# Geotechnical Levee Practice

## Scope

This procedure covers the geotechnical practice for levee evaluation, analysis, design, construction and maintenance of levees in accordance with Sacramento District and USACE guidance and regulation. Sacramento District standard practice may differ from published USACE guidance.

This procedure does not cover levee inspections, O&M Manuals, Engineering Considerations and Instructions to Field Personnel (ECIFP), and the FEMA certification process.

## Policy

This guidance applies to all Sacramento District personnel and Architect-Engineer (A-E) Firms engaged in work on California Central Valley **flood control levees** for the Sacramento District.

## Responsibility

The PDT Member is responsible for following this guidance on projects with flood control levees.

The Chief of Soil Design Section is responsible for ensuring that training and guidance are provided to all new employees and that A-E Firms providing assistance to the District are fully briefed. All task orders to IDIQ firms for levee work will include this guidance.

## Distribution

Chief of Geotechnical & Environmental Engineering Branch

Chief of Design Branch

Chief of Engineering Support Branch

Chief of A-E Administration Section

Chief of Cost Engineering Section

Chief of Soil Design Section

PDT Member

## Ownership

The Chief of Geotechnical & Environmental Engineering Branch [John.R.Hess@usace.army.mil?Subject=REFP10L0-Geotechnical Levee Practice] is responsible for ensuring that this document is necessary and that it reflects actual practice.

## References

Refer to:

- *EM 1110-1-1804 Geotechnical Investigations [http://www.usace.army.mil/publications/eng-manuals/em1110-1-1804/toc.htm]*
- *EM 1110-1-1904 Settlement Analysis [http://www.usace.army.mil/publications/eng-manuals/em1110-1-1904/entire.pdf]*
- *EM 1110-2-301 Guidelines for Landscape Planting and Vegetation Management at Floodwalls, Levees, and Embankment Dams [http://www.usace.army.mil/publications/eng-manuals/em1110-2-301/entire.pdf]*
- *EM 1110-2-1601 Hydraulic Design of Flood Control Channels [http://www.usace.army.mil/publications/eng-manuals/em1110-2-1601/toc.htm]*
- *EM 1110-2-1901 Seepage Analysis and Control For Dams with CH 1 [http://www.usace.army.mil/publications/eng-manuals/em1110-2-1901/toc.htm]*
- *EM 1110-2-1902 Slope Stability [http://www.usace.army.mil/publications/eng-manuals/em1110-2-1902/toc.htm]*
- *EM 1110-2-1913 Design and Construction of Levees [http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]*
- *EM 1110-2-1914 Design, Construction, and Maintenance of Relief Wells [http://www.usace.army.mil/publications/eng-manuals/em1110-2-1914/entire.pdf]*
- *EM 1110-2-2300 General Design and Construction Considerations For Earth and Rock-Fill Dams [http://www.usace.army.mil/publications/eng-manuals/em1110-2-2300/toc.htm]*
- *EM 1110-2-2301 Test Quarries and Test Fills [http://www.usace.army.mil/publications/eng-manuals/em1110-2-2301/toc.htm]*
- *EM 1110-2-2302 Construction with Large Stone [http://www.usace.army.mil/publications/eng-manuals/em1110-2-2302/entire.pdf]*
- *EM 1110-2-2502 Retaining and Flood Walls http://www.usace.army.mil/publications/eng-anmuals/em1110-2-2502/toc.htm*
- *EM 1110-2-2504 Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures [http://www.usace.army.mil/publications/eng-manuals/em1110-2-2503/toc.htm]*
- *EM 1110-2-3104 Structural and Architectural Design of Pumping Stations http://www.usace.army.mil/publications/eng-manuals/em1110-2-3104/toc.htm*
- *ER 1110-1-1807 Procedures for Drilling in Earth Embankments [http://www.usace.army.mil/publications/eng-regs/er1110-1-1807/entire.pdf]*
- *ER 1110-2-1150 Engineering and Design For Civil Works Projects [http://www.usace.army.mil/publications/eng-regs/er1110-2-1150/entire.pdf]*
- *ETL 1110-2-286 Use of Geotextiles* Under Riprap [http://www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-286/entire.pdf]*
- *ETL 1110-2-334 Design and Construction of Grouted Riprap [http://www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-334/entire.pdf]*
- *ETL 1110-2-556 Risk-Based Analysis in Geotechnical Engineering for Support of Planning Studies [http://www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-556/toc.html]*

