ULDC Criteria and Basis of Design Report
for the RD17 Levee System

Prepared for: *Cities of Lathrop & Manteca* *February 25, 2016*

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Contents

1.0 Introduction

The cities of Lathrop and Manteca entered into a contract with Peterson Brustad Inc. (PBI) on July 15, 2014 to analyze the RD 17 levees utilizing the State of California Urban Levee Design Criteria (ULDC), and to identify deficiencies and countermeasures. The levees are currently accredited to FEMA standards per 44CFR 65.10, and the cities desire to achieve an Urban Level of Protection (ULOP) by 2025. Also, RD 17 has recently completed Phases 1 and 2 of their Levee Seepage Repair Project (LSRP), and plans to initiate construction on Phase 3 (final phase) in the summer of 2016. The current ULDC analysis scope will assume that all 3 phases have been completed.

This memorandum describes criteria to be utilized in evaluating the levees. PBI's general approach is to evaluate the levees to *minimum* ULDC standards in order to identify where levees comply and don't comply. This approach will maximize the extent of "no-work" reaches. Then, for non-compliant segments, criteria are identified for countermeasures which often incorporate an additional factor of safety to be conservative and to hedge against changing future conditions, such as changing standards, hydrology, sea level rise, etc. In other words, affordability of achieving an ULOP depends on minimizing the work footprint, but once a decision is made to improve a reach, it should be made stout with the goal of avoiding the need to revisit the reach in the future.

For non-compliant levee reaches, the additional factor of safety is applied to work elements which cannot be easily enlarged in the future, such as slurry walls, new or modified pressure pipeline crossings, encroachments, and right of way. In these cases, a future expansion/enlargement would represent a substantial reconstruction effort. For other elements, future expansion/enlargement would be an incremental addition, so it is not necessary to overbuild initially. Freeboard is a special case. Due to hydraulic impact analysis/mitigation requirements under USACE's 33 USC Section 408 permission authority, raising a Federal levee is very difficult to permit. But most of the work for a levee raise can be completed without actually "topping off" the levee. Topping off could then be handled at a later time if found to be necessary. For non-Federal levees, Section 408 permission is not required, so levee raising to accommodate a factor of safety can be completed as part of the ULDC improvements.

This Technical Memorandum (TM) is arranged to correspond to Chapter 7 of the May 2012 ULDC. Where standards in the ULDC do not require amplification or clarification, they are not repeated.

2.0 Levee Survey and Stationing

Horizontal and vertical survey control has been established for the project based on recoverable control monuments. Horizontal control is referenced to the California Coordinate System of 1983, Zone 3, U.S. Foot units (CA83IIIF) and vertical control is referenced to the North American Vertical Datum of 1988 (NAVD88). Aerial photogrammetry has been used to develop the background topographic mapping along the levee alignment within the project study area. Aerial based topographic mapping has been prepared at a mapping scale of 1" = 40' and a 1' contour interval showing all visible surface features, contours, and spot elevations within the mapping limits.

3.0 Design Water Surface Elevation (DWSE), ULDC Sec 7.1

1. The FEMA approach will be used per ULDC Section 7.1.1.

2. 200-year hydrology was taken from the DWR Central Valley Hydrology Study, as documented in the PBI report, *200-year Freeboard Analysis & Floodplain Mapping within* RD17, dated May 23, 2014 (see Volume 1, Section 7.1, Attachment A). Modeling assumptions for upstream levees matches ULDC 7.1.1 without exception.

3. 200-year flood water surface profiles were developed by PBI as documented in the *200-year Freeboard Analysis &Floodplain Mapping within RD 17*, dated May 23, 2014. The hydraulic analysis included independent technical review by MBK Engineers, Inc.. The water surface profiles are based on a median estimate of 200-year hydrology and hydraulics, sometimes stated as a 50% assurance estimate. The modeling assumes debris loading on bridges per ULDC 7.1.1 without exception. Because the reach is relatively straight at flood stage, water surface super elevation is not a needed adjustment.

4. Adjustments for sea level rise were included in the hydraulic analysis. Intermediate sea level rise projections out to year 2050 conditions were assumed as documented in the PBI report, *San Joaquin River Delta Base Flood Elevation Refinement, Stage Frequency Analysis*, dated September 2, 2010 (see Volume 1, Section 7.19, Attachment A).

5. For initial ULDC analysis and determination of whether work will be required to achieve ULDC, the DWSE = median 200-year flood water surface profile.

