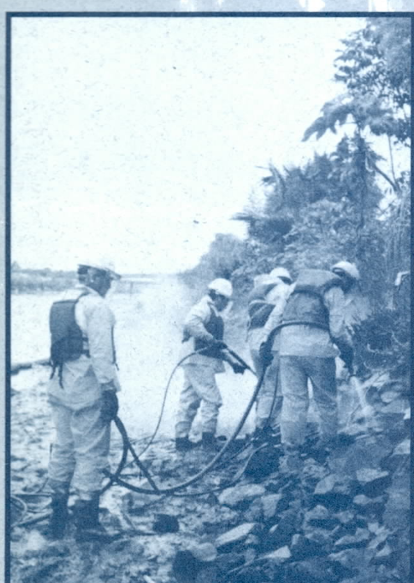
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL DESIGN REPORT MCMICKEN DAM PRINCIPAL SPILLWAY MARICOPA COUNTY, ARIZONA CONTRACT FCD 2004C029 PCN 202.01.26



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Ninyo & Moore

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PREPARED FOR:
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November 16, 2005
Project No. 600996001

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Mr. Michael Greenslade, P.E.
Flood Control District of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009-6399

Subject: Alternatives Analysis and
Preliminary Remedial Design Report
McMicken Dam Principal Spillway
Maricopa County, Arizona
Contract FCD 2004C029/PCN 202.01.26

Dear Mr. Greenslade:

Submitted herewith is our report on the Alternatives Analysis and Preliminary Remedial Design for the McMicken Dam Principal Spillway. This report relates the key findings, understandings, and recommendations developed during a workshop held on September 8, 2005. We have also included drawings showing preliminary concepts to repair the noted defects of the Principal Spillway.

We appreciate the opportunity to be of service to you during this phase of the project. If you have any questions or comments regarding this report, please call at your convenience.

Sincerely,
NINYO & MOORE

A. Tom MacDougall
Project Engineer

Registered Professional Engineer (Civil) CERTIFICATE NO. 31423 ROBERT W. McMICHAEL Date Signed 11-16-05 ARIZONA, U.S.A.

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1. INTRODUCTION

In accordance with your Notice to Proceed dated February 9, 2005, we have analyzed repair alternatives and developed a preliminary remedial design for the McMicken Dam Principal Spillway Remediation and Alternative Selection Project (PCN 202.01.26). The purpose of our assignment was to develop and evaluate repair alternatives to address potential failure modes (PFM) related to the Principal Spillway at McMicken Dam in Surprise, Arizona. This report presents the results of our evaluation; as well as our conclusions and preliminary repair design recommendations related to the project.

1.1. Scope of Services

The scope of our services for this portion of the project generally included:

- Evaluating the results presented in our *Field Exploration Data Report* dated August 8, 2005.
- Developing a list of the remaining Category I or Category II PFMs.
- Formulating various repair alternatives to address the PFMs.
- Preparing an alternative evaluation matrix to aide in systematically ranking and assessing each proposed alternative.
- Planning and coordinating an Alternatives Analysis Workshop. The evaluation process utilized a strength/weakness analysis and a matrix.
- Selecting preferred remediation alternatives and developing a conceptual repair.
- Preparing this report detailing the workshop conclusions, and the preliminary design recommendations.

1.2. Report Organization

Section 1 introduces the report. A brief history of observed issues at McMicken Dam Principal Spillway and a review of the previously performed services for this project is presented in Section 2. Section 3 describes the formulation of the alternatives. The analysis and results of the alternatives evaluation are presented in Section 4. Section 5 describes the preferred alternative selected during the workshop and provides preliminary design recommendations. Section 6 presents the limitations associated with our services.

2. PROJECT BACKGROUND

McMicken Dam is approximately 10 miles long and is located to the east and north of the White Tanks Mountains near Surprise, Arizona as shown in Figure 1. The Principal Spillway is a reinforced concrete box-channel located in the northern portion of the dam, approximately 0.5 miles southwest of Grand Avenue as shown in Figure 2. The dam is operated and maintained by the Flood Control District of Maricopa County (the District) and is a jurisdictional dam due to its height and storage capacity. It was classified as a "high hazard" dam by the Arizona Department of Water Resources (ADWR) due to the potential downstream impacts if a failure were to occur.

An ADWR Annual Inspection Report (dated June 20, 1990) and the Phase I Structural Assessment Report (URS Corporation dated June, 2003) stated that the Principal Spillway was showing indications of possible distress. The District retained Ricker, Atkinson, and McBee (RAM) to initially evaluate observed distresses at the Principal Spillway. Following RAM's work, the District retained Ninyo & Moore to continue the evaluation and develop repair alternatives for the Principal Spillway.

Ninyo & Moore compiled and presented existing information related to the Principal Spillway in our *Data Summary Report* dated May 27, 2005. Ninyo & Moore, with its subconsultants Jim Talbot, Kimley-Horn & Associates, Herb Schumann & Associates, and Structural Grace, performed a site reconnaissance on April 19, 2005. During the site reconnaissance, field observations were made of the following: the spillway channel, the bridge, the embankment crest, the upstream and downstream embankment slopes adjacent to the spillway, the earthen outlet channel, the emergency spillway, and other onsite features. On April 20, 2005, Ninyo & Moore, their subconsultants, and the District held a Failure Modes and Effects Analysis (FMEA) workshop. During the FMEA workshop, potential failure modes were identified; and the likelihood, the cause(s), and the consequences (or effects) of failure by the identified modes were considered. This systematic analysis generally provided enhanced understanding and insight on the risk exposure associated with selected features of the Principal Spillway. Twelve PFMs were identified and evaluated during the FMEA workshop. Of the 12 PFMs, three were considered Category I (highlighted), one was considered a Category II (considered but not highlighted), five were assigned Category III (needs more information to allow for classification), one was not considered to be a Failure Mode, and two were combined into an existing PFM. Additional information relating to the FMEA analysis was presented in our report entitled *Failure Modes and Effects Analysis Report* dated June 17, 2005. To address the Category III PFMs, additional structural analysis and geotechnical exploration was accomplished and is presented in our *Field Exploration Data Report* dated August 8, 2005.

The geotechnical evaluation, including laboratory analysis of on-site soils, and the structural analysis indicated that, of the original 12 PFMs, four should be classified as Category I or II and should be remedied. These four PFMs included:

- Internal erosion through the embankment or transverse cracks near the Principal Spillway causes a breach;
- Internal erosion along the soil-channel interface of the Principal Spillway causes a breach;
- The spillway channel walls and/or floors fail due to defective drainage system which leads to an uncontrolled release; and
- Overtopping of the dam at the Principal Spillway leads to uncontrolled release.

The District requested that the consultant team consider optional improvements to the Principal Spillway. These could be included in the remedial design if convenient; however, these were not intended to address the noted PFMs. The optional improvements included: repair the leaking Beardsley Canal Siphon, increase the capacity of the existing bridge, and relocate the reservoir water level instrumentation to the Principal Spillway.

3. ALTERNATIVE FORMULATION

On August 3, 2005, the project consultant team developed repair alternatives to address the above-noted PFMs and requested optional improvements. Various ideas were suggested during a brainstorming session. Those ideas were narrowed to 13 repair concepts that would later be analyzed in more detail. The consultant team chose to develop narrowly focused repair concepts to address failure modes individually. Following the analysis of each repair alternative, the preferred alternative would be "built-up" by compositing the preferred "focused" alternatives. The 13 potential repair alternatives are listed below.

- Alternative 1 - Extend Center Filter/Drain to Principal Spillway and Along Backside of Channel Walls
- Alternative 2 – Restore Dam Crest (and Bridge) Elevation in Vicinity of Principal Spillway
- Alternative 3 - Install Geomembrane on Upstream Slope
- Alternative 4 - Install Inclined Filter on Downstream Slope
- Alternative 5 - Relocate and/or Reconstruct the Principal Spillway
- Alternative 6 - Design and Construct an Additional Spillway
- Alternative 7 - Realign the Beardsley Canal
- Alternative 8 - Reconfigure the Spillway Chute
- Alternative 9 - Brace or Stiffen Walls
- Alternative 10 - Apply Water Barrier or Liner to Siphon
- Alternative 11 - Restore Stilling Basin Sub-Floor and Wall Drains
- Alternative 12 - Remove, Redesign, and Build a New Wall and Sub-Floor Drain System
- Alternative 13 - Abandon Existing Stilling Basin Drainage System

In preparation for the Alternatives Analysis Workshop, the consultant team set forth criteria to be used in the evaluation of the alternatives. These evaluation criteria included: the effect on the failure modes, the effect on optional improvements, the level of design effort that would be needed, the potential for resulting negative consequences, the cost, and the anticipated life of the repair. Based on these criteria, an evaluation matrix was developed to assist in record keeping and alternative selection.

Preliminary cost estimates for construction were developed in consultation with an earthwork contractor experienced in earthen dam construction. The total costs were generally based on an estimate of the anticipated time, labor, equipment, and materials needed, as well as the complexity of the design and construction. Following the alternative formulation meeting, it was also decided that a strength/weakness analysis, a technique used in failure mode analysis, would be used in combination with the evaluation matrix. The strength/weakness analysis was anticipated to provide an enhanced understanding of each alternative.

4. ANALYSIS OF REPAIR ALTERNATIVES

An Alternatives Analysis Workshop was held on September 8, 2005 at the District offices. During the workshop, the participants evaluated the 13 above-listed repair alternatives utilizing strength/weakness analysis and an evaluation matrix. The workshop participants are listed in Table 1.

Table 1 – Workshop Participants

Name	Affiliation	Position
James Talbot, P.E.	Independent Consultant	Facilitator
Michael Greenslade, P.E.	Flood Control District of Maricopa County	Dam Safety Engineer
Dennis Duffy, PhD, P.E.	Flood Control District of Maricopa County	Dam Safety Engineer
David Jensen, P.E.	Kimley-Horn	Hydrology/ Hydraulics Consultant
Joe M. Rumann	Flood Control District of Maricopa County	Hydrologist
Robert McMichael, P.E.	Ninyo & Moore	Geotechnical Engineer
Steven Nowaczyk, P.E.	Ninyo & Moore	Geotechnical Engineer
John Dowell	Ninyo & Moore	Geotechnical Engineer
Tom MacDougall	Ninyo & Moore	Geotechnical Engineer
Mark Vinson, P.E.	Structural Grace	Structural Consultant

In the following sections, we provide descriptions of the alternatives, a summary of the strength weakness analysis, a summary of the alternative evaluation, and the results of the evaluation. The Evaluation Matrix is presented in Figure 3 and summarizes considerations for the proposed repair alternatives.

4.1. Alternative 1 - Extend Center Filter/Drain to Principal Spillway and Along Backside of Channel Walls

4.1.1. Description

Alternative 1 proposed extending the existing centerline filter/drain to the Principal Spillway and continuing the drain downstream along the backside of the spillway channel walls to the Beardsley Canal siphon. The purpose of this alternative is to mitigate the potential for internal erosion through the embankment near the Principal Spillway, including internal erosion from flow through known existing transverse cracks and flow along the soil-channel interface. This alternative would also relieve water pressure from building up on backside of the channel walls.

In 1984, as part of the McMicken Dam Restoration Project, a filter/drain was installed just downstream of the crest centerline. The existing filter/drain is approximately 30 inches wide and consists of a crushed rock (approximately "2-inch minus" gravel) wrapped in a geotextile. The geotextile on the upstream side of the trench is a non-coated fabric designed as a filter and designed to allow seepage to pass through the fabric. The geotextile on the downstream side of the trench is coated to hinder seepage. The filter/drain extends vertically from approximately elevation 1,332 feet mean sea level (MSL) relative to the National Geodetic Vertical Datum - 1929 (NVGD29) up to approximately 1,357 feet MSL (NVGD29). This is approximately 4 feet below the crest elevation. Laterally, RAM reported (pg 27 of Report dated April 1, 2004) that the drain terminates approximately 23.5 feet north of the north Principal Spillway wall, and 28.1 feet south of the south spillway wall. Within this non-filtered zone, there is an increased potential for internal erosion in transverse cracks or along the soil-channel interface.

This proposed repair consists of installing a filter that ties into the existing filter/drain, extends to the outside of the walls on both the north and south sides of the Principal Spillway, and connects just downstream of the existing antiseep collar. The new filter/drain would continue along the backside of the spillway walls to the Beardsley Canal Siphon. The filter/drain would consist of either a graded material or a drain rock that includes a filter fabric (similar to the existing design). A PVC drain pipe would be installed in the trench to aide in collecting and diverting seepage. The outlet drain pipes would either cross the Beardsley Canal Siphon or outlet into the stilling basin. At the outlet of the drain pipes, a one-way valve (PVC pressure, flap-gate, or similar) would be used. Figure A-1, in Appendix A, depicts this repair concept.

4.1.2. Strength / Weakness Analysis

The workshop participants listed strengths and weaknesses associated with implementing this repair alternative. The participants noted that it would be beneficial to extend the centerline filter/drain as was intended in 1984, and that there would be an existing centerline drain to tie into. By extending the drain material along the backside of the channel walls, collected seepage would have an outlet and wall drainage could be provided. When excavating to place the wall drainage material, the backsides of the channel walls could be observed as was suggested in the FMEA on April 20, 2005. The construction would likely be a relatively short duration and thus have a limited time of vulnerability, possibly eliminating the need for a cofferdam. The repair would not require the re-design of hydraulics or re-evaluation of the hydrology. Another benefit noted was that this would not be a novel repair concept in that center drains and wall backdrains have been successfully implemented in the past on other projects.

Some weaknesses were noted regarding this repair concept. With the configuration of the bridge, the slope of the embankment, and the angle of the channel walls, construction would be difficult and likely require trench boxes and hand excavation in some areas, particularly near the spillway walls. The dam would be subject to a breach if an impoundment event were to occur simultaneously with construction, specifically while the excavation is open before the installation of the filter/drain material. Also, this repair concept would not address the potential for seepage beneath the spillway channel floor. The positive and negative aspects of this alternative are summarized in Table 2.

Table 2 – Alternative 1 - Extend Center Drain/Filter to Channel Walls and Continue Downstream as Wall Drain

Weakness / Negative	Strength / Positive
• Difficult to construct • Vulnerable to failure in a storm event during construction • Does not address seepage under the spillway floor	• Tie into existing centerline filter/drain (continuity with existing) • Provides outlet for collected seepage • Provides wall drainage • Provides an opportunity to inspect the backside of the spillway walls • Short duration of vulnerability • No redesign of hydraulics • Based on previous experience, can be done

4.1.3. Impact on Failure Modes

This repair alternative, if implemented, would mitigate three of the four noted PFMs: internal erosion through embankment cracks, internal erosion along the soil-channel interface, and (if detailed appropriately) failure of the spillway channel by overstressing the spillway walls. It should be noted that the workshop participants discussed the potential for seepage beneath the spillway floor and it was decided that, based on the results of the field exploration, this was no longer considered a failure mode. The Pleistocene soils that underlie the spillway channel floor from within the chute section to the stilling basin floor, have low erosion and collapse potentials and provide an effective cutoff for sub-floor seepage. It should also be noted that, by installing the wall back drain material, the existing stilling basin drains would need to be abandoned. This repair concept does not address the potential for overtopping.