 Content written by USACE, Sacramento District, Engineering Division, GEEB

- *ETL 1110-2-569 Design Guidance For Levee Underseepage* [http://www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-569/entire.pdf]
- *The California Code of Regulations, Title 23, Waters, Division 1 Reclamation Board* [http://weblinks.westlaw.com/toc/default.aspx?Abbr=ca%2Dadc&AP=CAT23&ItemKey=CAT23&RP=%2Ftoc%2Fdefault%2Ewl&Service=TOC&RS=WEBL8.02&VR=2.0&SPa=CCR-1000&fragment - CAT23]
- *44 CFR § 65.10 Mapping of Areas Protected by Levee Systems* [http://www.fema.gov/pdf/nfip/44cfr6510.pdf]
- *33 CFR § 208 Navigation and Navigable Waters, Chapter II Corps of Engineers, Department of The Army, part 208 Flood Control Regulations* [http://ecfr.gpoaccess.gov/e/ecfr.orig/ecfrbrowse/Title33/33cfr208_main_02.tpl]
- Recommendations For Seepage Design Criteria, Evaluation and Design Practices, Final Report of the 2003 CESPK Levee Task Force
- USBR 7310-89 Procedure for Constant Head Hydraulic Conductivity Tests in Single Drill Holes
- *Technical Memorandum No. 3-424 Investigation of Underseepage and Its Control. Lower Mississippi River Levees, Volumes 1 and 2* [http://libweb.wes.army.mil/uhtbin/hyperion/TM-3-424.pdf]

## Definitions

Refer to *Glossary of Engineering Quality System Terms and Acronyms [REFQ10L0]*, for definitions not listed here.

CESPK - US Army Corps of Engineers, Sacramento District

CESPK-ED-G - US Army Corps of Engineers, Sacramento District, Engineering Division, Geotechnical & Environmental Engineering Branch

CPT - Cone Penetrometer Test

DWR - California Department of Water Resources

FE - Finite Element software/program

FEMA - Federal Emergency Management Agency

FLOOD SEASON - Defined in Title 23, as either 1 November thru 15 April or 15 July depending on the stream

GMS - Groundwater Monitoring System

LSTF - Sacramento District's 2003 Levee Seepage Task Force

OMC - Optimum Moisture Content

PED - Preconstruction Engineering and Design

SOP - Standard Operating Procedure

SPT - Standard Penetration Test

## General

The Project Delivery Team (PDT) should include active and regular participation by representatives of our Partners such as the State and local agencies. Each PDT, upon organization, should meet to determine design approach and determine criteria to be applied to the project. Departures from the standard practice of levee design will be brought to the attention of the Chief of Soil Design Section and the Chief of Geotechnical & Environmental Engineering Branch. Geotechnical design conflicts that cannot be resolved within the PDT will be addressed in accordance with the District's conflict resolution process.

Engineering judgment should be exercised. A senior geotechnical engineer or a senior geotechnical engineer and a journeyman or junior engineer will typically be assigned to the PDT.

An internal Quality Control review and Independent Technical Review (ITR) will be provided in accordance with District, Engineering Division, and Geotechnical & Environmental Engineering Branch policy. ITR is not needed for smaller, non-controversial projects. A-E Geotechnical work products and designs should be reviewed by the Chief of Soil Design Section and the Chief of Geotechnical & Environmental Engineering Branch at all critical project milestones.

### Guidance

The Geotechnical & Environmental Engineering Branch and our design agents (A-E) will incorporate the following guidance / procedures in all current and future levee projects covering reconnaissance, feasibility, design, FEMA certification and maintenance. Levee investigations and analysis will be tailored to the nature of the levee project.

