Plans and Specifications for Dams & Levees

Kansas Dam Safety Conference
March 6, 2018
Manhattan, KS

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A. Design and Design Review

- **Problems Caused by Poor Investigation/ Design/Plans**
  - **History of Problems**
- **Design**
  - **Preparing Plans & Specification: Information Needed**
  - **Potential Failure Modes Analysis: Why?/benefits!**
  - **Plans/Drawings**
  - **Specifications**
  - **Design Review**

History of Problems

- **Incomplete information**
- **Inaccurate drawings and specifications**
- **Level of Engineers Expertise?**
  - **Experience & Expertise Matters**
  - **Small Dams/Large Dams**
- **Experience Required!**
  - **Design Experience**
  - **Construction Experience**
- **Construction Contractor Experience with water retaining structures**
  - **A dam/levee is not a roadway embankment!**

Geotechnical Investigation?
No – too expensive, cut corners!

Insufficient investigation or direction

Great idea - low cost hydraulic fill dams!

We don’t need a geologist for design!

History of Problems

- **Poor Construction Techniques/Lack of Quality Control**

Just follow the design, the design is fine!

Independent Review Implemented following this event!

In Summary

- **A lot of things can go wrong**
- **Poorly informed/shortsighted decisions can be made**
- **Peer/Independent/Regulatory Reviews are important**
- **Dam and Levee Design carries a big responsibility**
  - **Safety (Dam & Levee Safety) is of paramount Importance**

B. Preparing Plans and Specifications

- **Information Needed prior to:**
  - **Design Requirements – Design Reports**
    - **Approving Agency Requirements (Content/Standards)**
    - **Other Regulatory Requirements**
  - **Organization & Responsibilities**
    - **Establishing clear understanding of each parties interests, requirements and expected outcomes**
  - **Public Issues**

Design Requirements/Design Basis

- **What is the objective of the design?**
  - **New Structure: History of site (greenfield, brownfield…..)**
  - **Modification/Rehabilitation Project: inspection reports, O&M records, new operation requirements**
- **Statutes, codes, standard of practice**
- **Engineering investigations and studies**
- **Design report with analysis and calculations**

State Regulatory Requirements

- **Statutes and Regulations for the Specific Jurisdiction:**
  - **Actual requirements and responsibilities**
  - **Enforceable statutes and regulations**
- **Dam/Levee Safety Guidelines:**
  - **Establishes criteria and requirements in interpreting statutes**
  - **Submittals are likely to be more complete**

Other Regulations/Jurisdictions Involved

- **Water Rights/Surface Water Permits**
- **Water Quality**
- **Corps of Engineers**
- **Storm Water Pollution Prevention (BMPs)**
- **Funding Agencies**
- **Other: SHPO, DOT, County**

Team Organization and Responsibilities

- **Owner's Role**
  - **Private Owners**
  - **Public Owners**
- **Project Manager**
- **Design Team**
- **Regulatory Agencies**
- **Constructor**

Owner's Role and Ultimately Responsible for:

- **The quality and success of a constructed project**
- **Determining project requirements balancing cost and performance**
- **Initial cost versus life cycle cost**
- **Retaining professionals for areas that are outside of their primary experience areas**
- **Responsible for providing adequate financing**

Private Owners

- **Stronger interest in economic factors (short and long term costs, economic risk, return on investment, etc.)**
- **Can be more responsive than public owners**
- **Can be “penny pinchers”**

Public/Agency Owners

- **Generally have set rigid procedures that they operate under**
- **Projects developed over an extended period of time will be more subject to changes by agency representatives, budgets**
- **Slower response and decision making (often decision making is by committee)**
- **Impacts due to staff turnover/transfers over an extended project schedule: For example:**
  - **Lack of knowledge of the history and basis of design**
  - **Back tracking to previous alternatives, new alternatives etc.**
  - **Different interpretation of regulations, policies, criteria**

Public Issues Related to the Project

- **Outside Impacts Other than Dam Safety Issues – Interagency Cooperation**
  - **Example: Produced water ponds may fall under jurisdiction of another agency.**

Pre-Design Studies that may be Required & Their Importance

- **Hydrology Report/Hazard Classification**
- **Geotechnical/Geology Report**
- **Report Addenda**
- **Other**

C. Potential Failure Modes Analysis and Review

- **Provides focus on critical structure/features to consider in more detail!**
- **Design should include a potential failure modes (PFMA)**
  - **If at review stage PFMA is not available, perform an abbreviated PFMA**

For Example! Why have a PFMA?

- **Seepage is *inevitable!* Where will it go?**
  - **What damage can it do?**
- **Operator and/or equipment failures *will occur* !**

Taum Sauk Dam

Potential Failure Modes Analysis

- **PFMA's are a course in and of itself**
- **Potential Failure Modes are covered here only as a brief example of the benefit provided to design and review**

Dam Failure Modes

- **Historically, about 1 in 100 dams constructed have failed**
  - **This statistic has not changed much over time**

Evaluate Potential Failure Modes Prior to Design/Performing Review

- **Failures are usually due to a linkage of conditions and circumstances**
- **How can this dam/levee fail and what are the consequences?**
- **Consider actions to mitigate failure potential:**
  - **Design measures**
  - **Construction quality control/assurance**
  - **Monitoring and maintenance**

Classification of Causes of Failure

Foundation	• Abnormal behavior
Structural	• Failure of deficiency of some component (not included elsewhere)
Spillway	• Some defective condition
Overtopping	• Flood
Piping	• Erosion of foundation/embankment
Sliding	• Slide present at dam site
Unknown	

Classification of Causes of Failure and Percent of Failures

Foundation	• Abnormal behavior	10%
Structural	• Failure of deficiency of some component (not included elsewhere)	19%
Spillway	• Some defective condition	13%
Overtopping	• Flood	22%
Piping	• Erosion of soil occurring	20%
Sliding	• Slide present at dam site	10%
Unknown		6%

What are General Modes of Failure to Consider in a PFMA?

- **Flood-induced failure**
- **Piping of embankment dams**
- **Embankment slope/foundation instability of embankment dams**
- **Earthquake related failure**
- **Structural failure (e.g. failure of a concrete dam or hydraulic structure foundation)**

Flood-induced Failure of Embankment Dams

- **Overtopping, erosion, and embankment breach**
- **Inadequate hydraulic spillway capacity**
- **Structural inadequacy of spillway foundation**
- **Inadequate overtopping protection**
- **Inadequate erosion protection**
- **Piping due to increased reservoir load and pore pressures during flooding**