6. If work is required in a reach, DWSE = 200-year flood water surface profile plus a 1-foot factor of safety to accommodate uncertainties and future modifications to hydrology. This will apply to both Federal and non-Federal levees.

4.0 Minimum Top of Levee (MTOL), ULDC Sec 7.2

The MTOL is DWSE plus the greater of 3’ or (wind setup + wave runup). Where wind setup and wave runup exceed 3’, wave runup mitigation will be investigated using measures such as elevated roadways, shallow foreshore, berms, jetties, and evergreen tree strips. Wave mitigation will be analyzed using EM 1110-2-1100 and EM 1110-2-1614. Wave mitigation does not reduce wind setup, however. If cost-effective, wave mitigation will be used to reduce MTOL to DWSE+3’.

5.0 Other Miscellaneous Hydraulic Information

Additional sections of the ULDC reference other water surface profiles (WSPs) and hydraulic information required for this evaluation. These are documented in PBI’s TM dated February 10, 2016, City of

Lathrop and City of Manteca ULDC Evaluation Design Water Surface Elevation (see Volume 1, Section 7.1).

1. The 10-year WSP, required for Seismic Vulnerability analyses (ULDC 7.7.1), was computed using the same approach and assumptions described for the 200-year WSP.

2. The 500-year WSEs, required for Hydraulic Top of Levee (HTOL) calculations (ULDC 7.4, 7.5) were computed using the same approach and assumptions as for the 200-year WSP.

3. HTOL is computed as the lower of (a) the median 200-year WSE + 3' or (b) the 500-year WSE

4. Rapid drawdown data is needed for slope stability calculations (ULDC 7.4.2). This was computed based on HEC-RAS modeled stage hydrographs for the 200-year event. The difference between the peak stage and the stage 30 days following the peak will be used for rapid drawdown calculations.

5. An erosion analysis is required per ULDC 7.10. Peak channel velocities from the 200-year HEC-RAS analysis will be used to assess erosion potential, along with wave runup shear stress.

6. 1955 design WSE is needed for assessment of penetrations, ULDC 7.13. This WSE was provided by USACE and based on their Design Memorandum dated December 23, 1955.

The PBI TM dated February 8, 2016, *Minimum Top of Levee and Hydraulic Top of Levee* (see Volume 1, Section 7.2) covers ULDC-relevant water surface profiles and hydraulic information needed for ULDC evaluation.

6.0 Soil Sampling, Testing, and Logging, ULDC Sec 7.3

Previous Studies and Reports

The levee evaluation will consider recent and previous subsurface explorations and laboratory analyses that were published in the following reports:

1. ENGEO, 2014 – Reclamation District 17, Mossdale Tract, Phase III Levee Seepage Project.

2. DWR Urban Levee Evaluations, April 2014 – Supplemental Geotechnical Data Report Addendum, Reclamation District 17.

3. ENGEO, 2011 – Reclamation District 17, Mossdale Tract, Phase 3 Levee Seepage Project.

4. DWR Urban Levee Evaluations, July 2010 – Supplemental Geotechnical Data Report, Reclamation District 17, Draft 2.

5. DWR Urban Levees Evaluations, October 2008 – Phase 1 Geotechnical Data Report, Reclamation District 17.

6. William Lettis & Associates, Inc. 2008 – Surficial Geologic Map of the Eastern Side of the San Joaquin River, along RD-17 Levee System near Stockton and Lathrop, California. (provided by DWR)

7. ENGEO, 2006 – Geotechnical Exploration and Levee Evaluation for the River Run Project.

8. ENGEO, 2004 – Draft Preliminary Geotechnical Report of the 220-Acre Mixed Use development along the eastern side of the San Joaquin River in South Lathrop.

9. ENGEO, 2004 – Geotechnical Exploration, Central Lathrop Specific Plan.

10. Kleinfelder West, Inc. 1989 - Geotechnical Exploration for the Weston Ranch project.

11. Kleinfelder West, Inc. 1987 – Evaluation of Levees Bordering Reclamation District 17.

Proposed Exploration Program

Soil sampling, testing, and logging will be done to characterize the geotechnical condition of the levee system. Where sources of available information exist (i.e. ULE, RD17 LSRP evaluations, locally available information, etc.) the existing data may be used to supplement new soils testing. The proposed exploration program will include an additional approximately 125 cone penetration tests (CPTs) and approximately 25 rotary wash borings. The locations of the CPTs and borings will be determined such that their location relative to the levee in traverse cross section and frequency relative to the longitudinal profile will generally comply with the intent of ULDC criteria. Explorations will also be performed at locations that have had historical issues during high water events, and locations that have been identified as potentially problematic with respect to existing geomorphologic and/or geophysical studies.