Refer to the following for initial design guidance:

- *EM 1110-2-1913 Design and Construction of Levees* *[http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]*
- *EM 1110-2-1914 Design, Construction, and Maintenance of Relief Wells* *[http://www.usace.army.mil/publications/eng-manuals/em1110-2-1914/entire.pdf]*
- *ER 1110-2-1150 Engineering and Design For Civil Works Projects* *[http://www.usace.army.mil/publications/eng-regs/er1110-2-1150/entire.pdf]*

Refer to the following for additional guidance:

- *ETL 1110-2-556 Risk-Based Analysis in Geotechnical Engineering for Support of Planning Studies [http://www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-556/toc.html]*
- *The California Code of Regulations, Title 23, Waters* *[http://weblinks.westlaw.com/toc/default.aspx?Abbr=ca%2Dadc&AP=CAT23&ItemKey=CAT23&RP=%2Ftoc%2Fdefault%2Ewl&Service=TOC&RS=WEBL8.02&VR=2.0&SPa=CCR-1000&fragment#CAT23]*

 

- *44 CFR § 65.10 Mapping of Areas Protected by Levee Systems* [http://www.fema.gov/pdf/nfip/44cfr6510.pdf]
- *33 CFR § 208 Navigation and Navigable Waters, Chapter II Corps of Engineers, Department of The Army, part 208 Flood Control Regulations* [http://ecfr.gpoaccess.gov/e/ecfr.orig/ecfrbrowse/Title33/33cfr208_main_02.tpl].

The PDT member will regularly brief project status to the Chief of Geotechnical & Environmental Engineering Branch. Any departure from standard practice, controversy, budget overruns, or schedule slips shall immediately be brought to the attention of the Chief of Soil Design Section and Chief of Geotechnical & Environmental Engineering Branch.

## Background Information and Data

## Geographic Information Systems (GIS)

All existing geotechnical data will be obtained with an exhaustive search of Corps, State, and local sponsor records. The geotechnical data will be entered into a GIS database for all projects.

Exploration data should be entered in a manner / form that will allow detailed review of subsurface conditions at a single boring and for select reaches in longitudinal and transverse profiles. Include generalized stick log profiles.

Laboratory test results can be summarized by reach and entered into the GIS.

Performance history will be retrieved from all appropriate sources, including Corps, State, and local sponsor files. The location and photographs of erosion, slides, slumps, seepage, boils, piezometric and observation well data, and flood fights vs. water surface elevation for each event, will be entered into the GIS database. Local sponsor and State "levee logs" will be obtained and interviews will be conducted with knowledgeable State and local sponsor personnel.

The regional and site geology should be developed and entered into the GIS.

A project specific geomorphology study will be conducted for significant projects and entered into GIS.

## Feasibility Studies

## Guidance

Feasibility level geotechnical work should be planned and accomplished with the objective of developing project alternative designs to a degree sufficient to accomplish cost estimates with appropriate contingencies. Levee remediation techniques and alternatives should be fully evaluated during feasibility. Feasibility level geotechnical work should not be designed to accomplish PED design level work. Exploration programs for Feasibility should be designed based on existing explorations and the need for additional exploration data that supports Feasibility cost estimates with appropriate contingencies.

 

Refer to *ER 1110-2-1150 Engineering and Design For Civil Works Projects* *[http://www.usace.army.mil/publications/eng-regs/er1110-2-1150/entire.pdf]*

## Explorations for Levee Studies

A considerable amount of geotechnical data should be obtained during feasibility. Geotechnical explorations should be located to supplement the existing exploration subsurface data. New explorations should be located based on the geology, geomorphology, and performance history. All new geotechnical data will be entered into the GIS.

The frequency of explorations should be tailored to the project. Explorations should generally be located on 1000 to 2000 ft horizontal spacing, at the waterside toe, levee crown, landside toe, and on the landside of the levee (0 to 500 ft away from the levee). The exploration program should include a geomorphology review of landforms using aerial photography. Explorations should be laid out to explore landforms, where possible, rather than just using evenly spaced intervals. Judgment will be exercised to adequately capture levee and foundation variability, and to study more critical and unique locations, such as sumps and pump stations.

Exploration (SPT, CPT, trenches) depths should be sufficient to characterize subsurface conditions. To evaluate seepage conditions: extend the primary explorations to the bottom of the deeper pervious layers, and extend waterside and landside explorations below the waterside and landside “impervious” blanket layer. Explorations should extend to a depth of at least three times the levee height into the levee foundation and a minimum of one exploration per mile should extend to the bottom of the aquifer. To evaluate stability and settlement, extend explorations to competent material. Exploration depths in the range of 40 to 100 ft will be common. Continuous SPT sampling or CPT can be useful in exploring the top stratum where there is a gradational change from clay to silt to fine sand, to assist in determining the top stratum thickness.

