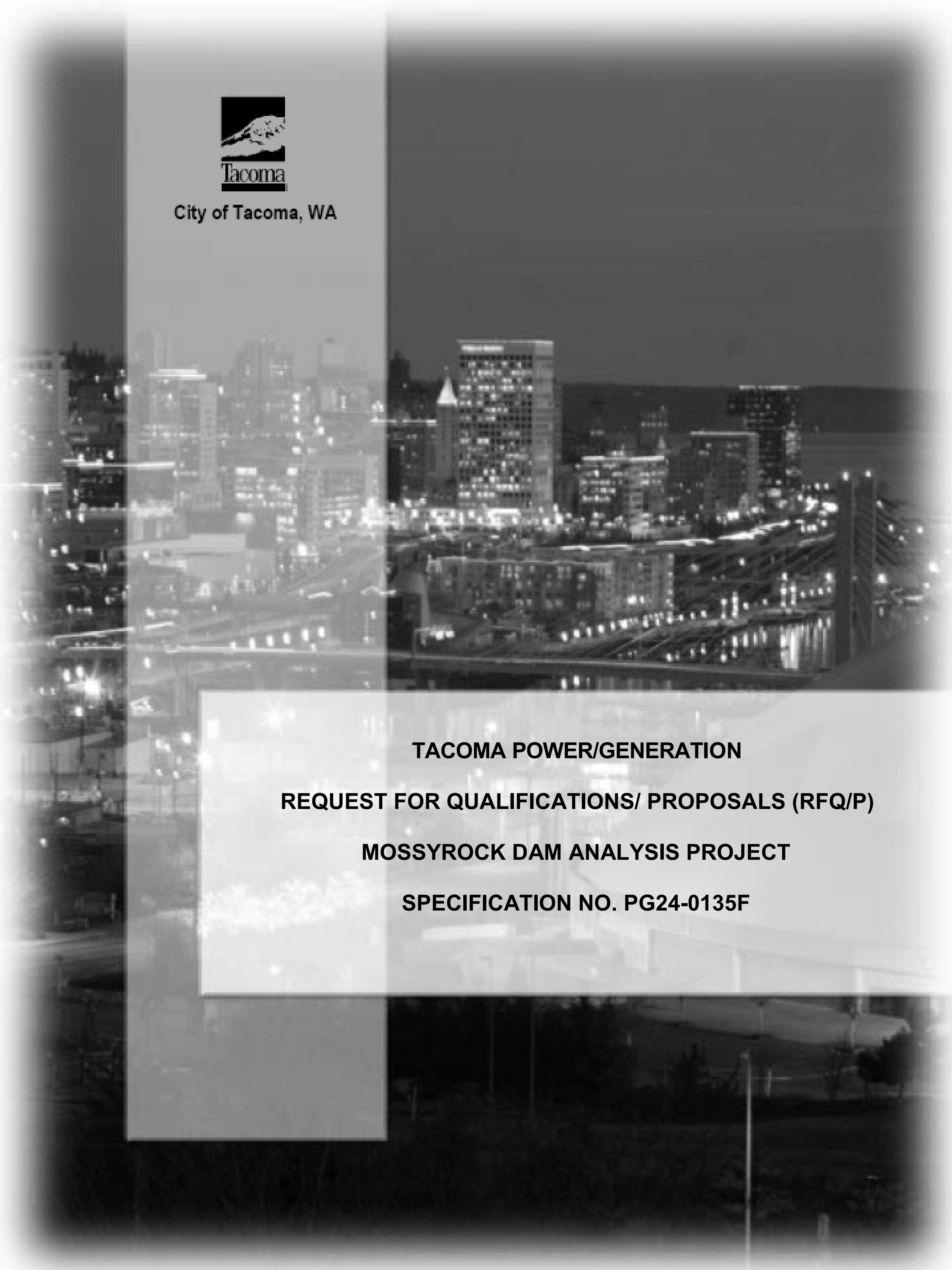

City of Tacoma, WA

TACOMA POWER/GENERATION

REQUEST FOR QUALIFICATIONS/ PROPOSALS (RFQ/P)

MOSSYROCK DAM ANALYSIS PROJECT

SPECIFICATION NO. PG24-0135F

City of Tacoma
Tacoma Power/Generation

REQUEST FOR QUALIFICATIONS/PROPOSALS PG24-0135F
Mossyrock Dam Analysis Project

Submittal Deadline: 11:00 a.m., Pacific Time, Tuesday, September 17, 2024

Submittals must be received by the City's Procurement and Payables Division prior to 11:00 a.m. Pacific Time. For electronic submittals, the City of Tacoma will designate the time of receipt recorded by our email, sendbid@cityoftacoma.org, as the official time of receipt. This clock will be used as the official time of receipt of all parts of electronic bid submittals. Late submittals will be returned unopened and rejected as non-responsive.

Submittal Delivery: Sealed submittals will be received as follows:

By Email: sendbid@cityoftacoma.org Maximum file size: 35 MB. Multiple emails may be sent for each submittal.

Bid Opening: Submittals must be received by the City's Procurement and Payables Division prior to 11:00 a.m. Pacific Time. Sealed submittals in response to a RFB will be opened Tuesday's at 11:15 a.m. by a purchasing representative and read aloud during a public bid opening held at the Tacoma Public Utilities Administrative Building North, 3628 S. 35th Street, Tacoma, WA 98409, conference room M-1, located on the main floor. They will also be held virtually Tuesday's at 11:15 a.m. Attend via this link or call 1 (253) 215 8782. Submittals in response to an RFP, RFQ or RFI will be recorded as received. As soon as possible, after 1:00 PM, on the day of submittal deadline, preliminary results will be posted to www.TacomaPurchasing.org.

Solicitation Documents: An electronic copy of the complete solicitation documents may be viewed and obtained by accessing the City of Tacoma Purchasing website at www.TacomaPurchasing.org.

- Register for the Bid Holders List to receive notices of addenda, questions and answers and related updates.
- Click here to see a list of vendors registered for this solicitation.

Pre-Proposal Meeting: A pre-proposal meeting will be held on Wednesday, August 28th, 2024, at 10:00 AM at the Mayfield Project Office, 253 Hydro Ln. Silver Creek, WA 98585. A site visit to Mossyrock Dam will follow the office meeting.

Project Scope: Create a calibrated and defensible 3D stability model for Mossyrock Dam that meets the current state-of-practice standards for analysis of concrete dams, from which clear conclusions can be drawn.

Estimate: N/A

Paid Sick Leave: The City of Tacoma requires all employers to provide paid sick leave as set forth in Title 18 of the Tacoma Municipal Code and in accordance with State of Washington law.

Americans with Disabilities Act (ADA Information: The City of Tacoma, in accordance with Section 504 of the Rehabilitation Act (Section 504) and the Americans with Disabilities Act (ADA), commits to nondiscrimination on the basis of disability, in all of its programs and activities. Specification materials can be made available in an alternate format by emailing the contact listed below in the *Additional Information* section.

Title VI Information:
"The City of Tacoma" in accordance with provisions of Title VI of the Civil Rights Act of 1964, (78 Stat. 252, 42 U.S.C. sections 2000d to 2000d-4) and the Regulations, hereby notifies all bidders that it will affirmatively ensure that in any contract entered into pursuant to this advertisement, disadvantaged business enterprises will be afforded full and fair opportunity to submit bids in response to this invitation and will not be discriminated against on the grounds of race, color, national origin in consideration of award.

Additional Information: Requests for information regarding the specifications may be obtained by contacting Ryan Foster, Senior Buyer by email to rFoster1@cityoftacoma.org.

Protest Policy: City of Tacoma protest policy, located at www.tacomapurchasing.org, specifies procedures for protests submitted prior to and after submittal deadline.

Meeting sites are accessible to persons with disabilities. Reasonable accommodations for persons with disabilities can be arranged with 48 hours advance notice by calling 253-502-8468.

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SUBMITTAL CHECK LIST

This checklist identifies items to be included with your submittal. Any submittal received without these required items may be deemed non-responsive and not be considered for award.

Submittals must be received by the City of Tacoma Purchasing Division by the date and time specified in the Request for Proposal page.

The following items make up your submittal package:	☑
One electronic copy of your complete submittal package	
Signature Page (Appendix B)	
Record of Prior Contracts (Appendix B)	
Content To Be Submitted (Section 12)	
After award, the following documents will be executed:	
Sample Professional Services Contract (Appendix C)	
Certificate of Insurance and related endorsements (Appendix C)	

1. INTRODUCTION

Mossyrock Dam is a double-curvature arch dam standing 606 feet high, making it the tallest dam in Washington State. The Dam was constructed in 1968 and is located in Lewis County on the Cowlitz River near the town of Mossyrock in south-western Washington. Mossyrock Dam is owned by the City of Tacoma, Department of Public Utilities, Light Division (dba Tacoma Power) and is operated under the Federal Energy Regulatory Commission (FERC) License No. 2016-WA. The Development provides power generation, flood storage, recreation, and flows for downstream fish habitat. The Development has a high hazard potential classification. Appendix A provides general information and site drawings for the Mossyrock Development.

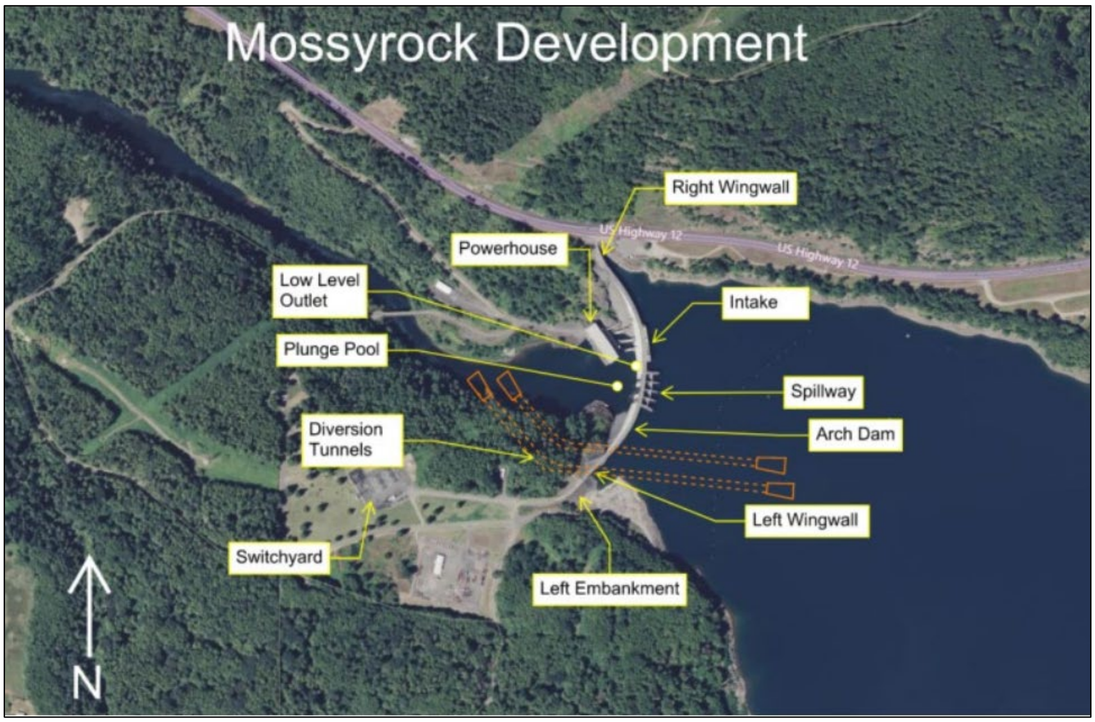

Figure 1 - Overview of Development Structures at Dam Site

Over the past two decades, changes in the understanding of regional seismicity have resulted in significant increases to the seismic hazard at Mossyrock Dam. As the understanding of regional seismicity has progressively changed, Tacoma Power has completed several iterations of analysis to maintain a state-of-practice understanding of the Dam's seismic performance.

Due to these seismic hazard increases and in response to the uncertainties associated with the numerically estimated performance of the Dam (when subjected to large magnitude seismic loads) Tacoma Power lowered the normal operating reservoir as an Interim Risk Reduction Measure (IRRM) in 2017. The maximum reservoir elevation by design is EL. 778.5-feet; due to self-curtailment, the reservoir is being held at a new normal maximum of EL. 749.0-feet until alternative or permanent risk reduction measures are implemented. A Board of Consultants (BOC) was convened in 2017 to evaluate the seismic performance and potential failure modes associated with the increased seismic hazard at the development. The BOC remains active and will be in-place for the duration of the risk evaluation and risk reduction effort.

The latest iteration of numerical structural modeling was completed in 2020 which included a non-linear explicit finite element analysis (FEA) of the dam, spillway and piers, thrust block, and gravity wing walls with time histories developed in 2018. Since the 2020 update to the FEA, Tacoma Power funded a series of field investigations that included both Performance Based Tests (PBT) and Flow-Induced Monitoring (FIM). The results of these performance tests combined with seismic event data recorded onsite in 2010 by Strong Motion Accelerometers (SMAs) provide valuable insight into the Dam's fundamental dynamic characteristics.

In August 2023, the latest iteration of the Seismic Hazard Assessment (SHA) was submitted to the FERC and is pending review and acceptance. The SHA included a site-specific probabilistic seismic hazard analysis (PSHA) and a deterministic seismic hazard analysis (DSHA). For Mossyrock Dam the mean peak ground acceleration (PGA) value is currently estimated at 0.80g (10,000-year return period) and 0.65g (5,000-year return period).

Also in 2023, a Potential Failure Modes Analysis (PFMA) and Level 2 Risk Assessment (L2RA) was performed as part of a Comprehensive Assessment (CA) for Mossyrock Dam's FERC Part 12D Independent Consultant (IC) inspection. The CA identified a number of potential failure modes (PFMs) as risk drivers that require additional analysis to evaluate. 125 candidate PFMs were brainstormed, 27 were judged to be credible and were estimated, 7 were judged to be credible and estimated for damage state, and 19 were judged to be asset management concerns.

The credible PFMs are organized into 5 general structures: Arch Dam and Thrust Blocks, Spillway, Spillway Gate, Freeboard Dike, and Left Embankment Dam. There are 4 credible PFMs that are related to the concrete superstructure of the Dam. These PFMs are as follows:

PFM Number: MR-AD-1S

Description: Failure of the Header Beam Leads to Failure of the Arch – a seismically induced failure of the header beam over the spillway leads to cracking and the development of isolated blocks which move out of place and cause an uncontrolled reservoir release.

PFM Number: MR-AD-3S

Description: Failure of the Arch Dam due to instability of a Thrust Block along the Concrete/Rock Interface – a seismic event causes a thrust block to slide at the concrete/rock interface, which causes instability of the arch dam and leads to an uncontrolled reservoir release.

PFM Number: **MR-AD-6N/F/S**

Description: Rock Block Instability Causes Failure of the Dam – normal, flood, or seismic loading causes downstream mobilization of a rock block, leading to instability of the dam and uncontrolled reservoir release.

PFM Number: **MR-SP-1S**

Description: Spillway Pier(s) Fail Leading to Uncontrolled Release Through Spillway Section (without failure of the header beam) – a seismic event causes the reinforced concrete piers to crack and the rebar to fail, leading to displacement of the piers, damage to the gate, and ultimately uncontrolled reservoir release over the spillway.

Furthermore, there were 50 recommendations that resulted from the CA process. Recommendation #2023-13 (*below*) was the single recommendation that focused on the need for updated numerical modeling and dam analyses.

Recommendation #2023-13

- Determine if updated analyses of the arch dam, thrust blocks, and wingwalls in their current configuration are likely to resolve performance concerns identified during the PFMA. If appropriate, update these analyses considering the updated SHA and addressing comments made during the 2023 PFMA and L2RA. The following should be considered:
  - Conduct initial analyses of the model under normal operating conditions and calibrate the model to the Performance Based Testing results. Then calibrate the model at the current reservoir restriction level.
  - Use the existing model to evaluate the effects of the higher SHA.
  - Evaluate the effects of the contraction joints in the header beam and the stability of the header beam when subject to gate loads and arch dam movement either by inclusion of sufficient detail in the analysis or by further post-analysis evaluation.
  - Evaluate the potential for out of phase movement between the spillway gates and the header beam.
  - Include the shear keys in the arch dam cantilever joints.
  - Include the buttresses at the intake structure in the model.
  - Evaluate the stability of the dam and spillway under the reduced reservoir level to verify if the reservoir level restriction is a valid risk reduction measure.

- Compare observed cracking in the spillway pier's to analysis predictions and evaluate the impacts on cracking.
- Determine if thermal loadings should be considered in the analysis and provide a clear description of the conclusion.
- Conduct analyses for extreme flood loading, such as the PMF.
- Verify that the appropriate structural and fluid elements are being used, and that the fluid elements do not inadvertently apply suction. Compare the results of the three-dimensional analysis of the thrust blocks and wingwalls to conventional two-dimensional analyses, assess the sensitivity to uplift, and consider measuring uplift if appropriate.

Following the CA, a *draft* Analysis Basis Document (ABD) was developed as a plan of analysis to evaluate the most recently identified failure modes and address the IC's recommendation. The *draft* ABD is attached as Appendix A and serves as the Technical Specification for this solicitation. The *draft* ABD describes the baseline plan for future analysis and provides information that is assumed to be required to perform the analysis.

Tacoma Power is seeking a qualified engineering firm to evaluate, refine, and finalize the ABD, and create a defensible 3D stability model to present-day best practices, from which clear conclusions can be drawn. Considering that the *final* ABD document is likely to change the scope of the analysis effort, the task outline each firm should utilize in their proposal response is provided in Section 5 – Scope of Services and Deliverables. This task outline is based on the *draft* ABD.

Ultimately, the final analysis results will be used to gain a quantitative understanding of the PFMs (the incipient load in which the structure fails and the associated breach size/outflow of the failure), address the IC recommendation, evaluate project risk drivers, and allow Tacoma Power to make risk-informed decisions to initiate a stability enhancement program for Mossyrock Dam. The results will become the stability analysis of record and be submitted to the FERC for their review and acceptance.

To learn more about the City of Tacoma, visit www.cityoftacoma.org.

The City anticipates awarding one (1) Consultant Contract for a period of performance of two (2) years with an option to extend two (2), one-year extensions.

These services are budgeted at an estimated amount ranging from $500,000 to $1,000,000 with a scheduled completion of approximately 6-12 months after issuance of a notice to proceed.

Proposals submitted and/or the selected Consultant(s) may be used for projects of similar type and scope at the sole discretion of the City for up to one year.

2. SUMMARY OF RELEVANT PAST ANALYSIS

As mentioned previously, many studies, reports, and analyses have been conducted at the Mossyrock Development to maintain a state-of-practice understanding of the Dam's performance. Table 1 below provides an abbreviated timeline of events to better communicate historical context, with the focus being on the record of past stability analysis. As indicated, this is not a comprehensive timeline of events for analysis. It will be the consultant's responsibility to review all past reports and determine what is most relevant to this scope of work request.

Copies of all past analysis and reports on record will be available to qualified firms as determined by Tacoma Power. Qualified firms will be required to utilize the Supplemental Information Request Non-Disclosure Agreement (Appendix B) to obtain this additional bid documentation as it is considered Critical Energy Infrastructure Information (CEII).

The stability analysis of record requested by this solicitation will be required to synthesize the conclusions of past stability analyses and validate (or) challenge those conclusions within the new analysis of record.

Table 1 – Summary of Relevant Past Analysis (abbreviated timeline of events)

Report Date	Study/Report	Notes	Doc. ID /Source
January 1990	Structural Analysis of Mossyrock Dam	Addendum to the 5-year Part 12D Inspection Report	MZ 5550 Harza (1990)
July 2002	Mossyrock and Mayfield Dams, Probable Maximum Flood Study	Current Analysis of Record	MZ 6400 MWH (2002)
November 2002	Independent Consultant Inspection Report, Mossyrock Dam	-	MZ 6415 Kollgaard and Bowes (2002)
January 24, 2008	Finite Element Model - ANSYS	As a result of the 2002 Part 12D IC Inspection; Analyzed dam as an elastic solid accounting for the behavior of the vertical contraction joints	MZ 6675 Hatch (2008)
December 2008	Independent Consultant Inspection Report, Mossyrock Dam	-	MZ 6601 URS (2008)

Report Date	Study/Report	Notes	Doc. ID /Source
November 2010	Earthquake Record	Recorded earthquake was used to validate the model	Section 8 STID
February 15, 2011	Update to 2008 Finite Element Model - ANSYS	As a result of the 2007 Part 12D IC Inspection; updated 2008 analysis	MZ 6675 Hatch (2011)
April 22, 2011	Deformation Modulus, Mossyrock Dam	Assess foundation deformation modulus of 2008 FEA	MZ6645-1 Golder (2011)
April 29, 2011	Non-linear static and seismic implicit FEA of dam, spillway and piers, thrust block, and wing wall	-Include missing gravity sections from previous 2011 analysis -Create analysis model with linear material model and non-linear contact elements at dam/foundation and vertical contraction joint interfaces -Static analysis in ANSYS -Implicit, massless foundation seismic analysis in ANSYS. Hydrodynamic interaction included with lumped masses -Non-linear, distinct element, massed foundation seismic analysis in 3DEC. Hydrodynamic interaction included with solid elements	MZ 6675-1 Hatch (2011)
November 27, 2012	Non-linear seismic explicit FEA of dam, spillway and piers, thrust block, and wing wall	-Convert previous ANSYS model for input into LS-DYNA -Explicit, massed foundation seismic analysis in LS-DYNA. Hydrodynamic interaction included with solid elements	MZ 6705 Hatch (2012)

Report Date	Study/Report	Notes	Doc. ID /Source
December 1, 2013	Independent Consultant Inspection Report, Mossyrock Dam	-	MZ6750 Tetra Tech and W.D. Edwards Consulting (2013)
November 13, 2014	Ductility evaluation of the Spillway Piers	Deliverable 1 – Analysis Update (status of on-going work)	MZ 6760 URS (2014)
December 11, 2014	Ductility evaluation of the Spillway Piers	Deliverable 1 – Completed report detailing ductility eval of spillway piers	MZ 6775 URS (2014)
August 27, 2015	Spillway Pier Strength Interactions and Submodel Re-evaluation	Deliverable 2 – Conclusion report evaluating potential vulnerabilities of spillway piers	MZ 6780 AECOM (2015)
July 30, 2018	Seismic Hazard Assessment	-	MZ6840 Gannett Fleming (2018)
January 31, 2019	Independent Consultant Inspection Report, Mossyrock Dam	-	MZ6870 Tetra Tech and WD Edwards Consulting (2019)
June 11, 2020	Non-linear seismic explicit FEA of dam, spillway and piers, thrust block, and wing wall	-Previous model was reanalyzed for updated seismic ground motions which are significantly more severe than those analyzed in 2012 -Contact elements were added at seven lift lines elevations -Report remains as *DRAFT*	MZ2024-019 Hatch (2020)
October 15, 2022	Performance Based Testing and Analysis of Mossyrock Dam	-	Engineering Innovations, LLC (2022)
December 1, 2023	Independent Consultant Inspection of the Mossyrock Development	Comprehensive Assessment Report, Mossyrock Development	MZ2023-013 HDR (2023)
March 31, 2023	Time Histories and Seismic Hazard Assessment	Pending FERC Acceptance	Gannett Fleming (2023)

3. PROGRAM TEAM & WORK BY OTHERS

The bidder must understand that this solicitation is one(1) project within a Risk Reduction Program (RRP) consisting of multiple projects and Consultants. Considering that other projects within the RRP will utilize the results/outputs of this Analysis Project and that this Analysis Project will require inputs from other consultants working in parallel, it is essential that the consultant awarded this contract understand how their work contributes to the broader RRP and if necessary, modify their scope of work accordingly. Tacoma Power will lead the coordination effort between the full program consultant team; however, it will be required that each program team member clearly identify interdependencies.

For reference, the program contributors have been divided as follows:

FERC - Regulatory Oversight

- Doug Johnson Regional Engineer, FERC PRO
- Katie Clarkson, Branch Chief, FERC PRO
- Chris Humphrey, Project Engineer, FERC PRO
- Dr. Idriss, FERC Independent Consultant
- Jim McHenry, FERC DC
- Binod Yadav, FERC DC

Board of Consultants

- Robert Cannon, BOC Member, Schnabel Engineering
- Glenn Tarbox, BOC Member, Tarbox Engineering
- Ivan Wong, BOC Member, Lettis (LCI)

Subject Matter Experts (SME)

- Seismic Hazard Assessment and Time Histories – Gannett Flemming
- Performance Based Testing – Engineering Innovations, LLC
- Independent 3rd Party FEA Model Quality Control – TBD
- Part 12D Independent Consultants – HDR Engineering

Analysts and Designers

- Mossyrock Dam Analysis Project (*this solicitation*): TBD

General Scope - Create a defensible 3D stability model to present-day best practices, from which clear conclusions can be drawn. This includes all Arch Dam, Thrust Block and Spillway Pier PFMs.

- Left Embankment Analysis and Remediation Project: TBD

General Scope – Analyze seismic performance and, if required, design a seismic remediation of the Left Embankment such that stability is maintained during and after a large magnitude event. This includes all Left Embankment Dam PFMs.

- Spillway Gate Seismic Remediation Project: TBD

General Scope – Analyze seismic performance and design a seismic remediation for each spillway gate such that stability is maintained during and after a large magnitude event. This includes all Spillway Gate and Trunnion PFMs.

- Rock Block Instability Assessment Project: TBD

General Scope – Conduct field geological mapping of left and right abutment and assessment of potential rock wedge instabilities, including kinematic wedge analyses and limit equilibrium. This includes all Foundation PFMs.

- Alternative Risk Reduction Measure for Potential Spillway Pier Seismic Instability: TBD

General Scope - This project is intended to be an alternative/substitute to the current IRRM lake elevation restriction by reducing the downstream consequences of spillway pier failure by adding removable bulkheads or stoplogs to the spillway bays (downstream of the piers). This is associated with Spillway Pier PFMs.

4. GENERAL PROJECT OBJECTIVES

Below is a summary of the high-level objectives associated with this solicitation:

1. Create a calibrated and defensible 3D stability model that meets the current state-of-practice standards for analysis of concrete dams, from which clear conclusions can be drawn. The model must be acceptable to Tacoma Power and to the FERC.
2. Analyze the dam for the current estimated normal, flood, and seismic loads and assess the strength and stability of the dam as it currently exists. The final analysis will serve as the FERC accepted analysis of record and will provide baseline results for use in a Level 4 Risk Assessment (L4RA)
3. Understand the performance of the various components of the dam under a range of progressively increasing seismic loads, identifying the loading and mechanism of failure for each key component.

4. Gain a quantitative understanding of how identified failure modes interact, whether the initiation of one failure mode could lead to the development of a larger failure, and the breach size of the failure throughout the progression.
5. Identify the strengthening measures required such that the dam meets acceptance criteria for the currently estimated normal, flood, and seismic loads.

See Section 5 for a breakdown of tasks which aim to align with these objectives.

5. SCOPE OF SERVICES AND DELIVERABLES

It is the City's intent to select a consultant based on qualifications and abilities of the firm and key project individuals. The scope of services for this solicitation are defined by the task list presented below. This task list is derived from the draft ABD (Appendix A) and includes associated deliverable descriptions. Each firm must utilize this task list when preparing their proposal response. As shown below, one of the initial tasks is to evaluate, refine, and finalize the ABD document. As such, approved updates to the ABD document would influence the scope of this contract *after* award.

Task 1: Project Kick-off and Site Visit

Consultant team to coordinate and lead a kick-off meeting at Mossyrock Dam.

Deliverable(s):

- Prior to the site visit, submit a Pre-Inspection Plan which includes the purpose of inspection, identification of what site data will be collected and why it is significant, and any clarification questions regarding the scope of work.
- Submit a meeting agenda to guide the visit.
- Submit a post visit memo with meeting minutes documenting what site data was collected, how it will be used, key findings, and any notable discussion.

Task 2: Drone Mapping and Bathymetric Survey

Conduct an initial baseline survey of the Mossyrock Development utilizing drone-based lidar scanning data acquisition and multibeam (w/ side scan sonar) to confirm Dam Geometry. Data resolution must be in alignment with state-of-practice modeling techniques. The footprint and required resolution of the survey to be defined by the proposer as needed to develop an accurate, detailed, defensible numerical model.

Deliverable(s):

- Detailed flight plan including bathymetric data collection processes. A report outlining equipment, methodology and accuracies obtained.
- Electronic PDF of the survey, prepared by a licensed surveyor, depicting the existing site conditions at the Mossyrock Development, both upstream and downstream.
- Gridded point file of the GSM in ASCII X,Y,Z format.

- Autodesk Civil3D drawing containing the gridded points and ground surface model including bathymetry.
- XML file containing the ground surface model including bathymetry.
- Raw point cloud of data

Task 3: Program Team Consultation and Coordination

As mentioned in Section 3, this dam analysis project contributes to a broader RRP. Credible PFMs have been organized into general categories and assigned to different consultant teams to mitigate associated risks. This dam analysis project is the central information hub of the broader effort and requires a high level of transparency and cooperation with other Tacoma Consultants to ensure program success. This task is dedicated to conducting program team meetings and clearly identifying project interdependencies amongst the program team members and documenting what information needs to be received or transmitted for broader program success.

Deliverable(s):

- Develop and maintain a milestone schedule for the coordination efforts and publish/maintain a status chart of all coordination efforts. Identify critical path items. Develop a project storyline communicating the purpose for each milestone meeting, who needs to attend, and what specific goals need to be achieved.
- Participate and co-lead (w/ Tacoma Power) ongoing Mossyrock Dam Analysis Program Meetings with all program SME's, Analysts, and Designers. Assume a total of 5 meetings will be needed. Prepare an agenda and develop meeting minutes for each meeting.
- Required Model Outputs - Obtain written memos from each Program Team Member identifying what Model Outputs are required to successfully complete their evaluation or design effort. Document why its needed, whether it is achievable, and if it is, what anticipated accuracy tolerances are reasonable to expect.
- Required Model Inputs - Generate written memos for Tacoma to provide to each SME contributor requesting specific model input data. For example, this would include a memo providing the requirements for the development of the seismic load time histories. A formalized response from each SME will be required providing an assessment of the appropriateness and suitability of using such data/analysis. Communicate and document how data/analysis generated from SME contributors will be used in model development, calibration, and during model runs to produce accurate analysis results.

Task 4: Finalize Analysis Basis Document (ABD)

Following the Comprehensive Assessment in 2023, a *draft* Analysis Basis Document (ABD) was developed as a plan of analysis to evaluate the most recently identified failure modes and provide a roadmap of the steps required to complete the analysis. The *draft* ABD is attached as Appendix A and serves as the Technical Specification for this solicitation. The *draft* ABD describes the baseline plan for future analysis and provides information that is assumed to be required to perform the analysis. This task is dedicated to evaluating, revising, and finalizing the *draft* ABD. As such, approved revisions to the ABD document are anticipated to influence the scope of this contract after award. The draft ABD is provided for bid purposes and it is expected that the successful bidder will develop and author their own ABD work-product.

Finalization of the ABD is broken down into several progressive subtasks, as shown below.

- **Task 4.1: Review Project Data, Evaluate Suitability of Existing Model, and Prepare Gap Analysis Report**

  Review project history, past analyses, reference drawings, original dam construction photos, past stability analyses, recently completed FERC Part 12 Comprehensive Assessment and previous PFMAs, supporting technical information document (STID), available survey data, operational loading conditions, and any pertinent historical information on record.

  Following the review, perform a gap analysis to identify data gaps in material properties, loading conditions, existing numerical model limitations, etc.

