Definite Plan for the Lower Klamath Project

Appendix A – Risk Management Plan

KLAMATH RIVER RENEWAL CORPORATION

June 2018

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Acronyms and Abbreviations

BOC	Board of Consultants
CA	California
CEQA	California Environmental Quality Act
CMAR	Construction Manager at Risk
cfs	cubic feet per second
DB	Design-Builder
DSOD	California Division of Safety of Dams
DWR	Department of Water Resources
EAP	Emergency Action Plan
FERC	Federal Energy Regulatory Commission
ID	Identification
KRRC	Klamath River Renewal Corporation
NEPA	National Environmental Policy Act
PFMA	Potential Failure Modes Analysis
QA	Quality Assurance
QC	Quality Control

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Chapter 1: Plan Objectives and Background

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1. PLAN OBJECTIVES AND BACKGROUND

1.1 Plan Objectives

The implementation of any project comes with uncertainty and risk that can affect schedule, budget, and project performance. This is even more applicable to large, multi-disciplinary and high profile projects. Successful implementation includes planning to identify and manage those uncertainties and risks. Section 7.2 of the Klamath Hydroelectric Settlement Agreement (KHSA), as amended, sets forth the essential elements of a risk management plan to be included in and implemented as part of the Definite Plan. These elements include the following:

- Insurance, performance bond, or similar measures as required by Appendix L to the KHSA
- Accounting procedures that will result in the earliest practicable disclosure of any actual or foreseeable cost overrun
- Appropriate mechanisms to modify or suspend performance of any task subject to such cost overrun; and
- Measures to reduce risks of cost overruns, delays, or other impediments to dam removal

This plan addresses these requirements as follows:

- Section 2 identifies the insurance, bonds and other surety arrangements to be secured by the Klamath River Renewal Corporation (KRRC) in compliance with Appendix L to the KHSA
- Section 3 identifies KRRC's preferred progressive design-build project delivery method and plan for a competitive process for selecting its dam removal contractor, and negotiation of construction agreements
- Section 4 includes a design and construction risk register and measures to reduce risks of cost overruns, delays, or other impediments to dam removal

The objective of this Risk Management Plan is to provide a tool and processes to identify and quantify the design and construction risks that are particular to the Lower Klamath Project (Project), assign those risks to the appropriate party, develop design and construction risk management strategies to reduce or eliminate the risk, and to manage and re-evaluate the risks as we progress through the project lifecycle.

1.2 Project Background & Overview

The proposed Project is described in Sections 4 through 7 of the Definite Plan, and generally includes the decommissioning and full removal of four dam developments (Iron Gate, Copco No. 1 and No. 2, and J.C. Boyle) on the Klamath River approximately 200 miles from the Pacific Ocean in the states of Oregon and California by the KRRC. Figure 1.2-1 provides an overview of the Klamath River watershed and the locations of the four dams. The Project objectives are to restore free-flowing river conditions and volitional fish passage by the complete removal of dams, power generation facilities, water intake structures, canals, pipelines, and ancillary buildings. The Definite Plan also describes a partial removal alternative which is presented for purposes of environmental review. Under the partial removal alternative, the objectives of a free-flowing river conditions and volitional fish passage would be achieved, but portions of each dam would remain in place, along with ancillary buildings and structures such as powerhouses, foundations, tunnels, and pipes.

Prior to removal of the dams and hydropower facilities, the KRRC will drawdown the water surface elevation in each reservoir as low as possible to facilitate accumulated sediment evacuation and to create a dry work area for facility removal activities. In order to meet drawdown timing and duration, specific infrastructure modifications are required at Iron Gate and Copco No. 1 dams in advance of drawdown. In general, drawdown will begin on January 1 of the drawdown year, and will extend through March 15 of the same year.

After drawdown is accomplished, dam and hydropower facility removal will begin, and the KRRC will stabilize remaining reservoir sediments to the extent feasible. Full reservoir area restoration will begin after drawdown, and extend throughout the year, and possibly into the subsequent year. Vegetation establishment could extend several years.

Other key project components include measures to address aquatic and terrestrial resources, road and bridge improvements, relocation of the City of Yreka's pipeline across Iron Gate Reservoir and associated diversion facility improvements, flood improvements downstream, as well as demolition of various recreation facilities adjacent to the reservoirs.

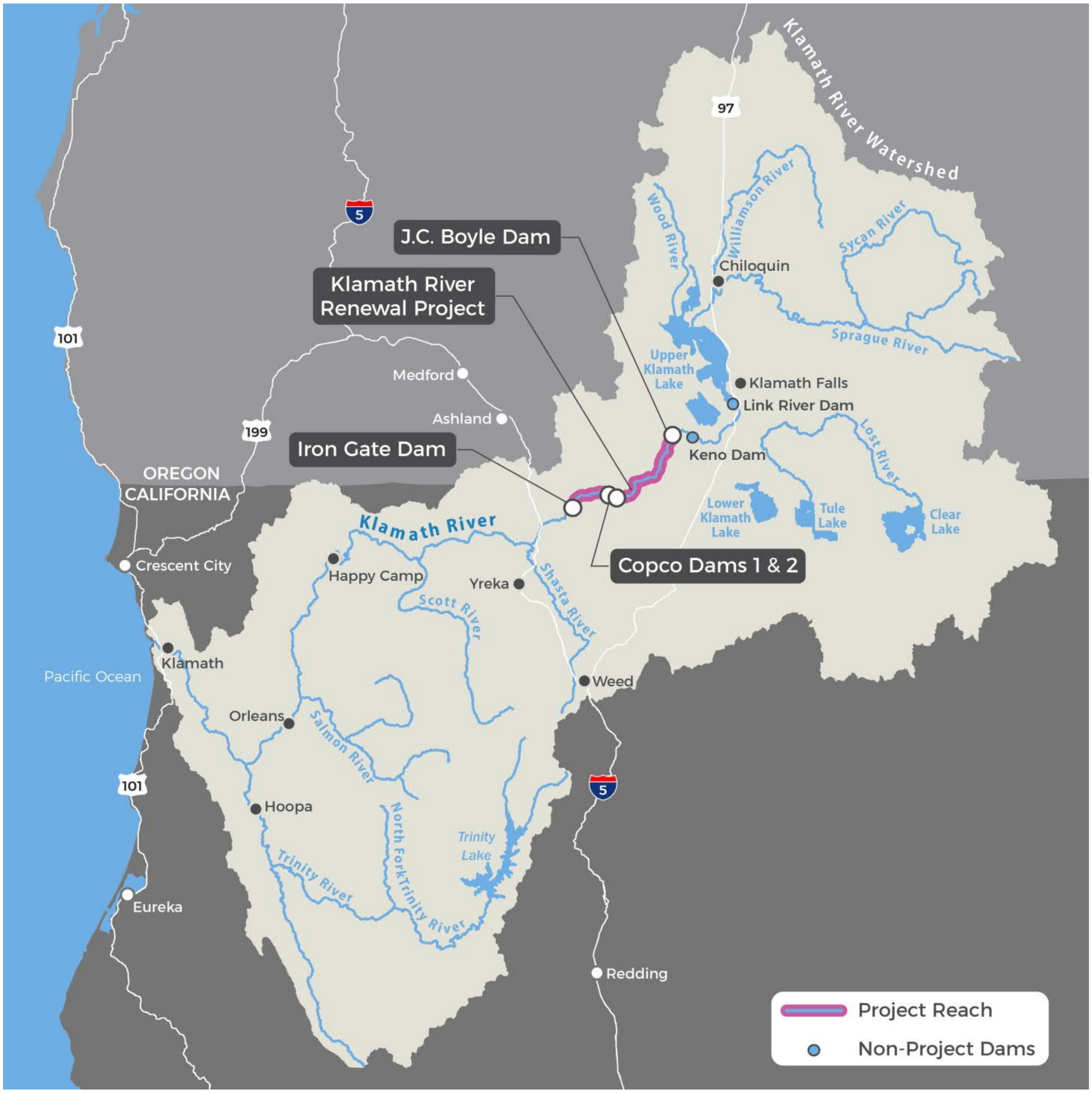

Figure 1.2-1 Klamath River Watershed and Facilities Locations

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Chapter 2: Insurance, Bonds and Other Surety Arrangements

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2. INSURANCE, BONDS AND OTHER SURETY ARRANGEMENTS

2.1 Overview

This section of the Risk Management Plan identifies the insurance, bonds and other surety arrangements that KRRC will maintain in fulfillment of its obligations under Appendix L of the KHSA and prudent business practices. KRRC developed this plan with specialized guidance and advice from Willis Towers Watson (Willis). Willis is a global firm that provides a wide range of insurance brokerage, reinsurance, and risk management consulting services1. Working with Willis as its insurance advisor, KRRC has established and will maintain a robust insurance program to minimize liability risks to the Project and to KRRC.

2.2 Insurance

2.2.1 Overview

KRRC will maintain two insurance programs, each of which will be designed to address different insurance needs and requirements over time. Prior to the commencement of dam removal activities, the insurance currently maintained by KRRC is best viewed as a corporate insurance program that is intended to address KRRC's general risks as a business entity (discussed below as the Corporate Insurance Program). The project-specific insurance needs and requirements in connection with the proposed Project cover a broader range of risks, and are directly responsive to the requirements of Appendix L to the KHSA (discussed below as the Project Insurance Program).

2.2.2 Timing

KRRC's Corporate Insurance Program is in place and is described below. KRRC's project-specific coverages will be established and implemented as part of the dam removal contractor procurement process. KRRC will incorporate these coverages in the RFP for KRRC's dam removal contractor and will be incorporated into the dam removal contract that is ultimately executed by KRRC and the dam removal contractor. KRRC has begun the process of introducing insurers to the Project, with an eye toward selecting the insurer or insurers that offer the best options for project coverage. This will be determined after the insurers have completed their review of the Project.

Once the scope, limits and providers of the project coverages have been finally determined, the actual insurance policies will be put in place in coordination with the beginning of the dam removal work to which

[1] Additional information regarding this firm may be found at https://www.willistowerswatson.com/en/about-us/overview

they relate, including certain preliminary site work. For example, insurance for design work will be in place at the time the dam removal contract becomes effective, as KRRC contemplates a design-build contract structure. Insurance for the actual removal activities may not be in place until removal work is ready to commence.

2.2.3 Corporate Insurance Program

KRRC intends its Corporate Insurance Program to address KRRC's general risks as a business entity and includes the following:

- $1,000,000 Commercial General Liability policy which is supplemented by a $5,000,000 Umbrella policy
- $10,000,000 Directors and Officers policy that protects the KRRC's board members
- Worker's Compensation and Employer's Liability policy with a $1,000,000 limit for the KRRC employee(s)
- Commercial Automobile policy with $1,000,000 in limits
- Commercial Property policy that covers the KRRC's scheduled property

KRRC's liability insurance policies name PacifiCorp, the State of Oregon, the State of California, and their respective officers, agents, employees, and members as additional insureds in accordance with the requirements of the Amended KHSA. Certificates of insurance evidencing that policies of insurance providing such provisions, coverages, and limits as set forth above are included as Appendix B.

2.2.4 Project Insurance Program

The Project Insurance Program will be an "owner controlled insurance program" or OCIP for purposes of securing certain project coverages. Under an OCIP, the owner establishes a Commercial General Liability and Umbrella insurance program in which contractors and subcontractors enroll for coverage, rather than requiring each contractor or subcontractor to procure insurance independently. The net result is a more comprehensive, seamless and efficient insurance program which precludes insurers from denying coverage based on a claim that a different insurer is responsible. By consolidating the risks into a single insurance program, this approach best removes cross-litigation costs caused by multi-party losses on a construction project. This is because the same policy essentially covers each contractor and subcontractor.

An OCIP also allows the project sponsor/owner to control and design the coverage it intends to procure and the cost of coverage. Specific decisions regarding which policies to purchase, when to purchase them, and what insurance limits to obtain are largely driven by the timing and structure of the dam removal. That said, KRRC sets forth below the current expectations regarding its project-specific insurance program.

While KRRC will base the final project-specific insurance requirements on KRRC's discussions with potential insurers and the development of the dam removal contractor RFP, KRRC expects to secure the following project-specific coverages:

- Commercial General Liability (CGL): KRRC will obtain primary Commercial General Liability coverage with limits of $2,000,000 per occurrence and $4,000,000 general aggregate. This policy will be dedicated to this Project. The policy will extend liability coverage to the dam removal contractor and all eligible subcontractors for their work at this Project. The policy will also respond to third-party damage from the construction activity after the Project. This tail coverage will last for ten years or to the statute of repose for the respective state of construction operations. This tail coverage will trigger once the Project has reached substantial completion.
- Umbrella Liability: The OCIP by an Umbrella Liability policy of $200,000,000 in limits will augment the liability coverage provided by KRRC's CGL policy. This policy will follow the terms and conditions of the underlying primary CGL. This Umbrella limit will cover all enrolled parties, which is an added value for smaller subcontractors that cannot afford such high limits.
- Worker's Compensation/Employer's Liability: KRRC will require that all contractors and subcontractors maintain at all times Worker's Compensation and Employer's Liability coverage. This coverage will be maintained in the amounts no less than the applicable statutory requirements for Worker's Compensation and $1,000,000 for Employer's Liability. Because this coverage is statutory, it is not efficient to include it in the OCIP, which each contractor and subcontractor will procure directly.
- Commercial Automobile Liability: KRRC will require that all contractors and subcontractors maintain auto liability insurance limits no less than $1,000,000 combined single limit per accident for bodily injury and property damage. This coverage will also be outside the OCIP and KRRC's contractors and subcontractors will procure it directly to cover all owned, leased and non-owned vehicles used in connection with the work.
- Builder's Risk/Inland Marine or Commercial Property Insurance: Builder's risk insurance is a type of insurance typically associated with vertical construction where an improvement is increasing in value and where the cost of restoration increases as the Project progresses, such as the construction of an office building. In procuring it for a dam removal project, a slightly unconventional analysis will apply to determining prudent limits of coverage. KRRC anticipates obtaining coverage for 100% of the replacement value of any salvaged material or property. KRRC will purchase builder's risk as a project-specific property coverage.
- Contractor's Pollution Liability (CPL): KRRC anticipates that coverage of up to $100,000,000 limits will be included as part of the project program. It will be a dedicated policy covering all contractors and subcontractors at the project site with no enrollment process.
- Fixed Site Pollution Liability: KRRC will acquire this coverage outside the OCIP and will go into effect when KRRC acquires title to the dam facilities and will be in an amount up to $100,000,000. It is the intent to underwrite this policy with the same insurers and in conjunction as the CPL policy to address any pre-existing environmental damages.

- Professional Liability/Errors and Omissions Insurance: This coverage will be required under the terms of KRRC's design contract procurement, whether on a stand- alone basis or as part of a design-build procurement. It will go into effect when KRRC retains the design professional. KRRC expects the coverage limits to be up to $25,000,000. In addition, KRRC will consider whether to purchase an Owner's Protective Professional Indemnity (OPPI) insurance policy as a back-stop to all the design professional's' liability available limits coverage. KRRC will make this decision based on the size, experience and financial strength of the selected design team and their respective insurance limits available to the Project. Coverage limits selected may be as high as 20-40% of the value of construction.

These policies name PacifiCorp, the State of Oregon, the State of California, and their respective officers, agents, employees, and members as additional insureds in accordance with the requirements of the KHSA. KRRC will provide certificates of insurance evidencing that policies of insurance providing such provisions, coverages, and limits as set forth above to PacifiCorp and the States before any contract for dam removal is effective and before dam removal work begins.

2.2.5 Independent Board of Consultants

The Board of Consultants (BOC) will review the forgoing insurance coverages. The BOC includes a member or members with expertise in insurance coverage and bonding for large and complex civil construction projects. KRRC will implement any further recommendations that the BOC may provide with respect to the foregoing insurance coverage.

2.2.6 Ongoing Evaluation

KRRC and Willis will review all policies of insurance on a not-less-than-annual basis to make sure that they are sufficient and cost effective relative to other insurance products and risk management tools as may subsequently become available.

2.3 Bonds

2.3.1 Requirements and Timing

Appendix L to the Amended KHSA addresses bonding requirements. Bond requirements include bid bonds, performance bonds (in an amount equivalent to original contract value) and payment bonds (in an amount equivalent to original contract value). These bonds will be secured in connection with awarding contracts to undertake decommissioning activities. One or more of KRRC's vendors and contractors will maintain these bonds (and/or parent company guaranty or standby letter of credit). KRRC will require that all bonds be obtained from financially sound surety companies.

2.3.2 Performance Bond

The performance bond securing the contractor's performance under the dam removal contract will be in the full amount of the dam removal contract. The contractor's surety company issuing the bond will determine the form of bond: however, AIA Form 312 is the predominant form in use at this time. To the extent alternate forms are used, they will be substantively similar.

2.3.3 Independent Board of Consultants

The BOC will review and approve its proposed bonding requirements. KRRC will implement any further recommendations that the BOC may provide with respect to bonding requirements. Because the performance bond backstops the dam removal contractor's performance, it cannot be issued until the dam removal contract is in place and will be issued at that time.

2.3.4 Ongoing Evaluation

As with insurance, KRRC and Willis will periodically review the amount and form of bonds (and/or parent company guaranty or standby letter of credit) to make sure that they are sufficient and cost effective relative to other products and risk management tools as may subsequently become available.

2.4 Specialty Corporate Indemnitor

2.4.1 Overview

Appendix L to the KHSA requires KRRC to identify and contract with a specialty corporate indemnitor (a Liability Transfer Corporation, or LTC) to protect the states of Oregon, California and PacifiCorp from potential liability that may be uninsurable or underinsured. KRRC will fulfill this requirement in consultation with the States and PacifiCorp and in connection with the design and implementation of the insurance program discussed above. KRRC will use this risk management tool to address certain risks not covered by KRRC's insurance Program. Parameters established by the KHSA to assess the sufficiency of a corporate indemnitor include:

- Appropriate capitalization (as agreed to by the States and PacifiCorp)
- Performance in projects of similar scope, magnitude, complexity and type
- Experience with federally regulated permitting processes
- Longevity in the industry

This requirement will be fulfilled in connection with the selection of the design-build contractor hired to implement the Definite Plan.

2.4.2 Structure and Timing

The LTC can be structured contractually, through third-party indemnities or potentially with additional special insurance products. The LTC may perform portions of the Project and will assume responsibility for various project risks, both during project execution and post-project (including the fulfillment of any long-term mitigation obligations established by the Definite Plan or regulatory approvals). The "gap" between the general responsibilities to be assumed by the general contractor and the program of required insurance has yet to be determined. Defining and filling this gap is an ongoing process, as KRRC seeks to better define construction costs, measures to lower construction costs, and measures to manage construction risk. KRRC expects to fulfill this requirement concurrently with the execution of the contract for dam removal.

2.4.3 Independent Board of Consultants

The BOC will review the potential and appropriate risks that may be transferred to a LTC. KRRC anticipates obtaining BOC guidance on this risk management tool concurrently with its efforts to identify a proposed contractor and negotiate a progressive design-build contract with a guaranteed maximum construction price. KRRC's final decision on how best to use this risk management tool is, however, subject to the approval of the states of Oregon, California and PacifiCorp, in consultation with the Federal Parties, whose approval may not be unreasonably withheld.

Chapter 3: Project Delivery Method

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3. PROJECT DELIVERY METHOD

3.1 Overview of Progressive Design-Build Delivery Method

KRRC is pursuing a competitive process for selecting its dam removal contractor, or design-builder. KRRC contemplates structuring the dam removal contract as a progressive design-build contract under which, after selection, the designated design-builder will then spend six to nine months studying the project area and designing its removal program before the final guaranteed maximum price is locked in. KRRC expects this design process to begin in the first quarter of 2019. When KRRC finalizes the cost of the dam removal work under the contract through the negotiation of a guaranteed maximum price, the circumstances that most often lead to cost overruns for which the owner remains responsible - unknown site conditions – while not eliminated will have been significantly narrowed even beyond where it is today. As a result, final pricing will be determined prior to KRRC's acceptance of the project license.

The progressive design-build contract KRRC expects to enter into will provide that one overall contractor will complete both design and deconstruction on an integrated basis and will assure that, absent contractually defined uncontrollable circumstances, the work will be performed with minimal cost overruns. Thus, any project costs incurred within the defined work scope that are in excess of the guaranteed price will be the responsibility of the project contractor, not KRRC.

In addition to committing to a guaranteed maximum price, the project contractor will agree to complete the Project and perform the work to specified technical standards by a guaranteed completion date. Proposers will be required to include detailed proposals on their proposed means and methods of dam removal, consistent with regulatory requirements. Means and methods that offer greater promise of lessening potential liability or lowering costs can be scored higher in determining the proposal offering the best value. Daily liquidated damages will be payable to KRRC for unexcused delays, and KRRC will not be responsible for any cost overruns except those caused by predetermined risks that are outside the project contractor's ability to reasonably manage and control. A qualified construction-management entity will oversee the performance of the dam decommissioning and removal work under the project agreement.

This integrated project-delivery approach will be particularly useful for the Project because it will mitigate several elements of project-completion risk, in addition to the general price risk inherent in all construction projects. Integrated project delivery involves a self-selected team of highly qualified firms whose business interests are aligned, thus decreasing the risk of disputes among team members. By addressing multiple aspects of the work in a single contract, integrated project delivery also has the key advantage of creating one point of accountability for the Project, allowing KRRC to bring a claim against a single entity for any flawed work. Furthermore, considering that dam removal is a specialized area, integrated project delivery gives the prequalified entity the opportunity to make an innovative and cost-effective proposal to execute the work. Additional benefits of integrated project delivery include accelerated project delivery and improved project quality.

3.2 Risk Transfer

Risks transferred to the project contractor under the project agreement will include the risk of unexcused delays; unexpected work that the project contractor needs to perform to carry out the basic work scope; unavailability of materials; non-compliance with the decommissioning plan, applicable law and governmental approvals; intellectual property infringement; and the risk of exacerbating any existing hazardous substances or other pollution conditions. These risks are regarded in the industry as within the control of the project contractor team and are generally assumed contractually by the contractor without adding a risk premium to the contract price. KRRC will retain the risk of any delays caused by (i) uncontrollable circumstances (such as changes in law, force majeure, the discovery of cultural relics, and dam conditions unknown at the time the contract is entered into); (ii) any work scope changes directed by KRRC; and (iii) the inaccuracy of any information provided by KRRC to the project contractor that formed the basis of the decommissioning plan and that could not reasonably be verified by the project contractor.

3.3 Retained Risk; Project Contingency

If accurate information is supplied to the project contractor, no scope changes are requested by KRRC after contract execution, and no uncontrollable circumstances occur, the project contractor will be obligated to complete the Project for the guaranteed maximum price (which is based on competitively bid elements of the construction work) established at contract signing. On the other hand, if any of the risks retained by KRRC occur, KRRC as the project owner will bear the costs. Accordingly, the project budget will include an appropriate contingency reserve for any such risks, and KRRC will use insurance and other mechanisms to manage these risks.

Section 2.6 of Appendix P of the Definite Plan discusses contingency reserves, based on updated construction costs and are summarized here. A design contingency was set at 10% of the construction cost, which is a typical value for a level of design presented in the Definite Plan. In addition, KRRC used a value of 20% of the construction cost for construction contingencies for the dam removal estimates, which is a typical value for this stage of project development. KRRC applied the design and construction contingencies (total of 30%) as a percentage of construction cost and added to the overall estimate of project costs. Based upon current project cost estimates, KRRC applied design and construction contingencies of approximately $58 million and $68 million to the partial removal and full removal alternative estimates of project cost, respectively.

3.4 Contractor Selection Process

KRRC will choose the project contractor using a two-stage qualifications-based-selection (QBS) process. The first stage will involve a request for qualifications (RFQ), and the second stage will involve a request for proposals (RFP). QBS standards during the RFQ will include:

- Past performance of similar projects in scope, magnitude (complexity and size, such as but not limited to performance of work at multiple locations at the same time), and type (waterway work; environmentally regulated, etc.)
- Sufficient financial strength, including basic financial metrics such as corporate net worth and profitability
- Experience with federally regulated permitting processes
- Longevity in industry.

KRRC will invite three or four pre-qualified firms to make project submittals on a competitive proposal basis in response to a RFP issued by KRRC. KRRC will set forth the requirements for making project proposals in the RFP and will base them on the terms of the Definite Plan. KRRC will select the proposer submitting the best value proposal (best overall price and technical merit) to perform the work and enter into a comprehensive project agreement with KRRC. The states of California and Oregon and PacifiCorp will have the opportunity to review and comment on the selection process and resulting project agreement to assure that their interests are protected and that the project work will be properly carried out. KRRC may divide the work into two or three segments, contracted separately, as determined by KRRC to be in its best interests.

3.5 Performance Security; Indemnities

Section 2.3 addresses performance security and indemnities. The project contractor will furnish a conventional performance bond from a financially sound surety company, further assuring KRRC that the contractor will perform the project agreement as required. As an alternative, or in addition to a performance bond, KRRC may also ask the project contractor to provide a parent company guaranty or to furnish a standby letter of credit securing performance of the project agreement. KRRC will have the right to call upon any such guaranty or to draw on any such letter of credit if a project contractor fails to perform and use the proceeds to pay any non-performance damages it is owed under the project agreement. The project contractor will also indemnify KRRC for any loss or expense incurred by third parties resulting from an unexcused breach of the contract or any negligence or willful misconduct by the contractor. Each party, as is conventional in contracts of this nature, will waive the right to make a claim for punitive or consequential damages.

3.6 Construction Management

A qualified construction-management entity will provide oversight of the project contractor, including detailed design review and full construction-management services throughout the duration of the project agreement. The construction manager will participate in the contractor's design development meetings and will review all final design documents developed by the contractor. KRRC anticipates detailed reviews at the 60%, 90% and 100% completion levels, as well as review of final Construction Documents (plans, specifications, design report and cost estimate). The construction manager will be involved in recurring activities such as progress meetings, pay estimates, weekly progress reporting, and schedule updates. These recurring activities are the basic machinery for transferring information, making decisions, and identifying potential risks during construction. The construction manager will meet weekly with the contractor to review the current status of completed work onsite. The contractor will prepare and KRRC will review and approve a written safety plan that the selected contractor would be required to follow, thus providing a uniform approach toward project safety.

3.7 Independent Board of Consultants

The BOC will review project documents as well as dam removal schedules, plans and specifications, staging sequence, and supporting engineering studies. KRRC will incorporate any recommendations with respect to the proposed project delivery method into its project documents, contractor selection process, and project management procedures.

Chapter 4: Design & Construction Risk Register

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4. DESIGN & CONSTRUCTION RISK REGISTER

4.1 Overview

This Section identifies construction risks (in the form of a risk register) and estimates their likelihood and consequences of occurrence, ranking those risks to determine which pose the greatest risk to the Project, and developing risk management strategies for the highest ranking risks. The risk register will be a living document prepared with the participation of the full project team (KRRC, consultants, stakeholders, etc.) eventually including the Design-Builder (DB) or Contractor. This draft plan is based on the Project as it has been described and developed in the Federal Energy Regulatory Commission (FERC) Definite Plan for Decommissioning (KRRC 2018) (Definite Plan).

The plan will be updated periodically by the full project team to add newly identified risks, and adjust risks that have been previously identified either upward or downward.

The risk register identifies design and construction risks as they are recognized throughout the duration of the Project. KRRC has assigned each identified risk its own unique Risk identification (ID) number and categorized into one of seven risk categories, which are described in further detail in Section 4.2. Risk ID numbers are not necessarily sequential, since they were derived from an initial broader list that may not have all moved forward. The register also includes specific information and data associated with each risk as follows:

- A description of the risk
- The root cause(s) of the risk
- The risk's relationship to the four phases of the Project
- The primary impact aspect of the risk
- The likelihood (probability) that the risk will occur
- A rating of the impact or consequence if the risk event occurred
- A risk score (rating) by combining the likelihood and related consequence
- A summary of risk management measures
- The assigned owner of the risk

As the risk register is further developed and implemented, responsible parties from the Owner and DB will be assigned to further define and implement risk management measures identified for each risk. As risks are avoided or mitigated, or as new relevant information is obtained, risk category, score and rating will be updated to reflect the latest information.

Since the risk register will evolve and KRRC will update it throughout the life of the Project, ongoing assessment and reporting will be necessary. Reporting and other continuing risk management activities are discussed in Section 4.8.

4.2 Risk Category

KRRC has categorized each risk into one of the following general categories:

1. Environmental – These are design and construction risks primarily related to environmental aspects of the Project. Environmental aspects and associated risks could involve existing or future biological, cultural or other environmental conditions/species, potential construction related effects such as air quality or noise, or potential downstream environmental effects.
2. Permitting – Risks that are primarily related to environmental compliance and permitting. This includes process-related considerations, requirements associated with compliance and acquisition of all necessary regulatory permits.
3. Design – These are risks primarily related to development of the project design and subsequent performance of associated Project features. Risks could involve performance failures as a result of incorrect assumptions or calculations, incomplete or inaccurate drawings and specifications, etc.
4. Procurement and Construction - Risks primarily related to the procurement of a DB or Contractor, and with actual construction of the Project including labor, equipment, material, existing conditions, subsurface conditions, site safety, etc. Procurement related risks could involve the procurement process and/or contract negotiation. Construction related risks could involve DB quality of work or production, as well as health and safety.
5. Operations and Maintenance - Risks primarily related to post-construction project performance and maintenance. The project team anticipates minimal long-term operations and maintenance requirements.
6. External - These are risks primarily related to events or conditions outside of the control of the Project, such as unforeseen site conditions, forces of nature (e.g. floods and wildfires), etc.
7. Organizational - These are risks primarily related to the project organization, governance and associated constraints such as financing/funding, access agreements, funding agreements, transfer agreements, etc.

4.3 Phases

Each identified risk will exist during particular phases of the Project. The Project phases include the following:

1. Planning: The period until KRRC selects a DB for implementation. Activities during the Planning phase include data collection, preliminary field investigations, preliminary design, permitting and regulatory consultation and application development, contract work packaging to define the

intended scopes of work to most efficiently achieve the project schedule and other project objectives, selection of the appropriate project delivery method for each contract work package, and procurement activities for selecting a DB for each work package. Such procurement activities will involve, depending on delivery method, development and preparation of the Requests for Qualifications and Proposals for a DB, evaluation of proposals, and negotiation of the associated contracts.

2. Design: Design is the period during which the detailed and final design of the Project is performed. Activities during this phase include field investigations for final design, final design, permitting activities, and regulatory review and approval of the final design documents.
3. Construction: The period during which construction activities to implement the final design actually take place. Activities during the Construction Phase include mobilization, preparation of the site, pre-reservoir drawdown construction activities, other early construction activities, dam and appurtenances demolition activities, followed by site restoration.
4. Post-Construction: The period following dam removal and site restoration.

The risk register shows each risk in relation to the four phases (see Figure 4.3-1 for example). Phases during which the risk could be realized are indicated by red, and earlier phases during which risk mitigation can be developed and implemented are indicated by yellow.

Risk ID	Risk Category	Phase	Risk Description	Root Cause(s)	Planning Phase	Design Phase	Construction Phase	Post-Construction Phase
19	Proc & Const	Construction	General changed field condition (geotechnical, existing utilities, hazardous materials, and biological resources) leads to redesign, project delays and/or cost overruns	Field condition differs from documented findings	M	M	A	
20	External	Construction	Wetter-than-expected weather during construction increases costs and causes delays	Climate change; Hydrology	M	M	A	

Note: M = period when management strategies are developed; A = period when risk may be actualized

Figure 4.3-1 Risk Register Phases Designation Example

4.4 Primary Aspect of Risk

For additional classification and subsequent data processing, KRRC categorized each identified risk as one of four primary risk aspects as follows:

1. Time: The consequence of the risk is greatest with respect to the project schedule.

2. Cost: The consequence of the risk is greatest with respect to the project budget.
3. Safety: The consequence of the risk is greatest with respect to the safety of workers and the public.
4. Environmental Impact: The consequence of the risk is greatest with respect to the environment.

Any risk will include more than one of the four aspects. The categorization by aspect is a tool to help assess the risk in these four different areas.

4.5 Risk Score and Rating

The risk score and rating is a function of the probability of the risk occurring and the consequence if the risk were to occur. Probability of occurrence is broken into five different categories to provide sufficient ranges of likelihood, as listed below:

- Probability Score of 5: Risk has a 60% or greater probability of occurrence, meaning it is very likely to occur
- Probability Score of 4: Risk has a 40 to 59% probability of occurrence, meaning it is likely to occur
- Probability Score of 3: Risk has a 20 to 39% probability of occurrence, meaning it is less likely to occur
- Probability Score of 2: Risk has a 10 to 19% probability of occurrence, meaning it is unlikely to occur
- Probability Score of 1: Risk has a less than 10% probability of occurrence, meaning it is very unlikely to occur

Consequence of the risk occurring is also broken into five different categories to provide sufficient ranges for the consequences of impact. Since impacts for various risks can apply to one or more aspects or categories, it can be difficult to quantify all risks using the same metric (e.g. cost increase in $, etc.). For that reason, engineering and management judgment is involved when assigning consequence of impact scores. A high level of coordination and collaboration among key project decision makers is necessary for assigning consequence of impact scores. Table 4.5-1 provides some general guidance on consequence of impact scores under aspect categories identified in Section 4.4.

The risk score is calculated by multiplying the probability of risk by the consequence of impact, and then categorizing or rating the risk as low, moderate, or high as shown on the risk score matrix in Table 4.5-2. As shown in the risk score matrix, any risk that has a consequence of impact score of 5 is categorized as a very high risk.

Table 4.5-1 Consequence of Impact Definition for Various Aspects

	CONSEQUENCE OF IMPACT				
PRIMARY ASPECT	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Time	No or little impact to schedule	Schedule delay of less than 3 months	Schedule delay of 3 to <6 months	Schedule delay of 6 to 12 months	Schedule delay of more than 12 months
Cost	<$1M	$1M-$5M	$5M-$10M	$10M-$30M	$30M-50M
Safety	No or little impact to public safety	Number of individuals exposed to minor safety risk less than 5	Number of individuals exposed to minor safety risk greater than 5	Number of individuals exposed to serious safety risk less than 5	Number of individuals exposed to serious safety risk more than 5, or any life threatening risk (1 or more)
Environmental Impact	No significant impact to any environmental resource	Short-term impact that is insignificant	Short-term impact that is significant. Long-term impact that is insignificant.	Long-term significant impact to non-listed species	Long-term significant impact to fisheries or listed species

Table 4.5-2 Risk Score and Ranking Matrix

Probability of Occurrence	5 (60-100%)	5	10	15	20	25
	4 (40-59%)	4	8	12	16	20
	3 (20-39%)	3	6	9	12	15
	2 (10-19%)	2	4	6	8	10
	1 (1-9%)	1	2	3	4	5
		1	2	3	4	5
		Consequence of Impact				

4.6 Risk Status

As the Project develops and is implemented, the status of identified risks will be assigned using the following codes:

1. Open: risks that continue to pose a threat for the Project. These are risks that may or may not have occurred that will not expire until some future date
2. Managed: risks which have had risk management measures implemented such that the likelihood of occurrence or consequences of occurrence has been reduced to a level that the Project can accept in the event the risk occurs
3. Expired: risks that may, or may not, have occurred but no longer pose a threat to the Project. When a risk expires, the probability becomes zero thereby making the risk score zero

4.7 Risk Strategy

During development and implementation of the Project, KRRC will assign the risk strategy to identified risks using the following codes:

1. Manage: Risk management seeks to reduce the likelihood of the risk occurring and/or the consequence of the risk, should it occur.
2. Avoid: Avoidance of the risk eliminates the likelihood of the risk occurring and/or the consequence of the risk, should it occur.
3. Transfer: Transference of the risk makes the risk either partially or completely another party's responsibility.
4. Accept: Acceptance recognizes that the risk cannot be fully managed, avoided, or transferred.
5. Shared: Shared risk means that the liability associated with the risk can be partially transferred (as described above), but certain aspects of the risk remain with the KRRC and will need to be managed, avoided or accepted.

4.8 Continuing Risk Management

As mentioned above, KRRC will update the risk register throughout the life of the Project, involving ongoing assessment and reporting. The project team will manage and track the risk register through all phases of the Project.

Once KRRC selects a DB, they will be required to develop their own risk register, which will focus solely on the design and construction phases of the Project.

4.8.1 Risk Workshops

Subsequent to the initial identification of risks, KRRC will conduct a series of risk workshops at strategic points throughout the Project duration. The goal of these risk workshops will be to further update and refine risks, conduct evaluations and explore mitigation opportunities, while engaging new partners in the Project and the risk management process. Possible times for subsequent risk workshops may include:

- After the CEQA Draft Environmental Impact Report public review period ends
- After the Board of Consultants 2018 review of the Definite Plan is complete
- Upon engagement of Progressive Design-Builder for design work
- After key permits are issued (e.g. FERC Surrender order)
- Prior to first commencement of significant construction activities
- Midpoint of construction, or prior to significant phase(s) of construction

4.8.2 Monitoring and Control

During each risk management meeting, the attendees will review status, risk score and risk management opportunities for all risks active in the current project phase. Output of the risk management meeting shall be an updated risk register for distribution.

Responsibilities for meeting facilitation and reporting are as follows:

Phase	Responsible	Draft to PM	Final Version
Planning	Owner's Project Manager	-	✓
Design	DB/CMAR Project Manager	✓	-
	Owner's Project Manager	-	✓
Construction	DB/CMAR Project Manager	✓	-
	Owner's Project Manager	-	✓

Project monthly progress reports will include a list of open risks, the status of associated risk management actions, and any changes to action completion dates. A narrative will explain any significant exceptions to risk management action completion dates. KRRC will report any new risks.

KRRC will not delete expired risks (i.e. those that have occurred but no longer pose a threat to the Project) – these will remain on the risk register as closed items, or they will be transferred to a register of expired risks for record purposes.

Planning & Design Phases

At a minimum, KRRC will complete quarterly updates throughout the planning phase, with more frequent updates likely required during the detailed design and construction phases.

Construction Phase

KRRC will hold routine risk management meetings at least once every two months. The owners assigned to risks in the current project phase will attend these meetings.

4.8.3 Closing Risk Registers and Lessons Learned

Closing risk registers involves documenting all managed risks and final impacts on the overall Project. Impacts include, but are not limited to, impacts on project costs and schedule. KRRC will similarly document monitored but unmitigated risks. This information will be available for use on future projects, and can be used to adjust severity and probability indices, better define risk tolerance levels and improve risk management efforts.

The PM will prepare a Lessons Learned Report when the risk register is closed. The primary focus will be to identify activities which were highly effective, effective, partially effective, or not effective, and to recommend ways to improve overall effectiveness for risk management activities.

4.9 Risk Register

The current risk register is included as Appendix A. Each risk is categorized by project phase, and the root cause of each such risk is identified. The risk register identifies the primary aspects of each such risk, as well as probability, impact and weight, and provides an overall ranking for each risk. The risk register identifies a strategy for managing each risk, and risk management measures, where appropriate. Finally, the risk register identifies the risk owner and the status of each risk. As noted above, the risk register will evolve and be updated throughout the life of the Project, involving ongoing assessment and reporting.

Chapter 5: References

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5. REFERENCES

KRRC 2018. Definite Plan for the Lower Klamath Project, Klamath River Renewal Corporation. June 2018.

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Attachment A Risk Register

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Risk ID	Risk Category	Phase	Risk Description	Root Cause(s)	Planning Phase	Design Phase	Construction Phase	Post-Construction Phase	Primary Aspect of Risk	Probability (P)	Impact (I)	Risk Weight (P x I)	Overall Rating	Strategy	Risk Management Measure	Risk Owner	Risk Status
11	Proc & Const	Planning	Bid process or result (if traditional DB) or RFP selection (if progressive DB) is protested	DB(s) not selected protest bid	A				Time	2 Unlikely (10-19%)	3 Moderate	6	Med	Manage	Develop fair bid evaluation process that is clearly defined in RFP; Consider bid preparation stipend: Clearly define bid protest process in RFP.	Owner	Open
12	Proc & Const	Planning	Procurement process fails to result in a contract	Negotiation of contract terms or price fails	A				Time	1 Very Unlikely (1-9%)	3 Moderate	3	Low	Manage	Use prequalification process that values similar experience in reaching cost agreements; Develop fair bid evaluation process that is clearly defined in RFP.	Owner	Open
16	Organizational	Design	Engineer's estimate lower than GMP for PDB or low bids for traditional DBB on smaller work packages	Project perceived as risky; Lack of competition	M	A			Cost	3 Less Likely (20-39%)	4 High	12	Med	Manage	Robust Engineer's estimate to include Monte Carlo analyses; Independent review of Engineer's estimate, Include adequate contingency for project risk; Utilize project delivery method that provides Contractor's progress cost estimates to control budget (PDB or CMAR). Close coordination and transparency on costs and associated assumptions during progress cost estimated prepared by DB or CMAR; Provide contract exit strategy that Owner can terminate for convenience and implement alternate delivery approaches.	Owner	Open
17	Proc & Const	Design	DB Designer/Contractor dispute leads to schedule delays and cost increases	Designer does not have sufficient budget or 'skin in the game'.	M	A	A		Time	2 Unlikely (10-19%)	3 Moderate	6	Med	Manage	Consider contractual measures to maximize design/contractor collaboration such as require Designer to be a partner rather than a subcontractor and provisions that oblige Contractor to continue work even when dispute arises.	PDB	Open
18	Proc & Const	Design	Failure to agree to GMP during detailed design (if PDB or CMAR delivery method)	Disconnect between DB and Owner		A			Time	2 Unlikely (10-19%)	4 High	8	Med	Share	Robust Engineer's estimate to include Monte Carlo analyses; Independent review of Engineer's estimate, Include adequate contingency for project risk; Utilize project delivery method that provides Contractor's progress cost estimates to control budget (PDB or CMAR). Close coordination and transparency on costs and associated assumptions during progress cost estimated prepared by DB or CMAR; Provide contract exit strategy that Owner can terminate for convenience and implement alternate delivery approaches.	Owner / PDB	Open
19	Proc & Const	Construction	General changed field condition (geotechnical, existing utilities, hazardous materials, and biological resources) leads to redesign, project delays and/or cost overruns	Field condition differs from documented findings	M	M	A		Time	3 Less Likely (20-39%)	3 Moderate	9	Med	Manage	Comprehensive field investigation and documentation.	Owner	Open
20	External	Construction	Wetter-than-expected weather during construction increases costs and causes delays	Climate change; Hydrology	M	M	A		Time	2 Unlikely (10-19%)	4 High	8	Med	Accept	Consider defining anticipated rain days in contract as a number greater than average; Contract requirement for contractor plan for wetter-than-expected weather.	Owner / Force Majeure	Open
21	External	Construction	Flows higher than expected during instream construction window leads to schedule delays	Unanticipated river flows	M	M	A		Time	2 Unlikely (10-19%)	3 Moderate	6	Med	Accept	Rigorous flow analyses during planning/design; Set performance requirement in contract (define return period of flow that contractor required to be prepared for).	Owner / Force Majeure	Open
22	External	Construction	Fire in watershed increases erosion and sediment	Lightning; Accidental; Arson; Combined with storm		M	A	A	Cost	2 Unlikely (10-19%)	3 Moderate	6	Med	Accept	Fire Management Plan has been developed and Contractor will be required to prepare their own Fire Management Plan.	Owner / Force Majeure	Open
23	External	Construction	Fire in watershed during construction causes construction delays	Lightning; Accidental; Arson; combined with storm		M	A		Time	3 Less Likely (20-39%)	4 High	12	Med	Accept	Develop and implement emergency response plan for fire management.	Owner / Force Majeure	Open
24	External	Construction	Earthquake damages temporary construction	Earthquake occurs near project	M	M	A		Cost	1 Very Unlikely (1-9%)	2 Low	2	Low	Accept	Consider specifying a contract defined design earthquake for temporary construction.	Owner	Open
25	Design	Construction	Design errors or omissions lead to Project delays or cost overruns	Design error.		M	A		Cost	3 Less Likely (20-39%)	2 Low	6	Med	Transfer	Comprehensive design review; proactive QA/QC.	Owner's Eng	Open
26	Proc & Const	Construction	Construction errors (quality control)	EOR fails to properly inspect or direct work in the field; QC failures	M		A		Cost	3 Less Likely (20-39%)	3 Moderate	9	Med	Transfer	Clear contract requirements; Owner review and enforcement of Contractor QA/QC Plan and rigorous Owner audit and spot testing to confirm results	PDB	Open
27	Proc & Const	Construction	DB unable to obtain construction permits (e.g. County encroachment permits) in time for construction	Poor planning, insufficient communication, difficulty negotiating requirements		M	A		Time	2 Unlikely (10-19%)	4 High	8	Med	Share	Owner coordination with Contractor for proactive communication with Counties; Contingency planning for delayed start during first year of construction	PDB	Open
29	External	Construction	Quantity overruns on earthwork, concrete demolition, etc.	Existing as-built data, exploratory data not adequate or accurate	M	M	A		Time	3 Less Likely (20-39%)	2 Low	6	Med	Accept	Obtain new topographic and bathymetric data for use by Designer and Contractor; Rigorous QA by Owner on design calculations and assumptions related to earthwork volumes	Owner	Open

Risk ID	Risk Category	Phase	Risk Description	Root Cause(s)	Planning Phase	Design Phase	Construction Phase	Post-Construction Phase	Primary Aspect of Risk	Probability (P)	Impact (I)	Risk Weight (P x I)	Overall Rating	Strategy	Risk Management Measure	Risk Owner	Risk Status
31	Proc & Const	Construction	Public safety at construction site	Public safety measures insufficient to keep out public	M		A		Public Safety	1 Very Unlikely (1-9%)	5 Very High	5	High	Share	Development of appropriate health and safety qualifications, experience and other requirements during the procurement process, as well as active overview and enforcement of the Contractor's health and safety and site security plans. No public access to work areas.	Owner's Eng / PDB	Open
32	Design	Construction	Copco lake reservoir rim or local slope failure along access roads	Slope instability, inadequate access road condition assessment prior to construction. Design analyses unable to be made for all geologic conditions and slope geometries; insufficient data		M	A		Time	2 Unlikely (10-19%)	4 High	8	Med	Share	Comprehensive field investigation and design review; Develop plan to address slope failures along Copco Road if they were to occur during reservoir drawdown.	Owner / PDB	Open
33	Design	Construction	Failure of temporary cofferdams result in demolition delays	Conservative design of cofferdams; unanticipated foundation conditions		M	A		Time	2 Unlikely (10-19%)	2 Low	4	Low	Transfer	Comprehensive field investigation, review of original construction, and design review	PDB	Open
34	Design	Construction	Dam or similar structure fails during drawdown	Failure mode not investigated or analyzed properly		M	A		Public Safety	1 Very Unlikely (1-9%)	5 Very High	5	High	Transfer	Rigorous detailed design analysis surrounding dam safety during drawdown; Completion of the FERC Potential Failure Modes Analysis process; Close coordination with the FERC regional office and state dam safety authorities; Implement FERC Emergency Action Plan, as appropriate.	PDB	Open
35	Env	Construction	Release of hazardous material (other than from construction equipment) to river during construction	Contractor activities result in unanticipated release of hazardous material into river	M	M	A		Envir Impact	1 Very Unlikely (1-9%)	5 Very High	5	High	Transfer	Completion of the Phase 1 hazardous material assessments and follow-up evaluations, appropriate health and safety qualifications, experience and other requirements during the procurement process, implementation of BMPs to avoid or contain the release of hazardous material, as well as active overview and enforcement of the Contractor's Hazardous Material Management Plan.	PDB	Open
36	Design	Construction	Reservoir sediment more difficult to access than anticipated, causing construction delays (restoration)	Lack of material properties understanding	M	M	A		Cost	2 Unlikely (10-19%)	2 Low	4	Low	Share	Comprehensive investigation and testing during planning and detailed design phase (with DB or Contractor input).	Owner / PDB	Open
37	Env	Construction	Special-status species presence delays construction	Unanticipated species found onsite cause stop work	M	M	A		Envir Impact	2 Unlikely (10-19%)	4 High	8	Med	Manage	Pre-construction surveys; Design planning; Require work areas to be cleared prior to nesting season; Proactive surveys for nesting activity during nesting season; Proactive nesting mitigation measures during nesting season.	Owner / PDB	Open
38	Env	Construction	Bald and Golden Eagle present within restriction buffer that delays construction	Did not identify birds prior to construction	M	M	A		Time	2 Unlikely (10-19%)	4 High	8	Med	Transfer	Additional surveys to identify nest locations in the years leading up to construction; Implementation of the avoidance and minimization measures identified in the Definite Plan; Effective transfer of risk through Contract terms to Design-Builder.	PDB	Open
39	Env	Construction	Loss of significant freshwater mussels in 1st year of demolition	Suspended sediment and bedload movement.			A		Envir Impact	3 Less Likely (20-39%)	3 Moderate	9	Med	Manage	Obtain latest research on relocation techniques and bring in industry experts during detailed design; Implement risk management measures.	Owner / Force Majeure	Open
40	Permit	Construction	Construction mitigation permit requirements not satisfied	Limited environmental mitigation measures available do not meet time and budget constraints		M	A		Envir Impact	3 Less Likely (20-39%)	3 Moderate	9	Med	Transfer	Coordination between Designer, Contractor, and permitting agencies; Satisfy permit requirements.	Owner / PDB	Open
41	Env	Construction	Unanticipated non-burial related cultural resources (foundations, barns, etc.) discovered during reservoir drawdown or construction (beyond current allowance)	Non-burial cultural resource not disclosed or already known about	M		A		Cost	2 Unlikely (10-19%)	2 Low	4	Low	Manage	Identification of existing cultural resources to the extent feasible; Ongoing coordination with Native American groups and local historical societies; Development of treatment measures that would implemented following drawdown or during construction	Owner / Force Majeure	Open
42	Env	Construction	Known cultural resource damaged during construction	Mitigation measures fail to protect resource	M		A		Cost	2 Unlikely (10-19%)	3 Moderate	6	Med	Manage	Identification of existing cultural resources to the extent feasible; Ongoing coordination with tribes and local historical societies to assess potential damage and identify measures.	PDB	Open
43	Env	Construction	Unanticipated human burial sites, human remains, or funerary items discovered within reservoir areas during reservoir drawdown - requiring cessation of construction activities for a long duration.	Burial site not disclosed or already known about	M		A		Time	2 Unlikely (10-19%)	4 High	8	Med	Manage	Identification of existing cultural resources to the extent feasible; Ongoing coordination with Native American groups and local historical societies; Development of an Inadvertent Discovery Plan, Monitoring Plan, and NAGPRA Plan of Action, and rapid response plan to address the possibility of burial sites becoming exposed during drawdown.	Owner / Force Majeure	Open

Risk ID	Risk Category	Phase	Risk Description	Root Cause(s)	Planning Phase	Design Phase	Construction Phase	Post-Construction Phase	Primary Aspect of Risk	Probability (P)	Impact (I)	Risk Weight (P x I)	Overall Rating	Strategy	Risk Management Measure	Risk Owner	Risk Status
44	Env	Construction	Unanticipated human burial site discovered during other construction activities - requiring cessation of construction activities for a short time (beyond current allowance)	Burial site not disclosed or already known about	M	M	A		Time	2 Unlikely (10-19%)	3 Moderate	6	Med	Manage	Identification of existing cultural resources to the extent feasible; Ongoing coordination with Native American groups and local historical societies; Development of an Inadvertent Discovery Plan, Monitoring Plan, and NAGPRA Plan of Action to address the possibility of burial sites being discovered during construction.	Owner / Force Majeure	Open
45	Proc & Const	Construction	Reservoir drawdown impacts water quality more severely than anticipated causing project regulatory shutdown	Permit conditions and/or inadequate modeling of water quality; duration of drawdown extends past March due to extreme weather	M	M	A		Envir Impact	2 Unlikely (10-19%)	4 High	8	Med	Accept	Perform comprehensive water quality studies prior to construction; Implement risk management measures needed to comply with water quality requirements.	Owner's Eng / PDB	Open
46	Design	Construction	Reservoir drawdown and subsequent operation results in greater than anticipated erosion at bridges or along channel creating passage barrier	Local hydrodynamics result in greater than modeled erosion or scour	M	M	A	A	Cost	2 Unlikely (10-19%)	2 Low	4	Low	Accept	Comprehensive design review; Design additional scour protection for bridges if determined to be needed; Develop monitoring and mitigation plan for during and post reservoir drawdown.	Owner's Eng	Open
47	Proc & Const	Construction	Reservoir dewatering and subsequent operations have greater than anticipated effects on diversion intakes for irrigation/livestock	Greater than predicted suspended sediment and bedload movement	M	M	A	A	Cost	3 Less Likely (20-39%)	2 Low	6	Med	Share	Comprehensive field investigation and design review; Develop plan for monitoring/mitigating intakes during reservoir drawdown.	Owner / PDB	Open
48	Design	Construction	Reservoir dewatering and subsequent operation has greater than anticipated effects on groundwater wells	Difficult to investigate and analyze groundwater relationships		M	A	A	Cost	2 Unlikely (10-19%)	2 Low	4	Low	Share	Comprehensive field investigation and design review; Implement Groundwater Well Management Plan for evaluating changes in groundwater post-reservoir drawdown and proactively mitigate impacted wells.	Owner / PDB	Open
49	Env	Construction	Reservoir dewatering and subsequent operations have greater than anticipated effect on downstream channel aggradation/flooding	Evacuated coarse sediment is greater than anticipated leading to increased channel aggradation and associated flooding		M	A	A	Cost	3 Less Likely (20-39%)	3 Moderate	9	Med	Accept	Rigorous assessment on transport and flooding during detailed design; Monitoring post-drawdown; Raise awareness that active channel management program needed; Implement measures to manage channel aggradation and flood risk.	Owner	Open
50	External	Construction	Public safety risk in downstream channel during reservoir drawdown	Outreach and public safety measures insufficient to keep out public creating potential risk to public safety during drawdown (increased flows)	M	M	A		Public Safety	1 Very Unlikely (1-9%)	5 Very High	5	High	Manage	Comprehensive education and outreach plan; Detailed review and QA of safety program; Development of a Reservoir Dewatering Awareness Plan that will include procedures for notifying public of the schedule and anticipated flows for reservoir drawdown.	Owner / PDB	Open
51	Design	Construction	Slope failure blocks river or diversion intake	Upstream shell material less pervious than assumed in design; error in rapid-drawdown slope stability analyses; design analyses unable to be made for all geologic conditions and slope geometries; insufficient data	M	M	A		Envir Impact	2 Unlikely (10-19%)	5 Very High	10	High	Share	Comprehensive field investigation and design review; Develop slope monitoring plan for implementation during drawdown; Stockpile riprap for repairs of slope if local failures occur.	Owner / PDB	Open
52	Proc & Const	Construction	Copco No. 1 and/or Iron Gate Dam large gate procurements delay gate installation resulting in delay of reservoir drawdown	Design error; scheduling error; manufacturer requires additional information; construction error		M	A		Time	2 Unlikely (10-19%)	4 High	8	Med	Manage	Early detailed design; Early involvement of the Contractor to initiate gate procurement activities including input from the gate fabricator; Contractual milestones with liquidated damages; Early Contractor input including planning underwater work to modify/demo the existing Iron Gate Dam gate structure.	PDB	Open
53	Proc & Const	Construction	Copco. No.1 and Iron Gate Dam tunnel modifications are more difficult to construct causing schedule and cost overruns	Changed site condition or design omission	M	M	A		Time	3 Less Likely (20-39%)	2 Low	6	Med	Share	Comprehensive field investigation and design review; Early Contractor input as well as transparent Contractor progress cost estimates based on proven means and methods.	PDB	Open
54	Proc & Const	Construction	Copco No. 1 or Iron Gate Dam diversion gate malfunctions during drawdown resulting in delay of reservoir drawdown	Design or Construction error		M	A		Time	1 Very Unlikely (1-9%)	5 Very High	5	High	Transfer	Proactive QA/QC during design; Include backup systems for operating the gates in the design and construction including special inspections and testing of the gates prior to drawdown.	PDB	Open
55	External	Construction	Copco No. 1 and/or Iron Gate Dam diversion tunnel intake blocked by debris during drawdown reducing flow capacity	Debris within reservoir blocks intake		M	A		Envir Impact	2 Unlikely (10-19%)	3 Moderate	6	Med	Share	Maximizing the size of the intakes to match the size of the gates; Design debris grating for intake with ability to clear debris from grating.	Owner / PDB	Open
58	Proc & Const	Construction	Copco No. 1 concrete demolition production not adequate to meet project schedule	Inadequate equipment, staff, environmental issues, unfavorable weather			A		Time	2 Unlikely (10-19%)	3 Moderate	6	Med	Transfer	Contract requirements including milestones; Flexibility for 24-hr work 7 days per week; Obtain concrete cores for strength testing to inform DB assumptions regarding drilling and blasting; Early Contractor involvement to avoid shortages of labor and equipment.	PDB	Open
59	Proc & Const	Construction	Copco No. 2 cannot continue to generate power after January 2020	Insufficient water available in Klamath River or water quality too poor		M	A		Cost	2 Unlikely (10-19%)	3 Moderate	6	Med	Accept	Confirm allowable water quality for operation; Evaluate Klamath River flows for potential for too little water to better understand probability of occurrence.	Owner	Open

Risk ID	Risk Category	Phase	Risk Description	Root Cause(s)	Planning Phase	Design Phase	Construction Phase	Post-Construction Phase	Primary Aspect of Risk	Probability (P)	Impact (I)	Risk Weight (P x I)	Overall Rating	Strategy	Risk Management Measure	Risk Owner	Risk Status
60	Proc & Const	Construction	Iron Gate Dam 16.5-ft x 18-ft diversion gate cannot be installed due to as-built drawings of gate guides not matching existing conditions	Unable to survey gate slot until demo complete		M	A		Time	2 Unlikely (10-19%)	3 Moderate	6	Med	Share	Early gate fabrication and installation with sufficient float to allow time for gate modifications, if needed.	PDB	Open
63	Design	Construction	Iron Gate Dam embankment experiences slope failure of upstream shell during reservoir drawdown	Upstream shell material less pervious than assumed in design; error in rapid-drawdown slope stability analyses	M	M	A		Public Safety	1 Very Unlikely (1-9%)	4 High	4	Med	Share	Comprehensive field investigation and design review; Develop slope monitoring plan for implementation during drawdown; Stockpile riprap for repairs of slope if local failures occur.	Owner / PDB	Open
64	Proc & Const	Construction	Iron Gate Dam excavation production less than required to complete excavation by required date	Inadequate planning, equipment, staff, or unforeseen environmental issues, unfavorable weather			A		Public Safety	2 Unlikely (10-19%)	5 Very High	10	High	Transfer	Contractual milestones; Flexibility for 24-hr work 7 days per week; Higher cofferdams for planned breach; Early Contractor involvement to avoid shortages of labor and; Development and implementation by the Contractor of an effective FERC Emergency Action Plan (EAP).	PDB	Open
65	External	Construction	Iron Gate Dam or J.C. Boyle dam overtopped during excavation by storm water flows in excess of 100-year event resulting in dam failure	Climate change; increased variability in precipitation patterns	M	M	A		Public Safety	1 Very Unlikely (1-9%)	5 Very High	5	High	Accept	Require that the dam height during excavation not be less than needed to safely pass a 150-year event through the diversion tunnel; Completion of the FERC Potential Failure Modes Analysis process; Implement EAP, if necessary; Close coordination with the FERC regional office and state dam safety authorities.	Owner / Force Majeure	Open
66	Env	Construction	Iron Gate Hatchery shutdown due to inadequate water supply	New water supply or treatment facilities do not provide suitable supply for hatchery operations, resulting in lowered production	M	M	A	A	Envir Impact	3 Less Likely (20-39%)	3 Moderate	9	Med	Manage	Rigorous design of replacement supply; Pilot treatment technology; Proactive QA/QC during construction.	Owner	Open
68	Environmental	Post-Construction	Greater than anticipated effect on downstream biological resources	Effect of suspended sediment causes greater than anticipated impact to given species	M		A	A	Envir Impact	3 Less Likely (20-39%)	5 Very High	15	High	Manage	Develop appropriate aquatic resource measures through coordination with the regulatory agencies; Implement risk management measures to address effect on downstream resources.	Owner	Open
69	Environmental	Post-Construction	Limited recovery of fish species of concern	Fish recovery does not meet agency expectations	M	M	M	A	Envir Impact	2 Unlikely (10-19%)	2 Low	4	Low	Manage	Aquatic Resource (AR) measures included in Project.	Owner	Open
70	Environmental	Post-Construction	Bald and Golden Eagle net loss within 5 years of construction completion	Mitigation and rehabilitation measures provided insufficient protection				A	Envir Impact	3 Less Likely (20-39%)	4 High	12	Med	Accept	Proactively monitor species before and during construction; Implement additional risk management measures.	Owner	Open
71	Environmental	Post-Construction	Bat roosts do not meet success criteria requiring additional mitigation	Predictive model of bat roost effectiveness is incorrect	M	M	M	A	Envir Impact	2 Unlikely (10-19%)	1 Very Low	2	Low	Manage	Agency input into performance requirements in DB contract and design; Proactive QA/QC during construction.	Owner	Open
72	Environmental	Post-Construction	Habitat restoration goals not satisfied in field	Constructed project component does not meet agency expectations	M	M	M	A	Envir Impact	2 Unlikely (10-19%)	3 Moderate	6	Med	Transfer	Agency input into performance requirements in DB contract and design; Proactive QA/QC during construction.	PDB	Open
73	External	Post-Construction	Large seismic event up to design Maximum Credible Earthquake (MCE) occurs after project completion that results in blockage of Klamath River	Large seismic event causes catastrophic landslide or slope failure		M		A	Public Safety	1 Very Unlikely (1-9%)	2 Low	2	Low	Transfer	Develop clear design requirements for PDB contract; Work with dam safety authorities to set reasonable design criteria and associated durations.	Owner / Force Majeure	Open
78	Operational & Maintenance	Post-Construction	Unanticipated maintenance or repair required during regulatory monitoring and reporting period (e.g. plant establishment, tributary passage blockage, etc.)	Agency success criteria not met during post-construction period	M	M	M	A	Cost	3 Less Likely (20-39%)	3 Moderate	9	Med	Share	Development of management plans to clearly identify success criteria; Develop maintenance triggers and overall approval process; Comply with management plans.	Owner / PDB	Open
80	Proc & Const	Construction	J.C. Boyle Dam excavation production less than required to complete excavation by required date	Inadequate planning, equipment, staff, or unforeseen environmental issues, unfavorable weather			A		Public Safety	2 Unlikely (10-19%)	3 Moderate	6	Med	Share	Contractual requirements including milestones; Flexibility for 24-hr work 7 days per week; Higher cofferdams for planned breach; Early Contractor involvement to avoid shortages of labor and equipment.	PDB	Open
82	Env	Construction	Hydraulic oil or other hazardous material from construction equipment release to river during construction	Contractor mechanical equipment failure result in unanticipated release of hazardous material into river	M		A		Envir Impact	4 Likely (40-59%)	3 Moderate	12	Med	Transfer	Contractor required to develop a Spill Prevention, Control, Countermeasure (SPCC) Plan and active overview and enforcement of the SPCC Plan.	PDB	Open
87	Proc & Const	Construction	Plant pathogens reduce plants available for restoration work	Pathogens introduced at nurseries	M	M	A	A	Cost	3 Less Likely (20-39%)	2 Low	6	Med	Share	Contract requirements for nurseries and for care of plants; Quality Control/Quality Assurance.	PDB	Open
89	External	Construction	Reservoir ice impedes sediment flushing during reservoir drawdown	Ice on one or more reservoirs during drawdown might impede sediment erosion			A		Envir Impact	3 Less Likely (20-39%)	4 High	12	Med	Accept	None.	Owner / Force Majeure	Open
90	External	Construction	River channel locates in unexpected location during reservoir drawdown	Channel relocates on historic terrace rather than original channel			A		Cost	1 Very Unlikely (1-9%)	3 Moderate	3	Low	Accept	Contractor to develop a mitigation plan during design to move river into original channel.	Owner / Force Majeure	Open
91	External	Construction	Unknown fish passage barriers are found during drawdown	Unknown pre-existing barriers exposed during drawdown	M	M	A	A	Cost	4 Likely (40-59%)	1 Very Low	4	Med	Accept	Review of historic documents for evidence of barriers; Require Contractor to develop contingency plan to evaluate for barriers following reservoir drawdown and actions to remove barriers during dam removal.	Owner / Force Majeure	Open

Risk ID	Risk Category	Phase	Risk Description	Root Cause(s)	Planning Phase	Design Phase	Construction Phase	Post-Construction Phase	Primary Aspect of Risk	Probability (P)	Impact (I)	Risk Weight (P x I)	Overall Rating	Strategy	Risk Management Measure	Risk Owner	Risk Status
93	Permit	Planning	Western Pond Turtle becomes Federally listed during permitting process	Project effect on listed species	A	A	A		Time	4 Likely (40-59%)	3 Moderate	12	Med	Manage	Proactive coordination with appropriate regulatory agencies on likely requirements and associated field work; Address contingency in consultations.	Owner / Force Majeure	Open
95	Env	Construction	Unanticipated human burial site discovered between Iron Gate Dam and Humbug Creek during reservoir drawdown and post construction (beyond current allowance)	Burial site not disclosed or already known about exposed due to erosion of channel banks during elevated flows during drawdown.	M		A	A	Cost	3 Less Likely (20-39%)	2 Low	6	Med	Manage	Identification of existing cultural resources to the extent feasible; Ongoing coordination with Native American groups and local historical societies; Development of an Inadvertent Discovery Plan, Monitoring Plan, and NAGPRA Plan of Action, and rapid response plan to address the possibility of burial sites becoming exposed.	Owner / Force Majeure	Open
96	Env	Post-Construction	Weeds outcompete native plants and site restoration goals are not met	Proliferation of weeds	M	M	M	A	Cost	2 Unlikely (10-19%)	2 Low	4	Low	Share	Contract warranty period; Post-construction maintenance requirements in contract.	Owner / PDB	Open
97	Environmental	Construction	Northern spotted owl, bald eagle or golden eagle nests during construction period, requiring restrictions on construction timing and activity.	Bird creates new nest during construction.	M	M	A		Time	2 Unlikely (10-19%)	1 Very Low	2	Low	Accept	Monthly monitoring during breeding season.	Owner	Open
103	External	Planning	Differing Site Condition claim during Yreka Water Supply Pipeline Crossing Construction.	Adequate geotechnical subsurface information is not readily available. Unanticipated subsoil conditions are encountered or claimed to have been encountered during construction.	M	M	A		Cost	2 Unlikely (10-19%)	3 Moderate	6	Med	Manage	Conduct an adequate and thorough geotechnical exploration program in conformance with standard practice and describe subsoil conditions in terms of a geotechnical baseline report (GBR) and a geotechnical data report (GDR).	Owner	Open

Appendix B Figures – CONTAINS CEII – REDACTED

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Appendix C Figures – Other

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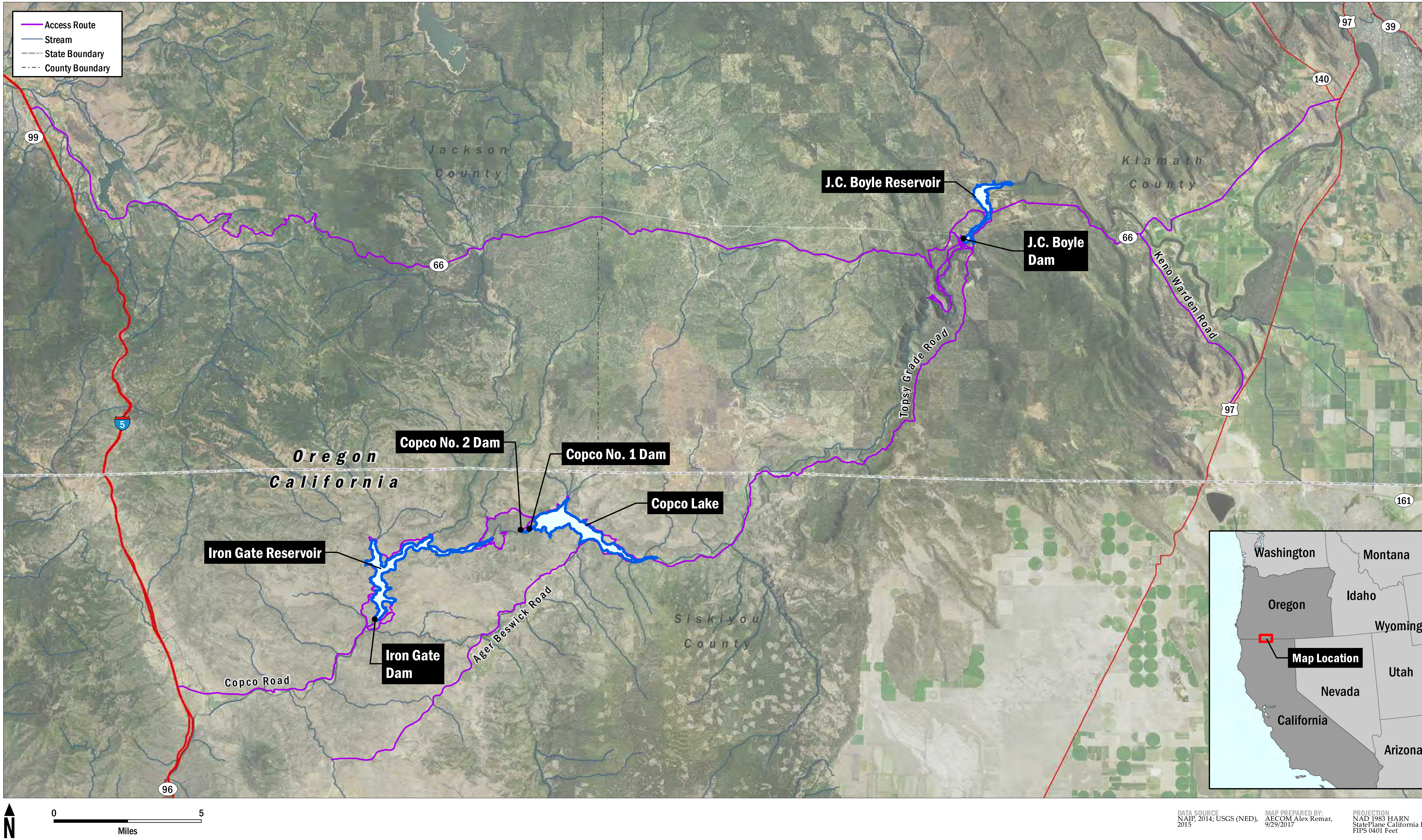

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 9/29/2017

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

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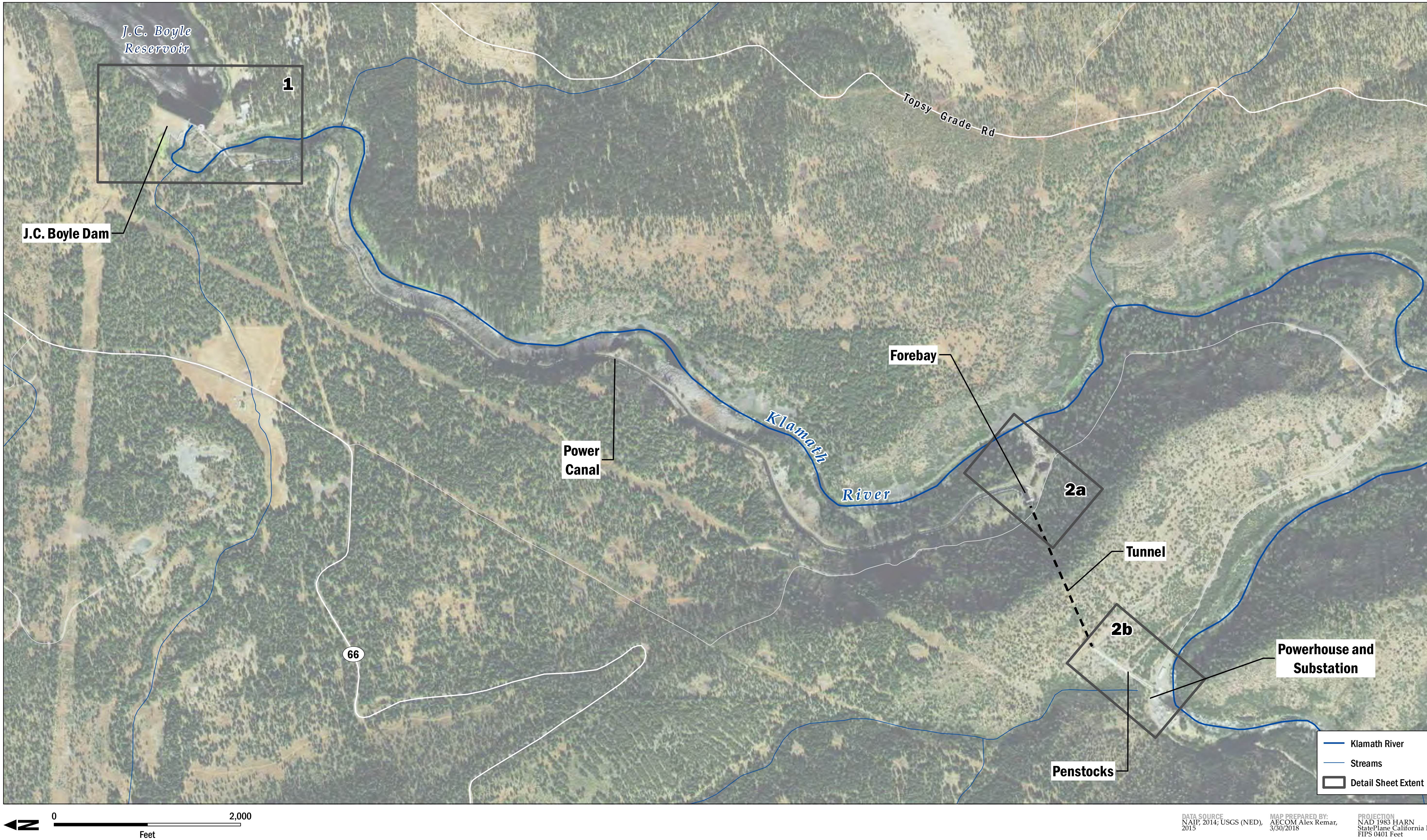
FIGURE 1.2-2
Project Vicinity and Access

AECOM Oakland CA 3/30/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_2_1-1__JCB_ExistingFeatures_Overview.mxd



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 3/30/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

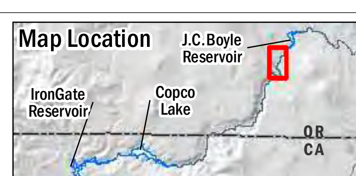
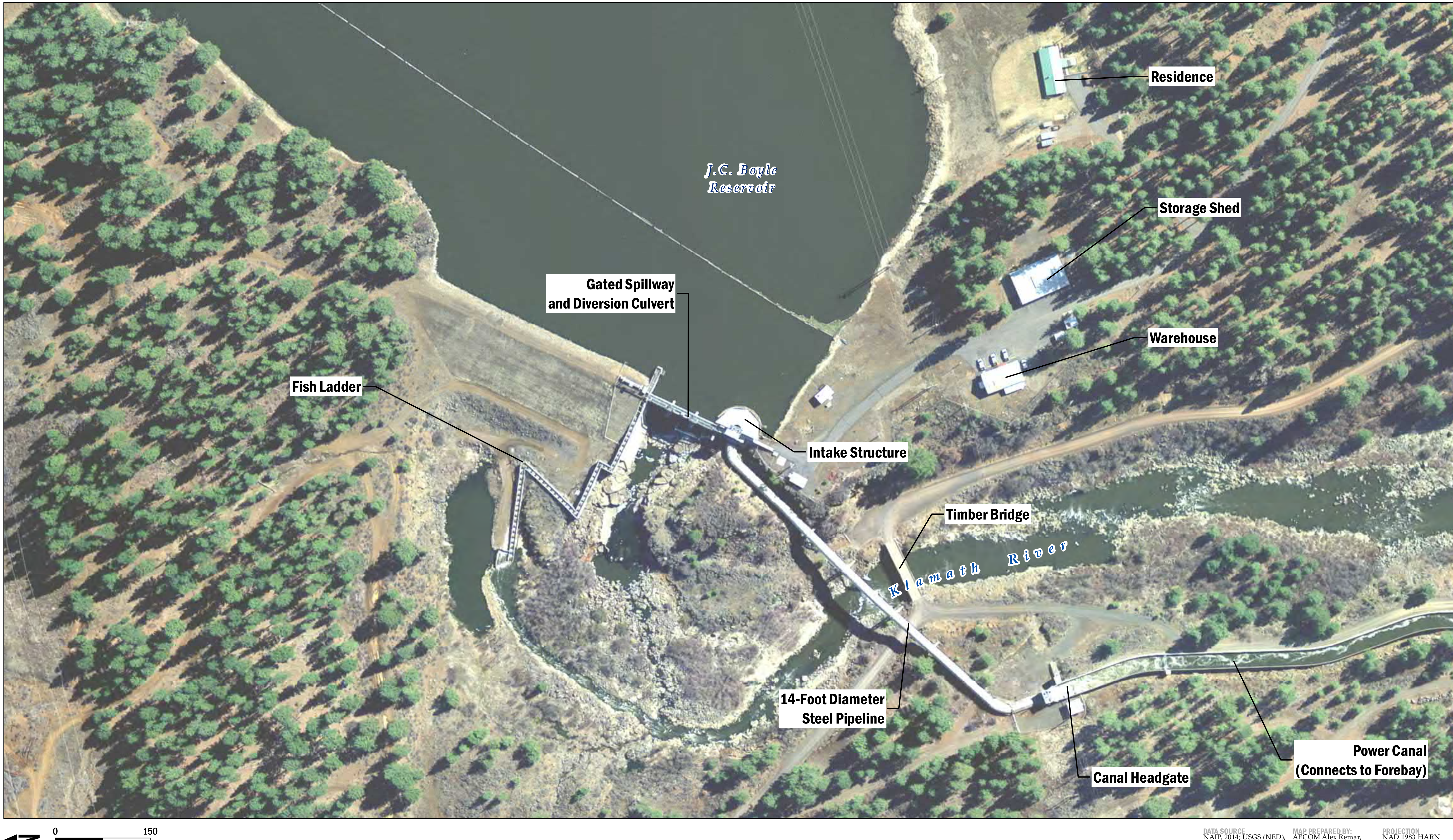


FIGURE 2.1-1
J.C. Boyle Dam Existing Features Overview Sheet

AECOM Oakland CA 9/29/2017 USER latha.chandrasekaran PATH L:\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\CEQA_Report\Figure_2_1-1__JCB_ExistingFeatures_Sheet1.mxd



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 9/29/2017

PROJECTION
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AECOM
Klamath River Renewal Corporation
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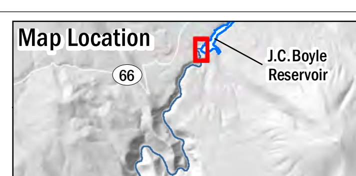

FIGURE 2.1-1

J.C. Boyle Dam Existing Features
Sheet 1 of 2

2A - FOREBAY AND SPILLWAY

2B - PENSTOCKS AND POWERHOUSE

0 150
Feet

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

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Klamath River Renewal Project

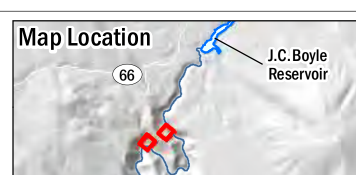
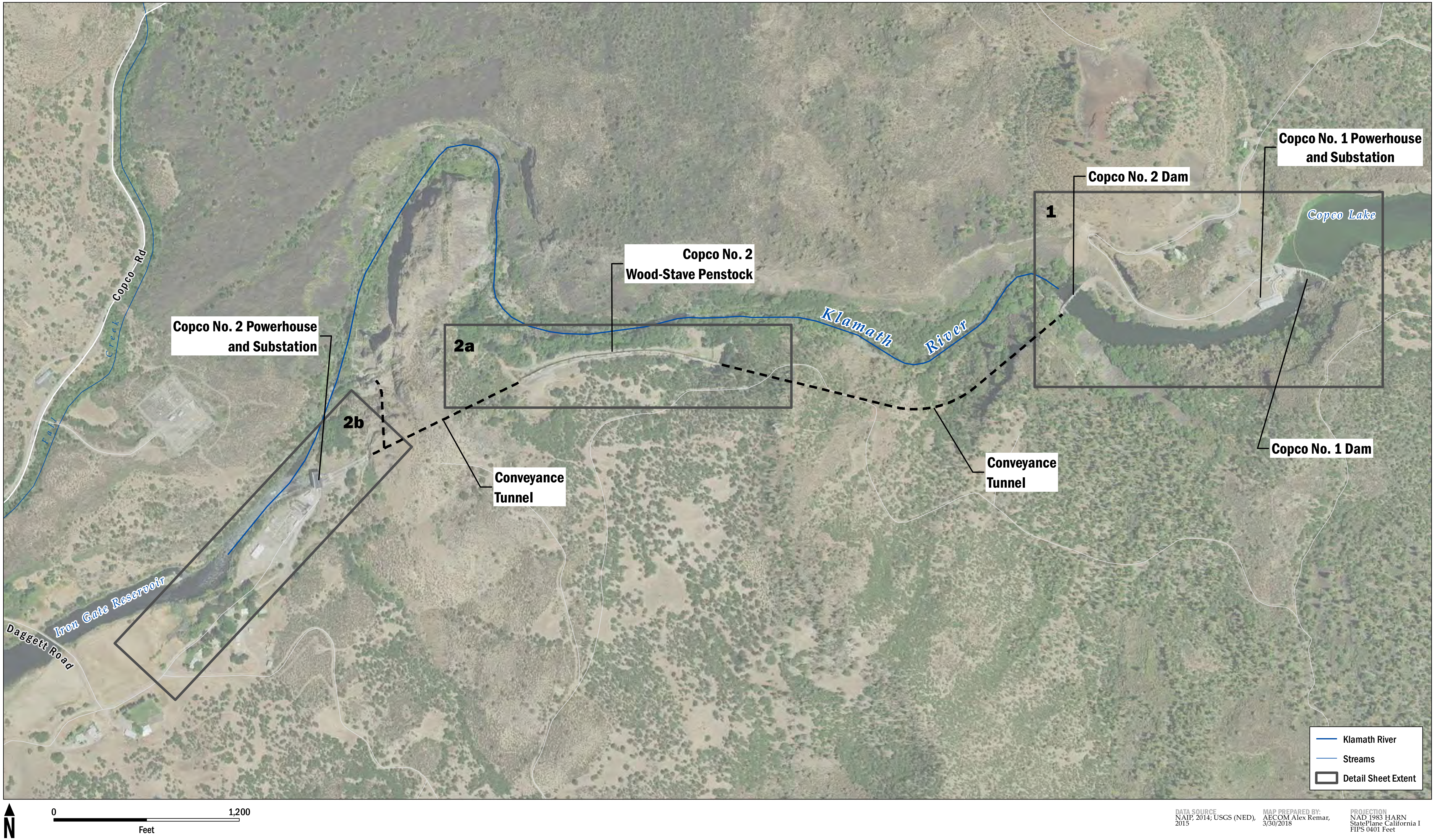


FIGURE 2.1-1

J.C. Boyle Dam Existing Features
Sheet 2 of 2

AECOM Oakland CA 3/30/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_2_2-1__Copco_ExistingFeatures_Overview.mxd



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 3/30/2018

PROJECTION
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Klamath River Renewal Project

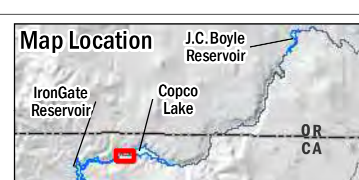

FIGURE 2.2-1

Copco No. 1 and Copco No. 2 Dams Existing Features Overview Sheet

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_2_2-1__Copco_ExistingFeatures_Sheet1.mxd

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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PROJECTION
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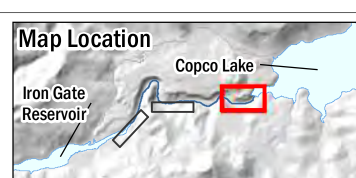

FIGURE 2.2-1

Copco No. 1 and Copco No. 2 Dams Existing Features
Sheet 1 of 2

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2A - COPCO NO. 2 WOOD-STAVE PENSTOCK

2B - COPCO NO. 2 POWERHOUSE

N

0 300

Feet

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

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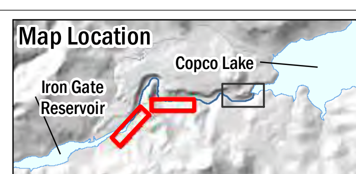
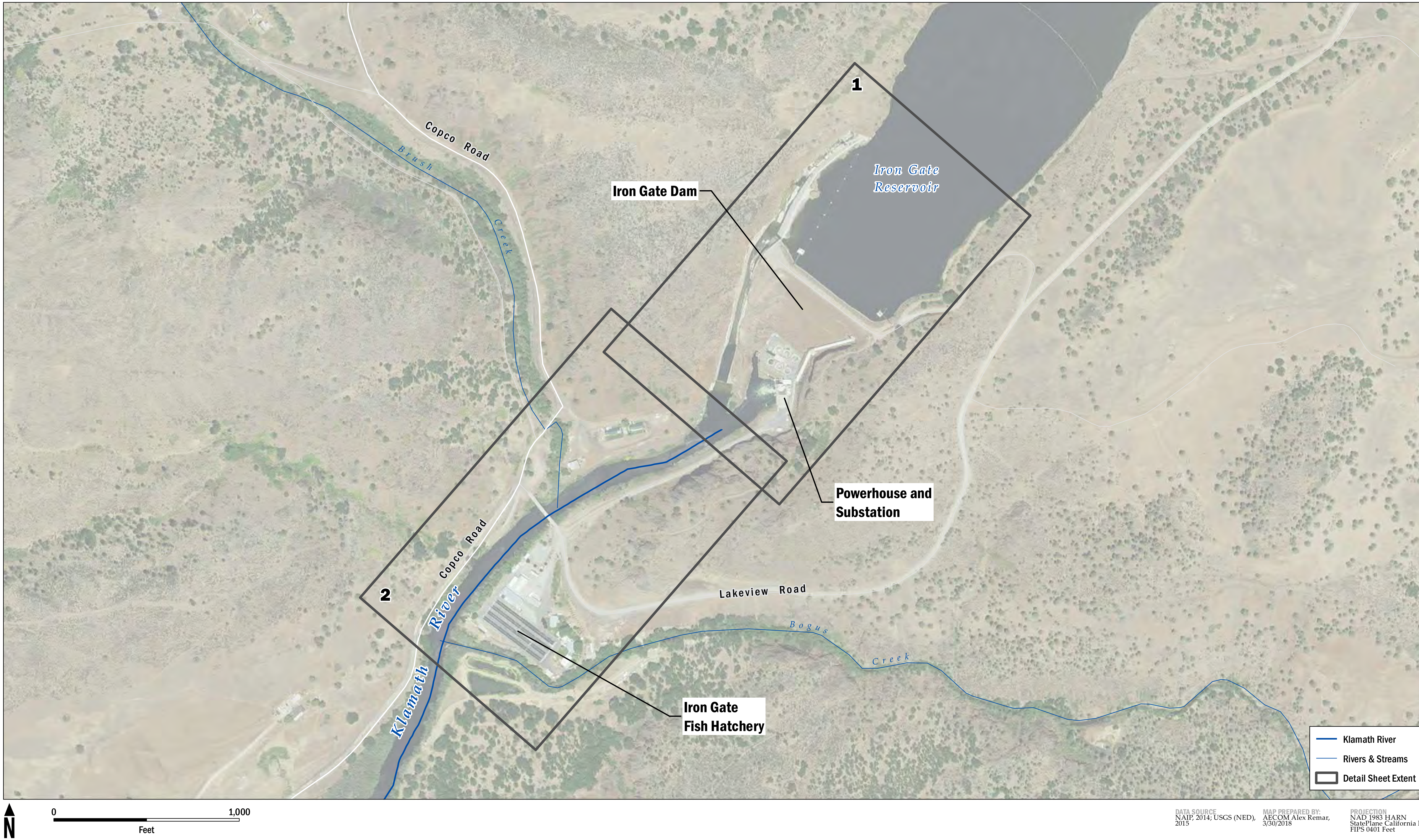


FIGURE 2.2-1

Copco No. 1 and Copco No. 2 Dams Existing Features
Sheet 2 of 2



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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PROJECTION
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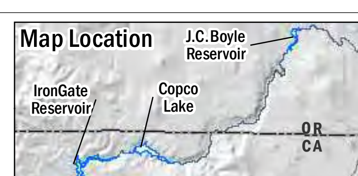
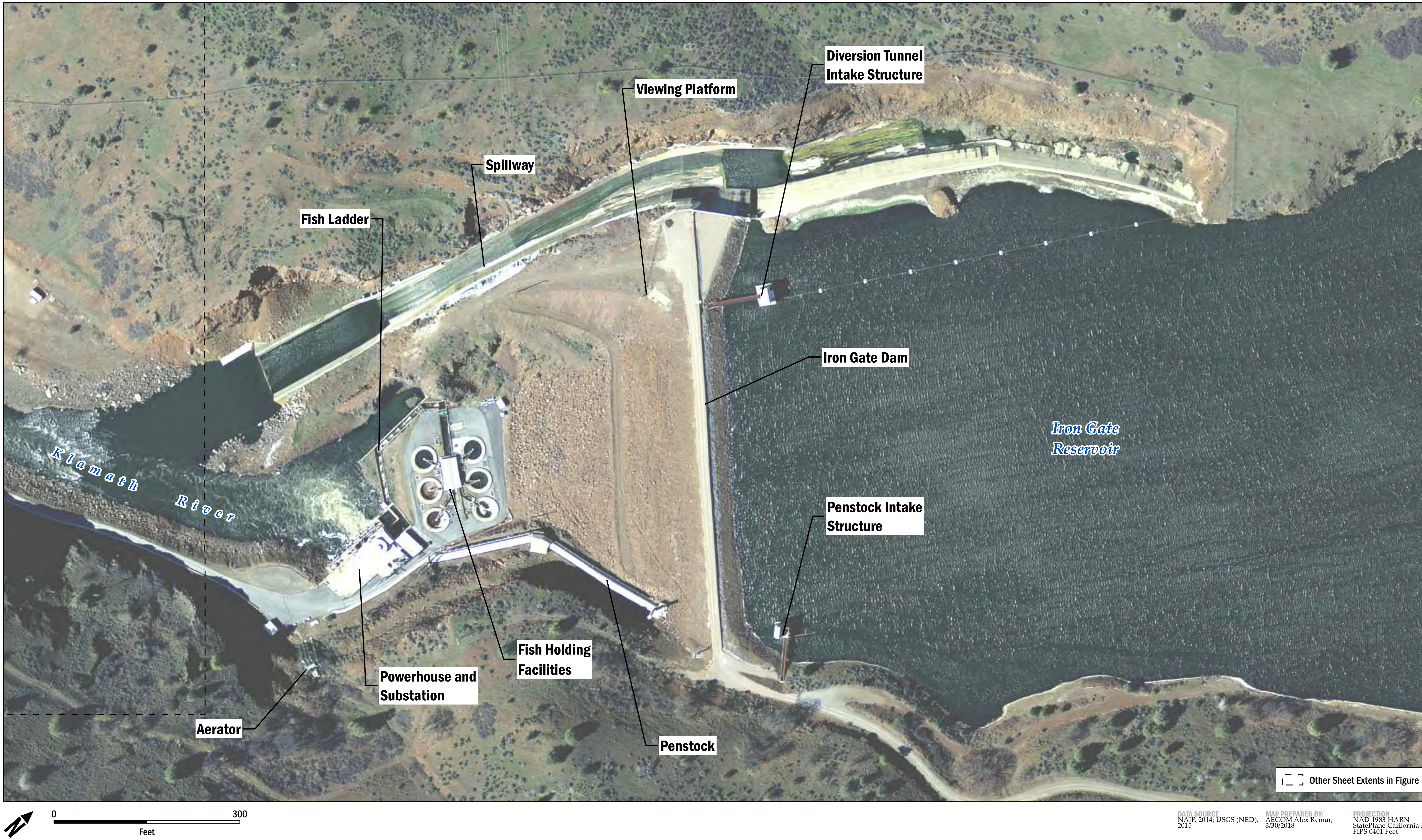


FIGURE 2.4-1
Iron Gate Dam Existing Features Overview Sheet



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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PROJECTION
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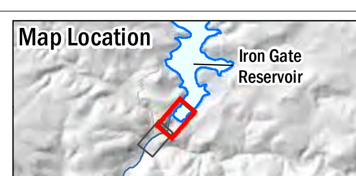

FIGURE 2.4-1
Iron Gate Dam Existing Features
Sheet 1 of 2

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
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Klamath River Renewal Project

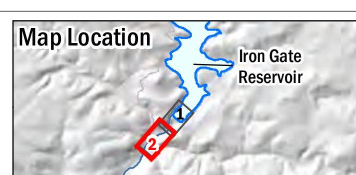
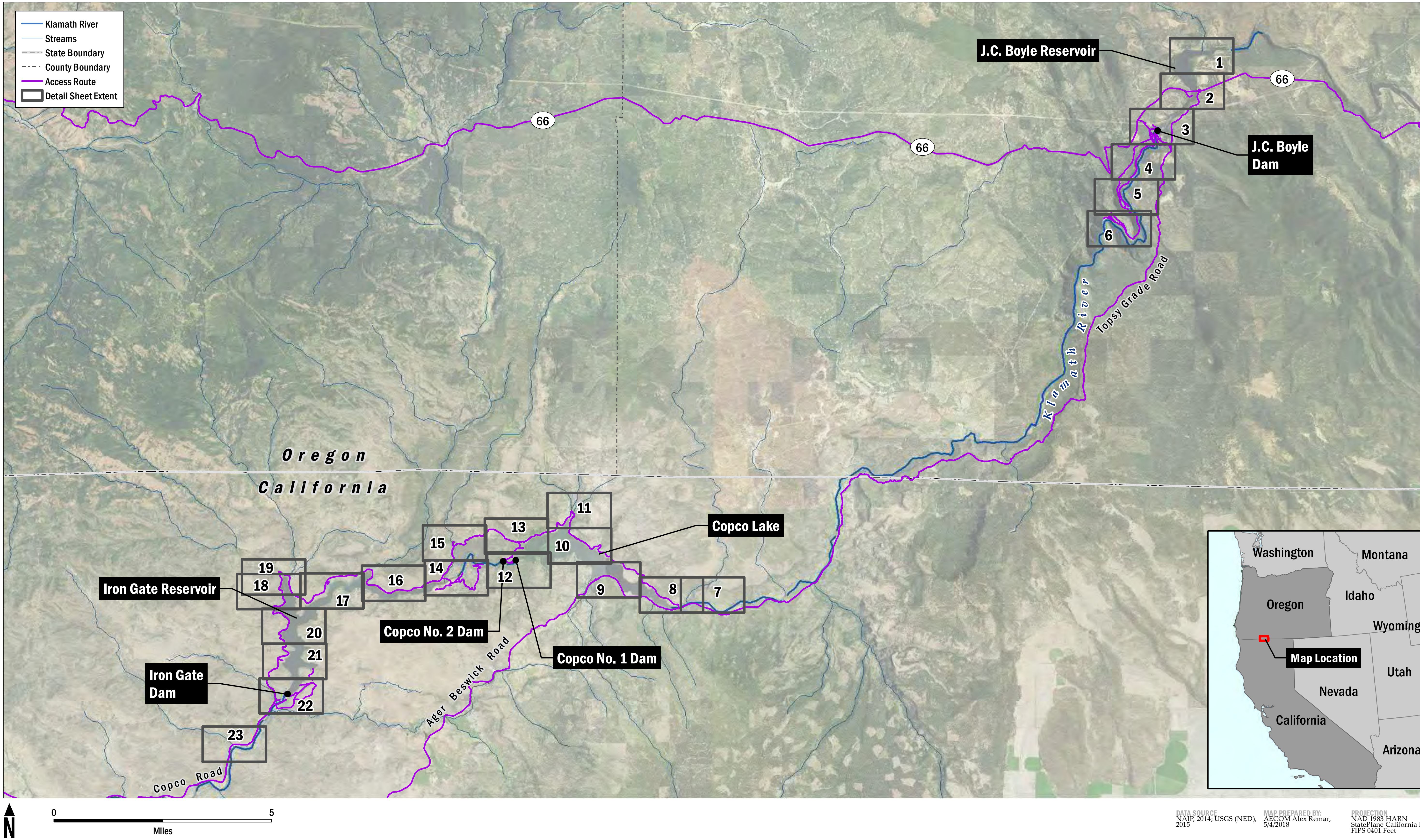


FIGURE 2.4-1
Iron Gate Dam Existing Features
Sheet 2 of 2



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

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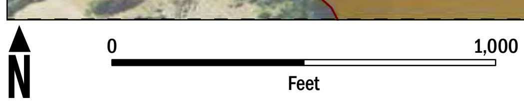
FIGURE 5.1-1
Project Limits of Work and Access
Overview Sheet

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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PROJECTION
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FIPS 0401 Feet

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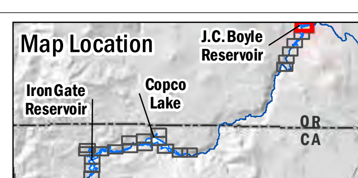
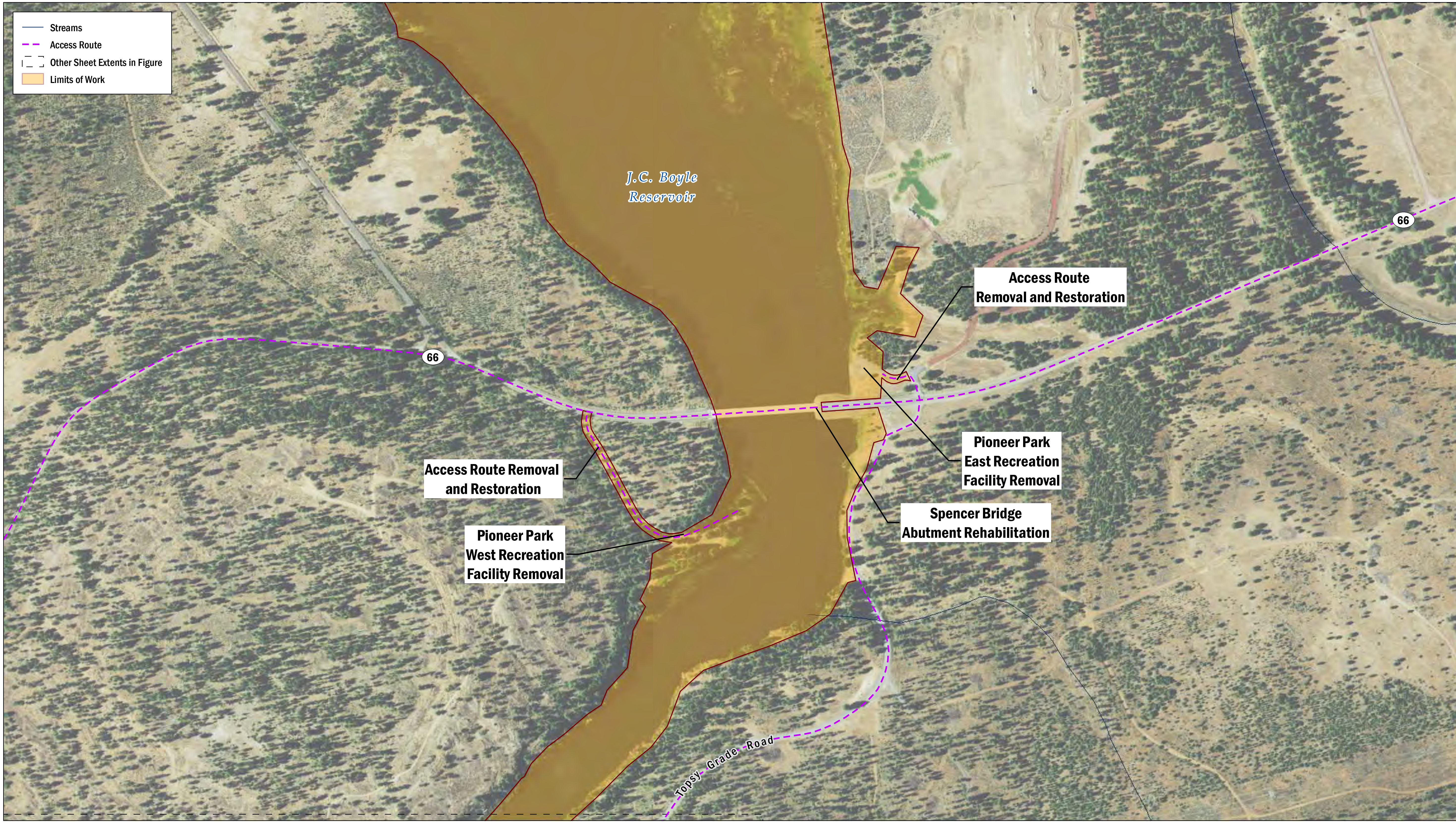


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 1 of 23



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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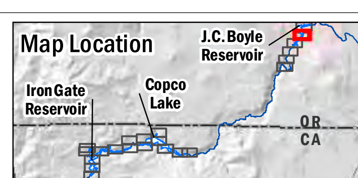
PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

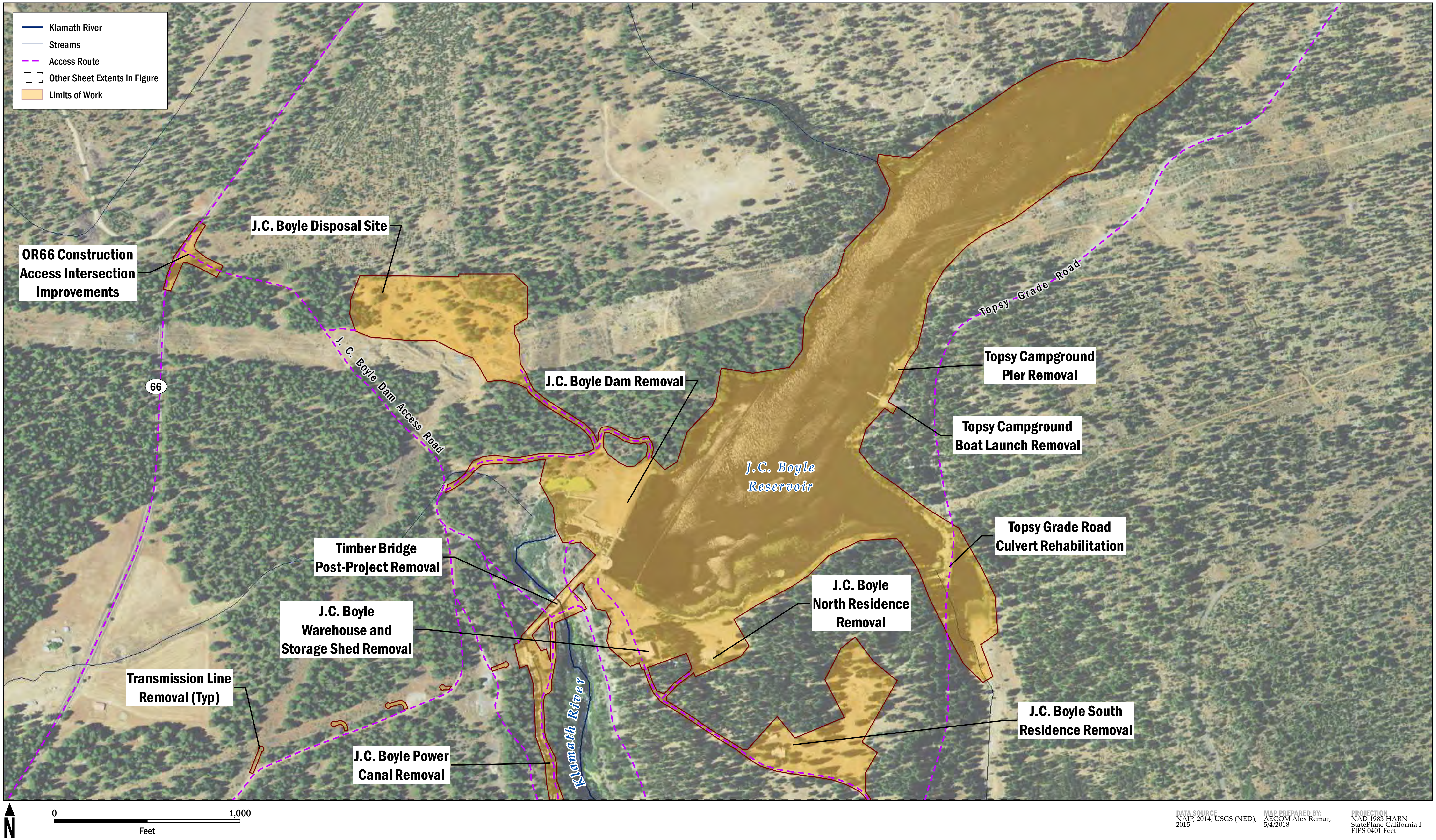
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 2 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

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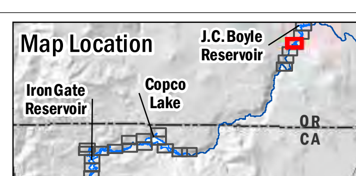
Klamath River Renewal Project

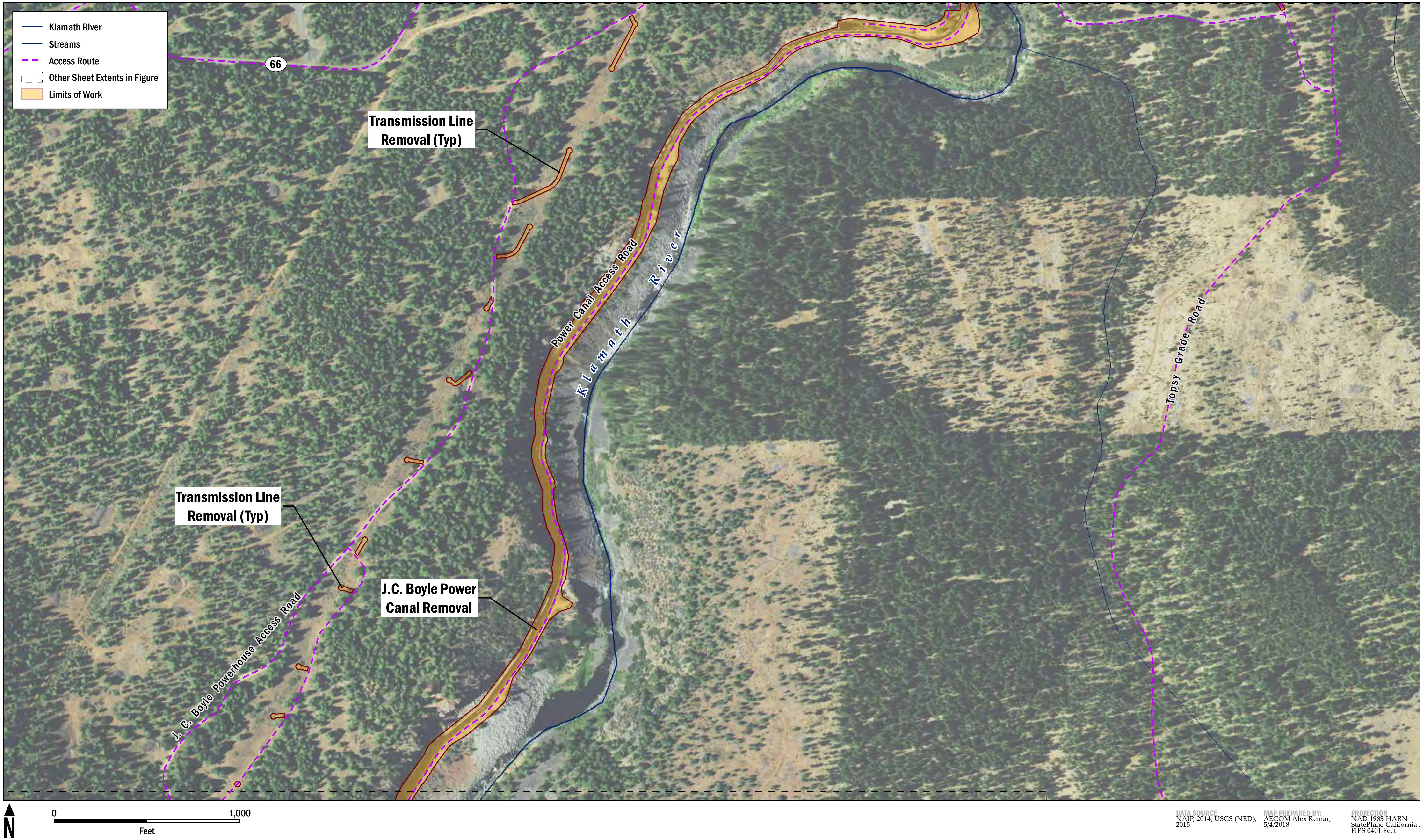


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 3 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

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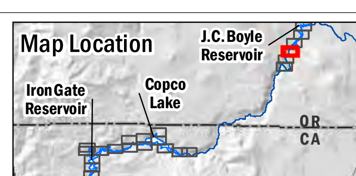
Klamath River Renewal Corporation
Klamath River Renewal Project

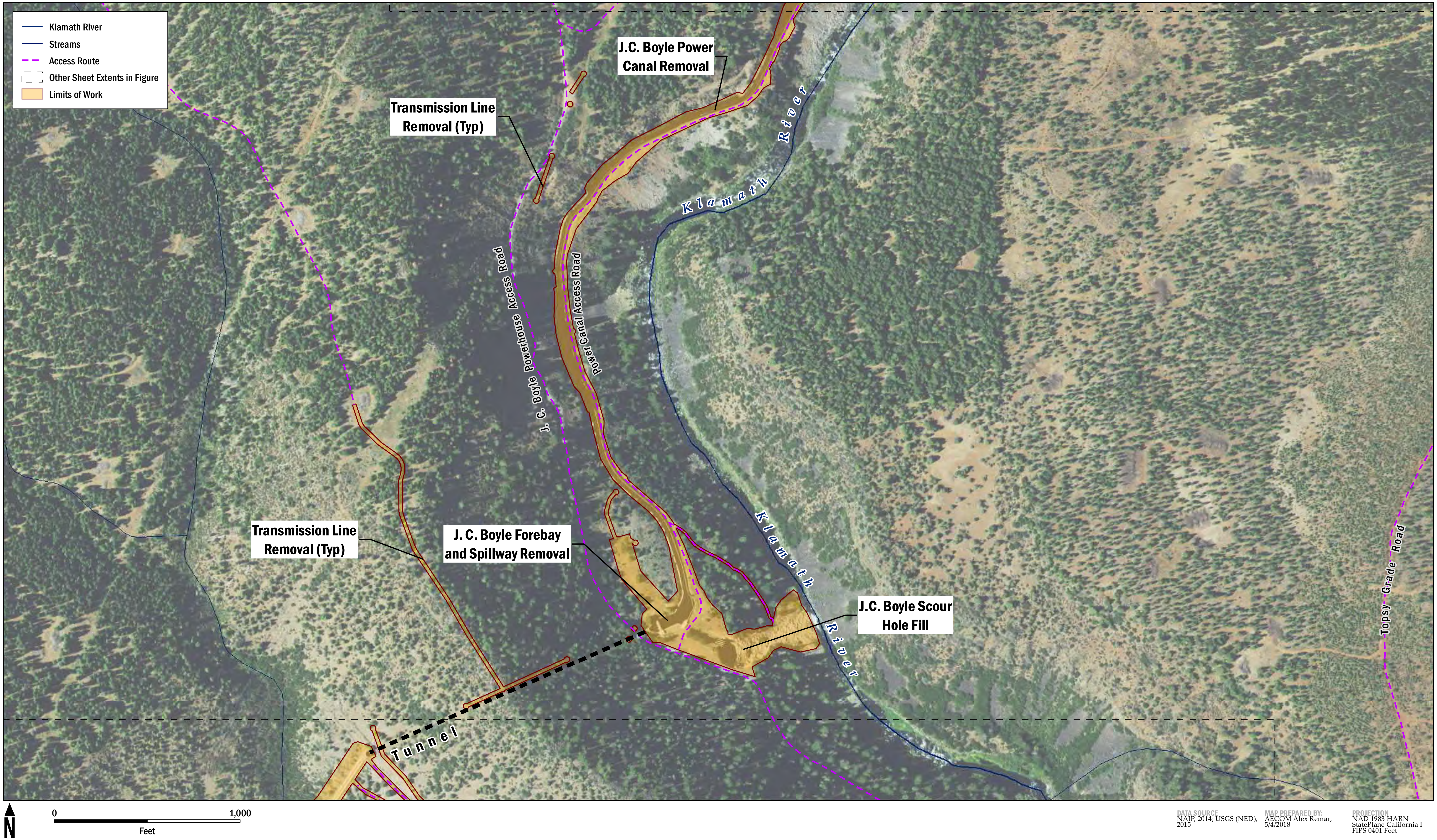


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 4 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

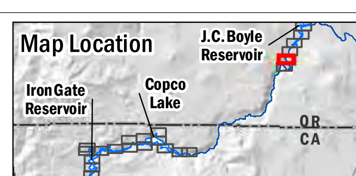


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

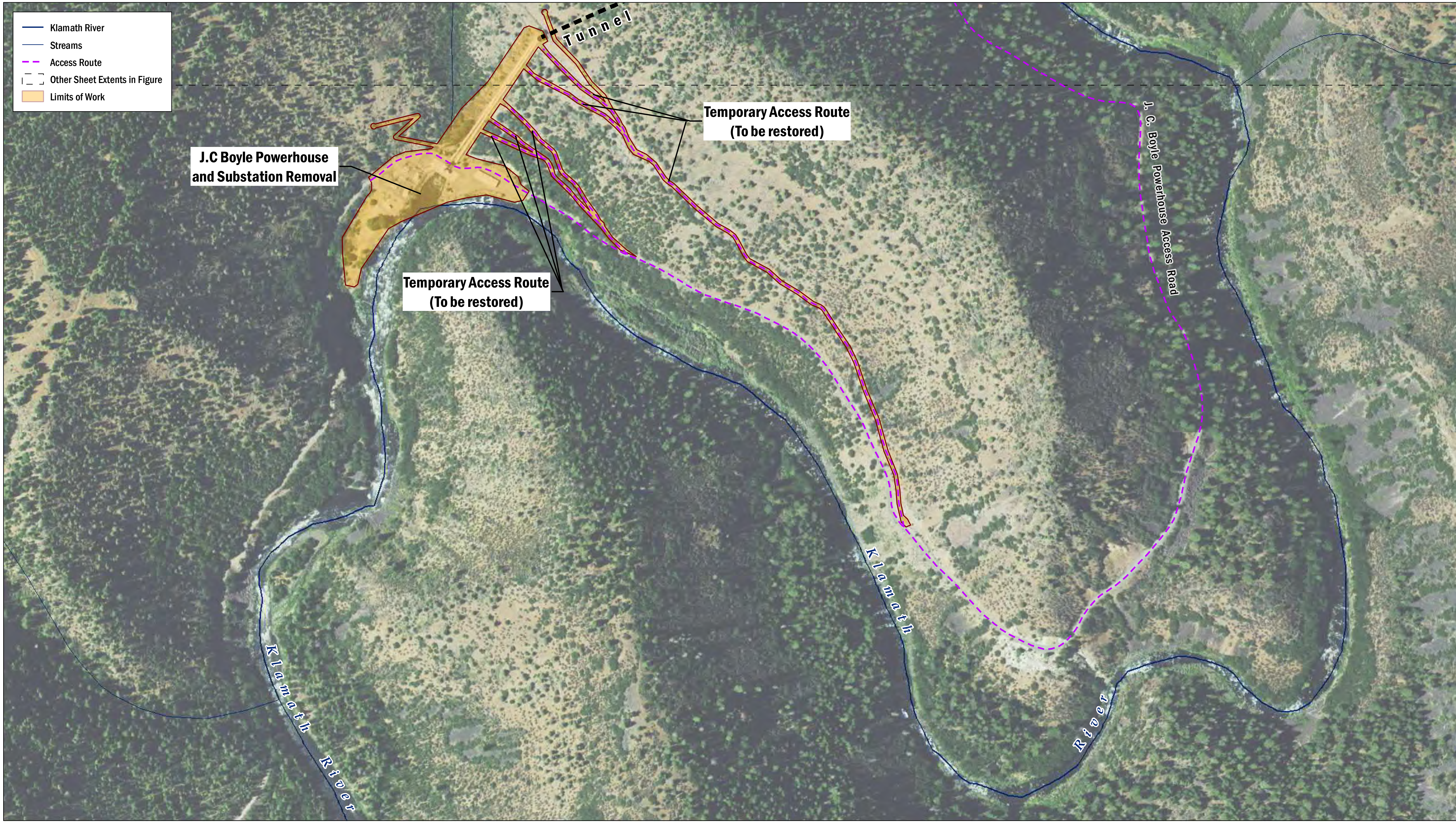
PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 5 of 23



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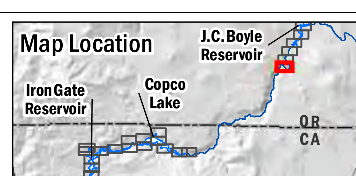
DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 6 of 23

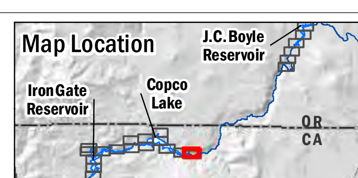
AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

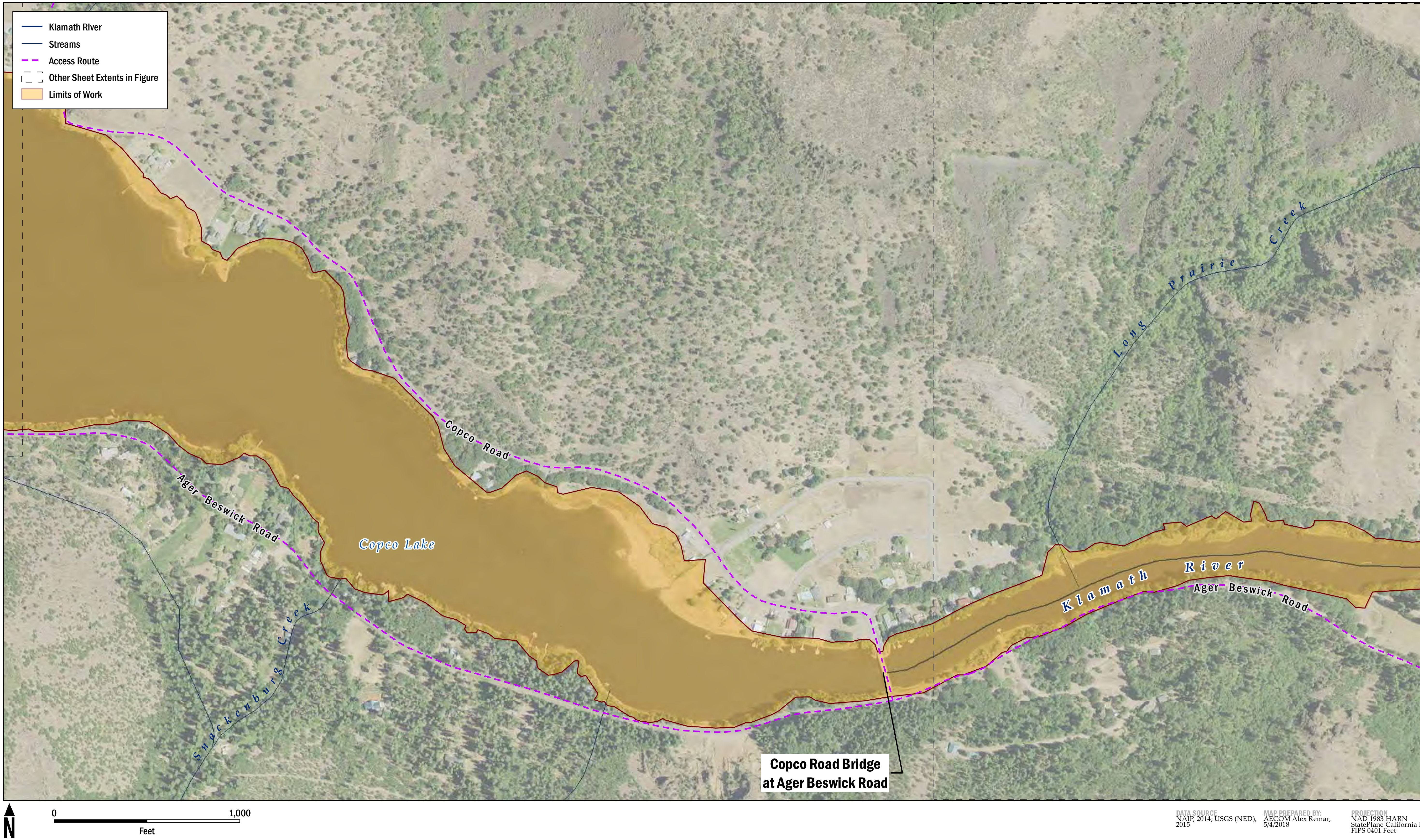
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 7 of 23

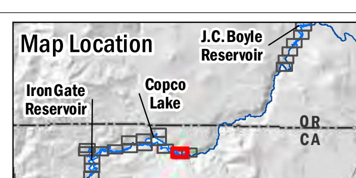


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

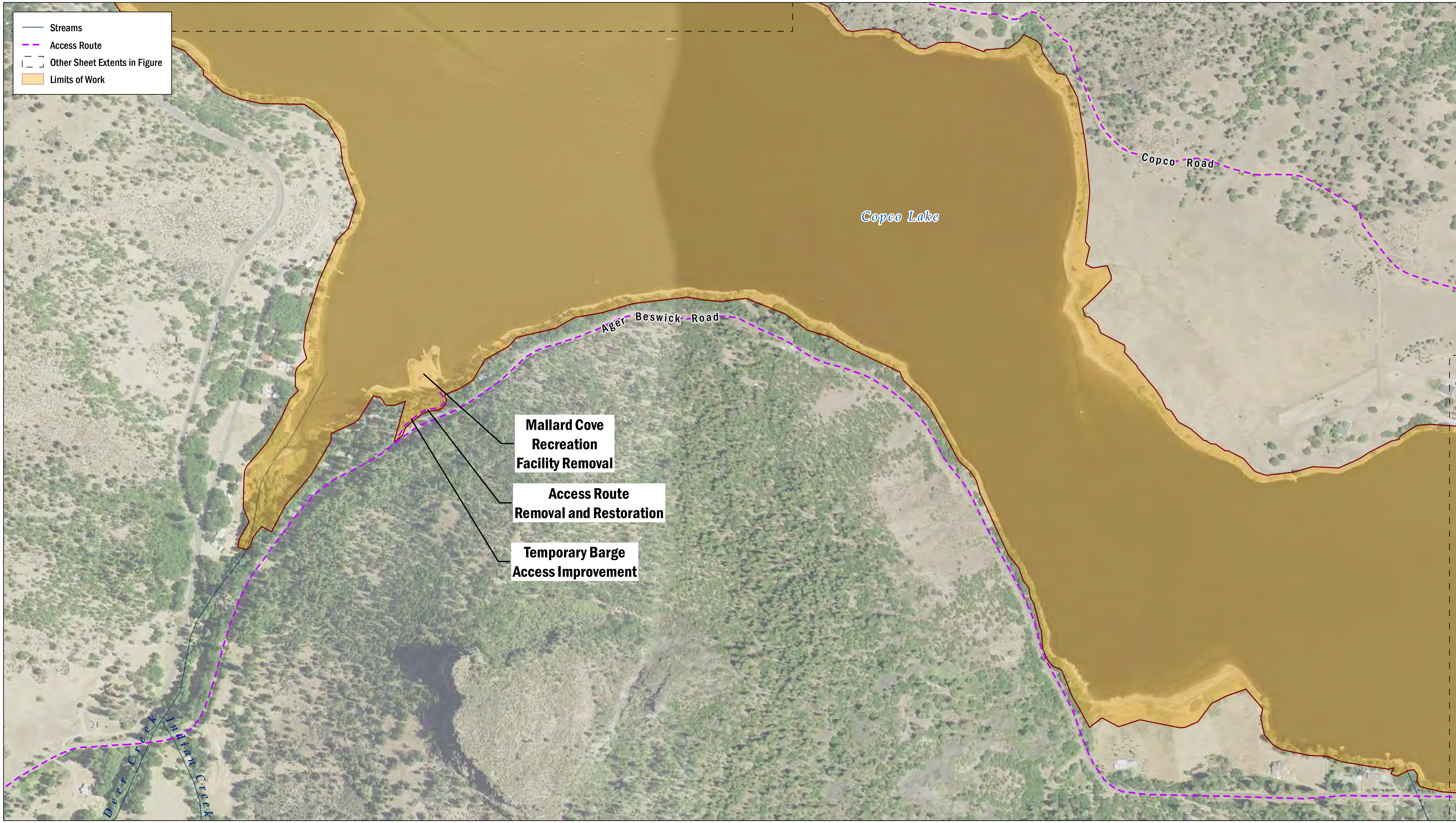


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 8 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd



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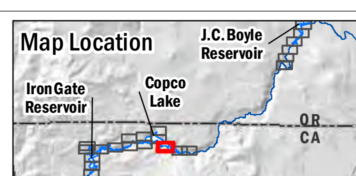
Feet

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

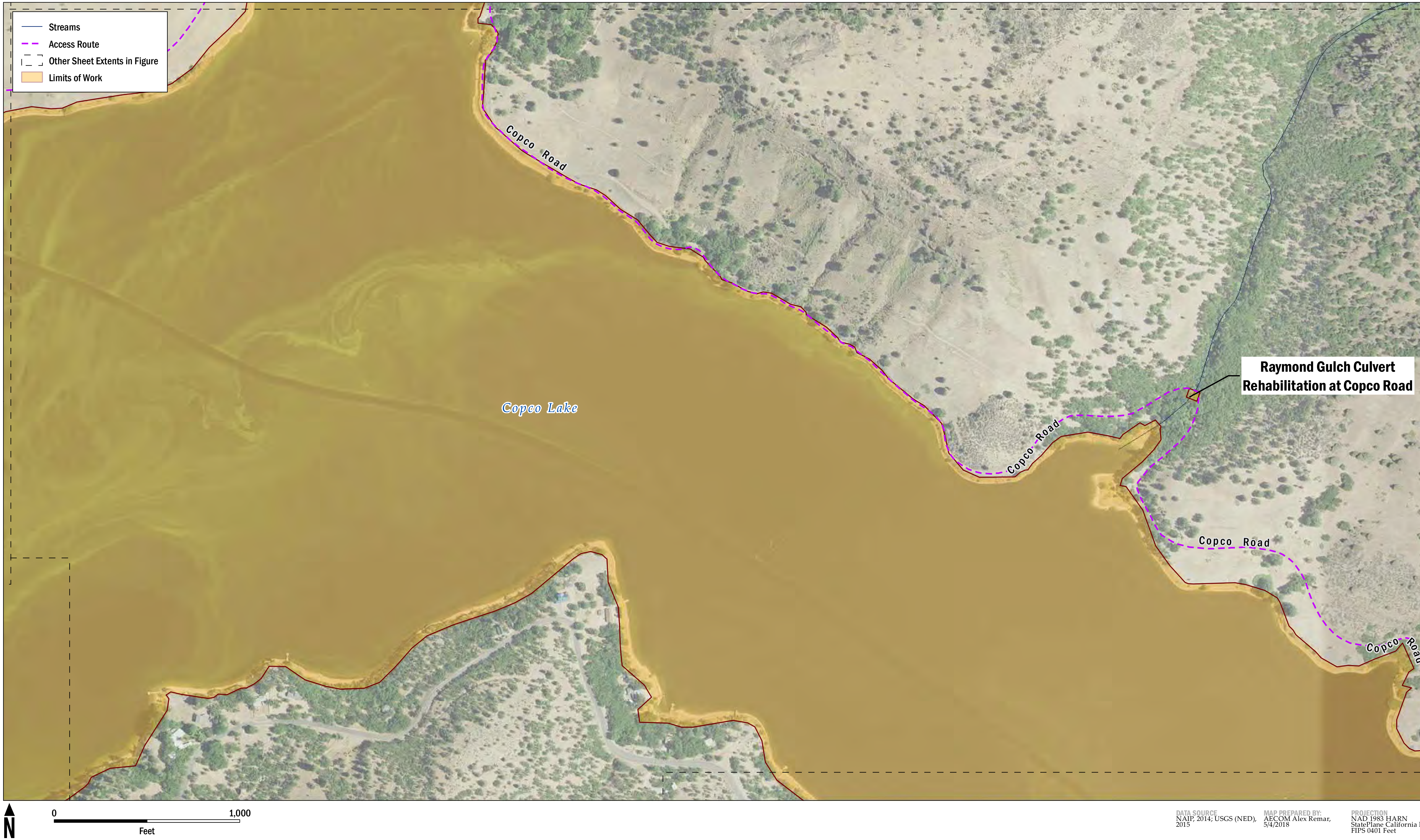


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access

Sheet 9 of 23

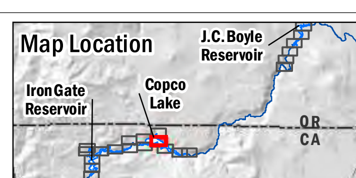


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

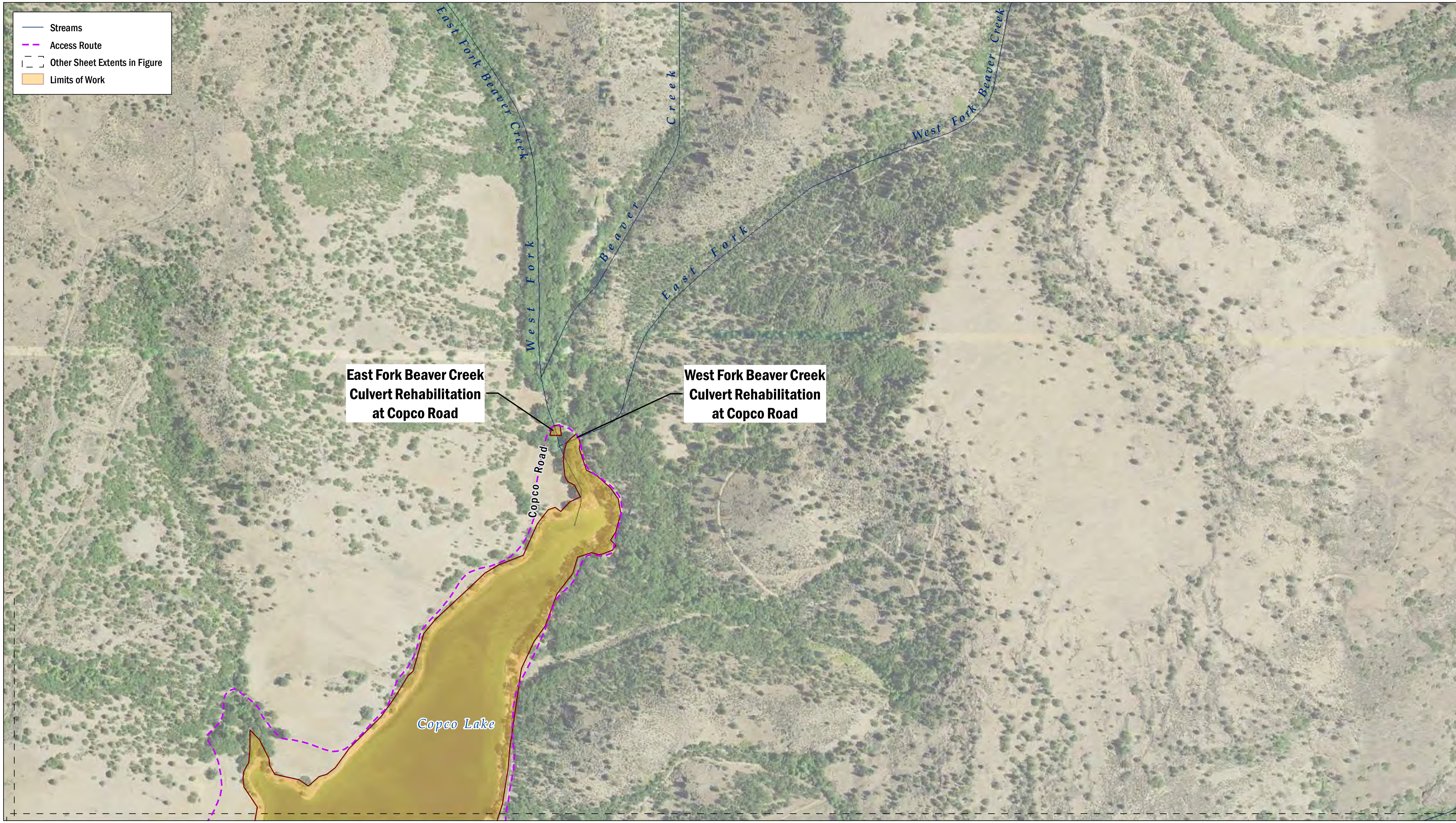
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 10 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd



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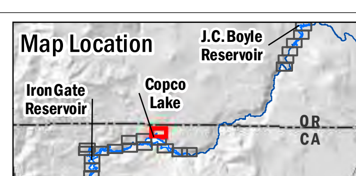
0 1,000
Feet