4.1.4. Optional Improvements

The proposed repair alternative provides a convenient opportunity to improve the request by the District to relocate the instrumentation. It also provides the opportunity to inspect the backside of the existing channel walls as was suggested in the FMEA on April 20, 2005. Based upon the inspection, if needed, tiebacks or other appropriate repairs can be performed.

4.1.5. Level of Design Effort

Workshop participants evaluated the level of design effort for this repair would be moderate. Design considerations should include the following: gradation of drain material, connecting the existing centerline filter/drain to the newly installed filter/drain, abutting the new filter/drain to the existing backside of spillway wall (near the anti-seep collar), discharging the collected seepage, and emergency backfilling procedures in the event of a storm event during construction.

4.1.6. Resulting Major Negative Consequences

A negative consequence was identified during the alternatives analysis. During the short duration of construction, there is an increase in the potential for a breach of the dam. To address this potential breach, a temporary emergency action plan would be required, the season in which construction is performed could be limited to a historically "dry" time of year, a series of cofferdams could be used to provide flood protection during construction, and/or the owner may decide to accept the increased risk.

4.1.7. Preliminary Cost Estimate

A preliminary cost estimate range for the construction of this alternative is between $150,000 and $250,000. Three potential failure modes are addressed by this alternative. Thus the cost per failure mode addressed is between $50,000 and $83,000.

4.1.8. Intended Duration of Repair

Alternative 1 is considered to be a long-term repair.

4.1.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative be advanced to the preliminary design stage.

4.2. Alternative 2 - Restore Dam Crest (and Bridge) Elevation in Vicinity of Principal Spillway

4.2.1. Description

Alternative 2 was proposed to address the PFM of overtopping at the Principal Spillway. In 1984, as part of the McMicken Dam Restoration Project, the elevation of the dam crest was restored to 1,361 feet MSL (NGVD29) by adding approximately 2 feet of vertical fill. Recent elevation data, as well as visual observations indicate that the existing crest is depressed approximately 1 to 2 feet in the vicinity of the Principal Spillway, suggesting that the crest was not raised in this area.

The proposed repair would involve raising the crest elevation in the vicinity of the Principal Spillway to match the surrounding grade and restore the original design crest elevation. The deck of the concrete bridge would likely need to be raised to match the new grade. Figure A-2, in Appendix A, depicts this repair alternative.

4.2.2. Strength/Weakness Analysis

Workshop participants noted strengths for utilizing this alternative to reduce the potential for overtopping. The design to raise the crest would be relatively simple and the bridge could be improved at the same time. If needed, to reduce added stress on the channel walls, a lightweight material could be utilized instead of fill soil.

Negatives were also considered. By raising the height of the dam with soil, there would be an increase in pressure transmitted to the walls of the spillway. Additional structural improvements to the spillway walls may be needed. Yet, if a lightweight material, such as a lightweight concrete, were used to raise the elevation of the dam, there would be less of an impact of the structural aspects of the spillway walls. Raising the height of the dam would necessitate raising the elevation of the bridge deck. The use of a lightweight composite grate could raise the elevation of the bridge without adding considerable weight to the existing structure. It was noted in the workshop that recent hydrologic studies from the Whitman Drainage Area (Entellus, 2005) indicate that improvements to emergency spillway could lower the maximum water surface elevation, and thus reduce the potential for overtopping of the dam, which would eliminate the need to restore the crest elevation. The positive and negative aspects noted are summarized in the Table 3 below.

Table 3 – Alternative 2 - Restore Dam Crest (and Bridge) Elevation in Vicinity of Principal Spillway

Negatives	Positives
• Other considerations could eliminate need for this option • Structural design of spillway could be affected • May require the strengthening of the walls of the spillway	• Potential to improve bridge in process • Simple design options are available • Lightweight fill materials could be investigated

4.2.3. Impact on Failure Modes

This repair alternative, if implemented, would mitigate one of the four PFMs: overtopping near the Principal Spillway.

4.2.4. Optional Improvements

This repair alternative allows for the opportunity to improve (e.g., widen or increase load capacity) the bridge, if desired. Following discussion, the District decided not to improve the bridge at this time due to the cost increase of needing to strengthen the channel walls. The proposal to raise the elevation of the bridge deck with a lightweight fill or riser was deemed by the workshop participants to be a functional necessity and not an improvement to the usability of the bridge.

4.2.5. Level of Design Effort

The level of design effort is considered to be moderate. Design considerations should include structural analysis and possibly the design of a bracing system for the spillway walls based on the additional weight of raising the dam crest elevation and improving the bridge.

4.2.6. Resulting Major Negative Consequences

One negative consequence identified during the alternatives analysis was the potential to overstress the spillway walls by adding fill and weight to the bridge decking.

4.2.7. Preliminary Cost Estimate

A preliminary cost estimate range for the construction of this alternative is between $75,000 and $150,000. One potential failure mode is addressed by this alternative.

4.2.8. Intended Duration of Repair

Alternative 2 is considered to be a long-term repair.

4.2.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative be advanced to the preliminary design.

4.3. Alternative 3 - Install Geomembrane on Upstream Slope

4.3.1. Description

In order to mitigate the potential for internal erosion through the embankment near the Principal Spillway, installing a geomembrane was proposed to act as an upstream seepage cutoff. This proposed alternative would reduce the likelihood of seepage through embankment or foundation cracks or discontinuities. A synthetic liner (HDPE or similar) could be installed a few feet below the ground surface, anchored on the crest, toed into the foundation soils (likely a few feet into the Pleistocene deposits) and extend laterally approximately 80 feet out from each side of the spillway. The membrane would also need to be fastened to the spillway walls. This concept is shown in Appendix A, Figure A-3.

4.3.2. Strength/Weakness Analysis

Positive and negative aspects were identified for this repair concept. Whereas the liner could laterally overlap the existing centerline filter/drain to provide a seepage cutoff, a physical connection to the filter/drain would be unfeasible and leave a potential seepage path between intersecting transverse and longitudinal cracks. Moreover, the amount to overlap would be a relative guess, rather than based on a tested design procedure. This alternative would provide the benefit of installing an upstream cutoff beneath the spillway channel. The associated negative aspect noted was that there would potentially be a very high pressure gradient across the toe (bottom) of the geomembrane. Another potential negative with the use of geomembranes is that ADWR, the regulatory agency, may have reservations about approving their use in this application. The District has successfully installed these in other dams that are performing well to date (although without reservoir filling), but the concept of a membrane is to impede seepage as opposed to depressurize it, as in the case of the filter/drain concept. One additional positive noted was that this repair could be used in combination with a filter/drain to provide redundancy. The positive and negative aspects noted are summarized in the Table 4 below.

Table 4 – Alternative 3 - Install Geomembrane on Upstream Slope

Negatives	Positives
• No connection to the existing centerline filter/drain	• Can overlap the centerline filter
• Indeterminate amount of overlap	• Can provide cutoff under floor upstream of the spillway
• Past installations have not been tested	• Has been successfully installed in the past
• Regulatory acceptance	• Can be used in conjunction with filters to provide redundancy
• Provides no drainage or relief of pressure	• Negates need for drainage or relief of pressure
• High gradient at base	
• Finite life	

4.3.3. Impact on Failure Modes

This repair alternative, if implemented, would mitigate two of the four noted PFMs: internal erosion through cracks or embankment discontinuities, and internal erosion along the soil-channel interface. However, this would be dependant on maintaining a seal between the channel and the geomembrane.

4.3.4. Optional Improvements

Optional improvements were not identified that could be easily addressed at the time of implementing this alternative.

4.3.5. Level of Design Effort

The level of design effort is considered to be low. Design considerations should include determining the appropriate depth of the toe down, protecting the crest anchors from damage, putting an appropriate depth of fill on the geomembrane and stabilizing the soil on top of the liner. Additional design consideration should involve the length of overlap between seams, the overlap distance with the centerline filter/drain, and the appropriate method to seal the liner to the spillway channel.

4.3.6. Resulting Major Negative Consequences

The potential for high pressure gradients across the bottom of the membrane from the upstream side to the downstream side of the liner could result in performance problems. Another problem would be creating an unstable slope by the soil cover sliding on the surface of the smooth membrane.

4.3.7. Preliminary Cost Estimate

A preliminary cost estimate range for the construction of this alternative is between $75,000 and $150,000. Two potential failure modes are addressed by this alternative resulting in a cost-per-failure-mode-addressed of $33,000 to $75,000.

4.3.8. Intended Duration of Repair

Alternative 3 is considered to be a long-term repair.

4.3.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative not be advanced to the preliminary design stage.

4.4. Alternative 4 - Install Inclined Filter on Downstream Slope

4.4.1. Description

Alternative 4 was proposed to address PFM 1, or the potential for internal erosion through the embankment near the Principal Spillway. The proposed repair concept involves installing an inclined filter and chimney drain on the downstream slope. The proposed filter would be a specifically graded granular material, approximately 2 feet thick, and would be installed about 2 feet below the embankment surface (i.e., would have 2 feet of fill on top of the filter). The filter would daylight at the toe of the dam. Figure A-4, in Appendix A, depicts this repair alternative.

4.4.2. Strength/Weakness Analysis

Strengths and weakness of this repair alternative were discussed. The downstream filter could laterally overlap the existing centerline filter/drain, although it would not necessarily connect directly unless special design and construction measures were utilized. Similar to the geomembrane, if a physical connection was not made, but overlap was used, the distance needed to overlap would be unknown. It was noted that construction would be relatively easy and should not necessitate the construction of a cofferdam. Another positive is that many dams and levees utilize this type of filter and drainage system and this system generally performs well. This alternative would not provide mitigation for hydrostatic build-up on the backside of spillway channel walls. If insufficient overburden was used to cover the filter/drain, a blow-off type failure could occur. It is likely that back-wall pressures would be increased due to the increase of soil mass and collected seepage would be directed to the downstream toe of the dam where it may get trapped because of the Beardsley Canal. The positive and negative aspects noted are summarized in the Table 5 below.

Table 5 – Alternative 4 - Install Inclined Filter on Downstream Slope

Negatives	Positives
• Does not connect with centerline filter	• Could overlap the centerline filter
• Does not provide drainage for spillway walls and floor	• Easy to construct
• Must provide overburden to prevent blow-off	• Have been installed on other structures
• Overburden will add to spillway load	• Special construction could connect to centerline filter
• Diverts seepage to downstream toe	
• Indeterminate overlap distance	

4.4.3. Impact on Failure Modes

This repair alternative, if implemented, would mitigate one of the four PFMs: internal erosion through cracks or embankment discontinuities.

4.4.4. Optional Improvements

Optional improvements were not identified that could be easily addressed at the time of implementing this alternative.

4.4.5. Level of Design Effort

The level of design effort is considered to be low. Design considerations should include determining the appropriate fill thickness that should be placed on top of the filter and the length of overlap needed with the centerline filter/drain.

4.4.6. Resulting Major Negative Consequences

The potential for internal erosion would still exist if a physical connection with the centerline filter/drain was not made. Another potential negative consequence would be that the inclined filter may create an unstable downstream slope.

4.4.7. Preliminary Cost Estimate

A preliminary cost estimate range for the construction of this alternative is between about $100,000 and $200,000. One potential failure mode is addressed by this alternative.

4.4.8. Intended Duration of Repair

Alternative 4 is considered an interim repair and would be in-place until a long-term repair could be designed and constructed.

4.4.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative not be advanced to the preliminary design stage.

4.5. Alternative 5 - Relocate and/or Reconstruct the Principal Spillway

4.5.1. Description

It was proposed to redesign and reconstruct (and possibly relocate) a new Principal Spillway to address the four PFMs. The alternative did not include specifics; however, the consultant team wanted to generally compare this repair concept to others. The repair concept involved destroying the existing spillway, and redesigning and constructing a new spillway in either the same location or in an alternate location.

4.5.2. Analysis

Initial discussions indicated that this repair concept was very costly and may not address any of the noted failure modes. Moreover, by implementing this alternative, additional failure modes or new downstream issues may arise. Based on these initial observations, neither the strength/weakness, nor the alternative analyses were performed for this alternative. The workshop participants do not recommended that this alternative be advanced to the preliminary design stage.

4.6. Alternative 6 - Design and Construct an Additional Spillway

4.6.1. Description

Alternative 6 would involve maintaining or improving the existing spillway, and adding a secondary spillway in another location. The concept was proposed to evaluate if designing and constructing an additional Principal Spillway could mitigate overtopping and uplift on the stilling basin floors. An additional outlet would change the hydrologic routing and thereby change the loading conditions on the existing Principal Spillway. The loading changes would affect the potential for overtopping and possibly the tail water elevation and thus the uplift on the stilling basin floor.

4.6.2. Analysis

Similar to Alternative 5, and based upon the anticipated cost, design effort, and potentially negatives consequences, Alternative 6 was not considered to be a viable alternative. This alternative was not evaluated further.

4.7. Alternative 7 - Realign the Beardsley Canal

4.7.1. Description

The purpose of this alternative is to eliminate (or reduce complications relating to) the intersection between the spillway channel and the Beardsley Canal. The existing Beardsley Canal siphon has been observed to leak, and also would experience the greatest uplift pressures of the stilling basin sections. By re-routing the canal, and potentially avoiding conflict with the spillway channel, the spillway walls would not leak and uplift pressures on the base of the siphon portion of the stilling basin could be reduced. Alternative 7 is depicted in Appendix A, Figure A-5.

4.7.2. Strength/Weakness Analysis

Positives and negatives associated with realigning the Beardsley Canal were discussed by the workshop participants. The cost would be high relative to the benefit achieved, although some cost sharing with the owner (Maricopa Water District) could be anticipated. This alternative would also facilitate the repair of channel floor drainage by reducing the potential uplift pressures. The permitting and timing of construction may be very complex and difficult. The maintenance issue of periodic leaking could be mitigated, yet this alternative does not address failure modes. The strengths and weaknesses of this alternative are summarized in the Table 6.

Table 6 – Alternative 7 - Realign the Beardsley Canal

Negatives	Positives
• Very expensive	• Solve leakage problems into stilling basin
• Problems with present are not severe	• Less maintenance
• Current maintenance is low	• May be cost shared by owner of canal
• Permitting is difficult	• Reduce the potential uplift pressures on the stilling basin floor.
• Does not address failure modes	

4.7.3. Impact on Failure Modes

This repair alternative, if implemented, would not mitigate any identified failure modes, but would address a maintenance issue.

4.7.4. Optional Improvements

Optional improvements were not identified that could be easily addressed at the time of implementing this alternative.