Laboratory testing will be directed at obtaining soil classification/index properties, strength, hydraulic conductivity, compressibility, and other physical characteristics, in general conformance with ULDC.

7.0 Slope Stability for Evaluation and Design Criteria, ULDC Sec 7.4

Geotechnical Stability Criteria

The slope stability safety factors adopted for stability analyses are based on FEMA guidelines, USACE, and ULDC guidelines. The slope stability factors of safety are tabulated here:

TABLE 3.3.2-1
Minimum Slope Stability Factors of Safety (FS)

Sudden Drawdown (Case II)	Steady Seepage(Case III)		Earthquake (Case IV)
	DWSEL	HTOL	
1.0 – 1.2*	1.4	1.2	1.0

*FS=1.0 applies to pool levels prior to drawdown for conditions where the water levels are unlikely to persist for long periods preceding drawdown. FS=1.2 applies to pool level, likely to persist for long periods prior to drawdown.

The ULDC specifies that the rapid drawdown shall be considered from the DWSEL, and that the amount of drawdown should be established based on site-specific hydrologic data. For the purposes of this study, a drawdown from the design flood stage based on a project specific hydraulic evaluation will be used.

Geotechnical Stability Analysis

Slope stability models will be prepared using site topography, subsurface stratigraphy from new and existing explorations, soil strengths from laboratory testing and previous investigations, and pore water pressures obtained from seepage models. The results of the slope stability analyses will be presented on graphics showing the idealized subsurface stratigraphy. A FS that is calculated using SLOPE/W will also be presented on this graphic. Potential failure surfaces were forced to intersect the levee crest in order to prevent the program from converging to shallow slumps on the levee slopes; results of slope stability analysis represent the occurrence of a potential slide plane of sufficient size to potentially impact levee integrity. Particularly in non-circular slope stability calculations, the most critical and reasonable failure plane is reported, which may not necessarily be the lowest factor of safety calculated by SLOPE/W. Engineering judgment will be utilized when reporting the critical FS.

Where low factors of safety are calculated, alternate mitigation options will be considered to improve stability. Flattening and and/or widening of the levee prism would likely be the preferred mitigation alternative; however, based on our understanding of the construction, past performance, and previous geotechnical studies of the RD17 levee system, we do not anticipate slope stability to be a significant concern for this evaluation.

8.0 Underseepage for Intermittently Loaded Levees, ULDC Sec 7.5

Geotechnical Seepage Criteria

Underseepage occurs when hydraulic head forces water to seep through the foundation soils. A hydraulic gradient is the drop in head over a given distance; an exit gradient is the vertical hydraulic gradient of the modeled condition at or near the landside toe of the feature being analyzed. When a blanketing/confining soil layer is present at or near the ground surface in the seepage model, average gradients (drop in head across the thickness of the blanket layer) are calculated and reported. Where a blanketing layer is not present, we report the localized maximum gradient (as representing the exit gradient) by selecting a flow net quadrant along the surface of the seepage model.

Based on USACE Engineering Manual 1110-2-1913 (as modified by ETL 1110-2-569) and the 2012 ULDC, the current guidance for upward gradients through soils with a minimum saturated unit weight of 112 pcf saturated soils at the toe of the levee (exit gradient) should be no greater than 0.5 and no greater than 0.8 at the toe of a seepage berm with a minimum width equal to four times the height of the levee crown above the landside toe. When modeling a scenario that incorporates the HTOL, the ULDC specifies the average exit gradient should be no greater than 0.6 at the levee toe, with less than twenty percent degradation at the toe of a seepage berm, for berms less than 100 feet wide. Where drained or undrained seepage berms exist, or are proposed, the landside ground surface will not be assumed to represent a "ditch, canal, or depression" condition as described in Section 7.5 of the ULDC.

Through seepage is a condition that occurs when the upstream water stage in a cross section rises above the landside embankment toe elevation, and the phreatic water surface through the levee embankment daylights onto the landside slope. This can cause localized instability, unraveling of the landside levee slope soils, and, potentially, progressive mobilization of embankment soils (piping) causing levee failure. Where the modeled conditions calculate through seepage, the reported through seepage height is the difference in elevation between the landside toe of slope and the elevation at which the phreatic water surface exists on the slope. Generally, when through seepage is calculated in an analysis through seepage mitigation is recommended unless the levee embankment is comprised of non-erodible soils.

