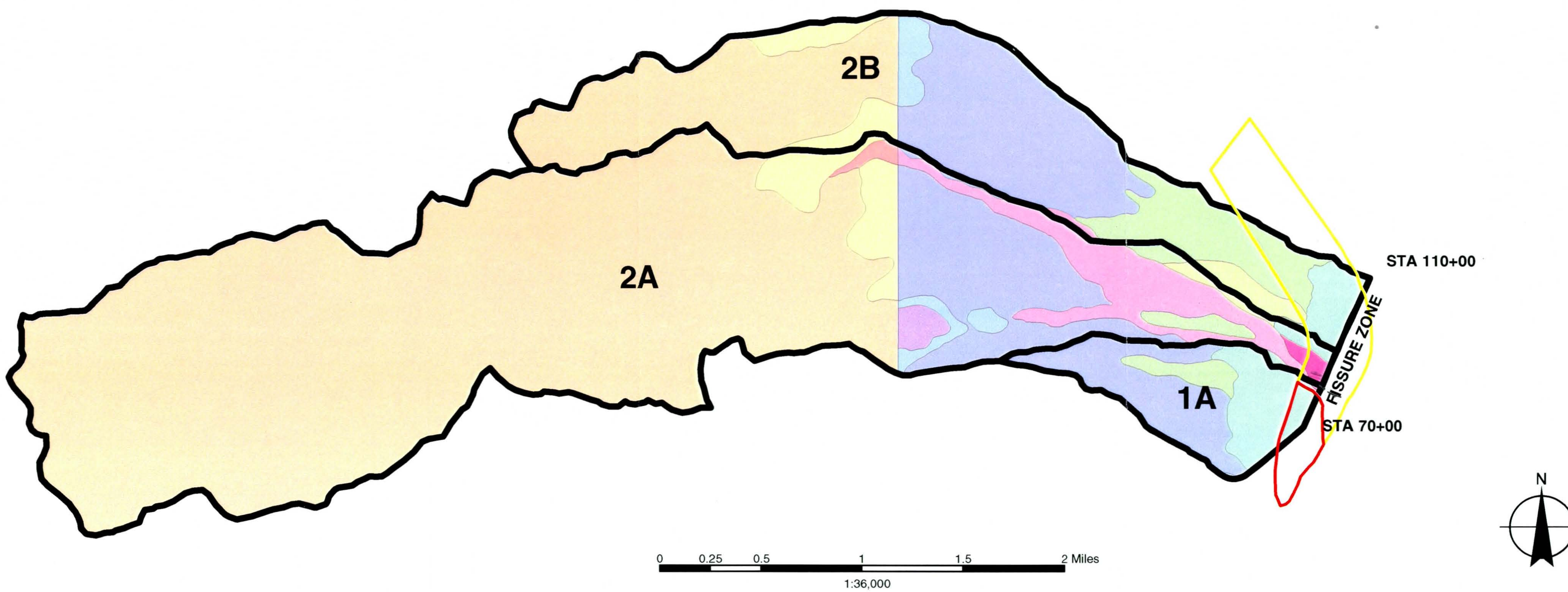
Subbasin

Fissure Risk

- High
- Moderate

Soil Types

- 10-Loamy Sand
- 100-Sandy Loam
- 48-Silty Clay
- AGB-Sandy Loam
- AHC-Sandy Loam
- AkB-Sandy Loam
- CO-Sandy Loam
- EPDSandy Clay Loam
- RS-Rock Outcrop
- TB-Sandy Loam
- Vr-Loam



JOB NO.:	2-117-001066
DESIGN:	MCG/LAH
DRAWN:	EMP
DATE:	12/20/02
SCALE:	1 " = 3,000 '

McMicken Dam Fissure Risk Zone Remediation Project
Contract FCD 2002C011
Maricopa County, Arizona

**ALTERNATIVES ANALYSIS, INITIAL SCREENING
SURFICIAL SOILS MAP**

FIGURE
13

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TABLES

TABLE 1
EVALUATION CRITERIA

1. Performance Criteria

Reduce the risk to the District/ protect the public
Degree to which it provides comparable flood protection
Protect against foundation settlement
Protect against embankment piping
Protect against erosion/piping of foundation soils
Potential for being affected by subsidence
Potential for being affected by future earth fissure development
Ease of repair
Redundancy
Ability to monitor

