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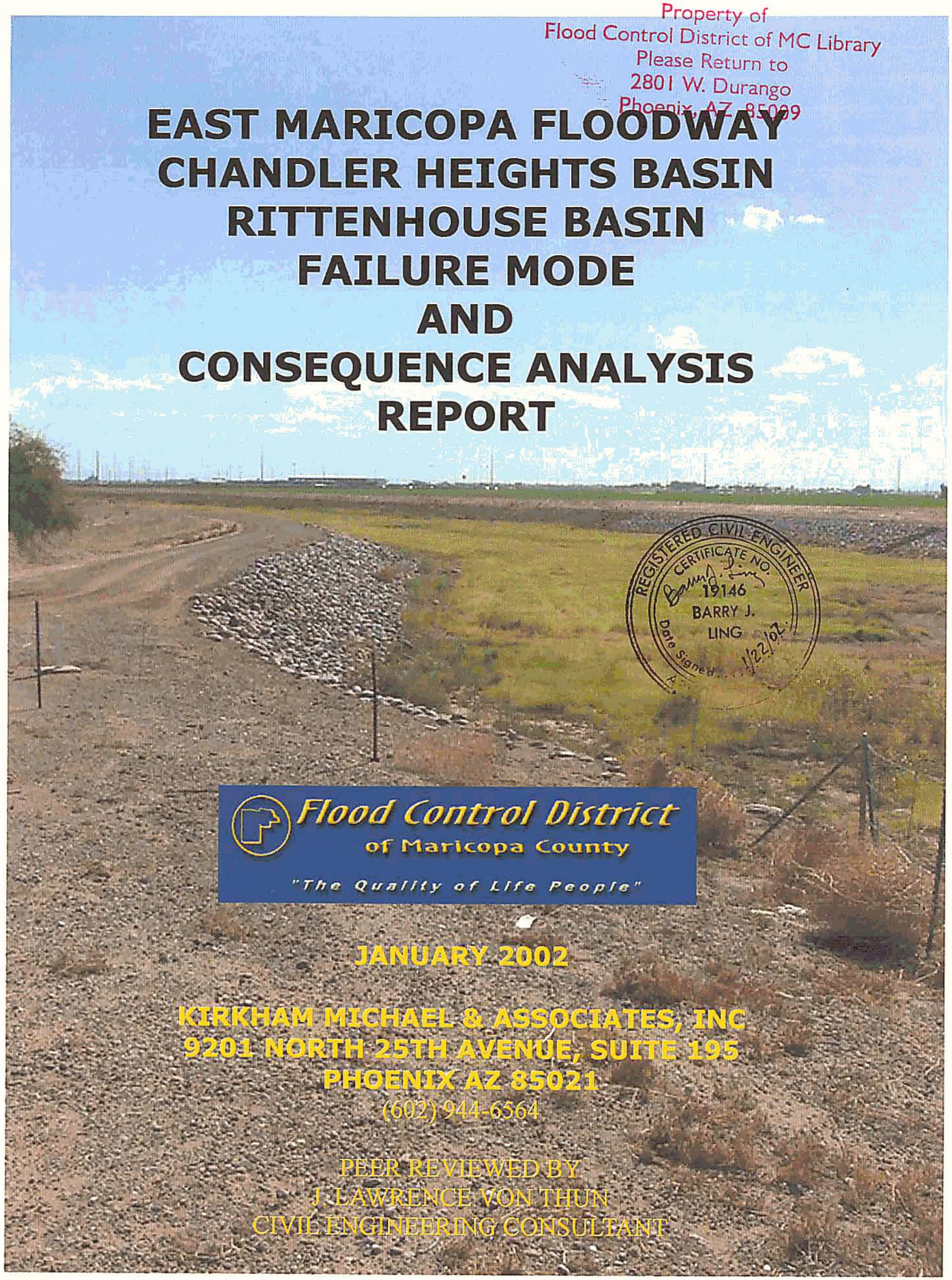

EAST MARICOPA FLOODWAY
CHANDLER HEIGHTS BASIN
RITTENHOUSE BASIN
FAILURE MODE
AND
CONSEQUENCE ANALYSIS
REPORT

REGISTERED CIVIL ENGINEER
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Date Signed 1/22/02

Flood Control District
of Maricopa County
"The Quality of Life People"

JANUARY 2002

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EAST MARICOPA FLOODWAY
RITTENHOUSE BASIN
CHANDLER HEIGHTS BASIN
FAILURE MODE and CONSEQUENCE ANALYSIS REPORT

Prepared For:

Flood Control District
Of
Maricopa County

January 11, 2001

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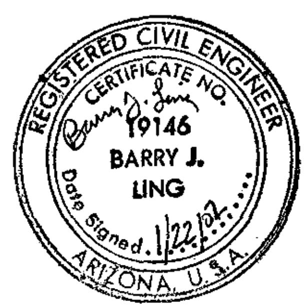

EAST MARICOPA FLOODWAY
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I. EXECUTIVE SUMMARY

The following items are recommendations for further action based on the discussions presented in this report:

The resulting freeboard in the basin designs is more than is required for wind and wave action, since the freeboard is controlled by hydraulic factors that affect bottom depth and water storage elevation.

The alternatives are to:

(a) Consider raising the basin bottoms, resulting in lower freeboards in the basins for the design storm. Also, design the emergency spillways to maximize the utilization of the freeboard for events greater than the design storm.

(b) Maintain the depths and freeboard as designed, taking advantage of its multiple benefits in reducing risks and uncertainties including the:

- Potential to handle larger design storms (e.g. perhaps 200 year event or greater)
- Potential to handle different types of hydrologic events than planned or in design (multiple storm events, different timing of inflows than considered in design).
- Effects of the high sensitivity of the weirs in acceptance of flow rate and quantity
- Effects of potential differential subsidence or tilt

Adequate freeboard should be provided in the Queen Creek Channel where the levees border adjacent residential neighborhoods. The Flood Control District (FCD) and National Resource Conservation Service (NRCS) criteria should be used.

Geomembranes or filters are considered advisable between the channels and the basins and between the basins and outlying areas, especially in the areas where premature failure could result in third party property damage, and secondarily in areas where the District would incur repair costs.

This is of concern where adjacent lands are lower than the top of the basin or channel embankment or levee.

An alternative that could be considered is widening the levees, which does not eliminate the potential failure modes, but reduces their likelihood of occurrence. If the levees are widened to 50 feet or so for aesthetics the membranes may not be required except in cases such as Rittenhouse Channel and Queen Creek where the channel bottom elevations are significantly higher than the basin bottom elevations.