Geotechnical Seepage Analysis

The results of the seepage analyses will be presented in a graphical format. A "Geometry Model" showing the idealized stratigraphy utilized in the SEEP/W software and a calculated "Total Head Contours" cross section showing the idealized stratigraphy and the calculated total head contours will be provided. The total head graphic is where potential through seepage breakouts are identified (relative to the landside levee toe), and exit gradients are displayed.

On the total head graphic, typically where the ground surface soils are free-draining non-cohesive materials (sands), the localized maximum gradient is noted. Where a blanketing layer exists, and average gradient (drop in total head divided by the vertical thickness of the blanketing layer) is calculated across the blanketing layer. The average gradient is calculated as follows:

$$i(avg) = \frac{\Delta h}{t}$$

i(avg), Average Gradient
Δ h, Drop In Head Across Blanketing Layer(s)
t, Vertical Thickness of Blanketing Layer(s)

The critical locations to determine exit gradients, as per underseepage design criteria, are the landside levee toe and seepage berm toe (where one is modeled). Additional gradient data at other locations (such as any nearby ditches or ground surface depressions) may be presented on the analytical figure as well; the intent of this is to provide the reader with a more in-depth understanding of the model and its results.

When a drained seepage berm is incorporated into the seepage model, the resulting total head at the ground surface is typically less than the elevation at the same point. When calculating the average gradient at the toe of the levee with a seepage berm (which also serves to check the uplift at the toe of the improved levee), the total head at the ground surface has been made equal to the ground surface elevation; this results in a slightly less conservative average gradient, but is the standard of practice for this calculation.

Also noted on the total head graphic is the occurrence of calculated through seepage. A breakout point is indicated on the graphic and the approximate height of the through seepage relative to the landside levee toe is noted.

When a drained seepage berm is introduced into the model, the location of the phreatic water surface within the berm section is checked to determine if the drainage section has sufficient capacity to convey seepage flows. If the drainage section of the berm has sufficient capacity to convey the seepage flows collected by the filter and drainage layer, the phreatic surface will remain within or below the drain rock section. Should the phreatic surface enter into the berm fill material above the drainage section of the berm, the capacity of the drainage section in the berm is considered insufficient.

Underseepage Analysis

Based on our analysis, and in accordance with the Geotechnical Seepage Criteria discussed in this Technical Memorandum, should seepage calculations indicate exit gradients as not meeting criteria, seepage mitigation(s) will be considered. Our understanding is that RD-17 prefers a landside seepage berm to mitigate under seepage. By installing a landside seepage berm, RD-17 is able to expand the area in which they are able to flood fight, have readily available soil to flood fight with (if needed in an emergency), and reduce the risk of landside encroachments negatively affecting the levee. If it is determined that a seepage berm is not feasible due to landside constraints, a fully penetrating seepage cutoff wall then becomes the preferred alternative to mitigate underseepage. Other mitigation approaches will also be considered on a case-by-case basis.

Though Seepage Analysis

Through seepage, where identified, should be evaluated to determine if mitigation would be necessary. Considerations for a through seepage evaluation are:

- Exit height of through seepage above the landside levee toe of the embankment.
- The types of soil in the embankment and what type of soil the through seepage is exiting onto the surface from.
- Slope of the embankment over which the through seepage is exiting onto.
- Quantity of through seepage flow.

Based on our analysis and in accordance with the Geotechnical Seepage Criteria discussed in this Technical Memorandum, should a through seepage concern be identified, seepage mitigation(s) will be considered. Our understanding is that the preferred through seepage mitigation for RD 17 levee projects is a drained seepage berm and/or flattening of the landside slope. If it is determined that a chimney drain system or flattening of the landside slope is not feasible due to physical constraints, a shallow seepage cutoff wall then becomes the preferred alternative to mitigate through seepage. Other mitigation approaches will also be considered on a case-by-case basis.

9.0 Frequently Loaded Levees, ULDC Sec 7.6

A frequently loaded levee analysis is required based on guidelines in ULDC 7.6. 15-minute flow data is available through the DWR data library for the San Joaquin River gage stations at Old River (SJL) and at Mossdale (MSD) and can be reduced into a flow-duration curve to identify the 10% exceedance flow (ie- the flow that is equaled or exceeded 36 days per year on average). The HEC-RAS model will be run for this flow, and the resulting WSP will be compared to the land-side levee toe elevations. Anywhere that the stage is at least 1-foot above the landside toe will be flagged as a frequently loaded levee. This analysis is documented in PBI's February 23, 2016 TM *Frequently Loaded Levee Analysis* (Volume 1, Section 7.6).