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

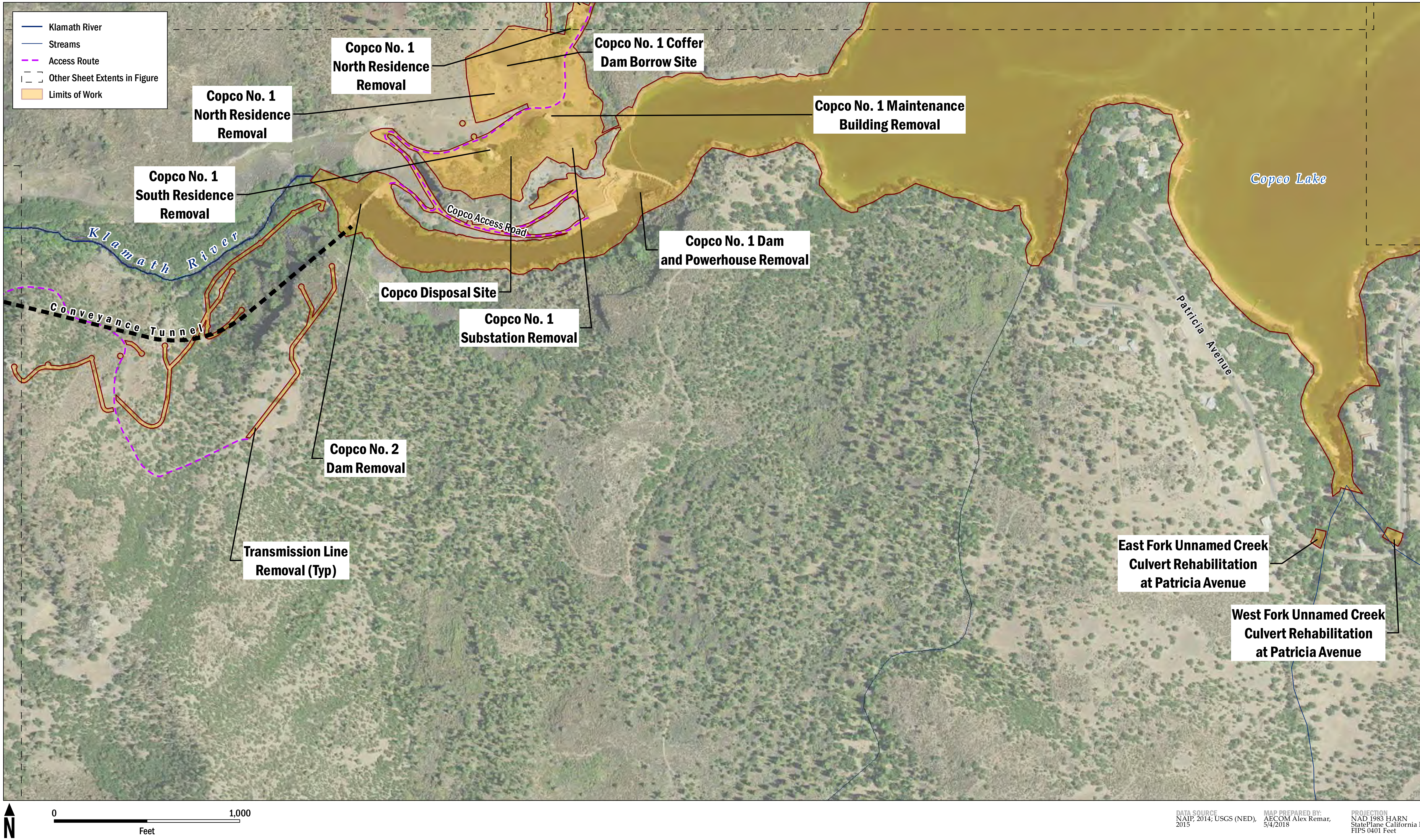
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 11 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

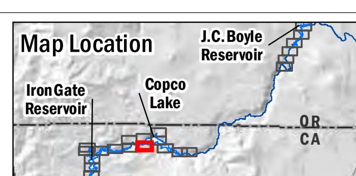


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

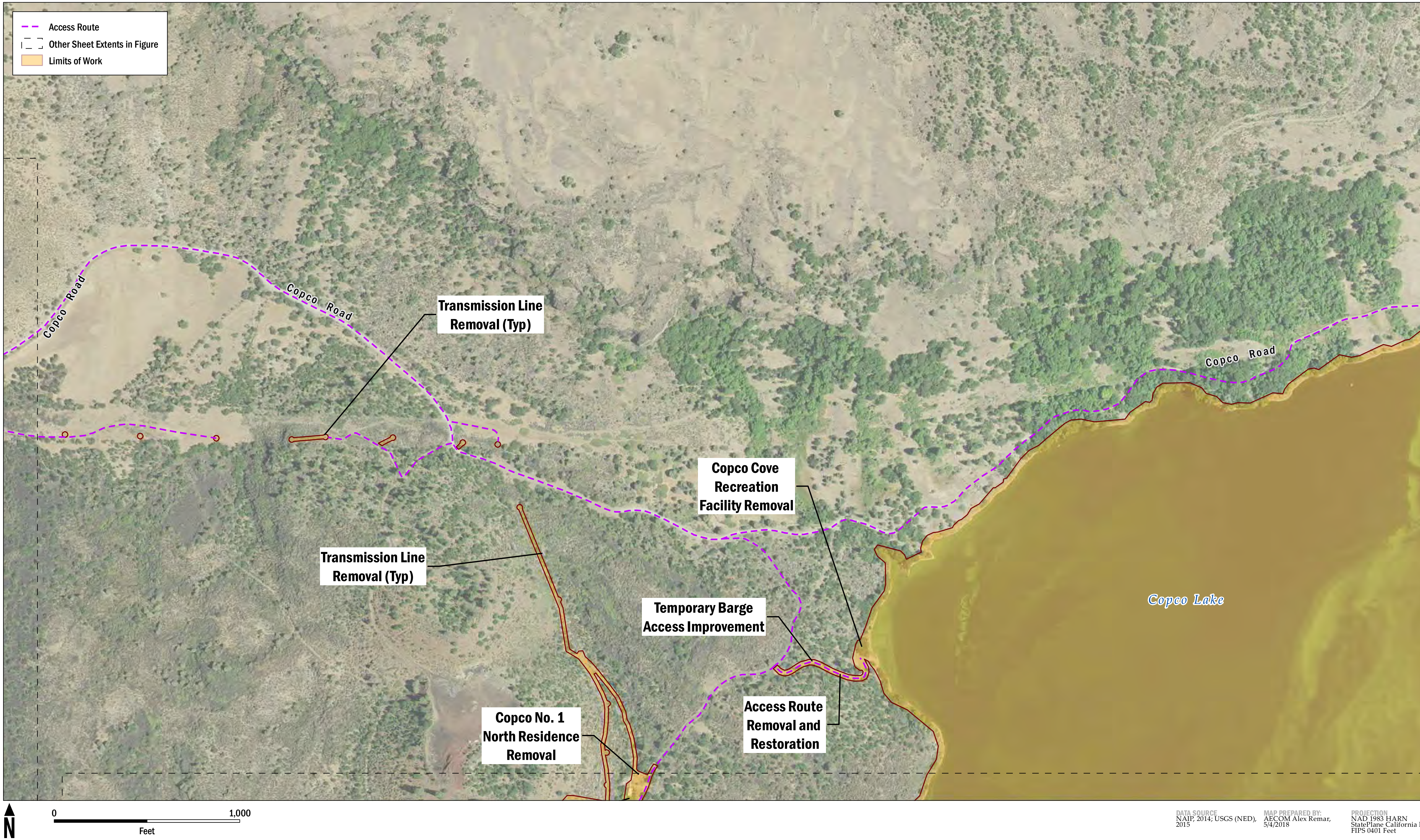


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 12 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

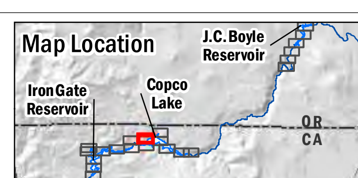


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

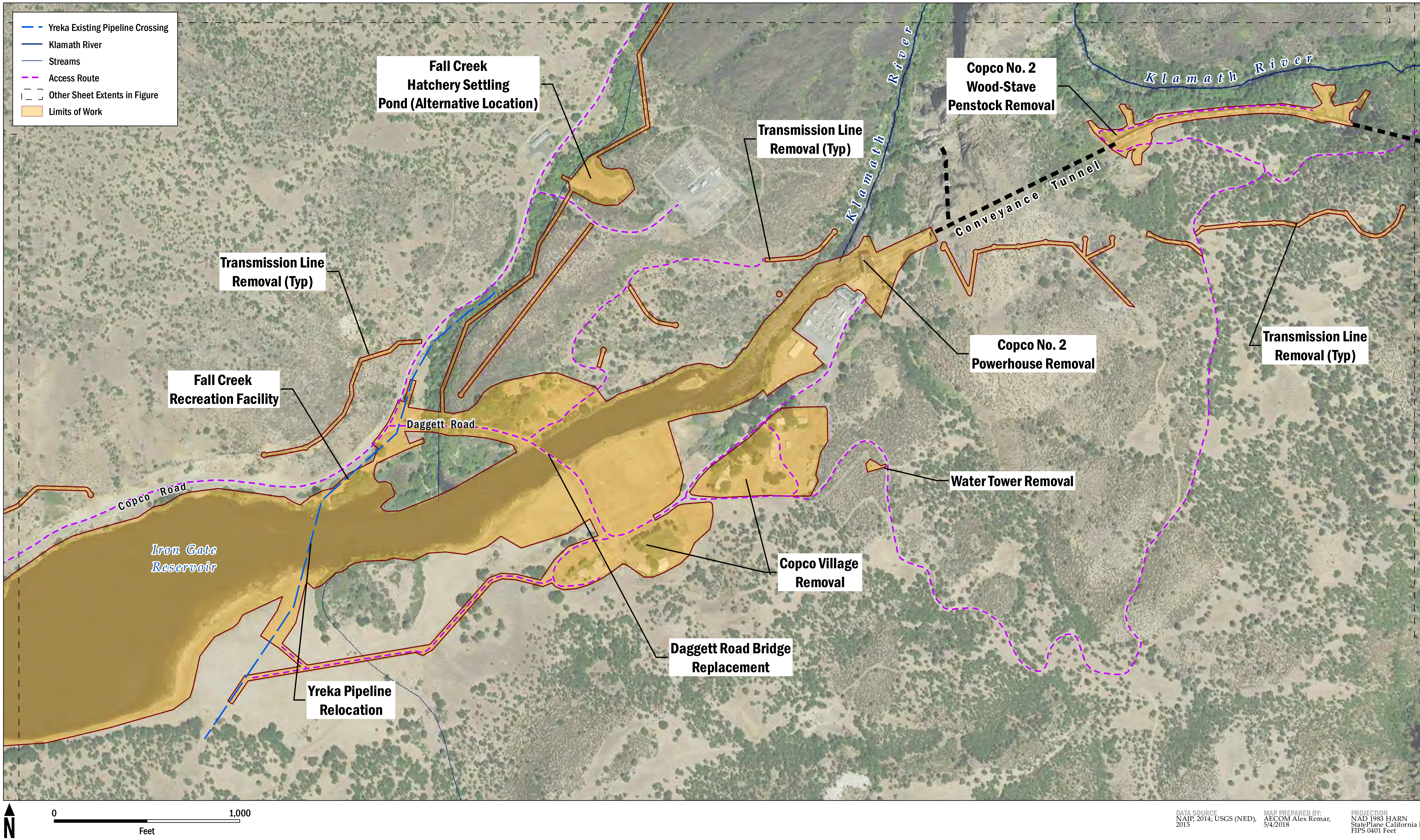
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 13 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

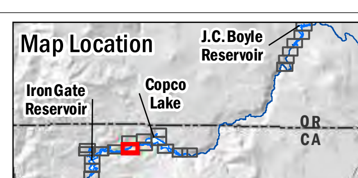


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



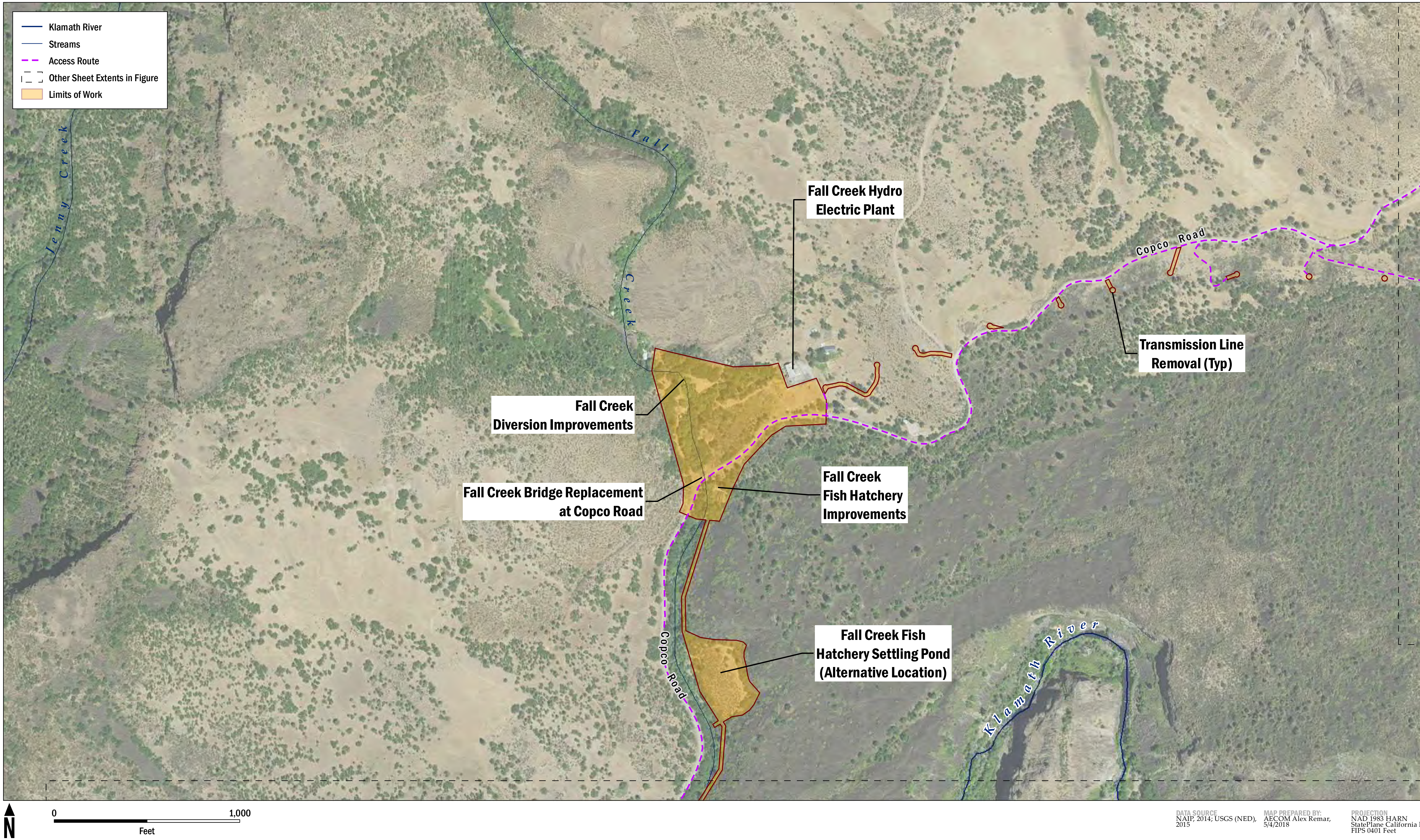
Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access

Sheet 14 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

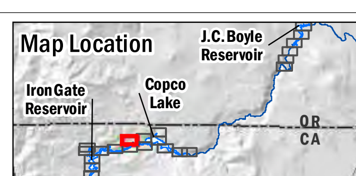


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

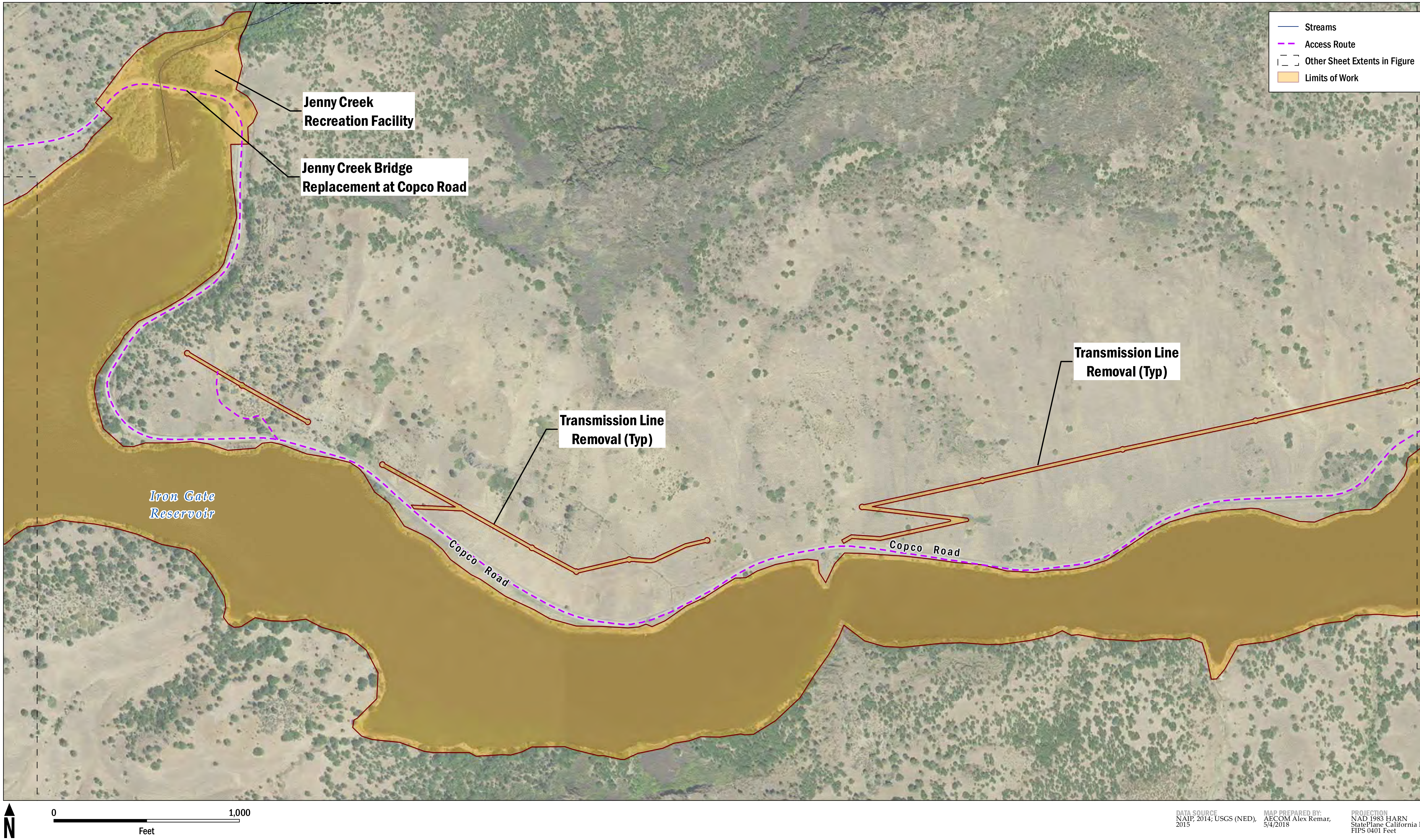


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access

Sheet 15 of 23

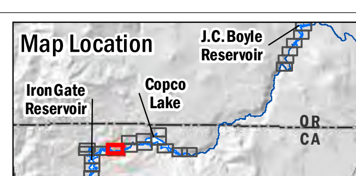


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

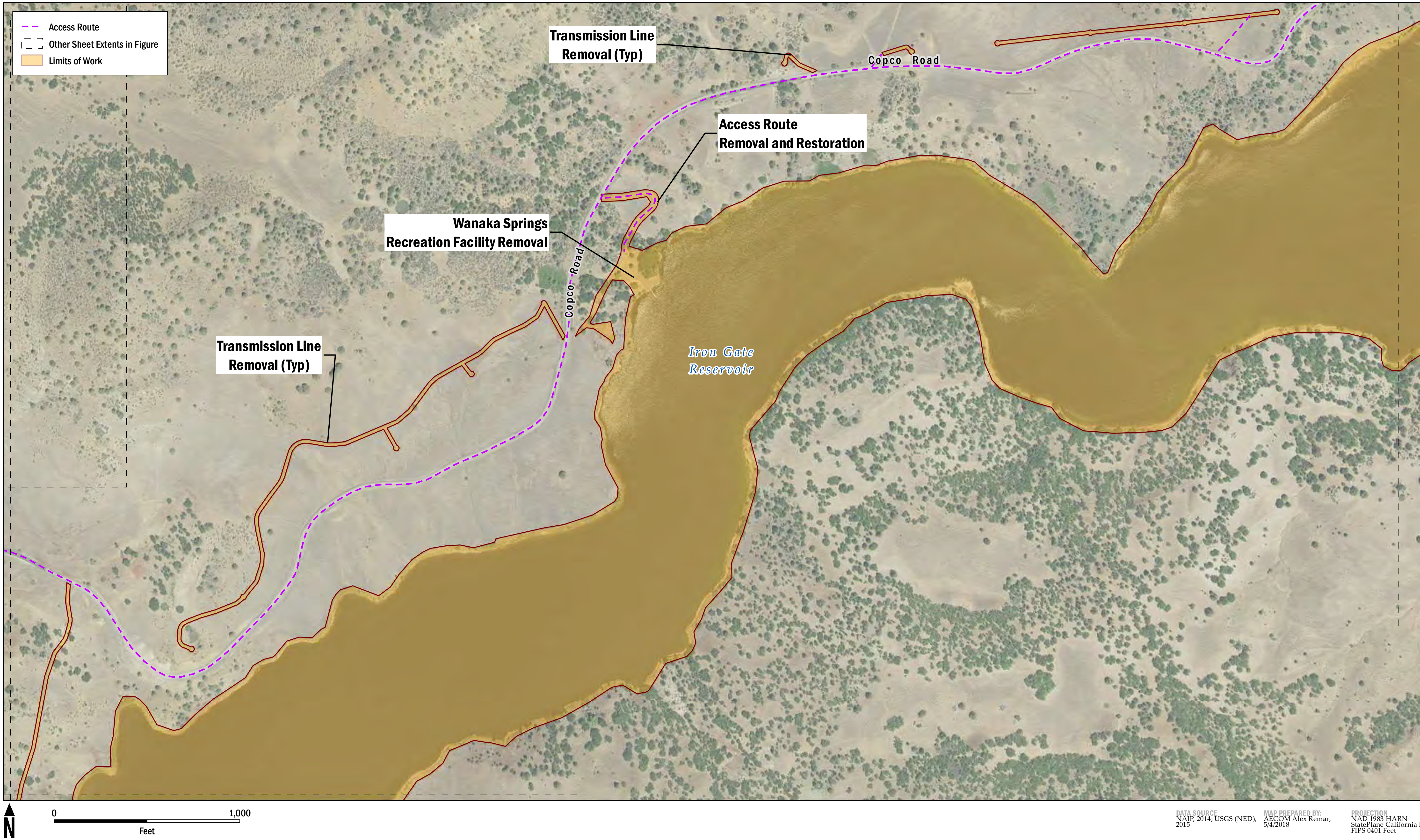
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 16 of 23

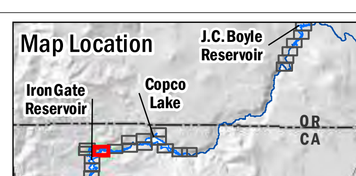


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

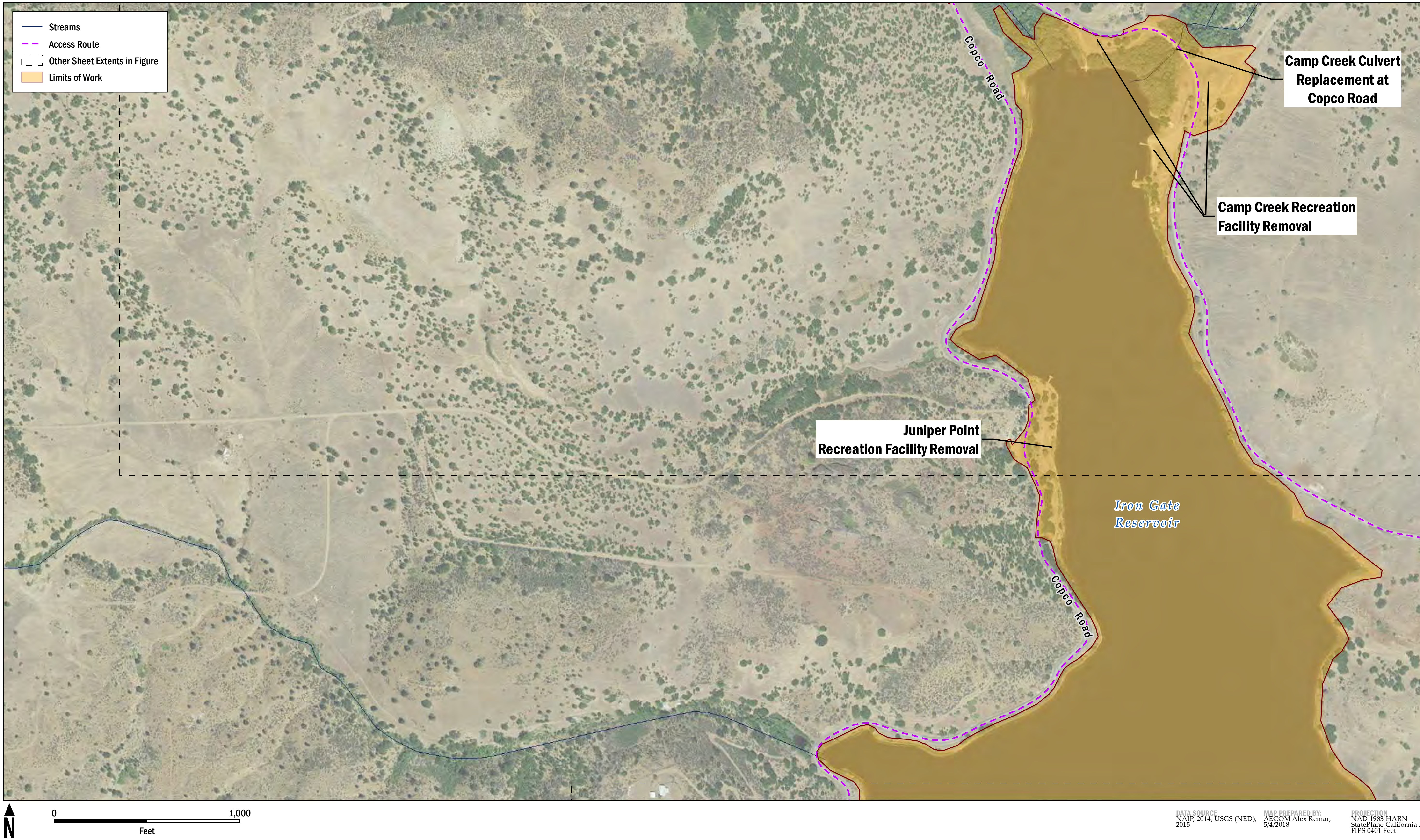


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 17 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

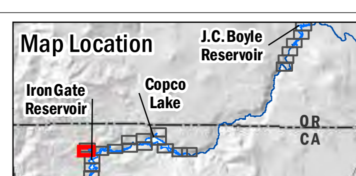


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

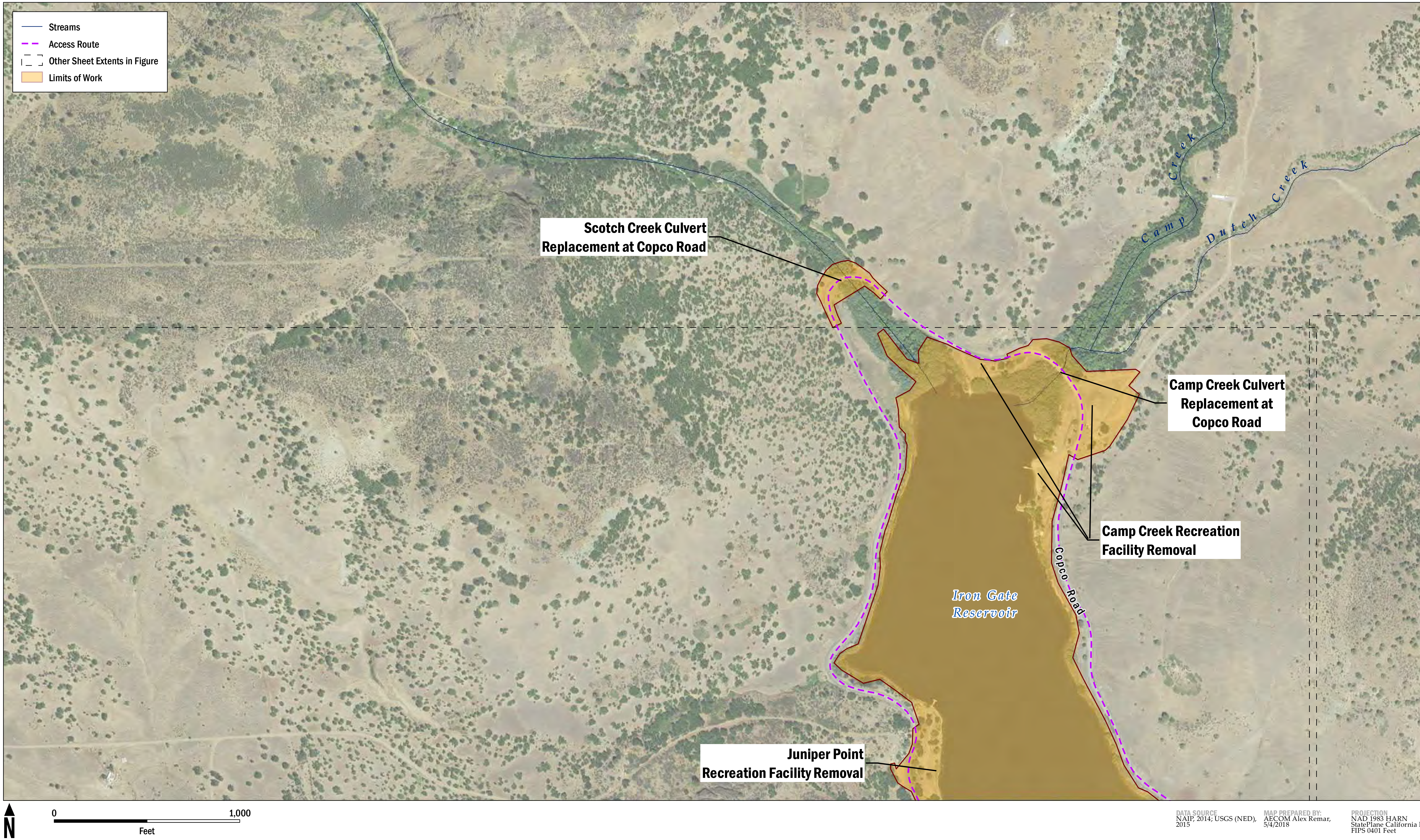
PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 18 of 23

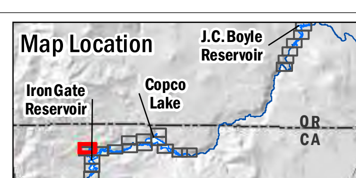


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access

Sheet 19 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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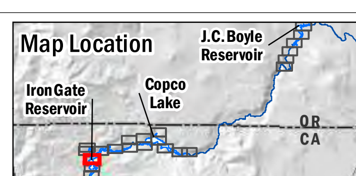
PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

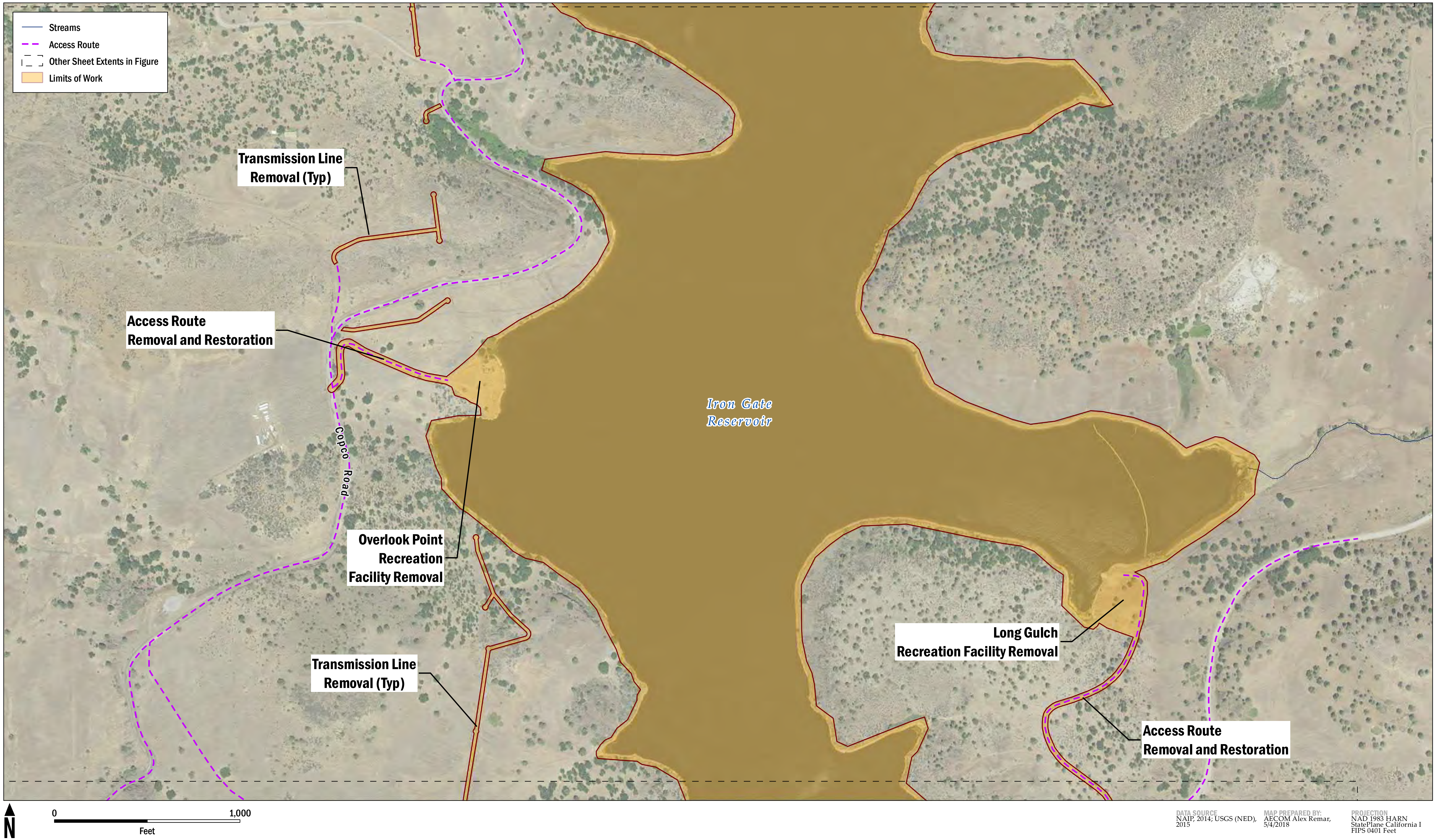
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 20 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

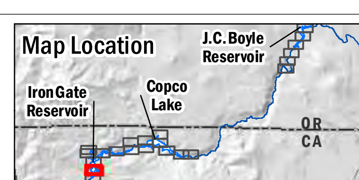


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

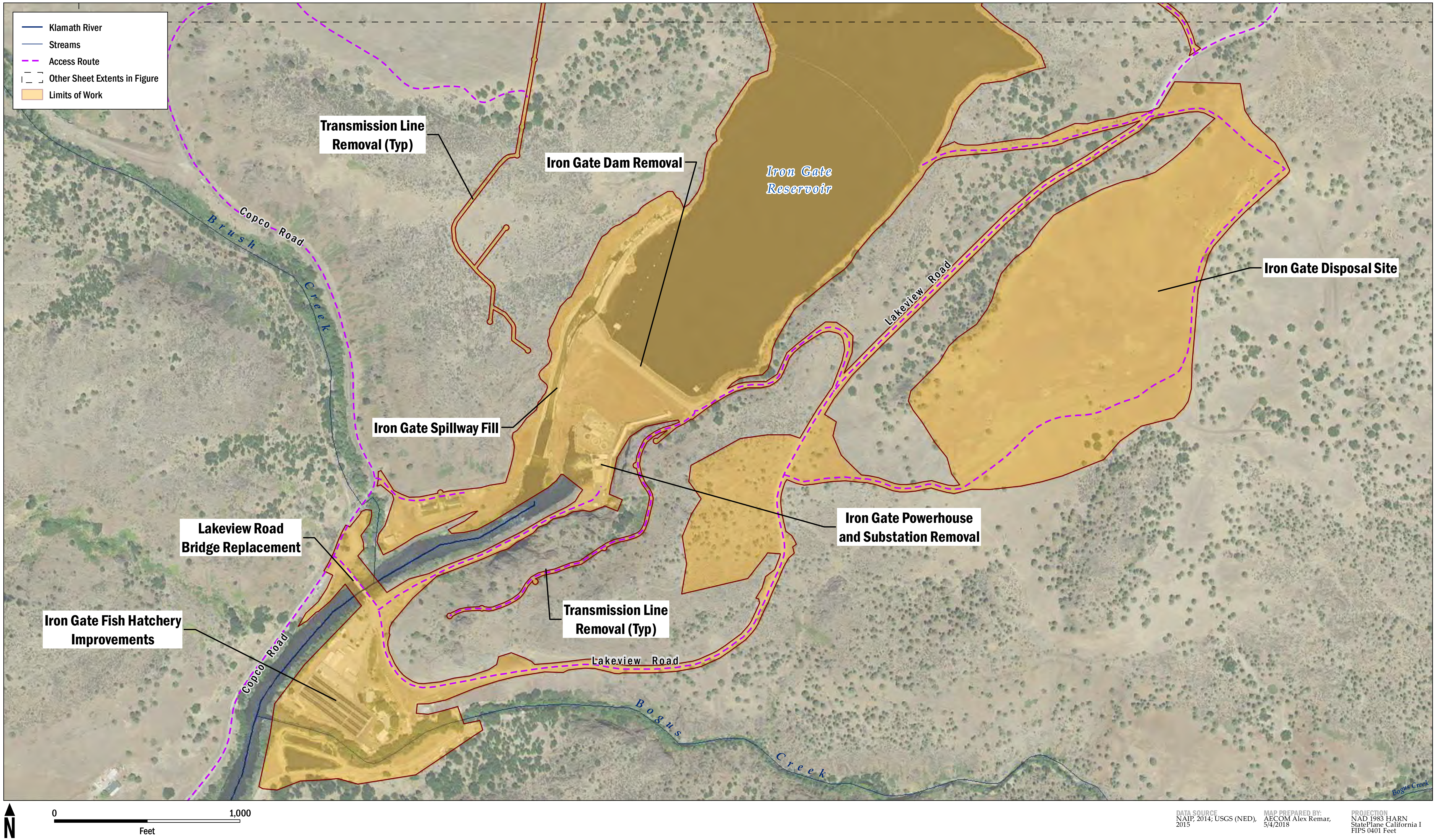


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 21 of 23

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_1-1_ProjectLimitsOfWorkAndAccess_Sheets.mxd

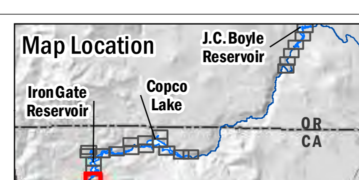


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1

Project Limits of Work and Access
Sheet 22 of 23

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
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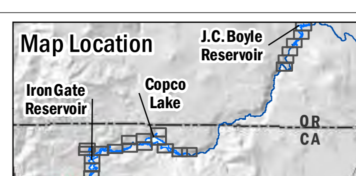
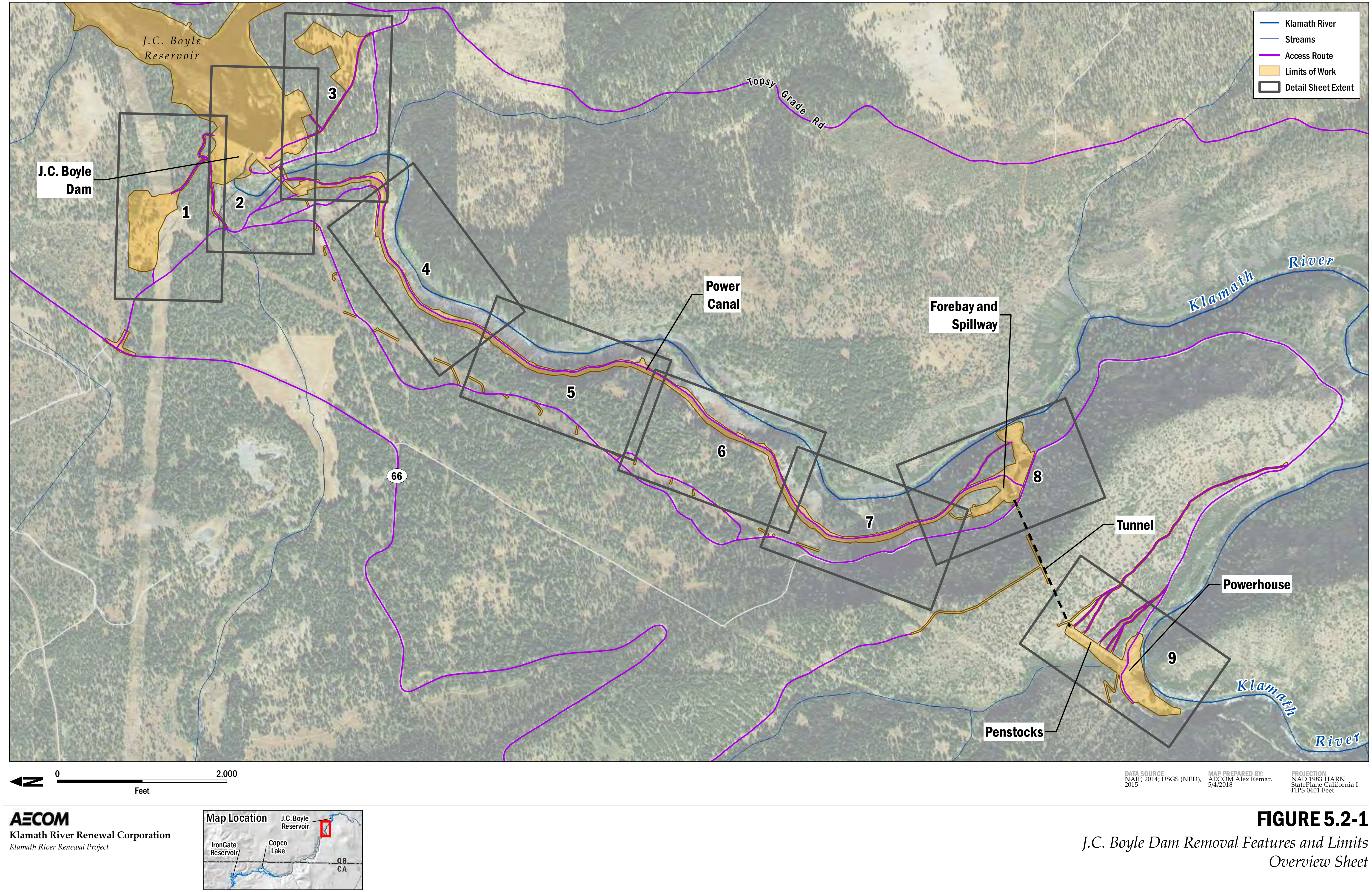
PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.1-1
Project Limits of Work and Access
Sheet 23 of 23



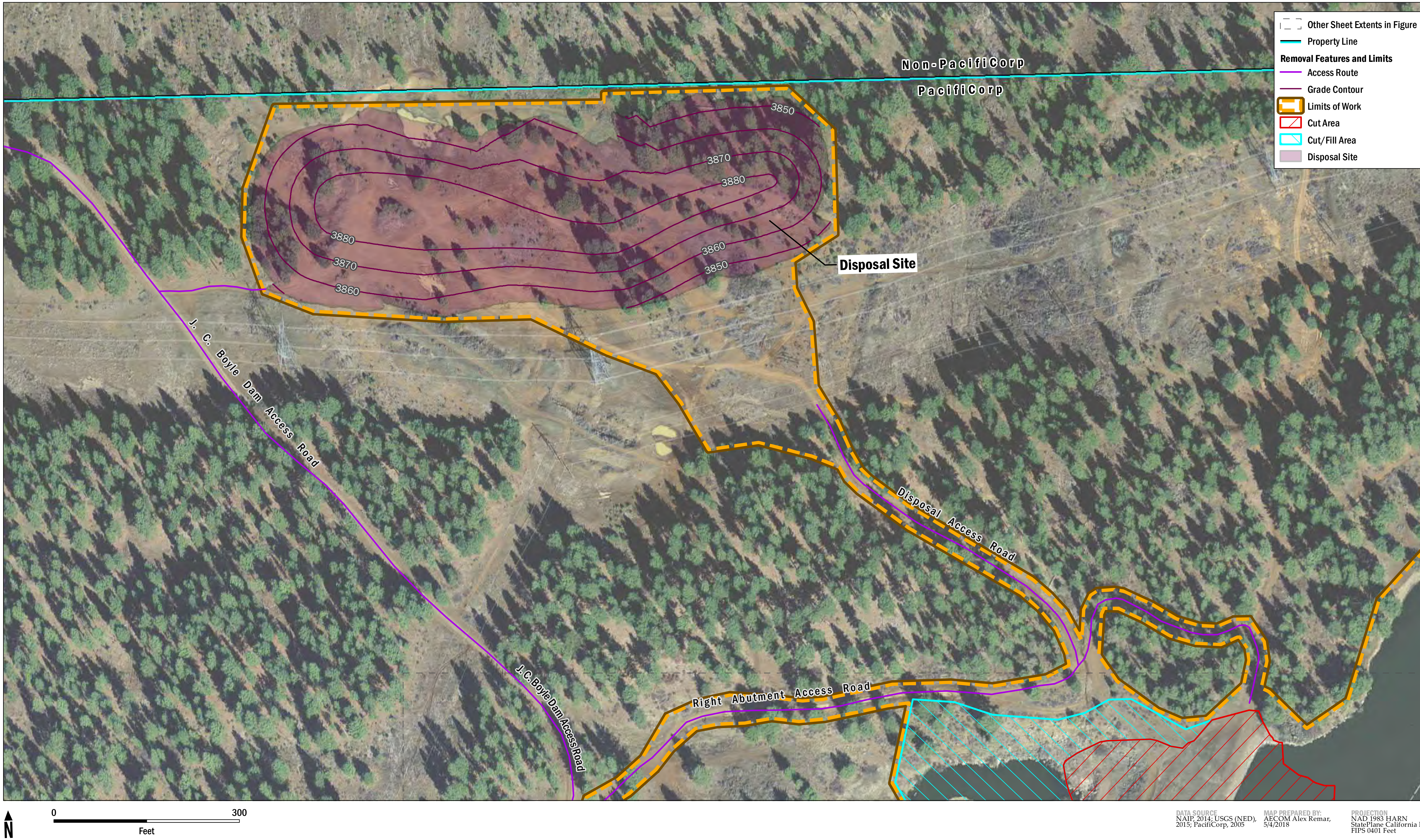
DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

FIGURE 5.2-1
J.C. Boyle Dam Removal Features and Limits
Overview Sheet



DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

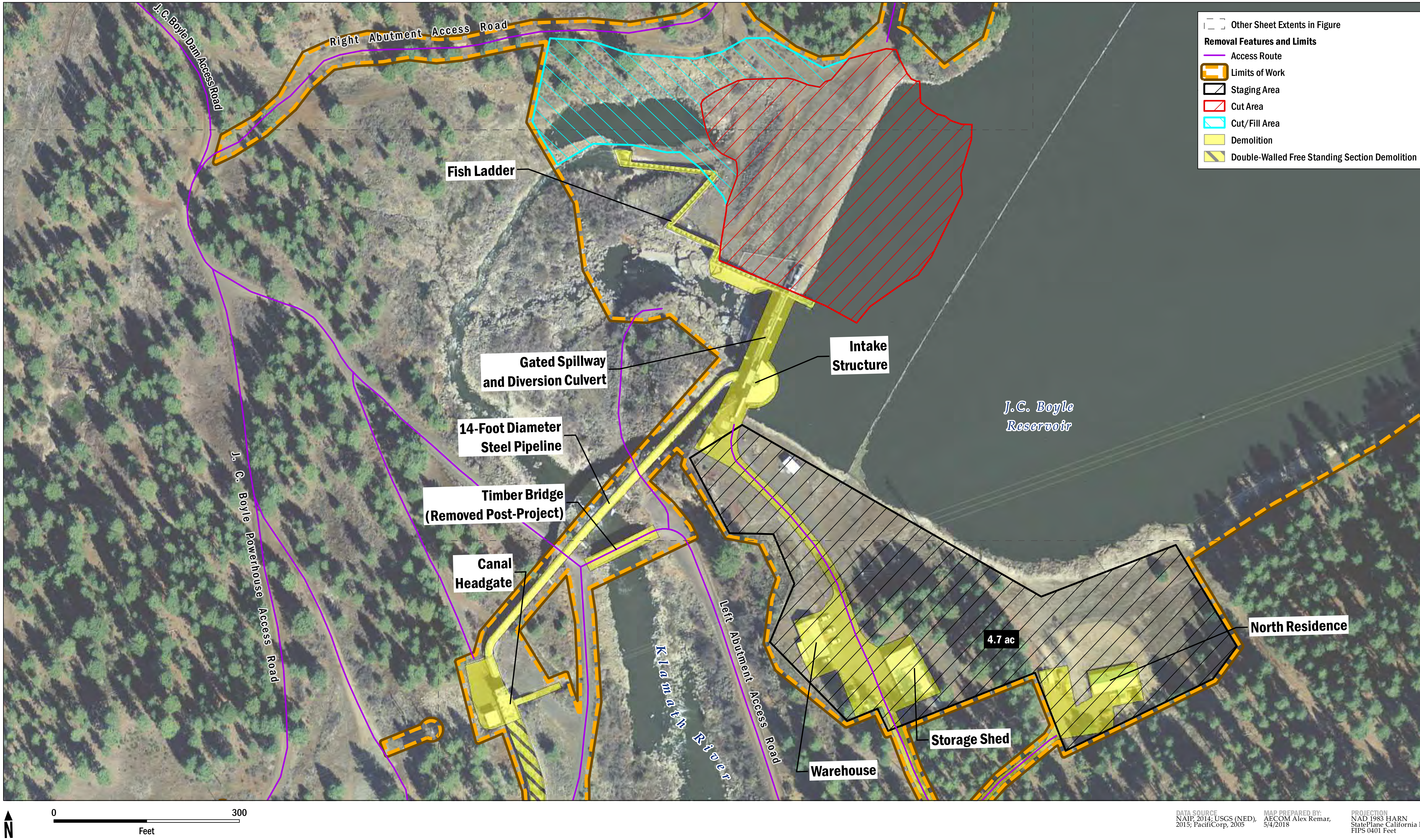
Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1

J.C. Boyle Dam Removal Features and Limits

Sheet 1 of 9

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_2-1_JCB_RemovalFeatureAndLimits_Sheets.mxd

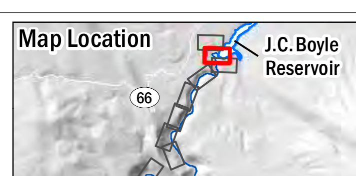


DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

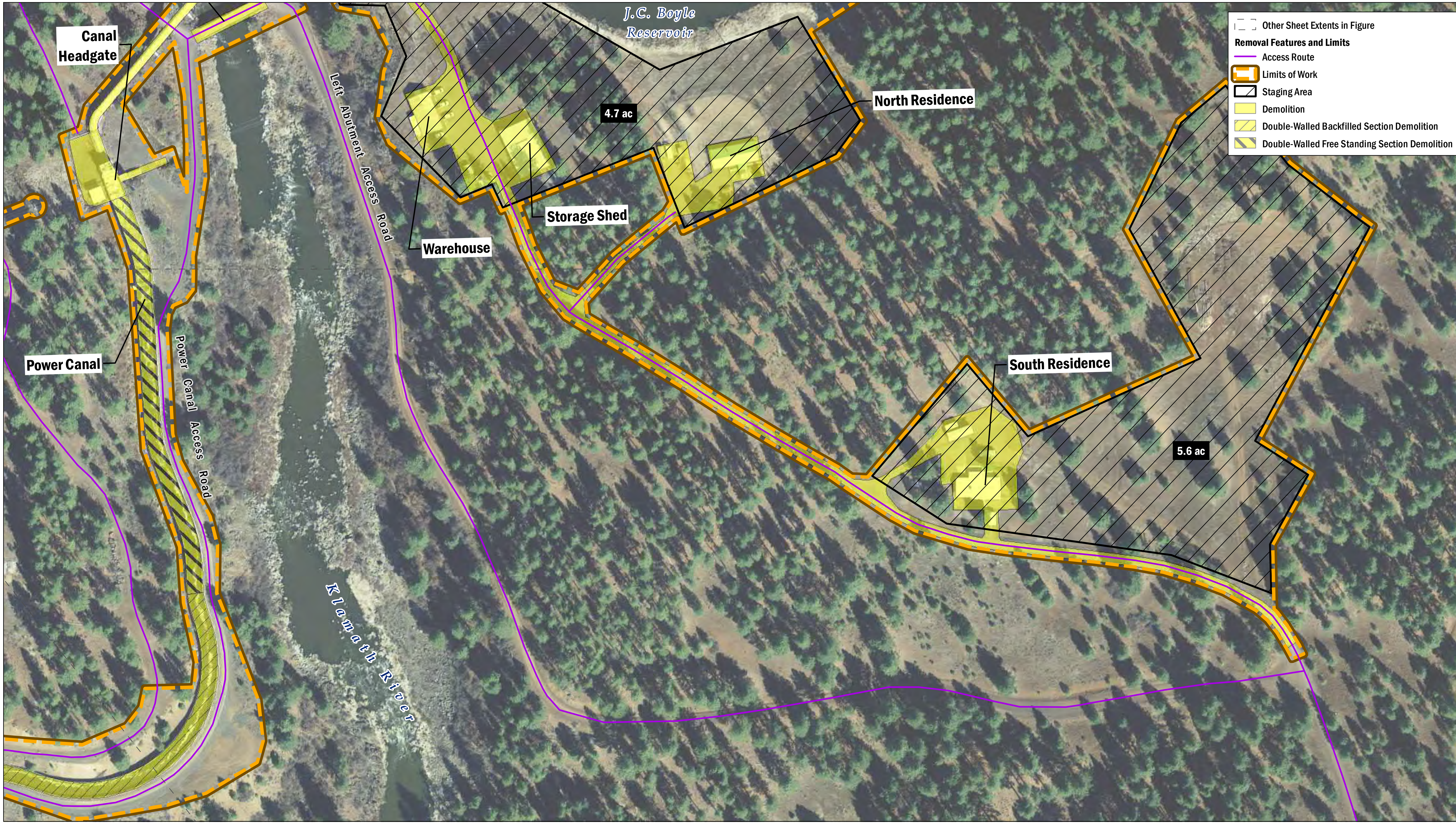


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1

J.C. Boyle Dam Removal Features and Limits

Sheet 2 of 9



DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

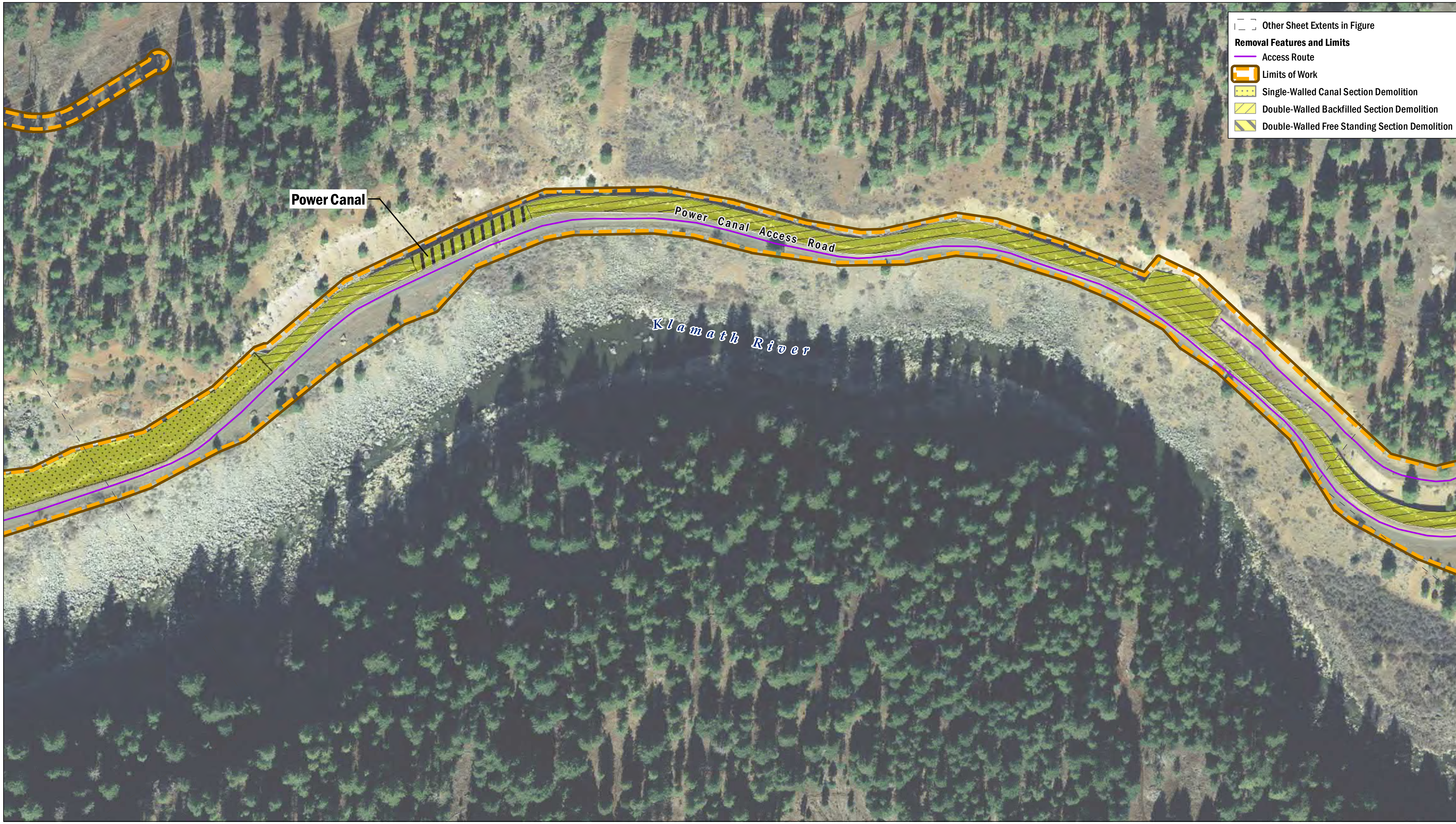
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1

J.C. Boyle Dam Removal Features and Limits

Sheet 3 of 9



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Feet

DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

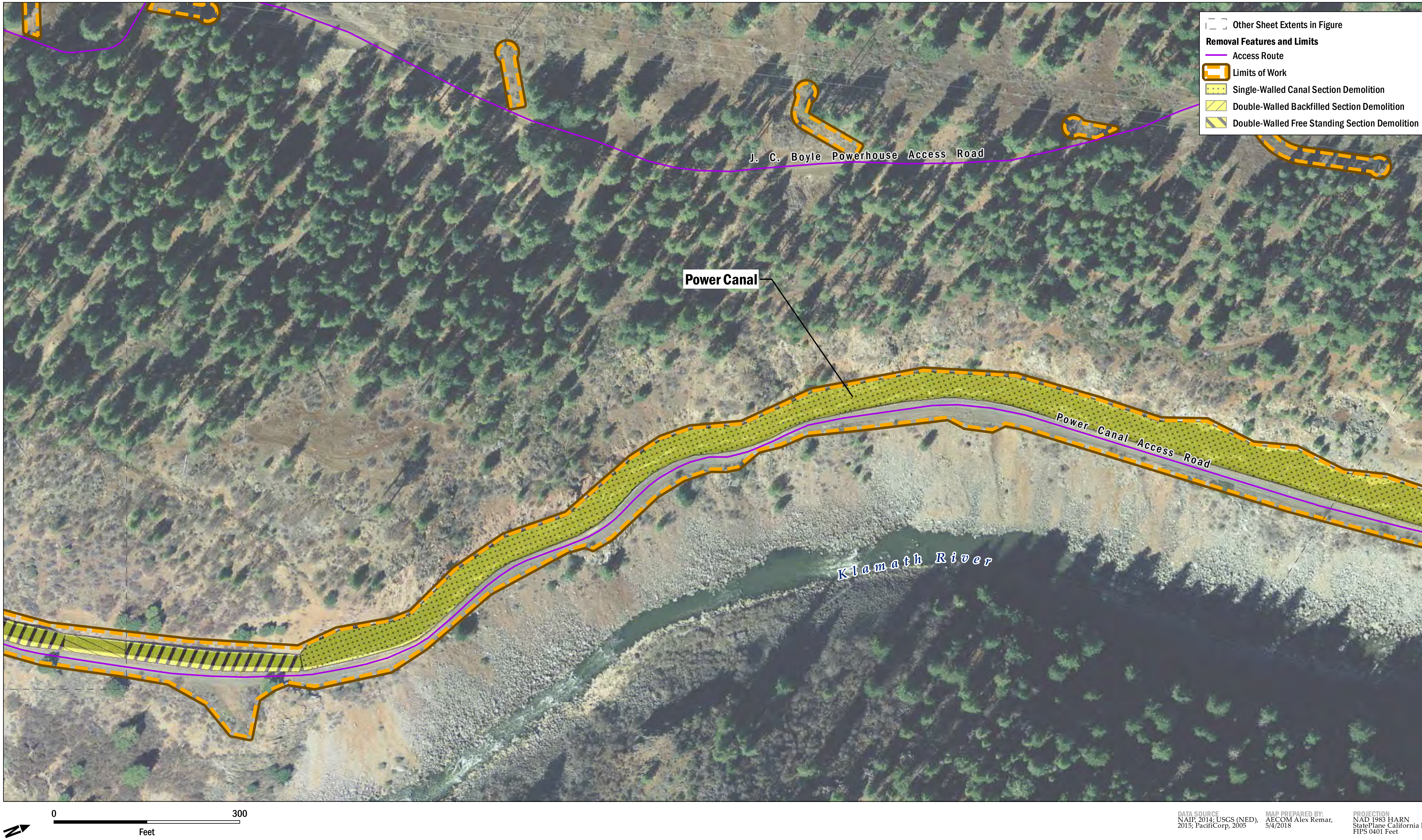
PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Map Location
J.C. Boyle Reservoir
66

Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1
J.C. Boyle Dam Removal Features and Limits
Sheet 4 of 9

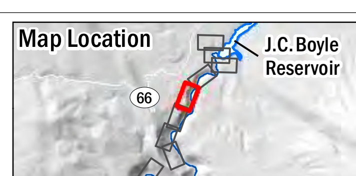


DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1
J.C. Boyle Dam Removal Features and Limits
Sheet 5 of 9

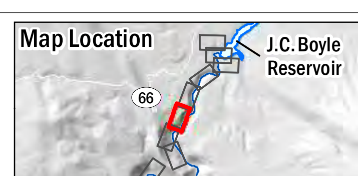
AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_2-1_JCB_RemovalFeatureAndLimits_Sheets.mxd

DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1

J.C. Boyle Dam Removal Features and Limits

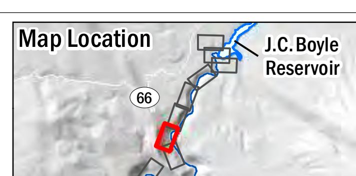
Sheet 6 of 9

DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

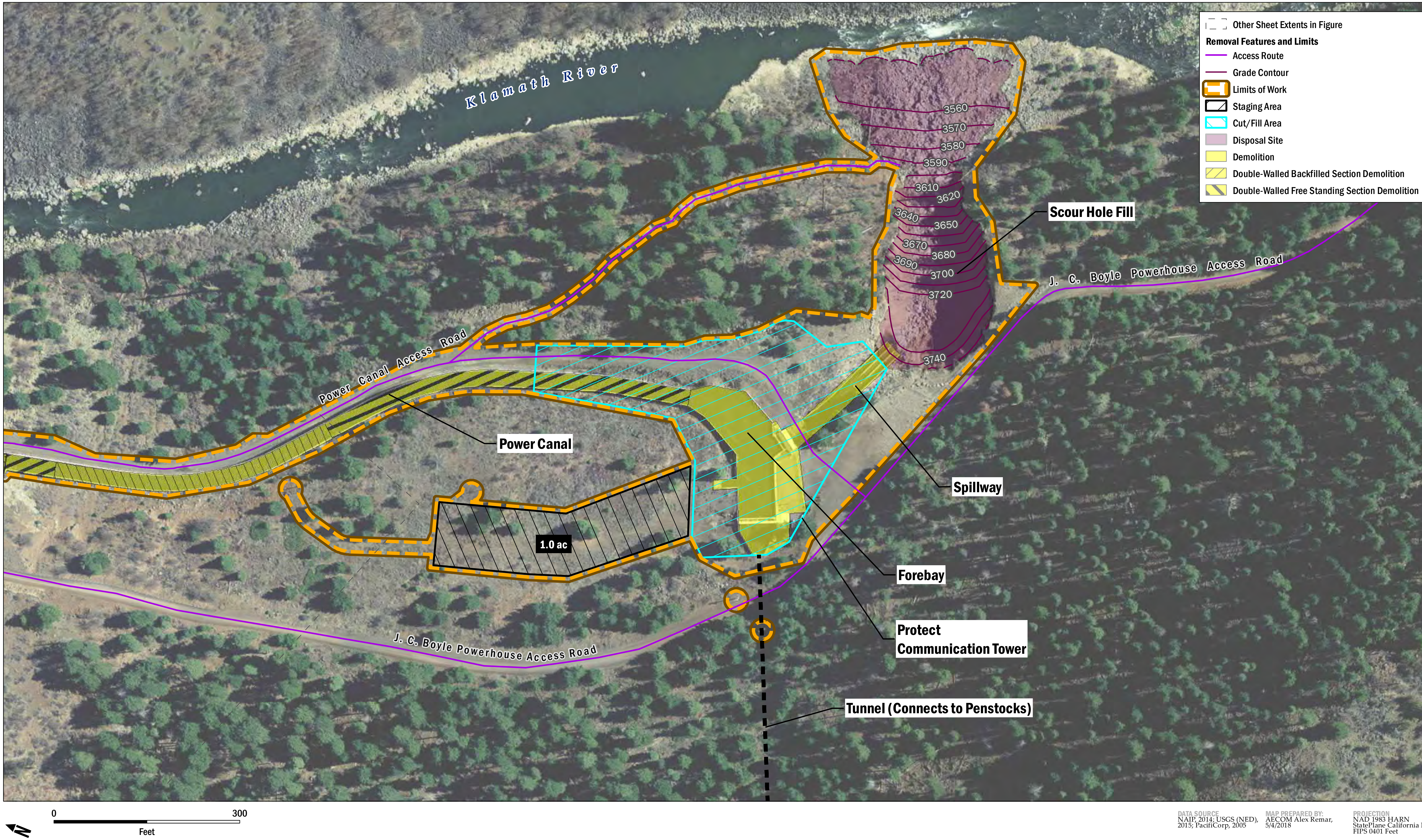
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1

J.C. Boyle Dam Removal Features and Limits
Sheet 7 of 9



DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

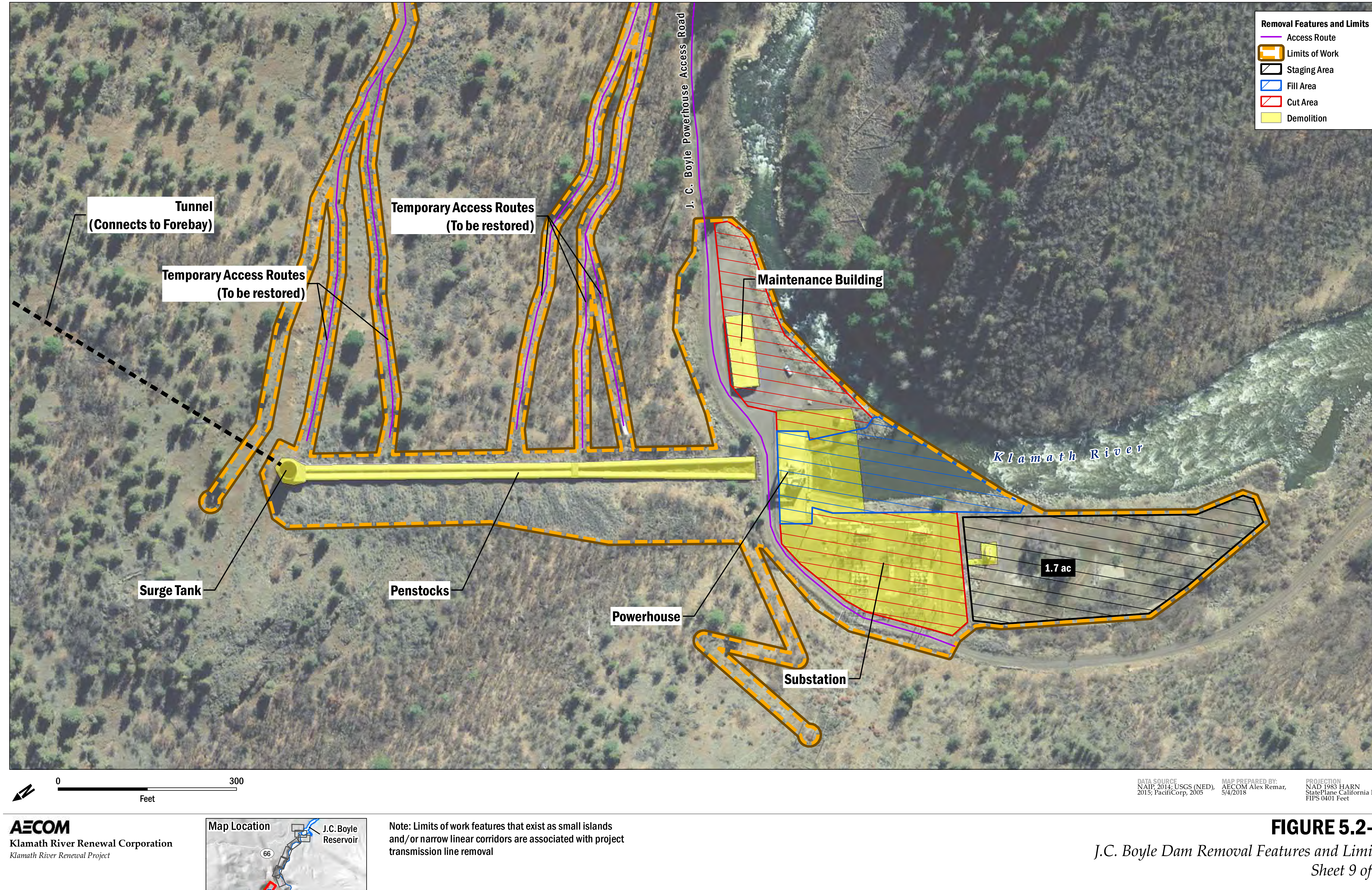
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1

J.C. Boyle Dam Removal Features and Limits

Sheet 8 of 9



DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

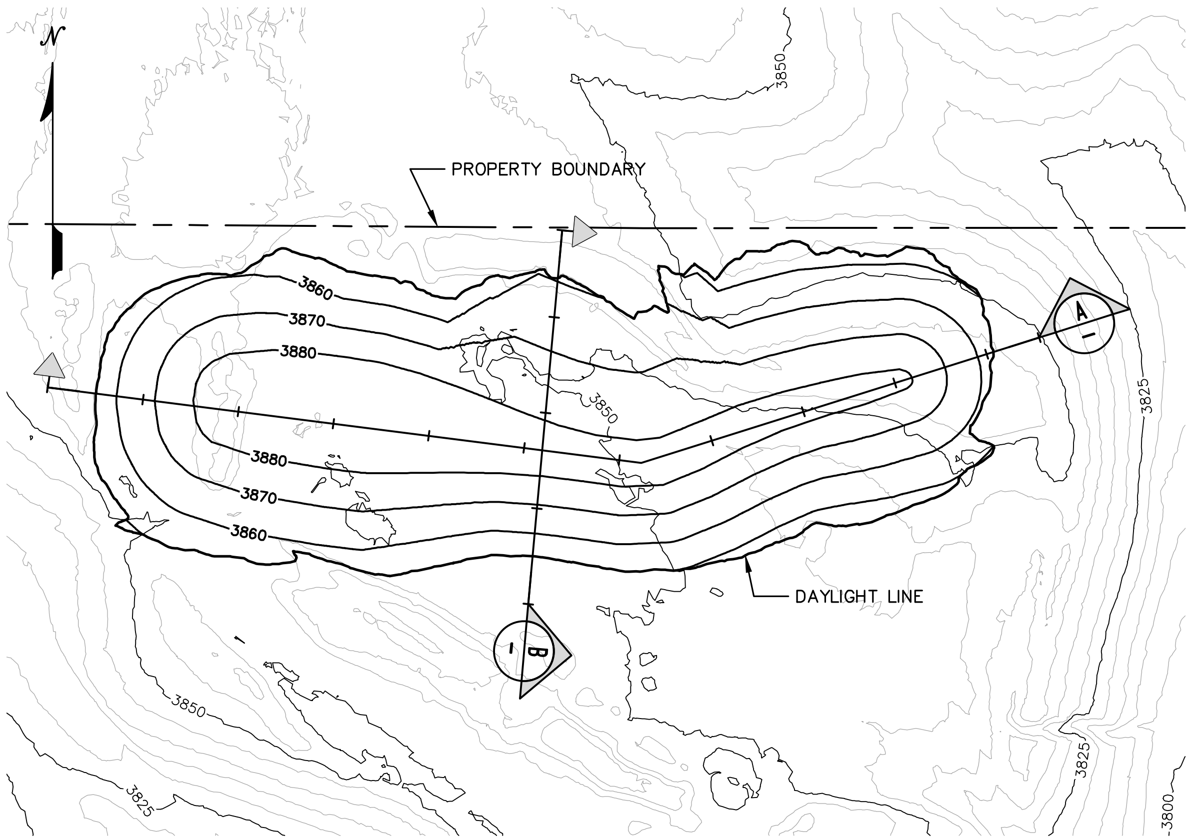
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.2-1

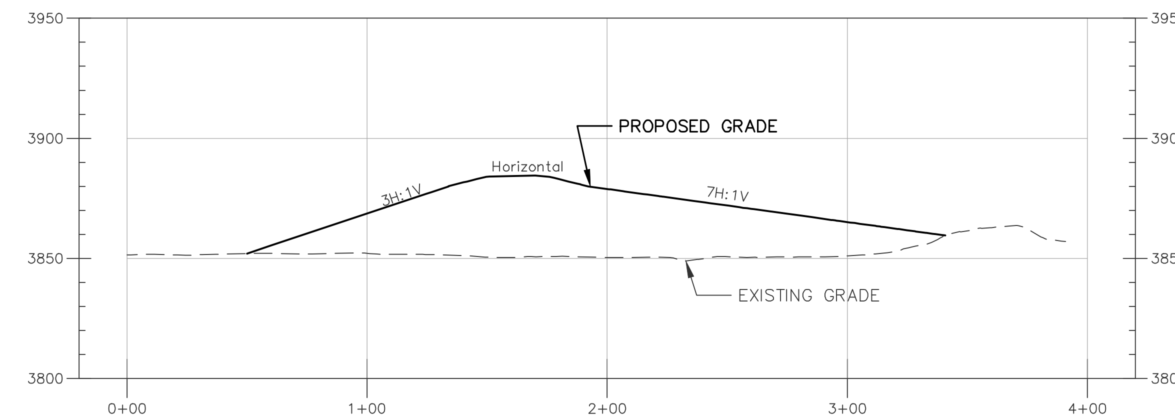
J.C. Boyle Dam Removal Features and Limits

Sheet 9 of 9

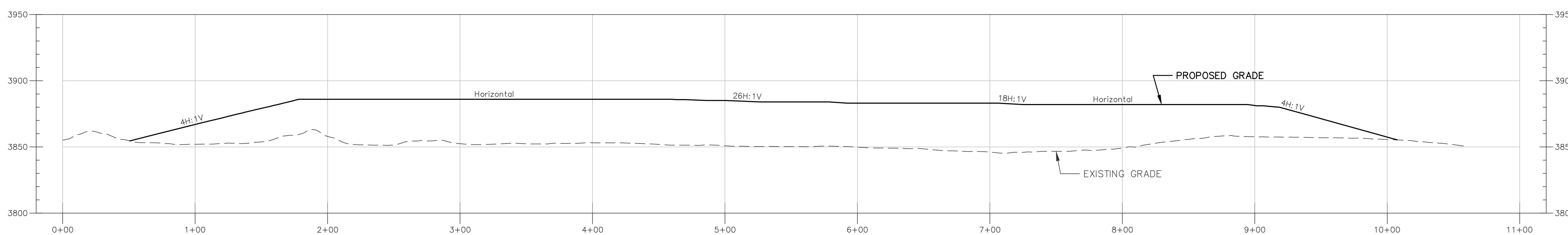


PLAN

0 100 200
HORIZ 1"=200'



B SECTION
HORIZ 1"=80', VERT 1"=80'



A SECTION
HORIZ 1"=80', VERT 1"=80'

FIGURE 5.2-8
J.C. Boyle Right Abutment Disposal Site Plan & Sections

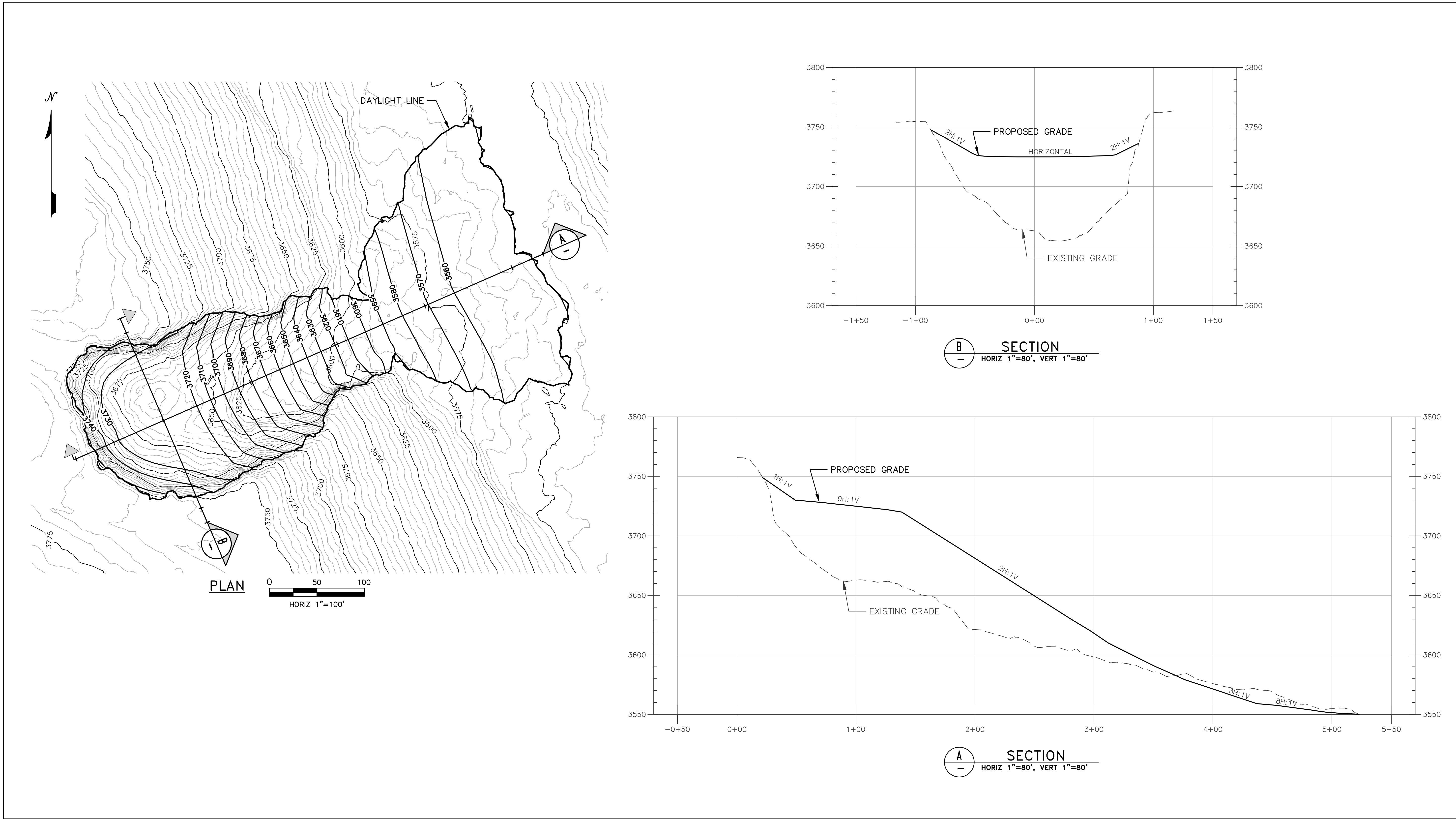
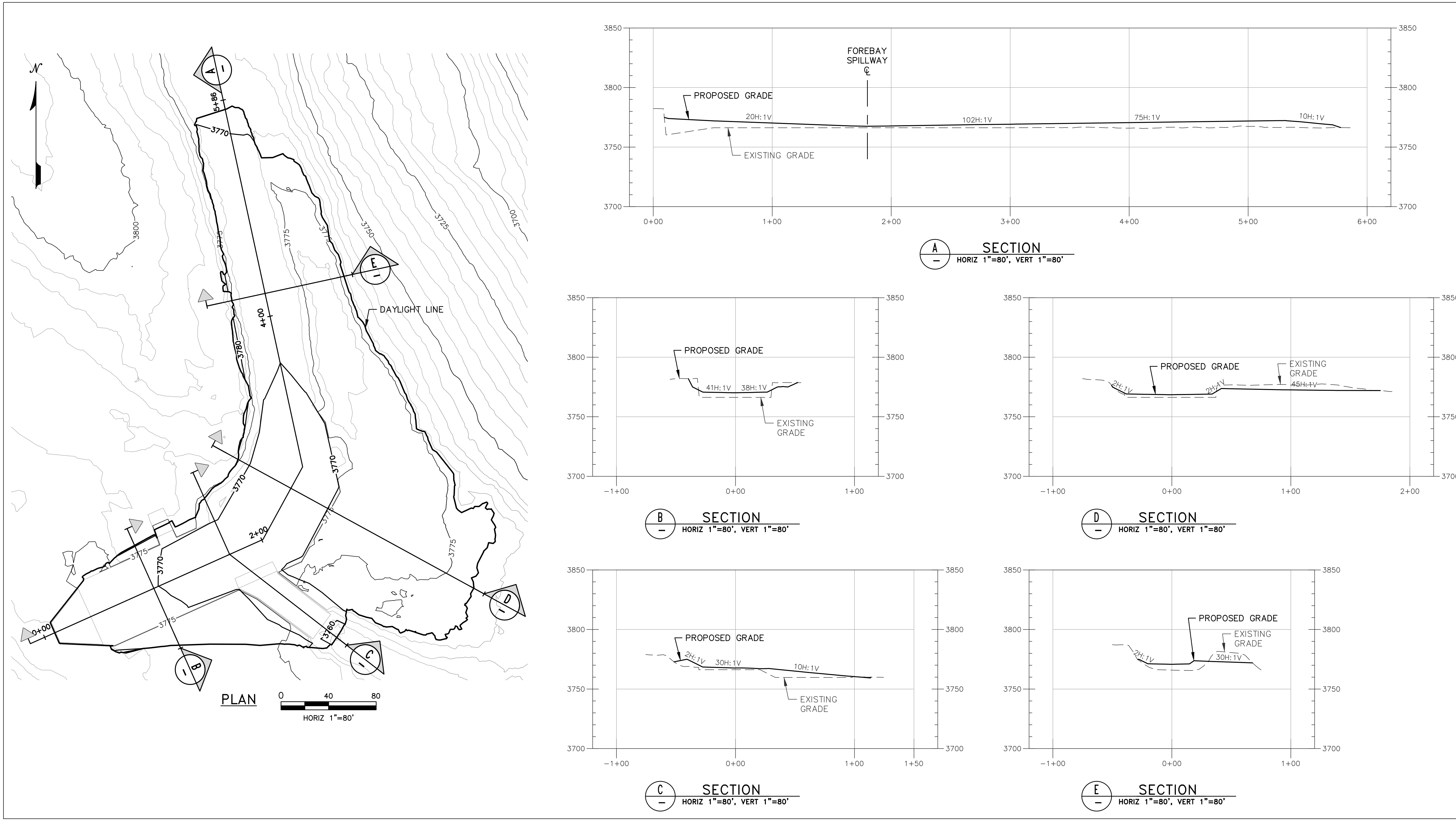


FIGURE 5.2-9

J.C. Boyle Forebay Spillway Scour Hole Backfill Plan & Sections



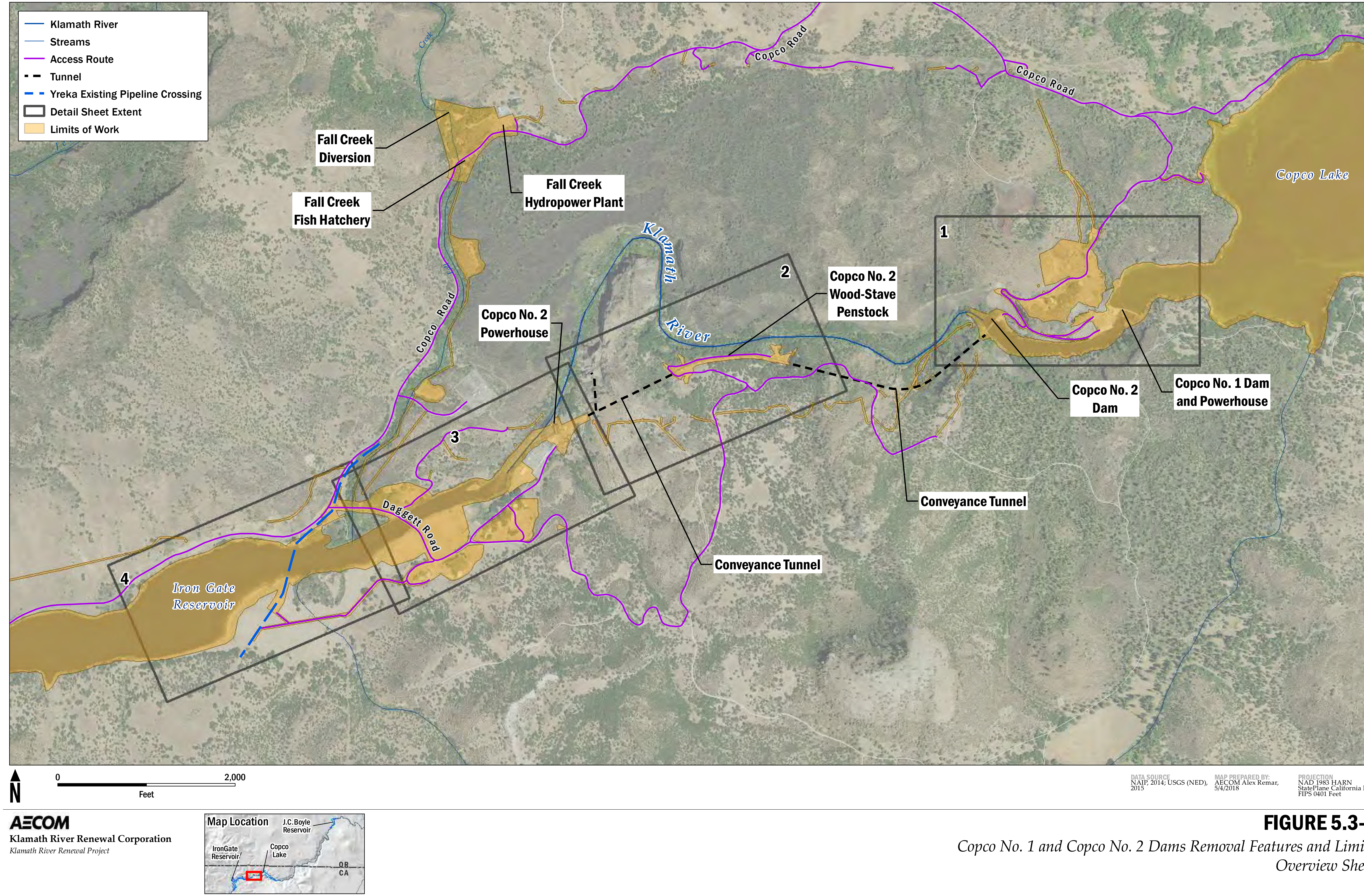
AECOM

Klamath River Renewal Corporation

Klamath River Renewal Project

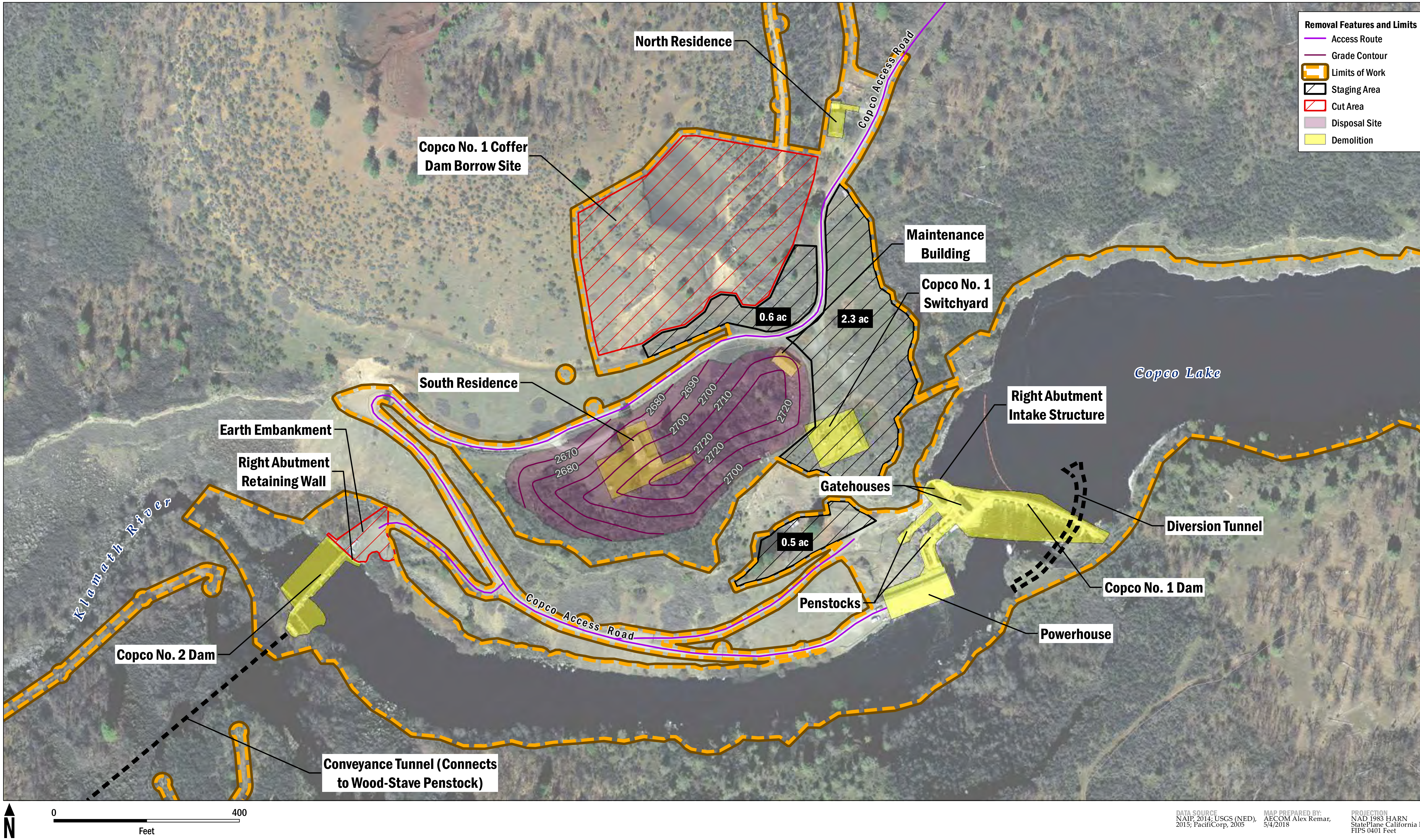
FIGURE 5.2-11

J.C. Boyle Forebay Backfill Plan & Sections



AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

FIGURE 5.3-1
Copco No. 1 and Copco No. 2 Dams Removal Features and Limits Overview Sheet

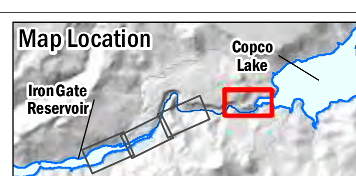


DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

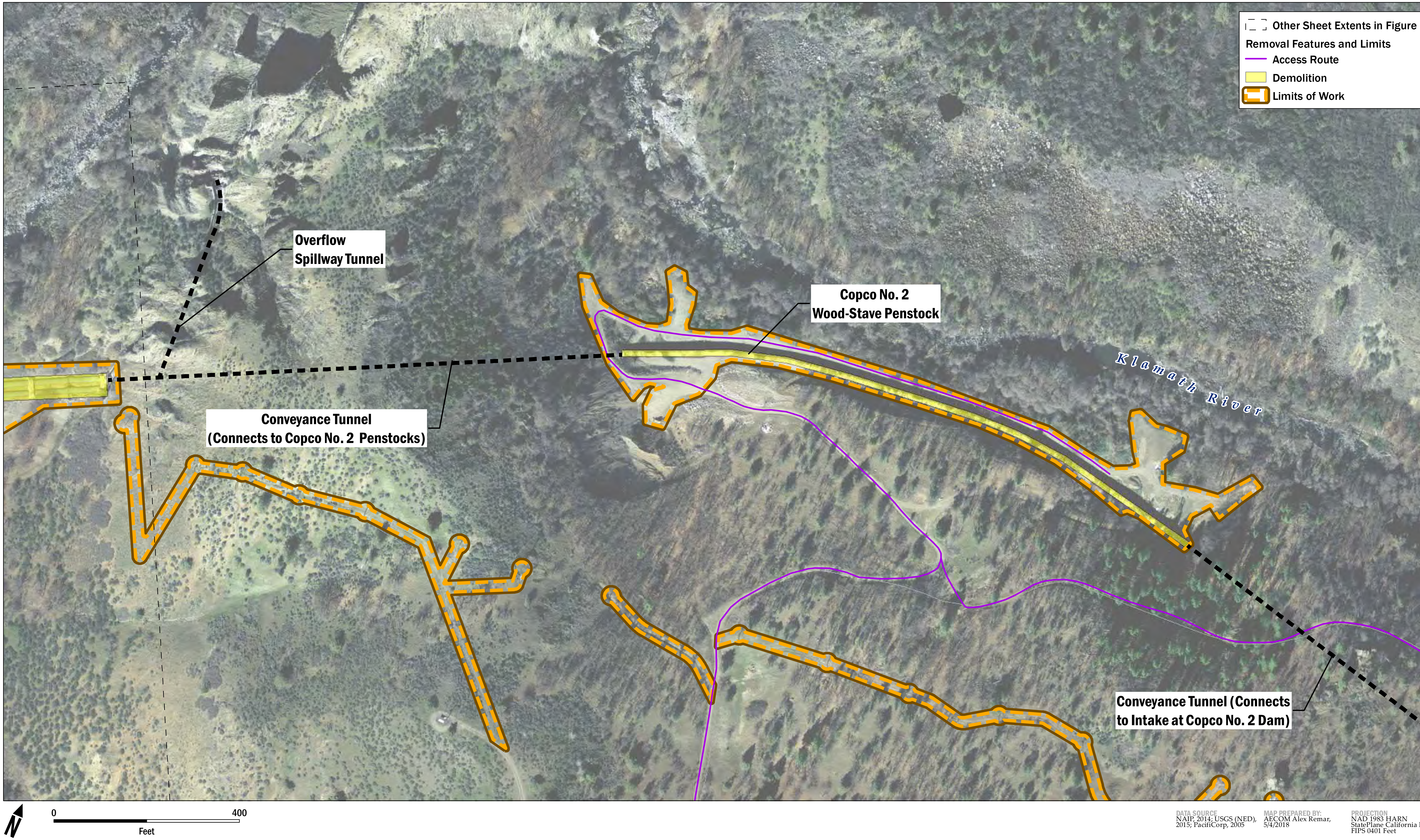
AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.3-1
Copco No. 1 and Copco No. 2 Dams Removal Features and Limits
Sheet 1 of 4

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_3-1_Copco_RemovalFeatureAndLimits_Sheet2.mxd

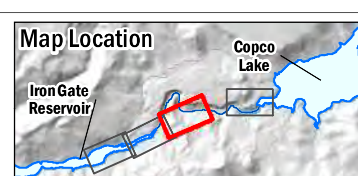


DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

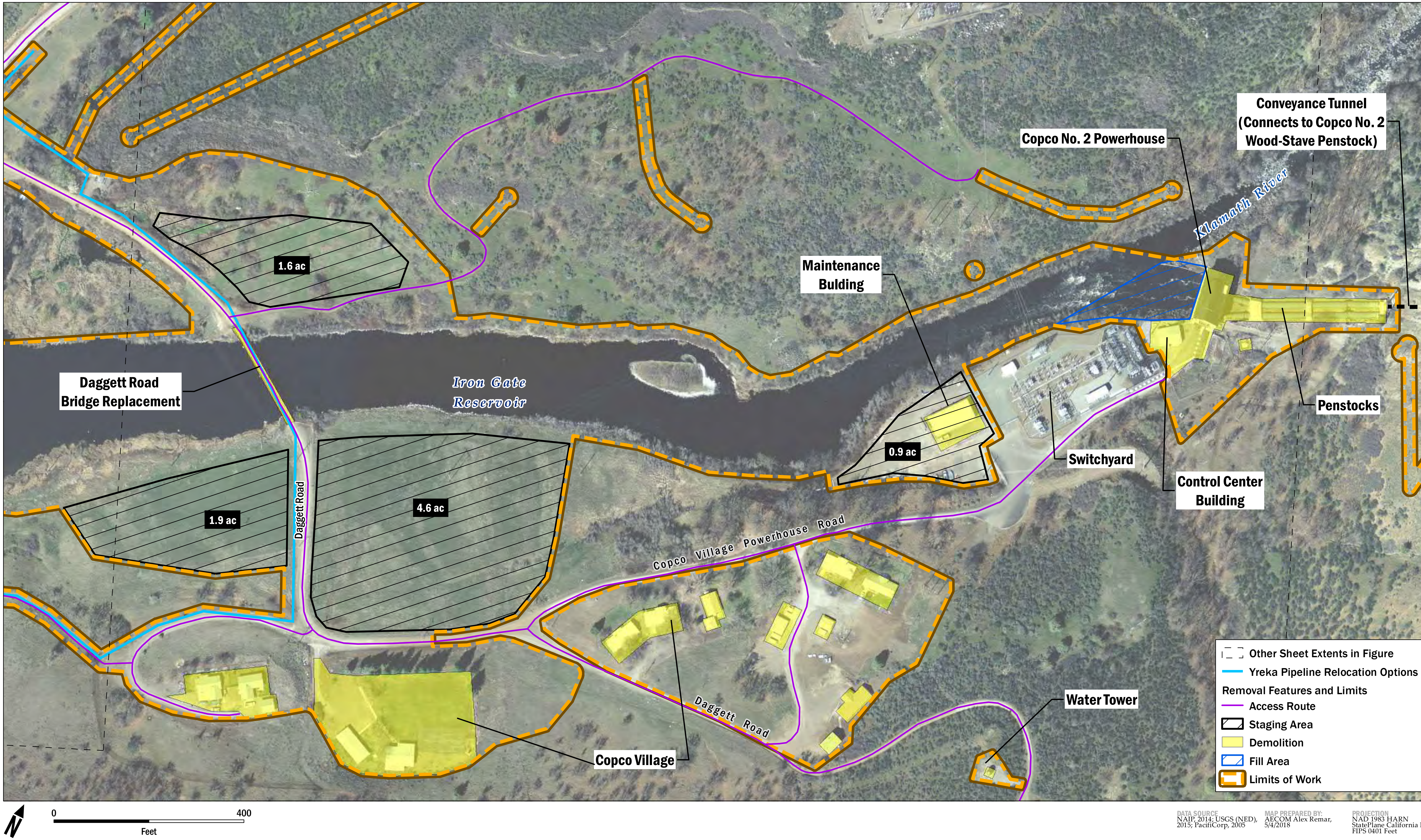


Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.3-1

Copco No. 1 and Copco No. 2 Dams Removal Features and Limits
Sheet 2 of 4

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_3-1_Copco_RemovalFeatureAndLimits_Sheet3.mxd

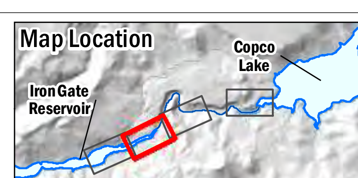


DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.3-1

Copco No. 1 and Copco No. 2 Dams Removal Features and Limits

Sheet 3 of 4

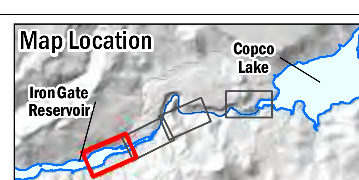
AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_3-1_Copco_RemovalFeatureAndLimits_Sheet4.mxd

DATA SOURCE
NAIP, 2014; USGS (NED), 2015; PacifiCorp, 2005

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.3-1

Copco No. 1 and Copco No. 2 Dams Removal Features and Limits
Sheet 4 of 4

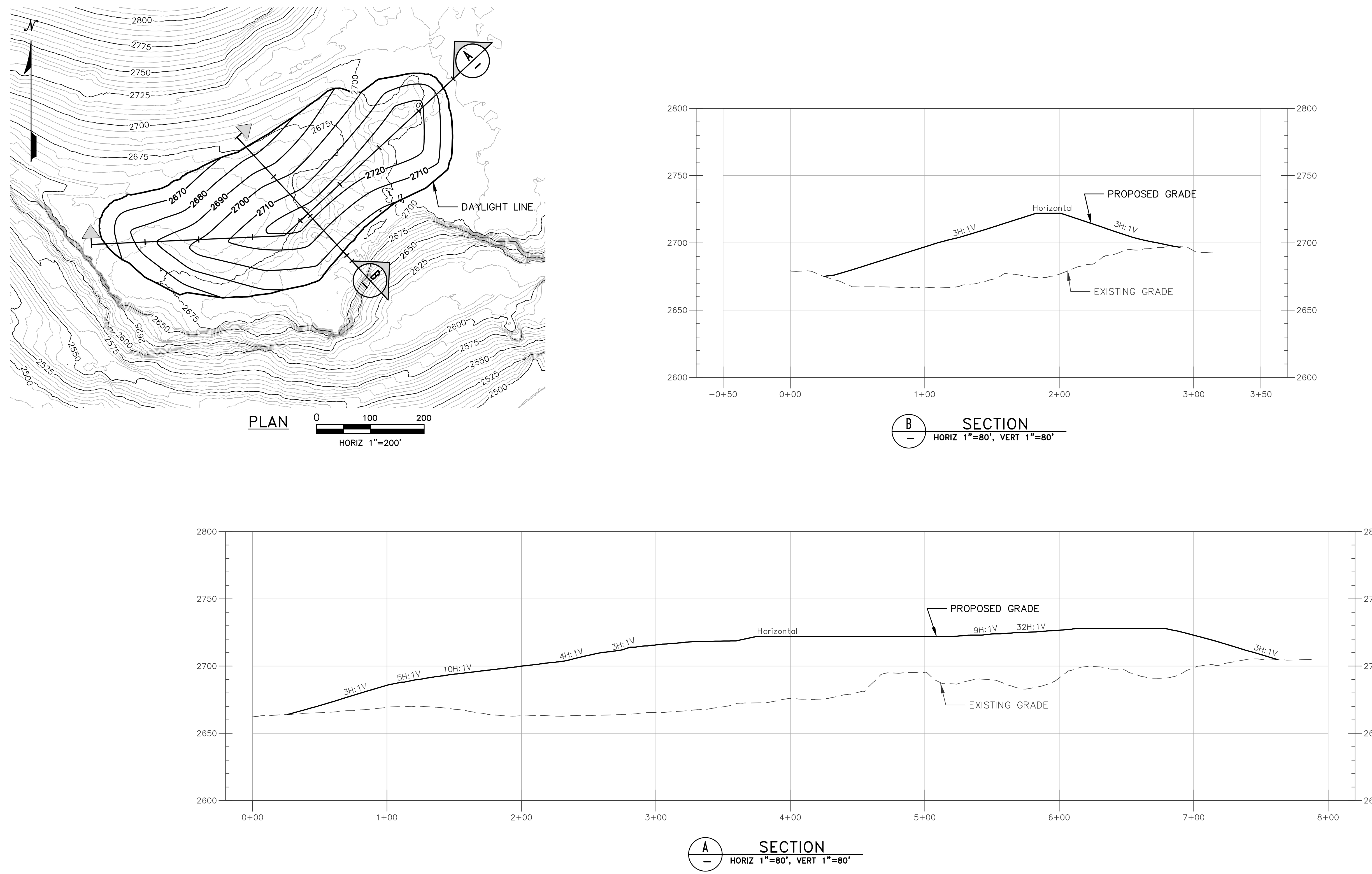
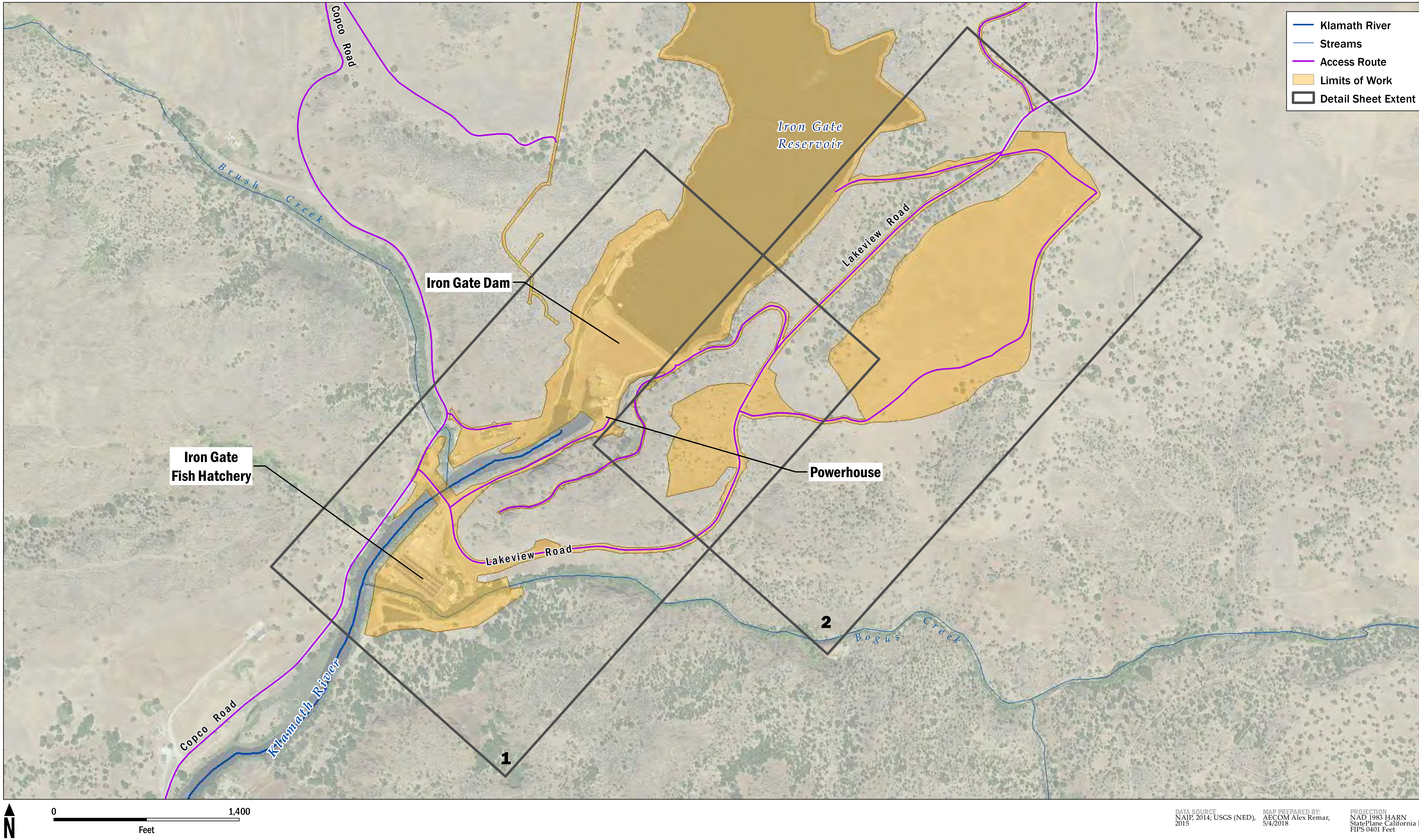


FIGURE 5.3-8

Copco No. 1 & Copco No. 2 Disposal Site Plan & Sections

AECOM Oakland CA 5/4/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_5_5-1_IG_RemovalFeatureAndLimits_Overview.mxd



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

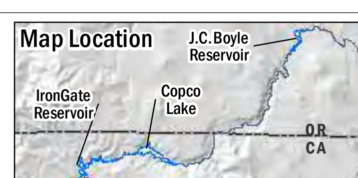
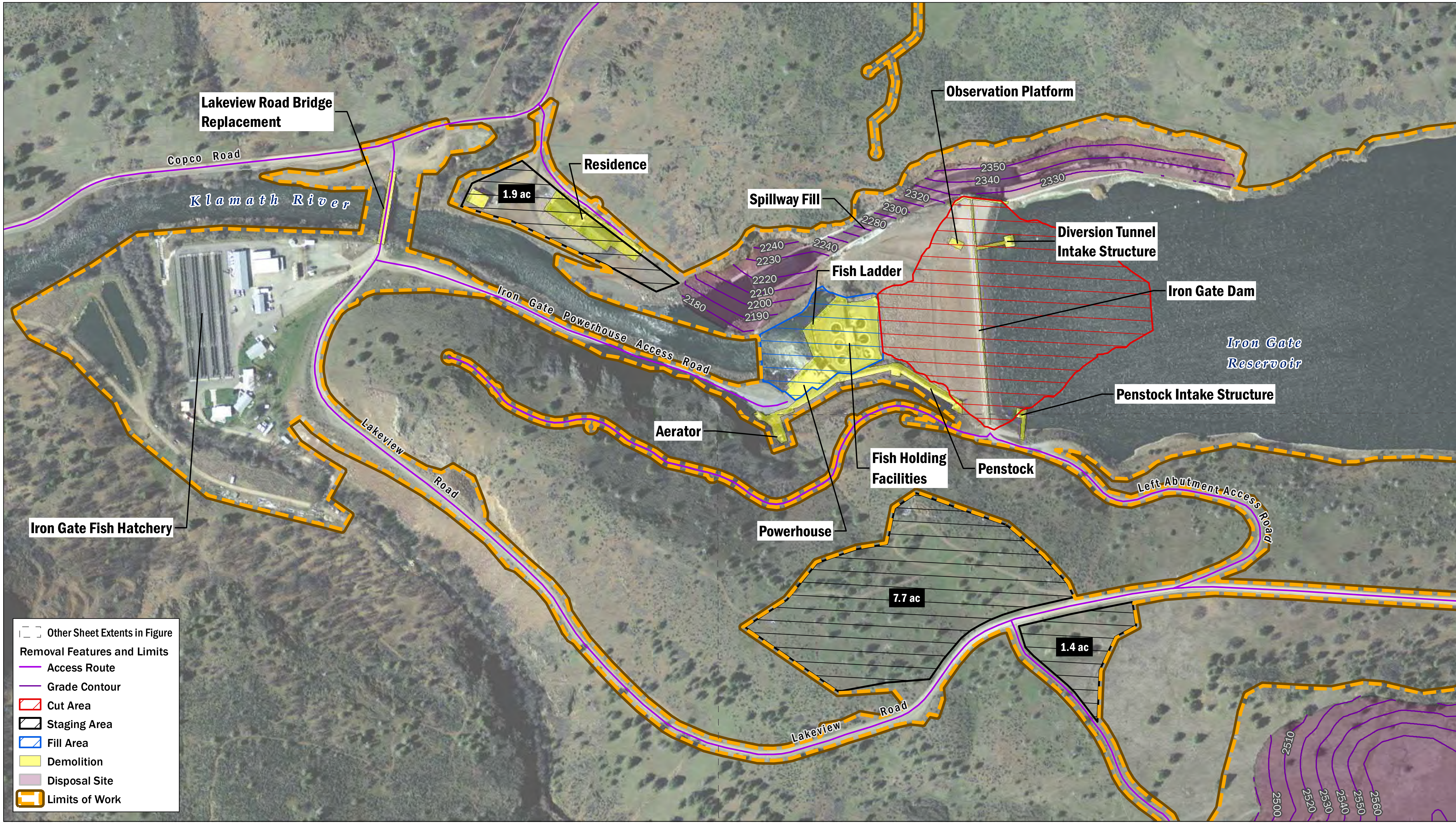


FIGURE 5.5-1

Iron Gate Dam Removal Features and Limits
Overview Sheet



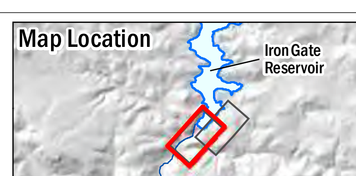
0 600
Feet

DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

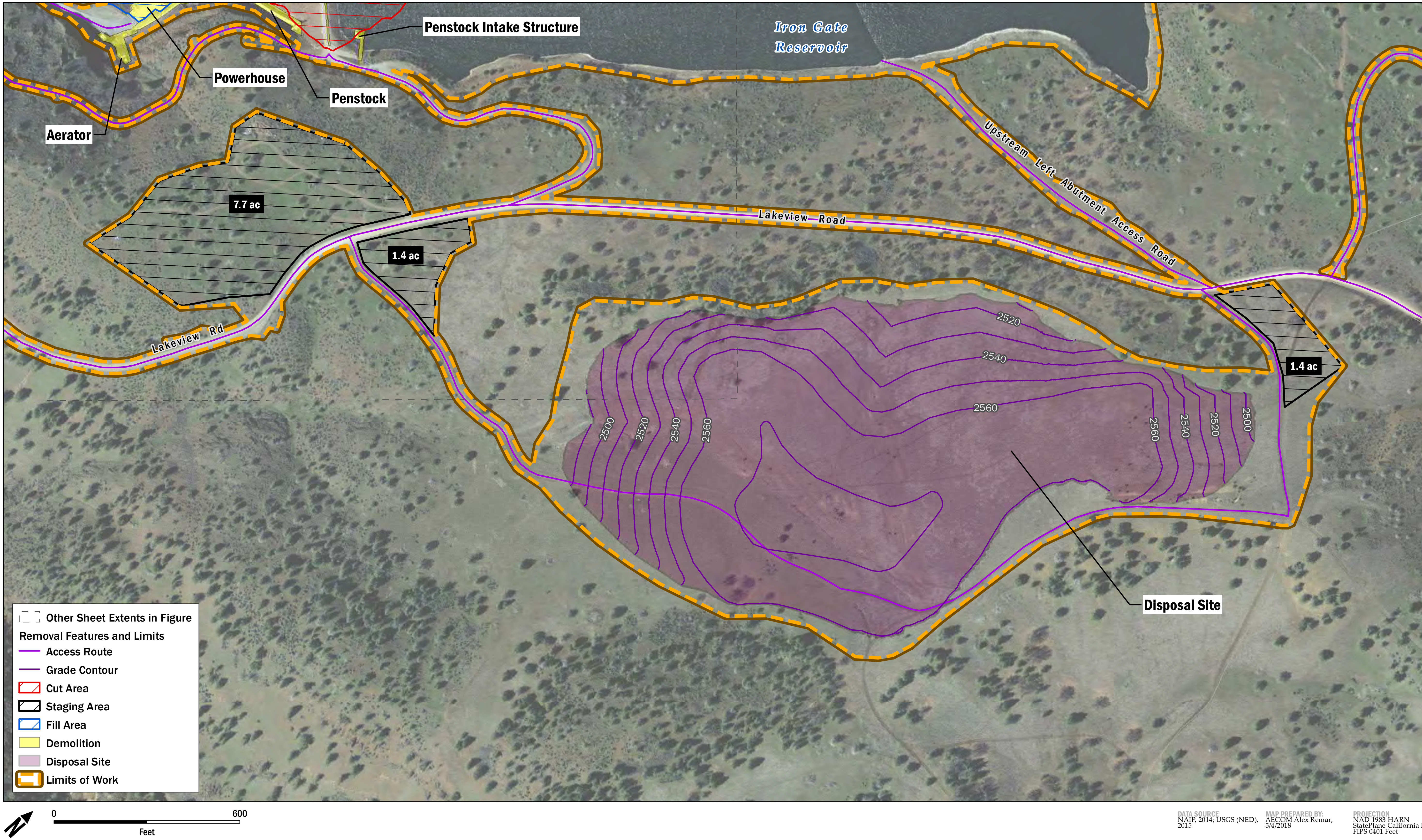
PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.5-1
Iron Gate Dam Removal Features and Limits
Sheet 1 of 2

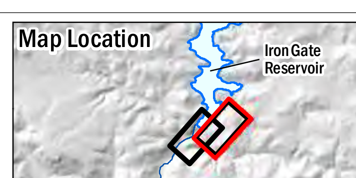


DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/4/2018

PROJECTION
NAD 1983 HARN StatePlane California I FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Note: Limits of work features that exist as small islands and/or narrow linear corridors are associated with project transmission line removal

FIGURE 5.5-1

Iron Gate Dam Removal Features and Limits
Sheet 2 of 2

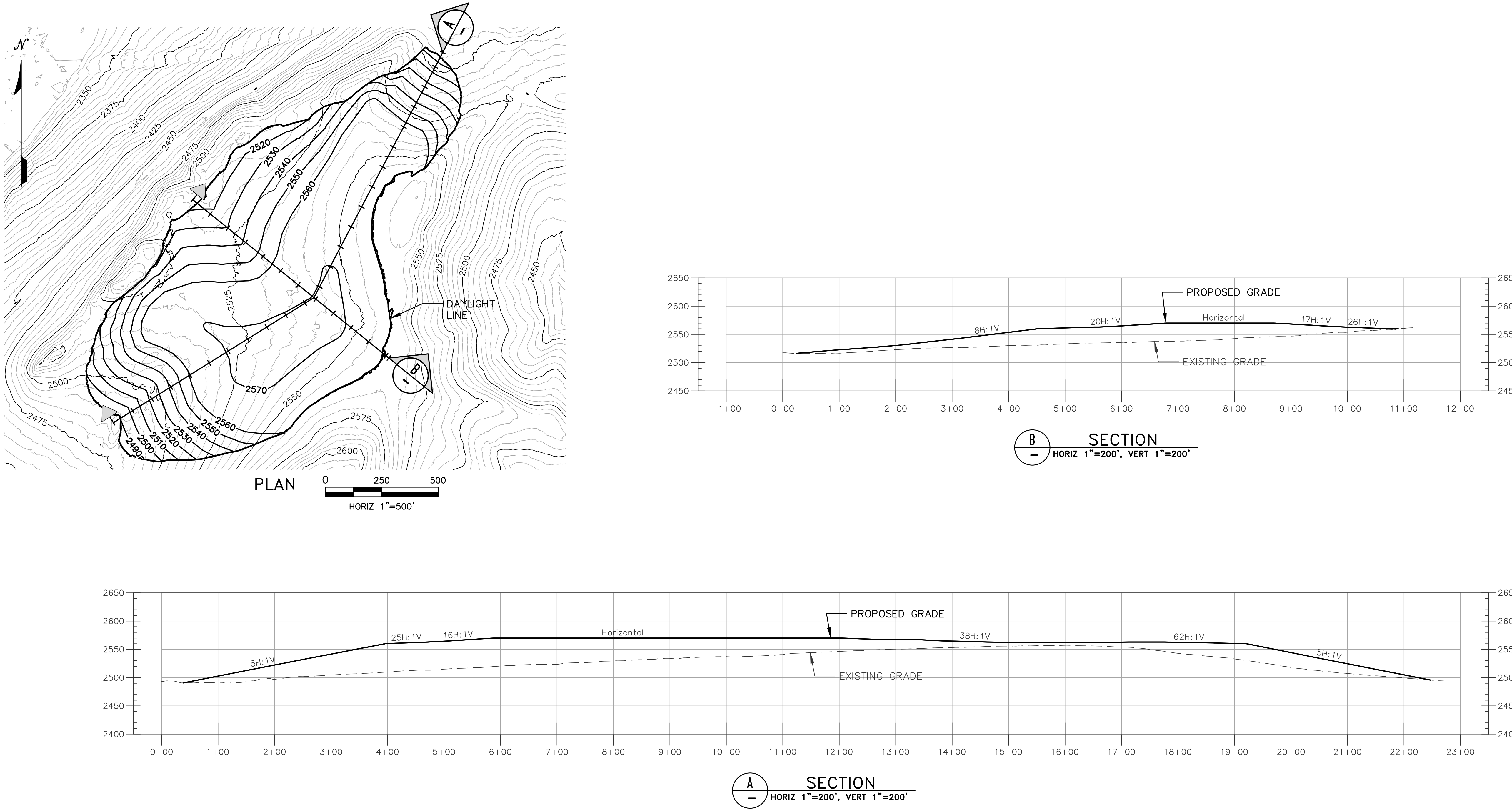


FIGURE 5.5-4

Iron Gate Disposal Site Plan & Sections

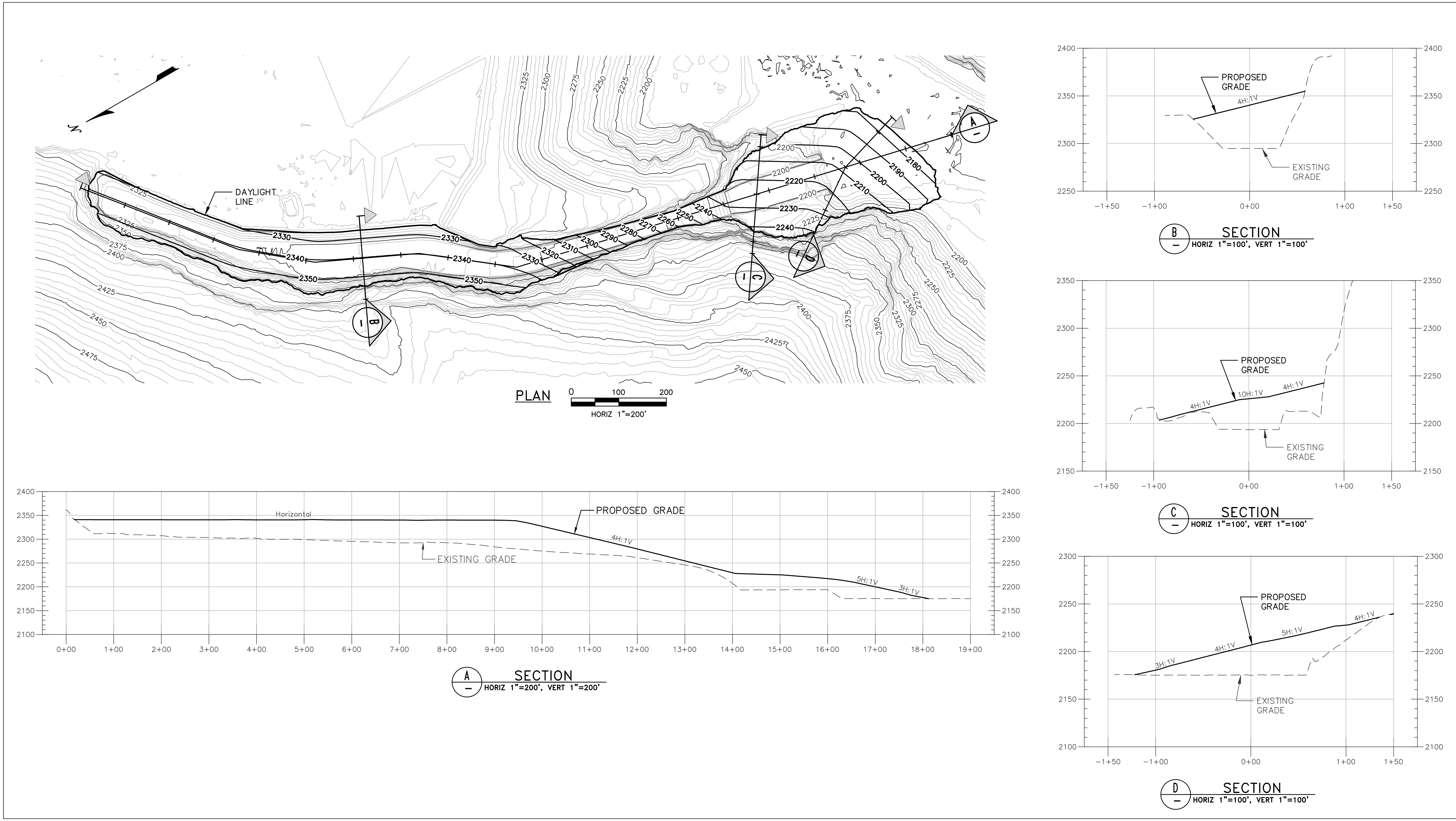


FIGURE 5.5-5

Iron Gate Spillway Backfill Plan & Sections

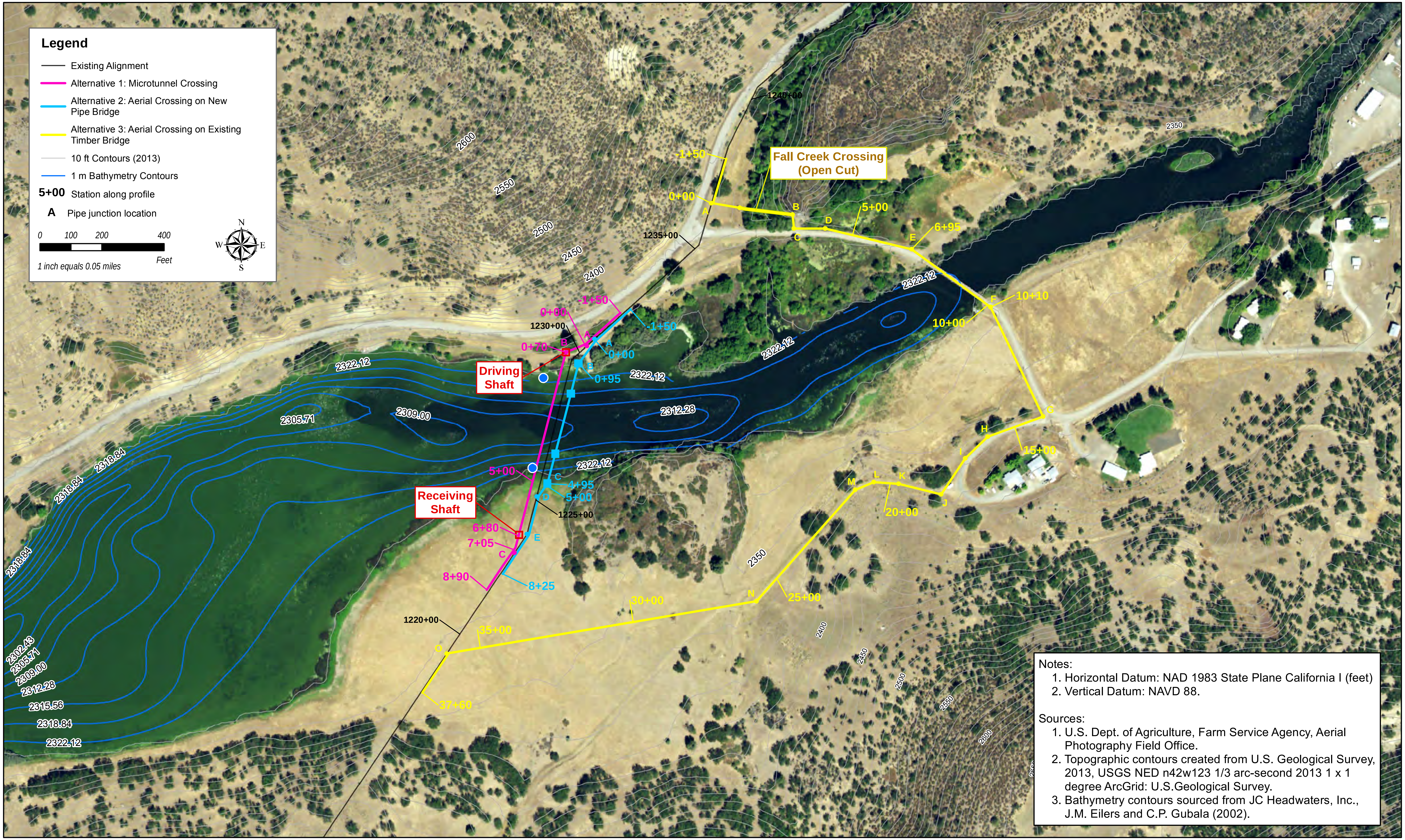


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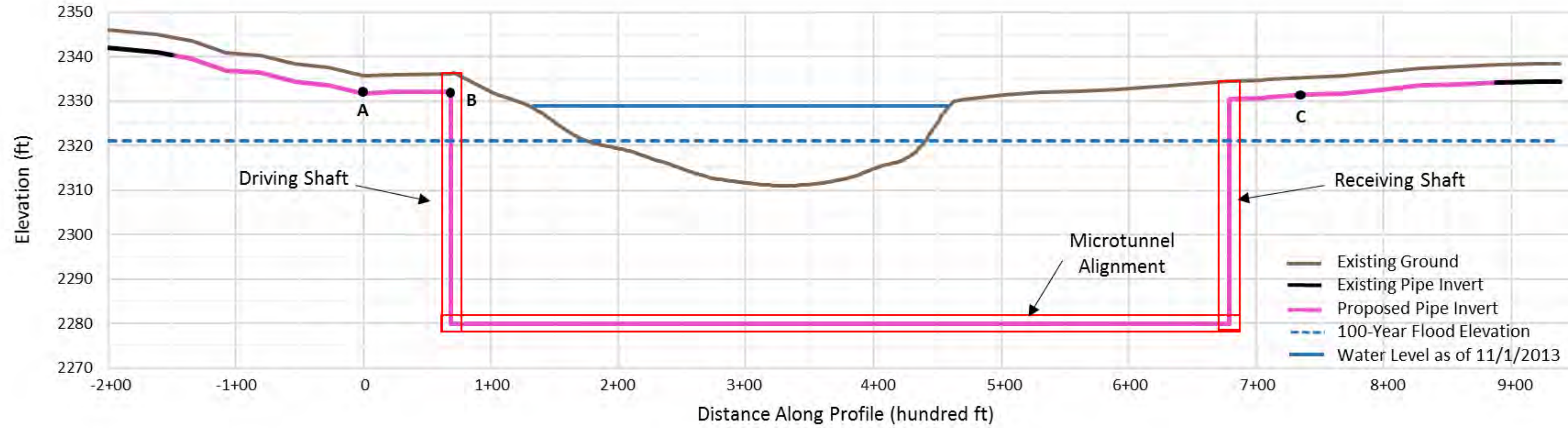
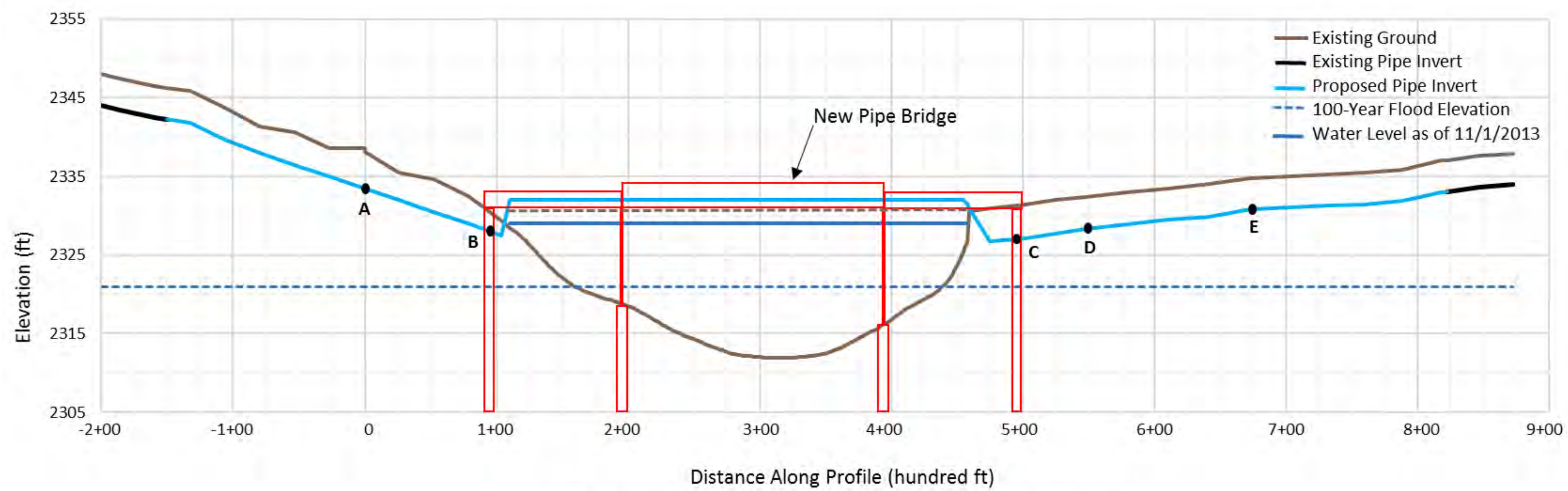
FIGURE 7.5-2: ALIGNMENTS FOR KLAMATH RIVER CROSSING CONCEPTUAL ALTERNATIVES

Klamath Dams Removal Project – Yreka Waterline Replacement

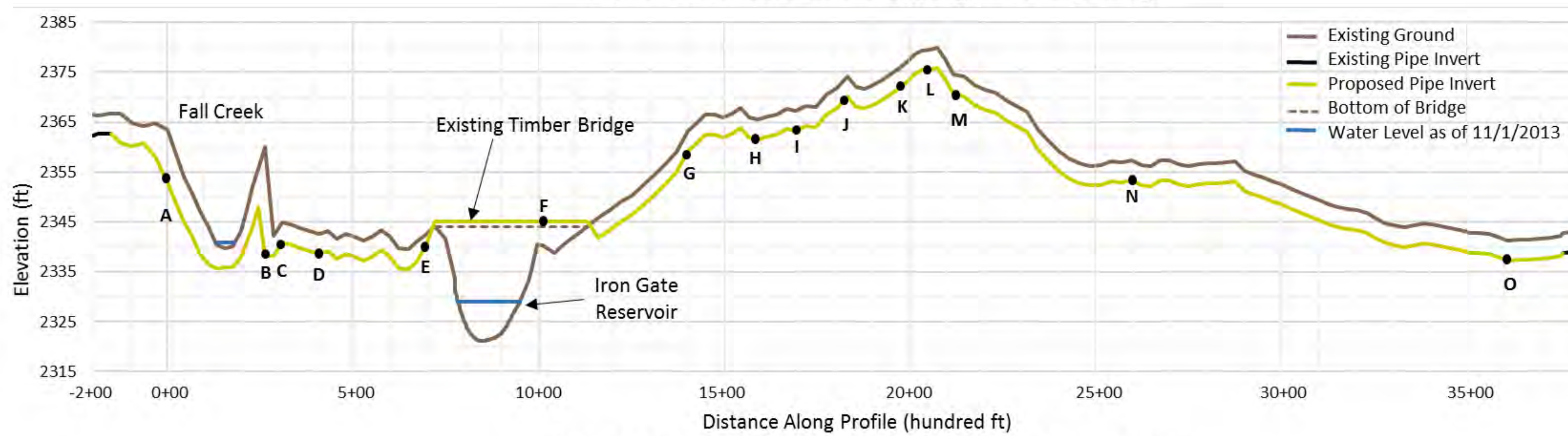
September 14, 2017



Profile for Alternative 1: Microtunnel



Profile for Alternative 2: Aerial Crossing on New Pipe Bridge

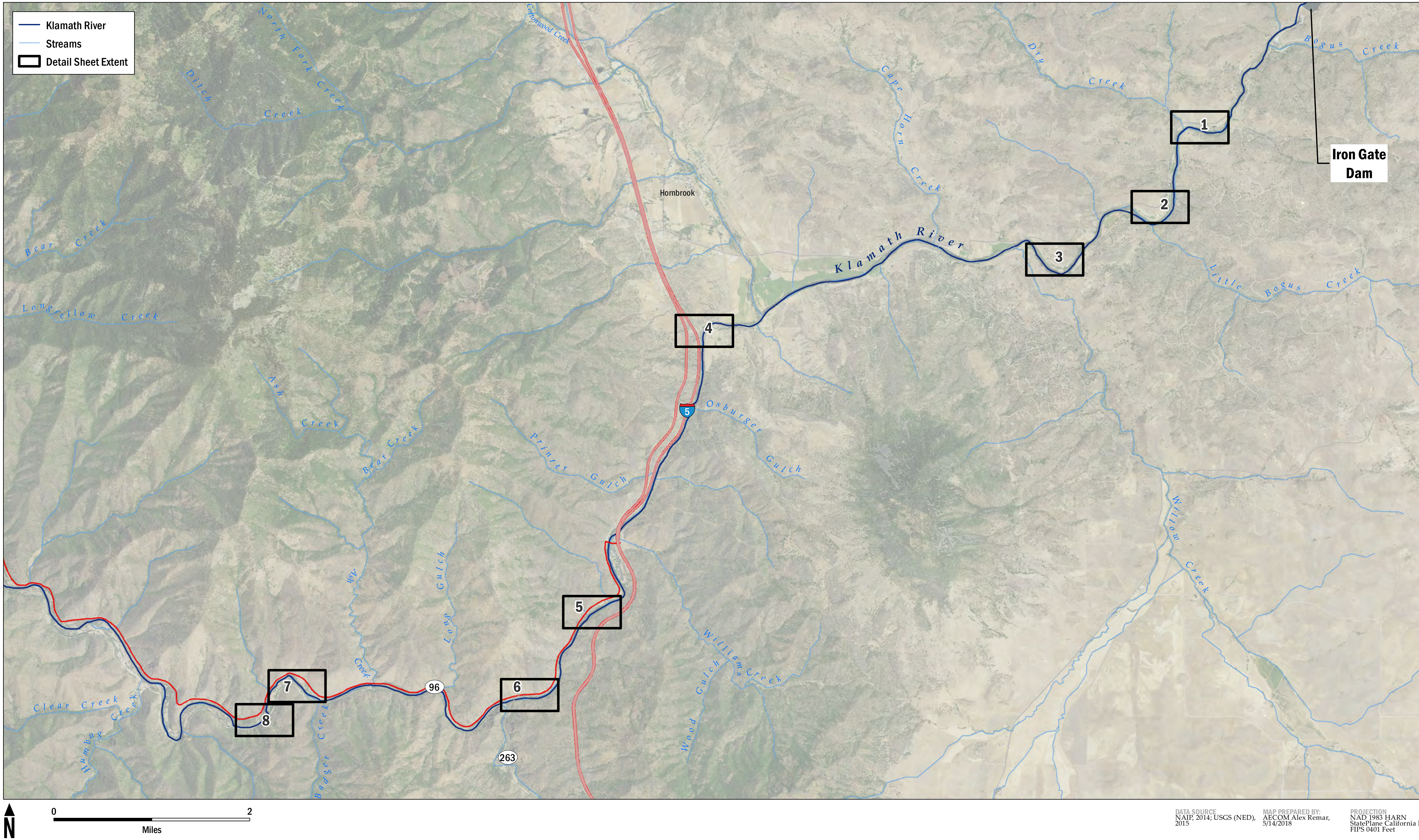


Profile for Alternative 3: Aerial Crossing on Existing Timber Bridge

FIGURE 7.5-3: PROFILES FOR KLAMATH RIVER CROSSING CONCEPTUAL ALTERNATIVES

Klamath Dams Removal Project – Yreka Waterline Replacement

September 14, 2017



DATA SOURCE
NAIP, 2014; USGS (NED), 2015

MAP PREPARED BY:
AECOM Alex Remar, 5/14/2018

PROJECTION
NAD 1983 HARN
StatePlane California I
FIPS 0401 Feet

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

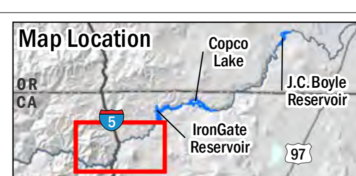
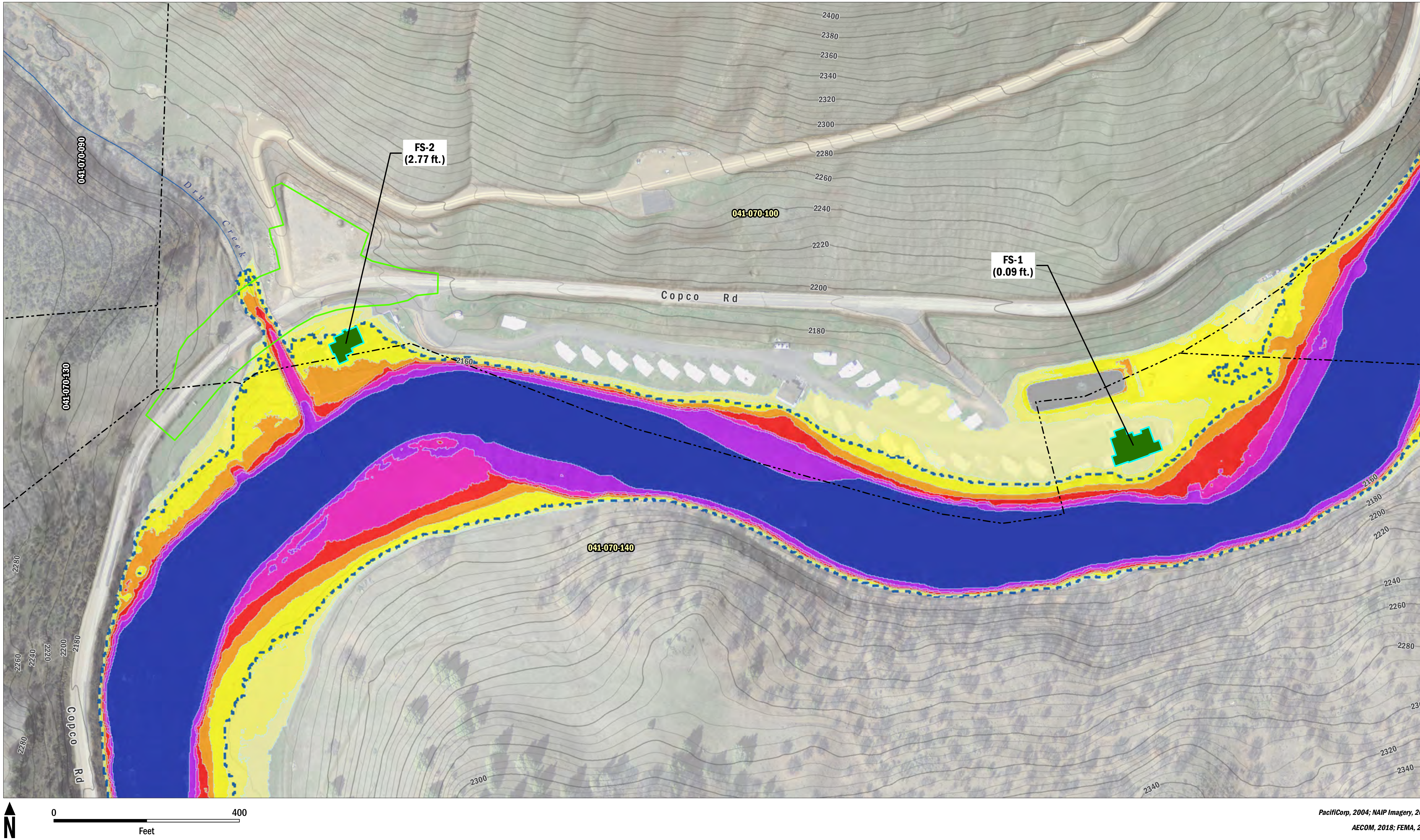


FIGURE 7.7-1

Structures in 100-Year Floodplain Following Dam Removal Overview Sheet



PacifiCorp, 2004; NAIP Imagery, 2014; AECOM, 2018; FEMA, 2011

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Map Area

Structure ID (avg. flood depth)
Floodproofing Structures
Parcels
Limits of Work
Pre-Dam Removal Flood Extent

Contours
5 ft.
20 ft.