2. Failure Consequences

Life
Property
Facility damage
Environmental damage

3. Time and Schedule

4. Cost

Capital
Operations and maintenance
Mitigation costs
Right-of-way costs

5. Environmental Considerations

Air quality
Water quality
Wildlife habitat
Threatened and endangered species
Traffic/transportation
Historic properties (cultural resources)
Socioeconomic
Prime and unique farmland
Environmental justice
Cumulative impacts
Least environmentally damaging practical alternative (LEDPA)
Impacts to waters of the US

6. Land Use

Right-of-way impacts
Land acquisition requirements
Land use changes
Potential enhancements

7. Opportunities for Additional Benefits

Additional flood protection
Revegetation for mitigation
Revenue generation/Excess land to sell

8. Aesthetics

9. Capability of Being Accommodated in Future Plans

TABLE 2
LIST OF SYSTEM ALTERNATIVES

1. No Action

2. Monitor Only

3. Rehabilitation

3A. New Embankment – Upstream
3B. New Embankment – Downstream
3C. New Embankment – Present Location

3D. RCC Structure – Upstream
3E. RCC Structure – Downstream
3F. RCC Structure – Present Location

3G. Soil Cement Structure – Upstream
3H. Soil Cement Structure – Downstream
3I. Soil Cement Structure – Present Location

3J. Upstream Blanket – Native Soils
3K. Upstream Blanket – Reverse Filter (Imported Soils)

3L. Crack Filler
3M. Grout Curtain
3N. Grout/Treat the Holocene Soils

4. Abandonment

4A. Upstream Dam and Dam Extension Outside Fissure Zone
4B. Upstream Dam and Dam Extension Within Fissure Zone

4C. Upstream Diversion and Dam Extension Outside Fissure Zone
4D. Upstream Diversion and Dam Extension Within Fissure Zone

5. Segment the Dam

5A. Segment with No Rehabilitation of Existing Dam
5B. Segment with Rehabilitation of Existing Dam
5C. Segment with Removal of Existing Dam with Basin Containment

TABLE 3
LIST OF SYSTEM COMPONENT ALTERNATIVES

1. Barriers to Flow through Embankment

- 1A. Plastic geomembrane barrier with soil cover backfill
- 1B. Bituminous geomembrane with soil cover backfill
- 1C. Hard protective cover barrier (5" fiber reinforced concrete)
- 1D. Hard protective cover barrier (articulated pavement blocks)
- 1E. Hard protective cover barrier (soil cement)
- 1F. Hard protective cover barrier (RCC)
- 1G. Center cutoff extending to existing grade
- 1H. Zoned embankment extending to existing grade

2. Protection Against Erosion/Piping of Holocene Soils

- 2A. Plastic geomembrane with flowable backfill in trench
- 2B. Plastic geomembrane with native backfill in trapezoidal trench
- 2C. Remove Holocene soils
- 2D. Center cutoff extending to Pleistocene soils
- 2E. Zoned embankment extending to Pleistocene soils

3. Protection Against Earth Fissure in Pleistocene Soils

- 3A. Plastic geomembrane with flowable backfill in trench
- 3B. Plastic geomembrane with native backfill in trapezoidal trench

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Table 4
Rainfall Loss Parameters For Each Subbasin

Subbasin ID	Basin Area sq. miles	Initial Loss inches	Uniform Loss Rate in/hr	RTIMP %
1A	0.560	0.95	0.18	0
2A	6.206	0.95	0.33	16
2B	2.129	0.95	0.23	8

Table 5
S-Graph Parameters For Each Subbasin

Subbasin ID	Basin Area sq. miles	Flow Path Length miles	Flow Path L_{ca} Miles	Flow Path Slope ft/mi	K_n inches	Lag hours
1A	0.56	1.60	0.78	94	0.025	0.28
2A	6.21	8.02	4.08	287	0.050	1.54
2B	2.13	5.22	1.46	288	0.050	0.89