Levees identified to be subject to frequent loading, as defined by the ULDC, will be evaluated with more stringent criteria than intermittently loaded levees with respect to stability and seepage analyses. These criteria include:

- A phreatic water surface lower than the that calculated using a steady-state seepage analysis is not allowed for the landside slope stability analysis;
- The minimum allowable landside slope stability factor of safety is 1.5 for steady-state seepage at the DWSE and 1.3 for steady-state seepage at the HTOL;
- The minimum rapid drawdown slope stability factor of safety is 1.2 for pre-drawdown water surface at the DWSE.

Additionally, seismic deformation of frequently loaded levees should be limited to less than 3 feet of total deformation and approximately 1 foot of vertical displacement. Consideration will be given for the potential and consequences of longitudinal cracking along the levee alignment, and recommendations will be provided for reducing seismic displacements in reaches subject to frequent loading

10.0 Seismic Vulnerability, ULDC Sec 7.7

The ULDC requires analyses of the seismic vulnerability of the levee system for the 200-year recurrence period ground motions. The guidelines suggest analyzing the seismic stability at the typical summer and typical winter water surface elevations. 15-minute stage data is available through the DWR data library for the San Joaquin River gage stations at Old River (SJL), at Mossdale (MSD), and at Brandt Bridge (BDT). Stages for the summer and winter months will be extracted for all available water years and will be averaged to come up with the “typical summer” and “typical winter” stages.

For intermittently loaded levees, if seismic deformation from the 200-year ground motions is expected, a remediation plan must be established in conformance with pertinent local, state and federal agencies. Interim repairs include restoring the levees grades and dimensions sufficient to protect against the 10-year flood with at least an additional 3 feet of freeboard, and should be performed within 8 weeks of the damage occurrence. In the event that seismic damage to the levee system is anticipated to be so widespread that it would be infeasible to provide interim repairs within 8 weeks, seismic strengthening of the levee system would be required.

Because the ULDC does not provide specific criteria for analysis, we anticipate generally basing our earthquake stability analyses on the USACE "Guidelines for Seismic Stability Evaluation of USACE Levees" (2011). The guidelines describe how to identify and screen for potentially liquefiable soil, how to perform seismic slope stability and how to estimate any associated horizontal and vertical deformation.

Based on our seismic stability analyses, an assessment of the level of earthquake induced damage will be provided for the entire levee alignment, and discretized according to typical seismic behavior. This estimate can be used to develop an Emergency Action Plan to meet the minimum requirements for the ULDC.

11.0 Levee Geometry, ULDC Sec 7.8

Minimum levee geometry criteria have previously been specified by various USACE guidance documents. The guidance for minimum levee geometry of the levee system is as follows:

- Sta. 0+00 to 645+00: French Camp Slough / San Joaquin River downstream of Old River
  The USACE operations and maintenance manual specifies the minimum levee geometry for this reach of Federal Project levee. According to the *Supplement to Standard Operation and Maintenance Manual, Lower San Joaquin River & Tributaries Project, Unit 2, Right Bank Levee of San Joaquin River and Left Bank of French Camp Slough within Reclamation District No. 17* dated May 1963, the minimum waterside and landside slopes shall be 2:1 (horizontal to vertical) and the minimum crown width shall be 12 feet.

- Sta. 645+00 to 985+95: San Joaquin River upstream of Old River / Walthall Slough / Dryland Levee
  The USACE operations and maintenance manual specifies the minimum levee geometry for this reach of Federal Project levee. According to the *Supplement to Standard Operation and Maintenance Manual, Lower San Joaquin River & Tributaries Project, Unit 2, Right Bank Levee of San Joaquin River and Left Bank of French Camp Slough within Reclamation District No. 17* dated May 1963, the minimum waterside slope shall be 3:1 (horizontal to vertical), the minimum landside slopes shall be 2:1 (horizontal to vertical), and the minimum crown width shall be 20 feet.

Levee cross sections will be cut from the topographic survey data. The levee geometry evaluation will be based on comparing the existing levee geometry with the appropriate minimum levee geometry criteria applied to the MTOL. Steeper slopes may be allowed in certain circumstances where there is limited space available, and where levees are demonstrated to meet minimum geotechnical criteria, such as seepage and stability.