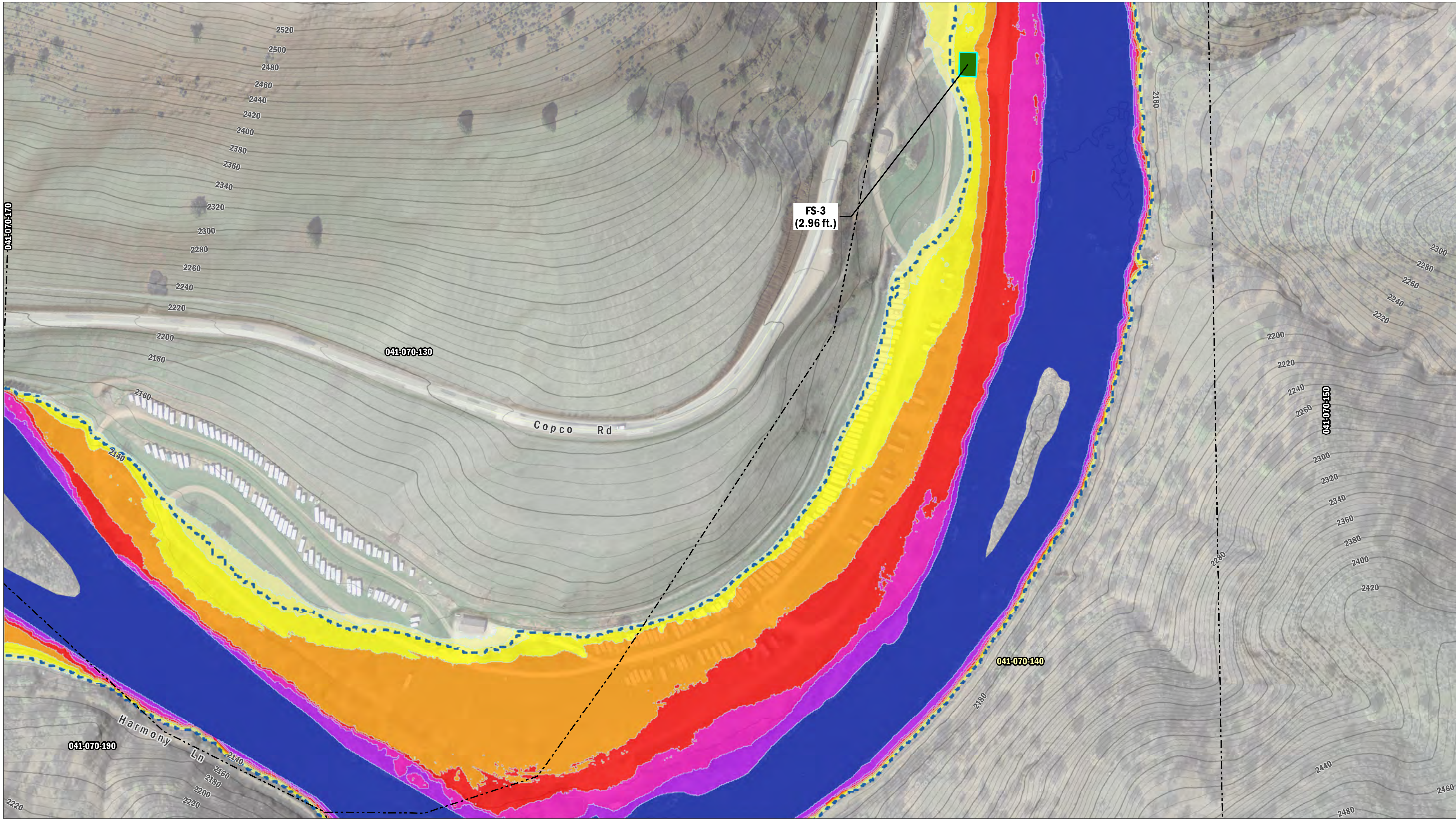
Post-Dam Removal Flood Depths (ft.)
0 - 1
1.01 - 2
2.01 - 4
4.01 - 6
6.01 - 8
8.01 - 10
10.01 - 15
15.01 - 20
> 20

Note: Parcel boundaries shown in this mapbook are data provided by Siskiyou County, CA, Klamath County, OR, PacifiCorp, and the Bureau of Land Management (BLM). There are inconsistencies among these datasets and between the datasets and LiDAR and aerial imagery. No ground-based parcel surveys have been completed; however, the County parcel data has been geo-rectified to align better with available LiDAR and aerial imagery data. APE and Sub Area 1 locations are based on field survey with GPS, LiDAR, and aerial imagery. Positions of the APE and Sub Area 1 with reference to parcel boundaries may be incorrect on the order of 10 to 50 feet.

FIGURE 7.7-1

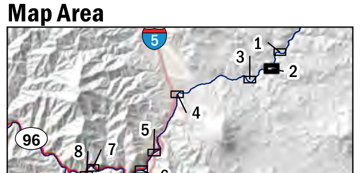
Structures in 100-Year Floodplain Following Dam Removal

Sheet 1 of 8



PacifiCorp, 2004; NAIP Imagery, 2014; AECOM, 2018; FEMA, 2011

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project



Structure ID (avg. flood depth)
Floodproofing Structures
Parcels
Pre-Dam Removal Flood Extent

Contours
5 ft.
20 ft.

Post-Dam Removal Flood Depths (ft.)
0 - 1
1.01 - 2
2.01 - 4
4.01 - 6
6.01 - 8
8.01 - 10
10.01 - 15
15.01 - 20
> 20

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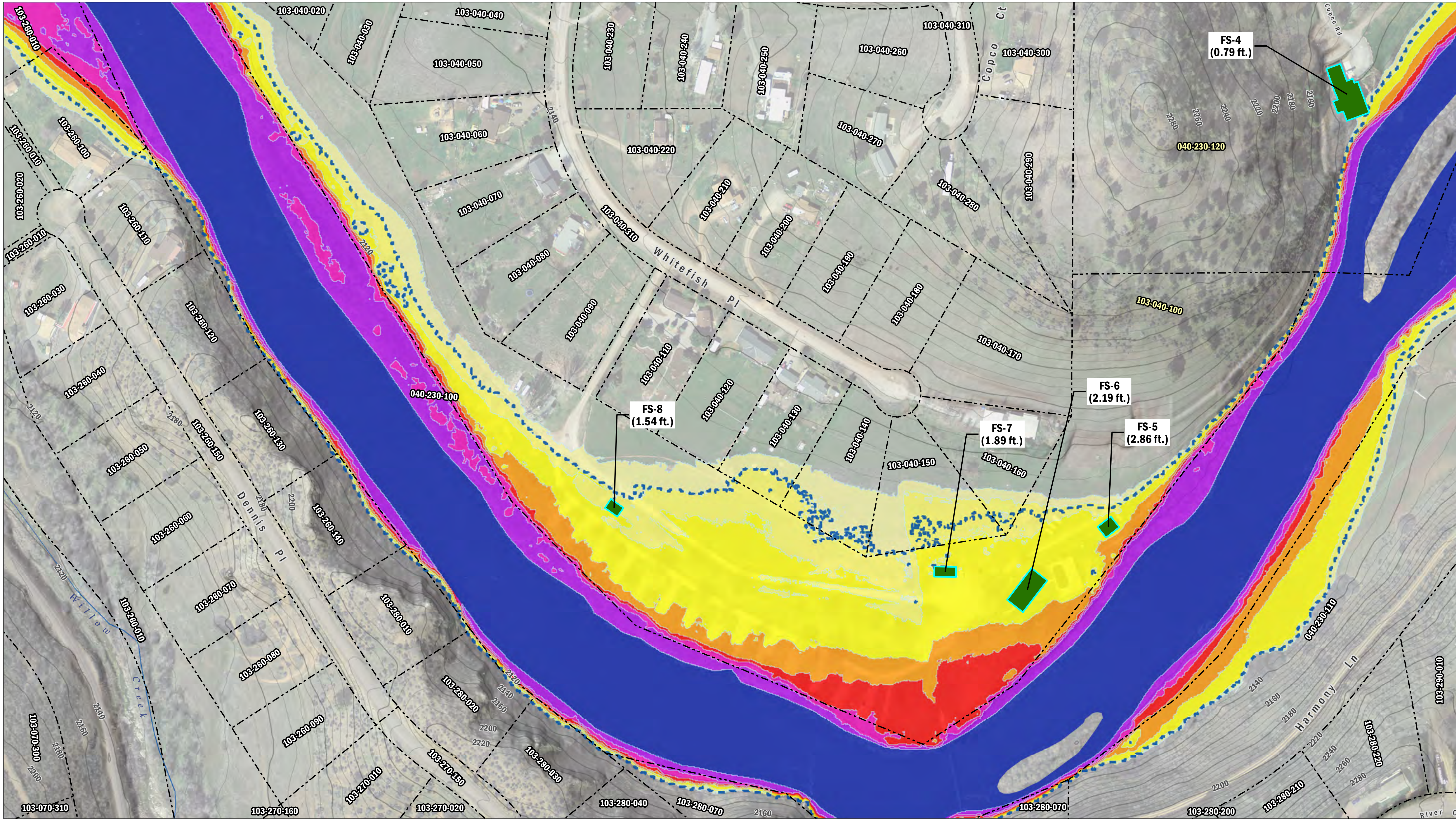
FIGURE 7.7-1
Structures in 100-Year Floodplain Following Dam Removal
Sheet 2 of 8

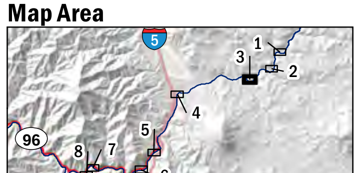
AECOM Oakland CA 5/14/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_7_7-1_Floodproofing_Sheets.mxd



PacifiCorp, 2004; NAIP Imagery, 2014;
AECOM, 2018; FEMA, 2011

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Map Area



Structure ID (avg. flood depth)
Floodproofing Structures
Parcels
Pre-Dam Removal Flood Extent

Contours
5 ft.
20 ft.

Post-Dam Removal Flood Depths (ft.)
0 - 1
1.01 - 2
2.01 - 4
4.01 - 6
6.01 - 8
8.01 - 10
10.01 - 15
15.01 - 20
> 20

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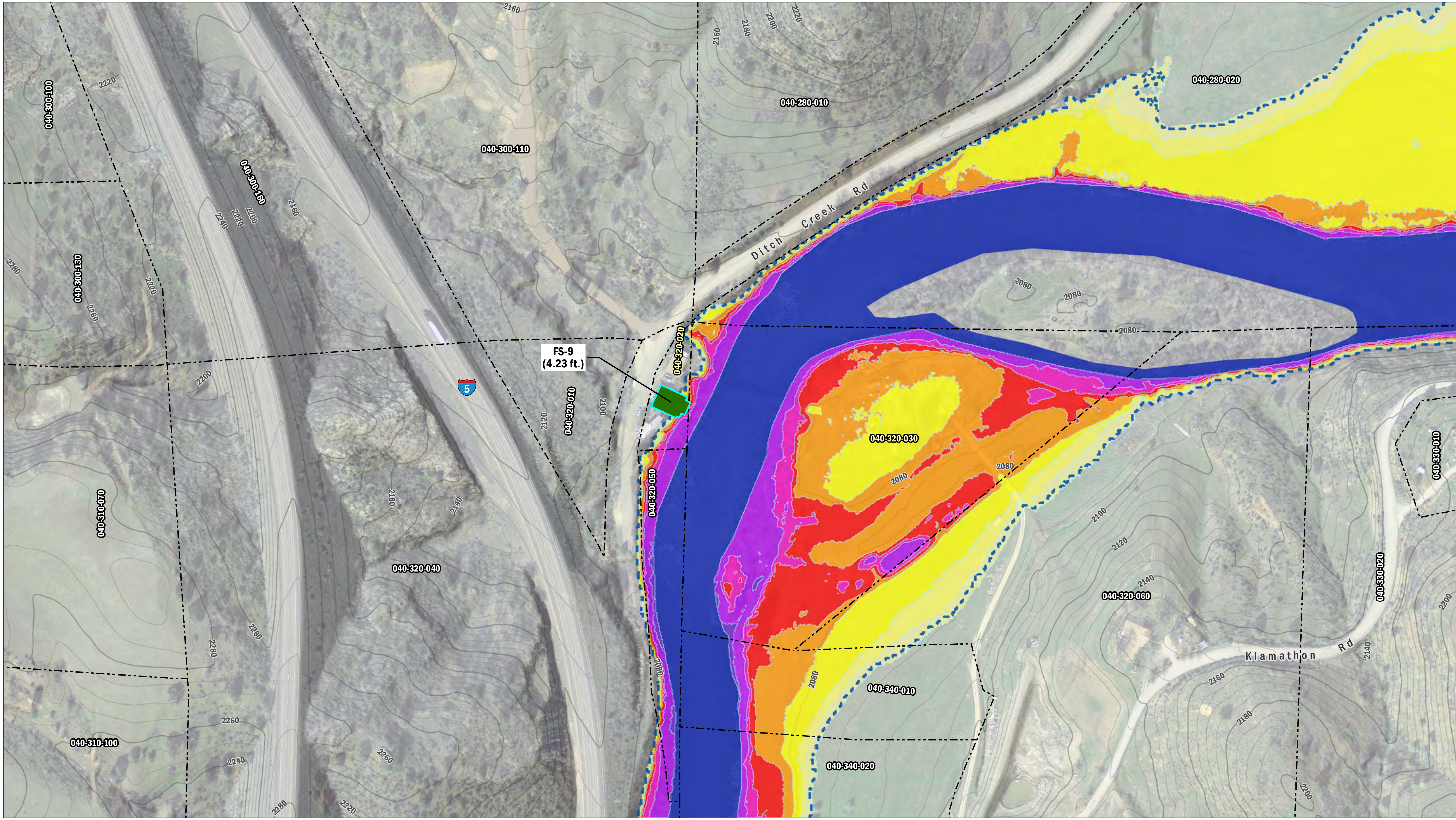
FIGURE 7.7-1
Structures in 100-Year Floodplain Following Dam Removal
Sheet 3 of 8



PacifiCorp, 2004; NAIP Imagery, 2014; AECOM, 2018; FEMA, 2011

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Map Area

Structure ID (avg. flood depth)
Floodproofing Structures
Parcels
Pre-Dam Removal Flood Extent

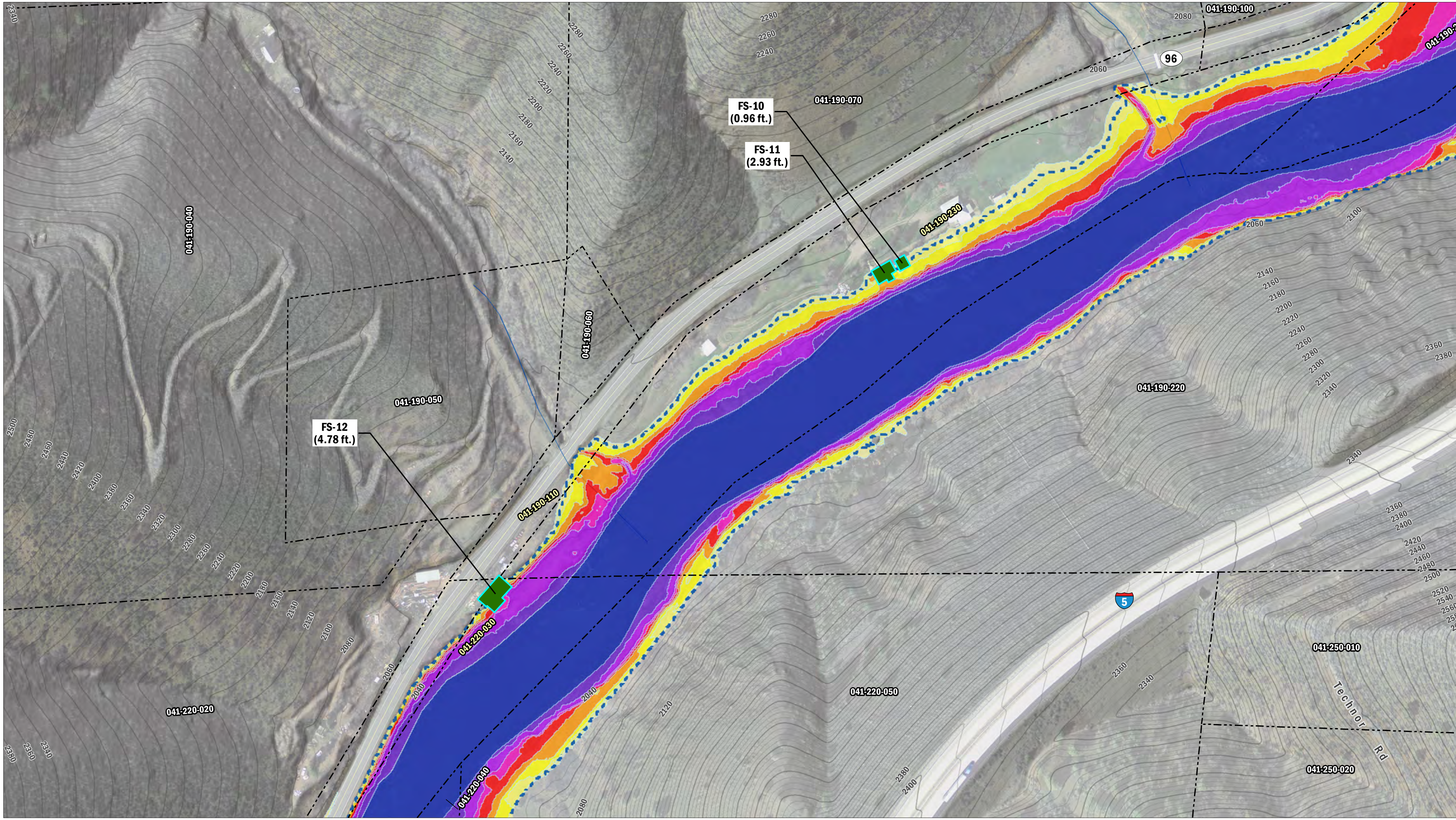
Contours
5 ft.
20 ft.

Post-Dam Removal Flood Depths (ft.)
0 - 1
1.01 - 2
2.01 - 4
4.01 - 6
6.01 - 8
8.01 - 10
10.01 - 15
15.01 - 20
> 20

Note: Parcel boundaries shown in this mapbook are data provided by Siskiyou County, CA, Klamath County, OR, PacifiCorp, and the Bureau of Land Management (BLM). There are inconsistencies among these datasets and between the datasets and LiDAR and aerial imagery. No ground-based parcel surveys have been completed; however, the County parcel data has been geo-rectified to align better with available LiDAR and aerial imagery data. APE and Sub Area 1 locations are based on field survey with GPS, LiDAR, and aerial imagery. Positions of the APE and Sub Area 1 with reference to parcel boundaries may be incorrect on the order of 10 to 50 feet.

FIGURE 7.7-1
Structures in 100-Year Floodplain Following Dam Removal
Sheet 4 of 8

AECOM Oakland CA 5/14/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_7_7-1_Floodproofing_Sheets.mxd



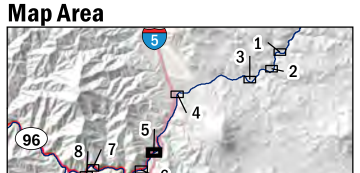
N

0 400
Feet

PacifiCorp, 2004; NAIP Imagery, 2014;
AECOM, 2018; FEMA, 2011

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Map Area



Structure ID
(avg. flood depth)
Floodproofing Structures
Parcels
Pre-Dam Removal Flood Extent

Contours
5 ft.
20 ft.

Post-Dam Removal Flood Depths (ft.)
0 - 1
1.01 - 2
2.01 - 4
4.01 - 6
6.01 - 8
8.01 - 10
10.01 - 15
15.01 - 20
> 20

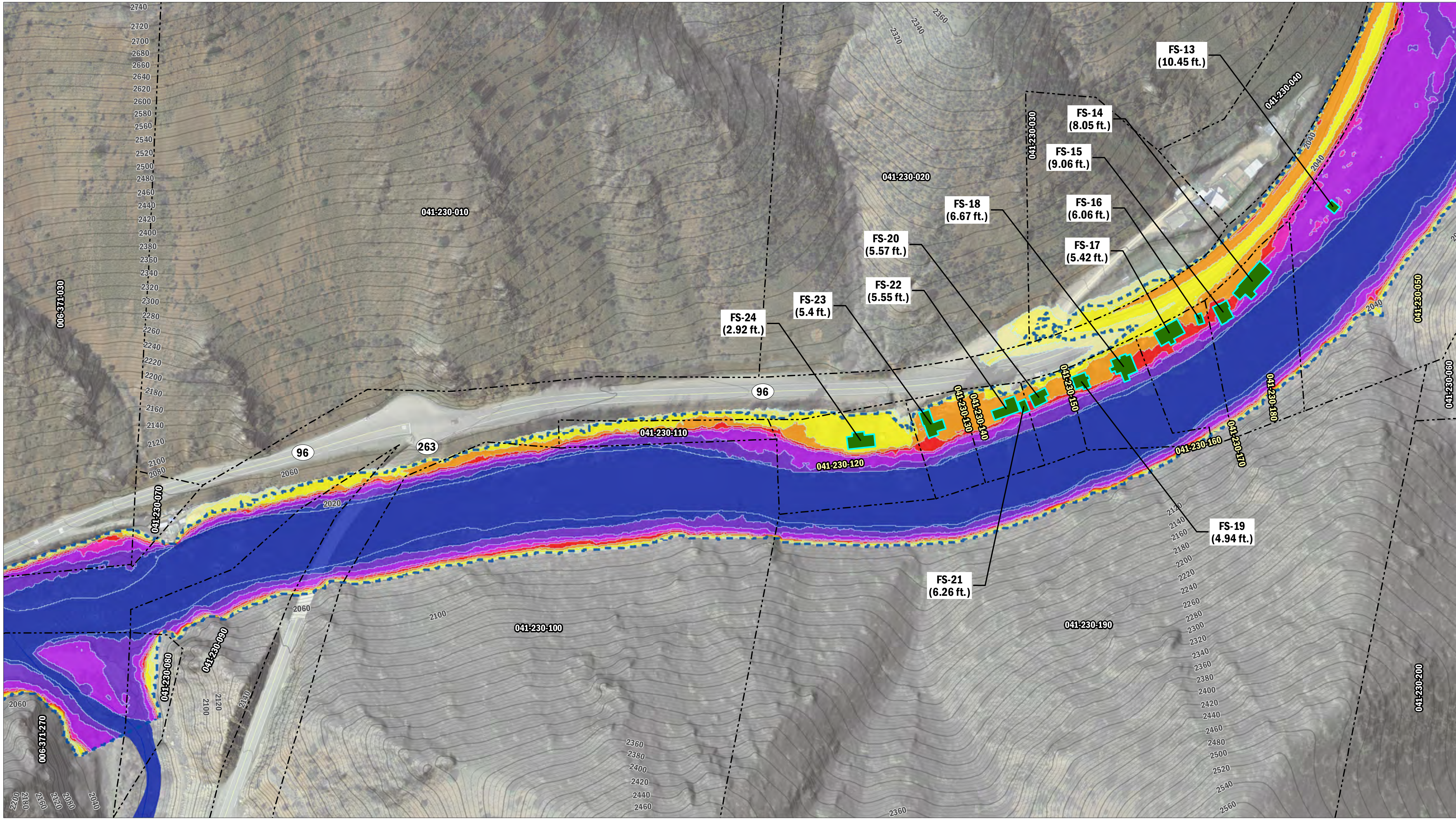
Note: Parcel boundaries shown in this mapbook are data provided by Siskiyou County, CA, Klamath County, OR, PacifiCorp, and the Bureau of Land Management (BLM). There are inconsistencies among these datasets and between the datasets and LiDAR and aerial imagery. No ground-based parcel surveys have been completed; however, the County parcel data has been geo-rectified to align better with available LiDAR and aerial imagery data. APE and Sub Area 1 locations are based on field survey with GPS, LiDAR, and aerial imagery. Positions of the APE and Sub Area 1 with reference to parcel boundaries may be incorrect on the order of 10 to 50 feet.

FIGURE 7.7-1

Structures in 100-Year Floodplain Following Dam Removal

Sheet 5 of 8

AECOM Oakland CA 5/14/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_7_7-1_Floodproofing_Sheets.mxd

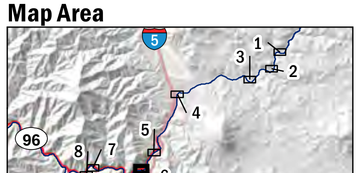


0 400
Feet

PacifiCorp, 2004; NAIP Imagery, 2014;
AECOM, 2018; FEMA, 2011

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Map Area



Structure ID (avg. flood depth)
Floodproofing Structures
Parcels
Pre-Dam Removal Flood Extent

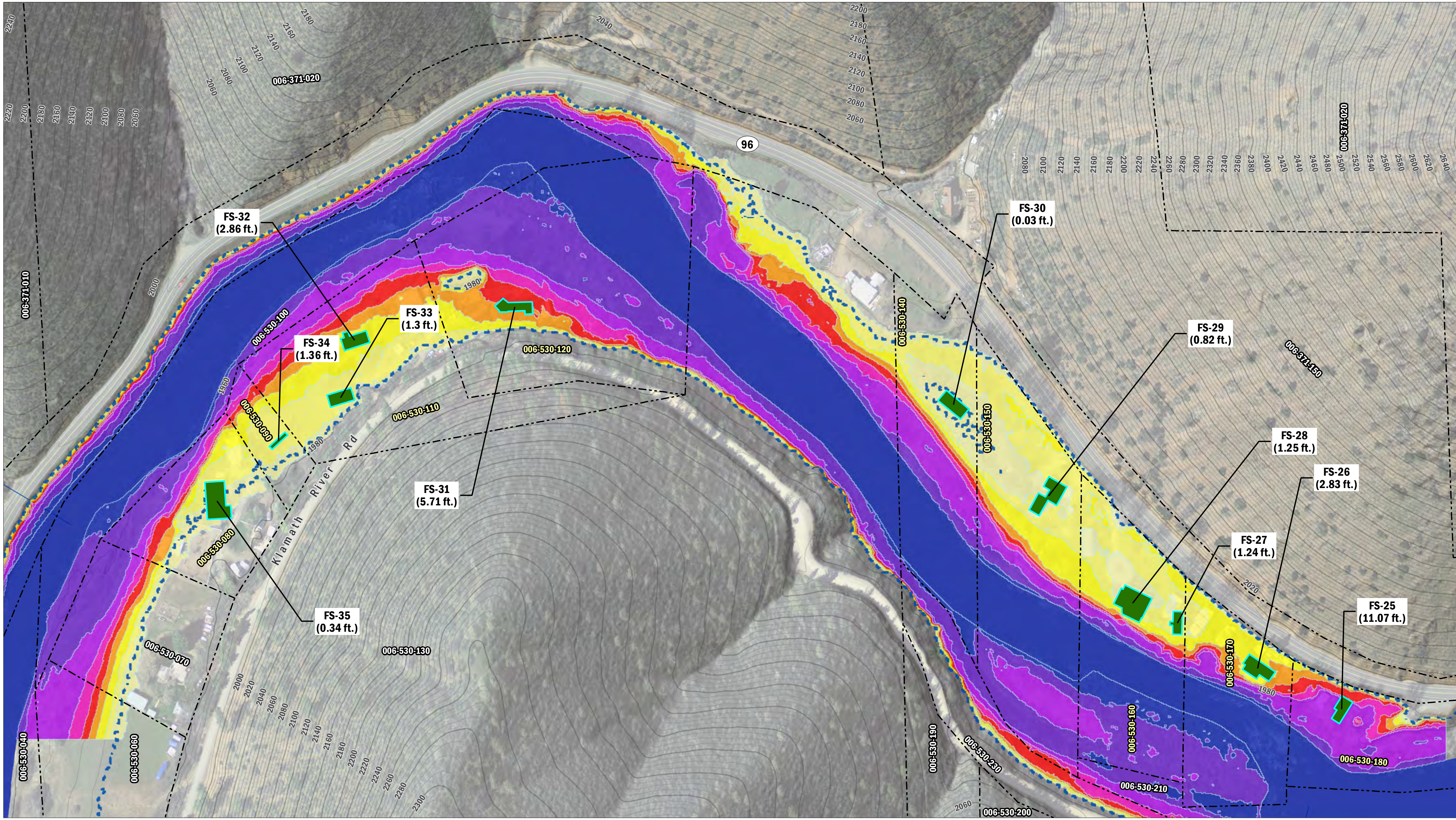
Contours
5 ft.
20 ft.

Post-Dam Removal Flood Depths (ft.)
0 - 1
1.01 - 2
2.01 - 4
4.01 - 6
6.01 - 8
8.01 - 10
10.01 - 15
15.01 - 20
> 20

Note: Parcel boundaries shown in this mapbook are data provided by Siskiyou County, CA, Klamath County, OR, PacifiCorp, and the Bureau of Land Management (BLM). There are inconsistencies among these datasets and between the datasets and LiDAR and aerial imagery. No ground-based parcel surveys have been completed; however, the County parcel data has been geo-rectified to align better with available LiDAR and aerial imagery data. APE and Sub Area 1 locations are based on field survey with GPS, LiDAR, and aerial imagery. Positions of the APE and Sub Area 1 with reference to parcel boundaries may be incorrect on the order of 10 to 50 feet.

FIGURE 7.7-1
Structures in 100-Year Floodplain Following Dam Removal
Sheet 6 of 8

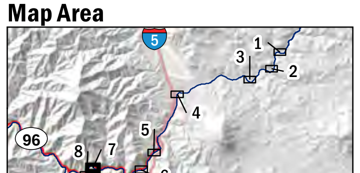
AECOM Oakland CA 5/14/2018 USER alexander.remar PATH \\Oakland\Oakland\Projects\Secure\Water\Klamath Dam\400-Technical\440 GIS\02_Maps\02_Map_Production_and_Reports\Def_Plan\Figure_7_7-1_Floodproofing_Sheets.mxd



PacifiCorp, 2004; NAIP Imagery, 2014;
AECOM, 2018; FEMA, 2011

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Map Area



Structure ID (avg. flood depth)
- Floodproofing Structures
- Parcels
- Pre-Dam Removal Flood Extent

Contours
- 5 ft.
- 20 ft.

Post-Dam Removal Flood Depths (ft.)
- 0 - 1
- 1.01 - 2
- 2.01 - 4
- 4.01 - 6
- 6.01 - 8
- 8.01 - 10
- 10.01 - 15
- 15.01 - 20
- > 20

Note: Parcel boundaries shown in this mapbook are data provided by Siskiyou County, CA, Klamath County, OR, PacifiCorp, and the Bureau of Land Management (BLM). There are inconsistencies among these datasets and between the datasets and LiDAR and aerial imagery. No ground-based parcel surveys have been completed; however, the County parcel data has been geo-rectified to align better with available LiDAR and aerial imagery data. APE and Sub Area 1 locations are based on field survey with GPS, LiDAR, and aerial imagery. Positions of the APE and Sub Area 1 with reference to parcel boundaries may be incorrect on the order of 10 to 50 feet.

FIGURE 7.7-1

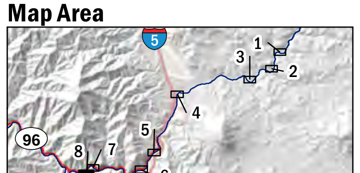
Structures in 100-Year Floodplain Following Dam Removal

Sheet 7 of 8

PacifiCorp, 2004; NAIP Imagery, 2014;
AECOM, 2018; FEMA, 2011

AECOM
Klamath River Renewal Corporation
Klamath River Renewal Project

Map Area



Structure ID
(avg. flood depth)

- Floodproofing Structures
- Parcels
- Pre-Dam Removal Flood Extent

Contours
- 5 ft.
- 20 ft.

Post-Dam Removal Flood Depths (ft.)
- 0 - 1
- 1.01 - 2
- 2.01 - 4
- 4.01 - 6
- 6.01 - 8
- 8.01 - 10
- 10.01 - 15
- 15.01 - 20
- > 20

Note: Parcel boundaries shown in this mapbook are data provided by Siskiyou County, CA, Klamath County, OR, PacifiCorp, and the Bureau of Land Management (BLM). There are inconsistencies among these datasets and between the datasets and LiDAR and aerial imagery. No ground-based parcel surveys have been completed; however, the County parcel data has been geo-rectified to align better with available LiDAR and aerial imagery data. APE and Sub Area 1 locations are based on field survey with GPS, LiDAR, and aerial imagery. Positions of the APE and Sub Area 1 with reference to parcel boundaries may be incorrect on the order of 10 to 50 feet.

FIGURE 7.7-1
Structures in 100-Year Floodplain Following Dam Removal
Sheet 8 of 8

Appendix D Dam Stability Analyses

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AECOM
300 Lakeside Drive, Suite 400, Oakland, CA 94612
USA
aecom.com

Project name:
Klamath River Renewal Project

Project ref:
60537920

To: Klamath River Renewal Coporation

From:
John Roadifer, Kanax Kanagalingam, Benjamin Choy

CC:

Date:
June 20, 2018

Technical Memorandum

Subject: Definite Plan for the Lower Klamath Project
Analysis of Stability of J.C. Boyle and Iron Gate Dams During Reservoir Drawdown

INTRODUCTION

AECOM prepared this technical memorandum in support of the design for the removal of the Iron Gate Dam and J.C. Boyle Dam, which are located on the Klamath River in northern California and southern Oregon, respectively. The purpose of this technical memorandum is to review existing geotechnical data related to the Iron Gate and J.C. Boyle embankments, characterize the materials in the embankments, and evaluate the stability of the upstream slopes of the embankments under various conditions of rapid drawdown of the reservoirs prior to dam removal.

Iron Gate Dam is a 189-foot high zoned earthfill embankment, as measured from the crest to the rock foundation. The crest of the dam is at El. 2343[1] feet. The crest of the dam is 20 feet wide, and the dam is approximately 740 feet long. The embankment upstream slopes are 2:1 (H:V) above El. 2328 feet, 2.5:1 from El. 2328 feet to 2300 feet, and 3H:1V below El. 2300 feet. The downstream slopes are 1.75:1 above El. 2323 feet and 2:1 below El. 2323 feet. The dam also features a 29-foot wide bench and a 10-foot wide bench at El. 2275 feet on the upstream side and downstream side, respectively. The dam consists of a central impervious clay core, an upstream and a downstream compacted pervious shell with filter zones and a downstream drain. A 10-foot thick layer of riprap protects the upstream slope of the dam against erosion. A 5-foot thick riprap layer is present on the downstream slope. In 2003, the dam crest was raised 5 feet from El. 2338 feet to 2343 feet by over-steepening the upstream and downstream slopes. To provide additional freeboard, a sheet pile was installed upstream of the dam centerline that extends five (5) feet above the dam crest to an El. of 2348 feet.

J.C. Boyle Dam consists of two portions: an earthfill embankment on the right side and a concrete spillway and gravity section on the left side. This technical memorandum evaluates the earthfill embankment portion of the dam. The earthfill embankment is a 68-foot high zoned earthfill embankment. The crest of the dam is at El. 3800 feet. The crest of the embankment is 15 feet wide and approximately 413 feet long. The upstream slopes are 2.5:1 (H:V) above El. 3780 feet and 3H:1V below El. 3780 feet. The downstream slopes are 2.5:1. The downstream slope also includes a 16-foot wide bench at El. 3768 feet. The internal zoning of the dam consists of a central impervious clay core, an upstream and a downstream compacted pervious shell consisting of sand and gravels. A filter blanket underlies the downstream shell. Erosion protection of the upstream slope is provided by a 3-foot thick riprap layer above El. 3680 feet. A 2-foot thick riprap layer below El. 3768 feet protects the downstream slope against erosion due to elevated tailwater.

EXISITNG DATA REVIEW

[1] All elevations in this memorandum are in the original datum unless otherwise indicated.

A review of existing available pertinent information for Iron Gate Dam and J.C. Boyle Dam were performed as part of this study to judge whether additional geotechnical investigation would have to be conducted for evaluating the dams for the rapid drawdown conditions. The reviewed information included design drawings, laboratory testing data for the borrow source materials, construction history, specifications, previous stability analyses, and post construction subsurface investigation. The results from the review indicate the followings:

- Representative analysis cross sections can be developed at the maximum section using the design drawings for both the Iron Gate Dam and the J.C. Boyle Dam.
- A reasonable material characterization of embankment materials, in particular the core and shell materials, can be developed using the information in the construction history, drawings, and specifications for the two dams. The source of materials, loose lift thickness and compaction efforts were discussed in those documents (California Oregon Power Company, 1960a and Unknown Publisher, Unknown Date). The results from a post-construction subsurface investigation conducted for J.C. Boyle Dam in 1994 (Black and Veatch, 1998) provide additional information for shell material characterization.
- Material properties necessary for performing slope stability and seepage analyses can be reasonably developed using the reviewed information. The reviewed information included laboratory shear strength and permeability tests conducted on the borrow source materials (California Oregon Power Company, 1960b and Unknown Date) and previous rapid drawdown analyses performed by others (Bechtel, 1968, Department of Water Resources, 1986, Black and Veatch, 1998, and PanGEO, 1998) .

The existing information for both dams are deemed sufficient to perform rapid drawdown analyses with targeted sensitivity analysis to address uncertainties associated with material properties as discussed later in this memorandum.

MATERIAL CHARACTERIZATION

Iron Gate Dam

Iron Gate Dam, which was built in 1961, is a zoned earth and rock fill dam. The dam consists of six (6) main zones: an upstream pervious shell (Zone I), a downstream pervious shell (Zone II), a central impervious core (Zone III), a transition (Zone IA) upstream of the core, a downstream chimney two-stage filter (Zone IV and Zone IVA) and drain (Zone V), and a downstream blanket filter (Zone IV) and drain (Zone V). The analysis section for rapid drawdown stability is the maximum cross section as shown on Figure 1.

The shell materials mainly consist of locally borrowed, pervious talus rock and gravel placed in 3-foot loose lifts, moisture conditioned, and compacted with four (4) passes of 72-inch vibratory roller (PanGEO, 2006). The weight of the roller was not indicated in the documents reviewed. The impervious core mainly consists of high plasticity clay from a local borrow source. The core material was placed in 8-inch loose lifts and compacted to not less than 95% of the maximum dry density as determined by ASTM D698 (California Oregon Power Company , 1960a and PanGEO, 2006). The upstream transition zone consists of graded talus rock and is approximately 20 feet in thickness. The downstream chimney and blanket filters consist of fine sand to gravel and were constructed in three (3) vertical layers (California Oregon Power Company, 1960a). Based on the design drawings, the thicknesses of the chimney and blanket filters are 20 feet and 5 feet, respectively. The downstream chimney and blanket drains consist of selected talus, gravel, or other excavations that is essentially free of materials smaller than the #100 sieve (California Oregon Power Company, 1960a). The dam was founded on basalt that is generally hard, blocky, heavily jointed, and moderately weathered (DSOD, 1986).

Iron Gate Dam Material Properties

The shear strength parameters of shell and core are very important for the rapid drawdown analysis. Shear strength parameters for the core material were developed mainly based on results from isotropic consolidated undrained triaxial tests (TX-ICU) conducted on samples obtained from borrow sources during borrow source evaluation (California Oregon Power Company, 1960b). The results of the triaxial tests are included in Attachment A. However, no laboratory shear strength tests are available for the shell and other embankment materials. Therefore, shear strength parameters for these materials were selected based on available information such as the type of construction, parameters used in previous analyses, and published data (NAVFAC, 1986 and EPRI, 1990). As mentioned above, the shell materials consist of talus rock and gravel, which were compacted during placement. Based on the published data, the effective friction angle for compacted gravelly materials would be greater than 37 degrees. For this rapid drawdown analysis, the shell materials were conservatively assigned an effective friction angle of 35 degrees. In addition, transition zone, chimney filter and drain, and blanket filter and drain were compacted during placement. Therefore, these materials were also assigned an effective friction angle of 35 degrees. The bedrock is modeled as impenetrable in the slope stability model. Table 1 summarizes these engineering parameters (best estimate parameters) used in the slope stability analyses.

The unit weights for different embankment zones were selected based on the laboratory tests conducted on the samples collected from proposed borrow areas, compaction test results on samples collected during dam construction, previous analyses (DWR, 1986 and PanGEO, 2006), and published data (NAVFAC, 1986 and EPRI, 1990).

The permeability values for the core and shell materials were selected based on the results from the falling head permeability tests performed on samples from the core and shell material borrow sources during borrow source evaluation. The results of the falling head permeability tests are included in Attachment B. Permeability values of the filter, chimney drain, the blanket drain, the riprap, and the random fill were estimated based on the characteristics of the materials, published data, and engineering judgment. The permeability parameters were selected conservatively based on typical ranges (Holtz and Kovacs, 1981), which is included in Attachment C. Table 1 summarizes permeability parameters used in the seepage analysis.

Anistropic ratios (k_h/k_v) typically range from 1 to 4 for uniform soil deposits without significant interbedding or stratification but can be higher for soil deposits with significant stratification. An anisotropic ratio of 10 for the core is selected considering the nature of the materials and its placement method. For the shell and random fill, an anisotropic ratio of 2 was selected as typical anisotropic ratios for similar materials range from 1 to 2. Anisotropic ratio for the filter/drain and riprap is selected to be 1 as the materials are expected to drain freely in both directions.

Table 1. Material Properties Used for the Analyses of Iron Gate Dam

Material	Unit Weight (pcf)	Effective Stress		Total Stress		Horizontal Permeability, k_h (cm/s)[1,3]	k_h/k_v
		Cohesion, c' (psf)	Friction Angle, ϕ' (°)[1,2]	Cohesion, c (psf)	Friction Angle, ϕ (°)		
Core	130	0	22	300	16	1.00E-07	10
Shell	135	0	35	-	-	8.00E-03	2
Filter/ Drain/ Transition Zones	135	0	35	-	-	1.00E-02	1
Riprap	135	0	35	-	-	1.00E-02	1
Random Fill	135	0	25	-	-	8.00E-03	2

Note:
1. The parameter that was used for sensitivity analyses is provided in parenthesis.
2. For compacted sand and gravel materials, the friction angles are typically greater than 34 degrees (NAVFAC, 1986 and EPRI, 1990).
3. For clean coarse materials, permeability ranges from 10^{-3} cm/s to 1 cm/s per Holtz and Kovacs (1981).

J.C. Boyle Dam

The earthfill embankment of the J.C. Boyle Dam is a zoned earth fill dam built in 1958. The dam consists of two (2) major zones: a central impervious clay core (Zone 1) and the upstream and downstream pervious shells (Zone 2). A filter blanket with thickness of 12 inches was placed between the Zone 2 materials and its foundation for the whole downstream area. An 18-inch thick gravel drain zone was also installed over part of the downstream foundation. A waste rock fill was placed at the downstream toe of the dam. Ripraps are placed on both the upstream and downstream sides of the dam. For analysis purpose, the gravel drain is modeled as part of the filter blanket. The rapid drawdown analyses were performed on maximum cross section of J.C. Boyle Dam, which is shown on Figure 2.

The impervious clay core is constructed of selected clay materials, which are described as rust colored sandy clay with some pea gravel. The shell materials were constructed of a mixture of well graded gravel with sand and well graded sand. Based on the specifications, the embankment materials were to be constructed in 8-inch loose lift and compacted with a minimum of twelve (12) passes of sheepfoot rollers to obtain a minimum of 95% of the dry density which correspond to the optimum moisture content of the materials placed The filter blanket is approximately 12 inches thick and consists of well graded sandy gravel. The waste rock fill was constructed of gravel placed under water without compaction. Specific information regarding size and compaction effort is not available for the upstream and downstream ripraps and the gravel drain. The dam is mostly founded on basalt with the exception of the right abutment, which is founded on satisfactory overburden (Bechtel, 1968).

J.C. Boyle Dam Material Properties

The effective shear strength parameters for the core material are developed based on the results of direct shear tests performed on samples from core borrow sources during borrow source evaluation. The results show that the effective friction angle is greater than that of Iron Gate Dam's core. This is consistent with the material descriptions which suggest that the core in J.C. Boyle Dam consists of lower plasticity clay and pea gravel. The results of the direct shear test are included in Attachment D. The total stress shear strength parameters are not available from the direct shear tests. For the purpose of rapid drawdown slope stability analysis, those parameters were conservatively assumed the same as those of the Iron Gate Dam core. No laboratory shear strength data are available for the other embankment materials. Previous slope stability analyses performed by others selected the shear strength parameters based on the SPT blow count data (Black and Veatch, 1998). Review of available data suggests that the shell materials consist of up to 50% of gravel. The shear strength parameters that were previously selected did not account for the presence of high gravel percentage in the shell material. Considering the high gravel content, the borrow source, and how the shell material was placed and compacted, for the purpose of the rapid drawdown analysis a friction angle of 34 degrees (the previous analysis used a friction angle of 37 degrees) was assumed. The strength parameters of the riprap are conservatively assumed to be the same as the shell materials as the anticipated effect from the riprap on the overall stability performance is not significant due to its relative thickness to the shell. The bedrock is modeled as impenetrable in the slope stability model. Table 2 summarizes the best estimate engineering parameters used in slope stability analyses.

As no total strength parameters are available for the core materials, a sensitivity analysis is performed on the strength parameters for the core materials. Total cohesion of 100 psf and total friction angle of 12 degrees were conservatively selected considering very soft soil conditions for this sensitivity analysis. This sensitivity analysis also considers a lower effective friction angle of 19.4 degrees for the core materials, which was selected based on the lowest values from the direct shear tests. As the core is relatively thin compared to the shell, it is anticipated that reducing the strength parameters for the core materials will not significantly impact the analysis results. Table 2 includes the engineering parameters used in the sensitivity analysis in parenthesis.

Compaction tests performed on the samples from the core and shell borrow sources during borrow source evaluation were used as the basis for unit weight of the materials. The results of the compaction tests are included in Attachment E. The selection of the unit weight used in the rapid drawdown analysis is based on the compaction test results, published data (NAVFAC, 1986 and EPRI, 1990), and previous analyses. Table 2 summarizes the unit weights used in the slope stability analysis.

Falling head permeability tests performed on samples from the core borrow sources during borrow source evaluation were used as the basis for permeability values of the core material. The results of the permeability test are included in Attachment F. Permeability values for the shell materials and filter blankets are estimated based on results of the grain size analysis using the Kozemy-Carmen permeability correlations, characteristics of the materials, published data, and engineering judgement. The permeability of the riprap is assumed to be the same as the shell materials, whereas the permeability of the wasterock fill is assumed to be the same as the shell. Table 2 summarizes the best estimate engineering properties used in the seepage analyses.

Similar to Iron Gate Dam, anisotropic ratios of 10 and 2 are selected for the core and shell materials with the exception of riprap, respectively. An anisotropic ratio of 1 is selected for the ripraps.

In addition, a set of sensitivity analysis was performed based on typical permeability ranges for gravel and sand materials (Holtz and Kovacs, 1981). This set of sensitivity analysis conservatively assumes the lower permeability values within the typical ranges for the shell, riprap, filter blanket, and waste rock fill. Table 2 includes the engineering parameters used in the sensitivity analysis in parenthesis.

Table 2. Material Properties Used for the Analyses of J.C. Boyle Dam

Material	Unit Weight (pcf)	Effective Stress		Total Stress		Horizontal Permeability, k_h (cm/s)[1,3]	k_h/k_v
		Cohesion, c' (psf)	Friction Angle, ϕ' (°)[1,2]	Cohesion, c (psf)[1]	Friction Angle, ϕ (°)[1]		
Core	120	0	27 (19)	300 (100)	16 (12)	1.71E-04	10
Shell	130	0	34	-	-	6.62E-01 (4.00E-03)	2
Upstream Riprap	140	0	34	-	-	1.04E-00 (4.00E-03)	1
Downstream Riprap	140	0	34	-	-	1.04E-00 (4.00E-03)	1
Filter Blanket	125	0	35	-	-	1.04E-00 (4.00E-03)	2
Waste Rock Fill	145	0	40	-	-	6.62E-01 (4.00E-03)	2

Note:
1. The parameter that was used for sensitivity analyses is provided in parenthesis.
2. For compacted sand and gravel materials, the friction angles are typically greater than 34 degrees (NAVFAC, 1986 and EPRI, 1990).
3. For clean coarse materials, permeability ranges from 10^{-3} cm/s to 1 cm/s per Holtz and Kovacs (1981).

PREVIOUS SLOPE STABILITY ANALYSIS PERFORMED BY OTHERS

Iron Gate Dam

After the construction of the Iron Gate dam, stability analyses of the dam were originally performed by the Division of Safety of Dams (DSOD) in 1962 (DWR, 1986). The slope stability analyses were performed for static, rapid drawdown, and pseudo-static loading conditions with assumed effective friction angles of 30 and 17 degrees with no cohesion for the shell and core, respectively. A minimum factor of safety of 1.67 was calculated for the rapid drawdown conditions. Bechtel Corporation analyzed stability of the embankment in 1968 using effective friction angles of 35 degrees for the shell and 22 degrees for the core. The rapid drawdown analysis performed as part of Bechtel's analyses calculated a minimum factor of safety of 1.99 (DWR, 1986). In 1986, DSOD reanalyzed the dam by assigning an effective friction angle of 35 degrees for the shell zones and drained zones, and calculated a minimum factor of safety of 2.00 for rapid drawdown. These stability evaluations were then updated in 1995 and 2004 to account for the then planned dam raises (Section 8 of STID, 2015). The existing dam incorporates the sheet-pile raised crest, and has an effective crest elevation of 2348.0 feet.

As the latest stability analysis, PanGEO performed the preliminary assessment of the stability of upstream slope under rapid drawdown conditions and presented the results in a technical memorandum (PanGEO, 2008).

J.C. Boyle Dam

Based on available information, two (2) rapid drawdown analyses were performed in 1968 and 1996 (Bechtel, 1968 and Black and Veatch, 1996). The 1968 analysis assumed a very conservative strength for the shell materials, in which the shear strength of the shell materials was assumed to be the same as the shear strength of the core materials (effective friction angle of 26 degrees). The phreatic surface used in the analysis was derived by a flow net analysis, which considered partial pore dissipation within the shell materials. The rapid drawdown analysis resulted in a factor of safety of 1.03. In 1994, three (3) borings were drilled on the downstream side of the dam to collect additional subsurface information for better material characterization for the shell materials. Based on the results of this subsurface investigation, the 1996 analysis assumed a higher shear strength for the shell material (effective friction angle of 37 degrees). No additional seepage analysis was performed, and the phreatic surface from the 1968 analysis was assumed in the 1996 analysis. The rapid drawdown analysis resulted in a factor of 1.88.

CURRENT RAPID DRAWDOWN ANALYSIS

Sudden or rapid drawdown is the most critical condition controlling the lowering of the reservoir prior to dam removal because deep slides in the upstream slope of the dam during the drawdown could lead to dam failure. Rapid drawdown reduces the total stress on the upstream face and lowers the head driving seepage through the embankment. The shear stresses within the upstream slope increase which may lead to instability. In principle, the stability of the upstream slope can be evaluated using either total stress (undrained) or effective stress (drained) strength parameters. The rapid drawdown analysis approach used for this Project involves the following steps:

1. Develop analysis sections and material properties,
2. Establish a base case by performing conventional rapid drawdown stability analysis under instantaneous drawdown for two scenarios that provide the upper and lower bound for stability of the dams during rapid drawdown:
    a. The first scenario (least conservative bound) assumes full pore pressure dissipation within the pervious shell after drawdown from the steady state condition.
    b. The second scenario (most conservative bound) assumes no pore pressure dissipation within the pervious shell from after drawdown from the steady state condition.
3. Perform transient drawdown analysis for various drawdown rates:
    a. Seepage analysis to determine the location of the phreatic surface at different time steps during reservoir drawdown
    b. Slope stability analysis for each corresponding phreatic surface during reservoir drawdown.
4. Additional sensitivity analyses, if needed.

SEEP/W (Geo-Studio, 2016) presents a method for using uncoupled transient seepage analysis along with limit equilibrium to evaluate the stability of slopes affected by changing hydraulic boundary conditions such as the conditions during rapid drawdown. The latest version of the USBR Embankment Dam design standards (2011) recommends using the effective stress approach with pore pressures from uncoupled transient seepage analysis to analyze stability following rapid drawdown. For these reasons, a transient analysis was considered as listed above. Because the shells of the dams are constructed of pervious materials rapid drawdown of the reservoir level behind the dams will result in concurrent (but slower) lowering of the phreatic surface (groundwater level) in the upstream shell of the dams. To account for this, transient seepage analyses are required. The computer programs SEEP/W and SLOPE/W (Geo-Studio, 2016) were utilized for the seepage and slope stability. SEEP/W is a two-dimensional, finite element analysis software program that has the capability to analyze both steady-state and transient seepage conditions. Slope/W is used to perform limit equilibrium slope stability analyses. Slope/W uses the phreatic surface developed in SEEP/W as input to the stability analysis. The limit equilibrium slope stability calculations use Spencer’s method, which satisfies both moment and force equilibrium simultaneously.

Acceptance Criterion

According to the Engineering Manual (EM-110-2-1902) of United States Army Corps of Engineers (USACE), the factor of safety for the rapid drawdown analyses of the upstream slope of the dam should be greater than the range of 1.1 to 1.3. Given, the importance of safety to both workers on site and the public downstream of the dams, the minimum rapid drawdown factor of safety for transient seepage analyses is selected to be 1.3.

Analysis Results

Rapid drawdown slope stability analyses were performed to calculate the minimum factors of safety for the following five (5) scenarios as described below:

1. Instantaneous drawdown from steady state condition with full pore pressure dissipation in the shell materials (least conservative bound).
2. Instantaneous drawdown from steady state condition with no pore pressure dissipation in the shell materials (most conservative bound).
3. Slow drawdown rate (3 ft/day for Iron Gate Dam and 2 ft/day for J.C. Boyle Dam)
4. Intermediate drawdown rate (6 ft/day for Iron Gate Dam and 5 ft/day for J.C. Boyle Dam)
5. Rapid drawdown rate (10 ft/day for Iron Gate Dam and 10 ft/day for J.C. Boyle Dam)

For Iron Gate Dam, the reservoir was drawn down from El. 2328 feet to El. 2202 feet. For J.C. Boyle Dam, the reservoir was drawn down from El. 3793 feet to El. 3762 feet. The results of the rapid drawdown slope stability analyses for Iron Gate Dam are summarized in Table 3. Table 3 also includes the results of the sensitivity analyses, which consider the potential lower bound strength for the shell materials. The results of rapid drawdown slope stability analyses for J.C. Boyle Dam are summarized in Table 4. Table 4 also includes the results of the sensitivity analyses, which consider the lower bounds for both the core strength and the shell permeability. The analysis results for the best estimate parameters are also shown on Figures 3 through 7 for Iron Gate Dam, and on Figures 8 through 12 for J.C. Boyle Dam. It should be noted that the plotted phreatic surfaces shown on the figures for the transient rapid drawdown analyses correspond to the phreatic surfaces at the specific time when the calculated factors of safety are minimum.

Table 3. Rapid Drawdown Slope Stability Analysis Results for Iron Gate Dam

Scenario	Factors of Safety for Best Estimate Parameters	
	Mid-Slope	Full-Slope
1. Instantaneous drawdown, full pore pressure dissipation	1.91	2.02
2. Instantaneous drawdown, no pore pressure dissipation within upstream shell	1.42	1.46
3. Slow drawdown rate (3 ft/day)	1.51	1.77
4. Intermediate drawdown rate (6 ft/day)	1.49	1.74
5. Rapid drawdown rate (10 ft/day)	1.48	1.70

Table 4. Rapid Drawdown Slope Stability Analysis Results for J.C. Boyle Dam

Scenario	Factor of Safety for Best Estimate for Core Strength		Factor of Safety from Sensitivity Analyses Using Potential Lower Bound Strength for Core	
	Mid-Slope	Full-Slope	Mid-Slope	Full-Slope
1. Instantaneous drawdown, full pore pressure dissipation	2.06 (2.06)	1.86 (1.86)	1.97 (1.97)	1.85 (1.85)
2. Instantaneous drawdown, no pore pressure dissipation within upstream shell	1.11 (1.12)	1.18 (1.18)	1.10 (1.10)	1.18 (1.18)
3. Slow drawdown rate (2 ft/day)	1.77 (1.76)	1.84 (1.74)	1.70 (1.70)	1.83 (1.73)
4. Intermediate drawdown rate (5 ft/day)	1.78 (1.76)	1.85 (1.66)	1.70 (1.69)	1.83 (1.66)

5. Rapid drawdown rate (10 ft/day)	1.78 (1.72)	1.85 (1.61)	1.75 (1.69)	1.82 (1.61)

Note: The values in parenthesis refer to the results of the sensitivity analysis using the lower permeability for the shell materials.

Conclusions

Rapid drawdown analysis results for the Iron Gate Dam and J.C. Boyle Dam indicate that the calculated factors of safety are greater than the selected minimum factor of safety of 1.3 for all cases analyzed except some cases instantaneous drawdown without any pore pressure dissipations for the J.C. Boyle Dam. However, in these cases, the minimum factors of safety are still within the range recommended by USACE. In addition, it should be noted that these cases conservatively assume no pore pressure dissipation within the upstream shell. Based on the analyses, reservoir drawdown could be as high as 10 feet/day. However, we recommend that reservoir drawdown be 5 feet/day, except as noted for J,C. Boyle Dam below.

It is our understanding that the demolition of J.C. Boyle Dam includes removal of concrete stoplogs within two diversion culverts. The removal of the concrete stoplogs (likely by blasting) will result in drawdown of approximately 10 feet for the first culvert and 8 feet for the second culvert within less than 24 hours. Although we conclude that the J.C. Boyle Dam will perform satisfactorily under these rapid drawdown conditions, we recommend a hold period of one week be implemented between removal of the stoplogs from the first culvert until the stoplogs from the second culvert are removed to allow for pore pressure dissipation.

The analysis results indicated that no slope instability would result during reservoir drawdown. However, there is a potential for shallow slumping along the upstream embankment slopes due to the potential strength loss of surficial materials during the drawdown. Therefore, we recommend frequent visual inspection during the reservoir drawdown process. If any shallow slumping is observed, riprap can be placed to provide additional resistance.

It is recommended that instrumentation should be installed to monitor the upstream slopes during reservoir drawdown for dam removal. The types of recommended instrumentation include survey monuments, inclinometers, and piezometers. Daily readings are recommended to closely monitor if there are any unanticipated slope movements or pore pressure accumulation. It is also recommended that the instrumentation be installed the year prior to reservoir drawdown. The piezometers would be monitored during reservoir drawdown to confirm that the transient phreatic surfacewithin the upstream shell of the dam falls as the reservoir elevation drops.

Limitations

AECOM represents that our services were conducted in a manner consistent with the standard of care ordinarily applied as the state of practice in the profession within the limits prescribed by our client. No other warranties, either expressed or implied, are included or intended in this technical memorandum.

Background information and other data have been furnished to AECOM by Pacific Corp and/or third parties, which AECOM has used in preparing this technical memorandum. AECOM has relied on this information as furnished, and is neither responsible for nor has confirmed the accuracy of this information.

The analyses and results presented in this report are for the current study only and should not be extended or used for any other purposes.

References

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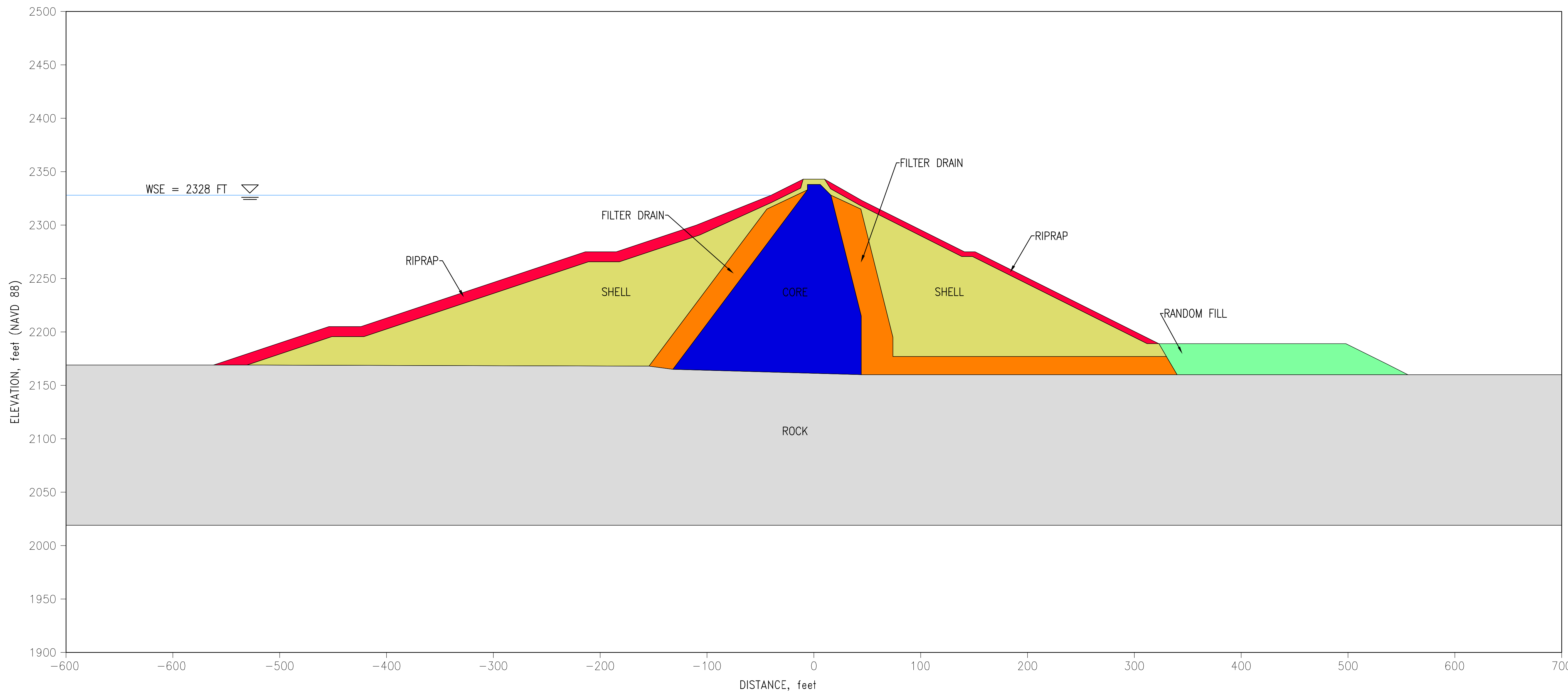
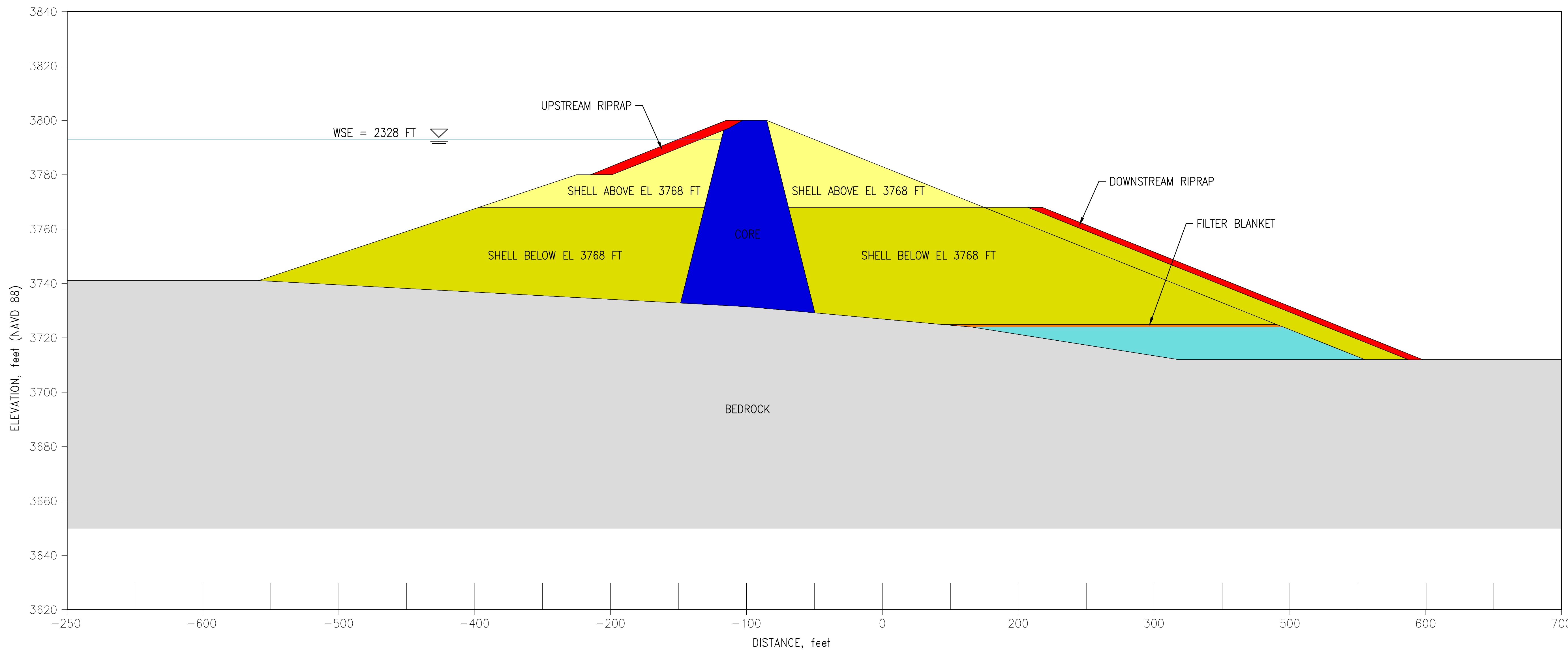
Figures



PROJECT NUMBER 60537920	PREPARED BY KANAX KANAGALINGAM	KLAMATH RIVER DAM REMOVAL	ANALYSIS MODEL GEOMETRY IRON GATE DAM	FIGURE 1
REVISION 0	CHECKED BY BENJAMIN CHOY			



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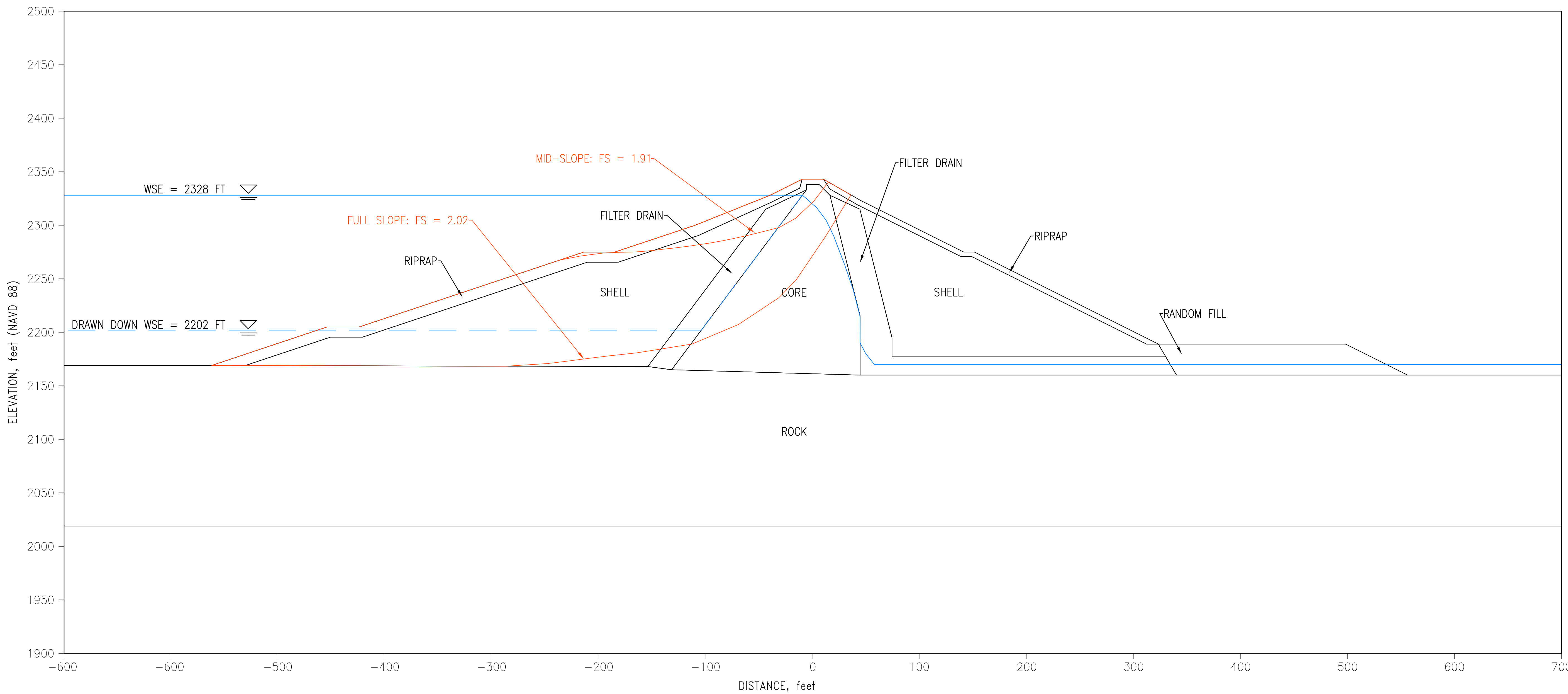
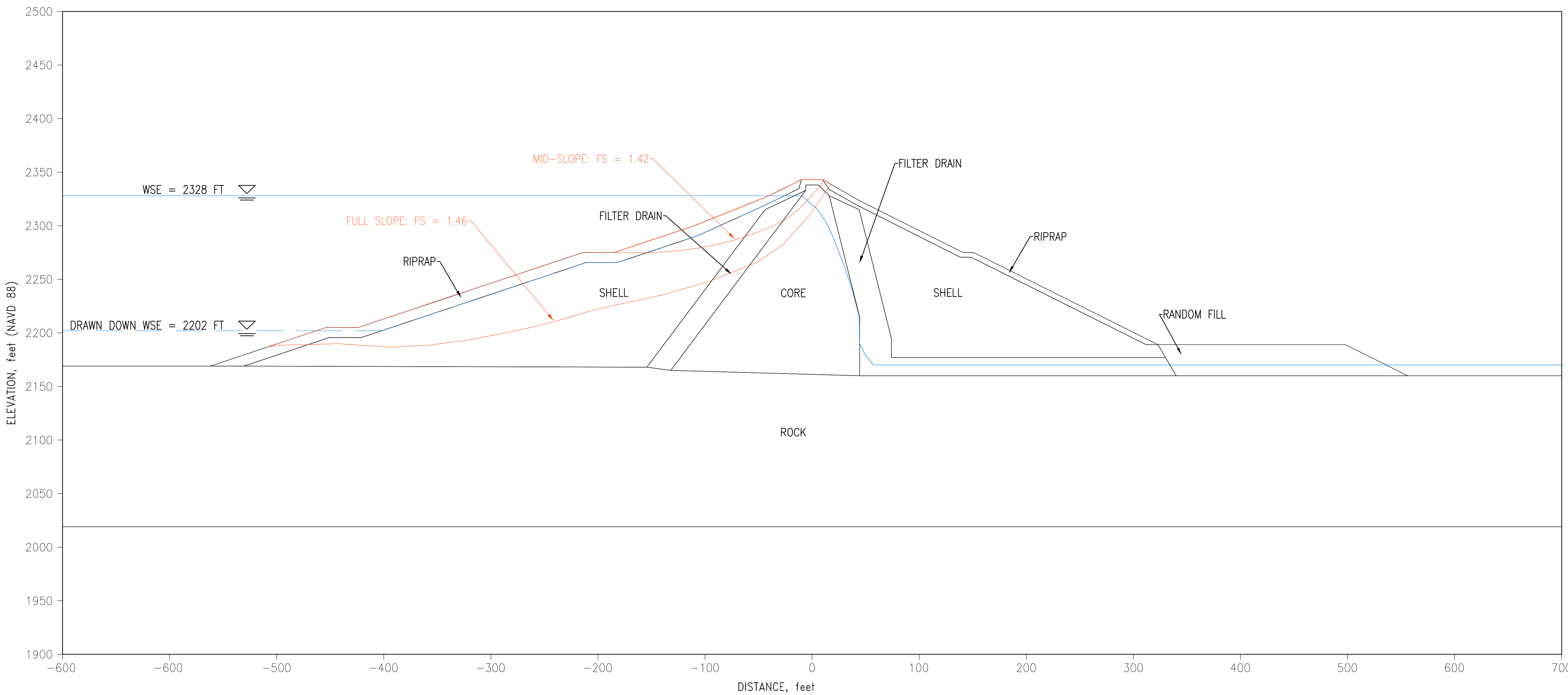
PROJECT NUMBER	PREPARED BY	KLAMATH RIVER DAM REMOVAL	ANALYSIS MODEL GEOMETRY JC BOYLE DAM	FIGURE
60537920	BENJAMIN CHOY			2
REVISION	CHECKED BY			
0	KANAX KANAGALINGAM			



PROJECT NUMBER 60537920	PREPARED BY KANAX KANAGALINGAM	KLAMATH RIVER DAM REMOVAL	RAPID DRAWDOWN STABILITY ANALYSIS IRON GATE DAM INSTANTANEOUS DRAWDOWN SCENARIO FULL PORE PRESSURE DISSIPATION	FIGURE 3
REVISION 0	CHECKED BY BENJAMIN CHOY			



PROJECT NUMBER 60537920	PREPARED BY KANAX KANAGALINGAM	KLAMATH RIVER DAM REMOVAL	RAPID DRAWDOWN STABILITY ANALYSIS IRON GATE DAM INSTANTANEOUS DRAWDOWN SCENARIO NO PORE PRESSURE DISSIPATION	FIGURE 4
REVISION 0	CHECKED BY BENJAMIN CHOY			

PLOT BY: BENJAMIN.CHOY − Sep 07, 2017 − 2:19:24pm
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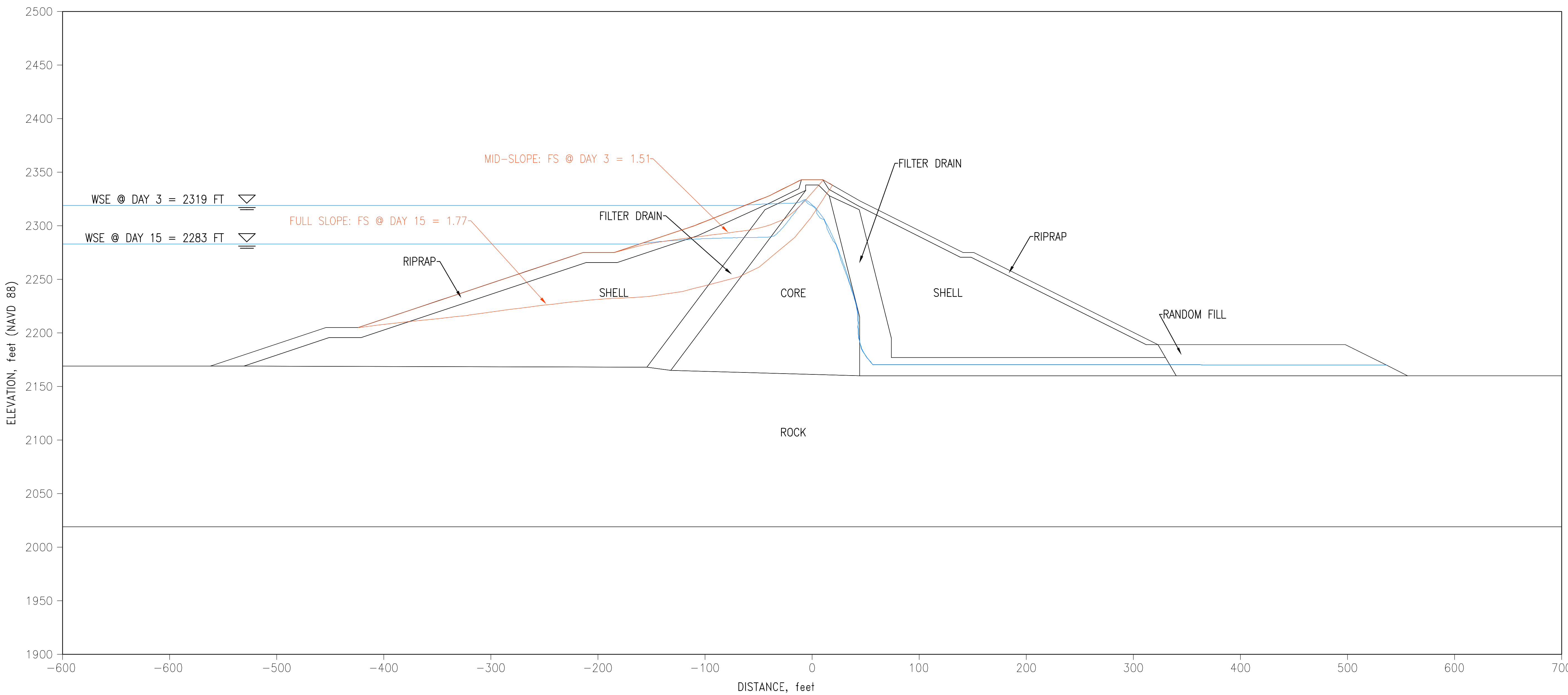

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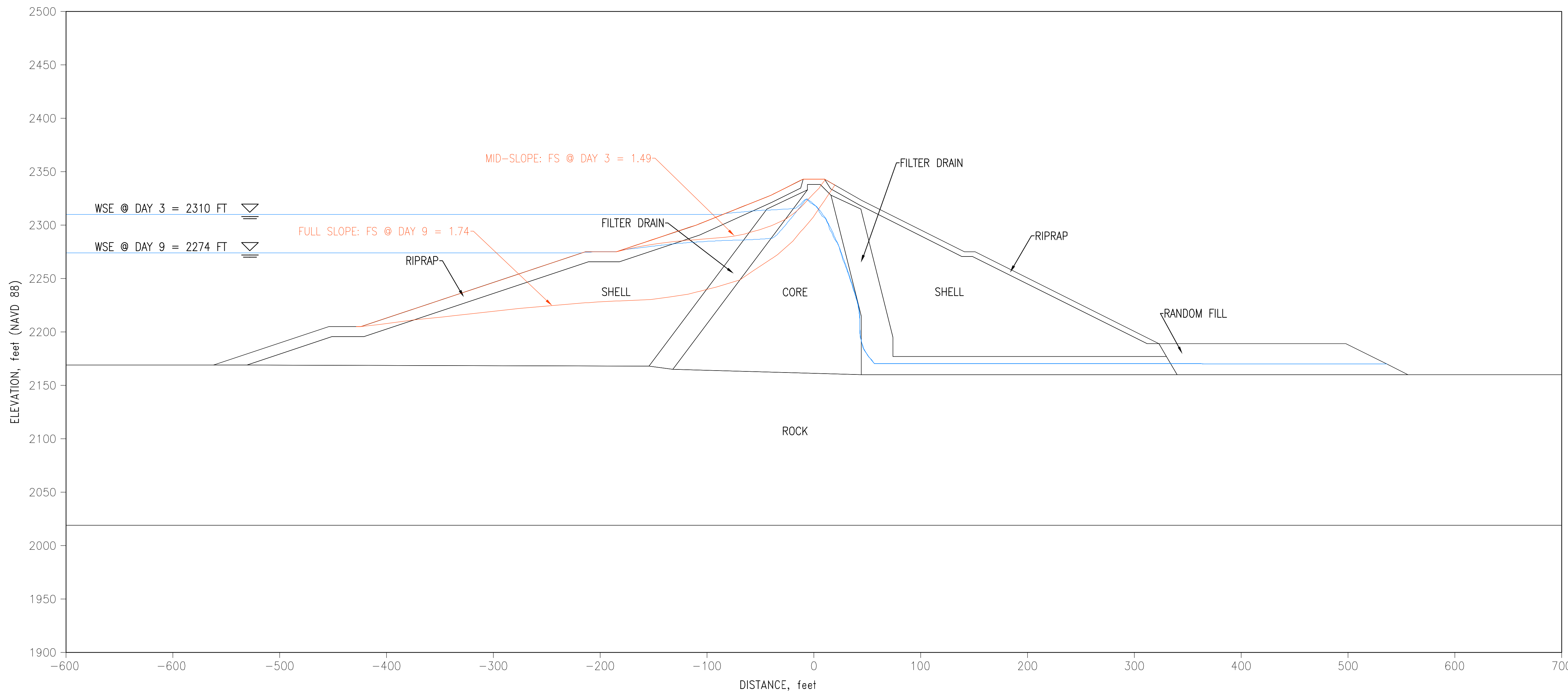
PROJECT NUMBER 60537920	PREPARED BY KANAX KANAGALINGAM	KLAMATH RIVER DAM REMOVAL	RAPID DRAWDOWN STABILITY ANALYSIS IRON GATE DAM SLOW DRAWDOWN SCENARIO 3 FT/DAY DRAWDOWN RATE	FIGURE 5
REVISION 0	CHECKED BY BENJAMIN CHOY			



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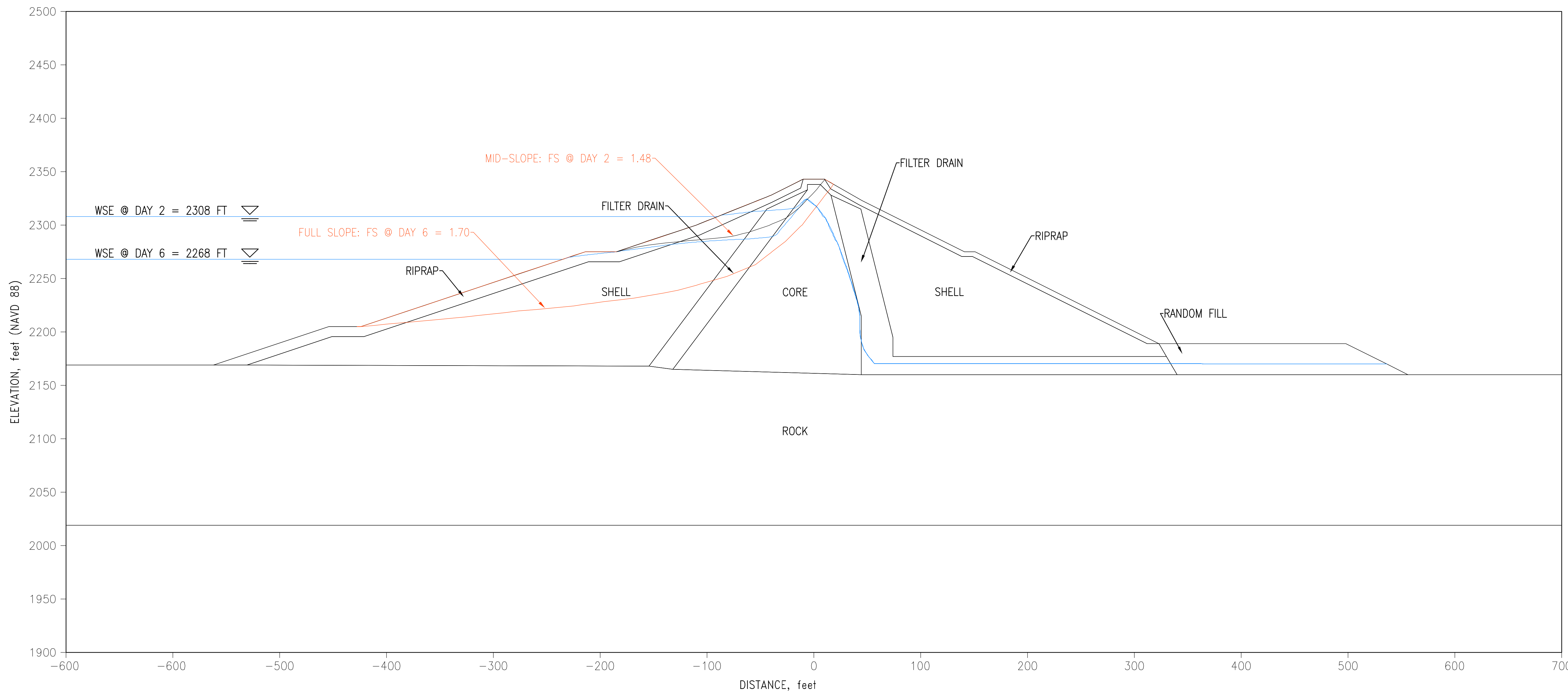
PROJECT NUMBER	PREPARED BY			
60537920	KANAX KANAGALINGAM	KLAMATH RIVER DAM REMOVAL	RAPID DRAWDOWN STABILITY ANALYSIS IRON GATE DAM SLOW DRAWDOWN SCENARIO 6 FT/DAY DRAWDOWN RATE	FIGURE 6
REVISION	CHECKED BY			
0	BENJAMIN CHOY			



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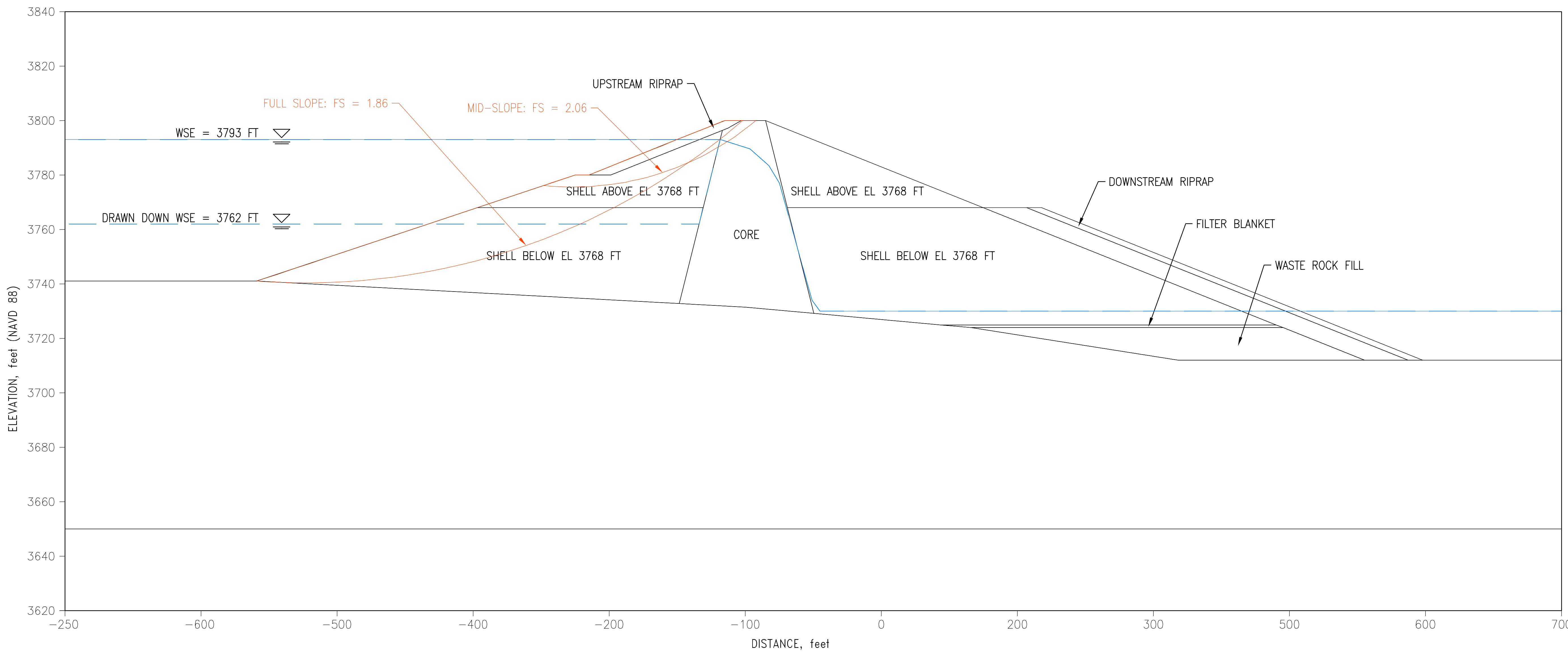
REVISION 0	CHECKED BY BENJAMIN CHOY			



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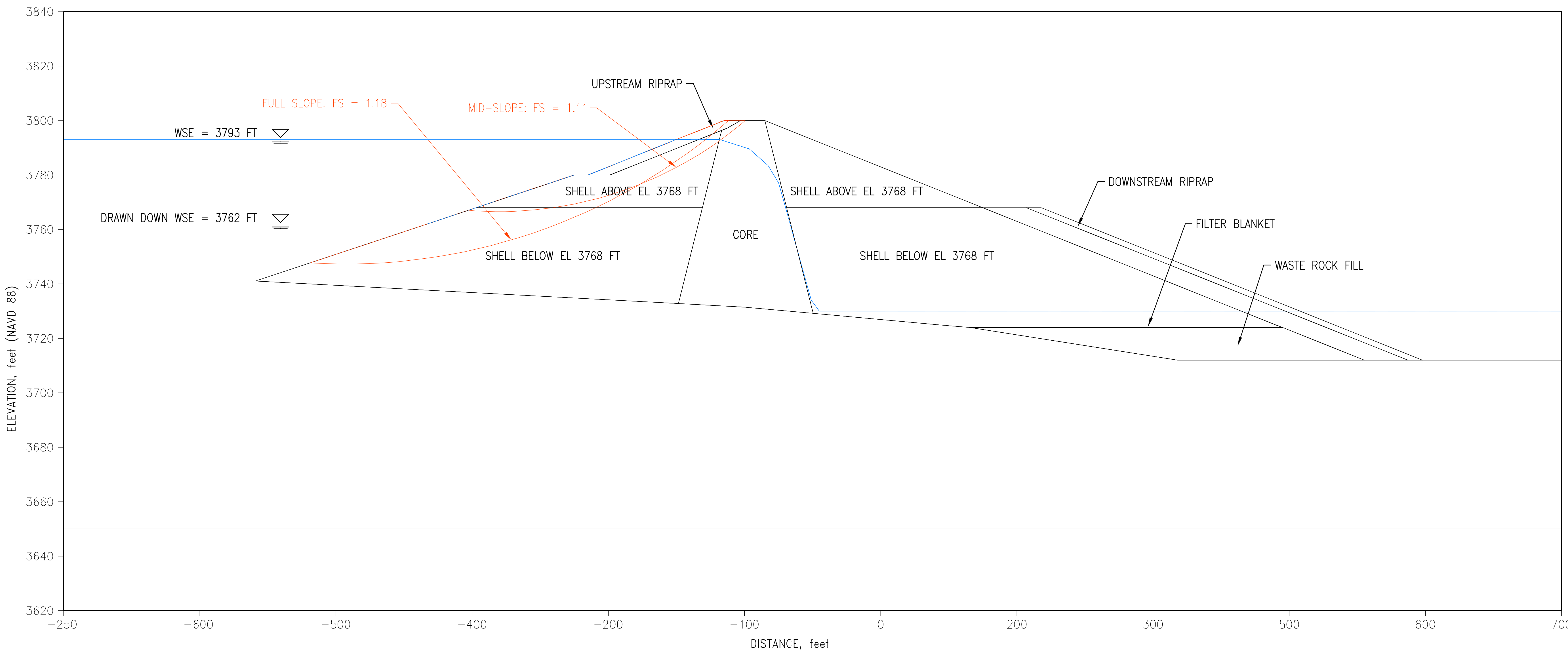
PROJECT NUMBER 60537920	PREPARED BY BENJAMIN CHOY	KLAMATH RIVER DAM REMOVAL
REVISION 0	CHECKED BY KANAX KANAGALINGAM	

RAPID DRAWDOWN STABILITY ANALYSIS
JC BOYLE DAM
INSTANTANEOUS DRAWDOWN SCENARIO
FULL PORE PRESSURE DISSIPATION

FIGURE
8



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REVISION 0	CHECKED BY KANAX KANAGALINGAM		FIGURE 9

PLOT BY: BENJAMIN.CHOY – Sep 12, 2017 – 4:29:57pm
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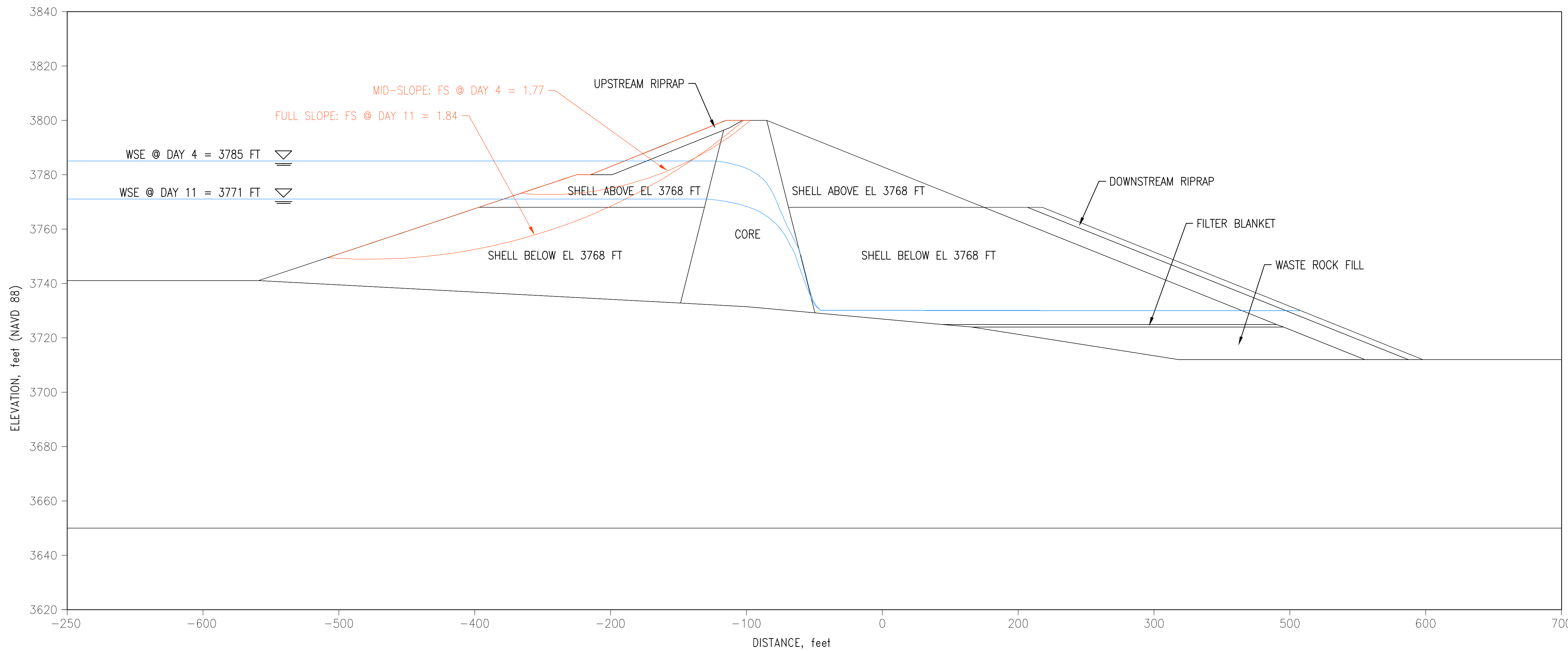

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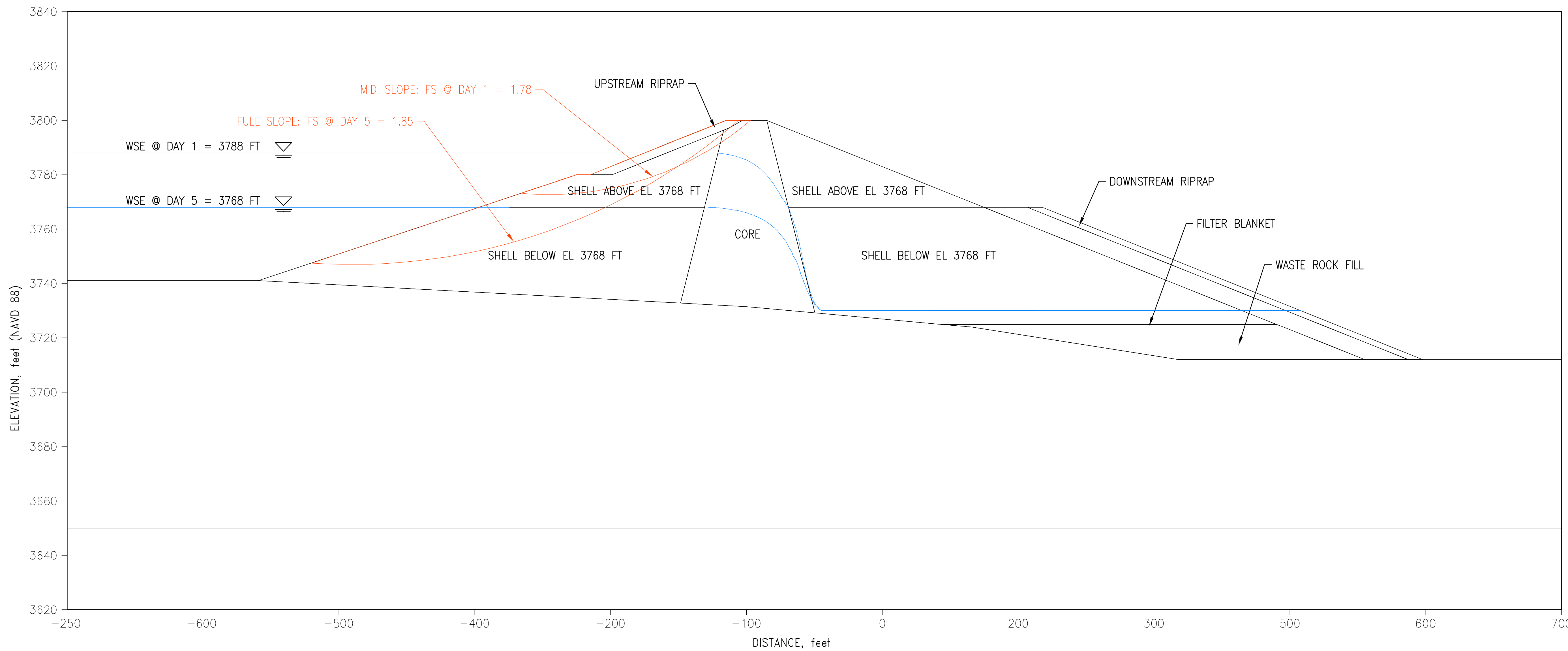
PROJECT NUMBER	PREPARED BY	KLAMATH RIVER DAM REMOVAL	RAPID DRAWDOWN STABILITY ANALYSIS JC BOYLE DAM SLOW DRAWDOWN SCENARIO 2 FT/DAY DRAWDOWN RATE	FIGURE
60537920	BENJAMIN CHOY			10
REVISION	CHECKED BY			
0	KANAX KANAGALINGAM			



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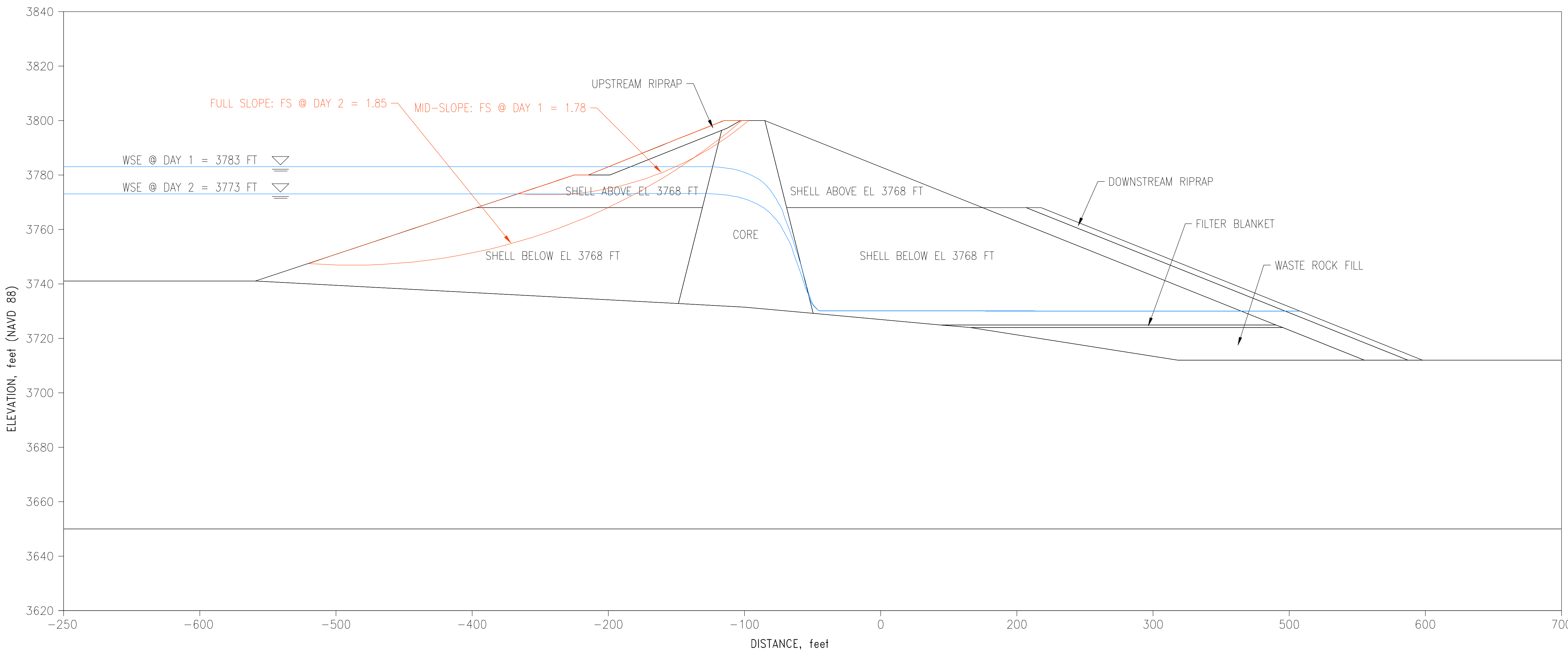
PROJECT NUMBER 60537920	PREPARED BY BENJAMIN CHOY	KLAMATH RIVER DAM REMOVAL	RAPID DRAWDOWN STABILITY ANALYSIS JC BOYLE DAM SLOW DRAWDOWN SCENARIO 5 FT/DAY DRAWDOWN RATE	FIGURE 11
REVISION 0	CHECKED BY KANAX KANAGALINGAM			



PROJECT NUMBER 60537920	PREPARED BY BENJAMIN CHOY	KLAMATH RIVER DAM REMOVAL	RAPID DRAWDOWN STABILITY ANALYSIS JC BOYLE DAM SLOW DRAWDOWN SCENARIO 10 FT/DAY DRAWDOWN RATE	FIGURE 12
REVISION 0	CHECKED BY KANAX KANAGALINGAM			

Attachment A Triaxial Test Results

CABLE, HANX

ABBOT A. HANKS, INC.

ESTABLISHED 1866

1300 SANSOME STREET · SAN FRANCISCO 11, CALIFORNIA · EXBROOK 7-2464

Engineers
Assayers
Chemists
Metallurgists
Spectrographers
Soils and Foundations
Consulting · Testing · Inspecting

File No. 1732.1
Lab. No. 46938

May 11, 1960

Mr. W. L. Warren
Assistant Chief Engineer
The California Oregon Power Company
216 West Main Street
Medford, Oregon

Re: Iron Gate Dam
Soil Samples

Dear Sir:

Enclosed are the findings from tests performed on soil samples marked Hole No. 1, which is the only sample for which all tests are complete. Tests of remaining samples are in various stages of completion.

As you may recall from your recent visit, there appeared to be a possibility that samples from Holes 2 and 3 had been mislabelled. It now appears that all samples marked Holes 2 and 3 are nearly identical, and we are performing further tests to distinguish between them. It is quite possible that these soils are exceptionally sensitive to seasoning period, owing to the porous nature of the parent rock, and that test results, particularly optimum moisture content, are influenced by the length of seasoning period. We have completed triaxial shear and consolidation tests on the sample labelled Hole No. 2, but are not yet certain that the samples were compacted at optimum moisture content and maximum density.

We shall advise you of results of our identification tests, and shall forward sets of test data as they are completed.

Very truly yours,

ABBOT A. HANKS, INC.

L. O. Long

L. O. Long

LOL:hms
Encls.
Reports to:
3-The California Oregon Power Company

Iron Gate Dam
Klamath River
File No. 1732.1

Abbot A. Hanka, Inc.
Lab. No. 46938
May 10, 1960

TEST RESULTS

Hole No. 1.
Specific Gravity: 2.77.

Triaxial Shear Test

	Sample A	Sample B	Sample C
Chamber Pressure, psi	15	50	80
Unit Dry Weight at Compaction, lb/ft^3	103.3	103.6	104.3
Moisture Content at Compaction, %	21.3	22.1	20.8
Unit Dry Weight at Test, lb/ft^3	103.0	108.6	110.5
Moisture Content at Test, %	23.7	21.6	20.4
Degree of Saturation at Test, %	97	100+	100
Maximum Deviator Stress, psi	36	60	77
Pore Pressure at Max. Deviator Stress, psi	4	9	23

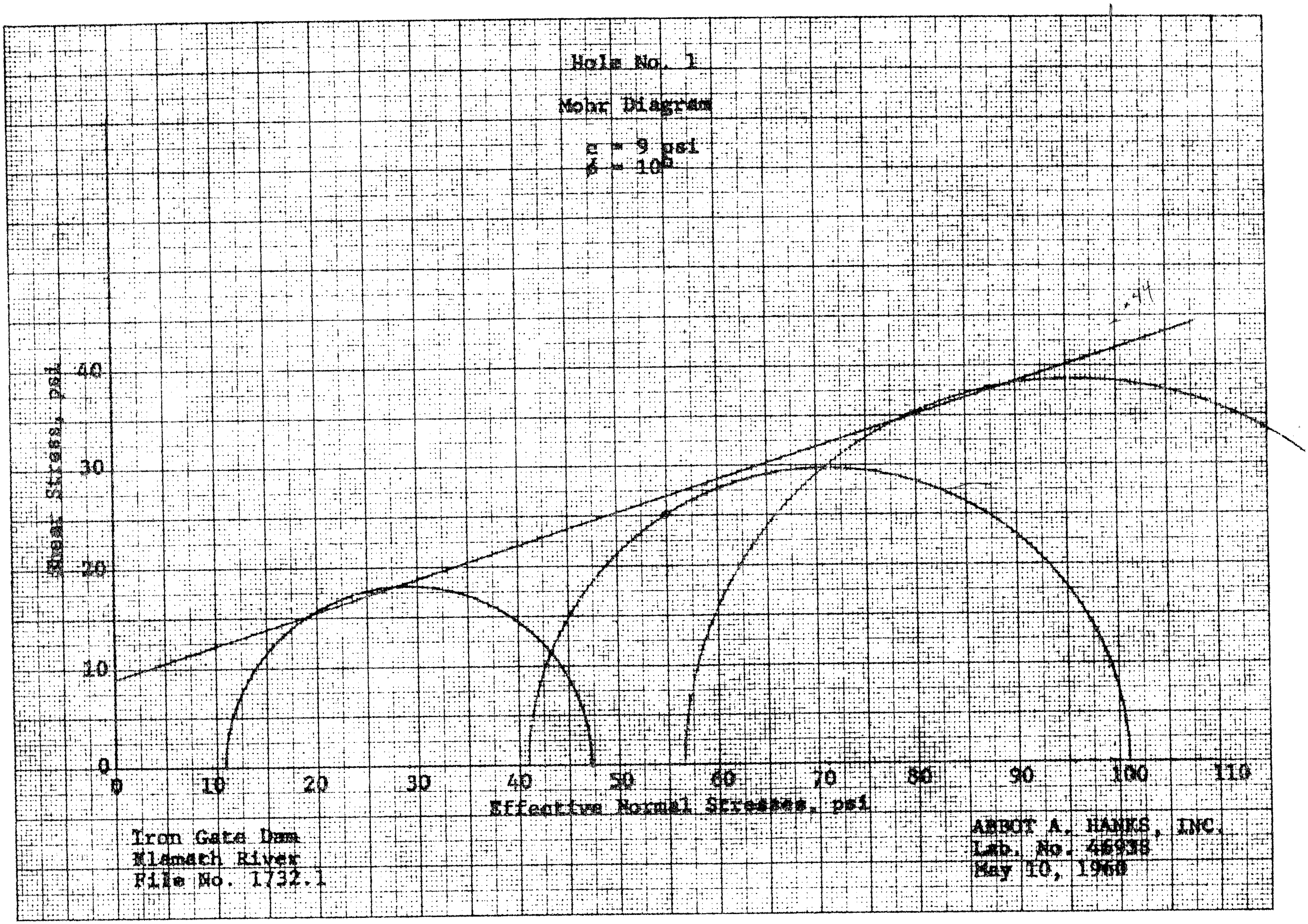
Permeability Test
(Constant Head Test)

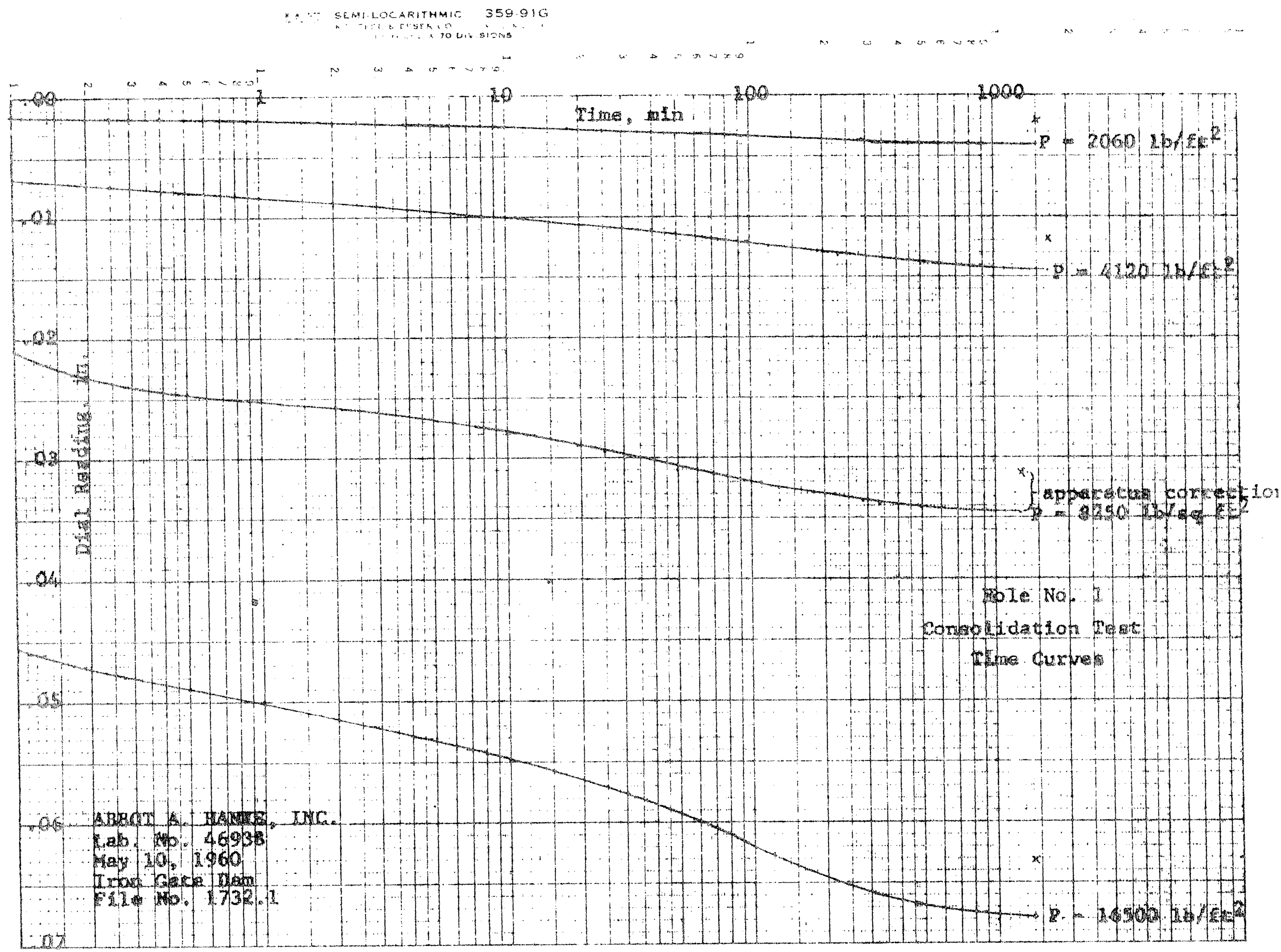
Unit Dry Weight at Compaction, lb/ft	100.6
Moisture Content at Compaction, %	23.6
Moisture Content at Test, %	24.4
Degree of Saturation at Test, %	95
Permeability coefficient, ft per yr	Less than .01
" " , cm/sec	Less than 10^{-8}

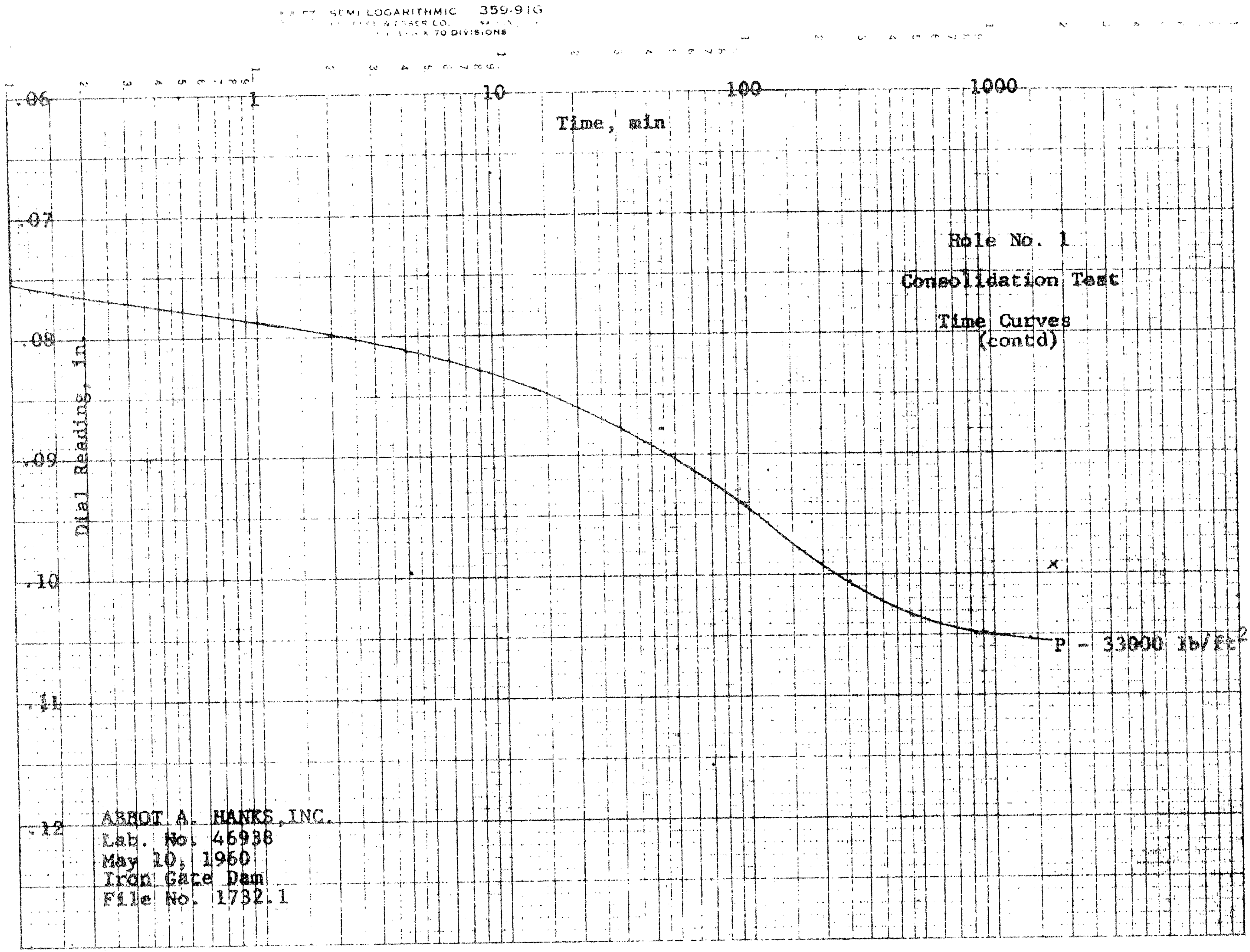
~~Refuck~~ ~~Fettler~~

~~Optimum moisture – 22% 22%~~

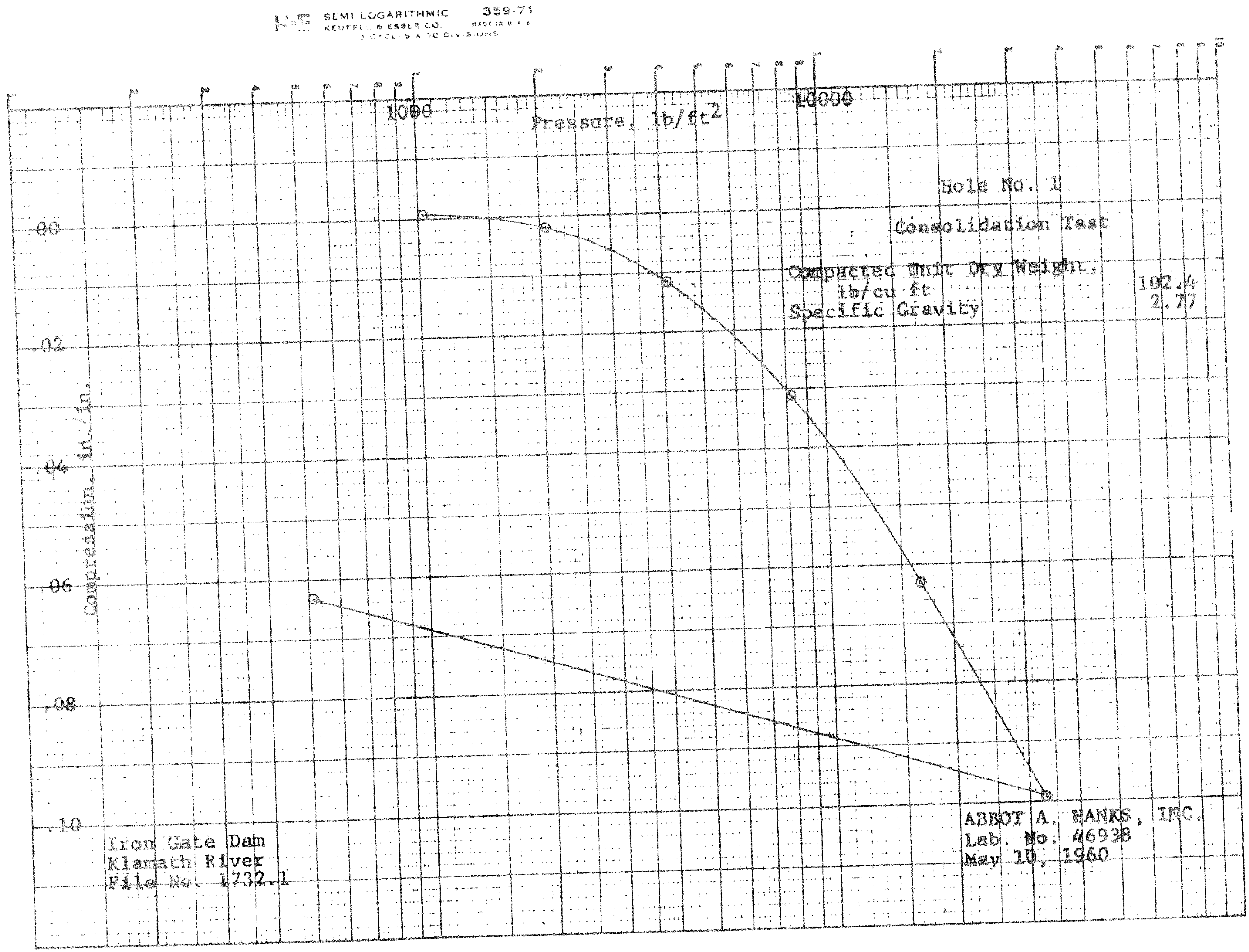
~~Max dry density 102.8 lb/cu ft. 102~~


Hole No. 1
Mohr Diagram
c = 9 psi
ø = 10°
.44
Shear Stress, psi
0
10
20
30
40
0
10
20
30
40
50
60
70
80
90
100
110
Effective Normal Stresses, psi
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
May 10, 1960


K&E SEMI-LOGARITHMIC 359-91G
Time, min
1
10
100
1000
Dial Reading, in.
.00
.01
.02
.03
.04
.05
.06
.07
P = 2060 lb/ft2
P = 4120 lb/ft2
apparatus correction
P = 8250 lb/sq ft2
P = 16500 lb/ft2
Hole No. 1
Consolidation Test
Time Curves
ABBOT A. HANKS, INC.
Lab. No. 46938
May 10, 1960
Iron Gate Dam
File No. 1732.1



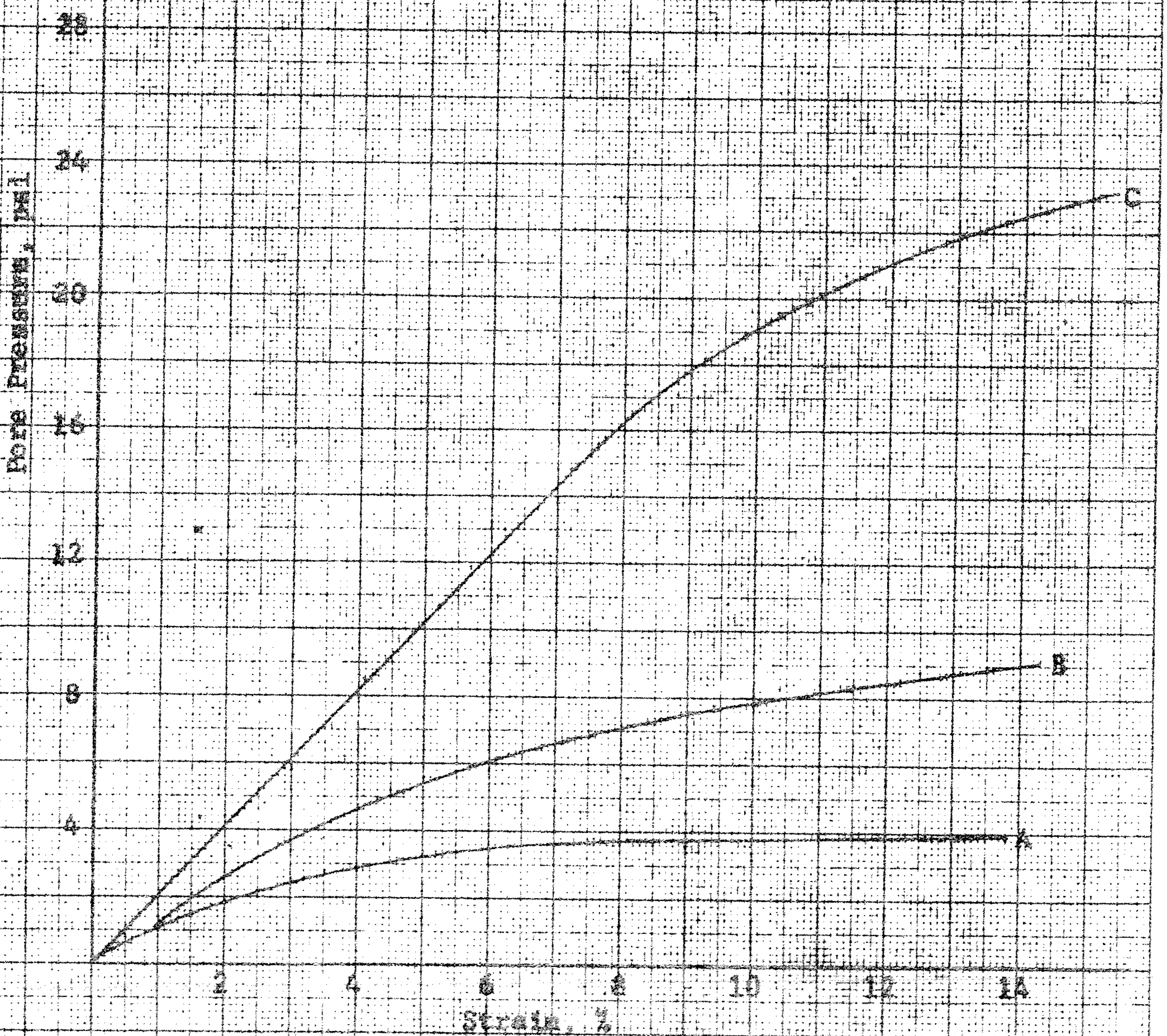
SEMI-LOGARITHMIC 359-91G
70 DIVISIONS
Time, min
1
10
100
1000
Dial Reading, in
.06
.07
.08
.09
.10
.11
.12
Hole No. 1
Consolidation Test
Time Curves
(contd)
P - 33000 lb/ft2
ABBOT A. HANKS, INC.
Lab. No. 46938
May 10, 1960
Iron Gate Dam
File No. 1732.1


SEMI LOGARITHMIC 359-71
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS
1000
10000
Pressure, lb/ft²
Compression, in./in.
.00
.02
.04
.06
.08
.10
Hole No. 1
Consolidation Test
Compacted Unit Dry Weight, lb/cu ft 102.4
Specific Gravity 2.77
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
May 10, 1960

Hole No. 1

Triaxial Shear Test

Pore Pressure-Strain Relationships



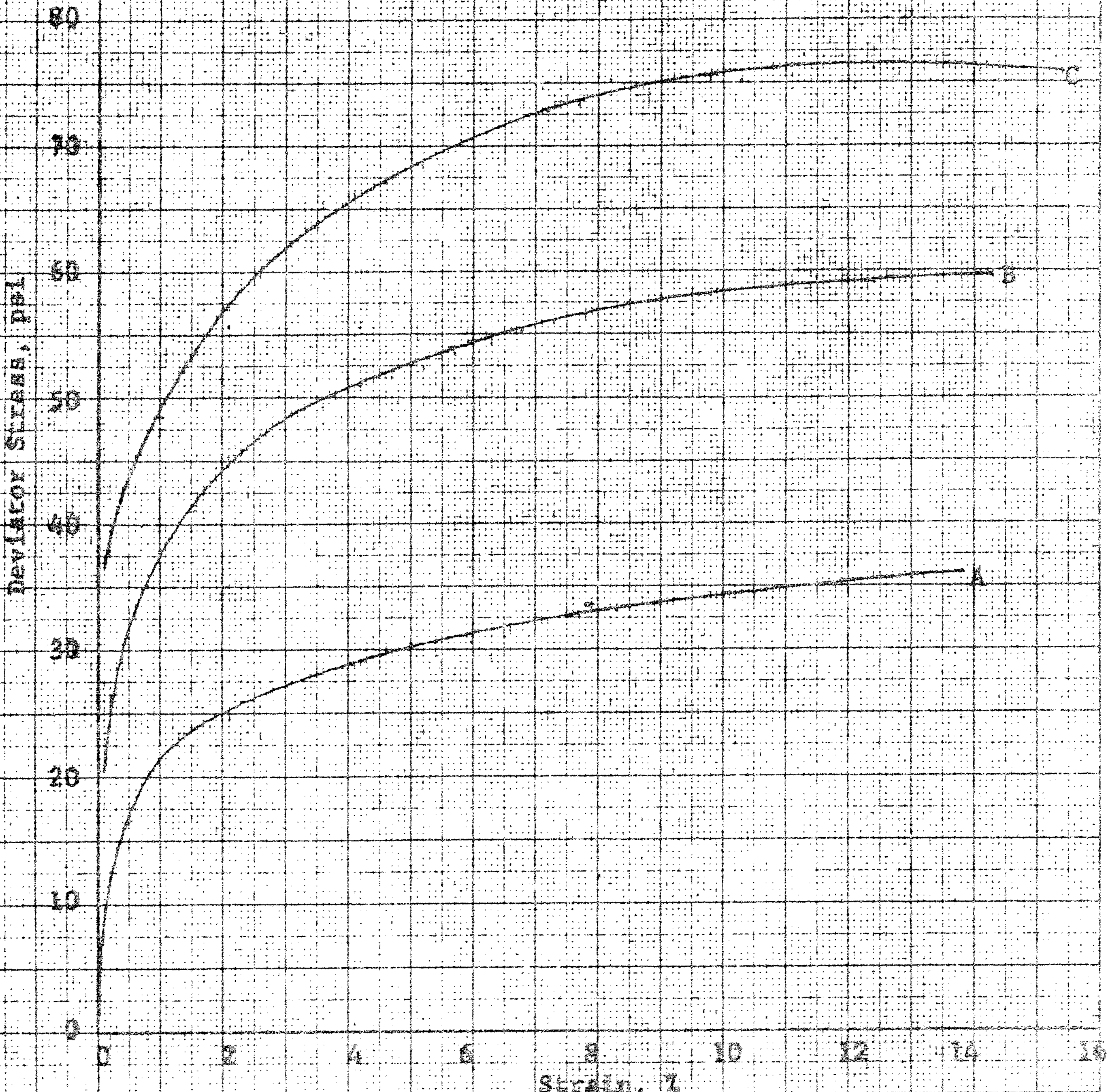
Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46938
May 10, 1960

Hole No. 1

Triaxial Shear Test

Stress-Strain Relationships



Iron Gate Dam
Klamath River
File No. 1782.1

ABBOT A. HANKS, INC.
Lab. No. 46938
May 10, 1960

BRANCH LABORATORY 1086 MARTIN AVENUE • SANTA CLARA • CHERRY 8 5262
BRANCH OFFICE 10 DE LUCA PLACE • SAN RAFAEL • GLENWOOD 4 8650

CABLE HANX

ABBOT A. HANKS, INC.
ESTABLISHED 1866

1300 SANSOME STREET • SAN FRANCISCO 11, CALIFORNIA • EXBROOK 7 2464

Engineers
Assayers
Chemists
Metallurgists
Spectrographers
Soils and Foundations
Consulting · Testing · Inspecting

File No. 1732.1
Lab. No. 46938

June 29, 1960

Mr. W. L. Warren
Assistant Chief Engineer
The California Oregon Power Company
216 West Main Street
Medford, Oregon

Re: Iron Gate Dam
Soil Samples

Dear Mr. Warren:

Enclosed are results of triaxial tests that were performed on Sample No. 2 before it was noted that this sample required an exceptionally small compactive effort relative to the other samples submitted.