More borings are needed to verify the elevations of the Holocene soils in the sideweir locations to assist in a design that would remove such soil and replace it by an engineered fill.

Existing levees adjacent to the residential neighborhoods in the Chandler Heights Basin need to be reconstructed using engineered fills.

These fills need to be addressed in the final geotechnical report.

Additional investigations are needed along a portion of the NRCS levee at the Chandler Heights Basin site adjacent to the sedimentation basin to determine what construction modifications may be needed to meet the new design functions.

A system is needed for monitoring future subsidence in the Chandler Heights Basin.

ASU should be contacted to see if they would include the basin in their research grant project on radar interferometry.

Trash racks must include protection against floating debris in the sedimentation basin outlet at Chandler Heights Basin.

Sustained attention should be given in conjunction with the basin development to developing and maintaining an access-operation plan and warning system related to persons and property.

The warning system should identify conditions when flood flows are being carried in the contributory channels regardless of whether any flows are projected to enter the basins.

II. INTRODUCTION

The East Maricopa Floodway (EMF) was constructed by the NRCS (then the Soil Conservation Service) in the 1980s. Its capacity is to be enhanced by the development of two basins for temporary storage that are designed to be utilized for floods exceeding 1 in 10 year events and to control discharges to acceptable capacity in the EMF through a 1 in 100 year event.

The embankments and levees forming the proposed Rittenhouse and Chandler Heights Basins and separating the basins from the East Maricopa Floodway, the Rittenhouse Channel, the Queen Creek channel, and Sanokai Wash are to be constructed by leaving in place unexcavated natural earth formations in order to avoid costly excavation and reconstruction of engineered levees and embankments. Most of these would be embankments, which don't extend above the adjacent land outside the basin or channel. But in some locations along Queen Creek and in the Chandler Heights Basin levees will result whose tops will be higher than adjacent land outside the channel or basin. The design team of Kirkham Michael was concerned whether an approach to reduce the potential for various types of failures might be unnecessarily expensive, if only to provide a level of protection against risk. The Kirkham Michael team recognized that these decisions must necessarily include considerations of risk as well as proper design, and asked their client, the Flood Control District of Maricopa County, to participate in discussions of the risks so that District personnel could become more familiar with the situations and could better determine acceptable risk levels for their project. The District had assembled a separate team to evaluate risks associated with numerous small dams that the District had inherited from NRCS, and it seemed that the dam assessment team members could help with this new risk assessment. The dam assessment team had adopted a process called Failure Mode and Consequence Analysis (FMCA), and suggested that the same approach could be modified for use with the detention basins.

A Failure Mode and Consequence Analysis is a comprehensive review and discussion by a group of experienced engineers and operations personnel of all available information for a project. The purpose, for a project in the design stage, is to develop an understanding of the potential failure modes and consequences and to use that understanding in the design of the structures and their operation. An FMCA was conducted for the proposed Rittenhouse and Chandler Heights Basins on December 5, 2001. Mr. Larry Von Thun, PE, Consulting Engineer, who viewed the site and reviewed background materials on December 4th, facilitated the FMCA. The other members of the FMCA discussion team are as follows:

- Paul Stears, PE, Project Manager for the District
- David Degerness, Senior Staff Hydrologist for the District
- George Beckwith, PE, Geologist Consultant to the District
- Barry Ling, PE, Kirkham Michael's Project Manager
- David A. Violette, PE, Kirkham Michael's Lead Hydraulic and Civil Engineer
- Charlie Joy, PE, Kirkham Michael's Hydrologic Engineer
- Bob McMichael, PE, Geotechnical Engineering Manager for Ninyo and Moore
- Steve Nowaczyk, PE, Geotechnical Engineer for Ninyo and Moore
- George Lopez-Cepero, PE, Hydrologic Modeling Manager for Primatech, LLC
- Ken Euge, PG, Subsidence Expert from Geological Consultants

The last four persons represent firms that are part of Kirkham Michael's design team and performed project assignments leading to the predesign reports for the two detention basins.

The materials available for review prior to the discussion were the ***East Maricopa Floodway Rittenhouse Basin Predesign Study*** draft report and the ***East Maricopa Floodway Chandler Heights Basin Predesign Study*** draft report. These comprehensive reports included the background information on the project, the hydrologic and geotechnical reports as well as the design plan.

The purpose of this report is to present the findings from the Failure Modes and Consequence Analysis of the planned design and operation of these natural embankments and levees, along with the associated risks and consequences, and to identify possible additional investigations and alternative risk reduction measures.

DESCRIPTION OF BASINS

The proposed basins are the Rittenhouse Basin (RB) and the Chandler Heights Basin (CHB). These are described in detail in the predesign reports. Figure 25 from the Rittenhouse report and Figure 34 from the Chandler Heights report are included in the Appendix for reference here. In each case, these figures present the concept plan for the respective basins.

The District will construct the detention basins and their associated flood control features. The Town of Gilbert may construct recharge and/or multiuse facilities in the resulting basins, to be considered in intergovernmental agreements now being discussed between the two agencies. The Roosevelt Water Conservancy District (RWCD) owns the land under the existing Queen Creek channel at Chandler Heights Basin, and has its own plans for incorporating recharge features in that area. Discussions have begun between RWCD and the District to possibly incorporate the RWCD features into the flood control plan.

III. THE FMCA PROCESS

The Failure Mode and Consequences Analysis started with the team members offering potential failure modes for consideration. As these were presented, the group discussed them in order to gain a better understanding of the mode. Various team members offered further detail and insight to the others from their own specialty, or from the work they did on the project.

With a long list of potential failure modes, the members then grouped some together, where though there might be a different cause or driving force the failure mode or type might be similar. This reduced the number of separate modes and resulted in seven specific failure modes for further analysis and another group that were not studied in detail. The seven important failure modes are discussed in the first three subsections of the Potential Failure Modes Categorized section of this report, and the remaining items in the fourth subsection of that section.

The final step had each team member list what that person had learned from the FMCA process as it pertained to this project. The results of this part of the workshop are shown in the Summary of Major Findings section at the end of this report.

IV. POTENTIAL FAILURE MODES CATEGORIZED

After each potential failure mode was proposed, an attempt was made to get a clear understanding of the failure mechanism and process. The team identified reasons why the potential failure mode was and was not likely to develop by pointing out positive factors against its occurrence and adverse factors contributing toward the possibility of its occurrence. After completing the discussion on each failure mode the team then categorized the potential failure mode according to the following scheme:

- Highlighted
- Considered but not highlighted
- Lacking in some information to allow classifying
- Ruled out

Each potential failure mode is grouped in like categories in the write-up below. A more complete description of the category is given first followed by a description of the potential failure mode. The listing of adverse and positive factors for each failure mode follows.