12.0 Interfaces and Transitions, ULDC Sec 7.9

In transitioning from an improved condition to an unimproved condition with a satisfactory under seepage analysis, or from one type of mitigation to another type of mitigation, a length of transitional or overlapping improvement is proposed. For the LSRP, the minimum length of this transition and/or overlap has been 300 feet. However, transition/overlap calculation guidance has been provided by DWR and its consultants.

The calculation method involves the following:

- Utilizing a representative cross sectional analysis, determine the rate at which the total head is dissipated in the model (drop in head over distance) for the DWSE loading.
- Understanding that the critical exit gradient at the toe of the levee is 0.5 for the DWSE, and knowing the thickness of the blanket at the toe of the levee where the transition is proposed (taken from the analytical cross section), calculate the necessary drop in head across the blanketing layer (Δh_c, critical head change).
- Find the difference (x, transitional head) between the Δh_c and the calculated drop in head from the cross sectional model ($\Delta h_{(calc)}$); this is the amount of total head that needs to be dissipated.
- Multiply the transitional head by the drop in head over distance to calculate a transition/overlap length.

13.0 Erosion, ULDC Sec 7. 10

Erosion evaluation will be based on:

- Levee material properties from Section 6.0 above
- Allowable material sheer stresses following methods in EM 1110-2-1913, EM 1110-2-1601, EM 1110-2-1416, and EM 1110-2-1418.
- Flow velocities identified via the process described in Section 5.0 above.
- Wave heights calculated per Section 20.0 below.
- Past performance based on existing levee geometry (Section 11 above), periodic inspections, post-flood inspections, and special circumstances such as boat wakes.

Mitigation for riverine erosion may include geometry repairs, vegetation, riprap, or other hardscape measures. Mitigation for wave erosion is the same, with the addition of measures to break the waves prior to impacting the levee slope. Wave break mechanisms include elevated roadways, jetties, berms, shallow foreslope, and evergreen tree strips. Wave mitigation will be analyzed using EM 1110-2-1100 and EM 1110-2-1614.

14.0 Right of Way, ULDC Sec 7. 11

Levee easements along the entire levee alignment will be researched and mapped utilizing aerial photography and topographic mapping to best fit. Any additional monument ties or boundary resolution, other than what has already been gathered and/or accomplished, will generally not be performed. Existing easements will be compared with the 20-foot-wide landside zone and 15-foot-wide waterside zone per ULDC requirements. Alternatives for acceptable landside zones will be considered for those portions of the levee system that currently have development within 20 feet of the landside toe of the levee. The need for additional easements to maintain acceptable clear zones or inspection zones will be identified, and recommendations will be made appropriately.

15.0 Encroachments, ULDC Sec 7.12

Using aerial photography and topographic mapping, existing encroachments within the required levee right-of-way and required geometry prism will be evaluated. Per ULDC guidelines, sound engineering judgement will be exercised in assessing the impact of these identified encroachments on the reliable performance of the levee system for the full range of loading up to the HTOL. Unacceptable encroachments will be identified, and recommendations for remediation, such as removal, relocation, and/or reconstruction, will be made.

16.0 Penetrations, ULDC Sec 7.13

All existing pipes and conduits within the levee prism or levee right of way (ROW) will be evaluated to determine ULDC compliance. Penetrations that are considered high hazards will be removed or modified to restore the reliability of the levee. For other penetrations that are not considered to be a high hazard, but have not been permitted, a penetration remediation plan will be put in place to address eventual permitting or removal of all such penetrations.

A hazard determination will follow a 2-staged approach:

> **Stage 1: Preliminary Assessment-** The type of pipe, its invert elevation as it runs through the levee, presence or absence of a positive closure device, age of pipe, field observations, and potential consequences if the levee were to fail at the pipe location will all go into the Preliminary Assessment.
>
> A pipe that passes this assessment will be considered low hazard; a pipe that does not pass will either be considered high hazard, or will be routed through a Stage 2: Condition Assessment Test.

Stage 2: Condition Assessment Tests- Pipes that either did not pass the Preliminary Assessment or that have unknown parameters will undergo additional condition assessment tests including TV inspections and/or pressure tests.