We are also enclosing miscellaneous test results not shown on previously submitted reports.

If you require additional tests of Sample No. 2, we should have a complete new sample of about 100 lb.

Very truly yours,

ABBOT A. HANKS, INC.

L. O. Long

L. O. Long

LOL:hms
Encls.
Reports to:
15-The California Oregon Power Company

Iron Gate Dam
Klamath River
File No. 1732.1

Abbot A. Hanks, Inc.
Lab. No. 46938
July 1, 1960

TEST RESULTS

Hole No. 2.
Specific Gravity: 2.77.

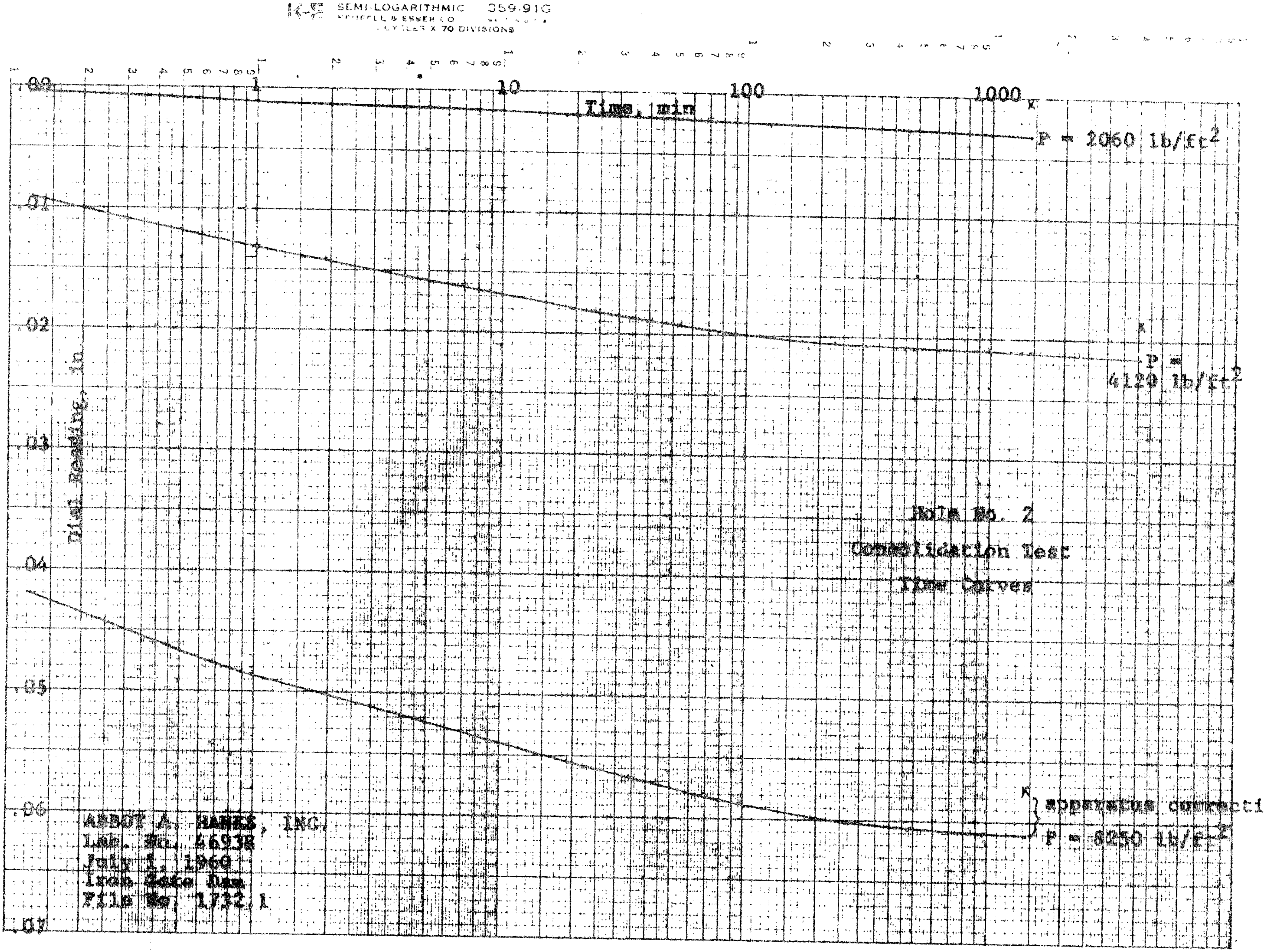
Triaxial Shear Test

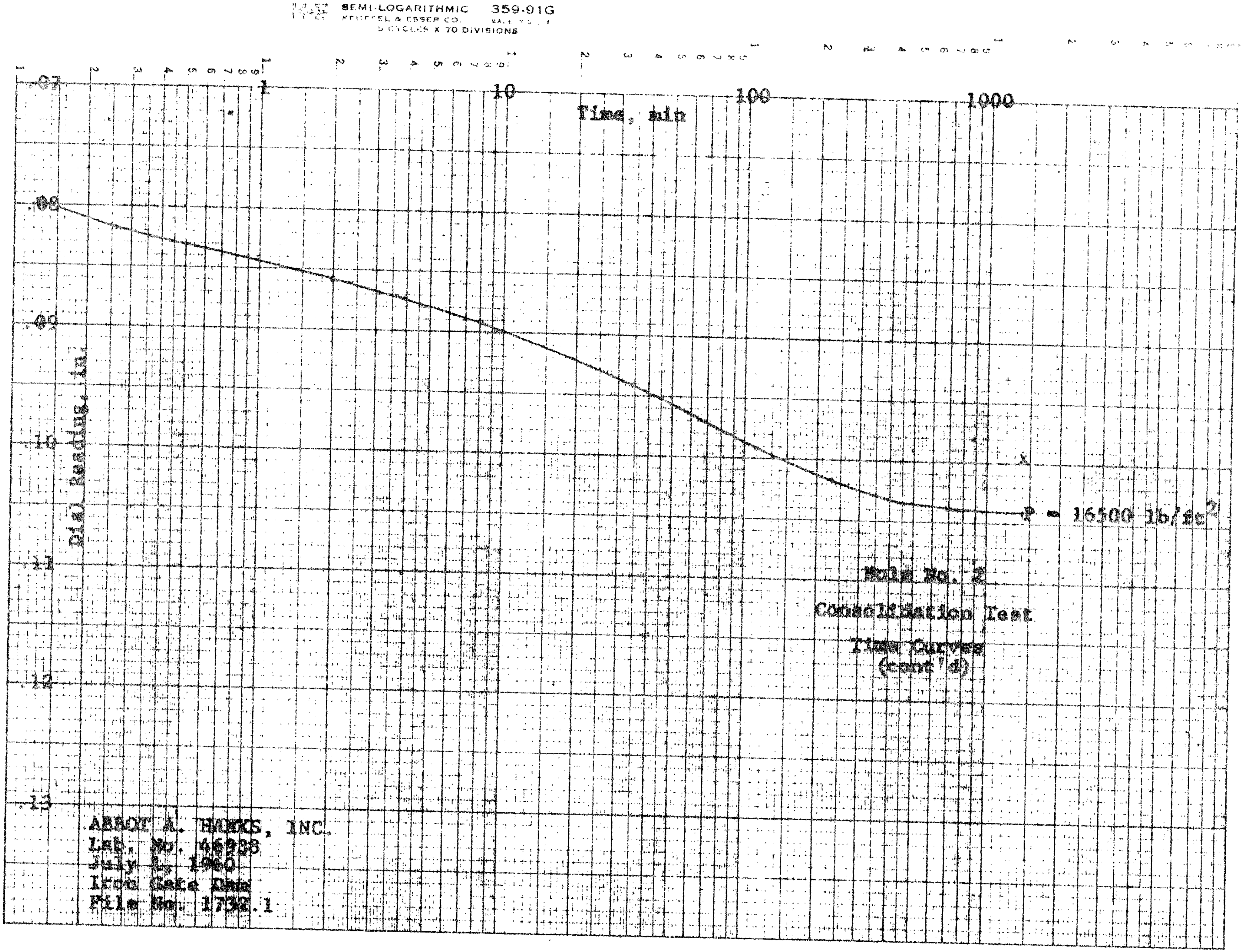
	Sample			
	A	B	C	D
Chamber Pressure, psi	15	50	50	80
Unit Dry Weight at Compaction, lb/ft^3	98.0	95.1	98.8	99.3
Moisture Content at Compaction, %	21	21	21	21
Unit Dry Weight at Test, lb/ft^3	99.4	109.0	106.3	100.2
Moisture Content at Test, lb/ft^3	24.4	22.3	21.6	20.3
Degree of Saturation at Test, %	93	100+	97	93
Maximum Deviator Stress, psi	19	40	45	69
Pore Pressure at Maximum Deviator Stress, psi	8	26	24	15

~~[illegible]~~

~~Optimum moisture 21 21~~

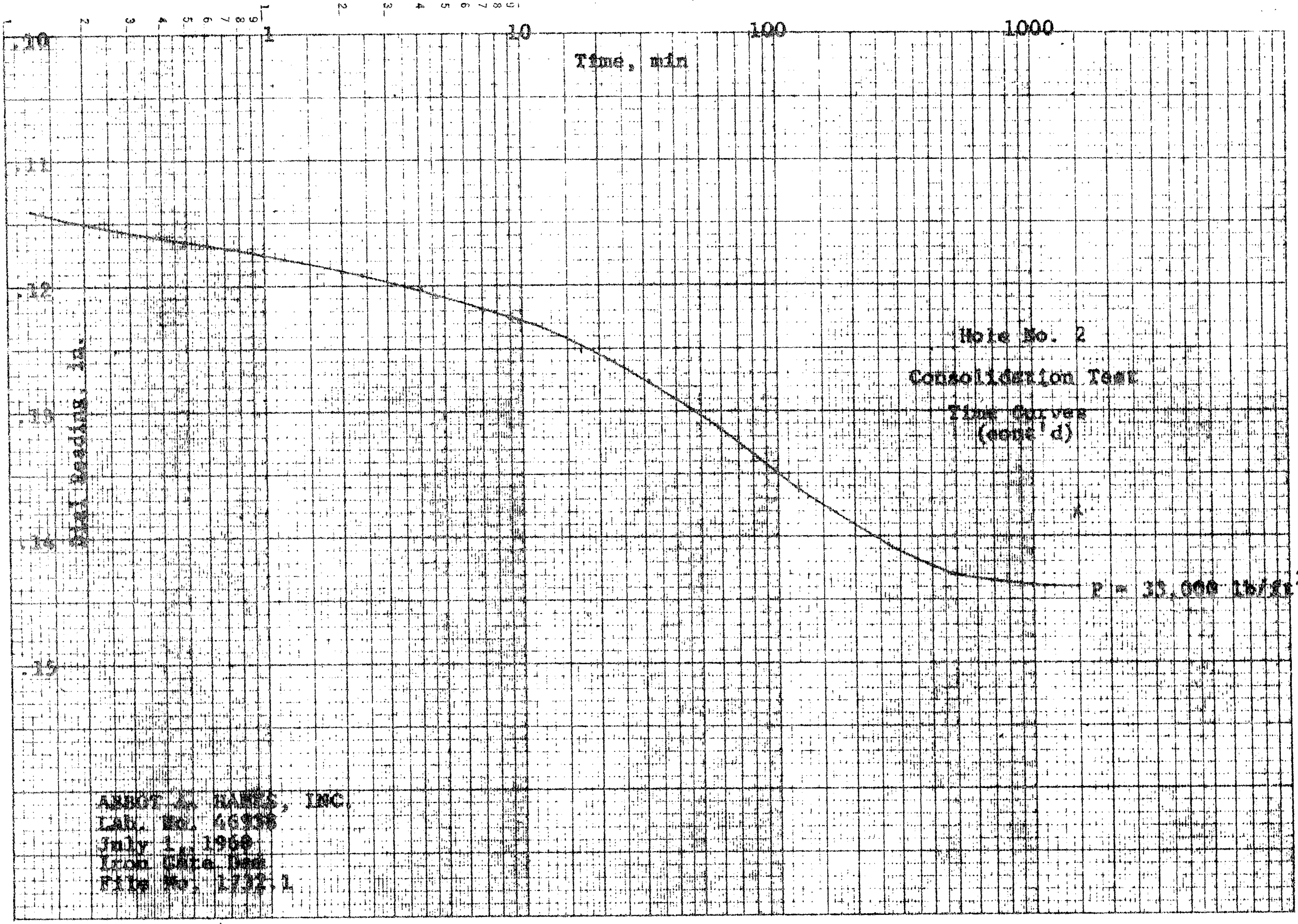
~~max dry density 102.8 103~~

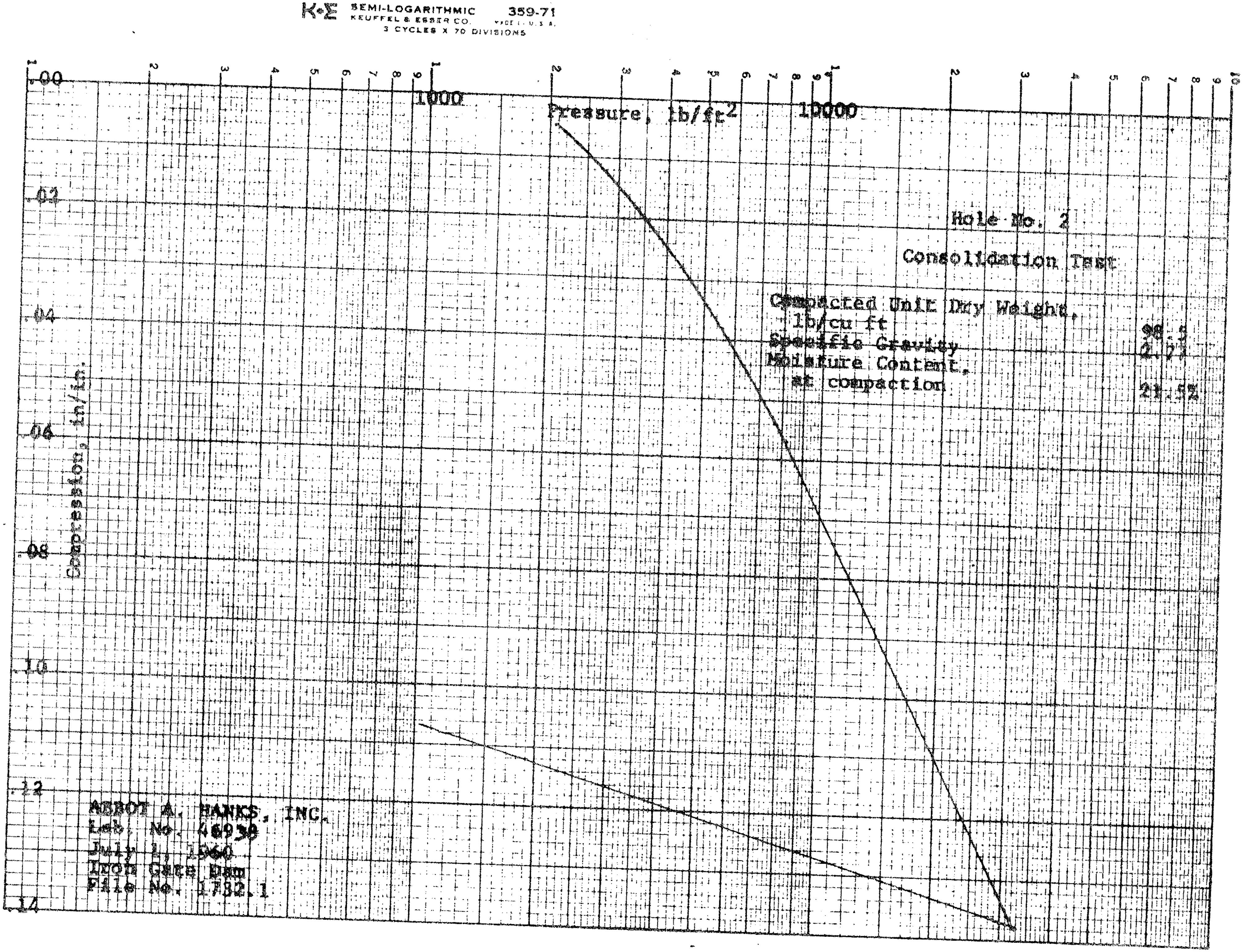

K&E SEMI-LOGARITHMIC 359-91G
KEUFFEL & ESSER CO.
3 CYCLES X 70 DIVISIONS
Time, min
1
10
100
1000
Dial Reading, in.
.00
.01
.02
.03
.04
.05
.06
.07
P = 2060 lb/ft²
P = 4120 lb/ft²
P = 8250 lb/ft²
apparatus correcti
Hole No. 2
Consolidation Test
Time Curves
ABBOT A. HANKS, INC.
Lab. No. 46938
July 1, 1960
Iron Gate Dam
File No. 1732.1



SEMI-LOGARITHMIC 359-91G
KEUFFEL & ESSER CO.
5 CYCLES X 70 DIVISIONS
Time, min
1
10
100
1000
Dial Reading, in.
.07
.08
.09
.10
.11
.12
.13
P = 16500 lb/ft²
Consolidation Test
(cont'd)
ABBOT A. HANKS, INC.

K+E SEMI-LOGARITHMIC 359-91G
KEUFFEL & ESSER CO.
5 CYCLES X 70 DIVISIONS

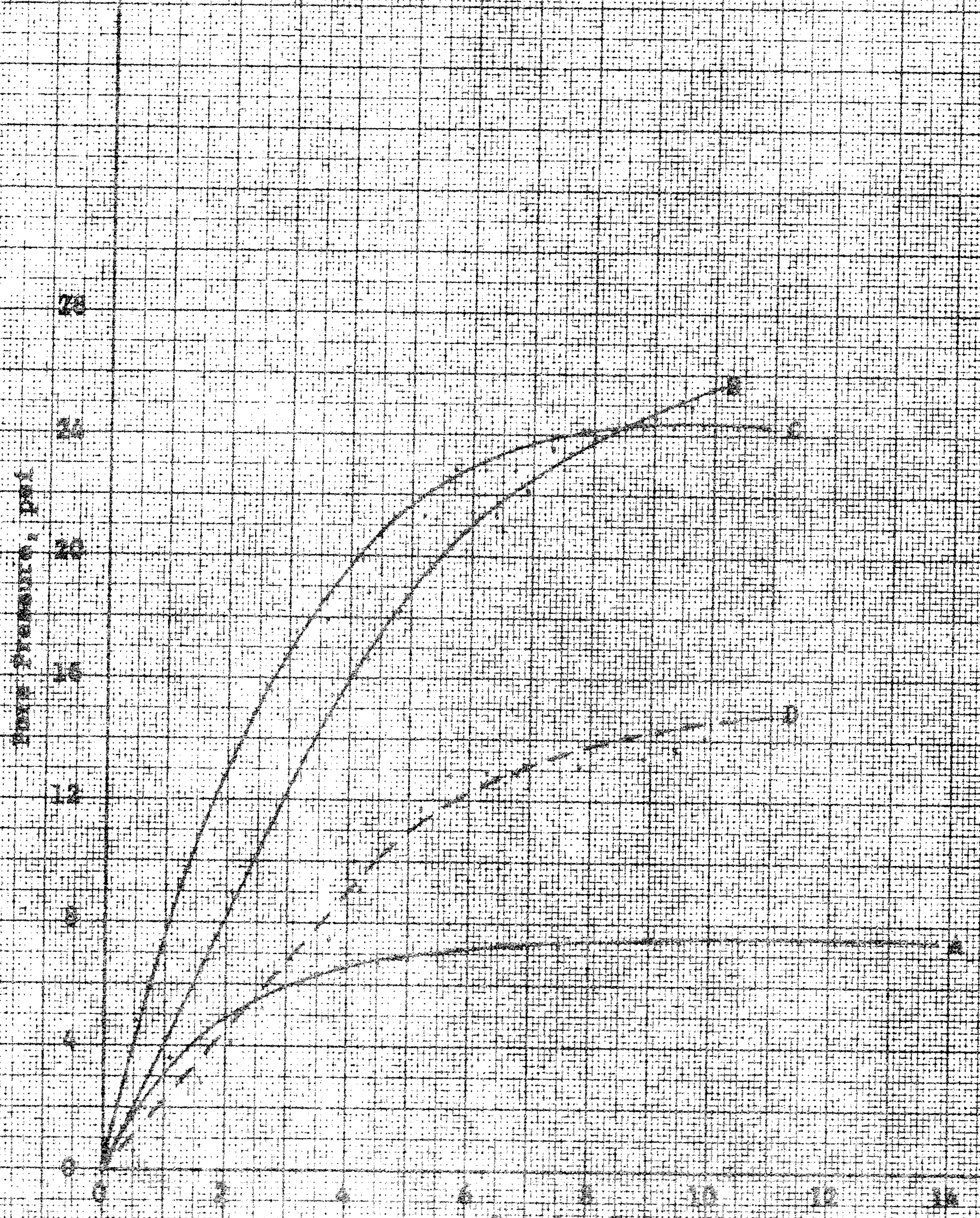



K+E SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
Pressure, lb/ft²
1000
10000
Compression, in/in.
.00
.02
.04
.06
.08
.10
.12
.14
Hole No. 2
Consolidation Test
Compacted Unit Dry Weight, lb/cu ft 98.5
Specific Gravity 2.73
Moisture Content, at compaction 21.5%
ABBOT A. HANKS, INC.
Lab. No. 46930
July 1, 1960
Iron Gate Dam
File No. 1732.1

Hole No. 2

Triaxial Shear Test

Pore Pressure-Strain Relationships



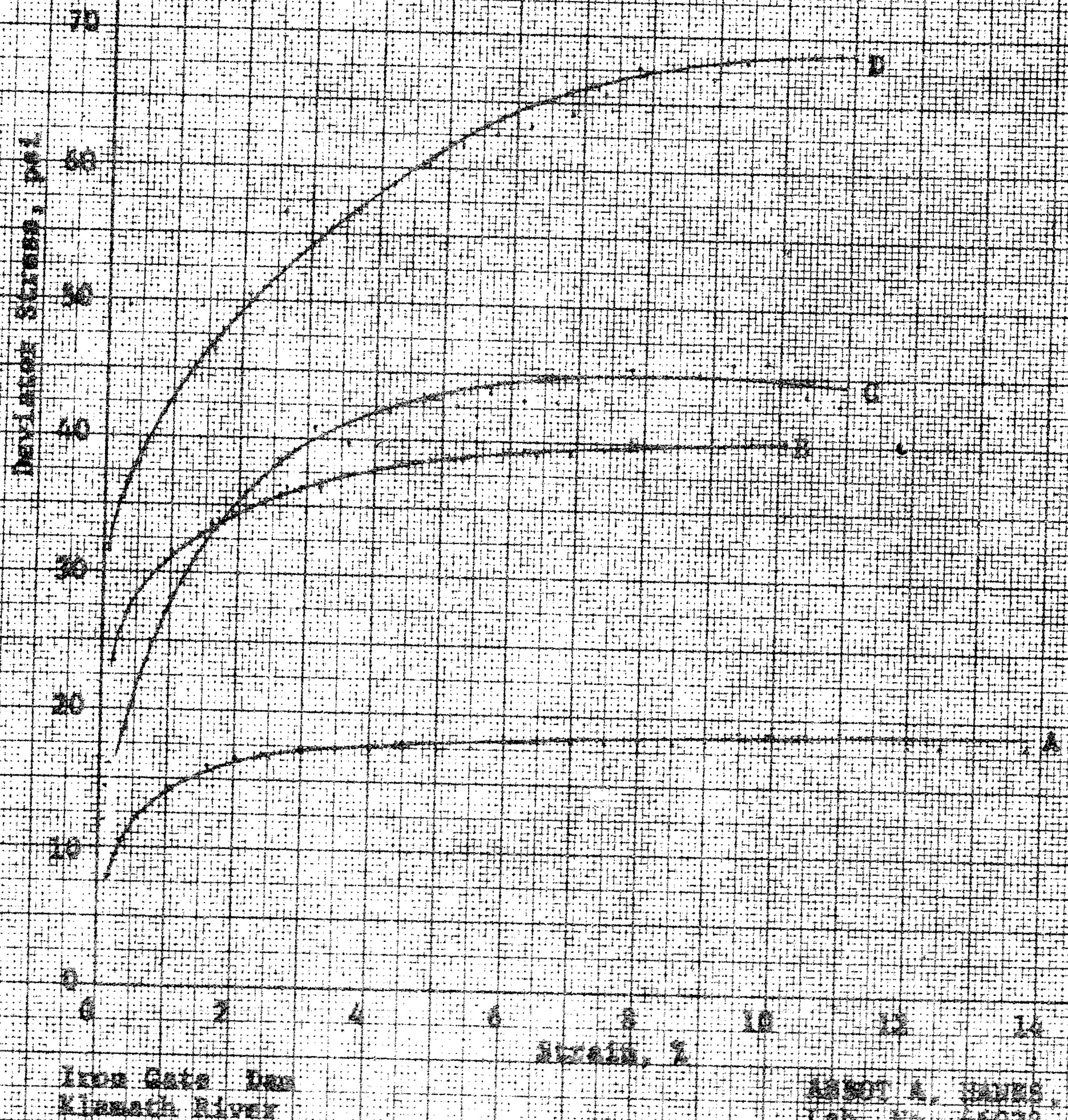
Iron Gate Dam
Klamath River
File No. 1732.1

Abbot A. Hanks, Inc.
Lab. No. [illegible]
July 1, [illegible]

Hole No. 2

Triaxial Shear Test

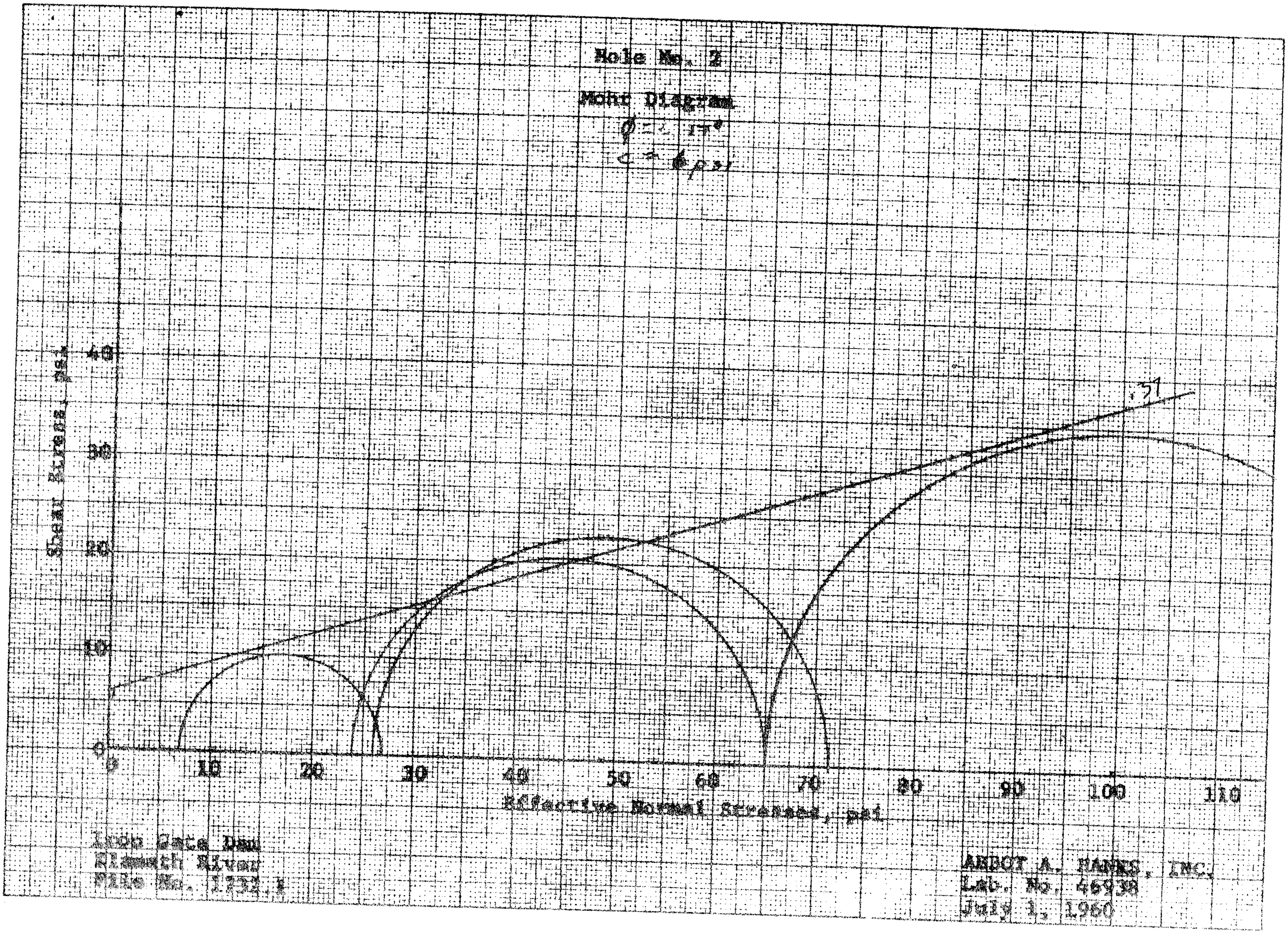
Stress-Strain Relationships



Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46938
July 1, 1960

K+E 10 X 10 TO THE CM. KEUFFEL & ESSER CO. 359-14G MADE IN U.S.A.



BRANCH LABORATORY 1086 MARTIN AVENUE • SANTA CLARA • CHERRY 8-5262
BRANCH OFFICE 10 DE LUCA PLACE • SAN RAFAEL • GLENWOOD 4-8650

CABLE, HANK

ABBOT A. HANKS, INC.
ESTABLISHED 1866

1300 SANSOME STREET • SAN FRANCISCO 11, CALIFORNIA • EXBROOK 7-2464

Engineers
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Chemists
Metallurgists
Spectrographers
Soils and Foundations
Consulting · Testing · Inspecting

File No. 1732.1
Lab. No. 46938

June 3, 1960

Mr. W. L. Warren
Assistant Chief Engineer
The California Oregon Power Company
216 West Main Street
Medford, Oregon

Re: Iron Gate Dam
Soil Samples

Dear Mr. Warren:

Enclosed are the findings from tests performed on soil samples marked Hole No. 3.

Very truly yours,

ABBOT A. HANKS, INC.

Donald W Radbruch

Donald W. Radbruch

hms
Encls.
Reports to:
3-The California Oregon Power Company

Iron Gate Dam
Klamath River
File No. 1732.1

Abbot A. Hanks, Inc.
Lab. No. 46938
June 3, 1960

TEST RESULTS

Hole No. 3
Specific Gravity: 2.76

Triaxial Shear Test

	Samples A	Samples B	Samples C
Chamber Pressure, psi	15	50	80
Unit Dry Weight at Compaction, lb/ft^3	104.4	104.5	103.5
Moisture Content at Compaction, %	21.9	22.0	22.1
Unit Dry Weight at Test, lb/ft^3	105.3	107.5	109.2
Moisture Content at Test, lb/ft^3	24.0	22.4	23.5
Degree of Saturation at Test, %	100+	100+	100+
Maximum Deviator Stress, psi	34	59	79
Pore Pressure at Max. Deviator Stress, psi	2	5	2

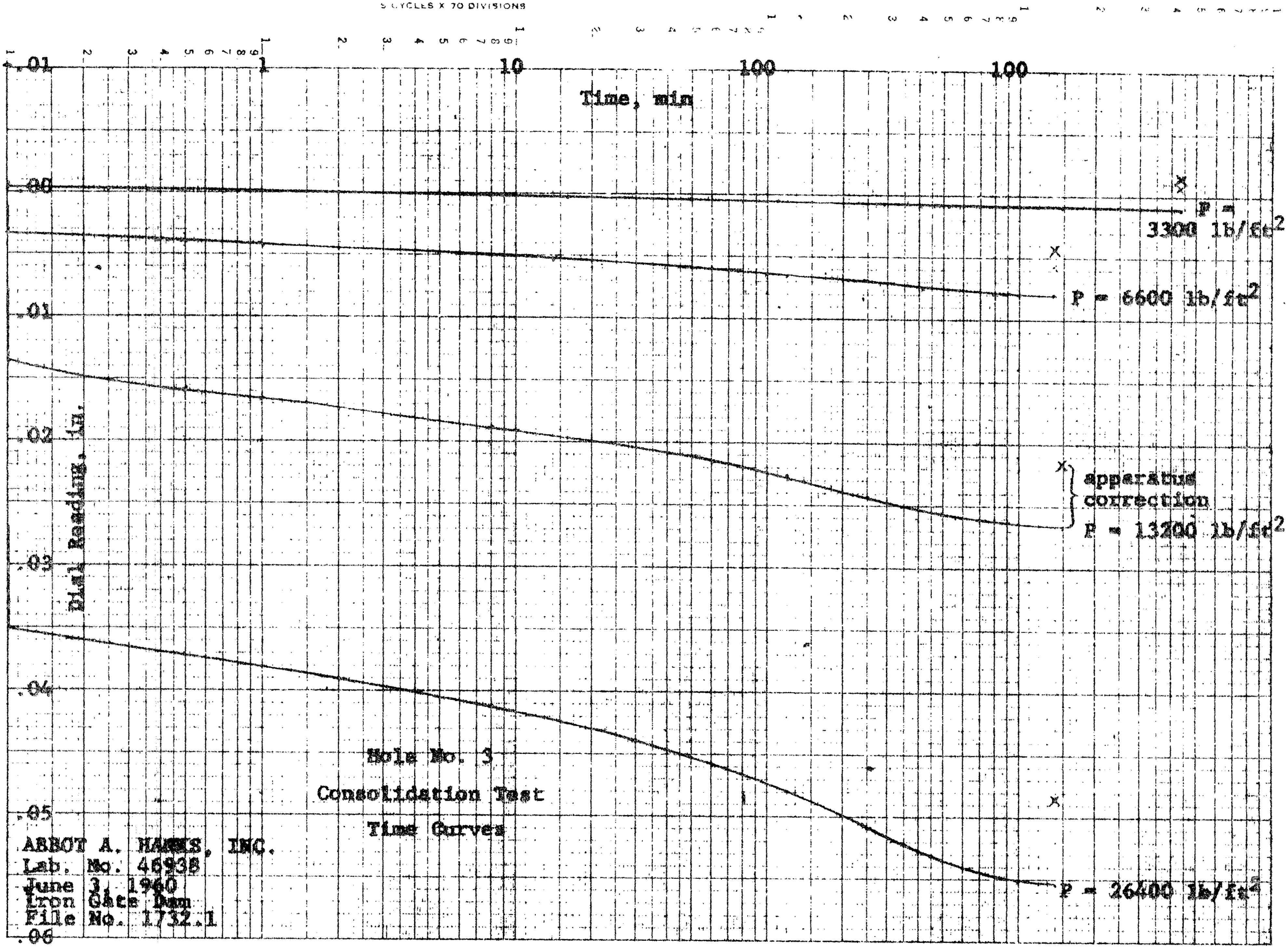
Permeability Test
(Constant Head Test)

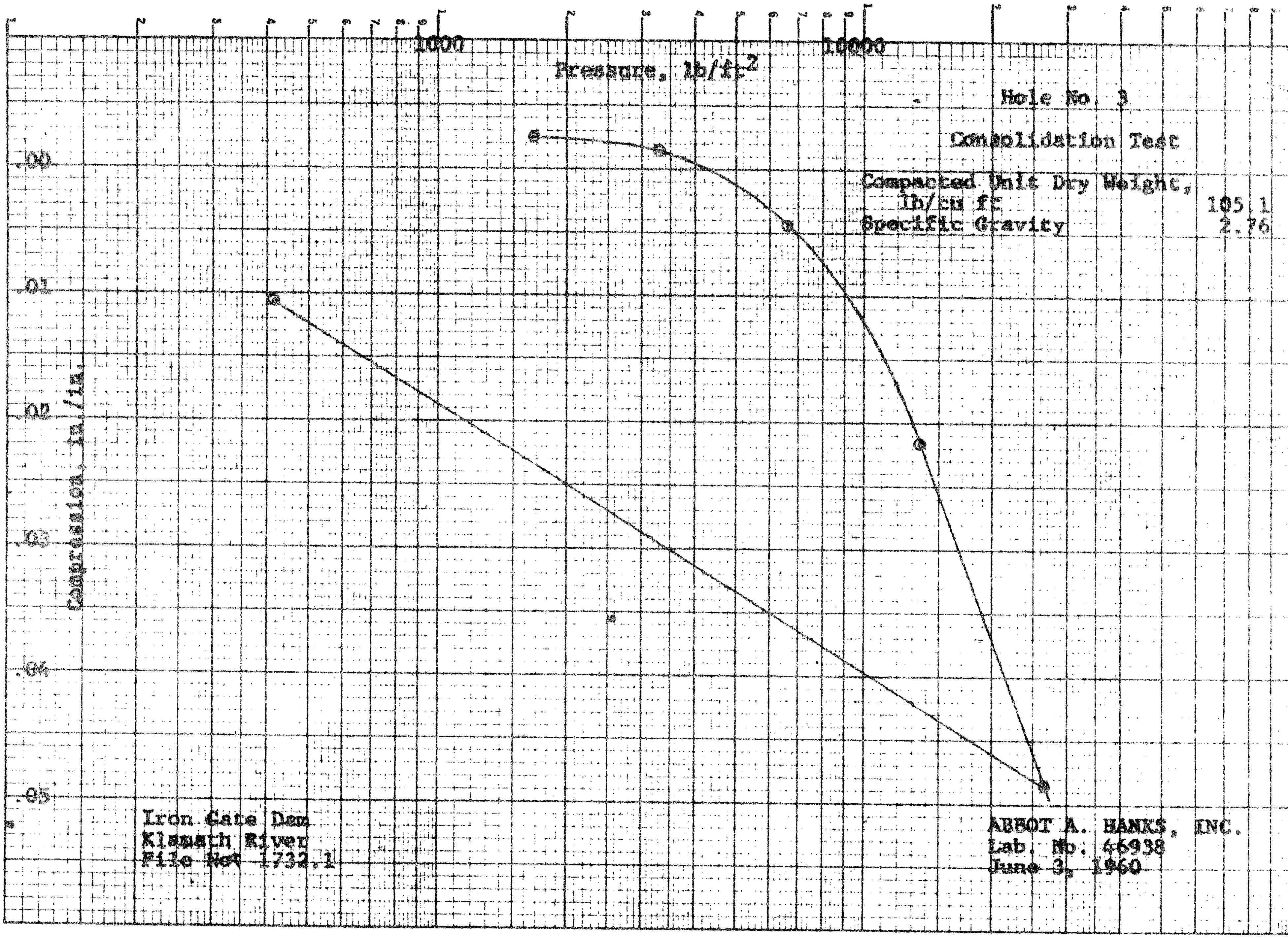
Unit Dry Weight at Compaction, lb/ft^3	106.5
Moisture Content at Compaction, %	22.0
Moisture Content at Test, %	23.1
Degree of Saturation at Test, %	100+
Permeability Coefficient, ft per yr	Less than .01
" " , cm/sec	Less than 10^{-8}

~~Report Letter~~

~~Optimum moisture 15.3 15.5~~

~~Max. Dry density 111.6 111.5~~

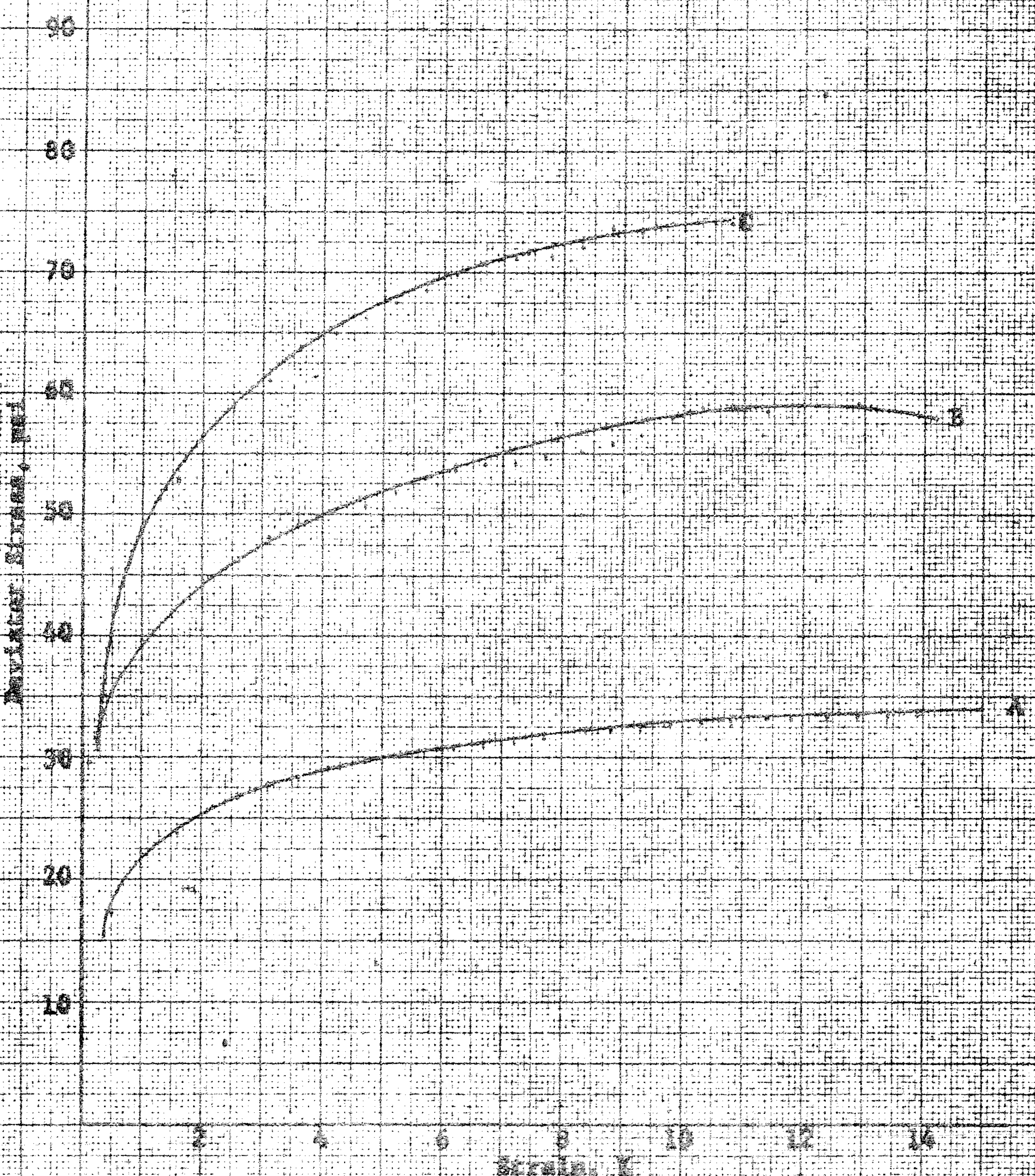

.01
1
10
100
100
Time, min
.00
.01
.02
.03
.04
.05
.06
Dial Reading, in.
P = 3300 lb/ft²
P = 6600 lb/ft²
apparatus correction
P = 13200 lb/ft²
P = 26400 lb/ft²
Hole No. 3
Consolidation Test
Time Curves
ABBOT A. HANKS, INC.
Lab. No. 46938
June 3, 1960
Iron Gate Dam
File No. 1732.1


1000
10000
Pressure, lb/ft^2
Hole No. 3
Consolidation Test
Compacted Unit Dry Weight, lb/cu ft 105.1
Specific Gravity 2.76
.00
.01
.02
.03
.04
.05
Compression, in./in.
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
June 3, 1960

Hole No. 3

Triaxial Shear Test

Stress-Strain Relationships



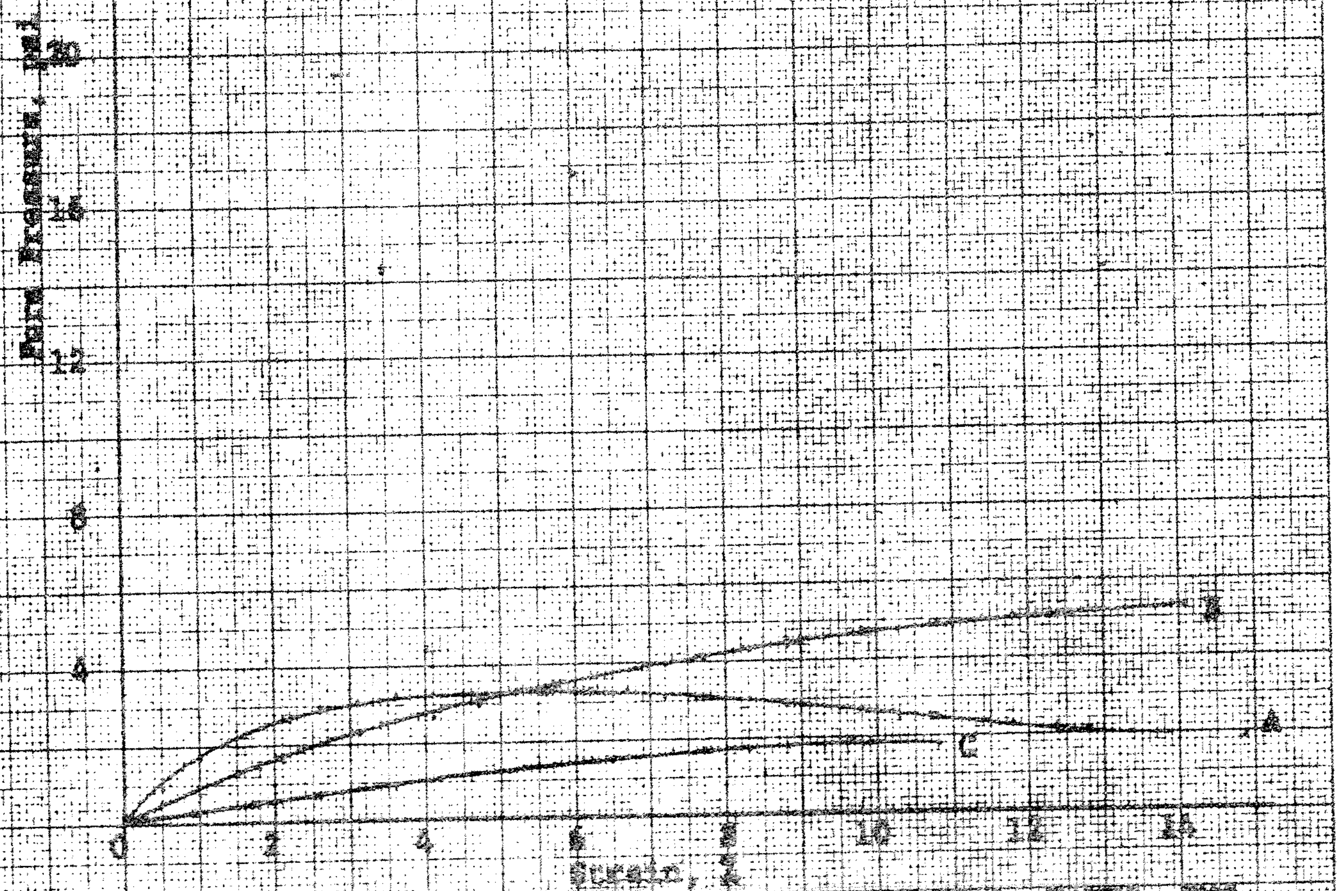
Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46938
June 3, 1960

Hole No. 3

Triaxial Shear Test

Pore Pressure-Strain Relationships



Iron Gate Dam
Klamath River
File No. 1732.1

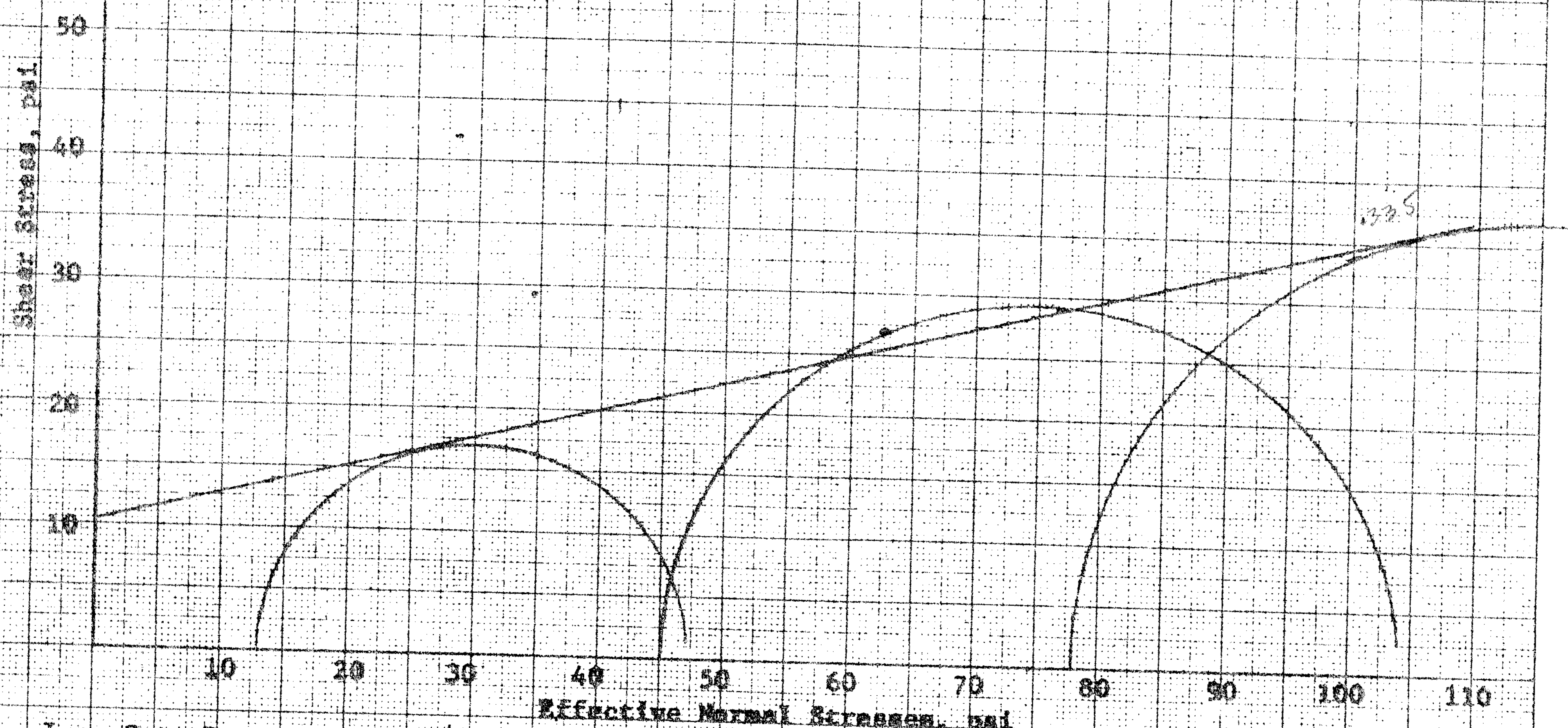
Abbot A. Hanks, Inc.
Lab. No. [illegible]
June 2, 1960

K+E 10 X 10 TO THE CM. 359-14G
KEUFFEL & ESSER CO. MADE IN U.S.A.

Hole No. 3

Mohr Diagram

c = 10 psi
ϕ = 14°



Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46938
June 3, 1960

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BRANCH OFFICE 10 DE LUCA PLACE • SAN RAFAEL • GLENWOOD 4-8650

CABLE HANX

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File No. 1732.1
Lab. No. 46938

June 9, 1960

Mr. W. L. Warren
Assistant Chief Engineer
The California Oregon Power Company
216 West Main Street
Medford, Oregon

Re: Iron Gate Dam
Soil Samples

Dear Mr. Warren:

Enclosed are the findings from tests performed on soil samples marked Hole No. 4.

You will note that the permeability coefficient of the first sample is 3000 times the permeability coefficient of the second sample. We attribute this large difference to the differences in both density and moisture content at compaction. The second sample, compacted at 16% moisture content, appeared to be somewhat over optimum moisture.

Very truly yours,

ABBOT A. HANKS, INC.

Donald W Radbruch

Donald W. Radbruch

LOL:hms
Encls.
Reports to:
3-The California Oregon Power Company

Iron Gate Dam
Klamath River
File No. 1732.1

Abbot A. Hanks, Inc.
Lab. No. 46938
June 8, 1960

TEST RESULTS

Hole No. 4
Specific Gravity: 2.77

Triaxial Shear Test

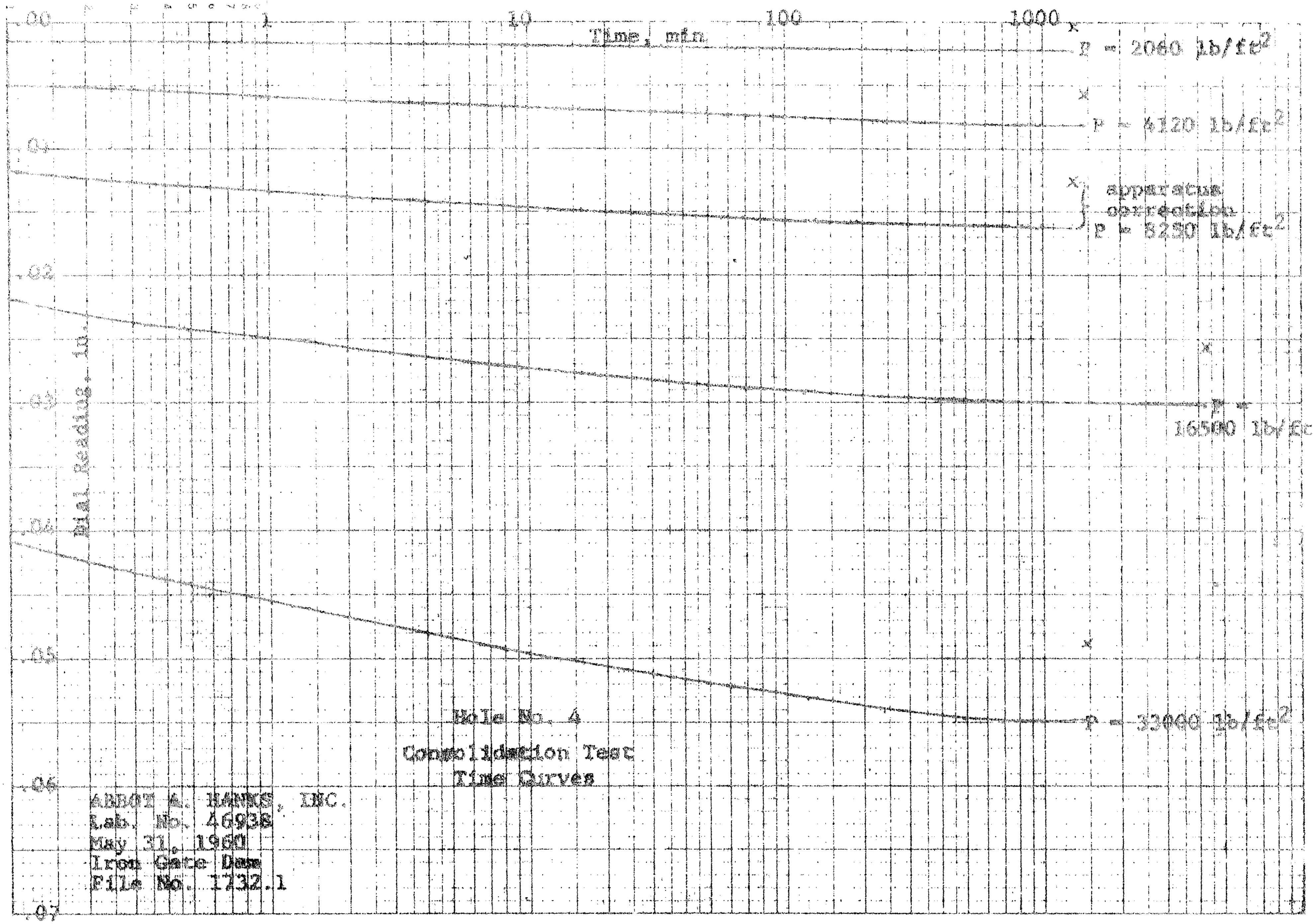
	Sample A	Sample B	Sample C
Chamber Pressure, psi	15	50	80
Unit Dry Weight at Compaction, lb/ft^3	112.8	112.3	116.5
Moisture Content at Compaction, %	13.8	13.6	15.4
Unit Dry Weight at Test, lb/ft^3	112.8	114.2	119.4
Moisture Content at Test, lb/ft^3	16.5	17.6	16.0
Degree of Saturation at Test, %	87	96	100
Maximum Deviator Stress, psi	34	85	152
Pore Pressure at Max. Deviator Stress, psi	3	18	9

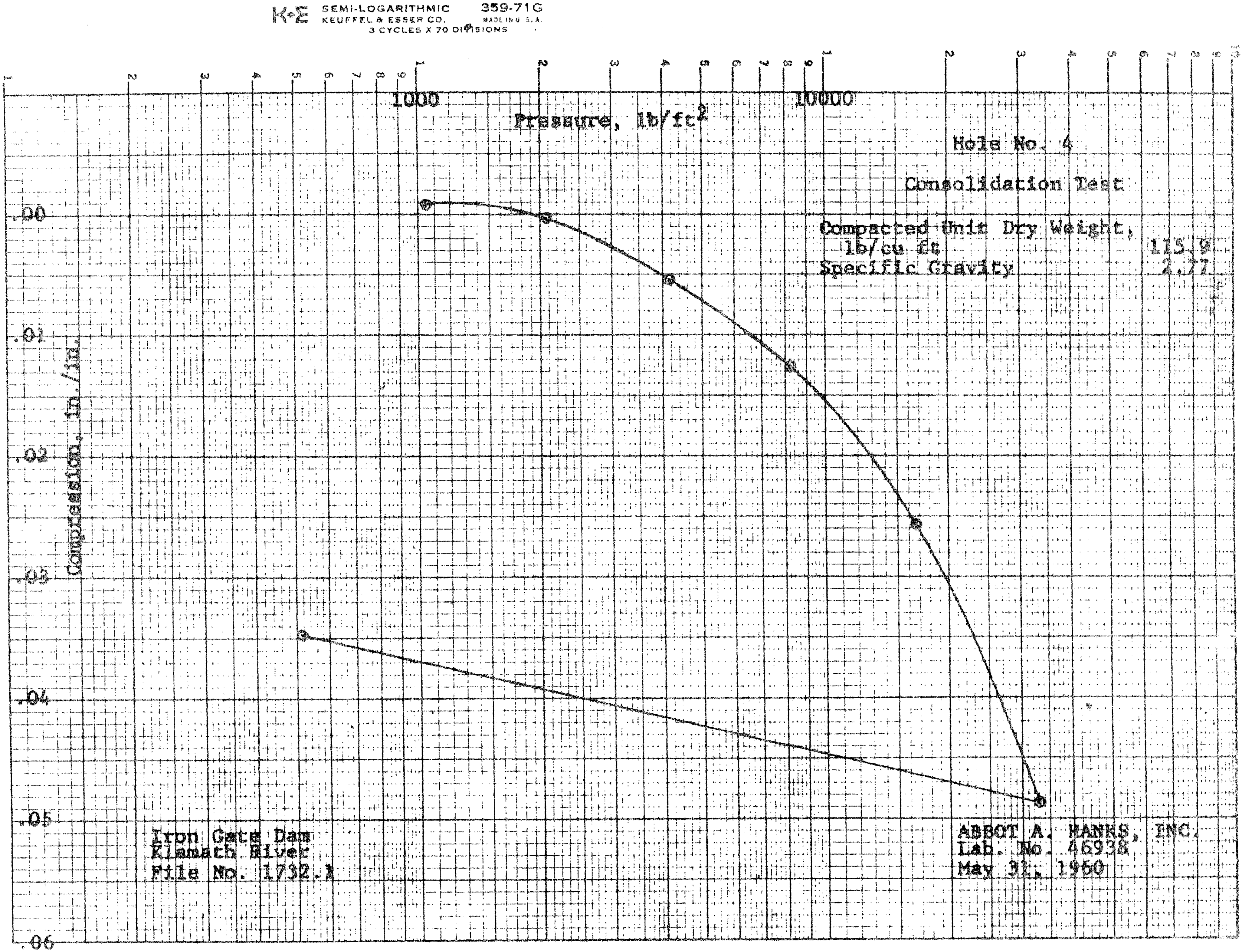
Permeability Tests
(Constant Head Tests)

Unit Dry Weight at Compaction, lb/ft^3	113.3
Moisture Content at Compaction, %	14.3
Moisture Content at Test, %	20.4
Degree of Saturation at Test, %	100+
Permeability Coefficient, ft per yr	30-40
" " , cm/sec	$3\text{-}4 \times 10^{-5}$

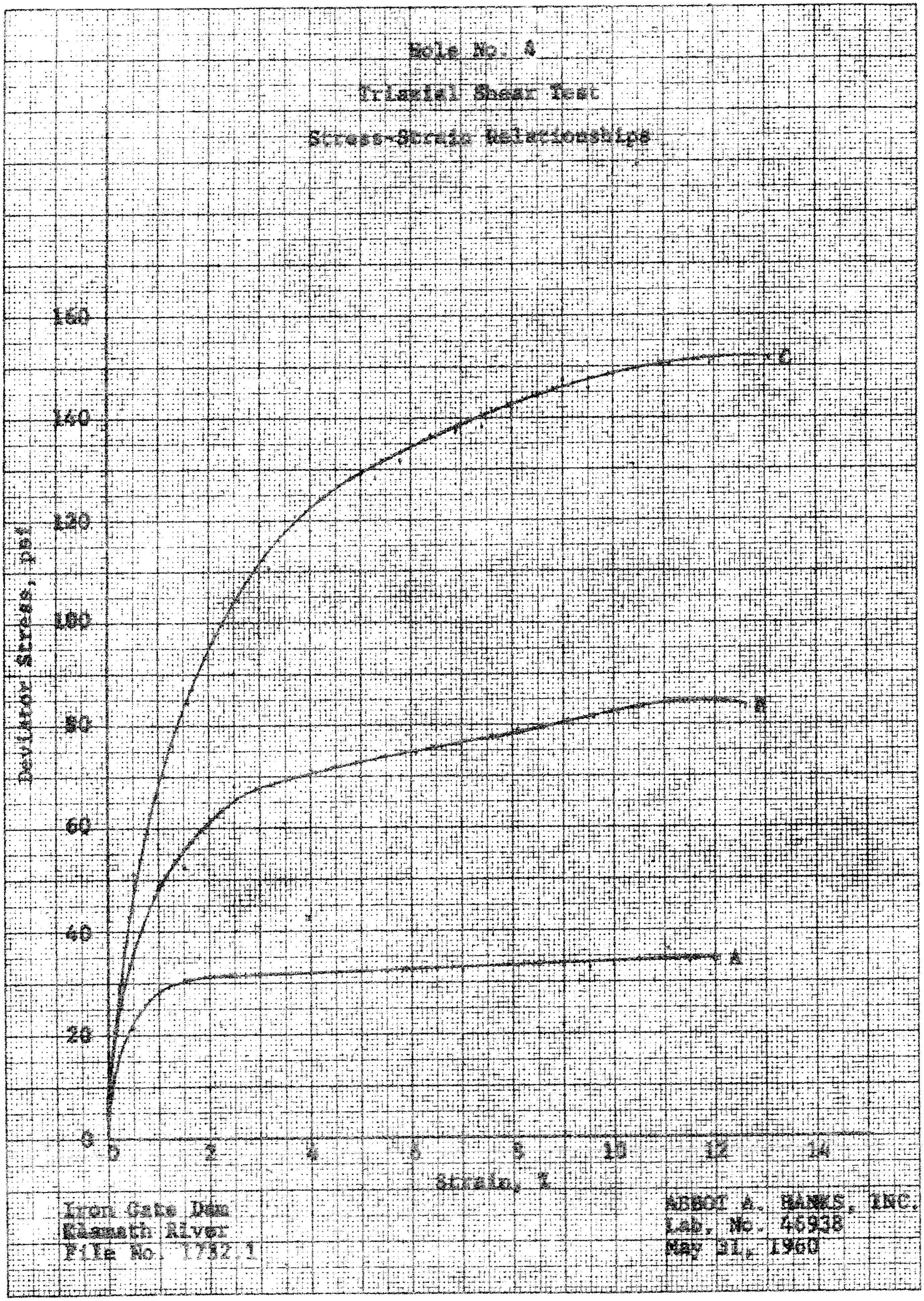
Unit Dry Weight at Compaction, lb/ft^3	116.2
Moisture Content at Compaction, %	16.0
Moisture Content at Test, %	17.0
Degree of Saturation at Test, %	97
Permeability Coefficient, ft per yr	.01-.04
" " , cm/sec	$1\text{-}4 \times 10^{-8}$

	Report	Letter
Optimum moisture	14.5	14-15
Max dry density	115.9	115


Time, min
Dial Reading, in.
p = 2060 lb/ft²
p = 4120 lb/ft²
apparatus correction
p = 8250 lb/ft²
p = 16500 lb/ft²
p = 33000 lb/ft²
Hole No. 4
Consolidation Test
Time Curves
ABBOT A. HANKS, INC.
Lab. No. 46938
May 31, 1960
Iron Gate Dam
File No. 1732.1



K+E SEMI-LOGARITHMIC 359-71G
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
1000
10000
Pressure, lb/ft²
Hole No. 4
Consolidation Test
Compacted Unit Dry Weight, lb/cu ft 115.9
Specific Gravity 2.77
Compression, in./in.
.00
.01
.02
.03
.04
.05
.06
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
May 31, 1960

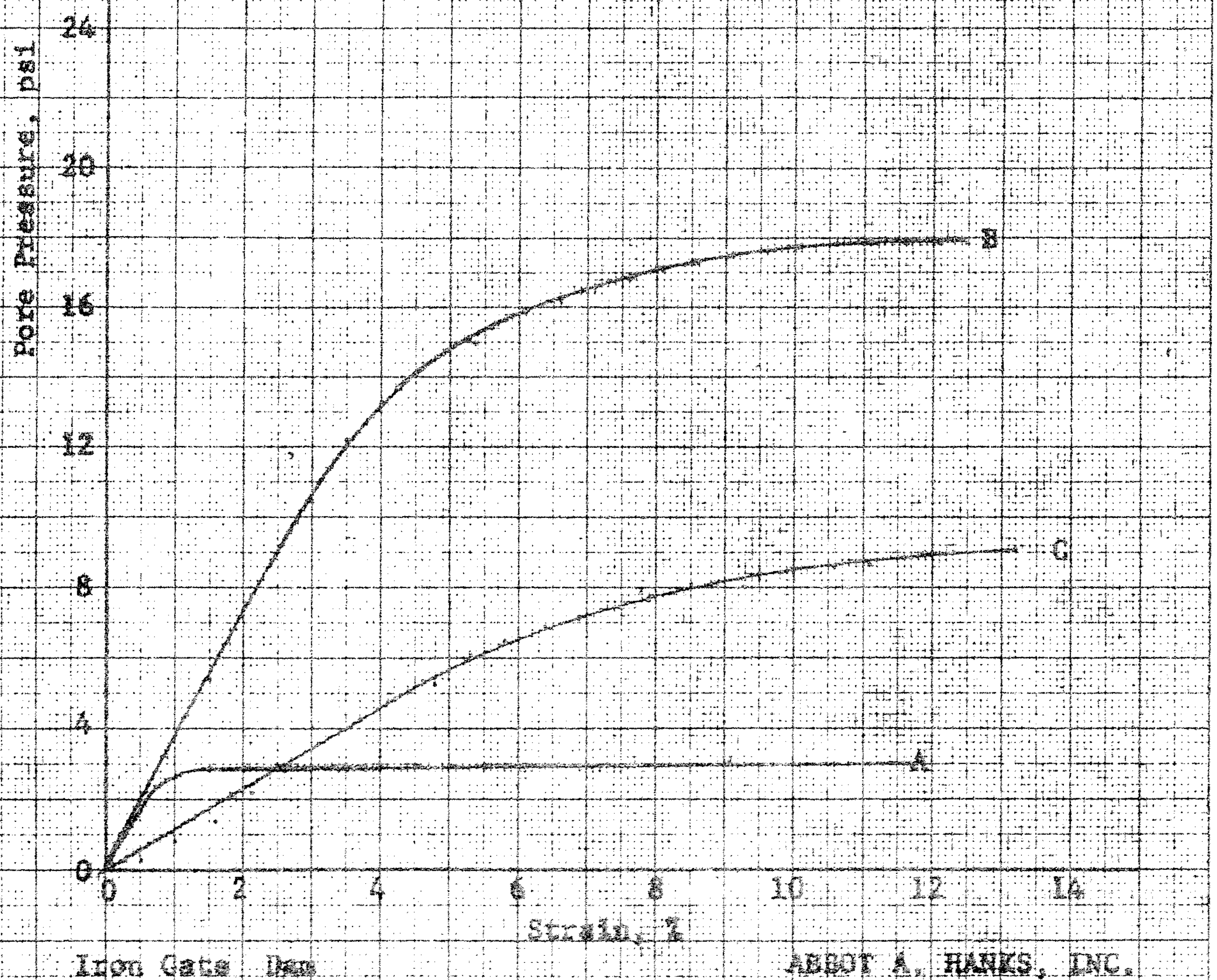


Hole No. 4
Triaxial Shear Test
Stress-Strain Relationships
Deviator Stress, psi
0
20
40
60
80
100
120
140
160
Strain, %
0
2
4
6
8
10
12
14
C
B
A
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
May 31, 1960
10 X 10 TO THE CM. 359-14G
KEUFFEL & ESSER CO. MADE IN U.S.A.

Hole No. 4

Triaxial Shear Test

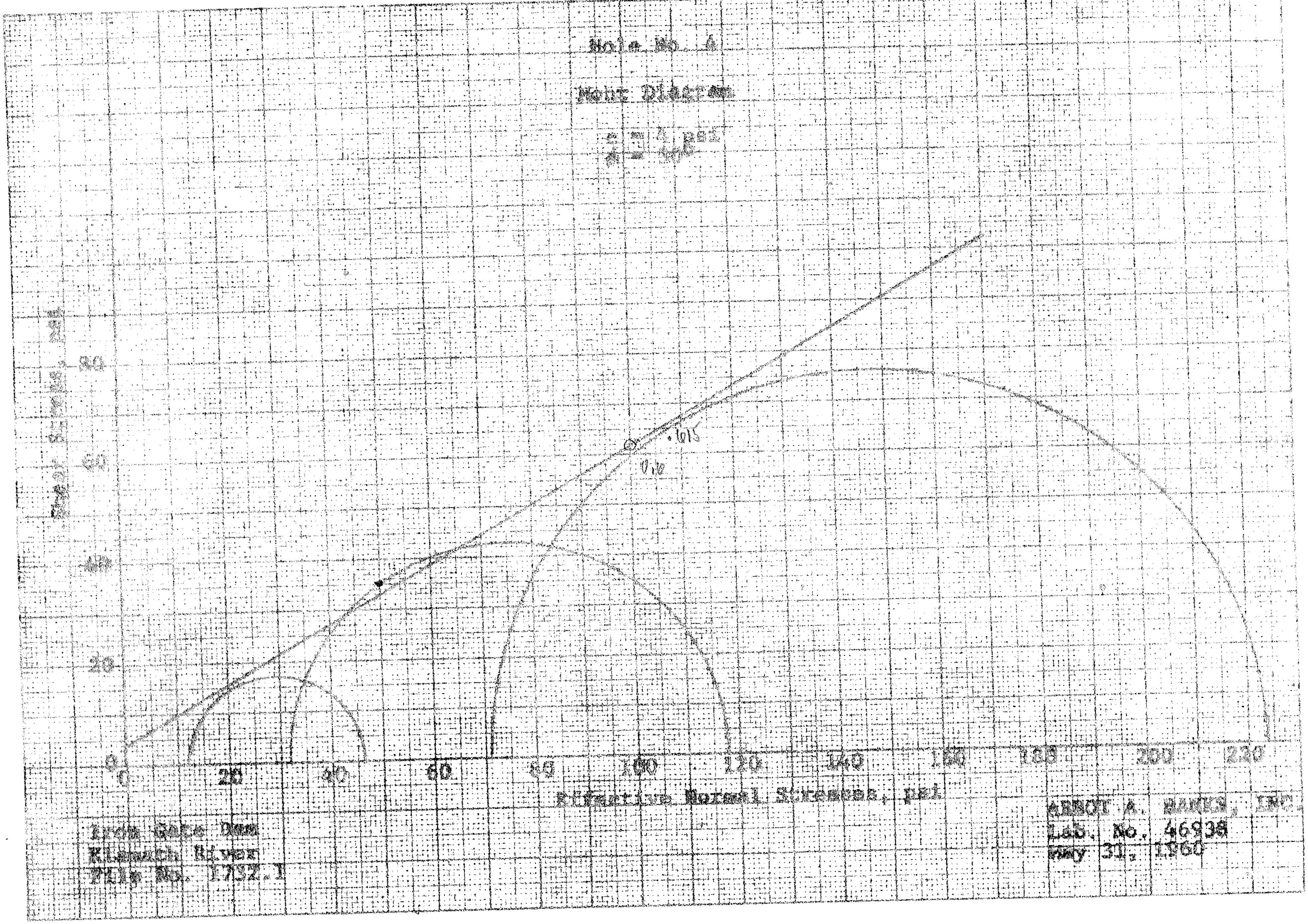
Pore Pressure-Strain Relationships



Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46938
May 31, 1960

K&E 10 X 10 TO THE CM. 359-14G
KEUFFEL & ESSER CO.



BRANCH LABORATORY 1086 MARTIN AVENUE · SANTA CLARA · [illegible]

BRANCH OFFICE 10 DE LUCA PLACE · SAN RAFAEL · GLENWOOD 4 [illegible]

CABLE HANKS

ABBOT A. HANKS, INC.

[illegible]

1300 SANSOME STREET · SAN FRANCISCO 11 CALIFORNIA · EXBROOK 2 [illegible]

Engineers
Assayers
Chemists
Metallurgists
Spectrographers
Soils and Foundations
Consulting · Testing · Inspecting

File No. 1732.1
Lab. No. 46938

June 9, 1960

Mr. W. L. Warren
Assistant Chief Engineer
The California Oregon Power Company
216 West Main Street
Medford, Oregon

Re: Iron Gate Dam
Soil Samples

Dear Mr. Warren:

Enclosed are the findings from tests performed on soil samples marked Hole No. 7.

Very truly yours,

ABBOT A. HANKS, INC.

Donald W Radbruch

Donald W. Radbruch

hms
Encls.
Reports to:
3-The California Oregon Power Company

Iron Gate Dam
Klamath River
File No. 1732.1

Abbot A. Hanks, Inc.
Lab. No. 46938
June 9, 1960

TEST RESULTS

Hole No. 7
Specific Gravity: 2.74

Triaxial Shear Test

	Samples A	B	C	D
Chamber Pressure, psi	15	50	80	80
Unit Dry Weight at Compaction, lb/ft^3	109.1	110.0	110.0	109.3
Moisture Content at Compaction, %	17.6	17.3	19.0	19.3
Unit Dry Weight at Test, lb/ft^3	106.7	111.5	114.7	114.8
Moisture Content at Test, lb/ft^3	22.6	19.3	18.7	19.8
Degree of Saturation at Test, %	100+	100	100	100+
Maximum Deviator Stress, psi	22	67	77	79
Pore Pressure at Max. Deviator Stress, psi	6	12	23	17

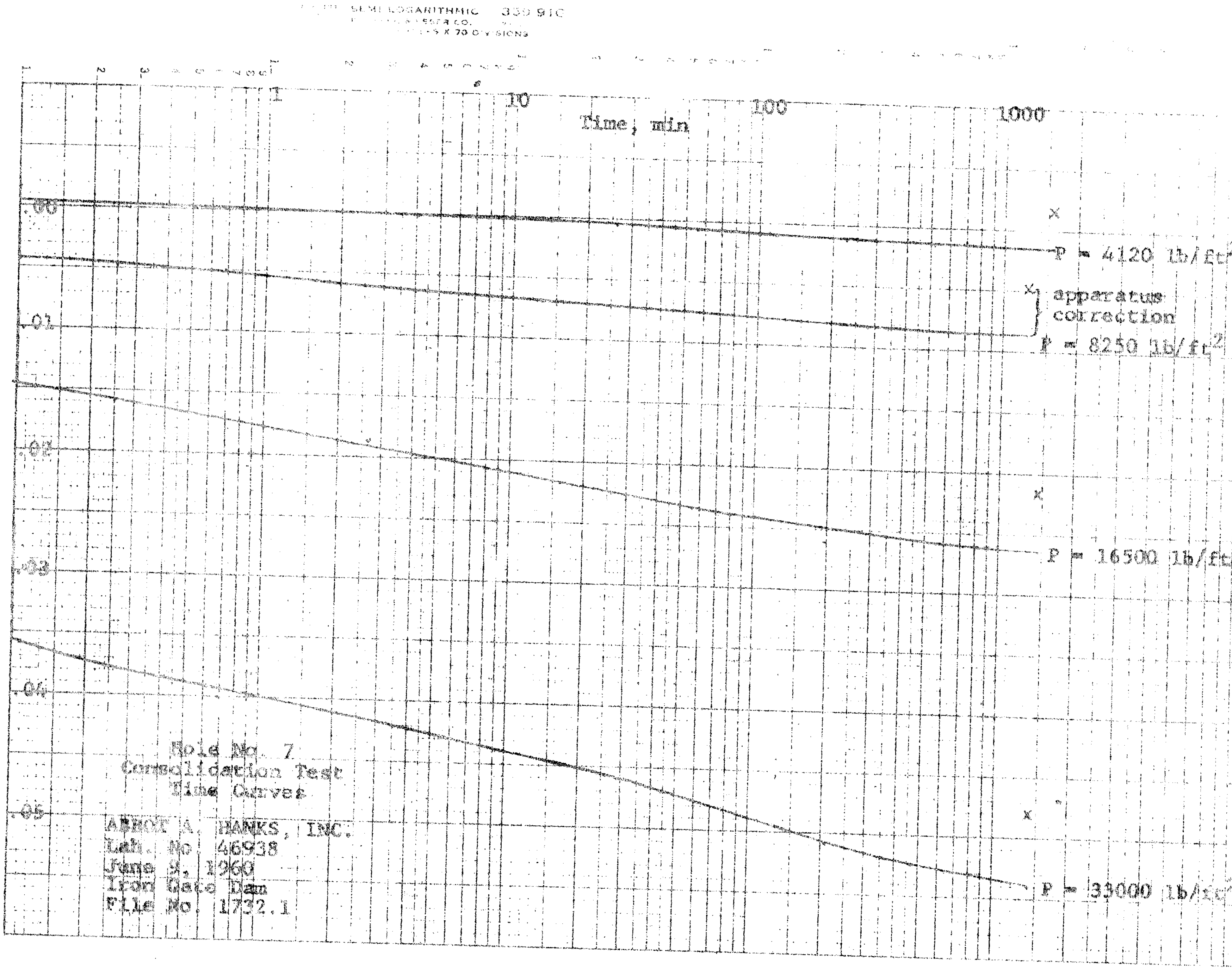
Permeability Test
(Constant Head Test)

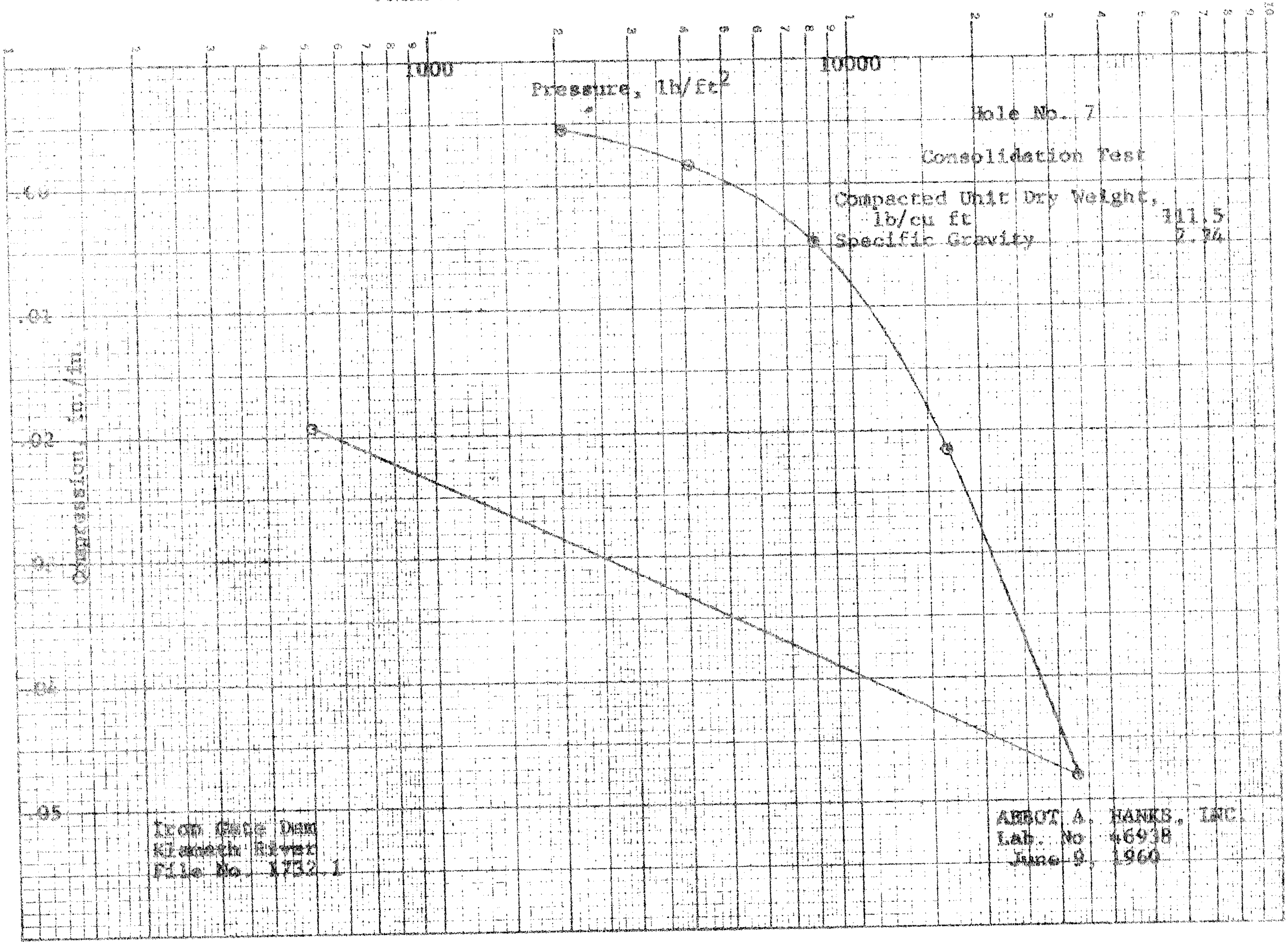
Unit Dry Weight at Compaction, lb/ft^3	109.3
Moisture Content at Compaction, %	17.8
Moisture Content at Test, %	19.7
Degree of Saturation at Test, %	96
Permeability Coefficient, ft per yr	Less than .01
" " , cm/sec	Less than 10^{-8}

Report
~~Letter~~ ~~a~~ Letter

~~Optimum moisture~~ 15.2 15

Max. ~~Dry density~~ 117.6 116.0

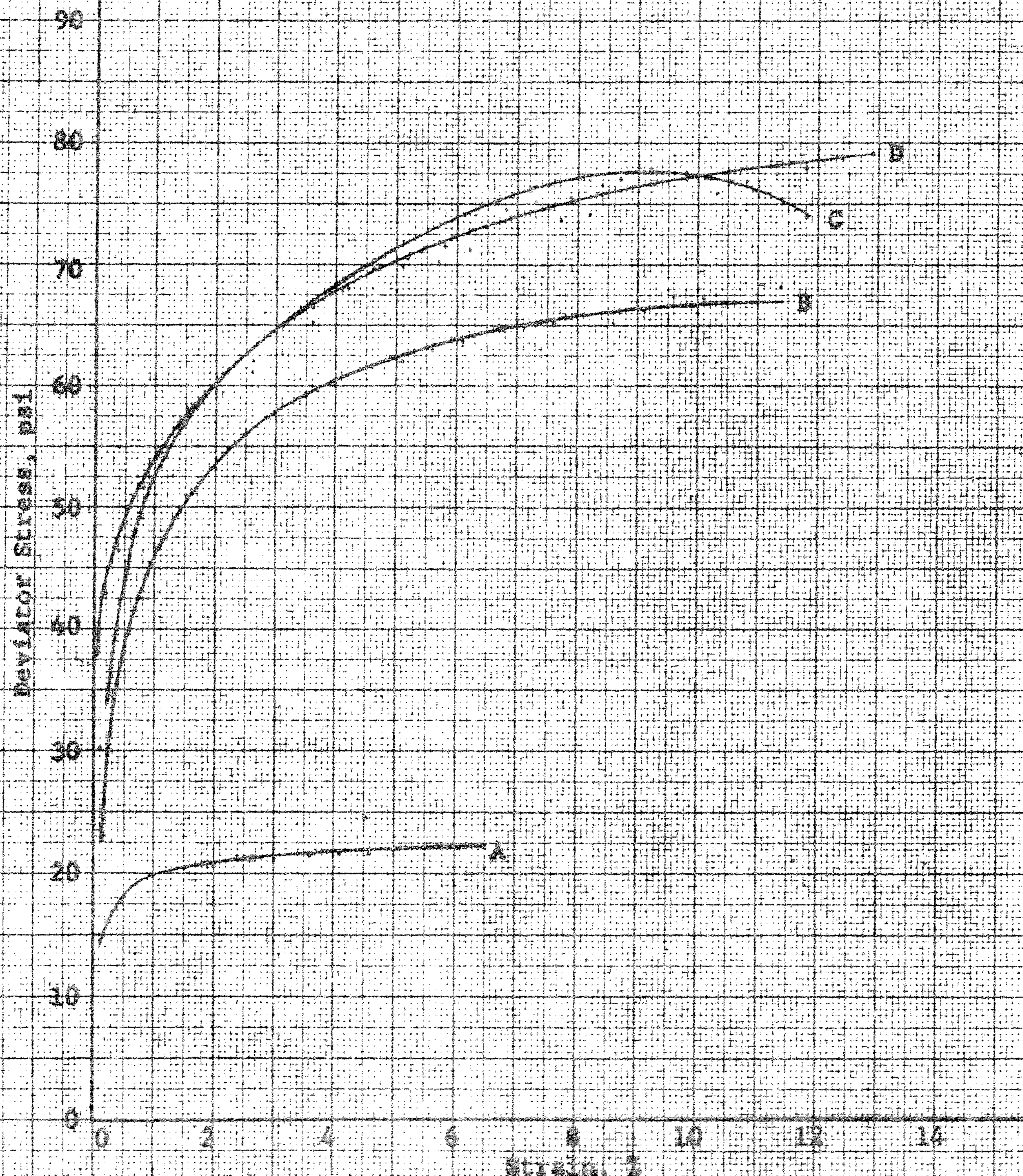

SEMI-LOGARITHMIC 359-91C
Time, min
1
10
100
1000
.00
.01
.02
.03
.04
.05
P = 4120 lb/ft^2
apparatus correction
P = 8250 lb/ft^2
P = 16500 lb/ft^2
P = 33000 lb/ft^2
Hole No. 7
Consolidation Test
Time Curves
ABBOT A. HANKS, INC.
Lab. No. 46938
June 8, 1960
Iron Gate Dam
File No. 1732.1


1000
10000
Pressure, lb/ft^2
Compression, in./in.
.00
.01
.02
.03
.04
.05
Hole No. 7
Consolidation Test
Compacted Unit Dry Weight, lb/cu ft 111.5
Specific Gravity 2.74
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No 46938
June 9, 1960

Hole No. 7

Triaxial Shear Test

Stress-Strain Relationships



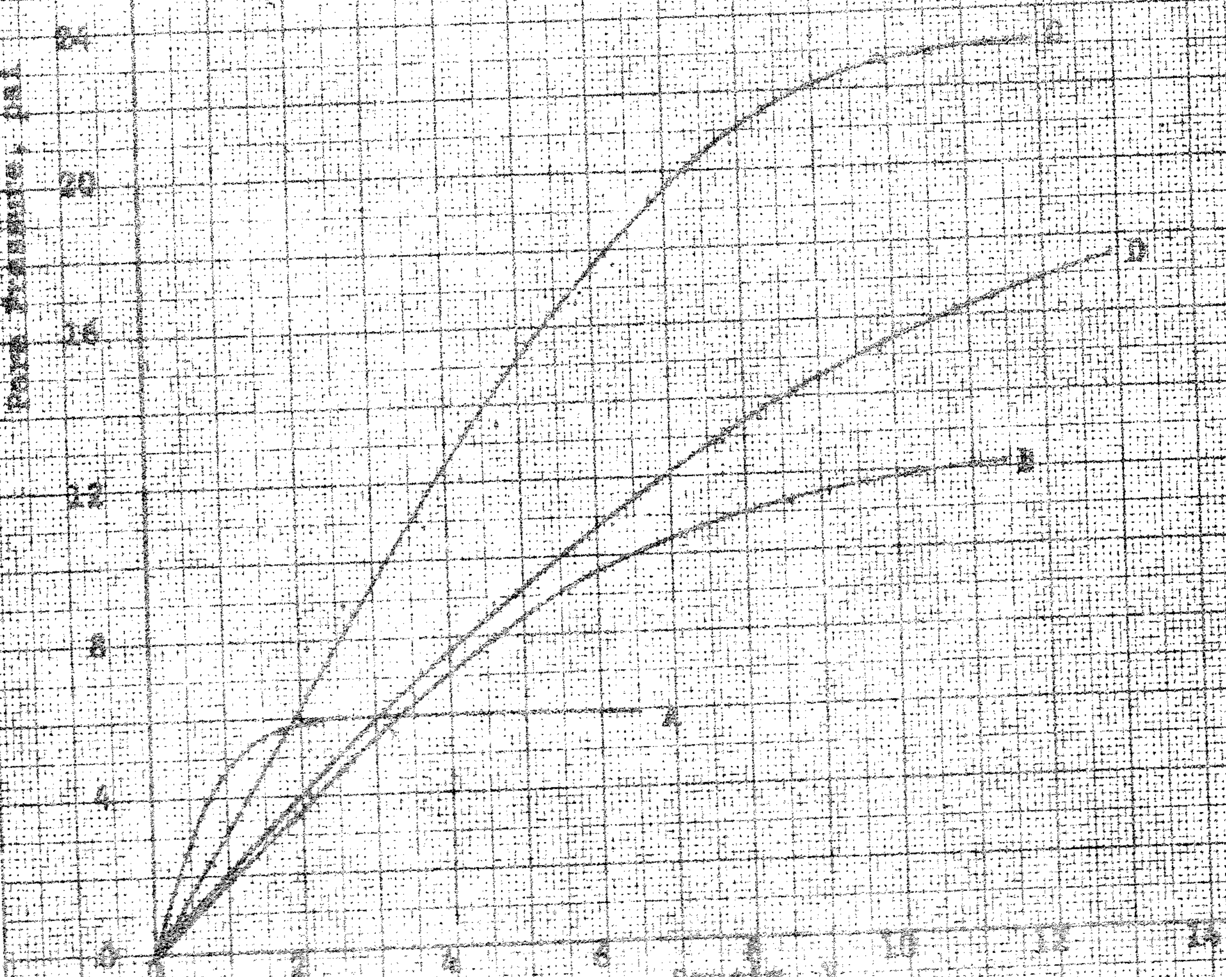
Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46836
June 9, 1960

Hole No. 7

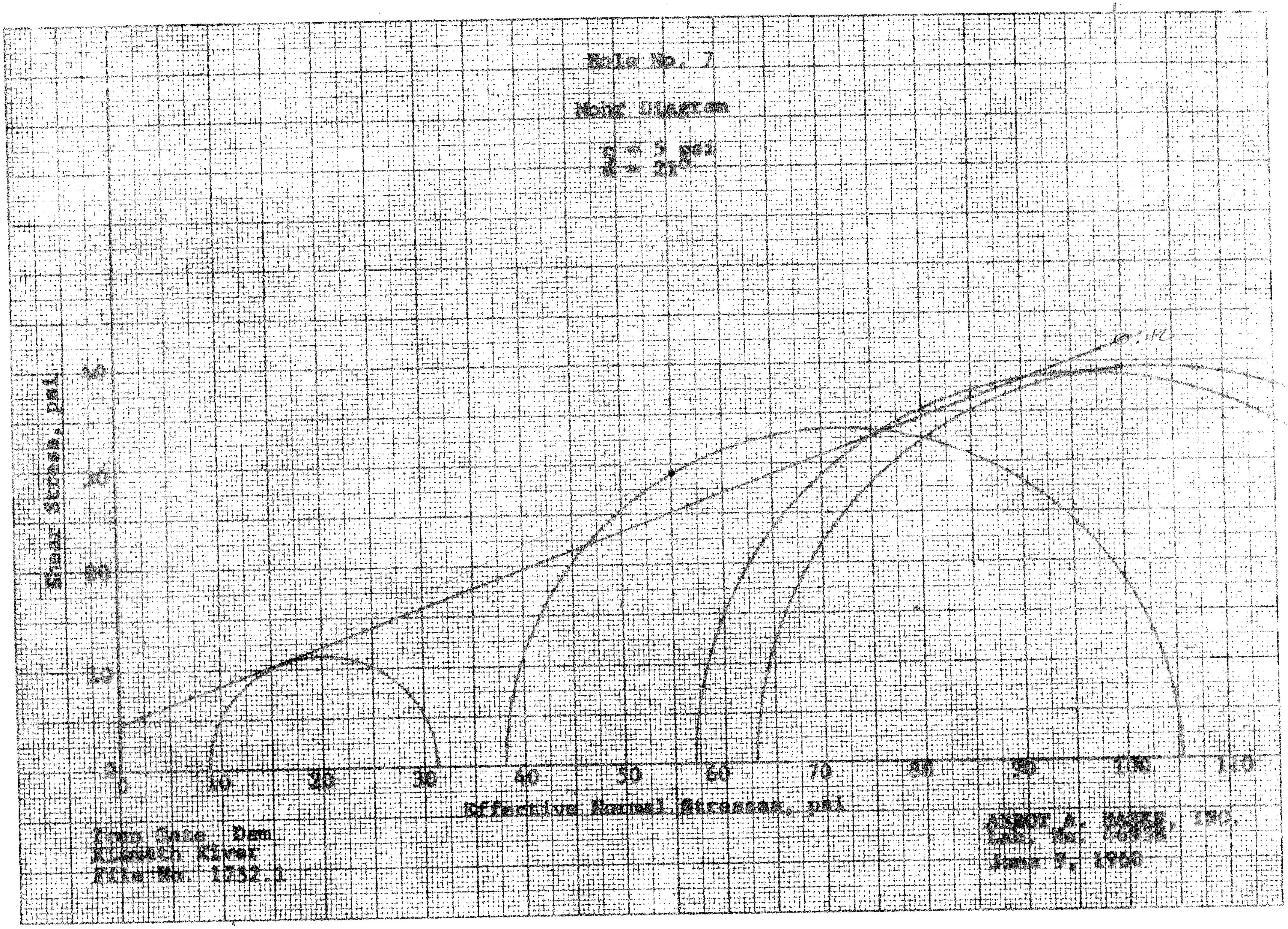
Triaxial Shear Test

Pore Pressure-Strain Relationships



Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46956
June 9, 1960


Hole No. 7
Mohr Diagram
Shear Stress, psi
Effective Normal Stresses, psi
0
10
20
30
40
50
60
70
80
90
100
110
Iron Gate Dam
Klamath River
File No. 1732.1
Abbot A. Hanks, Inc.

BRANCH LABORATORY 1080 MARTIN AVENUE • SANTA CLARA • CHERRY 3-7797
BRANCH OFFICE 10 DE LUCA PLACE • SAN RAFAEL • GLENWOOD 4-8850

CABLE HANKS

ABBOT A. HANKS, INC.

1300 SANSOME STREET • SAN FRANCISCO 11, CALIFORNIA • EXBROOK 7-1161

Engineers
Assayers
Chemists
Metallurgists
Spectrographers
Soils and Foundations
Consulting Testing Inspecting

File No. 1732.1
Lab. No. 46938

May 24, 1960

Mr. W. L. Warren
Assistant Chief Engineer
The California Oregon Power Company
216 West Main Street
Medford, Oregon

Re: Iron Gate Dam
Soil Samples

Dear Mr. Warren:

Enclosed are the findings from tests performed on soil samples marked Hole No. 8.

Very truly yours,

ABBOT A. HANKS, INC.

Donald W Radbruch

Donald W. Radbruch

hms
Encls.
Reports to:
3-The California Oregon Power Company

Iron Gate Dam
Klamath River
File No. 1732.1

Abbot A. Hanks, Inc.
Lab. No. 46938
May 18, 1960

TEST RESULTS

Hole No. 8
Specific Gravity: 2.75

Triaxial Shear Test

	Sample A	Sample B	Sample C
Chamber Pressure, psi	15	50	80
Unit Dry Weight at Compaction, lb/ft^3	98.6	99.7	98.9
Moisture Content at Compaction, %	19.9	19.9	20.1
Unit Dry Weight at Test, lb/ft^3	95.4	100.6	102.9
Moisture Content at Test, lb/ft^3	28.4	26.1	25.0
Degree of Saturation at Test, %	98	100+	100+
Maximum Deviator Stress, psi	21	48	66
Pore Pressure at Max. Deviator Stress, psi	5	13	30

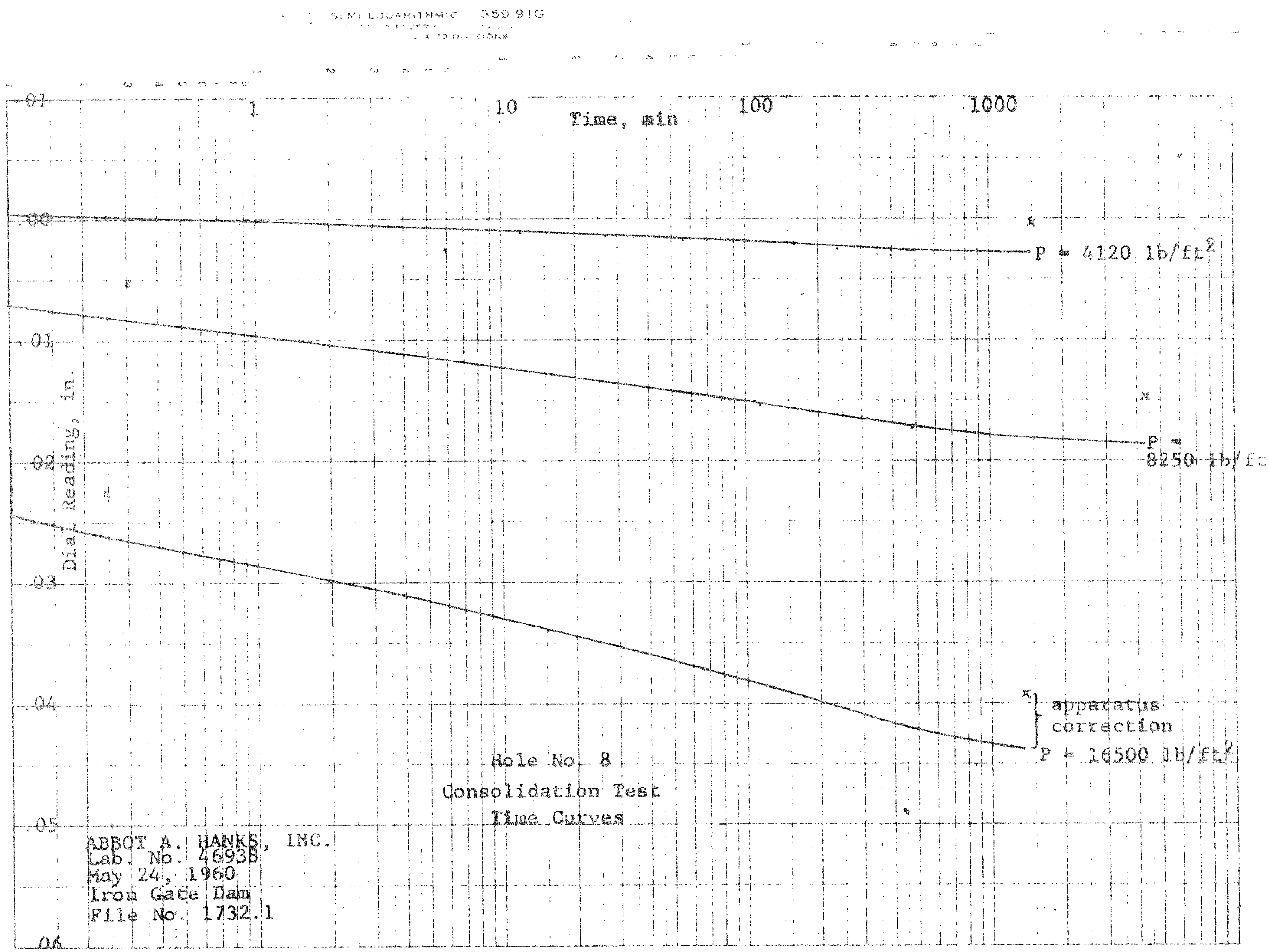
Permeability Test
(Constant Head Test)

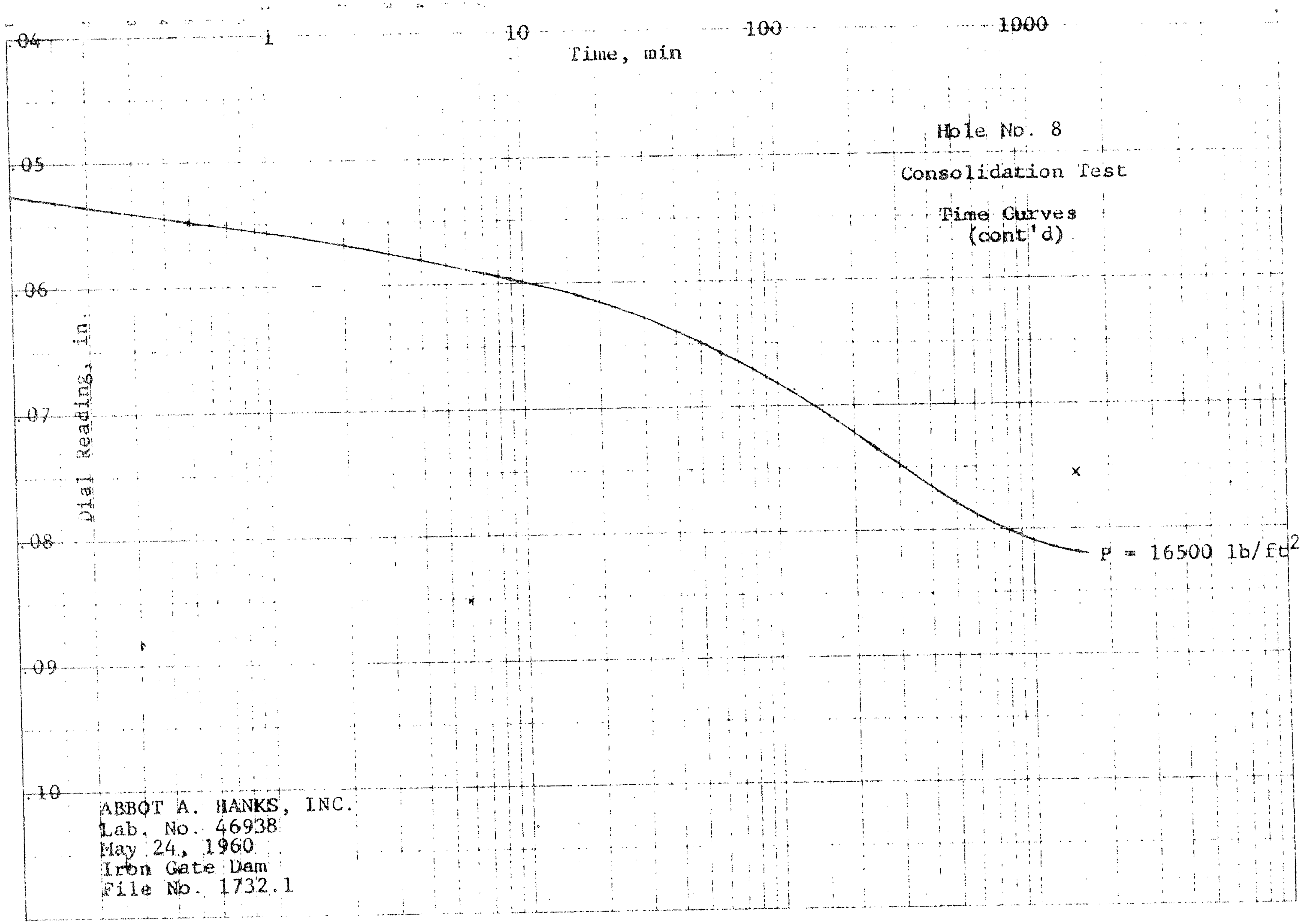
Unit Dry Weight at Compaction, lb/ft^3	100.8
Moisture Content at Compaction, %	21.1
Moisture Content at Test, %	25.4
Degree of Saturation at Test, %	100
Permeability Coefficient, ft per yr	Less than .01
" " , cm/sec	Less than 10-8

~~Report~~ letter

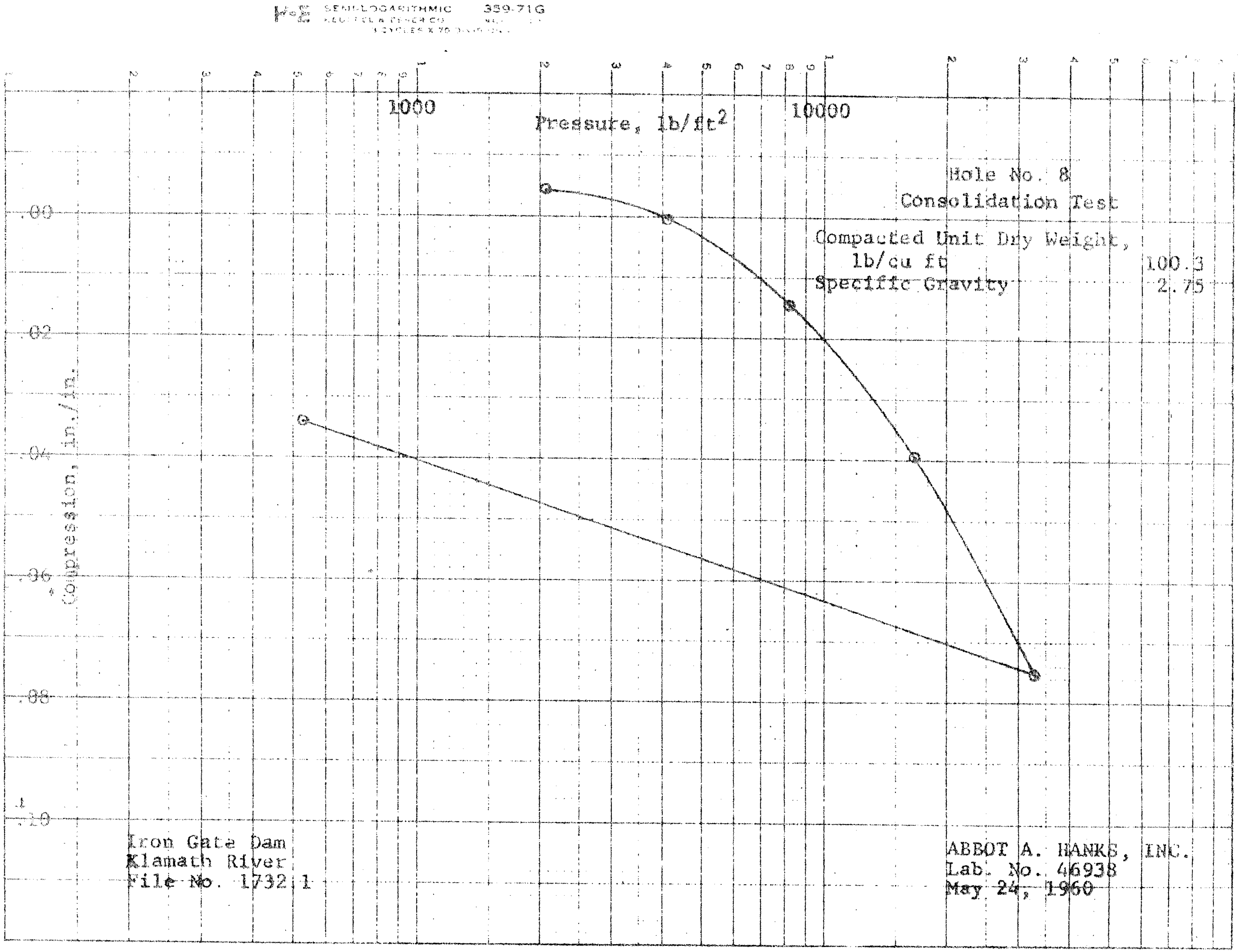
~~Optimum moisture~~ 17.2 17.5

~~Max. dry density~~ ~~107.8~~ ~~100.0~~


SEMI-LOGARITHMIC 359 91G
Time, min
1
10
100
1000
Dial Reading, in.
.00
.01
.02
.03
.04
.05
.06
P = 4120 lb/ft²
P = 8250 lb/ft
apparatus correction
P = 16500 lb/ft²
Hole No. 8
Consolidation Test
Time Curves
ABBOT A. HANKS, INC.
Lab. No. 46938
May 24, 1960
Iron Gate Dam
File No. 1732.1



Time, min
1
10
100
1000
Dial Reading, in.
.04
.05
.06
.07
.08
.09
.10
Hole No. 8
Consolidation Test
Time Curves
(cont'd)
p = 16500 lb/ft2
ABBOT A. HANKS, INC.
Lab. No. 46938
May 24, 1960
Iron Gate Dam
File No. 1732.1

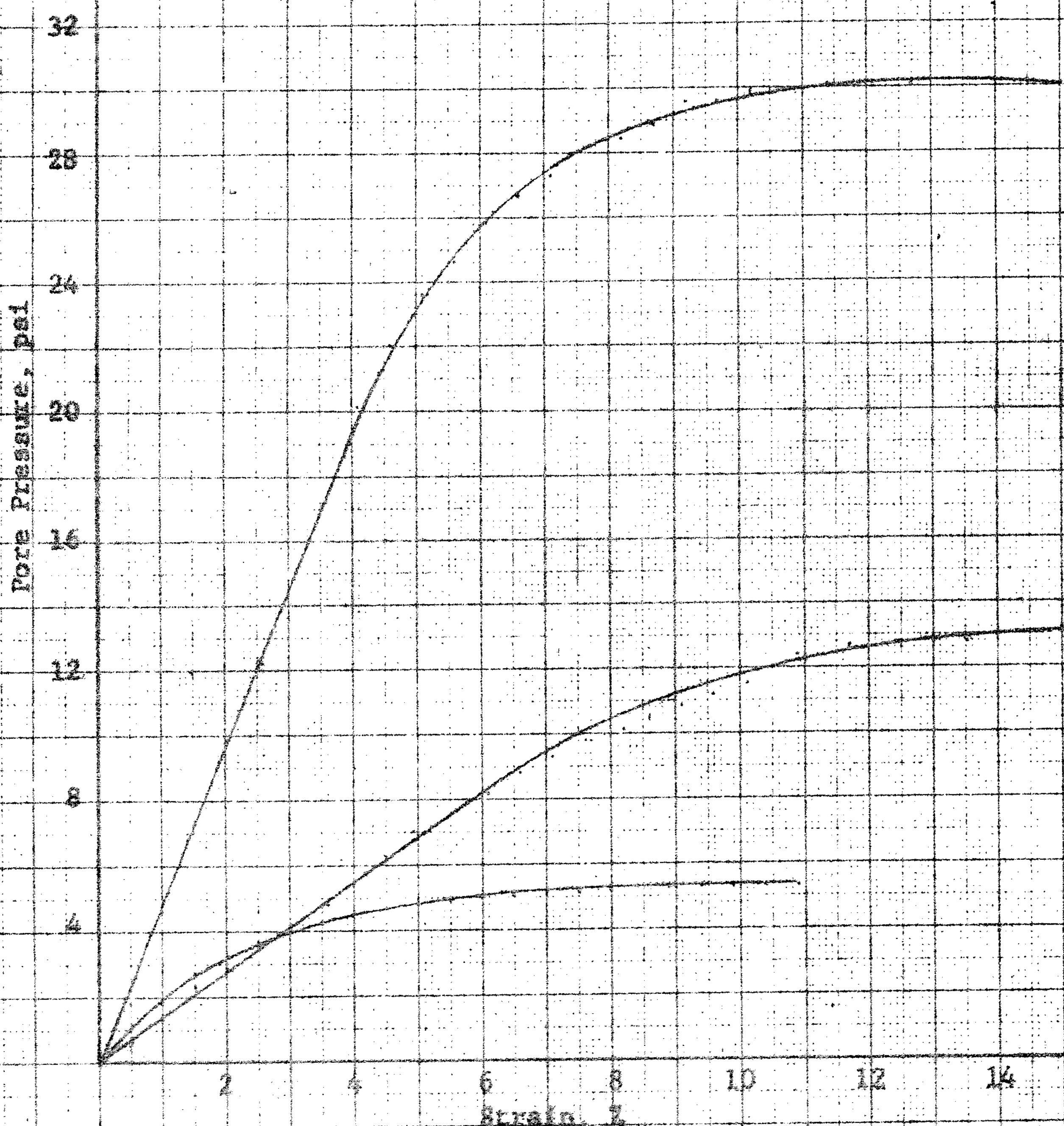


SEMI-LOGARITHMIC 359-71G
1000
10000
Pressure, lb/ft²
Compression, in./in.
.00
.02
.04
.06
.08
.10
Hole No. 8
Consolidation Test
Compacted Unit Dry Weight, lb/cu ft 100.3
Specific Gravity 2.75
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
May 24, 1960

Hole No. 8

Triaxial Shear Test

Pore Pressure-Strain Relationships



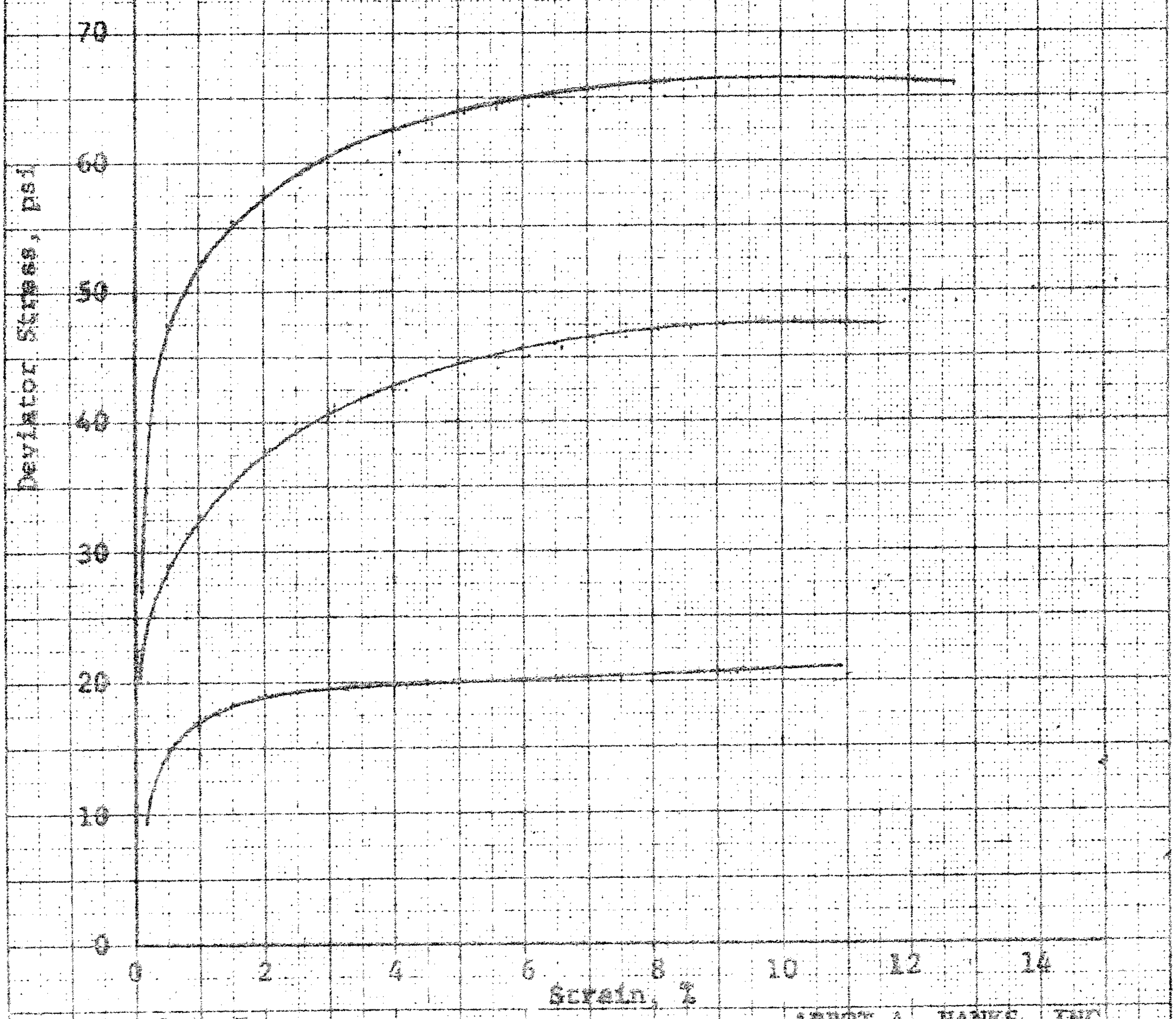
Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46938
May 18, 1960

Hole No. 8

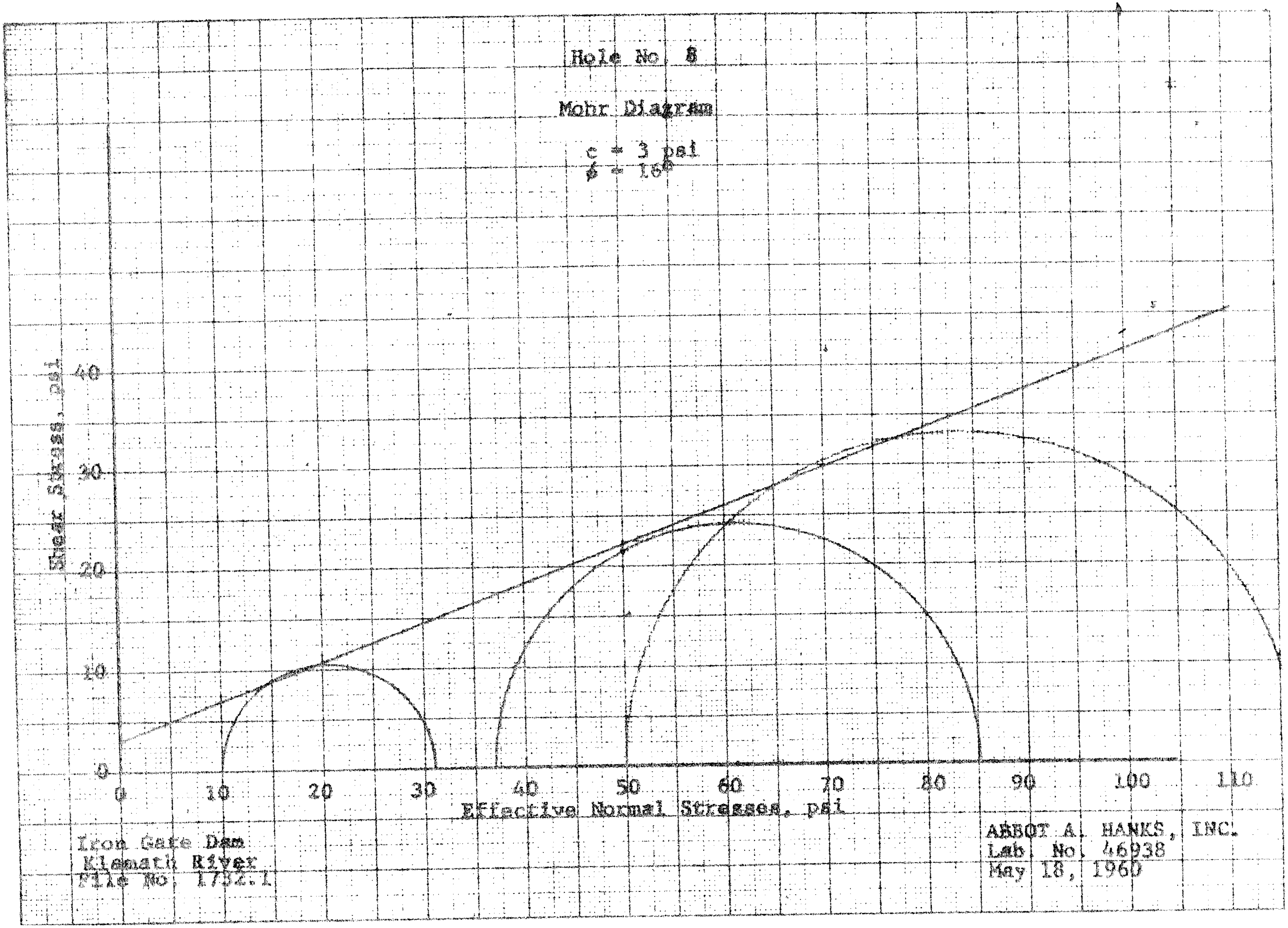
Triaxial Shear Test

Stress-Strain Relationships



Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46938
May 16, 1960


Hole No. 8
Mohr Diagram
c = 3 psi
ϕ = 16°
Shear Stress, psi
0
10
20
30
40
0
10
20
30
40
50
60
70
80
90
100
110
Effective Normal Stresses, psi
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
May 18, 1960

BRANCH LABORATORY 1086 MARTIN AVENUE • SANTA CLARA • CHERRY 8 5262 CABLE HANX
BRANCH OFFICE 10 DE LUCA PLACE • SAN RAFAEL • GLENWOOD 4 8550

ABBOT A. HANKS, INC.

ESTABLISHED 1866

1300 SANSOME STREET • SAN FRANCISCO 11, CALIFORNIA • EXBROOK 7 2464

Engineers
Assayers
Chemists
Metallurgists
Spectrographers
Soils and Foundations
Consulting · Testing · Inspecting

File No. 1732.1
Lab. No. 46938

May 19, 1960

Mr. W. L. Warren
Assistant Chief Engineer
The California Oregon Power Company
216 West Main Street
Medford, Oregon

Re: Iron Gate Dam
Soil Samples

Dear Sir:

Enclosed are the findings from tests performed on soil samples marked Hole No. 11.

Very truly yours,

ABBOT A. HANKS, INC.