Table 6
Summary Of Model Results

HEC-1	Basin	100-Year		200-Year		500-Year		PMF	
ID	Area sq. mi.	Q cfs	Volume af	Q cfs	Volume af	Q cfs	Volume af	Q cfs	Volume af
1A	0.56	770	50	800	60	1,000	80	6,100	330
2A	6.21	3,300	600	3,400	620	4,400	830	21,000	3,600
2B	2.13	1,600	210	1,700	220	2,200	290	10,400	1,300
FRZR-I	8.90	4,600	850	4,800	890	6,300	1,200	28,300	5,200

Table 7
Stage-Storage Relation For The Segmentation Of The "Red" Fissure Zone

Stage feet	Surface Area acres	Volume Incremental acre-ft	Volume Cumulative acre-ft
1346	5	0	0
1348	19	23	23
1350	26	45	67
1352	35	60	128
1354	41	76	203
1356	48	89	292
1358	78	124	417
1360	89	167	584
1362	101	190	774

Table 8
Stage-Storage Relation For The Segmentation Of The Entire Fissure Zone

Stage feet	Surface Area acres	Volume Incremental acre-ft	Volume Cumulative acre-ft
1342	4	0	0
1344	13	16	16
1346	22	35	50
1348	53	72	123
1350	71	123	245
1352	91	161	407
1354	107	198	604
1356	123	230	834
1358	143	266	1100
1360	164	306	1406
1362	186	350	1756

TABLE 9
ALTERNATIVE ANALYSIS -- UNRANKED SYSTEMS EVALUATION MATRIX

	Performance Criteria Weight = 100	Reduce Risk to District/Protect Public	Degree Which Provides Comparable Flood Protection	Protect Against Foundation Settlement	Protect Against Embankment Piping	Protect Against Erosion/Piping of Foundation Soils	Potential for Being Affected by Subsidence	Potential for Being Affected by Future Earth Fissures	Ease of Repair	Redundancy	Ability to Monitor	Score	**Failure Consequences Weight = 100**	Life	Property	Facility Damage	Environmental Damage	Score	**Time & Schedule Weight = 60**	Score	**Capital Cost Weight = 60**	Score	**Other Costs Weight = 40**	Operations & Maintenance	Mitigation Costs	Right-of-Way Costs	Score	**Environmental Considerations Weight = 50**	Historic Properties (cultural resources)	Impact to Waters of the US	Score	**Opportunities for Additional Benefits - Weight = 25**	Additional Flood Protection	Revegetation for Mitigation	Revenue Generation/Excess Land to Sell	Potential Enhancements	Score	**Accommodation Capability Weight = 25**	Score	**Aesthetics Weight = 10**	Score	**Total**
3. Rehabilitation																																											