Great care should be exercised when drilling through embankments. Drilling in embankments with fluid is restricted. *Refer to ER 1110-1-1807 Procedures for Drilling in Earth Embankments* *[http://www.usace.army.mil/publications/eng-regs/er1110-1-1807/entire.pdf]*.

CPTs should be correlated with SPTs. To correlate CPT data, locate some CPT holes adjacent to SPT holes. Material descriptions from the SPT holes should be verified with an appropriate level of laboratory soil classification test data. After correlating the CPT data, there should be at least one SPT hole drilled and sampled for every 5 to 10 CPT holes.

Explorations should have sampling and in-situ testing at frequencies necessary to obtain the engineering characteristics of the levee and foundation soil layers. Engineering properties include but may not be limited to strength, compressibility, unit weight, gradation, plasticity, and permeability.

Exploratory drilling may be supplemented by appropriate geophysical methods selected to aid in developing subsurface information and geomorphologic mapping.

Cross sections should be selected for monitoring, and instrumentation should be installed at strategic locations to gather additional in-situ permeability data and to adjust seepage models. Explorations can be converted to piezometers.

Each distinct reach should have one set of piezometers. One set consists of three piezometers plus a water side staff gage or bench mark. Typical piezometer locations are as follows: one piezometer at landside top of levee, one at landside toe, and one at some distance landside of the toe; or one piezometer at landside toe of levee, and two at locations up to 500 feet landside of the toe. Locations of piezometers in areas subject to seepage shall be determined based on geomorphology and other site specific geotechnical considerations.

Piezometer monitoring and seepage and stability model adjustments should continue as new data becomes available. Seepage and stability models will be adjusted to reflect piezometric data and levee performance in response to flood or high water events.

### Explorations for Borrow

Responsibilities for providing levee borrow materials will be determined with Project Management and Local Sponsors. Borrow areas should be explored using a backhoe or trackhoe to excavate trenches. Representative samples should be retrieved for laboratory testing. Testing should include gradation, Atterberg limits, insitu moisture content, compaction, remolded strength, and permeability. Refer to *EM 1110-2-1913 Design and Construction of Levees* *[http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]* for additional information on borrow areas.

### Feasibility Design

Cost estimates will be performed by Cost Engineering Section, not Geotechnical & Environmental Engineering Branch. Geotechnical & Environmental Engineering Branch should provide cost input to the Cost Engineering Section.

Probabilistic methodologies can be used in the evaluation of subsurface conditions and expected levee performance, (i.e. probabilistic based analyses, etc.) for Feasibility Studies. The probabilistic approach to levee evaluation as outlined in *ETL 1110-2-556, Risk Based Analysis in Geotechnical Engineering for Support of Planning Studies* *[http://www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-556/toc.html]*, should not be used in design.

The feasibility design will be deterministic as provided for in *EM 1110-2-1913, Design and Construction of Levees* *[http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]*. The selected design water surface should not be referred to as the PNP water surface / elevation.

## Preconstruction Engineering and Design

Refer to *EM 1110-2-1913 Design and Construction of Levees* *[http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]*.

## Explorations

Additional explorations will be conducted during final design stages to optimize the design and help determine limits of the preferred alternative. The GIS database will be continually updated.

The frequency of explorations should be tailored to the project. Explorations could generally be located on 500 to 1000 ft horizontal spacing along the waterside toe, levee crown, landside toe, and landward and waterward of the levee (0 to 500 ft away from the levee). Geomorphology (landform analysis) should be used to develop exploration locations and to characterize levee conditions. Judgment should be exercised to adequately capture levee and foundation variability, and to study more critical and unique locations, such as sumps and pump stations.

As needed, additional laboratory and in-situ testing should be accomplished during PED.

## Design Analysis

Levee design will include consideration of landside and waterside stability, erosion control, thru-levee seepage control, underseepage control, and settlement. Levee design will be deterministic in accordance with the selected references.

Seepage models will normally be run assuming steady state conditions have developed. A design water surface profile should be provided to the geotechnical engineer by the PDT. Parametric analysis should be conducted to check design assumptions and whether criteria are met. These analyses can also help determine where additional explorations should be conducted.

Representative permeabilities should be selected based on experience in the area. This experience should be gained by using field and laboratory test data, and permeability estimates derived from grain size distribution correlations. The permeability of the pervious strata and the less pervious top stratum are critical to the analysis and should be determined.