HIGHLIGHTED FAILURE MODES

These are the failure modes considered to be of greatest significance considering load probability, magnitude of consequence, and likelihood of adverse response. A failure mode was considered likely if physical possibility was evident, and conditions and events leading to failure seemed reasonable and credible. These failure modes are highlighted for the attention of the owner and designer and in general would warrant some risk reduction action or further investigation.

Potential Failure Mode #1 – Piping / Seepage Erosion

Piping or seepage is considered to occur through the levee or embankment either into or out of a basin. This could happen with flows in the adjacent EMF and no water stored in the basin, or when water in stored in the basin and flows in the EMF have subsided. The failure mode requires a differential head across the levee or embankment, a deposit of material of a porous nature through which water can easily move, and a developed water flow through it with a high enough velocity to erode material above or below the deposit. The failure mechanism is seepage erosion of silt bordering the gravel flow path. This is not true piping, as a phreatic surface would not be developed. For the failure mode to develop within the short time frame available the path has to be very open and well developed, and further the entry needs to be relatively unrestricted for the path to continue expanding. If the pathway expands to form a cavity, then two consequences are possible.

1. The cavity remains as a defined cavity and the flow passes into or out of the basin much the same (relatively slowly) as it would through the flap gates on the way out of the basin or over the weir on the way into the basin.
2. The cavity collapses and a breach forms across the levee, which would result in a somewhat faster inflow or exit than with the planned facilities.

In the first case the adverse impact is minimal and the main cost is repair. In the second case there is the potential for damage to property within and outside the basin.

Adverse Factors (Likely)

- Scattered gravel layers, encountered in samples as high as about elevation 1,296 feet, were observed within CHB (Sample size is very small when compared to basin size, however)
- Pre-existing utility and trench penetrations are possible in what will become embankments
- Very erodible silts are possibly present above and below the gravels
- Soil strata is potentially found at depths that are likely to cause problems
- People and property will be in the basins and could be subject to flooding

Positive Factors (Not Likely)

- This is a decelerating process generally but could be accelerating if the inflow source is relatively unrestricted (e.g. gravel layer is very wide at inlet and narrows through levee.
- Flooding events are very infrequent
- Both the EMF and the basins will have low hydraulic gradients on the order of 5-10 feet
- Breach flow release is probably small, which will allow time for people to escape since the basins are so large
- The gravel layers are probably above the basin bottom at RB
- Flow velocities would generally not be expected to be high enough to be erosive (see the sedimentation / erosion / deposition chart in the Appendix)

Consequences

- Repair costs are expected to be generally high - especially under weirs
- People must be evacuated from basin areas during or in anticipation of flood events
- The consequences are generally much more significant for leaks from channels to basin or from channel to outside property.
- A danger exists of flooding homes outside the Queen Creek Channel and property outside EMF at CHB since the developed land is lower than the top of the levee.

Potential risk reduction measures

- Monitoring should be done by District maintenance personnel for progressive development of seepage problems or piping
- The design should include a geomembrane, agriculture drain, or other cutoff wall or other means to prevent piping between channel to basin
- A geotechnical engineer should look for gravel layers exposed during construction
- The design team should map gravel layers by doing more borings during design
- An early warning for evacuation of the basin areas should be developed during design
- Wider levees could be used to increase the flow path length

Potential Failure Mode #2 – Cracking

Crack develops due to self-weight settlement, fissuring, or collapse of embankment or basin bottom soils after wetting of basin. This can result in a process of seepage erosion of materials along the crack. If the crack did not self-heal then it would widen as a function of the depth and velocity of the flow. The breach extent would be limited as a function of the differential head, the time it would take the basin to drain or fill, and the rate of widening (erosion resistance of the side wall material). For the case of flow from the basin into the EMF channel the adverse impact is minimal and the main cost is repair. In the other case there is the potential for damage to property within and outside the basin

Adverse Factors (Likely)

- Openings in soils will occur rapidly - process starts immediately
- There are known fissures 1 ¾ miles from CHB, and fissuring is a known problem in many areas
- The collapse potential relatively high – a crack most likely to be longitudinal, but could be transverse
- Problems with the irrigation system may cause inadvertent saturation
- There are wedges of fill in the basin that may be more susceptible to cracking
- Queen Creek may have intentional groundwater recharge, which could cause differential settlement cracking

Positive Factors (Not Likely)

- Currently collapse potential appears low based on results from a few (8-10) tests
- Rebuilt areas would be controlled fills

Consequences

- Same as Potential Failure Mode #1

Potential risk reduction measures

- Prewet basin areas during construction to detect susceptible cracking areas
- The District maintenance personnel should perform ongoing monitoring for potential fissuring development
- During design, specify fill materials and techniques to help avoid cracking
- Add a geomembrane cutoff system to levees and embankments - especially in the areas where flow from the channel into the basin could occur. This is a more positive method to resist this failure mode than installing a filter using an agriculture type drain system because the filter may not be successful as a vertical crack stopper.
- District maintenance personnel should perform frequent inspections after construction
- Develop evacuation procedures for multiuse areas

Potential Failure Mode #7 – Outlet blocked

If a basin outlet gets blocked it could prevent or restrict release of stored water in the basin within the required time frame. This is initially a failure mode only in a technical sense not a physical sense in that the project does not successfully meet its drainage requirements. It becomes potentially a failure mode in a physical sense if the basin is needed again as a result of a subsequent storm prior to its emptying. In such a case the flows down the EMF may not be attenuated as planned.