  Deliverable(s):

  - Prepare a project "needs" memo that clearly lists the input data required to develop a comprehensive and defensible 3D stability model to present-day best practices.
  - Provide a synthesized summary of past analysis and the conclusions reached. Identify conclusions that will need to be challenged or validated and what data will be carried forward and utilized (include justification).
  - Prepare a data gap analysis report identifying what information was reviewed and what information is missing and why the missing information is relevant.
  - Prepare an evaluation memo which assesses the latest numerical model. Provide justification for utilizing it as a baseline for analysis (or) whether it should be replaced in its entirety.
  - Coordinate and lead a meeting with Tacoma Power staff to review identified data gaps and develop recommendations for how to proceed with obtaining information as required.

- **Task 4.2: Finalize Project Functional Requirements and Risk Drivers**

  Finalize the functional requirements for a state-of-practice analysis model of Mossyrock Dam and identify the applicable acceptance criteria. Perform a systematic review of analysis functional requirements and prepare a finalized list of PFMs and Analysis Considerations (AC), based on the CAR/L2RA and other applicable past analysis.

Deliverable(s):

- Prepare a standalone project functional requirement memo documenting critical PFMs, identified model functional requirements, and applicable acceptance criteria needed to gain a quantitative understanding. Upon approval the content of this memo will be incorporated into the final ABD document.

➢ **Task 4.3: Quality Assurance, Quality Control and Verification Plan**

The verification and validation of the complex dam-foundation-reservoir model is key to the success of this project. This task is to develop a QA/QC procedure for the FEA model that will be used as a self-assessment tool as well as a verification tool for an independent QA/QC review which Tacoma Power will manage external to the scope of this proposal. The individual components (dam, foundation, and reservoir) and the complete assembled model will be checked by the consultant and independently by a Tacoma Power supplied QA/QC inspector. The QA/QC program must facilitate this requirement by presenting input parameters and communicating the limitations of the analysis. It is intended that this plan becomes part of the finalized ABD.

Deliverable(s):

- Prepare a standalone QA/QC plan for the model development.
- Prepare a standalone verification plan that demonstrates that the model works as intended. It is assumed that sensitivity analyses will be performed to further enhance the verification and validation of the dam-foundation-reservoir model.

➢ **Task 4.4: Final Analysis Report Template**

The clear presentation and organization of information within the Final Analysis Report is essential. Therefore, prior to any analysis, the framework, outline, format and presentation style of the Final Analysis Report must be presented in the ABD (see Task 10 herein for related details). Bullet point requirements of each report section must be communicated to gain group consensus. It is intended that this template becomes part of the finalized ABD.

Deliverable(s):

- Develop and submit for approval a draft Final Analysis Report Template.

➢ **Task 4.5: Finalization of the ABD**

This task is dedicated to authoring and finalizing an Analysis Basis Document (ABD). The consultant must ensure the ABD includes the analysis criteria for a defensible 3D stability model to present-day best practices. The ABD will be authored by the consultant and become the final technical specifications for the project. The ABD must develop a roadmap of the steps required to achieve the General Project Objectives listed in Section 4 of this solicitation. The final ABD must provide the following:

1. A roadmap of the steps required to complete the analysis and the output deliverables.
2. A description of the project, project goals, and the past analyses.
3. An assessment of the critical PFMs identified in the L2RA and an identification of the model features required to analyze them.
4. An evaluation of the information and testing data available for the material properties and a recommendation of values to be used in the analysis.
5. A description of the model calibration plan and the techniques to be implemented.
6. A description and discussion of the analysis methods, loads and load combinations, and acceptance criteria that should be used in the analysis and evaluation of the dam.
7. A plan of model runs to complete the analysis.
8. A QA/QC and Verification Plan.
9. A Final Analysis Report Template
10. An identification of how this analysis fits in to the broader RRP goal of performing a project wide Level 4 Risk Assessment (L4RA).

Deliverable(s):

- Submit a Final Analysis Basis Document

<u>Task 5:   3D Finite Element Model</u>

This task is dedicated to creating a defensible 3D stability model to present-day best practices, from which clear conclusions can be drawn. A *single*, global model of all dam features is required. A number of previous analyses have been performed and an analysis model exists. The 2020 3D FEA model will be supplied as a starting point of consideration. Accordingly, this task is divided into three (3) subtasks: Task 5.1 for assessing the usability of the existing 2020 model, Task 5.2 for updating the previous model (if applicable), Task 5.3 for developing an entirely new model if the previous model is unusable.

***NOTE**: For bidding purposes, please submit an estimated resource loaded schedule for each subtask shown unless the proposer can definitively conclude (at the time of submission) the existing model will not be used as a starting point. If applicable, communicate this in a clear statement.*

- **Task 5.1: Assessment of Existing Model**

This task is dedicated to the assessment of the existing 3D finite element model and the preparation of an Assessment Memorandum. The memo must provide a professional evaluation of the existing model with clear justification for why it should (or) shouldn't be used for the intended purpose. The memo must include a recommendation section providing next steps. All previous model input and output data will be supplied by the City upon request.

Deliverable(s):

- Prepare and submit a formal Existing Model Assessment Memorandum

➢ **Task 5.2: Update Using Existing Stability Model**

This task is dedicated to creating a defensible 3D stability model to present-day best practices using the existing model as a starting point.

Deliverable(s):

- Submit a self-assessment QA/QC Report as developed in Task 4
- Submit model input files for 3rd Party Review and Comment
- Address recommendations from 3rd Party Review

➢ **Task 5.3: Develop an Entirely New Stability Model**

This task is dedicated to creating a defensible 3D stability model to present-day best practices considering the existing model cannot be used.

Deliverable(s):

- Submit a self-assessment QA/QC Report as developed in Task 4
- Submit model input files for 3rd Party Review and Comment
- Address recommendations from 3rd Party Review

Task 6: Model Calibration

This task is dedicated to model calibration. Calibration techniques and results must be transparent and well documented and provide confidence in the reliability of the model. This task includes several subtasks ranging from data review, calibration methodology, data validation, and results reporting.

➢ **Task 6.1: Evaluate Existing Data and Prepare Methodology for Calibration**

The consultant must review all potential calibration data that would provide valuable insight into the Dam's fundamental response characteristics and prepare a calibration methodology memo complementary to the methodology presented in the ABD. Known available calibration data includes the following: Historical construction monitoring reports, Performance Based Tests (PBT), Flow-Induced Monitoring (FIM), seismic event data recorded onsite in 2010 by Strong Motion Accelerometers (SMAs), geotechnical site data, and historical dam deflection and performance monitoring data. The consultant must also identify data shortcomings and assess the value of gathering additional calibration data.

Deliverable(s):

- Prepare and submit a Calibration Methodology Report which includes synthesized descriptions of what data is available and how it will be used and assessed.
- Prepare a simple table presenting the following: all potential model calibration opportunities available to the analyst, the significance of each calibration opportunity, what model calibration is available with existing data, and what value there is in gathering additional data (estimating the impact on modeling results).

➢ **Task 6.2: Cross-validate PBT Results**

This task is dedicated to the cross-validation of the Performance Based Tests (PBT) results. Two different, complementary techniques are identified: the enhanced frequency domain decomposition (EFDD) and the stochastic subspace identification (SSI).

The procedure to perform the EFDD technique consists of decomposing the system output into a set of single degree-of-freedom systems, which are independent for each mode. The SSI technique is a time-domain method which consists of adjusting a parametric model to the time series recorded by the PBT sensors. Verification of PBT results via these two independent techniques will provide confidence in the analysis results.

Deliverable(s):

- Prepare and submit a Technical Memo documenting the results of the cross-validation effort.

➢ **Task 6.3: Model Calibration and Reporting**

This task is dedicated to adjusting/calibrating the dynamic material properties of the dam-foundation-reservoir model to the measured natural frequencies. This report must clearly communicate the results of utilizing dam and foundation material properties and adjusting the properties until the natural frequencies and mode shapes computed from the finite element model match the measured natural frequencies from the PBT and any other creditable calibration info. Justification shall be given for modulus values obtained in this manner which would highlight site characteristics (e.g., deterioration, cracking, and weak areas) and foundation features (e.g., jointing, discontinuities, and changing rock types). For the purposes of this solicitation, assume a total of ten (10) model runs for calibration reporting as shown in Table 2, below.

Table 2: Calibration Runs

No.	Model	Task	Load	Reservoir		Foundation	Contacts			Remarks
							Base	Lift Joints	Vertical Construction Joints	
1 to 10	SW	6	AVT Calibration	Restricted	Added Mass	Mass	Tied	Tied	Tied	Assume 10 Runs

Deliverable(s):

- Prepare and submit a Model Calibration Report
- Submit a self-assessment QA/QC Report as developed in Task 4 for Model Calibration
- Submit model input files for 3rd Party Review and Comment
- Address recommendations from 3rd Party Review

Task 7: Perform Preliminary Explicit Analysis

This task is dedicated to preliminary explicit analysis. This task has been incorporated with the assumption that final analysis of record results may take considerable time to formulate and report. The need for expedited preliminary analysis is driven by assumed project interdependencies within the RRP. Three(3) subtasks for this analysis are shown below, followed by a *common* list of deliverables:

- **Task 7.1: Benchmark Performance and Input for Embankment Evaluation**

  This subtask is for the analysis of the assumed Normal (N), Probable Maximum Flood (PMF), and Seismic (EQ) load combinations which will serve as a benchmark for the performance of the dam. These runs are summarized in Table 3, below. These runs will also be used to generate amplified topographic seismic ground motions for input into the analysis of the Left Embankment Analysis and Remediation Project. For the purposes of this solicitation, assume a total of seven (7) model runs.

Table 3: Initial Analysis Model Runs

No.	Load		Reservoir		Foundation	Contacts			Remarks
						Base	Lift Joints	Vertical Construction Joints	
11	N		Restricted	Pressures	Mass	Active	Tied	Active	-
12			Normal						
13	PMF		Flood						
14	EQ	5,000	Restricted	Added Mass			Tied or Active		Use one seed time history for scaling
15			Normal						
16		10,000	Restricted						
17			Normal						

- **Task 7.2: Seismic Progressive Loading Analysis**

  This subtask is for seismic progressive loading analysis, in which the model will be analyzed for a series of progressively more intense earthquake return periods. Failure of the components will be checked, and where a component failure is identified, additional stabilizing measure will be added in the model. The analysis will then progress to the next earthquake return period with the stabilization measure included. The analysis runs are summarized in Table 4, below. For the purposes of this solicitation, assume a total of four (4) model runs.

Table 4: Seismic Progressive Loading Analysis Model Runs

No.	Load		Reservoir		Foundation	Contacts			Remarks
						Base	Lift Joints	Vertical Construction Joints	
18	EQ	2,500	Normal	Added Mass	Mass	Active	Tied or Active	Active	Use one seed time history for scaling
19		3,750							
20		7,500							
21		15,000							

- **Task 7.3: Targeted Breach Analysis**

This subtask is for targeted breach analysis. These analyses will be performed for two (2) credible PFMs which have been identified with having the potential to initiate progressive failure:

PFM Number: MR-AD-1S

Spillway pier/header beam failure: It was postulated during the CA that failure of the spillway piers could initiate failure in the header beams and subsequently cause a "smiley" failure in the arch. To analyze this possibility, the critical earthquake return period that causes pier failure will need to be identified.

Assumed Analysis for this Proposal:

CDPM2 damage plasticity model, i.e., Grassl et al. (2011,2013) is a non-linear concrete material model capable of modeling concrete cracking and reinforcement yielding & failure. CDPM2 model is an updated version of Lee and Fenves (1998). CDPM2 model is implemented in LS-DYNA as *MAT_273. The CDPM2 model will be used to determine an approximate failure plane in the pier when subjected to the identified earthquake. If the non-linear analysis indicates that the pier failure plane could cause the failure to progress to the header beams, the dam will be analyzed with the header beams removed to determine the extent of the arch failure and the final breach size. Note, the decision for the removal of the header beams is because if the spillway piers fail at the ogee-spillway pier joint or if the header beams themselves fail, the header beams may most likely detach from the structure. If the critical return period is below the 5,000 or 10,000 YRP events, an analysis with the header beams removed will be performed for those events to determine the final breach size.

The successful proposer may, after award, request a substitute modeling software through a technical memo detailing the similarities and differences between the software.

PFM Number: MR-AD-3S

Thrust block sliding: It is possible that sliding of the thrust block will cause a loss in arch action and subsequent failure of the arch. To analyze this possibility, the critical earthquake return period that causes the thrust blocks to slide will need to be identified.

Assumed Analysis for this Proposal:

The dam will be analyzed with the thrust block allowed to continue to slide, to determine the extent of damage in the arch and the final breach size. If the critical return period is below the 5,000 or 10,000 YRP events, an analysis will be performed for those events to determine the final breach size.

For the purposes of this solicitation, assume a total of seven (7) model runs as shown below in Table 5.

Table 5: Targeted Breach Size Analysis Model Runs

No.	Load		Description
22	EQ	Critical Pier Failure Return Period	Non-linear analysis to determine the critical failure plane in the piers
23			If piers could initiate header beam failure, analysis with the header beams removed to determine extent of arch failure and final breach size.
24		5,000	Analysis with header beams removed. Dependent on critical pier failure return period.
25		10,000	
26		Critical Thrust Block Failure Return Period	Analysis with the thrust block allowed to slide indefinitely, to determine extent of arch failure and final breach size.
27		5,000	Analysis with the thrust block allowed to slide indefinitely. Dependent on critical Thrust block failure return period.
28		10,000	

Combined Task 7.1, 7.2 and 7.3 Deliverable(s):

- Preliminary Analysis Report clearly communicating the results of Task 7.1-7.3 utilizing the reporting template developed and approved under Task 4.
- Provide a standalone technical memorandum that validates (or) challenge the conclusions reached in past stability analyses. Provide clear justifications for why the conclusions are consistent or different.
- Embankment Analysis Earthquake Input Memo – Input ground motions including topographic amplification effects for the embankment analysis.
- Submit model input files for 3rd Party Review and Comment.
- Address recommendations from 3rd Party Review.

Task 8: Field Investigation and Laboratory Testing Program (if needed)

This task is dedicated to developing a plan for a field investigation and laboratory testing program depending on understandings gained from Task 4.1 – Review Existing Data, Task 6- Model Calibration, and Task 7 – Perform Preliminary Explicit Analysis.

Deliverable(s):

- Submit for approval a Field Investigation Program with clear justification for each recommendation (or) submit a memo documenting why a Field Investigation Program is not warranted. The Field Investigation Program will need to meet FERC acceptance requirements.

Task 9: Perform Sensitivity Analysis

This task is dedicated to performing a sensitivity analysis after review of the preliminary analysis results developed in Task 7. The purpose of this placeholder task is to perform more detailed analyses where warranted. For the purposes of this solicitation, assume a total of five (5) model runs for sensitivity analysis.

Sensitivity analysis items may include:

- Using tied nodes at the vertical contraction joints to find the forces acting on the shear keys.
- Placing additional contact elements at the spillway piers to account for cracked failure planes.
- Placing additional contact elements at additional lift lines.
- More detailed analysis of hydrodynamic interaction using fluid acoustic element.
- Analysis of a range of values of key input parameters.

Additional items may be checked as identified during the review of the preliminary analysis.

Deliverable(s):

- Submit for approval a Sensitivity Analysis Plan based on the result of the preliminary analysis. Include justifications for each proposed model run.
- Submit for approval a Sensitivity Analysis Memo clearly communicating the results utilizing the reporting template developed and approved under Task 4.4.
- Submit model input files for 3rd Party Review and Comment.
- Address recommendations from 3rd Party Review.

Task 10: Perform Final Runs

This task is dedicated to performing the final analysis runs for the analysis of record purposes.

The final analysis results will be used to gain a quantitative understanding of the PFMs (both failure loads and breach outflow), address the IC recommendation, evaluate project risk drivers, and allow Tacoma Power to make risk-informed decisions regarding the scope of a stability enhancement program at Mossyrock Dam.

These results will become the stability analysis of record and be submitted to the FERC for their review and acceptance.

The analysis runs are summarized in Table 6, below. For the purposes of this solicitation, assume a total of four (4) model runs for sensitivity analysis.

Table 6: Final Analysis Model Runs

No.	Load		Reservoir		Foundation	Contacts			Remarks
						Base	Lift Joints	Vertical Construction Joints	
29	N		Normal	Pressures	Mass	Active	Tied	Active	Include the updates from field investigation and laboratory testing program (if needed)
30	PMF		Flood	Pressures	Mass	Active	Tied	Active	
31	EQ	5,000	Normal	Added Mass	Mass	Active	Tied or Active	Active	Use 7 time histories for each return period
32	EQ	10,000	Normal		Mass	Active	Tied or Active	Active	

The analysis results for the existing conditions will be prepared as two drafts for review (Rev A and B) and final (Rev 0).

The final report template prepared in Task 4 will be updated based on all previous tasks completed and be resubmitted for approval.

The final analysis report for the existing conditions will include an introduction, description of the analysis methodology, analysis results and conclusions and recommendations. The report will be a technical document that utilizes tables and graphical methods to convey the analysis results. The reporting objective is to present the analysis process and results in a manner that is easily understandable and instills confidence in the modeling and justifies/supports the results. The minimum content provided in each section of the existing conditions report would include the following:

<u>Executive Summary</u>

- Summary of conclusions

Introduction

- Overview of what is presented.
- How the work applies to previous applicable technical memorandums and prior work.
- Purpose of the work and its relevance to the overall project progression and goals.

Methodology

- An explanation of why the analysis model(s) selected, how it was used and its limitations.
- Definition of the loads applied to the model.
- Description of the analysis runs performed with reference to the run matrices included as tables in the report.

Results

- Estimated limit loads for each vulnerability identified based on the analysis modeling. Many of the vulnerabilities are due to seismic loading so the limit loads would be expressed in "seismic withstand" return period event.
- Discuss the confidence in the results and identify limitations (e.g., may need additional data or model runs, etc.).
- Tables and graphical methods to convey the modeling and results.
- Annotated figures to point out and explain key items.

Conclusions and Recommendations

- Summaries of analysis findings with corresponding conclusions. Make a solid case. This model will be reviewed by FERC, BOC members, and TP's Independent Consultants prior to final acceptance.
- Discussion of analysis results including the performance of the structure under various load cases with a performance summary table (i.e., pass or fail) against the identified PFM's and other additional considerations.
- Identification of key vulnerabilities and estimate load limits for structural and operational system in the dam with the vulnerabilities tied to PFMs and analysis considerations. In the case of Mossyrock, this will include the spillway piers, thrust blocks, ridge/header beam, arch, spillway gate house, etc.
- Discussion regarding how the piers affect the performance of the dam and how the reservoir elevation restrictions affect the response of the dam.
- Discussion regarding potential for "smiley" failure in crest. Identify the breach size in the event a "smiley" failure occurs.

- Presentation of recommended next steps based on the analysis findings and conclusions utilizing tables and annotated figures.

Deliverable(s):

- Final Analysis Report.
- Provide a technical memo addressing all comments from CA recommendation #2023-13.
- Submit model input files for 3rd Party Review and Comment.
- Address recommendations from 3rd Party Review.

Task 11: Develop a Digital Visualization of the Results

This task is dedicated to a presentation summarizing the analysis results for the existing dam which will be given to Tacoma Power, the BOC, and the FERC.

The presentation will include a digital visualization of the results specifically designed to simulate dam failure scenarios under progressively increasing load conditions. The presentation and simulations will be used to visually communicate the analysis results to project stakeholders.

Deliverable(s):

- Digital Visualization of the Results
- Results PowerPoint Presentation

Task 12: Stability Enhancement Program

This task is dedicated to proposing and evaluating structural and operational intervention alternatives to address key vulnerabilities. Identify the strengthening measures required such that the dam meets acceptance criteria for the currently estimated normal, flood, and seismic loads. For bidding purposes, assume 5 model runs will be required to analyze mitigation scenarios.

Deliverable(s):

- Technical memo presenting potential strengthening measures.
- Analysis Report documenting performance of dam with strengthening measures included in the model.
- Submit model input files for 3rd Party Review and Comment.
- Address recommendations from 3rd Party Review.

6. CONTRACT TERM

The contract will be for a two-year period with the option to renew the contract two additional one-year terms. The City reserves the right to cancel the contract for any reason, by written notice, as stipulated in the contract.

7. CALENDAR OF EVENTS

This is a tentative schedule only and may be altered at the sole discretion of the City.

Contract may be issued after Public Utility Board and/or City Council approval.

The anticipated schedule of events concerning this RFQ/P is as follows:

Publish and issue RFQ/P:	**8/14/2024**
Pre-Proposal Meeting:	**8/28/2024**
Pre-Submittal Questions:	**8/30/2024**
Response to Questions:	**9/6/2024**
Submittal Due Date:	**9/17/2024**
Submittal Evaluated:	**9/23/2024**
Interviews/presentations, on or about:	**9/30/2024**
Award Recommendation:	**October 2024**
Public Utility Board/City Council Approval:	**November 2024**

8. INQUIRIES

8.1 Questions should be submitted to Ryan Foster via email to rfoster1@cityoftacoma.org. Subject line to read:

PG24-0135F – Mossyrock Dam Analysis Project – *VENDOR NAME*

8.1 Questions are due by 3 pm on the date included in the *Calendar of Events* section.

8.2 Questions marked confidential will not be answered or included.

8.3 The City reserves the discretion to group similar questions to provide a single answer or not to respond when the requested information is confidential.

8.4 The answers are not typically considered an addendum.

8.5 The City will not be responsible for unsuccessful submittal of questions.

8.6 Written answers to questions will be posted along side the specifications at www.tacomapurchasing.org

9. PRE-PROPOSAL MEETING

A pre-proposal meeting will be held on Wednesday, August 28th, 2024, at 10:00 AM at the Mayfield Project Office, 253 Hydro Ln. Silver Creek, WA 98585. A site visit to Mossyrock Dam will follow the office meeting.

10. DISCLAIMER

The City is not liable for any costs incurred by the Respondent for the preparation of materials or a submittal submitted in response to this RFP, for conducting any presentations to the City, or any other activities related to responding to this RFP, or to any subsequent requirements of the contract negotiation process.

11. EVALUATION CRITERIA

A Selection Advisory Committee (SAC) will review and evaluate submittals. The relative weight of each scoring criteria is indicated in the table below.

Criteria	Max Points
Statement of Qualifications of the Numerical Modeling Team & Past Experience	**30**
Statement of Qualifications of the Project Managers, Technical Writers, and Supporting Staff	**15**
Project Approach Methodology and Understanding of Project Scope	**15**
Resource Loaded Schedule with Suggestions to Expedite Schedule	**15**
Assessment of Draft ABD	**10**
Quality Control/Quality Assurance (QA/QC) Approach	**10**
Professional Services Contract Exceptions	**5**
Total	**100**

After the evaluation, the SAC may conduct interviews of the most qualified Respondents before final selection.

11.1 The SAC may select one or more respondent to provide the services required.

11.2 The City reserves the right to visit facilities of selected Respondents for the purpose of validating qualifications.

11.3 The SAC may use references to clarify information in the submittals and interviews, if conducted, which may affect the rating. The City reserves the right to contact references other than those included in the submittal.

11.4 A significant deficiency in any one criteria is grounds for rejection of the submittal as a whole.

12. CONTENT TO BE SUBMITTED – This section represents 100% of the possible scoring criteria.

Proposals should formatted as 8 ½” x 11”. A “page” is defined as one single-side of a document that has written text or graphics. The font should be Times New Roman or Arial with font size no smaller than 11 and the margins shall be 0.75” or greater. Submittals should be limited to a maximum of 40 pages, double-sided, or 80 pages total, excluding any required forms or resumes. All pages that exceed the specified page limit will not be part of the evaluation.

A full and complete response to each of the “CONTENT TO BE SUBMITTED” items is expected in a single location; do not cross reference to another section in your submittal.

Information that is confidential must be clearly marked and provide an index identifying the affected page number(s) and locations(s) of such identified materials. See Section 1 of the Standard Terms and Conditions – Solicitation 1.06 for Public Disclosure : Proprietary or Confidential Information.

Respondents are to provide complete and detailed responses to all items below. Submittals that are incomplete or conditioned in any way that contain alternatives or items not called for in this RFQ/P, or not in conformity with law, may be rejected as being non-responsive. The City will not accept any submittal containing a substantial deviation from the requirements outlined in this RFQ/P.

Submittals should present information in a straightforward and concise manner, while ensuring complete and detailed descriptions of the respondent’s/team’s abilities to meet the requirement of this RFQ/P. Emphasis will be on completeness of content. The written submittals should be prepared in the sequential order as outlined below.

The City reserves the right to request clarification of any aspect of a firm’s submittal, or request additional information that might be required to properly evaluate the submittal. A firm’s failure to respond to such a request may result in rejection of the firm’s submittal. Firms are required to provide responses to any request clarification within two (2) business days.

Requests for clarification or additional information shall be made at the sole discretion of the City. The City’s retention of this right shall no way diminish a Proposer’s responsibility to submit a submittal that is current, clear, complete and accurate.

12.1 Statement of Qualifications of the Numerical Modeling Team and Past Experience – 30 points

- Describe the technical experience and expertise your team has had with similar projects and contracts. This section shall include descriptions of specific experience your team has with each of the tasks, as applicable in the Scope of Work. Include resumes as attachments to the proposal. Include projects that have received FERC acceptance.

- Only give the names and relevant background and experience of the key personnel who would be directly involved in tasks listed in the Scope of Work. List all subconsultants.

- Discuss technical lead’s experience with the proposed analysis software and specific experience successfully developing and calibrating a numerical model.

12.2 Statement of Qualifications of the Project Managers, Technical Writers, and Supporting Staff – 15 points

- Describe the project management experience and expertise your team has had with similar projects and contracts. Describe also the technical writing experience and expertise your team has had with similar projects and contracts. This section shall include descriptions of specific experience your team has with each of the tasks, as applicable in the Scope of Work. Include resumes as attachments to the proposal.

- Only give the names and relevant background and experience of the key personnel who would be directly involved in tasks listed in the Scope of Work. List all sub-consultants.

- Discuss the proposed approach for organizing and synthesizing technical data into easy-to-read reports. Include an example executive summary of a numerical analysis report. Describe reporting capabilities.

- Provide a draft project management plan.

12.3 Project Approach Methodology and Understanding of Project Scope – 15 points

- Discuss the Overall Team's approach and methodology to the Scope of Work. Include ideas and methods your Team would propose to implement the Scope of Work. Specify the Scope of Work implementation plan.

- Describe the approach for staffing, sub-consultant usage, change management, decision tracking, and communication management. Provide a draft communication plan. Provide examples that demonstrate the team's ability to partner and participate within a program.

- Demonstrate a clear understanding of the overarching project scope.

- Include an assessment of the project scope and discussion on appropriateness and cost-effectiveness. Include any tasks or studies suggested to be included in the Scope of Work.

- Discuss any challenges that are anticipated.

12.4 Resource Loaded Schedule with Suggestions to Expedite Schedule – 15 points

- Provide a schedule for the proposed tasks listed in the Scope of Work in order of precedence. Identify the critical path and any task dependencies. Evaluators will assume this is the most aggressive schedule available to the firm.

- Include estimated hours to perform each task with a resource breakdown by job title.

- Include suggestions for how to improve upon the proposed schedule. If improvements are identified, include an alternate schedule which incorporates the suggested improvements. Include estimated hours with breakdown by job title.

- Include a statement that accepts responsibility for completing the proposed services in view of the firm's current and projected workload. Evaluators will assume this is the most aggressive schedule available to the firm.

12.5 Assessment of Draft Analysis Basis Document (ABD) and Scope of Work - 10 points

- Provide a brief evaluation of the proposed technical approach including an assessment of the draft ABD and the scope of work.

- Include a brief discussion on whether utilizing the existing numerical model as a starting point for model creation is a prudent approach.

12.6 Quality Control / Quality Assurance (QA/QC) Approach - 10 points

Describe your firm's approach for QA/QC as it applies to this scope of work. Identify the key areas of work that require a high level of QA/QC. Describe how to ensure QA/QC transparency to project stakeholders (Owner, BOC, and FERC).

12.7 Professional Services Contract Exceptions – 5 points

Do you take exceptions to any of the City of Tacoma's Sample Professional Services Contract? List exceptions.

13. INTERVIEWS / ORAL PRESENTATIONS

An invitation to interview may be extended to Respondents based on SAC review of the written submittals. The SAC reserves the right to adjust scoring based on additional information and/or clarifications provided during interviews. The SAC may determine additional scoring criteria for the interviews following evaluation of written submittals.

The City reserves all rights to begin contract negotiations without conducting interviews.

Respondents must be available to interview within three business days notice.

If interviews are conducted, the SAC will schedule the interviews with the contact person provided in the SOQs. Additional interview information will be provided at the time of invitation. At this time, it is anticipated that the main objective of the interview will be for the SAC to meet the project manager and key personnel that will have direct involvement with the project and hear about their relevant experience and expertise. The City does not intend to meet with firm officials unless they are to be directly involved with the project.

Following interviews, submittals will be rescored using the same criteria as in Section 14 below.

14. RESPONSIVENESS

Respondents agree their submittal is valid until a contract(s) has been executed.

All submittals will be reviewed by the City to determine compliance with the requirements and instructions specified in this RFQ/P. The Respondent is specifically notified that failure to comply with any part of this RFQ/P may result in rejection of the submittal as non-responsive. The City reserves the right, in its sole discretion, to waive irregularities deemed immaterial.

The final selection, if any, will be that submittal which, after review of submissions and potential interviews, in the sole judgement of the City, best meets the requirements set forth in this RFQ/P.

15. ACCEPTANCE / REJECTION OF SUBMITTALS

Respondents are advised that the City reserves the right to cancel award of this Contract at any time before execution of the Contract by both parties if cancellation is deemed to be in the City's best interest. In submitting a Submittal, Respondents agree that the City is not liable for any costs or damages for the cancellation of an award.

The City reserves the right and holds at its discretion the following rights and options:

- To waive any or all informalities
- To award one or more contracts
- To not award a contract
- To issue subsequent solicitation

16. CONTRACT OBLIGATION

Awardee shall be required to comply with 2 CFR part 25, and obtain a unique entity identifier and/or be registered in the federal System for Award Management as appropriate.

The selected Respondent(s) will be expected to execute a contract with the City. As part of the negotiation process, Respondents may propose amendments to the contract, but the City, at its sole option, will decide whether to open discussion on each proposed amendment and determine the final contract to be used. At a minimum, any contract will incorporate the terms and conditions contained herein. The Submittal contents of the successful Respondent may become contractual obligations if a contract ensues.

17. STANDARD TERMS AND CONDITIONS

City of Tacoma Standard Terms and Conditions apply.

18. INSURANCE REQUIREMENTS

Successful proposer will provide proof of and maintain the insurance coverage in the amounts and in the manner specified in the City of Tacoma Insurance Requirements contained in this solicitation. Please see Appendix C.

19. PARTNERSHIPS

The City will allow firms to partner in order to respond to this RFP. Respondents may team under a Prime Respondent's submittal in order to provide responses to all sections in a single submission; however, each Respondent's participation must be clearly delineated by section. The Prime Respondent will be considered the responding vendor and the responsible party at contract award. All contract negotiations will be conducted only with the Prime Respondent. All contract payments will be made only to the Prime Respondent. Any agreements between the Prime Respondent and other companies will not be a part of the agreement between the City and the Prime Respondent. The City reserves the right to select more than one Prime Respondent.

20. COMMITMENT OF FIRM KEY PERSONNEL

The Respondent agrees that key personnel identified in its submittal or during contract negotiations as committed to this project will, in fact, be the key personnel to perform during the life of this contract. Should key personnel become unavailable for any reason, the selected Respondent shall provide suitable replacement personnel, subject to the approval of the City. Substantial organizational or personnel changes within the agency are expected to be communicated immediately. Failure to do so could result in cancellation of the Contract.