Failure Modes – Dam Overtopping

Failure Modes – Dam Overtopping

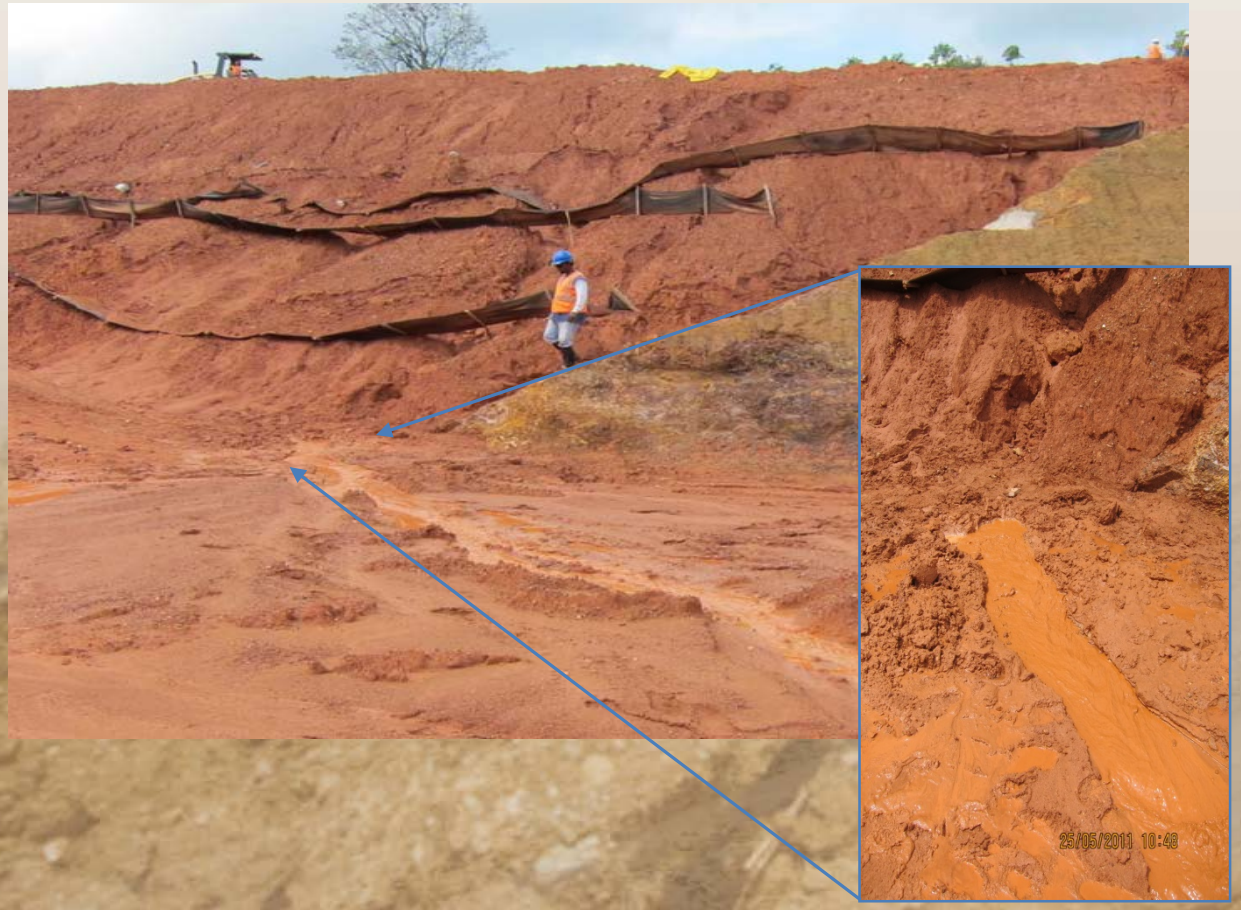
Foundation Piping/Erosion

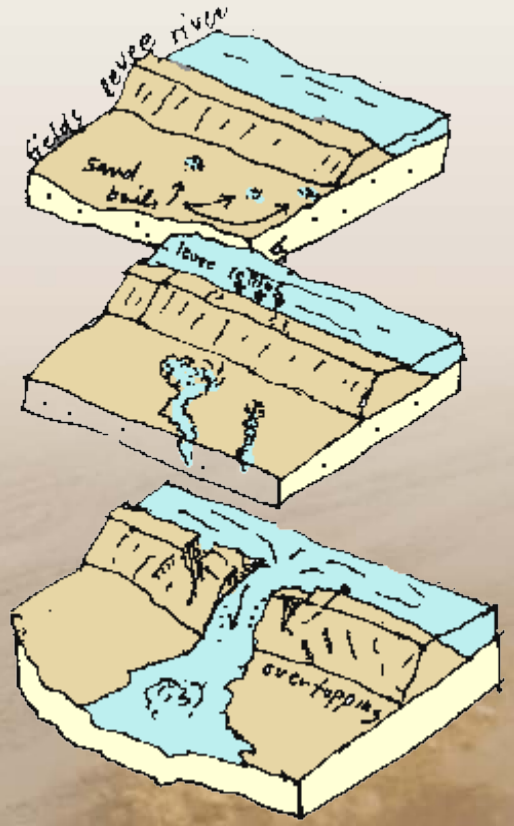
Failure Due to Piping

- **Piping/foundation conditions are the predominant cause of embankment dam failures**
- **Caused by development of preferred seepage paths, cracking, high hydraulic gradients, inadequate filtering**
- **Embankment, foundation, and contacts:**
  - **Along embankment penetrations**
  - **Loss of soil into damaged or deteriorated conduits**
  - **Loss of soil into rock fractures or voids**

Embankment/Foundation Piping (2013)

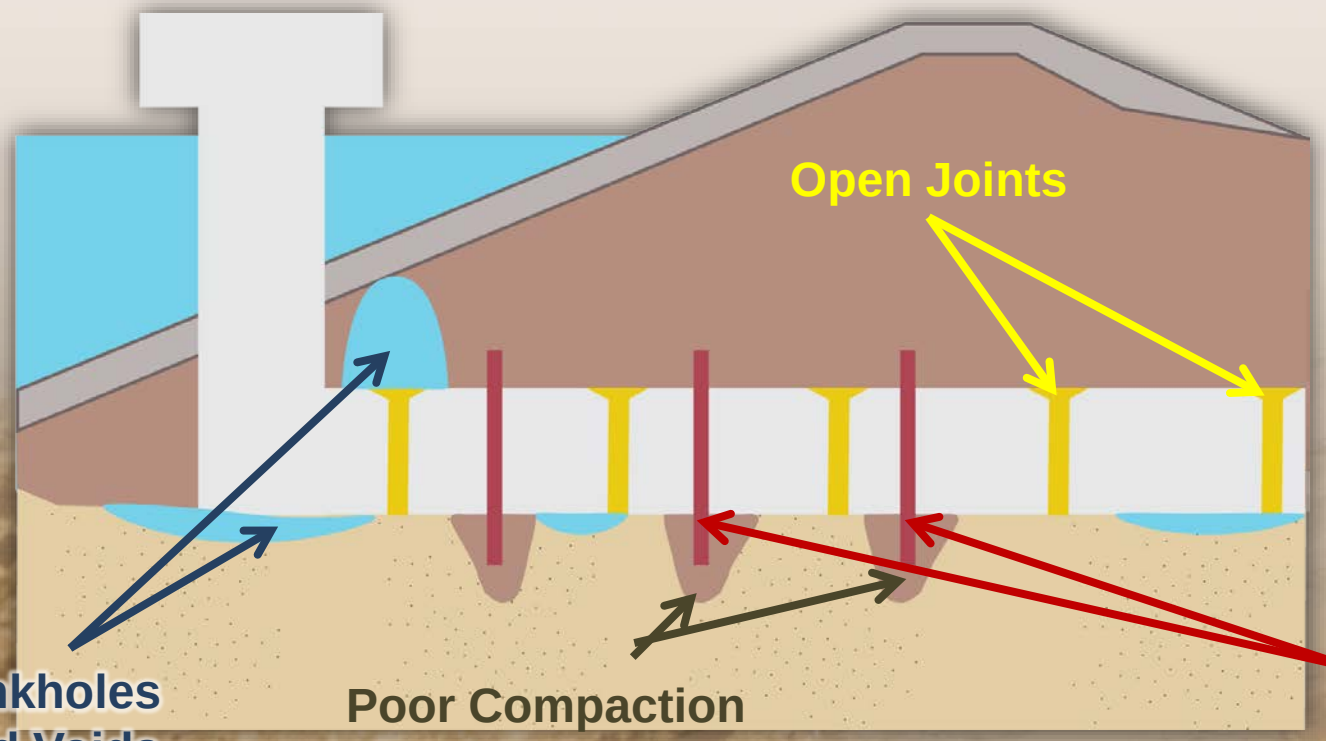
- **If left untreated, piping can result in the eventual breach of the dam**

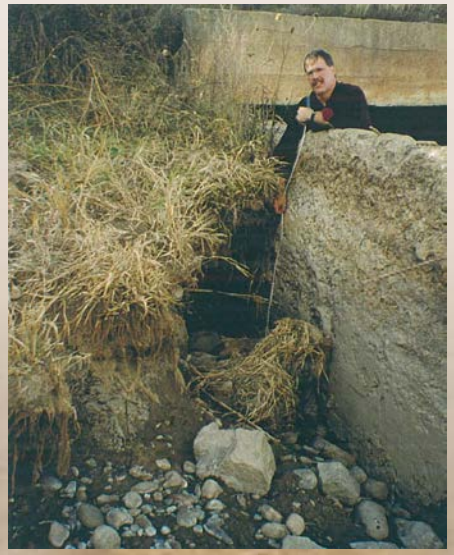




Failure Modes – Piping Along Conduits

- **Seepage/piping**
- **Erosion into conduit**
- **Flow out of conduit**
- **Structural failure**





Does Design Protect Against Failure Modes?

- **Design has to consider the structure and the site**
  - **Dam/levee and foundation must be designed to function together**
- **Most failures can be attributed to simple, sometimes apparently insignificant details**
  - **Sophisticated designs have failed due to oversights in elementary conditions**
- **Old structure built before modern design standards were developed**

Accidents and Failures Provide Important Lessons

- **Tendency to think in *averages* must be avoided**
  - **Failures occur where the dam, foundation or structure is the weakest**
- **Design must include particular focus on potential weaknesses**
- **Water is relentless and will find ANY Weakness**

Teton Dam (Relatively Modern Design): Failure Sequence

Summary of Failure Modes Assessment

- **Variability of natural conditions does not lend itself to:**
  - **Standard guidelines or “cookbook” approaches in Dam/Levee Engineering**
  - **Design does not end until construction is completed**
- **The only “sure thing” in Dam Engineering is that “conditions will change”**

Therefore: Defensive Engineering Required

- **Assess the possible detrimental circumstances**
- **Incorporate protective elements to cope with each circumstance**
- **To assess possible occurrences the Site conditions must be known and understood**
- **Individuals responsible for budget must understand that knowledge gained is essential and worth the price**
- **Defensive engineering = belt + suspenders**