4.7.5. Level of Design Effort

The level of design effort is considered to be high. Design considerations would include crossing the outlet channel, construction timing and sequencing, removing the existing siphon and reconstructing a portion of the stilling basin, as well as any consideration related to canal design (e.g., grade, alignment, lining, foundation, etc.).

4.7.6. Resulting Major Negative Consequences

Major negative consequences were not identified for this alternative.

4.7.7. Preliminary Cost Estimate

A preliminary cost estimate for the construction of this alternative is between about $500,000 and $1,000,000. No potential failure modes are addressed by this alternative.

4.7.8. Intended Duration of Repair

Alternative 7 is considered to be a long-term repair.

4.7.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative not be advanced to the preliminary design stage.

4.8. Alternative 8 - Reconfigure the Spillway Chute

4.8.1. Description

This proposed repair would likely eliminate the need for the Beardsley Canal Siphon, and the ponding that occurs in the stilling basin and outlet channel during and after impoundment events. Approximately 500 feet downstream from the stilling basin, the channel invert elevation is approximately 5 feet higher than the base-of-spillway elevation; thus, ponding occurs. The concept is to gently slope the spillway until it bridges over the Beardsley Canal and from there, either continue the gentle slope or install a chute to a stilling basin located downstream of the current location. Figure A-6, in Appendix A, depicts this alternative.

4.8.2. Strength/Weakness Analysis

Positives and negatives associated with reconfiguring the spillway chute were discussed by the workshop participants. The cost would be high relative to the benefit achieved. Some benefits would include addressing the maintenance issue of the leaking siphon and solving the potential for hydrostatic pressure to build up on the backside of channel walls. However, permitting would be difficult and there may be adverse hydraulic affects to the Beardsley canal by removing the siphon. The strengths and weaknesses of this alternative are summarized in the Table 7.

Table 7 – Alternative 8 - Reconfigure the Spillway Chute

Negatives	Positives
• Expensive to construct • Limited benefits • Permitting difficult • Affects hydraulics of Beardsley Canal system	• Solve leakage and maintenance issues at Beardsley Canal • Reduces potential for failure of stilling basin via uplift pressures

4.8.3. Impact on Failure Modes

Alternative 8, if implemented, would mitigate one of the four identified PFMs: failure of the spillway channel by overstressing the spillway walls.

4.8.4. Optional Improvements

This alternative would address the leaking siphon which is considered a maintenance issue.

4.8.5. Level of Design Effort

The level of design effort associated with this alternative was considered to be high. Design considerations would involve redesigning the hydraulics of both the Beardsley Canal and the Principal Spillway. The spillway would need a full geotechnical and structural design, and aesthetic issues would need to be considered.

4.8.6. Resulting Major Negative Consequences

The potentially high spillway walls extending well downstream of the Principal Spillway may require aesthetic planning, public input, and expensive modifications before approval. The hydraulics of the Beardsley Canal may be adversely affected.

4.8.7. Preliminary Cost Estimate

A preliminary cost estimate range for the construction of this alternative is approximately $500,000 and $1,000,000. One potential failure mode is addressed by this alternative.

4.8.8. Intended Duration of Repair

This alternative is considered a long-term repair.

4.8.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative not be advanced to the preliminary design stage.

4.9. Alternative 9 - Brace or Stiffen Walls

4.9.1. Description

The purpose of this repair alternative is to strengthen the spillway channel walls and thereby mitigate the potential for wall collapse due to overstressing (caused by excessive hydrostatic pressure build up). This repair concept would either add cross-channel braces or struts; tiebacks, or side wall stiffeners to increase the lateral capacity of the existing channel walls.

4.9.2. Analysis

Sidewall stiffeners would likely change the structural stresses in the walls of the spillway requiring redesign and reconstruction. Similar to Alternatives 5 and 6, Alternative 9 was not considered to be a viable alternative at this time. However, the final design should include an optional item to address potentially overstressed walls. Following the inspection of the backside of channel walls (presumably during construction), the decision can be made whether to perform the optional repair.

4.10. Alternative 10 - Apply Water Barrier to Siphon

4.10.1. Description

The purpose of patching or lining the siphon would be to reduce both the potential for seepage from leaks that could saturate the backside of the channel walls, or the existing maintenance issues related to the leaks in the stilling basin walls. At the time of our field inspection, we observed two leaks in the siphon: one through the spillway wall on the south side of the stilling basin, and one at a joint in the east side of the siphon wing-wall. There may be other leaks that were not apparent. This repair would involve stopping flow in the canal (or coordinating construction with the annual dry period), and either patching any suspected leaks with a filler material (e.g., cement, polyurethane, silicon, etc.), or lining the existing siphon with water-tight membrane.

4.10.2. Strength/Weakness Analysis

This repair would not address any identified failure modes, but would reduce the maintenance issues associated with a leaking stilling basin walls and joints. The repair would be relatively low cost and simple to perform. The cost could also be shared or borne by the Maricopa Water District, which owns the Beardsley Canal. However, the District would have to get the owner to agree to perform this repair. The positive and negative points of this alternative are summarized in the following table.

Table 8 – Alternative 10 - Apply Water Barrier to Siphon

Negatives	Positives
• Would require owner permission	• Low Cost • Simple • Solves nuisance • Could be accomplished during the annual "dry out" period

4.10.3. Impact on Failure Modes

Alternative 10, if implemented, would not mitigate any PFMs.

4.10.4. Optional Improvements

This alternative would address the leaking siphon which is considered a maintenance issue.

4.10.5. Level of Design Effort

The level of design effort is considered to be low. Design considerations should include utilization of a time-tested product that seals across expansion joints and small discontinuities.

4.10.6. Resulting Major Negative Consequences

No negative consequences were identified.

4.10.7. Preliminary Cost Estimate

A preliminary cost estimate for the construction of this alternative is approximately between $20,000 and $50,000. No potential failure modes are addressed by this alternative.

4.10.8. Intended Duration of Repair

This alternative is considered to be an interim repair based on the life of the sealant or liner material. Participants anticipated that periodic maintenance would still be needed, but at less frequent intervals than are currently needed.

4.10.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative be advanced to the preliminary design stage.

4.11. Alternative 11 - Restore Stilling Basin Sub-Floor and Wall Drains

4.11.1. Description

This alternative would reduce the potential for channel wall failure caused by hydrostatic forces on the backside of the walls or underside of the stilling basin floor. The concept involves removing the existing system and re-constructing the drainage, but with the same design as originally intended. The locations and size of drain pipe would be very similar to the originally constructed drainage system. The repair would likely use a poly-vinyl chloride (PVC) pipe, and replace the existing "permeable fill" with new permeable fill.

4.11.2. Analysis

This alternative was not considered to be viable. The workshop participants considered that due to the difficulty to restore, as well as the poor past performance of the sub-floor drains (and therefore the potential for poor future performance), this alternative should not be carried forward in evaluation or design.

4.12. Alternative 12 - Remove, Redesign, and Build a New Wall and Sub-Floor Drain System

4.12.1. Description

Similar to Alternative 11, the purpose of this concept is to avoid overstressing the channel walls or floors that would result from hydrostatic pressure. The concept includes removing the existing drainage system, and installing a newly designed system that relieves pressure build-up. The newly designed system could involve changes in elevation or location of weep holes, permeable back fill, etc.

4.12.2. Strength/Weakness Analysis

The positive and negatives were considered for Alternative 12. It would be relatively easy to construct the wall back drainage system when constructing other improvements (e.g., Alternative 1). The subfloor drains are, however, impractical to replace and would likely create future maintenance or repair issues.

Table 9 – Alternative 12 - Remove, Redesign, and Build a New Wall and Sub-Floor Drain System

Negatives	Positives
• Not practical to replace drain under floor • Even if drain under floor is replaced, it will be difficult to maintain	• The wall back-drains could be constructed easily in combination with other repairs

4.12.3. Impact on Failure Modes

Alternative 12, if implemented, would mitigate one of the four PFMs: failure of the spillway channel by overstressing the spillway walls.

4.12.4. Optional Improvements

In general, the workshop participants agreed that floor anchors (i.e. tie downs) were a better option that repairing the sub-floor drains to resist potential uplift pressures.

4.12.5. Level of Design Effort

The level of design effort is considered to be low. Design considerations should include the potential uplift pressures, back-wall pressures, and seepage paths.

4.12.6. Resulting Major Negative Consequences

No negative consequences were identified.

4.12.7. Preliminary Cost Estimate

A preliminary cost estimate for the construction of this alternative is between approximately $100,000 and $200,000. One potential failure mode is addressed by this alternative.

4.12.8. Intended Duration of Repair

This alternative is considered to be a long-term repair.

4.12.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative be advanced to the preliminary design stage, and floor anchors be considered rather than replacing the sub-floor drains.

4.13. Alternative 13 - Abandon Existing Drainage System

4.13.1. Description

Alternative 13 proposed abandoning the existing drainage system in place by filling it with cement grout. This alternative was suggested so that the workshop participants could evaluate if it would be preferable to grout the voids in the existing drain pipes, or to simply abandon them without grout.

4.13.2. Strength/Weakness Analysis

The workshop participants listed strengths and weaknesses associated with implementing this repair alternative. The participants noted that repair would reduce the potential for the migration of fines into the possible voids inside the existing piping or the loss of ground as a result of structural failure of the pipe (e.g., crushing). Grouting the pipes may also reduce the potential for water to be diverted through the drain pipes into the foundation soils beneath the stilling basin floor. However, pressurized grouting techniques could easily damage the stilling basin floor, the Beardsley Canal, or spillway walls by overstressing them. It may be ineffective to place grout in the pipes using a non-pressurized technique. Table 10 presents a summary of the strength/weakness analysis for alternative 13.

Table 10 – Alternative 13 - Grout Existing Drainage System

Negatives	Positives
• May overstress if grout is pressurized • May be ineffective if grout is non-pressurized	• May reduce future migration of fines or loss of ground due to crushed pipe • May reduce potential for seepage to be diverted through the open drains into foundation soils.

4.13.3. Impact on Failure Modes

Alternative 13, if implemented, would not directly mitigate any PFMs.

4.13.4. Optional Improvements

Utilizing a non-pressurized grout would be a preferred option.

4.13.5. Level of Design Effort

The level of design effort associated with this alternative is considered to be low. The grout mix design should be carefully considered.

4.13.6. Resulting Major Negative Consequences

Overstressing walls and floors if pressurized placement techniques are used could result in damage to the spillway channel.

4.13.7. Preliminary Cost Estimate

A preliminary cost estimate range for the construction of this alternative is between approximately $5,000 and $10,000. No potential failure mode is directly mitigated by this alternative.

4.13.8. Intended Duration of Repair

This alternative is considered to be a long-term repair.

4.13.9. Result of Evaluation

Based on the above-outlined evaluation, the workshop participants recommended that this alternative be advanced to the preliminary design stage, considering non-pressurized grout.

4.14. Preferred Alternative Summary

Based on the analysis of the 13 proposed alternatives, the workshop participants recommended that elements of five alternatives be combined into the "preferred alternative" and advanced to a preliminary design stage. The recommended (or preferred) alternative, therefore, should be a combination of the following:

- Alternative 1 - extending the existing filter/drain to the spillway walls and continuing along the back side of the channel walls (with the option of relocating water-level instrumentation);
- Alternative 2 - raising the dam crest and bridge deck elevations;
- Alternative 10 - applying a water barrier to the Beardsley Canal Siphon;
- Alternative 12 - replacing stilling basin wall drains and anchoring the stilling basin floor; and
- Alternative 13 - abandoning the existing drainage system under the stilling basin floor with a non-pressurized grout.

This preferred alternative addresses the four failure modes and provides the opportunity to easily address two of the optional improvements suggested by the District: repair the leaking siphon and relocate the water-level instrumentation. The preliminary cost estimates for the design and construction of the preferred alternative is approximately $500,000. A breakdown of the cost estimate is provided on Figure 4. More detailed recommendations relating to the preferred alternative are presented in Section 5. Preliminary design plans have been included in Appendix B.

5. PRELIMINARY DESIGN RECOMMENDATIONS

In this section, we present our preliminary design recommendations for the McMicken Dam Principal Spillway improvements. These recommendations are based on our site observations, the results of the FMEA workshop held on April 20, 2005, the subsequent field exploration and structural analysis, and the Alternatives Analysis Workshop held on September 8, 2005. In the sections that follow, we provide more detailed recommendation for the preferred alternative. Preliminary design plans have been prepared and are included in Appendix B.

5.1. Filter / Drain System

We recommend the following with respect to the filter/drain system:

1. A new filter/drain system should be installed between the existing centerline filter/drains and the spillway channel walls (both north of, and south of the Principal Spillway). The new filter/drain should abut the existing filter/drain and intersect the spillway walls on the downstream side of the existing 4-foot anti-seep collar. The bottom of this filter/drain should extend 2 or more feet below the Holocene/Pleistocene contact and the top should extend to within 2 feet of the final elevation of the dam crest and be overlain by low permeable, structural fill, or embankment material.

2. The filter/drain should also extend along the backside of the channel walls from the downstream side of the anti-seep collar to the Beardsley Canal Siphon. A perforated PVC collector pipe should be installed at the base of the filter/drain trench to divert collected seepage to an outlet. The base of the trench should be sloped to provide drainage toward the easternmost existing weep hole in the stilling basin wall. The top of the filter/drain material should extend to within 2 feet of the ground surface and be overlain by a low-permeable structural fill, or embankment material. Within the stilling basin section, a low permeable fill should be placed below the filter/drain material. We recommend that a one-way valve be installed at the outlet to hinder channel flow from entering the drain pipe and soils behind the channel walls. We recommend that broad, sweeping turns be utilized as opposed to sharp 90-degree angle turns in the piping for clean-out and inspection purposes.

3. The filter/drain should consist of graded sand designed to meet the Natural Resource Conservation Service filter criteria. Within the acceptable filter gradation limits, the filter/drain material should be on the "coarse-side" of the curve, or have the coarse-grained portion of the filter curve adjusted to increase the permeability of the filter/drain material. Based on a cursory evaluation, a mixture of 70 percent ASTM C-33, fine aggregate and 30 percent ASTM C-33, No. 8 aggregate may provide the desired gradation.

We suggest that the District consider relocating the water-level instrumentation to the spillway channels. Currently, the intake that measures the water level in the reservoir is such that low flow events are not recorded. By relocating the pressure transducer to the Principal Spillway, more accurate readings of spillway flows can be made and low flow events could be monitored and recorded. An intake to a sealed transducer could be installed through the base of the channel wall at the time the filter/drain was installed or along the inside face of the spillway wall. The existing transmitter housing (on the crest above the pressure transducer) could be utilized by installing wiring to the new transducer location.

5.2. Stilling Basin Floor Anchors

As discussed in Section 4.12, we recommend that tie-down anchors be installed within the stilling basin area to resist uplift pressures associated with the abandonment of the sub-floor drainage system. Based on our review of the design memorandums prepared by the United States Army Corps of Engineers (USACE) for the original construction of the spillway, the uplift pressure under the stilling basin area could be as high as approximately 1,200 pounds per square foot. The stilling basin area in question is on the order of 36 feet wide by 49 feet long. As such the estimated worst-case uplift load is approximately 2,100 kips. We estimate the weight of the structure in this area to be approximately 1,000 kips; resulting in approximately 1,100 kips of uplift load to resist.