21. AWARD

After the Respondent(s) is selected by the SAC and prior to award, all other Respondents will be notified via email by the Purchasing Division.

Once a finalist (or finalists) has been selected by the Selection Advisory Committee, contract negotiations with that finalist will begin, and if a contract is successfully negotiated, it will, if required, be submitted for final approval by the Public Utility Board and/or City Council.

22. ENVIRONMENTALLY PREFERABLE PROCUREMENT

In accordance with the City's Sustainable Procurement Policy and Climate Action Plan, it is the policy of the City of Tacoma to encourage the use of products or services that help to minimize the environmental and human health impacts of City Operations. Respondents are encouraged to incorporate environmentally preferable products or services that have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose. This comparison may consider raw materials acquisition, products, manufacturing, packaging, distribution reuse, operation, maintenance or disposal of the product or service.

The City of Tacoma encourages the use of sustainability practices and desires any awarded contractor(s) to assist in efforts to address such factors when feasible for:

- Durability, reusability, or refillable;
- Pollutant releases, especially persistent bioaccumulative toxins (PBTs), low volatile organic compounds (VOCs), and air quality and stormwater impacts;
- Toxicity of products used;
- Greenhouse gas emissions, including transportation of products and services, and embodied carbon
- Recycled content;
- Energy and water resource efficiency;

23. PROPRIETARY OR CONFIDENTIAL INFORMATION

The Washington State Public Disclosure Act (RCW 42.56 et seq.) requires public agencies in Washington make public records available for inspection and copying unless they fall within the specified exemptions contained in the Act, or are otherwise privileged. Documents submitted under this RFP shall be considered public records and, with limited exceptions, will be made available for inspection and copying by the public.

Information that is confidential or proprietary must be clearly marked. Further, an index must be provided indicating the affected page number(s) and location(s) of all such identified material. Information not included in said index will not be reviewed for confidentiality or as proprietary before release.

24. ADDENDUMS

In the event it becomes necessary to revise any part of this RFP, an addendum will be posted alongside specifications at www.tacomapurchasing.org. Failure to acknowledge addendum(s) on the required Signature Page may result in a submittal being deemed non-responsive by the City.

25. LEAP REQUIREMENTS

This project has no LEAP requirements, however, the City of Tacoma is committed to equality in employment for WA-State approved Apprentices, City of Tacoma residents, residents of local economically distressed areas, youth, veterans, minorities, and women. Please contact the LEAP Office for assistance in locating qualified employees. Visit the LEAP website for more information.

26. EQUITY IN CONTRACTING

This project has no EIC requirements, however, the City of Tacoma is committed to encouraging firms certified through the Washington State Office of Minority and Women's Business Enterprise to participate in City contracting opportunities. See **TMC 1.07 Equity in Contracting Policy** at the City's Equity in Contracting Program website.

APPENDIX A

Analysis Basis Document (ABD)

General Project Data Reference

Drawings & Photos

Mossyrock Dam Analysis Project

Analysis Basis Document (ABD)

DRAFT FOR RFP

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Executive Summary

Mossyrock Dam is a concrete arch dam located on the Cowlitz River in Washington and owned and operated by Tacoma Power. The increase in regional seismicity have raised concerns about the ability of the dam to withstand seismic loads. The normal operating reservoir elevation has been lowered as a result of these concerns, which is inhibiting the ability to generate power and causing a loss in revenue for Tacoma Power.

A recent Level 2 Risk Assessment (L2RA) performed as part of a Comprehensive Assessment (CA) of the dam has identified a number of Potential Failure Modes (PFMs) related to the seismic strength and stability of the dam which require additional analysis to understand the performance of the dam. Tacoma Power is seeking to develop a plan of analysis that will provide the information required to evaluate these failure modes and address any deficiencies. The goals of the analysis are as follows:

1. Create an analysis model that meets the current state-of-practice standards for analysis of concrete dams.
2. Analyze the dam for the current estimated normal, flood, and earthquake loads and assess the strength and stability of the dam as it currently exists.
3. Understand the performance of the various components of the dam under a range of progressively increasing seismic loads.
4. Understand how identified failure modes interact, whether the initiation of one failure mode could lead to the development of a larger failure, and the final breach size of the failure.
5. Identify the strengthening measures required such that the dam meets acceptance criteria for the currented estimate normal, flood, and seismic loads.

The consultant must develop a plan of analysis that will achieve these goals. This analysis basis document (ABD) describes the analysis plan and provides the key information required to perform the analysis. The ABD provides:

1. A roadmap of the steps required to complete the analysis and the output deliverables.
2. A description of the project, project goals, and the past analyses.
3. An assessment of the critical PFMs identified in the L2RA and an identification of the model features required to analyze them.
4. An assessment of the most recent analysis model and an identification of the modifications required to bring the model up to current state-of-practice standards.
5. An evaluation of the information and testing data available for the material properties and a recommendation of values to be used in the analysis. A site survey is recommended before the beginning of the analysis.
6. A description and discussion of the analysis methods, loads and load combinations, and acceptance criteria that should be used in the analysis and evaluation of the dam.
7. A plan of model runs to complete the analysis.
8. A QA/QC plan.

9. An identification of how this analysis fits in to the longer term goal of performing a Level 4 Risk Assessment (L4RA).

1. Introduction

Mossyrock Dam, constructed in 1968, is located in Lewis County on the Cowlitz River near the town of Mossyrock in south-western Washington. State Highway 12 passes near the right abutment of the dam. The Mossyrock Dam, owned by the City of Tacoma/Tacoma Public Utilities (Tacoma Power), is operated under the Federal Energy Regulatory Commission (FERC) License No. 2016-WA.

A Potential Failure Modes Analysis (PFMA) and Level 2 Risk Assessment (L2RA) was performed as part of a Comprehensive Assessment (CA) for Mossyrock Dam in 2023 as part of a FERC Part 12D Independent Consultant (IC) inspection. The CA identified a number of potential failure modes (PFMs) as risk drivers that require additional analysis to evaluate. This Analysis Basis Document (ABD) provides the analysis criteria and assumptions and defines a 3D FE modelling plan for Mossyrock Dam to address and further evaluate these PFMs that were identified as risk drivers.

The FE analysis will be performed to assess the strength and stability of the structures at Mossyrock Dam. The results will be used to evaluate project risk drivers and, ultimately, allow Tacoma Power to make risk-informed decisions to initiate a stability enhancement program for the Mossyrock Dam.

1.1 Analysis Objectives

The intent of the 2023 Mossyrock Dam analysis project is to create a defensible 3D stability model to present-day best practices, from which clear conclusions can be drawn. Specifically, this includes:

- Review and document relevant background information including the recently completed FERC Part 12 Comprehensive Assessment (CA) of the project.
- Review of dam acceptance criteria including gate operations. This review will include acceptance criteria from FERC as well as Tacoma Power performance requirements.
- Review the structural potential failure modes (PFMs) developed during the CA and highlighted by the Level 2 Risk Analysis (L2RA) and determine appropriate analyses and analysis considerations to help refine the understanding of the PFMs. The PFMs are discussed in Section 2.
- Prepare a draft Analysis Basis Document (ABD) that outlines an analysis plan to address the risk drivers coming out of the CA and review of project functional requirements (this document).
- Perform the analysis using a single, global model of the dam. The 2012 and 2020 3D FE models will be used as a starting point to better understand various factors affecting the performance of the dam:
    - Understand how current seismic analysis methods have changed since the previous 2012/2020 results. Update the seismic 2012/2020 finite element analyses (FEA) to

use the current day effective earthquake input methodology presented by Chopra and Lokke (or) develop an entirely new stability model not using the existing model as a starting point.

  - Understand the effects of the reservoir restriction by running both the restricted and unrestricted reservoir elevations for static and seismic loads. The model will be analyzed with both reservoir elevations and the stress distributions, deformations, and natural frequencies will be compared to understand the behavior and performance of the dam.

- Provide ground motions developed using the foundation model that can be used to evaluate the stability of the left embankment.
- Perform an initial analysis and evaluate the results to identify any additional failure modes which were not identified in the L2RA that require analysis.
- Estimate the loading at which the piers experience significant (unrepairable) damage to be evaluated following FERC and USACE guidelines.
- Evaluate the performance of the header beam and load path potential for a "smiley" failure. See Figure 1-3 for the header beam. Identify the breach size if a "smiley" failure occurs.
- Prepare analysis results for presentation to the Board of Consultants (BOC) and the FERC, communicating dam performance limits of various components for the considered PFMs.
- Characterize the performance of the components highlighted in the identified PFMs using the outlined acceptance criteria.
- Identify and clearly document the effects of various analysis assumptions, including model inputs and outputs.
- Complete a final analysis which will serve as the FERC-accepted analysis of record and will provide baseline results for use in a Level 4 Risk Assessment (L4RA).
- Develop a digital visualization to simulate dam failure scenarios under progressively increasing load conditions. The visualization, including failure videos from the FE model that show the global displacements of the blocks, will clearly communicate the results to all project stakeholders.

1.1.1 Analysis Basis Document

This document represents the first step in the analysis program described above. This document provides:

- A roadmap of the steps involved in the analysis program and descriptions of the output deliverables.
- An identification of the analysis goals and the model requirements to meet these goals.
- A summary of the previous analyses and analysis models, and an assessment of the improvements required to meet the current analysis goals.
- A presentation and discussion of the material properties, analysis methods and procedures, loads and load combinations, acceptance criteria, and QA/QC procedures that will be used in the analysis.

1.2 Project Deliverables

See RFP for a list of project deliverables.

1.3 Summary of Past Analysis Results

Several analyses have been performed for Mossyrock Dam. An overview of these analyses is presented in Table 1-1.

Table 1-1: Mossyrock Analysis History

Date	Purpose	Action	Results	Source
April 29, 2011	Non-linear static and seismic implicit FEA of dam, spillway and piers, thrust block, and wing wall	-Create analysis model with linear material model and non-linear contact elements at dam/foundation and vertical contraction joint interfaces -Static analysis in ANSYS -Implicit, massless foundation seismic analysis in ANSYS. Hydrodynamic interaction included with lumped masses -Non-linear, distinct element, massed foundation seismic analysis in 3DEC. Hydrodynamic interaction included with solid elements	- Dam was found to be stable for normal, PMF and seismic loads - Dam is expected to crack on horizontal lift joints during the earthquake, but remains stable - Spillway piers have bending factors of safety of less than one for seismic loads - Wing walls were found to be stable and they have negligible effect on dam performance - 3DEC discrete element model predicted smaller sliding displacements compared to the ANSYS model, likely due to the additional foundation damping used in 3DEC -ANSYS massless foundation model was over-predicting seismic response. Recommended to calibrate model against measured accelerations from recent earthquakes at the dam.	Hatch (2011)
November 27, 2012	Non-linear seismic explicit FEA of dam, spillway and piers, thrust block, and wing wall	-Convert previous ANSYS model for input into LS-DYNA -Explicit, massed foundation seismic analysis in LS-DYNA. Hydrodynamic interaction included with solid elements	-Seismic response of the massed foundation LS-DYNA model was less than that of the massless foundation ANSYS model -Sam was found to be stable for the analyzed normal and seismic loads. -Spillway piers have bending factors of safety less than one for the seismic loads	Hatch (2012)

Date	Purpose	Action	Results	Source
June 11, 2020	Non-linear seismic explicit FEA of dam, spillway and piers, thrust block, and wing wall	-Previous model was reanalyzed for updated seismic ground motions which are significantly more severe than those analyzed in 2012 -Contact elements were added at seven lift lines elevations	-Sliding displacements at the base are relatively small -Dam is expected to crack on horizontal lift joints during the earthquake -Displacements of up to 4 in at the lift lines were computed, but the blocks returned to equilibrium after the seismic event.	Hatch (2020)

The 2020 analysis model is shown in Figure 1-1 to Figure 1-3.

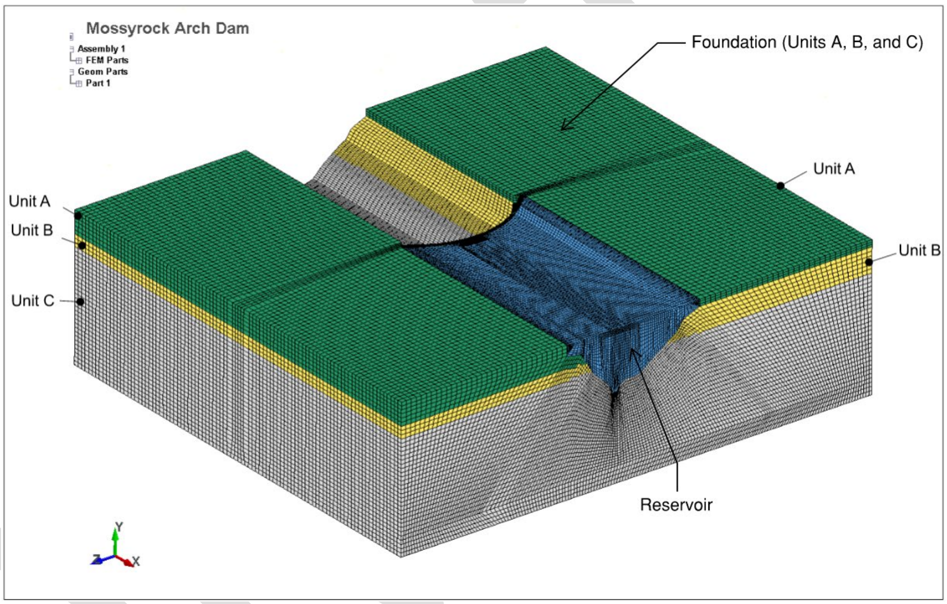

Figure 1-1: 2020 FEA Model

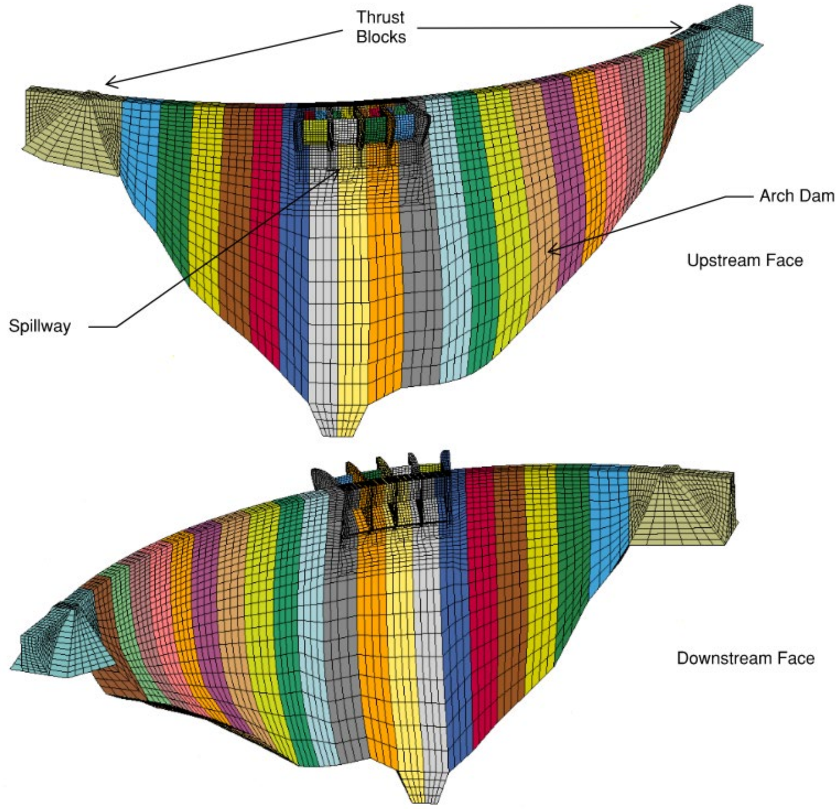

Figure 1-2: 2020 Dam Mesh

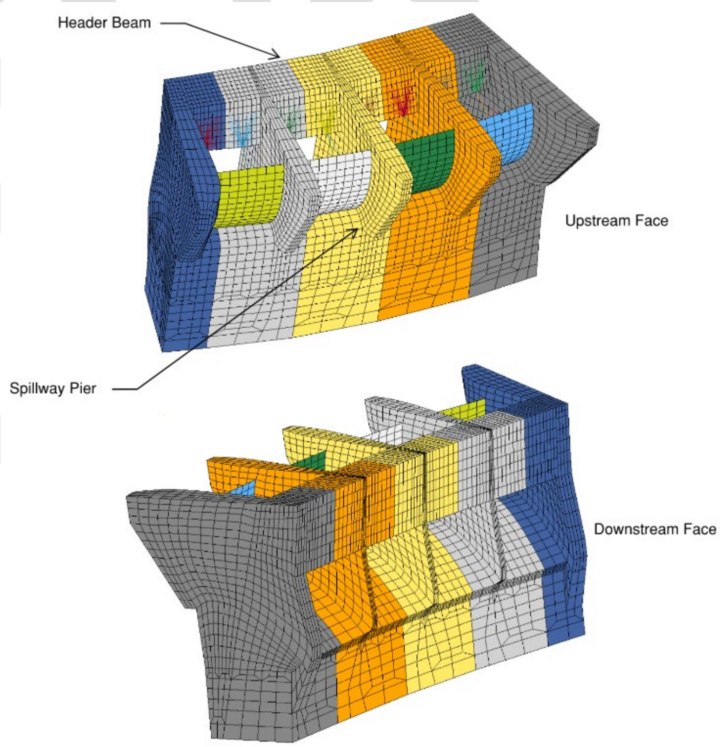

Figure 1-3: 2020 Spillway Mesh

2. Potential Failure Modes and Model Functional Requirements

2.1 Potential Failure Modes

The potential failure modes (PFMs) were most recently assessed as part of the 2023 Level 2 Risk Analysis and CA performed by HDR (HDR, 2023). The structural PFMs that were carried forward are briefly summarized below:

- MR-AD-1S Failure of the Header Beam Leads to Failure of the Arch – a seismically induced failure of the header beam over the spillway leads to cracking and the development of isolated blocks which move out of place and cause an uncontrolled reservoir release.
- MR-AD-3S Failure of the Arch Dam due to Instability of a Thrust Block along the Concrete/Rock Interface – a seismic event causes a thrust block to slide at the concrete/rock interface, which causes instability of the arch dam and leads to an uncontrolled reservoir release.
- MR-AD-6N/F/S Rock Block Instability Causes Failure of the Dam – normal, flood, or seismic loading causes downstream mobilization of a rock block, leading to instability of the dam and uncontrolled reservoir release. *{Partial Scope – see Section 2.2 Functional Requirements}*
- MR-SP-1S Spillway pier(s) Fail Leading to Uncontrolled Release Through Spillway Section (without failure of the header beam) – a seismic event causes the reinforced concrete piers to crack and the rebar to fail ,leading to displacement of the piers, damage to the gate, and ultimately uncontrolled reservoir release over the spillway.
- MR-SG-1N/F Failure of Gate Under Normal and Flood Conditions – Trunnion Friction – during operation, friction at the trunnion causes a build up of moment, buckling a critical member and causing catastrophic failure of one spillway gate, which leads to an uncontrolled reservoir release. *{Not in Scope of this Analysis}*
- MR-SG-1S Failure of Gate Under Seismic Condition – a seismic event produces hydrodynamic and inertial loads on the gate that overstress the gate members, causing critical members to fail and leading to catastrophic failure of up to four gates and uncontrolled release. *{Not in Scope of this Analysis}*
- MR-SG-2S A&B Failure of Trunnion Baseplate Anchorage – the seismic event produces loads that cause overload of the gate anchorage, leading to loss of the gate and uncontrolled reservoir release. *{Not in Scope of this Analysis}*

2.2 Model Functional Requirements

The functional requirements of the model were determined based on the analyzed PFMs. Functional requirements derived from each of the listed PFMs are described in Table 2-1.

Table 2-1: Model Functional Requirements

PFM	Analysis Requirement	Functional Requirement of the Model
MR-AD-1S Header Beam Failure leading to Arch Dam Failure	Stresses in and displacements of the header beam and the arch dam must be determined by the analysis.	Header beam and arch dam will be explicitly modelled and included as part of a global model of the dam with a mesh dense enough to accurately compute the stresses. Vertical contraction joints in the header beam and the dam must be modelled with contact elements to allow the joints to open, , close, and slide relative to the arch dam. All applicable loads on the header beam, including the gate loads, will be applied.
MR-AD-3S Thrust Block Sliding Failure at the Concrete/Rock Interface	The complex three dimensional static and seismic force vectors acting on the thrust blocks and the sliding displacements they produce must be determined by the analysis.	Thrust blocks will be explicitly modelled and included as part of a global model of the dam. Contact elements will be used at the Concrete/Rock Interface to allow any potential sliding to occur.
MR-AD-6N/F/S Rock Block Instability	If this failure mode is not ruled out by the foundation drone survey, the complex three dimensional static and seismic force vectors acting on the rock block and the sliding displacements they produce must be determined by the analysis.	Foundation will be explicitly modelled and included as part of a global model of the dam. The rock block will be analyzed in a separate geotechnical program using forces extracted from the model or the block will be explicitly modelled with contact elements that allow sliding displacement to occur.
MR-SP-1S Spillway Pier(s) Failure	The complex three dimensional static and seismic force vectors acting on the spillway piers must be determined by the analysis.	Spillway piers will be explicitly modelled and included as part of a global model of the dam. The model will be calibrated using the AVT/PBT test data. The mesh will be dense enough through the thickness of the pier to accurately predict the bending moments.

2.3 Assessment of Existing Model

A number of previous analyses have been performed and an analysis model exists. The consultant will need to identify the model features that are considered adequate and inadequate for the current analysis. An *example* list is provided below:

- A model of the arch dam, thrust blocks, spillway and spillway piers, header beam exists, and rock foundation exists.
- The model includes contact elements at several lift lines.
- The model exists in the LS-DYNA format.

- The mesh may be sufficiently refined for the purposes of this analysis.
- The boundary conditions may need to be modified such that the Lokke/Chopra Effective Earthquake Input method can be used . Perfectly matched layer (PML) elements will be used at the boundary. This will allow the spatial variability of the ground motion to be modeled, which will result in a more accurate estimate of the loads on the dam components. This improvement requires minimal effort because of a recently added feature in LS-DYNA (i.e., *Load_Seismic_SSI). See the discussion in Section 5.1.7.1.
- The main analysis will be performed using added mass to account for hydrodynamic interaction. Added mass will be calculated using Westergaard's exact solution and will be added to the model.
- The analysis model of the dam will be calibrated using the results of ambient vibration testing (AVT). See discussion in Section 4.8.
- If sensitivity studies using a fluid mesh are required, the existing mesh will need to be updated and include the reservoir mesh.
- If a pier sensitivity study is required, contact elements will be placed at the pier/ogee interface in the global model to allow the pier to rock.
- The mesh around the thrust blocks needs to be refined to better account for the transition between the concrete dam and the embankments.

3. Material Properties

The assumed material properties which will be used in the initial analysis are summarized in Table 3-1. These values are estimated based on the best available information as described in the subsections below. Where appropriate, these values will be calibrated using the previous Ambient Vibration Testing (AVT) data.

Table 3-1: Summary of Material Properties

Material	Property	Static Analysis	Dynamic Analysis	Remarks
Concrete	Compressive Strength	5400 lb/in^2		Golder's (1990) Test Results
	Poisson's Ratio	0.2		USBR (2006)
	Unit Weight	150 pcf		
	Elastic Modulus	2.8 x 10^6 lb/in^2	4.0 x 10^6 lb/in^2	Initial value selected based on (Kollgaard, 2002). However, This value will be confirmed by further investigation and AVT.
	Flexural Tensile Strength – Parent Concrete	490 lb/in^2	735 lb/in^2	N/a
	Flexural Tensile Strength – Lift Joints	300 lb/in^2	450 lb/in^2	N/a
	Parent Concrete Shear Strength (Shear Keys)	c = 680 psi & Phi = 45 degrees		N/a
Foundation Rock	Intact Rock Deformation Modulus (E_i)	Zone A: 2.4 x 10^6 lb/in^2 Zone B: 1.6 x 10^6 lb/in^2 Zone C: 4.4 x 10^6 lb/in^2		See Section 3.3.
	Rockmass Deformation Modulus (E_{rm})	Zone A: 1.2 x 10^6 lb/in^2 Zone B: 0.8 x 10^6 lb/in^2 Zone C: 2.8 x 10^6 lb/in^2		See Section 3.3.
	Cohesion	Zone A: 0.953 MPa Zone B: 1.116 MPa Zone C: 2.107 MPa		See Section 3.3.
	Friction Angle	Zone A: 54° Zone B: 50° Zone C: 54°		See Section 3.3.
	Poisson's Ratio	0.2 – 0.3		Golder (2011)
	Unit Weight	165 pcf		N/a
Concrete/Rock Interface	Peak Friction Angle	55 degrees		N/a
	Residual Friction Angle	38 degrees		N/a

3.1 Summary of Past Field Investigations and Laboratory Test Results

A rock mechanics study of Mossyrock Dam was published by Kleiner & Acker in January 1971. This document discussed the extensive testing program that was performed at the site to determine the modulus of elasticity of the dam foundation, including in-situ jacking tests, dynamic downhole geophysical measurements, unconfined compression tests on core samples, and deformation meters measuring the actual response of the foundation.

Golder (1990) conducted limited field investigations at Mossyrock Dam. The investigations included taking core samples through the mass concrete and across the dam/foundation interface at several locations. Four concrete and two dam/foundation interface samples were tested in a laboratory and used to estimate the material properties.

In February 2010, Golder conducted a field reconnaissance and structural geology mapping program of accessible bedrock outcrops to help evaluate the integrity of the dam foundation. This came from Recommendation 13 in the Mossyrock Hydroelectric Development Cowlitz River Project – Inspection of Project Works report in 2008 (Golder, 2011). Geology of the bedrock, discontinuity data, and rock deformation parameters were discussed in this field program.

3.2 Concrete Properties

3.2.1 Deformation Properties

3.2.1.1 Poisson's Ratio

A Poisson's ratio value of 0.2 was adopted in the previous analysis and will be used as the initial value in this analysis. This is a standard value for analysis of mass concrete dams (USBR, 2006).

3.2.1.2 Modulus of Elasticity

The modulus of elasticity values were adopted from a previous independent consultant report (Kollgaard, 2002). It is unclear exactly how this value was derived, but it likely comes from the core testing that is noted above. This value will be used as a starting point which will be further refined using AVT calibration.

3.2.2 Strength Properties

3.2.2.1 Concrete Compressive Strength

Concrete compressive strength was obtained from limited testing of the concrete at the dam (Golder, 1990). Testing of four samples gave an average value of 5,400 lb/in^2, which is adopted in this analysis. Note that it is recommended that additional 6-inch diameter concrete cores be taken at the beginning of the analysis to increase the statistical viability of this value.

3.2.2.2 Concrete Tensile Strength

Concrete testing of four samples indicates a mean splitting tensile strength of 446 lb/in^2. However, one of the four tests gave a low value, which if neglected gives a mean splitting tensile strength of 483 lb/in^2 (Golder, 1990).

2018 FERC Chapter 11 Section 11-3.7.2 provides three methods to obtain estimates of tensile strength from f'c: ACI Modulus of Rupture, Raphael's method for splitting tensile strength and a well-known equation of 0.1f'c. It was shown in the literature [Raphael, 1984] that the splitting tensile strength has a very good relationship with the compressive strength. Raphael's equation for static splitting tensile strength is given below.

$$f_{t\_split} = 1.7(f_c')^{2/3}$$

Where:

f_{t_split} = concrete splitting tensile strength
f_c' = concrete compressive strength

While concrete compressive strength has been shown to increase over time, often well beyond the original design strength, concrete tensile strength does not similarly increase.

This is because the tensile strength is dependent on the original bond strength between the aggregate and the cement, which does not increase. Given the results of a tensile splitting test and Raphael's equation, the compressive strength of concrete dam at the time of construction in late 1960s, can be estimated as follows:

$$f_{c\_construction} = (\text{ft\_split}\ /1.7)^{3/2} = (446\ /1.7)^{3/2} = 4{,}250 \text{ psi}$$

This value should be used in the determination of all derived tensile and shear strength values rather than the tested compressive strength which includes age related strength gain.

The flexural tensile strength (modulus of rupture) is obtained from ACI 318 for the parent concrete as:

$$f_{t\_MOR} = 7.5\ (f_c')^{1/2} = \ 7.5\ (4250)^{1/2} = 490\ psi$$

As recommended by 2018 FERC Chapter 11, the tensile strength can be increased by 50 percent to account for the high-rate effects of the seismic loading. Therefore, the flexural static and dynamic tensile strength for parent concrete will be assumed as 490 psi and 735 psi.

Tensile strength across lift lines is generally lower than concrete placed monolithically (i.e., parent concrete) which is conservatively estimated as 60 percent of the parent's tensile strength. Therefore, the flexural static and dynamic tensile strength for lift joints will be assumed as 300 psi and 450 psi.

The finite element model will include a select number of horizonal lift joints which will be allowed to crack if the tensile strength of concrete is exceeded. It is recommended to a friction angle of 45 degrees for unbonded or cracked lift joints (ACI 318-19 Table 22.9.4.2).

3.2.2.3 Shear Strength of Shear Keys at Vertical Contraction Joints

The vertical contraction joints have vertical contraction joints that resist vertical and upstream-downstream movement between monoliths during different load conditions including seismic. The shear strength of these keys was assessed using a FERC recommended approach FERC (2018, Reference 8). This assessment indicates that the shear strength of concrete would be approximately 16 percent of the uniaxial compressive strength 680 psi i.e., 0.16 x 4,250 psi, without accounting for the increased shear capacity that has been observed under dynamic loading.

In addition to the shear key shear resistance, a friction angle of 45 degrees is estimate based on ACI (ACI 318-19 Table 22.9.4.2). The friction at the vertical contraction joint interface, excluding the contribution of the shear keys, varies because it is depend on the normal load on the joint. The shear forces at the joints will be monitored during the analysis to determine if the loads exceed the capacity of the shear keys.

3.3 Rock Properties

3.3.1 Input Data for Rock Properties Assessment

3.3.1.1 Uniaxial Compressive Strength (UCS)

Golder's (2010) rock mass characterization for deformation parameters provided an estimation of the UCS value per rock unit.

- Unit A: average UCS of 5,467 psi or 38 MPa, based on point load test results on grab samples from poorly exposed outcrops.

- Unit B: estimate UCS of 4,350 psi or 30 MPa, based on descriptions provided and knowledge of basalts from other locations.
- Unit C: estimate 10,152 psi or 70 MPa, based on descriptions provided and knowledge of basalts from other locations.

3.3.1.2 Geological Strength Index (GSI)

The GSI (Hoek and Marinos, 2000) for the rock mass underlying Mossyrock Dam was determined through a review of historical reports and foundation photos (Tacoma Power, 2021; Golder, 2010; Butler & Engstrom, 1968).

Three nearly vertical joint sets were identified in all three rock units exposed at Mossyrock Dam (Butler & Engstrom, 1968). This is generally consistent with the findings by Golder (2010), with one additional shallow-dipping joint set identified during their 2010 field reconnaissance, and our observations of jointing shown on the available rock foundation photos. For this assessment, it was assumed a minimum of 3-4 joint sets present at Mossyrock Dam.