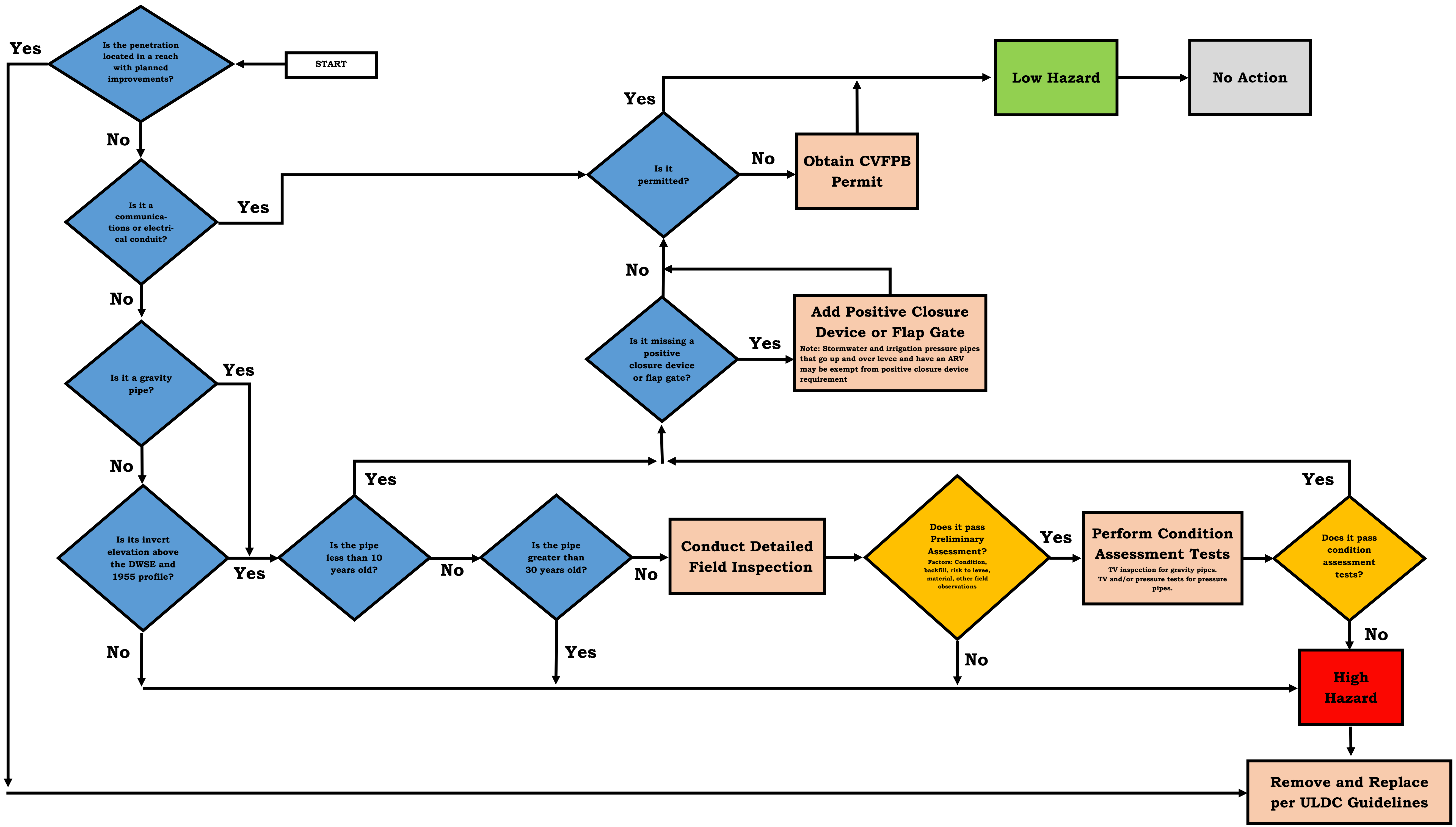
Pipes that are determined to be high hazards will be removed and replaced to the ROW boundary, or deficiencies corrected. If replacement is necessary, it is desirable to place the new penetration outside of the levee prism.

All low hazard pipes will be evaluated to see if they interfere with other ULDC improvements. If they interfere with the construction of levee improvements, they will be cut and repaired accordingly, otherwise they will be left in place.

A decision tree is provided on the following page to describe the general process for hazard determinations.

ULDC Assessment of Pipe Penetrations

PETERSON . BRUSTAD . INC
ENGINEERING . CONSULTING



17.0 Floodwalls, Retaining Walls, and Closure Structures, ULDC Sec 7.14

No existing floodwalls, retaining walls, or closure structures are present in the RD17 levee system. In the event that floodwalls, retaining walls, or closure structures are necessary due to restrictions on widening the levee prism, the structures will be designed according to EM 1110-2-1913, EM 1110-2-2502, EM 1110-2-6067 and EM 1110-2-571. The improved levees will need to meet the same geotechnical criteria with respect to stability and seepage analysis as those covered in Section 7.0 and Section 8.0 of this Technical Memorandum.