Adverse Factors (Likely)

- Trash in channels can float in to block outlets
- Plantings can be washed out and move to block outlets
- Manual operation of sluice gates

Positive Factors (Not Likely)

- Regular maintenance by the District is good
- Sluice gates at the basin outlet are a safety valve if the sedimentation basin outlet gets plugged on CHB, because the blocked flows will spill over weir into the basin where they can be released through the gated outlet

Consequences

- Basin may be filled prematurely during an event, resulting in less reduction in EMF flows
- Basin may take longer than 36 hours to drain

Potential risk reduction measures

- Trash racks should be designed to reduce or avoid blocking
- Sed basin outlet will have a log boom or similar to trap floating trash

Potential Failure Mode #5 – Basin settles or subsides

It is possible for the basin to settle or subside under the weir or in levees or embankments. Settlements beneath a weir could cause disruption, cracking, or differential displacement across the top of the weir. The weir displacements could adversely impact the designed flow into the basin. Displacements of the levee or embankment surface would be unlikely to do much more than cause loss of freeboard. This potential failure mode would be a "failure" of the system to function fully as designed but would not (in general) result in adverse consequences other than requirements to repair the weir and/or the levee. (Settlement of the basin itself is possible at CHB but was not considered a failure mode since settlements will be less than six inches)

Adverse Factors (Likely)

- Porous, gravelly Holocene soils are present at both basin locations
- In the RB, Holocene soils are generally above the basin floor and in the levee along the EMF (about 8' below grade)

Positive Factors (Not Likely)

- In the CHB, Holocene soils are generally about 15' below grade
- Outside of weirs or outlet structures some settlement is not likely a problem

Consequences

- Weirs could displace unevenly, causing unpredictable flow patterns

Potential risk reduction measures

- Design a French drain through basin bottoms to handle minor settlement
- Prewet excavated areas in the basins to encourage early settling that can be remedied at that time

- Use vibratory compaction to reduce the potential for settling
- Overexcavate foundations (through the Holocene soil layers) to provide positive foundation at both CHB and RB sideweirs

CONSIDERED, BUT NOT HIGHLIGHTED

These failure modes were considered to be of lesser significance and likelihood than those highlighted. The reasons for the lesser significance are described. Although of lesser significance, risk reduction actions may still be appropriate

Potential Failure Mode #3 – Hydrologic-related

This potential failure mode relates to the ability of the project as it is designed to meet its goals of attenuation / controlling flows in the EMF to specified levels. This could result if:

- Flood flows enter the EMF or the inflow channels at different sequences than the analysis considered,
- If a flood exceeds the design flood
- If back to back floods occur

Adverse Factors (Likely)

- There are EMF channel capacity restrictions upstream of RB which may be reduced in the future, increasing flows downstream
- Discharges from dams upstream could increase inflow
- There is much hydrologic uncertainty in flood sequences and amounts
- A general area-wide storm followed or preceded by a separate localized storm is a realistic possibility and may result in different flows than modeled

Positive Factors (Not Likely)

- The EMF cannot carry much more than 100 year flood to RB area
- New rainfall data being analyzed predicts lower point rainfall rates (but, this data is preliminary and has not been adopted yet)

Consequences

- Flooding of homes could happen due to overtopping at sedimentation basin at CHB and the EMF
- Flooding can occur downstream from flow in the EMF corridor

Potential risk reduction measures

- Modify the basin hydraulics during design to reduce the excess freeboard in the basins
- Raise the sedimentation basin emergency spillway in CHB by ½ foot to 1 foot
- Run the model using full freeboard to determine impacts from higher flows

Potential Failure Mode #4 – Weirs do not function as planned

If the sideweirs do not handle flows as planned it could result in more or less than the design rate and volume of inflow to the basin, which in turn would result in less than optimal control of the flow downstream in the EMF.

Adverse Factors (Likely)

- The sideweir design at RB is very sensitive and the sideweir at Queen Creek channel in CHB is fairly sensitive
- Sideweir performance is sensitive to elevation (settlement of weir could cause a problem)

Positive Factors (Not Likely)

- The presence of freeboard compensates if more flow than intended goes into the basins

Consequences

- Small changes cause large differences in flow into the basins
- Sensitivity in the sideweirs may result in local design goals and effects not being met, though overall flows may increase downstream only by 5 to 10 %.

Potential risk reduction measures

- Design sideweir foundations to prevent settlement and monitor for settlement
- Assess impacts of Queen Creek Recharge Project during design and use this information in design of the sideweir at CHB

MORE INFORMATION NEEDED TO ALLOW CLASSIFICATION

The team members to some degree lacked information about these failure modes to allow a confident judgment on their significance, and thus additional analyses or investigations may be recommended. After this additional information becomes available the failure mode may be moved into one of the other categories.

Potential Failure Mode #6 – Differential subsidence

Differential subsidence (also known as tilt) is a factor in the CHB only, since there are no known fissures in the RB area. The failure mode in this instance is disruption in the design plan as a result of the elevations changing such that weir flows, freeboard allowances, flap gate operation, and spillway discharges could all change.

Adverse Factors (Likely)

- Reports estimate 2 to 4 feet of additional subsidence over the next 20 to 30 year time period, although no recent data is available

Positive Factors (Not Likely)

- Recharge of the groundwater under Queen Creek may help to slow subsidence
- There is a general rise in groundwater table in the area which may also reduce subsidence rates
- Where newer data has been obtained the subsidence rates have been lower.
- Gilbert, Mesa, and Chandler have all been proposing groundwater recharge in the area
- Roosevelt Water Conservancy District is also planning groundwater recharge in the area

Consequences

- The EMF would settle at the north, decreasing hydraulic gradient as it passes by the CHB
- Loss of freeboard on basin would occur if one end settled more than the other

Potential risk reduction measures

- The District should monitor settlement of basin, emergency spillways, and sideweirs on a long-term basis using either GPS or radar interferometry for one mile radius around CHB
- The District can build added freeboard in the future as needed when settlement occurs
- The EMF hydraulics can be revised in the future as needed
- Planned recharge projects may help stabilize general subsidence in the area
- Assess design accommodation

RULED OUT - NOT PHYSICALLY POSSIBLE, EXTREMELY REMOTE, OR VERY LOW CONSEQUENCES.

The following issues or items were brought up as "other considerations", and then discussed and dismissed without itemizing adverse (likely) and positive (unlikely) factors. The team was satisfied that they did not warrant significant design reconsideration. These issues included:

- Inflow weirs becoming obstructed
- District not able to operate manual release gates during an event
- The basin warning system fails (the team did decide to emphasize the need for development of good operation / warning plans related to the use of the basins)
- Terrorist activity – lack of a sustained reservoir places this at low priority for activity of this kind
- Consequences of channel blockage from a levee failure
- Sloughing of embankment or levee faces due to saturation by irrigation piping or rill erosion
- Seismic effects
- Actual future hydrologic conditions are different than those used in the model
- Overtopping failure

V. SUMMARY OF MAJOR FINDINGS

At the conclusion of the session, the participants itemized their own major findings and understandings they thought had been reached via the discussions. The individual findings have been grouped below in areas related to:

- Failure Modes
- Consequences
- Implied Actions – Investigations / Risk Reductions
- General or Apparent Conclusion Reached

In some instances similar or closely related findings and understandings were grouped and additional information was provided to illustrate the context and impact of the finding.