The rockmass at Mossyrock Dam was subdivided into three sub-horizontal bedrock units (Butler & Engstrom, 1968). Each unit's characteristics are determined based on the information provided in the aforementioned historical reports and summarized as follows:

- Unit A: Massive porphyritic andesite with numerous flow breccia zones. Andesite is generally fresh to slightly weathered, medium to light gray, jointed, medium strong to strong (ISRM [1981] field strength estimate of R3 to R4). Localized zones of oxidized flow breccias are reported as common but were not observed directly during Golder's 2010 field reconnaissance. Numerous randomly oriented cooling joints result in an overall blocky appearance and joints are filled with clay alteration products. Selected representative GSI for Unit A is 60 (55 – 70 range).
- Unit B: Amygdaloidal basalt with zones of flow breccia and dense porphyritic basalt. Unit B rock is fresh to slightly weathered, dark gray to black, jointed, weak to medium strong (ISRM [1981] field strength estimate of R2 to R3). Amygdaloidal basalt in this unit is susceptible to air slacking on exposure to the atmosphere. Surface rock has a field strength of R1 to R2, but the strength likely improves with depth to that of the rock exposed in Units A and C (R3 to R4) (Golder, 2010). Selected representative GSI for Unit B is 60 (55 – 65 range).
- Unit C: Massive sequence of andesite, fine grained platy andesite, agglomerate, and flow breccia. Unit C is described as some of the hardest rock within the project area, despite the lack of field estimate UCS value reported. A local characteristic of this unit is the presence of platy andesite, which is described as a result of closely spaced joints and have a tendency to fracture into small blocks after being exposed. Due to the layering nature of massive andesite (with a potential higher GSI value) and platy, jointed andesite (with a possible lower GIS value), Unit C's GSI range is conservatively determined to be wider than that of Unit A and B. Selected representative GSI for Unit C is 65 (55 – 75 range).

Due to the sequencing nature of various rock types with different thickness within each bedrock unit, a weighted average approach was adapted to mathematically estimate the GSI value for each unit. A generalized geological section of the three rock units at Mossyrock Dam (Butler & Engstrom, 1968) was used in this calculation. The resulting GSI ranges are plotted in Figure 3-1 below:

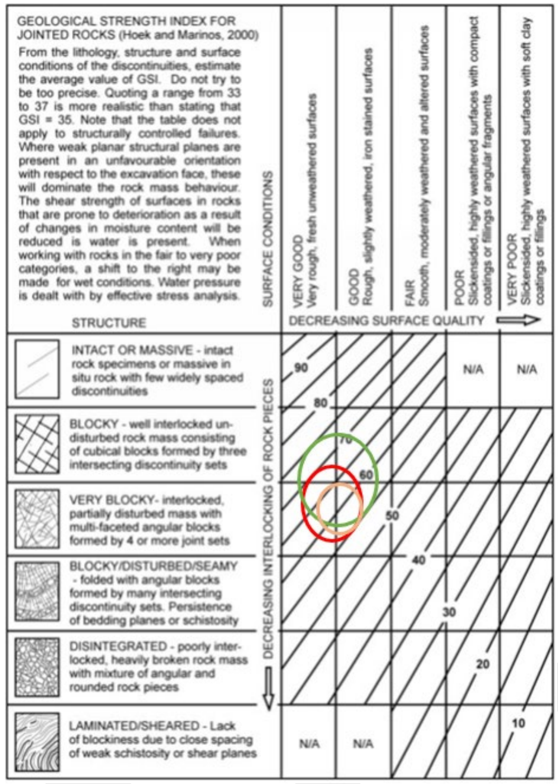

Figure 3-1: Geological Strength Index for Jointed Rock Masses (adapted from Hoek & Marinos, 2000). Red: Unit A; Orange: Unit B; Green: Unit C.

3.3.1.3 *Disturbance Factor (D)*

The disturbance factor, D, varies with distance from a free face due to blast damage and ranges between 0 and 1 (0 for undisturbed rock mass and 1 for highly disturbed rock mass). The disturbance factor significantly affects the deformation modulus (Hoek & Diederichs, 2006), although it should be noted that the disturbance factor applies only to the first 1-2 m of the bedrock and the deformation modulus applies to 50% of the height of the dam into the rockmass. The chosen D = 0 was used to calculate the rock mass cohesion, friction angle, and the deformation modulus. According to Tacoma Power (2021), an extensive foundation treatment was applied at Mossyrock Dam, which included routine sand blasting of all rock surfaces, removal of altered and least competent rocks, and thorough inspection (especially for Unit B) prior to clearing for concrete placement. Construction records (Tacoma Power, 2021) also suggest that the damaged rock was removed from the dam foundations prior to concrete pouring.

3.3.1.4 *Material Constant for Intact Rock (m_i)*

The constant m_i in the Hoek-Brown criterion was selected based on typical literature values of rock types (Hoek and Diedericks, 2006). The m_i value for andesite or basalt is 25 ± 5, breccia is 19 ± 5, and agglomerate is 19 ± 3. The weighted average approach (see Section 3.3.1.2) was utilized to estimate the material constant value per each rock unit:

- Unit A: 23
- Unit B: 24
- Unit C: 22

3.3.1.5 *Minimum Principal Stress (σ_3)*

The minimum principal stress per rock unit is calculated using the equation below:

$$\sigma_3 = \left(\gamma_{concrete} - \frac{1}{2}\gamma_{water}\right)\mathrm{h}$$

Where:

$\gamma_{concrete}$: unit weight of concrete (kN/m^3)

γ_{water}: unit weight of water (kN/m^3)

h: height of dam (m)

The height of the dam for each rock unit was estimated from Figure 3-2 (Coombs, 1989). This value was determined from the top of the dam (El. 789 ft) to the lowest point of bedrock per rock unit.

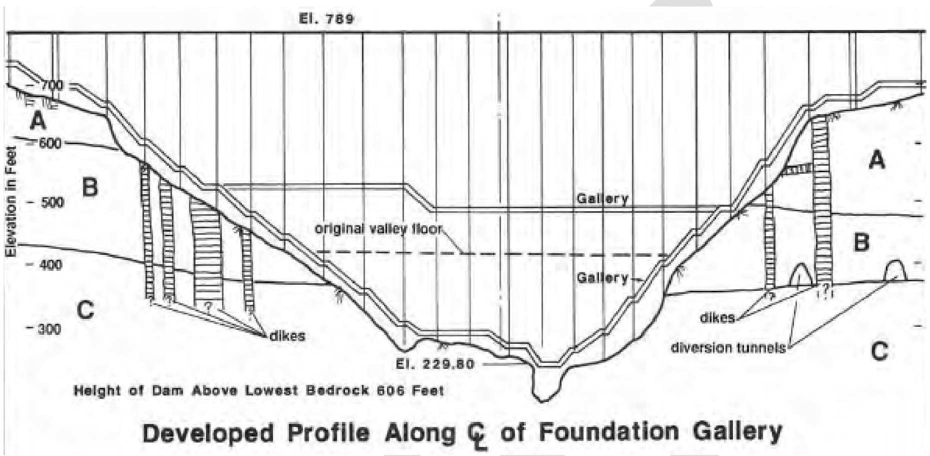

Figure 3-2: Mossyrock Dam profile and elevation (Coombs, 1989).

The minimum principle stress per rock unit was estimated as below:

- Unit A: 1.77 MPa
- Unit B: 2.63 MPa
- Unit C: 3.72 MPa

3.3.1.6 Modulus Ratio (MR)

Either the intact rock deformation modulus (Ei) or modulus ratio (MR) can be used as an input parameter for the rock properties assessment at Mossyrock Dam.

As mentioned above, Kollgaard (2002) reported Ei values for all rock units in an independent consultant report. However, it is unclear how these values were derived. Therefore, conservative utilization of the MR method was used in this assessment.

Estimated the modulus ratio of all three rock units using literature values (Hoek and Diederichs, 2006) and the weighted average approach (see Section 3.3.1.2). The MR value for each rock unit is estimated as follows:

- Unit A: 435 (370 – 500)
- Unit B: 365 (275 – 455)
- Unit C: 435 (360 – 510)

3.3.2 *Output Data for Rock Properties Assessment*

The rock mass parameters provided in Section 3.3.1 were input into RSData software (RocScience Inc., 2022) to obtain an estimate of the Hoek-Brown Failure Criterion (Hoek & Diederichs, 2006) and Mohr-Coulomb failure criterion of the rock mass.

3.3.2.1 *Intact Modulus (E_i)*

Using UCS and MR values, the intact modulus Ei was calculated in RSData (RocScience Inc., 2022) based on the following equation:

$$E_i = UCS \times MR$$

As part of this assessment, compare Kollgaard (2002) E_i results with the E_i values from Hoek and Diederichs (2006), which were calculated from UCS and MR values (estimated in Section 3.3.1.1 and 3.3.1.6). Table 3-2 showcases the compared E_i values for all rock units between Kollgaard (2002) and an estimation from RSData (RocScience Inc., 2022).

Table 3-2: Compared Intact Modulus Values for Rockmass at Mossyrock Dam

Rock Unit	Intact Rock Modulus of Deformation (E_i) (psi)	
	Kollgaard (2002)	RSData
Unit A	2.5×10^6	2.4×10^6 (2.0×10^6 – 2.8×10^6)
Unit B	1.5×10^6	1.6×10^6 (1.2×10^6 – 2.0×10^6)
Unit C	3.0×10^6 *	4.4×10^6 (3.7×10^6 – 5.2×10^6)
**Value provided by Kollgaard (2002) and was used in Hatch Energy (2008) finite element model*		

In comparison, similar E_i values of Unit A and B to that of Kollgaard (2002) and a higher Ei value of Unit C. This can be explained by the uncertainty in the empirical relationship between UCS, MR, and E_i. It is understood that an intact modulus of 1.5×10^6 psi was reported for Unit C, based on some testing that was published by Kleiner & Acker (1971) and Golder (2011). The results from this assessment suggest a higher Ei value for Unit C, which may be explained by newer technology and calculation methods within a 50-year period.

3.3.2.2 *Deformation Modulus (E_{rm})*

Using the input parameters in Section 3.3.1, the deformation modulus values for all three rock units from RSData (RocScience Inc., 2022) we obtained. As part of this assessment, comparison of the E_{rm} findings with that of Kleiner & Acker (1971) and Golder (2010). Table 3-2 showcases the compared Erm values for all rock units from three aforementioned sources.

Table 3-3: Compared Deformation Modulus Values for Rockmass at Mossyrock Dam

Rock Unit	Deformation Modulus (E_{rm}) (psi)		
	Kleiner & Acker (1971)*	Golder (2010)	RSData
Unit A	2.4×10^6 (in-situ jacking test) 4.4×10^6 (laboratory core test) 5.1×10^6 (downhole geophysics)	1.5×10^6 ($0.7 \times 10^6 – 2.6 \times 10^6$)	1.2×10^6 ($0.8 \times 10^6 – 2.0 \times 10^6$)
Unit B	1.3×10^6 (in-situ jacking test) 1.2×10^6 (actual modulus based on response of foundation deformation gages)	0.4×10^6 ($0.3 \times 10^6 – 1.5 \times 10^6$)	0.8×10^6 ($0.5 \times 10^6 – 1.3 \times 10^6$)
Unit C	3.5×10^6 (laboratory core test) 4.9×10^6 (downhole geophysics)	2.3×10^6 ** ($1.2 \times 10^6 – 4.8 \times 10^6$)	2.8×10^6 ($1.5 \times 10^6 – 4.2 \times 10^6$)

**Selected results from Kleiner & Acker (1971) are presented in this table, based on the authors' recommendation that the geology of the rock should be considered when deciding which method(s) would serve as better deformation modulus indicators and provide more accurate deformation modulus results.*

***Result does not reflect prior understanding of Kleiner & Acker (1971) findings for Unit C (Golder, 2011).*

In comparison, for the rock mass deformation modulus, similar values for all units to those obtained by Golder (2010) and lower values than that of the rock modulus Kleiner & Acker (1971). This can be explained by the newer technology and calculation methods within a 50-year period from the 1971 results. Furthermore, Kleiner & Acker (1971) acknowledged their methods for determining the elastic modulus (or deformation modulus) of Mossyrock Dam foundation were not accurate indicators of the actual foundation response and the values obtained must be applied with judgement to select design modulus values.

3.3.2.3 Cohesion (c) and Friction Angle (Φ)

Using the input parameters in Section 3.3.1, the cohesion and friction angle values for all three rock units from RSData (RocScience Inc., 2022), which can be found in Table 3-4.

Table 3-4: Cohesion and Friction Angle of Rockmass at Mossyrock Dam

Rock Unit	RSData	
	Cohesion (MPa)	Friction Angle (°)
Unit A	0.953 (0.827 – 1.234)	54 (51 – 58)
Unit B	1.116 (0.976 – 1.263)	50 (46 – 53)
Unit C	2.107 (1.633 – 2.792)	54 (49 – 57)

3.3.3 Recommended Rock Mass Parameters

Based on the discussion, calculation and analysis provided above, the recommended rock mass parameters are presented in Table 3-1.

3.3.4 Foundation Rock Discontinuities

The 2023 Mossyrock Dam CA, based on a Level 2 Risk Assessment (L2RA) (HDR, 2023), identified rock block failure at the abutments as a potential failure mode (PFM) risk drivers. Both abutments were evaluated, but a horizontal layer of ash at the right abutment that daylights downstream of the dam was highlighted. Historic construction photos indicate that the layer passes along the right abutment contact. The ash layer is shown in Figure 3-3. After a review of available historical photographs (Tacoma Power, 2021), a geological mapping program is recommended using a drone survey to obtain data on the potential rock wedge.

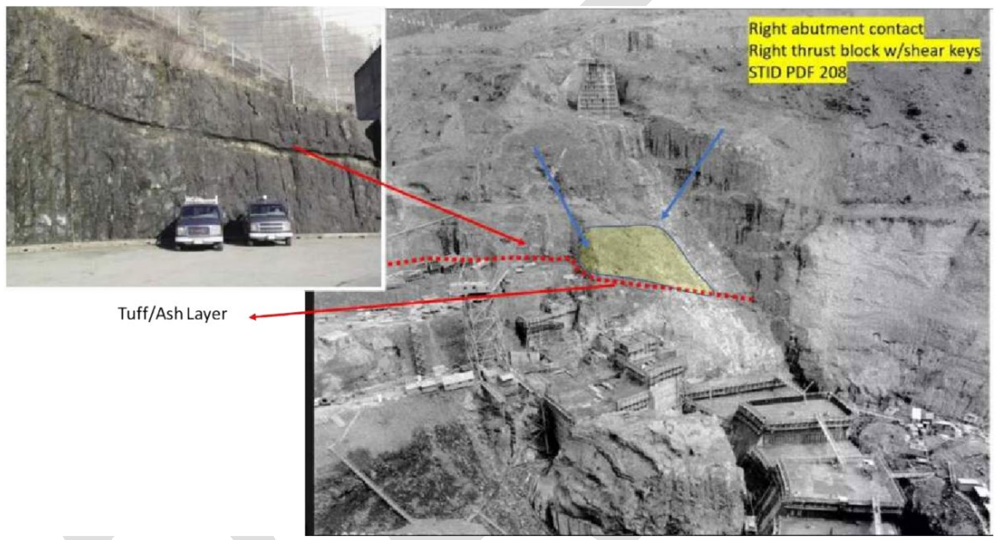

Figure 3-3: Ash Layer at Right Abutment of Mossyrock Dam (HDR, 2023)

The viability of the rock wedge will first be evaluated using the results of the foundation drone survey. If the rock wedge is considered viable, it will not be explicitly modelled in the initial analysis runs, but will be evaluated using the outputs of the analysis. The force vectors at the rock wedges will be extracted compared to the sliding resistance of the wedge using the program SWEDGE from RocScience. Explicit modelling will be considered for future analyses based on the results of the initial analysis. If an explicit rock wedge model is recommended, the geometry of the wedge will be included in the foundation model with contact elements at the block interface that allow sliding to occur.

The geological mapping and rock wedge analysis will be completed by others and incorporated into the model as appropriate.

3.4 Concrete-Rock Interface

3.4.1 Concrete-Rock Interface Geometry

The concrete-rock interface (CRI) cross valley and upstream-downstream topography will be included in the model. The intent is to capture significant changes in geometry that may affect dam performance.

3.4.2 Shear Strength of Concrete-Rock Interface

The Golder (1990) report provided shear test results for two samples taken from the concrete/rock interface at the left thrust block. The two samples were bonded and the following tests were done:

- Bond-break shear strength (Run 1)
- Unbonded shear strength at various normal stresses (Runs 2 to 4).

3.4.2.1 Dam/Foundation Interface Bond-Break Shear Strength

The bond-break shear strength is summarized in Table 3-5.

Table 3-5: Bond-Break Shear Strength Summary

Sample	Measured Shear Strength, lb/in^2	Estimated Cohesion and Friction Angle*	
		Cohesion (c), lb/in^2	Friction angle (ϕ), deg
MOS-4	551	51	45
MOS-5	474	456	45

* Cohesion is calculated assuming ø=45° using the applied normal stress from the test

An effective friction angle assuming no cohesion should be estimated based on the foundation conditions at the time of construction as documented with construction photographs. It is likely that the estimated bond-break strengths given in Table 2-3 would not be used to estimate the effective friction angle used in analysis since they are likely not representative of the variability of conditions along the foundation interface.

3.4.2.2 Unbonded Joint Shear Strength

The concrete/rock interface cores were tested as unbonded samples after the cohesive bond was broken. The samples are small and a correction must be made for the sample roughness.

The shear strength results are quite variable due to the roughness of the joint samples. In this section, the results are evaluated to determine a suitable peak and residual friction angle for use in sliding stability calculations.

The peak shear strength of a joint is determined using the equation

$$\tau = \sigma_n \cdot \tan(\phi_b + i)$$

Where:

τ = peak shear strength
σ_n = normal stress applied across the joint
ϕ_b = friction angle
i = roughness of the joint

The basic friction angle can be computed from shear strength test by subtracting the "i" measured during the test from the measured mobilized friction angle. The residual friction angle can be computed by subtracting the measured roughness (i) from the shear test results if the shear displacements are sufficiently large. The Mossyrock concrete/rock interface samples were small (typical contact area was less than 4 in^2), therefore shear displacements of 0.3 to 0.5 in. should be sufficiently large to obtain the residual shear strength.

The corrected friction angle, ϕ is determined from the test results as follows:

$$\phi = \tan^{-1}\left(\frac{\tau}{\sigma_n}\right) - i$$

where τ and σ_n are measured during the shear strength test. The vertical and horizontal displacements measured during the direct shear test are used to determine i of the tested joint as follows:

$$i = \tan^{-1}\left(\frac{dv}{dh}\right)$$

Where:

dv = vertical change in displacement
dh = horizontal change in displacement

The friction angle is corrected for the roughness, i, measured during the test. Hence:

$$\phi_{corrected} = \phi - i$$

At shear displacements of 0.4 to 0.5 inch using small samples, the residual friction angle can be determined. The results of the tests indicate a conservative estimate of a peak friction angle of 55 degrees and a residual friction angle of 38 degrees.

As noted previously, the shear displacement required to reduce the shear strength of a small sample to residual shear strength is relatively small and in the range of 0.3 to 0.5 in. There is very little information on the shear displacement required to reduce to residual strength for large samples. Geertsema (2003) tested large granite joint samples (350 x 350 mm) in direct shear. The samples had roughness identified with the joint roughness coefficient which varied from 6 to 12. He found that after the samples had undergone a shear displacement of 6.8 in., it had lost only one-third of the joint roughness. Therefore, on larger joints it is expected that displacements significantly greater than 6 inches would be required to reduce the friction angle to a residual friction angle.

3.5 Additional Field Investigations

The preliminary analysis will be performed using the material properties described in Table 3-1. However, additional investigations could be beneficial in the following areas:

- Additional concrete cores would be beneficial in more precisely determining the material properties. The previous investigations test four concrete cores. At least few more cores would give greater confidence in the assumed values.
- No additional foundation rock drilling and cores at concrete-rock interface are required.
- Geological mapping program using a drone survey be performed to obtain data on the potential rock wedge.

4. Finite Element Model

4.1 Finite Element Analysis Programs

FEA programs solve complex problems through solving the related partial differential equations (PDEs) representing the physical phenomena. However, FEA programs cannot directly solve the PDEs; rather, they employ matrix equations using the implicit and explicit method to solve the PDEs for linear and nonlinear problems.

This analysis will be performed using the explicit analysis method using either the SMP or MPP solver in LS-DYNA. The decision to use SMP or MPP will be made based on the number of runs, the run times, and the cost of the computational power. Explicit analysis is best suited for dynamic, impulse, contact, and material nonlinear problems. The acceleration values at the node are solved in explicit analysis. Note for implicit analysis, the aim is to calculate displacements at each node. The explicit algorithm uses a central difference rule to integrate the equation of motions explicitly through time. Satisfying the dynamic equilibrium at the beginning of the time increment provides accelerations. Also, since no large matrices are stored in the explicit method, the computation time, computer memory, and disk storage requirements are minimal compared to the implicit method. For explicit analysis, we recommend using LS-DYNA. LS-DYNA is well known and is generally accepted in dam engineering. A summary of the factors recommending LS-DYNA is presented in Table 4-1.

Table 4-1: Implicit vs Explicit FE Analysis

Analysis Type	Software	Formulation of the Equations of Motion	Suitable Applications	Remarks
Implicit	ANSYS	When we have a stiffness matrix and a known set of forces, they lead to a system of linear equations. Solving this system allows us to determine the displacements. (force =stiffness x displacement)	Implicit methods are well-suited for a broad spectrum of problems, including both linear and nonlin ear, two-dimensional, and three-dimensional scenarios . These methods handle static, dynamic, and flow-related issues (such as thermal and seepage responses). However, as a problem becomes increasingly nonlinear (with factors like material cracking, contact sliding, or large displacements), or when the load speed escalates, the explicit method may be more appropriate.	• The selection of LS-DYNA for our current project was driven by several compelling factors: • Nonlinear Seismic Analysis: LS-DYNA excels in handling nonlinear seismic scenarios, crucial for understanding structural behavior during earthquakes. • Sliding Simulation: LS-DYNA can simulate sliding at contact elements under earthquake loads, providing valuable insights into stability.

Analysis Type	Software	Formulation of the Equations of Motion	Suitable Applications	Remarks
Explicit	LS-DYNA	The kinematics of a model are employed to calculate accelerations. When an applied force acts on the structure, it induces movement. The model's elements experience strain at specific rates and counteract the load, following the fundamental relationship: force = mass × acceleration.	Explicit methods necessitate small time steps, which are determined by the highest natural frequency of the model. These methods exhibit conditional stability in relation to the time step size. Remarkably, these methods demand minimal computer memory, as there is no need to store large matrices. Explicit methods are best suited for a class of problems: • High speed dynamic problems, i.e., earthquake analysis. • Contact problems where independent bodies are affecting each other • Material degradation problems, like concrete cracking or steel yielding	• Computational Efficiency: LS-DYNA significantly reduces computational time, optimizing our analysis process. • Fluid Element Integration: Fluid elements can be included to model dam-reservoir interaction, a critical aspect of the project. • Direct Earthquake Input Method: The inclusion of the Lokke and Chopra direct earthquake input method directly within LS-DYNA streamlines the workflow. • Industry Acceptance: LS-DYNA enjoys widespread industry acceptance, including recognition by organizations like FERC. It is actively used by USBR and USACE. • Proven Track Record: The existing model for the Mossyrock Dam was successfully developed using LS-DYNA, reinforcing its reliability.

Analysis Type	Software	Formulation of the Equations of Motion	Suitable Applications	Remarks
			• Dam-Reservoir interaction via fluid elements.	

4.2 Geometric Model of Concrete Structures and Rock Foundation Updates

A 3D finite element mesh of Mossyrock Dam exists which includes the dam, spillway, piers, thrust block, wing wall, and rock foundation. The model is shown in Figure 1-1. This model could be used as a starting point for the new analysis. The foundation topography model will be updated based on the results of the drone survey of the dam. The drone survey will also be used to confirm the geometry of the concrete dam. See the discussion of model updates in Section 2.3.

4.3 Element Type

The dam, foundation, and reservoir will be modeled with eight-noded 3D hexahedral elements. A discussion related to different elements for dam, foundation rock, and reservoir is presented in this section.

4.3.1 Solid Elements

For explicit analysis with LS-DYNA, the dam and foundation will be modeled with eight-node solid elements. It is noted that typically in explicit formulations, lower-order (reduced integration) finite elements with only one integration point at the center of the element are employed to reduce the computation effort. However, the finite element mesh for explicit formulation models usually have greater element density than models used for implicit formulations in order to attain more accurate estimates of stresses and displacements. Fully integrated elements with 8 integration points will be used to model the dam, thus accuracy of the analysis will be acceptable. Also, the foundation will be modeled with reduced-integration elements to reduce the computational demands of the analysis.

4.3.2 Fluid Elements

Fluid elements can be used to accurately include static and dynamic reservoir pressures in the analysis of a dam. However, analysis with fluid elements can be difficult and time intensive, as complex geometries require refined meshes to avoid spurious results. Therefore, the initial analysis will be performed using the exact Westergaard (Zanger) lumped masses to represent hydrodynamic interaction. Note that for initial runs, if the reservoir is not represented by fluid elements, then the hydrostatic load will be applied as element face pressure in the static case. This analysis will be used to assess whether a more refined analysis using fluid or acoustic elements to represent hydrodynamic interaction is necessary or beneficial.

If the results of the initial analysis indicate that a fluid element analysis is required, eight-noded fluid or acoustic elements will be used to represent the reservoir mesh. The reservoir elements in LS-DYNA will be modeled with reduced integration. The reduced (single point) integration scheme calculates the fluid pressure at the center of the element which is acceptable because the reservoir mesh is relatively fine.

4.3.3 Contact Elements

LS-DYNA has different types of contact elements available to model tied, tie-break and sliding, etc. for various analysis. LS-DYNA allows the user to define the shear strength with friction angle and cohesion values at any given joint. Section 7 provides information regarding contact details, i.e., the bond assumptions for different analysis cases.

4.4 Model Meshing Parameters

In the case of explicit analysis, a fine mesh will be used. The element size for explicit analysis mesh is dependent on the material property values for concrete and rock, respectively. Thus, a fine mesh is generally required to satisfy the respective element size requirements.

For modeling the piers, at least four elements through the thickness will be modeled to capture the bending of the piers. Also, for reservoir elements, the element size would be kept less than 50 feet in each direction. This is based on the element size requirement for explicit analysis. A finer fluid mesh will be used around the spillway piers.

4.5 Hourglass Control

Hourglass modes are nonphysical, non-energy modes of deformation that produce zero strain and no stress. Hourglass modes occur only in under-integrated (single integration point) solid, shell, and thick shell elements. These modes are oscillatory in nature and tend to have periods that are much shorter than those of the overall structural response. They result in mathematical states that are not physically possible and adversely affect the analysis results. They typically have no stiffness and give a zig zag appearance to mesh deformations that are reminiscent of an hourglass. The occurrence of hourglass deformations in an analysis can invalidate analysis results and needs to be addressed. LS-DYNA has various algorithms for inhibiting hourglassing. These algorithms can be divided into two classes – viscous and stiffness control. The viscous hourglassing control only stops the hourglass mode from developing further; stiffness hourglassing will push the element back towards its undeformed configuration. Therefore, it is recommended that hourglassing be addressed using the Flanagan-Belytschko 1981 approach, i.e., using the stiffness type approach that requires exact volume integration for solid elements. LS-DYNA technical support has indicated that a good way to reduce hourglassing is to refine the finite element mesh.

4.6 Vertical Contraction Joints

The contact surface contraction joints will be initially modeled with a 45º friction angle for the concrete-to-concrete interaction. If required, forces will be extracted from the model to evaluate the capacity of the shear keys. The locations of the vertical contraction joints are shown in Figure 4-1.

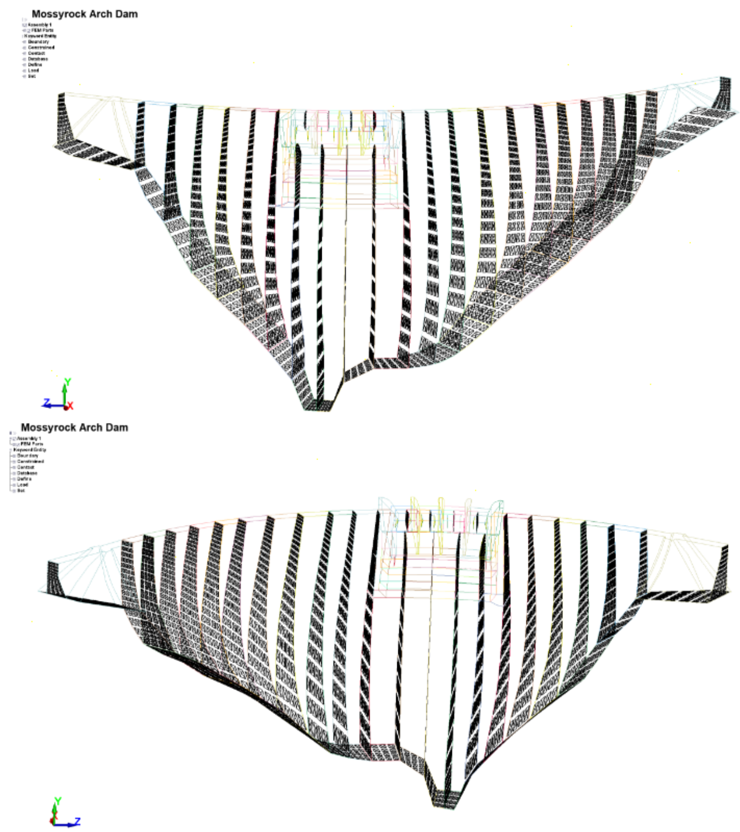

Figure 4-1: Vertical Contraction Joint Contact Elements, from 2012 Analysis Model

4.7 Horizontal Lift Joints

The horizontal lift joints will be modeled with contact elements and will be allowed to open, close and slide during the analysis. Section 7 provides information regarding contact details, i.e., the bond assumptions for different analysis cases. The elevations of the selected horizontal lift lines are shown in Figure 4-2. The locations of the horizontal contact elements are shown in Figure 4-3.

Figure 4-2: Lift Line Elevations

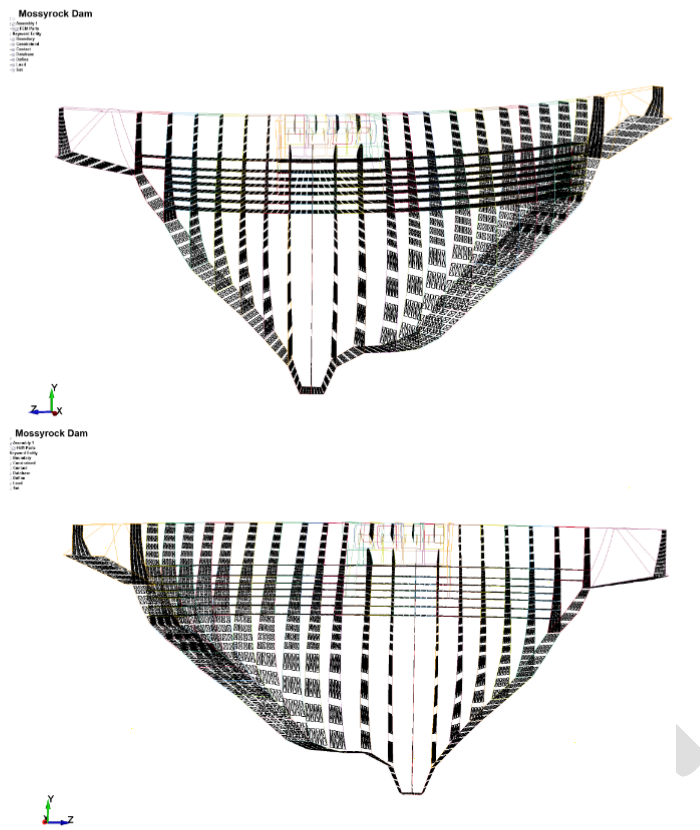

Figure 4-3: Horizontal and Vertical Contraction Joint Contact Elements, from 2020 Analysis Model

4.8 Ambient Vibration Testing

4.8.1 Verification and Validation of AVT Results

Ambient vibration testing (AVT) has been performed at Mossyrock Dam by Dr. Zee Duron and Dr. Robert Hall. The AVT results will first be verified and validated via the two different, complementary techniques: the enhanced frequency domain decomposition (EFDD) and the stochastic subspace identification (SSI). The EFDD technique is an enhanced frequency domain method and the procedure consists of decomposing the system output into a set of single degree of freedom systems, which are independent for each mode. The singular values are estimated from the spectral density of the single degree of freedom systems and the configuration of the modes is estimated from the singular vectors by selecting the highest peaks of the responses.