Tie-down or uplift anchors typically consist of an augered hole that is filled with concrete, grout or epoxy. The uplift resistance is generated by the frictional resistance between the anchor and the surrounding soil and can be estimated by multiplying the frictional resistance of the underlying soils with the surface area of the anchor. Using the uplift load from above and an allowable soil frictional resistance of 1,000 pounds per square foot, we estimate that up to about 10 tie-down anchors will be needed for this project. These anchors should be approximately 12 inches in diameter and extend about 35 feet deep.

Helical anchors are also used frequently to resist uplift pressures and loads. These anchoring systems utilize a helical vane or screw to generate uplift resistance. In addition, they generate little or no spoils and typically do not have to be filled with concrete, grout or epoxy.

The size and depth of this type of anchoring system is typically developed by the contractor performing the work based on the site-specific soil conditions and the loads that are needed to be overcome.

5.3. Restore Crest Elevation

In the vicinity of the Principal Spillway, the crest elevation should be restored to its original design elevation. Recently the District converted datums from NGVD29 to the North American Vertical Datum, 1988 (NAVD88). Accordingly, the restored crest elevation should be 1362.9 feet MSL (NAVD88), which is approximately 1,361 feet MSL (NGVD29). The approximate elevations shown on the preliminary plans (see Appendix B) are referenced to NAVD88. Either engineered fill, consisting of borrow material from the pool area, or a lightweight fill could be utilized. Oversteepening of the embankment slopes should generally be avoided or slopes should be stabilized. As such, we recommend that engineered fill be placed on the upstream and downstream slopes so that the upstream is approximately at a slope ratio of 2.5 vertical to 1 horizontal or flatter and the downstream slope ratio is approximately a 2 vertical to 1 horizontal or flatter. If desired, a reinforced earth slope may be utilized to avoid the fill soils being above the top of the adjacent spillway channel walls. Reinforced earth could consist of soil cement, Geogrid-reinforcement, or similar concepts.

The elevation of the bridge deck will need to be raised for continued functionality and use. We recommend that a lightweight composite riser be attached to the exiting bridge deck. A lightweight riser would have a limited impact on the capacity reduction of the bridge and would likely avoid the need for strengthening or bracing the channel walls. We recommend that the bridge riser be securely attached to the existing bridge. Additional information regarding lightweight risers are available at http://www.creativepultrusions.com/index.html and similar websites. The loading and structural design of the spillway walls and bridge can be evaluated for various bridge materials. Repair materials and methods should be used that will not require reconstruction of the spillway walls or bridge deck.

5.4. Apply Water Barrier to Siphon

During the period that the Beardsley Canal is dried up we suggest that the interior walls of the siphon be visually evaluated by a qualified engineer. Noticeable cracks within the concrete walls observed during this evaluation should be filled with a polyurethane material. Polyurethanes are an engineering material created by a production process that mixes polyisocyanate and polyol chemicals. The combination allows polyurethanes to be formulated with greatly varying properties, from stiff and hard to soft and flexible (the strength of plastics or the flexibility of rubbers), depending on the desired application. Because polyurethanes are controllable, they can be dispensed as a flexible foam, froth, elastomer, rigid forms, spray, pour or injected material.

For this project we recommend that the polyurethane either be applied directly from the concrete surface or be injected into the wall via small diameter drilled holes. The injection method would likely produce a better result; however, permission to drill into the wall may be difficult to obtain.

After the noticeable cracks are filled with a polyurethane material, we recommend the wall surfaces be coated with a crystalline concrete waterproofing material to reduce future water seepage issues. This method uses a catalytic reaction to seal the pores, capillaries and shrinkage cracks that occur naturally in concrete. Crystalline waterproofing penetrates several inches into concrete. As hairline cracks form over the life of concrete, crystalline waterproofing continues to activate in the presence of moisture and seal additional gaps. It consists of a dry powder compound of Portland cement, very fine treated silica sand, and proprietary chemicals. Combining the product with water and applying it to the surface of concrete results in a catalytic reaction that forms several inches of non-soluble crystalline fibers within the pores and capillary tracts of concrete. This seals the concrete against the penetration of water or liquids from all directions.

5.5. Environmental and Permitting Considerations

We are not aware of any environmental permits that would be needed for the recommended improvements. Coordination with the Maricopa Water District would be required to apply a water retarder to the inside of the Beardsley Canal Siphon. Approval of the proposed modifications by ADWR as well as an ADWR permit is needed. We suggest involving the USACE in the review and approval process.

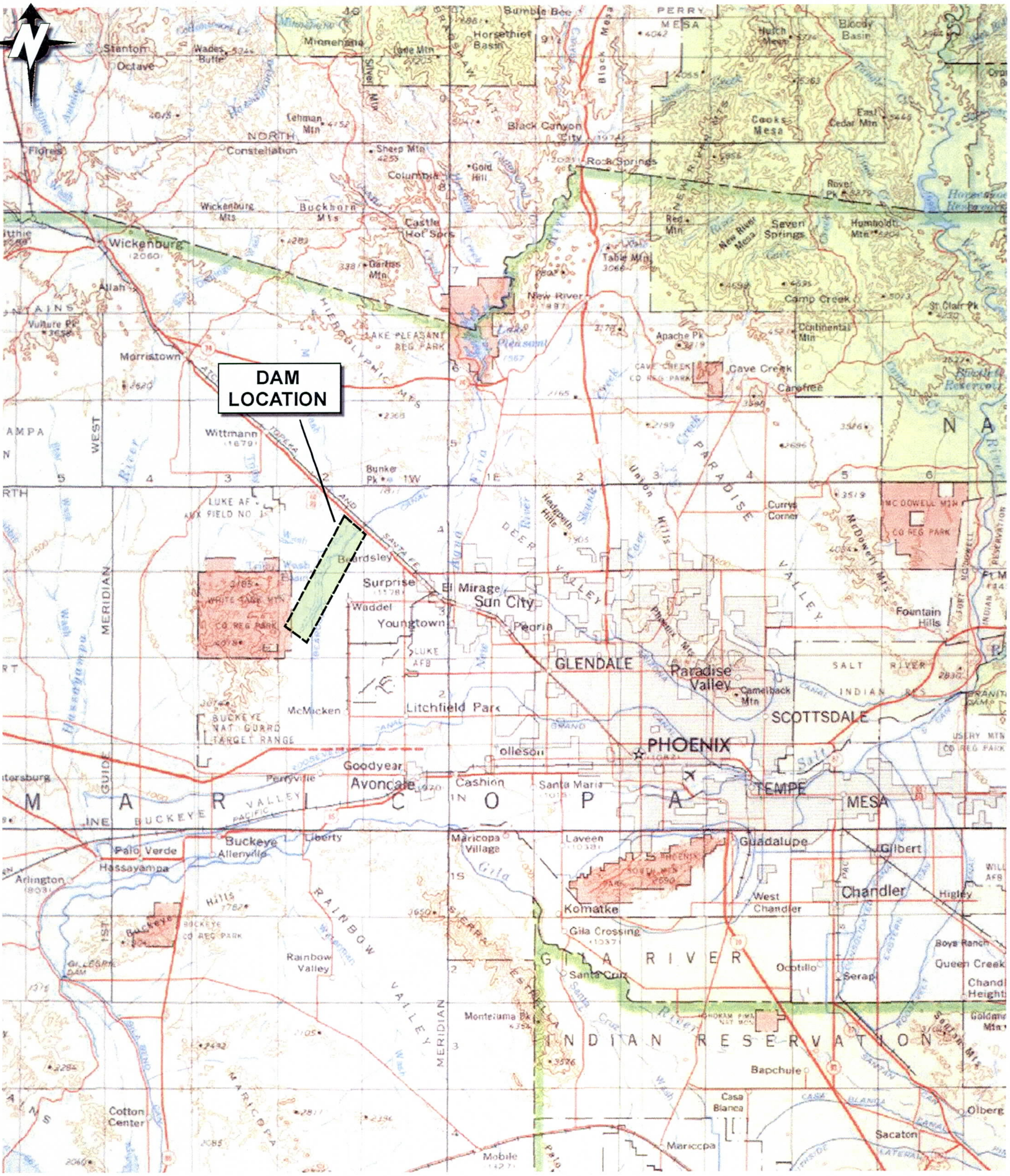
6. LIMITATIONS

The services described in this report have been conducted in general accordance with current practice and the standard of care exercised by engineering consultants performing similar tasks in the project area. No warranty, expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. Our conclusions and recommendations are based on an analysis of the observed site conditions and the references listed. If actual conditions differ from those described in this report, our office should be notified and additional recommendations, if warranted, can be provided upon request.

There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during repairs. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Additional subsurface evaluation will be performed upon request. Please also note that our evaluation was limited to assessment of the certain aspects of the project, and did not include evaluation of environmental concerns or the presence of hazardous materials.

It should be understood that the purpose of our study was to evaluate the geotechnically related cause(s) of distress to the subject structure and to provide recommendations for repair of the existing distress features. Our recommendations are not intended to bring the site improvements into compliance with the current codes for new construction at the site. Further, the recommendations provided in this report are not intended to protect the site improvements against future seismic shaking beyond what is currently recognized as standard by the industry. The code requirements for repair of existing structures are generally less stringent than the requirements for replacement of existing structures or for new construction. Should new construction be contemplated at the site, the governing agencies may require compliance with the more stringent codes. In addition, future soil movement may occur, even after repairs are made to the residence. Minor cracking should, therefore, be expected in the future.

This report is intended for preliminary design purposes only. It does not provide sufficient data to prepare an accurate bid by contractors. It is suggested that the bidders and their geotechnical consultant perform an independent evaluation of the subsurface conditions in the project areas. The independent evaluations may include, but not be limited to, review of other geotechnical reports prepared for the adjacent areas, site reconnaissance, and additional exploration and laboratory testing.

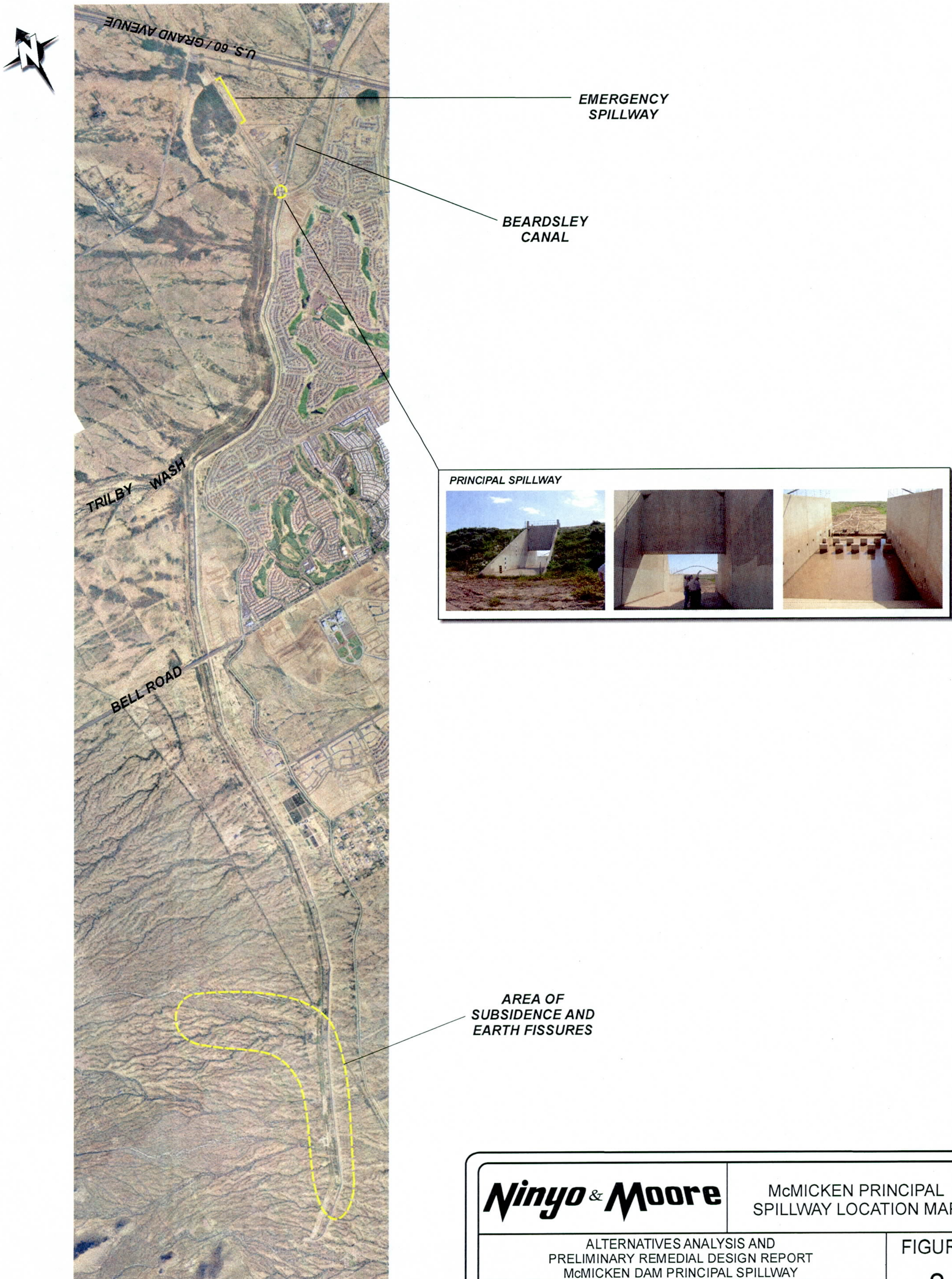


0 50,000

Approximate Scale:
1 inch = 50,000 feet

SOURCE: US Geological Survey 500K topographic map, Phoenix, Arizona, rev. 1981.