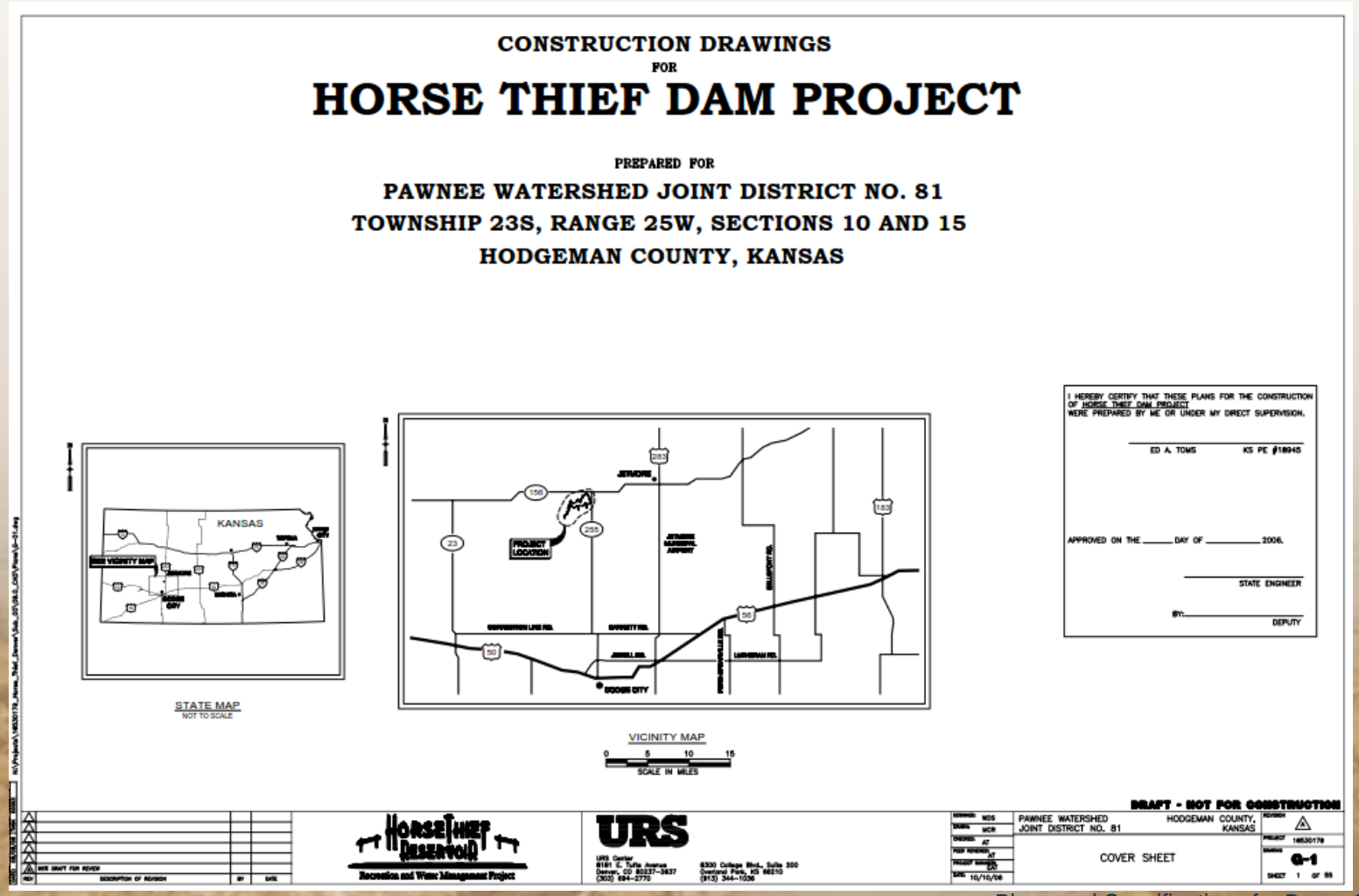
D. Design Plans/Drawings

- **Criteria, Codes, and Standards**
  - **Owner's Criteria**
  - **Design Engineer's Criteria**
  - **State and Federal Criteria**
  - **National Standards**
- **Design Basis**
  - **Data Reports**
  - **Design Reports**

Design Drawings (Planning/ Understanding the Plan Set)

- **CADD Standards**
  - **Dam Projects vs. Buildings and Roads Projects**
  - **Cover sheet requirements**
  - **Signature Requirements**
  - **Numbering of sheets**

What is Required by the Permitting Agency?



CONSTRUCTION DRAWINGS
FOR
HORSE THIEF DAM PROJECT

PREPARED FOR
PAWNEE WATERSHED JOINT DISTRICT NO. 81
TOWNSHIP 23S, RANGE 25W, SECTIONS 10 AND 15
HODGEMAN COUNTY, KANSAS

I HEREBY CERTIFY THAT THESE PLANS FOR THE CONSTRUCTION OF HORSE THIEF DAM PROJECT WERE PREPARED BY ME OR UNDER MY DIRECT SUPERVISION.

ED A. TOMS KS PE #18945

APPROVED ON THE _____ DAY OF _____ 2006.

STATE ENGINEER

BY: _____ DEPUTY

STATE MAP
NOT TO SCALE

VICINITY MAP
0 5 10 15
SCALE IN MILES

DRAFT - NOT FOR CONSTRUCTION

HORSE THIEF RESERVOIR
Recreation and Water Management Project

URS

PAWNEE WATERSHED JOINT DISTRICT NO. 81
HODGEMAN COUNTY, KANSAS

COVER SHEET

G-1

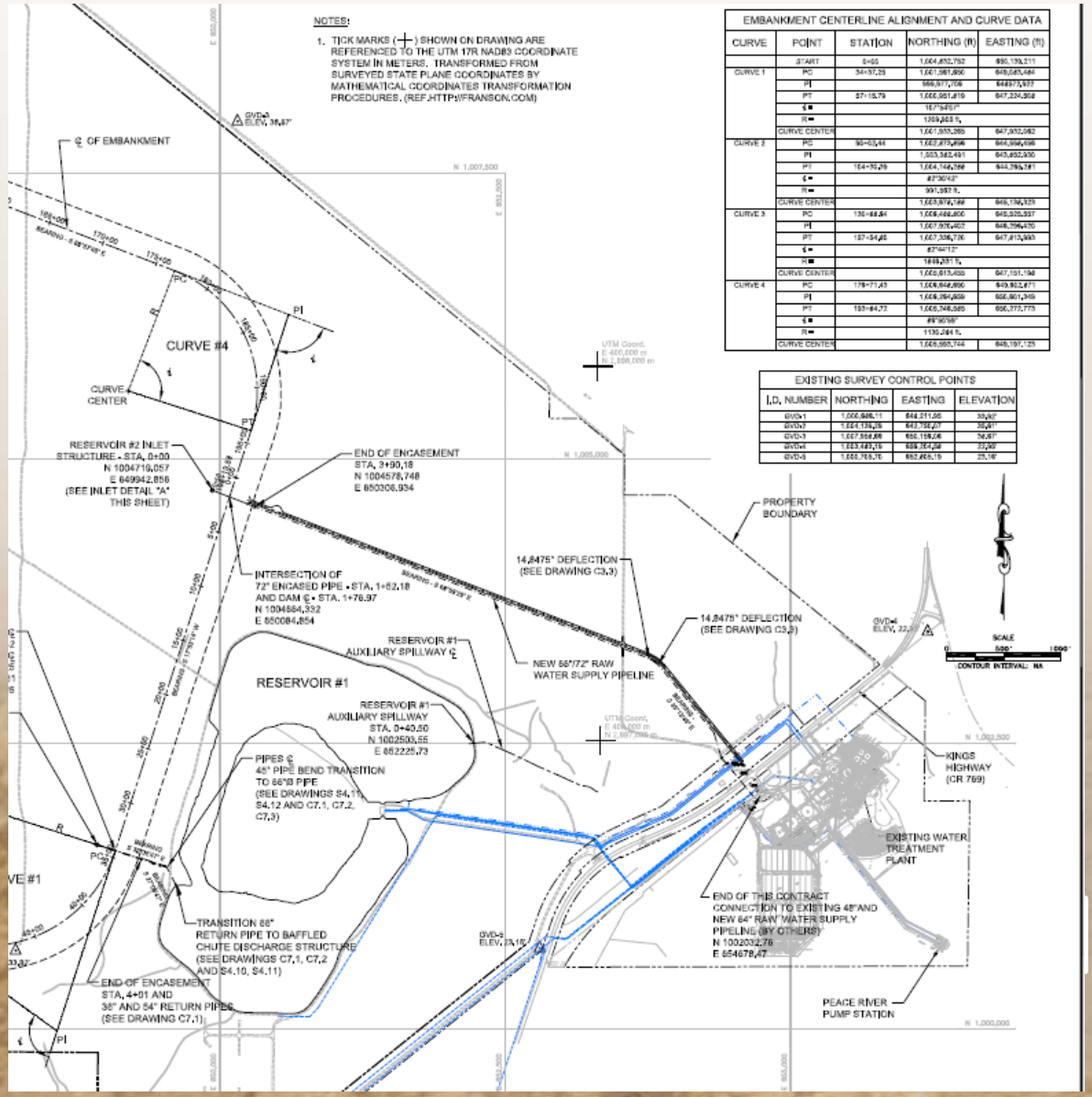
Survey Control

- **One of the most difficult problems encountered in design and construction is conflicts in survey control systems or inadequate survey control**
- **USGS, USCG&S monuments, state plane coordinates, project coordinates**
  - **What is the basis for topographic maps (quad sheets and new mapping)?**
  - **LiDAR: Ground confirmation?**
  - **What was used for hydrology, field investigations, design, etc…?**
  - **GIS and coordinate systems**
- **What is the basis for gage height or elevation controlling the storage authorization?**

Project Layout and Survey Control:

- **Is survey control clearly established?**
  - **Develop survey control drawing early and have checked**
  - **Is the topography/digital surface sufficiently accurate for design?**
    - **Field confirmation at structures and key features**
  - **Stationing vs. coordinates**
  - **Establish stationing: dam axis, outlet centerline, etc.**
  - **All disciples for all of the structures must use the same stationing/coordinate system**