The SSI technique is a time domain method which consists of adjusting a parametric model to the time series recorded by the sensors. SSI method takes a matrix of the time history data, and performs a series of geometric manipulations which results in a set of mathematical models that represent the system that produces the data; the analysis provides modes based on those models. The advantage of the SSI is more accurate modal estimations, especially in the lower frequencies when the data is properly decimated. The disadvantage is that the SSI method takes a considerable amount of time for analysis, and is not easily applied to broadband data. In contrast, the EFDD method is very quick and allows for the user to pick modes anywhere in the frequency range of interest.

4.8.2 Calibration of the FE Model

The natural frequencies of the finite element model are proposed to be calibrated via ambient vibration testing (AVT). The modulus of concrete and rock will be adjusted in the finite element model to match the results from ambient vibration testing The AVT also provides means to calibrate the natural frequencies of the spillway piers. See Section 7.1.

4.9 Damping and Half Bandwidth Method

The analysis will be performed assuming 5% damping However, it is almost impossible to impose 5% damping on the modal frequencies in a nonlinear seismic analysis. Therefore, it is important to estimate damping in the model associated with the natural frequency of the dam. The half power bandwidth method will be used to determine the damping in the model. The half power bandwidth method is usually applied to single-degree-of-freedom systems, but it can be applied to well-separated modes in multi-degree-of-freedom systems as well. This method assumes that half the power dissipation in a model occurs in the frequency band between F_1 and F_2, where F_1 and F_2 are the frequencies corresponding to the amplitude at natural frequency F_n divided by √2. The natural frequency of the structure will be determined using ambient vibration testing.

The damping ratio is:

$$\xi = \frac{F_2 - F_1}{2\ x\ F_n}$$

A sine wave input (chirp) with a logarithmically varying frequency from 1 to 50 Hz over 10 seconds will be used as an input to the model to estimate the damping in the model using the half bandwidth method

4.10 Massed Foundation Analysis

The seismic analysis of the dam considers the foundation with mass. A much more rigorous analysis is achieved by considering mass in the foundation, but the modeling becomes more complex. To realistically evaluate the response of the dam subjected to a seismic event, it is important to incorporate the effects of interaction of the dam and foundation in the analysis. Therefore, the analysis must be carried out in the time domain using the finite element analysis to account for non-homogeneous foundation properties and nonlinearity in the governing equations. In the time history analysis, the earthquake acceleration is applied at the base of the foundation and it propagates vertically by an elastic wave propagation mechanism until it reaches the top of the foundation. The size of foundation in the numerical model is finite compared to the semi-infinite foundation in the physical model. The seismic waves are reflected from the boundaries of the numerical model. This seismic wave scattering due to the artificial boundaries in the numerical model results in altering the frequency content of the input seismic and amplitude ground motion as the wave propagates through the deformable foundation rock.

Therefore, non-absorbing boundaries with perfectly matched layers (PMLs) will be implemented in the finite element model. PMLs are very effective in absorbing all of the incoming waves from the elastic bounded domain, thus they help in modeling the foundation as a semi-infinite mass.

4.11 Previous Mesh Evaluation

The quality of the previous 2012 and 2020 meshes of the dam were evaluated. The distortion index feature in LS-PrePost was used to check for highly distorted elements. The distortion index produces an index value between 1 and 0, where 1 is a completely undistorted element. The element distortion indices for all elements are shown in Figure 4-4. The elements with an index value less than 0.5 are highlighted in Figure 4-5. Note that the vast majority of the elements have an index value greater than 0.5, and those with lower values are isolated to areas of transition in mesh density.

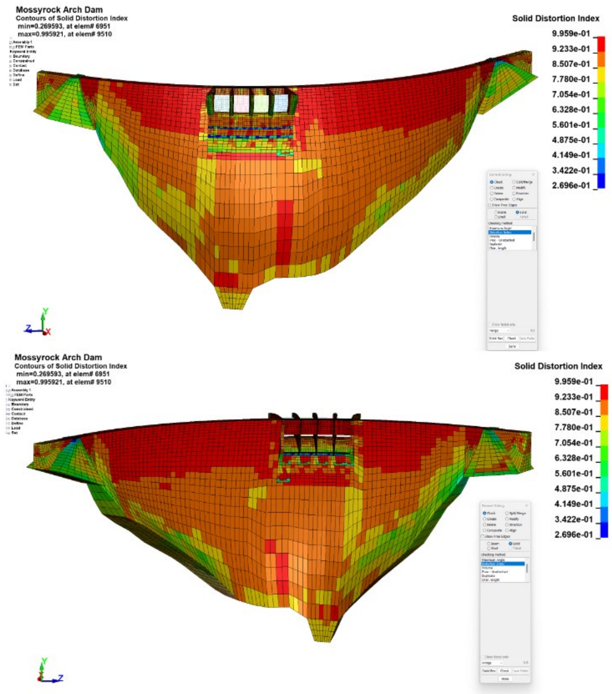

Figure 4-4: Element Distortion Indices, All Elements

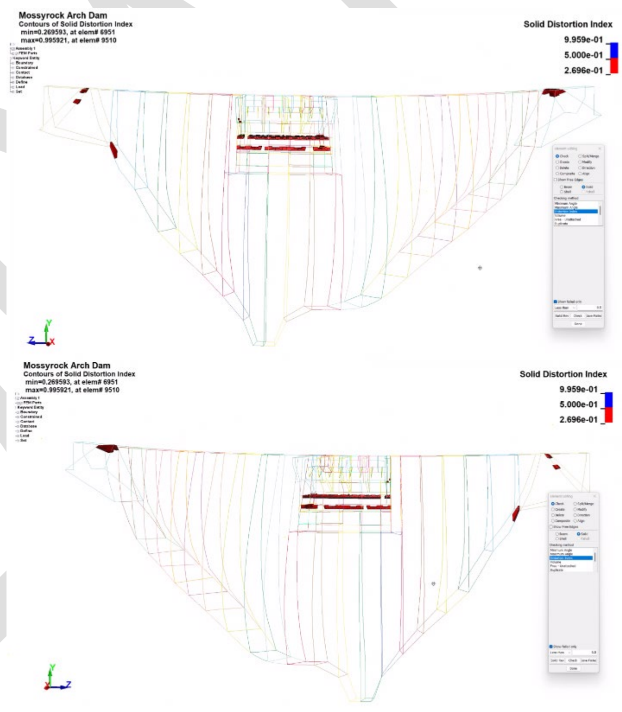

Figure 4-5: Element with Distortion Index Less Than 0.5

4.12 Sub Models

N/A

5. Load and Load Combinations

5.1 Loads

The individual loads are discussed in the following sections.

5.1.1 Dead Load

The self-weight of the dam will be included in the analysis.

5.1.2 Hydrostatic Loads (Normal and PMF)

The hydrostatic load will be applied as a triangular pressure distribution on the upstream face of the dam computed with the equation:

$$p = \gamma_w h$$

Where:

p = hydrostatic pressure
γ_w = unit weight of water, taken as 62.4 pcf
h = depth of water under consideration.

5.1.3 Uplift Pressure

Uplift pressure will be included for static and dynamic load cases in accordance with FERC Ch 11 guidelines. Linearly varying uplift pressure from headwater to tailwater was applied at the dam-foundation interface and horizontal lift joints. Uplift pressures during dynamic analysis will be assumed to remain constant throughout the seismic load duration. Uplift pressures will be applied as equal and opposite element face pressures within contact surfaces during the finite element analyses.

5.1.4 Silt Load

Appropriate silt loading will be applied based on the upstream survey results. For static load cases, the buoyant density of silt will be assumed 85 pcf. Similarly, during a seismic event the dynamic silt load will be calculated like a Westergaard hydrodynamic load. For this dynamic load case, the equivalent silt density of 85 pcf will be considered instead of the unit weight of water and applied as a load to the structure. The need for upstream bathymetry required to estimate the silt load will be evaluated.

5.1.5 Gate Load

The gate loads will be directly applied on the piers and appropriate hydrodynamic mass will be lumped on the adjoining pier nodes for dynamic load cases.

5.1.6 Hydrodynamic Loads

The initial analysis will be performed using exact Westergaard (Zanger, 1952 and Kuo, 1982) lumped masses to represent hydrodynamic interaction. This analysis will be used to assess whether a more refined analysis using solid or acoustic elements to represent hydrodynamic interaction is necessary or beneficial.

5.1.6.1 Hydrodynamic Loads – Added Mass Approach

The Westergaard approach represents hydrodynamic pressures by considering an added mass of water on the dam face moving along with the dam. Westergaard derived an exact solution for hydrodynamic pressures on a dam assuming the dam is rigid and has a vertical face. Westgaard also published the following approximation, which is often used in analysis of dams:

$$p(y) = \frac{7}{8} \cdot \gamma_w \sqrt{H(H-y)}$$

Where:

p(y) = Depth below water surface

γ_w = unit weight of water

H = Total height of reservoir

USBR has noted that this approximation can over or underestimate hydrodynamic pressure depending on the height of the structure (USBR, 2011). USBR provided the exact Westergaard solution for maximum pressure on the dam face:

$$p = \frac{8\alpha wh}{\pi^2} \sum_{1,3,5,..}^{n} \frac{1}{n^2 c_n} \sin \frac{n\pi y}{2h}$$

$$c_n = \sqrt{1 - \frac{16wh^2}{n^2 gkT^2}}$$

Where:

y = depth below water surface

w = weight of water per unit volume

g = acceleration due to gravity

α = maximum horizontal acceleration of foundation divided by g

T = period of horizontal vibration of the foundation

T = time

K = modulus of elasticity of water

USBR notes that for a reservoir with a height of 600 feet, the approximate formula underestimates the peak pressure load with a 7% difference (USBR, 2011). The difference between the distributions is shown in Figure 5-1.

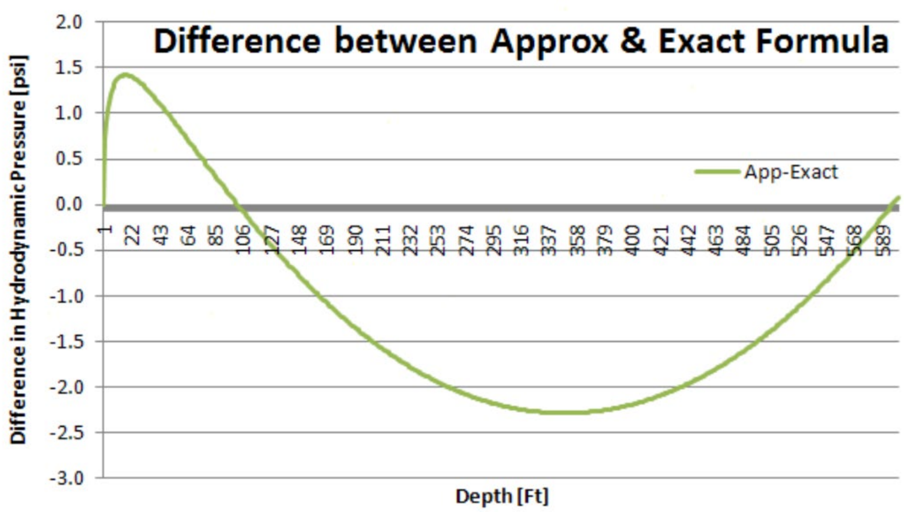

Figure 5-1: Difference between Approximate and Exact Westergaard Hydrodynamic Pressure Distributions, H = 600 feet (USBR, 2011)

Westergaard's exact solution will therefore be used to compute hydrodynamic pressure/added mass for the initial analysis of Mossyrock Dam.

5.1.6.2 Hydrodynamic Loads – Fluid Element Modeling

A sensitivity analysis with the reservoir modelled using solid elements can be performed if necessary. If required, displacement-based, three-dimensional solid fluid elements would be used to model the reservoir. The fluid elements are available in LS-DYNA and their performance has been verified in past projects. The fluid mesh would be connected to the foundation through a tied contact surface. The interface between the reservoir and the dam can either be a tied or a sliding contact surface.

5.1.7 Earthquake Load

The scope of work requires analysis for different earthquake load cases, i.e., 2,500, 3,750, 5,000, 7,500, 10,000 and >10,000 year return period events. The earthquake time histories for different return periods will be provided by Tacoma Power. Because a massed foundation is being used, the earthquake load will be applied using the Lokke and Chopra (2019) direct finite element method.

5.1.7.1 Earthquake Input Method

The current state of practice does not provide earthquake time histories generated from a point source model, but rather the earthquake time histories developed by the seismologist are for a free-field flat box on hard rock. As a result, it is not possible to exactly identify the location of the free-field point. However, for Mossyrock Dam the topography appears to be reasonably flat around the dam abutments, and thus the free-field will be assumed to be at top of the 1D columns for both left and right abutments. In other words, the control point for the earthquake deconvolution would be at the crest of the dam. As mentioned earlier, the nodal responses from 1D columns will be applied to the 2D systems and subsequently to the 3D model to be used for earthquake analysis with dam.

5.2 Load Combinations

The considered load combinations are summarized below.

5.2.1 Dam

The load combinations for the dam are summarized in Table 5-1 below. Uplift will be assumed linear from headwater (HW) to tailwater (TW).

Table 5-1: Summary of Loading Conditions for Mossyrock Dam

Loading No.	Load Acronym	Load Description	Headwater Elevation (ft)	Tailwater Elevation (ft)	Earthquake	Spillway Gate	Intake Gate
1	N	Normal Operating Condition	El. 778.5	N/A	N/A	Closed	Open
		Normal Operating Condition – Restricted Reservoir	El. 749.0	N/A	N/a	Closed	Open
2	PMF	Probable Maximum Flood	El. 785.8	To be confirmed	N/A	Open	Closed
3	EQ	NOC + Earthquake	El. 778.5	N/A	Different cases with 1 in 2.5k, 3.75k, 5k, 10k, and >10k return periods	Closed	Open

5.2.2 Gates

N/A

6. Acceptance Criteria

The acceptance criteria for the dam are based on FERC Chapter 3 and Chapter 11 guidelines. The acceptance criteria for the spillway piers and other reinforced concrete elements are based on USACE EM 1110-2-6053 (USACE, 2007). The acceptance criteria for steel structures are based on USACE EM 1110-2-2107 (USACE, 2022), which recommends evaluating the structures following AISC 360-16.

6.1 Dam Acceptance Criteria

6.1.1 Minimum Sliding Factor of Safety

Recommended minimum factors of safety for sliding for a high or significant hazard potential dam when cohesion is included and neglected are shown in Table 6-1. The minimum sliding factors of safety apply both to dam-foundation joint and horizontal lift joints.

Table 6-1: Minimum Sliding Factor of Safety

Load Case	Factor of Safety	
	With Cohesion	Without Cohesion
Normal	3.0	1.5
Probable Maximum Flood	2.0	1.3
Earthquake	N/A	
Post Earthquake	1.3	1.3

Note that these values are FERC requirements for sliding stability, but a progressive seismic loading analysis will also be performed to determine where the factors of safety drop below 1.0. The progressive analysis is described in Section 7.2. Knowing when the factors of safety drop below 1.0 are also useful for the proposed L4 risk analyses.

6.1.1.1 Dam/Foundation Interface

The 3D finite element model results will be used to compute the sliding factors of safety. The finite element model contains nonlinear contact surfaces at the dam/foundation contact and at the vertical contraction joints between monoliths. The nonlinear contact surfaces allow loads to be redistributed from areas where shear or tensile stress is computed. The following describes how the factor of safety values against sliding will be calculated:

First, perform the analysis as recommended above using the friction angle of 55º to represent the dam-foundation joint. Then gradually decrease the friction angle until the analysis does not converge, i.e., the dam becomes unstable. The factor of safety against sliding is calculated by:

$$SFOS = \frac{\tan \phi_{assumed}}{\tan \phi_{min}}$$

Where:

SFOS = Sliding factor of safety
$\phi_{assumed}$ = Assumed foundation interface friction angle, 55 degrees in this analysis
ϕ_{min} = Minimum friction angle where the analysis converges

However, 3D finite element analyses are computationally expensive, and thus alternatively the dam can be checked for a minimum friction angle required to satisfy the sliding factor of safety requirements. From Table 6-1, the required factor of safety for the normal load case is 1.5. Thus, if the dam is stable for $\theta = tan^{-1}(tan(55^{\circ})/1.5) = 43.5^{\circ}$, then it can be concluded that the dam successfully satisfied the sliding factor of safety criteria given by FERC guidelines. Table 6-2 resents the reduced dam-foundation friction angle to satisfy the sliding stability criteria.

Table 6-2: Reduced Dam-Foundation Friction Angle to Satisfy the Sliding Stability Criteria

Load Case	Factor of Safety without Cohesion	Dam-Foundation Interface Joint Friction Angle	Reduced Dam-Foundation Interface Joint Friction Angle
Normal	1.5	55º	43.5º
Probable Maximum Flood	1.3	55º	47.5º
Earthquake	1.1	55º	52.3º
Post-Earthquake	1.3	55º	47.5º

6.1.1.2 *Dam Lift Joints*

Section 7 provides information regarding contact details, i.e., the bond assumptions for different analysis cases. Therefore, as discussed in Section 6.1.1 the stability criteria will be satisfied by reducing the friction angle to determine lift joint specific factors of safety.

6.1.2 Allowable Concrete Stress

Table 6-3 presents required factor of safety and allowable compressive and tensile stresses for concrete per FERC Guidelines. Refer to Section 3.2 for a summary of concrete properties.

Table 6-3: Required Factor of Safety and Allowable Compressive and Tensile Stresses for Concrete

Load Case	Factor of Safety	Allowable Compressive Stress in Concrete	Allowable Tensile Stress in Concrete*
Normal	1.5	3,600 psi	200 psi
Probable Maximum Flood	1.3	4,150 psi	230 psi
Earthquake	N/A		
Post-Earthquake	1.3	4,150 psi	230 psi

*Note – These values are based on the estimated splitting tensile strength. See discussion in Section 3.2.2.2 of modification of these values for evaluation of linear FEA models.

6.1.3 Allowable Displacement

The FERC guidelines do not provide allowable limits on displacement and relative slip displacements. In general, concrete dams are expected to be able to withstand movements of several inches. This will be reviewed further during the analysis. If overturning becomes the critical failure mode, displacement may become less relevant. Otherwise, the magnitude of displacement could affect the post-seismic stability since asperities along sliding interfaces may be sheared off and result in a reduction in the shear capacity. Engineering judgement will be required and documented to assess the effect of sliding on the post-event friction angle.

6.2 Strength of Reinforced Concrete Elements

USACE prescribes a DCR approach for materially linear strength evaluation of lightly reinforced concrete hydraulic structures (USACE, 2007), which is applicable to the spillway piers at Mossyrock Dam. First, a C_1 factor is computed for the considered structure. This factor is used to increase moment demands for the case where the forces from a linear structural model are not sufficient to displace the structure to the expected maximum inelastic displacement. The DCR and factor are computed with the following equations:

$$DCR = \frac{C_1 M_D}{M_N}$$

$$C_1 = \left(1.0 + (SR - 1)\frac{T_0}{T}\right)\left(\frac{1}{SR}\right) \leq 1.5 \; if \; T \leq T_0$$

$$C_1 = 1.0 \; if \; T > T_0$$

Where:

DCR = Demand-to-Capacity Ratio
C_1 = equal energy response modification factor
M_D = Elastic moment demand from linear analysis, kip-ft
M_N = Nominal moment capacity, kip-ft
SR = M_D/M_N
T = fundamental period of the structure, seconds
T_0 = period corresponding to the peak acceleration response, seconds

The factor will be checked using the fundamental period extracted from the model and confirmed by AVT.

The allowable damage control and serviceability DCRs are summarized in Table 6-4. The serviceability criteria indicate the limit beyond which permanent inelastic displacements would be predicted, while the damage control criteria indicate the limit beyond which catastrophic failure may occur.

Table 6-4: USACE Reinforce Concrete Seismic DCR Criteria

Force	Damage Control DCR	Serviceability DCR
Moment	2.0	1.0
Shear	1.0	0.8

USACE prescribes a method for evaluating the results of a linear time history analysis adopted from FEMA 273. In this procedure, an allowable moment is calculated using the DCR and C_1 described above. The moment demand as a function of time is extracted from the model and compared to the allowable moment value. Up to three excursions above this level are considered acceptable; any additional excursions indicate that the structure does not have adequate strength to withstand the earthquake loads.

6.3 Hydraulic Steel Structures

N/A

7. Analysis Runs

There are various combinations of finite element models that will be required to complete the Mossyrock Analysis and Risk Review Work Plan scope of work. A preliminary list of the finite element model runs to validate the AVT results and calibrate the model, and complete the explicit analysis are provided in the tables below.

The radial gate evaluation will be performed in a separate SAP2000 or STAAD pro model. The gate evaluation will include the structural amplification over the height of the structure. Also, a 2D stability analysis for the wing walls will be performed.

7.1 AVT Calibration Analysis

The model will first be calibrated using the available AVT data. The calibration runs are summarized in Table 7-1.

Table 7-1: AVT Calibration Model Runs

No.	Load	Reservoir		Foundation	Contacts			Remarks
					Base	Lift Joints	Vertical Construction Joints	
1 – 10	AVT Calibration	Restricted	Added Mass	Mass	Tied	Tied	Tied	Assume 10 Runs

A validated model for Mossyrock Dam should capture the dominant behavioral characteristics (observed during PBT) that control the dam's response to extreme loading conditions including:

- Spectral Behavior
- Energy Dissipation
- Frequency Content
- Interaction Effects of Spillway Piers, Foundation, Thrust Blocks and Reservoir
- Spectral Spreading Effects

An expanded description of these characteristics follows:

Spectral Behavior

- The model must be able to reproduce the observed spectral behavior in the dam, including.
- Split resonant behavior associated with water and spillway interactions.
- Flat spectral response in the upper portion of the dam and spillway section
- Overall spectral density

Energy Dissipation

- The model's transient response should be tuned to produce similar decay characteristics observed during PBT.

Frequency Content

- The frequency band over which the model is valid should be determined by comparing the frequency content in the model's transient response to the content in the PBT responses.

- The CGT force pulse can be used as an input to the model, which can then produce transient responses for evaluating both energy dissipation and frequency content.

Spillway Pier Coupling Effects

- The model's ability to represent the coupled interactions in the spillway must be checked against measured behavioral effects i.e.
- Tuning the model pier resonances to observed values (note reservoir elevation during PBT)
- Ensuring the model's fundamental (dam) resonance is below the fundamental pier resonances, a key to the pier's actual behavior and representation in the model.

Foundation Amplification and Thrust Block Flexibility

- Amplification between the foundation and the upper portion of the dam for the model should be compared to PBT based estimates.
- The dam's left thrust block is more flexibility than the right thrust block and the model should reflect this condition.

Reservoir Water Effects

- Evidence of water compressibility effects at the dam must be evaluated. There is value in using both lumped added mass and compressible water representations for the reservoir.

Spectral Spreading Effects

- A key and favorable characteristic of Mossyrock Dam observed in the recorded responses is its ability to spread its spectral responses at higher load levels.
- The model's ability to demonstrate this characteristic is key to understanding how the dam's linear state changes as loading increases and provides insights into the dam's ability to withstand extreme loading events.
- Demonstrating a model's spectral spreading effects requires a series of analyses in which the intensity of the interactions between the upper portion of the dam and its spillway piers are adjusted from low to high intensity, thereby illustrating the model's spectral spreading characteristics.

Model validation based solely on resonant frequencies is not adequate for the evaluation of Mossyrock Dam.

- Because resonant behavior is controlled by interface conditions between components and mass participation which can change as loading intensity increases.
- These changes will result in different spectral or linear states, and as a result, it is not important to focus on one condition.

Specific numerical values or tolerances for matching model to observed behavior must. be determined by the analyst in collaboration with Tacoma Power.

7.2 Preliminary Analysis

The preliminary analysis phase will involve three subphases, described below:

1. Analysis for the assumed N, PMF, and EQ load combinations, to serve as a benchmark for the performance of the dam. These runs are summarized in Table 7-2.

2. Seismic progressive loading analysis, in which the model will be analyzed for a series of progressively more intense earthquake return periods. Failure of the components will be checked, and where a component failure is identified, additional stabilizing measure will be added in the model. The analysis will then progress to the next earthquake return period with the stabilization measure included. The analysis runs are summarized in Table 7-3

3. Targeted breach analysis, summarized in Table 7-4. These analyses will be performed for two identified failure modes which have the potential to initiate progressive failure:

   i) Spillway pier/header beam failure: It is possible that failure of the spillway piers could initiate failure in the header beams and subsequently cause a “smiley” failure in the arch. To analyze this possibility, the critical earthquake return period that causes pier failure, determined in the previous phase, will be identified. CDPM2 damage plasticity model, i.e., Grassl et al. (2011,2013) is a non-linear concrete material model capable of modelling concrete cracking and reinforcement yielding & failure. CDPM2 model is an updated version of Lee and Fenves (1998). CDPM2 model is implemented in LS-DYNA as *MAT_273. The CDPM2 model will be used to determine an approximate failure plane in the pier when subjected to the identified earthquake. If the non-linear analysis indicates that the pier failure plane could cause the failure to progress to the header beams, the dam will be analyzed with the header beams removed to determine the extent of the arch failure and the final breach size. Note, the decision for the removal of the header beams is because if the spillway piers fail at the ogee-spillway pier joint or if the header beams themselves fail, the header beams will most likely detach from the structure. If the critical return period is below the 5,000 or 10,000 YRP events, an analysis with the header beams removed will be performed for those events to determine the final breach size.

   ii) Thrust block sliding: It is possible that sliding of the thrust block will cause a loss in arch action and subsequent failure of the arch. To analyze this possibility, the critical earthquake return period that causes the thrust blocks to slide, determined in the previous phase, will be identified. The dam will then be analyzed with the thrust block allowed to continue to slide, to determine the extent of damage in the arch and the final breach size. If the critical return period is below the 5,000 or 10,000 YRP events, an analysis will be performed for those events to determine the final breach size.

Table 7-2: Initial Analysis Model Runs

<table>
<tr><th rowspan="2">No.</th><th rowspan="2" colspan="2">Load</th><th rowspan="2" colspan="2">Reservoir</th><th rowspan="2">Foundation</th><th colspan="3">Contacts</th><th rowspan="2">Remarks</th></tr>
<tr><th>Base</th><th>Lift Joints</th><th>Vertical Construction Joints</th></tr>
<tr><td>11</td><td rowspan="2" colspan="2">N</td><td>Restricted</td><td rowspan="3">Pressures</td><td rowspan="7">Massed</td><td rowspan="7">Active</td><td rowspan="3">Tied</td><td rowspan="7">Active</td><td rowspan="3">-</td></tr>
<tr><td>12</td><td>Normal</td></tr>
<tr><td>13</td><td colspan="2">PMF</td><td>Flood</td></tr>
<tr><td>14</td><td rowspan="4">EQ</td><td rowspan="2">5,000</td><td>Restricted</td><td rowspan="4">Added Mass</td><td rowspan="4">Tied or Active</td><td rowspan="4">Use one seed time history for scaling</td></tr>
<tr><td>15</td><td>Normal</td></tr>
<tr><td>16</td><td rowspan="2">10,000</td><td>Restricted</td></tr>
<tr><td>17</td><td>Normal</td></tr>
</table>

Table 7-3: Seismic Progressive Loading Analysis Model Runs

<table>
<tr><th rowspan="2">No.</th><th rowspan="2" colspan="2">Load</th><th rowspan="2" colspan="2">Reservoir</th><th rowspan="2">Foundation</th><th colspan="3">Contacts</th><th rowspan="2">Remarks</th></tr>
<tr><th>Base</th><th>Lift Joints</th><th>Vertical Construction Joints</th></tr>
<tr><td>18</td><td rowspan="4">EQ</td><td>2,500</td><td rowspan="4">Normal</td><td rowspan="4">Added Mass</td><td rowspan="4">Massed</td><td rowspan="4">Active</td><td rowspan="4">Tied or Active</td><td rowspan="4">Active</td><td rowspan="4">Use one seed time history for scaling</td></tr>
<tr><td>19</td><td>3,750</td></tr>
<tr><td>20</td><td>7,500</td></tr>
<tr><td>21</td><td>15,000</td></tr>
</table>

Table 7-4: Targeted Breach Size Analysis Model Runs

No.	Load		Description
22	EQ	Critical Pier Overstressing Return Period	Non-linear analysis to determine the critical failure plane in the piers
23	EQ	Critical Pier Overstressing Return Period	If piers could initiate header beam failure, analysis with the header beams removed to determine extent of arch failure and final breach size.
24	EQ	5,000	Analysis with header beams removed. Dependent on critical pier failure return period.
25	EQ	10,000	Analysis with header beams removed. Dependent on critical pier failure return period.
26	EQ	Critical Thrust Block Failure Return Period	Analysis with the thrust block allowed to slide indefinitely, to determine extent of arch failure and final breach size.
27	EQ	5,000	Analysis with the thrust block allowed to slide indefinitely. Dependent on critical Thrust block failure return period.
28	EQ	10,000	Analysis with the thrust block allowed to slide indefinitely. Dependent on critical Thrust block failure return period.

7.3 Sensitivity Analysis

Sensitivity analyses will be conducted after review of the preliminary analysis results. The purpose of this phase is to perform more detailed analyses where it is felt it is warranted by the results of the preliminary analysis. We will allocate a total of 5 additional runs for sensitivity analyses. Sensitivity analysis items may include:

- Using tied nodes at the vertical contraction joints to find the forces acting on the shear keys.
- Placing additional contact elements at the spillway piers to account for cracked failure planes.
- Placing additional contact elements at additional lift lines.
- More detailed analysis of hydrodynamic interaction using fluid acoustic element.
- Analysis of a range of values of key input parameters.

Additional items may be checked as identified during the review of the preliminary analysis. Note that it is not anticipated that sensitivity analyses will require the creation of additional sub models.

7.4 Final Analysis

The final analysis will be performed for the analysis of record purposes and they will act as a baseline for future quantitative risk analysis. The analysis runs are summarized in Table 7-5.

Table 7-5: Final Analysis Model Runs

No.	Load		Reservoir		Foundation	Contacts			Remarks
						Base	Lift Joints	Vertical Construction Joints	
29	N		Normal	Pressures	Mass	Active	Tied	Active	Include the updates from field investigation and laboratory testing program
30	PMF		Flood	Pressures	Mass	Active	Tied	Active	
31	EQ	5,000	Normal	Added Mass	Mass	Active	Tied or Active	Active	Use 7 time histories for each return period
32	EQ	10,000	Normal		Mass	Active	Tied or Active	Active	

7.5 Analysis Files

The analysis input files for the performed model runs will be supplied to Tacoma Power for review.

8. Model Calibration

The 3D finite element model will be calibrated to match the results from ambient vibration testing. The elastic modulus of concrete and rock will be adjusted to match the natural frequency results obtained from AVT/PBT.