3A. New Embankment - Upstream		4	5	4	4	4	3	4	3	5	3	390		3	3	3	3	300	3	180	4	240		3	2	3	107		3	3	150		3	1	3	2	56	2	50	2	20	1493
3B. New Embankment - Downstream		4	5	4	4	4	3	4	3	5	3	390		3	3	3	3	300	3	180	4	240		3	3	3	120		3	3	150		3	1	3	2	56	2	50	2	20	1506
3D. RCC Structure - Upstream		4	5	4	4	4	2	5	3	5	3	390		4	4	4	4	400	3	180	1	60		4	2	3	120		3	3	150		3	1	3	2	56	2	50	2	20	1426
3E. RCC Structure - Downstream		4	5	4	4	4	2	5	3	5	3	390		4	4	4	4	400	3	180	1	60		4	3	3	133		3	3	150		3	1	3	2	56	2	50	2	20	1440
3G. Soil Cement Structure - Upstream		4	5	4	4	4	2	5	3	5	3	390		4	4	4	4	400	3	180	1	60		4	2	3	120		3	3	150		3	1	3	2	56	2	50	2	20	1426
3H. Soil Cement Structure - Downstream		4	5	4	4	4	2	5	3	5	3	390		4	4	4	4	400	3	180	1	60		4	3	3	133		3	3	150		3	1	3	2	56	2	50	2	20	1440
3J. Upstream Blanket - Native Soils		3	3	1	3	4	3	4	2	4	2	290		3	3	3	3	300	3	180	3	180		2	2	3	93		2	2	100		2	1	3	2	50	2	50	2	20	1263
3K. Upstream Blanket - Reverse Filter (Imported Soils)		3	3	1	3	4	3	4	2	4	2	290		3	3	3	3	300	3	180	3	180		2	2	3	93		2	2	100		2	1	3	2	50	2	50	2	20	1263
3L. Crack Filler		3	3	1	4	4	1	1	2	2	1	220		3	3	3	3	300	4	240	2	120		2	4	4	133		3	3	150		2	1	3	2	50	2	50	3	30	1293
3M. Grout Curtain		3	3	1	3	4	1	1	2	2	1	210		3	3	3	3	300	4	240	2	120		2	4	4	133		3	3	150		2	1	3	2	50	2	50	3	30	1283
3N. Grout Holocene Soils		3	3	1	3	4	1	1	2	2	1	210		3	3	3	3	300	4	240	2	120		2	4	4	133		3	3	150		2	1	3	2	50	2	50	3	30	1283
4. Abandonment w/Dam Extension																																											
4A. Upstream Dam		4	5	4	4	4	5	4	3	5	3	410		3	3	2	3	275	2	120	3	180		4	2	3	120		2	2	100		3	2	4	2	69	4	100	2	20	1394
4B. Upstream Diversion		5	4	5	5	4	4	4	4	4	4	430		5	5	4	5	475	2	120	3	180		3	2	3	107		2	2	100		3	2	4	2	69	4	100	2	20	1600
5. Isolation w/Dam Extension																																											
5A. Multiple Segments with No Rehabilitation of Existing Dam		4	5	3	3	3	3	3	2	4	3	330		4	4	2	4	350	3	180	4	240		3	3	2	107		2	2	100		3	1	3	2	56	3	75	2	20	1458
5B. Segment with Limited Rehabilitation of Existing Dam		4	5	4	4	4	3	4	3	4	3	380		4	4	2	4	350	2	120	3	180		3	3	2	107		2	2	100		3	1	3	4	69	3	75	3	30	1410
5C. Segment with Modification of Existing Dam and Basin Containment		5	4	4	5	4	4	5	4	4	3	420		5	5	2	5	425	2	120	3	180		3	3	2	107		2	2	100		3	1	3	4	69	3	75	4	40	1535