Survey Control Point Table/Plan



EMBANKMENT CENTERLINE ALIGNMENT AND CURVE DATA				
CURVE	POINT	STATION	NORTHING (ft)	EASTING (ft)
	START	0+00	1,004,652.752	650,139.211
CURVE 1	PC	34+37.39	1,001,561.890	649,083.484
	PI		999,977.706	649,973.937
	PT	57+15.79	1,000,951.819	647,234.958
	℄ =		15°13'45.1"	
	R =		1359.263 ft.	
	CURVE CENTER		1,001,553.385	647,952.082
CURVE 2	PC	90+03.44	1,002,875.896	644,994.698
	PI		1,003,342.491	643,652.930
	PT	104+10.29	1,004,144.388	644,296.781
	℄ =		87°30'42"	
	R =		991.382 ft.	
	CURVE CENTER		1,003,879.188	645,136.325
CURVE 3	PC	136+68.84	1,006,488.800	645,525.557
	PI		1,007,930.407	646,296.470
	PT	157+54.46	1,007,336.730	647,813.993
	℄ =		87°44'12"	
	R =		1418.231 ft.	
	CURVE CENTER		1,005,813.450	647,151.198
CURVE 4	PC	179+71.43	1,008,844.890	649,902.871
	PI		1,009,394.859	652,601.345
	PT	193+44.73	1,008,346.585	656,272.773
	℄ =		89°30'59"	
	R =		1130.244 ft.	
	CURVE CENTER		1,006,555.744	646,197.125

EXISTING SURVEY CONTROL POINTS			
I.D. NUMBER	NORTHING	EASTING	ELEVATION
GVD-1	1,000,846.11	644,211.05	33.97
GVD-2	1,004,139.26	647,756.27	35.97
GVD-3	1,007,564.68	650,159.06	34.97
GVD-4	1,003,449.16	656,354.38	33.98
GVD-5	1,000,768.76	652,865.19	25.18

Design Plans

- **Plan Set Structure**
  - **Letter / Number Convention**
- **How are the drawings organized?**

Structure/Feature?

LIST OF DRAWINGS

DRAWING NO.	SHEET NO.	TITLE
GENERAL		
G–1	1	COVER SHEET
G–2	2	LIST OF DRAWINGS AND GENERAL NOTES
G–3	3	LEGEND AND ABBREVIATIONS
G–4	4	STRUCTURAL NOTES
G–5	5	LOCATION MAP
G–6	6	SURVEY CONTROL
G–7	7	EXISTING SITE PLAN, BORROW AREA, AND STAGING AREAS
G–8	8	GENERAL PLAN, STORAGE CURVE, AND SPILLWAY DISCHARGE RATING CURVES
G–9	9	LOCATION MAP OF TEST HOLES AND TEST PITS
G–10	10	EXPLORATION LEGEND
G–11	11	DAM EXPLORATION BORINGS – SHEET 1 OF 3
G–12	12	DAM EXPLORATION BORINGS – SHEET 2 OF 3
G–13	13	DAM EXPLORATION BORINGS – SHEET 3 OF 3
G–14	14	PRINCIPAL SPILLWAY EXPLORATION BORINGS
G–15	15	AUXILIARY SPILLWAY EXPLORATION BORINGS
DEMOLITION, EXCAVATION, AND DIVERSION		
E–1	16	GENERAL DEMOLITION PLAN
E–2	17	GENERAL EXCAVATION PLAN
E–3	18	FOUNDATION TREATMENT DETAILS
E–4	19	TEMPORARY DIVERSION CHANNEL PLAN, PROFILE, AND TYPICAL DETAILS
E–5	20	EXISTING STREAM REALIGNMENT AND REGRADING
DAM EMBANKMENT		
D–1	21	EMBANKMENT PLAN AND PROFILE
D–2	22	EMBANKMENT SECTIONS AND DETAILS – SHEET 1 OF 3
D–3	23	EMBANKMENT SECTIONS AND DETAILS – SHEET 2 OF 3
D–4	24	EMBANKMENT SECTIONS AND DETAILS – SHEET 3 OF 3
D–5	25	DRAINAGE BLANKET PLAN AND PROFILE
D–6	26	EMBANKMENT GRADING AND INSTRUMENTATION PLAN
D–7	27	INSTRUMENTATION DETAILS
PRINCIPAL SPILLWAY		
PS–1	28	PRINCIPAL SPILLWAY – PLAN AND PROFILE
PS–2	29	PRINCIPAL SPILLWAY – INTAKE STRUCTURE PLAN AND SECTIONS

Organized by Discipline & Feature?

GENERAL

DRAWING No.	SHEET No.	DRAWING TITLE
G0.1	1	TITLE SHEET AND LOCATION MAP
G0.2	2	DRAWING INDEX
G0.3	3	DRAWING INDEX
G0.4	4	GENERAL SITE PLAN
G0.5	5	FIELD INVESTIGATION LOCATION MAP - NORTH
G0.6	6	FIELD INVESTIGATION LOCATION MAP - SOUTH

CIVIL

DRAWING No.	SHEET No.	DRAWING TITLE
C1.1	52	EMBANKMENT AND RESERVOIR GENERAL PLAN
C1.2	53	SURVEY CONTROL PLAN AND EMBANKMENT LAYOUT PLAN - NORTH
C1.3	54	SURVEY CONTROL PLAN AND EMBANKMENT LAYOUT PLAN - SOUTH
C1.4	55	TYPICAL EMBANKMENT CROSS SECTIONS (1 OF 2)
C4.1	88	OUTLET AND SPILLWAY PLAN
C4.2	89	OUTLET PLAN AND PROFILE

STRUCTURAL

DRAWING No.	SHEET No.	DRAWING TITLE
S1.1	133	DOWN DRAIN DISCHARGE STRUCTURE - STRUCTURAL
S2.1	134	RESERVOIR SUPPLY STRUCTURE - PLAN AND SECTION
S2.2	135	RESERVOIR SUPPLY STRUCTURE - REINFORCEMENT PLAN, SECTION AND DETAILS
S4.1	136	LOW LEVEL INLET - CONCRETE PLAN, SECTIONS, AND DETAILS
S4.2	137	INTAKE TOWER STRUCTURE - SECTIONS AND DETAILS
S4.3	138	INTAKE TOWER - STRUCTURE PLAN, SECTIONS AND DETAILS

Feature 4

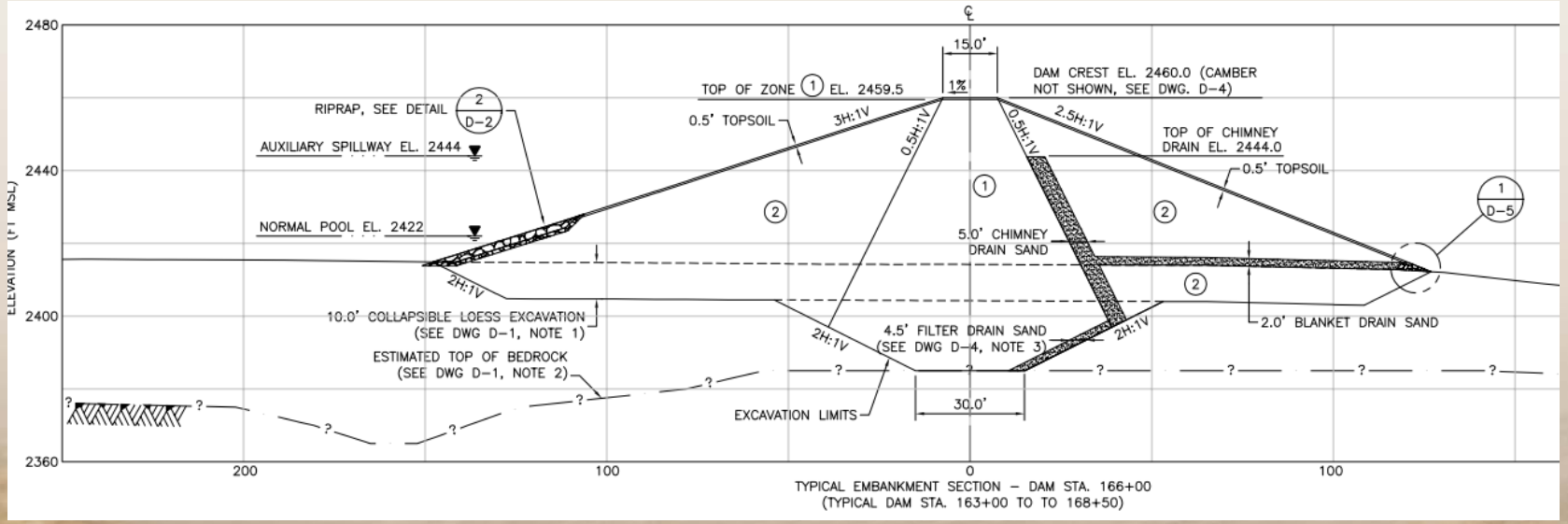
Drawings should include:

- **Major Components shown by:**
  - **Plan View**
  - **Profiles**
  - **Sections**
  - **Details**
  - **Notes**