Ninyo & Moore		DAM LOCATION MAP
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL DESIGN REPORT McMICKEN DAM PRINCIPAL SPILLWAY		FIGURE 1
PROJECT No: 600996001	FILE No: 996vmap1005	DATE: 11/05



Ninyo & Moore		McMICKEN PRINCIPAL SPILLWAY LOCATION MAP	
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL DESIGN REPORT McMICKEN DAM PRINCIPAL SPILLWAY			FIGURE 2
PROJECT No: 600996001	FILE No: 996arl1005port	DATE: 11/05	

Proposed Alternative Repair / Improvement	1 Extend Center Drain/Filter to P. S. Walls and Continue Downstream as Backdrainage and Outlet	2 Raise Dam Elevation at P.S. (and Raise Bridge)	3 Install Geomembrane on u/s slope	4 Install Inclined Filter on Downsteam Slope	5 Relocate P.S. (Close and Reconstruct new P.S.)	6 Relocate a 2nd P.S. (Additional to existing P.S.)	7 Relocate Beardsley Canal	8 Reconfigure Spillway Chute to Bridge B. Canal	9 Brace / Stiffen Walls	10 Patch or Line Siphon	11 Restore stilling basin backdrains	12 Remove and replace stilling basin backdrains	13 Abandon Existing Drainage System
Type I / II Failure Modes	Reduces to Category IV? (Y/N)												
1 Internal Erosion through near-by cracks	Yes	No	Yes	Yes	Not Analyzed	Not Analyzed	No	No	Not Analyzed	No	Not Analyzed	No	No
2 Seepage along or beneath outside of P.S.channel walls	Yes	No	Yes	No	Not Analyzed	Not Analyzed	No	No	Not Analyzed	No	Not Analyzed	No	No
3 Stilling Basin Drains Fail resulting in failure of channel walls or floor	Yes*	No	No	No	Not Analyzed	Not Analyzed	No	Yes	Not Analyzed	No	Not Analyzed	Yes	No*
4 Overtopping Near P.S.	No	Yes	No	No	Not Analyzed	Not Analyzed	No	No	Not Analyzed	No	Not Analyzed	No	No
Optional Improvements					Not Analyzed	Not Analyzed			Not Analyzed		Not Analyzed		
A Leaking Siphon	N	N	N	N	Not Analyzed	Not Analyzed	Y	Y	Not Analyzed	Y	Not Analyzed	N	N
B Improve Bridge	N	Some	N	N	Not Analyzed	Not Analyzed	N	N	Not Analyzed	N	Not Analyzed	N	N
C Relocate Instrumentation	Some	N	N	N	Not Analyzed	Not Analyzed	N	N	Not Analyzed	N	Not Analyzed	N	N
Other Optional Items or Improvements	Could address wall drains and gives opportunity to inspect backside of wall			Could tie into center filter	Not Analyzed	Not Analyzed			Not Analyzed		Not Analyzed	Anchor Floor Slab	
Level of Design Effort — High					Not Analyzed	Not Analyzed	X	X	Not Analyzed		Not Analyzed		
Level of Design Effort — Moderate	X	X			Not Analyzed	Not Analyzed			Not Analyzed		Not Analyzed		
Level of Design Effort — Low			X	X	Not Analyzed	Not Analyzed			Not Analyzed	X	Not Analyzed	X	X
Any Resulting Major Negative Consequences? (Y/N)	Short vunerability to Flood	May require strengthening walls	Unknown Overlap Length & High Gradients across toe	Unknown Overlap Length & No Drainage Outlet	Not Analyzed	Not Analyzed		Potential aesthetic issues	Not Analyzed		Not Analyzed		Could overstress structure
Estimated Cost	$150K - $250K	$75K - $150K	$75K - $150K	$100K - $200K	2M - 4M	1.5M - 3M	$500K - 1M	$500K - 1M	$250K - $500K	$20K - $50K	$100K - $200K	$100K - $200K	$5K - $10K
Estimate Cost per Failure Mode Addressed					Not Analyzed	Not Analyzed			Not Analyzed		Not Analyzed		
Type of Repair/ Improvement — Interim				X	Not Analyzed	Not Analyzed			Not Analyzed	X	Not Analyzed		
Type of Repair/ Improvement — Long-term	X	X	X		Not Analyzed	Not Analyzed	X	X	Not Analyzed		Not Analyzed	X	X
Notes	* To address PFM, this must be detailed appropriately Must consider uplift on stilling basin floor	If needed, lightweight fill could be considered			Costly, No hydraulic Reason, many downstream issues	Costly, No hydraulic Reason, many downstream issues		Would need to check with MWD to see how it would affect the hydraulics of the canal		May require future maintenance		May abandon sub-floor drain and/or seal beneath weep holes with Low permeable Matierial	Must coordinate with anchoring floor and strengthening walls

Ninyo & Moore

ALTERNATIVES EVALUATION MATRIX

ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL REPORT McMICKEN DAM SPILLWAY

FIGURE 3

PROJECT No: 600996001 | FILE No: 996matrix1005 | DATE: 11/05

IMPROVE CENTER AND WALL DRAINS

Item	Description	Unit	Estimated Unit Cost	Approximate Amount	Estimated Cost ($)
A	Clear and Grub	SY	$ 3.00	500	$ 1,500.00
B	Excavation of bench	CY	$ 20.00	200	$ 4,000.00
C	Excavation of trenches	LF	$ 150.00	300	$ 45,000.00
D	Disposal of Trench Spoils	CY	$ 5.00	1000	$ 5,000.00
E	Backfill with Select Filter Material	LF	$ 250.00	300	$ 75,000.00
F	Backfill bench with filter zone	CY	$ 50.00	200	$ 10,000.00
G	Tie into existing Filter	Each	$ 2,000.00	2	$ 4,000.00
H	PVC - Installed	LF	$ 60.00	300	$ 18,000.00
I	Destroy Existing Drainage System	Each	$ 2,000.00	2	$ 4,000.00
J	Connect PVC to Weeps	Each	$ 1,500.00	2	$ 3,000.00
K	Final Grading	SY	$ 8.00	500	$ 4,000.00
L	Erosion Protection	SY	$ 20.00	550	$ 11,000.00
				Task Subtotal	$ 184,500.00

TIE DOWN ANCHORS

Item	Description	Unit	Estimated Unit Cost	Approximate Amount	Estimated Cost ($)
A	Coring	Each	$ 750.00	10	$ 7,500.00
B	Anchor Installation	Each	$ 4,000.00	10	$ 40,000.00
C	Tie into Stilling Basin Slab	Each	$ 1,500.00	10	$ 15,000.00
D	Concrete Finishing	SY	$ 15.00	500	$ 7,500.00
				Task Subtotal	$ 70,000.00

RESTORE CREST ELEVATION

Item	Description	Unit	Estimated Unit Cost	Approximate Amount	Estimated Cost ($)
A	Bridge	Each	$ 7,500.00	1	$ 7,500.00
B	Bridge Installation	Each	$ 4,000.00	1	$ 4,000.00
C	Fill placement and Grading	CY	$ 40.00	200	$ 8,000.00
				Task Subtotal	$ 19,500.00

PATCH and LINE SIPHON

Item	Description	Unit	Estimated Unit Cost	Approximate Amount	Estimated Cost ($)
A	Patch Concrete	SF	$ 5.00	1500	$ 7,500.00
B	Apply Water Seal	SF	$ 7.00	1500	$ 10,500.00
C	Apply Elastic Polymer to Joints	LF	$ 10.00	100	$ 1,000.00
				Task Subtotal	$ 19,000.00

RELOCATE INSTRUMENTATION

Item	Description	Unit	Estimated Unit Cost	Approximate Amount	Estimated Cost ($)
A	Extend Line	LF	$ 25.00	100	$ 2,500.00
B	Install Transducer	Each	$ 2,500.00	1	$ 2,500.00
C	Radar to locate Spot	Each	$ 2,000.00	1	$ 2,000.00
D	Core Wall	Each	$ 750.00	1	$ 750.00
E	Install Flexible Membrane	Each	$ 1,500.00	1	$ 1,500.00
F	Test Program	Each	$ 2,500.00	1	$ 2,500.00
				Task Subtotal	$ 11,750.00

MOBILIZATION & PERMITS

Item	Description	Unit	Estimated Unit Cost	Approximate Amount	Estimated Cost ($)
A	Mobilization	Each	$ 5,000.00	2	$ 10,000.00
B	Environmental Permits (Incl. Prep)	Each	$ 5,000.00	1	$ 5,000.00
C	ADWR Permits (Incl. Prep)	Each	$ 5,000.00	1	$ 5,000.00
D	Permit close-out	Each	$ 2,000.00	1	$ 2,000.00
E	District Permits / Update as-builts	Each	$ 3,000.00	1	$ 3,000.00
				Task Subtotal	$ 25,000.00

DESIGN / ENGINEERING

Item	Description	Unit	Estimated Unit Cost	Approximate Amount	Estimated Cost ($)
A	Review and Compile Information	Hrs	$ 100.00	40	$ 4,000.00
B	Update Topo & Structure Survey	Hrs	$ 80.00	100	$ 8,000.00
C	30% Design	Hrs	$ 100.00	80	$ 8,000.00
D	60% Design	Hrs	$ 100.00	60	$ 6,000.00
E	90% Design	Hrs	$ 100.00	80	$ 8,000.00
F	100% Design	Hrs	$ 100.00	40	$ 4,000.00
G	Specifications	Hrs	$ 100.00	80	$ 8,000.00
H	CQA plan	Hrs	$ 100.00	50	$ 5,000.00
I	QA during Construction	Hrs	$ 65.00	550	$ 35,750.00
				Task Subtotal	$ 86,750.00

Construction Subtotal	$ 329,750.00
Design Subtotal	$ 86,750.00
Contengincy (20%)	$ 83,300.00
Total	**$ 499,800.00**