TABLE 10
ALTERNATIVE ANALYSIS -- RANKED
SYSTEMS EVALUATION MATRIX

Ranking		**Performance Criteria Weight = 100**	Reduce Risk to District/Protect Public	Degree Which Provides Comparable Flood Protection	Protect Against Foundation Settlement	Protect Against Embankment Piping	Protect Against Erosion/Piping of Foundation Soils	Potential for Being Affected by Subsidence	Potential for Being Affected by Future Earth Fissures	Ease of Repair	Redundancy	Ability to Monitor	Score	**Failure Consequences Weight = 100**	Life	Property	Facility Damage	Environmental Damage	Score	**Time & Schedule Weight = 60**	Score	**Capital Cost Weight = 60**	Score	**Other Costs Weight = 40**	Operations & Maintenance	Mitigation Costs	Right-of-Way Costs	Score	**Environmental Considerations Weight = 50**	Historic Properties (cultural resources)	Impact to Waters of the US	Score	**Opportunities for Additional Benefits - Weight = 25**	Additional Flood Protection	Revegetation for Mitigation	Revenue Generation/Excess Land to Sell	Potential Enhancements	Score	**Accommodation Capability Weight = 25**	Score	**Aesthetics Weight = 10**	Score	**Total**
1	4B. Upstream Diversion		5	4	5	5	4	4	4	4	4	4	430		5	5	4	5	475	2	120	3	180		3	2	3	107		2	2	100		3	2	4	2	69	4	100	2	20	1600
2	5C. Segment with Modification of Existing Dam and Basin Containment		5	4	4	5	4	4	5	4	4	3	420		5	5	2	5	425	2	120	3	180		3	3	2	107		2	2	100		3	1	3	4	69	3	75	4	40	1535
3	3B. New Embankment - Downstream		4	5	4	4	4	3	4	3	5	3	390		3	3	3	3	300	3	180	4	240		3	3	3	120		3	3	150		3	1	3	2	56	2	50	2	20	1506
4	3A. New Embankment - Upstream		4	5	4	4	4	3	4	3	5	3	390		3	3	3	3	300	3	180	4	240		3	2	3	107		3	3	150		3	1	3	2	56	2	50	2	20	1493
5	5A. Multiple Segments with No Rehabilitation of Existing Dam		4	5	3	3	3	3	3	2	4	3	330		4	4	2	4	350	3	180	4	240		3	3	2	107		2	2	100		3	1	3	2	56	3	75	2	20	1458
6	3E. RCC Structure - Downstream		4	5	4	4	4	2	5	3	5	3	390		4	4	4	4	400	3	180	1	60		4	3	3	133		3	3	150		3	1	3	2	56	2	50	2	20	1440
6	3H. Soil Cement Structure - Downstream		4	5	4	4	4	2	5	3	5	3	390		4	4	4	4	400	3	180	1	60		4	3	3	133		3	3	150		3	1	3	2	56	2	50	2	20	1440
8	3D. RCC Structure - Upstream		4	5	4	4	4	2	5	3	5	3	390		4	4	4	4	400	3	180	1	60		4	2	3	120		3	3	150		3	1	3	2	56	2	50	2	20	1426
8	3G. Soil Cement Structure - Upstream		4	5	4	4	4	2	5	3	5	3	390		4	4	4	4	400	3	180	1	60		4	2	3	120		3	3	150		3	1	3	2	56	2	50	2	20	1426
10	5B. Segment with Limited Rehabilitation of Existing Dam		4	5	4	4	4	3	4	3	4	3	380		4	4	2	4	350	2	120	3	180		3	3	2	107		2	2	100		3	1	3	4	69	3	75	3	30	1410
11	4A. Upstream Dam		4	5	4	4	4	5	4	3	5	3	410		3	3	2	3	275	2	120	3	180		4	2	3	120		2	2	100		3	2	4	2	69	4	100	2	20	1394
12	3L. Crack Filler		3	3	1	4	4	1	1	2	2	1	220		3	3	3	3	300	4	240	2	120		2	4	4	133		3	3	150		2	1	3	2	50	2	50	3	30	1293
13	3M. Grout Curtain		3	3	1	3	4	1	1	2	2	1	210		3	3	3	3	300	4	240	2	120		2	4	4	133		3	3	150		2	1	3	2	50	2	50	3	30	1283
13	3N. Grout Holocene Soils		3	3	1	3	4	1	1	2	2	1	210		3	3	3	3	300	4	240	2	120		2	4	4	133		3	3	150		2	1	3	2	50	2	50	3	30	1283
15	3J. Upstream Blanket - Native Soils		3	3	1	3	4	3	4	2	4	2	290		3	3	3	3	300	3	180	3	180		2	2	3	93		2	2	100		2	1	3	2	50	2	50	2	20	1263
15	3K. Upstream Blanket - Reverse Filter (Imported Soils)		3	3	1	3	4	3	4	2	4	2	290		3	3	3	3	300	3	180	3	180		2	2	3	93		2	2	100		2	1	3	2	50	2	50	2	20	1263

JOB NO.: 2-117-001066
DESIGN: LAH
DRAWN: EMP
DATE: 12/19/02
SCALE: 1 " = 300 '

McMicken Dam Fissure Risk Zone Remediation Project
Contract FCD 2002C011
Maricopa County, Arizona

ALTERNATIVES ANALYSIS, INITIAL SCREENING
Fissure Risk Zones, Local Washes, Major Water Features