9. Quality Control and Assurance Plan

The verification and validation of the complex dam-foundation-reservoir model is key to the success of this project. The individual components (dam, foundation, and reservoir) and the complete assembled model will be checked independently to verify the input parameters and to fully understand the limitations of the analysis. Sensitivity analyses will be performed to further enhance the verification and validation of the dam-foundation-reservoir model. The following lists important items that will be checked to understand the stress and stability of Mossyrock Dam:

1. Dam:

    - Proper finite element mesh size. A practical review of the previous Mossyrock FE model the ensure that a reasonable of mesh size for dam is obtained. Recommendations regarding mesh size given in USBR (2005) will be also be considered.
    - Proper application of loads i.e., self-weight, hydrostatic, uplift, hydrodynamic etc.
    - Proper spillway gates, piers, and header beam modelling.
    - Post processing of the analysis results to estimate various factor of safety values.
    - Modelling of the interaction between dam, reservoir, and foundation.
    - Nonlinear behavior of sliding, opening, and closing of contact elements at various joints.
    - Damping in the dam-reservoir- foundation model.

2. Foundation

    - Proper modelling of the foundation and surrounding topography near the dam site.
    - Seismic input in 2D and 3D model.
    - Location of EQ control point.
    - Spatial variation of input earthquake ground motion at the dam-foundation interface.
    - Modelling of semi-infinite foundation domain.

3. Reservoir

    - Proper modelling of dam-reservoir interaction and application of hydrostatic and hydrodynamic loads.
    - Static and dynamic loads applied as a result of silt in the reservoir.
    - Modelling of semi-infinite reservoir domain (for fluid/acoustic element cases).

4. Seismic Earthquake Input

    - The effective earthquake input in the model will be verified and validated. The location of EQ control point will be selected after a review of the dam site topography and foundation properties.

5. Damping

    - A benchmark analysis will be completed for estimation of damping using the half bandwidth method with a sine sweep analysis.

6. Spillway Piers

    - Evaluation methodology for spillway piers

7. QA procedure for FE model

    - The FE model development including input files, loads, boundary conditions, etc., must be documented in a transparent QA process.

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GENERAL PROJECT DATA

Structure: Mossyrock Dam

Type: Double Curvature Arch

Height Above Tailrace: 360 feet

Height Above Foundation: 606 feet

Crest Length:

Arch:	1,264.54 feet
Left Earth Embankment:	210 feet
Left Gravity	75 feet
Left Thrust Block	127.35 feet
Right Thrust Block	91.25 feet
Right Gravity	105.2 feet

Top of Dam Elevation: 785 feet

Parapet Wall Elevation: 788 feet

Top Width: 27 feet

Base Width: 199 feet

Axis Alignment: Circular

Central Angle: 79.75 degrees

Radius of Axis: 908.5 feet

Foundation Gallery: Yes

Grout Curtain: Yes

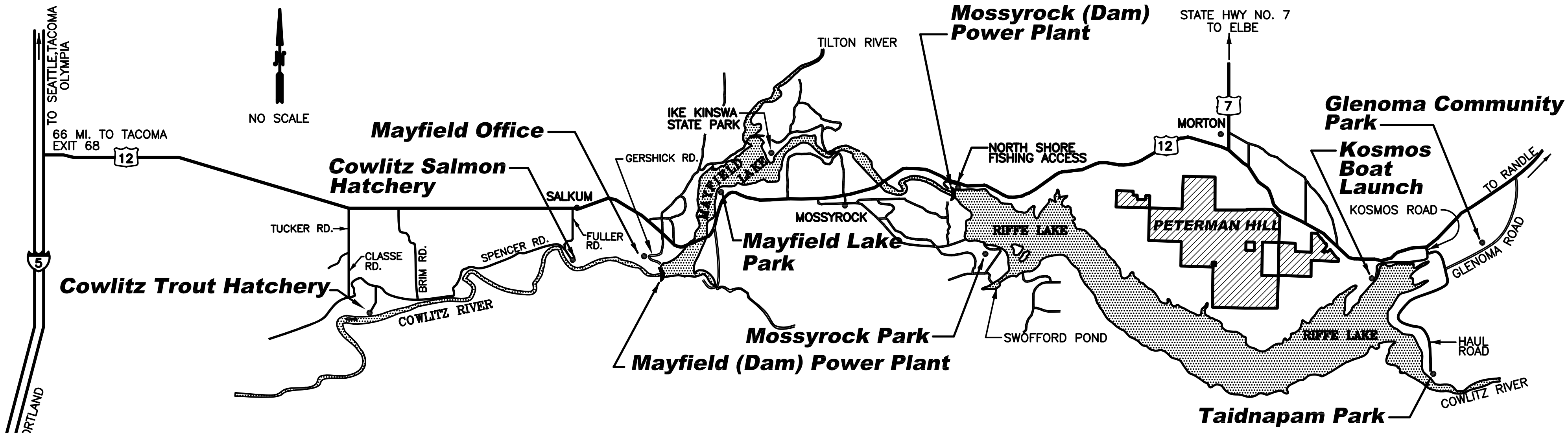
Drains:

- Foundation: Yes
- Internal: No

Solid Parapet: Yes

- Height: 3.0 feet

Center Arch Spillway: The spillway is located in the center of the arch and is regulated by four (4) radial gates (42.5 feet wide by 50 feet high). The spillway was designed as an integral part of the arch dam forming a crest type, gated overflow spillway structure.



COWLITZ PROJECT AREA MAP

Cowlitz River Project

TACOMA POWER

DIRECTIONS-

COWLITZ TROUT HATCHERY
TO HATCHERY.FROM TACOMA, TAKE I-5 SOUTH, DRIVE 66 MI. TO EXIT 68, "MORTON". TURN LEFT ONTO HWY. 12 EAST, DRIVE 7 MI., TURN RIGHT ONTO TUCKER RD. (GROCERY STORE WILL BE ON THE LEFT). FOLLOW TUCKER RD. 1.5 MI., VEER LEFT ONTO CLASSE RD. AT "T" TURN LEFT ONTO SPENCER RD. FOLLOW SPENCER RD. 2 MI. AND TURN RIGHT ONTO COWLITZ GAME FISH HATCHERY DRIVEWAY. FOLLOW DRIVEWAY .75 MI.

COWLITZ SALMON HATCHERY
FROM TACOMA, TAKE I-5 SOUTH, DRIVE 66 MI. TO EXIT 68, "MORTON". TURN LEFT ONTO HWY. 12 EAST, DRIVE 12 MI., TURN RIGHT ONTO FULLER RD. FOLLOW FULLER RD. TO "T". TURN LEFT AND TRAVEL 1.1 MI. CONTINUE DOWNHILL TO SALMON HATCHERY.

GLENOMA COMMUNITY PARK
FROM TACOMA, TAKE I-5 SOUTH, DRIVE 66 MI. TO EXIT 68, "MORTON". TURN LEFT ONTO HWY. 12 EAST, DRIVE APPROXIMATELY 40 MI. AND TAKE A RIGHT TURN ON KOSMOS ROAD AND FIRST LEFT ONTO IMPROVED DIRT ROAD (CHAMPION HAUL ROAD). FOLLOW CHAMPION HAUL ROAD APPROXIMATELY 3/4 MILE TO FIRST LEFT, GLENOMA ROAD. TRAVEL APPROXIMATELY 1/2 MILE TO PARK.

KOSMOS BOAT LAUNCH
FROM TACOMA, TAKE I-5 SOUTH, DRIVE 66 MI. TO EXIT 68, "MORTON". TURN LEFT ONTO HWY. 12 EAST, DRIVE APPROXIMATELY 40 MI. AND TAKE A RIGHT TURN ON KOSMOS ROAD AND FOLLOW SIGNS TO THE BOAT LAUNCH.

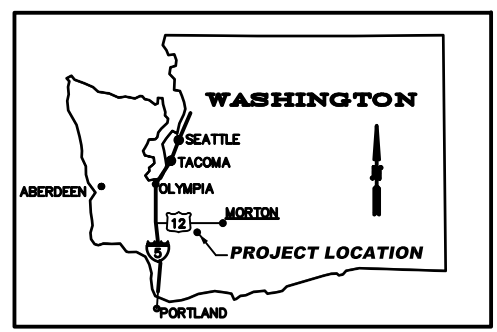
MAYFIELD LAKE PARK
FROM TACOMA, TAKE I-5 SOUTH, DRIVE 66 MI. TO EXIT 68, "MORTON". TURN LEFT ONTO HWY. 12 EAST, DRIVE EAST APPROXIMATELY 19 MI., TURN LEFT ONTO BEACH ROAD (APROX. 1 MILE PAST MAYFIELD LAKE BRIDGE). TRAVEL 1/2 MILE TO PARK.

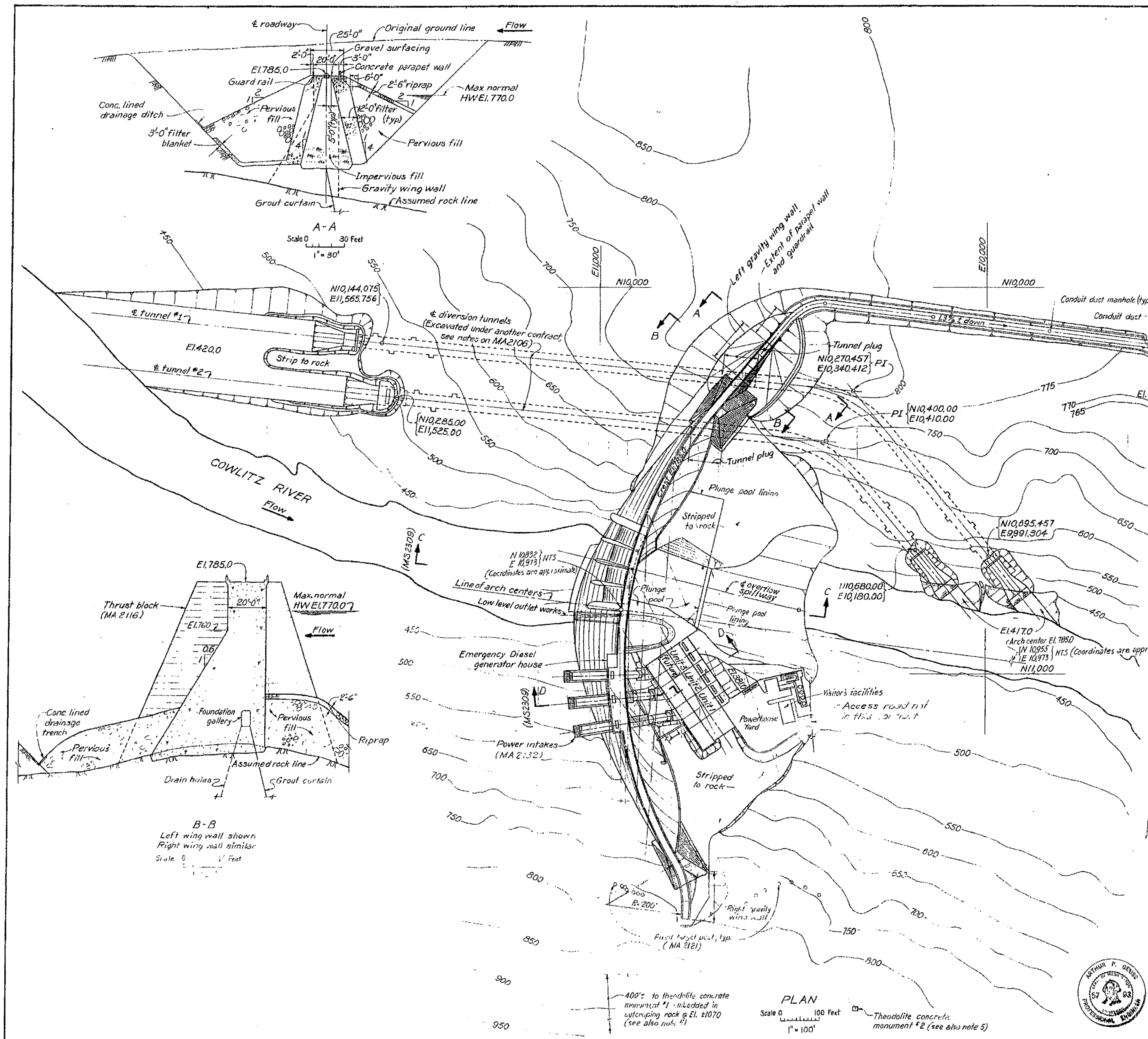
MAYFIELD OFFICE BUILDING, DAM & POWERHOUSE
FROM TACOMA, TAKE I-5 SOUTH, DRIVE 66 MI. TO EXIT 68, "MORTON". TURN LEFT ONTO HWY. 12 EAST, DRIVE 14 MI., TURN RIGHT JUST BEFORE SMALL STORE ONTO GERSHICK RD. FOLLOW GERSHICK RD. TO CYCLONE FENCE/GATE. PASS THROUGH GATE AND FOLLOW ONE-LANE ROAD TO MAYFIELD OFFICE ON THE LEFT. TO REACH THE POWERHOUSE, CONTINUE DOWN HILL TO THE END OF THE ROAD.

MOSSYROCK PARK
MOSSYROCK PARK IS LOCATED ABOUT 90 MILES SOUTH OF TACOMA IN LEWIS COUNTY NEAR THE TOWN OF MOSSYROCK. FROM TACOMA TAKE I-5 SOUTH TO STATE ROUTE 12 (EXIT 68 "MORTON"). TURN LEFT EASTBOUND ON STATE ROUTE 12 FOR APPROXIMATELY 21 MILES. TURN RIGHT AT LIGHT ON WILLIAMS STREET. CONTINUE ON WILLIAMS STREET TO THE TOWN OF MOSSYROCK. WHEN YOU REACH THE "T", TURN LEFT ONTO EAST STATE STREET AND GO FOR 3 MILES TO MOSSYROCK PARK ENTRANCE.

MOSSYROCK POWERHOUSE
FROM TACOMA, TAKE I-5 SOUTH, DRIVE 66 MI. TO EXIT 68, "MORTON". TURN LEFT ONTO HWY. 12 EAST, DRIVE APPROXIMATELY 21 MI. TO WILLIAMS ST. (TRAFFIC LIGHT) AND TURN RIGHT. CONTINUE ON WILLIAMS ST. FOR 0.4 MILE TO STATE STREET. TURN LEFT (EAST) ON EAST STATE ST. FOR 2.9 MILES TO YOUNG ROAD. TURN LEFT (NORTH) ON YOUNG ROAD AND FOLLOW YOUNG ROAD FOR .9 MILE AND TURN RIGHT AT MOSSYROCK DAM VIEW POINT SIGN. GO .5 MILE AND TURN LEFT ON ONION ROCK LANE GO 1.3 MILES TO DAM/POWERHOUSE.

TAIDNAPAM PARK
FROM TACOMA, TAKE I-5 SOUTH, DRIVE 66 MI. TO EXIT 68, "MORTON". TURN LEFT ONTO HWY. 12 EAST, DRIVE APPROXIMATELY 40 MI. AND TAKE A RIGHT TURN ON KOSMOS ROAD AND FIRST LEFT ONTO IMPROVED DIRT ROAD (CHAMPION HAUL ROAD). FOLLOW CHAMPION HAUL ROAD APPROXIMATELY 4 MILES TO TAIDNAPAM PARK ENTRANCE.





REFERENCE DRAWINGS:

Work this drawing with MS 2309
Diversion Tunnels MA2106
Geometry of Arch MA2113
Powerstation-General Arrangement MP2100
Foundation Excavation MA2110
Spillway & Roadway Details MA2123
Yard MP 2126
Switchyard MH 4100
Power Intake & Outlet Works MA 2132

NOTES:

1. All elevations are in feet above mean sea level.
2. The project grid is tied with the Lambert Grid at section corner. 9 | 10 / 16 | 15 — T12N-R3E WM As follows:

LAMBERT	PROJECT
N443,240.00	N10,000.00
E1,514,975.06	E10,000.00

3. Rock lines in sections indicated refer to "Volcanic Bedrock" only.
4. Earthwork symbols: excavation : fill :
5. Theodolite setting devices for theodolite monuments will be furnished by others and installed under this contract.
6. Revised shape of arch dam is not shown on this drawing; for revised shape see drawings MA 2113 & 2114, latest revision.

NO.	REVISION	ISSUE DATE	BY	APP'D	DATE
2	Added coordinates for line of arch centers, revised plunge pool excav., added note 6, visitors facilities	11/4/64	TEG	APG	11/11/64
1	Added plunge pool lining	8/13/64	TEG	APG	

CITY OF TACOMA
DEPARTMENT OF PUBLIC UTILITIES
MAJOR PROJECTS DIVISION

MOSSYROCK PROJECT
GENERAL

GENERAL PLAN & SECTIONS

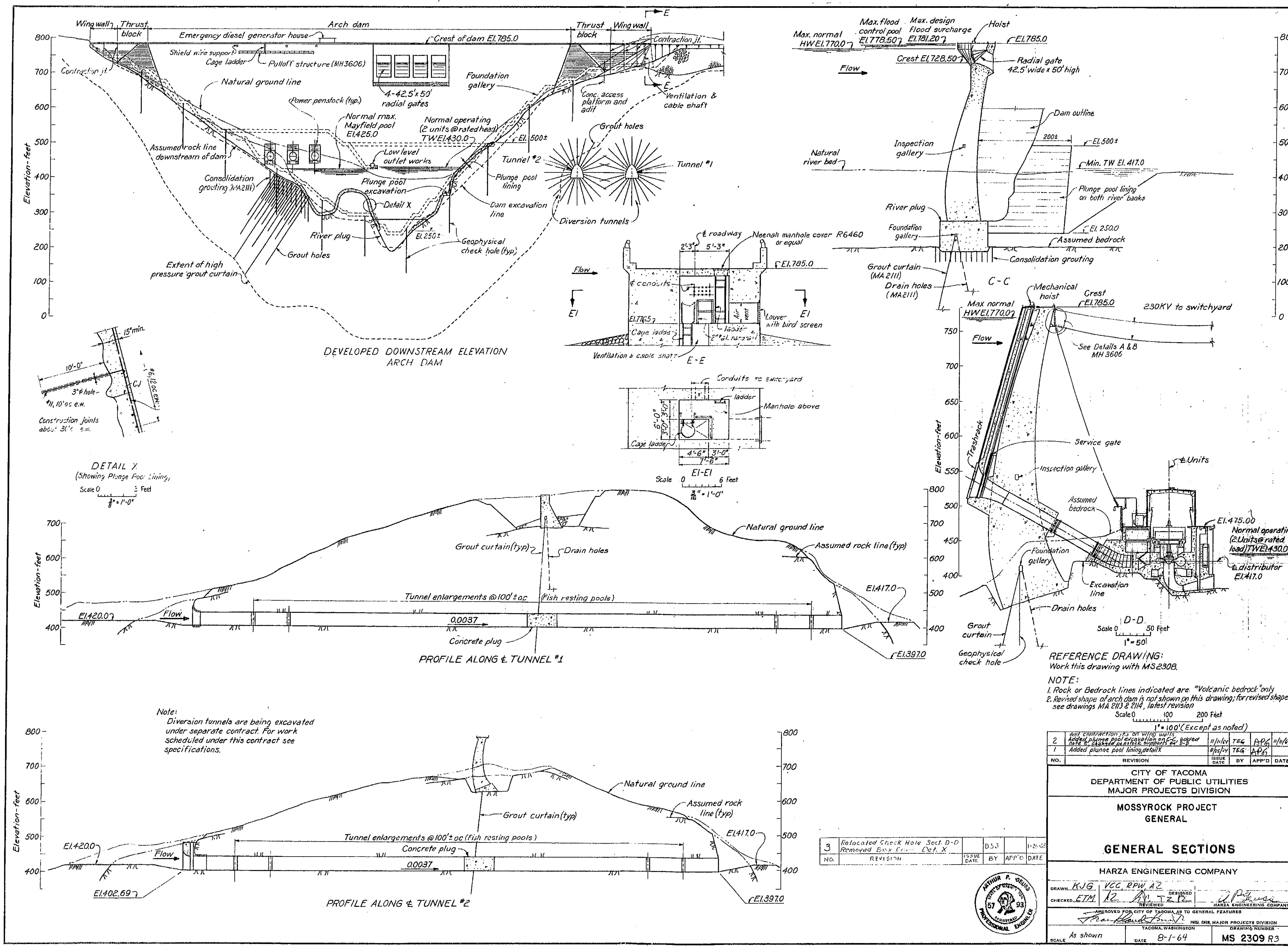
HARZA ENGINEERING COMPANY

DRAWN KJG VCC RPW — CHECKED ETM — DESIGNED — REVIEWED — HARZA ENGINEERING COMPANY

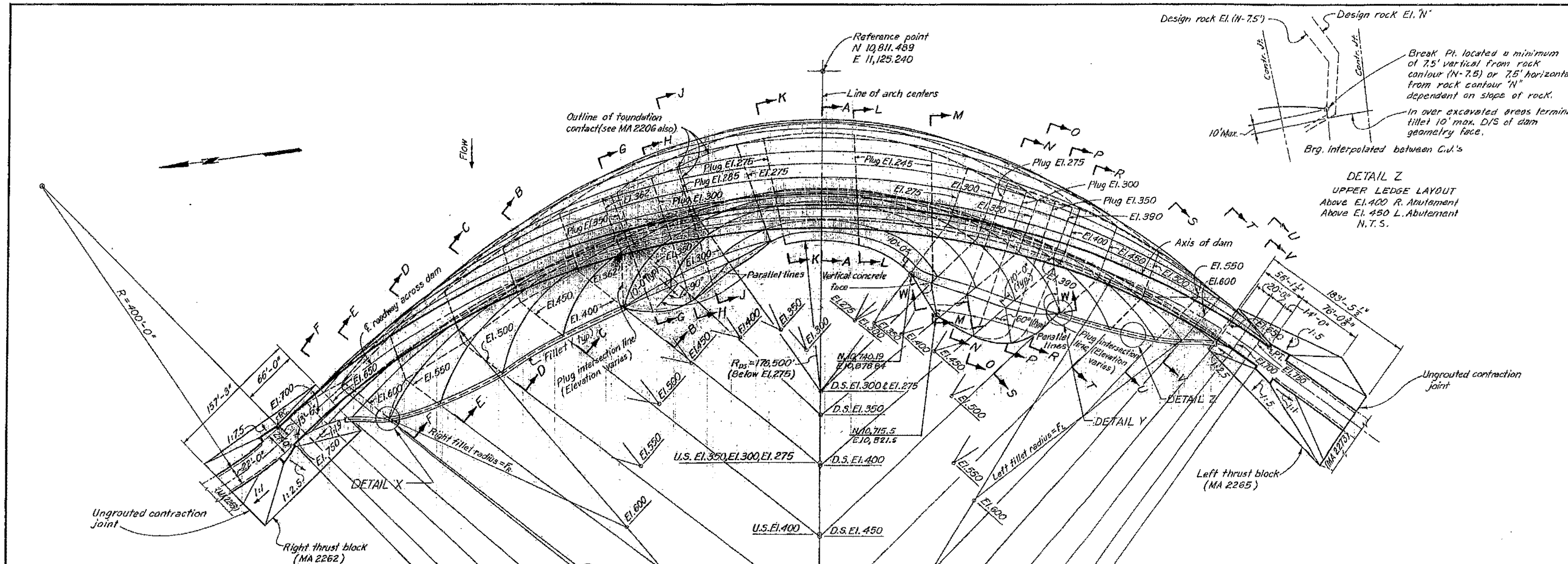
APPROVED FOR CITY OF TACOMA AS TO GENERAL FEATURES — PROJ. ENGR. MAJOR PROJECTS DIVISION

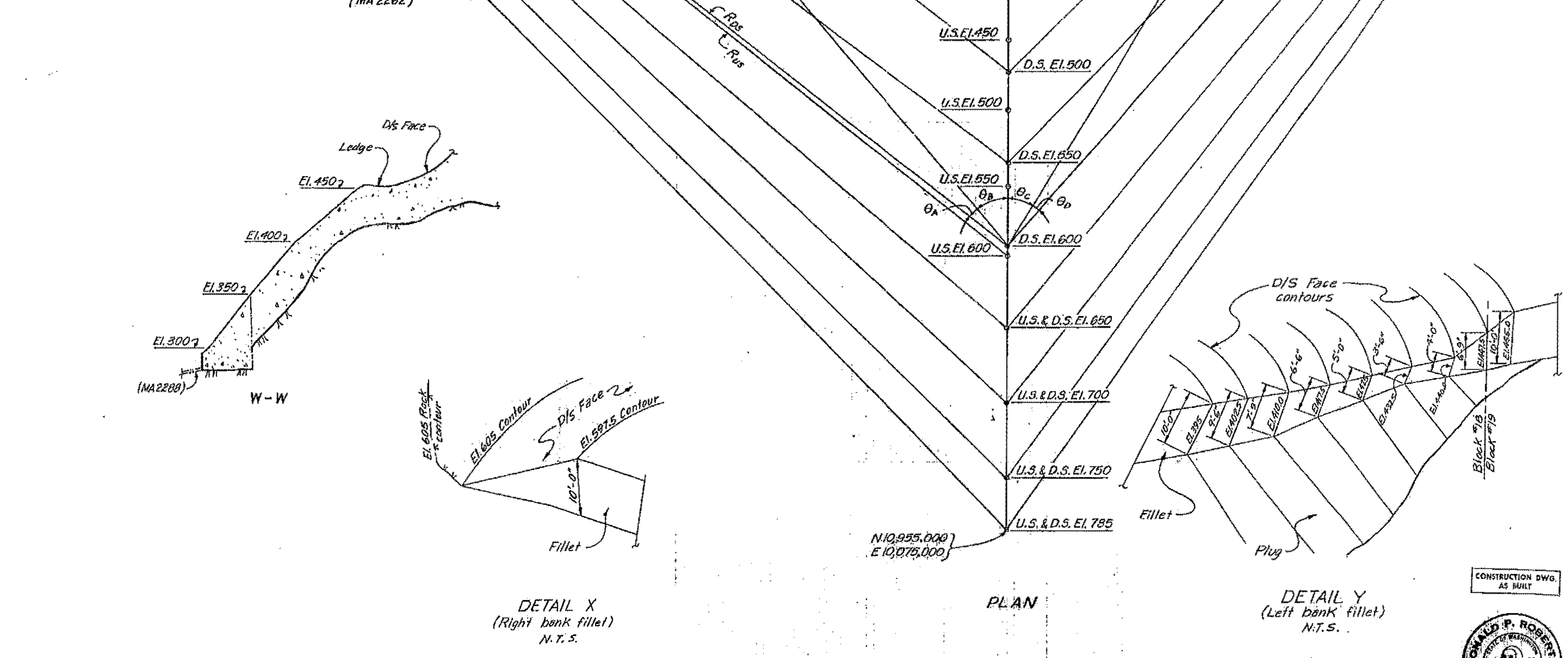
TACOMA, WASHINGTON

SCALE As shown | DATE 8-1-64 | DRAWING NUMBER MS 2308 R2



DEVELOPED DOWNSTREAM ELEVATION ARCH DAM
Wing wall
Thrust block
Arch dam
Emergency diesel generator house
Crest of dam El.785.0
Shield wire support
Cage ladder
Pulloff structure (MH3606)
Contraction jt.
Natural ground line
4-42.5'x50' radial gates
Foundation gallery
Power penstock (typ.)
Normal max. Mayfield pool El.425.0
Normal operating (2 units @ rated head) TW El.430.0
El.500±
Conc. access platform and adit
Ventilation & cable shaft
Grout holes
Tunnel #2
Tunnel #1
Assumed rock line downstream of dam
Low level outlet works
Consolidation grouting (MA2111)
Plunge pool excavation
Plunge pool lining
Detail X
Dam excavation line
Diversion tunnels
River plug
El.250±
Geophysical check hole (typ.)
Grout holes
Extent of high pressure grout curtain
Elevation-feet
DETAIL X (Showing Plunge Pool Lining)
Construction joints about 30' c. e.w.
E-E
Ventilation & cable shaft
Neenah manhole cover R6460 or equal
El.785.0
Louver with bird screen
El-El
Conduits to switchyard
Manhole above
Cage ladder
Scale 0 6 Feet
3/16" = 1'-0"
C-C
Max. normal HW El.770.0
Max. flood control pool El.778.50
Max. design flood surcharge El.781.20
Hoist
El.785.0
Crest El.728.50
Radial gate 42.5' wide x 50' high
Flow
Dam outline
Inspection gallery
El.500±
Natural river bed
Min. TW El.417.0
Plunge pool lining on both river banks
River plug
Foundation gallery
El.250.0
Assumed bedrock
Consolidation grouting
Grout curtain (MA2111)
Drain holes (MA2111)
D-D
Mechanical hoist
Crest El.785.0
230KV to switchyard
See Details A & B MH 3606
Trashrack
Service gate
Inspection gallery
Assumed bedrock
℄ Units
El.475.00
Normal operating (2 Units @ rated load) TW El.430.0
℄ distributor El.417.0
Foundation gallery
Excavation line
Drain holes
Grout curtain
Geophysical check hole
Scale 0 50 Feet
1" = 50'
PROFILE ALONG ℄ TUNNEL #1
Natural ground line
Grout curtain (typ)
Drain holes
Assumed rock line (typ)
Tunnel enlargements @ 100' ± oc (Fish resting pools)
El.420.0
El.417.0
0.0037
Concrete plug
El.397.0
PROFILE ALONG ℄ TUNNEL #2
Note: Diversion tunnels are being excavated under separate contract. For work scheduled under this contract see specifications.
El.402.69
REFERENCE DRAWING: Work this drawing with MS2308.
NOTE:
1. Rock or Bedrock lines indicated are "Volcanic bedrock" only.
2. Revised shape of arch dam is not shown on this drawing; for revised shape see drawings MA 2113 & 2114, latest revision.
Scale 0 100 200 Feet
1" = 100' (Except as noted)
3 Relocated Check Hole Sect. D-D Removed Box Crit. Det. X
2 Added plunge pool excavation on C-C, added contraction jts. on wing walls
1 Added plunge pool lining detail X
NO. REVISION ISSUE DATE BY APP'D DATE
CITY OF TACOMA
DEPARTMENT OF PUBLIC UTILITIES
MAJOR PROJECTS DIVISION
MOSSYROCK PROJECT
GENERAL
GENERAL SECTIONS
HARZA ENGINEERING COMPANY
DRAWN KJG VCC RPW AZ
CHECKED ETM
APPROVED FOR CITY OF TACOMA AS TO GENERAL FEATURES
TACOMA, WASHINGTON
SCALE As shown
DATE 8-1-64
DRAWING NUMBER MS 2309 R3





REFERENCE DRAWINGS:

Work this drawing with : MA 2231, MA 2232, MA 2232A
General plan : MS 2310
Arch dam excavation : MA 2206

NOTES:

1. Excavation, apurtenant structures, roadway and accesses not shown.
2. Concrete lines in river plug below El. 245 are not shown and will follow sound rock lines as determined by the Engineer.
3. For concrete contact with rock, see contour drawing SK280 sheet 1 thru 6

Scale 0 50 100 Feet
1" = 50'

NO.	REVISION	ISSUE DATE	BY	APP'D	DATE
As	Details X, Y, & Z added, revised Sec. W-W		WJW		3/20/69
3	River plug revised & section W-W added	1-28-66			1-28-66
2	Left arch abutment plug revised	1.17.66			1.17.66
1	Thrust blocks revised	9.16.65			9.16.65