Pertaining to Failure Modes

A. Potential piping / seepage erosion failures or fissure failures could occur through the levee or embankment walls from two different loading conditions.

The first loading condition would be as the water surface elevation in the filled basins exceeds the water surface elevation in the channels. Although this is the primary loading condition, we expected to examine as it relates to the requirement of a reservoir containing water, on reflection turned out to be of lesser importance for three reasons:

1. Water would be present in the basin (loading the levee or embankment walls) less often than it would be in the channels (water only enters the basins when floods exceed the 10-year flood)
2. The differential head between the basin and the channel would be quite small, as the flap gates would begin draining the basin as soon as the water in the channel is lower than the basin level. Thus the differential in the levels remains relatively small.
3. The consequences of a piping or fissure related failure from the basin into the channels is very small during the "draining out phase." Any embankment failures of this type would not be catastrophic and would not represent a significant increase in threat to life and or property. The only foreseeable adverse consequence is the repair of the piping or fissure breach.

The second loading condition in which piping / seepage erosion failures or fissure failures could occur in the levee or embankment walls is when the water surface elevation in the channels exceeds the water surface elevation in the basins. In this case, the protection against a piping or fissure related failure primarily relates to protecting against channel waters entering the basin from the channels during flood events that would not fill the basin, or that would prematurely fill the basin in larger floods.

B. At Chandler Heights Basin, another piping / seepage erosion failure mode exists. There is a potential for a breach of either the EMF or Queen Creek channels to the adjacent areas. This potential failure mode does not strictly relate to the basin performance but it does relate to overall project performance.

C. The freeboard applied to the basin design was based on wind and wave considerations, however it appears that several other factors could be added to freeboard considerations. These include:

1. Potential to handle larger design storms (e.g. perhaps 200-year event or greater)
2. Since the risk from wind and wave erosion appears to be low, the possibility of reducing the available freeboard to reduce project costs and to provide more useable land for resale and aesthetics could be explored.

3. Potential to handle different types of hydrologic events than planned for in design (multiple storm events, different timing of inflows than considered in design).
4. High sensitivity of weir designs to acceptance of flow (rate and quantity)
5. Differential subsidence – see next finding

D. There is a potential for differential subsidence (tilt) in the region of the CHB basin and the tilt potentially affects the flow of the EMF. If the tilt occurs in the manner anticipated, the effect would be a drop in the upstream segments of the EMF with respect to the downstream segments. This would have the effect of lowering the available freeboard in the basin at the upper end and reducing or possibly even reversing the gradient in the EMF. The potential effects on the system could include:

1. Earlier / more often operation of the basin,
2. More head against the levee or embankment than anticipated at the upper end
3. Less total capacity / earlier overtopping of the basin.

E. There are significant geotechnical design / potential failure mode issues, these include:

1. The depth and extent of Holocene soils especially in the area of the foundations of the concrete structures
2. The potential for permeable deposits to exist adjacent to erodible deposits

F. The potential for wetting-induced differential settlement is a significant problem for levees, embankments, and sideweirs

Pertaining to Consequences

G. The two most significant consequences that relate to third parties due to the potential failure modes identified appear to be:

1. Losses in the multiuse area due to damages to parked cars or other private property within the basins
2. Losses to homes outside the Queen Creek / Sanokai Wash channel area and property outside the EMF in the same locale

Providing defense against the failure modes that could lead to these consequences would thus appear to have top priority. Thus membrane protection against flow from the EMF channel into the basin at Rittenhouse and Chandler Heights and of the Queen Creek into the basin and out of the channel to adjacent properties would appear to be highest priority.

H. The two most significant consequences related to the District's operating budget appear to be the cost of repairs resulting from appearance of a levee cavity or breach (even if it did no significant harm) and most significantly damage to a concrete structure from displacing, tilting or cracking

I. The failure modes identified do not appear to result in a rapid rate of failure

Pertaining to Implied Actions – Investigations / Risk Reduction

J. It would be instructive to investigate how the system functions under events greater than 100 years, including evaluating the ability of freeboard available in the channels and basins to handle more remote events.

K. We need to address the geotechnical concerns by:

   1. Further investigations during design
   2. Constructing engineered fills to reconstruct existing levees adjacent to residential areas

L. Review design criteria for possible changes

M. The sideweir foundations should be supported over non-collapsing soils. Therefore, it is recommended to overexcavate existing Holocene soils

N. More information is needed on the depth of the Holocene layers

O. We need to look at emergency spillway elevation and design at both sites

Pertaining to General or Apparent Conclusions Reached

P. A geomembrane filter (cut-off) could potentially address most structural concerns The geomembrane filter appears to be logical for all areas giving a higher degree of confidence against a possible break through of the levee and the resulting need for repair

Q. There is a need for cutoff walls between the basins and the EMF and Queen Creek

R. The unengineered nature of the levees puts us at a disadvantage as compared to an engineered fill

S. Settlement cracks could develop in the levees, which may cause some concern in the park environment

T. The available freeboard may accommodate tilting at the Chandler Heights basin site.

U. Seismic issues are minimal

VI. APPENDIX

Figures from the Predesign Reports showing basin concept plans
Sedimentation / erosion plot