Donald W Radbruch

Donald W. Radbruch

hms
Encls.
Reports to:
3-The California Oregon Power Company

Iron Gate Dam
Klamath River
Rile No. 1732.1

Abbot A.H anks, Inc.
Lab. No. 46938
May 19, 1960

TEST RESULTS

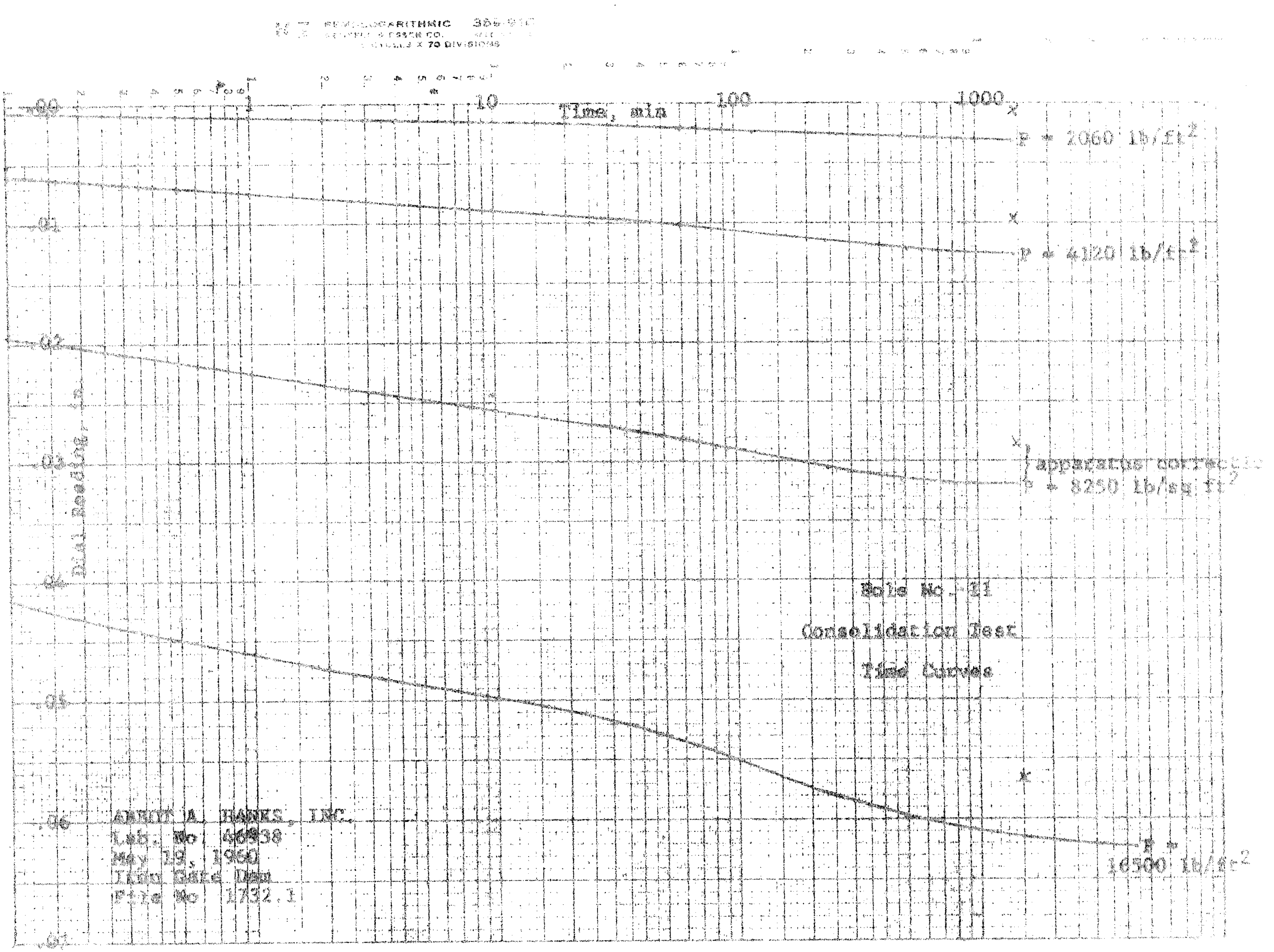
Hole No. 11
Specific Gravity: 2.75

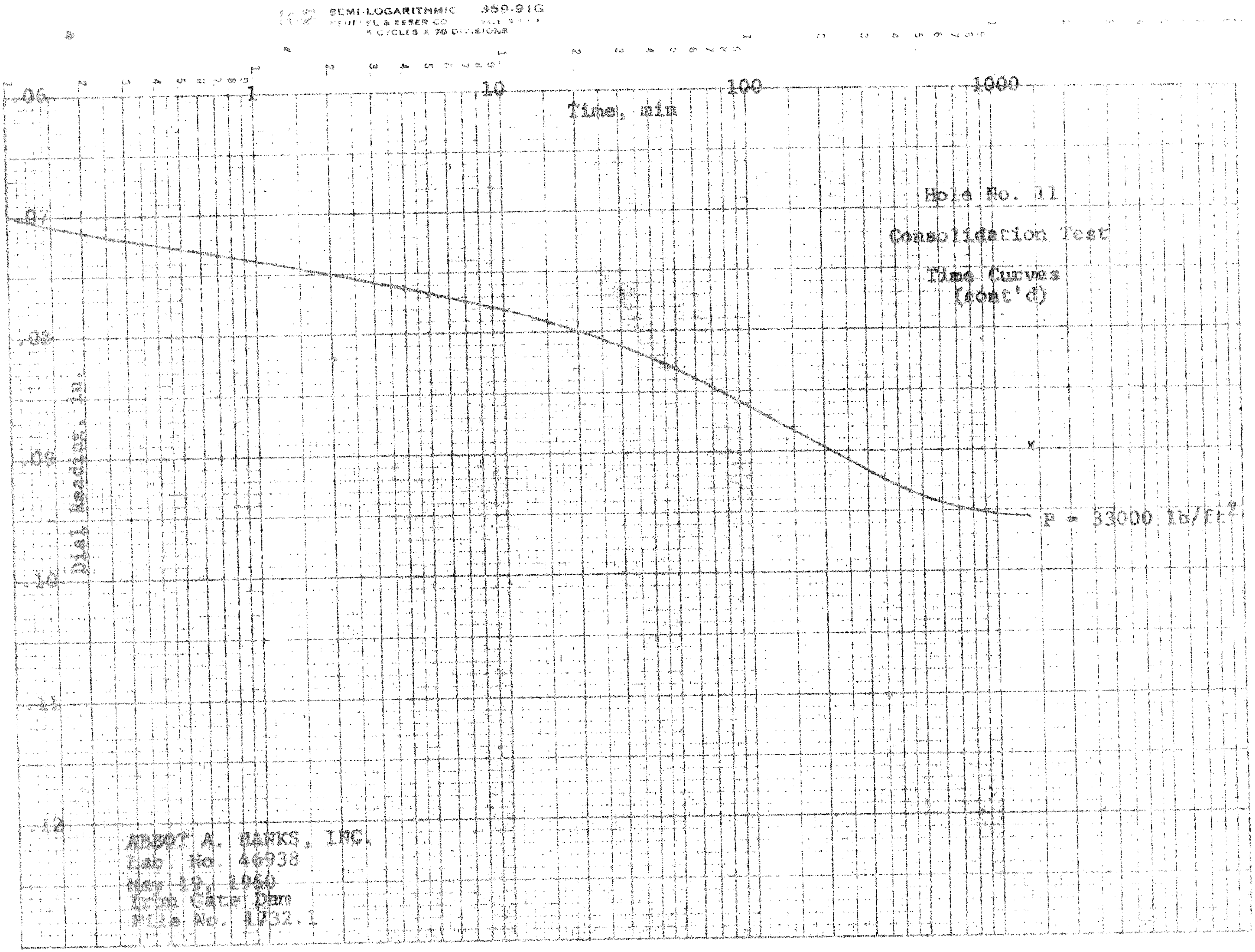
Triaxial Shear Test

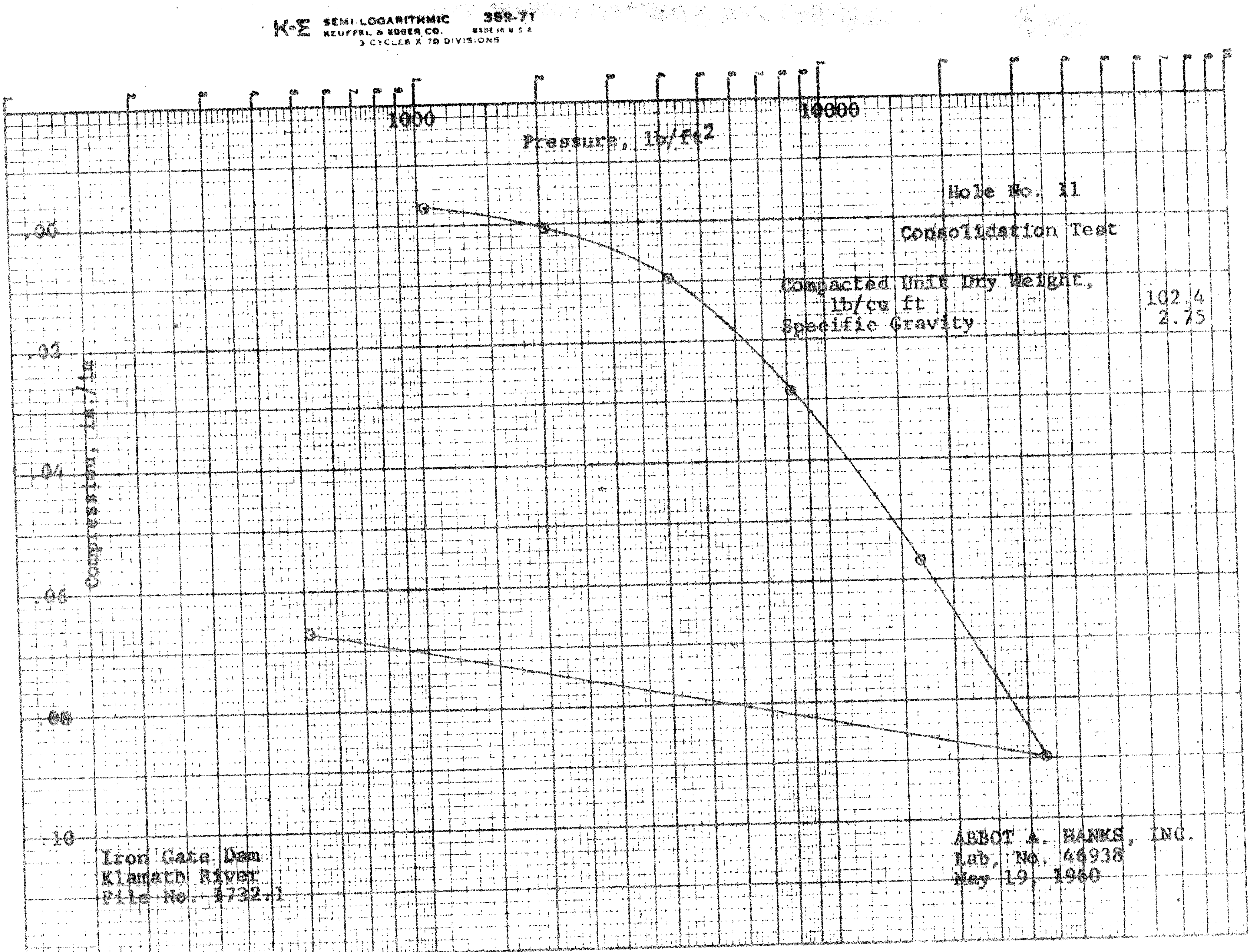
	Sample A	Sample B	Sample C
Chamber Pressure, psi	15	50	80
Unit Dry Weight at Compaction, lb/ft^3	101.5	101.7	102.1
Moisture Content at Compaction, %	22.2	21.7	22.0
Unit Dry Weight at Test, lb/ft^3	102.3	105.1	107.6
Moisture Content at Test, lb/ft^3	25.0	22.9	21.7
Degree of Saturation at Test, %	100	100	100
Maximum Deviator Stress, psi	21	55	73
Pore Pressure at Max. Deviator Stress, psi	5	7	22

Permeability Test
(Constant Head Test)

Dry Density at Compaction, lb/ft^3	101.0
Moisture Content at Compaction, %	22.4
Permeability Coefficient, ft per yr	Less than .01
" " , cm/sec	Less than 10^{-8}


SEMI-LOGARITHMIC 359-91C
KEUFFEL & ESSER CO.
5 CYCLES X 70 DIVISIONS
Time, min
1
10
100
1000
Dial Reading, in
.00
.01
.02
.03
.04
.05
.06
.07
P = 2060 lb/ft^2
P = 4120 lb/ft^2
apparatus correct
P = 8250 lb/sq ft^2
P = 16500 lb/ft^2
Hole No. 21
Consolidation Test
Time Curves
ABBOTT A. HANKS, INC.
Lab. No
May 19, 1960
File No 1732.1

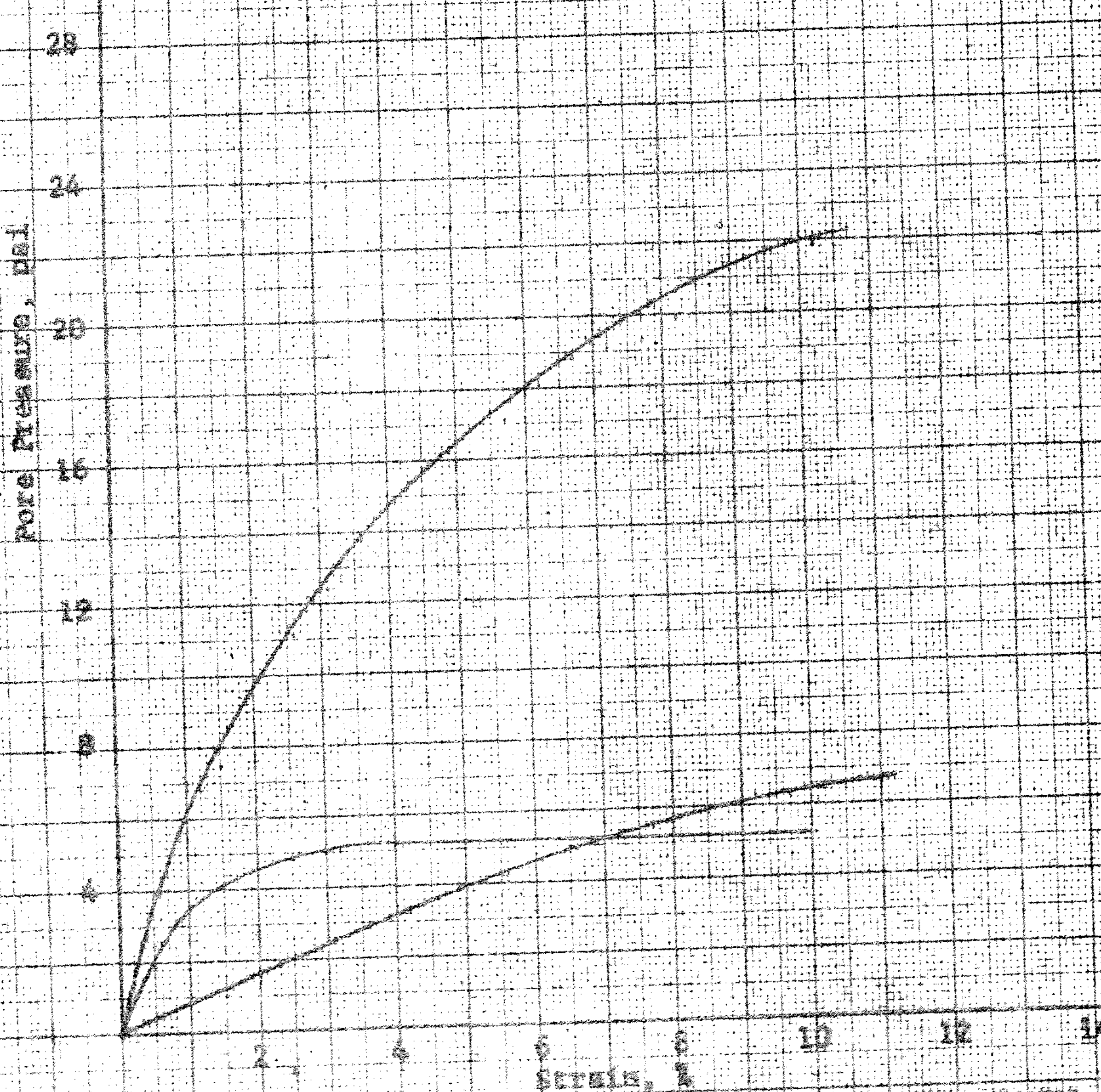

SEMI-LOGARITHMIC 359-91G
KEUFFEL & ESSER CO.
5 CYCLES X 70 DIVISIONS
Time, min
1
10
100
1000
Dial Reading, in.
.06
.07
.08
.09
.10
.11
.12
Hole No. 11
Consolidation Test
Time Curves
(cont'd)
P = 33000 lb/Ft²
ABBOT A. HANKS, INC.
Lab. No. 46938
File No. 1732.1


K+E SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
1000
10000
Pressure, lb/ft2
Compression, in./in.
.00
.02
.04
.06
.08
.10
Hole No. 11
Consolidation Test
Compacted Unit Dry Weight, lb/cu ft 102.4
Specific Gravity 2.75
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
May 19, 1960

Hole No. 11

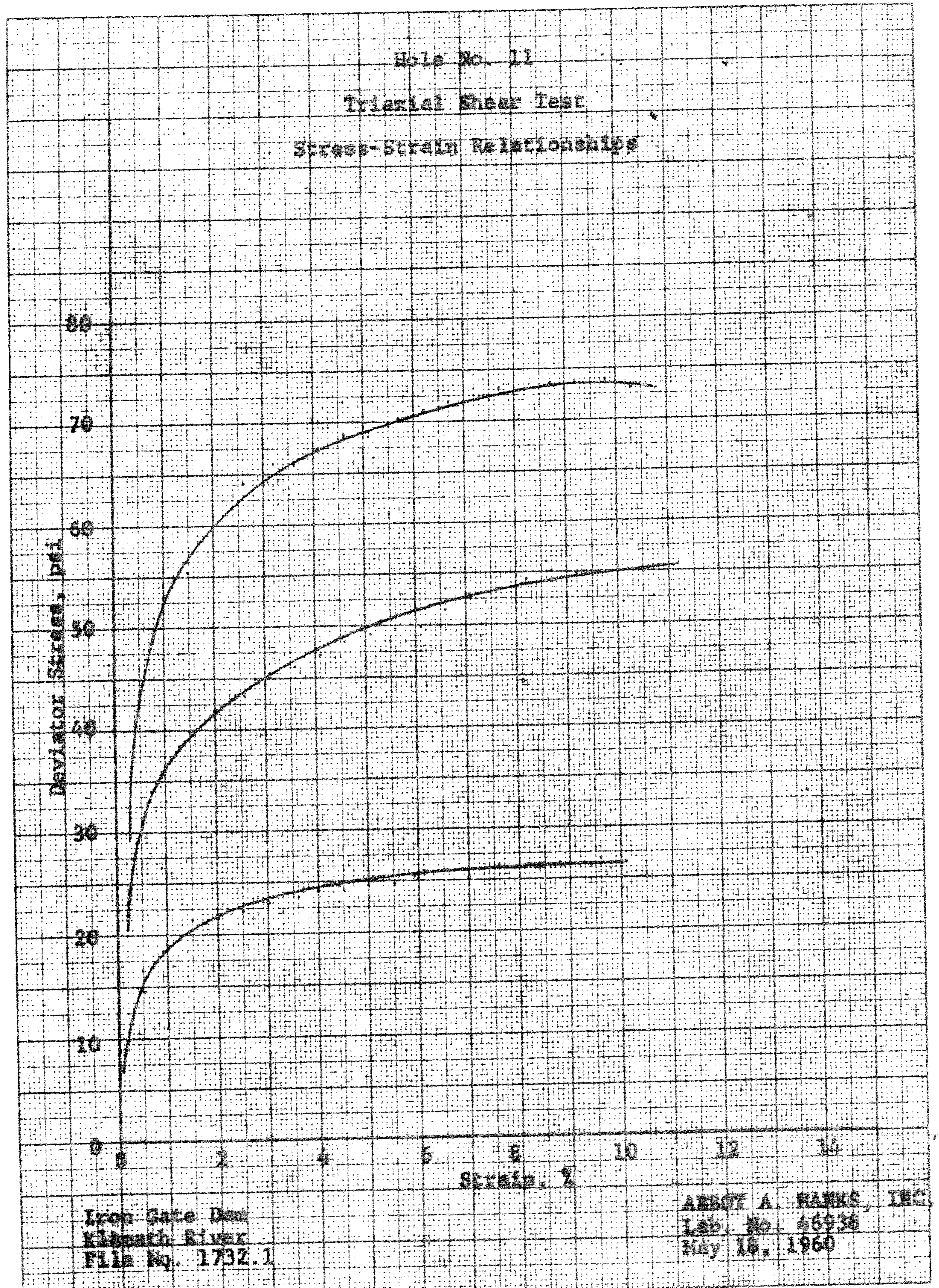
Triaxial Shear Test

Pore Pressure-Strain Relationships

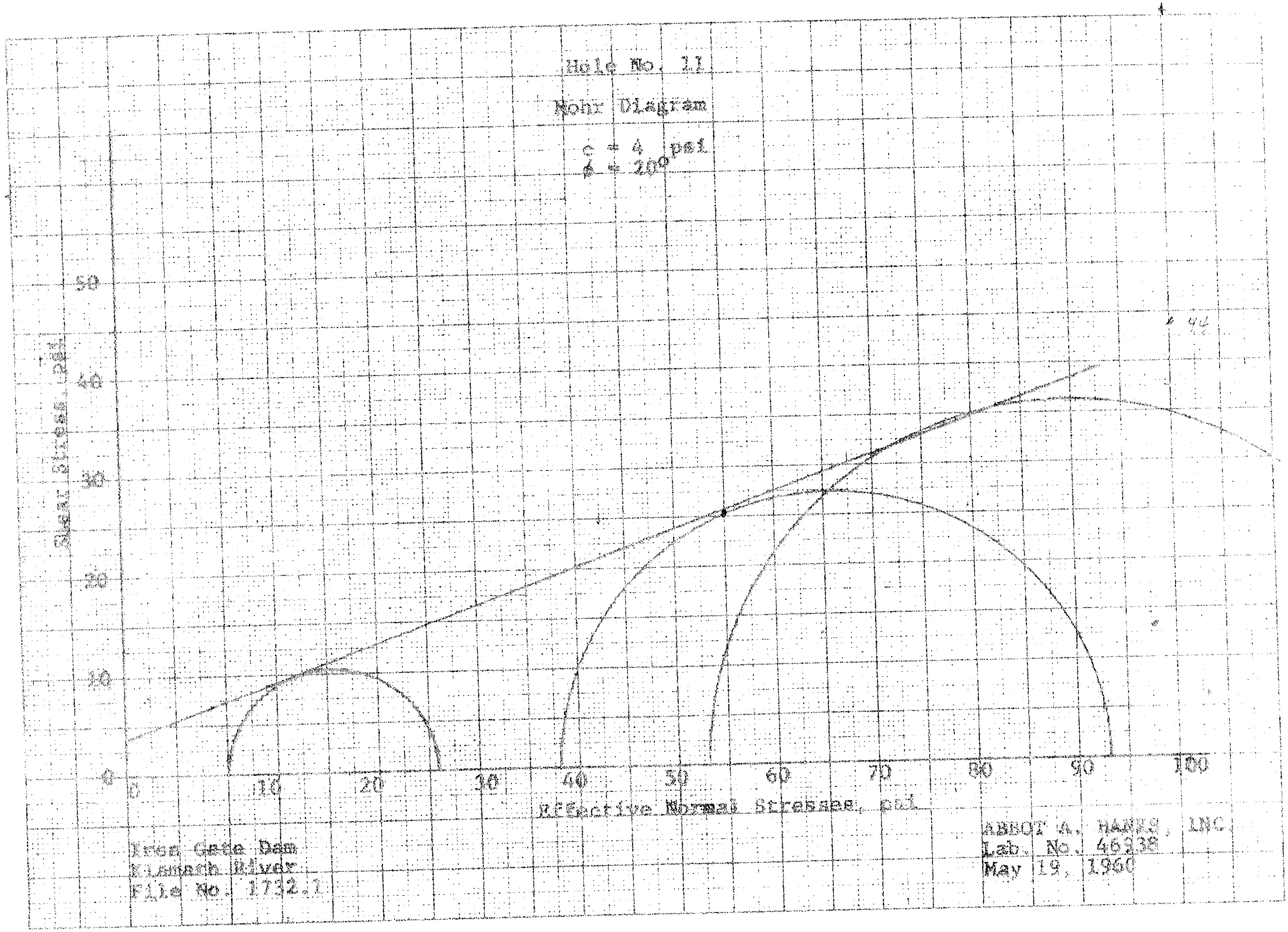


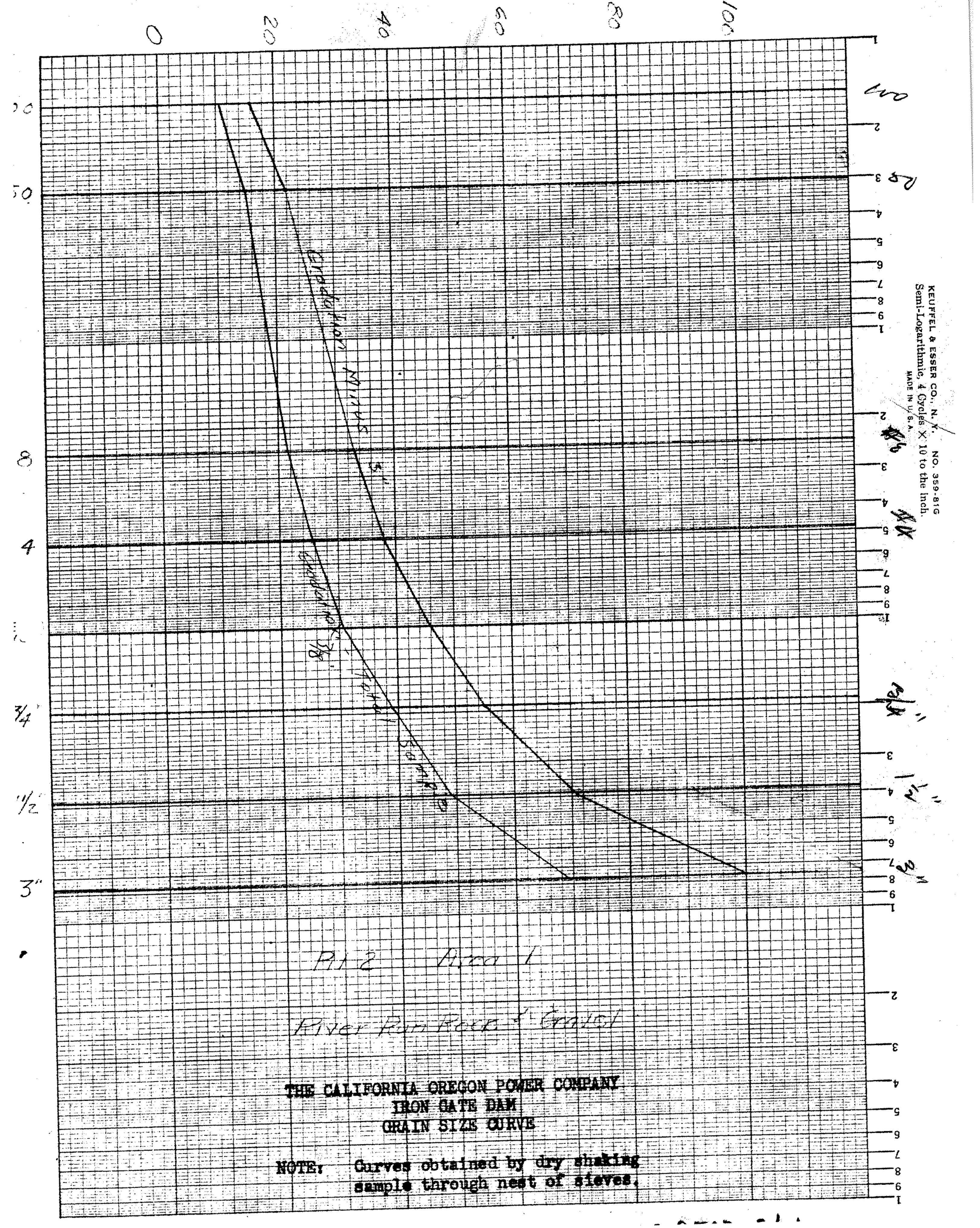
Iron Gate Dam
Klamath River
File No. 1732.1

ABBOT A. HANKS, INC.
Lab. No. 46936
May 19, 1960


Hole No. 11
Triaxial Shear Test
Stress-Strain Relationships
Deviator Stress, psi
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
12
14
Strain, %
Iron Gate Dam
Klamath River
File No. 1732.1
ABBOT A. HANKS, INC.
Lab. No. 46938
May 18, 1960

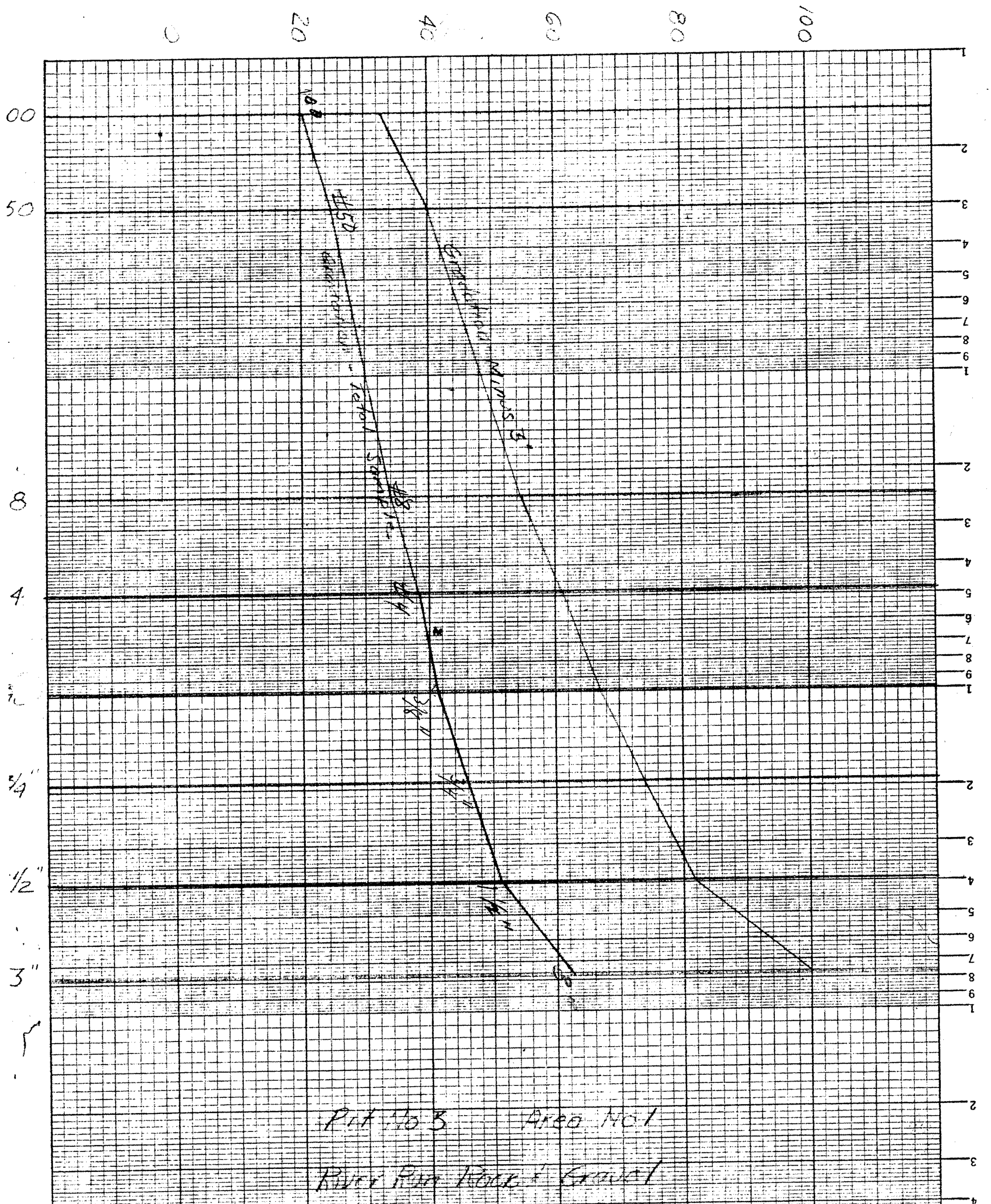
K&E 10 X 10 TO THE CM. 359-14G
KEUFFEL & ESSER CO.





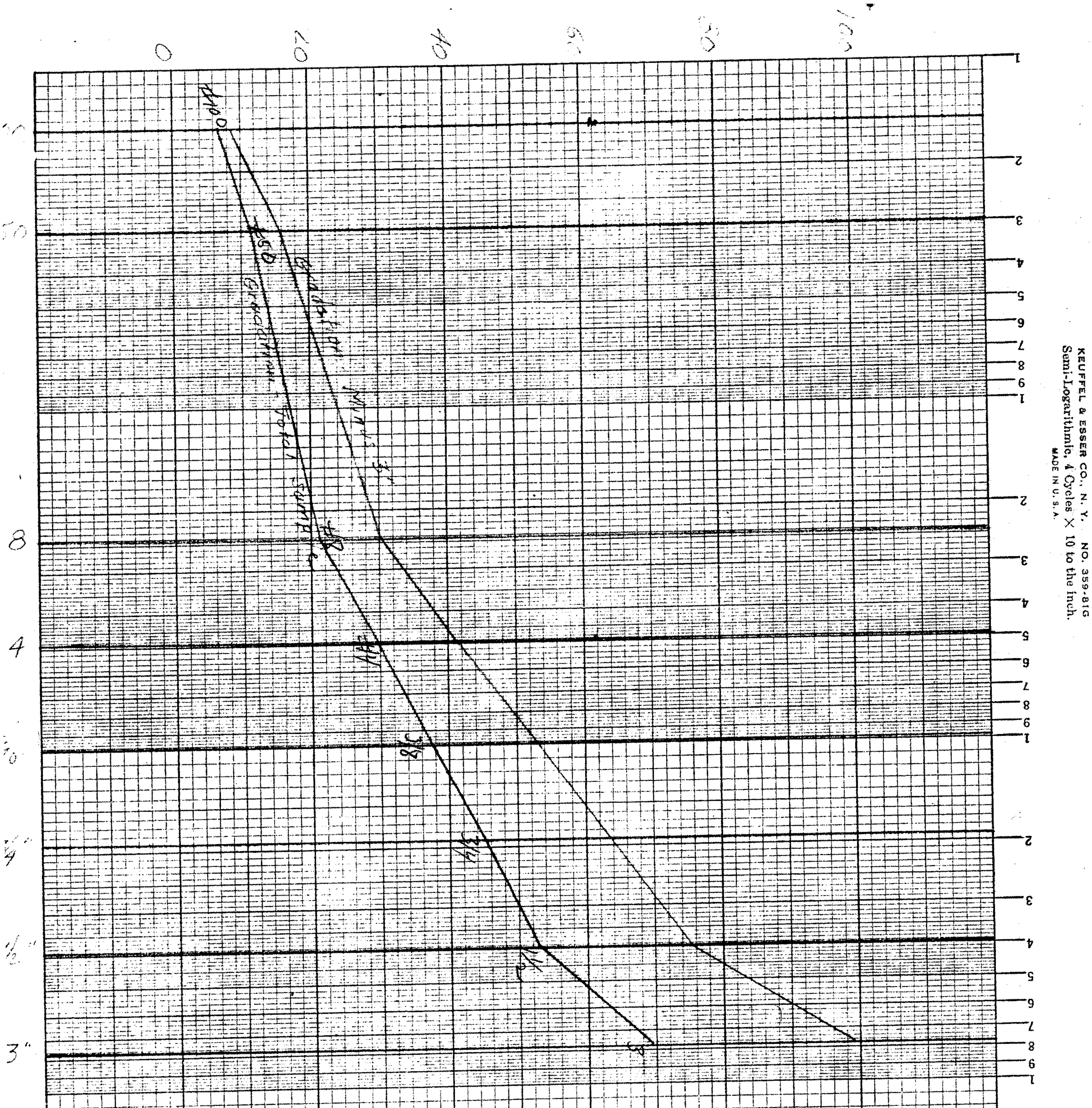
THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE: Curves obtained by dry shaking sample through nest of sieves.



THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

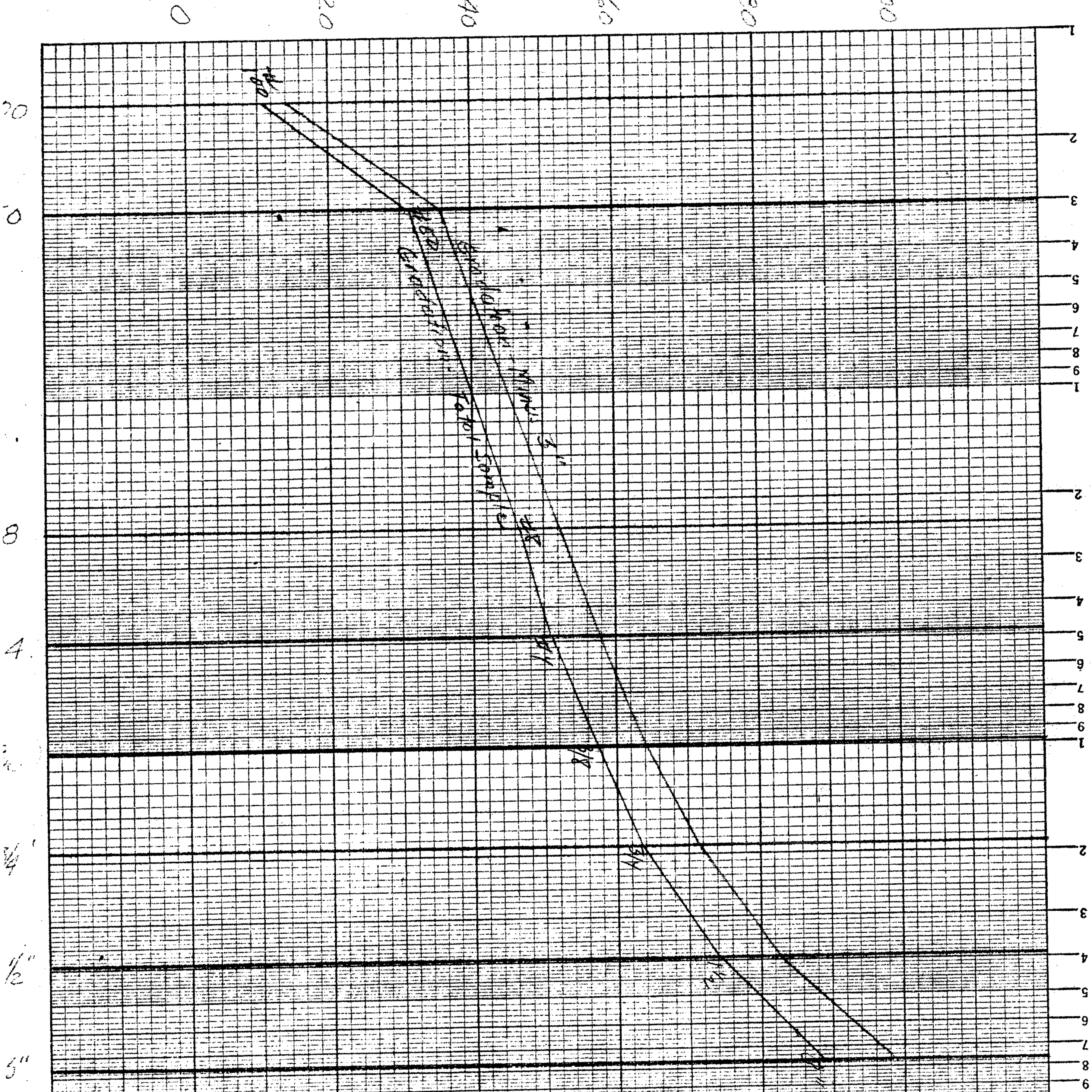
NOTE: Curves obtained by dry shaking sample through nest of sieves.



Pit No 2 Area 5

THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE; Curves obtained by dry shaking sample through nest of sieves.

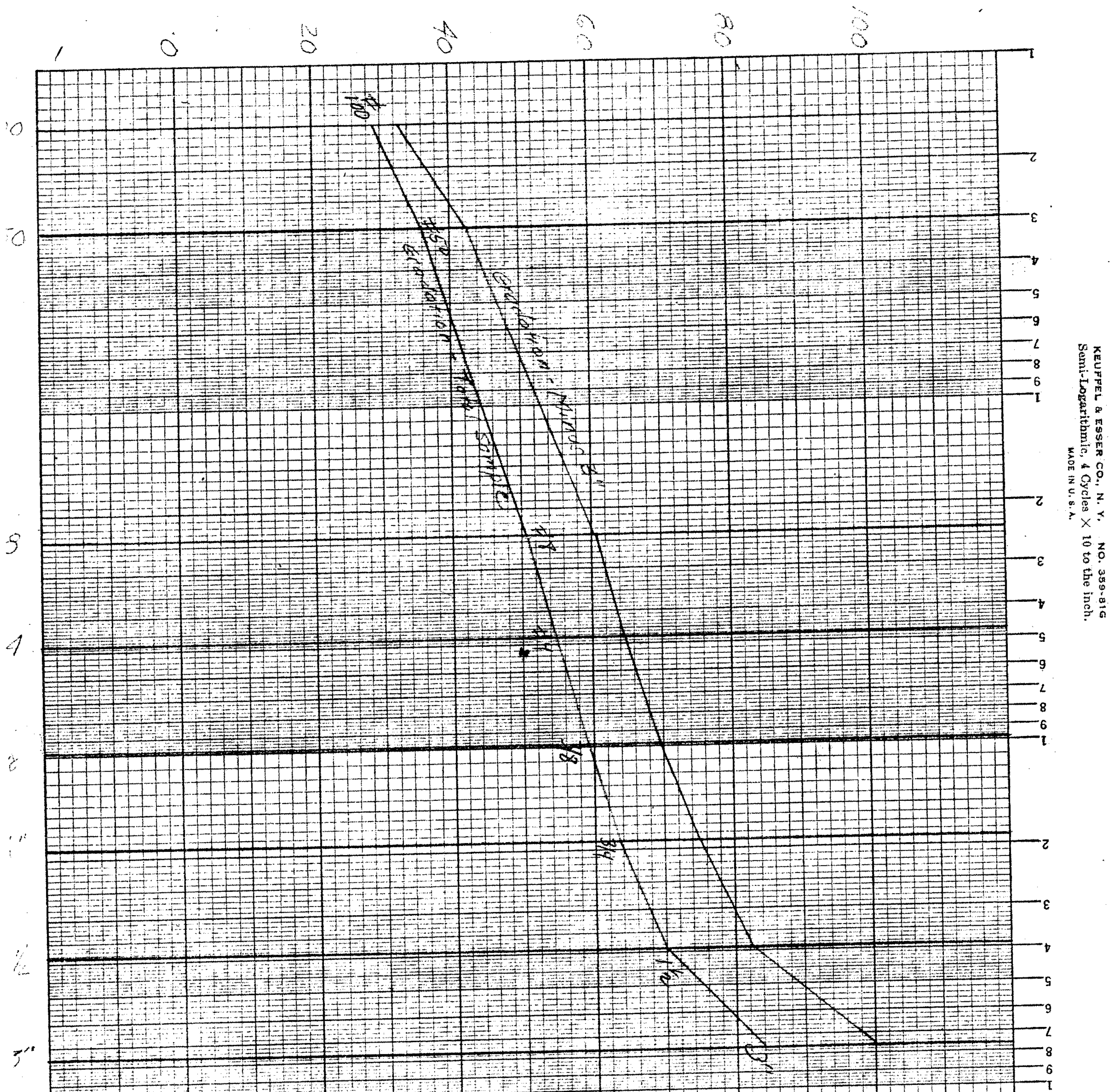


Pit No 3 Area 5

River Run Bank's Gravel

THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE: Curves obtained by dry shaking sample through nest of sieves.



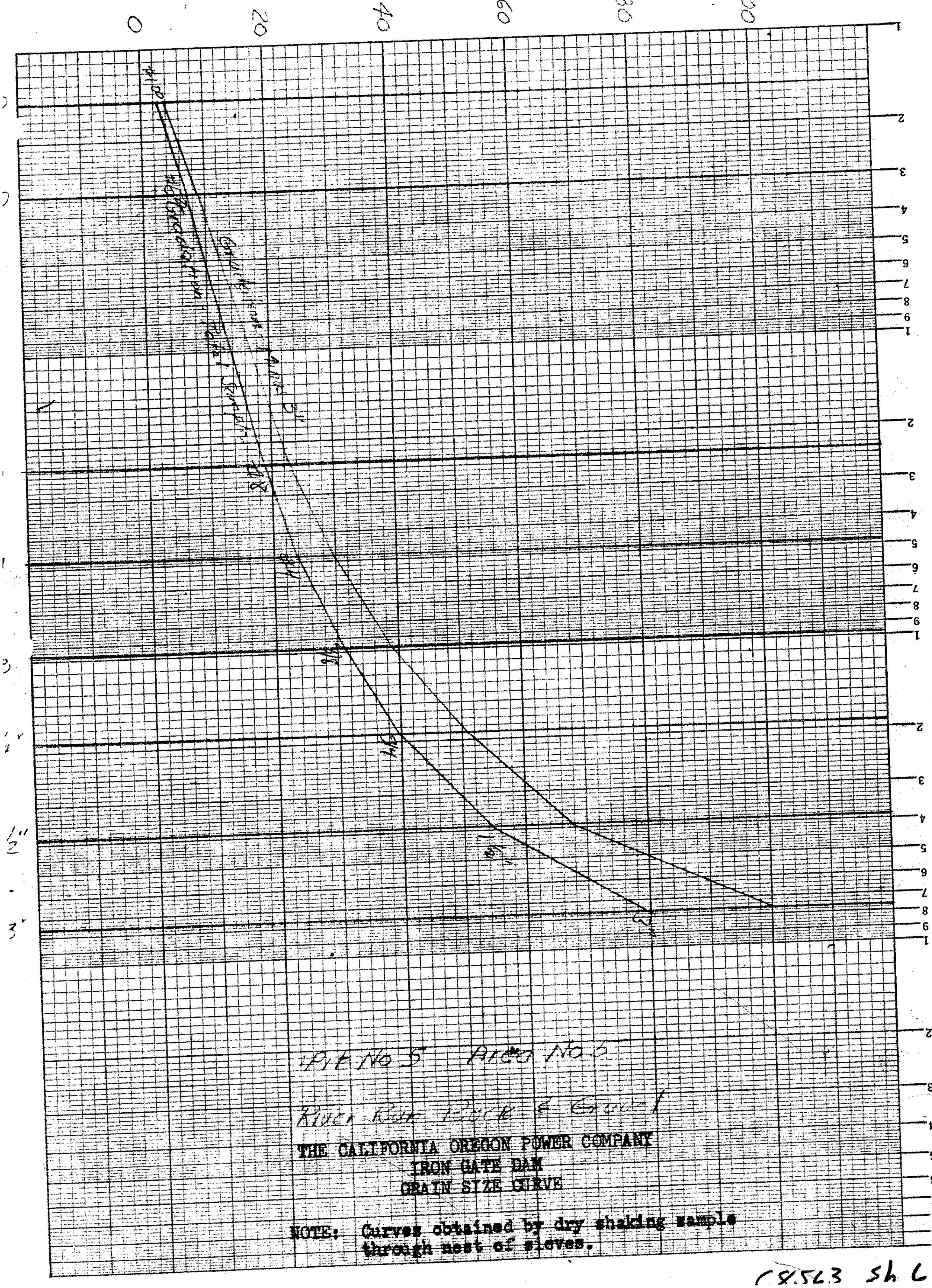
Pit No 4 Area 5

River Run Rock & Gravel

THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE: Curves obtained by dry shaking sample through nest of sieves.

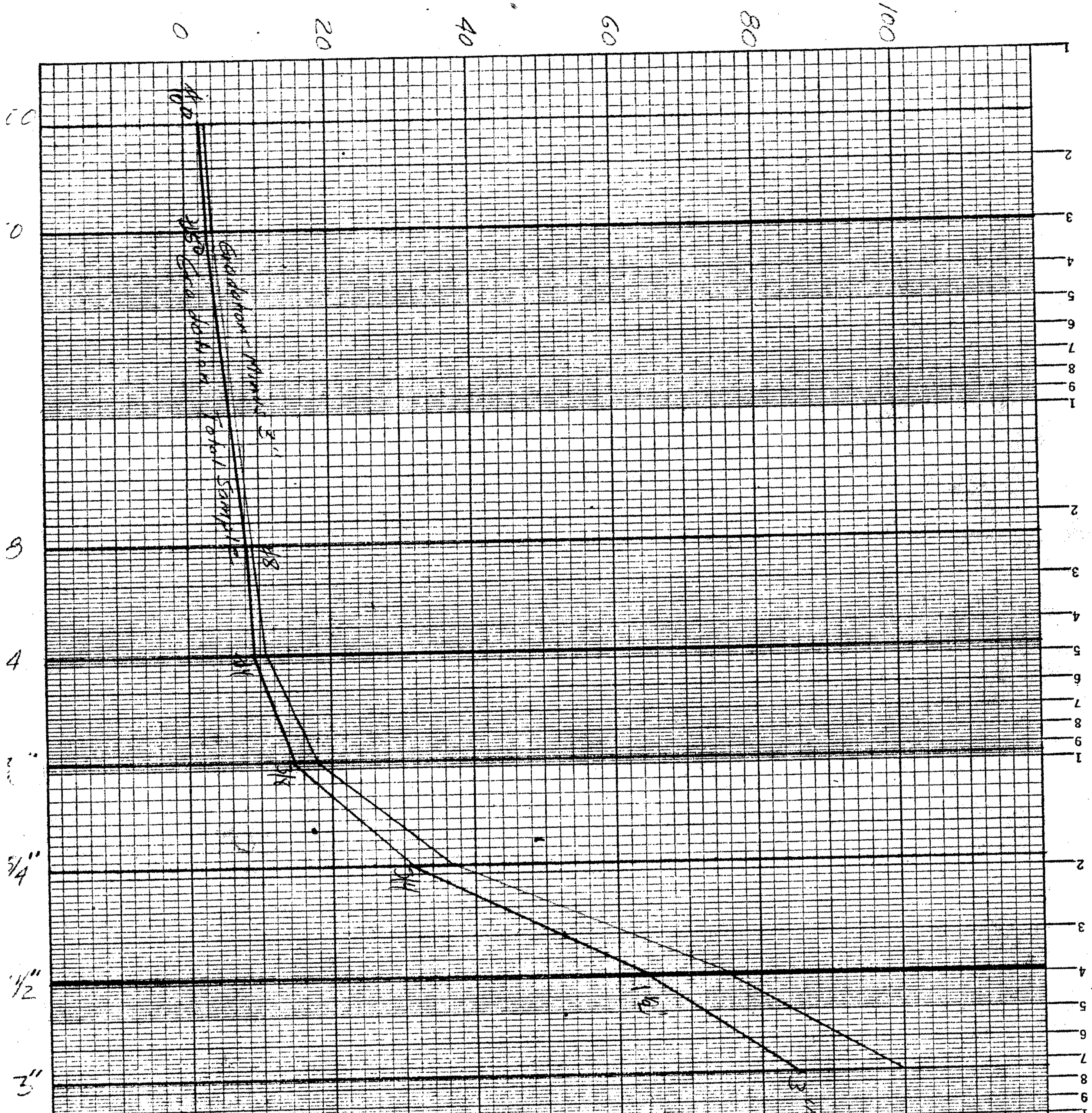
C 9563 545



THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE: Curves obtained by dry shaking sample through nest of sieves.

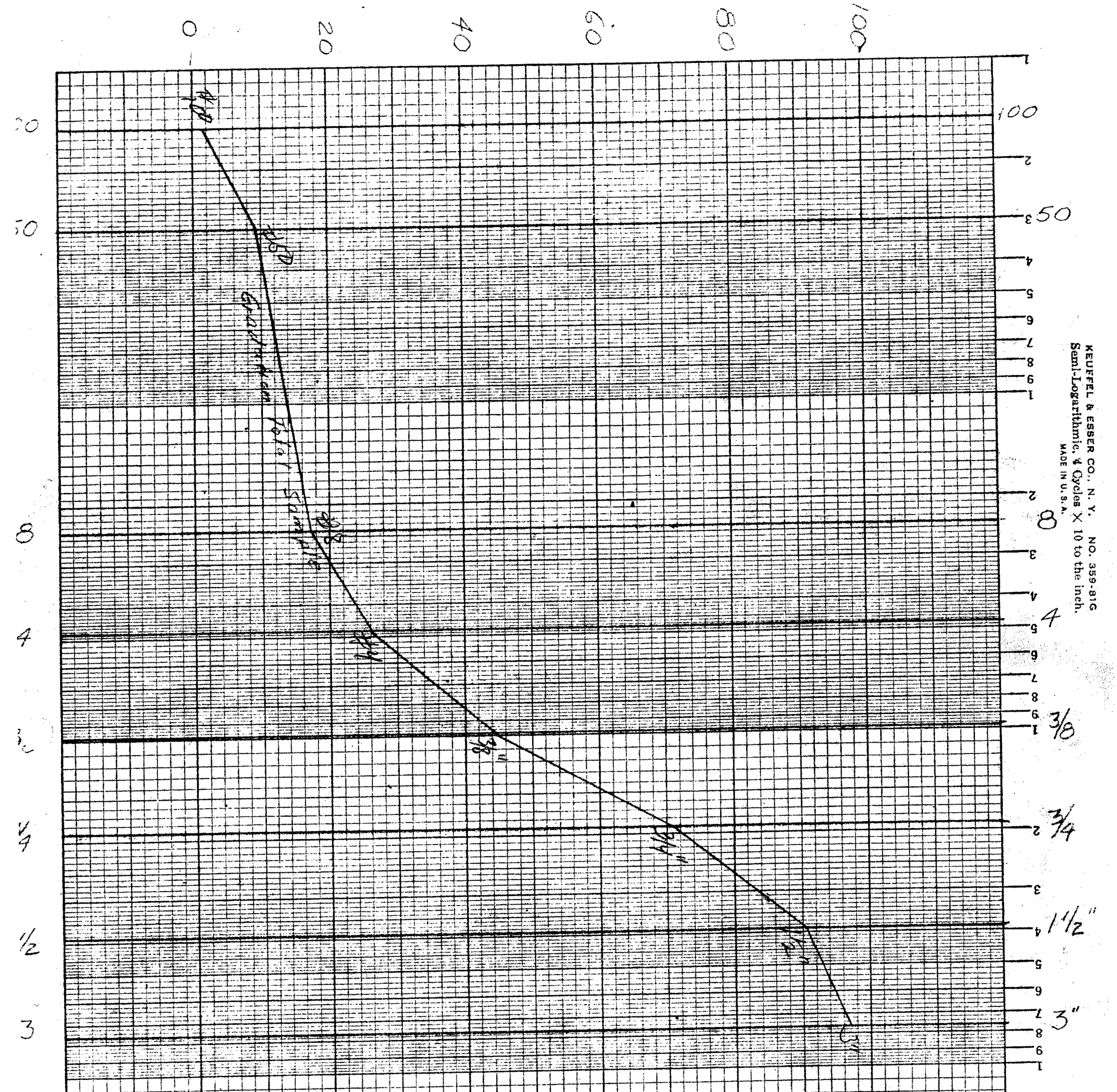
C8.563 Sh 6



Pit 1 Dodson Area
Basaltic Talus

THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

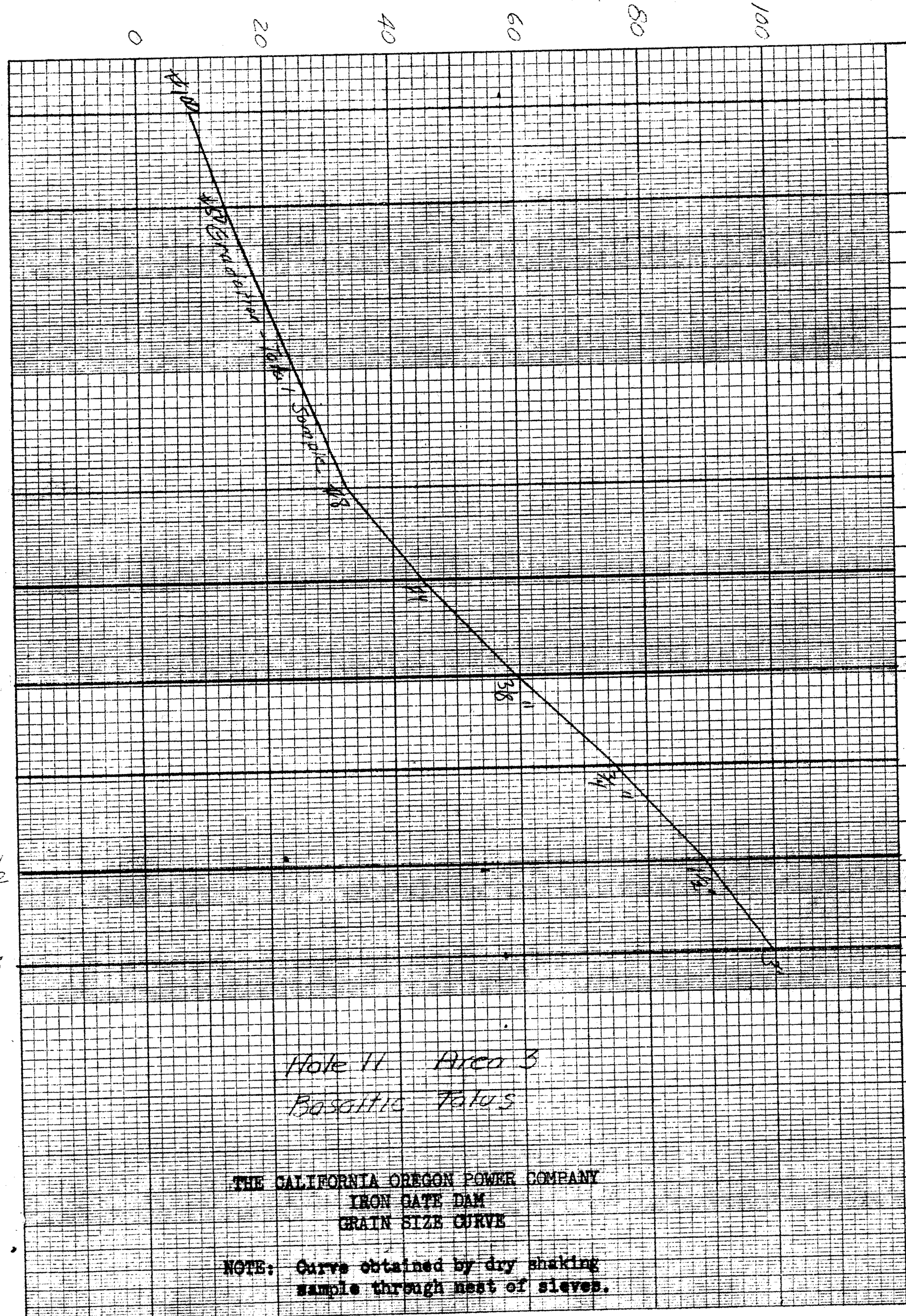
NOTE: Curves obtained by dry shaking sample through nest of sieves.



Hole No 9 Area No 3
Basaltic Talus

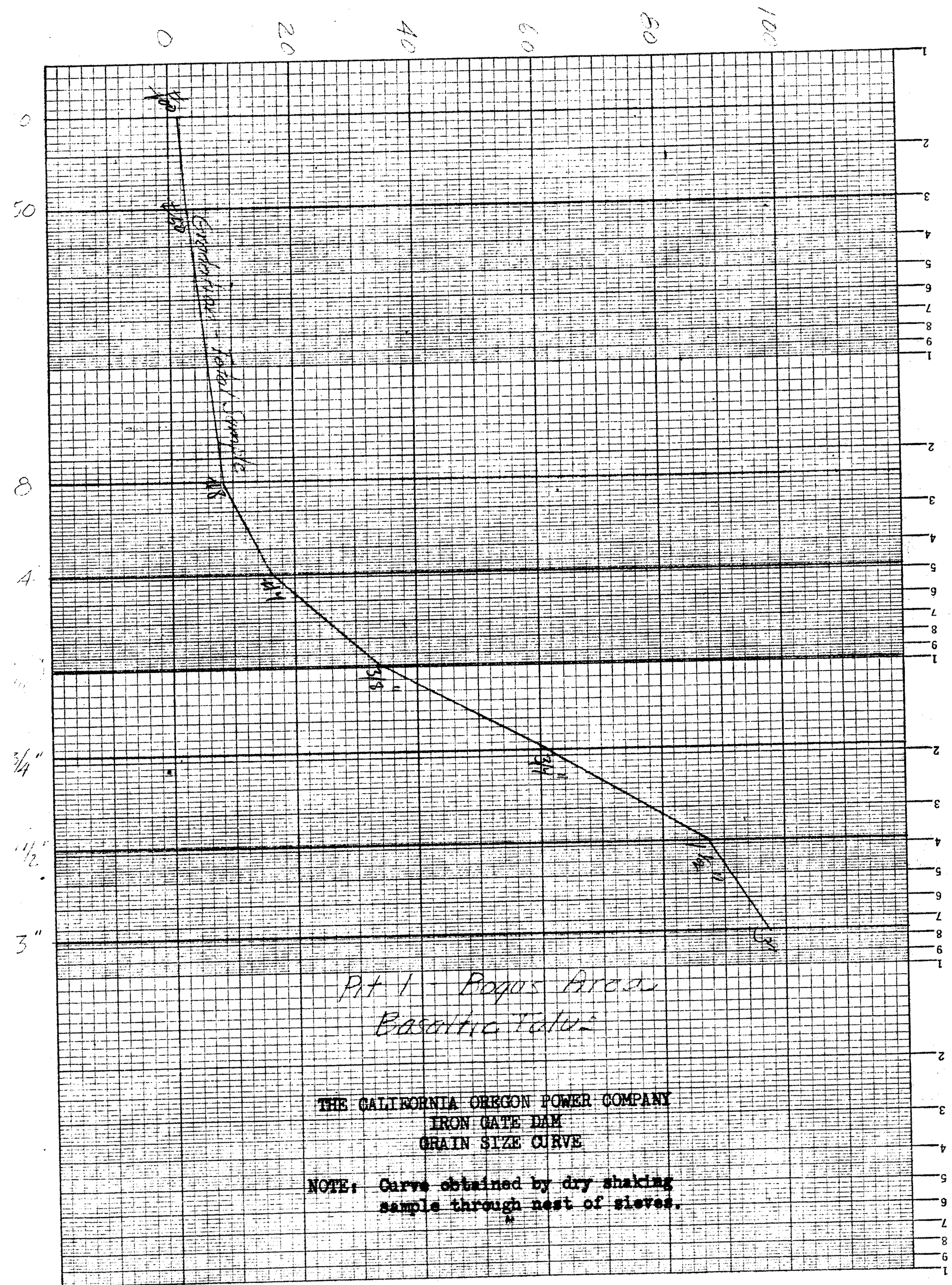
THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE: Curve obtained by dry shaking sample through nest of sieves.



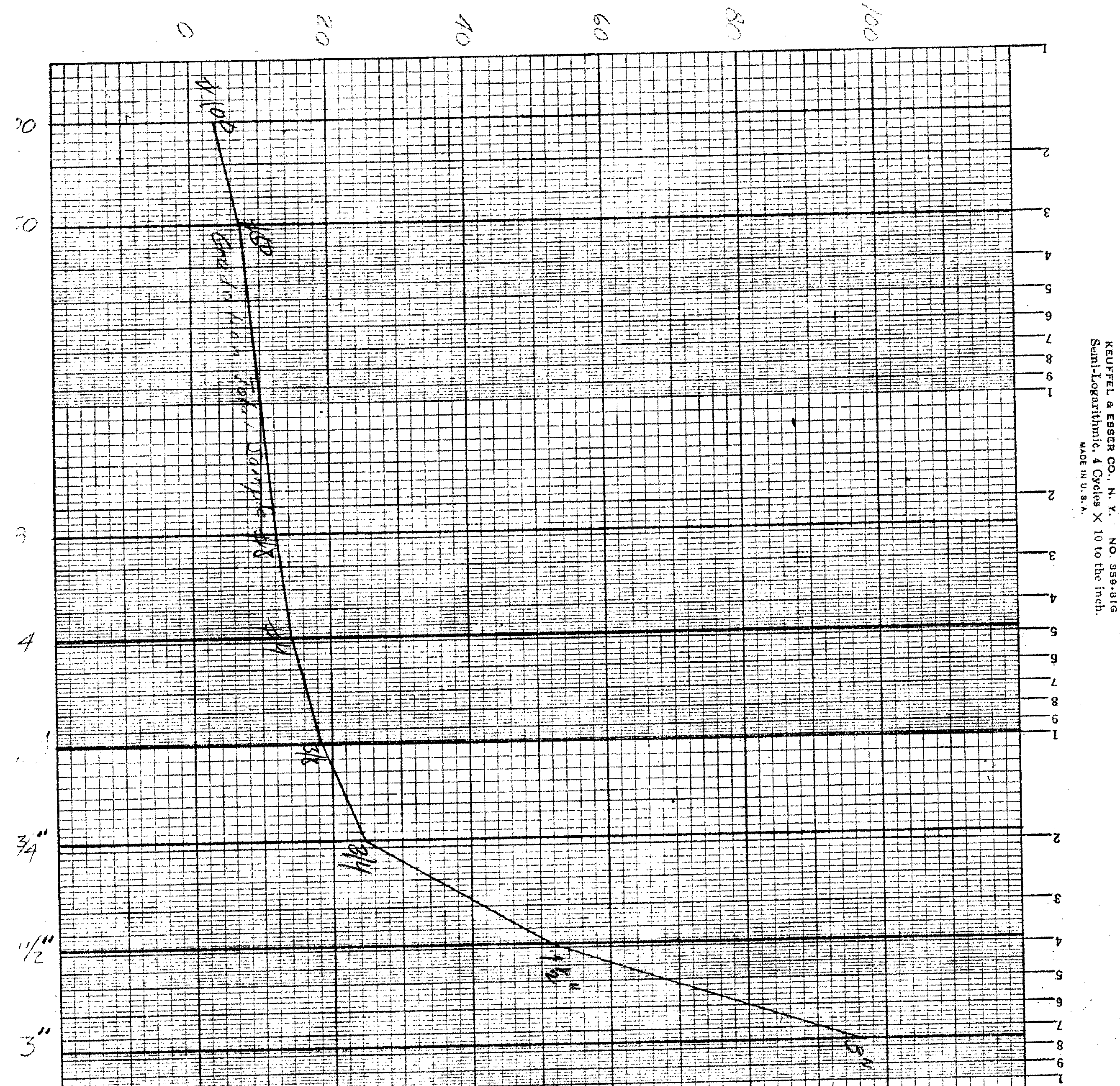
THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE: Curve obtained by dry shaking sample through nest of sieves.



THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE: Curve obtained by dry shaking sample through nest of sieves.

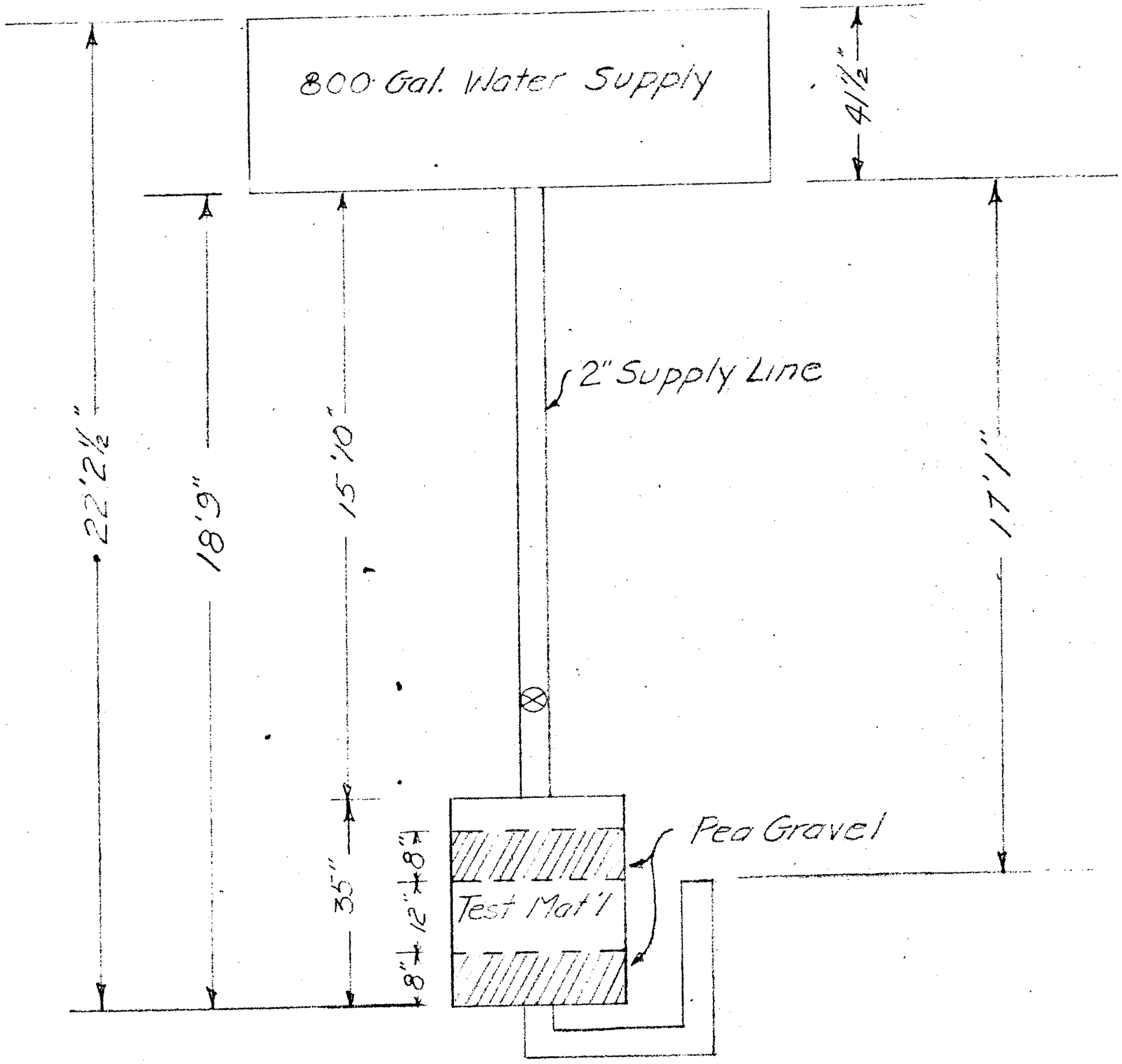


Pit 1 Summit Area

Basalt Talus

THE CALIFORNIA OREGON POWER COMPANY
IRON GATE DAM
GRAIN SIZE CURVE

NOTE: Curves obtained by dry shaking sample through nest of sieves.



Permeability Test Method
No Scale
Iron Gate Project

DRAWN BY
TRACED BY
CHECKED BY
APPROVED BY
SCALE
DATE 7-20-60

SEC. | TWP. | RANGE
SCHOOL DIST. | ROAD DIST.

THE CALIFORNIA OREGON POWER COMPANY

J. O.
J. O. REQ.
MAP NO.
AREA
RURAL ☐ URBAN ☐
C 8560

BRANCH LABORATORY 1086 MARTIN AVENUE • SANTA CLARA • CHERRY 8-5262 CABLE HANX
BRANCH OFFICE 61 JORDAN STREET • SAN RAFAEL • GLENWOOD 4-8650

ABBOT A. HANKS, INC.
ESTABLISHED 1866
1300 SANSOME STREET • SAN FRANCISCO 11, CALIFORNIA • EXBROOK 7-2464

Engineers
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Spectrographers
Soils and Foundations
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File No. 1732.2
Lab. No. 52348

August 8, 1961

The California Oregon Power Company
Iron Gate Project
Post Office Box 201
Hornbrook, California

Re: Iron Gate Dam - P. O. #39636
Soil Tests, Sample 16+00 300' L

Gentlemen:

Based on tests of four specimens compacted in the range of 81 to 82 lb per cu ft, it appears that the intergranular strength factors of the above sample in a consolidated shear test with pore pressures measured are as follows:

Friction angle	11½ - 15½ degrees
Cohesion	450 - 800 lb/sq ft.

This soil is a highly plastic, impervious clay. Consolidation was extremely slow, requiring 10 days to complete the consolidation and saturation of each 2 in. diameter by 4 in. length specimen. An extremely long seasoning period was also necessary to attain uniformity of moisture content prior to compaction of specimens at the specified moisture content.

We are proceeding with tests of Sample 12+00 400' L, and will submit details of all tests upon completion.

Very truly yours,

ABBOT A. HANKS, INC.

L. O. Long

L. O. Long

LOL:hms
Reports to:
3-Iron Gate Project, Hornbrook, Calif.
1-The California Oregon Power Company, Medford, Ore.

BRANCH LABORATORY: 1086 MARTIN AVENUE • SANTA CLARA • CHERRY 8-5262
BRANCH OFFICE: 61 JORDAN STREET • SAN RAFAEL • GLENWOOD 4-8650

CABLE: HANX

ABBOT A. HANKS, INC.
ESTABLISHED 1866

1300 SANSOME STREET • SAN FRANCISCO 11, CALIFORNIA • EXBROOK 7-2464

Engineers
Assayers
Chemists
Metallurgists
Spectrographers
Soils and Foundations
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File No. 1732.2
Lab. No. 52348, 52871

October 20, 1961

Mr. M. L. Warren
Assistant Chief Engineer
The California Oregon Power Co.
216 Main Street
Medford, Oregon

Re: Iron Gate Project Samples

Dear Mr. Warren:

Attached are the findings from triaxial shear tests performed on soil samples marked "12+00, 400'L", and "16+00, 300'L".. The triaxial tests were performed in the same manner as described in our letter of June 29, 1960.

Complete saturation was not attained in the tests because, when confined under the higher lateral pressures, the specimens were virtually impermeable, and complete saturation could not be attained even by application of a high vacuum on the top of the specimens and a small positive pressure on the base.

You will note that we did not submit data for a specimen of sample 16+00, 300'L at 80 psi chamber pressure. The data for this specimen was not consistent with the remainder of the test data, and it appears likely that there was leakage of the membrane during the test. If you feel that a repetition

MM

of the test at 80 psi would serve a useful purpose, we should be pleased to repeat the test.

We should be pleased to discuss any questions in connection with these tests.

Very truly yours,

ABBOT A. HANKS, INC.

L. O. Long

L. O. Long

LOL:hms
Encls.
Reports to:
3-The California Oregon Power Co.

Iron Gate Project
The California Oregon Power Company
File No. 1732.2

Abbot A.Hanks, Inc.
Lab. No. 52348
October 17, 1961

TABLE NO. I

Sample: 16 + 00 300'L.
Soil Type: Dark yellow-brown clay.

Sample	A	B	C	D
Chamber Pressure, psi	15.5	15	50	50
Unit Dry Weight at Compaction, lb/ft^3	81.3	81.2	82.7	82.5
Moisture Content at Compaction, %	25.0	24.6	24.2	23.7
Unit Dry Weight at Test, lb/ft^3	76.8	74.7	84.7	84.7
Moisture Content at Test, %	42.3	36.8	--	35.3
Degree of Saturation at Test, %	94	80	--	97
Maximum Deviator Stress, psi	15	18	43	35
Pore Pressure at Maximum Deviator Stress, psi	6	4	1	2

Iron Gate Project
The California Oregon Power Company
File No. 1732.2

Abbot A. Hanks, Inc.
Lab. No. 52871
October 17, 1961

TABLE NO. II

Sample: 12 + 00, 400'L.
Soil Type: Very dusky red clay.

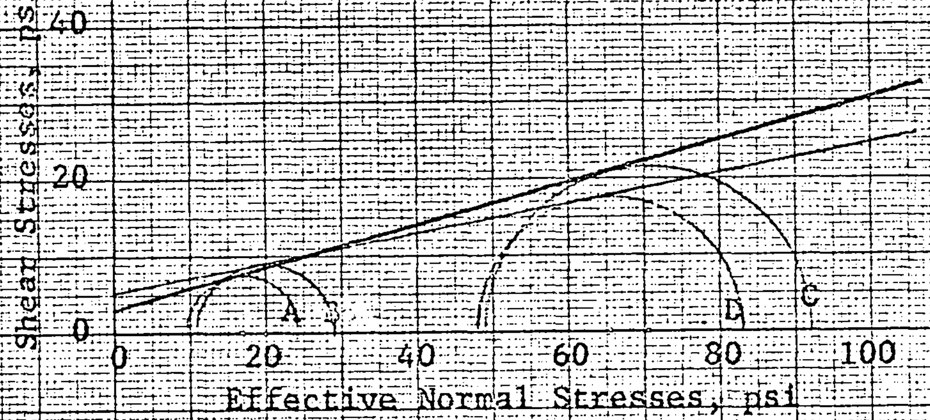
Sample	A	B	C
Chamber Pressure, psi	15	50	80
Unit Dry Weight at Compaction, lb/ft^3	88.6	86.7	86.9
Moisture Content at Compaction, %	24.5	23.5	24.5
Unit Dry Weight at Test, lb/ft^3	81.6	89.2	91.0
Moisture Content at Test, %	36.3	30.7	27.2
Degree of Saturation at Test, %	89	94	86
Maximum Deviator Stress, psi	16	48	81
Pore Pressure at Maximum Deviator Stress, psi	1	4	1

hms

Sample 16+00, 300'L

MOHR DIAGRAM

c = 3-5½ psi
ϕ = 11-15°



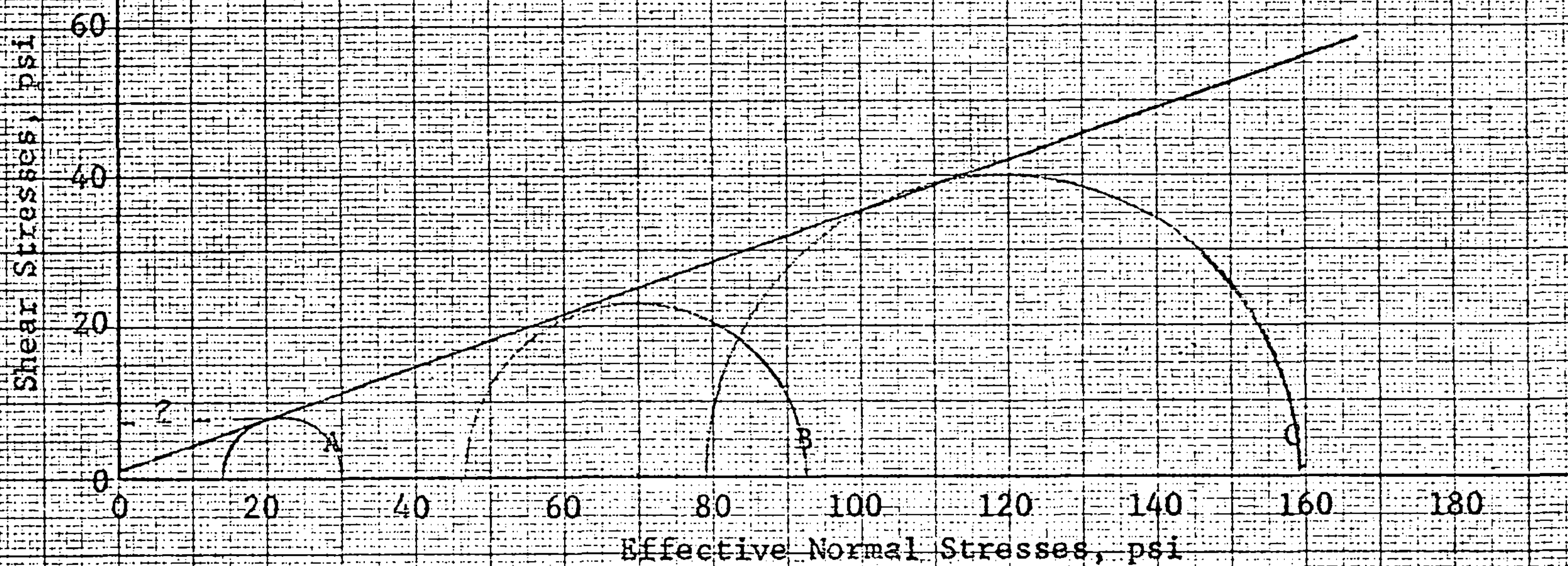
Iron Gate Dam
File No. 1732.2

ABBOT A. HANKS, INC.
Lab. No. 52348

Sample 12+00, 400'L

MOHR DIAGRAM

$c = 1$ psi
$\phi = 20^{\circ}$



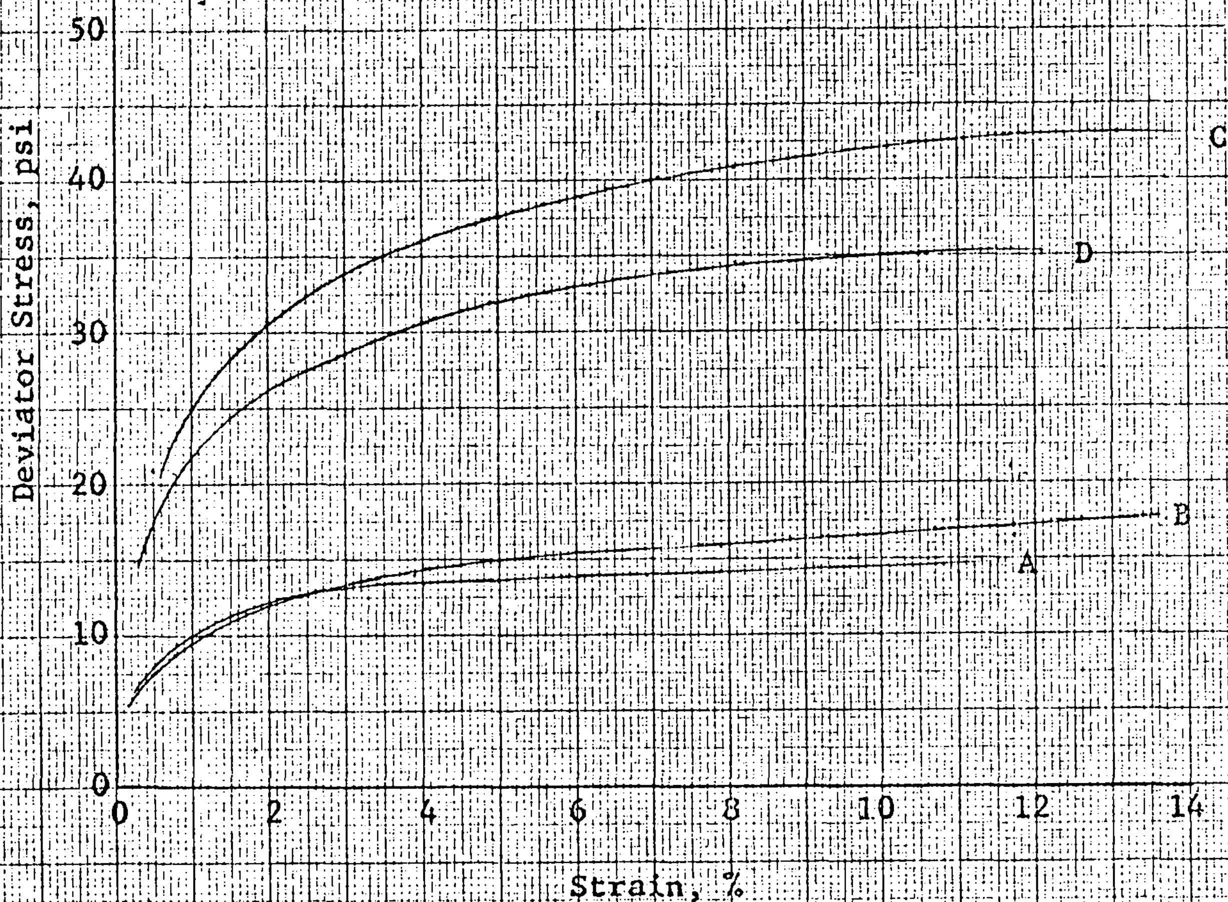
Iron Gate Dam
File No. 1732.2

ABBOT A. HANKS, INC.
Lab. No. 52871

Sample 16+00, 300'L

TRIAXIAL SHEAR TEST

Stress-Strain Relationships



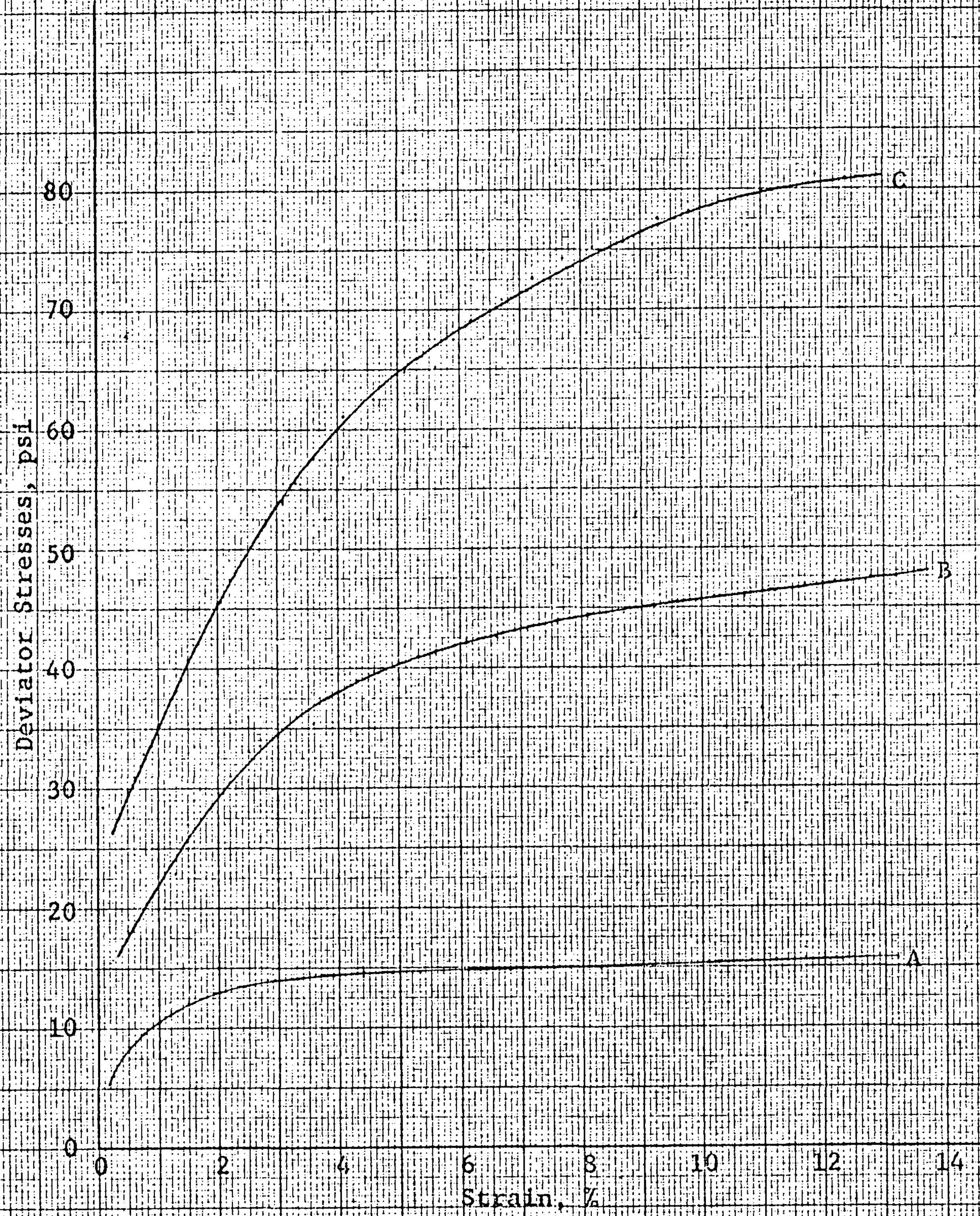
Iron Gate Dam
File No. 1732.2

ABBOT A. HANKS, INC.
Lab. No. 52348

Sample 12+00, 400'L

TRIAXIAL SHEAR TEST

Stress-Strain Relationships



Iron Gate Dam
File No. 1732.2

ABBOT A. HANKS, INC.
Lab. No. 52871

Attachment B Falling Head Permeability Tests

Undrained, consolidated triaxial shear tests with pore pressure measurements, consolidation tests, and constant head permeability tests were performed on representative samples of material for each hole by Abbot A. Hanks Laboratory in San Francisco. Before each test the material was compacted to near optimum moisture and maximum dry density. The results of these tests are shown in Abbot A. Hanks report as Plate IV. For convenient reference, the permeability coefficient, the angle of internal friction and cohesion for the material from each hole are tabulated below:

HOLE NO.	COHESION p.s.i.	psf	ANGLE OF INTERNAL FRICTION	PERMEABILITY FT/YEAR Less than	COEFFICIENT CM/SEC Less than
1.	9	1300	10°	.01	10-8
2.	6	860	17°	-	-
3.	10	1440	14°	.01	10-8
4.	4	580	30°	.01 - .04	1-4 x 10-8
7.	5	720	21°	.01	10-8
8.	3	430	16°	.01	10-8
11.	4	580	20°	.01	10-8
		844 psf	7) 128 (18° av.		

The quantities of the impervious materials available in Areas "A" and "5", are estimated to be 264,000 cubic yards. The quantities in Area "1" are estimated to be 57,000 dubic yards. However, most of Area "1" will be inundated by backwater from the construction of the cofferdam so, in order to utilize this material, it will be necessary that it be stockpiled, which does not seem practical.

2. Pervious Shell Materials

Two types of pervious materials were investigated:

A. Gravels in the flood plain of the river in Areas "1" and "5"

B. Talus deposits of basaltic rock in Area "3", Bogus Creek Area, Summit Area and Dodson Area.

Sample Area "1"	% Passing #100 Sieve	% Moisture	Dry Density Lbs/cu ft	Wet Density Lbs/cu ft	Permeability Coefficient Ft/Day
Pit 2, 1-14' Depth	15	8	119.5	129.2	11.1
Pit 3, 3-12' "	21	7	128.5	138.2	17.6
Area "5"					
Pit 2, 2-16' Depth	9	9	129.5	141.5	12.6
Pit 3, 2-12' "	14	9	137.5	151.0	.59
Pit 4, 4-20' "	33	11	105.0	118.0	8.94
Pit 5, 4-16' "	3	9	125.0	137.0	3.95

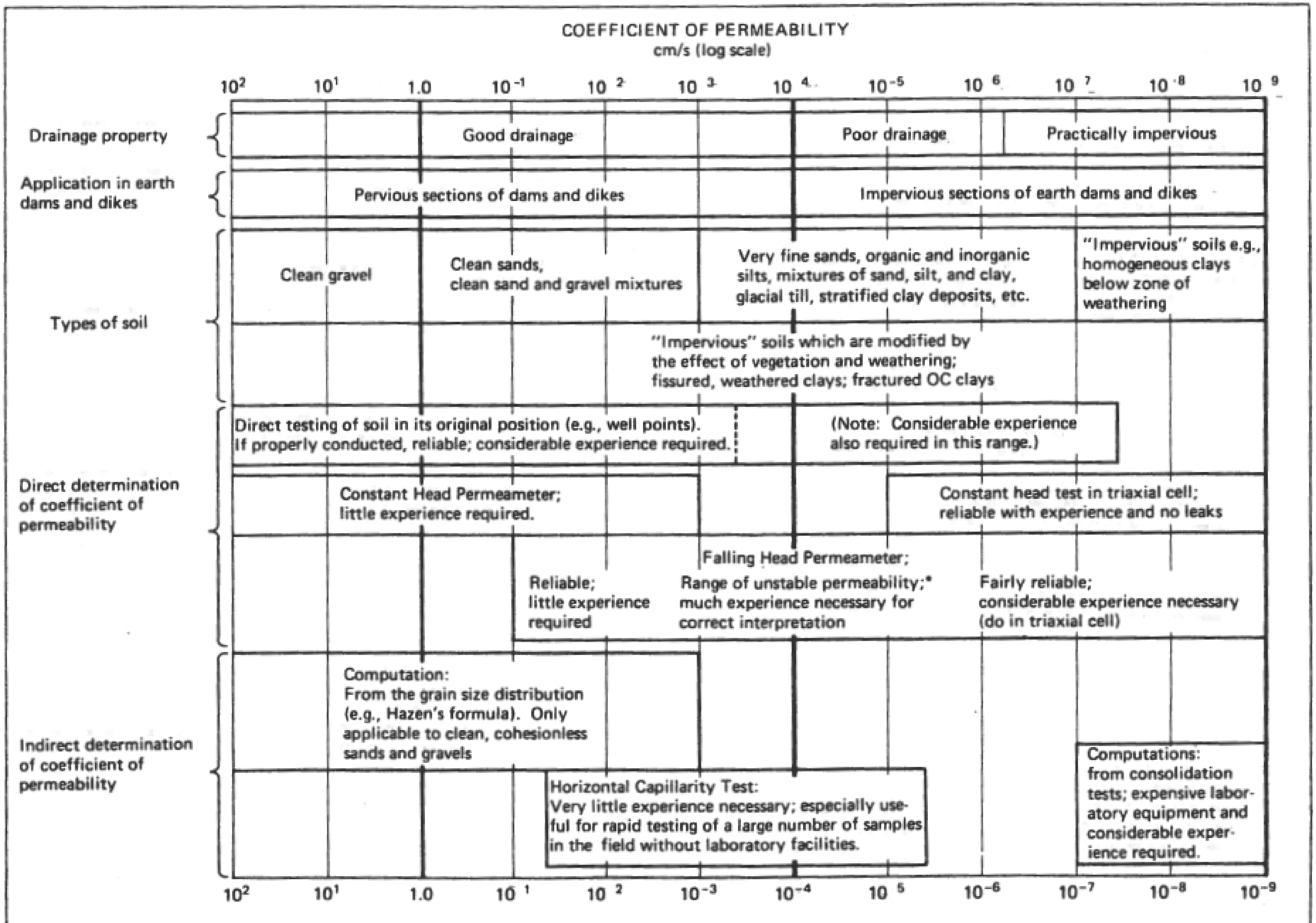
The estimated quantity of gravel materials in Area "1" is 90,000 cubic yards, which can be obtained without stockpiling the impervious material overlining the gravels, and in Area "5", is 381,000 cubic yards, making a total of 471,000 cubic yards.

Talus deposits.

The talus material was tested in a manner similar to that described in the section headed "Gravels". No settlement was noted after the permeability test on any of the samples of talus material. The results of the grain size distribution tests are shown on Drawing C-8563, Sheets 7 through 11, and attached hereto as Plate V. The results of the permeability tests are tabulated below:

Sample Area "3"	% Passing #100 Sieve	% Moisture	Dry Density Lbs/cu ft	Wet Density Lbs/cu ft	Permeability Coefficient Ft/Day
Hole 9, 0-12' Depth	7	8	125.2	135.5	21.2
Hole 11, 0-6' "	9	13	116.5	134.0	5.45
Dodson Area					
Pit 1, 0-10' Depth	2	7	118.5	127.2	19.2
Bogus Area					
Pit 1, 10' Depth	8	8	113.3	124.0	10.5
Pit 1, 0-9' "	2	9	112.2	122.5	25.9
Summit Area					
Pit 1, 0-7' Depth	4	9	117.5	128.5	9.65

Attachment C Typical Permeability Ranges



*Due to migration of fines, channels, and air in voids.

Attachment D Direct Shear Test Results

Direct shear tests were performed on each sample by Pittsburgh Laboratories. Results were unobtainable on Type 3 and Type 4 because of shear ring binding and mechanical interlocking of coarse sand particles. It is felt however that the shearing resistance of Types 3 and 4 is very similar to Types 2 and 3 and therefore may be used in design. The shear resistance of Types 1 and 2 are as follows:

Type No.	1	2	Avg.
Cohesion (Tons/sq/ft/)	.37	1.64	1.00
Angle of Internal Friction (Ø)	34.4°	19.4°	26.9°

A stability analysis was made using approximate methods, the above average test values and the section shown on Plate V. This analysis indicates that a factor of safety of approximately 2.25 will be obtained.

The volume of the material available as determined from the drill holes is as follows:

Types 1, 2 and 3 - 96,000 cubic yards
" 4 - - - - - - - 55,000 " "

Field observation indicates that additional material is available on the borders of the areas drilled which is similar to the material tested.

CONCLUSIONS:

It is concluded that the earthen embankment of Big Bend Dam may be constructed of the materials which have been analyzed in this report to the approximate typical section as shown on Plate V, and to specifications attached hereto entitled "Earthwork Specifications for Big Bend Dam" and labelled "Appendix 1".

The impervious core of the embankment, Zone 1, should be constructed of the materials classified in this report as Types 1, 2 and 3. The moisture content of these materials is about 25% and the maximum dry density between 85 and 95 lbs per cubic foot. The "yardstick" for construction should be set for this section at 25% moisture and 90 lbs per cubic foot. As construction progress is made, the "yardstick" may be varied to more closely conform to field results.

Zone 2 of the embankment, the semi-pervious section, should be constructed of the material classified as Type 4. The optimum moisture content of this material is about 18% with a dry density, including the gravel, of 128 lbs per cubic foot. Again, as field results are obtained, this "yardstick" may be varied.

Attachment E Compaction Test Results

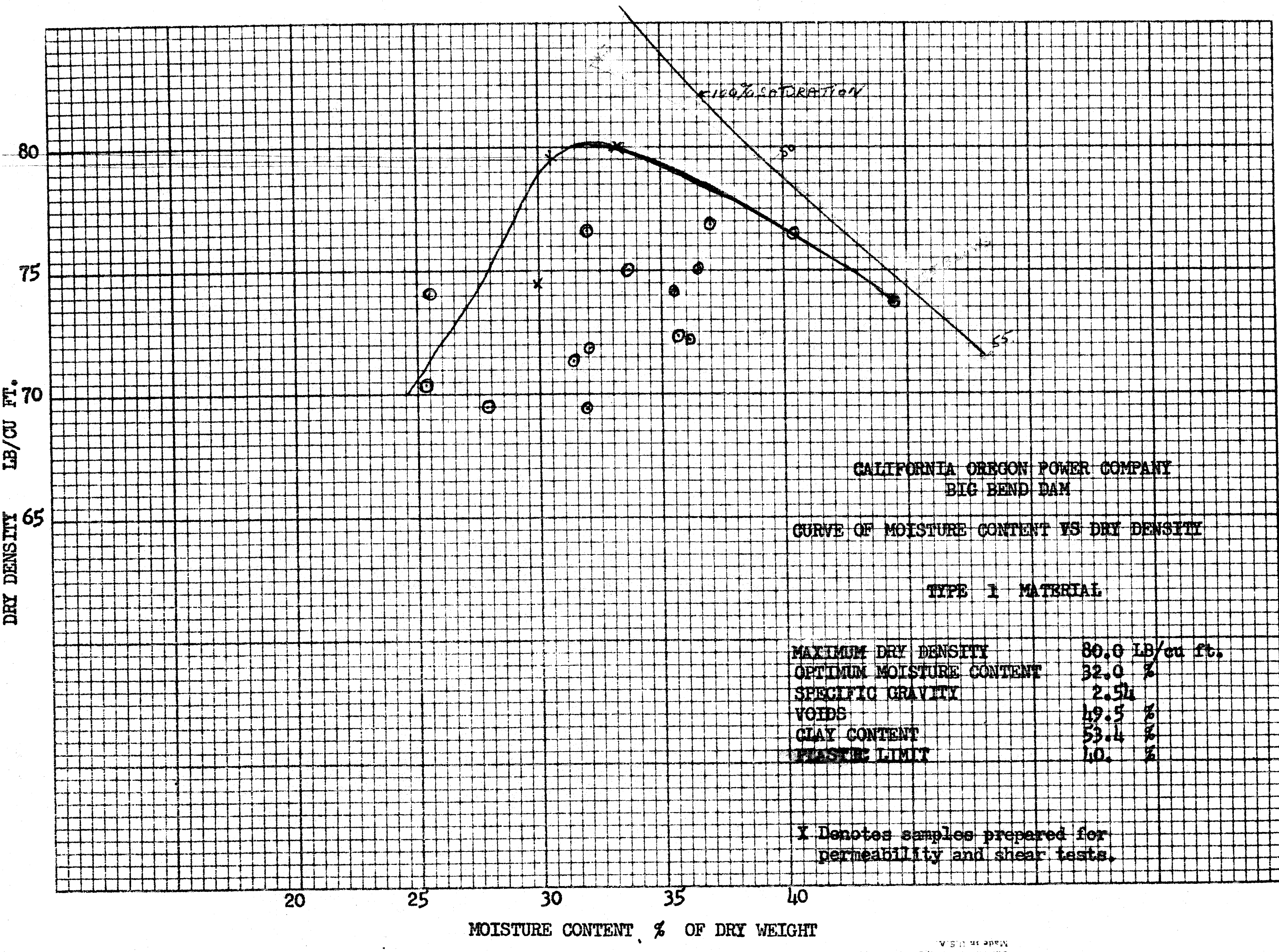
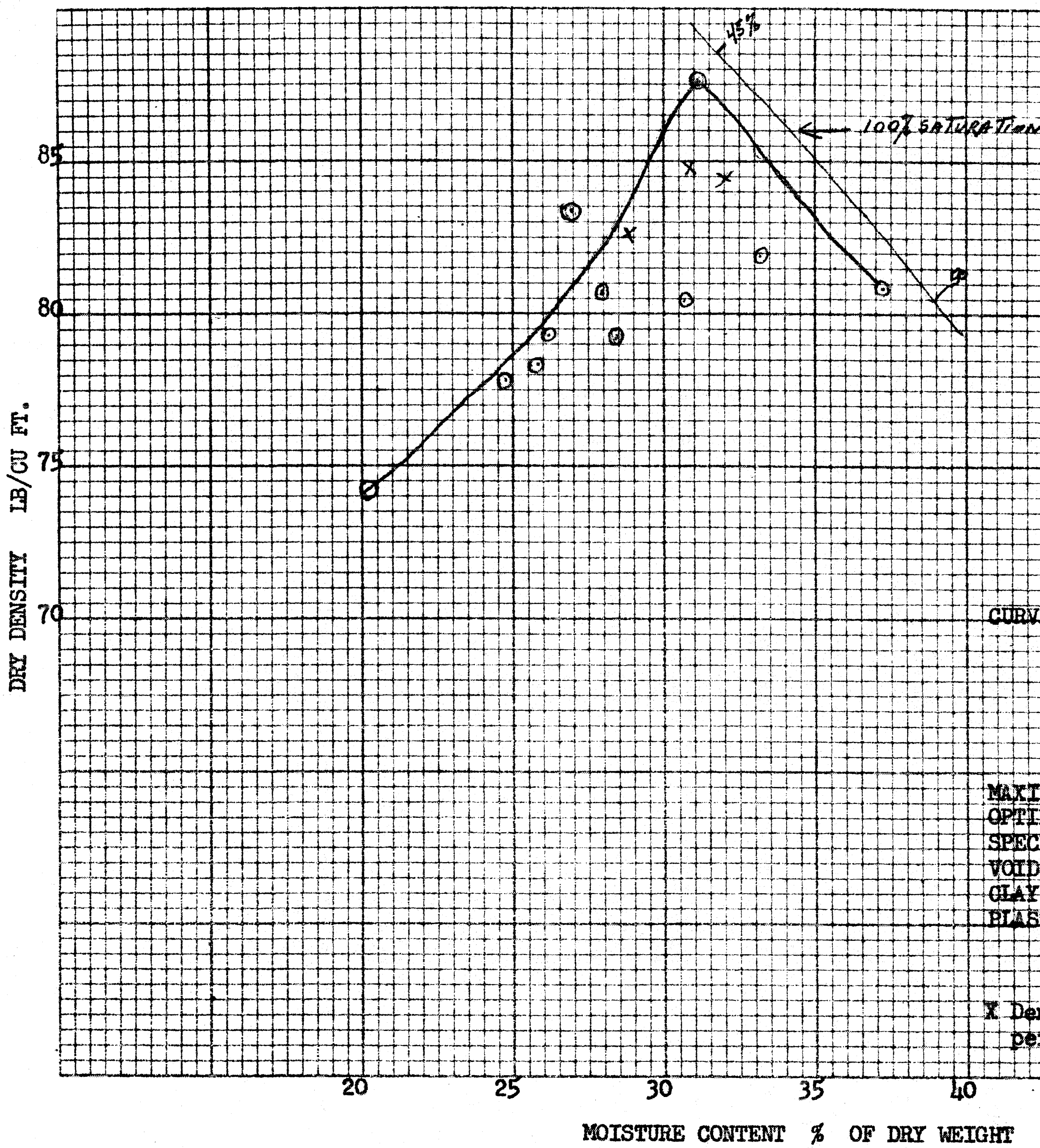


PLATE III - Sheet No. 1



CALIFORNIA OREGON POWER COMPANY
BIG BEND DAM

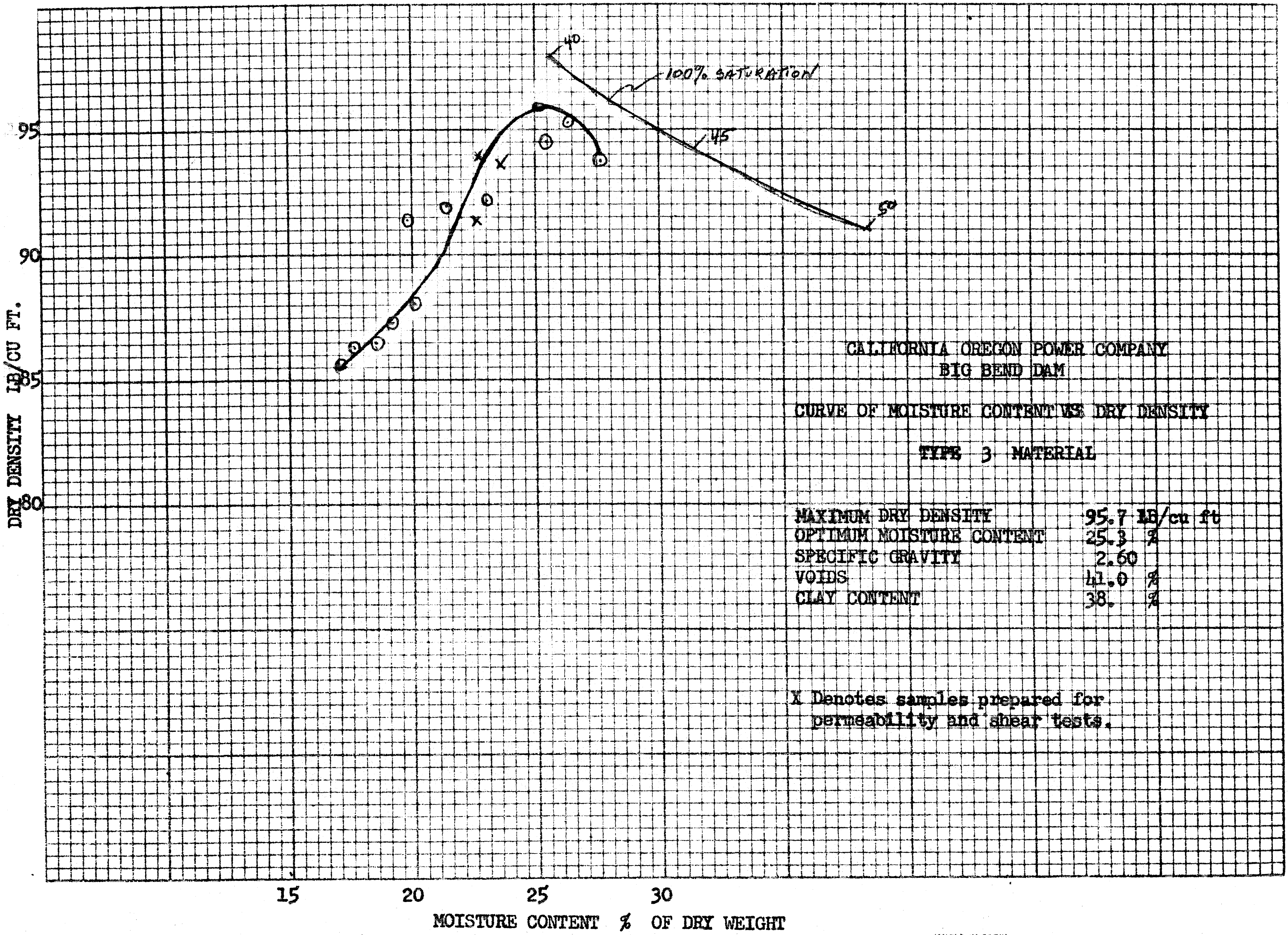
CURVE OF MOISTURE CONTENT VS DRY DENSITY

TYPE 2 MATERIAL

MAXIMUM DRY DENSITY	87.6 LB/cu ft.
OPTIMUM MOISTURE CONTENT	31.1 %
SPECIFIC GRAVITY	2.58
VOIDS	45.5 %
CLAY CONTENT	50.0 %
PLASTIC LIMIT	40. %

X Denotes samples prepared for permeability and shear tests.

PLATE III - Sheet No. 3



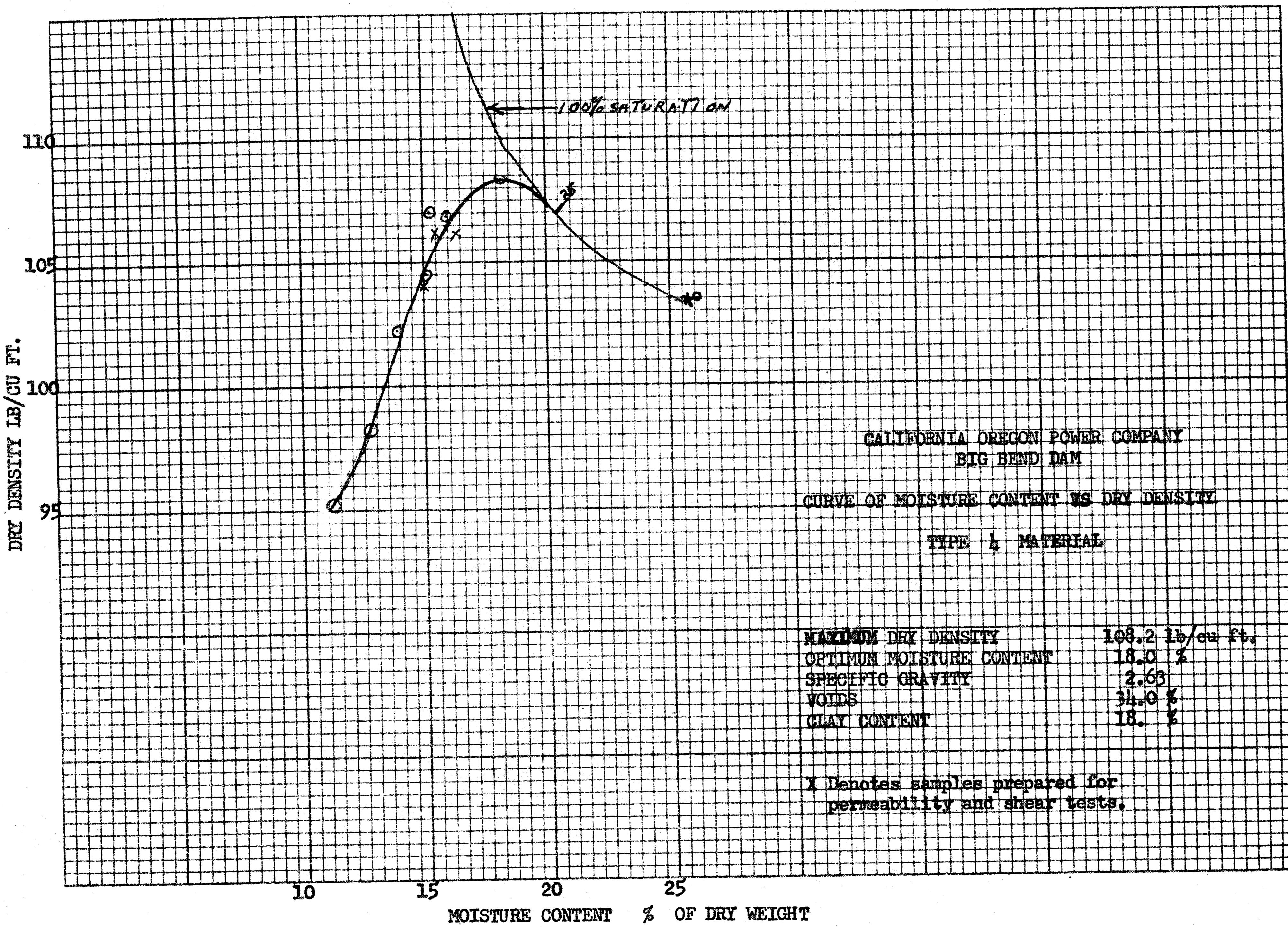
CALIFORNIA OREGON POWER COMPANY
BIG BEND DAM

CURVE OF MOISTURE CONTENT VS DRY DENSITY

TYPE 3 MATERIAL

MAXIMUM DRY DENSITY	95.7 LB/cu ft
OPTIMUM MOISTURE CONTENT	25.3 %
SPECIFIC GRAVITY	2.60
VOIDS	41.0 %
CLAY CONTENT	38. %

X Denotes samples prepared for permeability and shear tests.



CALIFORNIA OREGON POWER COMPANY
BIG BEND DAM

CURVE OF MOISTURE CONTENT VS DRY DENSITY

TYPE 4 MATERIAL

MAXIMUM DRY DENSITY	108.2 lb/cu ft.
OPTIMUM MOISTURE CONTENT	18.0 %
SPECIFIC GRAVITY	2.63
VOIDS	34.0 %
CLAY CONTENT	18. %

X Denotes samples prepared for permeability and shear tests.

No.911-10 10 x 10 to 1" The A. Lietz Co., San Francisco Made in U.S.A.

PLATE III - Sheet No. 4

Attachment F Permeability Test Results

	In Place Moisture	Clay Content (Percent)	Specific Gravity of Particles	% Finer than #4 Sieve
Avg.	19.7	35	2.64	51
Max.	26.9	48	2.72	63
Min.	14.5	24	2.58	39

Number of Samples - 14.

Note: Material passing the No. 4 sieve was not plastic. Could not roll 1/8" diameter thread due to sand grains. Specific gravity of the rock (larger than #4 sieve) = 2.64.

The curves showing the moisture content dry density relation of the material finer than the No. 4 sieve are shown on Plate III, Sheet #4. At an optimum moisture content of 18%, the dry density was 108.2 lb/cu ft. with 34% voids. When the material passing the No. 4 sieve and the larger material are combined, the theoretical density can be computed as follows:

$$Drs = \frac{Ds\ Dr}{PD_s + (1-P)\ D_r}$$

Where Drs = Theoretical density of combination
Ds = Density of soil
Dr = Density of rock
P = Percentage of rock (expressed as decimal)

$$Drs = \frac{(108.2)\ (62.4)\ (2.64)}{(.49)\ (108.2) + (.51)\ (165)} = 130 \text{ lb/cu ft.}$$

The above value is a theoretical quantity - which normally cannot be obtained in practice due to the interferance to compaction by the rock. A more practical equation is as follows:

$$Drs = (1-P)\ D_s + 0.9\ P\ Dr$$

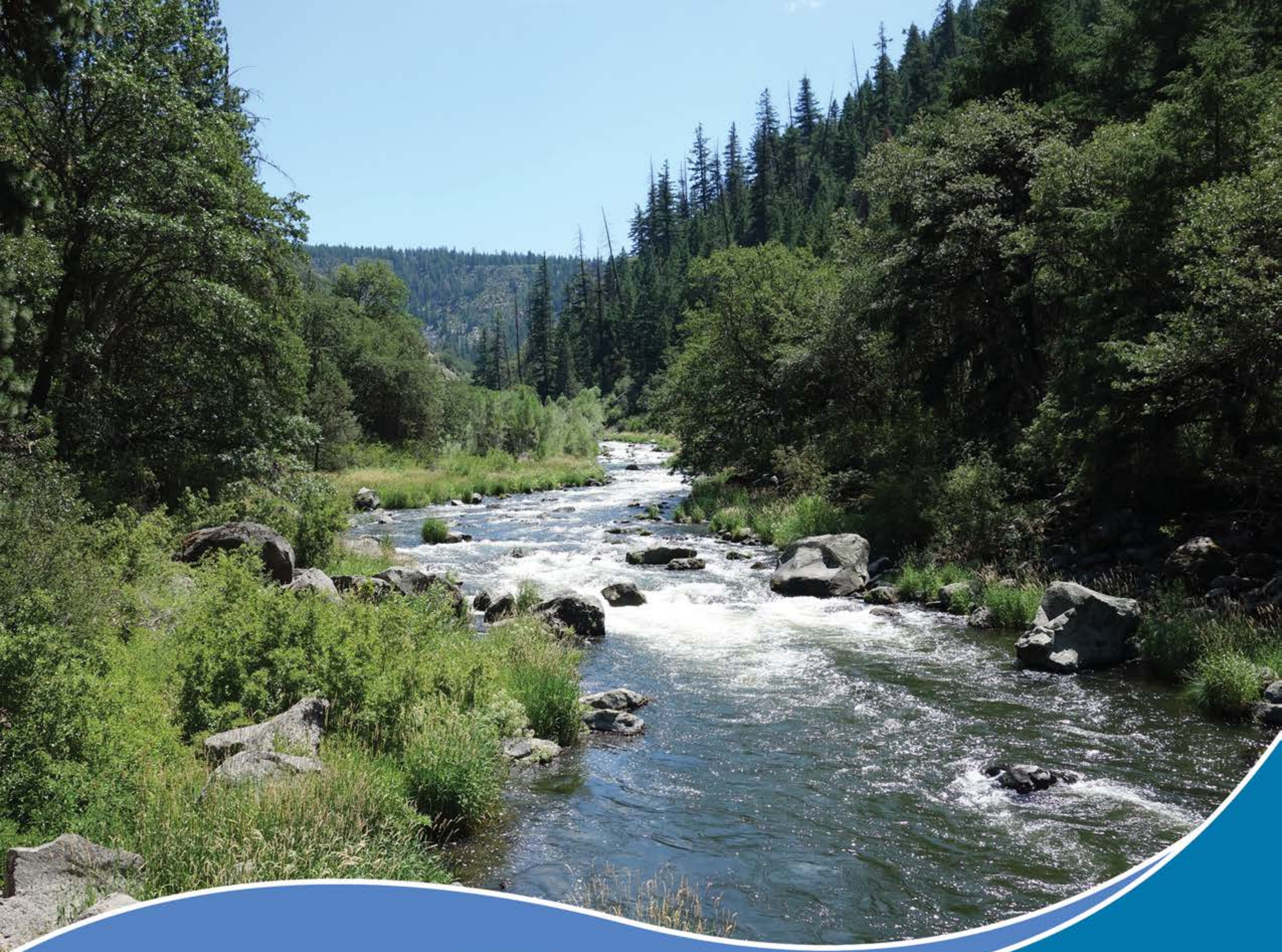
$$Drs = (1-.49)\ 108.2 + 0.9\ (.49)\ (165) = 128 \text{ lb/cu ft.}$$

II. Qualitative capillarity tests were performed on each of the four types of material. The test consisted of placing a 4" diameter by 4" high compacted sample of the material in a pan of water. In each case the sample of material became saturated in approximately 4 hours. After 48 hours, no sloughing or breakdown of the sample had taken place.

Permeability tests by the falling head method were performed on each type of material by Pittsburgh Testing Laboratories. The permeability was determined to be as follows:

Type 1	-	0.0000187	centimeters	per	second
" 2	-	0.0000155	"	"	"
" 3	-	0.000226	"	"	"
" 4	-	0.00000383	"	"	"

These co-efficients of permeability fall within the impervious sections of earth dams or dikes as classified by Casagrande and Fadum, Harvard University. The permeability test on Type No. 4 material was performed on the material passing the No. 4 sieve. While this material seems to have the smallest permeability, the gravel content is so high (50%) as to make the overall material questionable as to watertightness.



Definite Plan for the Lower Klamath Project

Appendix E – Reservoir Rim Stability Evaluation

KLAMATH
RIVER RENEWAL
CORPORATION

June 2018

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Prepared for:

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Acronyms and Abbreviations

DEM	Digital Elevation Model
EM	Engineering Manual
ICU-TX	Isotopically Consolidated Undrained Tri-Axial Strength Test
KRRC	Klamath River Renewal Corporation
MC	Modified California Sampler
pcf	Pounds-Force per Cubic Foot
psf	Pounds-Force per Square Foot
SPT	Standard Penetration Test
USACE	United States Army Corp of Engineers

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Chapter 1: Introduction

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1. INTRODUCTION

The purpose of this evaluation is to summarize relevant geologic background information, recent field reconnaissance and explorations, and any assessments or analyses completed to assess reservoir rim stability at J.C. Boyle, Copco No.1 and Iron Gate reservoirs.

When discussing reservoir rim stability during drawdown at the various reservoir locations, it is important to differentiate between the potential for deep-seated large landslides, which could impact residences and other resources adjacent to the rim, and shallower slides of material beneath the current water surface, which would only impact resources within the local limited slide footprint. The methodology used and amount of data available for the current analyses does not allow for the prediction of exactly where and how many of these shallow slides may occur. This evaluation largely discusses the potential for deep-seated landslides, which have the greatest potential to cause large impacts to resource areas. The methodology KRRC used for evaluation of reservoir rim stability included the following steps:

1. A desktop geologic study of the reservoir rims including a literature review of previous geologic studies of the area and a review of available aerial photography.
2. A geologic reconnaissance along the reservoir rims
3. Field investigations and laboratory testing of soil samples in areas with potential instabilities.
4. Analysis of cross-sections and material properties based on available data, geotechnical field investigations, and laboratory testing.
5. Rapid drawdown and other slope stability analyses. The rapid drawdown analysis assumed instantaneous drawdown unless determined that transient analysis was needed.
6. Develop a map showing areas of identified potential impacts.

Based on the United States Army Corp of Engineers (USACE) Slope Stability Engineering Manual (EM-110-2-1902) (USACE, 2003), Table 1-1 shows criteria developed for factors of safety. The following sections summarize geologic conditions and evaluations of the reservoir rims behind J.C. Boyle, Copco No. 1, and Iron Gate dams for potential instability during reservoir drawdown.

Table 1-1 Slope Stability Criteria

Case	Minimum Factor of Safety
Existing Conditions	1.11
Rapid Drawdown	1.15
Long-Term (post drawdown)	1.5
Historical Drawdown	1.11

Notes:

1. Case used as a check of the model. Anything over a factor of safety of 1.1 would be considered acceptable.

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Chapter 2: J.C. Boyle Reservoir

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2. J.C. BOYLE RESERVOIR

KRRC based the assessment presented in this section on preliminary bathymetric data. KRRC will perform additional geologic mapping and interpretation once recently collected bathymetric data is finalized.

2.1 Previous Investigations

Previous investigations are the subsurface geologic data related to J.C. Boyle Dam (Black & Veatch, 1998) and sediment sampling (Shannon & Wilson, 2006). Neither of these investigations were deep enough to provide useful information concerning rim stability. However, based on KRRC's 2017 geologic site reconnaissance and review of existing materials, KRRC determined no additional exploratory borings were required.

2.2 Geologic Characterization

The following discussion of geologic conditions at J.C. Boyle Reservoir is excerpted from PanGEO (2008). Topography for the area around the reservoir is gently sloping (less than 10%) to rolling terrain without many steep slopes other than on stratovolcanoes that are scattered around the region. Upstream and downstream of the dam, the Klamath River has cut a series of deep canyons into the volcanic rocks that mantle this part of northeastern California and southeastern Oregon. These canyons have slopes up to about 60 degrees. Bands of 30 and 40 degree slopes form NW-SE-oriented lineations in the topography; one of these bands forms the upstream boundary of the topographic bowl that the reservoir is located within.

Bedrock geology in the J.C. Boyle area is complex, characterized by inter-fingered volcanic deposits from a variety of sources less than 5 million years old that are part of the High Cascade stratovolcanic deposits. Common lithologies include hard, resistant basalt and basaltic andesite and less resistant volcaniclastic deposits. The area is characterized by several stratovolcanoes (Mount McLoughlin, Chase, Hamaker, Buck, and Surveyor Mountains) as well as dozens of smaller vents that erupted lavas and volcaniclastic materials. Younger alluvium and colluvium (at least 18,000 years old) are present on some of the slopes and as gently sloped terraces around the margins of the reservoir. An outcrop of very light grayish tan diatomite is present along the margin of the reservoir on the north side of the river by the prominent eastward bend. The outcrop is at least 10 feet high and located at the foot of a rounded hill mapped as glacial material. The diatomite is underlain by black sand and is possibly interbedded with volcaniclastic material.

Faulting is prominent in the J.C. Boyle Reservoir area. The faulting appears to display a normal sense of offset associated with the extensional tectonics of the Basin Range geomorphic province. The bowl topography of the reservoir area likely owes its configuration, in part, to being within a down-dropped basin. One prominent fault system is a fault that trends northwest through the northeast corner of the reservoir extent. The fault is down-dropped to the southwest, and the fault forms the southwest boundary of the hard rock canyon located upstream of the reservoir. To the northwest of the dam site, another fault system exists along the east side and through the middle of a prominent hill. This fault appears to mark the west side of the down-dropped block that forms the reservoir basin, as the fault is down to the northeast.

Review of topographic data and reconnaissance of the reservoir slopes indicate that no landslides are present adjacent to the reservoir. Furthermore, the land surface surrounding the J.C. Boyle Reservoir is generally low gradient and underlain by competent materials.

2.3 Conclusions

The geologic reconnaissance of the J.C. Boyle Reservoir rim did not reveal obvious stability problems. Based on the results of the geologic reconnaissance, the historic performance of the slopes above the reservoir level, and the bathymetry, KRRC concluded that deep-seated large landslides are less likely. Therefore, stability analyses for the rim of J.C. Boyle Reservoir are deemed not required to support the preliminary design. Shallower slides could occur in the surficial soil deposits around the reservoir rim and on the reservoir slopes that are currently below the reservoir surface.

Chapter 3: Copco No. 1 Reservoir

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3. COPCO NO. 1 RESERVOIR

Copco No. 1 Dam and reservoir are mostly underlain by volcanic and volcaniclastic rock of the Western Cascades Volcanics group. Younger volcanic rock of the High Cascades Volcanics group is present at the dam site and at the western end of reservoir, as well as on parts of the canyon rim. Quaternary fluvio-lacustrine diatomaceous deposits are present around much of the reservoir rim and in the reservoir bed as terrace deposits with surfaces both above and below the modern reservoir level.

PanGEO (2006) suggests the slight possibility of drawdown-induced block sliding where hard strong volcanic flow rocks are underlain by saturated tuffaceous beds and bedding dips into the valley. Hammond (1983) reports several low to moderate dip angles of volcaniclastic beds into the valley, but there is no evidence of previous slope instability at these locations.

3.1 Historical Investigations and Reservoir Drawdowns

3.1.1 Historical Investigations

The available subsurface geologic data is limited to only the recent reservoir sediment sampling (Shannon & Wilson, 2006). For the investigation, Shannon & Wilson used a barge mounted CME-45 to continuously sample the reservoir sediments using either a pushed piston sampler or a driven MC sampler. No drilling was used to clean the hole between samples and casing was used when needed in a few locations. Twelve explorations were completed in the reservoir, which showed reservoir sediments ranging from 0.5 to 10 feet in thickness. These borings were examined and used to define the sediment thickness in the analysis profiles when applicable. No other useful investigations for rim stability were found.

3.1.2 Historical Reservoir Drawdowns

Copco No. 1 reservoir levels between November 1, 1978, and December 31, 2016, were reviewed by the KRRC for historical occurrences of reservoir drawdown. The three most significant drawdown events occurred in 1982, 2014, and 2015 (see Figure 3-1).

The maximum daily drawdown rate of 2 feet per day occurred in 2014 when the reservoir was drawn down nearly 14 feet. Based on inquiries made to PacifiCorp, slope failures were not observed in connection with the three reservoir drawdown events, although there was no specific effort made to determine whether slope failures occurred (email with Demian Ebert August 2, 2017).

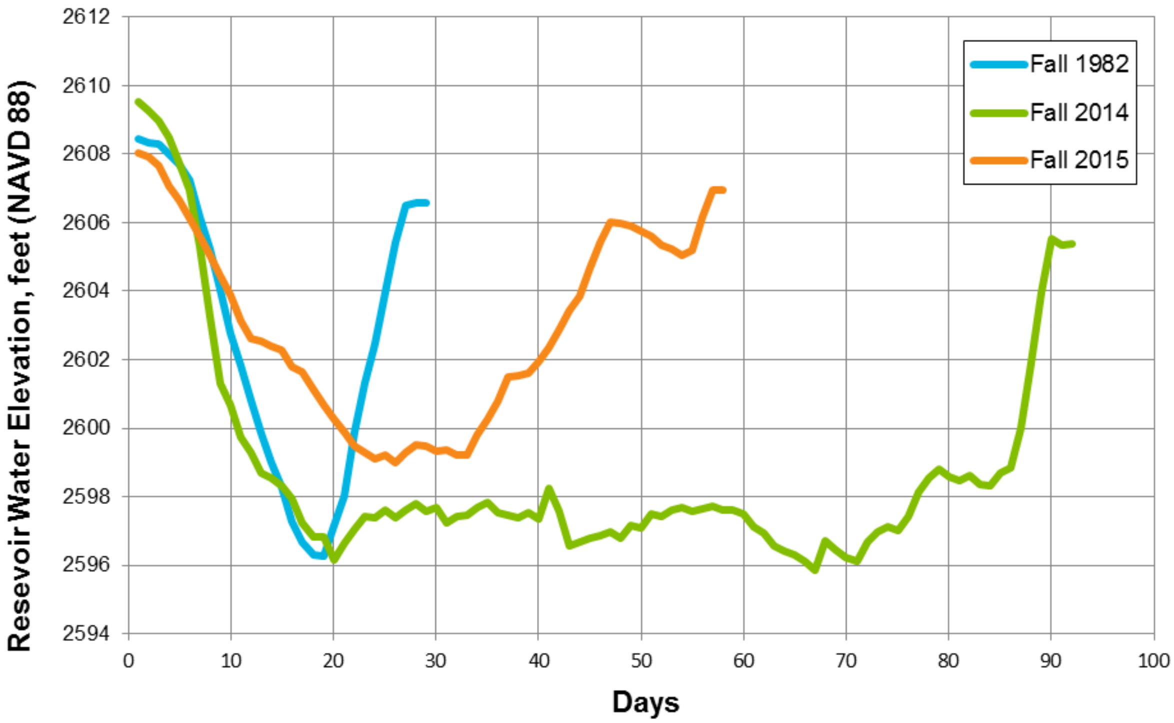

Figure 3-1 Copco Lake Maximum Historical Drawdown Events (1978 to 2016)

3.2 Project Investigations and Laboratory Testing

KRRC performed geologic mapping and a subsurface investigation with lab testing at Copco No. 1 reservoir to characterize and analyze the stability of the fluvio-lacustrine terrace deposits present around much of the rim of the reservoir and within the reservoir bed.

Access to the overland shoreline surfaces was not available, so KRRC performed drilling over water from a small platform barge using a CME-45 drill rig. Ten rotary wash borings were advanced into the reservoir bed between February 1 and 14, 2018, by Taber Drilling of West Sacramento. The boring depths ranged from 12 to 97 feet. Boring locations are shown on the geologic map (Figure 3-2). Table 3-1 summarizes the exploratory boring data, including depth and elevation of volcanic bedrock, where encountered. Boring logs are presented in Attachment B and a summary of the subsurface conditions are presented in Section 3.2.1.

KRRC obtained soil samples using standard penetration test (SPT) and 2.5-inch I.D. modified California (MC) drive samplers and 3-inch diameter thin-walled Shelby tubes. The tubes were advanced by direct push or with a hydraulically activated piston sampler (Osterberg). KRRC recorded blow counts at 6-inch intervals for drive samples and hydraulic gage down pressure necessary to advance Shelby tubes was noted.

Table 3-1 Summary of Exploratory Boring Data

Boring Id No.	Total Depth (feet)	Northing	Easting	Elevation (feet)	Depth to Rock (feet)
BC-01	30.4	2608898	6476516	2593.1	27.5
BC-02	64.6	2608331	6476958	2596.3	63
BC-02	96.5	2606643	6474657	2580.8	>96.5
BC-04	73.5	2604812	6472949	2593.1	69.5
BC-05	20.5	2604139	6474515	2597.8	17.5
BC-06	15.4	2605112	6476050	2574.9	7.5
BC-07	15.9	2605439	6477039	2577.8	15.5
BC-08	11.5	2605190	6480346	2582.4	-
BC-08a	85.2	2605249	6480346	2579.8	83.5
BC-09	70.5	2602526	6483561	2598.2	>71.5
BC-10	43	2604959	6472871	2575.1	39

KRRC sent samples to Cooper Testing Laboratory in Palo Alto, California. Lab testing performed included:

- Moisture Content (ASTM D2216)
- Moisture and Density (ASTM D7263B)
- Atterberg Limits (ASTM D4318)
- Grain Size Analyses with and without Hydrometer (ASTM D6913 & ASTM D7928)
- Percent Fines (ASTM D1140)
- Unconsolidated Undrained Triaxial Strength Test (ASTM D2850)
- Consolidated Undrained Triaxial Strength Test (ASTM D4767m)

The laboratory test results are provided in Attachment C and a summary of the laboratory test results received at the time of writing this report are shown in Section 3.4.1.