Ninyo & Moore

McMICKEN PRINCIPAL SPILLWAY COST ESTIMATE

ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL DESIGN REPORT McMICKEN DAM PRINCIPAL SPILLWAY

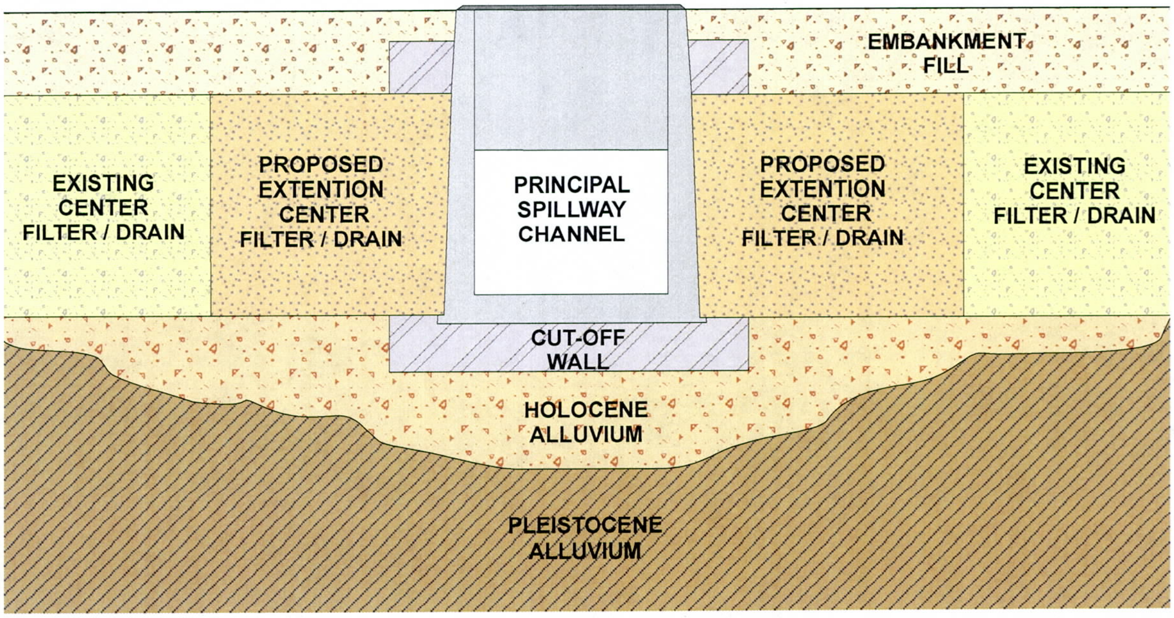
FIGURE 4

PROJECT No:	FILE No:	DATE:
600996001	996tbl1105	11/05

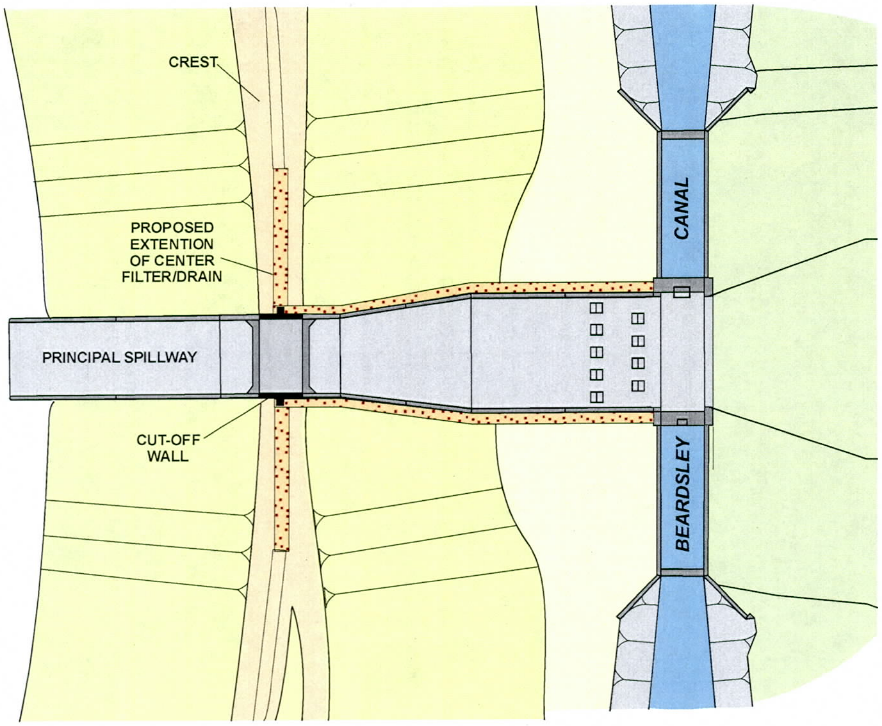
APPENDIX A

DEPICTIONS OF PROPOSED ALTERNATIVES

CENTER FILTER/DRAIN



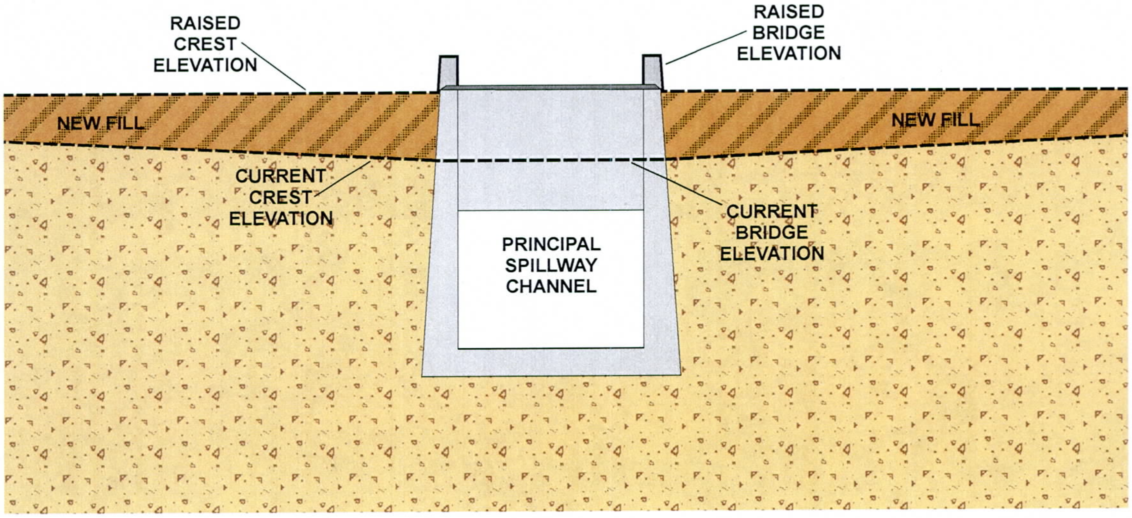
CROSS-SECTIONAL VIEW

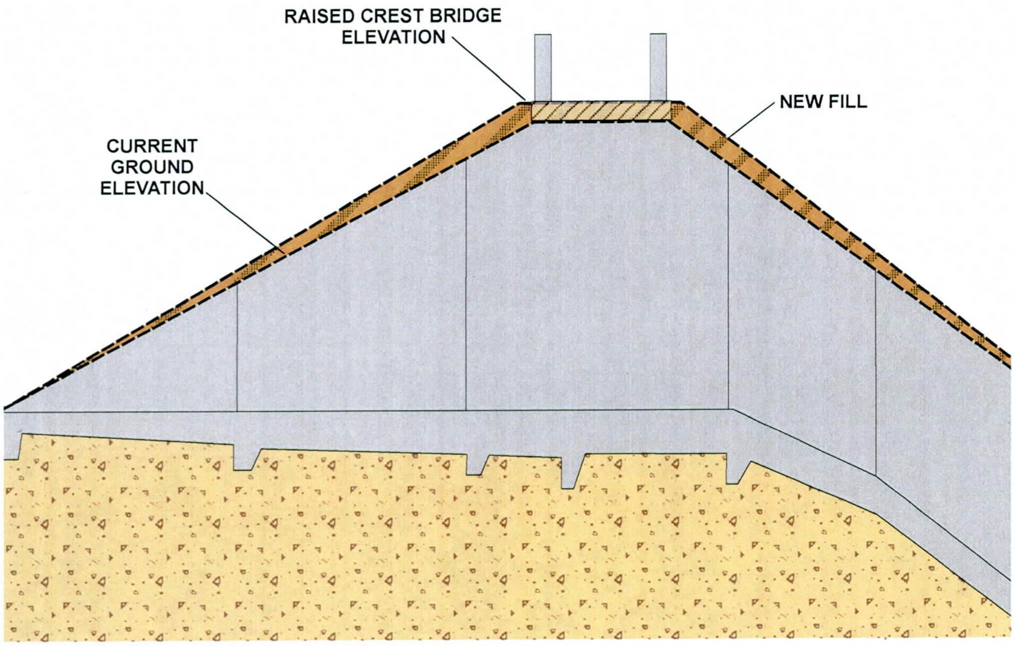


NOT TO SCALE

Ninyo & Moore	CENTER FILTER/DRAIN	
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL REPORT McMICKEN DAM SPILLWAY		FIGURE A-1
PROJECT No: 600996001	FILE No: PosterA1	DATE: 11/05

RAISE CREST ELEVATION

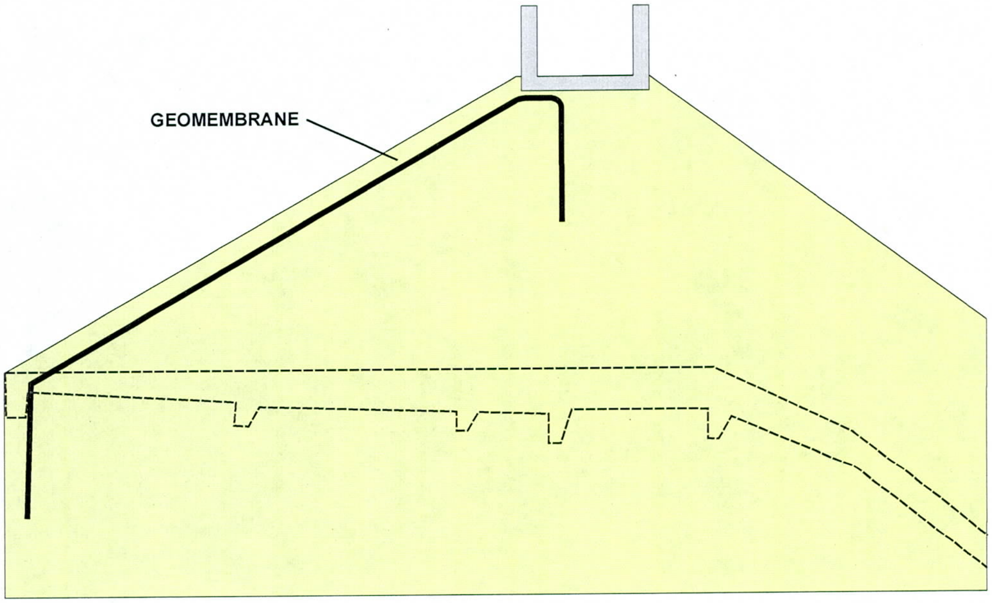


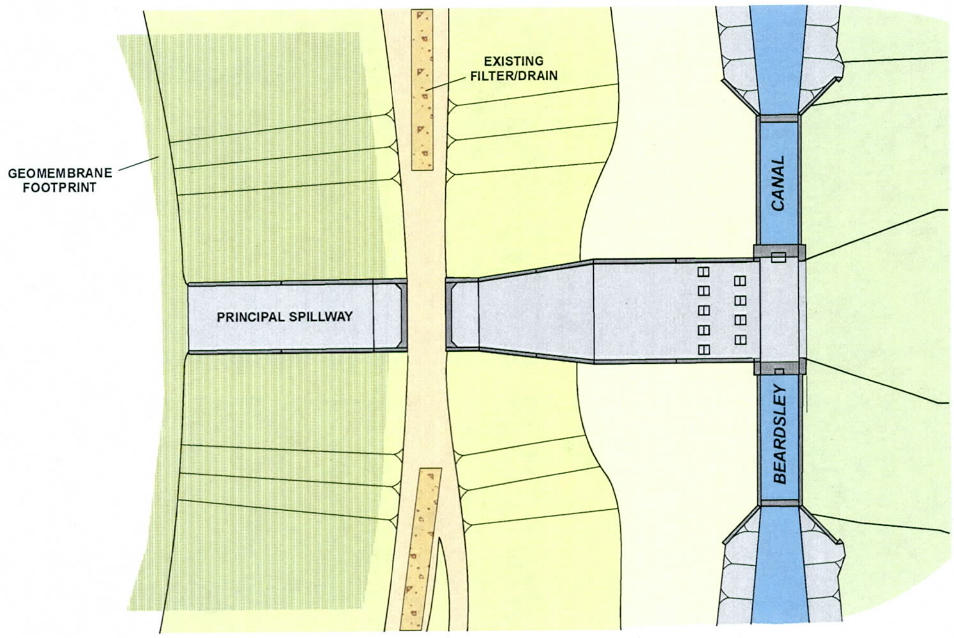


NOT TO SCALE

Ninyo & Moore	RAISE CREST ELEVATION		
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL REPORT McMICKEN DAM SPILLWAY			FIGURE A-2
PROJECT No: 600996001	FILE No: PosterA4	DATE: 11/05	

INSTALL GEOMEMBRANE

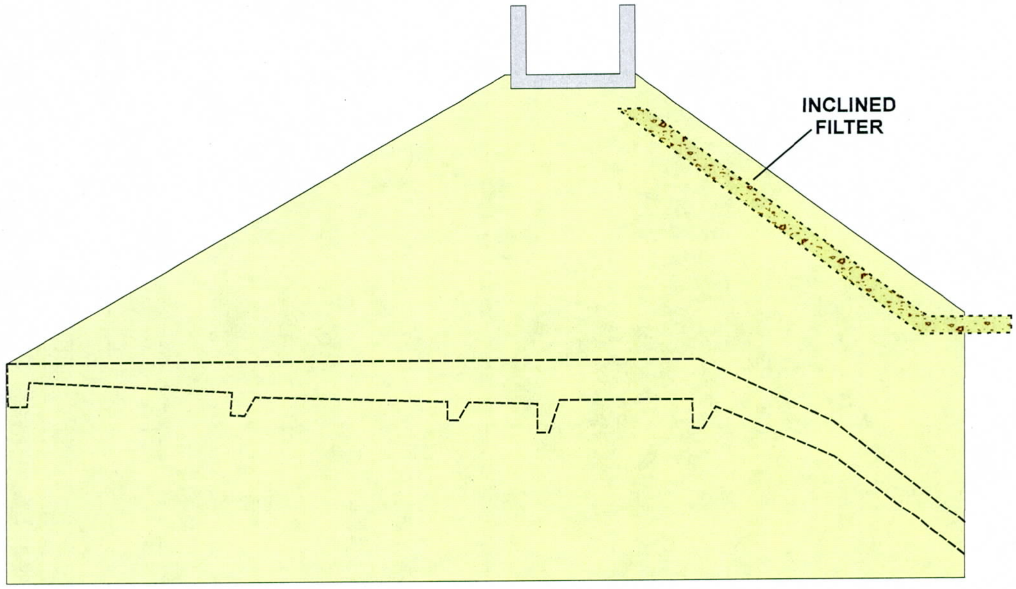


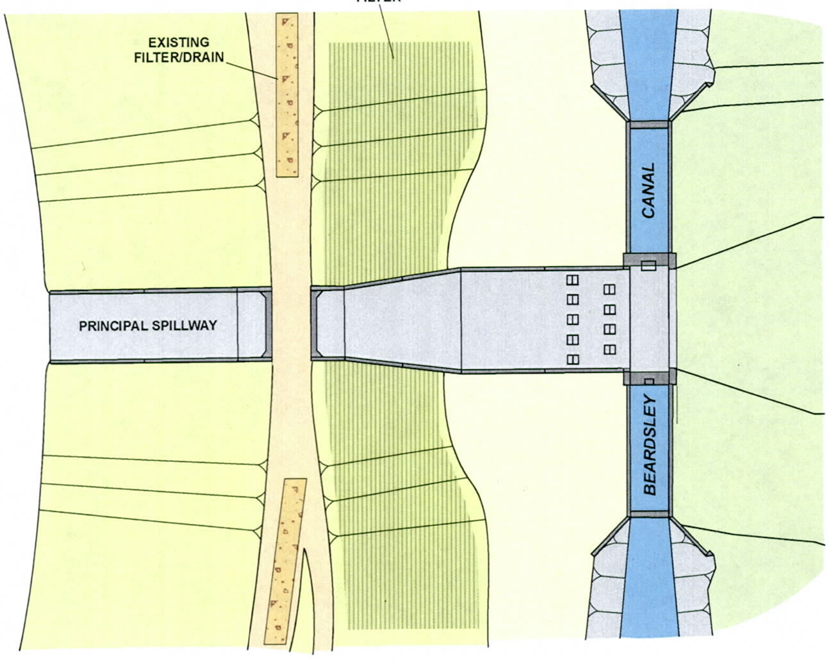


NOT TO SCALE

Ninyo & Moore	GEOMEMBRANE		
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL REPORT McMICKEN DAM SPILLWAY			FIGURE A-3
PROJECT No: 600996001	FILE No: PosterA2	DATE: 11/05	

INSTALL INCLINED FILTER ON DOWNSTREAM SLOPE





NOT TO SCALE

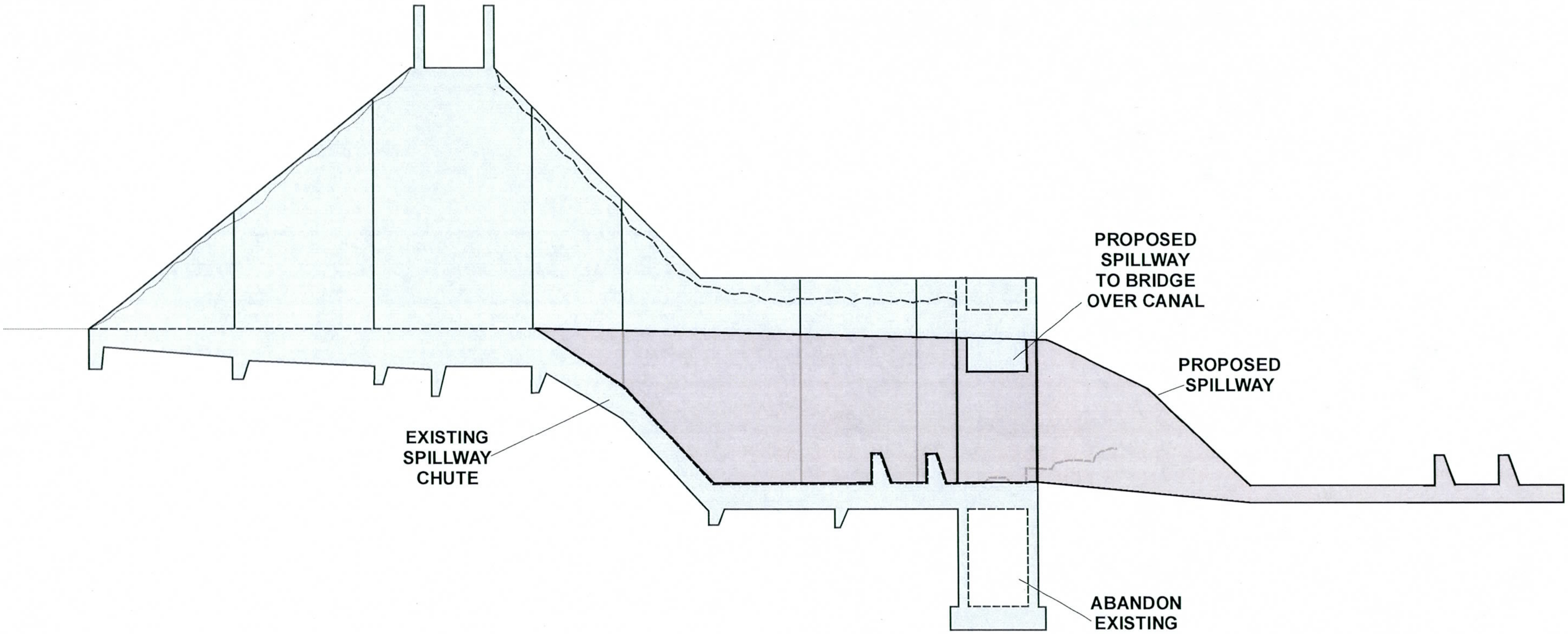
Ninyo & Moore	INSTALL INCLINED FILTER ON DOWNSTREAM SLOPE		
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL REPORT McMICKEN DAM SPILLWAY			FIGURE A-4
PROJECT No: 600996001	FILE No: PosterA3	DATE: 11/05	