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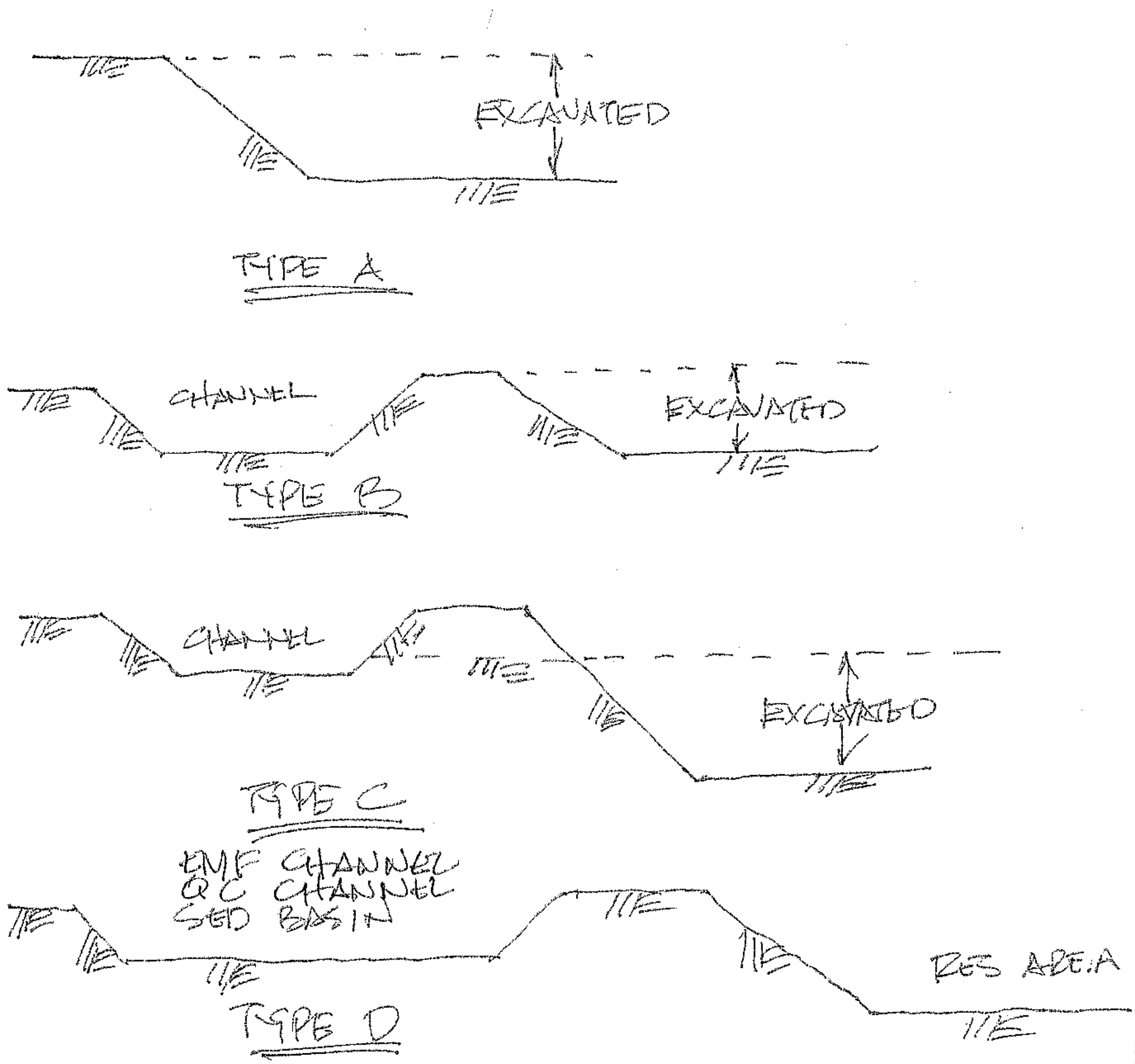
Job number: ____________

Sheet ________ of ________

Project: ______________________________ Date: ____________

Subject: ______________________ Designed: ________ Checked: ________



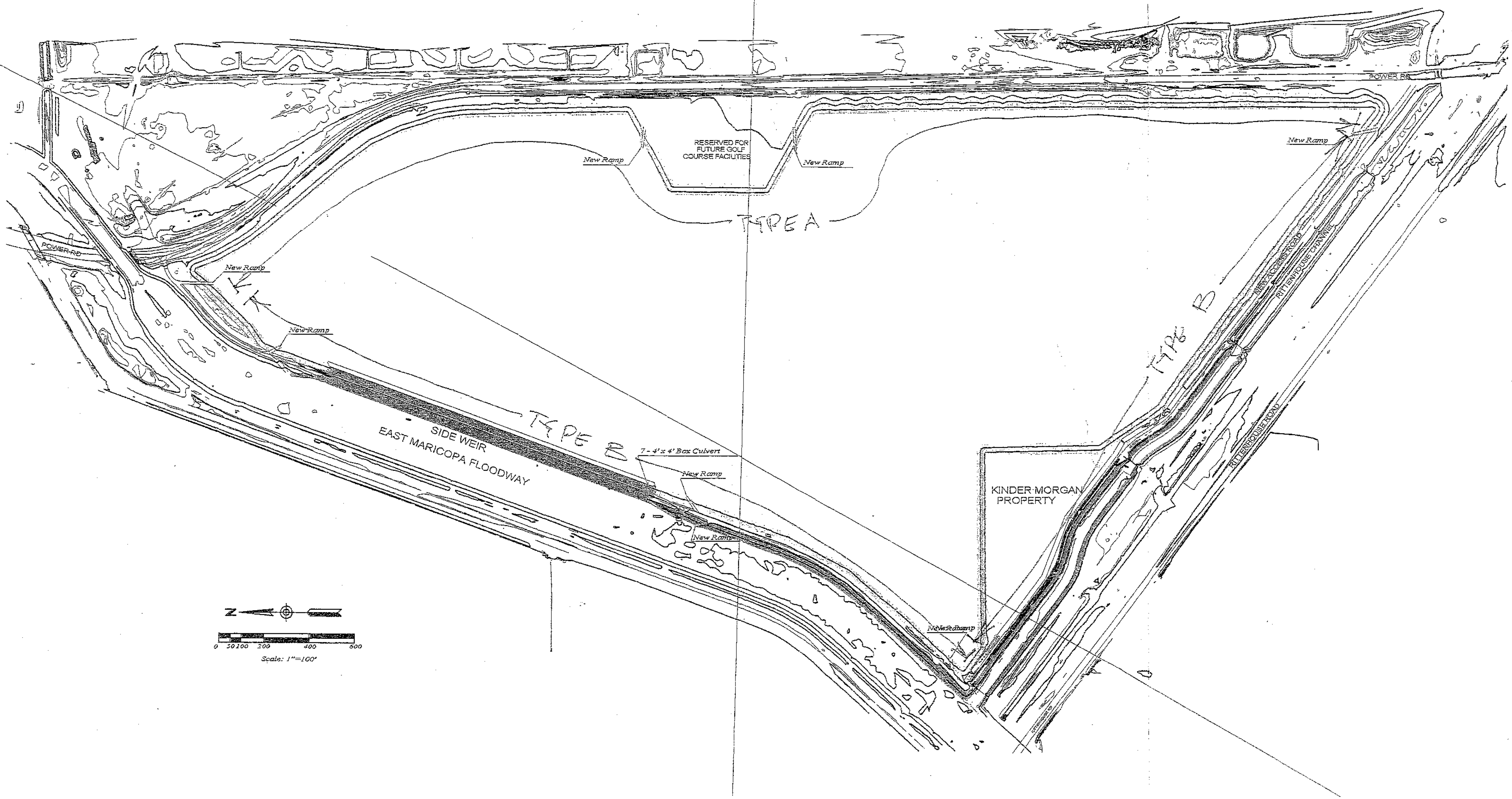


Figure 25. This sketch shows the planned improvements to create the Rittenhouse Basin. The typical sections shown cut in this sketch are shown in more detail in Figure nn.