3.2.1 Summary of Subsurface Conditions from Borings

Borings encountered between 1 and 11 feet of very soft, recent lake sediments typically consisting of organic rich clayey sand to sandy clay/silt occasionally with coarse sand and small gravel clasts of weak, friable diatomite. The diatomite gravel was encountered at near shore borings and likely was derived from relatively recent bluff erosion along the shoreline.

Below the recent reservoir sediment, all the borings except BC-01 encountered alluvial terrace deposits and/or colluvium consisting of soft/loose to dense/stiff gravels, sands, and clays between 3 feet and 14 feet thick. Cobbles were observed in gravelly layers with a layer primarily of cobbles observed in BC-03.

Below the alluvial terrace deposits/colluvium or recent reservoir sediments, various forms of diatomite or diatomaceous clays were observed in all but borings BC-06 and BC-07, with thicknesses ranging from 6.5 feet in BC-09 to greater than 86 feet in BC-03. The various forms of diatomite encountered included diatomite rock, clayey diatomite, diatomaceous clay, and weakly cemented diatomite pieces.

Finally, below the diatomite or alluvial terrace deposits, volcanic bedrock was encountered consisting of basalt, andesite, cinders, volcaniclastic sandstone, and volcaniclastic/intrusive bedrock of various weathering and strength. While the strength of the volcanic bedrock varied, it was all considerably stronger than the materials above; no coring was performed to retrieve samples for strength testing since failure surfaces during reservoir drawdown are not likely to pass through the bedrock.

3.3 Geologic Characterization

3.3.1 Previous Mapping

Previously published mapping around Copco reservoir include:

- *Volcanic Formations Along the Klamath River Near Copco Lake, Siskiyou County,* PAUL E. HAMMOND, Department of Geology, Portland State University, Portland, Oregon; California Geology, May 1983.
- *Geology of the Macdoel Quadrangle,* HOWEL WILLIAMS , California Division of Mines and Geology Bulletin 151, November, 1949
- *Circular Soil Structures in Northeastern California*, PETER H. MASSON, California Division of Mines and Geology Bulletin 151, November, 1949
- *Geotechnical Report, Klamath River Dam Removal Project, California and Oregon, Project No. 07-153,* PanGEO Incorporated, prepared for Philip Williams & Associates, Ltd. And California State Coastal Conservancy, August, 2008
- *Geologic Map of the Weed Quadrangle,* D. L. Wagner and G. J. Saucedo, California Division of Mines and Geology, 1987)

These maps primarily show bedrock units, with surficial deposits typically not differentiated. Williams shows terrace deposits around Copco reservoir as diatomite and suggests it may have economic value. Wagner and Saucedo show the terrace deposits around Copco reservoir as lacustrine in origin. Hammond provides the most detailed descriptions of volcanic bedrock, but the area covered extends west only to the upstream end of Iron Gate reservoir, and mapping does not differentiate surficial deposits. Hammond also reports a maximum age for Copco basalt of 0.14 million years, based on Potassium/Argon isotope analysis of one sample. No other published ages of the Copco basalt are available.

3.3.2 Geologic and Surficial Mapping

Geologic reconnaissance along public right of ways and at Copco No. 1 dam site was performed several times during summer and fall of 2017. KRRC performed reconnaissance of the reservoir shoreline on October 4, 2017 using a boat and, to a lesser extent, during subsurface investigations in February, 2018.

KRRC used observations made during field investigations, preliminary results of subsurface investigation, and previously published maps to develop a geologic surficial map of Copco reservoir (Figure 3-2). Surficial deposits and landforms were identified on high-resolution topographic (LiDAR, 2010) and bathymetric (GMA, 2018) surface data for the shoreline and reservoir bed areas, respectively. This mapping focused on identifying the full extent of the quaternary lacustrine terrace deposits along the shoreline and any large, deep seated landslides or other areas of potential instability within the shoreline slopes.

Figure 3-2: Geologic Overview of Copco Lake (Attachment A)

Surficial Deposits

Previously undifferentiated surficial deposits around much of Copco reservoir include talus and rockfall debris, colluvium, alluvium and alluvial fans associated with tributary drainages, and older, likely Quaternary, fluvio-lacustrine terrace deposits, described below.

No large-scale landslides have been identified in either the terrestrial or submarine slopes around Copco reservoir by this or previous studies. PanGEO (2008) identified two small to medium-size inactive landslides on the north shore and concluded that these are not likely to be reactivated by reservoir lowering, due to their position above the reservoir rim. One notable feature is a large alluvial fan on the north side of the reservoir, just west of Spannus Gulch. PanGEO (2008) states that the location of this fan between tributary drainages suggests that the feature could be colluvial or landslide related, but if this is the case, the feature is likely ancient and inactive. Additionally, there is a notch in the bedrock at the head of this fan suggesting that the fan was once associated with Spannus Gulch, which now flows down a steeper, bedrock channel to the east. To confirm this interpretation, boring BC-09 was located offshore of the feature and results indicate it is a relatively thin alluvial fan deposit overlying Quaternary lacustrine deposits. For this study, KRRC identified one medium size slide deposit just above the reservoir level on the south shore. This feature appears rocky and is interpreted as a rock slide/fall deposit. Based on the limited extent below the water, low submarine relief and rocky nature of the deposit, it is very unlikely that this feature will be affected by reservoir drawdown.

Surficial deposits and landforms mapped during this study and shown on Figure 3-2 include:

- Active channel alluvium associated with pre-dam Klamath river (Qac)
- Flood plain deposits associated with the pre-dam Klamath river (Qfp)
- Alluvial fans (Qaf)
- Undifferentiated alluvium, usually associated with tributary drainages (Qa)
- Local accumulations of colluvium (Qc)

- Talus deposits (Qtl)
- Landslide deposits (Qls)
- Debris flow deposits (Qdf)
- Fluvio-lacustrine terrace deposits (Qtg, Qt, and Qtl), described below

Fluvio-Lacustrine Terrace Deposits

Fluvio-lacustrine terrace deposits surround much of the shoreline of Copco reservoir, extending to approximately 40 feet above the current reservoir level. These consist of diatomite, fine-grained diatomaceous reservoir sediment and dense, coarse-grained alluvial deposits. The terrestrial (onshore) extent of these deposits has been mapped (see Figure 3-2) by KRRC on modern topography and aerial imagery, based on field reconnaissance and modified from previous mapping by Williams (1949), Hammond (1983), and PanGEO (2008). The diatomite and lacustrine sediments were presumably deposited in a freshwater lake setting formed by volcanic damming of the Klamath River at or near the Copco No. 1 dam site by the 0.14 million-year-old Copco basalt.

Coarse-grained alluvial deposits were encountered on submarine terrace surfaces in borings (BC-03, BC-08/8a, and BC-10) and observed in shoreline deposits in the upstream half of the reservoir, occasionally interbedded with fine-grained lacustrine deposits. In the borings, these deposits ranged from 3 to 8 feet thick, likely representing river deposits after a partial volcanic dam breach with base level several tens of feet higher than that of the modern Klamath River. The degree of weathering and thickness of overlying soil suggest these deposits are geologically old, perhaps as little as a few thousand years younger than the emplacement of the Copco basalt. Upstream alluvial deposits, locally interbedded with diatomaceous lake sediments, are likely of similar age; however, surficial coarse-grained deposits may be much younger.

The most extensive on-shore deposits of diatomite are along the downstream south shore and along the Beaver Creek arm of the reservoir on the north shore where the deposits form a flat-lying to gently dipping surface, into which steep shoreline bluffs have been formed by modern shoreline erosion. Along much of the rest of the shoreline, the diatomite is present as a relatively thin wedge or prism, often with a modern colluvial/alluvial depositional capping layer. In this case, the maximum extent of the deposits was based on elevation and morphology. In other areas, bedrock was exposed at the shoreline and the diatomite was not observed on the slopes, presumably due to wave and/or hillslope and tributary channel erosion. The diatomite along the shoreline and at shallow depths in borings is generally a light gray to light tan colored material which is low density and weak to very weak. In the more extensive deposits, near-vertical bluffs have formed in the diatomaceous deposits as a result of undercutting due to wave erosion and failure of the weak material. In some places, this erosion has exposed volcanic bedrock at the base of the bluffs, indicated with thick black line on Figure 3-2.

Where the toe of the terrestrial diatomite terrace deposit lies above the current high lake level, the response of the slope to rapid drawdown are determined by the properties and geometry of the underlying volcanic and volcaniclastic strata. Where the toe of the terrestrial diatomite terrace deposit lies below the current high lake level, the response of the slope to rapid reservoir drawdown are determined by the properties of the diatomite deposits, the thickness of the diatomite deposits, and the properties of the underlying material. Lacustrine diatomite deposits also exist completely below the current range of reservoir levels, and appear as prominent benches in the bathymetry. Along the south shore, this bench is mostly continuous and ranges between 100 and 300 feet wide. Along the north shore, the terrace bench is wider, with large peninsulas extending to the south with very steep to near vertical side slopes.

Mapped terrace deposits include:

- Quaternary alluvial terrace deposits, with gravels (Qtg)
- Quaternary fluvio-lacustrine terrace deposits, undifferentiated (Qt)
- Quaternary lacustrine deposits (Qtl)

The thickness of lacustrine diatomaceous sediments in borings further from the shoreline indicate that this material is likely present beneath surficial terrace and alluvial fan deposits in the upstream part of the reservoir bed and shoreline areas.

High Cascade Volcanics

Copco Basalt (Qb), a 0.14 million years old intracanyon flow unit (Hammond 1983), outcrops at the west end of the reservoir and likely underlies some of the western (downstream) submarine terrace deposits. This unit erupted from vents on both sides of the Klamath River, damming the river to form a lake that was approximately 35-40 feet higher than the modern reservoir (Hammond 1983). Other Quaternary basalt lava flows (QTb) unconformably overlie the older volcanics of the Western Cascades Group to form the generally flat-lying rim rock at the topo of the slopes around much of Copco No. 1 reservoir, but more prominent to the north.

Western Cascade Volcanics

Volcanic and volcaniclastic bedrock of the Western Cascade Volcanics around the rim include Spannus Ranch Andesite, undifferentiated intrusives, and several members of the Bogus Mountain volcaniclastic beds.

The Spannus Ranch Andesite consists mainly of pyroxene andesite flows with interbeds of lithic breccia (PanGEO 2008).

The Bogus Mountain Beds consist of interstratified tuff-breccia, volcaniclastic sandstone and tuffs, with thinner interbedded andesite flows. The strata tend to be greenish gray, and the tuffs and sandstones are fine to medium grained. One of the basal members of the Bogus Mountain Beds has been dated at roughly 23 million years old (Hammond, 1983).

For this mapping effort, the Western Cascade volcanics are not differentiated and are presented at Tertiary Volcanics (Tv)

3.4 Stability Analyses

This section presents the current results from material characterization, segment and cross section selection, and slope stability analyses. KRRC is still completing analyses and will update this evaluation once they are finalized. KRRC completed the following steps for the analyses:

1. Develop material properties
2. Complete generalized slope stability models assuming diatomite slopes with different slope heights and angles
3. Produce a map highlighting potential areas of instability using a Graphical Information System (GIS) model
4. Select segments
5. Create and analyze a conservatively representative cross section in segments with areas of potential instability

The section s below discuss further details of the analyses.

3.4.1 Material Characterization

Based on blow count data, field descriptions of soils, and laboratory test results, KRRC divided the subsurface materials into three layers, as summarized below. Attachment C provides the laboratory results and Table 3-2 shows the chosen analysis parameters . Attachment B provides blow counts and soil descriptions on the boring logs.

Diatomite

The diatomite consists of a low density material that is significantly weaker than the underlying bedrock materials. In addition, the material has a low permeability (about $1x10^{-6}$ cm/s) and will behave as an undrained material during reservoir drawdown, regardless of the drawdown rate. Several different types of diatomite were observed including a rock like diatomite (referred to as diatomite in the boring logs), diatomite that had more of an elastic silt like behavior (referred to as diatomite with elastic silt in the boring logs), and a weakly cemented diatomite. Properties of the diatomite with elastic silt were chosen to represent all the types of diatomite since it was the most common type observed. Table 3-2 and Figure 3-3 summarize strength testing of the diatomite.

Fluvio-Lacustrine Terrace Deposit with Gravel

In general, the fluvio-lacustrine terrace deposit with gravel is a relatively dense layer of alluvium, colluvium, or lacustrine deposit with significant amounts of gravel. The material generally has a relatively high permeability and will likely behave as a drained material during rapid drawdown. KRRC chose material properties based on lab data (as summarized in Table 3-2 below), blow counts, and material descriptions.

Recent Reservoir Sediments

The recent reservoir sediments generally consist of very soft silt, sand, or clay, which have been deposited since Copco Dam was constructed. KRRC chose material properties based on lab data (as summarized in Table 3-2 below), blow counts, material description, and testing of similar material from other reservoirs.

Volcanic Bedrock

Bedrock was encountered in eight of the ten borings completed. The rock consisted of basalt, andesite, volcanic sandstone, and volcanic cinder from the Copco/Quarternary Basalt and Bogus Mountain Beds formations. The rock is significantly stronger than the diatomite, fluvio-lacustrine terrace deposits, and recent reservoir sediments. The properties of the bedrock were chosen based on field descriptions and laboratory testing of two rock cores completed in Iron Gate Reservoir (see Section 4), and previous experience with similar rock. The strength parameters were calculated using Hoek-Brown (Hoek et. al., 2002) procedures.

Table 3-2 Summary of Material Properties for Slope Stability Analyses

Material	Mositure (%)	Dry Unit Weight (pcf)	Gravel (%)	Sand (%)	Fines (%)	LL	PI
Diatomite[1]	μ: 116.7 N: 22 σ: 40.3	μ: 43.1 N: 17 σ: 15.3	μ: 0.0 N: 7 σ: 0.0	μ: 0.6 N: 7 σ: 0.4	μ: 99.4 N: 7 σ: 0.4	μ: 111 N: 7 σ: 15	μ: 51 N: 7 σ: 40
Fluvio-Lacustrine Terrace Deposit with Gravel	μ: 30.3 N: 3 σ: 4.5	μ: 121.4 N: 2 σ: 5.4	μ: 42.2 N: 3 σ: 37.3	μ: 33.4 N: 3 σ: 27.8	μ: 24.4 N: 3 σ: 34.9	μ: 111 N: 2 σ: 2.8	μ: 51 N: 2 σ: 2.8
Recent Lake Sediments[2]	μ: 38.9 N: 2 σ: 5.9	μ: NA N: 0 σ: NA	μ: 3.5 N: 3 σ: 0.7	μ: 40.3 N: 3 σ: 10.6	μ: 56.1 N: 3 σ: 11.2	μ: 41 N: 2 σ: 10.6	μ: 16 N: 2 σ: 10.6

μ = Mean
N = Number of data points
σ = Standard deviation

1. Does not include weakly cemented diatomite gravel
2. One sample (BC-02, S-01) was removed from statistics due to it being an outlier (more gravelly than others)

Table 3-3 Summary of Material Properties for Slope Stability Analyses

Layer	Unit Weight (pcf)	Undrained (Total) Strength Parameters		Drained (Effective) Strength Parameters	
		Φ (deg.)	C (psf)	Φ' (deg.)	C' (psf)
Recent Reservoir Sediments	90	0	100	-	-
Fluvio-Lacustrine Terrace Deposits with Gravel (Qtg)	120	-	-	35	0
Diatomite (Lacustrine Terrace Deposits, Ql)	82	19.9	660	35.3	150
Volcanic Bedrock	135	-	-	34	1110

Notes:
Φ = friction angle
C = cohesion

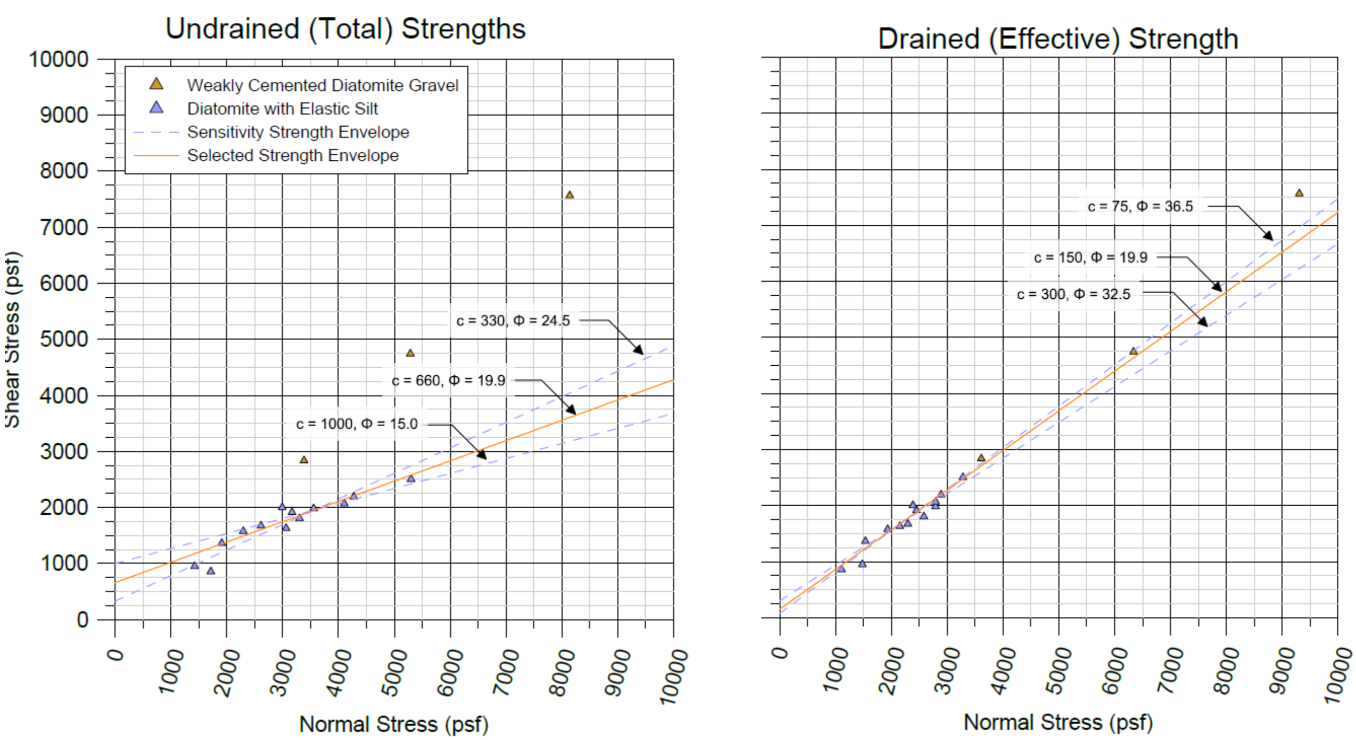

Figure 3-3 Selected Strength Envelopes

3.4.2 Segment and Cross Section Selection

To facilitate the rim stability analysis, KRRC separated the slopes within and around the reservoir rim into segments. Each segment is separated from the previous or following segment by a change in condition that could significantly change the slope stability analysis results. Some changes include a flattening or steepening of the slope, an increase in the slope height, or the mapped extent of the diatomite limiting the slope.

To aid in segment and cross section selection, KRRC performed a GIS analysis using results from a generalized slope stability analysis using the strength parameters in Table 3-3 and the methodology described in Section 3.4.3. In the generalized analysis, KRRC evaluated diatomite slopes of various heights and inclinations, providing a set of slope heights and inclinations that had a potential for instability (factor of safety less than 1.15). KRRC used the slope heights and inclinations in the GIS analysis to produce a map highlighting areas of potential concern, which was then used in segment and cross section selection.

After completing the GIS analysis and selecting segments, cross sections were selected at the most critical portion of each segment, as appropriate. KRRC created cross sections mostly for segments that the GIS analysis showed to be potentially unstable, and KRRC chose a few locations where the GIS analysis showed segments as stable to confirm those results.

Table 3-4 provides a list of the segments selected and some general information about them along with the results of the GIS analysis. Figure 3-4 shows a plan view of the segments and the status of the segment after slope stability analyses, as discussed below.

Table 3-4 Segment Description and GIS Assessment Summary

Segment	Segment Summary				GIS Analysis Result
	Approximate Length (feet)	Average Height (feet)	Average Slope (Horz:Vert)	Segment Differentiation	
N1	2,200	12.5 (range = 0 to 27)	5.2:1 (steepest = 1.2:1)	At downstream edge: by the start of the slope (at the edge of the diatomite) At upstream edge: by a decrease in the slope angle	Stable
N2	2,115	44.8 (range = 20 to 56)	2.5:1 (steepest = 0.3:1)	At downstream edge: by the start of the slope At upstream edge: by a decrease in the slope angle and increase in the slope height	Further Analysis Req.
N3	1340	18.0 (range = 1 to 40)	2.5:1 (steepest = 0.6:1)	At downstream edge by a decrease in the slope height At upstream edge by an increase in the slope height	Stable
N4	1,145	52.0 (range = 33 to 60)	2.8:1 (steepest = 0.3:1)	At downstream edge by a decrease in the slope angle and an increase in the slope height At upstream edge by an increase in the slope angle	Further Analysis Req.
N5	805	49.6 (range = 36 to 54)	2.0:1 (steepest = 0.7:1)	At downstream edge by an increase in the slope angle At upstream edge by a decrease in the slope height	Further Analysis Req.
N6	565	23.9 (range = 6 to 37)	2.7:1 (steepest = 1.1:1)	At downstream edge by a decrease in the slope height At upstream edge by the end of the slope	Stable
N7	400	-	-	At downstream edge by the start of the slope At upstream edge by an increase in the slope height	Not Completed (Further Analysis Required)
N8	2,030	40.0 (range = 11 to 52)	3.4:1 (steepest = 0.5:1)	At downstream edge an increase in the slope height At upstream edge by a decrease in the slope angle	Stable
N9	2,245	37.6 (range = 11 to 51)	3.8:1 (steepest = 1.2:1)	At downstream edge a decrease in the slope angle At upstream edge by an decrease in the slope angle	Stable
N10	2,420	19.8 (range = 9 to 28)	3.3:1 (steepest = 0.7:1)	At downstream edge a decrease in the slope angle At upstream edge by an increase in the slope angle	Not Completed (Further Analysis Required)
N11	925	-	-	At downstream edge an increase in the slope angle At upstream edge by an increase in the slope height	Not Completed (Further Analysis Required)
N12	2,665	28.6 (range = 6 to 43)	2.9:1 (steepest = 0.7:1)	At downstream edge an increase in the slope height At upstream edge by the end of the slope (decrease in the slope angle)	Not Fully Completed (Further Analysis Required)
N13	1,445	20.1 (range = 3 to 28)	3.2:1 (steepest = 1.5:1)	At downstream edge the start of the slope At upstream edge by an increase in the slope angle	Stable

Segment	Segment Summary				GIS Analysis Result
	Approximate Length (feet)	Average Height (feet)	Average Slope (Horz:Vert)	Segment Differentiation	
N14	505	37.6 (range = 1 to 45)	2.4:1 (steepest = 0.2:1)	At downstream edge an increase in the slope angle At upstream edge by a decrease in the slope height (at the edge of the diatomite)	Further Analysis Req.
N15	970	5.6 (range = 0 to 18)	4.5:1 (steepest = 1.8:1)	At downstream edge by a decrease in the slope height (at the edge of the diatomite) At upstream edge by an increase in the slope height (at the edge of the diatomite)	Stable
N16	370	52.0 (range = 16 to 59)	2.4:1 (steepest = 0.9:1)	At downstream edge by an increase in the slope height (at the edge of the diatomite) At upstream edge by a decrease in the slope angle and decrease in the slope height	Further Analysis Req.
N17	1,210	22.7 (range = 2 to 45)	3.7:1 (steepest = 1.1:1)	At downstream edge by a decrease in the slope angle and decrease in the slope height At upstream edge by an increase in the slope height (at the edge of the diatomite)	Stable
N18	1,455	-	-	At downstream edge by the start of the slope (increase in the slope angle) At upstream edge by the end of the slope (decrease in the slope angle)	Not Completed (Further Analysis Required)
N19	985	24.9 (range = 17 to 40)	3.8:1 (steepest = 1.1:1)	At downstream edge by the start of the slope (increase in slope angle) At upstream edge by an increase in the slope angle	Stable
N20	1,015	35.3 (range = 11 to 44)	3.0:1 (steepest = 0.6:1)	At downstream edge by an increase in the slope angle At upstream edge by a decrease in the slope height (edge of the diatomite)	Further Analysis Required
N21	670	9.0 (range = 0 to 15)	5.1:1 (steepest = 0.9:1)	At downstream edge by a decrease in the slope height (edge of the diatomite) At upstream edge by the end of the slope (edge of the diatomite)	Stable
S1	665	70.5 (range = 46 to 87)	3.8:1 (steepest = 0.8:1)	At downstream edge by the start of the slope (at the edge of the diatomite) At upstream edge by a decrease in the slope height (due to an intermediate plateau)	Further Analysis Req.

Segment	Segment Summary				GIS Analysis Result
	Approximate Length (feet)	Average Height (feet)	Average Slope (Horz:Vert)	Segment Differentiation	
S2	555	41.8 (range = 29 to 52)	3.7:1 (steepest = 0.6:1)	At downstream edge by a decrease in the slope height (due to an intermediate plateau) At upstream edge by a decrease in the slope height	Stable
S3	1,020	47.6 (range = 22 to 55)	2.4:1 (steepest = 0.6:1)	At downstream edge by a decrease in the slope height (due to an intermediate plateau) At upstream edge by a decrease in the slope height	Further Analysis Req.
S4	1,190	23.5 (range = 6 to 39)	2.9:1 (steepest = 0.4:1)	At downstream edge by a decrease in the slope height At upstream edge by the end of the slope (decrease in the slope angle)	Further Analysis Req.
S5	445	16.0 (range = 3 to 28)	3.0:1 (steepest = 1.2:1)	At downstream edge by a decrease in the slope height At upstream edge by the end of the slope (decrease in the slope angle)	Stable
S6	1,080	23.5 (range = 5 to 31)	3.0:1 (steepest = 1:1)	At downstream edge by the start of the slope (increase in slope angle) At upstream edge by an increase in the slope height	Stable
S7	350	49.2 (range = 31 to 66)	2.3:1 (steepest = 0.7:1)	At downstream edge by an increase in the slope height At upstream edge by a decrease in the slope angle	Further Analysis Req.
S8	1,410	48.8 (range = 36 to 59)	3.5:1 (steepest = 0.9:1)	At downstream edge by a decrease in the slope angle At upstream edge by a decrease in the slope height	Stable
S9	1,365	28.2 (range = 3 to 51)	2.4:1 (steepest = 0.4:1)	At downstream edge by a decrease in the slope height At upstream edge by an increase in the slope height	Further Analysis Req.
S10	670	66.0 (range = 42 to 79)	2.4:1 (steepest = 0.6:1)	At downstream edge by an increase in the slope height At upstream edge by the edge of observed bedrock along the shoreline	Further Analysis Req.
S11	765	70.0 (range = 32 to 82)	3.6:1 (steepest = 0.8:1)	At downstream edge by the edge of observed bedrock along the shoreline At upstream edge by the start of an intermediate plateau (decrease in slope height)	Further Analysis Req.

Segment	Segment Summary				GIS Analysis Result
	Approximate Length (feet)	Average Height (feet)	Average Slope (Horz:Vert)	Segment Differentiation	
S12	2,445	16.7 (range = 4 to 42)	3.7:1 (steepest = 0.9:1)	At downstream edge by the start of an intermediate plateau (decrease in slope height) At upstream edge by the end of an intermediate plateau (increase in slope height)	Stable
S13	640	20.5 (range = 7 to 29)	2.7:1 (steepest = 1.3:1)	At downstream edge by the start of an intermediate plateau (decrease in slope height) At upstream edge by an increase in the slope angle	Stable
S14	1,945	39.5 (range = 28 to 51)	2.1:1 (steepest = 0.2:1)	At downstream edge by an increase in the slope angle At upstream edge by the end of an intermediate plateau (increase in slope height)	Further Analysis Req.
S15	460	56.3 (range = 10 to 64)	1.9:1 (steepest = 0.2:1)	At downstream edge by the end of an intermediate plateau (increase in slope height) At upstream edge by a decrease in the slope angle	Further Analysis Req.
S16	1,105	35.5 (range = 6 to 44)	2.9:1 (steepest = 1:1)	At downstream edge by a decrease in the slope angle At upstream edge by a decrease in the slope height	Stable
S17	950	12.5 (range = 3 to 19)	3.6:1 (steepest = 1.3:1)	At downstream edge by a decrease in the slope height At upstream edge by the end of the slope (decrease in slope angle)	Stable
S18	1,565	20.7 (range = 5 to 29)	2.8:1 (steepest = 0.2:1)	At downstream edge by the start of the slope (increase in slope height) At upstream edge by a decrease in the slope height (edge of the diatomite)	Further Analysis Req.
S19	1,945	7.3 (range = 0 to 16)	4.5:1 (steepest = 1.2:1)	At downstream edge by the end of the slope (decrease in the slope height) At upstream edge by the end of the slope (decrease in slope angle)	Stable
S20	3,370	18.7 (range = 0 to 30)	3.7:1 (steepest = 0.2:1)	At downstream edge by the start of the slope (increase in slope angle) At upstream edge by the end of the slope (edge of the diatomite)	Stable

3.4.3 Slope Stability Analysis Methodology

The slope stability of individual sections (and the initial generalized analyses) was analyzed using the software SLOPE/W (GeoStudio 2018) and Morgenstern-Price's procedure (with a half-sine function) for the calculation of factor of safety. KRRC used a circular slip surface without optimization for the analyses unless otherwise noted.

The different analyses performed for the sections are discussed below. The rapid drawdown analyses were performed for every section analyzed, while the other existing conditions, long-term (post drawdown), and historical drawdown analyses were only performed on sections that had a factor of safety less than 1.15, to confirm the validity of the model.

Rapid Drawdown

Rapid drawdown analyses were performed using a staged rapid drawdown analysis approach proposed by Duncan et. al. (1990). During rapid drawdown, the stabilizing effect of the reservoir on the slope is absent but the pore water pressures within the slope remain high in materials with low permeability. The high pore pressures in combination with the lack of the stabilizing effect from the reservoir can lead to significantly reduced slope stability.

The diatomite was modeled with undrained shear strength parameters in the analysis. This model approach is reasonable considering the fact that the diatomite would take long time to drain because it has a very low permeability of about $1x10^{-6}$ cm/s. The recent reservoir sediment was also modelled in a similar fashion, although that choice is inconsequential to the stability of the slope overall since it makes up only a small percentage of the slope.

The groundwater was initially set as a horizontal line at Elevation +2,605 feet (the same as the existing conditions) and then drawn down to a horizontal line at the existing thalweg ground surface.

Historical Drawdown

Based on the historical drawdown information shown in Figure 3-1, KRRC performed a rapid drawdown analysis using the same method as the rapid drawdown analyses above but with a water level drop from Elevation +2,610 to +2,596. KRRC used this analysis to verify the model due to the fact that no landslides were observed during any of the previous drawdown events.

Existing Conditions

KRRC performed the existing condition analyses to assess the current stability of the slope. This analysis serves as verification of the model since there are no reported active slope instabilities around Copco No. 1 reservoir. These analyses used the drained (effective) strength parameters for all materials and the groundwater was set as a horizontal line at Elevation +2,605 feet based on the water level in the reservoir at the time of drilling.

Long-Term (Post Drawdown)

KRRC performed the long-term analyses to assess the stability of the slope after all the excess pore pressures from drawdown have dissipated. This analysis was also done to validate the model since the slopes, particularly those submerged in the reservoir, were at least semi-stable before the reservoir was filled. These analyses used drained (effective) strength parameters for the diatomite and groundwater was set as a horizontal line at the existing thalweg ground surface.

3.4.4 Slope Stability Analysis Results

A summary of the results of the slope stability analyses are presented below. KRRC used a factor of safety of 1.15 as the pass/fail criteria due to the critical nature of some areas and the lack of specific data at most of these locations. Figure 3-4 shows a plan view of the current analysis results, and Figure 3-5 shows cross section results for the rapid drawdown analyses.

Sensitivity Analyses

The shear strength of the diatomite is the parameter that has the greatest influence on the slope stability analysis results. Therefore, sensitivity analyses will be performed by assuming different interpretations of the laboratory strength test results for samples of diatomite, as shown in Figure 3-3 and summarized in Table 3-5. Using the strengths shown, any sections with factors of safety between 1.15 and 1.3 will be analyzed and included in the final report.

Table 3-5 Summary of Strength Parameters of Diatomite Used for Sensitivity Analysis

Strength Type	Selected Strength		Lower Cohesion Fit		Lower Friction Angle Fit	
	C (psf)	Φ (degrees)	C (psf)	Φ (degrees)	C (psf)	Φ (degrees)
Drained (effective) Strengths	150	35.3	75	36.5	300	32.5
Undrained (total) Strengths	660	19.9	330	24.5	1000	15

Figure 3-4 Summary of Segment Extents and Current Results (Attachment A)

Figure 3-5 Rapid Drawdown Analysis Cross Sections (Attachment A)

Table 3-6 Stability Analysis Summary

Segment	GIS Analysis Result	Cross Section Details		Slope Stability Analysis Results			
		Maximum Slope (H:V)	Slope Height (feet)	Rapid Drawdown	Historical Drawdown	Existing Conditions	Long-Term Conditions
N2	Further Analysis Req.	In Progress					
N4	Further Analysis Req.	In Progress					
N5	Further Analysis Req.	In Progress					
N7	Not Completed (Further Analysis Req.)	In Progress					
N9	Stable (GIS Analysis Check)	In Progress					
N10	Not Completed (Further Analysis Req.)	1.8:1	65	2.01	-	-	-
N11	Not Completed (Further Analysis Req.)	1.1:1	54	1.71	-	-	-
N12	Not Fully Completed (Further Analysis Req.)	In Progress					
N14	Further Analysis Req.	In Progress					
N16	Further Analysis Req.	In Progress					
N18	Not Completed (Further Analysis Req.)	In Progress					
N20	Further Analysis Req.	In Progress					
S1	Further Analysis Req.	1.9:1 (0.4:1 bluff)	163 (97 from water level)	1.09	1.66	1.53	2.26
S2	Stable (GIS Analysis Check)	In Progress					
S3	Further Analysis Req.	1.6:1	53	1.0	2.87	2.87	1.75
S4	Further Analysis Req.	In Progress					
S7	Further Analysis Req.	In Progress					
S8	Stable (GIS Analysis Check)	In Progress					
S9	Further Analysis Req.	In Progress					
S10	Further Analysis Req.	1.1:1	72	1.03	2.56	2.68	1.62

Segment	GIS Analysis Result	Cross Section Details		Slope Stability Analysis Results			
		Maximum Slope (H:V)	Slope Height (feet)	Rapid Drawdown	Historical Drawdown	Existing Conditions	Long-Term Conditions
S11	Further Analysis Req.	1.9:1	159 (81 from water level)	0.99	1.89	1.38	2.18
S14	Further Analysis Req.	In Progress					
S15	Further Analysis Req.	In Progress					
S18	Further Analysis Req.	0.7:1	29	1.39	-	-	-

3.4.5 Future Analyses and Investigations

While the analyses discussed above are still preliminary, the results indicate that certain areas or segments may have the potential for slope instability as a result of the project activities. Some of these segments are below the current reservoir water surface, and slope failures within these segments would not impact existing roads or private property/structures. KRRC does not propose additional field investigations for these segments.

For other segments, slope failure could result in impacts to existing roads or private property/structures. For each of these segments, KRRC will complete a boring or borings during the summer of 2018. KRRC will use boring logs and laboratory data to update the stability analyses completed to date to better understand the potential for slope failure and any project actions that may be required to offset the impact.

In addition to field investigations above, KRRC may complete additional analyses along certain segments, as appropriate, including:

- Deformation analysis of select profiles, as necessary, to assess the impact area of potential slope failures
- Sensitivity analyses of the impact of variations in the strength of the diatomite on the slope stability analysis results (as mentioned above)
- Analyses of possible engineered solutions (retaining wall, etc.), as appropriate

3.5 Conclusions

When discussing reservoir rim stability during drawdown, it is important to differentiate between the potential for deep-seated large landslides along the reservoir rim that could impact roads or property, and slides of material beneath the current water surface, which would only impact resources within the local limited slide footprint.

Minor, shallow slides of existing material beneath the existing reservoir water surfaces are possible during drawdown. These minor slides would not extend outside of the current reservoir footprint and would only potentially impact resources within the limited slide footprint (e.g. cultural resources). Some larger deeper slides are also possible within Copco No. 2 reservoir where submerged higher bluffs exist along the original Klamath River channel. These shallow slides and potential slides along the river channel pose no threat to roads or private property; however, KRRC will monitor these areas during and post-drawdown to assess any potential impact to existing cultural resources.

The geologic assessment and slope stability analysis summarized above indicate that certain segments along the Copco No. 1 reservoir rim have a potential for slope failure that could impact existing roads and/or private property. In some areas, the impact could be relatively minor, while in other areas the impact could be greater. Based on the referenced analysis, approximately 3,700 linear feet of slopes along Copco Road (north shore segments S4, S9, S11 and S15), and approximately 2,800 linear feet of slope adjacent to private property (along south shore – segments N9, N14, N16and N14) require additional field investigation and analysis to gain a more refined understanding of slope stability in those areas. Up to eight parcels along the referenced segments appear to have existing habitable structures that could potentially be impacted.

Additional field geologic data is required to confirm the potential for slope failure along the referenced reservoir rim segments. KRRC will complete the additional field investigation in July and August of 2018, followed by completion of a series of material property laboratory tests. KRRC will use results from the field investigation and laboratory testing to update stability assessments in the rim segments of concern in fall 2018. Should additional study determine that there is a high probability of slope failure in any of these areas, KRRC will consider the following actions to offset potential impacts:

1. For segments along Copco Road:
   a) Re-align of road segment away from rim slope
   b) Engineer structural slope improvements (e.g. drilled shafts or other structural elements that could be installed to resist slope movement)
2. For segments adjacent to property or structure:
   a) Move structure or purchase property
   b) Engineer structural slope improvements (e.g. drilled shafts or other structural elements that could be installed to resist slope movement)

Based on the low permeability of the diatomite, changing the drawdown rate would have minimal impact on the rapid drawdown stability analysis results. Therefore, KRRC is not proposing to limit the drawdown rate for drawdown of Copco No. 1 reservoir.

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Chapter 4: Iron Gate Reservoir

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4. IRON GATE RESERVOIR

4.1 Historical Investigations and Drawdowns

4.1.1 Historical Investigations

Historic subsurface geologic data at Iron Gate reservoir includes sediment sampling completed in 2006 (Shannon & Wilson, 2006). None of the borings for this previous investigation were deep enough to provide information useful for reservoir rim stability analysis.

4.1.2 Historical Drawdowns

Iron Gate Reservoir levels between January 1, 1979, and December 31, 2016, KRRC reviewed for historical occurrences of reservoir drawdown. The four most significant drawdown events occurred in the falls of 2004, 2014, 2015, and 2016 (see Figure 4-1).

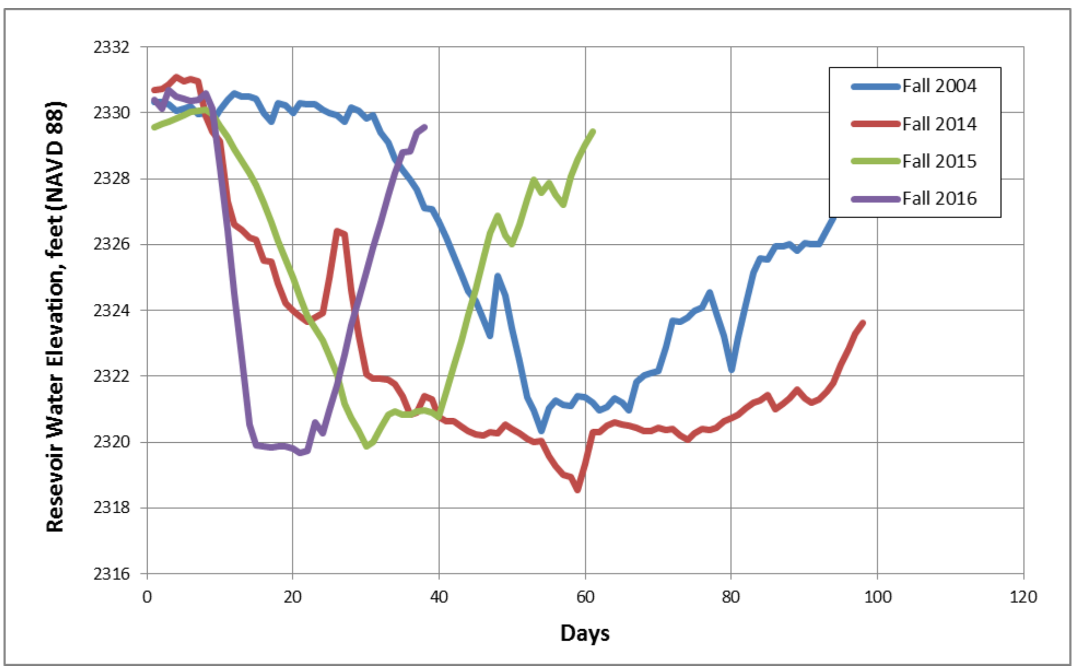

Figure 4-1 Iron Gate Reservoir Maximum Historical Drawdown Events (1979 to 2016)

The magnitude of the drawdowns ranged from about 9 feet to 14.5 feet. The maximum daily drawdown rate of 2 feet per day occurred in 2014. Based on inquiries made to PacifiCorp, there were no reported slope failures resulting from these drawdowns (email with Demian Ebert August 2, 2017).

4.2 Project Investigations

KRRC performed geologic mapping and subsurface investigations at Iron Gate Reservoir to characterize past landslides and for design of the replacement Yreka waterline.

Drilling within the reservoir area was performed over water from a small platform barge using a CME-45 drill rig for borings BI-01 and BI-03. Land-based drilling was performed with a truck-mounted CME-75 drill rig for BI-02. Taber Drilling of West Sacramento advanced the three rotary wash borings between February 20 and 23, 2018. The boring depths ranged from 22.2 to 67 feet. Figure 4-2 shows boring locations. Table 4-1 summarizes the exploratory boring data, including depth and elevation of volcanic bedrock, where encountered. Attachment A provides boring logs. KRRC obtained soil samples using standard penetration test (SPT) and 2.5-inch I.D. modified California (MC) drive samplers. KRRC recorded blow counts at 6-inch intervals for drive samples.

Table 4-1 Summary of Exploratory Boring Data (Iron Gate Reservoir)

Boring Name	Total Depth (feet)	Northing	Easting	Elevation (feet)	Depth to Rock (feet)
BI-01	22.2	2600814	6450534	2315.1	11.5
BI-02	67	2602024	6461383	2326.7	17.5
BI-03	35.1	2601812	6461399	2302.2	3.8

4.2.1 Summary of Subsurface Conditions

Boring BI-01 was completed to assess the rim stability around Iron Gate Reservoir. The boring encountered approximately 2 feet of recent lake sediment consisting of lean clay with organics which overlay approximately 9.5 feet of colluvium/residual soil consisting of lean clay. Below the colluvium/residual soil the boring encountered volcanic bedrock consisting of basalt and volcaniclastics.

Borings BI-02 and BI-03 were advanced as part of the design of the replacement Yreka waterline. While not directly related to rim stability, the results of these explorations were useful to develop estimates of rock strength for the analyses around Copco No. 1 reservoir. The two borings showed approximately 3.8 (BI-03) to 17.5 (BI-02) feet of alluvium (older and younger) consisting of lean clay with varying amounts of sand and gravel, clayey sand with gravel, and poorly graded gravel. Volcanic bedrock consisting of tuff breccia underlay the alluvium.

4.3 Geologic Characterization

4.3.1 Previous Mapping

Previously published geologic mapping of the Iron Gate Dam and lake area include:

- *Volcanic Formations Along the Klamath River Near Copco Lake, Siskiyou County,* PAUL E. HAMMOND, Department of Geology, Portland State University, Portland, Oregon; California Geology, May 1983.
- *Geology of the Macdoel Quadrangle,* HOWEL WILLIAMS , California Division of Mines and Geology Bulletin 151, November, 1949
- *Geotechnical Report, Klamath River Dam Removal Project, California and Oregon, Project No. 07-153,* PanGEO Incorporated, prepared for Philip Williams & Associates, Ltd. And California State Coastal Conservancy, August, 2008.
- *Geologic Map of the Weed Quadrangle,* D. L. Wagner and G. J. Saucedo, California Division of Mines and Geology, 1987)

PanGEO (2008) provide a thorough description of regional and local geology for Iron Gate area, including a geologic map compiled from Williams (1949) and Hammond (1983) that includes structural data from site reconnaissance in a 2008 Geotechnical Report for this project. Pertinent data is included in this evaluation.

4.3.2 Geologic and Surficial Mapping

Iron Gate Dam and its reservoir lie entirely within the Western Cascades geologic province. Hammond (1983) suggests that the volcaniclastic formation that he informally named the Beds of Bogus Mountain extends into the Iron Gate area (PanGEO 2008). Bedrock units include tuffaceous siltstones and sandstones, bouldery volcaniclastics and volcanic breccia, rhyolite tuff and tuff breccia, and pyroxene flow rocks. Geologic reconnaissance indicates generally shallow bedrock with a thin soil mantle. Surficial geologic units including landslide and alluvial deposits are not differentiated from the underlying volcanic rocks in previously published mapping.

PanGEO (2008) identified three possible landslide related features on the south rim of the reservoir (Figure 4-2), and characterized these as “weakly suggestive of old landslides ranging from small slumps only a few meters in size up to possible slides covering several square miles”. These existing features are considerations in the rim stability conclusions described in Section 4.4.

For this study, the KRRC reviewed the 2010 LiDAR-derived terrestrial digital elevation model (DEM), recently acquired high-resolution bathymetric survey data (GMA, 2018), and pre-dam stereoscopic aerial photographs (1944 and 1951) for the entire lake area. KRRC used these data to develop a detailed surficial geologic map (Figure 4-2). While some bedrock and structural data is included in this mapping, the primary intent is to identify larger surficial deposits along the lakeshore and in lake bed that could become unstable during drawdown. In addition to DEM and photo review, KRRC performed site reconnaissance along public roadways around the reservoir during the week of June 5, 2017, and the week of July 24, 2017. KRRC performed additional reconnaissance of the lake shoreline on October 5, 2017 using a small powered row boat. Based on preliminary reconnaissance, before bathymetric surveys were performed, boring BI-01 was located to investigate the toe zone of a possible landslide identified by PanGEO (2008). As noted in Section 4.2.1, the results of this boring did not indicate a slide deposit and encountered volcanic bedrock approximately 10 feet below the pre-dam surface.

Features previously identified by PanGEO as well as several other features with possible landslide morphology identified by the KRRC are delineated as shown on Figure 4-2. These features appear unchanged from 1944 and 1951 historical aerial photographs, and do not show indications of recent activity on the LiDAR/Bathymetric DEM. The morphology of the two larger features appears more consistent with differential erosion of different volcanic/volcaniclastic bedrock units or in the case of the western feature, possible volcanic flow collapse during or immediately after emplacement. The third, smallest potential landslide identified by PanGEO (2008) may represent a small, dormant slide, but the narrow width indicates a rather shallow slide surface that, if reactivated, does not pose a significant hazard.

The reservoir slopes in the area downstream of Jenny Creek exhibit some degree of bench and scarp morphology, sometimes associated with large, deep-seated landslides. The prevalence of outcrops with variable volcanic rock lithologies, the lack of indications recent activity, and consistent appearance on historic aerial photographs suggests that this morphology is most likely the result of bedrock structure, including volcanic flow rock emplacement, and differential weathering. Some of the bench surfaces may also be the result of past fluvial erosion.

One larger, likely landslide was identified along Copco Road within the peninsula between the east and west arms of the reservoir. KRRC based the identification on the presence of a subdued, 10- to 20-foot high break in slope that may represent the head scarp of a dormant, block-slide type feature. This feature does not have any indication of recent slope movement and is unchanged in historic aerial photos. As KRRC interprets the toe of this feature to lie in a small tributary drainage above the reservoir rim, it is very unlikely to be affected by drawdown.

Figure 4-2: Geologic Overview of Iron Gate Reservoir (Attachment A)

4.4 Conclusions

Much of the bedrock mapped around the rim of Iron Gate Reservoir consists of volcanic flow rock, rhyolite tuff and tuff breccia. The extent and morphology of these outcrops and general lack of surficial deposits suggest a shallow weathering profile that is interpreted to form generally stable reservoir slopes under drawdown conditions. Existing structural data (PanGEO 2008) and reconnaissance performed by the KRRC are in line with this interpretation.

Beds of Bogus Mountain are mapped at the very upstream end of the reservoir, but the outcrop pattern and structural measurements indicate the beds strike normal to the slope and dip gently to the east. PanGEO (2008) mapped volcaniclastic beds on the northwest arm of the reservoir, to the north and east of Juniper Point, dipping gently to the west. On the west facing, eastern slope of the reservoir, this orientation has the potential for structural block slide slope failure, however, the gentle slope, lack of historical movement and very low submarine relief indicate this type of failure is very unlikely in this area.

Shallower slides are likely to occur in the shallow surficial deposits around the reservoir rim and on the reservoir slopes that are currently below the reservoir surface. Small, shallow soil failures in the more deeply weathered volcaniclastic beds and in colluvial deposits present a minor hazard to Copco Road where the road is immediately adjacent to the shore. These slope failures are likely to be shallow and local, but may possibly require minor repair to maintain full use of the roadway. Minor repair may include installation of riprap on slope adjacent to Copco Road and/or road surface rehabilitation.

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Chapter 5: References

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5. REFERENCES

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Attachment A Figures

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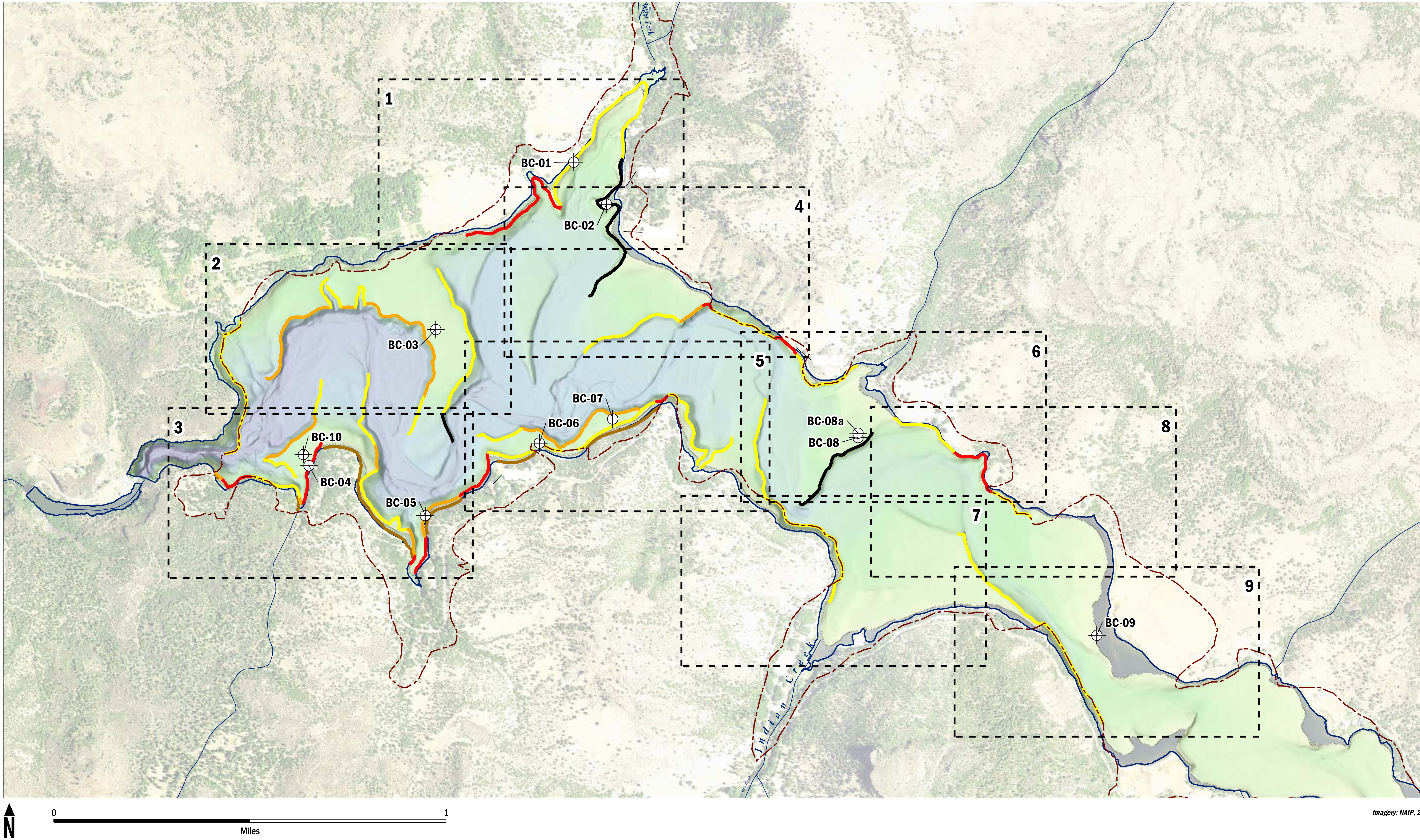
FIGURE 3-2
Geologic Overview of Copco Lake



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Klamath River Renewal Project

Borings

Mapbook Sheet Extent

Extent of Fluvio-Lacustrine Deposits

Volcanic Rock Exposed in Shoreline Notch

Current Reservoir Shoreline

Slope Failure Analysis Features

Incomplete Analysis

Stable Slope

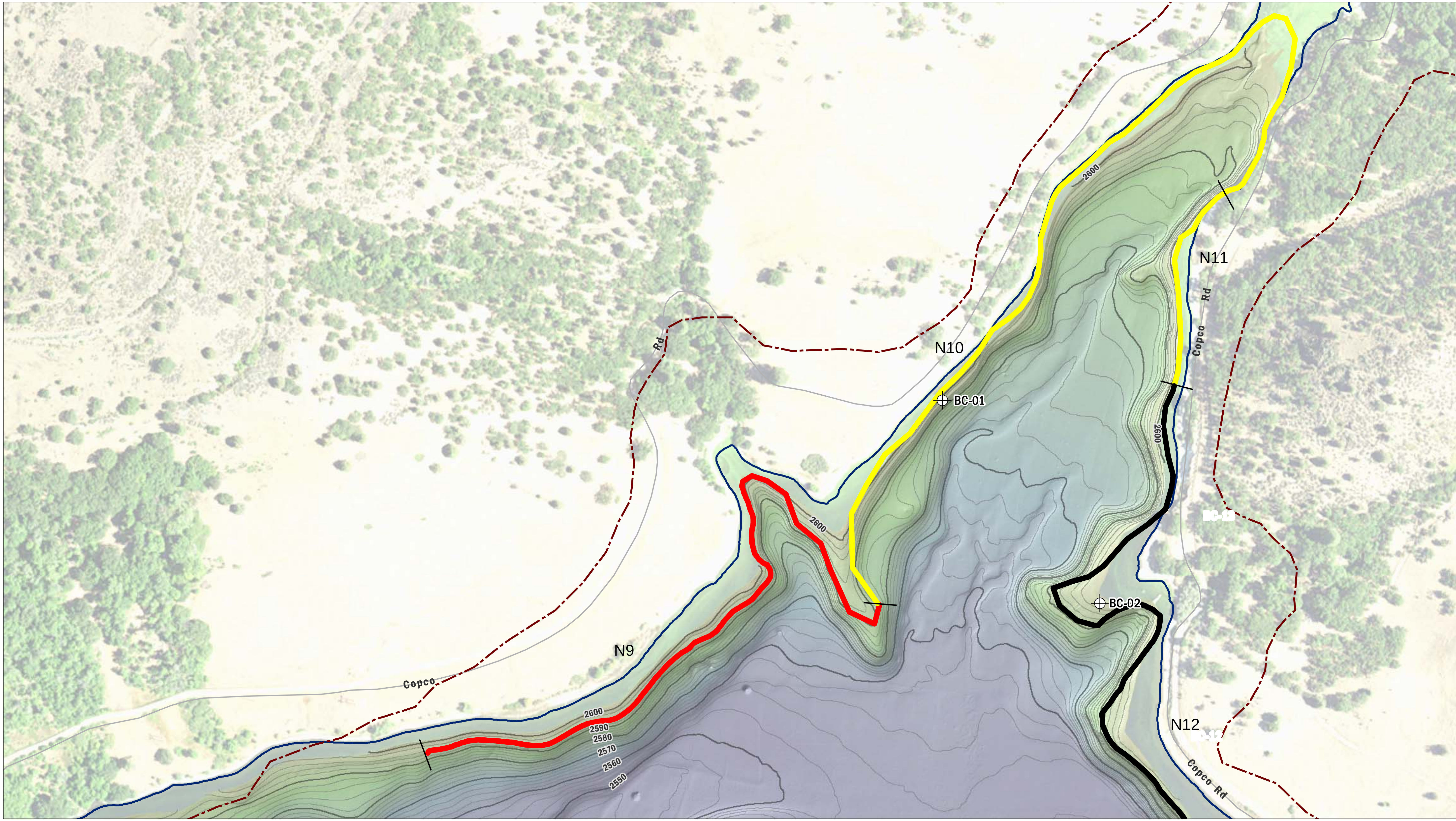
Potentially Unstable Slope (failure contained within reservoir)

Potentially Unstable Slope

FIGURE 3-4

Copco Dam - Slope Failure Analysis

Overview Map



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Imagery: NAIP, 2014

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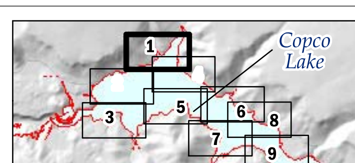


Borings

Extent of Fluvio-Lacustrine Deposits

Current Reservoir Shoreline

Slope Failure Analysis Features

Incomplete Analysis

Stable Slope

Potentially Unstable Slope

Bathymetric Contours

2 ft.

10 ft.

Segment Information

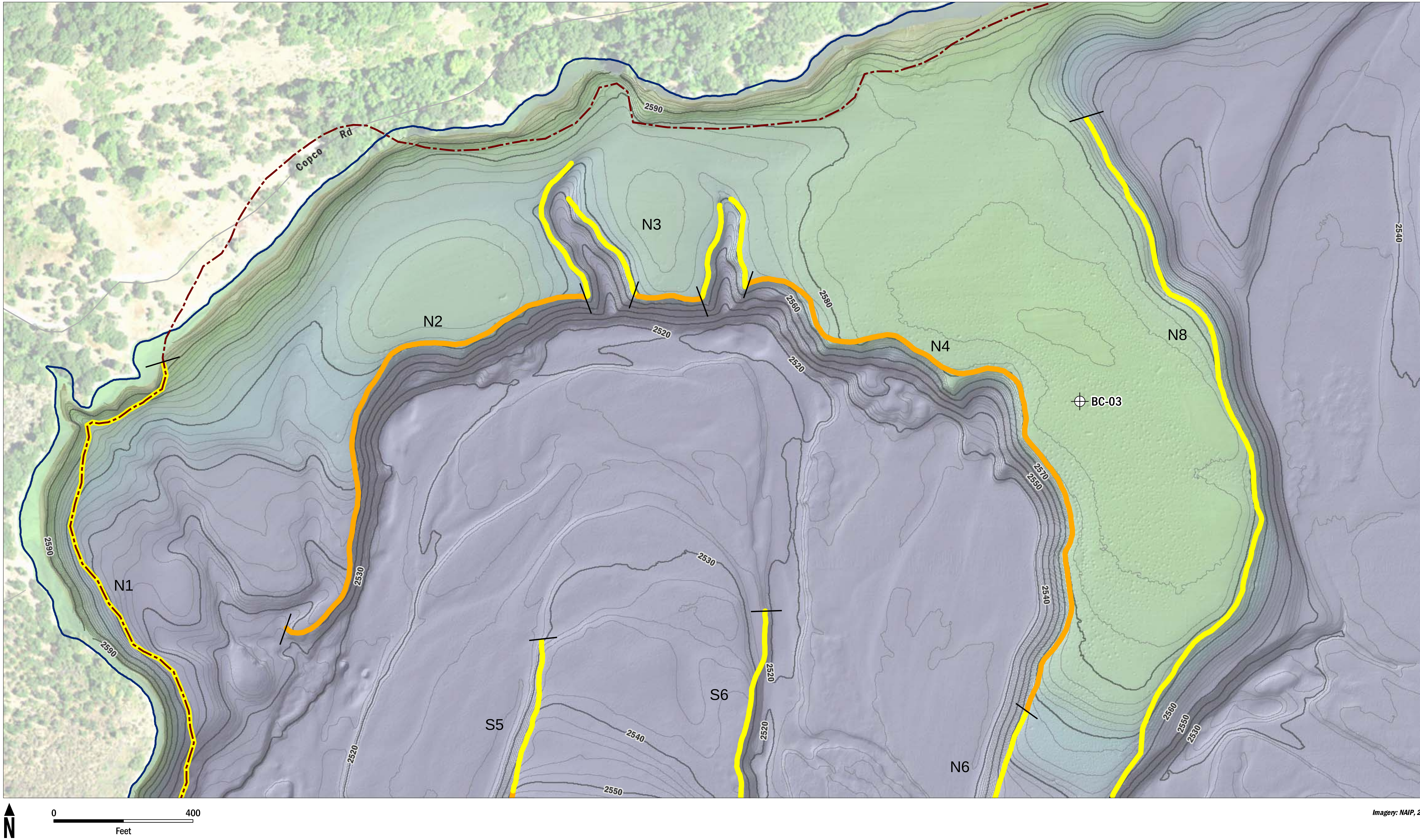
Segment Extents

N1 Segment Names

FIGURE 3-4

Copco Dam - Slope Failure Analysis

Sheet 1 of 9



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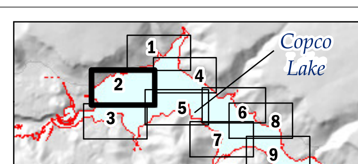


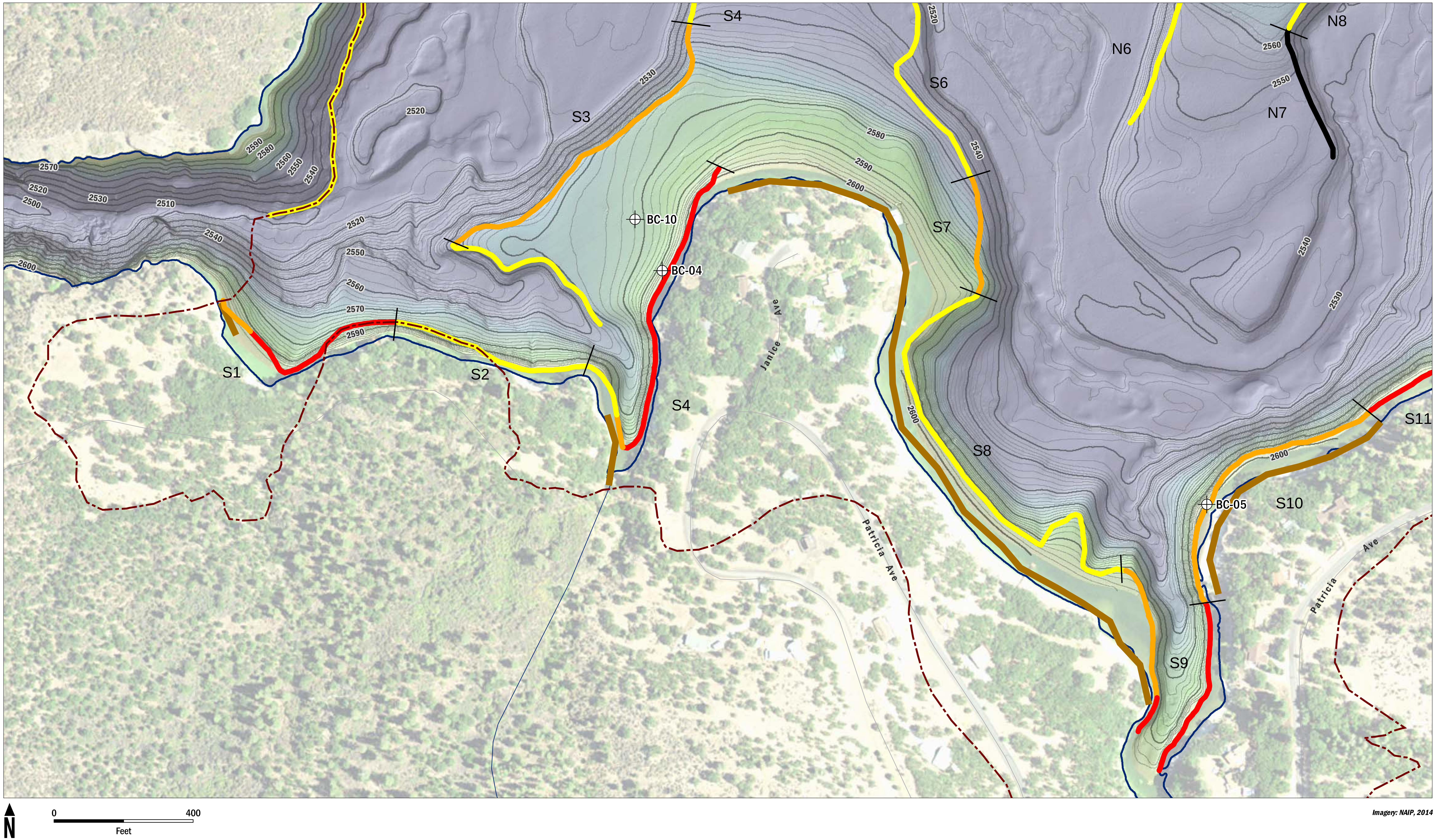
Borings
Extent of Fluvio-Lacustrine Deposits
Current Reservoir Shoreline

Slope Failure Analysis Features
Incomplete Analysis
Stable Slope
Potentially Unstable Slope (failure contained within reservoir)

Bathymetric Contours
2 ft.
10 ft.

Segment Information
Segment Extents
N1 Segment Names

FIGURE 3-4
Copco Dam - Slope Failure Analysis
Sheet 2 of 9



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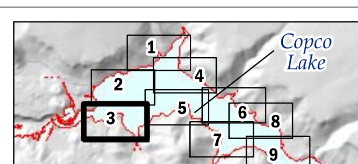


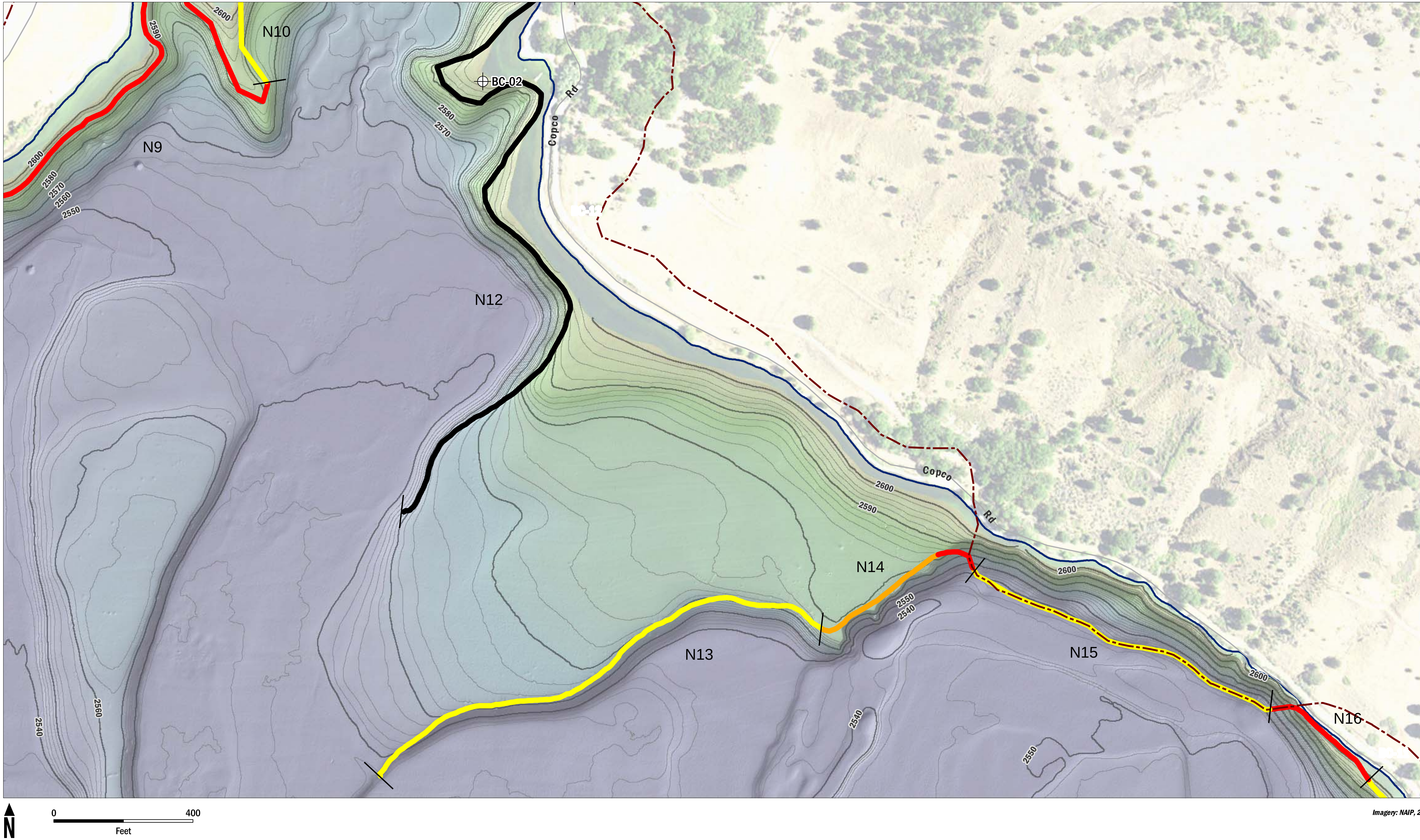
Borings
Extent of Fluvio-Lacustrine Deposits
Volcanic Rock Exposed in Shoreline Notch
Current Reservoir Shoreline

Slope Failure Analysis Features
Incomplete Analysis
Stable Slope
Potentially Unstable Slope (failure contained within reservoir)
Potentially Unstable Slope

Bathymetric Contours
2 ft.
10 ft.

Segment Information
Segment Extents
N1 Segment Names

FIGURE 3-4
Copco Dam - Slope Failure Analysis
Sheet 3 of 9



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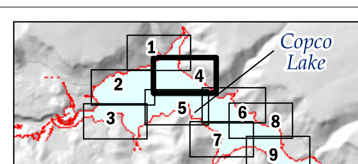


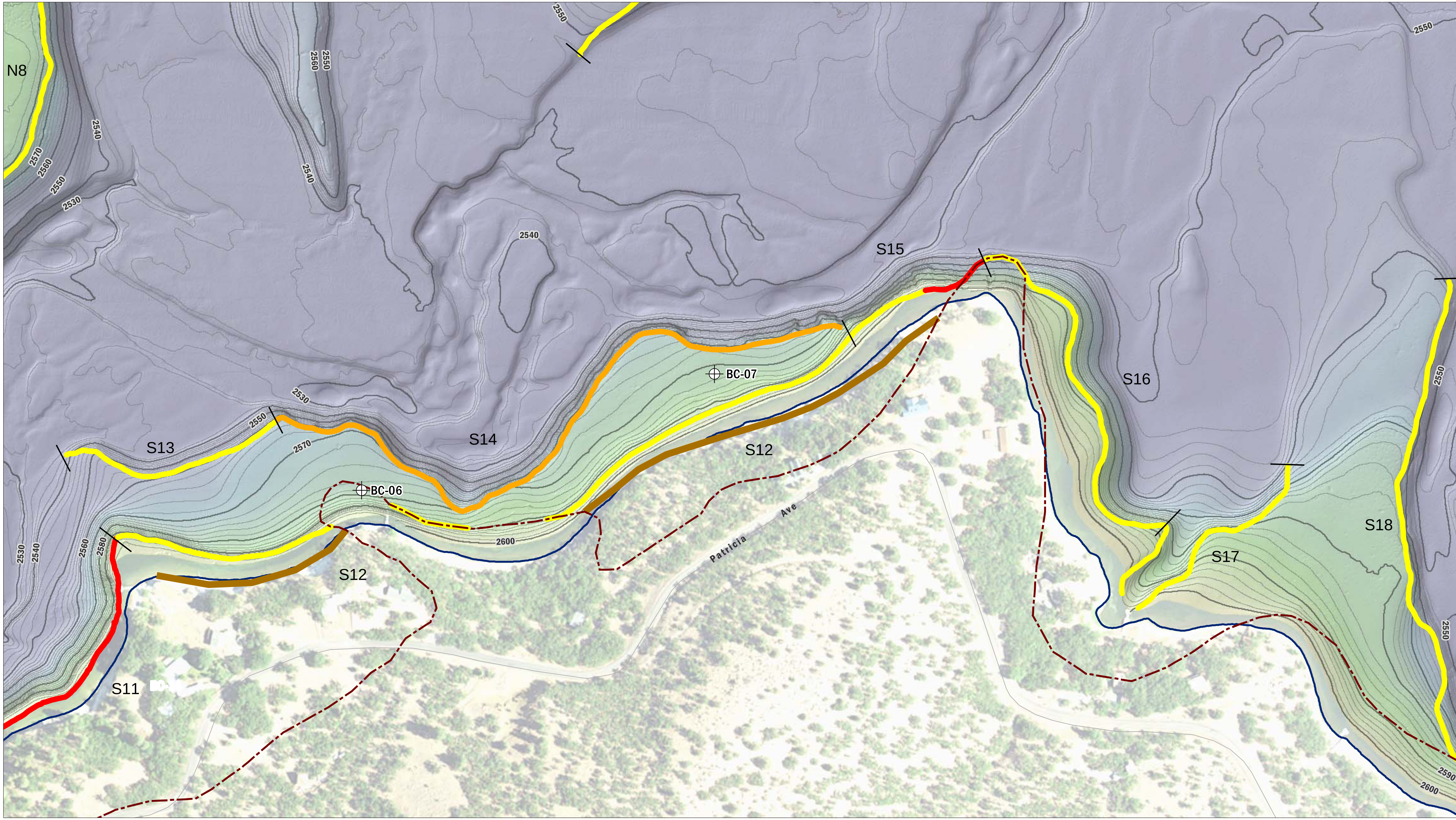
Borings
Extent of Fluvio-Lacustrine Deposits
Current Reservoir Shoreline

Slope Failure Analysis Features
Incomplete Analysis
Stable Slope
Potentially Unstable Slope (failure contained within reservoir)
Potentially Unstable Slope

Bathymetric Contours
2 ft.
10 ft.

Segment Information
Segment Extents
N1 Segment Names

FIGURE 3-4
Copco Dam - Slope Failure Analysis
Sheet 4 of 9



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Imagery: NAIP, 2014

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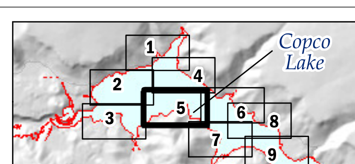
Klamath River Renewal Project



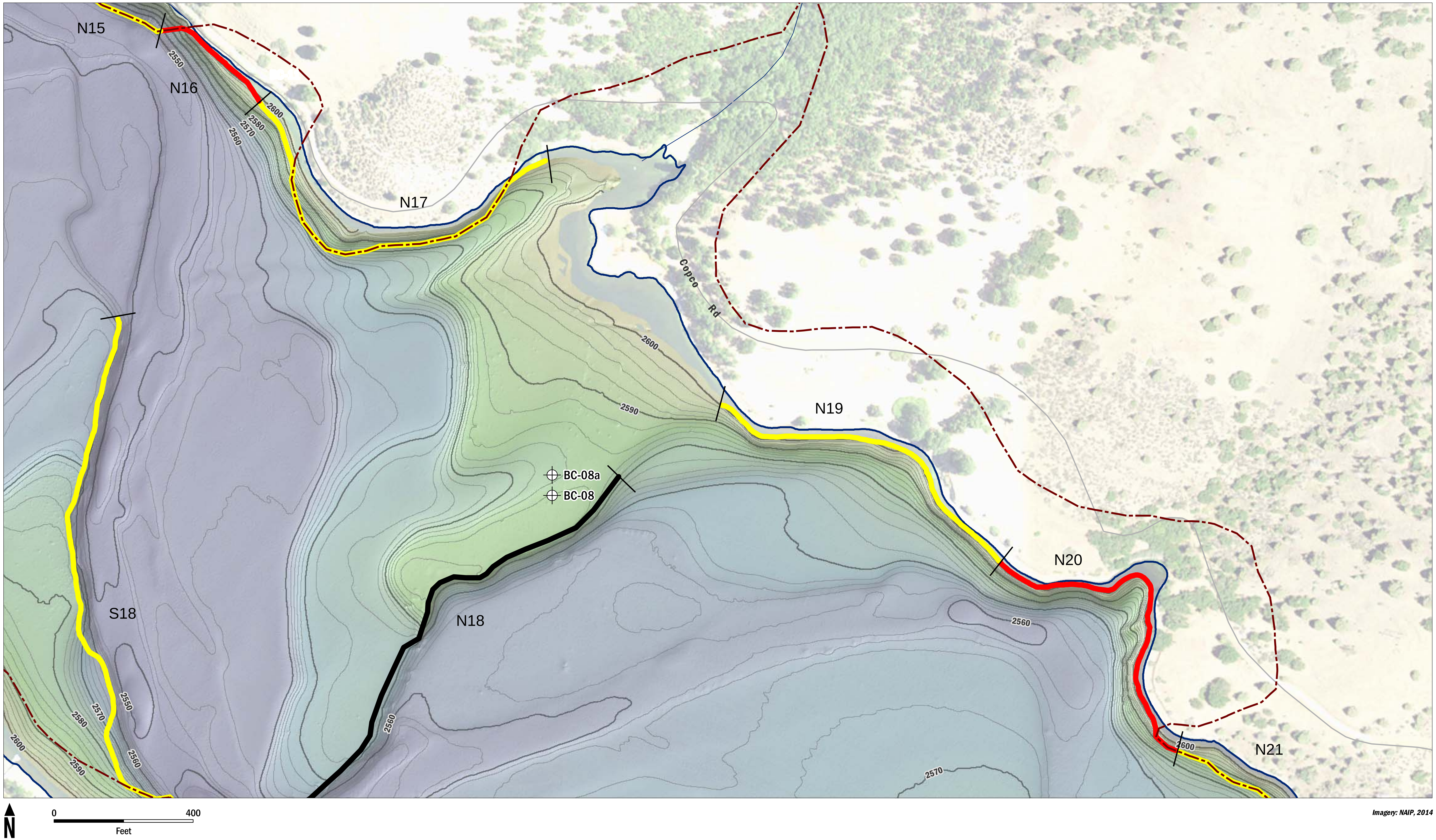
Borings
Extent of Fluvio-Lacustrine Deposits
Volcanic Rock Exposed in Shoreline Notch
Current Reservoir Shoreline

Slope Failure Analysis Features
Stable Slope
Potentially Unstable Slope (failure contained within reservoir)
Potentially Unstable Slope

Bathymetric Contours
2 ft.
10 ft.

Segment Information
Segment Extents
N1 Segment Names

FIGURE 3-4
Copco Dam - Slope Failure Analysis
Sheet 5 of 9



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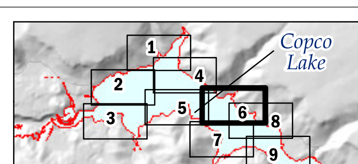


Borings
Extent of Fluvio-Lacustrine Deposits
Current Reservoir Shoreline

Slope Failure Analysis Features
Incomplete Analysis
Stable Slope
Potentially Unstable Slope

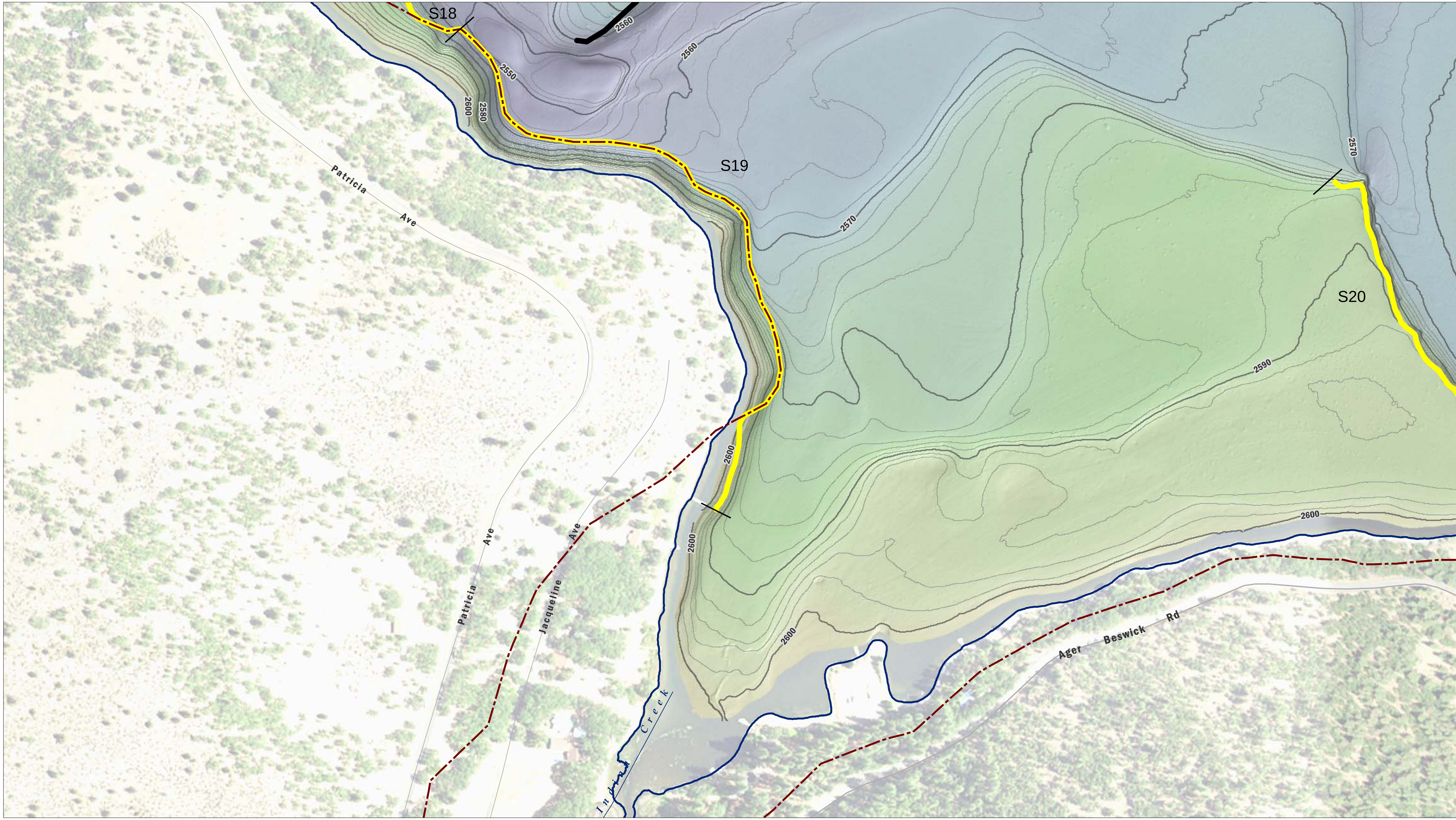
Bathymetric Contours
2 ft.
10 ft.

Segment Information
Segment Extents
N1 Segment Names

FIGURE 3-4

Copco Dam - Slope Failure Analysis

Sheet 6 of 9



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Imagery: NAIP, 2014

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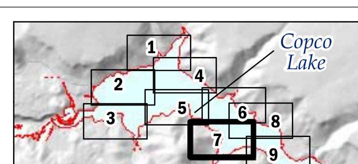
Klamath River Renewal Project



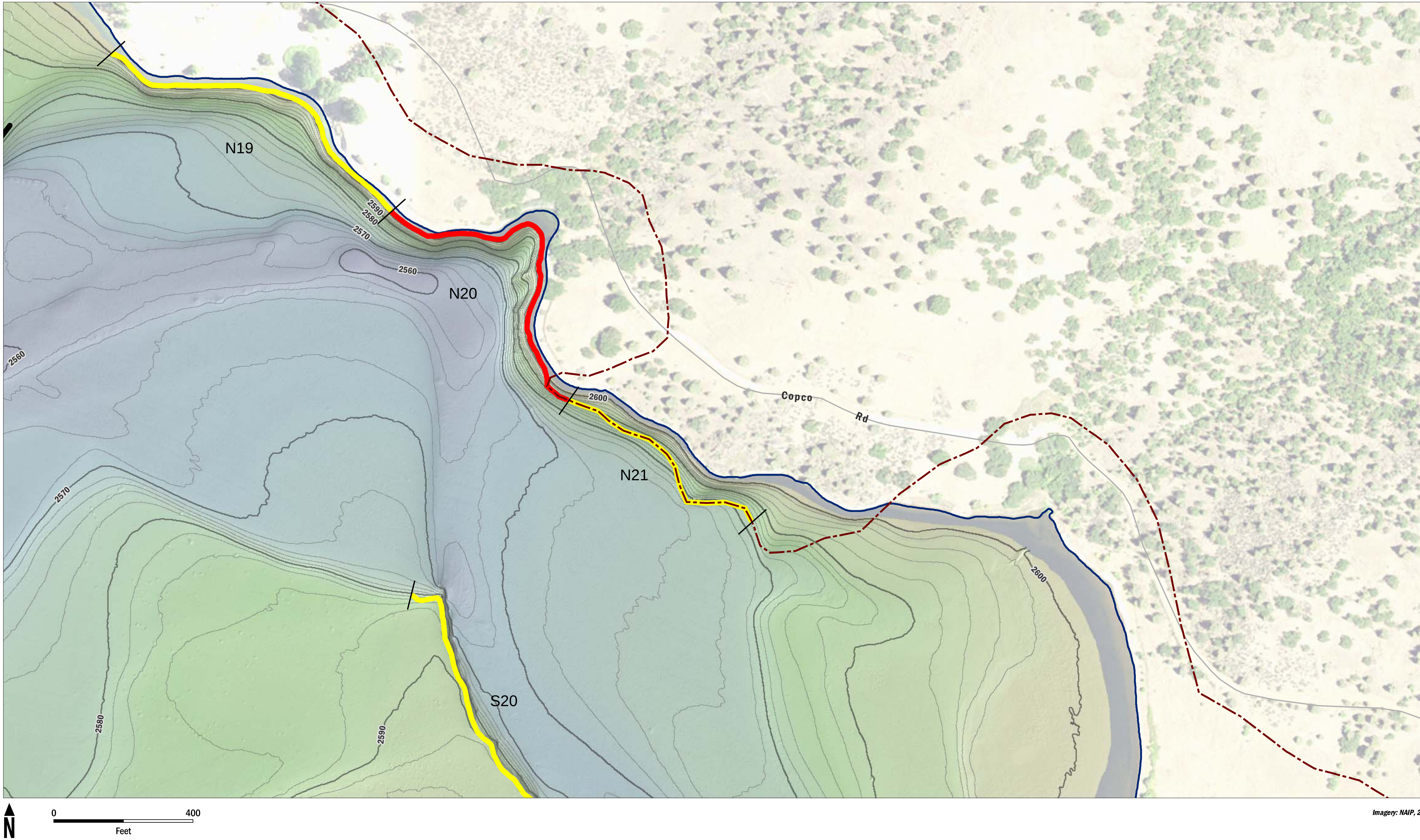
Extent of Fluvio-Lacustrine Deposits
Current Reservoir Shoreline

Slope Failure Analysis Features
Incomplete Analysis
Stable Slope

Bathymetric Contours
2 ft.
10 ft.

Segment Information
Segment Extents
N1 Segment Names

FIGURE 3-4
Copco Dam - Slope Failure Analysis
Sheet 7 of 9



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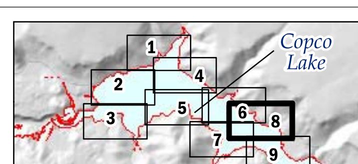


Extent of Fluvio-Lacustrine Deposits

Current Reservoir Shoreline

Slope Failure Analysis Features

Incomplete Analysis

Stable Slope

Potentially Unstable Slope

Bathymetric Contours

2 ft.

10 ft.

Segment Information

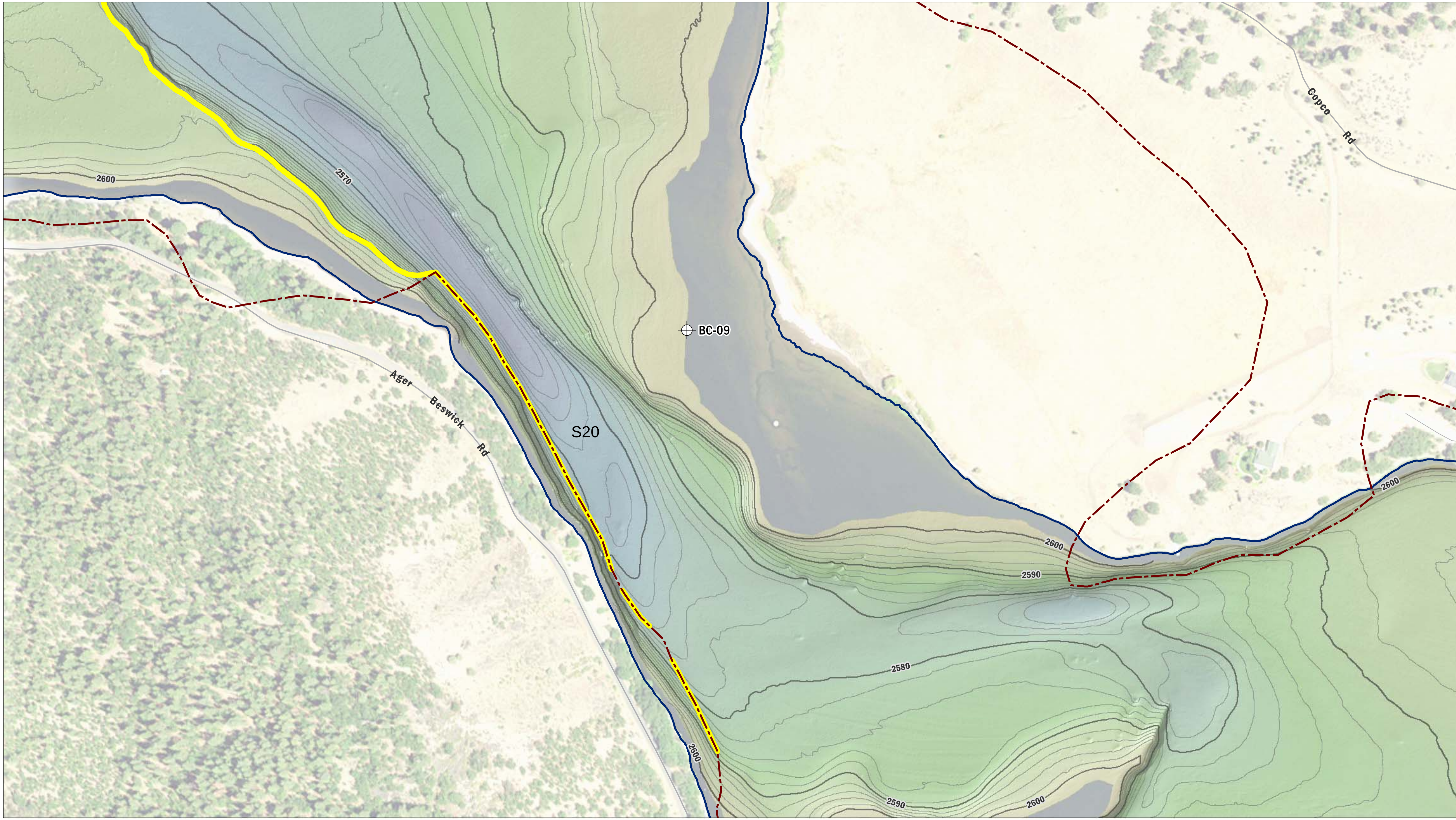
Segment Extents

N1 Segment Names

FIGURE 3-4

Copco Dam - Slope Failure Analysis

Sheet 8 of 9



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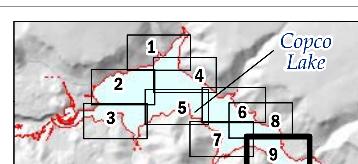


Borings

Extent of Fluvio-Lacustrine Deposits

Current Reservoir Shoreline

Slope Failure Analysis Features

Stable Slope

Bathymetric Contours

2 ft.

10 ft.

Segment Information

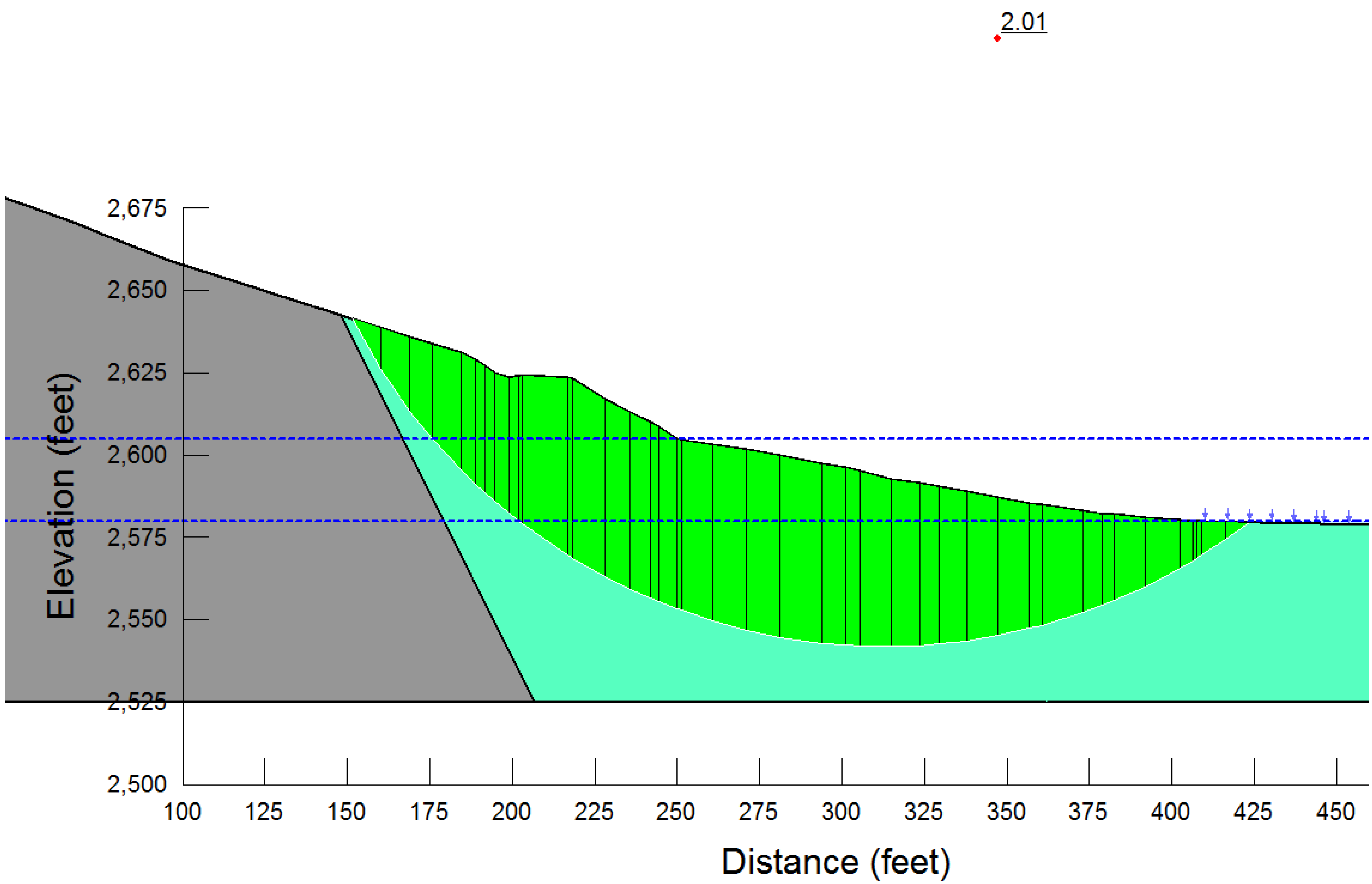
Segment Extents

N1 Segment Names

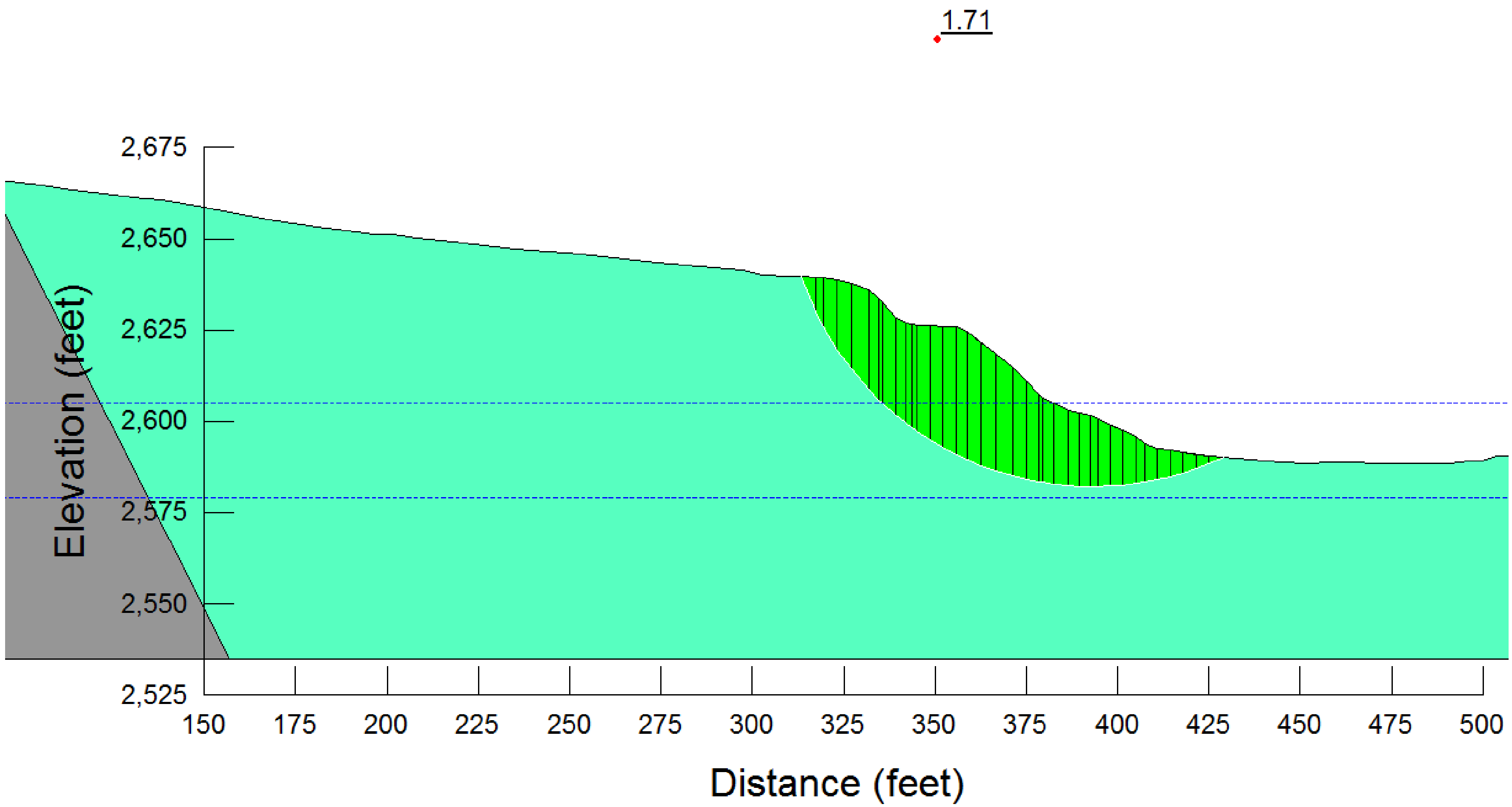
FIGURE 3-4

Copco Dam - Slope Failure Analysis

Sheet 9 of 9



Klamath River Renewal Corporation	Copco Reservoir Slope Stability Segment N10, Section 1 Rapid Drawdown Analysis	Figure 3-5a
AECOM		



Klamath River Renewal Corporation

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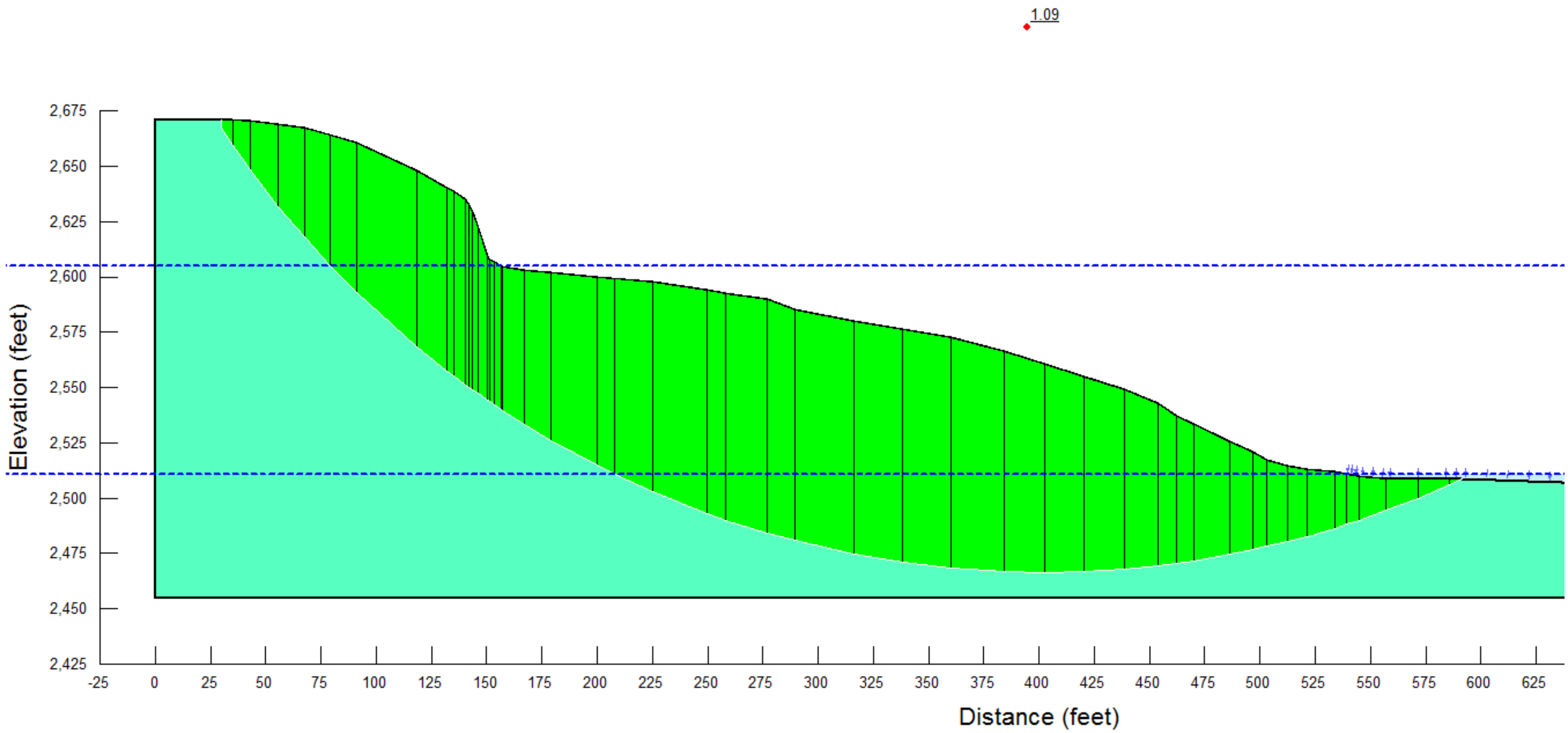
Copco Reservoir Slope Stability
Segment N11, Section 1
Rapid Drawdown Analysis

Figure 3-5b



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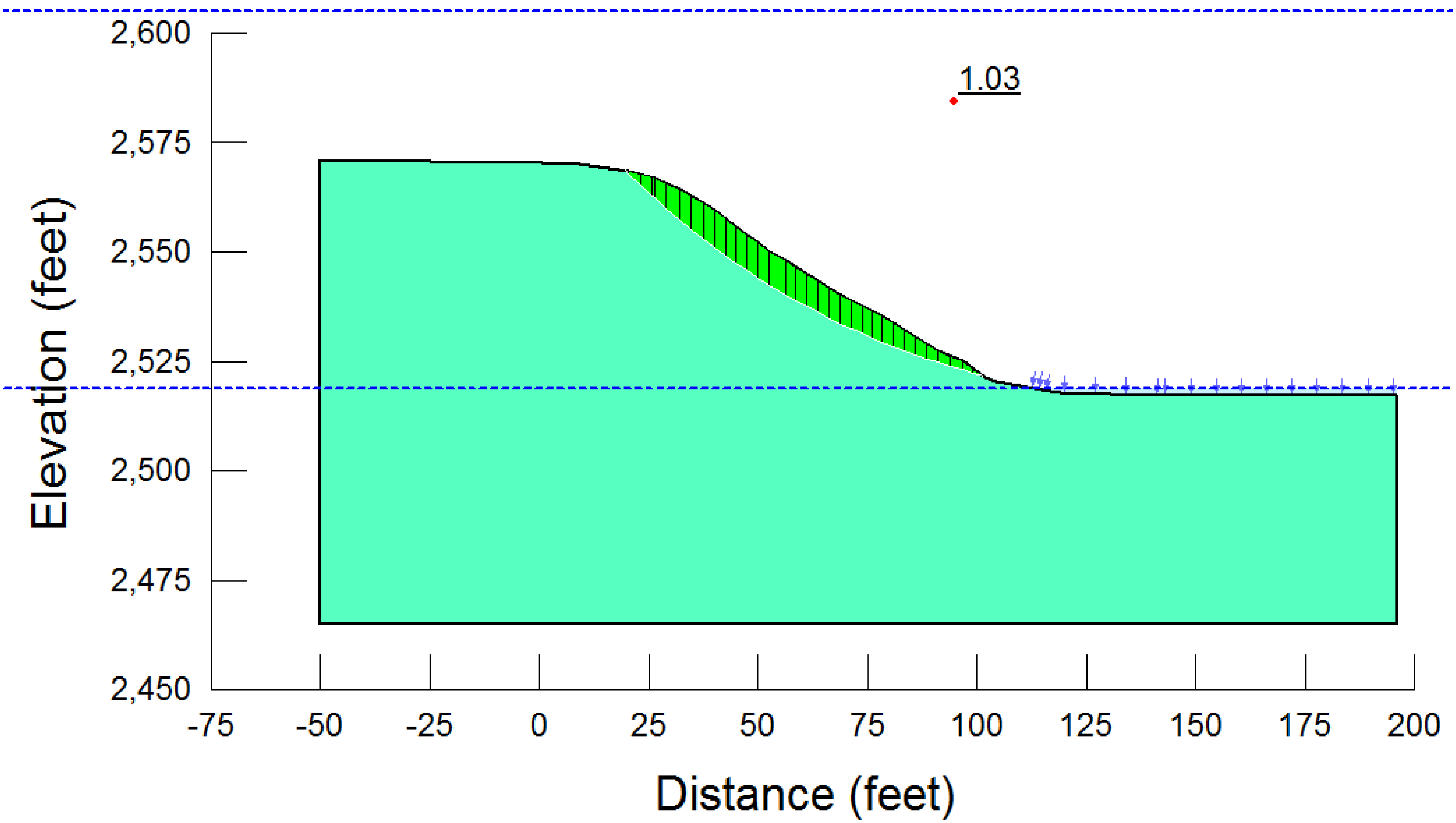

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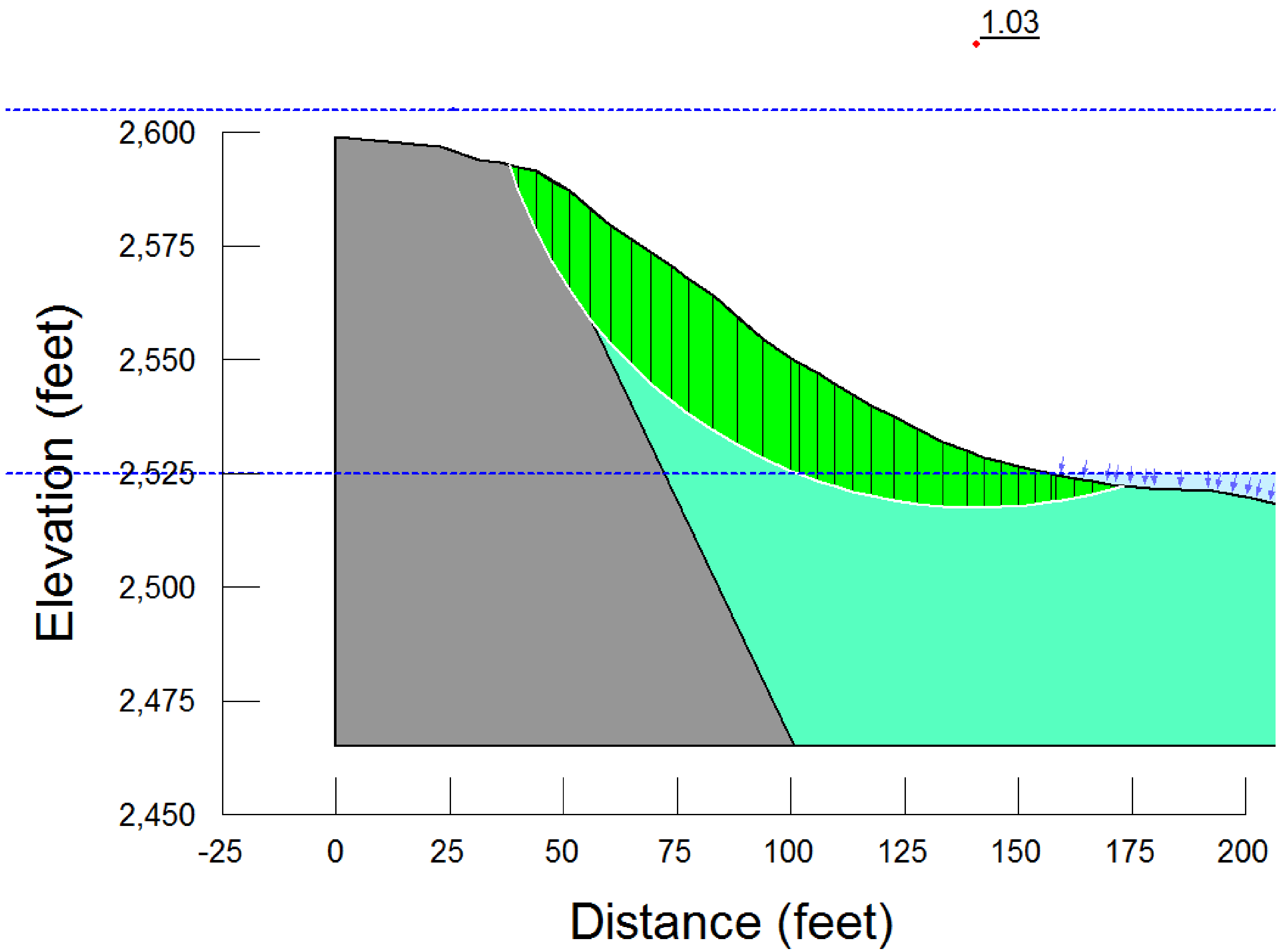
AECOM		



Klamath River Renewal Corporation	Copco Reservoir Slope Stability Segment S10, Section 1 Rapid Drawdown Analysis	Figure 3-5e
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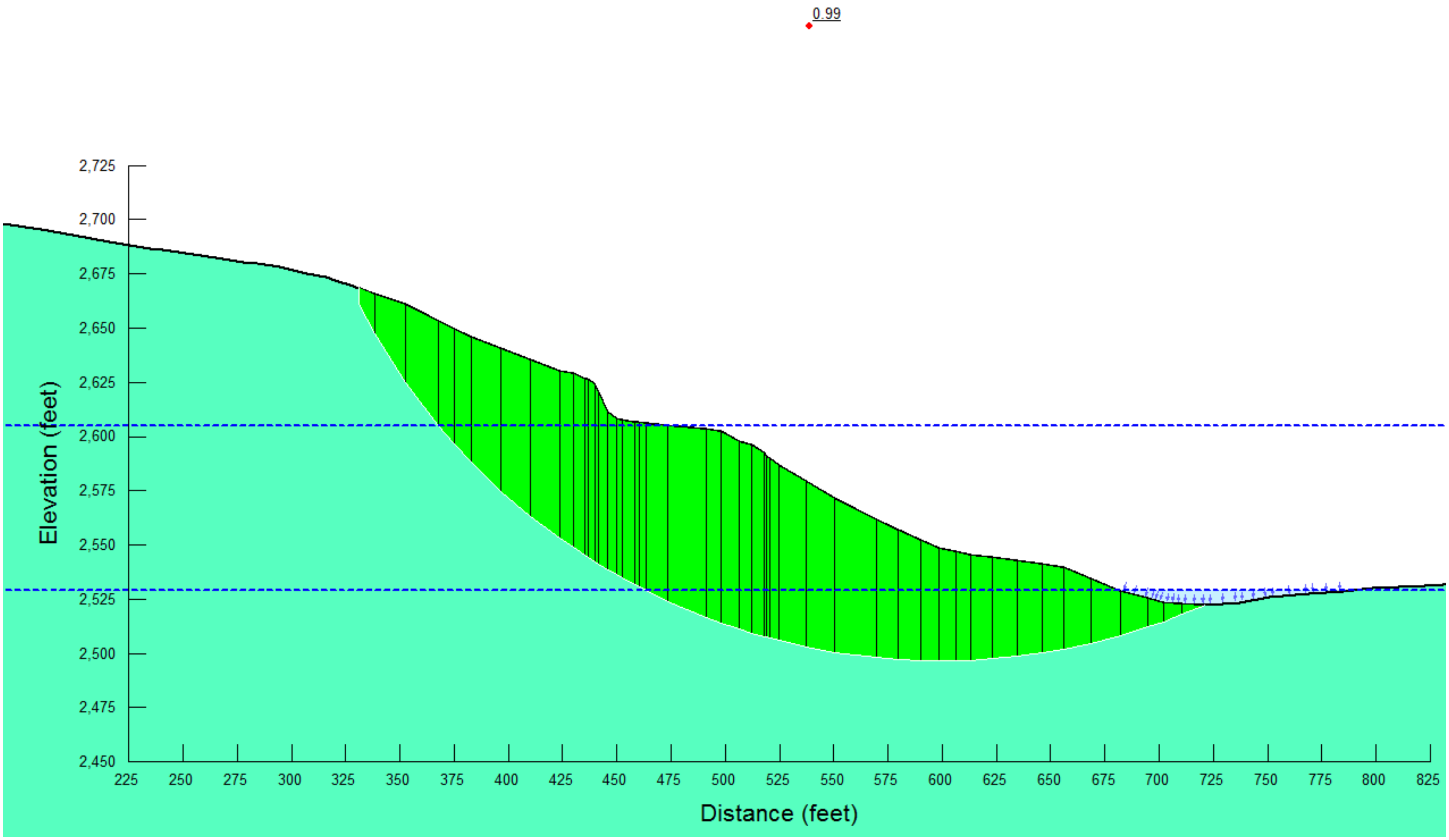

Klamath River Renewal Corporation	Copco Reservoir Slope Stability Segment S11, Section 1 Rapid Drawdown Analysis	Figure 3-5f
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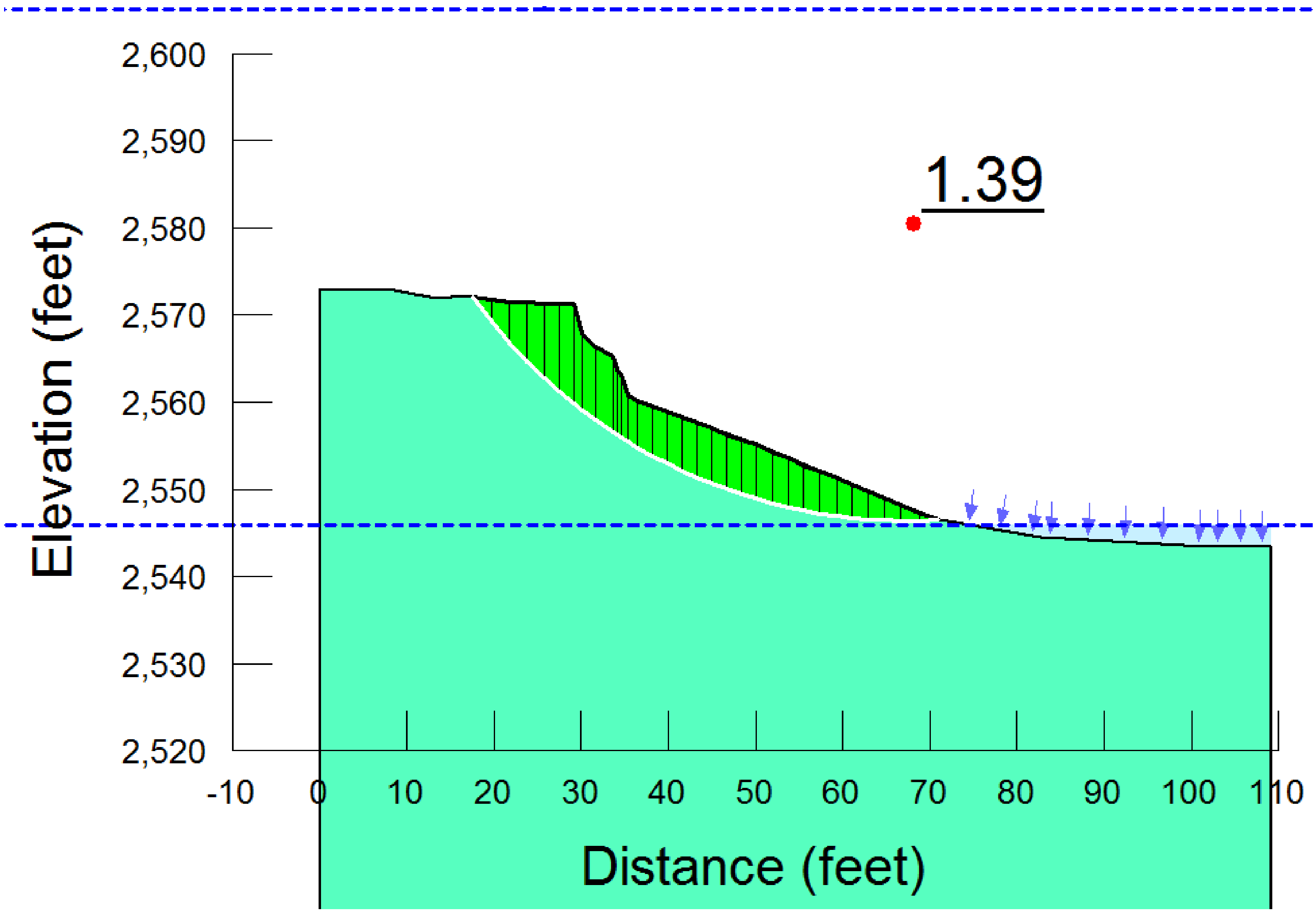

Klamath River Renewal Corporation	Copco Reservoir Slope Stability Segment S18, Section 1 Rapid Drawdown Analysis	Figure 3-5g
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Klamath River Renewal Project

FIGURE 4-2
Geologic Overview of Iron Gate Reservoir

Attachment B Boring Logs

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Project: Klamath River Dam Removal Project
Project Location: Klamath River
Project Number: 60537920

Key to Log of Boring

Elevation feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance blows/6-in.	SAMPLES: Recovery (inches)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Dry Unit Weight (pcf)	Fines Content (% <200 Sieve)	REMARKS AND OTHER TESTS
1	2	3	4	5	6	7	8	9	10	11	12

COLUMN DESCRIPTIONS

1 **Elevation:** Elevation in feet referenced to specified datum.

2 **Depth:** Depth in feet below the ground surface.

3 **Sample Type:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

4 **Sample Number:** Sample identification number.

5 **Sampling Resistance:** Number of blows required to advance driven sampler 12 inches beyond first 6-inch interval, or distance noted, using a 140-lb hammer with a 30-inch drop; or down-pressure for pushed sampler.

6 **Recovery:** Percentage of driven or pushed sample length recovered; "NA" indicates data not recorded.

7 **Graphic Log:** Graphic depiction of subsurface material encountered; typical symbols are explained below.

8 **Material Description:** Description of material encountered; may include density/consistency, moisture, color, and grain size.

9 **Water Content:** Water content of soil sample measured in laboratory, expressed as percentage of dry weight of specimen.

10 **Dry Unit Weight:** Density of soil as measured in the laboratory, in pounds per cubic foot

11 **Fines Content** Percentage passing the #200 sieve as measured in the laboratory

12 **Remarks and Other Tests:** Comments and observations regarding drilling or sampling made by driller or field personnel.