Permeability values that can be used as a guide are found in *Technical Memorandum No. 3-424* *[http://libweb.wes.army.mil/uhtbin/hyperion/TM-3-424.pdf]*. This source accounts for blanket thickness effects to permeability and past performance affects to the blanket. Empirical based permeability relationships can be found in Lambe and Whitman (1969), Casagrande and Fadum (1940), Sherard et al (1984), Mooretrench Corporation relationship developed by Byron Prugh (horizontal permeabilities), and *EM 1110-2-1913 [http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]*.

In Soil Design Section the Department of Defense Groundwater Modeling System (GMS) is the most often used analytical tool in seepage modeling. The seepage analysis in GMS is based on the SEEP2D finite element (FE) code.

A-E may use other finite element seepage modeling software. When A-E are involved in the design, their software should be checked by running comparable seepage models with GMS / SEED2D or equivalent computer based programs.

Blanket theory will be used to check the results of the FE modeling at some sections in every study, and may be used in lieu of GMS, depending on the geotechnical subsurface conditions.

The need for seepage remediation should be based on appropriate exit gradient threshold criteria, uplift or heave factor of safety, severity of seepage, and the performance history of the levee and foundation. The threshold exit gradient should be 0.5, with water at the design water surface elevation. The 0.5 threshold exit gradient criteria should only be used with appropriate levels of geotechnical explorations and data, past flood performance data, and provisions for adequate future monitoring, maintenance, and flood fighting abilities. In some cases, a lower exit gradient ranging from 0.3 to 0.5 may be applied at critical locations, (e.g. pump stations, sumps, swimming pools, areas on no landside access, or areas difficult to flood fight).

The need for slope stability remediation should be based on appropriate factors of safety and the performance history of the levee and foundation. Stability for end of construction, steady state seepage, and rapid drawdown cases will be analyzed. The minimum factors of safety should be in accordance with *EM 1110-2-1913, Design and Construction of Levees* *[http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]*.

## Design Measures

Erosion protection will be evaluated with Hydraulic Design Section staff. If required, erosion protection measures will be included in the project. Typically, if erosion is actively occurring and the waterside berm is less than 30 ft wide, erosion control is needed and will be evaluated.

Standard Levee Geometry - The minimum levee section should have a 3H : 1V waterside slope, a minimum 20 ft. wide crown for main line levees, major tributary levees, and bypass levees, a minimum 12 ft. wide crown for minor tributary levees, a 3H : 1V landside slope, a minimum 20 ft. wide landside easement, and a minimum 15 ft. waterside easement. Existing levees with landside slopes as steep as 2H:1V may be used in rehabilitation projects if landside slope performance has been good. Easements are necessary for maintenance, inspection, and floodfight access.

Underseepage cutoff walls should be designed to tie into an impervious layer and form a full / complete cutoff. However, if an impermeable layer does not exist within a practical depth, say about 80 ft., consideration can be given to the use of relief wells. Slurry trench cutoff walls through the levee will have a soil-cement-bentonite or cement-bentonite backfill. Slurry trench cutoff walls constructed at the levee toe can be constructed with soil-bentonite backfill.

If underseepage is not an issue, thru-levee seepage can be addressed with a relatively narrow seepage/stability berm or relatively shallow cutoff wall that ties into an impervious foundation material.

A seepage berm can be designed as an impervious berm, semipervious berm, or pervious berm. Typically a seepage berm should be designed as a semipervious berm with a drainage layer. The drainage layer can be clean sand or a drain blanket consisting of a drain rock layer with adjacent filter layers. Seepage berms should have a minimum width of 4 times the maximum levee height in a reach. The maximum seepage berm width should typically be 300 ft. The maximum calculated exit gradient at the end of a berm should be 0.8. A seepage berm will typically vary from about 5 ft. thick at the levee toe to about 3 ft. thick at the berm toe. Uplift at the levee toe should be checked to verify that a 5 ft. thick berm is sufficient to resist uplift.

Berm construction in the Delta is usually staged to prevent overstressing the foundation. Typically no more than 4 ft of fill should be placed at any one location before stopping to monitor. This assumes that the 4-ft thick fill is constructed in multiple lifts. The rate of settlement should be monitored and will usually determine when the second 4-ft thick fill can be placed.