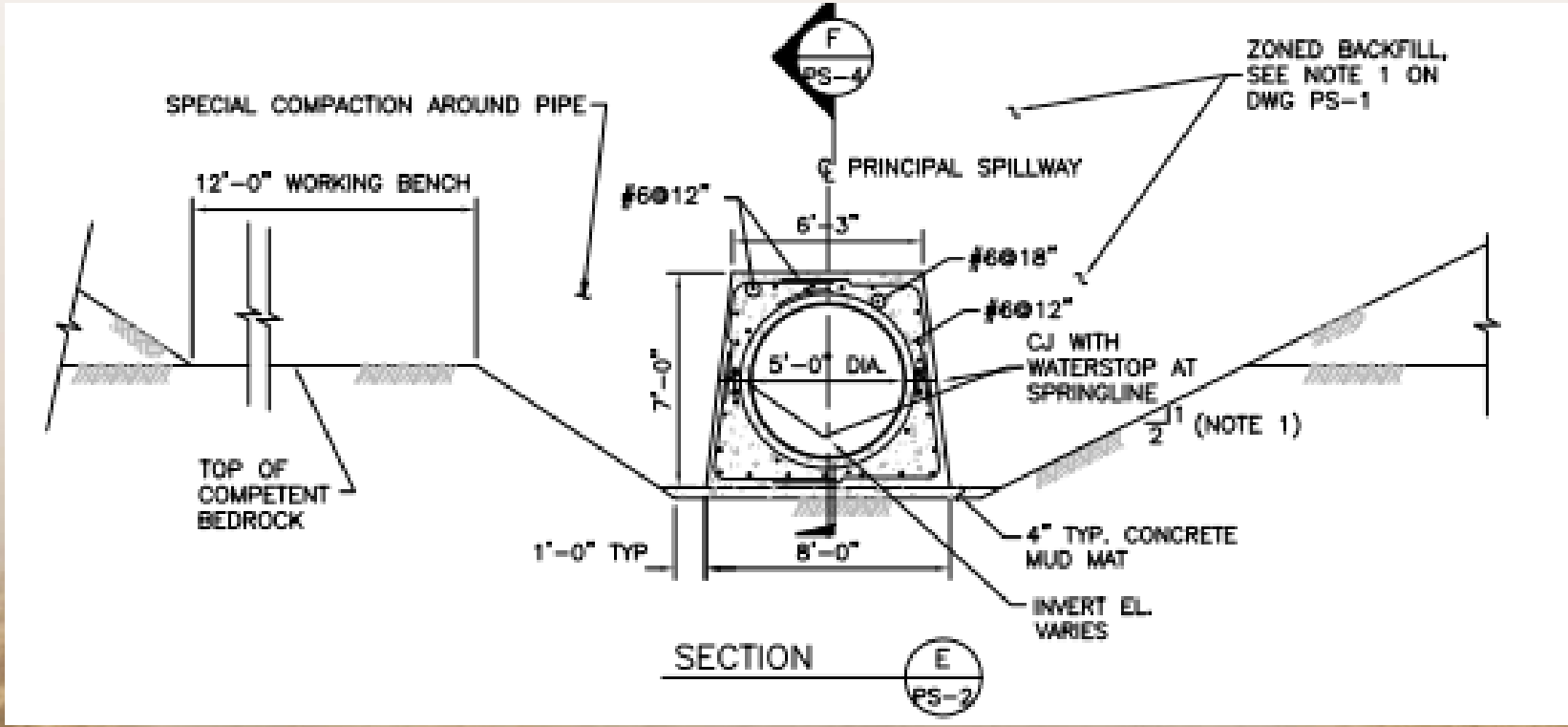
Drawing Orientation/Convention

- **Protocols typically:**
  - **North (top for plan views)**
  - **Upstream (to the left)**
  - **Left/right abutment (when looking downstream)**
  - **Slope**
    - **Slope reference 3:1 or 1:3, horizontal to vertical**
    - **To clarify, recommend 3H:1V**

Zoned Earth fill Dam:



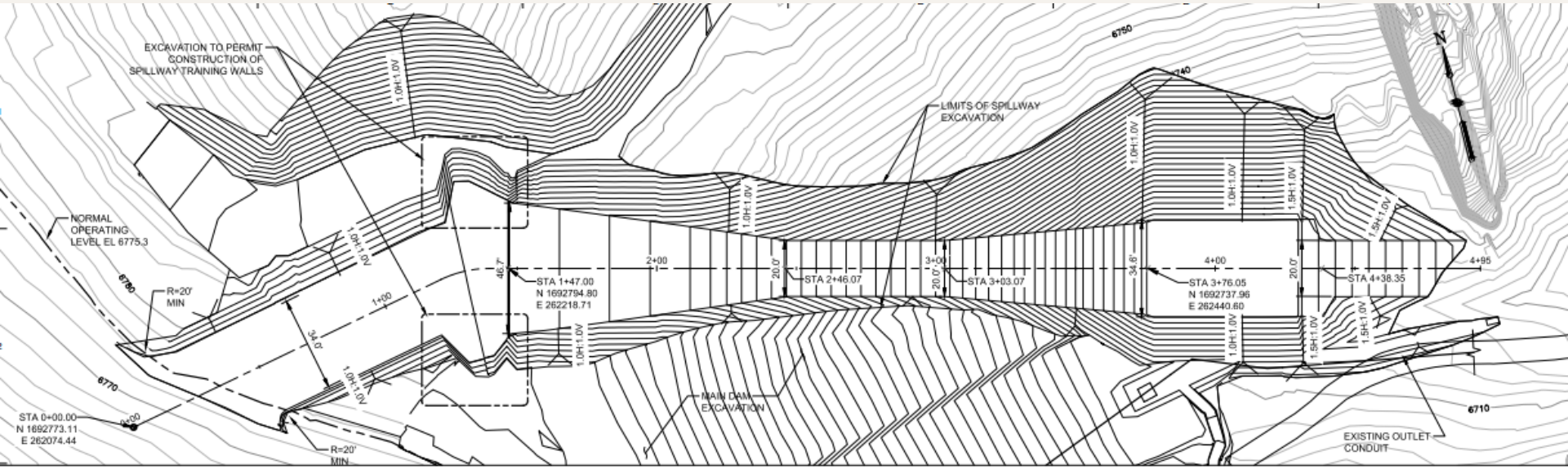
Details


F
PS-4
ZONED BACKFILL, SEE NOTE 1 ON DWG PS-1
SPECIAL COMPACTION AROUND PIPE
℄ PRINCIPAL SPILLWAY
12'-0" WORKING BENCH
#6@12"
6'-3"
#6@18"
#6@12"
CJ WITH WATERSTOP AT SPRINGLINE
7'-0"
5'-0" DIA.
1/2 (NOTE 1)
TOP OF COMPETENT BEDROCK
1'-0" TYP
8'-0"
4" TYP. CONCRETE MUD MAT
INVERT EL. VARIES
SECTION
E
PS-2

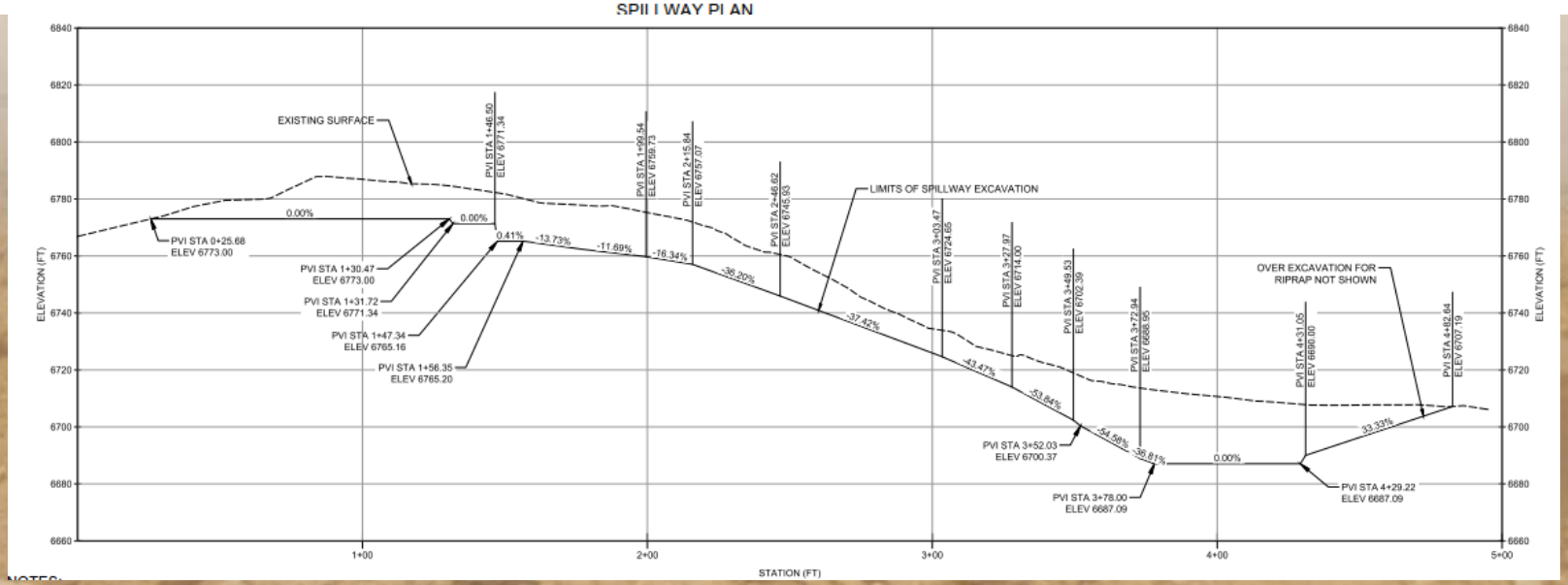
Focus on the foundation details:

- **Foundation details**
  - **Materials**
  - **Cutoff**
  - **Curtains**
  - **Treatments**
- **Compare to geotechnical data / assumptions**
  - **Identified stratigraphy**
  - **Foundation PFM's**

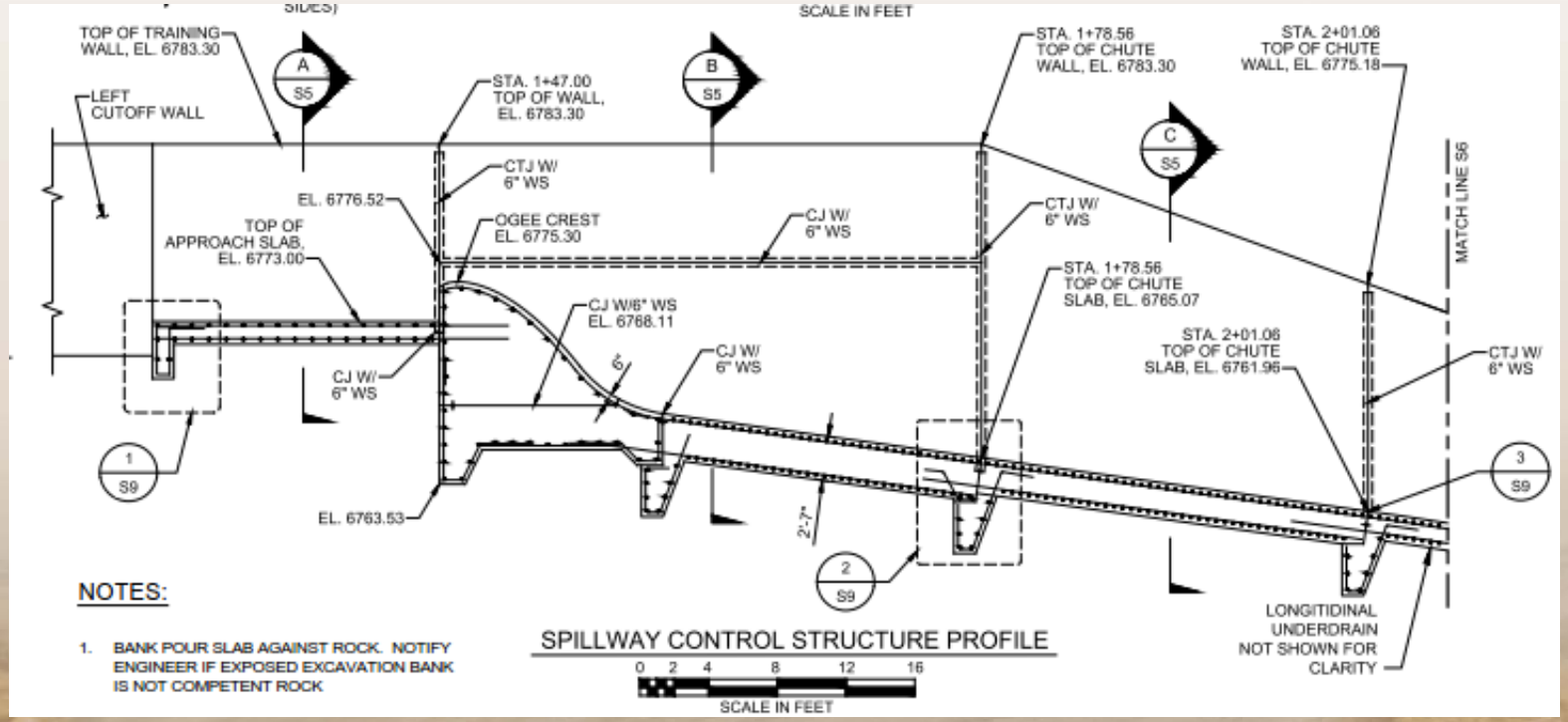
Spillway Plan & Profile:



SPILLWAY PLAN



Structural Detailing



F. The Specifications

- **What are Specifications?**
  - **Definition: A statement prescribing materials, dimensions, and workmanship for something to be built, installed, or manufactured.**
- **The drawings define the geometry of a project: dimensions and details, interfaces, etc.**
- **Specifications are intended to complement the drawings by providing the nature of the materials, workmanship and procedures to be used in executing the project.**

HISTORY TEST:

WHAT WAS THE FIRST SPECIFICATION?

Was This the First Specification?

Make yourself an ark of resin (or gofer wood); make rooms in the ark and cover it inside and out with pitch. This is how you are to make it; the length of the ark three hundred cubits, its breadth fifty cubits; and its height 30 cubits. Make the roof (or window) for the ark and finish it to a cubit above; and set the door of the ark on its side; make it with lower, second and third decks.

– (Genesis 6:14)

What does the term “Specification” refer to?

- **When Specifications are referred to, the actual content can vary**
- **In a broad view, references to specifications are not necessarily limited to the “technical portions” alone**
- **Specifications can be everything that is bound into the specification document such as:**
  - **Invitation to Bid, Bidding documents, General Conditions of the Contract (i.e., “boilerplate”), special provisions, technical sections, etc.**

Project Manual/Plans, Specifications and Contract Documents

- **"Contract Documents" would more appropriately describe the content that includes:**
  - **Invitation to Bid**
  - **Bidding Documents**
  - **General Conditions**
  - **Supplemental Conditions**
  - **Contract Agreement**
  - **Technical Specifications and Drawings**
- **Project Manual is also a more descriptive reference that encompasses all of these sections**

Contract Documents Consists of…

Bidding Requirements	Contract Documents
Invitation to Bid	Agreement/Contract
Instructions to Bidders	Performance and Payment Bonds
Information Available to Bidders	General Conditions of the Contract
Bid Forms	Supplementary Conditions
Bid Bonds	Technical Specifications
	Drawings
	Addenda

Types of Contract Documents

- **Historically, Contract Documents/Specifications have been prepared in whatever manner suited the engineer. This has varied by engineering firm, or organization, and even varies at times within the same organization. Formats today generally include:**
  - **“Standard Specifications” (for example, Department of Transportation and Municipalities, firm or agency standardized guide specification)**
  - **Federal Acquisition Regulation (FAR) based specifications**
  - **“Project Feature” based organization**
  - **“Trade Based” organization**

Standard Municipal/DOT Specifications

- **Department of Transportation**
  - **Covers all general contract conditions and technical specifications for all types of construction that can be reasonably anticipated for a transportation project.**
  - **Special Provisions define changes, additions or deletions to the standard specifications for a specific project.**
  - **Majority of DOT projects involve repetitive work with standard details, materials and execution (i.e., asphalt paving, Portland Cement paving, guard rail, etc…)**
  - **Standard payment items.**
- **Projects with repetitive details, section, approaches amenable to standardization (Roadways, pipelines etc.)**

Federal Agency Specification

CONSTRUCTION SPECIFICATIONS

1	-	Clearing
2	-	Clearing and Grubbing
5	-	Pollution Control
6	-	Seeding, Sprigging, and Mulching
7	-	Construction Surveys for Layout, Control and Measurement
8	-	Mobilization and Demobilization
11	-	Removal of Water
21	-	Excavation
23	-	Earthfill
26	-	Salvaging and Spreading Topsoil
31	-	Concrete for Major Structures
34	-	Steel Reinforcement
51	-	Corrugated Metal Pipe Conduits
52	-	Steel Pipe Conduits
53	-	Ductile Iron Pipe Conduits
61	-	Rock Riprap
81	-	Metal Fabrication and Installation
91	-	Chain Link Fence
94	-	Contractor Quality Control
209	-	Field Office
400	-	Foundation Preparation
402	-	Foundation Anchors
403	-	Dental, Bedding, Leveling, and Facing Concrete
404	-	Roller Compacted Concrete
405	-	RCC Test Section
406		RCC Contraction Joints
407	-	Crack Control Notches
408	-	Dam Instrumentation
409	-	Tree/Shrub Planting

MATERIAL SPECIFICATIONS:

521	-	Aggregates for Drain Fill and Filters
522	-	Aggregates for Portland Cement Concrete
523	-	Rock for Riprap
531	-	Portland Cement
532	-	Mineral Admixtures for Concrete
533	-	Chemical Admixtures for Concrete
534	-	Curing Compound (for Concrete)
535	-	Preformed Expansion Joint Filler
536	-	Sealing Compound for Joints in Concrete and Concrete Pipe
537	-	Non-Metallic Waterstops
539	-	Steel Reinforcement (for Concrete)
551	-	Metallic Coated Corrugated Steel Pipe
553	-	Ductile-Iron Pipe and Fittings
554	-	Steel Pipe and Fittings
581	-	Metal
582	-	Galvanizing
583	-	Coal Tar Epoxy Paint

- **FAR Based Specifications**
  - **Similar to DOT standard specifications procedure: However, Federal Acquisition Regulations govern the contract terms, etc.**
- **Some agencies have template specifications specific to their types of projects**