TYPICAL MATERIAL GRAPHIC SYMBOLS

- Diatomite
- Diatomite with Elastic Silt
- Weakly Cemented Diatomite
- Fat Clay with varying amounts of sand and gravel; diatomaceous in some areas
- Lean Clay with varying amounts of sand and gravel; diatomaceous in some areas
- Organic Silt
- Clayey Sand
- Silty Sand with varying amounts of sand and gravel
- Clayey Gravel with varying amounts of sand
- Well Graded Gravel with varying amounts of sand
- Volcanic Clastics
- Volcanic Cinder
- Volcanic Sandstone
- Andesite
- Basalt

TYPICAL SAMPLER GRAPHIC SYMBOLS

- Modified California Sampler (2.5-inch outer diameter)
- Standard Penetration Test
- Shelby tube (thin walled 3-inch outer diameter)

OTHER GRAPHIC SYMBOLS

GENERAL NOTES

KEY TO DESCRIPTIVE TERMS USED ON CORE LOGS

DISCONTINUITY DESCRIPTORS

a Dip of discontinuity, measured relative to a plane normal to the core axis.

b **Discontinuity Type:**

- F - Fault
- J - Joint
- Sh - Shear
- Fo - Foliation
- V - Vein
- B - Bedding

c **Aperture (inches):**

- W - Wide (0.5-2.0)
- MW - Moderately Wide (0.1-0.5)
- N - Narrow (0.05-0.1)
- VN - Very Narrow (<0.05)
- T - Tight (0)

d **Type of Infilling:**

- Bi - Biotite
- Cl - Clay
- Ca - Calcite
- Ch - Chlorite
- Ep - Epidote
- Fe - Iron Oxide
- H - Healed
- My - Mylonite
- CR - Crushed Rock
- Mn - Manganese
- No - None
- Py - Pyrite
- Qz - Quartz
- Sd - Sand
- Se - Serpentine
- Si - Silty
- Uk - Unknown

e **Amount of Infilling:**

- Su - Surface Stain
- Sp - Spotty
- Pa - Partially Filled
- Fi - Filled
- No - None

f **Surface Shape of Joint:**

- Pl - Planar
- Wa - Wavy
- St - Stepped
- Ir - Irregular

g **Roughness of Surface:**

- Slk - Slickensided [surface has smooth, glassy finish with visual evidence of striations]
- S - Smooth [surface appears smooth and feels so to the touch]
- SR - Slightly Rough [asperities on discontinuity surfaces are distinguishable and can be felt]
- R - Rough [ridges and side-angle steps are evident; asperities are clearly visible; surface feels very abrasive]
- VR - Very Rough [near-vertical steps and ridges occur on discontinuity surface]

ROCK FRACTURING

Description	Recognition
Intensely Fractured	Fractures spaced less than 2 inches apart
Highly Fractured	Fractures spaced 2 inches to 1 foot apart
Moderately Fractured	Fractures spaced 1 foot to 3 feet apart
Slightly Fractured	Fractures spaced 3 feet to 10 feet apart
Massive	Fracture spacing greater than 10 feet

ROCK WEATHERING / ALTERATION

Description	Recognition
Residual Soil	Original minerals of rock have been entirely decomposed to secondary minerals, and original rock fabric is not apparent; material can be easily broken by hand
Completely Weathered/Altered	Original minerals of rock have been almost entirely decomposed to secondary minerals, although original fabric may be intact; material can be granulated by hand
Highly Weathered/Altered	More than half of the rock is decomposed; rock is weakened so that a minimum 2-inch-diameter sample can be broken readily by hand across rock fabric
Moderately Weathered/Altered	Rock is discolored and noticeably weakened, but less than half is decomposed; a minimum 2-inch-diameter sample cannot be broken readily by hand across rock fabric
Slightly Weathered/Altered	Rock is slightly discolored, but not noticeably lower in strength than fresh rock
Fresh/Unweathered	Rock shows no discoloration, loss of strength, or other effect of weathering/alteration

ROCK STRENGTH

Description	Recognition	Approximate Uniaxial Compressive Strength (psi)
Extremely Weak Rock	Can be indented by thumbnail	35 - 150
Very Weak Rock	Can be peeled by pocket knife	150 - 700
Weak Rock	Can be peeled with difficulty by pocket knife	700 - 3,600
Moderately Strong Rock	Can be indented 5 mm with sharp end of pick	3,600 - 7,200
Strong Rock	Requires one hammer blow to fracture	7,200 - 14,500
Very Strong Rock	Requires many hammer blows to fracture	14,500 - 36,000
Extremely Strong Rock	Can only be chipped with hammer blows	>36,000

Project: Klamath River Dam Removal Project	Log of Boring BC-01
Project Location: Klamath River	Sheet 1 of 2
Project Number: 60537920	

Date(s) Drilled	2/5/2018 - 2/6/2018	Logged By	B. Kozlowicz	Checked By	D. Simpson
Drilling Method	Rotary Wash	Drill Bit Size/Type	4-inch Tricone	Total Depth of Borehole	30.4 feet
Drill Rig Type	Barge Mounted CME-45	Drilling Contractor	Taber Drilling	Surface Elevation	2597.1
Groundwater Level(s)	12.3 feet above ground surface (2/5 at 15:15)	Sampling Method(s)	2.5-inch ID Mod Cal, SPT	Hammer Data	Auto hammer (140 lb, 30-inch drop)
Borehole Backfill	Bentonite cement grout to 10 feet bgs	Location		Coordinates	N 2608898 E 6476516

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0		S01	1 1 0 (1)	1.8		SILT WITH SAND AND GRAVEL (ML), very soft, very dark gray to black (2.5Y 3/1 to 2.5/1), fine to coarse grained sand, subangular to rounded gravel, sand and gravel consists of diatomite clasts. [Recent Lake Sediment]				Sampler fell 18 inches on last blow
2595											Advance 6-inch casing to 6 feet with hammer (hard/stiff at about 3.5 feet)
	5										Advance 6-inch casing to 8 feet with hammer
2590			S02	4 3 4 (7)	1.5		Becomes soft, dark olive brown (2.5Y 3/3) to very dark grayish brown (2.5Y 3/2) with trace gravel	43			LL = 33 PL = 25 PI = 8
	10						DIATOMITE, light olive brown (2.5Y 5/4), highly weathered, extremely weak, highly fractured, friable [Lacustrine Diatomaceous Terrace (Ql)]				
2585			S03	7 6 6 (12)	1.2			99		46	2/5/18 16:45 EOD 2/6/18 8:30 BOD Advance 6-inch casing to 11 feet with hammer
	15										
2580											
	20										
2575			S04	3 2 5 (7)	1.4		Becomes soft with iron staining on irregular subvertical fractures	93	99		LL = 85 PL = 51 PI = 34 1% Sand 99% Fines
	25										

AECOM

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	25										
2570											
							BASALT, black (10Y 2.5/1), highly to completely weathered, friable				Cuttings become dark greenish gray sandy clay; slower drilling
			S05	31 50/6"	0.6						
	30		S06	50/5"	0.4						
							TOTAL DEPTH = 30.4 FEET				
2565											
	35										
2560											
	40										
2555											
	45										
2550											
	50										
2545											

Project: Klamath River Dam Removal Project
Project Location: Klamath River
Project Number: 60537920

Log of Boring BC-02

Date(s) Drilled	**2/5/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**64.6 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2599.6**
Groundwater Level(s)	**9.4 feet above ground surface (2/5 at 9:00)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT, 3-inch Shelby Tube**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2608331 E 6476958**

Elevation feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance	SAMPLES: Recovery (feet)	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0					SANDY LEAN CLAY (CL), very soft, very dark gray (2.5Y 3/1) to black (2.5Y 2.5/1), trace fine rounded gravel [Recent Lake Sediment]				
			S01	2 10 12 (22)	1.7	CLAYEY GRAVEL WITH SAND (GC), stiff/medium dense, very dark grayish brown (10YR 3/2), subangular to rounded fine to coarse gravel up to 2 inches in diameter, fine to coarse sand [Fluvio-Lacustrine Terrace Deposit with Gravel (Qtg)]		28		Drove sampler for extra 6 inches (last three blowcounts reported) 52% Gravel 20% Sand 28% Fines Advanced 6-inch casing to 3.8 feet with hammer
2595	5									
			S02	5 5 10 (15)	0.2	Black angular basalt cobble				
			S03	18 10 10 (20)	1.2	DIATOMITE, olive to olive yellow (5Y 4/3 to 2.5Y 6/6), moderately to highly weathered, extremely weak, highly fractured, with sub-horizontal bedding and irregular sub-vertical fractures, friable [Lacustrine Diatomaceous Terrace (Ql)]				Drove sampler for extra 6 inches (last three blowcounts reported) Advanced 6-inch casing to 8.8 feet with hammer
2590	10		S04	11 9 9 (18)	0.8					
						Becomes light yellowish brown (2.5Y 6/4), extremely weak/clayey, moderately fractured				
2585	15		S05	4 4 6 (10)	1.2		84	99		LL = 105 PL = 59 PI = 46 1% Sand 99% Fines
						DIATOMITE WITH ELASTIC SILT, greenish gray (10Y 5/1), soft to extremely weak, highly fractured, friable [Lacustrine Diatomaceous Terrace (Ql)]				
2580	20		S06	200 psi	2.3		148		32	About 50% WCR TX-ICU
2575	25			3						

Project: Klamath River Dam Removal Project
Project Location: Klamath River
Project Number: 60537920

Log of Boring BC-02

Elevation, feet	Depth, feet	Samples: Type	Samples: Number	Samples: Sampling Resistance	Samples: Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	25		S07	2 3 (5)	1.4						
											About 25% to 50% WCR
2570	30										
2565	35		S08	200 to 500 psi	2.1			149		33	TX-ICU
2560	40										Cuttings become very dark gray
							Increase in plasticity, soft, olive (5Y 5/3) and very dark gray to black (2.5Y 2.5/1 to 2.5Y 3/1) in ~2.5-inch beds, sub-horizontal bedding				
2555	45		S09	3 3 4 (7)	1.5			178	100		LL = 187 PL = 85 PI = 102 1% Sand 99% Fines
2550	50										

AECOM

Elevation, feet	Depth, feet	Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
2545	55		S10	2 3 5 (8)	1.5			171		30	
2540	60										
			S11	50/3"	0.3		BASALT, black (10Y 2.5/1), slightly weathered, strong; recovered as angular gravel up to 1-inch in diameter [Copco/Quaternary Basalt (Qb)]				Harder drilling, small black basalt chips in cuttings
2535	65						**TOTAL DEPTH = 64.6 FEET**				
2530	70										
2525	75										
2520	80										

Project: Klamath River Dam Removal Project
Project Location: Klamath River
Project Number: 60537920

Log of Boring BC-03

Date(s) Drilled	**2/6/2018 - 2/7/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**96.5 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2584.6**
Groundwater Level(s)	**24.3 feet above ground surface (2/6 at 12:00)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT, 3-inch Shelby Tube, HQ Core Barrel**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2606643 E 6474657**

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						ORGANIC SILT WITH SAND (OL), very soft, very dark grayish brown (2.5Y 3/2) [Recent Lake Sediment]	35	67		Sampler settled to 1-foot; drove sampler for extra 6 inches (last three blowcounts reported) LL = 48 PL = 25 PI = 23
			S01	1 2 3 (5)	2		LEAN CLAY WITH SAND (CL), soft, black (5Y 2.5/2), fine grained sand, trace rounded gravel, small angular rock fragements, and fine rootlets [Colluvium/Resdiual Soil]				
2580	5		S02	4 3 2 (5)	0.6		Without gravel	25		80	3% Gravel 29% Sand 68% Fines Advanced 6-inch casing to 4 feet (stiff from 3 feet)
							Subrounded gravel up to 2.5-inch in diameter with clayey infill [Fluvio-lacustrine Terrace Deposits with Gravel (Qtg)]				Hard chattering drilling Switch to rock core bit with SPT sampler
2575	10		R1		0.1						
							DIATOMITE, olive brown to dark grayish brown (2.5Y 4/3 to 2.5Y 4/2), massive, extremely weak, bedding/fractures not present [Lacustrine Diatomaceous Terrace (Ql)]				Faster drilling from 10.5 to 11.5 feet
			S03	6 3 2 (5)	0.1						Return fluid becomes olive
2570	15		R2		0.2						Advanced 6-inch casing to 14 feet with hammer
			S04	6 4 5 (9)	1						Switch back to tricone bit
2565	20										
							DIATOMITE WITH ELASTIC SILT, dark grayish brown (2.5Y 4/2), massive/soft to very soft [Lacustrine Diatomaceous Terrace (Ql)]				
2560	25			3				80	100		LL = 69

AECOM

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	25		S05	3 4 (7)	1.3						PL = 59 PI = 10 100% Fines
2555	30										
2550	35										
2545	40		S06	200 to 400 psi	2.5			85		27	TX-ICU
								90		25	TX-ICU
							Increase in plasticity, soft, dark greenish gray (10Y 4/1), 1 to 2-inch beds/lenses of very dark gray to black clay				
2540	45										Cutting very dark greenish gray
2535	50										

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
2530	55										
2525	60										
2520	65		S07	5 5 7 (12)	1.5						2/6/18 16:25 EOD 2/7/18 8:30 BOD Cuttings greenish black
2515	70										
2510	75										
2505	80		S08	100 psi	0						

Project: Klamath River Dam Removal Project **Project Location:** Klamath River **Project Number:** 60537920	**Log of Boring BC-03** Sheet 4 of 4

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
2500	85		S09		0.25						
2495	90		S10		1			120		16	TX-ICU
2490	95		S11	7 5 5 (10)	0.3						Driller out of rods
							TOTAL DEPTH = 96.5 FEET				
2485	100										
2480	105										
2475	110										

Project: Klamath River Dam Removal Project
Project Location: Klamath River
Project Number: 60537920

Log of Boring BC-04

Date(s) Drilled	**2/1/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**73.5 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2595.1**
Groundwater Level(s)	**11.8 feet above ground surface (2/1)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT, 3-inch Shelby Tube**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2604812 E 6472949**

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
2595	0						SILTY SAND (SM), very loose, very dark brown (10YR 2/2), trace subangular diatomite gravel up to 0.75 inches in diameter [Recent Lake Sediment]				6-inch casing settles to 1.5 feet
									44		5% Gravel 51% Sand 44% Fines
			S01	1 0 1 (1)	2		Becomes organic rich and softer/looser with increased nonplasctic fines				Sampler advanced 1 foot on first blow and 2.5 feet on second blow
2590	5										Advanced 6-inch casing to 5.5 feet with hammer
							SANDY LEAN CLAY (CL), very loose/very soft, very dark brown (10YR 2/2), trace fine gravel and coarse organics [Recent Lake Sediment]				
									58		3% Gravel 39% Sand 58% Fines
			S02	2 3 3 (6)	2						Drove sampler for extra 6 inches (last three blowcounts reported)
2585	10										Advanced 6-inch casing to 11 feet (resistance at 11 feet)
			S03	4 11 18 (29)	1.3		WEAKLY CEMENTED DIATOMITE GRAVEL, medium dense, light olive brown (2.5Y 5/4), angular diatomite gravel, weakly cemented and friable with sub-horizontal bedding and sub-vertical fractures [Lacustrine Diatomaceous Terrace (Ql)]		41		Advanced 6-inch casing to 12.5 feet with hammer 9% Gravel 50% Sand 41% Fines
			S04	400 psi	2			61		59	TX-ICU
								54		65	TX-ICU
2580	15										
											100 percent WCR
			S05	400 psi	2.5			105		42	TX-ICU
2575	20										
							DIATOMITE WITH ELASTIC SILT, soft to completely weathered, light greenish gray (5GY 7/1) [Lacustrine Diatomaceous Terrace (Ql)]				
			S06	200 to 400 psi	2.5			155		32	TX-ICU
	25										

AECOM

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
2570	25										Lost circulation to 27.5 feet
							Becomes mottled with very pale brown (10YR 8/3) and light greenish gray (5GY 7/1) with 10 degree bedding				
			S07	2 3 5 (8)	1.8						Drove sampler for extra 6 inches (last three blowcounts reported) About 50% WCR
2565	30										
			S08	200 to 500 psi	1.5			117	99	37	TX-ICU LL = 60 PL = 24 PI = 36 1% Sand 99% Fines About 75% WCR
2560	35										
							Becomes with 0.25-inch very dark gray (5Y 3/1) 10-degree beds (varves?) and vertical dark gray (5Y 4/1) stained fractures				
2555	40										
			S09	1 1 1 (2)	2						About 50% to 75% WCR
2550	45										
2545	50										
			S10	200 to 400 psi	2.5			161		31	TX-UU

Project: Klamath River Dam Removal Project	**Log of Boring BC-04**
Project Location: Klamath River	
Project Number: 60537920	Sheet 3 of 3

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
								154		32	TX-ICU
2540	55										
2535	60						DIATOMITE, highly to completely weathered, pale yellow to olive yellow (2.5Y 6/6 to 2.5Y 8/4) with orange oxidation stain/mottling; fine grained vitreous gypsum xtals along very dark gray (5Y 3/1) sub-vertical fractures [Lacustrine Diatomaceous Terrace (Ql)]				
			S11	2 2 2 (4)							
2530	65										
2525	70						ANDESITE(?); moderatly to highly weathered, medium strong, fine to medium grained [Bogus Mountain Beds]				Hard drilling, very dark gray to black volcanic fragments in cuttings
			S12	30 50/5"							
							TOTAL DEPTH = 73.5 FEET				
2520	75										
2515	80										

AECOM

Project: Klamath River Dam Removal Project	Log of Boring BC-05
Project Location: Klamath River	Sheet 1 of 1
Project Number: 60537920	

Date(s) Drilled	**2/2/2018, 2/8/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**20.5 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2601.1**
Groundwater Level(s)	**8.2 feet (2/2 at 11:00) and 6.6 (2/8 at 12:15) feet above ground surface**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT, 3-inch Shelby Tube**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2604139 E 6474515**

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						SILTY SAND WITH GRAVEL (SM), very loose, very dark grayish brown (2.5Y 3/2), greenish gray clayey diatomite gravel clasts up to 1-inch in diameter, nonplastic fines [Recent Lake Sediment]				Sampler advanced 2 feet under hammer weight
2600			S01	0 0 0 (0)	0.7						Advanced 6-inch casing to 5 feet with hammer
	5										
2595							Clayey gravel made up of mostly Diatomite clasts up to 0.75 inches in diameter				Drove sampler for extra 6 inches (last three blowcounts reported)
			S02	4 10 20 (30)			LEAN CLAY (CL), very stiff, very dark gray to very dark greenish gray (10Y 3/1 to 2.5Y 3/1), low to medium plasticity fines, trace highly to completely weathered clasts of diatomite [Fluvio-Lacustrine Terrace Deposit with Gravel (Qtg)]				Advanced 6-inch casing to 8.5 feet (refusal)
	10						DIATOMITE WITH ELASTIC SILT, extremely weak/very soft, greenish gray (5GY 6/1), 20-degree bedding and 90-degree fractures [Lacustrine Diatomaceous Terrace (Ql)]				2/2/18 EOD 2/8/18 BOD
2590			S03	2 1 1 (2)	1.5		Fine roots				
	15		S04	200 to 400 psi	2.2		Becomes medium stiff to stiff with olive yellow (2.5Y 6/6) with angular clasts, friable	135		35	TX-ICU
2585								30		93	TX-ICU
							VOLCANIC SANDSTONE, yellowish brown(10YR 5/6), highly to completely weathered, very weak, locally clayey				Harder drilling with yellowish to reddish brown rock chips in cuttings
	20		S05	32 50/5"							
2580							**TOTAL DEPTH = 20.5 FEET**				
	25										

Project: Klamath River Dam Removal Project Project Location: Klamath River Project Number: 60537920	**Log of Boring BC-06** Sheet 1 of 1

Date(s) Drilled	**2/2/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**15.4 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2577.8**
Groundwater Level(s)	**29.2 feet above ground surface (2/2 at 13:00)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2605112 E 6476050**

Elevation feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance	SAMPLES: Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						[Recent Lake Sediment]				Advanced 6-inch casing to 5 feet with hammer from 2 to 5 feet
2575							LEAN CLAY WITH SAND (CL), stiff, olive gray to dark olive gray (5Y 4/2 to 5Y 3/2), fine grained sand, low to medium plasticity fines, trace fine angular volcanic gravel and wood debris/roots [Colluvium]				
	5		S01	5 9 14 (23)	1.5						
2570							VOLCANIC SANDSTONE, dark greenish gray to black (5GY 4/1 to GLEY1 2.5/N), moderately to slightly weathered [Bogus Mountain Beds]				Harder drilling with gravelly cuttings
	10		S02	50/4"	0.3						Hard, slow drilling
2565											
	15		S03	50/4"							
							TOTAL DEPTH = 15.4 FEET				
2560											
	20										
2555											
	25										

Project: Klamath River Dam Removal Project
Project Location: Klamath River
Project Number: 60537920

Log of Boring BC-07

Date(s) Drilled	**2/2/2018 - 2/3/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**15.9 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2581.3**
Groundwater Level(s)	**26.2 feet above ground surface (2/2 at 15:30)**	Sampling Method(s)	**2.5-inch ID Mod Cal**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2605439 E 6477039**

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						[Recent Lake Sediments]				
2580			S01	0 0 0 (0)	2		FAT CLAY WITH SAND (CH), medium stiff, very dark gray (10YR 3/1), fine to medium grained sand, medium to high plasticity fines, trace rootlets [Colluvium/Residual Soil]				Sampler advanced 2 feet under weight of hammer Advanced 6-inch casing to 2 feet
			S02	5 7 8 (15)	1		Wood/roots up to 1-inch in size	34	65	88	LL = 60 PL = 24 PI = 36
	5										15% Gravel 20% Sand 65% Fines 2/2/18 16:15 EOD 2/3/18 8:30 BOD
2575											
			S03	2 5 4 (9)	0.6		CLAYEY SAND (SC), loose, very dark grayish brown (10YR 3/2), medium to coarse grained sand; medium plasticity fines; trace fine gravel with some diatomite clasts [Colluvium/Residual Soil]				Advanced 6-inch casing to 5 feet with hammer Angular diatomite gravel and wood fibers in cutting to about 13 feet Advanced 6-inch casing to 10 feet with hammer
	10										
2570											
			S04	9 9 7 (16)	1.5		POORLY GRADED SAND WITH SILT (SP-SM), loose to medium dense, coarse grained sand, dark greenish gray (10Y 4/1) subrounded to rounded diatomite gravel up to 1-inch in diameter in shoe [Colluvium/Residual Soil]		8		27% Gravel 65% Sand 8% Fines
	15		S05	20 50/4"			With shell hash				Hole caving; advanced 6-inbch casing to 14 feet with hammer
2565							VOLCANIC SANDSTONE, very weak, light olive brown to strong brown (2.5Y 5/4 to 7.5YR 5/8), highly to completely weathered, with irregular 5 to 10-degree bedding [Bogus Mountain Beds]				
							TOTAL DEPTH = 15.9 FEET				
	20										
2560											
	25										

Project: Klamath River Dam Removal Project	**Log of Boring BC-08**
Project Location: Klamath River	Sheet 1 of 1
Project Number: 60537920	

Date(s) Drilled	**2/3/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**11.5 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2586.2**
Groundwater Level(s)	**22.2 feet above ground surface (2/3 at 14:00)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2605190 E 6480346**

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						ORGANIC SILT TO ORGANIC CLAY (OL/OH), very soft, dark olive gray (5Y 3/2) with coarse organic debris				Advanced 6-inch casing to 3 feet with hammer past 1 foot
2585							FAT CLAY WITH SAND, stiff, black (5Y 2.5/2), fine grained sand, medium plasticity fines, trace angular to subrounded gravel up to 1.5 inches in diameter [Colluvium/Residual Soil]				
			S01	4 8 11 (19)	1.3			31			LL = 56 PL = 24 PI = 32
	5						WELL GRADED GRAVEL WITH SAND (GW), very dense, very dark grayish brown to black (10YR 3/2 to 10YR 2/1), broken rounded gravel up to 1.5 inches in diameter, medium to coarse grained sand, trace low plasticity fines [Fluvio-Lacustrine Terrace Deposit with Gravel (Qtg)]				Very hard drilling with volcanic rock chips in cuttings; switched to 2 7/8-inch drag but Blow counts affected by large particles
2580			S02	22 29 37 (66)	0.7						
	10										
2575							**TOTAL DEPTH = 11.5 FEET**				
	15										
2570											
	20										
2565											
	25										

AECOM

Project: Klamath River Dam Removal Project
Project Location: Klamath River
Project Number: 60537920

Date(s) Drilled	**2/14/18**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**85.2 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2583.5**
Groundwater Level(s)	**25.3 feet above ground surface (2/14 at 10:00)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2605249 E 6480346**

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						ORGANIC SILT (OL), very soft, very dark brown (10YR 2/2) [Recent Lake Sediment]				
2580											
	5		S01	9 20 50/4" (70/10")	2		CLAYEY SAND TO SANDY LEAN CLAY, loose/medium dense, black (10YR 2/1), fine to medium grained sand, medium plasticity fines, trace fine rounded gravel [Colluvium/Residual Soil]				Sampler sank to 4 feet; drove sampler for extra 18 inches (last three blowcounts reported, previous blows were 2-2-7)
			S02	50/5"	0.4		CLAYEY GRAVEL WITH SAND (GC), very dense, dark yellowish brown to very dark gray (10YR 4/6 to 10YR 3/1), subangular to rounded gravel and cobbles up to 3 inches in diameter in a sandy lean clay to clayey sand matrix [Fluvio-Lacustrine Terrace Deposit with Gravel (Qtg)]				Hard chattering drilling from 7 to 11 feet Advanced 6-inch casing to 8 feet with hammer
2575											
	10										
							DIATOMITE, light yellowish brown (2.5Y 6/4), extremely weak, with irregular 45 to 90-degree fractures with some iron staining and 0 to 15-degree fractures [Lacustrine Diatomaceous Terrace (Ql)]				Fast smooth drilling with olive brown diatomite cuttings
2570											
	15										Advanced casing to 15 feet with hammer
2565			S03	3 4 5 (9)	1.2						
	20										
2560											
	25										

Elevation feet	Depth, feet	Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	25										
2555											
	30										
							DIATOMITE WITH ELASTIC SILT; olive gray (5Y 4/2) and greenish black (10Y 2.5/1), very soft/extremely weak, 0.25 to 0.5-inch alternating beds [Lacustrine Diatomaceous Terrace (Ql)]				Cuttings become greenish gray
2550			S04	2 4 4 (8)	0						
	35										
2545											
	40										
2540											
	45										
2535											Cuttings become olive gray and greenish gray
	50										
2530											

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	55		S05	2 2 3 (5)	1.5			179	99		LL = 200 PL = 88 PI = 112 1% Sand 99% Fines
2525											
	60										
2520											
	65										
2515											
	70										
2510											
	75		S06	1 2 4 (6)							
2505											
	80										

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
2500											Harder drilling
	85		S07	50/3"	0.1		BASALT, black (10Y 2.5/1), slightly weathered, strong; recovered as angular gravel up to 1-inch in diameter [Copco/Quaternary Basalt (Qb)]				Tricone refusal
							TOTAL DEPTH = 85.2 FEET				
2495											
	90										
2490											
	95										
2485											
	100										
2480											
	105										
2475											
	110										

Project: Klamath River Dam Removal Project Project Location: Klamath River Project Number: 60537920	Log of Boring BC-09 Sheet 1 of 3

Date(s) Drilled	**2/13/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**70.5 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2601.7**
Groundwater Level(s)	**5.8 feet above ground surface (2/13 at 9:00)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT, 3-inch Shelby Tube, HQ Core Barrel**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2602526 E 6483561**

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						[Recent Lake Sediment]				Sampler advanced 2 feet under weight of hammer
2600			S01	0 0 0 (0)	1		FAT CLAY WITH SAND (CH), medium stiff, brown (10YR 4/3) [Alluvium/Residual Soil]				
			R01		1.4		CLAYEY GRAVEL (GC), dark gray (10YR 4/1) and yellowish brown (10YR 5/6), cored and wash subrounded to rounded basalt gravel and cobbles; some clayey sand matrix observed [Fluvio-Lacustrine Terrace Deposit with Gravel (Qtg)]				Set casing to 2 feet; hard driving at 2 feet (casing bouncing); switched to core bit
			R02		0						
	5		S02	4 2 7 (9)	1		DIATOMITE WITH ELASTIC SILT, medium stiff/weak, dark yellowish brown (10YR 4/4), trace fine grained sand [Lacustrine Diatomaceous Deposit (Ql)]				Advanced 6-inch casing to 4.5 feet
2595											
			S03	9 9 7 (16)	1						
	10										
2590							Becomes greenish gray (10Y 5/1), extremely weak/soft				
			S04	3 3 4 (7)	1.2						
	15										
2585											
	20										
2580								76	100	54	TX-UU
			S05	200 psi	1.7						LL = 74 PL = 53 PI = 21
	25							80		52	

Elevation feet	Depth, feet	Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	25										100% Fines TX-ICU
2575											
	30										
2570											
			S06	3 3 4 (7)	0						
	35										
2565											
			S07	3 3 5 (8)	1.8						Sampler advanced an additional 6 inches by pushing
	40										
2560											
	45										
2555											
	50										
2550											

Elevation, feet	Depth, feet	Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	55		S08	200 psi	0						
2545											
	60										
2540											
	65										
2535											
			S09	200 to 400 psi	2.5			92		47	TX-ICU
	70							96		46	TX-ICU
							TOTAL DEPTH = 70.5 FEET				
2530											
	75										
2525											
	80										
2520											

Project: Klamath River Dam Removal Project **Project Location: Klamath River** **Project Number: 60537920**	**Log of Boring BC-10** Sheet 1 of 2

Date(s) Drilled	**2/7/2018 - 2/8/2018**	Logged By	**B. Kozlowicz**	Checked By	**D. Simpson**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**43.0 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	**2578.2**
Groundwater Level(s)	**29.3 feet above ground surface (2/7 at 14:40)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT, 3-inch Shelby Tube**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Bentonite cement grout to 10 feet bgs**	Location		Coordinates	**N 2604959** **E 6472871**

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						[Recent Lake Sediment]				Set 6-inch casing to 4 feet (very soft to 2.5 feet)
2575							WELL GRADED GRAVEL WITH SAND (GW), dense, dark brown (10YR 3/3), subangular to rounded gravel up to 3 inches in diameter consisting of various volcanic lithologies [Fluvio-Lacustrine Terrace Deposit with Gravel (Qtg)]				
	5										Hard, chattering drilling
2570											
	10		S01	25 26 19 (45)	1.5				1		85% Gravel 15% Sand Advanced 6-inch casing to 9 feet with hammer
2565											Tricone bit refusal; rock core barrel used to advance
	15		S02	10 5 5 (10)	0.4		DIATOMITE WITH ELASTIC SILT, olive (5Y 5/3), medium stiff/extremely weak, with trace oxidation [Lacustrine Diatomaceous Terrace (Ql)]				Clayey diatomite curring; switched back to tricone bit Advanced 6-inch casing to 14 feet with hammer
2560											
	20										
2555											
	25			5			Becomes light olive brown (2.5Y 5/4) and olive brown (5Y 5/3)				

Elevation feet	Depth, feet	Type	Number	Sampling Resistance	Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	25		S03	4 6 (10)	1.3		with 0.1 to 0.5 inch 10-degree bedding and some oxidation stains				
2550											
	30										
2545											
	35										
2540							VOLCANIC CINDER, very dark brown (10YR 2/2), very weak/dense to very dense, medium to coarse grained weakly welded sand, friable with corestones and weakly expressed 10 to 15-degree bedding [Bogus Mountain Beds]				Harder drilling
	40		S04	200 to 400 psi	0.9						
			S05	6 20 37 (57)	1.5		ANDESITE/TUFF, reddish brown (5YR 5/3), strong brown (7.5YR 5/6), and dusky purple, highly to completely weathered, very weak, coarse grained [Bogus Mountain Beds]				
2535							**TOTAL DEPTH = 43.0 FEET**				
	45										
2530											
	50										
2525											

Project: Klamath River Dam Removal Project
Project Location: Klamath River
Project Number: 60537920

Log of Boring BI-01

Sheet 1 of 1

Date(s) Drilled	**2/20/2018**	Logged By	**K. Zeiger**	Checked By	**B. Kozlowicz**
Drilling Method	**Rotary Wash**	Drill Bit Size/Type	**4-inch Tricone**	Total Depth of Borehole	**22.2 feet**
Drill Rig Type	**Barge Mounted CME-45**	Drilling Contractor	**Taber Drilling**	Surface Elevation	
Groundwater Level(s)	**11.8 feet above ground surface (2/20)**	Sampling Method(s)	**2.5-inch ID Mod Cal, SPT**	Hammer Data	**Auto hammer (140 lb, 30-inch drop)**
Borehole Backfill	**Neat cement grout to the ground surface**	Location		Coordinates	**N 2600814 E 6450534**

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery (feet)	Graphic Log	MATERIAL DESCRIPTION	Water Content, %	Fines Content (%<#200 Sieve)	Dry Density, pcf	REMARKS AND OTHER TESTS
	0						LEAN CLAY WITH ORGANICS (CL), very soft, wet, dark red brown (5YR 3/4), twigs and roots [Recent Lake Sediment]				
			S-1	0 0 0 (0)	2		LEAN CLAY (CL), stiff, dry, dark red brown (5YR 3/4), trace rootlets, CaCO3 ribbons, developed soil texture [Colluvium/Residual Soil]				
	5										
			S-2	4 7 8 (15)	1.5						
	10		S-3	6 8 13 (21)	1						
			S-4	50/4"	0.3		BASALT, dark red brown (5YR 2.5/2), fresh, strong [QUARTERNARY VOLCANICS]				
	15										
			S-5	50/3"	0.1		VOLCANIC CLASTICS, mottled dark gray (2.5Y 4/1) and light yellow brown (2.5Y 6/4), slightly weathered, moderately strong, coarse grained with quartz phenocrysts [MIOCENE VOLCANICS]				
	20										
			S-6	50/3"	0.2						
							TOTAL DEPTH = 22.2 FEET				
	25										

Date(s) Drilled	**2/22/2018 - 2/23/2018**	Logged By	**K. Zeiger**	Checked By	**B. Kozlowicz**
Drilling Method	**Rotary Wash, HQ-3 Rock Core**	Drill Bit Size/Type	**4-inch solid stem auger, 3-7/8 inch tricone, 4-inch #2 diamond coring bit**	Total Depth of Borehole	**67.0 feet**
Drill Rig Type	**Truck mounted CME 75**	Drilling Contractor	**Taber Drilling**	Approx. Ground Surface Elevation	**2334.3 NAVD 88**
Groundwater Level	**4.8 feet (15:00 2/22)**	Sampling Methods	**2.5-inch ID Mod Cal, Rock Core**	Hammer Data	**Auto hammer (140 lbs, 30-inches)**
Borehole Backfill	**Neat cement to ground surface**	Borehole Location	**Iron Gate Reservoir**	Coordinate Location	**N 2602023 E 6461382**

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	SOIL SAMPLES: Type	Number	Blows / 6 in.	Recovery, %	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
2334	0								FAT CLAY WITH SAND (CH), stiff, very dark brown (7.5YR 2.5/3), moist, low plasticity fines, 10 percent rounded gravel up to 1-inch in diameter [Alluvium]						4-inch solid stem auger
2332	2														
2330	4								▽						
	5										S-1	6, 8, 13	1.3	14:30	LL = 78 PL = 28 PI = 50 11% Gravel 21% Sand 68% Fines
2328	6								← 2-inch rounded clasts with trace decomposed rootlets						
2326	8														
2324	10								SANDY FAT CLAY (CH), stiff, dry, brown (7.5YR 4/3), low plasticity fines, fine grained sand, trace rounded gravel up to 0.25 inches in diameter, CaCO3 ribbons [Older Alluvium/Residual Soil]		S-2	5, 7, 12	1.5	14:40	LL = 58 PL = 28 PI = 30 5% Gravel 33% Sand 62% Fines
2322	12														
	13														

Project: Klamath River Dam Removal Project
Project Location: Copco and Iron Gate Reservoirs
Project Number: 60537920

Log of Boring BI-02

Elevation, feet	Depth, feet	Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Drawing Number	MATERIAL DESCRIPTION	Type	Number	Blows / 6 in.	Recovery, %	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	13													
2320	14													First water at 14.0 feet; after 20 minutes at 4.8 feet
	15							SANDY FAT CLAY (CH), loose, brown (7.5YR 5/4), fine grained sand, low plascticity fines, trace rounded gravel up to 1-inch in diameter [Older Alluvium]		S-3	6, 6, 7	1.5	15:00	LL = 51 PL = 27 PI = 24 8% Gravel 40% Sand 53% Fines 4-inch casing to 14 feet Switch to rotary wash
2318	16													
	17													
2316	18	1	1	18	NA, NA, NA, NA, NA	0	1, 2; NR	TUFF BRECCIA, green gray (10Y 6/1), highly to completely weathered, extremely weak, intensely fractured with angular breccia clasts up to 1-inch, fine to medium grained matrix [Miocene Volcanics - Bogus Mountian Beds] 1: 60, J, N, No, No, Pl, SR 2: 10, J, MW, No, No, Wa, SR					1549 [21]	Refusal with tricone bit; switched to HQ rock core Clayey volcanics cuttings 100% fluid return
	19													
2314	20													
	21												1601	
2312	22	2		100	2, 3	48*	1, 2, 3, 3, 1, 4	Becomes moderately to slightly weathered, moderately strong, moderately fractured Rough, irregular fractures likely mechanical along weathered contacts of breccia clasts 1: 10, J, T, No, No, Wa, SR 2: 20-80, J, N, No, No, Ir-St, R 3: 10, J, MW, No, No, Wa, SR 4: 20, J, N, No, No, Wa, SR					1610 [22]	*Does not meet soundness criteria for RQD calculation
2310	24				1		m	Run break					1618	
	25	3		100	2, 1	100	1, 2, 1, 1	1: 30, J, N, No, No, Wa, SR 2: 5, J, T, H + ?, Pa, Wa, ?					1622 [21]	
2308	26													
	27						m	Run break					1629	
2306	28				1, 0		1, m	1: 5, J, N, No, No, Wa, SR					1634	
	29													

Elevation, feet	Depth, feet	Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Number	Lithology	MATERIAL DESCRIPTION	Type	Number	Blows / 6 in.	Recovery, %	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	29–30	4		100	1	100	2		TUFF BRECCIA, green gray (10Y 6/1), moderately to slightly weathered, moderately strong, moderately fractured with angular breccia clasts up to 1-inch, medium grained matrix [Miocene Volcanics - Bogus Mountian Beds] (continued) 2: 10-15, J, N, No, No, Wa-St, R					[30]	Broken while placing in the box
2304	30–31				1		2								100% fluid return
	31–32				0									1644	
2302	32–33				1		m 1		1: 10, J, N, No, No, Wa, SR					1647	
	33–34				2		1								
2300	34–35	5	2	100	1	96	2 3		2: 40, J, N, No, No, St, SR 3: 30, J, T, H+?, No, No, Wa?					[31]	
	35–36				1		4		4: 10, J, N, No, No, Wa-St, SR						
2298	36–37				0									1657	
	37–38				1		1		1: 10, J, N, No, No, Wa-St, R					1701	
2296	38–39				1		1								
	39–40	6		100	1	100	2		2: 15, J, T, No, No, Wa, SR					[26]	
2294	40–41				1										
	41–42				0		3		3: 30, J, N, No, No, Wa-Pl, SR					1712	
2292	42–43				1		1		1: 10, J, N, No, No, Wa, SR					1206	EOD 2/22/2018 BOD2/23/2018
	43–44				4		2		2: 10-30, J, T, No, No, Wa, SR						
2290	44–45	7		100	1	96	1							[43]	

Elevation, feet	Depth, feet	Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Number	Lithology	MATERIAL DESCRIPTION	Type	Number	Blows / 6 in.	Recovery, %	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	45				1		3		TUFF BRECCIA, green gray (10Y 6/1), moderately to slightly weathered, moderately strong, moderately fractured, angular breccia clasts up to 1-inch, fine to medium grained matrix [Miocene Volcanics - Bogus Mountian Beds] (continued) 3: 10-30, J, MW, No, No, Wa-Ir, SR-R						100% fluid return
2288	46		3		1		4		4: 30, J, N, No, No, Wa-Pl, SR					1213	
	47				0				Becomes strong, slightly fractured					1216	
2286	48				0										
	49	8		100	1	100	1 2		1: 20, J, MW, H+Ca, F, Wa, ? 2: 15, J, N, No, No, Wa-St, R					[25]	
2284	50				0										
	51				1		2							1228	
2282	52				0									1232	
	53				0										
2280	54	9		100	1	98	1		1: 30, J, N, No, No, St, R					[23]	
	55				0		m								Mechanical fractures from placing in box
2278	56				1		m 2		2: 20, J, N, No, No, Wa-St, SR					1245	
	57				1		1		1: 20, J, N, No, No, Wa, SR					1250	
2276	58				0										
	59	10		100	1	96	2		2: 10, J, N, No, No, Wa-St, R					[20]	
2274	60				0										100% fluid return
	61														

Project: Klamath River Dam Removal Project
Project Location: Copco and Iron Gate Reservoirs
Project Number: 60537920

Log of Boring BI-02

Elevation, feet	Depth, feet	ROCK CORE: Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Drawing Number	Lithology	MATERIAL DESCRIPTION	SOIL SAMPLES: Type	Number	Blows / 6 in.	Recovery, %	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	61		4		1		m m 3		TUFF BRECCIA, green gray (10Y 6/1), moderately to slightly weathered, strong, slightly fractured, angular breccia clasts up to 1-inch, fine to medium grained matrix [Miocene Volcanics - Bogus Mountian Beds] (continued) 3: 6, J, N, No, No, Wa, SR					1305	
2272	62				0									1311	Mechanically broken from placement in box
	63				1		1		1: 30, V, N-T, H+Ca, Fi, Wa, ?						
							2		2: 10, J, N, No, No, Wa-St, SR-R						
2270	64	11		100	0	72								[19]	
	65				1		3		3: 60, J/V, MW, Ca, Pa, Wa-Pl, SR						
2268	66				3		4 4 m		4: 60-70, J/V, N, H+Ca, Fi, Wa, ?					1327	
	67								**TOTAL DEPTH = 67.0 FEET**						
	68														
2266	69														
	70														
2264	71														
2262	72														
	73														
2260	74														
	75														
2258	76														
	77														

Date(s) Drilled	2/21/2018	Logged By	K. Zeiger	Checked By	B. Kozlowicz
Drilling Method	Rotary Wash, HQ-3 Rock Core	Drill Bit Size/Type	4-inch solid stem auger, 3-7/8 inch tricone, 4-inch #2 diamond coring bit	Total Depth of Borehole	35.1 feet
Drill Rig Type	Barge mounted CME 45	Drilling Contractor	Taber Drilling	Approx. Ground Surface Elevation	2302.2 NAVD 88
Groundwater Level	25.3 feet above ground surface (2/21)	Sampling Methods	2.5-inch ID Mod Cal, Rock Core	Hammer Data	Auto hammer (140 lbs, 30-inches)
Borehole Backfill	Neat cement to ground surface	Borehole Location	Iron Gate Reservoir	Coordinate Location	N 2601812 E 6461399

Elevation, feet	Depth, feet	Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Number	Lithology	MATERIAL DESCRIPTION	Type	Number	Blows / 6 in.	Recovery, %	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
2302	0							GP-GC	POORLY GRADED GRAVEL WITH CLAY (GP-GC), dark green gray (N 4/1), wet, loose, subangular to subrounded gravel up to 0.25-inch in diameter [Alluvium]						Advanced 5-inch casing to 3 feet
2300	2														
2298	4								TUFF BRECCIA, green gray (5G 6/1). highly weathered, weak to very weak, fine to medium grained matrix with angular to subrounded clasts up to 0.75 inches [Miocene Volcanics - Bogus Mountian Beds]		S-1	12 50/2.5"	0.7	10:10	LL = 51 PL = 27 PI = 24 61% Gravel 30% Sand 9% Fines Advanced 5-inch casing to 4 feet
2296	5.5–6	1		4	6+	0	1, 2		Becomes moderately weathered, weak, intensely fractured to locally crushed Most rough, irregular fractures likely mechanical due to weathering on clasts/matrix boundaries					1059	Refusal with tricone bit; switched to HQ-3
	6–7				6+		3, 4, 2, 5		1: 60, J, N, No, No, St, R 2: 40, J, T, No, No, St, R 3: 50-60, J, T, No, No, St, R 4: 30, J, MW, No, No, St, R 5: 10, J, N, No, No, St, R						
2294	7–8				6+		4, 4							[13]	
	8–9				6+		6, 4, 7		6: 40, J, N, No, No, Wa, SR 7: 70, J, T, No, No, Wa, SR						
	9–10				NA		5		NR						
2292	10–11	2		5	NA	14*	1		1: ~10, J, N, No, No, Wa, SR					1120 1143	LL = 58 PL = 28 PI = 30 5% Gravel 33% Sand 62% Fines
	11–12				4		2, 3, 3		2: 30, J, N-T, No, No, Wa-St, SR 3: 40-50, J, N, No, No, Wa-St, SR-R						
2290	12–13				5		4, 3, 4, 2		4: 20, J, MW, No, Wa, St, SR-R					[19]	Does not meet soundness criteria for RQD calculation

Project: Klamath River Dam Removal Project
Project Location: Copco and Iron Gate Reservoirs
Project Number: 60537920

Log of Boring BI-03

Elevation, feet	Depth, feet	Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Drawing Number	MATERIAL DESCRIPTION	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	13				5		5, 2, 2	TUFF BRECCIA, green gray (5G 6/1), moderately weathered, weak, intensely fractured to locally crushed, fine to medium grained matrix with angular to subrounded clasts up to 0.75 inches [Miocene Volcanics - Bogus Mountian Beds] (continued)		
2288	14				5		1, 2, 2	5: 30, J, N, No, No, Wa-Pl, SR		
	15	3		5	3	100*	1	1: 35, J, N, No, No, St, R Becomes slightly fractured, moderately strong	1159 1215	LL = 51 PL = 27 PI = 24 8% Gravel 40% Sand 53% Fines Packer test #1 from 15.1 to 35.1
2286	16				0					
	17				1		2	2: 30, J, N, No, No, Wa, SR	[23]	Does not meet soundness criteria for RQD calculation
2284	18				1		3	3: 20, J, T, No, No, Wa, SR		
	19				0					
2282	20	4		5	3	86*	1, 2, 3	Becomes highly fractured 1: 10, J, MW, No, No, Wa, SR 2: 25, J, T, No, No, Wa-St, SR-R 3: 10, J, MW, No, No, Wa, SR-R	1228 1239	
	21				2		3, 2	Becomes moderately fractured		
2280	22				1		3		[18]	
	23				0					
2278	24				1		3			
	25	5		5	0	48*			1256 1301	
2276	26				5		1, 2, 3, 3	Moderately to highly weathered, weak to very weak, fractures 1, 2, 3 are likely mechanical 1: 15, J, T, No, No, Wa, SR 2: 40, J, T, No, No, Wa-St, SR 3: 5-10, J, MW, No, No, Wa, SR		Clayey coating 26.5-27.2 is from when return hose got disconnected during run
	27				5		3, 3, 4, 5	4: 80, J, N, No, No, Wa-Ir, SR 5: 30, J/V, T, Ca, Pa, Pl-Wa, SR	[15]	
2274	28				6+		6	Crushed zone 6: 65, J, MW, Sd, Pa, Wa, SR		
	29									

Soil Samples columns (Type, Number, Blows / 6 in., Recovery, %) and Lithology column: no entries.

Elevation, feet	Depth, feet	Run No.	Box No.	Recovery, %	Fractures per Foot	R Q D, %	Fracture Drawing	Number	Lithology	MATERIAL DESCRIPTION	Type	Number	Blows / 6 in.	Recovery, %	Drill Time [Rate, ft/hr]	FIELD NOTES AND TEST RESULTS
	29				0					TUFF BRECCIA, green gray (5G 6/1), moderately weathered, moderately strong, moderately fractured, fine to medium grained matrix with angular to subrounded clasts up to 0.75 inches [Miocene Volcanics - Bogus Mountian Beds] (continued)						
2272	30	6		5	2	54*		1		Becomes intensely fractured 1: 5, J, N, No, No, Pl-Wa, SR					1321 1327	
								1								
	31				4			2 2		2: 20, J, N-MW, No, No, Wa, SR						
								3								
2270	32				0			1		3: 35, J, N, Ca+Sd, Pl, S					[15]	
	33				3			4 3		4: 30, J, N, No, No, Pl, SR						Does not meet soundness criteria for RQD calculation
2268	34				4			5 6		Becomes highly weathered, weak, crushed along a fracture? 5: 65, J, MW-W, Fe+Sd, Su+Pa, Pl, SR-R with ~0.75-inch Fe stained highly weathered rind 6: 10-20, J, T, No, No, Wa-Lr, SR					1347	
	35									**TOTAL DEPTH = 35.1 FEET**						
2266	36															
	37															
2264	38															
	39															
2262	40															
	41															
2260	42															
	43															
2258	44															
	45															

Attachment C Laboratory Testing Results

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Moisture-Density-Porosity Report

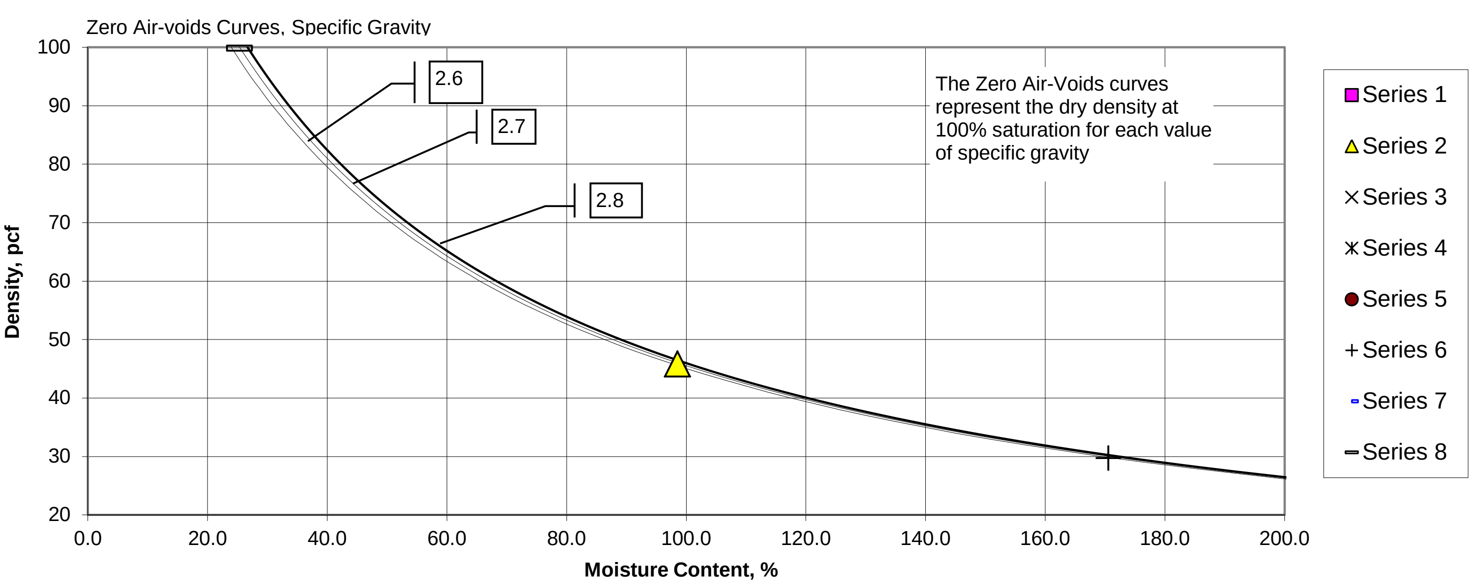
Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No:	020-251a	**Project No.**	60537920	**By:**	RU
Client:	AECOM	**Date:**	06/13/18		
Project Name:	Klamath River Dam Removal Project	**Remarks:**			

Boring:	BC-01	BC-01	BC-01	BC-02	BC-02	BC-02	BC-03	BC-03
Sample:	S-02	S-03	S04	S05	S09	S10	S-01	S-02
Depth, ft:	6.5	12.5-13	21.5	14.5	44.5	54.8-55.3	1	5.5-6.0
Visual Description:	Dark Olive Gray Sandy SILT	Light Yellowish Brown Sandy CLAY	Gray Elastic SILT	Gray Elastic SILT	Gray Elastic SILT	Black CLAY	Dark Olive Brown Sandy Lean CLAY	Dark Olive Brown Sandy CLAY w/ Gravel
Actual G_s								
Assumed G_s		2.70				2.70		2.70
Moisture, %	43.1	98.6	92.9	83.7	177.8	170.6	34.7	25.4
Wet Unit wt, pcf		91.0				80.3		125.2
Dry Unit wt, pcf		45.8				29.7		99.9
Dry Bulk Dens.pb, (g/cc)		0.73				0.48		1.60
Saturation, %		99.3				98.3		99.4
Total Porosity, %		72.8				82.4		40.8
Volumetric Water Cont,Θw,%		72.3				81.0		40.6
Volumetric Air Cont., Θa,%		0.5				1.4		0.2
Void Ratio		2.68				4.68		0.69
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.

Moisture-Density



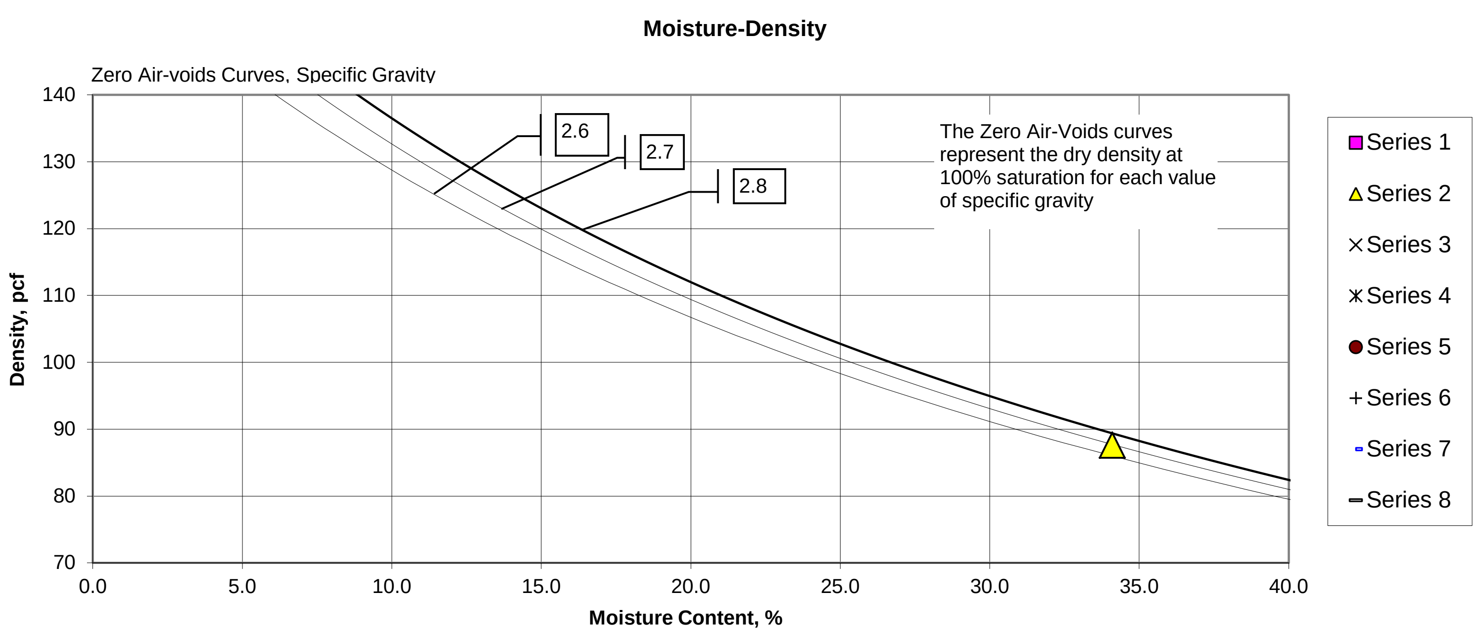
Moisture-Density-Porosity Report

Cooper Testing Labs, Inc. (ASTM D7263b)

CTL Job No:	020-251b	**Project No.**	60537920	**By:** RU
Client:	AECOM	**Date:**	06/13/18	
Project Name:	Klamath River Dam Removal Project	**Remarks:**		

Boring:	BC-03	BC-07	BC-08	BC-08A	BI-02	BI-02	BI-02	BI-03
Sample:	S05	S-02	S-01	S05	S1	S2	S3	S-1
Depth, ft:	24.5	4-4.5	3	54	5	10	15	3.5
Visual Description:	Light Olive Brown Elastic SILT	Very Dark Olive Brown Sandy Fat CLAY w/ Gravel	Dark Reddish Brown Sandy Fat CLAY	Light Olive Brown Elastic SILT	Dark Reddish Brown Sandy Fat CLAY	Yellowish Brown Sandy Fat CLAY	Yellowish Brown Sandy Fat CLAY	Olive Gray Poorly Graded GRAVEL w/ Silt & Sand
Actual G_s								
Assumed G_s		2.70						
Moisture, %	80.3	34.1	31.4	178.6	27.8	28.7	38.4	12.0
Wet Unit wt, pcf		117.5						
Dry Unit wt, pcf		87.6						
Dry Bulk Dens.pb, (g/cc)		1.40						
Saturation, %		99.5						
Total Porosity, %		48.1						
Volumetric Water Cont,Θw,%		47.8						
Volumetric Air Cont., Θa,%		0.2						
Void Ratio		0.93						
Series	1	2	3	4	5	6	7	8

Note: All reported parameters are from the as-received sample condition unless otherwise noted. If an assumed specific gravity (Gs) was used then the saturation, porosities, and void ratio should be considered approximate.



#200 Sieve Wash Analysis
ASTM D 1140

COOPER TESTING LABORATORY

Job No.: 020-251
Client: AECOM
Project: Klamath River Dam Removal Project
Project No.: 60537920
Date: 6/14/2018
Run By: MD
Checked By: DC

Boring:	BC-02	BC-03	BC-04	BC-04				
Sample:	S-01	S-01	S-01	S02				
Depth, ft.:	1-2	1	1.5	7				
Soil Type:	Dark Olive Brown Clayey GRAVEL w/ Sand	Dark Olive Brown Sandy Lean CLAY	Dark Olive Brown Clayey SAND	Dark Olive Brown Sandy CLAY				
Wt of Dish & Dry Soil, gm	1247.4	707.6	696.3	656.3				
Weight of Dish, gm	175.6	175.8	172.4	173.0				
Weight of Dry Soil, gm	1071.8	531.8	523.9	483.3				
Wt. Ret. on #4 Sieve, gm	556.7	16.7	22.3	15.6				
Wt. Ret. on #200 Sieve, gm	774.5	177.4	291.7	205.6				
% Gravel	**51.9**	**3.1**	**4.3**	**3.2**				
% Sand	**20.3**	**30.2**	**51.4**	**39.3**				
% Silt & Clay	**27.7**	**66.6**	**44.3**	**57.5**				

Remarks: As an added benefit to our clients, the gravel fraction may be included in this report. Whether or not it is included is dependent upon both the technician's time available and if there is a significant enough amount of gravel. The gravel is always included in the percent retained on the #200 sieve but may not be weighed separately to determine the percentage, especially if there is only a trace amount, (5% or less).

#200 Bulk Sieve Wash Analysis
ASTM D 1140m

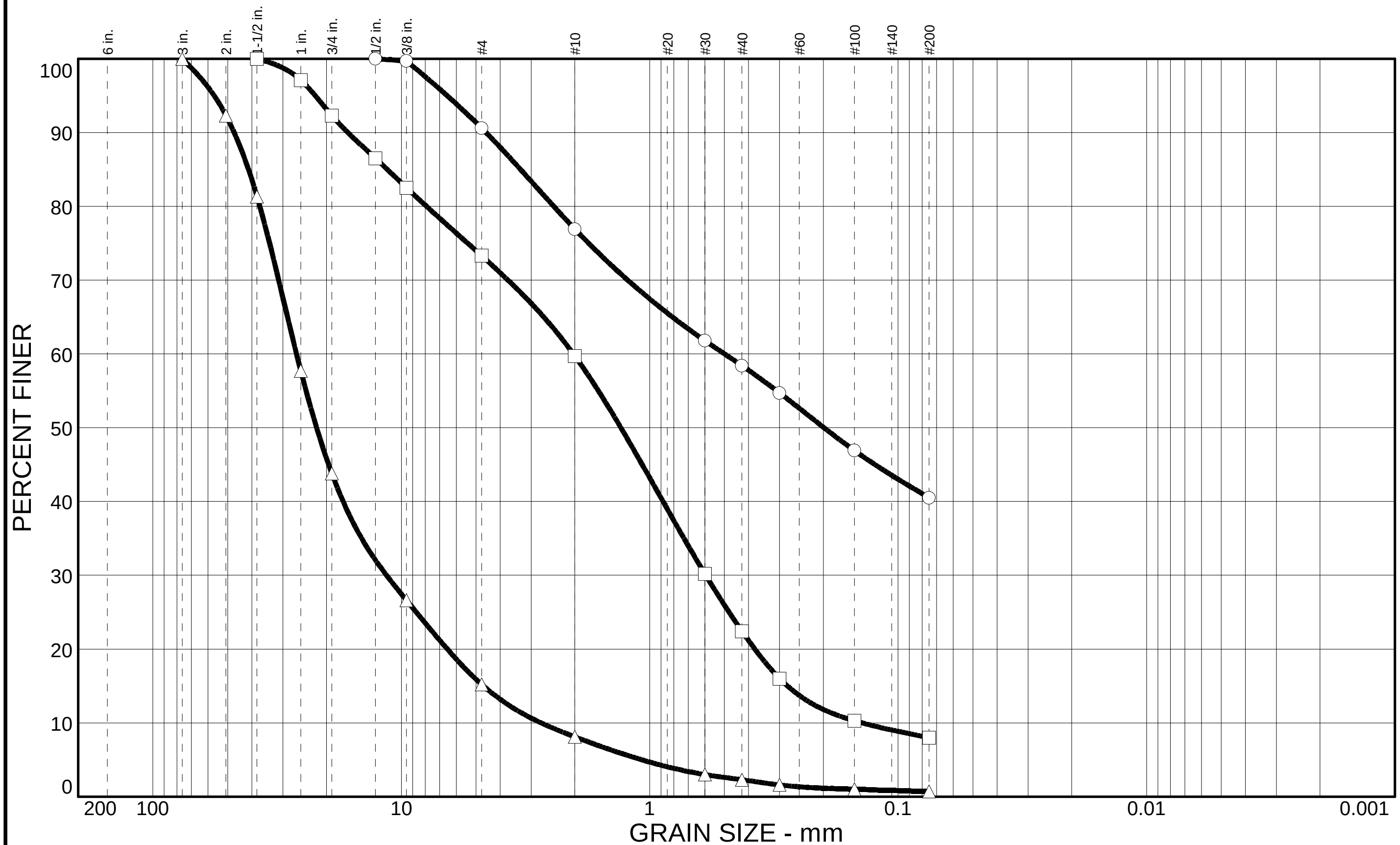
COOPER TESTING LABORATORY

Job No.:	020-251	**Project No.:**	60537920	**Run By:**	MD
Client:	AECOM	**Date:**	6/14/2018	**Checked By:**	DC
Project:	Klamath River Dam Removal Project				

Boring:	BC-07								
Sample:	S-02								
Depth, ft.:	4-4.5								
Soil Type:	Very Dark Olive Brown Sandy Fat CLAY w/ Gravel								
Bulk Sample wt. lb.	218.0								
Wt of Dish & Dry Soil <#4,gm	389.5								
Weight of Dish, gm	171.0								
Weight of Dry Soil <#4, gm	218.5								
Wt. Ret. on #4 Sieve, lb	33.1								
Wt. Ret. on #200 Sieve, gm	52.3								
% Gravel	**15.2**								
% Sand	**20.3**								
% Silt & Clay	**64.5**								

Remarks: As an added benefit to our clients, the gravel fraction may be included in this report. Whether or not it is included is dependent upon both the technician's time available and if there is a significant enough amount of gravel. The gravel is always included in the percent retained on the #200 sieve but may not be weighed separately to determine the percentage, especially if there is only a trace amount, (5% or less).

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		9.4	50.1	40.5					
□		26.7	65.3	8.0					
△		84.8	14.5	0.7					

SIEVE inches size	PERCENT FINER ○	□	△
3			100.0
2			92.3
1.5"		100.0	81.3
1"		97.1	57.7
3/4"		92.3	43.8
1/2"	100.0	86.5	
3/8"	99.7	82.5	26.6
GRAIN SIZE			
D_{60}	0.500	2.03	26.4
D_{30}		0.595	11.5
D_{10}		0.139	2.74
COEFFICIENTS			
C_c		1.25	1.82
C_u		14.56	9.65

SIEVE number size	PERCENT FINER ○	□	△
#4	90.6	73.3	15.2
#10	76.9	59.7	8.1
#30	61.8	30.2	3.0
#40	58.4	22.4	2.3
#50	54.7	16.0	1.6
#100	46.9	10.3	1.0
#200	40.5	8.0	0.7

SOIL DESCRIPTION

○ Reddish Brown Clayey SAND

□ Dark Olive Brown Well-Graded SAND w/ Silt & Gravel

△ Dark Olive Brown Well-Graded GRAVEL

REMARKS:

○

□ Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

△

○ Source: BC-04 Sample No.: S-03 Elev./Depth: 11-12.5'

□ Source: BC-07 Sample No.: S-04 Elev./Depth: 13'

△ Source: BC-10 Sample No.: S-01 Elev./Depth: 9.5'

COOPER TESTING LABORATORY

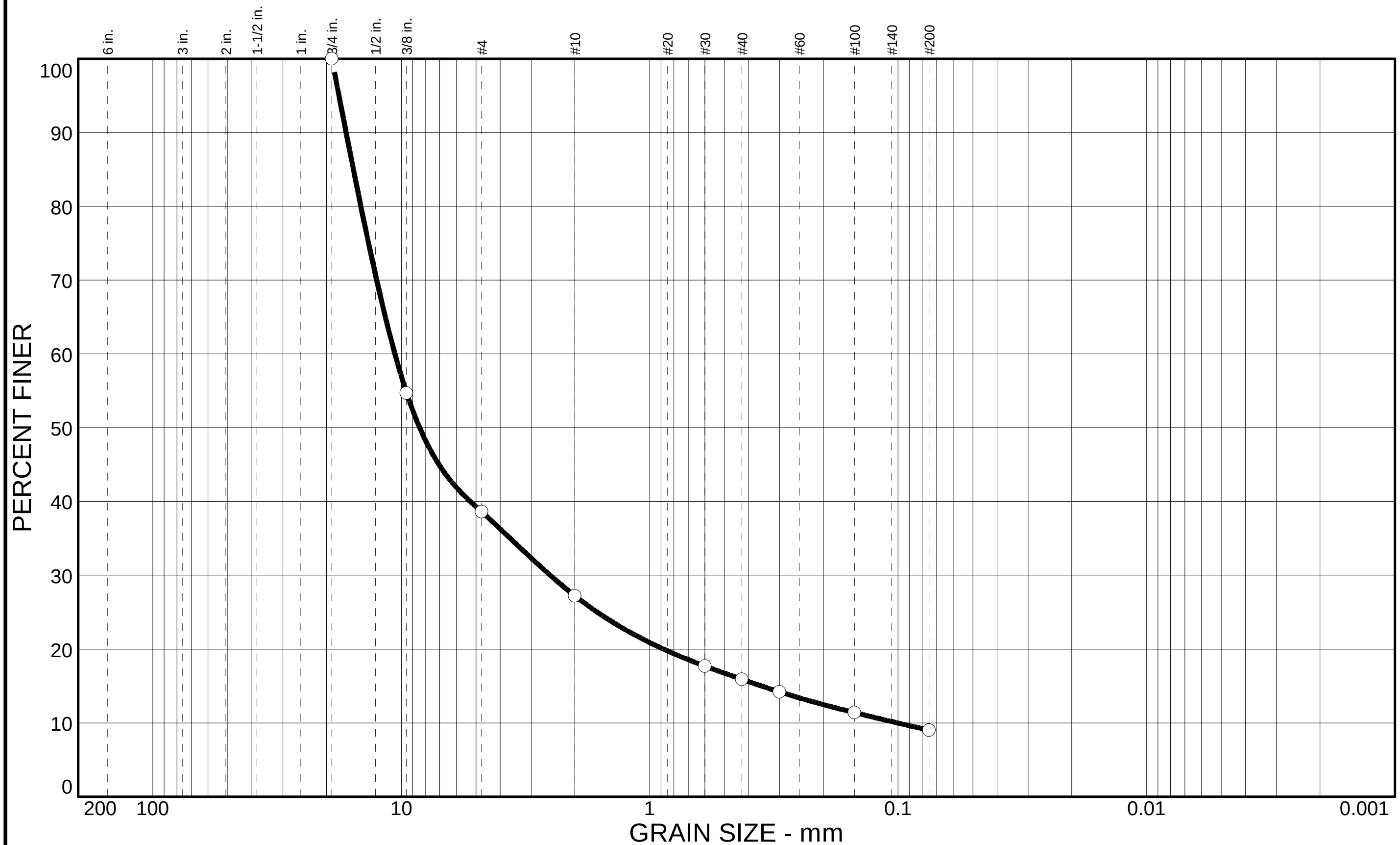
Client: AECOM

Project: Klamath River Dam Removal Project - 60537920

Project No.: 020-251

Figure

Particle Size Distribution Report



	% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY	USCS	AASHTO	PL	LL
○		61.4	29.6	9.0		GP-GM		26	41

SIEVE inches size	PERCENT FINER ○		
3/4"	100.0		
3/8"	54.7		
	GRAIN SIZE		
D_{60}	10.6		
D_{30}	2.52		
D_{10}	0.101		
	COEFFICIENTS		
C_c	5.92		
C_u	105.44		

SIEVE number size	PERCENT FINER ○		
#4	38.6		
#10	27.2		
#30	17.7		
#40	15.9		
#50	14.2		
#100	11.4		
#200	9.0		

SOIL DESCRIPTION
○ Olive Gray Poorly Graded GRAVEL w/ Silt & Sand

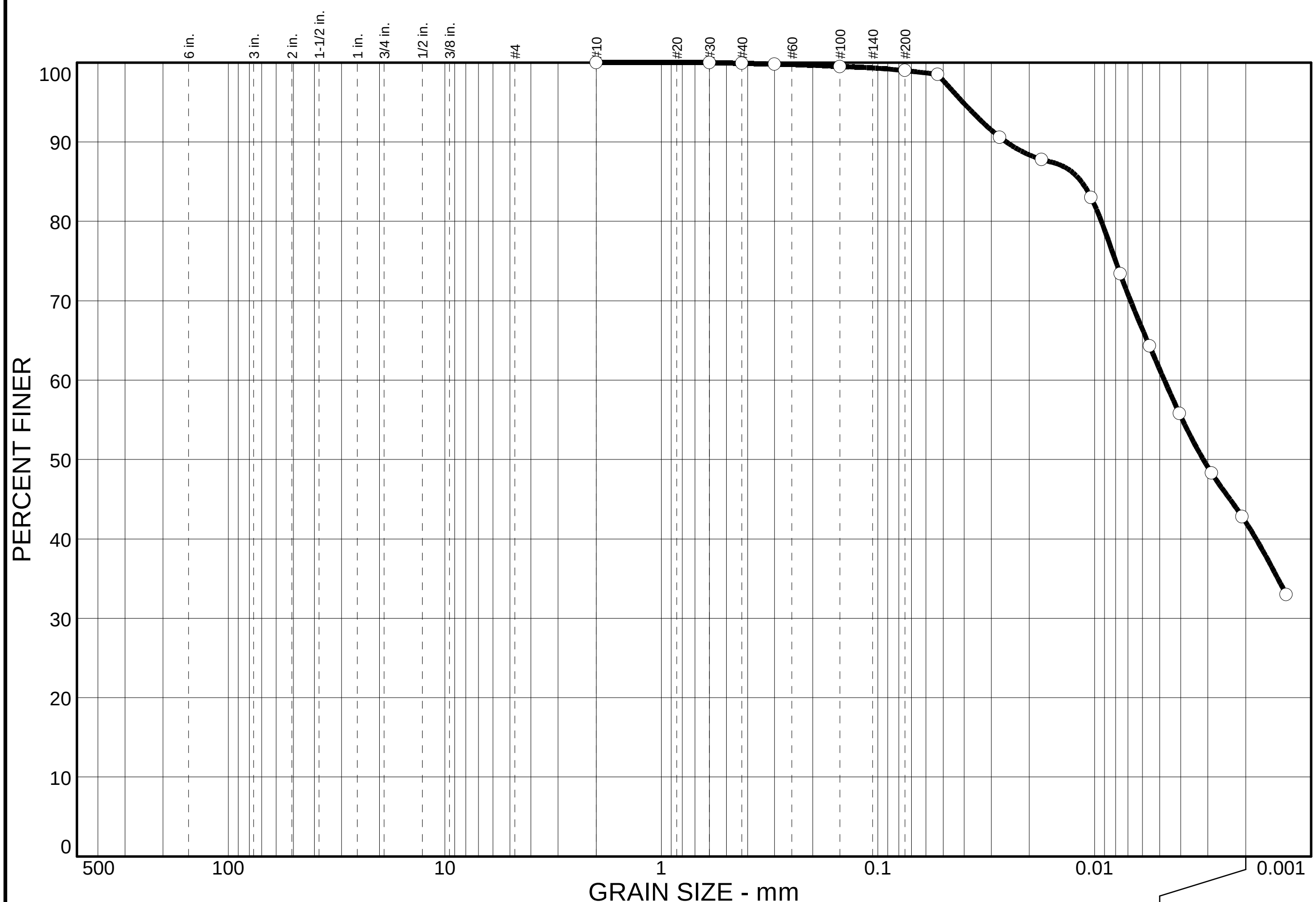
REMARKS:
○

○ Source: BI-03 Sample No.: S-01 Elev./Depth: 3.5'

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920
Project No.: 020-251 Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	1.0	56.9	42.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	100.0		
#40	99.9		
#50	99.8		
#100	99.5		
#200	99.0		
#270	98.5		
0.0274 mm.	90.6		
0.0176 mm.	87.8		
0.0104 mm.	83.0		
0.0076 mm.	73.4		
0.0056 mm.	64.3		
0.0041 mm.	55.8		
0.0029 mm.	48.3		
0.0021 mm.	42.8		
0.0013 mm.	33.0		

* (no specification provided)

Soil Description

Olive Gray Elastic SILT

Atterberg Limits

PL= 51 LL= 85 PI= 34

Coefficients

D_{85}= 0.0115 D_{60}= 0.0048 D_{50}= 0.0031
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

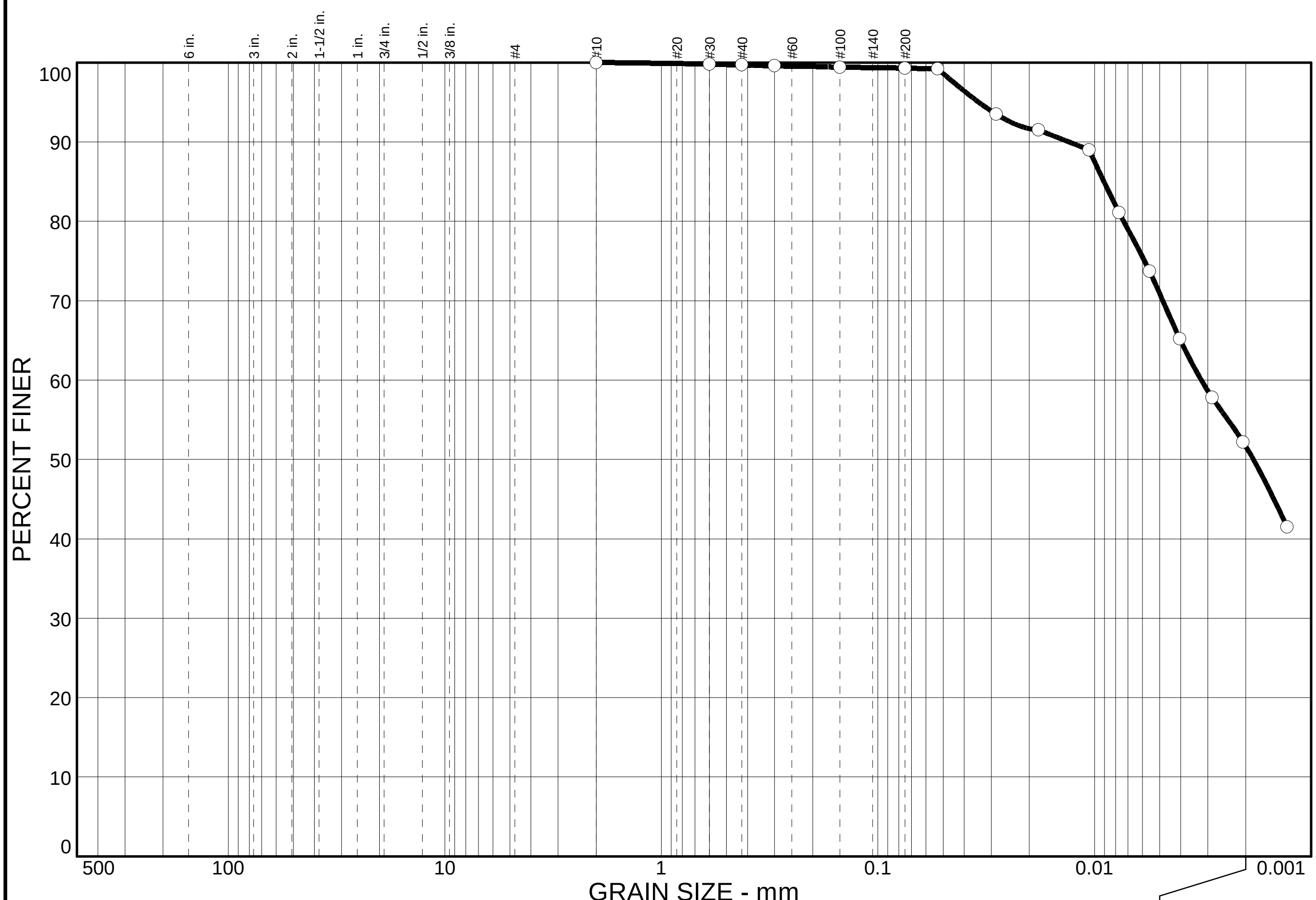
Sample No.: S-04 **Source of Sample:** BC-01 **Date:** 6/5/18
Location: **Elev./Depth:** 21.5'

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	0.7	47.7	51.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.8		
#40	99.7		
#50	99.6		
#100	99.4		
#200	99.3		
#270	99.2		
0.0285 mm.	93.5		
0.0182 mm.	91.5		
0.0106 mm.	89.0		
0.0077 mm.	81.1		
0.0056 mm.	73.7		
0.0040 mm.	65.2		
0.0029 mm.	57.8		
0.0021 mm.	52.2		
0.0013 mm.	41.5		

* (no specification provided)

Soil Description

Gray Elastic SILT

Atterberg Limits

PL= 59 LL= 105 PI= 46

Coefficients

D_{85}= 0.0090 D_{60}= 0.0032 D_{50}= 0.0018
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

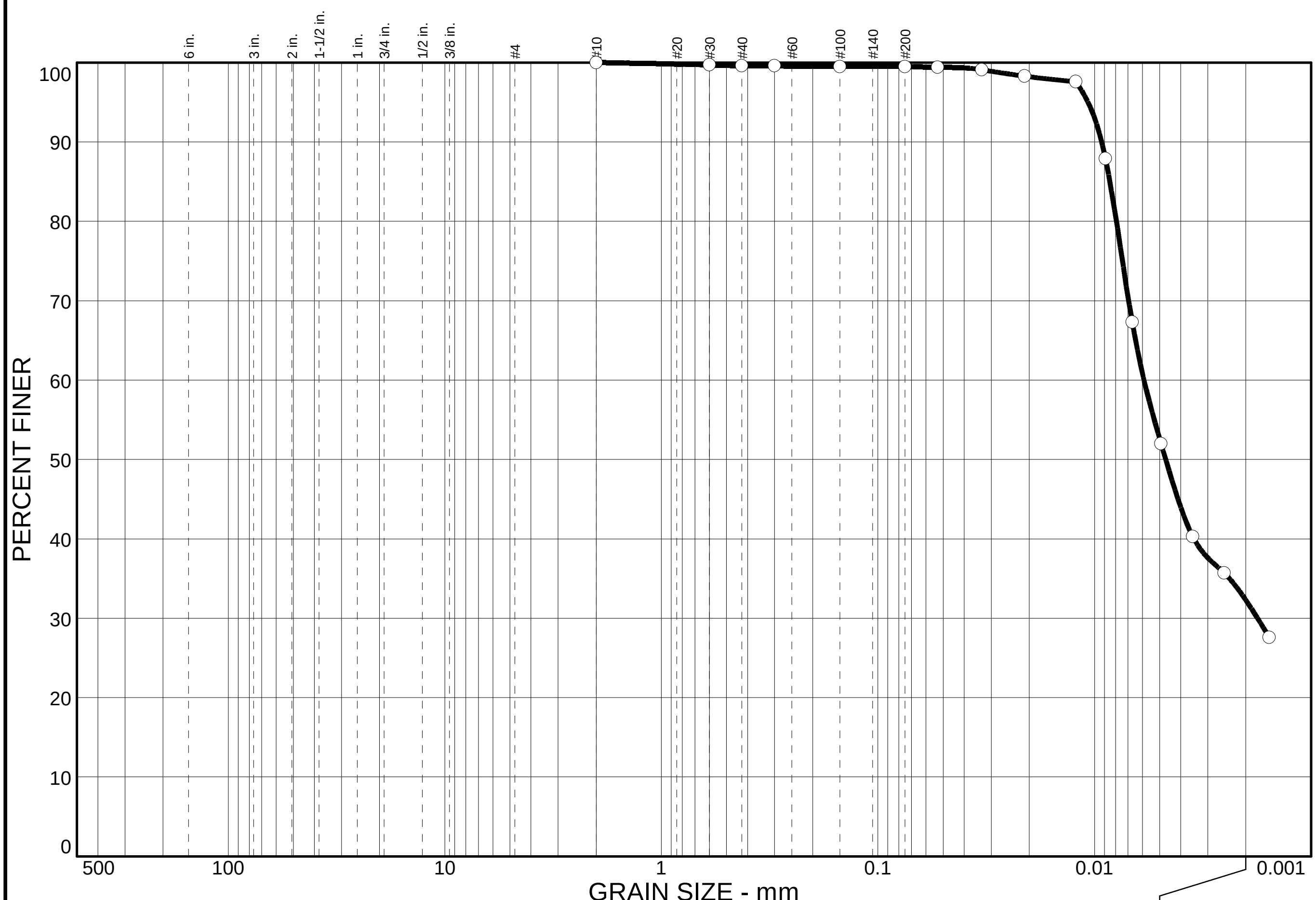
Sample No.: S-05 **Source of Sample:** BC-02 **Date:** 6/5/18
Location: **Elev./Depth:** 14.5'

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	0.5	67.2	32.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.7		
#40	99.6		
#50	99.6		
#100	99.5		
#200	99.5		
#270	99.4		
0.0331 mm.	99.1		
0.0210 mm.	98.3		
0.0122 mm.	97.6		
0.0089 mm.	87.9		
0.0067 mm.	67.3		
0.0049 mm.	52.0		
0.0035 mm.	40.3		
0.0025 mm.	35.7		
0.0016 mm.	27.6		

* (no specification provided)

Soil Description

Gray Elastic SILT

Atterberg Limits

PL= 85 LL= 187 PI= 102

Coefficients

D_{85}= 0.0085 D_{60}= 0.0059 D_{50}= 0.0047
D_{30}= 0.0018 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

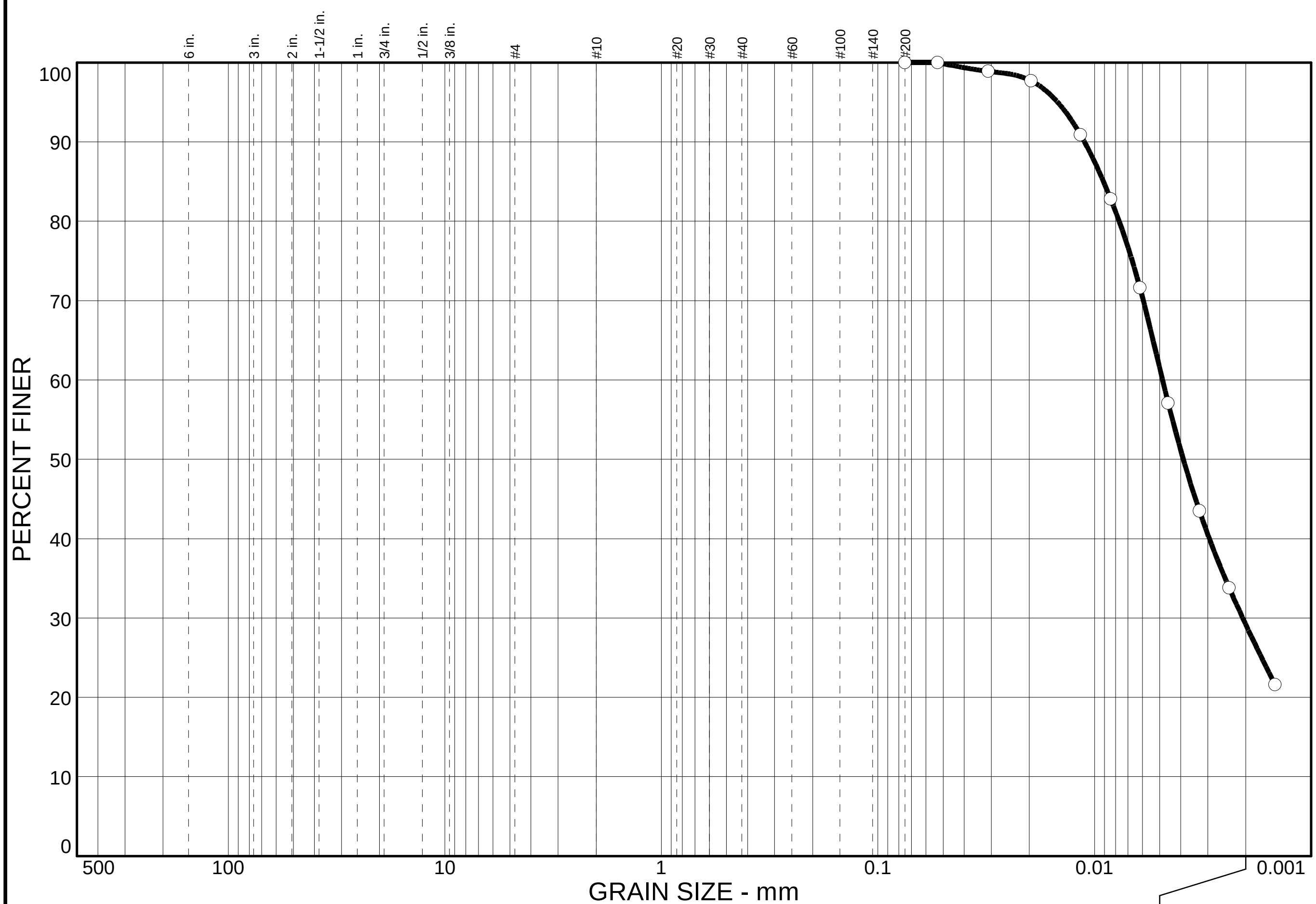
Sample No.: S-09 **Source of Sample:** BC-02 **Date:** 6/5/18
Location: **Elev./Depth:** 44.5'

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	0.0	70.9	29.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#200	100.0		
#270	100.0		
0.0309 mm.	98.9		
0.0196 mm.	97.7		
0.0116 mm.	90.9		
0.0084 mm.	82.8		
0.0062 mm.	71.6		
0.0046 mm.	57.1		
0.0033 mm.	43.5		
0.0024 mm.	33.8		
0.0015 mm.	21.6		

* (no specification provided)

Soil Description

Light Olive Brown Elastic SILT

Atterberg Limits

PL= 59 LL= 69 PI= 10

Coefficients

D_{85}= 0.0091 D_{60}= 0.0049 D_{50}= 0.0039
D_{30}= 0.0021 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

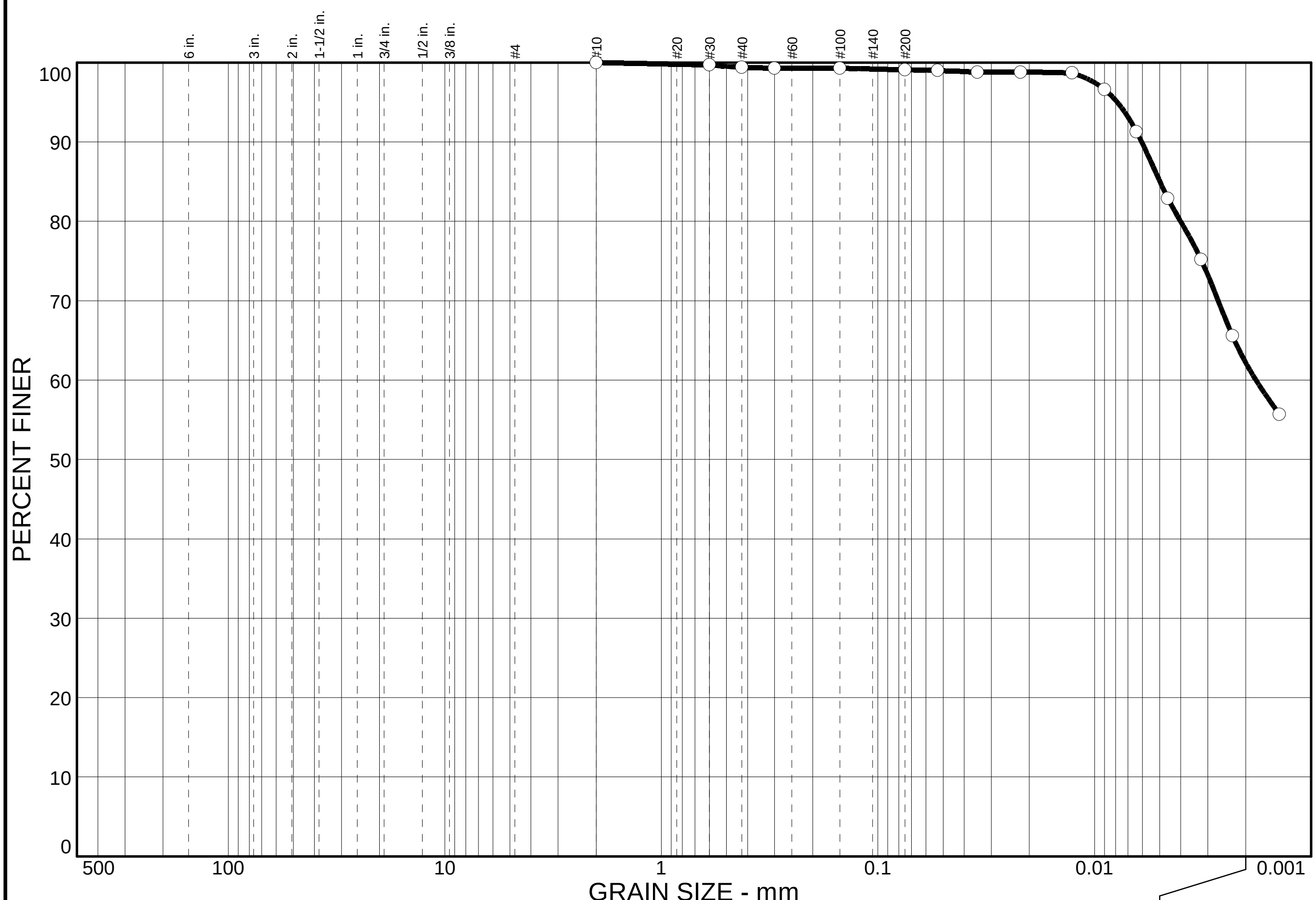
Sample No.: S-05 **Source of Sample:** BC-03 **Date:** 6/5/18
Location: **Elev./Depth:** 24.5'

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	0.9	37.0	62.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.7		
#40	99.4		
#50	99.3		
#100	99.3		
#200	99.1		
#270	99.0		
0.0347 mm.	98.8		
0.0219 mm.	98.8		
0.0127 mm.	98.7		
0.0090 mm.	96.6		
0.0064 mm.	91.3		
0.0046 mm.	82.9		
0.0032 mm.	75.2		
0.0023 mm.	65.6		
0.0014 mm.	55.7		

* (no specification provided)

Soil Description

Pale Brown Mottled Gray Elastic SILT

Atterberg Limits

PL= 85 LL= 120 PI= 35

Coefficients

D_{85}= 0.0050 D_{60}= 0.0018 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

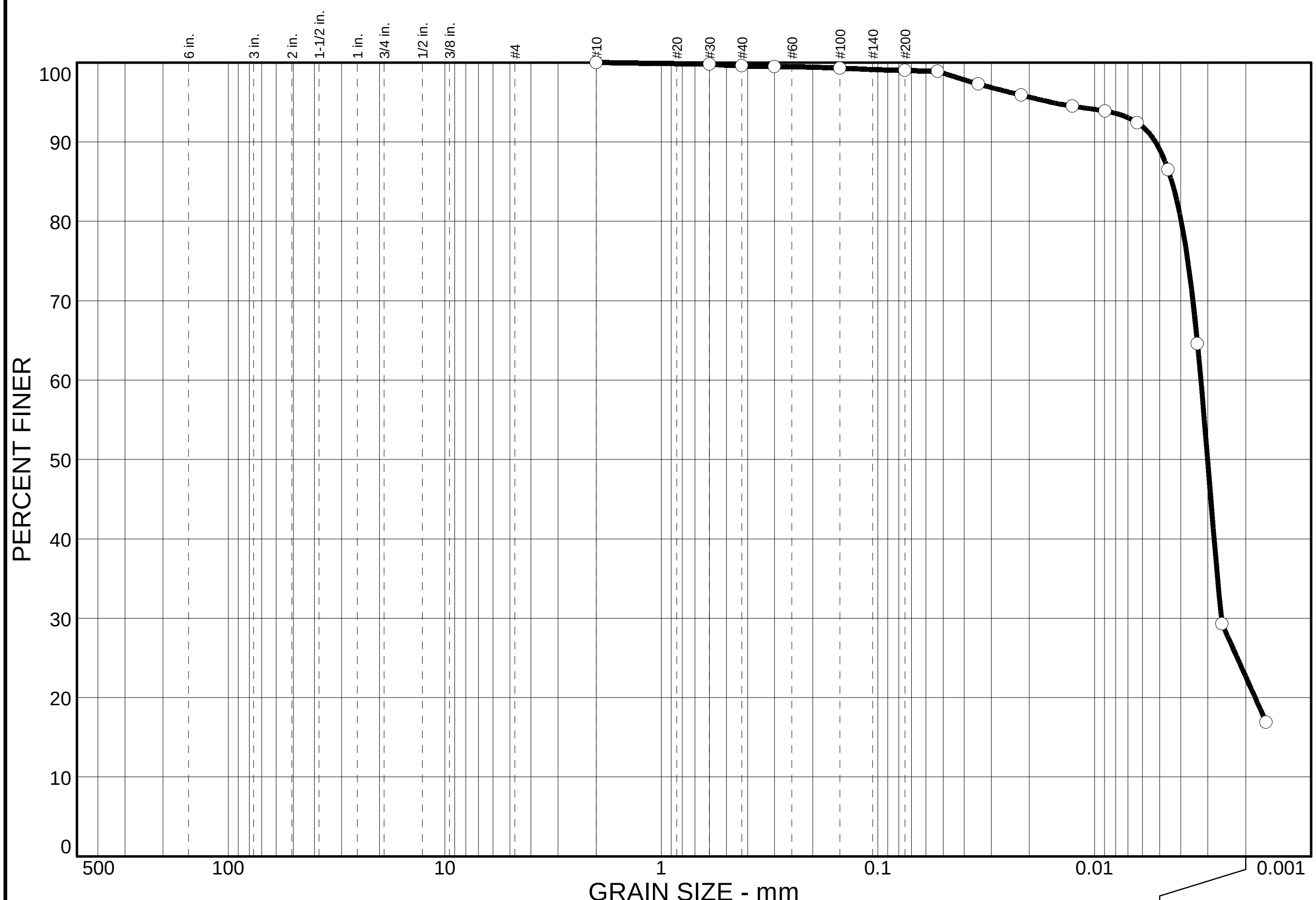
Sample No.: S-08 **Source of Sample:** BC-04 **Date:** 5/16/18
Location: **Elev./Depth:** 32.5(Tip-16")

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	1.0	76.4	22.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.8		
#40	99.6		
#50	99.5		
#100	99.3		
#200	99.0		
#270	98.9		
0.0343 mm.	97.3		
0.0218 mm.	95.9		
0.0126 mm.	94.5		
0.0089 mm.	93.9		
0.0063 mm.	92.4		
0.0046 mm.	86.5		
0.0034 mm.	64.6		
0.0026 mm.	29.3		
0.0016 mm.	16.9		

* (no specification provided)

Soil Description

Light Olive Brown Elastic SILT

Atterberg Limits

PL= 88 LL= 200 PI= 112

Coefficients

D_{85}= 0.0044 D_{60}= 0.0032 D_{50}= 0.0030
D_{30}= 0.0026 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

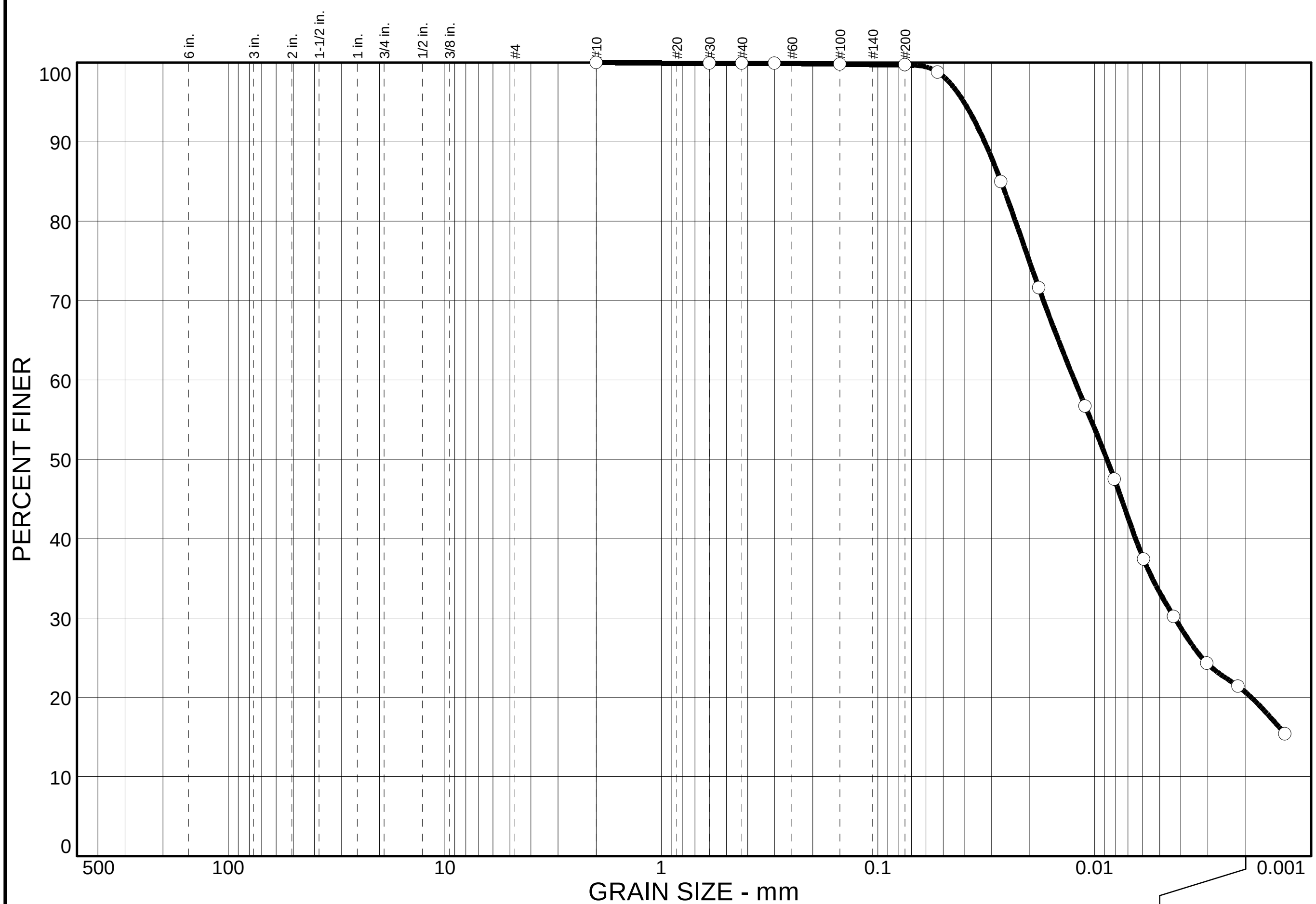
Sample No.: S-05 **Source of Sample:** BC-08A **Date:** 6/5/18
Location: **Elev./Depth:** 54'

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.0	0.3	79.1	20.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#30	99.9		
#40	99.9		
#50	99.9		
#100	99.8		
#200	99.7		
#270	98.8		
0.0270 mm.	85.0		
0.0181 mm.	71.6		
0.0110 mm.	56.7		
0.0081 mm.	47.5		
0.0059 mm.	37.4		
0.0043 mm.	30.2		
0.0030 mm.	24.3		
0.0022 mm.	21.4		
0.0013 mm.	15.4		

* (no specification provided)

Soil Description

Dark Gray Elastic SILT

Atterberg Limits

PL= 53 LL= 74 PI= 21

Coefficients

D_{85}= 0.0270 D_{60}= 0.0124 D_{50}= 0.0088
D_{30}= 0.0043 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= MH AASHTO=

Remarks

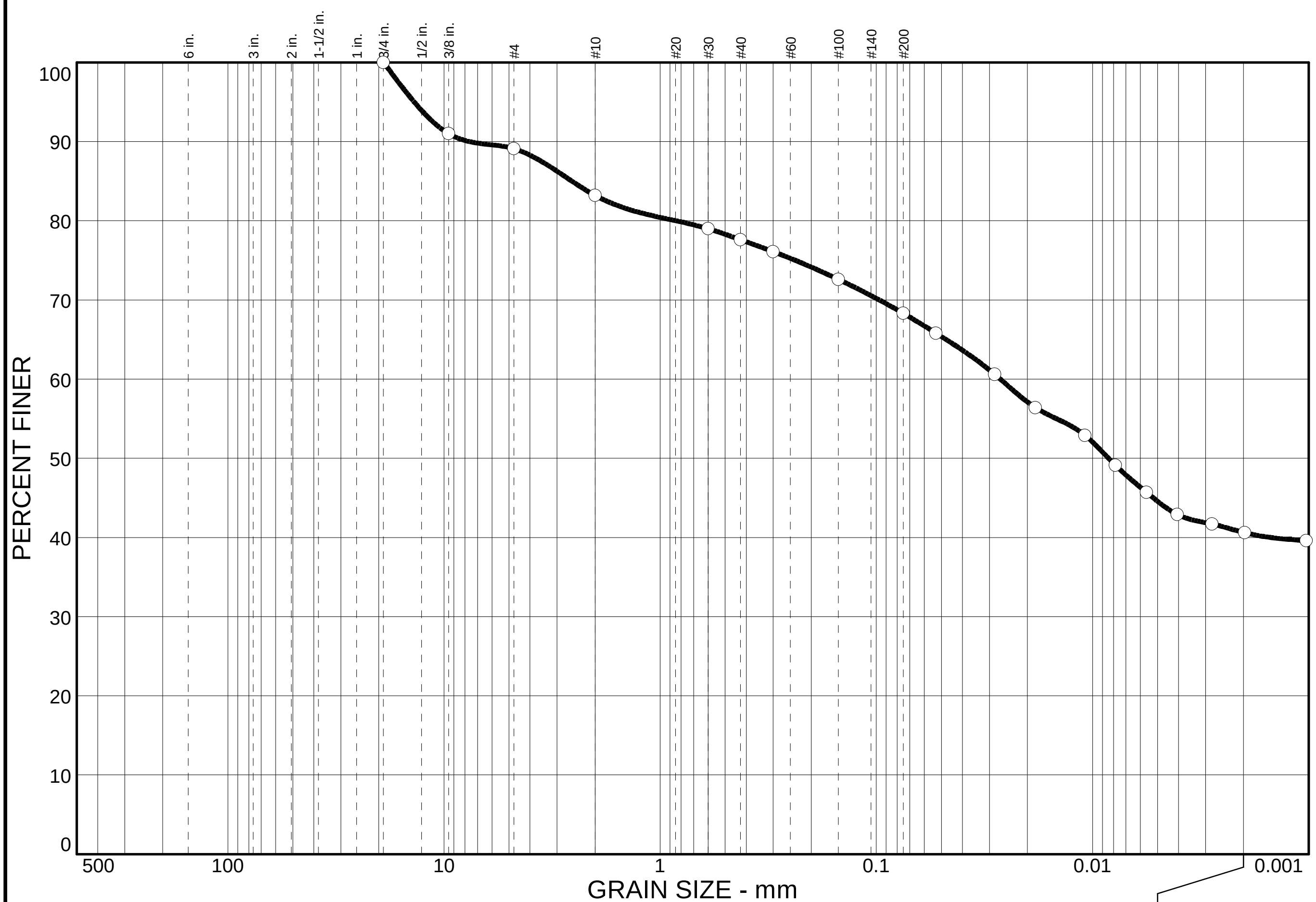
Sample No.: S-05 **Source of Sample:** BC-09 **Date:** 6/5/18
Location: **Elev./Depth:** 23(Tip-5")

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	10.9	20.8	27.7	40.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
3/8 in.	91.0		
#4	89.1		
#10	83.2		
#30	79.0		
#40	77.6		
#50	76.1		
#100	72.6		
#200	68.3		
#270	65.8		
0.0284 mm.	60.6		
0.0184 mm.	56.4		
0.0108 mm.	52.9		
0.0078 mm.	49.1		
0.0056 mm.	45.7		
0.0041 mm.	42.9		
0.0028 mm.	41.7		
0.0020 mm.	40.6		
0.0010 mm.	39.6		

* (no specification provided)

Soil Description

Dark Reddish Brown Sandy Fat CLAY

Atterberg Limits

PL= 28 LL= 78 PI= 50

Coefficients

D_{85}= 2.56 D_{60}= 0.0267 D_{50}= 0.0084
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CH AASHTO=

Remarks

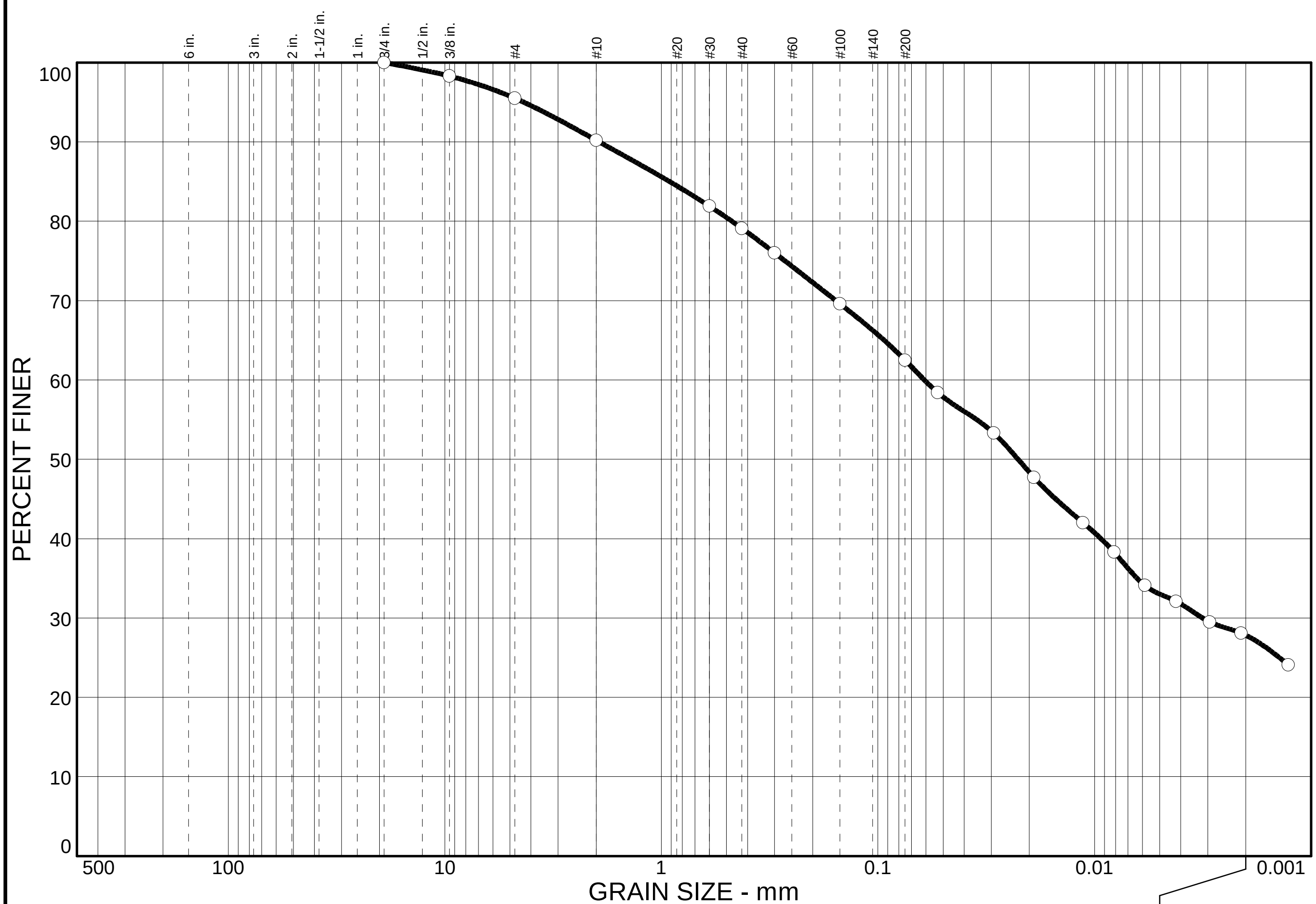
Sample No.: S-01 **Source of Sample:** BI-02 **Date:** 6/6/18
Location: **Elev./Depth:** 5'

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	4.5	33.0	34.7	27.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
3/8 in.	98.3		
#4	95.5		
#10	90.2		
#30	81.9		
#40	79.1		
#50	76.0		
#100	69.6		
#200	62.5		
#270	58.4		
0.0292 mm.	53.3		
0.0190 mm.	47.7		
0.0113 mm.	42.0		
0.0081 mm.	38.3		
0.0059 mm.	34.1		
0.0042 mm.	32.1		
0.0029 mm.	29.5		
0.0021 mm.	28.1		
0.0013 mm.	24.1		

* (no specification provided)

Soil Description

Yellowish Brown Sandy Fat CLAY

Atterberg Limits

PL= 28 LL= 58 PI= 30

Coefficients

D_{85}= 0.917 D_{60}= 0.0612 D_{50}= 0.0226
D_{30}= 0.0032 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CH AASHTO=

Remarks

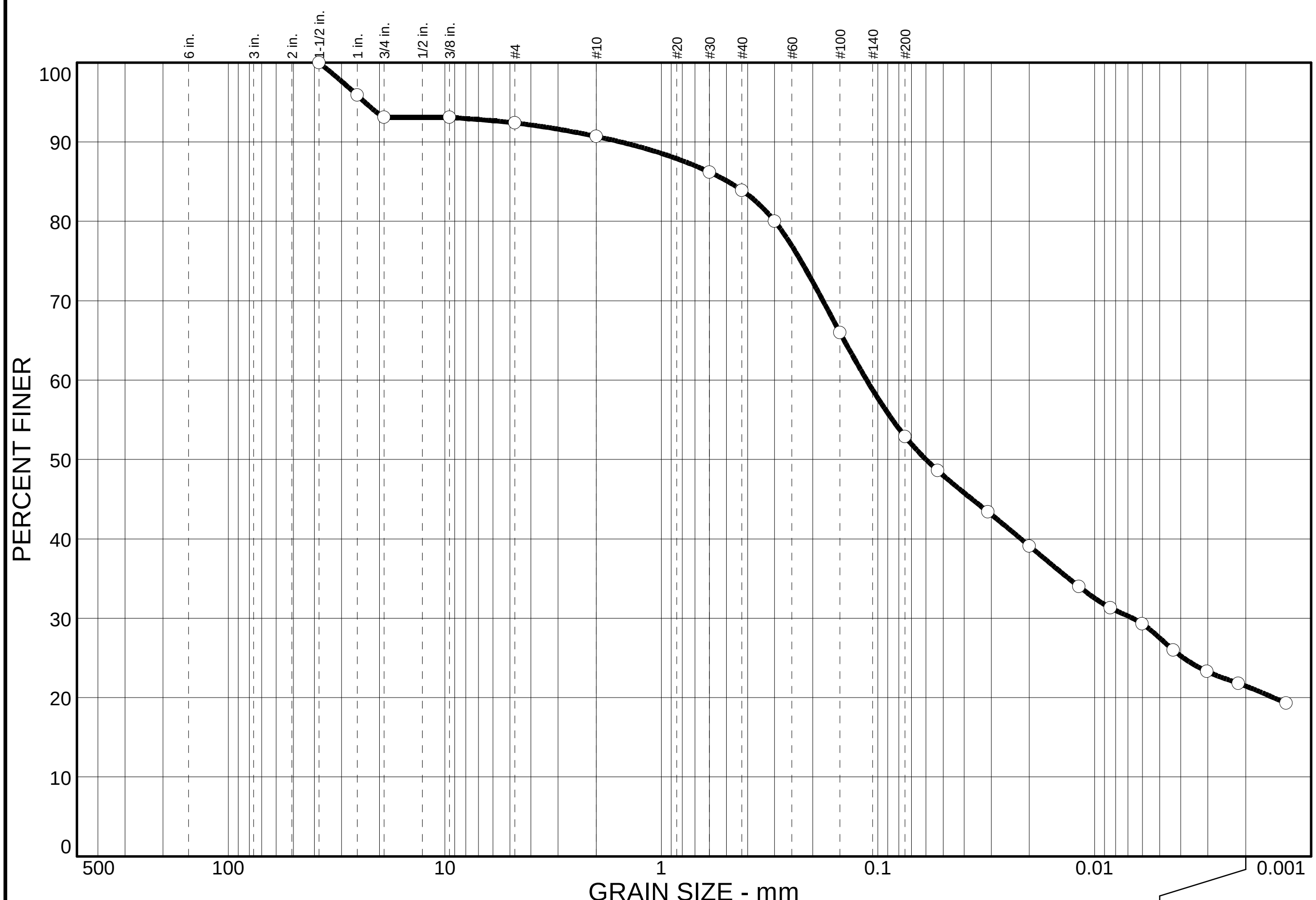
Sample No.: S-02 **Source of Sample:** BI-02 **Date:** 6/6/18
Location: **Elev./Depth:** 10'

COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	7.6	39.5	31.5	21.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5 in.	100.0		
1 in.	95.9		
3/4 in.	93.1		
3/8 in.	93.1		
#4	92.4		
#10	90.7		
#30	86.2		
#40	83.9		
#50	80.0		
#100	66.0		
#200	52.9		
#270	48.6		
0.0311 mm.	43.4		
0.0200 mm.	39.1		
0.0118 mm.	34.0		
0.0084 mm.	31.3		
0.0060 mm.	29.3		
0.0043 mm.	26.0		
0.0030 mm.	23.3		
0.0022 mm.	21.8		
0.0013 mm.	19.3		

* (no specification provided)

Soil Description

Yellowish Brown Sandy Fat CLAY

Atterberg Limits

PL= 27 LL= 51 PI= 24

Coefficients

D_{85}= 0.492 D_{60}= 0.113 D_{50}= 0.0601
D_{30}= 0.0067 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CH AASHTO=

Remarks

Due to the small sample size, relative to the largest particle size, this data should be considered to be approximate.

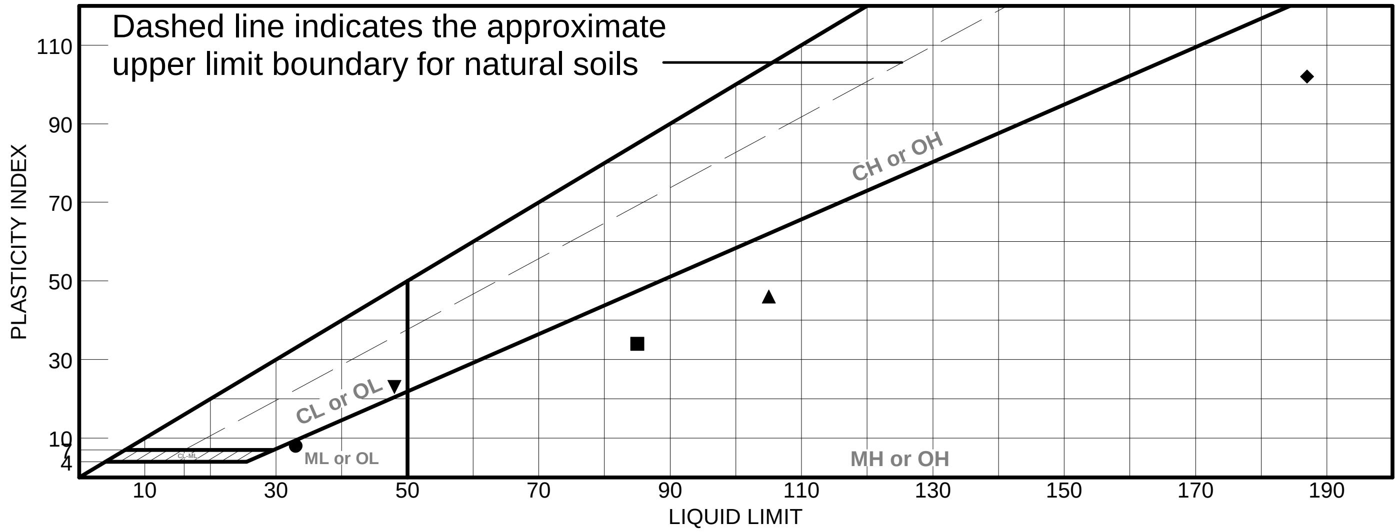
Sample No.: S-03 **Source of Sample:** BI-02 **Date:** 6/6/18
Location: **Elev./Depth:** 15'

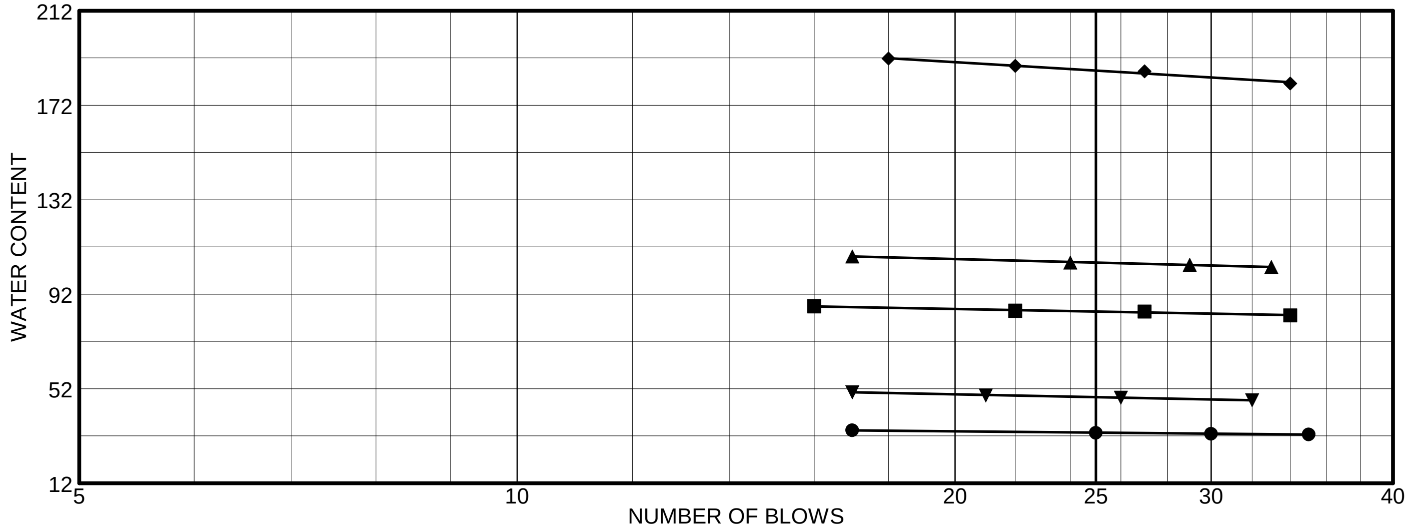
COOPER TESTING LABORATORY

Client: AECOM
Project: Klamath River Dam Removal Project - 60537920

Project No: 020-251 **Figure**

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Dark Olive Gray Sandy SILT	33	25	8			
■	Olive Gray Elastic SILT	85	51	34	99.9	99.0	MH
▲	Gray Elastic SILT	105	59	46	99.7	99.3	MH
◆	Gray Elastic SILT	187	85	102	99.6	99.5	MH
▼	Dark Olive Brown Sandy Lean CLAY	48	25	23			

Project No. 020-251 **Client:** AECOM

Project: Klamath River Dam Removal Project - 60537920

● **Source:** BC-01 **Sample No.:** S-02 **Elev./Depth:** 6.5'
■ **Source:** BC-01 **Sample No.:** S-04 **Elev./Depth:** 21.5'
▲ **Source:** BC-02 **Sample No.:** S-05 **Elev./Depth:** 14.5'
◆ **Source:** BC-02 **Sample No.:** S-09 **Elev./Depth:** 44.5'
▼ **Source:** BC-03 **Sample No.:** S-01 **Elev./Depth:** 1'

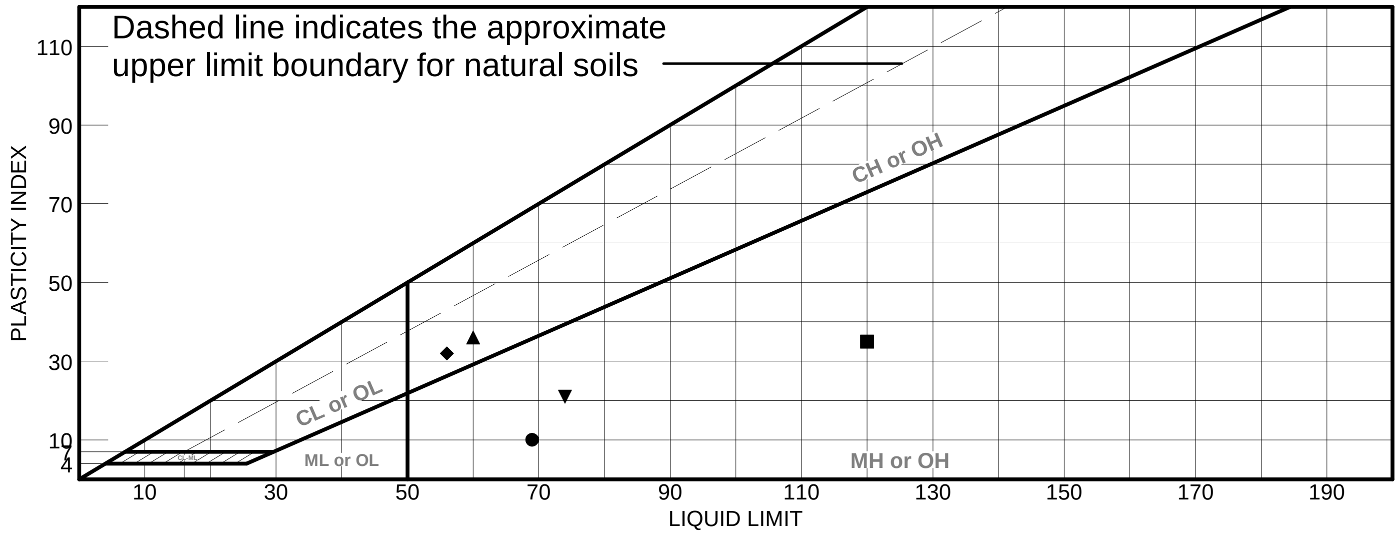
Remarks:
●
■
▲
◆
▼

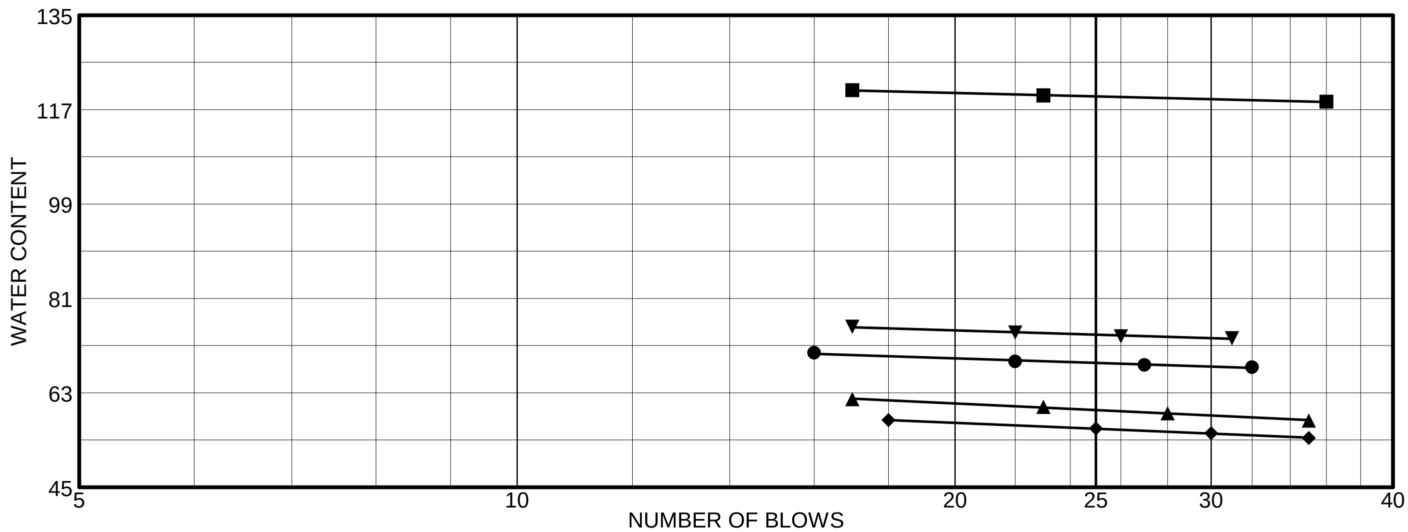
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Light Olive Brown Elastic SILT	69	59	10	100.0	100.0	MH
■	Pale Brown Mottled Gray Elastic SILT	120	85	35	99.4	99.1	MH
▲	Very Dark Olive Brown Sandy Fat CLAY w/ Gravel	60	24	36			
◆	Dark Reddish Brown Sandy Fat CLAY	56	24	32			
▼	Dark Gray Elastic SILT	74	53	21	99.9	99.7	MH

Project No. 020-251 **Client:** AECOM

Project: Klamath River Dam Removal Project - 60537920

● **Source:** BC-03	**Sample No.:** S-05	**Elev./Depth:** 24.5'
■ **Source:** BC-04	**Sample No.:** S-08	**Elev./Depth:** 32.5(Tip-16")
▲ **Source:** BC-07	**Sample No.:** S02	**Elev./Depth:** 4-4.5'
◆ **Source:** BC-08	**Sample No.:** S-01	**Elev./Depth:** 3.0'
▼ **Source:** BC-09	**Sample No.:** S-05	**Elev./Depth:** 23(Tip-5")

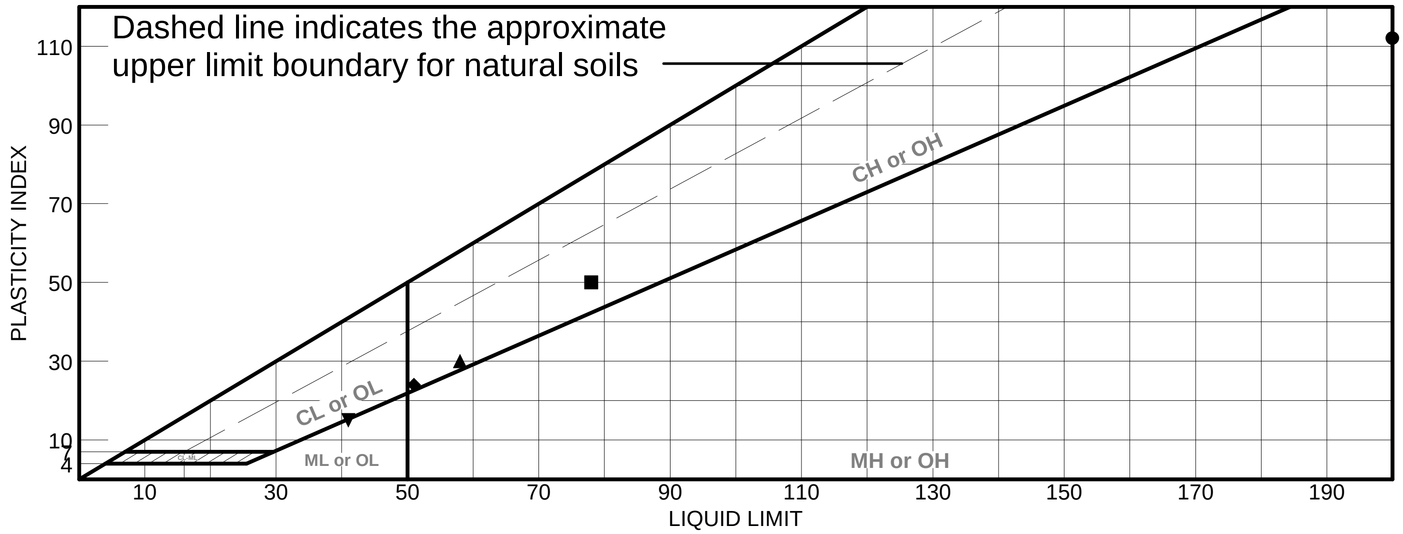
Remarks:
●
■
▲
◆
▼

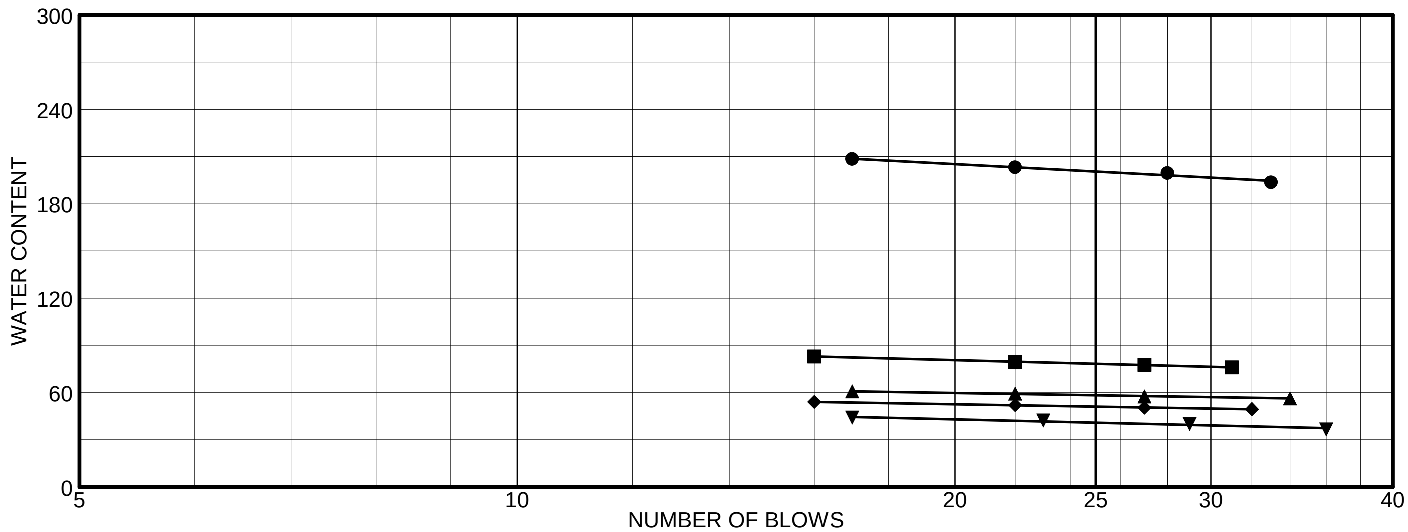
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Light Olive Brown Elastic SILT	200	88	112	99.6	99.0	MH
■	Dark Reddish Brown Sandy Fat CLAY	78	28	50	77.6	68.3	CH
▲	Yellowish Brown Sandy Fat CLAY	58	28	30	79.1	62.5	CH
◆	Yellowish Brown Sandy Fat CLAY	51	27	24	83.9	52.9	CH
▼	Olive Gray Poorly Graded GRAVEL w/ Silt & Sand	41	26	15	15.9	9.0	GP-GM

Project No. 020-251 **Client:** AECOM

Project: Klamath River Dam Removal Project - 60537920

● **Source:** BC-08A **Sample No.:** S-05 **Elev./Depth:** 54'
■ **Source:** BI-02 **Sample No.:** S-01 **Elev./Depth:** 5'
▲ **Source:** BI-02 **Sample No.:** S-02 **Elev./Depth:** 10'
◆ **Source:** BI-02 **Sample No.:** S-03 **Elev./Depth:** 15'
▼ **Source:** BI-03 **Sample No.:** S-01 **Elev./Depth:** 3.5'

Remarks:
●
■
▲
◆
▼

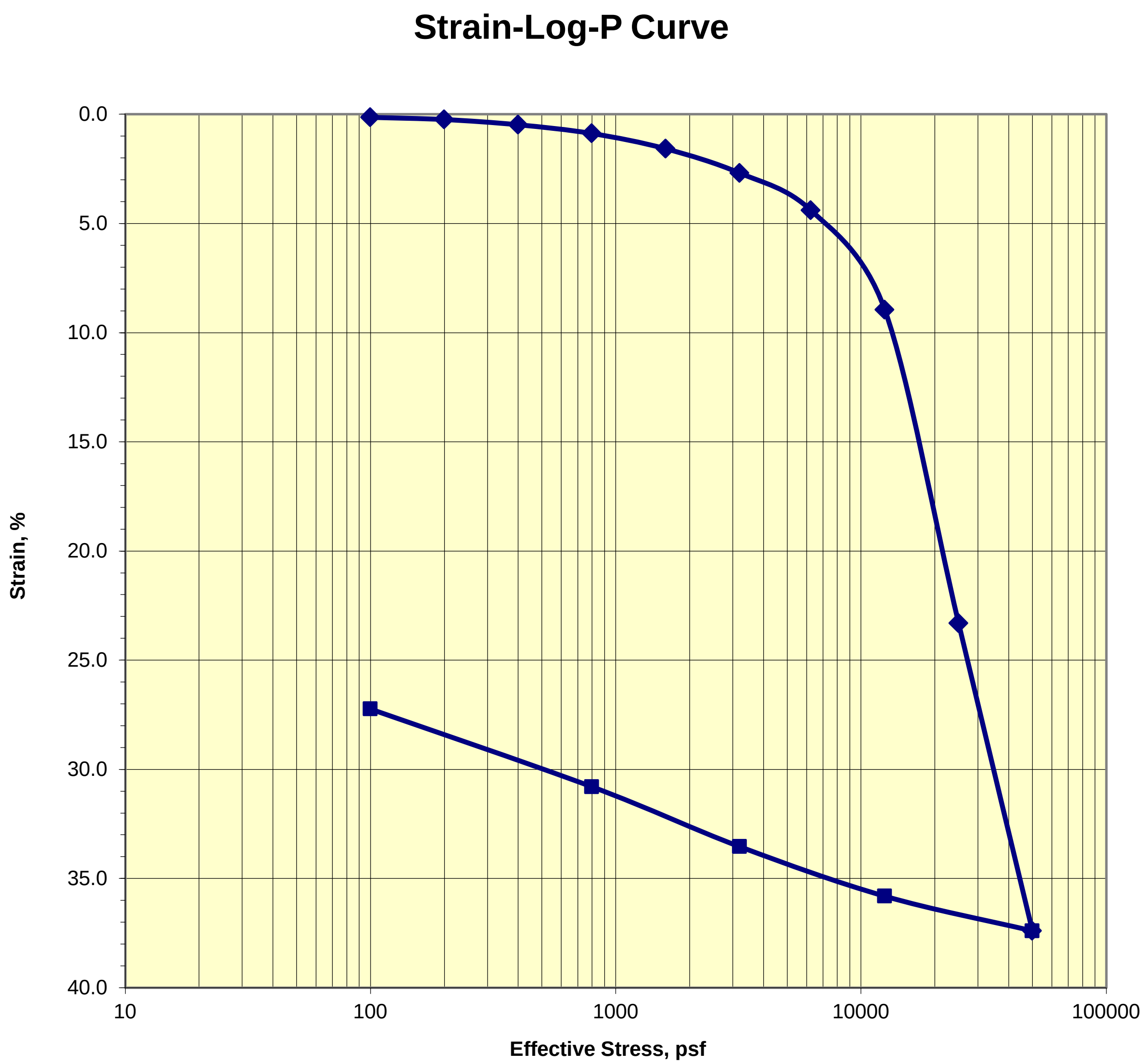
LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

Consolidation Test
ASTM D2435

Job No.:	020-251	**Boring:**	BC-04	**Run By:**	MD
Client:	AECOM	**Sample:**	S-08	**Reduced:**	PJ
Project:	60537920	**Depth, ft.:**	32.5(Tip-2")	**Checked:**	PJ/DC
Soil Type:	Pale Brown Mottled Gray Elastic SILT			**Date:**	6/1/2018

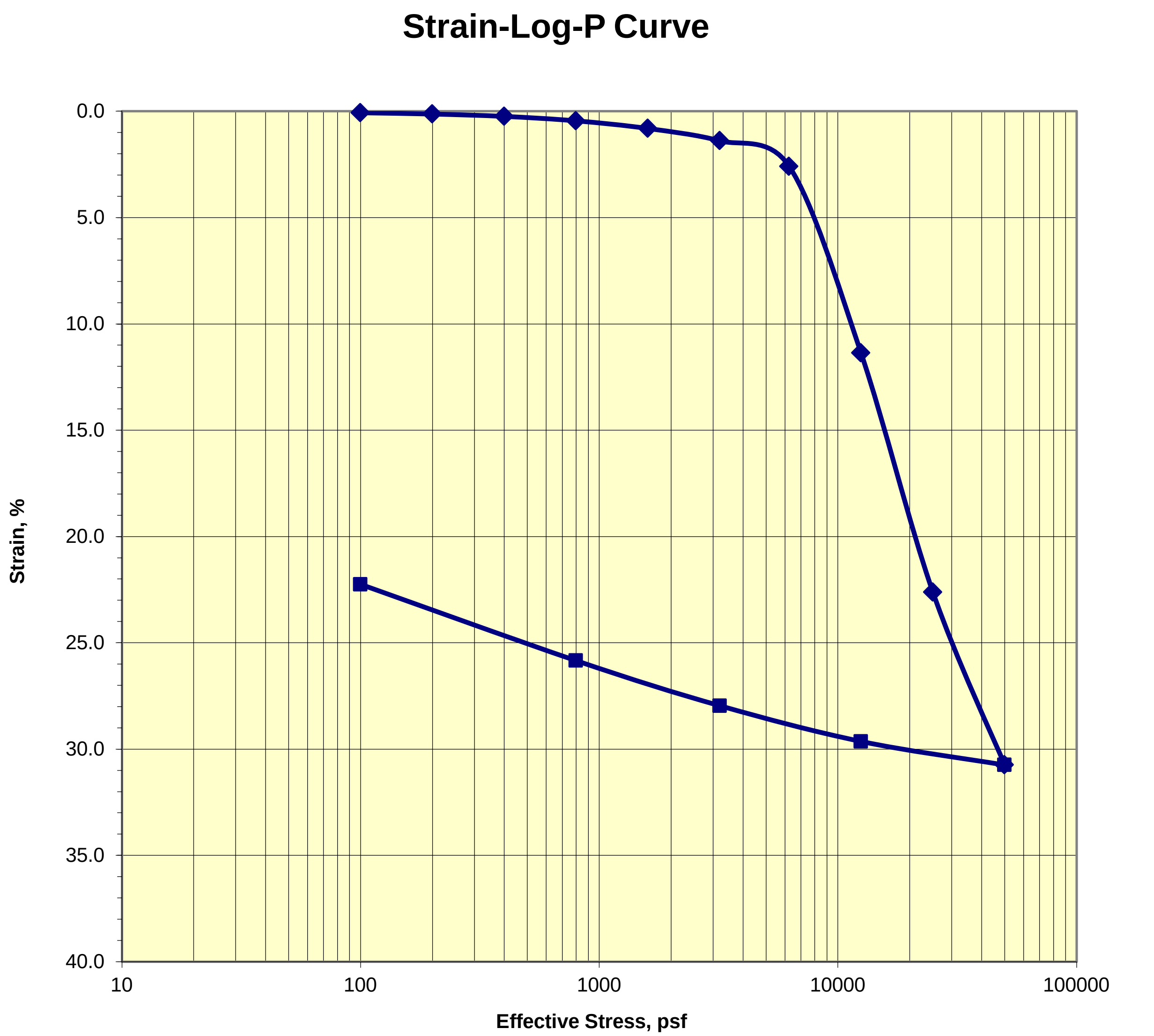


Assumed Gs 2.6	Initial	Final
Moisture %:	149.5	104.4
Dry Density, pcf:	32.1	43.7
Void Ratio:	4.058	2.715
% Saturation:	95.8	100.0

Remarks:

Consolidation Test
ASTM D2435

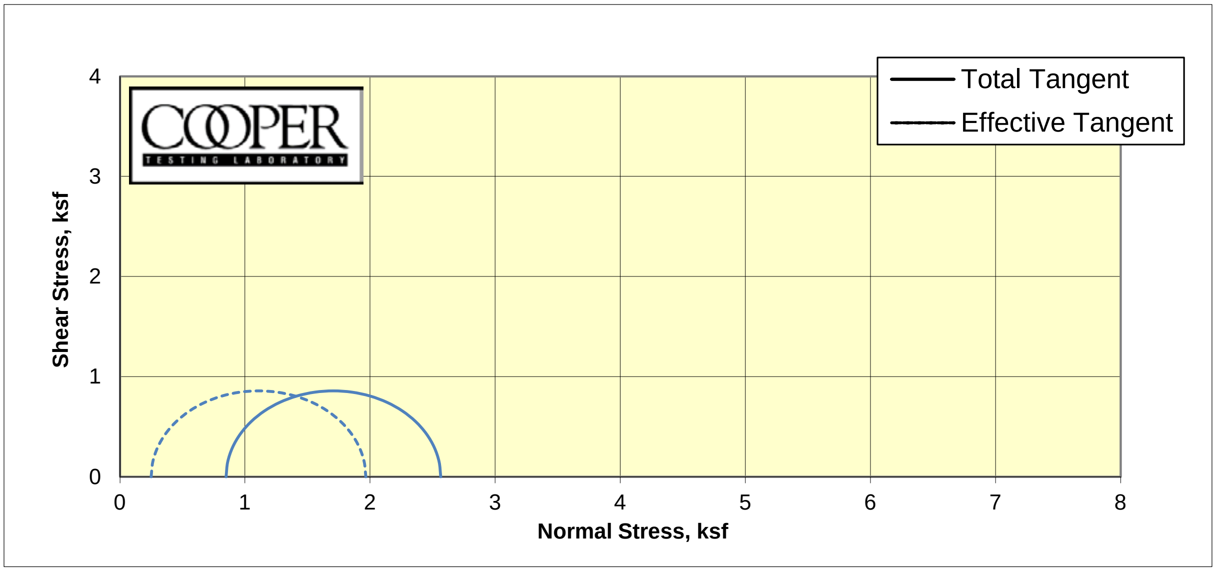
Job No.:	020-251	**Boring:**	BC-09	**Run By:**	MD
Client:	AECOM	**Sample:**	S-09	**Reduced:**	PJ
Project:	60537920	**Depth, ft.:**	68-70.5(Tip-20")	**Checked:**	PJ/DC
Soil Type:	Dark Greenish Gray CLAY (Silty)			**Date:**	6/1/2018

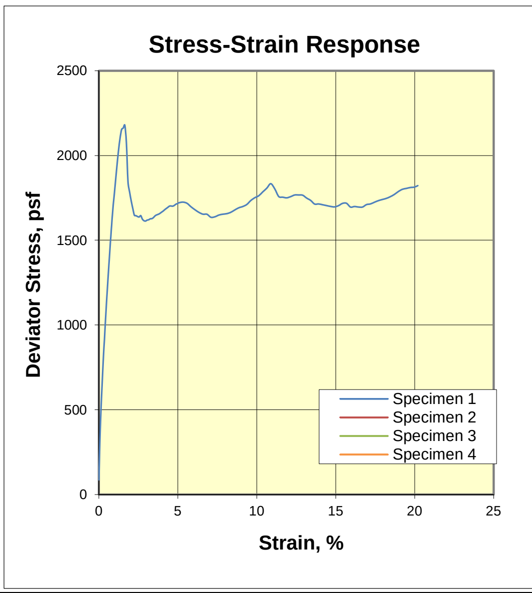


Assumed Gs 2.6	Initial	Final
Moisture %:	88.4	60.3
Dry Density, pcf:	48.6	63.2
Void Ratio:	2.340	1.568
% Saturation:	98.2	100.0