18.0 Animal Burrows, ULDC Sec 7.15

The proactive control of burrowing animals is already included in the normal operations and maintenance of the RD17 levee system. Per ULDC guidelines, an evaluation will be based on a levee inspection in which animal burrows will be identified that present a significant threat to levee integrity. Where O&M activities are not adequate to control rodents, permanent improvements will be recommended to address existing deficiencies and to improve existing operations and maintenance procedures.

19.0 Levee Vegetation, ULDC Sec 7.16

Vegetation control is included in the normal operations and maintenance of the RD17 levee system. Per ULDC guidelines, an evaluation will be based on a levee inspection in which trees and other woody vegetation on the levee and within 15 feet of the levee toes will be identified that present a significant threat to levee integrity. Recommendations will be made both to address existing deficiencies and to improve existing operations and maintenance procedures if necessary.

20.0 Wind Setup and Wave Runup, ULDC Sec 7.17

A wind setup and wave runup analysis will be conducted for areas where significant wind and wave action is expected to exceed 3-feet. The methodology for determining the wind setup and wave runup values are presented in the PBI report *SBFCA's Feather River West Levee Strengthening EIP Project: Wind Setup and Wave Runup Analysis* (January 10, 2011) and is based on standard practices detailed in:

- *Coastal Engineering Manual (CEM)*, EM 1110-2-1100
- *Shore Protection Manual (SPM)*
- *Process for the National Flood Insurance Program Levee System Evaluation*, EC 1110-2-6067
- Design of Coastal Revetments, Seawalls, and Bulkheads, EM 1110-2-1614.

Inputs for these computations include design wind speed, wind direction, fetch length, water depth along the fetch, slope coverage, and countermeasures. This analysis is documented in the PBI TM dated December 21, 2015, *Wind Setup and Wave Runup Calculations* (Volume 1, Section 7.17).

21.0 Security, ULDC Sec 7.18

Security evaluation will consist of researching and assessing RD17's security plan, specifically as it pertains to networked detection, deterrence, physical security, and intrusion interdiction during high threat periods. A levee inspection will be performed to verify the effectiveness of existing access controls along the levee. Recommendations will be made to address existing deficiencies, to improve existing operations and maintenance procedures if necessary, and to improve and/or develop an acceptable security plan for the levee system.

22.0 Sea Level Rise, ULDC Sec 7.19

Per ULDC guidelines, the effects of sea level rise (SLR) should be estimated and addressed for the duration over which a Finding that the urban level of flood protection may be valid. The PBI study *San Joaquin River Delta Base Flood Elevation Refinement Stage Frequency Analysis*, dated September 2, 2010 (Volume 1, Section 7.19), details methods used to determine stage-frequency statistics as well as SLR estimates at the Burns Cutoff (ID: B95660) and Rindge Pump (ID: B95620) gage stations located within the San Joaquin River tidal zone. The following table presents the estimated sea level rise at the Rindge Pump and Burns Cutoff gage stations.

Estimated Future Sea Level Rise from 2009

Year	*Sea Level Rise, ft*		
	Low	Intermediate	High
2030	0.1	0.2	0.6
2050	0.3	0.5	1.4
2080	0.5	1.1	3.2
2100	0.6	1.5	4.7

These estimates were prepared using EC 1165-2-211, which expired July 1, 2011, and has been replaced by ETL 1100-2-1. The PBI estimates will be reviewed against the new guidance and adjusted as appropriate. The intermediate SLR estimate, as projected out to the year 2050, will be incorporated into the HEC-RAS modeling to determine the effect, if any, it may have on WSELs along the RD 17 levee.

23.0 Emergency Actions, ULDC Sec 7.20

Evaluation of emergency actions will consist of researching, compiling, and assessing existing emergency and flood safety plans, both those prepared by RD17 and those prepared by other agencies having jurisdiction. Coordination will occur with the County, the various City agencies, fire departments, and other emergency response entities. It is anticipated that after all existing emergency and flood safety plans are compiled, no further recommendations will be necessary. If seismic vulnerability analyses (ULDC Section 7.7) require time-dependent restoration, the ER plan will address material source(s) and activities needed to quickly mobilize a contractor for repairs.