CONSTRUCTION DWG. AS BUILT

CITY OF TACOMA
DEPARTMENT OF PUBLIC UTILITIES
MAJOR PROJECTS DIVISION

MOSSYROCK PROJECT
ARCH DAM

GEOMETRY OF ARCH
SHEET 1

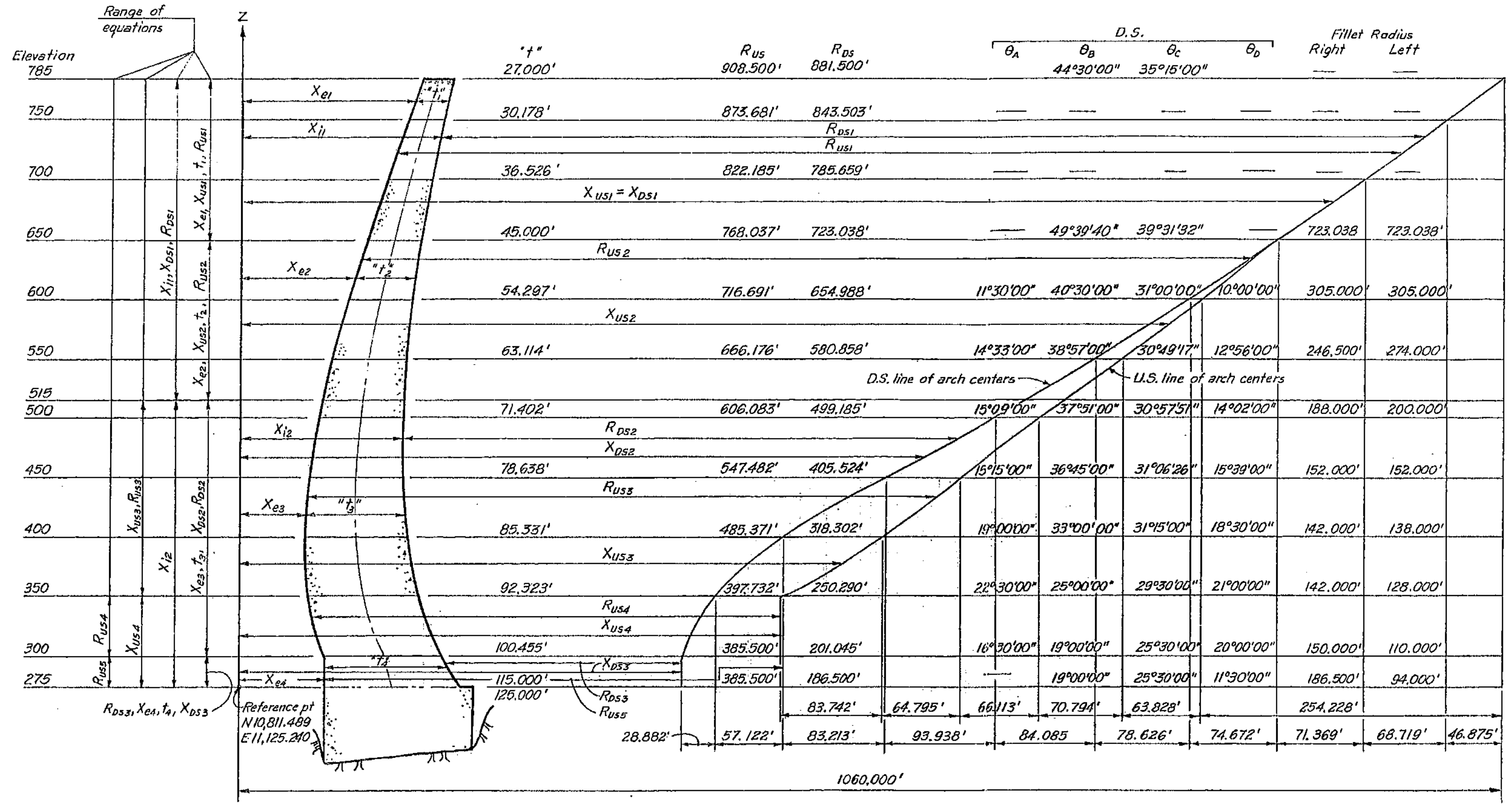
HARZA ENGINEERING COMPANY

DRAWN S.P.
CHECKED
DESIGNED
REVIEWED
HARZA ENGINEERING COMPANY

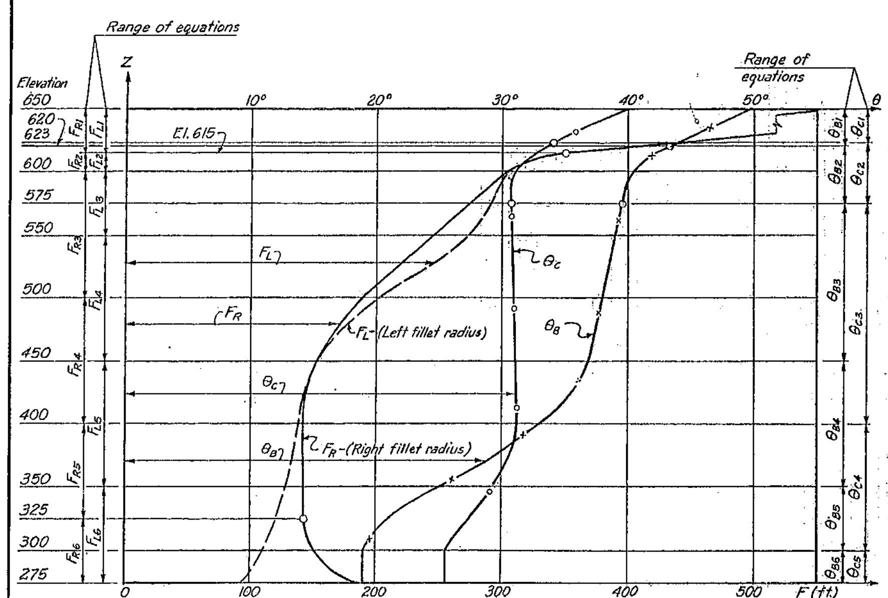
APPROVED FOR CITY OF TACOMA AS TO GENERAL FEATURES
MANAGER, MAJOR PROJECTS DIVISION

SCALE : As shown
TACOMA, WASHINGTON
DATE APRIL, 1965
DRAWING NUMBER MA2230 R3/AS

DRAWER NO.



A-A
BASIC SECTION ON LINE OF ARCH CENTERS



FILLET RADIUS AND CENTER ANGLE (θ_B, θ_C) CURVES

TABLE OF EQUATIONS: $X_e, X_i, t, X_{US}, X_{DS}, R_{US}, R_{DS}$

Variable	$t, R \text{ or } X = A + BZ + CZ^2 + DZ^3 + EZ^4$				
	A	B	C	D	E
X_{e1}	-24.1664	0.344444	—	—	—
X_{e2}	49.1356	-4.6500×10^{-2}	5.21259×10^{-4}	—	—
X_{e3}	80.7890	-0.444921	2.192813×10^{-3}	-2.33753×10^{-6}	—
X_{e4}	71.0000	—	—	—	—
X_{i1}	152.1605	-0.1652263	4.25240×10^{-4}	—	—
X_{i2}	186.0000	-0.646481	2.673225×10^{-3}	-3.459362×10^{-6}	—
t_1	176.3269	-0.509670	4.25240×10^{-4}	—	—
t_2	103.0249	-0.118726	-9.6019×10^{-5}	—	—
t_3	105.2110	-0.201560	4.80412×10^{-4}	-1.121832×10^{-6}	—
t_4	115.0000	-0.646481	2.673225×10^{-3}	-3.459362×10^{-6}	—
X_{US1}	187.5013	2.320123	-1.637860×10^{-3}	8.687700×10^{-7}	—
X_{US2}	-74.1972	5.802912	$-1.46298305 \times 10^{-2}$	1.5710105×10^{-5}	—
X_{US3}	225.6806	4.430068	$-2.2763405 \times 10^{-2}$	6.822200×10^{-5}	-6.866854×10^{-8}
X_{US4}	456.5000	—	—	—	—
X_{DS1}	187.5013	2.320123	-1.637860×10^{-3}	8.687700×10^{-7}	—
X_{DS2}	365.7073	0.2139210	1.557205×10^{-3}	3.237704×10^{-5}	-8.81087×10^{-8}
X_{DS3}	372.5000	—	—	—	—
R_{US1}	211.6677	1.975679	-1.637860×10^{-3}	8.687700×10^{-7}	—
R_{US2}	-123.3327	5.8494122	$-1.51510895 \times 10^{-2}$	1.5710105×10^{-5}	—
R_{US3}	144.8916	4.874989	$-2.4956218 \times 10^{-2}$	7.055953×10^{-5}	-6.866854×10^{-8}
R_{US4}	375.7110	0.444921	-2.192813×10^{-3}	2.33753×10^{-6}	—
R_{US5}	385.500	—	—	—	—
R_{DS1}	35.3408	2.485349	-2.063100×10^{-3}	8.687700×10^{-7}	—
R_{DS2}	179.7073	0.860402	-1.116020×10^{-3}	3.5836402×10^{-5}	-8.81087×10^{-8}
R_{DS3}	186.5000	0.646481	-2.673225×10^{-3}	3.459362×10^{-6}	—

REFERENCE DRAWINGS:
Work this drawing with: MA 2230, MA 2232

TABLE OF EQUATIONS: F_R, F_L, θ_B & θ_C

Variable	$F \text{ or } \theta = A + BZ + CZ^2 + DZ^3 + EZ^4$				
	A	B	C	D	E
F_{R1}	-3,273.7934	10.658216	—	—	—
F_{R2}	-917,437.0322	8,382.496899	-25.522150418	$2.590318224 \times 10^{-2}$	—
F_{R3}	-75.2500	1.170000	—	—	—
F_{R4}	43.7188	2.036250	$-1.4750000 \times 10^{-2}$	3.800000×10^{-5}	—
F_{R5}	142.0000	—	—	—	—
F_{R6}	186.5000	-2.030000	2.28000×10^{-2}	—	—
F_{L1}	-3273.7934	10.658216	—	—	—
F_{L2}	-917,437.0322	8382.496899	-25.522150418	$2.590318224 \times 10^{-2}$	—
F_{L3}	-12,623.5000	128.245000	-0.425600000	4.7200000×10^{-4}	—
F_{L4}	1,249.90625	-15.758750	7.135000×10^{-2}	-9.800000×10^{-5}	—
F_{L5}	156.59375	-0.936250	9.05000×10^{-3}	-2.200000×10^{-5}	—
F_{L6}	94.0000	0.671667	-4.44444×10^{-4}	-3.28889×10^{-5}	—
θ_{C1}	-37.21792	0.20464918	—	—	—
θ_{C2}	-6779.94074	82.7219020	-0.374334225	7.4718774×10^{-4}	$-5.54304749 \times 10^{-7}$
θ_{C3}	31.60714	-2.85714×10^{-3}	—	—	—
θ_{C4}	23.37611	8.08483×10^{-2}	2.41070×10^{-4}	-3.07142×10^{-6}	—
θ_{C5}	25.50000	—	—	—	—
θ_{B1}	-30.47778	0.2137037	—	—	—
θ_{B2}	8075.92205	-103.9974077	0.5049031682	$-1.090266353 \times 10^{-3}$	$+8.83790946 \times 10^{-7}$
θ_{B3}	32.90000	2.20000×10^{-2}	—	—	—
θ_{B4}	8.47656	0.2368125	-6.25000×10^{-5}	-2.100000×10^{-6}	—
θ_{B5}	18.70000	-2.40000×10^{-2}	1.440000×10^{-3}	—	—
θ_{B6}	19.00000	—	—	—	—

RELATIONS BETWEEN VARIABLES

$t_1 = X_{i1} - X_{e1}$
$t_2 = X_{i1} - X_{e2}$
$t_3 = X_{i2} - X_{e3}$
$t_4 = X_{i2} - X_{e4}$
$R_{DS1} = X_{DS1} - X_{i1}$
$R_{DS2} = X_{DS2} - X_{i2}$
$R_{DS3} = X_{DS3} - X_{i2}$
$R_{US1} = X_{US1} - X_{e1}$
$R_{US2} = X_{US2} - X_{e2}$
$R_{US3} = X_{US3} - X_{e3}$
$R_{US4} = X_{US4} - X_{e3}$
$R_{US5} = X_{US4} - X_{e4}$
Z = Elev. - 275.

CONSTRUCTION DWG. AS BUILT

DONALD P. ROBERTS — STATE OF WASHINGTON — 6772 — REGISTERED PROFESSIONAL ENGINEER

1" = 50'
Scale 0 50 100 Feet

NO.	REVISION	ISSUE DATE	BY	APP'D	DATE
As	No Asbuilt Revisions		WJW		3/21/69
2	Equation θ_{B1} revised	9/16/65	VET		9/16/65
1	Equation θ_{B2} revised	7/29/65	VET		7/29/65

CITY OF TACOMA
DEPARTMENT OF PUBLIC UTILITIES
MAJOR PROJECTS DIVISION

MOSSYROCK PROJECT
ARCH DAM

GEOMETRY OF ARCH
SHEET 2

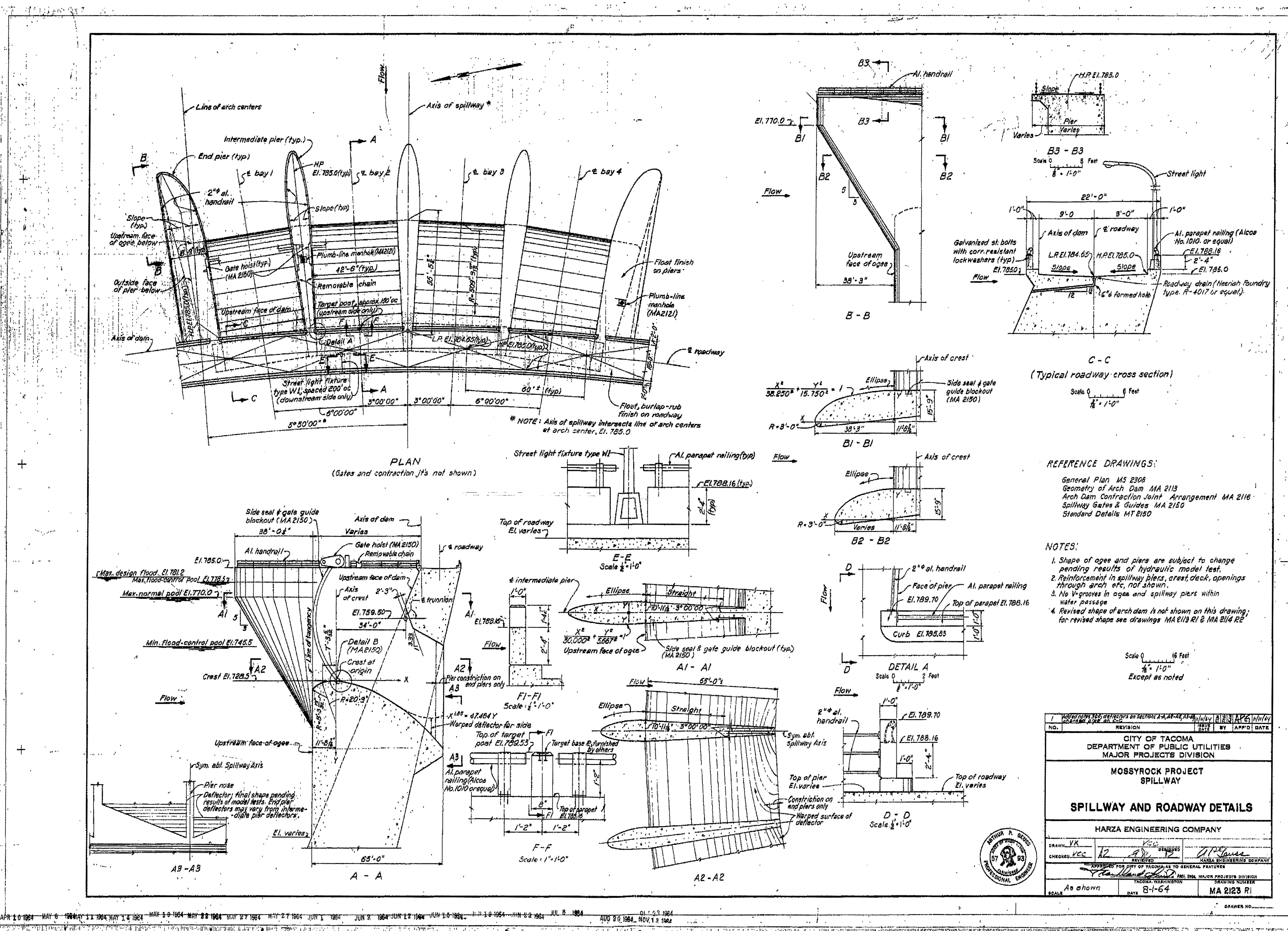
HARZA ENGINEERING COMPANY

DRAWN S.P. — DESIGNED — CHECKED — REVIEWED — HARZA ENGINEERING COMPANY

APPROVED FOR CITY OF TACOMA AS TO GENERAL FEATURES
MANAGER, MAJOR PROJECTS DIVISION

SCALE As shown — TACOMA, WASHINGTON — DATE APRIL, 1965 — DRAWING NUMBER MA2231 R2 /AS

DRAWER NO.


PLAN
(Gates and contraction jt's not shown)
Line of arch centers
Axis of spillway *
Intermediate pier (typ.)
End pier (typ)
℄ bay 1
℄ bay 2
℄ bay 3
℄ bay 4
2"φ al. handrail
Slope (typ)
Upstream face of ogee below
Gate hoist (typ.) (MA 2150)
Plumb-line manhole (MA2121)
Removable chain
Target post, approx. 100' oc (upstream side only)
Upstream face of dam
Outside face of pier below
Axis of dam
Float finish on piers
Float, burlap-rub finish on roadway
℄ roadway
Street light fixture type W1, spaced 200' oc (downstream side only)
* NOTE: Axis of spillway intersects line of arch centers at arch center, El. 785.0
B - B
B1 - B1
B2 - B2
B3 - B3
Upstream face of ogee
C - C
(Typical roadway cross section)
Street light
Axis of dam
℄ roadway
Al. parapet railing (Alcoa No. 1010 or equal)
Galvanized st. bolts with corr. resistant lockwashers (typ)
Roadway drain (Neenah Foundry type R-4017 or equal)
6"φ formed hole
E - E
F1 - F1
F - F
A1 - A1
A2 - A2
A3 - A3
A - A
DETAIL A
D - D
Upstream face of ogee
Side seal & gate guide blockout (typ.) (MA 2150)
Max. design flood El. 781.2
Max. flood-control pool El. 778.5
Max. normal pool El. 770.0
Min. flood-control pool El. 746.5
Crest El. 728.5
Warped deflector for side
Deflector; final shape pending results of model tests. End pier deflectors may vary from intermediate pier deflectors.
Flow
REFERENCE DRAWINGS:
General Plan MS 2308
Geometry of Arch Dam MA 2113
Arch Dam Contraction Joint Arrangement MA 2116
Spillway Gates & Guides MA 2150
Standard Details MT 2150
NOTES:
1. Shape of ogee and piers are subject to change pending results of hydraulic model test.
2. Reinforcement in spillway piers, crest, deck, openings through arch etc. not shown.
3. No V-grooves in ogee and spillway piers within water passage
4. Revised shape of arch dam is not shown on this drawing; for revised shape see drawings MA 2113 R1 & MA 2114 R2
Scale 1/16" = 1'-0" Except as noted
CITY OF TACOMA
DEPARTMENT OF PUBLIC UTILITIES
MAJOR PROJECTS DIVISION
MOSSYROCK PROJECT
SPILLWAY
SPILLWAY AND ROADWAY DETAILS
HARZA ENGINEERING COMPANY
Scale: As shown
Date: 8-1-64
MA 2123 R1

Project Aerial View

Downstream Elevation

Looking to Left Abutment

Upstream of Dam looking at Spillway Piers

Looking to Right Abutment

Upstream View of Spillway Piers

APPENDIX B

Signature Page

Record of Prior Contracts

Supplement Information Request (Optional)

SIGNATURE PAGE

CITY OF TACOMA
Tacoma Power/Generation

All submittals must be in ink or typewritten, executed by a duly authorized officer or representative of the bidding/proposing entity, and received and time stamped as directed in the **Request for Qualifications/Proposals page near the beginning of the specification**. If the bidder/proposer is a subsidiary or doing business on behalf of another entity, so state, and provide the firm name under which business is hereby transacted.

REQUEST FOR QUALIFICATIONS/PROPOSALS SPECIFICATION NO. PG24-0135F
MOSSYROCK DAM ANALYSIS PROJECT

The undersigned bidder/proposer hereby agrees to execute the proposed contract and furnish all materials, labor, tools, equipment and all other facilities and services in accordance with these specifications.

The bidder/proposer agrees, by submitting a bid/proposal under these specifications, that in the event any litigation should arise concerning the submission of bids/proposals or the award of contract under this specification, Request for Bids, Request for Proposals or Request for Qualifications, the venue of such action or litigation shall be in the Superior Court of the State of Washington, in and for the County of Pierce.

Non-Collusion Declaration

The undersigned bidder/proposer hereby certifies under penalty of perjury that this bid/proposal is genuine and not a sham or collusive bid/proposal, or made in the interests or on behalf of any person or entity not herein named; and that said bidder/proposer has not directly or indirectly induced or solicited any contractor or supplier on the above work to put in a sham bid/proposal or any person or entity to refrain from submitting a bid/proposal; and that said bidder/proposer has not, in any manner, sought by collusion to secure to itself an advantage over any other contractor(s) or person(s).

____
Bidder/Proposer's Registered Name

____
Address

____
City, State, Zip

____
Authorized Signatory E-Mail Address

____
E.I.No. / Federal Social Security Number Used on Quarterly Federal Tax Return, U.S. Treasury Dept. Form 941

____
E-Mail Address for Communications

____
Signature of Person Authorized to Enter into Contracts for Bidder/Proposer   Date

____
Printed Name and Title

____
(Area Code) Telephone Number / Fax Number

____
State Business License Number
in WA, also known as UBI (Unified Business Identifier) Number

____
State Contractor's License Number
(See Ch. 18.27, R.C.W.)

Addendum acknowledgement #1_____ #2_____ #3_____ #4_____ #5_____

THIS PAGE MUST BE SIGNED AND RETURNED WITH SUBMITTAL.

RECORD OF PRIOR CONTRACTS

NAME ______________________________ **ADDRESS**____

Type of Work ________________________________ **Specification No.** __________________________

Beginning Date	Completion Date	Contract With	Contact Person Phone #	Amount of Contract

Remarks: ____

SUPPLEMENTAL INFORMATION REQUEST (OPTIONAL)

(*Available with Signed NDA*)

NOTE: Additional drawings, photos, and reports associated with the Mossyrock Development are available to qualified consultants upon written request (using the NDA form provided). Please contact Mr. Paul Lennemann at plennemann@cityoftacoma.org (or) Mr. Matthew Wilson at mwilson@cityoftacoma.org.

TACOMA POWER

3628 South 35th Street
Tacoma, Washington 98409-3192

TACOMA PUBLIC UTILITIES

NON-DISCLOSURE AGREEMENT

This Non-Disclosure Agreement ("NDA") is entered into on the date shown on the signature page between Tacoma Power ("TP"), and (___________), ("Contractor"), sometimes collectively referred to as the "Parties."

RECITALS

TP has identified and designated certain information as confidential. For purposes of this Agreement, "Confidential Information" includes:

- TP customer information protected under RCW 19.29A, Consumers of Electricity;
- TP employee information;
- TP vendor information;
- All technical and business information or material that has or could have commercial value or other interest in the business or prospective business of TP;
- All information and material provided by TP which is not an open public record subject to disclosure under RCW 42.56, Public Records Act;
- All information of which unauthorized disclosure could be detrimental to the interests of TP or its customers, whether or not such information is identified as Confidential Information; and
- Any information identified and designated by TP as Security Sensitive Information (SSI), Critical Energy Infrastructure Information (CEII), and/or Bulk Electric System Cyber System Information (BCSI) in accordance with the State of Washington, Federal Energy Regulatory Commission (FERC) and/or North American Reliability Corporation (NERC), which have established regulations for the protection of sensitive plans, drawings, and records defined as SSI, CEII, and/or BCSI. SSI, CEII, and BCSI are further defined in Exhibit "A".

Because of the sensitive nature of such information that may be provided to the Contractor, Contractor must execute and deliver this NDA to TP prior to receiving such Confidential Information from TP.

NOW, THEREFORE, the Parties agree as follows:

1. **Incorporation by Reference.** The recitals set forth above are incorporated herein as if fully set forth.

2. **Confidential Information Disclosure.** All information and drawings that are disclosed by TP to the Contractor, which are designated as confidential, SSI, CEII, and/or BCSI, shall be protected hereunder as Confidential Information.

3. **Non-Disclosure.** Subject to the provisions of Section 4 and unless the parties agree otherwise, this non-disclosure obligation shall survive the termination of this NDA. Contractor shall not disclose or disseminate Confidential Information and shall:

A. Restrict disclosure of Confidential Information solely to its agents and employees with appropriate TP authorization and not disclose such Confidential Information to any others; and

B. Advise and require all of its officers, agents, employees, representatives, prospective and successful subcontractors, consultants and employees thereof with access to the Confidential Information to execute an NDA in this same form with TP prior to allowing them access to the Confidential Information; and

C. In the event third parties attempt to obtain the Confidential Information by legal process, the Contractor agrees that it will not release or disclose any Confidential Information until TP has received notice of the legal process and has been given reasonable opportunity to contest such release of information and/or to assert the confidentiality privilege.

4. **Ownership and Return of Confidential Information.** All Confidential Information shall remain the property of TP. Contractor is responsible for safeguarding and returning all Confidential Information or shall certify, by signed, statement delivered to TP, the destruction of all original Confidential Information provided along with any copies made by the Contractor. Such delivery shall be to TP,

   Attention: Paul Lennemann, Chief Dam Safety Engineer, 3628 S 35th St. Tacoma WA 98409

5. **Compliance Audit.** TP may audit Contractor's compliance with this NDA.

6. **Applicable Law.** This NDA is made under, and shall be construed according to, the laws of the State of Washington and the Federal Energy Regulatory Commission regulations. Venue for any action brought pursuant to this NDA shall, at TP's option, be in Pierce County Superior Court, Pierce County, Washington or in the United States District Court for the Western District of Washington.

7. **Assignment.** This NDA may not be assigned.

8. **Violations.** Contractor understands and agrees that TP is providing the Confidential Information to Contractor in reliance upon this NDA, and Contractor will be fully responsible to TP for any damages or harm caused to TP by a breach of this NDA by Contractor or any of its officers, directors, agents, employees, subcontractors, consultants or affiliates. Contractor acknowledges and agrees that a breach of any of its promises or agreements contained herein will result in irreparable injury to TP for which there will be no adequate remedy at law, and TP shall be entitled to apply for equitable relief, including injunction and specific performance, in the event of any breach or threatened breach or intended breach of this NDA by Contractor. Such remedies, however, shall not be deemed to be the exclusive remedies for any breach of the Agreement but shall be in addition to all other remedies available at law or in equity. In addition to injunctive relief, civil or criminal penalties may be imposed for each violation of this NDA.

9. **Attorney's Fees.** In the event it is necessary for TP to utilize the services of an attorney to enforce any of the terms of this NDA, it shall be entitled to compensation for its reasonable attorney's fees and costs. In the event any legal action becomes necessary to enforce the provisions of the NDA, the substantially prevailing party shall be entitled to reasonable attorney's fees and costs in addition to any other relief allowed, regardless of whether the dispute is settled by trial, trial and appeal, arbitration, mediation, negotiation or otherwise, and regardless of whether suit is formally filed.

10. **<u>Corporate Authority; Binding Signatures.</u>** The individual executing this NDA on behalf of Contractor warrants that he or she is an authorized signatory of the entity for which they are signing, and have sufficient institutional authority to execute this NDA.

11. **<u>Electronic Signatures.</u>** Signatures transmitted electronically shall be deemed valid execution of this NDA, binding on the parties.

12. **<u>Effective Date and Term.</u>** This NDA shall become effective immediately and remain in full force and effect until Contractor has returned all Confidential Information to TP provided, however, the obligations contained in Section 3 shall survive the termination of this NDA.

CONTRACTOR: Name: ______________________________

Address: ______________________________

____

Phone: ______________________________

Email: ______________________________

Signature: ______________________________

Print Name: ______________________________

Title: ______________________________

Date: ______________________________

EXHIBIT "A" – DEFINITION of CONFIDENTIAL INFORMATION

Definition of Critical Energy Infrastructure Information (CEII)

The Critical Energy Infrastructure Information (CEII) guidelines of the Federal Energy Regulatory Commission (FERC) define CEII as specific engineering, vulnerability, operational or detailed design information about proposed or existing critical energy infrastructure (physical or virtual) that relates to the production, generation, transportation, transmission or distribution of energy, could be useful to a person planning an attack on critical infrastructure, is exempt from mandatory disclosure, and gives strategic information beyond the location of the critical infrastructure. 18 CFR §388.113 and RCW 42.56.520.

Definition of Bulk Electric System Cyber System Information (BCSI)

The North American Electric Reliability Corporation (NERC) has been designated by the FERC, through the Energy Policy Act of 2005, to establish and enforce standards and requirements for the reliable operation of the Bulk Electric System. The Bulk Electric System includes the TP's electrical generation resources, transmission lines, and interconnections with neighboring electric systems. Information related to the TP's Bulk Electric System Cyber Systems (BCS) is required to be protected due to the sensitive security nature of such information, and the need to protect public safety (hereinafter referred to as "BCSI"). BCSI generally (not exclusively) is defined as information about the BCS that could be used to gain unauthorized access or pose a security threat to the BCS and affect the reliable operations of the Bulk Electric System. TP is required to protect this information including, but not limited to, network topology/diagrams; floor plans for computing centers; equipment layouts; security configuration information and other information as defined in the NERC standards. FERC Order No. 706, issued January 18, 2008; 18 CFR Part 40; and RCW 42.56.070.

Definition of Security Sensitive Information (SSI)

Security Sensitive Information is those portions of records assembled, prepared, or maintained to prevent, mitigate, or respond to criminal or terrorist acts, which are acts that significantly disrupt the ability of TP to fulfill its mission and goals and that manifest an extreme indifference to human life, the public disclosure of which would have a substantial likelihood of threatening public safety. SSI includes: (a) Specific and unique vulnerability assessments or specific and unique response or deployment plans, including compiled underlying data collected in preparation of or essential to the assessments, or to the response or deployment plans; (b) Records not subject to public disclosure under federal law that are shared by federal or international agencies, and information prepared from national security briefings provided to state or local government officials related to domestic preparedness for acts of terrorism; and (c) Information regarding the infrastructure and security of computer and telecommunications networks, consisting of security passwords, security access codes and programs, access codes for secure software applications, security and service recovery plans, security risk assessments, and security test results to the extent that they identify specific system vulnerabilities.

APPENDIX C

Sample Contract

City of Tacoma Insurance Requirements

SERVICES CONTRACT

Click here for the Contract Questionnaire Popup Quick Reference

Start Questionnaire | Finalize Document

THIS CONTRACT, made and entered into effective as of the ____ day of _________, 20__ (EFFECTIVE DATE) by and between the CITY OF TACOMA, a municipal corporation of the State of Washington (hereinafter referred to as the "CITY"), and **[INSERT legal name of Supplier exactly as it appears in Ariba]**, (hereinafter referred to as "CONTRACTOR");

In consideration of the mutual promises and obligations hereinafter set forth, the Parties hereto agree as follows:

1. Scope of Services/Work

The CONTRACTOR agrees to diligently and completely perform the services and/or deliverables consisting of [INSERT A BRIEF DESCRIPTION OF THE WORK TO BE PERFORMED] as is described in Exhibit XXXXX [A, B, ETC., if needed] attached hereto and incorporated herein.