Remarks:

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767





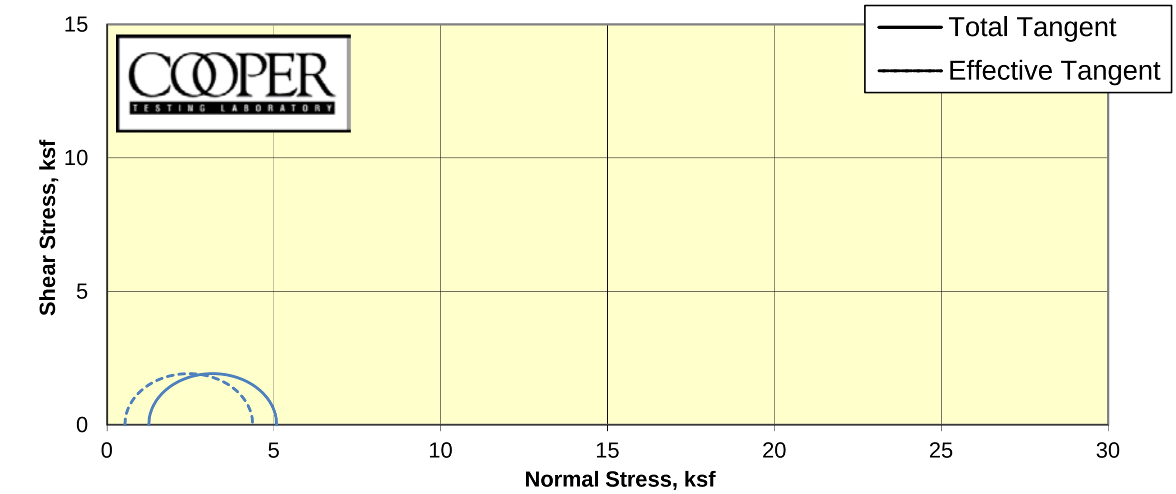
CTL Number:	020-251
Client Name:	AECOM
Project Name:	Klamath River Dam Removal Project
Project Number:	60537920
Date:	5/30/2018 By: MD/DC

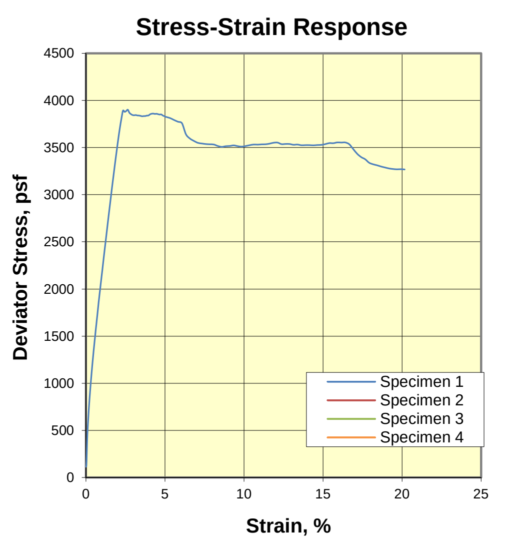
Total C	#DIV/0!	ksf
Total phi	#DIV/0!	degrees
Eff. C	#DIV/0!	ksf
Eff. Phi	#DIV/0!	degrees

©

Specimen	1	2	3	4
Boring	BC-02			
Sample	S-06			
Depth	19.5(Tip-2")			
Visual Description	Gray CLAY (Silty)			
MC (%)	147.5			
Dry Density (pcf)	31.6			
Saturation (%)	92.6			
Void Ratio	4.139			
Diameter (in)	2.86			
Height (in)	6.07			
	Final			
MC (%)	147.6			
Dry Density (pcf)	33.6			
Saturation (%)	100.0			
Void Ratio	3.838			
Diameter (in)	2.79			
Height (in)	6.02			
Cell Pressure (psi)	86.4			
Back Pressure (psi)	80.5			
	Effective Stresses At:			
Strain (%)	5.0			
Deviator (ksf)	1.716			
Excess PP (psi)	4.2			
Sigma 1 (ksf)	1.966			
Sigma 3 (ksf)	0.250			
P (ksf)	1.108			
Q (ksf)	0.858			
Stress Ratio	7.869			
Rate (in/min)	0.0005			

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767

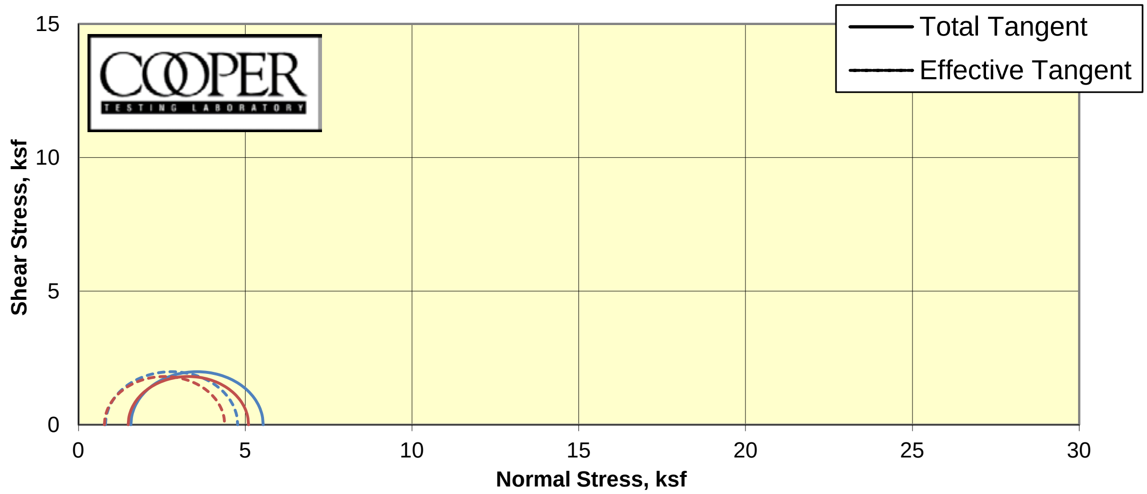


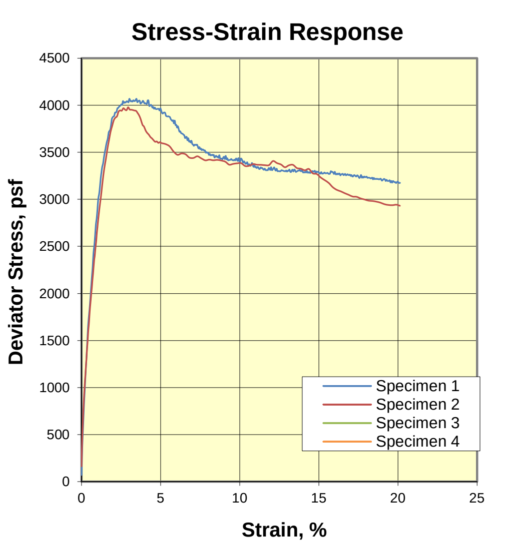


Specimen	1	2	3	4
Boring	BC-02			
Sample	S-08			
Depth	34.5(Tip-6")			
Visual Description	Pale Brown CLAY (Silty)			
MC (%)	148.8			
Dry Density (pcf)	32.7			
Saturation (%)	96.6			
Void Ratio	4.158			
Diameter (in)	2.87			
Height (in)	6.07			
	Final			
MC (%)	148.5			
Dry Density (pcf)	33.6			
Saturation (%)	100.0			
Void Ratio	4.010			
Diameter (in)	2.84			
Height (in)	6.02			
Cell Pressure (psi)	88.8			
Back Pressure (psi)	80.1			
	Effective Stresses At:			
Strain (%)	5.0			
Deviator (ksf)	3.832			
Excess PP (psi)	5.0			
Sigma 1 (ksf)	4.368			
Sigma 3 (ksf)	0.536			
P (ksf)	2.452			
Q (ksf)	1.916			
Stress Ratio	8.153			
Rate (in/min)	0.0005			

CTL Number:	020-251		
Client Name:	AECOM		
Project Name:	Klamath River Dam Removal Project		
Project Number:	60537920		
Date:	5/14/2018	By:	MD/DC
Total C	#DIV/0!	ksf	
Total phi	#DIV/0!	degrees	
Eff. C	#DIV/0!	ksf	
Eff. Phi	#DIV/0!	degrees	©

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767

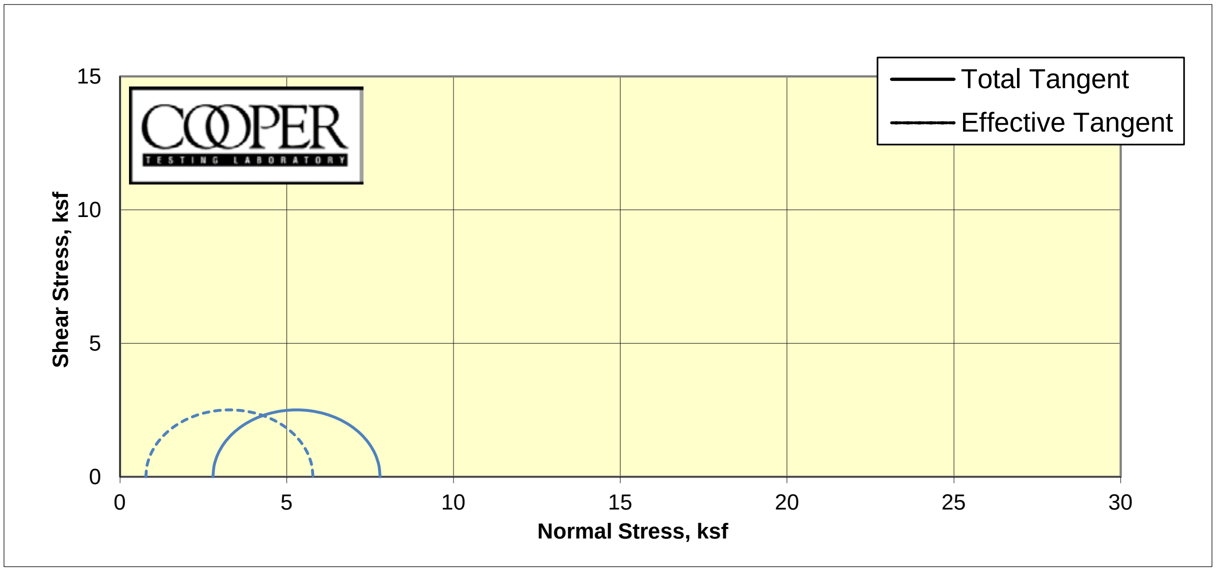


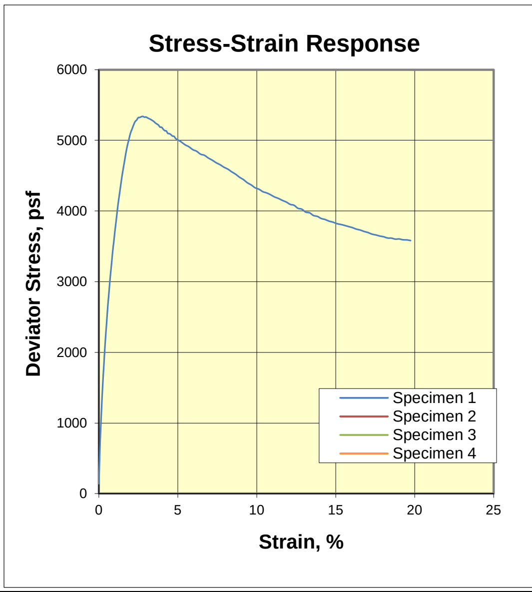


CTL Number:	020-251			
Client Name:	Klamath River Dam Removal Project			
Project Name:	60537920			
Project Number:	43237			
Date:	5/17/2018	By:	MD/DC	
Total C	#DIV/0!	ksf		
Total phi	#DIV/0!	degrees		
Eff. C	#DIV/0!	ksf		
Eff. Phi	#DIV/0!	degrees		©

Specimen	**1**	**2**	**3**	**4**
Boring	BC-03	BC-03		
Sample	S-06	S-06		
Depth	39.5-42(Tip-11")	39.5-42(Tip-4")		
Visual Description	Dark Gray CLAY (Silty)	Dark Gray CLAY		
MC (%)	84.9	90.1		
Dry Density (pcf)	50.2	47.7		
Saturation (%)	99.0	97.6		
Void Ratio	2.230	2.402		
Diameter (in)	2.87	2.87		
Height (in)	6.06	6.08		
	Final			
MC (%)	83.0	87.9		
Dry Density (pcf)	51.4	49.4		
Saturation (%)	100.0	100.0		
Void Ratio	2.158	2.285		
Diameter (in)	2.85	2.83		
Height (in)	6.02	6.04		
Cell Pressure (psi)	90.5	91.6		
Back Pressure (psi)	79.5	81.2		
	Effective Stresses At:			
Strain (%)	5.0	5.0		
Deviator (ksf)	3.966	3.607		
Excess PP (psi)	5.3	5.0		
Sigma 1 (ksf)	4.775	4.386		
Sigma 3 (ksf)	0.809	0.779		
P (ksf)	2.792	2.582		
Q (ksf)	1.983	1.804		
Stress Ratio	5.901	5.632		
Rate (in/min)	0.0005	0.0005		

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767

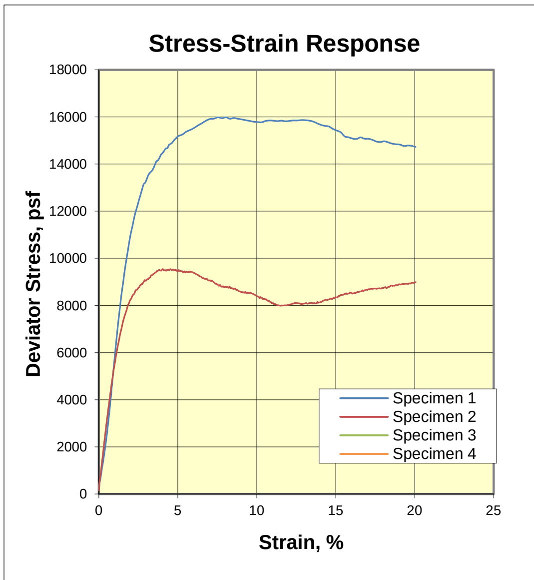




CTL Number:	020-251		
Client Name:	AECOM		
Project Name:	Klamath River Dam Removal Project		
Project Number:	60537920		
Date:	5/21/2018	By:	MD/DC
Total C	#DIV/0!	ksf	
Total phi	#DIV/0!	degrees	
Eff. C	#DIV/0!	ksf	
Eff. Phi	#DIV/0!	degrees	©

Specimen	1	2	3	4
Boring	BC-03			
Sample	S-10			
Depth	90(Tip-13")			
Visual Description	Dark Gray CLAY			
MC (%)	119.8			
Dry Density (pcf)	35.8			
Saturation (%)	88.1			
Void Ratio	3.533			
Diameter (in)	2.87			
Height (in)	6.08			
	Final			
MC (%)	116.3			
Dry Density (pcf)	40.3			
Saturation (%)	100.0			
Void Ratio	3.023			
Diameter (in)	2.69			
Height (in)	6.16			
Cell Pressure (psi)	99.9			
Back Pressure (psi)	80.5			
	Effective Stresses At:			
Strain (%)	5.0			
Deviator (ksf)	5.012			
Excess PP (psi)	14.0			
Sigma 1 (ksf)	5.788			
Sigma 3 (ksf)	0.777			
P (ksf)	3.283			
Q (ksf)	2.506			
Stress Ratio	7.452			
Rate (in/min)	0.0005			

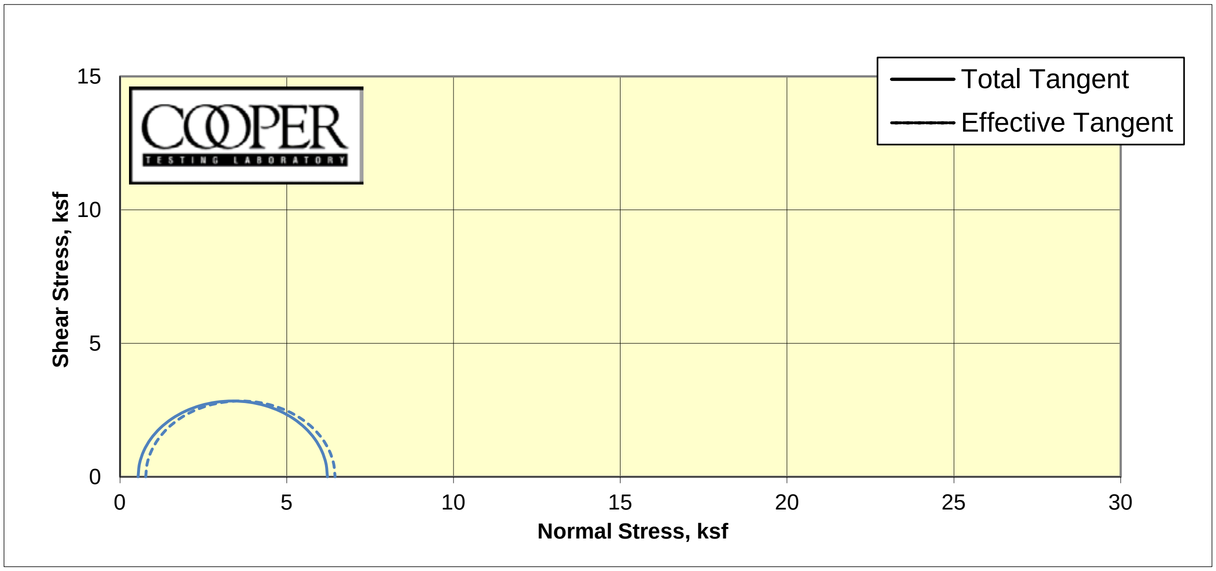
Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767

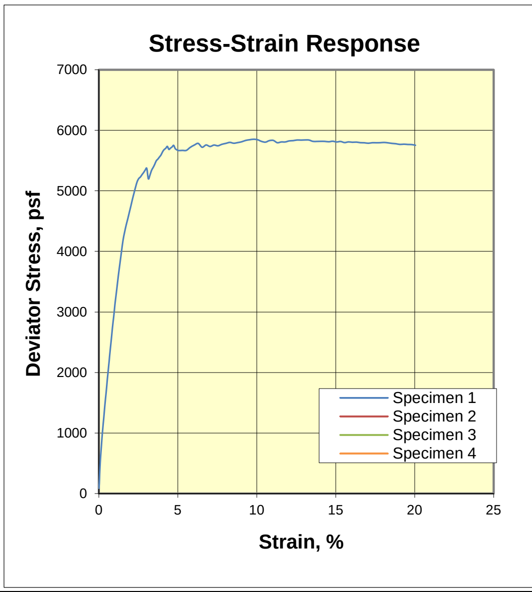


CTL Number:	020-251		
Client Name:	AECOM		
Project Name:	Klamath River Dam Removal Project		
Project Number:	60537920		
Date:	6/6/2018	By:	MD/DC
Total C	#DIV/0!	ksf	
Total phi	#DIV/0!	degrees	
Eff. C	#DIV/0!	ksf	
Eff. Phi	#DIV/0!	degrees	©

Specimen	1	2	3	4
Boring	BC-04	BC-04		
Sample	S-04	S-04		
Depth	12.5-14(Tip-15")	12.5-14.5(Tip-4")		
Visual Description	Brown Weathered Rock	Dark Brown Clayey GRAVEL (Weathered Rock)		
MC (%)	60.8	53.9		
Dry Density (pcf)	59.2	65.0		
Saturation (%)	90.8	93.7		
Void Ratio	1.740	1.497		
Diameter (in)	2.87	2.86		
Height (in)	6.06	6.06		
	Final			
MC (%)	61.4	54.7		
Dry Density (pcf)	62.5	67.0		
Saturation (%)	100.0	100.0		
Void Ratio	1.597	1.422		
Diameter (in)	2.80	2.82		
Height (in)	6.04	6.04		
Cell Pressure (psi)	83.2	82.9		
Back Pressure (psi)	79.2	79.1		
	Effective Stresses At:			
Strain (%)	5.0	5.0		
Deviator (ksf)	15.130	9.485		
Excess PP (psi)	-8.1	-7.3		
Sigma 1 (ksf)	16.872	11.080		
Sigma 3 (ksf)	1.741	1.594		
P (ksf)	9.306	6.337		
Q (ksf)	7.565	4.743		
Stress Ratio	9.688	6.949		
Rate (in/min)	0.0005	0.0005		

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767





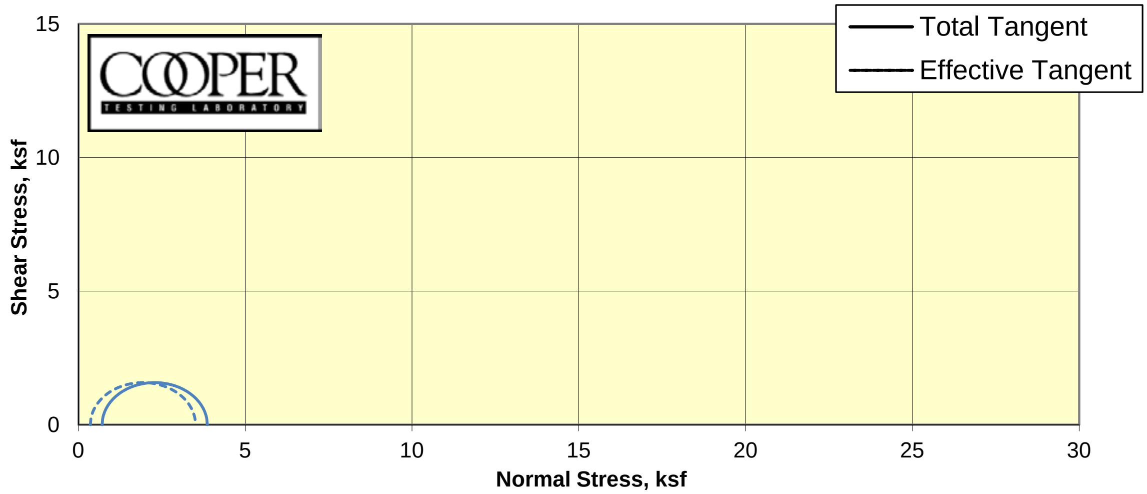
CTL Number:	020-251
Client Name:	AECOM
Project Name:	Klamath River Dam Removal Project
Project Number:	60537920
Date:	5/14/2018 By: MD/DC

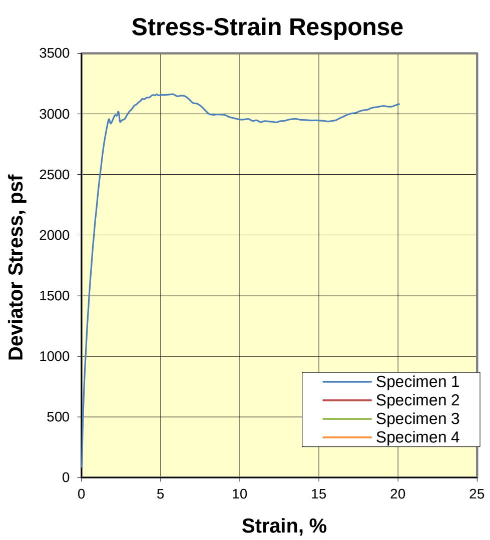
Total C	#DIV/0!	ksf
Total phi	#DIV/0!	degrees
Eff. C	#DIV/0!	ksf
Eff. Phi	#DIV/0!	degrees

©

Specimen	1	2	3	4
Boring	BC-04			
Sample	S-5			
Depth	17.5(Tip-6")			
Visual Description	Light Gray CLAY			
MC (%)	104.7			
Dry Density (pcf)	42.1			
Saturation (%)	94.2			
Void Ratio	3.000			
Diameter (in)	2.87			
Height (in)	6.08			
	Final			
MC (%)	105.4			
Dry Density (pcf)	43.8			
Saturation (%)	100.0			
Void Ratio	2.846			
Diameter (in)	2.82			
Height (in)	6.07			
Cell Pressure (psi)	84.0			
Back Pressure (psi)	80.2			
	Effective Stresses At:			
Strain (%)	5.0			
Deviator (ksf)	5.677			
Excess PP (psi)	-1.6			
Sigma 1 (ksf)	6.450			
Sigma 3 (ksf)	0.774			
P (ksf)	3.612			
Q (ksf)	2.838			
Stress Ratio	8.336			
Rate (in/min)	0.0005			

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767





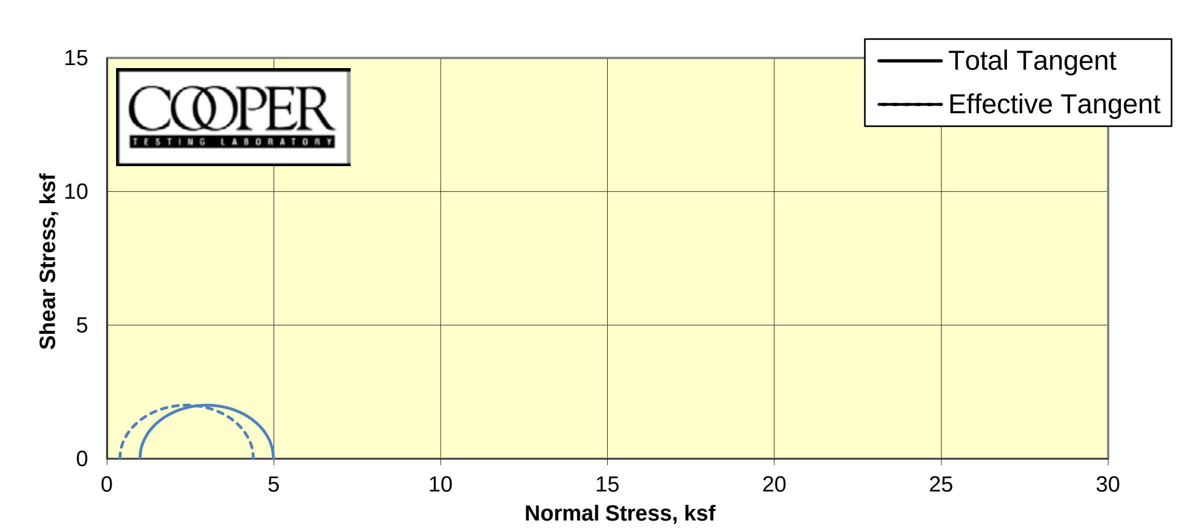
CTL Number:	020-251
Client Name:	AECOM
Project Name:	Klamath River Dam Removal Project
Project Number:	60537920
Date:	5/30/2018 By: MD/DC

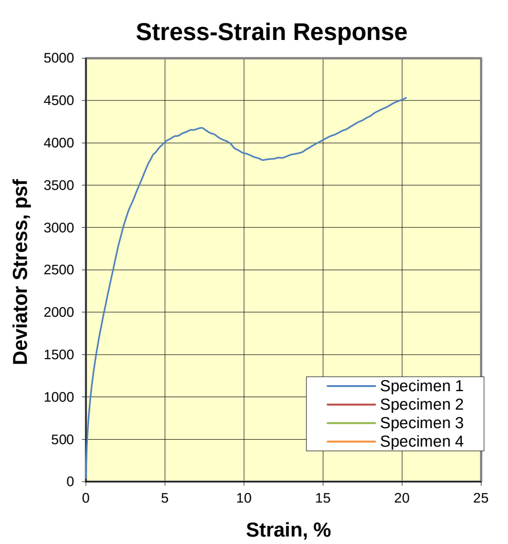
Total C	#DIV/0!	ksf
Total phi	#DIV/0!	degrees
Eff. C	#DIV/0!	ksf
Eff. Phi	#DIV/0!	degrees

©

Specimen	1	2	3	4
Boring	BC-04			
Sample	S-06			
Depth	22.5(Tip-2")			
Visual Description	Greenish Gray CLAY (Silty)/ SILT (slightly plastic)			
MC (%)	154.6			
Dry Density (pcf)	31.7			
Saturation (%)	97.4			
Void Ratio	4.127			
Diameter (in)	2.87			
Height (in)	6.07			
	Final			
MC (%)	152.8			
Dry Density (pcf)	32.6			
Saturation (%)	100.0			
Void Ratio	3.974			
Diameter (in)	2.83			
Height (in)	6.05			
Cell Pressure (psi)	85.0			
Back Pressure (psi)	80.1			
	Effective Stresses At:			
Strain (%)	5.0			
Deviator (ksf)	3.153			
Excess PP (psi)	2.5			
Sigma 1 (ksf)	3.511			
Sigma 3 (ksf)	0.358			
P (ksf)	1.935			
Q (ksf)	1.576			
Stress Ratio	9.796			
Rate (in/min)	0.0005			

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767



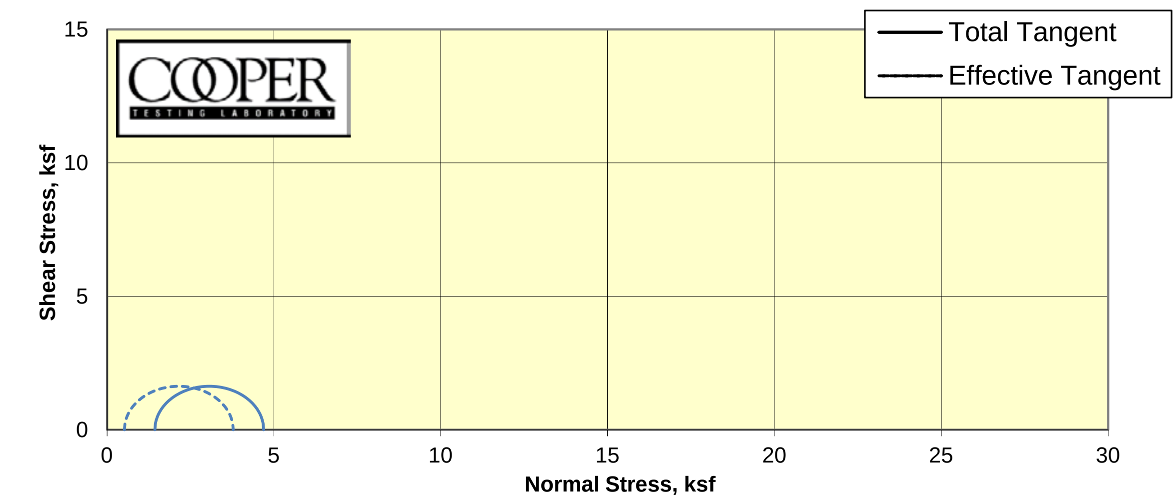


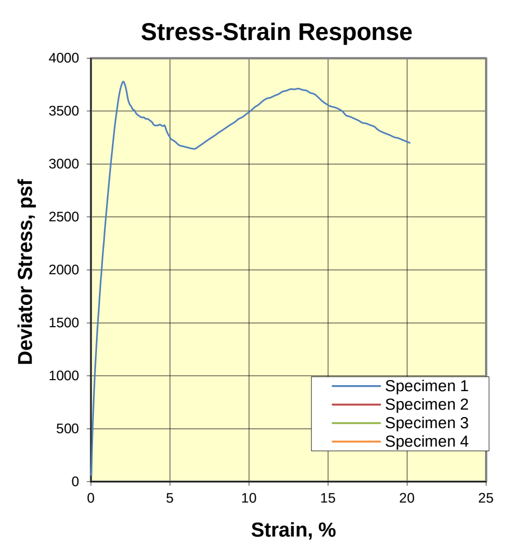
CTL Number:	020-251
Client Name:	AECOM
Project Name:	Klamath River Dam Removal Project
Project Number:	60537920
Date:	5/17/2018 By: MD/DC
Total C	#DIV/0! ksf
Total phi	#DIV/0! degrees
Eff. C	#DIV/0! ksf
Eff. Phi	#DIV/0! degrees

©

Specimen	1	2	3	4
Boring	BC-04			
Sample	S-08			
Depth	32.5(Tip-10")			
Visual Description	Pale Brown Mottled Gray Elastic SILT			
MC (%)	117.2			
Dry Density (pcf)	36.9			
Saturation (%)	89.7			
Void Ratio	3.397			
Diameter (in)	2.87			
Height (in)	6.08			
	Final			
MC (%)	115.5			
Dry Density (pcf)	40.5			
Saturation (%)	100.0			
Void Ratio	3.004			
Diameter (in)	2.76			
Height (in)	6.01			
Cell Pressure (psi)	86.8			
Back Pressure (psi)	80.0			
	Effective Stresses At:			
Strain (%)	5.0			
Deviator (ksf)	4.005			
Excess PP (psi)	4.2			
Sigma 1 (ksf)	4.390			
Sigma 3 (ksf)	0.385			
P (ksf)	2.388			
Q (ksf)	2.003			
Stress Ratio	11.403			
Rate (in/min)	0.0005			

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767

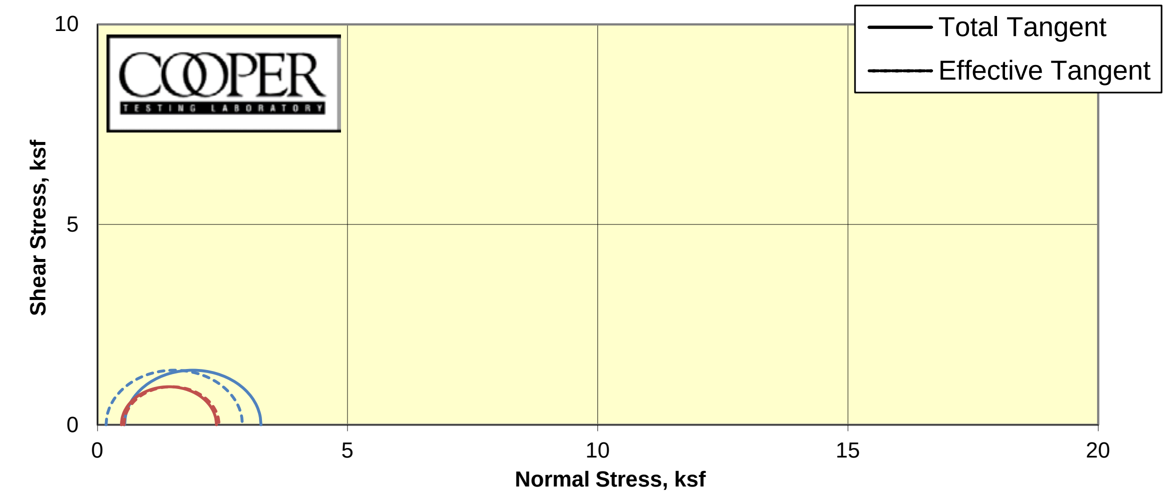


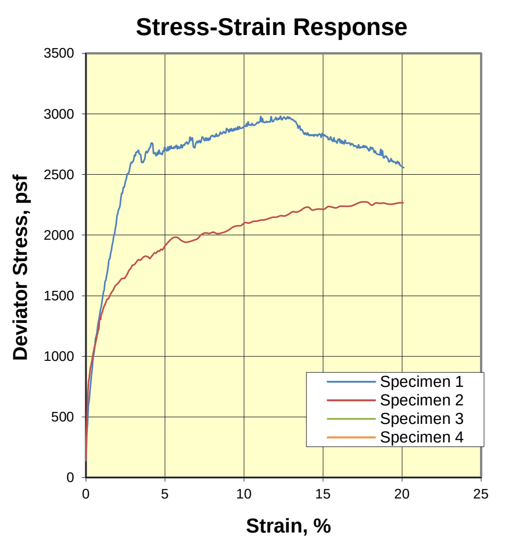


CTL Number:	020-251			
Client Name:	AECOM			
Project Name:	Klamath River Dam Removal Project			
Project Number:	60537920			
Date:	5/25/2018	By:	MD/DC	
Total C	#DIV/0!	ksf		
Total phi	#DIV/0!	degrees		
Eff. C	#DIV/0!	ksf		
Eff. Phi	#DIV/0!	degrees		©

Specimen	1	2	3	4
Boring	BC-04			
Sample	S-10			
Depth	52.5(Tip-4")			
Visual Description	Bluish Gray CLAY (Silty)/ SILT (slightly plastic)			
MC (%)	153.6			
Dry Density (pcf)	32.1			
Saturation (%)	97.9			
Void Ratio	4.156			
Diameter (in)	2.87			
Height (in)	6.08			
	Final			
MC (%)	151.2			
Dry Density (pcf)	33.0			
Saturation (%)	100.0			
Void Ratio	4.007			
Diameter (in)	2.84			
Height (in)	6.03			
Cell Pressure (psi)	90.6			
Back Pressure (psi)	80.6			
	Effective Stresses At:			
Strain (%)	5.0			
Deviator (ksf)	3.260			
Excess PP (psi)	6.3			
Sigma 1 (ksf)	3.784			
Sigma 3 (ksf)	0.523			
P (ksf)	2.154			
Q (ksf)	1.630			
Stress Ratio	7.229			
Rate (in/min)	0.0005			

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767

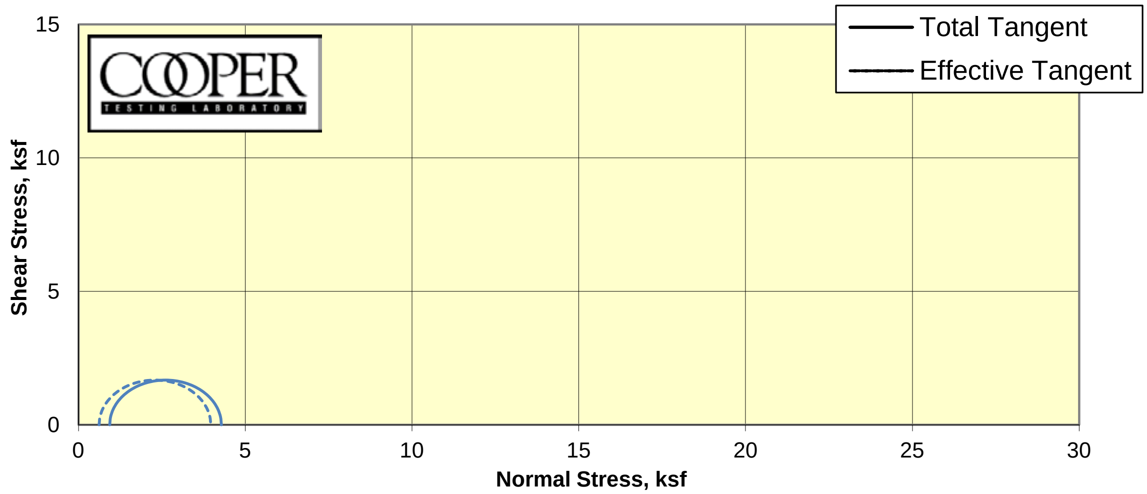


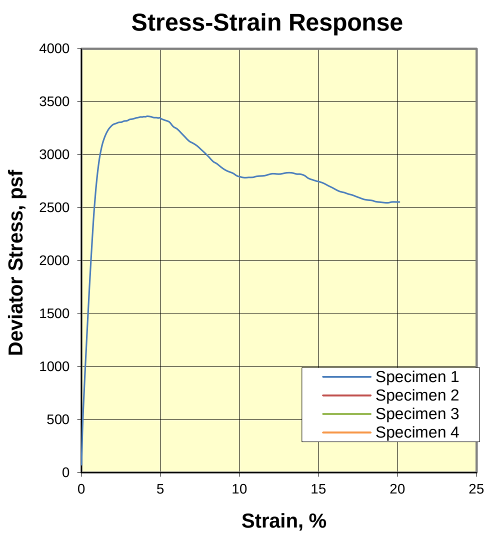


Specimen	1	2	3	4
Boring	BC-05	BC-05		
Sample	S-04	S-04		
Depth	14.5(Tip-16")	14.5(Tip-1")		
Visual Description	Olive CLAY (Silty)/SILT (slightly plastic)	Olive Mottled Yellow Clayey SAND/ Sandy CLAY		
MC (%)	135.1	30.0		
Dry Density (pcf)	35.4	92.8		
Saturation (%)	97.0	99.2		
Void Ratio	3.760	0.816		
Diameter (in)	2.87	2.87		
Height (in)	5.83	6.09		
	Final			
MC (%)	135.4	29.8		
Dry Density (pcf)	36.2	93.4		
Saturation (%)	100.0	100.0		
Void Ratio	3.656	0.805		
Diameter (in)	2.85	2.87		
Height (in)	5.80	6.07		
Cell Pressure (psi)	84.2	84.1		
Back Pressure (psi)	80.4	80.8		
	Effective Stresses At:			
Strain (%)	5.0	5.0		
Deviator (ksf)	2.725	1.900		
Excess PP (psi)	2.6	-0.4		
Sigma 1 (ksf)	2.899	2.431		
Sigma 3 (ksf)	0.173	0.531		
P (ksf)	1.536	1.481		
Q (ksf)	1.363	0.950		
Stress Ratio	16.726	4.577		
Rate (in/min)	0.0005	0.0005		

CTL Number:	020-251		
Client Name:	AECOM		
Project Name:	Klamath River Dam Removal Project		
Project Number:	60537920		
Date:	5/24/2018	By:	MD/DC
Total C	#DIV/0!	ksf	
Total phi	#DIV/0!	degrees	
Eff. C	#DIV/0!	ksf	
Eff. Phi	#DIV/0!	degrees	©

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767

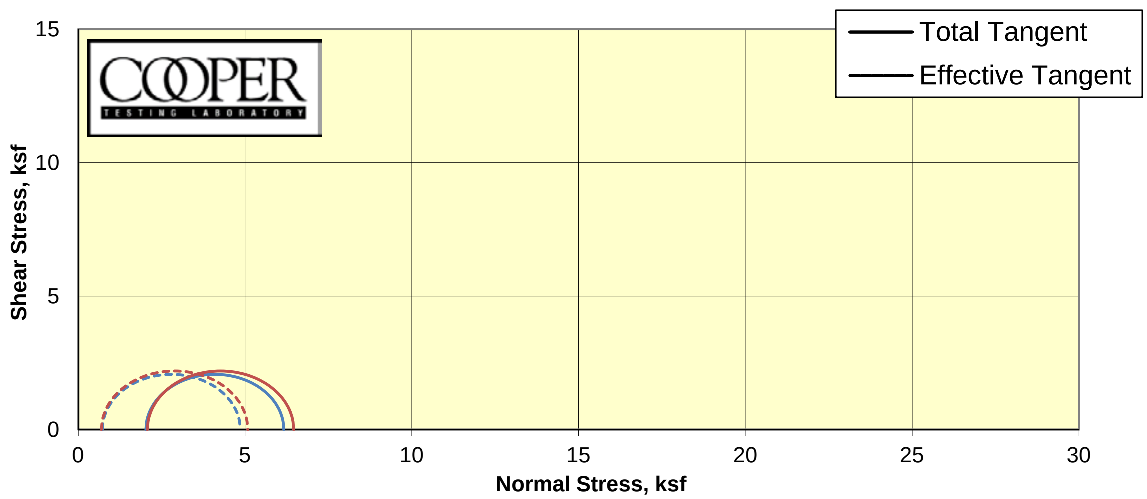


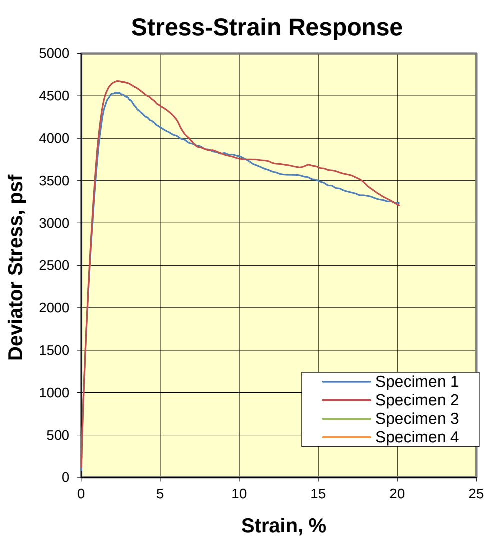


Specimen	1	2	3	4
Boring	BC-09			
Sample	S-05			
Depth	23(Tip-5")			
Visual Description	Dark Gray Elastic SILT			
MC (%)	79.5			
Dry Density (pcf)	51.9			
Saturation (%)	97.1			
Void Ratio	2.130			
Diameter (in)	2.87			
Height (in)	6.07			
	Final			
MC (%)	79.4			
Dry Density (pcf)	53.0			
Saturation (%)	100.0			
Void Ratio	2.065			
Diameter (in)	2.85			
Height (in)	6.04			
Cell Pressure (psi)	86.8			
Back Pressure (psi)	80.3			
	Effective Stresses At:			
Strain (%)	5.0			
Deviator (ksf)	3.348			
Excess PP (psi)	2.2			
Sigma 1 (ksf)	3.969			
Sigma 3 (ksf)	0.621			
P (ksf)	2.295			
Q (ksf)	1.674			
Stress Ratio	6.396			
Rate (in/min)	0.0005			

CTL Number:	020-251		
Client Name:	AECOM		
Project Name:	Klamath River Dam Removal Project		
Project Number:	60537920		
Date:	5/30/2018	By:	MD/DC
Total C	#DIV/0!	ksf	
Total phi	#DIV/0!	degrees	
Eff. C	#DIV/0!	ksf	
Eff. Phi	#DIV/0!	degrees	©

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767



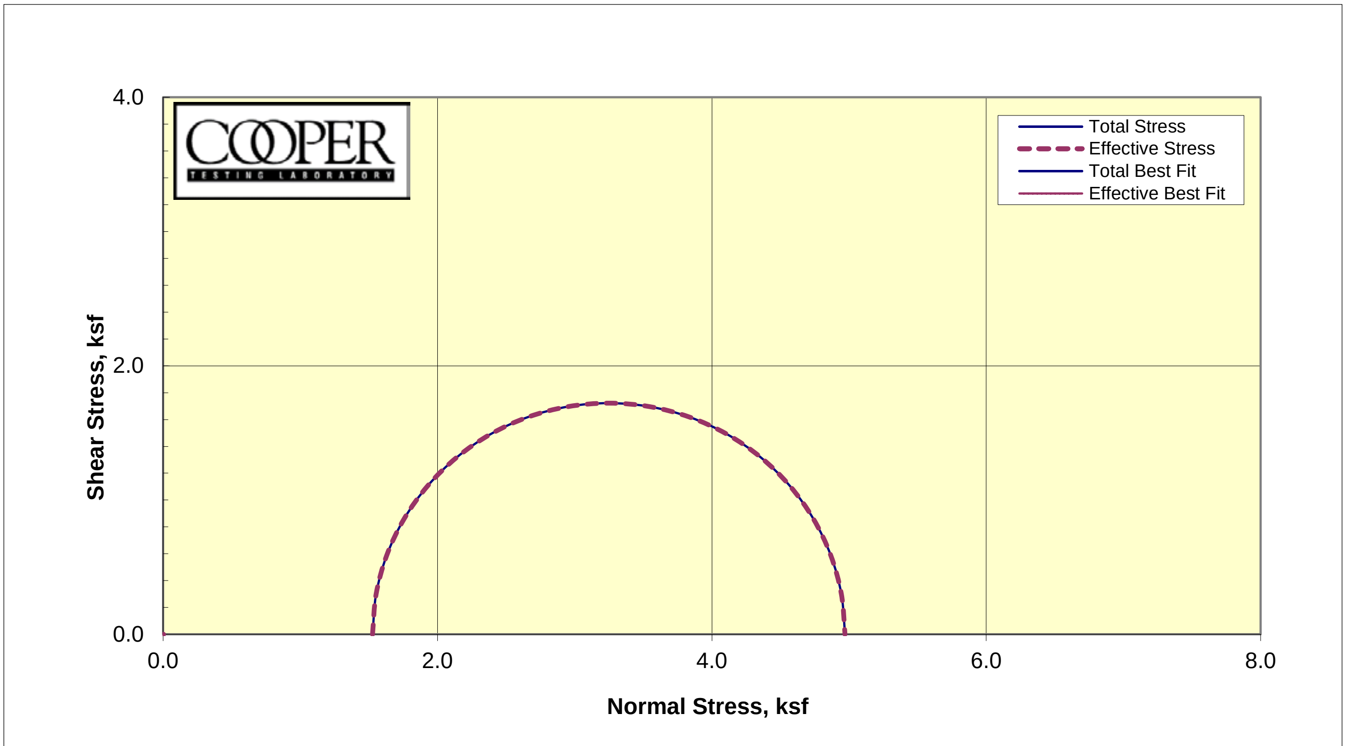


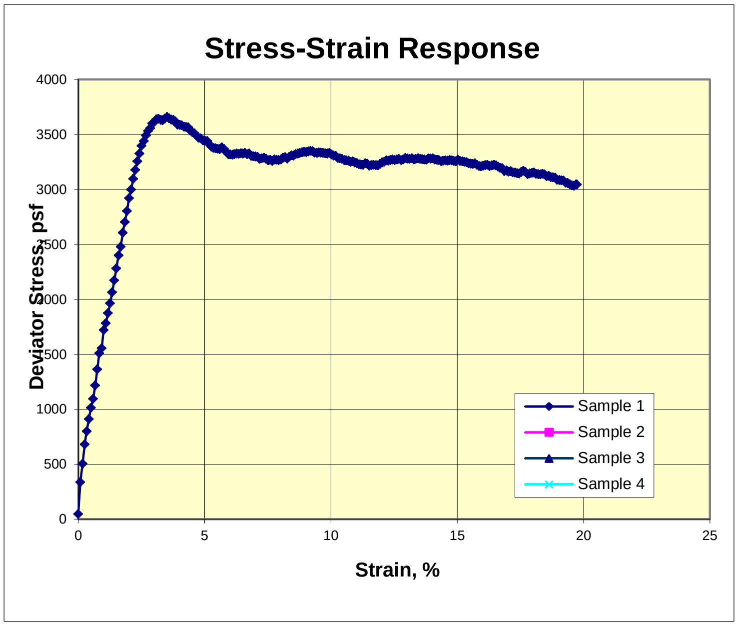
CTL Number:	020-251
Client Name:	AECOM
Project Name:	Klamath River Dam Removal Project
Project Number:	60537920
Date:	6/6/2018 By: MD/DC
Total C	#DIV/0! ksf
Total phi	#DIV/0! degrees
Eff. C	#DIV/0! ksf
Eff. Phi	#DIV/0! degrees ©

Specimen	1	2	3	4
Boring	BC-09	BC-09		
Sample	S-09	S-09		
Depth	68-70.5(Tip-10")	68-70.5(Tip-4")		
Visual Description	Dark Greenish Gray CLAY (Silty)/ SILT (slightly plastic)	Dark Greenish Gray CLAY (Silty)/ SILT (slightly plastic)		
MC (%)	92.0	95.5		
Dry Density (pcf)	47.2	46.1		
Saturation (%)	98.2	98.5		
Void Ratio	2.436	2.520		
Diameter (in)	2.87	2.87		
Height (in)	6.06	6.06		
	Final			
MC (%)	90.6	93.7		
Dry Density (pcf)	48.4	47.2		
Saturation (%)	100.0	100.0		
Void Ratio	2.355	2.436		
Diameter (in)	2.84	2.85		
Height (in)	6.03	6.02		
Cell Pressure (psi)	94.2	94.1		
Back Pressure (psi)	80.1	79.7		
	Effective Stresses At:			
Strain (%)	5.0	5.0		
Deviator (ksf)	4.134	4.387		
Excess PP (psi)	9.1	9.6		
Sigma 1 (ksf)	4.860	5.084		
Sigma 3 (ksf)	0.726	0.697		
P (ksf)	2.793	2.891		
Q (ksf)	2.067	2.194		
Stress Ratio	6.693	7.293		
Rate (in/min)	0.0005	0.0005		

Triaxial Unconsolidated-Undrained

(ASTM D2850m)



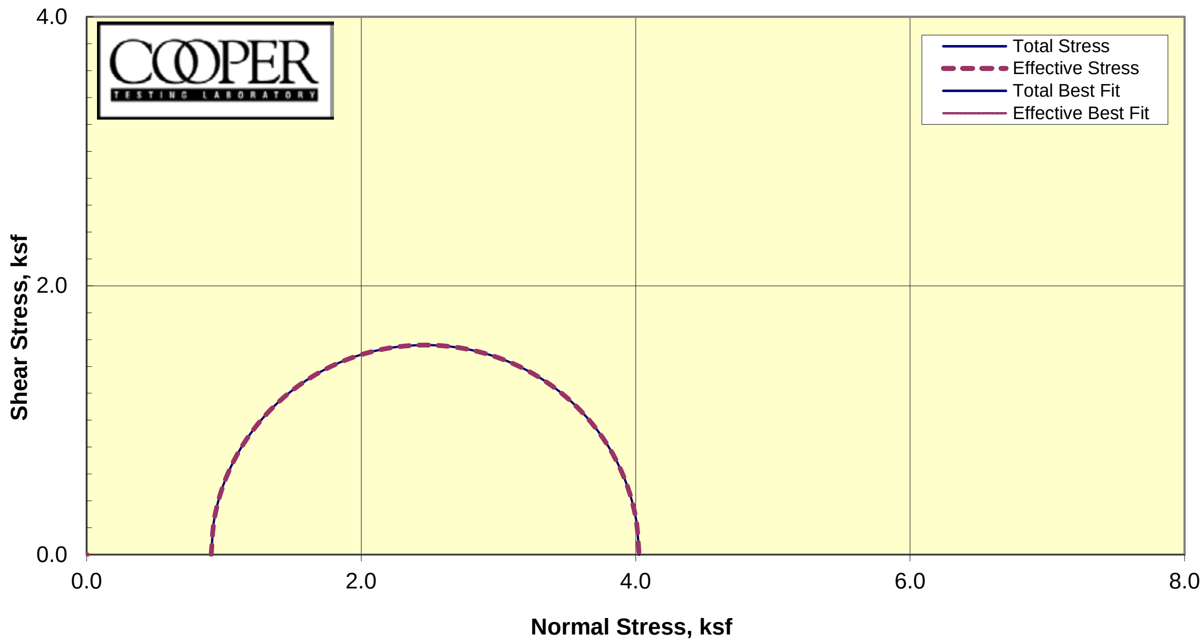


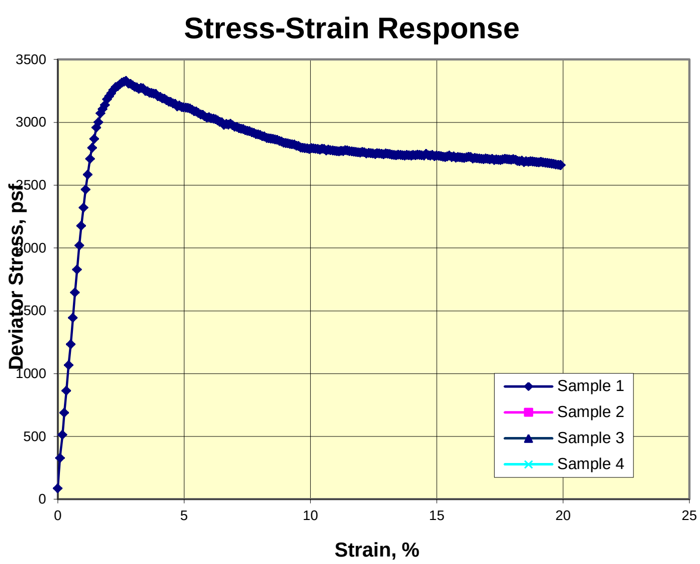
Sample:	1	2	3	4
MC, %	160.5			
Dry Dens, pcf	30.5			
Sat. %	95.9			
Void Ratio	4.519			
Diameter in	2.87			
Height, in	6.08			
	Final			
MC, %	163.5			
Dry Dens, pcf	31.1			
Sat. %	100.0			
Void Ratio	4.414			
Diameter, in	2.84			
Height, in	6.08			
Cell, psi	49.1			
BP, psi	38.5			
	Effective Stresses At:			
Strain, %	5.0			
Deviator ksf	3.444			
Excess PP	0.000			
Sigma 1	4.970			
Sigma 3	1.526			
P, ksf	3.248			
Q, ksf	1.722			
Stress Ratio	3.256			
Rate in/min	0.0588			
Total C	N/A	ksf		
Total Phi	N/A	Degrees		
Eff. C	N/A	ksf		
Eff. Phi	N/A	Degrees		

Job No.:	020-251	**Date:**	5/24/2018
Client:	AECOM		BY:MD/DC
Project:	60537920		
Sample 1)	BC-04_S-10 @ 52.5(Tip-18") Bluish Gray CLAY (Silty)		
Sample 2)			
Sample 3)			
Sample 4)			

REMARKS: Strengths picked at 5% strain.
*Sample was back-pressure saturated prior to shear.

Triaxial Unconsolidated-Undrained
(ASTM D2850m)





Sample:	1	2	3	4
MC, %	76.3			
Dry Dens, pcf	54.0			
Sat. %	97.1			
Void Ratio	2.121			
Diameter in	2.87			
Height, in	6.05			
	Final			
MC, %	76.6			
Dry Dens, pcf	54.9			
Sat. %	100.0			
Void Ratio	2.068			
Diameter, in	2.85			
Height, in	6.03			
Cell, psi	54.8			
BP, psi	48.5			
	Effective Stresses At:			
Strain, %	5.0			
Deviator ksf	3.118			
Excess PP	0.000			
Sigma 1	4.025			
Sigma 3	0.907			
P, ksf	2.466			
Q, ksf	1.559			
Stress Ratio	4.437			
Rate in/min	0.0588			
Total C	N/A	ksf		
Total Phi	N/A	Degrees		
Eff. C	N/A	ksf		
Eff. Phi	N/A	Degrees		

Job No.: 020-251 **Date:** 5/25/2018

Client: AECOM BY:MD/DC

Project: 60537920

Sample 1) BC-09_S-05 @ 23(Tip-13") Dark Gray Elastic SILT

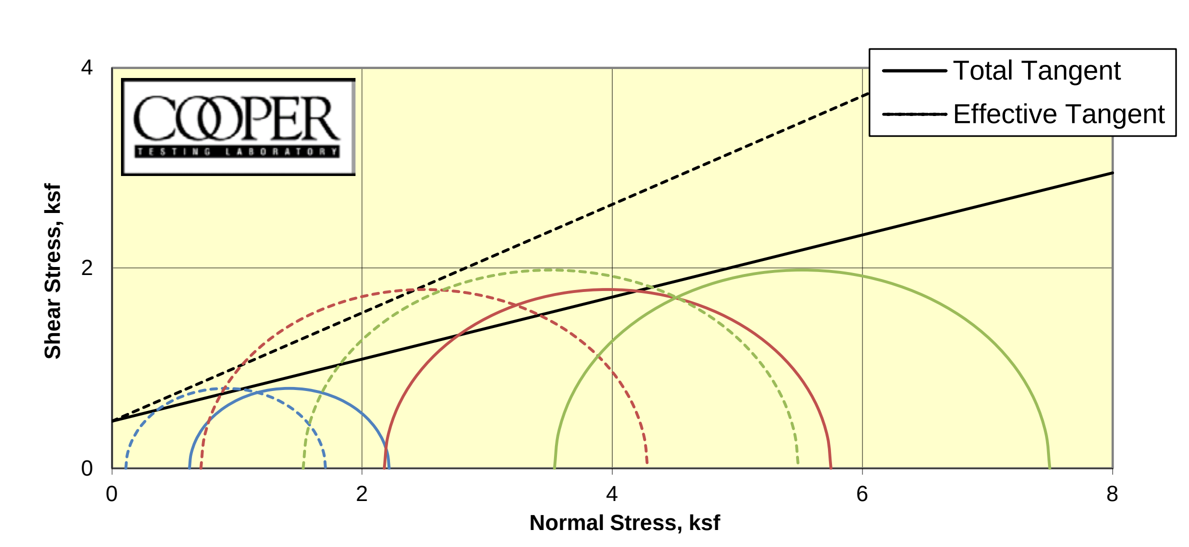
Sample 2)

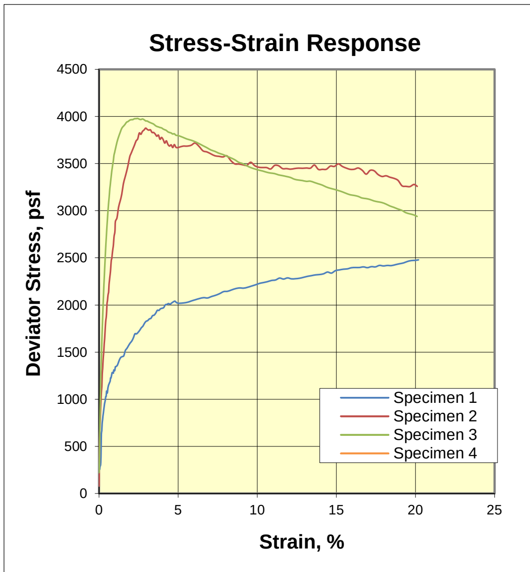
Sample 3)

Sample 4)

REMARKS: Strengths picked at 5% strain.
*Sample was back-pressure saturated prior to shear.

Consolidated Undrained Triaxial Compression with Pore Pressure
ASTM D4767





Specimen	1	2	3	4
Boring	Outcrop #1	Outcrop #1	Outcrop #1	
Sample				
Depth				
Visual Description	Pale Brown Siltstone (Diatomite)	Pale Brown Siltstone (Diatomite)	Pale Brown Siltstone (Diatomite)	
MC (%)	8.2	7.1	5.9	
Dry Density (pcf)	53.1	56.9	58.0	
Saturation (%)	10.2	9.7	8.4	
Void Ratio	2.176	1.961	1.907	
Diameter (in)	1.86	1.86	1.85	
Height (in)	4.00	4.00	4.00	
	Final			
MC (%)	78.4	73.5	71.9	
Dry Density (pcf)	54.1	56.5	57.3	
Saturation (%)	100.0	100.0	100.0	
Void Ratio	2.116	1.984	1.942	
Diameter (in)	1.85	1.87	1.87	
Height (in)	3.96	3.98	3.98	
Cell Pressure (psi)	124.0	135.0	144.9	
Back Pressure (psi)	119.7	119.8	120.4	
	Effective Stresses At:			
Strain (%)	2.0	2.0	2.0	
Deviator (ksf)	1.596	3.571	3.959	
Excess PP (psi)	3.5	10.2	14.0	
Sigma 1 (ksf)	1.708	4.282	5.488	
Sigma 3 (ksf)	0.111	0.712	1.529	
P (ksf)	0.909	2.497	3.509	
Q (ksf)	0.798	1.785	1.980	
Stress Ratio	15.338	6.018	3.589	
Rate (in/min)	0.0003	0.0003	0.0003	

CTL Number:	020-232		
Client Name:	AECOM		
Project Name:	Klamath		
Project Number:	60537920		
Date:	9/25/2017	By:	MD/DC
Total C	0.470	ksf	
Total phi	17.2	degrees	
Eff. C	0.470	ksf	
Eff. Phi	28.4	degrees	©

Remarks: The sample was delivered as singular 13" x 16" block. The specimens were trimmed into a brass tube 2" x 4". The orientation of the outcrop block was unknown. All samples were trimmed in the same approximate orientation. The material is highly structured and cemented. It disperses when exposed to water. All three specimens behaved differently during shear.

POINT LOAD TEST RESULTS
BI-02 and BI-03

Test Number	Test Order	Depth of Test	Boring Number	Date	Depth Interval Bottom	Depth Interval Top	Rock Type[1]	Diameter (D) (mm)	Diameter (D) (in)	Distance Between Contact Points (cm)	Distance Between Contact Points (in)	Length - Contact Points to End of Sample, L (in)	L/D[2]	Test Type[3]	Failure Load, P (kN)[4]	Uncorrected Point Load, I_S (Mpa)[5]	Size Correction Factor, F[6]	Point Load, $I_{S(50)}$ (MPa)[7]	Uniaxial Compressive Strength, s_c (Mpa)[8]	Uniaxial Compressive Strength, psi	Weathering	Notes
BI02-1-22.1	1	22.1	BI-02	4/11/2018	22.6	21.9	Volcanic Breccia	59.94	2.36	6.00	2.36	1.97	0.83	d	0.51	0.14	1.09	0.15	3	504	MW/SW	Bottom 3.5" broke on preexisting fracture plane prior to test. Sample broke on preexisting fracture plane during testing.
BI02-2-28.2	2	28.2	BI-02	4/11/2018	28.6	27.9	Volcanic Breccia	59.94	2.36	6.00	2.36	3.54	1.50	d	1.99	0.55	1.09	0.60	14	1968	MW/SW	Fractured between platens (see photo)
BI02-3-32.8	3	32.8	BI-02	4/11/2018	33.4	32.2	Volcanic Breccia	59.94	2.36	6.00	2.36	7.01	2.97	d	2.59	0.72	1.09	0.78	18	2561	MW/SW	Fractured between platens (see photo). Other breaks from rock core falling on table after testing.
BI02-4-37.4	4	37.4	BI-02	4/11/2018	37.7	37.2	Volcanic Breccia	59.94	2.36	6.00	2.36	2.68	1.13	d	2.53	0.70	1.09	0.76	17	2502	MW/SW	Fractured between platens (see photo)
BI02-5-42.8	5	42.8	BI-02	4/11/2018	43.1	42.5	Volcanic Breccia	59.94	2.36	6.00	2.36	3.86	1.63	d	2.00	0.56	1.09	0.60	14	1978	MW/SW	Fractured between platens (see photo). 1" long fracture propagated along the length of sample from the point load application.
BI02-7-55	7	55.0	BI-02	4/11/2018	55.4	54.7	Volcanic Breccia	59.94	2.36	6.00	2.36	3.74	1.58	d	1.41	0.39	1.09	0.43	10	1394	MW/SW	Fractured between platens (see photo). Platen penetrated into rock 3mm at failure.
BI02-8-57.3	8	57.3	BI-02	4/11/2018	57.6	57.0	Volcanic Breccia	59.94	2.36	6.00	2.36	3.23	1.37	d	1.5-2.0		1.09				MW/SW	Peak load not recorded. One of the broken halfs was retested in test BI02-9-57.1.
BI02-9-57.1	9	57.1	BI-02	4/11/2018	57.6	57.0	Volcanic Breccia	59.94	2.36	6.00	2.36	1.69	0.72	d	1.80	0.50	1.09	0.54	12	1780	MW/SW	Fractured between platens (see photo)
BI02-10-64.2	10	64.2	BI-02	4/11/2018	64.7	63.7	Volcanic Breccia	59.94	2.36	6.00	2.36	6.10	2.59	d	1.05	0.29	1.09	0.32	7	1038	MW/SW	Fractured between platens (see photo)
BI03-11-10.3	11	10.3	BI-03	4/11/2018	10.5	10.1	Volcanic Breccia	59.94	2.36	6.00	2.36	2.17	0.92	d	0.60	0.17	1.09	0.18	4	593	MW	Fractured between platens (see photo)
BI03-12-17.2	12	17.2	BI-03	4/11/2018	17.4	17.0	Volcanic Breccia	59.94	2.36	6.00	2.36	2.17	0.92	d	0.56	0.16	1.09	0.17	4	554	MW	Fractured between platens (see photo)
BI03-13-21.3	13	21.3	BI-03	4/11/2018	21.5	21.0	Volcanic Breccia	59.94	2.36	6.00	2.36	2.56	1.08	d	0.76	0.21	1.09	0.23	5	752	MW	Fractured between platens (see photo)
BI03-14-29.8	14	29.8	BI-03	4/11/2018	30.1	29.5	Volcanic Breccia	59.94	2.36	6.00	2.36	3.54	1.50	d	0.73	0.20	1.09	0.22	5	722	MW	Fractured between platens (see photo)
BI03-15-32.7	15	32.7	BI-03	4/11/2018	33.5	32.0	Volcanic Breccia	59.94	2.36	6.00	2.36	8.58	3.64	d	0.77	0.21	1.09	0.23	5	761	MW	Fractured between platens (see photo)

Notes:
1 Based on Drill Logs
2 ASTM D5731 calls for L/D > 0.5 for diametral test.
3 d = diametral, a = axial, b = block, ir = irregular lump
4 Reading from testing apparatus
5 $I_S = P/D^2$ (ASTM D5731 - for diametral test)
6 $F = (D/50)^{0.45}$ (ASTM D5731 - for diametral test)
7 $I_{S(50)} = I_S \times F$ (ASTM D5731)
8 $s_c = I_S \times K$; I_s is uncorrected point load index; K=24.5 for ~60 mm diameter cores (ASTM D5731)

F	Fresh
SW	Slightly Weathered
MW	Moderately Weathered
HW	Highly Weathered
CW	Completely Weathered

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-1
Report Date	5/17/2018
Drill Hole and Depth	BI-02; 48.9-50.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/30/2018

Distance, D		Load, P		Corrected Point Load Index $(D/50)^{0.45}$ P/D^2		Direction of Loading	
mm	in	kN	lbf	MPa	psi	A	B
60.86	2.40	0.74	166.352	0.22	31.66	1	
62.20	2.45	1.65	370.92	0.47	68.24		1
47.58	1.87	0.98	220.304	0.42	61.40	1	
79.15	3.12	3.23	726.104	0.63	91.95		1
82.44	3.25	3.00	674.4	0.55	80.18		1
39.71	1.56	0.86	193.328	0.49	71.31	1	

Average Point Load Strength in Direction A	0.38 MPa	54.79 psi
Average Point Load Strength in Direction B	0.55 MPa	80.12 psi

Point Load Strength Anisotropy Index
1.46

A = Parallel to core axis

B = Orthogonal to core axis

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

2028 E Ben White BLVD #240-2660
Austin, TX 78741

Laboratory Director: Dr. Fulvio Tonon, P.E.
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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-1-1
Report Date	5/17/2018
Drill hole and Depth	BI-02; 27-27.9 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Stress Rate	0.5 MPa/s	
Diameter of Specimen	60.54 mm	2.38 in
Height of Specimen	97.72 mm	3.85 in
Load at Peak	16.69 kN	3,752 lbf
Unconfined Compressive Strength	5.80 MPa	841 psi
Type of Failure	Non-Structural	

Note: The provided sample had a height-to-diameter ratio less than 2

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo Before Test

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

2028 E Ben White BLVD #240-2660
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Picture of the sample upon arrival at Tonon USA Laboratory: no core piece allowed preparation of a specimen with a height-to-diameter ratio between 2 and 2.5.

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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-1-2
Report Date	5/17/2018
Drill hole and Depth	BI-02; 48.9-50.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Stress Rate	0.5 MPa/s	
Diameter of Specimen	60.85 mm	2.40 in
Height of Specimen	127.87 mm	5.03 in
Load at Peak	34.80 kN	7,823 lbf
Unconfined Compressive Strength	11.97 MPa	1,736 psi
Type of Failure	Non-Structural	

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo Before Test

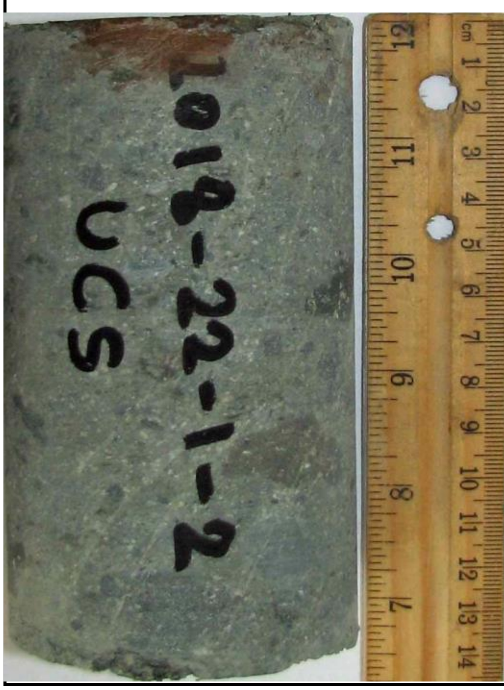

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

2028 E Ben White BLVD #240-2660
Austin, TX 78741

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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-1-3
Report Date	5/17/2018
Drill hole and Depth	BI-02; 55.4-56.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Stress Rate	0.5 MPa/s	
Diameter of Specimen	60.68 mm	2.39 in
Height of Specimen	128.33 mm	5.05 in
Load at Peak	45.59 kN	10,248 lbf
Unconfined Compressive Strength	15.77 MPa	2,288 psi
Type of Failure	Non-Structural	

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo Before Test

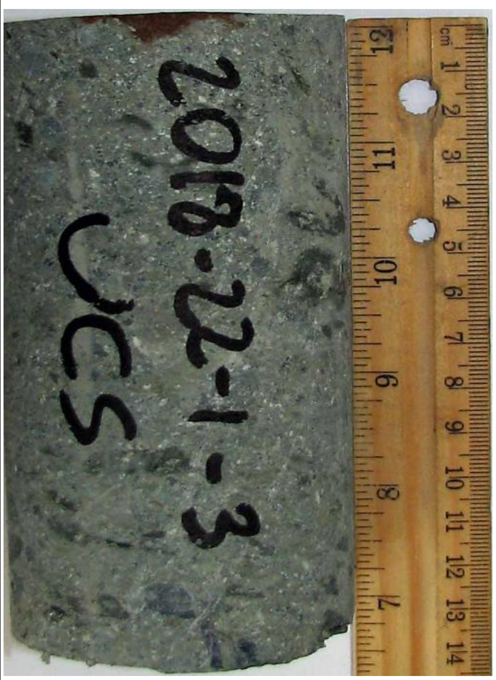
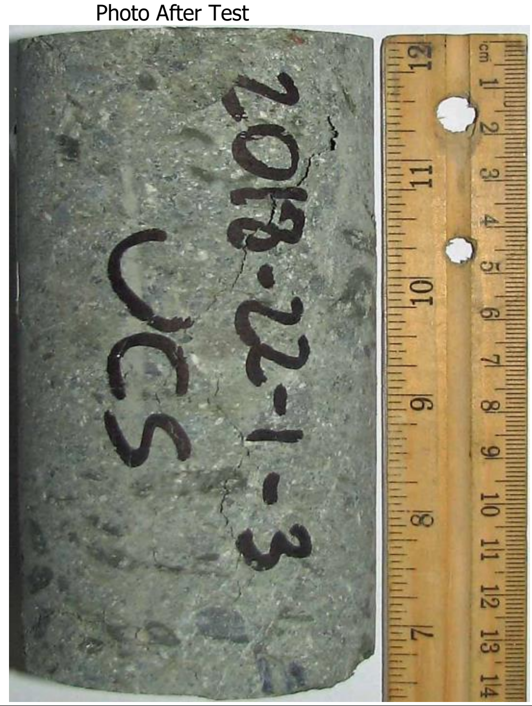


Photo After Test



Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-1-4
Report Date	5/17/2018
Drill hole and Depth	BI-03; 17.4-18.4 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Stress Rate	0.5 MPa/s	
Diameter of Specimen	60.59 mm	2.39 in
Height of Specimen	129.81 mm	5.11 in
Load at Peak	4.39 kN	987 lbf
Unconfined Compressive Strength	1.52 MPa	221 psi
Type of Failure	Non-Structural	

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 5/4/2018

Photo Before Test

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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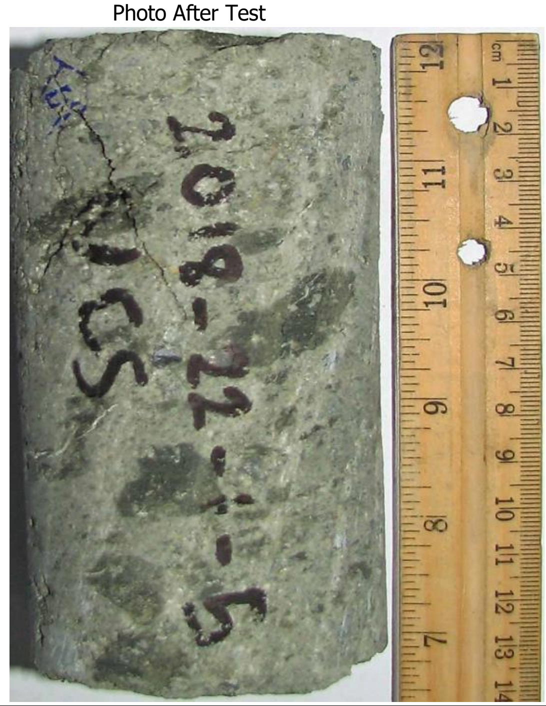
Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-1-5
Report Date	5/17/2018
Drill hole and Depth	BI-03; 21.5-22.9 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Stress Rate	0.5 MPa/s	
Diameter of Specimen	60.58 mm	2.39 in
Height of Specimen	125.67 mm	4.95 in
Load at Peak	6.99 kN	1,571 lbf
Unconfined Compressive Strength	2.43 MPa	352 psi
Type of Failure	Non-Structural	

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo Before Test

Photo After Test



Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

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Laboratory Director: Dr. Fulvio Tonon, P.E., Ph.D.
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Project Name	Klamath River Dam Removal	Rate of loading (0.05-0.35 MPa/s or 500-3,000 psi/min)	0.11 MPa/sec	957 psi/min
Location	Klamath River	Diameter (D)	60.94 mm	2.40 in
Client	Klamath River Renewal Corporation	Thickness (t)	22.88 mm	0.90 in
Client Project No.	60537920	Maximum Load (P)	6.53 kN	1,468 lbf
Registry No.	2018-22	Tensile strength (flat platens) $\sigma_t = 2P/\pi t D$	N/A	N/A
Report No.	2018-22-2-1	Tensile strength (curved platens) $\sigma_t = 1.272P/\pi t D$	1.90 MPa	275 psi
Report Date	5/17/2018	Direction of Loading	Orthogonal to the Borehole Axis	
Drill Hole and Depth	BI-02; 47-48.9 ft	Type of Failure	Non-Structural	
Rock Type	Volcanic Breccia	Conformance to dimensional Requirements $0.2 \le \frac{t}{D} \le 0.75$	$\frac{t}{D} =$ 0.38	OK
Geologic Unit	N/A			
Moisture Condition	As-received			

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo Before Test

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

Project Name	Klamath River Dam Removal	Rate of loading (0.05-0.35 MPa/s or 500-3,000 psi/min)	0.11 MPa/sec	957 psi/min
Location	Klamath River	Diameter (D)	60.84 mm	2.40 in
Client	Klamath River Renewal Corporation	Thickness (t)	24.67 mm	0.97 in
Client Project No.	60537920	Maximum Load (P)	5.25 kN	1,180 lbf
Registry No.	2018-22	Tensile strength (flat platens) $\sigma_t = 2P/\pi tD$	N/A	N/A
Report No.	2018-22-2-2	Tensile strength (curved platens) $\sigma_t = 1.272P/\pi tD$	1.42 MPa	206 psi
Report Date	5/17/2018	Direction of Loading	Orthogonal to the Borehole Axis	
Drill Hole and Depth	BI-02; 52-54.7 ft	Type of Failure	Non-Structural	
Rock Type	Volcanic Breccia	Conformance to dimensional Requirements $0.2 \le \frac{t}{D} \le 0.75$	$\frac{t}{D} =$ 0.41	OK
Geologic Unit	N/A			
Moisture Condition	As-received			

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo Before Test

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

Project Name	Klamath River Dam Removal	Rate of loading (0.05-0.35 MPa/s or 500-3,000 psi/min)	0.11 MPa/sec	957 psi/min
Location	Klamath River	Diameter (D)	60.74 mm	2.39 in
Client	Klamath River Renewal Corporation	Thickness (t)	26.84 mm	1.06 in
Client Project No.	60537920	Maximum Load (P)	1.51 kN	339 lbf
Registry No.	2018-22	Tensile strength (flat platens) $\sigma_t = 2P/\pi t D$	N/A	N/A
Report No.	2018-22-2-3	Tensile strength (curved platens) $\sigma_t = 1.272P/\pi t D$	0.38 MPa	54 psi
Report Date	5/17/2018	Direction of Loading	Orthogonal to the Borehole Axis	
Drill Hole and Depth	BI-03; 18.4-20.1 ft	Type of Failure	Non-Structural	
Rock Type	Volcanic Breccia	Conformance to dimensional Requirements $0.2 \le \frac{t}{D} \le 0.75$	$\frac{t}{D} =$ 0.44	OK
Geologic Unit	N/A			
Moisture Condition	As-received			

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo Before Test

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

Project Name	Klamath River Dam Removal	Rate of loading (0.05-0.35 MPa/s or 500-3,000 psi/min)	0.11 MPa/sec	957 psi/min
Location	Klamath River	Diameter (D)	60.26 mm	2.37 in
Client	Klamath River Renewal Corporation	Thickness (t)	33.83 mm	1.33 in
Client Project No.	60537920	Maximum Load (P)	0.55 kN	124 lbf
Registry No.	2018-22	Tensile strength (flat platens) $\sigma_t = 2P/\pi t D$	N/A	N/A
Report No.	2018-22-2-4	Tensile strength (curved platens) $\sigma_t = 1.272P/\pi t D$	0.11 MPa	16 psi
Report Date	5/17/2018	Direction of Loading	Orthogonal to the Borehole Axis	
Drill Hole and Depth	BI-03; 22.9-24.2 ft	Type of Failure	Non-Structural	
Rock Type	Volcanic Breccia	Conformance to dimensional Requirements $0.2 \le \frac{t}{D} \le 0.75$	$\frac{t}{D} =$ 0.56	OK
Geologic Unit	N/A			
Moisture Condition	As-received			

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo Before Test

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-3-1
Report Date	5/17/2018
Drill Hole and Depth (ft)	BI-02; 27-27.9 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/30/2018

Diameter	Length	Weight	Bulk Density	Bulk Density
(mm)	(mm)	(g)	(kN/m^3)	(pcf)
60.54	97.72	637.28	22.22	141.42

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

2028 E Ben White BLVD #240-2660
Austin, TX 78741

Laboratory Director: Dr. Fulvio Tonon, P.E.
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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-3-2
Report Date	5/17/2018
Drill Hole and Depth (ft)	BI-02; 48.9-50.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/30/2018

Diameter	Length	Weight	Bulk Density	Bulk Density
(mm)	(mm)	(g)	(kN/m^3)	(pcf)
60.85	127.87	891.59	23.51	149.67

Performed by: Dr. Fulvio Tonon, P.E., Ph.D. Checked by: Gloria Tonon-Kozma, P.E.

Tonon USA
Engineering, Measurements and Testing, LLC

Web: tononeng.com

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-3-3
Report Date	5/17/2018
Drill Hole and Depth (ft)	BI-02; 55.4-56.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/30/2018

Diameter	Length	Weight	Bulk Density	Bulk Density
(mm)	(mm)	(g)	(kN/m^3)	(pcf)
60.68	128.33	882.58	23.32	148.46

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-3-4
Report Date	5/17/2018
Drill Hole and Depth (ft)	BI-03; 17.4-18.4 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/30/2018

Diameter	Length	Weight	Bulk Density	Bulk Density
(mm)	(mm)	(g)	(kN/m^3)	(pcf)
60.59	129.81	830.07	21.75	138.44

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-3-5
Report Date	5/17/2018
Drill Hole and Depth (ft)	BI-03; 21.5-22.9 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/30/2018

Diameter	Length	Weight	Bulk Density	Bulk Density
(mm)	(mm)	(g)	(kN/m^3)	(pcf)
60.58	125.67	783.13	21.20	134.96

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

COMPANY WITH QUALITY SYSTEM CERTIFIED BY DNV GL = ISO 9001 =

Tonon USA
Engineering, Measurements and Testing, LLC

Web: tononeng.com

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-4-1
Report Date	5/17/2018
Drill Hole and Depth	BI-02; 27-27.9 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/27-30/2018

Method A: Caliper

Diameter (mm)	Length (mm)	Initial Weight (g)	Dry Weight (g)
		202.50	193.13

Moisture Content (%)	**Unit Weight (kN/m^3)**	**Unit Weight (pcf)**	**Dry Unit Weight (kN/m^3)**	**Dry Unit Weight (pcf)**
4.85				

Method B: Buoyancy

Weight (g)	Saturated Weight (g)	Suspended Weight (g)	Dry Weight (g)

Moisture Content (%)	**Unit Weight (kN/m^3)**	**Unit Weight (pcf)**	**Dry Unit Weight (kN/m^3)**	**Dry Unit Weight (pcf)**

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

2028 E Ben White BLVD #240-2660
Austin, TX 78741

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COMPANY WITH QUALITY SYSTEM CERTIFIED BY DNV GL = ISO 9001 =

Tonon USA
Engineering, Measurements and Testing, LLC

Web: tononeng.com

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-4-2
Report Date	5/17/2018
Drill Hole and Depth	BI-02; 48.9-50.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/27-30/2018

Method A: Caliper

Diameter (mm)	Length (mm)	Initial Weight (g)	Dry Weight (g)
		180.47	169.63

Moisture Content (%)	**Unit Weight (kN/m^3)**	**Unit Weight (pcf)**	**Dry Unit Weight (kN/m^3)**	**Dry Unit Weight (pcf)**
6.39				

Method B: Buoyancy

Weight (g)	Saturated Weight (g)	Suspended Weight (g)	Dry Weight (g)

Moisture Content (%)	**Unit Weight (kN/m^3)**	**Unit Weight (pcf)**	**Dry Unit Weight (kN/m^3)**	**Dry Unit Weight (pcf)**

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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Web: tononeng.com

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-4-3
Report Date	5/17/2018
Drill Hole and Depth	BI-02; 55.4-56.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/27-30/2018

Method A: Caliper

Diameter (mm)	Length (mm)	Initial Weight (g)	Dry Weight (g)
		175.36	165.73

Moisture Content (%)	**Unit Weight (kN/m^3)**	**Unit Weight (pcf)**	**Dry Unit Weight (kN/m^3)**	**Dry Unit Weight (pcf)**
5.81				

Method B: Buoyancy

Weight (g)	Saturated Weight (g)	Suspended Weight (g)	Dry Weight (g)

Moisture Content (%)	**Unit Weight (kN/m^3)**	**Unit Weight (pcf)**	**Dry Unit Weight (kN/m^3)**	**Dry Unit Weight (pcf)**

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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Austin, TX 78741

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Engineering, Measurements and Testing, LLC

Web: tononeng.com

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-4-4
Report Date	5/17/2018
Drill Hole and Depth	BI-03; 17.4-18.4 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/27-30/2018

Method A: Caliper

Diameter (mm)	Length (mm)	Initial Weight (g)	Dry Weight (g)
		84.27	74.93

Moisture Content (%)	**Unit Weight (kN/m^3)**	**Unit Weight (pcf)**	**Dry Unit Weight (kN/m^3)**	**Dry Unit Weight (pcf)**
12.46				

Method B: Buoyancy

Weight (g)	Saturated Weight (g)	Suspended Weight (g)	Dry Weight (g)

Moisture Content (%)	**Unit Weight (kN/m^3)**	**Unit Weight (pcf)**	**Dry Unit Weight (kN/m^3)**	**Dry Unit Weight (pcf)**

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-4-5
Report Date	5/17/2018
Drill Hole and Depth	BI-03; 21.5-22.9 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date Received: 4/24/2018	Date Opened: 4/24/2018	Date Tested: 4/27-30/2018

Method A: Caliper

Diameter (mm)	Length (mm)	Initial Weight (g)	Dry Weight (g)
		177.06	160.77

Moisture Content (%)	Unit Weight (kN/m^3)	Unit Weight (pcf)	Dry Unit Weight (kN/m^3)	Dry Unit Weight (pcf)
10.13				

Method B: Buoyancy

Weight (g)	Saturated Weight (g)	Suspended Weight (g)	Dry Weight (g)

Moisture Content (%)	Unit Weight (kN/m^3)	Unit Weight (pcf)	Dry Unit Weight (kN/m^3)	Dry Unit Weight (pcf)

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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COMPANY WITH QUALITY SYSTEM CERTIFIED BY DNV GL = ISO 9001 =

Tonon USA:
Engineering, Measurements and Testing, LLC

Web: tononeng.com

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-5-1
Report Date	5/17/2018
Drill Hole and Depth	BI-02; 51.3-51.7 ft
Rock Type	Volcanic Breccia
Formation	N/A
Surface Condition	Cut by Slab Saw

Apparatus, Pin R.-H.	West Cerchar, 55/56	
Direction of Scratch	Perpendicular to Core Axis	
Pin Wear (mm)	0.156	0.145
	0.142	0.124
	0.144	0.133
	0.162	0.129
	0.150	0.140
Average (mm)	0.143	
CAIs	**1.43**	
CAI	**1.89**	
Classification	**Medium Abrasiveness**	

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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Project Name	Klamath River Dam Removal	Apparatus, Pin R.-H.	West Cerchar, 55/56	
Location	Klamath River	Direction of Scratch	Perpendicular to Core Axis	
Client	Klamath River Renewal Corporation	Pin Wear (mm)	0.046	0.037
Client Project No.	60537920		0.083	0.069
Registry No.	2018-22		0.104	0.090
Report No.	2018-22-5-2		0.087	0.098
Report Date	5/17/2018		0.100	0.093
Drill Hole and Depth	BI-03; 25.1-26.1 ft	Average (mm)	0.081	
Rock Type	Volcanic Breccia	**CAIs**	**0.81**	
Formation	N/A	**CAI**	**1.28**	
Surface Condition	Cut by Slab Saw	**Classification**	**Medium Abrasiveness**	

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/30/2018

Photo After Test

Tested by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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Project Name	Klamath River Dam Removal
Project location	Klamath River
Client	Klamath River Renewal Corporation
Client's Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-7-1
Report Date	5/17/2018
Borehole and Depth	BI-02; 51.7-52 ft
Studied by	Lidia Scavo and Fulvio Tonon
Reviewed by	Gloria Tonon-Kozma

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 5/17/2018

A sample from borehole BI-02; 51.7-52 ft was analyzed under the polarized microscope to determine its mineralogical composition from a 25 X 40 mm (0.9 X 1.58 in) thin section.

Visual inspection of the sample suggests an igneous origin.

ROCK NAME: **BRECCIATED-ALTERED BASALT** (according to EN 12670).

Fig. 1 - Aspect of the studied sample (hand specimen).

Hand specimen – Visual inspection: It is a mafic, greenish and dusty material with a very weak behavior. It is composed of a dark and very fine groundmass with phenocrysts that are millimetric in size, and light to dark colored.

According to the Rock-Color Chart of the Geological Society of America, the groundmass color is Grayish Green (5G 5/2), and the phenocrysts are Grayish Green (10G 4/2) to Light Bluish Gray (5B 7/1).

The rock fizzes under hydrochloric acid, and it can be scratched by a metal tip.

Probable Origin: It is an altered Plagioclase-rich basaltic rock.

Mineralogy: Plagioclase, Clay Minerals, Olivine, Opaque Minerals, Volcanic Glass, Carbonates

Textures: The rock has a porphyric texture with a very fine and dark groundmass, in which there are Plagioclase crystals, rare Olivine crystals, Opaque Minerals, and many alteration Clay Minerals (predominantly Phyllosilicates such as Chlorite).
Plagioclase is the most common mineral phase: crystals are quite large and well zoned. Because of their golden color, clay minerals can be hardly distinguished from the groundmass, except for Chlorite that can be locally seen in amorphous greenish individuals.
Opaque Minerals are mainly made up of Oxides of the Hematite group.
Spotted Carbonates may be also identified.

Alteration and Mineral Suturing Condition: The rock is highly altered: even the largest phenocrysts show traces of intense alteration acted upon by clayey minerals; Plagioclase crystals are intensively fractured. These fractures are commonly filled with secondary clayey material in a "quasi-stylolithic" pattern.

Discontinuities: The rock shows a very pervasive fracture system: many of these fractures have not been filled with secondary mineralization, and they predominantly cross the groundmass. Fractures crossing phenocrysts are instead filled with clay minerals.

Description of Individual Minerals:

Minerals	Mineral Content (%)	Mohs Hardness	Grain Size (mm)	Description and Comments
Plagioclase	33.3	6	1.10	As individual crystals
Chlorite	1.67	2.5	0.05	Very variable in size, alteration single crystals
Oxides	6.67	5.5	0.02-0.8	Spotted Hematite individuals
Glass	50	5	Sub-micrometric	Makes up the groundmass
Clay	8.33	4	Sub-micrometric	Phyllosilicates, unresolvable at a microscopic scale
Weighted Average:		4.2	-	

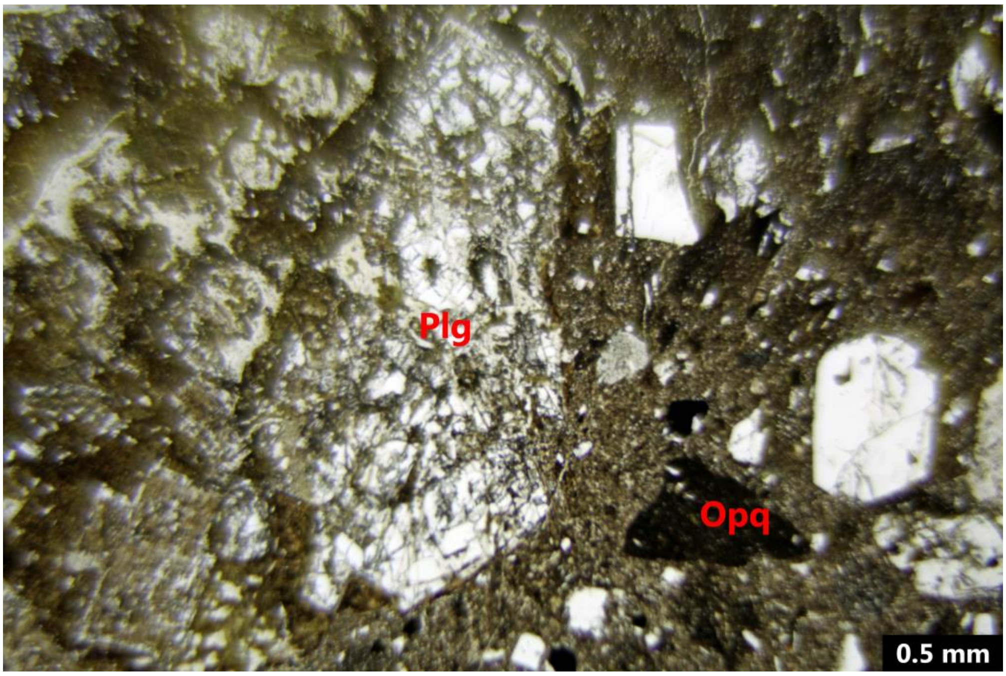

Fig. 2 - Plane polarized light. Field of view = 4 mm wide (magnification 4X). A view of the studied sample, showing an altered Plagioclase (Plg) crystal near to a big Hematite crystal (Opq).

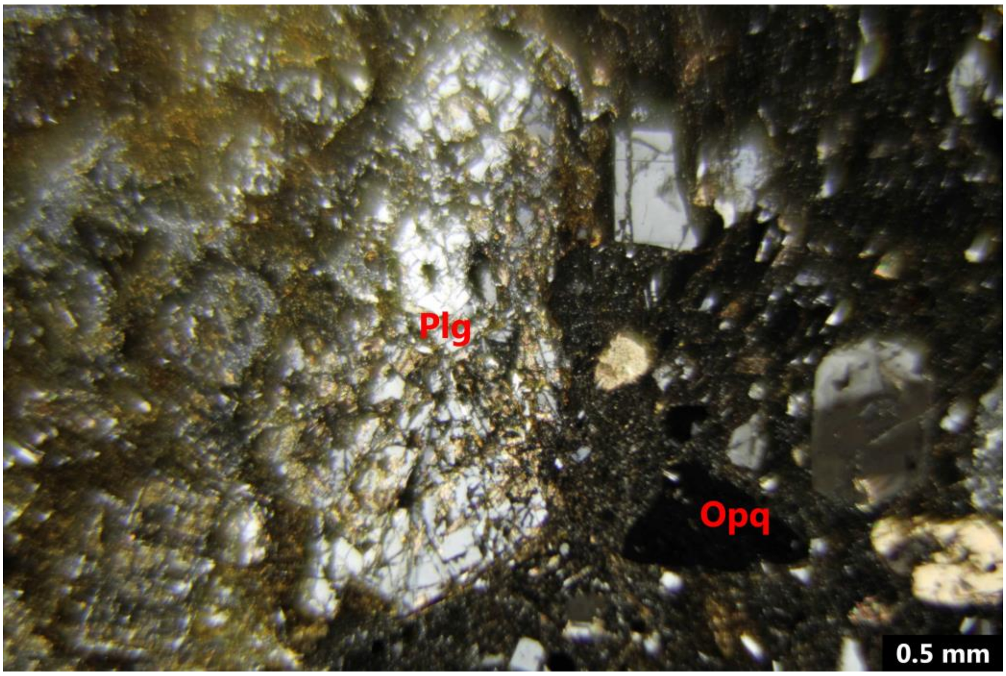

Fig. 3 - Cross polarized light. Field of view = 4 mm wide (magnification 4X). Same as Figure 2, but under crossed polars.

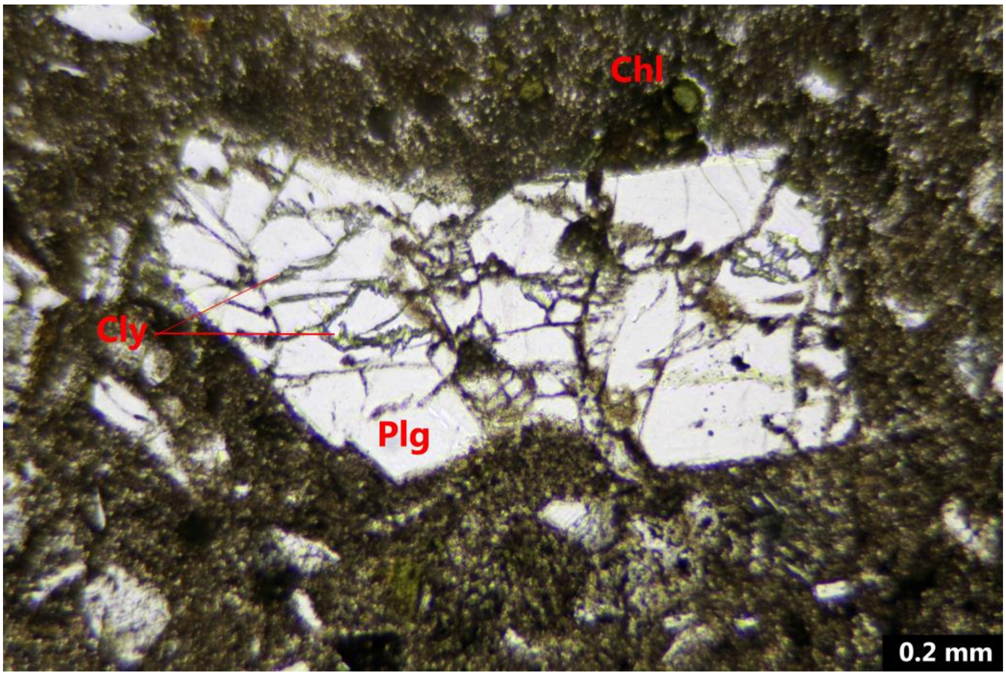

Fig. 4 - Plane polarized light. Field of view = 1.7 mm wide (magnification 10X). A detail of a Plagioclase grain, crossed by many fractures, all filled with Clay Minerals (Cly). Some Chlorite individuals (Chl) may be identified in the upper part of the picture.

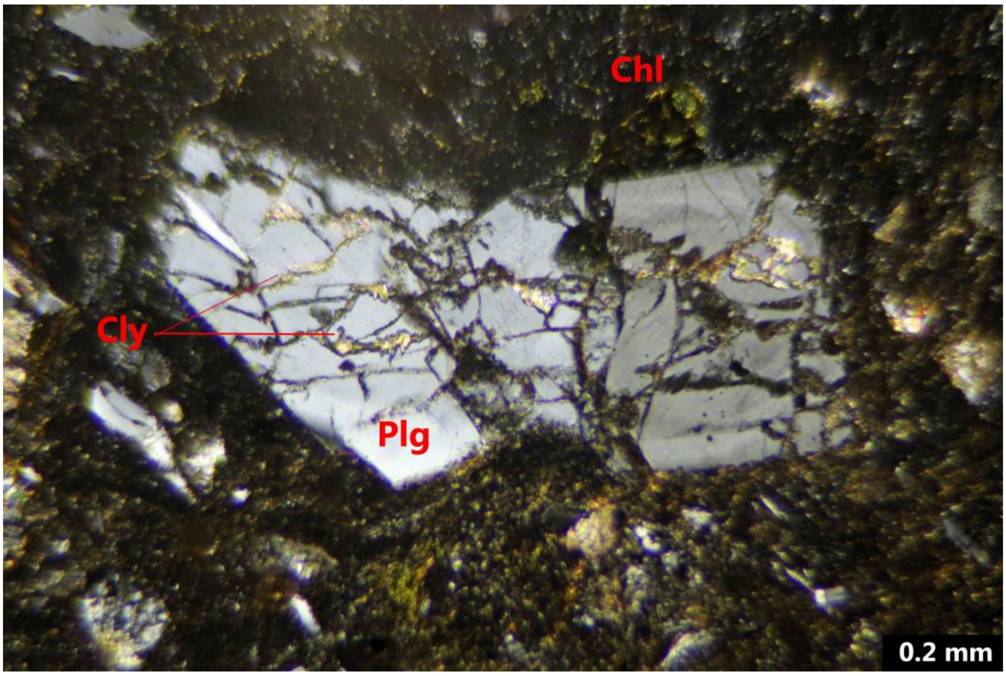

Fig. 5 - Cross polarized light. Field of view = 1.7 mm wide (magnification 10X). Same as Figure 4, but under crossed polars.

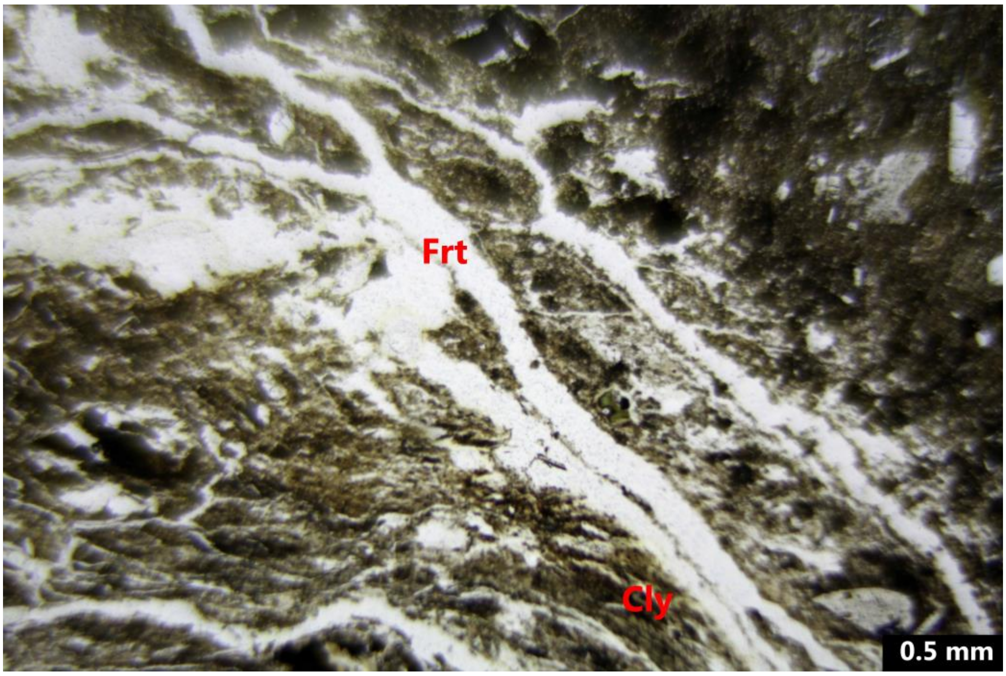

Fig. 6 - Plane polarized light. Field of view = 4 mm wide (magnification 4X). A selected area of the section with a well-developed fracture system (Frt).

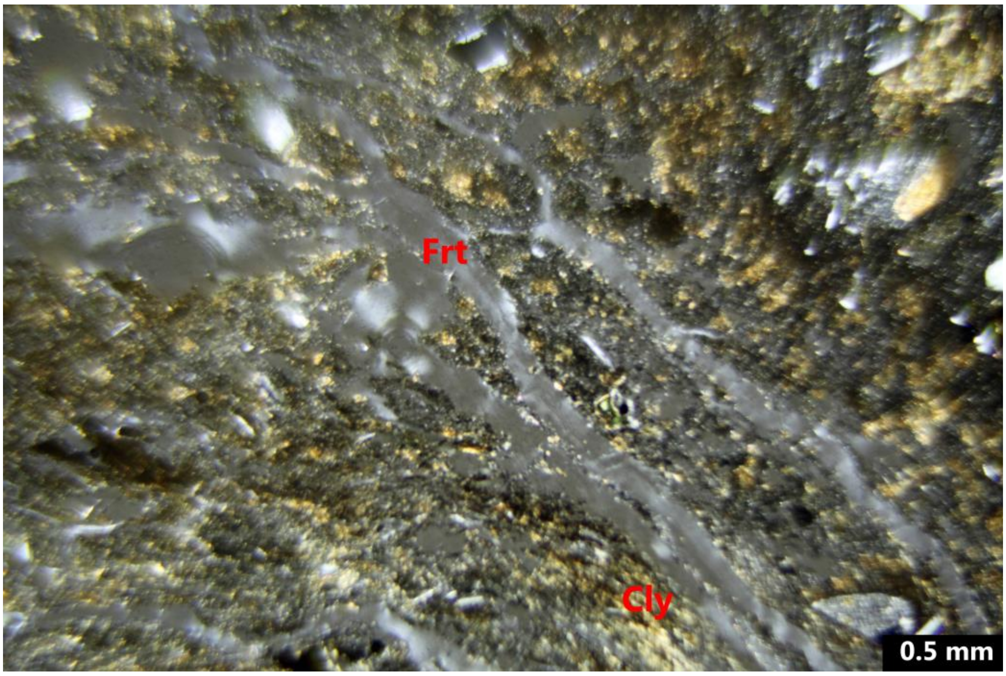

Fig. 7 - Cross polarized light. Field of view = 4 mm wide (magnification 4X). Same as Figure 6, but under crossed polars.

Project Name	Klamath River Dam Removal
Project location	Klamath River
Client	Klamath River Renewal Corporation
Client's Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-7-2
Report Date	5/17/2018
Borehole and Depth	BI-03; 20.8-21 ft
Studied by	Lidia Scavo and Fulvio Tonon
Reviewed by	Gloria Tonon-Kozma

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 5/17/2018

A sample from borehole BI-03; 20.8-21 ft was analyzed under the polarized microscope to determine its mineralogical composition from a 25 X 40 mm (0.9 X 1.58 in) thin section.

Visual inspection of the sample suggests an igneous origin.

ROCK NAME: **ALTERED VOLCANIC BRECCIA** (according to EN 12670).

Fig. 1 - Aspect of the studied sample (hand specimen).

Hand specimen – Visual inspection: It is a greenish mafic rock. It appears to be very weak, and it shows a dusty appearance. It is composed of a dark green groundmass with spotted whitish to bluish phenocrysts.

According to the Rock-Color Chart of the Geological Society of America, the groundmass color is Grayish Green (5G 5/2); clasts have colors ranging from Dark Greenish Gray (4G 4/1) to Light Bluish Gray (5B 7/1). The matter also shows alterations that are Dark Greenish Yellow (10Y 6/6).

The rock fizzes under hydrochloric acid, and it can be scratched by a metal tip.

Probable Origin: It is an altered volcanic breccia.

Mineralogy: Plagioclase, Volcanic Glass, Pyroxene, Chlorite, Clay Minerals, Opaque Minerals, Carbonates.

Textures: It is a mafic porphyritic rock with a chaotic structure: no preferred orientation may be identified.
Plagioclase is the most common constituent mineral: its crystals range from sub-millimetric in size to glassy and are usually well shaped. Zonation is irregular.
Some of the clasts are made up of extraneous volcanic clasts; they can be easily identified because of their color variation when compared to the rest of the thin section: these clasts display a different mafic content.
Secondary mineral phases are made up of rare Augite-Pyroxene, Chlorite, Carbonates and Opaque Minerals.
Very common, but not resolvable at a microscopic observation scale, are Volcanic Glass and Clay Minerals. Clay Minerals also represent the main alteration substance of the rock, which affects both the groundmass and the clasts.

Alteration and Mineral Suturing Condition: The sample shows a substaintial clayey alteration, with clear Chlorite individuals associated with very fine-grained Clay Minerals. Spotted secondary Carbonates can be found as fracture filling material.
Crystals in this thin section have well defined rims, but they are also affected by pervasive fractures both within the crystals and all around their boundaries.

Discontinuities: The rock is heavily fractured, with two classes of discontinuities: a first one made up of empty cracks crossing the groundmass and the crystals, and a second one made up of Carbonate-filled fractures, sometimes surrounding single crystals or clasts.

Description of Individual Minerals:

Minerals	Mineral Content (%)	Mohs Hardness	Grain Size (mm)	Description and Comments
Plagioclase	28.33	6	0.6	As single individuals or as the main part of many external clast groundmass
Chlorite	1.67	2	0.3	As individuals of secondary crystallization
Opaque Minerals	5	5.5	0.1	Spotted individuals of Hematite
Glass	41.67	5	Sub-micrometric	Makes up the groundmass
Pyroxene	1.67	5.5	0.2	Rare sub-euhedral crystals
Carbonates	5	4	0.06	As fracture filling material
Clay Minerals	16.67	2	Sub-micrometric	Phyllosilicates of secondary alteration
Weighted Average:		4.3	-	

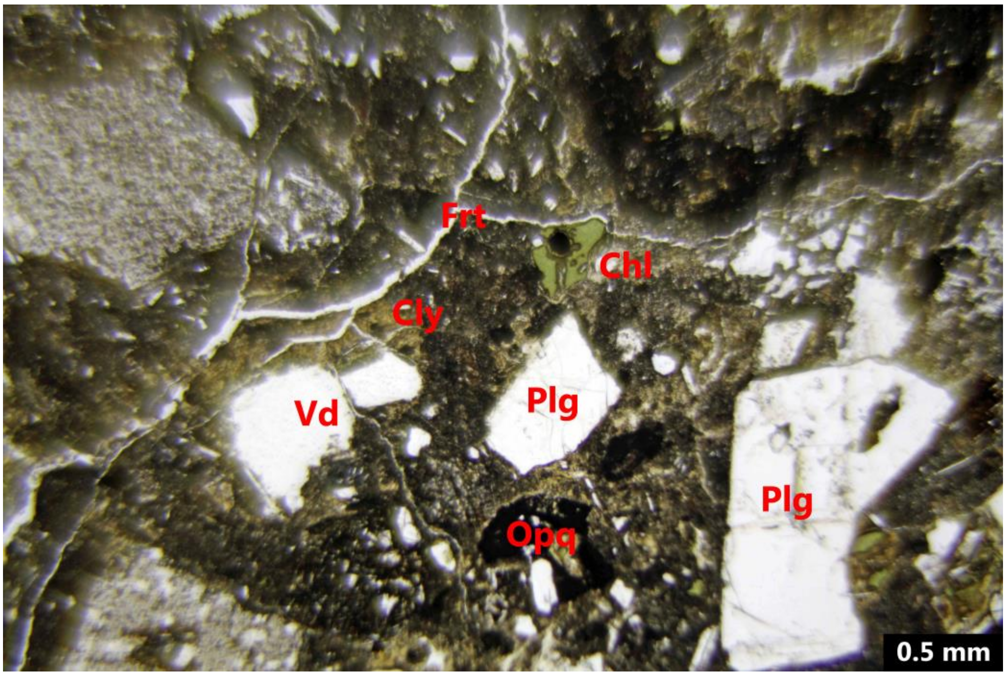

Fig. 2 - Plane polarized light. Field of view = 4 mm wide (magnification 4X). A view of the studied sample. The most common minerals are: Plagioclase (Plg), Clay Minerals (Cly), Opaque Minerals (Opq), and Chlorite (Chl). Also highlighted here are some structural features, such as fractures (Frt) and voids (Vd).

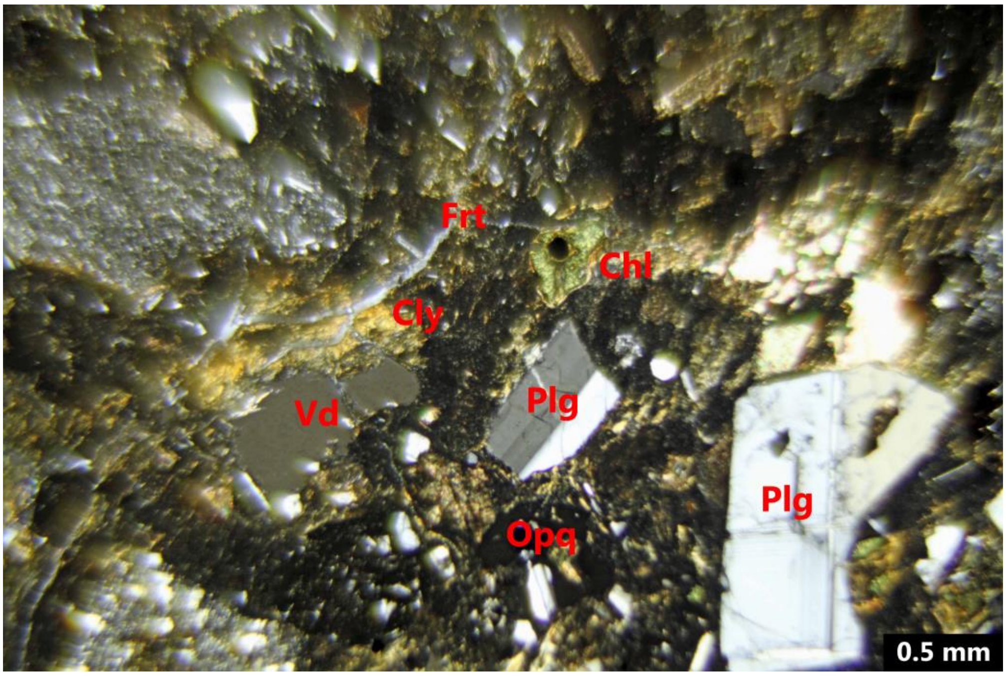

Fig. 3 - Cross polarized light. Field of view = 4 mm wide (magnification 4X). Same as Figure 2, but under crossed polars.

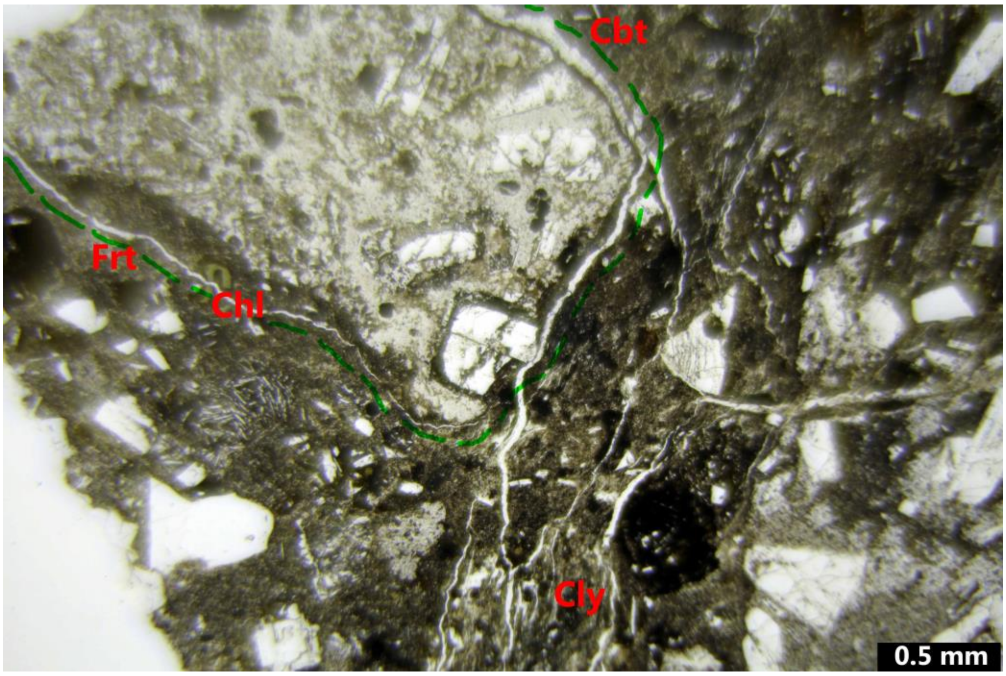

Fig. 4 - Plane polarized light. Field of view = 4 mm wide (magnification 4X). A view of a volcanic clast. A common feature of all the clasts in this thin section is the presence of fractures surrounding clast boundaries (follow the green dashed line). In this case the fracture is filled with secondary Carbonates (Cbt).

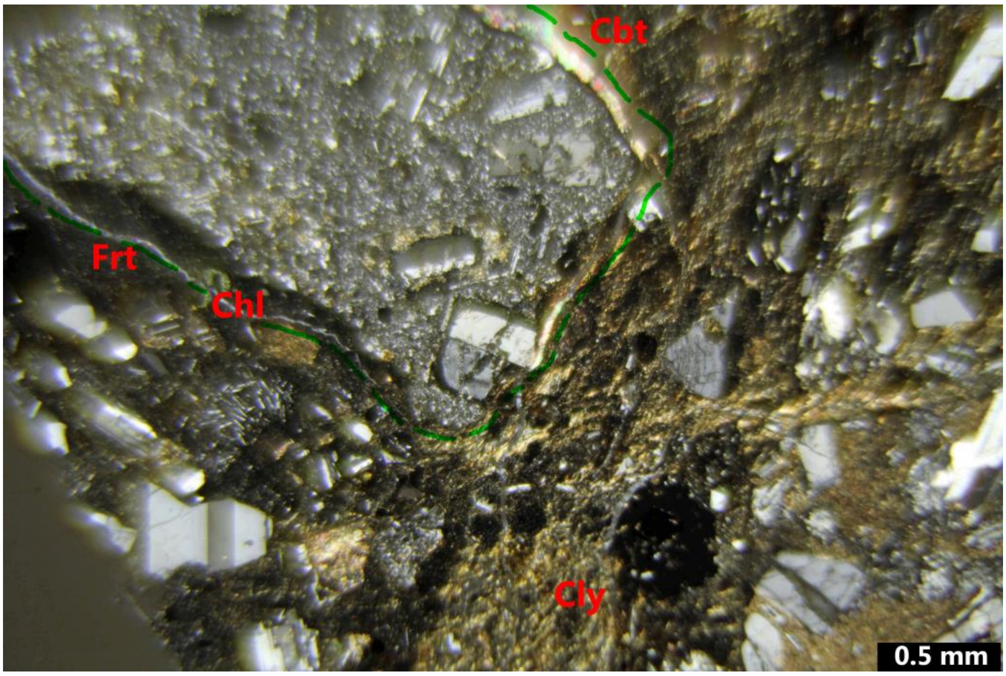

Fig. 5 - Cross polarized light. Field of view = 4 mm wide (magnification 4X). Same as Figure 4, but under crossed polars.

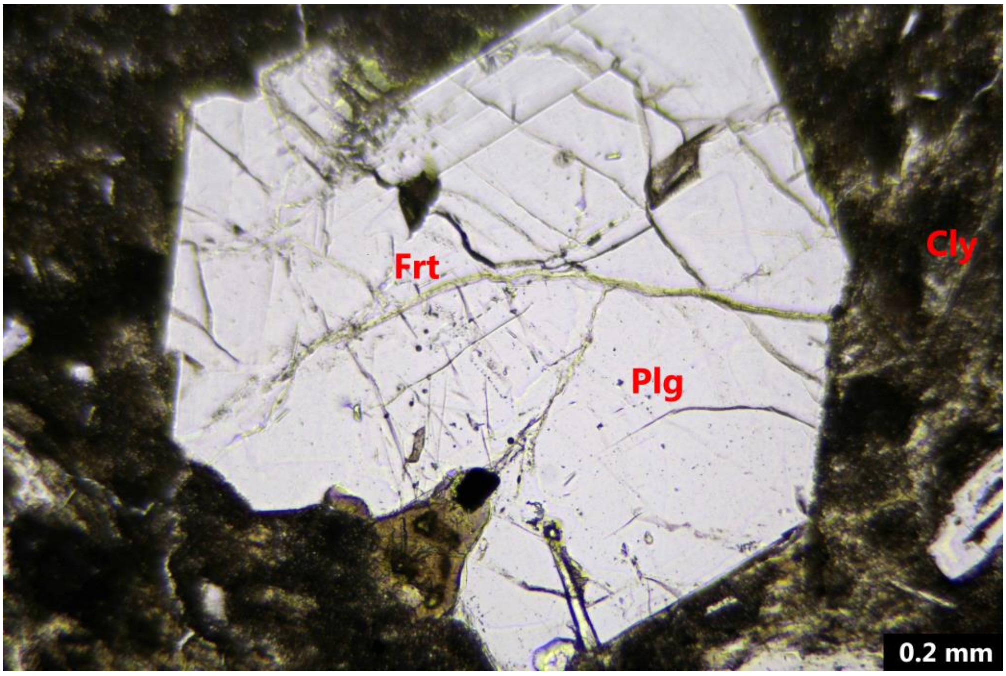

Fig. 6 - Plane polarized light. Field of view = 1.7 mm wide (magnification 10X). A detail of a Plagioclase crystal, showing grain alteration and suturing features: fractures cross the crystal and are also filled with Clay Minerals.

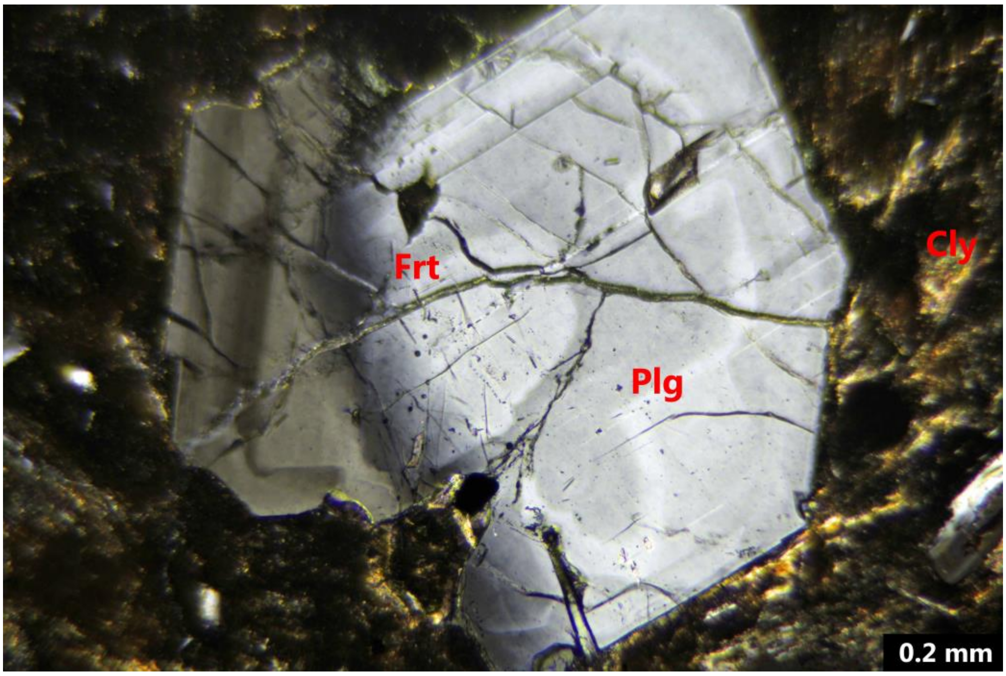

Fig. 7 - Cross polarized light. Field of view = 1.7 mm wide (magnification 10X). Same as Figure 6, but under crossed polars.

COMPANY WITH QUALITY SYSTEM CERTIFIED BY DNV GL = ISO 9001 =

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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-8-1
Report Date	5/17/2018
Drill Hole and Depth	BI-02; 27-27.9 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/24/2018

Mohs Hardness
3

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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COMPANY WITH QUALITY SYSTEM CERTIFIED BY DNV GL = ISO 9001 =

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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-8-2
Report Date	5/17/2018
Drill Hole and Depth	BI-02; 48.9-50.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/24/2018

Mohs Hardness
3

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-8-3
Report Date	5/17/2018
Drill Hole and Depth	BI-02; 55.4-56.3 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/24/2018

Mohs Hardness
3

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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Engineering, Measurements and Testing, LLC

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Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-8-4
Report Date	5/17/2018
Drill Hole and Depth	BI-03; 17.4-18.4 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/24/2018

Mohs Hardness
3

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

2028 E Ben White BLVD #240-2660
Austin, TX 78741

Laboratory Director:Dr. Fulvio Tonon, P.E., Ph.D.
Phone: +1-512-200-3051
E-mail: fulvio@tononeng.com

COMPANY WITH
QUALITY SYSTEM
CERTIFIED BY DNV GL
= ISO 9001 =

Tonon USA
Engineering, Measurements and Testing, LLC

Web: tononeng.com

Project Name	Klamath River Dam Removal
Location	Klamath River
Client	Klamath River Renewal Corporation
Client Project No.	60537920
Registry No.	2018-22
Report No.	2018-22-8-5
Report Date	5/17/2018
Drill Hole and Depth	BI-03; 21.5-22.9 ft
Rock Type	Volcanic Breccia
Geologic Unit	N/A
Moisture Condition	As-received

Date received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 4/24/2018

Mohs Hardness
3

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Project Name	Klamath River Dam Removal	Penetration rate	0.001 in/sec			
Location	Klamath River	Diameter of specimen	60.65	mm	2.39	in
Client	Klamath River Renewal Corporation	Height of specimen	64.62	mm	2.54	in
Client Project No.	60537920	Load at peak	27.81	kN	6,251	lbf
Registry No.	2018-22	45 Degree (Standard) Index	175			
Report No.	2018-22-8-1	Peak Slope Index	39			
Report Date	5/17/2018					
Drill Hole and Depth	BI-02; 50.3-51.3 ft					
Rock Type	Volcanic Breccia					
Geologic Unit	N/A					
Moisture Condition	As-received					

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 5/4/2018

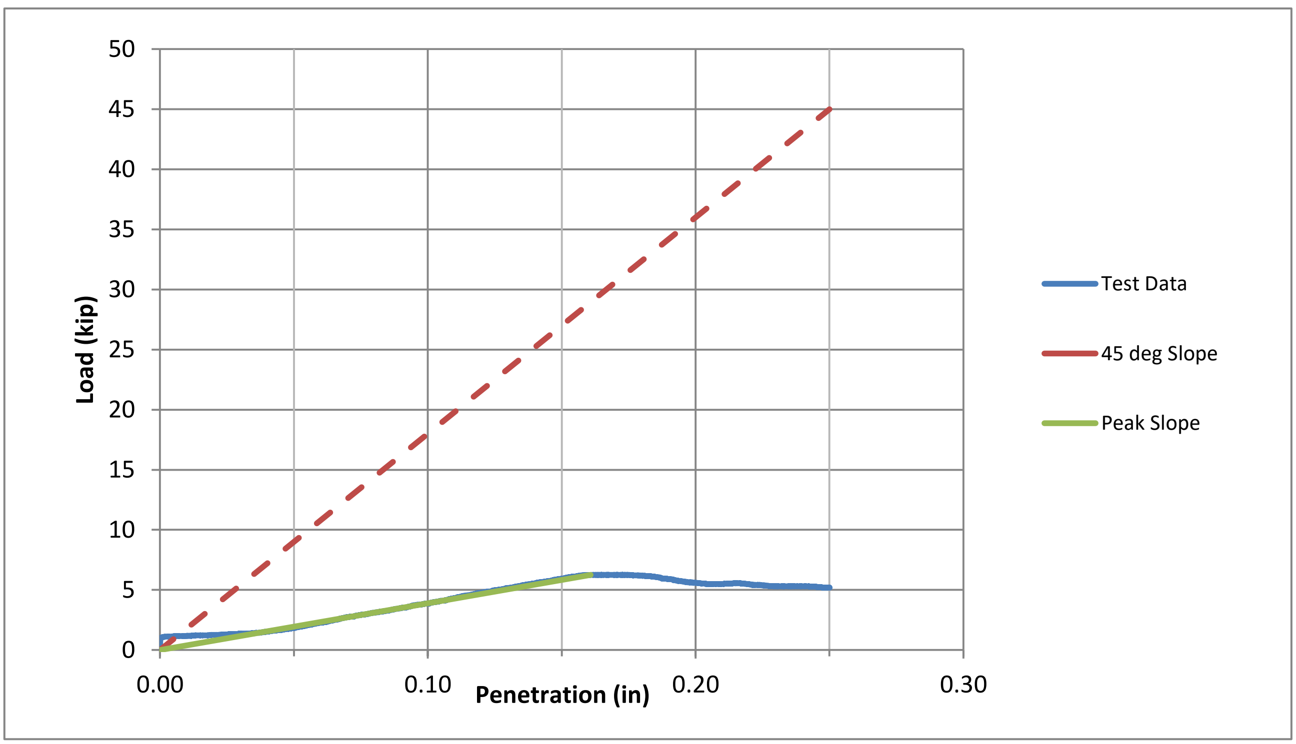

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Photo After Test

Performed by: Dr. Fulvio Tonon, P.E., Ph.D.

Checked by: Gloria Tonon-Kozma, P.E.

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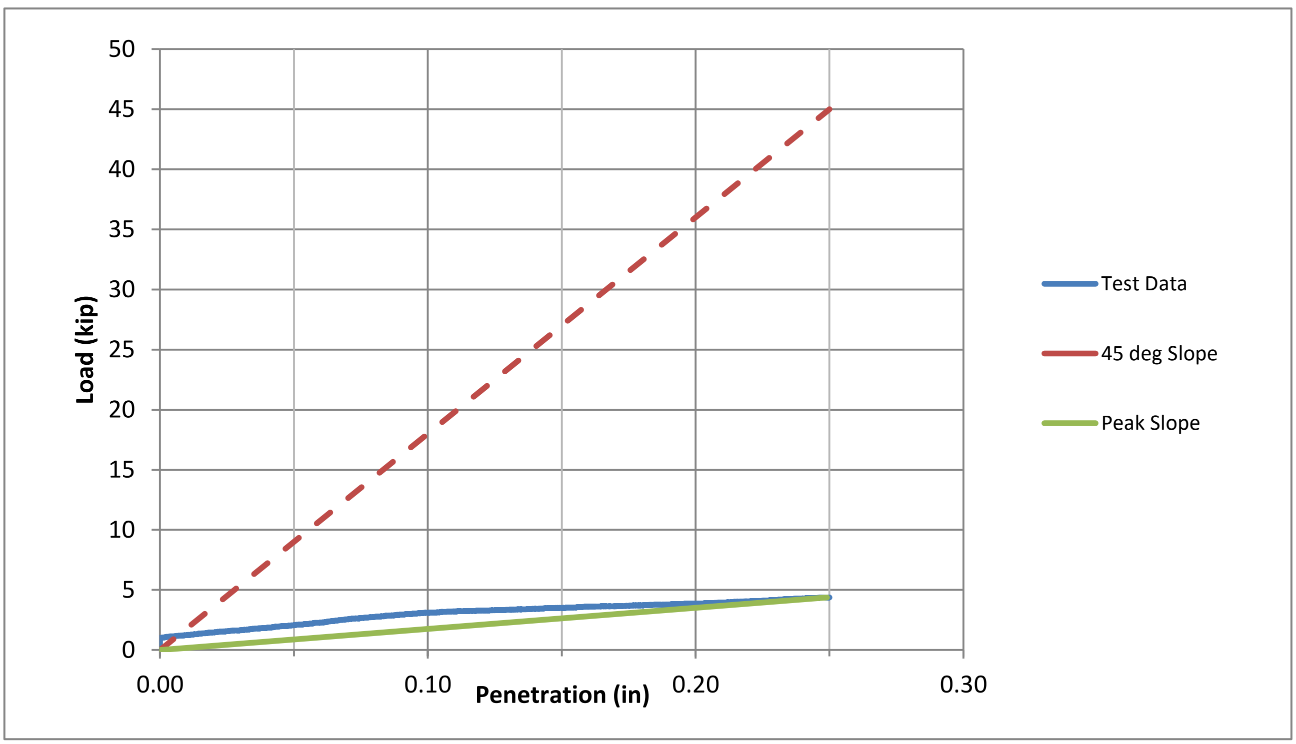
Project Name	Klamath River Dam Removal	Penetration rate	0.001 in/sec			
Location	Klamath River	Diameter of specimen	60.4	mm	2.38	in
Client	Klamath River Renewal Corporation	Height of specimen	67.53	mm	2.66	in
Client Project No.	60537920	Load at peak	19.46	kN	4,373	lbf
Registry No.	2018-22	45 Degree (Standard) Index	175			
Report No.	2018-22-8-2	Peak Slope Index	18			
Report Date	5/17/2018					
Drill Hole and Depth	BI-03; 24.2-25.1 ft					
Rock Type	Volcanic Breccia					
Geologic Unit	N/A					
Moisture Condition	As-received					

Date Received : 4/24/2018	Date Opened : 4/24/2018	Date Tested: 5/4/2018



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