REALIGN BEARDSLEY CANAL

NOT TO SCALE

Ninyo & Moore	REALIGN BEARDSLEY CANAL	
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL REPORT McMICKEN DAM SPILLWAY		FIGURE A-5
PROJECT No: 600996001	FILE No: PosterA7	DATE: 11/05

RECONFIGURE SPILLWAY CHUTE



NOT TO SCALE

Ninyo & Moore	RECONFIGURE SPILLWAY CHUTE		
ALTERNATIVES ANALYSIS AND PRELIMINARY REMEDIAL DESIGN REPORT McMICKEN DAM SPILLWAY			FIGURE A-6
PROJECT No: 600996001	FILE No: PosterA8	DATE: 11/05	

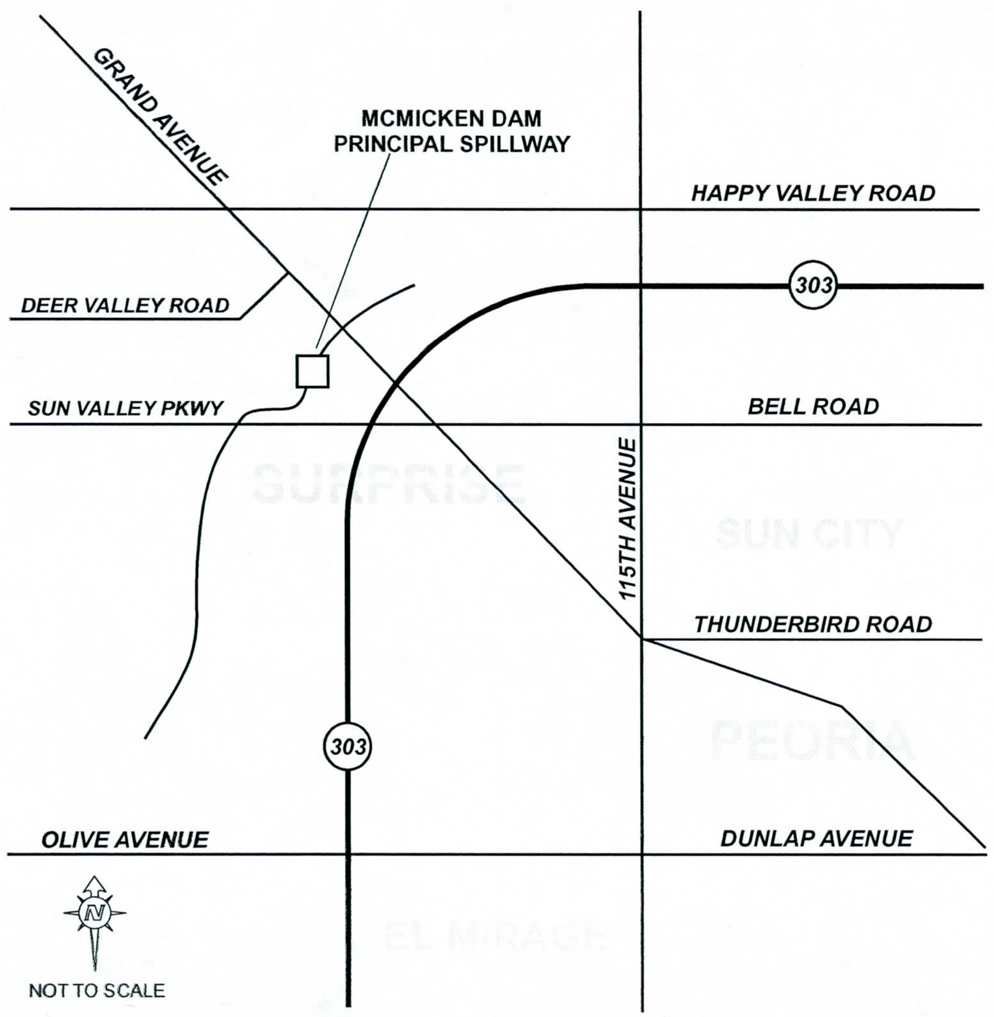
APPENDIX B

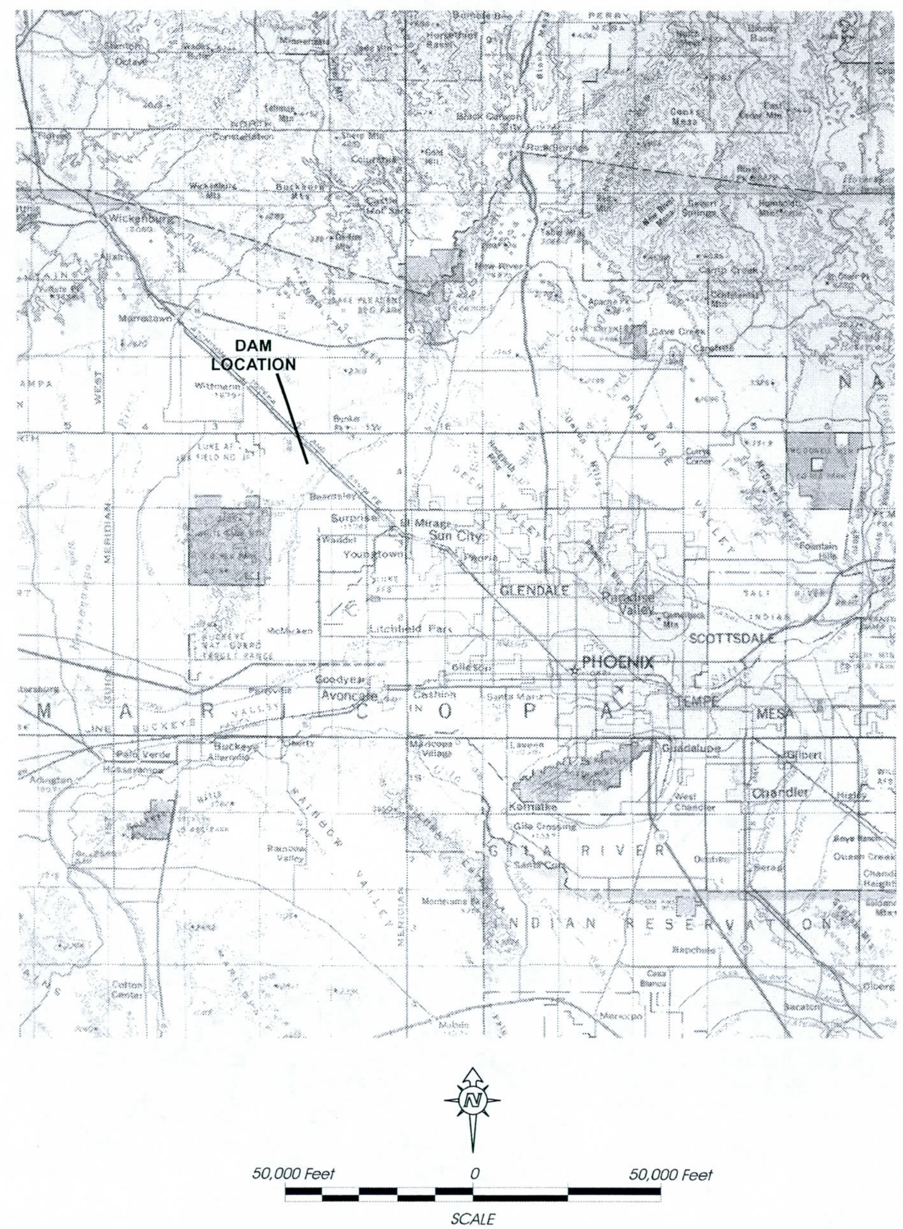
PRELIMINARY DESIGN DRAWINGS

PRELIMINARY DESIGN DRAWINGS
FOR
MCMICKEN DAM PRINCIPAL SPILLWAY
MARICOPA COUNTY, ARIZONA

GENERAL NOTES

1. Elevations are based on NAVD 1988.





SOURCE: U.S.G.S 500k Series Topographic Map, Surprise, Arizona, rev. 1981.

Ninyo & Moore

NO.	REVISION	BY	DATE
3			
2			
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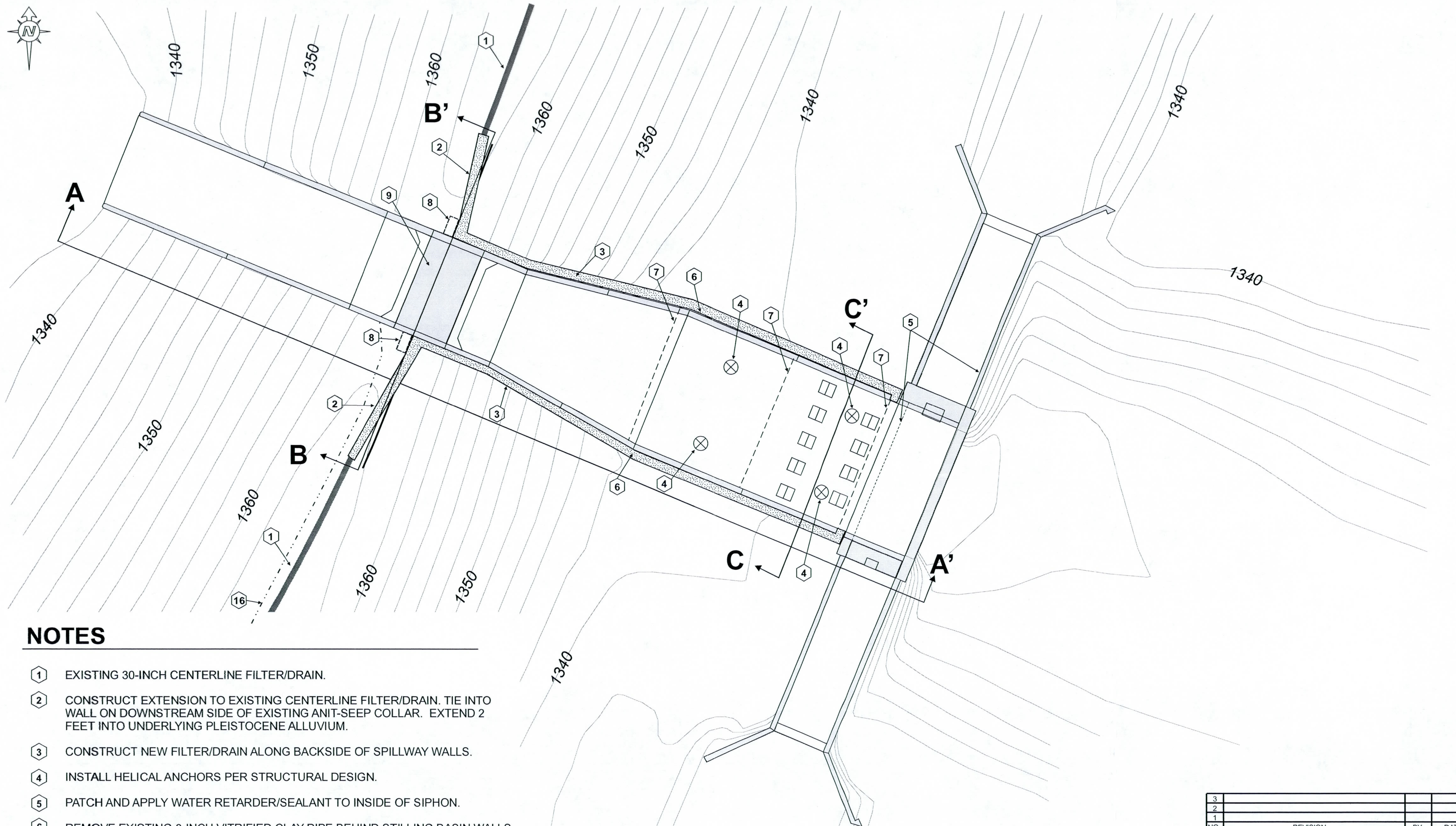
FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY
ENGINEERING DIVISION

MCMICKEN DAM PRINCIPAL SPILLWAY
MARICOPA COUNTY, ARIZONA

		BY	DATE
PRELIMINARY NOT FOR CONSTRUCTION	DESIGNED	ATM	11/05
	DRAWN	BSM	11/05
	CHECKED	JRD	11/05
DRAWING NO.	GENERAL NOTES		SHEET 1 OF 5



NOTES

1. EXISTING 30-INCH CENTERLINE FILTER/DRAIN.
2. CONSTRUCT EXTENSION TO EXISTING CENTERLINE FILTER/DRAIN. TIE INTO WALL ON DOWNSTREAM SIDE OF EXISTING ANIT-SEEP COLLAR. EXTEND 2 FEET INTO UNDERLYING PLEISTOCENE ALLUVIUM.
3. CONSTRUCT NEW FILTER/DRAIN ALONG BACKSIDE OF SPILLWAY WALLS.
4. INSTALL HELICAL ANCHORS PER STRUCTURAL DESIGN.
5. PATCH AND APPLY WATER RETARDER/SEALANT TO INSIDE OF SIPHON.
6. REMOVE EXISTING 8-INCH VITRIFIED CLAY PIPE BEHIND STILLING BASIN WALLS.
7. ABANDON EXISTING 8-INCH VITRIFIED CLAY PIPE BENEATH STILLING BASIN FLOORS BY FILLING WITH NON-PRESSURIZED GROUT.
8. EXISTING 4-FOOT ANTI-SEEP COLLAR.
9. RAISE BRIDGE AND ADJACENT CREST ELEVATION TO 1,363 FEET MSL (NAVD88).
16. (OPTIONAL) RELOCATE PRESSURE TRANSDUCER TO PRINCIPAL SPILLWAY.