SHEET 1

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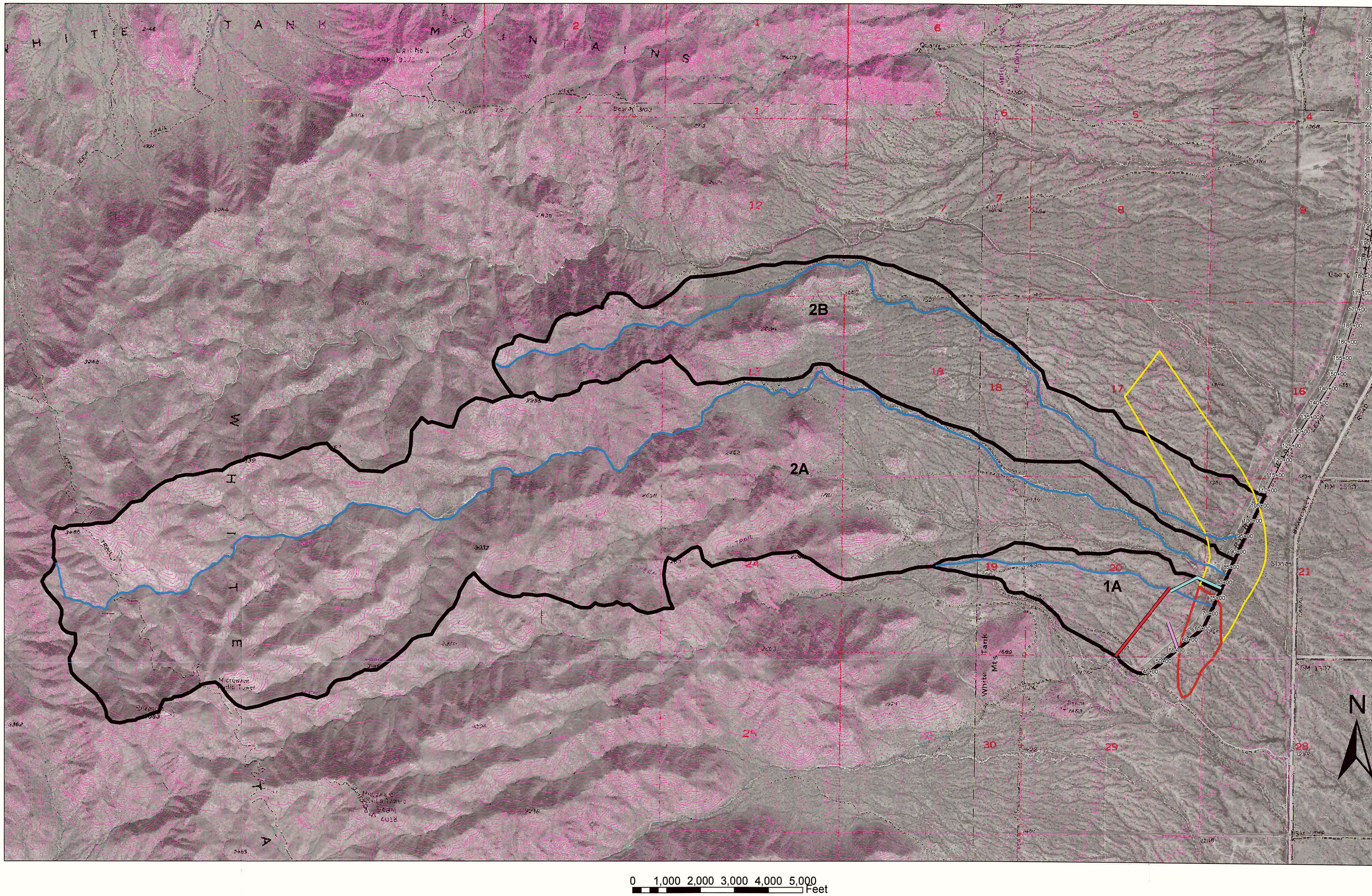

Legend

Earth Fissure Risk Zones

RISK

- High
- Moderate
- Dam SegmentationLine
- Dam Extension
- Upstream Diversion
- Flowlines
- Sub-basin

JOB NO.:	2-117-001066
DESIGN:	MCG/LAH
DRAWN:	EMP
DATE:	12/19/02
SCALE:	1 " = 1,500 '

McMicken Dam Fissure Risk Zone Remediation Project
Contract FCD 2002C011
Maricopa County, Arizona

ALTERNATIVES ANALYSIS INITIAL SCREENING
Sub-Basins, Risk Zones, Repair Alternatives

SHEET
2

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