2. Order of Precedence

To the extent there is any discrepancy or conflict between and/or amongst the terms of this Contract and Exhibit(s) __________, the controlling terms for this Contract will be interpreted in the following order of precedence, with the first listed being the most controlling, and the last listed being the least controlling: Contract, Exhibit ___, Exhibit _____. [INSERT EXHIBIT REFERENCES IN ORDER OF WHICH IS MOST CONTROLLING]

3. Changes to Scope of Work

The CITY shall have the right to make changes within the general scope of services and/or deliverables upon execution in writing of a change order or amendment hereto. If the changes will result in additional work effort by CONTRACTOR, the CITY will agree to reasonably compensate the CONTRACTOR for such additional effort up to the maximum amount specified herein or as otherwise provided by City Code.

4. On Call Contracts

If the services and deliverables performed under this Contract are on an on call or as assigned basis, service and deliverables may be assigned by Task Authorization or Statements of Work, are subject to Section 9, and cannot augment any other work that the CONTRACTOR is doing for the CITY on another Contract. Actual compensation will depend upon the actual purchases made by the City during the life of this Contract and will be paid at the rates set in Exhibit A

5. Term

All services shall be satisfactorily completed on or before [INSERT CONTRACT TERMINATION DATE] and this Contract shall expire on said date unless mutually extended by a written and executed Amendment to this Contract.

6. Renewals

At CITY's sole option, the Term of this Contract may be renewed for additional [INSERT THE RENEWAL PERIOD - 1 YEAR, ETC] periods, not to exceed [INSERT THE MAXIMUM NUMBER OF RENEWAL PERIODS]. CITY will provide written notice of its intent to exercise any renewal options at least 30 days prior to the then existing Term and a written Amendment to this Contract will be mutually executed.

7. Delay

Neither party shall be considered to be in default in the performance of this Contract to the extent such performance is prevented or delayed by any cause which is beyond the reasonable control of the affected party and, in such event, the time for performance shall be extended for a period equal to any time lost as a result thereof. In the event CONTRACTOR is unable to proceed due to a delay solely attributable to CITY, CONTRACTOR shall advise CITY of such delay in writing as soon as is practicable.

8. Compensation

The CITY shall compensate the CONTRACTOR for the services and deliverables performed under this Contract [in accordance with OR on the basis of] [INSERT DESCRIPTION OF COMPENSATION ARRANGEMENTS – REFERENCE EXHIBIT, TIME AND MATERIALS, LUMP SUM ETC.]

9. Not to Exceed Amount

The total price to be paid by CITY for CONTRACTOR'S full and complete performance of the Scope of Work hereunder shall not exceed $ [INSERT TOTAL AMOUNT OF CONTRACT] plus applicable taxes without a written and executed Amendment to this Contract. Said price shall be the total compensation for CONTRACTOR'S performance hereunder including, but not limited to, all work, deliverables, materials, supplies, equipment, subcontractor's fees, and all reimbursable travel and miscellaneous or incidental expenses to be incurred by CONTRACTOR.
In the event the CONTRACTOR incurs cost in excess of the sum authorized for service under this Contract, the CONTRACTOR shall pay such excess from its own funds, and the CITY shall not be required to pay any part of such excess, and the CONTRACTOR shall have no claim against the CITY on account thereof.

10. Payment

CONTRACTOR shall submit XXXXXXXX {monthly, weekly, annual, Contract milestone, etc.} invoices for services completed and/or deliverables furnished during the invoice period. Upon CITY'S request, CONTRACTOR shall submit necessary and appropriate documentation, as determined by the CITY, for all invoiced services and deliverables.

Payment shall be made through the CITY'S ordinary payment process, and shall be considered timely if made within 30 days of receipt of a properly completed invoice. All payments shall be subject to adjustment for any amounts, upon audit or otherwise, determined to have been improperly invoiced. The CITY may withhold payment to the CONTRACTOR for any services or deliverables not performed as required hereunder until such time as the CONTRACTOR modifies such services or deliverables to the satisfaction of the CITY.

11. Payment Method

The City's preferred method of payment is by ePayables (Payment Plus), followed by credit card (aka procurement card), then Electronic Funds Transfer (EFT) by Automated Clearing House (ACH), then check or other cash equivalent. CONTRACTOR may be required to have the capability of accepting the City's ePayables or credit card methods of payment. The City of Tacoma will not accept price changes or pay additional fees when ePayables (Payment Plus) or credit card is used. The City, in its sole discretion, will determine the method of payment for this Contract.

12. Independent Contractor Status

The services and deliverables shall be furnished by the CONTRACTOR as an independent Contractor, and nothing herein contained shall be construed to create an employer and employee relationship. The CONTRACTOR shall provide at its sole expense all materials, office space, and other necessities to perform its duties under this Contract, unless stated otherwise in this Contract. No payroll or employment taxes of any kind shall be withheld or paid by the CITY with respect to payments to CONTRACTOR. The payroll or employment taxes that are the subject of this paragraph include, but are not limited to, FICA, FUTA, federal income tax, state personal income tax, state disability insurance tax and state unemployment insurance tax. By reason of CONTRACTOR's status as an independent Contractor hereunder, no workers' compensation insurance has been or will be obtained by the CITY on account of CONTRACTOR. CONTRACTOR may be required to provide the CITY proof of payment of these said taxes and benefits. If the CITY is assessed or deemed liable in any manner for those charges or taxes, the CONTRACTOR agrees to hold the CITY harmless from those costs, including attorney's fees.

13. Services Warranty

The CONTRACTOR warrants that all services performed pursuant to this Contract shall be generally suitable for the use to which CITY intends to use said services and deliverables as expressed in the Scope of Work. In the performance of services under this Contract, the CONTRACTOR and its employees further agree to exercise the degree of skill and care required by customarily accepted good practices and procedures followed by professionals or service providers rendering the same or similar type of service. All obligations and services of the CONTRACTOR hereunder shall be performed diligently and completely according to such professional standards.

Unless a higher standard or longer periods of warranty coverage for product deliverables provided under this Contract is provided herein, CONTRACTOR agrees to correct any defect or failure of deliverables supplied under this Contract which occurs within one year from ________[FILL IN APPROPRIATE TIME FRAME, E.G. GO LIVE, FIRST USE, ETC]. During said warranty period, all of the costs (including shipping, dismantling and reinstallation) of repairs or corrections is the responsibility of the CONTRACTOR. If CONTRACTOR is not the manufacturer of the item of equipment, CONTRACTOR agrees to be responsible for this warranty and shall not be relieved by a lesser manufacturer's guarantee. This Contract warranty period shall be suspended from the time a significant defect is first documented by the CITY until repair or replacement by CONTRACTOR and acceptance by the CITY. In the event less than ninety (90) days remain on the warranty period (after recalculating), the warranty period shall be extended to allow for at least ninety (90) days from the date of repair or replacement and acceptance by the CITY.

14. Reliance on CITY Provided Data or Information

If the CONTRACTOR intends to rely on information or data supplied by the CITY, other CITY contractors or other generally reputable sources without independent verification, such intent shall be brought to the attention of the CITY.

15. Contract Administration

[INSERT NAME TITLE AND DEPARTMENT OF CONTRACT ADMINISTRATOR] for the CITY shall have primary responsibility for contract administration and approval of services to be performed by the CONTRACTOR, and shall coordinate all communications between the CONTRACTOR and the CITY.

16. Specific Personnel

If before, during, or after the execution of this Contract, CONTRACTOR represents to the CITY that certain personnel would or will be responsible for performing services and deliverables under this Contract, then the CONTRACTOR is obligated to ensure that said personnel perform said Contract services to the maximum extent permitted by law. This Contract provision shall only be waived by written authorization by the CITY, and on a case-by-case basis.

17. Right to Audit

During the Term of this Contract, and for six (6) years thereafter, the CITY shall have the right to inspect and audit during normal business hours all pertinent books and records of the CONTRACTOR and/or any sub-contractor or agent of CONTRACTOR that performed services or furnished deliverables in connection with or related to the Scope of Work hereunder as reasonably needed by CITY to assess performance, compliance and quality assurance under this Contract or in satisfaction of City's public disclosure obligations, as applicable.

CONTRACTOR shall, upon three (3) business days of receipt of written request for such inspection and audit from CITY, provide the CITY with, or permit CITY to make, a copy of any work-related books, accounts, records and documents, in whole or in part, as specified in such request. Said inspection and audit shall occur in Pierce County, Washington or such other reasonable location as the CITY selects. The CITY shall bear the cost of any inspection audit requested hereunder, provided, that if an inspection audit in accordance with the foregoing provisions discloses overpricing or overcharges (of any nature) by the CONTRACTOR to the CITY in excess of one percent (1%) of the total contract billings, in addition to making adjustments for the overcharges, the reasonable actual cost of the CITY's audit shall be reimbursed to CITY by CONTRACTOR. Any adjustments or payments that must be made as a result of any audit and inspection hereunder shall be made no later than 90 days from presentation of CITY's findings to CONTRACTOR.

CONTRACTOR shall ensure that the foregoing inspection, audit and copying rights of the CITY are a condition of any subcontract, agreement or other arrangement under which any other person or entity is permitted to perform the Scope of Work under this Contract.

18. Records Retention

The CONTRACTOR shall establish and maintain records in accordance with requirements prescribed by the CITY, with respect to all matters related to the performance of this Contract. Except as otherwise authorized by the CITY, the CONTRACTOR shall retain such records for a period of ______[INSERT THE TIME THE RECORDS SHOULD BE KEPT. MOST COMMON IS 6 YEARS] years after receipt of the final payment under this Contract or termination of this Contract.

If CONTRACTOR retains any City records or data hosted in a Cloud Service. CITY shall have the ability to access its records hosted in a Cloud Service at any time during the Term of this Contract. CITY may export and retrieve its records during the Term of the Contract and, no later than 30 days from the termination of this Contract, CONTRACTOR shall export CITY records to City's custody and control.

19. Notices

Except for routine operational communications, which may be delivered personally or transmitted by electronic mail all notices required hereunder shall be in writing and shall be deemed to have been duly given if delivered personally or mailed first-class mail, postage prepaid, to the parties at the following addresses:

CITY:	CONTRACTOR:
Name:	Name:
Title:	Title:
Address:	Address:
Telephone No.:	Telephone No.:
E-mail:	E-mail:

20. Termination

Except as otherwise provided herein, the CITY may terminate this Contract at any time, with or without cause, by giving ten (10) business days written notice to CONTRACTOR.

In the event of termination, all finished and unfinished work prepared by the CONTRACTOR pursuant to this Contract shall be provided to the CITY. In the event CITY terminates this Contract due to the CITY's own reasons and without cause due to the CONTRACTOR's actions or omissions, the CITY shall pay the CONTRACTOR the amount due for actual work and services necessarily performed under this Contract up to the effective date of termination, not to exceed the total compensation set forth herein. Termination of this Contract by CITY shall not constitute a waiver of any claims or remaining rights the CITY may have against CONTRACTOR relative to performance hereunder.

21. Suspension

The CITY may suspend this Contract, at its sole discretion, upon seven (7) business days' written notice to the CONTRACTOR. Such notice shall indicate the anticipated period of suspension. Any reimbursement for expenses incurred due to the suspension shall be limited to the CONTRACTOR'S reasonable expenses and shall be subject to verification. The CONTRACTOR shall resume performance of services under this Contract without delay when the suspension period ends. Suspension of this Contract by CITY shall not constitute a waiver of any claims or remaining rights the CITY may have against CONTRACTOR relative to performance hereunder.

22. Taxes

Unless stated otherwise in Exhibit A, CONTRACTOR is responsible for the payment of all charges and taxes applicable to the services performed under this Contract, and CONTRACTOR agrees to comply with all applicable laws regarding the reporting of income, maintenance of records, and all other requirements and obligations imposed pursuant to applicable law. If the CITY is assessed, made liable, or responsible in any manner for such charges or taxes, the CONTRACTOR holds CITY harmless from such costs, including attorney's fees.

If CONTRACTOR fails to pay any taxes, assessments, penalties, or fees imposed by any governmental body, including by Tacoma City ordinance, and including by a court of law, CITY will deduct and withhold or pay over to the appropriate governmental body those unpaid amounts upon demand by the governmental body. Any such payments shall be deducted from the CONTRACTOR's total compensation.

23. Licenses and Permits

The CONTRACTOR, at its expense, shall obtain and keep in force any and all necessary licenses and permits. The CONTRACTOR shall obtain a business license as required by Tacoma Municipal Code Subtitle 6B.20 and shall pay business and occupation taxes as required by Tacoma Municipal Code Subtitle 6A.30. If applicable, CONTRACTOR must have a Washington state business license.

24. Indemnification

CONTRACTOR shall indemnify, defend, and hold harmless the CITY, its officials, officers, agents, employees, and volunteers, from any and all claims, demands, damages, lawsuits, liabilities, losses, liens, expenses and costs arising out of the subject matter of this Contract; provided that this provision shall not apply to the extent that damage or injury results from the sole negligence of the CITY, or its officers, agents, or employees. This indemnification shall extend to and include attorneys' fees and the cost of establishing the right of indemnification hereunder in favor of the CITY. This indemnification shall survive the termination of this Contract.

It is expressly agreed that with respect to design professional services performed by CONTRACTOR herein, CONTRACTOR's duty of indemnification, including the duty and cost to defend, against liability for damages arising out of such services or out of bodily injury to persons or damage to property shall, as provided in RCW 4.24.115 apply only to the extent of CONTRACTOR's negligence.

CONTRACTOR hereby warrants and represents CONTRACTOR is owner of any products, solutions or deliverables provided and licensed under this Contract or otherwise has the right to grant to CITY the licensed rights under this Contract, without violating the rights of any third party worldwide. CONTRACTOR shall, at its expense, defend, indemnify and hold harmless CITY and its employees, officers, directors, contractors, agents and volunteers from any claim or action against CITY which is based on a claim against CITY for infringement of a patent, copyright, trademark, or other propriety right or appropriation of a trade secret.

25. Title 51 Waiver

CONTRACTOR specifically assumes potential liability for actions brought by the CONTRACTOR'S own employees against the CITY and, solely for the purpose of this indemnification and defense, the CONTRACTOR specifically waives any immunity under the state industrial insurance law, Title 51 RCW. THE CONTRACTOR RECOGNIZES THAT THIS WAIVER WAS THE SUBJECT OF MUTUAL NEGOTIATION.

26. Insurance

During the course and performance of the services herein specified, CONTRACTOR will maintain the insurance coverage in the amounts and in the manner specified in the City of Tacoma Insurance Requirements as is applicable to the services and deliverables provided under this Contract. The City of Tacoma Insurance Requirements documents are fully incorporated herein by reference.

Failure by City to identify a deficiency in the insurance documentation provided by Contractor or failure of City to demand verification of coverage or compliance by Contractor with these insurance requirements shall not be construed as a waiver of Contractor's obligation to maintain such insurance.

27. Nondiscrimination

The CONTRACTOR agrees to take all steps necessary to comply with all federal, state, and City laws and policies regarding non-discrimination and equal employment opportunities. The CONTRACTOR shall not discriminate in any employment action because of race, religion, creed, color, national origin or ancestry, sex, gender identity, sexual orientation, age, marital status, familial status, veteran or military status, the presence of any sensory, mental or physical disability or the use of a trained dog guide or service animal by a disabled person. In the event of non-compliance by the CONTRACTOR with any of the non-discrimination provisions of this Contract, the CITY shall be deemed to have cause to terminate this Contract, in whole or in part.

28. Conflict of Interest

No officer, employee, or agent of the CITY, nor any member of the immediate family of any such officer, employee, or agent as defined by City ordinance, shall have any personal financial interest, direct or indirect, in this Contract, either in fact or in appearance. The CONTRACTOR shall comply with all federal, state, and City conflict of interest laws, statutes, and regulations. The CONTRACTOR represents that the CONTRACTOR presently has no interest and shall not acquire any interest, direct or indirect, in the program to which this Contract pertains which would conflict in any manner or degree with the performance of the CONTRACTOR'S services and obligations hereunder. The CONTRACTOR further covenants that, in performance of this Contract, no person having any such interest shall be employed. The CONTRACTOR also agrees that its violation of the CITY'S Code of Ethics contained in Chapter 1.46 of the Tacoma Municipal Code shall constitute a breach of this Contract subjecting the Contract to termination.

29. City ownership of Work/Rights in Data and Publications

To the extent CONTRACTOR creates any Work subject to the protections of the Copyright Act (Title 17 U.S.C) in its performance of this Contract, CONTRACTOR agrees to the following: The Work has been specially ordered and commissioned by CITY. CONTRACTOR agrees that the Work is a "work made for hire" for copyright purposes, with all copyrights in the Work owned by CITY. To the extent that the Work does not qualify as a work made for hire under applicable law, and to the extent that the Work includes material subject to copyright, CONTRACTOR hereby assigns to CITY, its successors and assigns, all right, title and interest in and to the Work, including but not limited to, all patent, trade secret, and other proprietary rights and all rights, title and interest in and to any inventions and designs embodied in the Work or developed during the course of CONTRACTOR'S creation of the Work. CONTRACTOR shall execute and deliver such instruments and take such other action as may be required and requested by CITY to carry out the assignment made pursuant to this section. Any documents, magnetically or optically encoded media, or other materials created by CONTRACTOR pursuant to this Contract shall be owned by CITY and subject to the terms of this sub-section. To the maximum extent permitted by law, CONTRACTOR waives all moral rights in the Work. The rights granted hereby to CITY shall survive the expiration or termination of this Contract. CONTRACTOR shall be solely responsible for obtaining releases for the performance, display, recreation, or use of copyrighted materials.

30. Public Disclosure

This Contract and documents provided to the CITY by CONTRACTOR hereunder are deemed public records subject to disclosure under the Washington State Public Records Act, Chapter 42.56 RCW (Public Records Act). Thus, the CITY may be required, upon request, to disclose this Contract and documents related to it unless an exemption under the Public Records Act or other laws applies. In the event CITY receives a request for such disclosure, determines in its legal judgment that no applicable exemption to disclosure applies, and CONTRACTOR has complied with the requirements herein to mark all content considered to be confidential or proprietary, CITY agrees to provide CONTRACTOR ten (10) days written notice of impending release. Should legal action thereafter be initiated by CONTRACTOR to enjoin or otherwise prevent such release, all expense of any such litigation shall be borne by CONTRACTOR, including any damages, attorneys fees or costs awarded by reason of having opposed disclosure. CITY shall not be liable for any release where notice was provided and CONTRACTOR took no action to oppose the release of information. Notice of any proposed release of information pursuant to Chapter 42.56 RCW, shall be provided to CONTRACTOR according to the "Notices" provision herein.

31. Confidential or Proprietary Records Must be Marked

If CONTRACTOR provides the CITY with records that CONTRACTOR considers confidential or proprietary, CONTRACTOR must mark all applicable pages of said record(s) as "Confidential" or "Proprietary." If CONTRACTOR fails to so mark record(s), then (1) the CITY, upon request, may release said record(s) without the need to satisfy the notice requirements above; and (2) the CONTRACTOR expressly waives its right to allege any kind of civil action or claim against the CITY pertaining to the release of said record(s).

32. Duty of Confidentiality

CONTRACTOR acknowledges that unauthorized disclosure of information or documentation concerning the Scope of Work hereunder may cause substantial economic loss or harm to the CITY.

Except for disclosure of information and documents to CONTRACTOR's employees, agents, or subcontractors who have a substantial need to know such information in connection with CONTRACTOR's performance of obligations under this Contract, the CONTRACTOR shall not without prior written authorization by the CITY allow the release, dissemination, distribution, sharing, or other publication or disclosure of information or documentation obtained, discovered, shared or produced pursuant to this Contract.

CONTRACTOR shall inform its employees, agents, and subcontractors of the confidentiality obligations under this Contract and instruct them so as to ensure such obligations are met. If so requested by the CITY, the CONTRACTOR further agrees to require all such individuals and entities performing services pursuant to this Contract to execute a Confidentiality and Non-Disclosure Agreement in a form acceptable to CITY.

This Section shall survive for six (6) years after the termination or expiration of this Contract.

CITY is required to provide notice of the Red Flags Rules published by the Federal Trade Commission in Title 16 Code of Federal Regulations, Part 681 ("Rules") to all entities that receive confidential or otherwise protected personal information of CITY's customers. Terms in quotations in this Section refer to defined terms contained in the "Rules." CONTRACTOR is, as to "Covered Accounts" of CITY for which CONTRACTOR performs activities under the Contract, a "Service Provider." "Service Provider" will perform in accordance with its reasonable policies and procedures designed to detect, prevent, and mitigate the risk of identity theft and will promptly report to CITY any specific "Red Flag" incidents detected as to "Covered Accounts" of CITY and upon request by CITY will respond to or reasonably assist CITY in responding reported "Red Flags." This Section shall survive for six (6) years after the termination or expiration of this Contract.

33. Approval for Release of Information Related to Contract

If requested by CITY, CONTRACTOR shall not release any information or documentation concerning the work under this Contract or any part thereof for marketing, advertising, or other commercial activities or publication including, but not limited to, news releases or professional articles without CITY's prior written approval. CONTRACTOR may submit at any time for review and approval a generic abstract describing the component parts of the completed Scope of Services ("Project Abstract"). After receiving written approval of the Project Abstract from the CITY, the CONTRACTOR may make minor insignificant changes to the Project Abstract and use all or parts of the Project Abstract in proposals.

This Section shall survive for six (6) years after the termination or expiration of this Contract.

34. Dispute Resolution

In the event of a dispute pertaining to this Contract, the parties agree to attempt to negotiate in good faith an acceptable resolution. If a resolution cannot be negotiated, then the parties agree to submit the dispute to voluntary non-binding mediation before pursuing other remedies. This provision does not limit the CITY'S right to terminate authorized by this Contract.

35. Miscellaneous Provisions

Governing Law and Venue

Washington law shall govern the interpretation of this Contract. Pierce County shall be the venue of any mediation, arbitration, or litigation arising out of this Contract.

Assignment

The CONTRACTOR shall not assign, subcontract, delegate, or transfer any obligation, interest or claim to or under this Contract or for any of the compensation due hereunder without the prior written consent of the CITY.

No Third Party Beneficiaries

This Contract shall be for the sole benefit of the parties hereto, and nothing contained herein shall create a contractual relationship with, or create a cause of action in favor of, a third party against either party hereto.

Waiver

A waiver or failure by either party to enforce any provision of this Contract shall not be construed as a continuing waiver of such provisions, nor shall the same constitute a waiver of any other provision of this Contract.

Severability and Survival

If any term, condition or provision of this Contract is declared void or unenforceable or limited in its application or effect, such event shall not affect any other provisions hereof and all other provisions shall remain fully enforceable. The provisions of this Contract, which by their sense and context are reasonably intended to survive the completion, expiration or cancellation of this Contract, shall survive termination of this Contract.

Entire Agreement

This Contract and the attached Exhibits, as modified herein, contain the entire agreement between the parties as to the services to be rendered hereunder. All previous and contemporaneous agreements, representations or promises and conditions relating to the subject matter of this Contract are superseded hereby. The Parties hereto mutually acknowledge, understand and agree that the terms and conditions set forth herein shall control and prevail over any conflicting terms and conditions stated in any attachments hereto.

Modification

No modification or amendment of this Agreement shall be effective unless set forth in a written and executed Amendment to this Contract.

Direct Solicitation and Negotiation

For service contracts valued $25,000 or less the City signature authorizes waiver of competitive solicitation by “Direct Solicitation and Negotiation” of professional and personal services in accordance with Tacoma Municipal Code 1.06.256 and the Purchasing Policy Manual.

IN WITNESS WHEREOF, the Parties hereto have accepted and executed this Contract, as of the Effective Date stated above, which shall be Effective Date for bonding purposes as applicable. The undersigned Contractor representative, by signature below, represents and warrants they are duly authorized to execute this legally binding Contract for and on behalf of Contractor.

CITY OF TACOMA: By:	CONTRACTOR: By:

(City of Tacoma use only - blank lines are intentional)

Director of Finance: ____

City Attorney (approved as to form): ____

Approved By: ____

Approved By: ____

Approved By: ____

Approved By: ____

Approved By: ____

Approved By: ____

Approved By: ____

Approved By: ____

This Insurance Requirements shall serve as an attachment and/or exhibit form to the Contract. The Agency entering a Contract with City of Tacoma, whether designated as a Supplier, Contractor, Vendor, Proposer, Bidder, Respondent, Seller, Merchant, Service Provider, or otherwise referred to as "Contractor".

1. GENERAL REQUIREMENTS

The following General Requirements apply to Contractor and to Subcontractor(s) performing services and/or activities pursuant to the terms of this Contract. Contractor acknowledges and agrees to the following insurance requirements:

1.1. Contractor shall not begin work under the Contract until the required insurance has been obtained and approved by the City of Tacoma.

1.2. Contractor shall keep in force during the entire term of the Contract, at no expense to the City of Tacoma, the insurance coverage and limits of liability listed below and for Thirty (30) calendar days after completion of all work required by the Contract, unless otherwise provided herein.

1.3. Liability insurance policies, except for Professional Liability and Workers' Compensation, shall:

1.3.1. Name the City of Tacoma and its officers, elected officials, employees, and agents as **additional insured**

1.3.2. Be considered primary and non-contributory for all claims with any insurance or self-insurance or limits of liability maintained by the City of Tacoma

1.3.3. Contain a "Waiver of Subrogation" clause in favor of City of Tacoma

1.3.4. Include a "Separation of Insureds" clause that applies coverage separately to each insured and additional insured

1.3.5. Name the "City of Tacoma" on certificates of insurance and endorsements and not a specific person or department

1.3.6. Be for both ongoing and completed operations using Insurance Services Office (ISO) form CG 20 10 04 13 and CG 20 37 04 13 or the equivalent

1.3.7. Be satisfied by a single primary limit or by a combination of a primary policy and a separate excess umbrella

1.4. A notation of coverage enhancements on the Certificate of Insurance shall not satisfy these requirements below. Verification of coverage shall include:

1.4.1. An ACORD certificate or equivalent

1.4.2. Copies of requested endorsements

1.5. Contractor shall provide to City of Tacoma Procurement & Payable Division, prior to the execution of the Contract, Certificate(s) of Insurance and endorsements from the insurer certifying the coverage of all insurance required herein. Contract or Permit number and the City of Tacoma Department must be shown on the Certificate of Insurance.

1.6. A renewal Certificate of Insurance shall be provided electronically prior to coverage expiration via email sent annually to coi@cityoftacoma.org.

1.7. Contractor shall send a notice of cancellation or non-renewal of this required insurance within Thirty (30) calendar days to coi@cityoftacoma.org.

1.8. “Claims-Made” coverages, except for pollution coverage, shall be maintained for a minimum of three years following the expiration or earlier termination of the Contract. Pollution coverage shall be maintained for six years following the expiration of the Contract. The retroactive date shall be prior to or coincident with the effective date of the Contract.

1.9. Each insurance policy must be written by companies licensed or authorized (or issued as surplus line by Washington surplus line broker) in the State of Washington pursuant to RCW 48 with an (A-) VII or higher in the A.M. Best key rating guide.

1.10. Contractor shall not allow any insurance to be cancelled, voided, suspended, or reduced in coverage/limits, or lapse during any term of this Contract. Otherwise, it shall constitute a material breach of the Contract.

1.11. Contractor shall be responsible for the payment of all premiums, deductibles and self-insured retentions, and shall indemnify and hold the City of Tacoma harmless to the extent such a deductible or self-insured retained limit may apply to the City of Tacoma as an additional insured. Any deductible or self-insured retained limits in excess of Twenty Five Thousand Dollars ($25,000) must be disclosed and approved by City of Tacoma Risk Manager and shown on the Certificate of Insurance.

1.12. City of Tacoma reserves the right to review insurance requirements during any term of the Contract and to require that Contractor make reasonable adjustments when the scope of services changes.

1.13. All costs for insurance are included in the initial Contract and no additional payment will be made by City of Tacoma to Contractor.

1.14. Insurance coverages specified in this Contract are not intended and will not be interpreted to limit the responsibility or liability of Contractor or Subcontractor(s).

1.15. Failure by City of Tacoma to identify a deficiency in the insurance documentation or to verify coverage or compliance by Contractor with these insurance requirements shall not be construed as a waiver of Contractor’s obligation to maintain such insurance.

1.16. If Contractor is a government agency or self-insured for any of the above insurance requirements, Contractor shall be liable for any self-insured retention or deductible portion of any claim for which insurance is required. A certification of self-insurance shall be attached and incorporated by reference and shall constitute compliance with this Section.

2. SUBCONTRACTORS

It is Contractor's responsibility to ensure that each subcontractor obtain and maintain adequate liability insurance coverage that applies to the service provided. Contractor shall provide evidence of such insurance upon City of Tacoma's request. Failure of any subcontractor to comply with insurance requirements does not limit Contractor's liability or responsibility.

3. REQUIRED INSURANCE AND LIMITS

The insurance policies shall provide the minimum coverages and limits set forth below. Providing coverage in these stated minimum limits shall not be construed to relieve Contractor from liability in excess of such limits.

3.1 Commercial General Liability Insurance
Contractor shall maintain Commercial General Liability Insurance policy with limits not less than One Million Dollars ($1,000,000) each occurrence and Two Million Dollars ($2,000,000) annual aggregate. This policy shall be written on ISO form CG 00 01 04 13 or its equivalent and shall include product liability especially when a Contract is solely for purchasing supplies. It includes Products and Completed Operations for three years following the completion of work related to performing construction services. It shall be endorsed to include: A per project aggregate policy limit (using ISO form CG 25 03 05 09 or equivalent endorsement)

3.2 Commercial (Business) Automobile Liability Insurance
Contractor shall maintain Commercial Automobile Liability policy with limits not less than One Million Dollars ($1,000,000) each accident for bodily injury and property damage and bodily injury and property damage coverage for owned (if any), non-owned, hired, or leased vehicles. Commercial Automobile Liability Insurance shall be written using ISO form CA 00 01 or equivalent. Contractor must also maintain MCS 90 and CA 99 48 endorsements or equivalent if "Pollutants" are to be transported unless in-transit Pollution coverage is covered under required Contractor's Pollution Liability Insurance.

3.3 Workers' Compensation
Contractor shall comply with Workers' Compensation coverage as required by the Industrial Insurance laws of the State of Washington, as well as any other similar coverage required for this work by applicable federal laws of other states. Contractor must comply with their domicile State Industrial Insurance laws if it is outside the State of Washington.

3.4 Employers' Liability Insurance
Contractor shall maintain Employers' Liability coverage with limits not less than One Million Dollars ($1,000,000) each employee, One Million Dollars ($1,000,000) each accident, and One Million Dollars ($1,000,000) policy limit.

3.5 Professional Liability Insurance or Errors and Omissions
For contracts with professional licensing, design, or engineering services. Contractor and/or its subcontractor shall maintain Professional Liability or Errors and Omissions with limits of One Million Dollars ($1,000,000) per claim and Two Million Dollars ($2,000,000) in the aggregate covering acts, errors and omissions arising out of the professional services under this Contract. Contractor shall maintain this coverage for Two Million Dollars ($2,000,000) if the policy limit includes the payment of claims or defense costs, from the policy limit. If the scope of such design-related professional services includes work related to pollution conditions, the Professional Liability policy shall include Pollution Liability coverage.

3.6 Other Insurance

Other insurance may be deemed appropriate to cover risks and exposures related to the scope of work or changes to the scope of work required by City of Tacoma. The costs of such necessary and appropriate Insurance coverage shall be borne by Contractor.