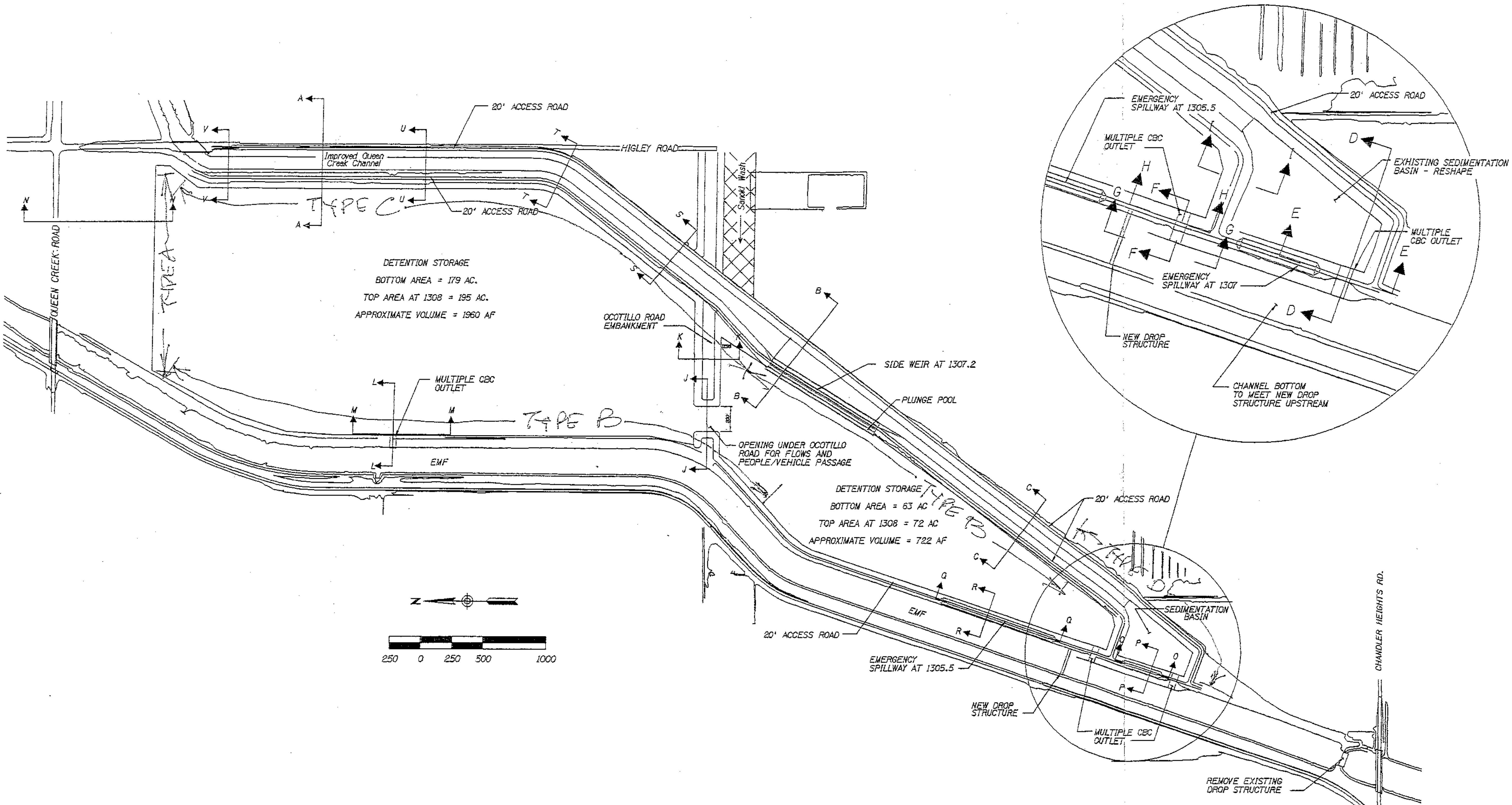
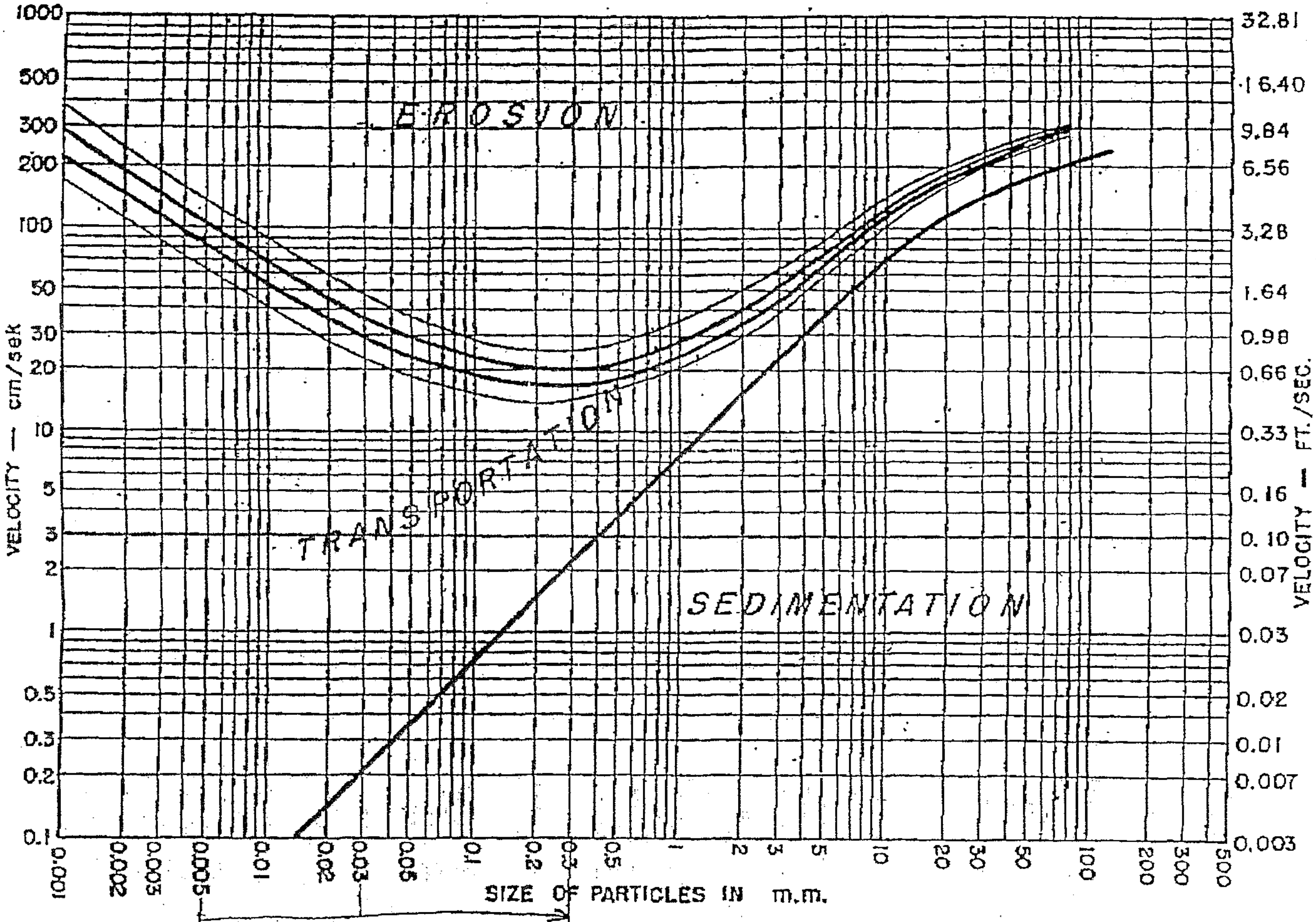
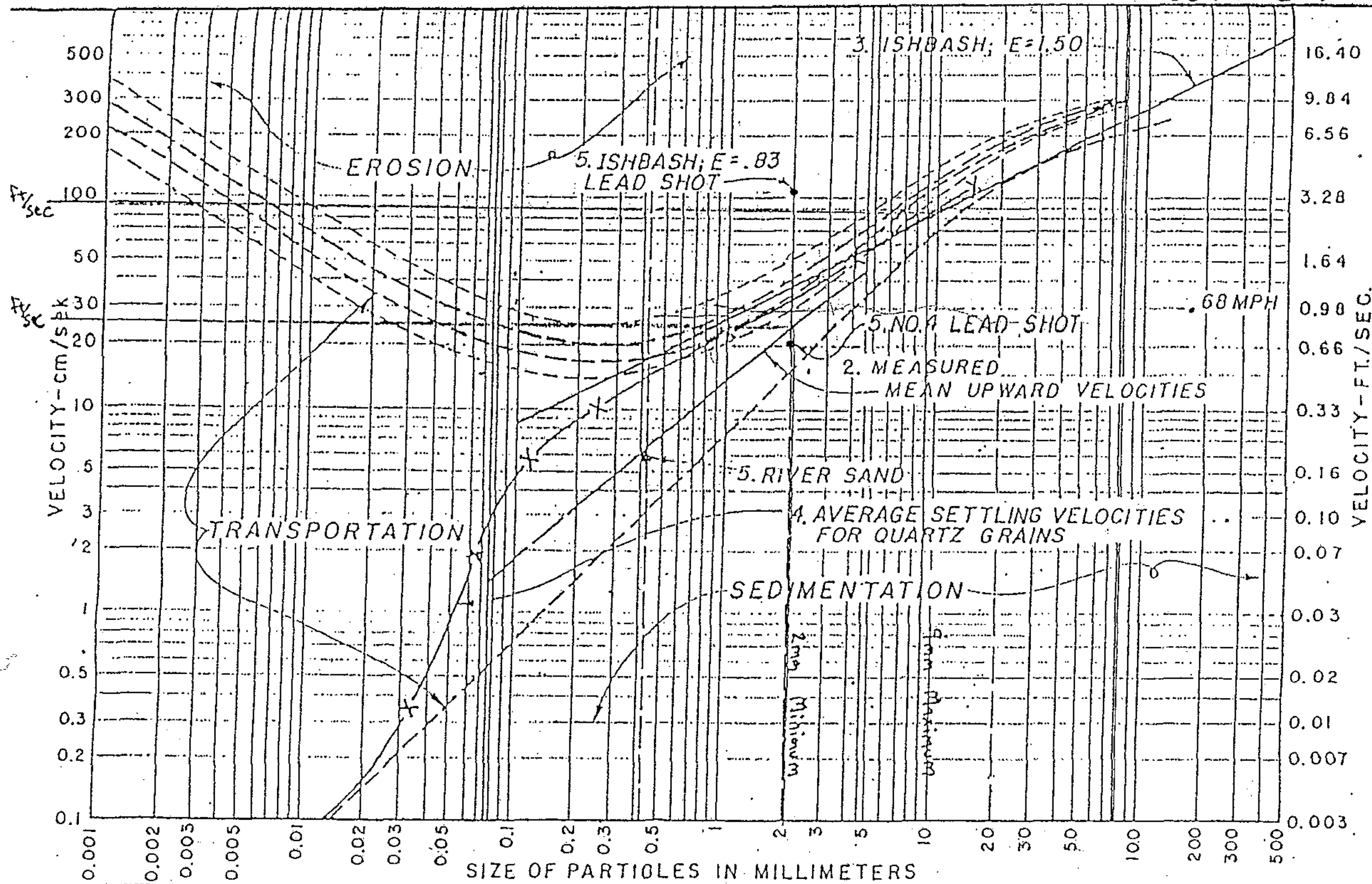


Figure 34. Chandler Heights Basin concept plan. See also the larger scale plan in the pocket at the rear of this report.. This plan shows the general arrangements for the preferred plan, and shows where typical sections are cut. Those typical sections are shown on the pages thatfollow.



THE CURVES FOR EROSION AND DEPOSITION OF A UNIFORM MATERIAL

88 ft/sec => 60mph



CLAY (PLASTIC) TO SILT (NON-PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Adapted from: F. Hjulström; Bulletin of Geol. Inst. of Upsala, Vol. XXX and 2. M.D. Campbell and J.H. Lehr; Water Well Technology; 3. S.V. Ishbash; 2nd Conf. on Large Dams, Vol. V, 1936; 4. W.W. Rubey, Amer. Jour. of Sci; Vol. 25, 1933. 5. C.A. Mockmore & J.W.; Dougherty; Vol. 100, Trans. ASCE.

VELOCITY CURVES FOR PIPING, EROSION, AND DEPOSITION OF SOILS

Source: (16)

FIGURE 13.