Non –Government Agency Specifications

- **Project Feature Based Organization**
  - **Each significant feature of a project is described completely within a single section (e.g Outlet Works, Instrumentation ….)**
- **Trade Based Organization**
  - **Earthfill**
  - **Concrete**
  - **Mechanical**
  - **Electrical**
- **Construction Specifications Institute (CSI)**

Widely Used Format: CSI's "MasterFormat"

- **MasterFormat is a system for organizing detailed construction information into a standard order or sequence on the basis of products and methods. CSI was adopted by the Associated General Contractors, American Institute of Architects and National Society of Professional Engineers.**
  - **Well organized division/technical sections**
  - **Consistent Divisions: Five Subgroups and 49 Divisions (Prior to 2004, Sixteen Divisions)**
- **Divisions are not renumbered if a Division is not used.**
  - **Same specification number from project to project**
- **The CSI is MasterFormat (albeit strongly slanted to building construction versus heavy civil construction) is the predominant format.**
  - **CSI does not publish specifications**

MasterFormat Organization

- **MasterFormat groups numbers and titles under the following Groups and Subgroups:**
  - **Procurements and Contracting Requirements**
    - **Division 00**
  - **CSI SubGroups**
    - **General Requirements: Division 01***
    - **Facility Construction : Division 02 through Division 19***
    - **Facility Services: Division 20 through Division 29**
    - **Site and Infrastructure: Division 30 through Division 39***
    - **Process Equipment: Division 40 through Division 49**

*** Primary SubGroups/Divisions used for dam and levee projects**

MasterFormat Sections

- **MasterFormat provides six digit numbers XX 00 00 (a revision of the previous 5 digit system):**
  - **First two digits refer to the Division with the next two digits representing broad-scope titles and are generally assigned in MasterFormat**
  - **For example: 03 00 00 refers to Specifications Division 3 – Concrete**
    - **03 10 00 Concrete Forming and Accessories**
    - **03 20 00 Concrete Reinforcing**
    - **03 30 00 Cast-in-Place Concrete**

Groups, Subgroups and Divisions

- **Procurement and Contracting Requirements Group**
  - **00 Procurement and Contracting***
    - **Introductory Information**
    - **Procurement Requirements**
    - **Contracting Requirements**
- **General Requirements Subgroup**
  - **01 General Requirements***

Groups, Subgroups and Divisions

- **Facility Construction Subgroup:**
  - 02 Existing Conditions*
  - 03 Concrete*
  - 04 Masonry
  - 05 Metals*
  - 06 Wood, Plastics, and Composites
  - 07 Thermal and Moisture Protection
  - 08 Openings
  - 09 Finishes
  - 10 Specialties
  - 11 Furnishings
  - 12 Special Construction
  - 13 Conveying Equipment
  - 14 Equipment
  - 15, 16, 17, 18, and 19 Future Expansion

Groups, Subgroups and Divisions

- **Facility Services Subgroup:**
  - **21 Fire Suppression**
  - **22 Plumbing**
  - **23 Heating, Ventilating and Air-conditioning (HVAC)**
  - **25 Integrated Automation**
  - **26 Electrical***
  - **27 Communications**
  - **28 Electronic Safety and Security**
  - **20, 24, and 29 Future Expansion**

Groups, Subgroups and Divisions

- **Site and Infrastructure Subgroup**:
  - **31 Earthwork***
  - **32 Exterior**
  - **33 Utilities**
  - **34 Transportation**
  - **35 Waterway and Marine Construction***
  - **30, 36, 37, 38, and 39 Future Expansion**

Major Changes: Specification in 2004 MasterFormat

- **Site Work Moved from Division 2 (Now 02 Existing Conditions) to Division 31 Earthwork**
- **Dam Construction: Division 35 Waterway and Marine Construction**
  - **35 71 00 Gravity Dams**
  - **35 72 00 Arch Dams**
  - **35 73 00 Embankment Dams**
  - **35 74 00 Buttress Dams**

Example Table of Contents

- **Construction Specification Institute (2004)**

PROJECT TABLE OF CONTENTS

DIVISION 01 - GENERAL REQUIREMENTS

DIVISION 03 - CONCRETE

Example Table of Contents: CSI Pre 2004/Post 2004

Pre 2004

DIVISION 3 - CONCRETE

03100	Concrete Formwork
03150	Concrete Joints and PVC Waterstops
03200	Concrete Reinforcement
03300	Cast-in-Place Concrete

Post 2004

PROJECT TABLE OF CONTENTS

DIVISION 01 - GENERAL REQUIREMENTS

01 11 00	SUMMARY OF WORK
01 14 00	WORK RESTRICTIONS
01 22 00.00 10	PRICE AND PAYMENT PROCEDURES
01 32 16.00 20	SMALL PROJECT CONSTRUCTION PROGRESS SCHEDULES
01 33 00	SUBMITTAL PROCEDURES
01 35 26	GOVERNMENTAL SAFETY REQUIREMENTS
01 42 00	SOURCES FOR REFERENCE PUBLICATIONS
01 45 00.00 10	QUALITY CONTROL
01 50 00	TEMPORARY CONSTRUCTION FACILITIES AND CONTROLS
01 57 19	TEMPORARY ENVIRONMENTAL CONTROLS
01 78 00	CLOSEOUT SUBMITTALS

DIVISION 03 - CONCRETE

03 30 53	MISCELLANEOUS CAST-IN-PLACE CONCRETE
03 37 29	TREMIE CONCRETE FOR CUTOFF WALL

Outline of CSI Sub-Sections

Part 1 – General	Part 2 – Products	Part 3 – Execution
Summary	Manufacturers	Acceptable Installers
References	Existing Products	Examination
Definitions	Materials	Preparation
Systems Descriptions	Manufactured Units	Erection
Submittals	Equipment	Installation
Quality Assurance	Components	Application
Delivery, Storage and Handling	Accessories	Construction
Project/Site Conditions	Mixes	Repair/Restoration
Sequencing	Fabrications	Re-installation
Scheduling	Finishes	Field Quality Control
Warranty	Source Quality Control	Adjusting
System Startup		Cleaning
Owner's Instructions		Demonstration
Commissioning		Protection
Maintenance		Schedules

Writing Specifications: (e.g., Descriptive Specification)

- **Detailed description of the required properties of a product, material or equipment, and the workmanship required for installation**
- **For example:**
  - **4 parts coarse aggregate**
  - **1 part fine aggregate**
  - **Water:cement ratio of 0.5:1**
- **A performance strength of 3000 psi at 28 days is implied (based on experience) but not specified**
- **Burden of the performance is assumed by the engineer when a detailed design or descriptive specification is used**

e.g. Performance Specifications

- **Specify a required level or range of performance for material or equipment (without unnecessary limitations on the method for achieving results), that becomes the responsibility of the contractor, supplier or manufacturer**
- **The physical parameters of performance that must be met and the method of testing and assuring performance criteria are met must be provided.**
- **Specifying a requirement of 3000 psi concrete is a performance specification**
- **Performance specifications give contractors the opportunity to be inventive in an efficient, economical manner**

Principles for Performance Specification Writing

- **Decide on level of performance specifying**
- **Each requirement should be stated only one time and in one place**
  - **This simplifies the retrieval of information and reduces the possibility of conflicts and discrepancies**
  - **Engineers Joint Contract Documents Committee (EJCDC) and the American Institute of Architects (AIA) provide a reference, "Uniform Location of Subject Matter and Information in Construction Documents" for coordinating construction documents**
  - **Everyone benefits from this standardized approach to placement of information in construction documents**
- **Use simple sentences: Declarative or imperative statements versus indicative (storybook type description)**

Keys to Effective Specification Writing / What to Look For!

- **Be consistent, concise and clear**
- **Be correct**
- **Be complete**
- **Avoid redundancies**

Use of “Or Equal”

- **Why use “or equal” for many procured items?**
  - **Substitutions or “Or Equal:”**
    - **For every product specified there are usually a number of similar products available**
  - **Preferences for a particular manufactured product**
  - **Cost savings if contractor has a “special” supplier**
- **Inappropriate limiting of suppliers**

Use of “Or Equal” (continued)

- **Where substitutions are to be allowed, specifications must include sufficient information to define the required function and the specific attribute required for the project**
- **This will allow a consistent and fair basis for evaluation of substitution requests**
- **Use of specifications listing several acceptable manufacturers can be used to promote competition while limiting the more wide open “substitution/or equal” process**

Using Referenced Standards in Specifications

- **Referenced standards are requirements set by authority, custom or general consensus and are established as accepted criteria (e.g. ASTM)**
- **Authors are typically architects, engineers, scientists, manufacturer's and product user's who are very knowledgeable about the referenced standard subject**
- **Save the engineer from writing an elaborate and lengthy specification**
- **BUT "Know the Standard"**
  - **They can create duplication/contradiction within the documents**
  - **Can contain hidden choices**

Design Plans & Specifications Review. Regulatory Agencies

- **Reference standards often define quality in terms of minimum requirements.**
  - **In some cases, may be too liberal. Exceptions may need to be made to the reference standards.**
- **Hidden choices can exist – for example:**
  - **Specifying cement to meet ASTM C150. The standard covers up to eight types of cement, with several optional requirements.**
  - **Without further delineation by the engineer, the contractor can be reasonably expected to select the least expensive option.**
- **Also referencing a standard does not ensure that the product is available at the time and in the location of the work.**