Ninyo & Moore

NO.	REVISION	BY	DATE
3			
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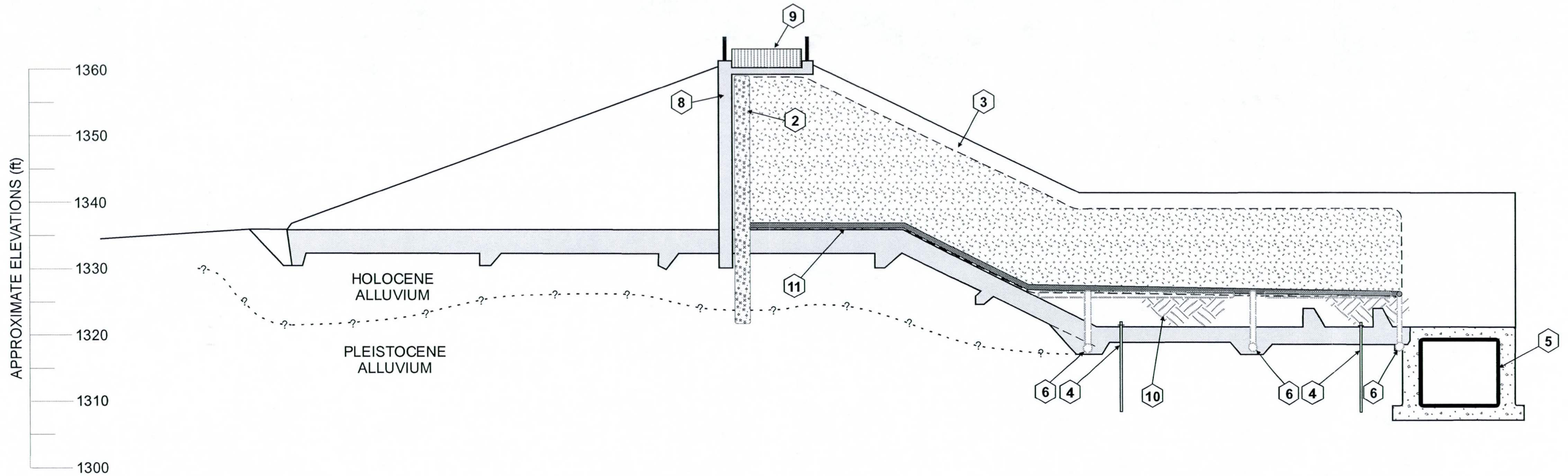
FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
ENGINEERING DIVISION

MCMICKEN DAM PRINCIPAL SPILLWAY
MARICOPA COUNTY, ARIZONA

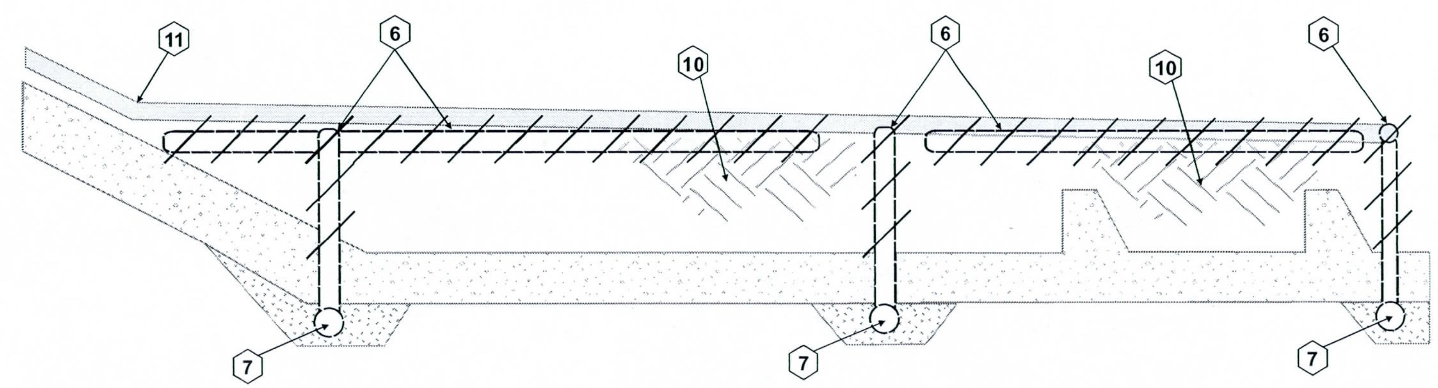
PRELIMINARY NOT FOR CONSTRUCTION		BY	DATE
	DESIGNED	ATM	11/05
	DRAWN	BSM	11/05
	CHECKED	JRD	11/05

DRAWING NO.	PRINCIPAL SPILLWAY IMPROVEMENTS	SHEET 2 OF 5



DRAIN PIPE DETAIL

NOT TO SCALE



NOTES

(2) CONSTRUCT EXTENSION TO EXISTING CENTERLINE FILTER/DRAIN. TIE INTO WALL ON DOWNSTREAM SIDE OF EXISTING ANIT-SEEP COLLAR. EXTEND 2 FEET INTO UNDERLYING PLEISTOCENE ALLUVIUM.

(3) CONSTRUCT NEW FILTER/DRAIN ALONG BACKSIDE OF SPILLWAY WALLS.

(4) INSTALL HELICAL ANCHORS PER STRUCTURAL DESIGN.

(5) PATCH AND APPLY WATER RETARDER/SEALANT TO INSIDE OF SIPHON.

(6) REMOVE EXISTING 8-INCH VITRIFIED CLAY PIPE BEHIND STILLING BASIN WALLS.

(7) ABANDON EXISTING 8-INCH VITRIFIED CLAY PIPE BENEATH STILLING BASIN FLOORS BY FILLING WITH NON-PRESSURIZED GROUT.

(8) EXISTING 4-FOOT ANTI-SEEP COLLAR.

(9) RAISE BRIDGE AND ADJACENT CREST ELEVATION TO 1,363 FEET MSL (NAVD88).

(10) PLACE LOW PERMEABLE MATERIAL BENEATH DRAIN PIPE.

(11) INSTALL PERFORATED PVC COLLECTOR PIPE.

20' 0 10' 20'

SCALE

Ninyo & Moore

NO.	REVISION	BY	DATE
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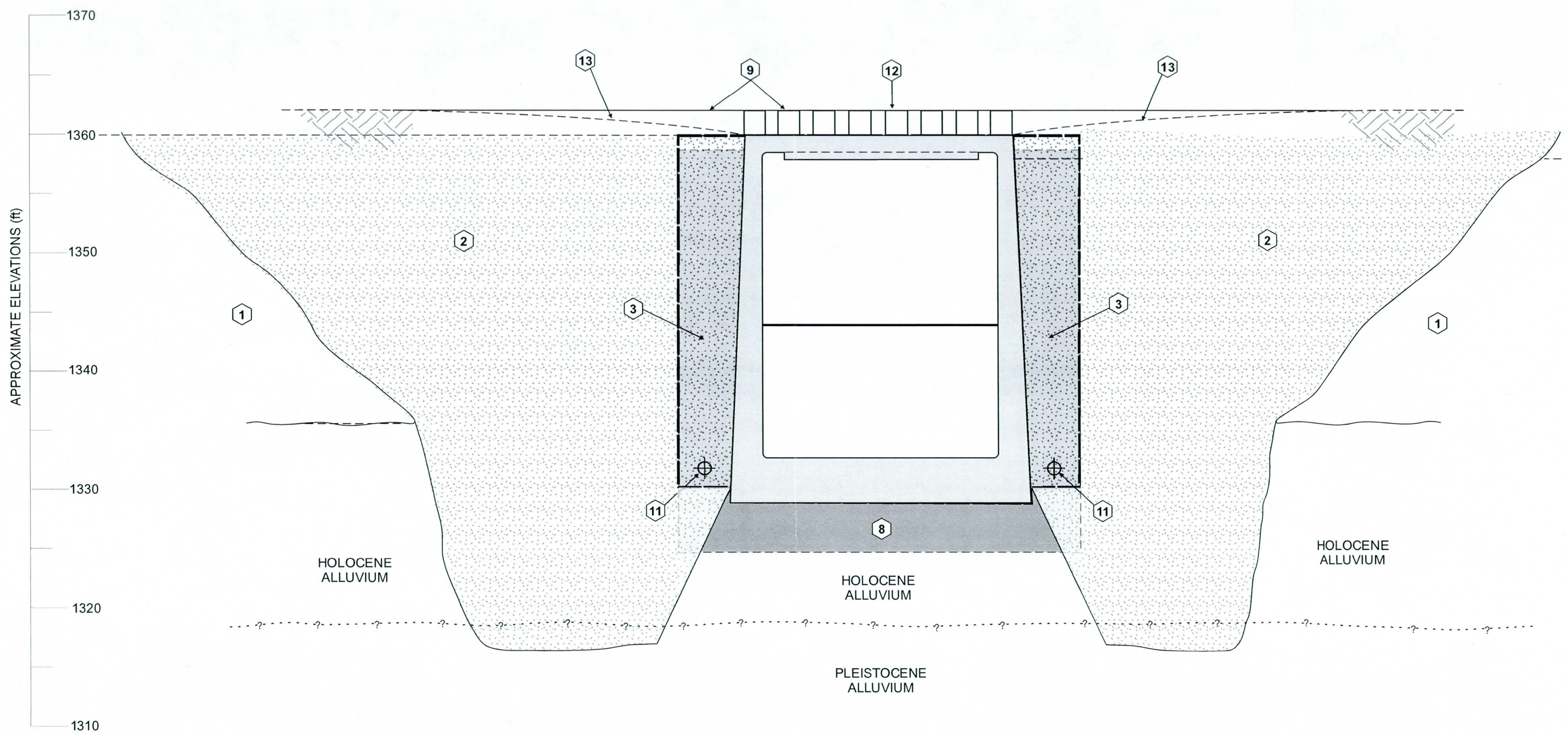
FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY
ENGINEERING DIVISION

MCMICKEN DAM PRINCIPAL SPILLWAY
MARICOPA COUNTY, ARIZONA

PRELIMINARY NOT FOR CONSTRUCTION		BY	DATE
	DESIGNED	ATM	11/05
	DRAWN	BSM	11/05
	CHECKED	JRD	11/05

DRAWING NO.	SECTION A - A'	SHEET 3 OF 5



NOTES

(1) EXISTING 30-INCH CENTERLINE FILTER/DRAIN.

(2) CONSTRUCT EXTENSION TO EXISTING CENTERLINE FILTER/DRAIN. TIE INTO WALL ON DOWNSTREAM SIDE OF EXISTING ANIT-SEEP COLLAR. EXTEND 2 FEET INTO UNDERLYING PLEISTOCENE ALLUVIUM.

(3) CONSTRUCT NEW FILTER/DRAIN ALONG BACKSIDE OF SPILLWAY WALLS.

(8) EXISTING 4-FOOT ANTI-SEEP COLLAR.

(9) RAISE BRIDGE AND ADJACENT CREST ELEVATION TO 1,363 FEET MSL (NAVD88).

(11) INSTALL PERFORATED PVC COLLECTOR PIPE.

(12) INSTALL LIGHTWEIGHT/COMPOSITE BRIDGE DECK WITH DECK SURFACE AT 1,361 FEET MSL (NAVD88). SECURELY FASTEN NEW BRIDGE DECK TO EXISTING BRIDGE DECK.

(13) EXISTING CREST ELEVATION.

10' 0 5' 10'
SCALE

Ninyo & Moore

NO.	REVISION	BY	DATE
3			
2			
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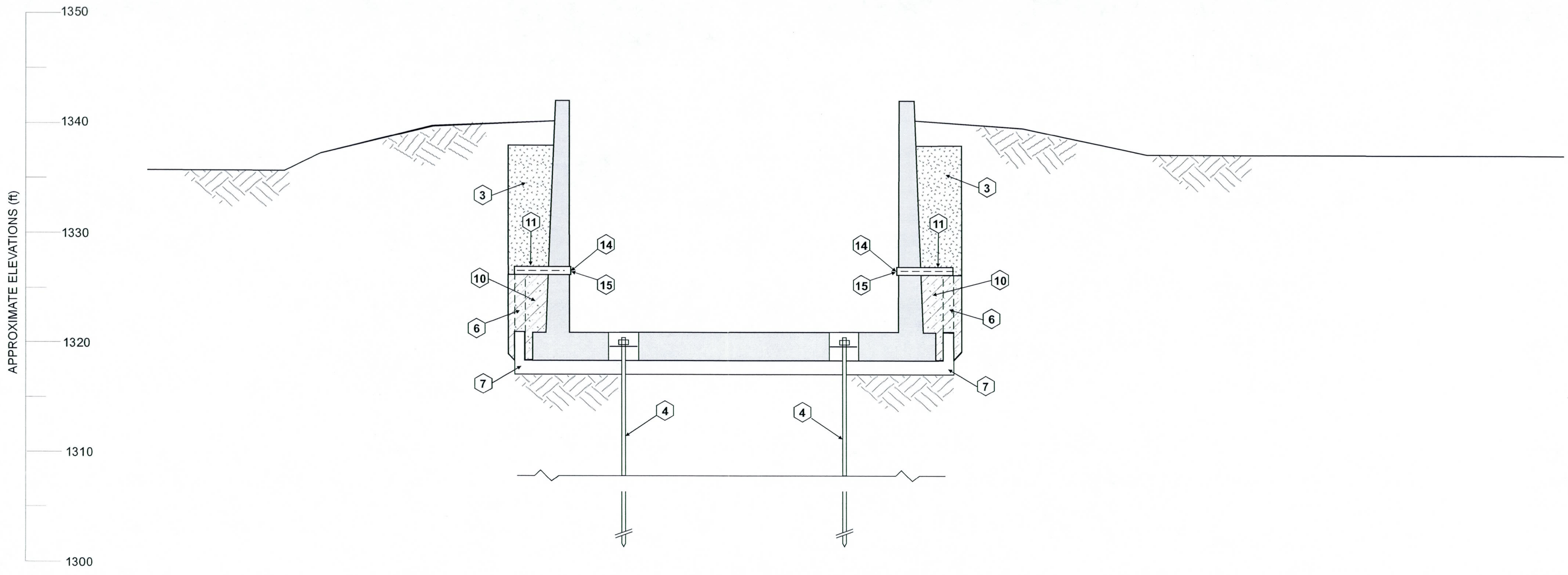
FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY
ENGINEERING DIVISION

MCMICKEN DAM PRINCIPAL SPILLWAY
MARICOPA COUNTY, ARIZONA

PRELIMINARY NOT FOR CONSTRUCTION		BY	DATE
	DESIGNED	ATM	11/05
	DRAWN	BSM	11/05
	CHECKED	JRD	11/05
DRAWING NO.	SECTION B - B'		SHEET 4 OF 5



NOTES

3. CONSTRUCT NEW FILTER/DRAIN ALONG BACKSIDE OF SPILLWAY WALLS.
4. INSTALL HELICAL ANCHORS PER STRUCTURAL DESIGN.
6. REMOVE EXISTING 8-INCH VITRIFIED CLAY PIPE BEHIND STILLING BASIN WALLS.
7. ABANDON EXISTING 8-INCH VITRIFIED CLAY PIPE BENEATH STILLING BASIN FLOORS BY FILLING WITH NON-PRESSURIZED GROUT.
10. PLACE LOW PERMEABLE MATERIAL BENEATH DRAIN PIPE.
11. INSTALL PERFORATED PVC COLLECTOR PIPE.
14. PLUG WEEP HOLES EXCEPT EASTERN MOST ON NORTH AND SOUTH WALLS.
15. INSTALL ONE-WAY VALVE ON EASTERN MOST WEEP HOLES ON NORTH AND SOUTH WALLS.

10' 0 5' 10'
SCALE

Ninyo & Moore

NO.	REVISION	BY	DATE
3			
2			
1			

FLOOD CONTROL DISTRICT
OF MARICOPA COUNTY
ENGINEERING DIVISION

MCMICKEN DAM PRINCIPAL SPILLWAY
MARICOPA COUNTY, ARIZONA

PRELIMINARY NOT FOR CONSTRUCTION		BY	DATE
	DESIGNED	ATM	11/05
	DRAWN	BSM	11/05
	CHECKED	JRD	11/05
DRAWING NO.	SECTION C - C'		SHEET 5 OF 5