Relief wells can typically be designed for a single row of wells about 5 to 15 feet off the levee toe, partially to fully penetrating. The minimum relief well spacing should be about 50 feet and the maximum relief well spacing should be about 200 feet. Closer spacing may be used at critical structures. The maximum calculated exit gradient between relief wells should be 0.5. Exit gradient criteria for relief wells should be compatible with the selected seepage berm criteria.

Ditches, ponds, and other excavations shall be located a safe distance from the levee determined by the results of seepage and slope stability analyses, using the same exit gradient as above. As a standard, ditches, ponds and other excavations shall be located a minimum of 20 ft. and a minimum distance of at least 10 times their depth, away from the levee toe. Borrow areas should be designed and located in accordance with *ETL 1110-2-569 Design Guidance For Levee Underseepage [http://www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-569/entire.pdf]*.

Levee design will be deterministic as provided for in *EM 1110-2-1913, Design and Construction of Levees [http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]*. The probabilistic approach to levee evaluation as outlined in *ETL 1110-2-556 Risk-Based Analysis in Geotechnical Engineering for Support of Planning Studies [http://www.usace.army.mil/publications/eng-tech-ltrs/etl1110-2-556/toc.html]* should not be used in levee design. The selected design water surface should not be referred to as the PNP water surface / elevation.

Utilities should be relocated from beneath levees and berms. Underground utilities are prohibited longitudinally along the levee or seepage or stability berms. If it is necessary to support overhead utilities above a seepage or stability berm by placing a support in the berm, a permanent reinforced concrete foundation should be installed through the berm and into the foundation. Refer to *The California Code of Regulations, Title 23, Waters, Division 1 Reclamation Board [http://weblinks.westlaw.com/toc/default.aspx?Abbr=ca%2Dadc&AP=CAT23&ItemKey=CAT23&RP=%2Ftoc%2Fdefault%2Ewl&Service=TOC&RS=WEBL8.02&VR=2.0&SPa=CCR-1000&fragment#CAT23]*, and *EM 1110-2-1913 Design and Construction of Levees [http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm]*.

The levee should not generally be used for environmental habitat. Where environmental habitat is included on the levee section, it should comply with existing O&M Manuals, and shall be reviewed by Geotechnical staff to insure it will not compromise levee performance.

## Levee Materials

Levees should be constructed of material that has at least 20 percent fines (material passing the # 200 sieve) and 100 percent passing the 2-inch sieve. The fines should have a Plasticity Index of at least 8 and less than 40, and a maximum Liquid Limit of 45. Levees should be compacted to a minimum 95% (ASTM D 698) at the OMC. The maximum allowable range in placement moisture contents should be from OMC minus 2% to OMC plus 2%.

Stone protection will be designed in collaboration with Hydraulic Design Section engineers. Typically Hydraulic Design Section will provide the Soil Design Section with the W50 (weight of median size stone) and W100 (weight of maximum size stone) for the stone needed to resist erosion. Soil Design will then provide the full gradation and required material properties.

A design document report (DDR) will be prepared for all levee designs.

Plans, Specifications and Engineering Considerations and Instructions to Field Personnel (ECIFP) should be prepared for all projects.

## FEMA Certification

At the initiation of each levee project, each PDT will determine if the project goal is to have the Corps provide levee certification for FEMA Floodplain Mapping. If one of the goals is FEMA certification, then the team will incorporate and follow the FEMA certification process *44 CFR § 65.10 Mapping of Areas Protected by Levee Systems [http://www.fema.gov/pdf/nfip/44cfr6510.pdf]*.

## Levee Construction

Inspection trenches for new levees will be excavated in accordance with Corps and State criteria.

Geotechnical engineer designers will visit the construction site to insure the design assumptions were correct and to provide technical assistance to Construction.

## Operations & Maintenance

Piezometer monitoring and seepage and stability model adjustments should continue as new data becomes available. Monitoring should continue throughout the life of the project. Seepage and stability models should be adjusted to reflect levee performance in response to flood or high water events.

Relief wells should be tested every 10 years, and if well capacity is significantly reduced, well rehabilitation should be conducted.

### Post-Flood Action

Post-flood lessons learned should be prepared for each significant flood event, from levee failures, levee incidents such as boils and piping, seepage, slides and slumps, from piezometric data and other pertinent information.

## Records

Soil Design Section will maintain appropriate record copies of work products.

 