Incorporating A Standard

- **Need to Incorporate Appropriately**
- **Name the issuing organization**
- **Number Designation and Title as printed on the actual standard**
- **Date of Issue: Standards are revised periodically**
  - **Revisions sometimes occur after the project is designed**
  - **When no date is included, different versions could result in contradictions. Contract could include a condition that "the most current standard at the time of the bid" is to be used**
  - **Some revisions are not desired by the designer**
- **Use a single location to establish the date of the reference standard that will apply, to avoid inadvertent conflicts within a specification or between sections**

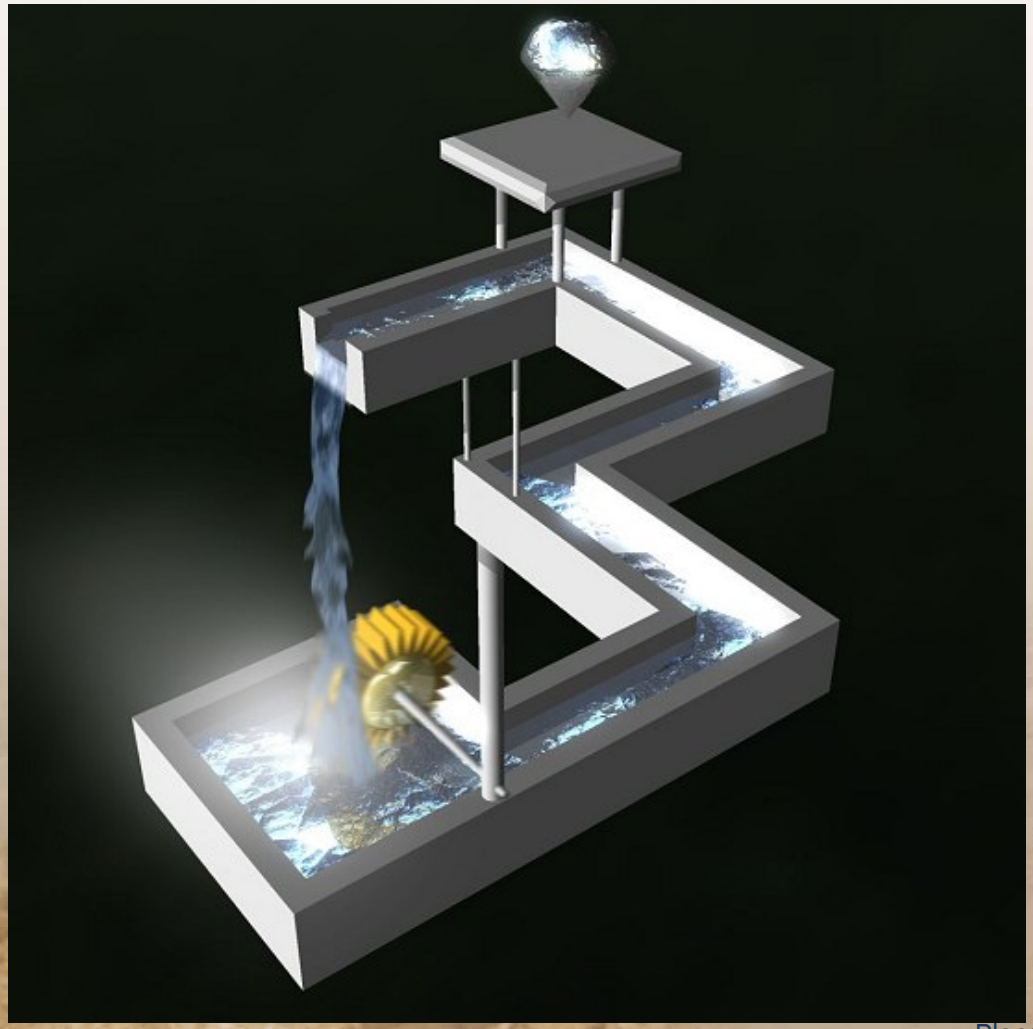
Specification Review – What to Look For! (continued)

- **Are ambiguous terms used in the text?**
  - **"Subject to approval of the Engineer"**
    - **Statement may be needed for a particular item**
    - **Appropriate for few specific "field fit" items**
  - **"To be determined in the field"**
    - **May be able to be established for design**
    - **How is a contractor to bid this phrase?**
  - **"In a workmanlike manner"**
    - **What does that mean?**
    - **How is it enforceable?**

F. Design Review: Why Review the Design PE's Work?

- **Rather than the question of why! Ask the question: What are the benefits of reviews?**
- **Internal Peer Review**
  - **Review by experienced senior engineer independent of the design team (Provides "forest vs. trees" perspective)**
  - **Quality control, liability reduction**
- **Regulatory Review**
  - **Safety, protection of the public, statutory requirements**
- **Independent Technical Review**
  - **Significant project with new/unusual design**
  - **Design features outside of the experience of the designer**
  - **Constructability**
  - **Provides a standard of practice perspective**

It is valuable to have a component of review for: Can it be Built?



Keys to All Reviews

- **Understanding Design Basis, Critical Features:**
  - **Hydrology and hazard potential classification**
  - **Geology and geotechnical foundation conditions**
    - **Foundation cutoff depth and foundation treatment**
  - **Borrow material to be used for dam construction**
  - **Engineering properties for dam and foundation**
  - **Stability and seepage analysis**
  - **Hydraulic discharge capacity (outlet works and spillway)**

Compare Design Basis/Analysis with what is shown on Drawings/Specifications:

- **Does the design conform to the design criteria in the report?**
  - **Established design standards**
  - **Special site constraints**
  - **Special project requirements**

Site Visit

- **Do the conditions shown on the drawings resemble the site?**
- **What is the site like? Access, springs/ wetland/swampy areas/rocky/boulders, areas with significant organics?**
- **Think through the design features with the "site" in mind**
- **"Plan in hand" site visits can detect potential design problems before they are encountered**

Review by Regulatory Agency

- **Should you review all of the features or just those related to dam safety?**
- **It is important to have a review policy to establish what will be review that meets statutory requirements and design review guidelines of the agency.**
  - **Checklist provides a method to assure that all of the appropriate features are reviewed.**
  - **Establishes a protocol and document trail for noting features not reviewed, variances from agency requirements, guidelines, preferences, etc.**
- **Note: Not a means to catch that the designer did not consider another alternative. Not responsible for duplicating all of the calculations**

Technical Review can miss important sections!

- **General Conditions and Contract Requirements to Look For in Technical Reviews**
  - **Some key sections that pertain to the implementation of the technical provisions are described in other sections of the contract documents.**
  - **For example: Substitutions, Or-equal provisions, submittal reviews, measurement and payment**
- **The General Conditions and Contract Agreement establish the rules between the Owner and the Contractor implementing the specifications.**
  - **Not always reviewed by regulatory staff**
  - **Reviewers need to recognize that there may be some conditions that are relevant to their areas of review**

Review Stages / Timing of Review

- **Final Design/Preliminary Design?**
- **Timing of comments/required changes is very important for all parties!**

95% Design Review Can be Frustrating

- **Designer is very resistant to changes because**
  - **A lot of “blood, sweat, and tears” have gone into developing a complete design**
  - **Design budget is mostly spent**
  - **Changes are viewed by some as critical of the designer’s ability**

95% Design Review Can be Frustrating (cont.)

- **Reviewer faces pressure of identifying whether recommendations are:**
  - **Critical or safety related**
  - **Really necessary considering that the design is considered complete by the owner and designer**
  - **Differences of professional opinion**
  - **Unnecessarily embarrassing to the designer**
  - **Owner/Client deadlines**
  - **Political pressure**

Coordination Points During Design

- **Hydrology and Hazard Classification are key early agreements that, if changed late in the design process, can significantly affect:**
  - **Decisions**
  - **Schedule**
  - **engineering effort (costs)**
- **Hazard Classification defines the Inflow Design Flood (IDF)**
  - **Spillway design & freeboard required to safely pass the IDF, determine the crest elevation**
  - **Any change during the design process will impact the entire design**

Coordination Points During Design (cont.)

- **Geology and geotechnical reports needed to:**
  - **Characterize the foundation**
  - **Identify the dam type (zoned or homogenous earth fill, rockfill, other…)**
  - **Underseepage cutoff type (cutoff trench, slurry wall, pressure grouting)**
- **Consider that the geotechnical investigation is not complete until the foundation has been excavated and the underseepage cutoff completed**

Keys to Minimize Impact of Review Comments

- **Establish Design Criteria at beginning of Project (by the preliminary design stage)**
- **Meetings between Designer and Reviewer at intermediate design stages**
- **Use review guidelines**
- **Document recommendations/decisions at meetings in writing**
- **Assign responsibility for documentation**

Example: General Conditions / Contract Provisions Review Should Include:

- **Submittal Requirements**
- **Project Coordination Meetings**
- **Don't forget the Substitution and "Or Equal" Procedures in General Conditions**
- **Quality Control Program**
- **Project Closeout**

F. Design of Dams and Levees carries a High degree of Responsibility

- **Dams and Levees that do not perform to the required level of protection pose a risk to life, property and the environment**
- **Level of Risk/Protection against of Failure is a Societal Burden**
  - **Primary duty of the Engineer is to minimize this hazard**
- **Dam/Levee Design Require Defensive Engineering**
  - **Design should include lines of defense so that if one fails, the next will takeover (i.e., a “belt and suspenders approach”)**

Questions